PhD Thesis

Science Mega-Project Communities; Mechanisms of Effective Global Collaboration?

Durham University, School of Government and International Affairs

Mark Robinson

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Declaration

This thesis is the result of my own work. Material from the published or unpublished work of others which is used in the thesis is credited to the author in question in the text.

Mark Robinson

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Word Count

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Dedication

This thesis is dedicated to Professor David Held (1951-2019)
My supervisor, my inspiration and my friend.
He picked me up when I was down, guided me when I was lost and he will always be in my thoughts.

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Finally, I would like to thank my mother, Joyce, and my children, Ann, Nick and Hannah for their enduring patience and love.

Any errors found within this thesis are mine alone.

Picture courtesy of ITER Organisation

"For the first time in history, we find industrialized nations forming partnerships to design and build complex, technological assets for which no nation alone can bear the cost, or the risk. By partnering together, the effort and cost is shared; the risk distributed, and; the benefits accrue to all."

extract from an interview, for this thesis
(and adapted from Uhran, 2015)
from
Mark Uhran
Head of Strategic Communications, Oak Ridge National Laboratory.
Formerly, Assistant Associate Administrator for the International Space Station at NASA HQ in Washington DC (2005 to 2012)

Science Mega-Project Communities;
Mechanisms of Effective Global Collaboration?

ABSTRACT

Thomas Hale and David Held in *Beyond Gridlock* (2017) define gridlock as the inability of countries to cooperate via international institutions to address policy problems that span borders; it refers both to deadlock or dysfunctionality in existing organisations and the inability of countries to come to new agreements as issues arise.

In the context of addressing these problems that span borders it is analytically valuable to consider global science mega-project (SMP) communities that have been remarkably effective in working against the gridlock trend. Three of the most insightful SMP case studies are those chosen for my research: the Conseil Européen pour la Recherche Nucléaire (CERN) community, the International Thermonuclear Experiential Reactor (ITER) nuclear fusion project community and the International Space Station (ISS) community. Previous research into these endeavours has focused on recounting the stories of their scientific discoveries and technical feats and innovations. This research has investigated the reasons behind these triumphs from a social sciences perspective.

The research problem, that this thesis answers, is *how do global SMPs achieve their effective collaboration pathways with Member States*. A qualitative, ethnographic research method was utilised to consider the case study organisations and the people in them. Interpretivism and critical realism research philosophies governed the design. Three underlying hypotheses concerning start-up conditions, dealing with constraints and governance and leadership, were tested to examine SMP performance. Through over seventy field work interviews, evidence was gathered, and analysis and validation showed that the majority of data supported the hypotheses. The analysis reveals which of the seven *Beyond Gridlock* pathways and associated mechanisms had been used by the SMP communities to overcome gridlock. This research identifies a new eighth pathway, concerning innovative funding, that it is proposed be added to the primary theory.

Two contributions emerged for consideration by others in the International Relations field. The first shows that communities should be primed and ready to exploit shifts in major power core interests in order to launch new endeavours and the second is how an ingeniously designed funding system allows Member States to commit to projects, permits the central IGOs to operate effectively and, at the same time, maintains support in the Member States' homelands.

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List of Abbreviations

To aid understanding, where appropriate, the case study or national affiliation has been included [in square brackets]

AAAS	American Association for the Advancement of Science
ATLAS	A Toroidal LHC ApparatuS [an instrument of the LHC]
ALICE	A Large Ion Collider Experiment [an instrument of the LHC]
ADITYA	[ITER] Experimental Indian tokamak
APS	American Physical Society
BIP	Background Intellectual Property
CANADARM	Canadian Robotic Arm used on the ISS
CERN	Conseil Européen pour la Recherche Nucléaire
Chang'e-4	Chinese Moon Landing Probe
CIA	Central Intelligence Agency
CLIC	Compact Linear Collider [a proposed replacement for the LHC]
CMA	[ITER] Construction Management Agent
CMS	Compact Muon Solenoid [an instrument of the LHC]
COLUMBUS	European Science Laboratory on the ISS
COPUOS	UN Committee on the Peaceful Uses of Outer Space
CSA	Canadian Space Agency
CSS	Chinese Space Station
DA	[ITER] Domestic Agency
DEMO	Demonstration Power Station [ITER Members future fusion devices]
DESTINY	US Science Laboratory on the ISS
DEXTRA	Canadian robotic servicing device used on the ISS
DG	Director General
DOD	[US] Department of Defense
DOE	[US] Department of Energy
DUNE	Deep Underground Neutrino Experiment
EAEC	European Atomic Energy Community
EAST	[China] Experimental Advanced Superconducting Tokamak
EC	European Commission
ECOSOC	Economic and Social Council
ECJ	European Court of Justice
ESA	European Space Agency
EIB	European Investment Bank
ELDO	European Launch Development Organisation
ESFRI	European Strategy Forum for Research Infrastructures
ESO	European Southern Observatory
ESRO	European Space Research Organisation
ESS	European Spallation Source
EU	European Union
EURATOM	Common in-use term for the EAEC
EVEDA	[Joint Europe-Japan] Engineering Validation and Engineering Design Activities
F4E	Fusion for Energy [EURATOM fusion energy IGO]
FAB	[ITER] Finance Audit Board
FAIR	Facility for Antiproton and Ion Research
FAO	[UN] Food and Agriculture Organization
FCC	Future Circular Collider [a proposed replacement for the LHC]
FNAL	Fermi National Accelerator Laboratory

G8	Group of 8 Industrialised Nations (Canada, France, Germany, Italy, Japan, Russia [currently suspended], UK and USA)
G8 + 5	G8 + 5 Developing Nations (Brazil, China, India, Mexico, and South Africa)
GDP	Gross Domestic Product
GIP	Generated Intellectual Property
GRI	Global Research Infrastructures
GSO	Group of Senior Officials [Expert group appointed by G8]
GSN	Global Solution Network
HARMONY	US connecting node on the ISS
HEL	[ITER] Highly Exceptional Loads
IAEA	International Atomic Energy Authority
IAP	Inter Academy Panel
ICRG	ITER Council Working Group on the Independent Review of the Updated Long-Term Schedule and Human Resources
ICSU	International Council of Scientific Unions
IdeaSquare	CERN Facility that hosts R & D projects and facilitates MSc student program
IGA	Intergovernmental Agreement [Common name for the ISS Space Station Treaty]
IGO	Intergovernmental Organisation
IKC	In-Kind Contributions
IKD	In-Kind Deliverables
IKM	In-Kind Management
IMF	International Monetary Fund
ILC	International Linear Collider [a proposed replacement for the LHC]
INTOR	International Tokamak Reactor
IO	ITER Organisation [the central HQ entity of the ITER project]
IP	Intellectual Property
IPCC	[United Nations] Intergovernmental Panel on Climate Change
IPR	Intellectual Property Rights
ISS	International Space Station
ITER	International Thermonuclear Experimental Reactor [Project]
ITERCAD	French national agency to provide hosting support to the ITER project
IUA	ITER Unit of Account [project currency used for valuation of contributions]
JAXA	Japan Aerospace Exploration Agency
JET	[EURATOM] Joint European Torus
JINR	[Russian] Joint Institute for Nuclear Research
JT-60	[ITER] Japanese magnetic fusion device [fusion reactor]
JCPOA	Joint Comprehensive Plan of Action [2015, Iran nuclear deal: China, France, Germany, EU, Iran, Russia, UK, USA (withdrew in 2017)]
JV	Joint Venture
KIBO	Japanese Science Laboratory on the ISS
KSTAR	Korea Superconducting Tokamak Advanced Research
LEP	Large Engineering Project
LEONARDO	US Multipurpose module on the ISS
LHC	Large Hadron Collider
LIGO	Laser Interferometer Gravitational-Wave Observatory
MAC	[ITER] Management Advisory Committee
MCB	[ISS] Multilateral Coordinating Board
MNC	Multi-National Corporation
MOU	Memorandum of Understanding
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organisation

NGO	Non-Governmental Organisation
NNI	Net National Income
NPT	[UN] The Treaty on the Non-Proliferation of Nuclear Weapons
NSC	[US] National Security Council
NSTX	[US] National Spherical Torus Experiment
PITF	[US] Political Instability Task Force
PROGRESS	Russian designation for cargo flights to the ISS
QIP	[ITER] Quadripartite Initiative Committee
R & D	Research and Development
RA	Royal Academy
RASSVET	Russian mini-research module on the ISS
ROSATOM	Russian State Atomic Energy Corporation
ROSCOSMOS	Russian State Space Corporation
SESAME	Synchrotron-light for Experimental Science and Applications in the Middle East
SDI	[US] Strategic Defence Initiative
SGIA	[Durham University] School of International and International Affairs
SLAC	Stanford Linear Accelerator Center
SLS	[NASA] Space Launch System
SMP	Science Mega-Project
SpaceX	Commercial company that manufactures and operates rockets and spacecraft
SSC	[USA] Superconducting Super Collider
STAC	[ITER] Science and Technology Advisory Committee
STEM	Science, technology, engineering, and mathematics
STFC	[UK] Science and Technology Facilities Council
STS	Space Transportation System [Space Shuttle flights numbering system; e.g. STS-7]
TOKAMAK	Russian acronym for Toroidalnaya Kamera s Magnitnymi Katushkami [English meaning is: Toroidal Magnetic Chamber]
TRANQUILITY	US connecting node on the ISS
UCLA	The University of California, Los Angeles
UIA	Union of International Associations
UN	United Nations
UNGA	UN General Assembly
UNICEF	UN International Children's Emergency Fund
UNESCO	UN Educational Scientific and Cultural Organization
UNFCCC	UN Framework Convention on Climate Change
UNISDR	UN International Strategy for Disaster Reduction
UNITY	US connecting node on the ISS
UNOG	United Nations Office at Geneva
UNSC P5	UN Security Council, Permanent Five Members (People’s Republic of China, France, Russian Federation, the United Kingdom, and United States of America)
US	United States [of America]
USSR	Union of Soviet Socialist Republics
WHO	World Health Organisation
WMO	World Meteorological Organization
WTO	World Trade Organisation
ZARYA	Russian functional cargo block module of the ISS
ZVEDNA	Russian Science module of the ISS

INTRODUCTION

International Relations Background

Collaboration at the global level has always been a challenge and Robert Keohane in *After Hegemony* points out that even when common interests exist cooperation often fails (Keohane, 1984: 49). More recently there are those who argue, such as Thomas Hale and David Held in *Beyond Gridlock*, that the complexity, interdependencies and interconnectivity of the modern world create new and grave global challenges that demand innovative collaborative solutions (Hale and Held, 2017: 15). They define gridlock as the inability of countries to cooperate via international institutions to address policy problems that span borders; it refers both to deadlock or dysfunctionality in existing organisations and the inability of countries to come to new agreements as issues arise. In this context it is analytically valuable to consider global science mega-project communities that have been remarkably effective in working against the gridlock trend. Three of the most insightful case studies are those chosen for my research: the Conseil Européen pour la Recherche Nucléaire (CERN) community, the International Thermonuclear Experiential Reactor (ITER) nuclear fusion project community and the International Space Station (ISS) community.

CERN has attracted a great deal of attention through its pathfinding science results that have captured the public's imagination. It has spawned a succession of Nobel prize winners for Physics and several notable spin-offs. The ITER project is comparatively unknown outside of its nuclear fusion community although it is potentially of the greatest global significance from an environmental point of view. The ISS has entered modern culture with astronauts from 18 countries providing a continuous human presence in low earth orbit since 2000.

Previous research into these endeavours has focused on recounting the stories of their scientific discoveries and technical feats and innovations. This research has investigated the reasons behind these triumphs from a social sciences perspective. Kenneth Abbott and Thomas Hale in *Orchestrating Global Solution Networks; a Guide for Organizational Entrepreneurs* (2014) identify a type of successful collaboration that they term as a global solution network (GSN). In my study of these Big Science projects, I will argue that they comprise GSNs of the highest order and have evolved complex processes and mechanisms to enable effective international collaboration.

Before exploring potential methods of collaboration to overcome the gridlock phenomenon, I will briefly consider the recent international relations history that has led us to where we are today. The aftermath of the catastrophic World War II saw widespread agreement that comprehensive international collaboration and global governance was needed. US President Harry Truman summed up the still raw emotions in his address to the United Nations Conference in San Francisco on 25th April 1945: "Nothing is more essential to the future peace of the world, than continued cooperation of the nations…if we do not want to die together in war, we must learn to live together in peace" (Truman Presidential Library, 1945). The UN Charter (UN, 1945) was duly signed by the 50 founding member nations on 26 June 1945. Following preparatory agreement at the UN Monetary and Financial Conference at Bretton Woods in July 1944, three accompanying institutions were created. The International Monetary Fund (IMF) was established to manage exchange rate stability. The World Bank to alleviate poverty and the General Agreement on Tariffs and Trade, replaced in 1994 by the World Trade Organisation (WTO, 1994), to be the international forum for negotiation between states and to oversee the application of trade agreements. Hopes were high, and the founders committed considerable resources to make the new institutions work. The pre-World War II utopian ideology espoused by the German sociologist Karl Mannheim (1936) seemed within grasp.

In the immediate post war period, the Bretton Woods system worked reasonably well and with other measures such as the US Marshall Plan contributed to rapid economic growth in western Europe and globally. This started to unwind in the early 1970s firstly when US President Richard Nixon ended the pegging of the US dollar to gold in 1971 which suddenly introduced global financial uncertainty especially for nations with perceived and/or genuinely weak currencies. The 1973 oil crisis further weakened the budgets of developing nations who depended on the Bretton Woods Financial Institutions for loans. In what the World Bank management team termed 'proactive policies', the introduction of harsher loan conditions eroded the institutions legitimacy with the very developing states they were mandated to assist. The operations of these institutions exposed the complexity and difficulty of tackling global issues. The financial crisis of the early 1980s forced re-examination of aid to 'developing nations' and by 1989, as Ngaire Woods explains, they were expected to meet specific policy recommendations articulated in the Washington Consensus (Woods, 2007: 250). These conditions aligned with fervent adoption of market-based decision making throughout western governments. The resultant flexible exchange rates, striving for balanced national budgets and de-regulation of capital markets further altered the *modus operandi* of the World Bank and IMF to the extent that nations looked to other sources of funding including private sources and regional solutions. The realism movement briefly faded with the end of the Cold

War but the march of neorealism, first explained by Kenneth Waltz (1979), reinforced the idea of an international system as merely a set of interacting nation state units. The plethora of new states resulting from the sudden break-up of the Soviet Union in 1991 and the rise of powerful non-state actors added to the impression of the world being unmanageable. To tackle this the UN has repeatedly attempted reform, most notably under Secretary General Kofi Annan who between 1997 and 2006 introduced several practical management improvements. Despite these efforts no International Organisations can consistently lead or govern characteristically non-cooperative states. During the second half of the cold war years (1970s to 1991) International Organisations increasingly struggled for funding and legitimacy in the wake of the two superpowers exercising their political, economic and military might. Post the cold-war, the unipolar power of the USA largely set the global agenda. Nuno Monteiro's analysis shows that this was problematic not least as many nations viewed the US as only acting on global issues when it served its national interests (Monteiro, 2014: 207).

By the beginning of the 21st century, growing pessimism found a home with the offensive realism ideology led by John Mearsheimer (2001); nation states, never certain of each other's actions and with survival as the overriding goal noticeably retreated into entranced positions. Nations self-interest and power politics hampered the Bretton Woods institutions from delivering on their stirring founding agreements. Attempts to re-bolster global institutions in the face of these pressures has mainly resulted in the extension of IO mandates well beyond the original founding agreements. IOs whose funding has been squeezed by member states, vigorously seek new stakeholders who can help them. These new backers then promote, either openly or covertly, their vested interests. This extension of mandates is therefore accompanied by the relentless addition of influential non-state actors, regional groupings, pressure groups and individual benefactors; all quite naturally with their own agendas. Fragmentation results, epitomised by the labyrinthian UN system of today with over 20 quasi-interdependent agencies with several funding streams (UN, 2019a). The ensuing inability to collectively take decisive actions on several areas of world-wide concern has become known as 'global gridlock'. Examples include uncertain international trade agreements, lack of nation state respect for human rights, difficulties in containing and eradicating global pandemics, the fragmentary efforts to combat climate change, slow international agreement of cyber security regulation and uncertainty in governing the non-proliferation of weapons of mass destruction. I will explain that, although these have different consequences in different settings, their effects often overlap and are often contested by practioners and academics. What is undisputed is that gridlock between nations in international collaboration is an unwelcome phenomenon. It is the accompanying academic study of potential solutions that I will now examine.

Global Gridlock

The detrimental effects of global gridlock on leading sectors of international concern including security, economy and the environment are analysed by Hale, Held and Young (2013). They point out that the damaging properties of gridlock are deeper and more wide-ranging with each passing year. The Trump Presidency may be marked by its unpredictability, but two factors seem certain: an entrenched national investment priority coupled with reluctant participation in international commitments. Long-standing US obligations such as the North Atlantic Treaty have been put under pressure and more recent ones such as the Paris Climate Agreement have been abandoned (UNFCCC, 2016). The UK's proposed exit from the European Union increases multi-polarity; in how many areas is still to be established. Populist political movements throughout the world, even if they do not achieve power, are driving nationalist agendas that mainstream political parties can no longer disregard. I will explain that, as identified by Hale, Held and Young (2013: 278), factors such as multipolarity, institutional inertia and institutional fragmentation are combining to make gridlock more entrenched and harder to combat. In addition, the problems that need to be addressed are themselves becoming steadily harder to solve and the need to address them ever more urgent: Economic crises simmer just below the surface of deepening political problems epitomised by despairing refugee migration. Intense societal security issues have cross-border facets that require cross-border solutions. Environmental experts increasingly and rightfully bemoan the slow progress in tackling extensive, cataclysmic climate change. A strong world leader that can provide an example in fostering global relationships to address these problems also seems an ever more distant possibility (Bremmer, 2012; 16). This lack of any rousing global direction coupled with national governments' fear of hampering economic growth undermines responsible and far-sighted International Organisations' decision making.

The late 20th Century saw the rise of Multinational Corporations (MNC) and the globalisation of production that many academics such as Stephen Krasner (2001) conclude has helped erode the scope and power of the State. Economic, cultural and political globalisation and their associated transnational forces are major topics and are not the direct subject here. In this research context, it is accurate to say that tough regulation of MNCs to force more accountable actions, such as in the environmental sphere, is both sparse and uncoordinated. Dan Plesch and Thomas Weiss (2015: 213) conclude that the burgeoning numbers of non-state actors have resources and energy but are not suited to tackling the largest global issues. They even go on to suggest that the non-state actors' efforts exacerbate the issue by collectively giving the false impression that they are making substantive progress. Non-governmental organisations (NGOs) can make good and worthy progress in their areas of speciality. However, their inherently uncoordinated polycentric approach fails to deliver material change in broader domains; it is this world of ‘overlapping communities of fate’, demarcated by Held (2004) that needs effective GSNs. The demand for global solutions is demonstrably not being met by the supply.

Given this gloomy backdrop what can academics do to aid the quest for a way through gridlock? What are the rules of the current game and how could they be re-written to improve global performance? Could academics and practioners combine to design a global system to overcome the aggravating effects of gridlock? History suggests tangible reform is either made directly after a shocking event such as a world-war or in painstakingly small steps. Can this pattern be broken and another, more planned and effective way be found? The penalties of failing to find *any* way out of the current wide-ranging and deepening global impasses demand that no stone on any pathway remains unturned. Global gridlock research has never just been about describing the problems; although this is essential to our understanding. The literature review will show that many authors explore solutions and invite debate on proposals. The proposition of this thesis is that the success of one field of international relations, where a path of global collaboration has been remarkably effective, warrants extra scrutiny. That field is global science mega-project communities to which I now turn.

Science Mega-Project communities as potential model pathways through global gridlock

The extent to which science diplomacy can influence wider political dimensions is unknown and as if to highlight this general uncertainty Davis and Patman (2015) qualify the upbeat title of their work ‘Globalisation and the Rise of Science Diplomacy’ with the phrase ‘New Day or False Dawn? Mega-projects such as those at CERN capture our collective imagination. Scientists investigate a wide range of physics, pushing back the frontiers of knowledge including the search for particles that could make up dark matter. CERN has a long history with research and development starting in the late 1950’s, construction of ever more capable infrastructure and experiments culminating in the first results from the world-leading Large Hadron Collider (LHC) in 2009. The reach of the results today is vast with over 3000 scientific collaborators located in 34 countries being actively involved (CERN, 2019). CERN exemplifies the large scale, long planning, complex interfaces and ground-breaking technical designs that are in play in these iconic Science Mega-Projects (SMPs). SMPs are typically multi-national collaborations primarily because no single participating national organisation has the capacity to undertake the scope, cost, and complexity on their own. The added effect of the collaboration is to strengthen scientific strategic alliances and share the development of expertise, equipment and ideas. The international partnership and sharing of the systemic risks with like-minded colleagues and their institutions is acknowledged, declared and celebrated by the SMP community's leadership as not merely desirable but *essential*. This starkly contrasts with the denial of many sovereign states to acknowledge that there is a joint need in other areas of global concern.

The widespread *modus operandi* of large natural science projects is that development and construction funding rely on members' in-kind contributions as well as cash payments. This guarantees that nations spend mainly in their own territories; known as *juste retour*. In contrast to centrally controlled in-cash arrangements, in-kind contributions result in control being distributed more widely. This dispersed power factor combined with the motive of pushing the frontiers of science and technology make these mega-projects extraordinarily challenging to manage. It has taken the greatest scientific minds with the assistance of diplomats, project managers and engineers to 'find a way' to overcome these challenges. Multi-disciplinary teams have tirelessly worked to develop, implement and manage effective global collaboration and this begs the question: how did the SMP communities achieve this? They negotiate with many of the same national governments and even the same departments within those nations that are stubbornly gridlocked when being directed by other Intergovernmental Organisations in other fields. The SMP teams are also often dealing with highly contentious matters outside of their core competencies. On the ITER project the negotiators had to agree the routine sharing of nuclear research intellectual property between the USA, China and Russia; nations that traditionally do not share any national nuclear information. What did they do differently that brought people, organisations, regulators and governments together to overcome obstacles and do notable deeds? This thesis analyses how SMP communities and their management teams have designed, built and operated ostensibly similar complex global collaboration models.

The solutions that have been put in place are intricate and have been developed over decades. Most remarkedly, they have consistently delivered results and thereby created their own type of legitimacy. In parallel to the welcome scientific outcomes themselves, they have forged innovative new ways in international collaboration, improved inter-state relations and, as I will show, even influenced world politics.

Research Timeliness

This section will firstly provide historical examples of where science collaborations have been the precursor and catalyst for improved international relations between states and then provide two reasons why this thesis is timely in today's global gridlock environment.

Davis and Patman (2015: 261) provide a compelling narrative of the longstanding links between science cooperation and international relations, where the former has often led the way. To support their claim they provide several examples, here I highlight three: 1) The US and USSR scientific communities' interactions, even during the tense gridlocked Cold-War years, are the most well-known linking of scientific cooperation and foreign relations. This pair of actors are central to two of the three case studies. 2) The 1961 US-Japan Committee on Science Cooperation, founded under US President John Kennedy's leadership, helped repair what he termed a 'broken dialogue' between the two countries. The USA and Japan both contribute to CERN's flagship LHC infrastructure and are full members of the other two case study communities. 3) Scientific interactions between Israel's Weizmann Institute of Science and Germany's Max Planck Society provided the first channels for discussions between the two estranged states after World War II. This led to the historic 1964 agreement whereby the Max Planck Society channelled funds provided by the German government to the Weizmann Institute's research projects. These ties helped lay the foundation not only for German-Israeli scientific cooperation, but also for the establishment of diplomatic relations between the two states one year later (Weizmann Institute, 2012). The acceptance of Germany back into the international community is a strong theme in the foundation of CERN.

The thesis is timely for two reasons: firstly, due to the general urgency that gridlock poses and secondly because of the re-emerging recognition of the pathfinding role science and the organisation of international science collaborations play in global affairs.

The unprecedented rise in connectivity that has led to advantages to trade and commerce has in parallel introduced new challenges that can quickly turn ostensibly unconnected domestic issues into global problems. The 2008 global financial crisis started with over-commitment by domestic US lenders to sub-prime mortgages. As Anthony Elson (2017), a former IMF insider, explained it was the poorly regulated international packaging of these high-risk loans, built on false assumptions, that meant the problem quickly affected shares and banking and ultimately led to a global recession. Security issues cross borders with ease and the very nature of potent nuclear, biological and chemical weapons, heap pressure on national Governments to find universal solutions to curb proliferation. Environmentalists' warnings of irreversible damage to the planet due to global warming grow louder with each passing month. Numerous areas of human endeavour are in urgent need of global coordinated actions that can start to address wide-reaching problems that cannot be resolved by domestic actions alone. Ian Goldin (2013) goes as far as to say that the 21st century will be defined by the extent to which we are able to increase the power and effectiveness of global institutions that are mandated to oversee and manage these areas.

There are examples where the urgency described above is well recognised and science-based solution grass-root followers, academics, intellectuals and governments are trying to act as quickly as possible and in good faith. These include the scientific advice provided by global experts to the United Nations Office for Disaster Risk Reduction when it formulated its Sendai Framework for Disaster Risk Reduction 2015-2030 (UNSIDR, 2015). The potential for increased cooperation on issues related to global research infrastructures has been recognised during international high-level meetings on science policy and in different fora since 2007. At the first G8 Ministerial meeting, held in Okinawa on 15 June 2008, a Group of Senior Officials was formed to take stock and explore cooperation on global science research infrastructures. The now expanded group is represented by government officials and experts in the areas of international research facilities and international relations from Australia, Brazil, Canada, China, the European Commission, France, Germany, India, Italy, Japan, Mexico, Russia, South Africa, UK, and USA. Participating countries have backed the enterprise and a Framework for Global Research Infrastructures (G8, 2013). The standing of science within society has also gained popular support with several large scale 'Marches for Science' taking place simultaneously in western capital cities to protest cuts to state research budgets; that is now a global movement (Marchforscience, 2019). Finally, with ever-tightening public budgets, that I outline in each of the case study chapters, SMP leadership and officials of the contributing members could benefit from academic scrutiny of their shared performance.

Analytical Structure

This introduction has provided the research context with respect to recent international relations, global governance and gridlock. It has raised the prospect that examination of the actions of SMP communities may provide insights into potential pathways through gridlock and finally has described why the time is ripe for the study. The thesis main body is divided into six chapters and a conclusion. To answer the research problem, this thesis has at its core three case studies chosen for a close examination of the issues across the mega-project life-cycle. In addition to the acknowledgements and bibliography, there are 3 appendices: Appendix A, Selected Overview of SMPs and their Communities, Appendix B, Interviewee Details and Appendix C, Interviewee Questions.

Chapter 1 provides a critical consideration of four strands of relevant literature. The first includes international relations theory regarding global collaboration and international organisations. This first area has an ample supply of excellent academic research material and is divided into four parts: realism, neo-realism, regime theory and international organisations theory. The second strand is the more recent and expanding body of academic material concerning global gridlock issues and potential solutions. The third is the sub-field of international relations known as science diplomacy. The final strand concerns mega-projects governance, leadership and performance issues. This last category has two sub-groups: general topic material which span the different mega-project areas and material specific to SMP communities. The chapter concludes by describing three analytical themes in the literature and identifies a significant research gap and ends with an explanation of the relevance of the literature to this thesis.

Chapter 2, Methodology, starts by defining the threshold for achieving SMP status and provides the justification for selecting the three case studies and states the research problem:

> *How do global Science Mega-Project Communities achieve their effective collaboration pathways with Member States?*

There are two related research questions: 1) do the subject SMP Communities utilise common diplomatic approaches in negotiating their founding arrangements and functioning in a collaborative way? 2) What - *if any* - are the political lessons learned by the subject SMP Communities that may provide clues in advancing global collaboration to overcome gridlock in other domains? The answer to this second related research question will lead to suggesting two contributions to knowledge.

The global SMP conceptual framework is then outlined to show the key determinates that underpin the research and the three hypotheses. The next section provides the reasons why the research philosophies of interpretivism and critical realism are more appropriate than others that were considered. The three stage (desk research, field research and data analysis and validation) methodological approach is then explained. How counterfactual evidence is gathered and considered is then covered before describing how limitations in the research are mitigated against and how ethical issues are handled. Finally, a chapter summary is provided.

Chapters 3-5 investigate the case studies, each one employing the same format. The first section covers the scientific problem that led to the establishment of the IGO tasked with tackling it and the historical aspects that led Member States to agree to take part. The founding international agreement is examined with respect to its negotiation, agreement, signature and ratification. The IGO organs, member state voting rights, commercial and funding arrangements are then analysed. The second section of each case study chapter then analyses the management of major constraints that have affected the project IGOs and their wider communities with emphasis on the findings from the case study interviews. The third sections analyse the governance and leadership dynamics, including the organisational culture, what leadership styles have proven to be the most productive, levels of focality and legitimacy and plans for future developments. Each case study chapter ends with an appraisal of the collaborative pathways and associated mechanisms that have been utilised.

Chapter 6 analyses and compares the results documented in the three case study chapters and comprises five sections. In section 1, I gather together the counterfactual arguments that span the three case studies together with my responses to each one. In section 2, I utilise the testing of the three hypotheses to frame the discussion. The degree to which the *Beyond Gridlock* pathways have been used by the case studies in respect of their support of each of the three Hypotheses is analysed. In section 3, I comment on common diplomatic, governance and leadership mechanisms that have been used to implement the pathways and point out where dissimilar mechanisms have been deployed. It is also in section 3 where the case for the inclusion of a novel 8th pathway, innovative funding, to global gridlock theory, is made. In section 4, I recap the common features of the three case studies. In section 5 I suggest two contributions to knowledge aimed at academics of global gridlock and those involved in inter-governmental collaboration initiatives in other domains.

The thesis conclusion draws together the case for the relevance and timeliness of the thesis and advocates where further research could be undertaken. The thesis structure is shown at Figure 1.

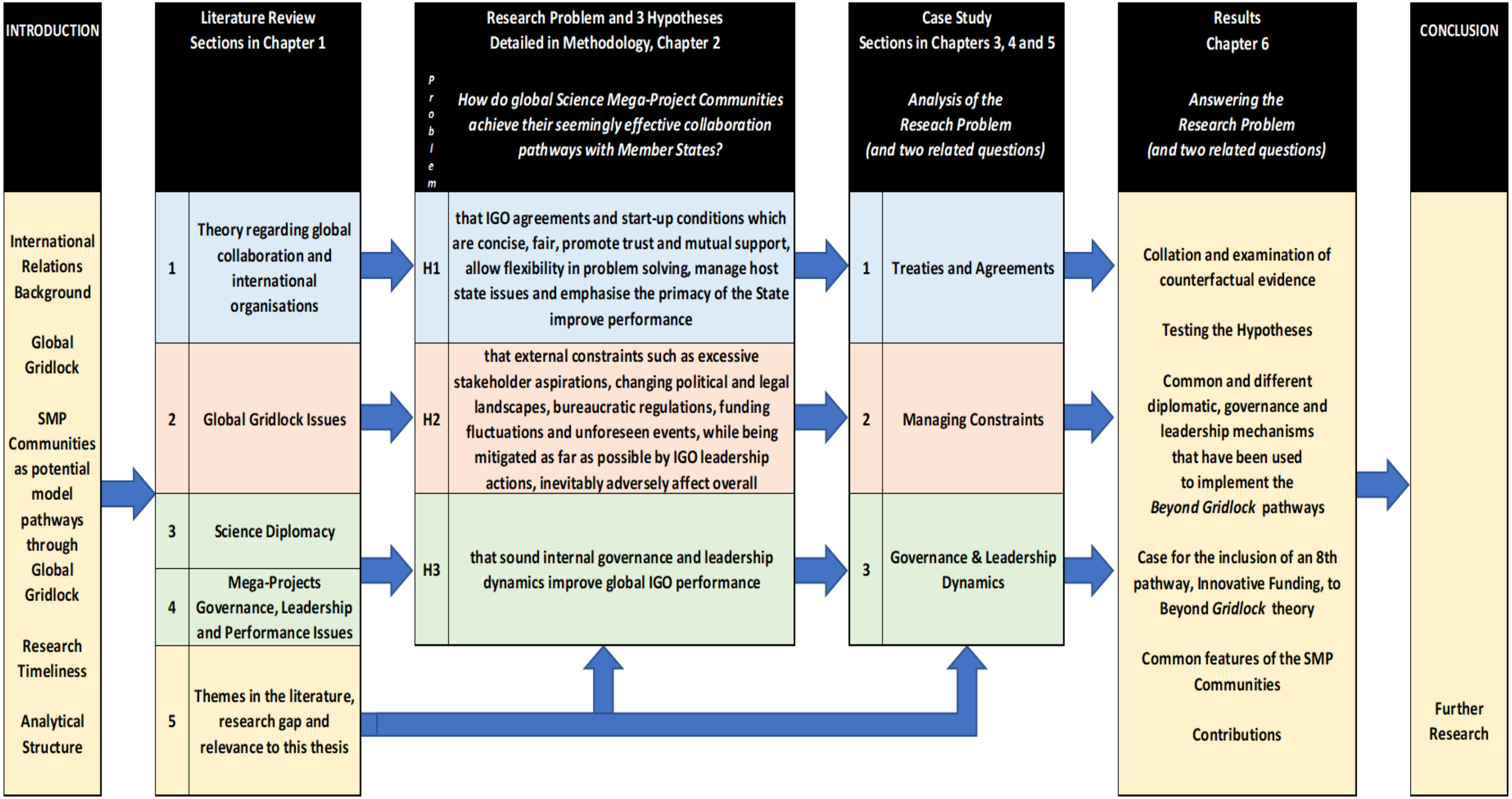

Figure 1; Thesis structure

Terms, nomenclature and notations

The scientific domain of the case studies means that the use of specialist terms, nomenclature and notations is unavoidable. The explanations for these are done here, at the outset, to avoid any confusion between concepts and to put the concepts in perspective.

Terms

Big Science

Where I use the term *Big Science* its meaning is the same as that of Alvin Weinberg (1967) when introducing the phrase in his book on the impact of Large-Scale Science on the US. Namely, it means ***large research infrastructures***.

Noble work

Noble work in SMP Communities means ***work of a high technical value and/or high scientific value and/or high monetary value.***

Rogue States

There is no universally accepted definition of a *rogue state*; Derek Smith (2006; 14) points out that even the grouping - which in the early 1990's comprised North Korea, Cuba, Iran, Libya and Iraq – is elastic and has a disputed membership. Although there is no definition there are widely held common characteristics of the type espoused by Elaine Bunn, who was the Deputy Assistant Secretary of Defense for Nuclear and Missile Defense Policy in the US DoD from 2013 to 2016. In her 2003 paper *Pre-emptive Action: When, How, and to What Effect* she lists the characteristics as ***those who brutalise their own people, display no regard for international law, threaten their neighbours and are determined to acquire weapons of mass destruction*** (Bunn, 2003). I will argue, in section 5.1, that in the early 1990's it is this latter anxiety that was the driving factor in the US reasoning to extend an invitation to the Russians to join the ISS. For this thesis therefore, I use the term as it applied at that moment of US decision making rather than be drawn in to the debate on the evolution of the rogue states narrative in US security policy which Alexandra Homolar (2010) and other academics in the security field of international relations have investigated.

SMP Communities

SMP Communities are products of complex social, scientific, technical, economic and political interdependencies. They have often taken decades to form, normalise and become effective They also reflect the ongoing relationship between their shared aims and the everyday world constraints of their Member States. In this research I adapt the concept of an epistemic community which Peter Haas (1992) defines as ***a network of professionals with recognised expertise and competence in a particular domain and an authoritative claim to policy-relevant knowledge within that domain.*** The concept is an important one in considering collaboration in the modern world. While it is not the focus of this thesis its use is unavoidable in understanding the internal workings of SMP communities. Each case study is an example of an epistemic community that comprises knowledge-based experts, but due to their size, complexity and global reach these are spread over many supporting sub-fields. This makes their boundaries difficult to define as they vary from Member State to Member State and vary over time.

The Haas definition and the presence of diverse boundary conditions that change over time need to be kept in mind when the term *SMP Community* is used throughout this paper and the terms *CERN Community*, *ITER Community* or *ISS Community* are used in the case study chapters. At the start of each case study chapter I outline the special features of each community at IGO level and provide examples of the community boundaries.

Wicked problems

In this thesis I use Keith Grint's framing from *Wicked Problems and Clumsy Solutions* (2008) for this term to mean ***problems that are persistent, tending to be insoluble and not presenting clear sets of alternative solutions.***

Nomenclature and notations

An extensive abbreviations list is provided (pages xvi to xviii). When an abbreviation is first used it is explained; it is then used in the rest of this thesis and only where necessary for emphasis is the reader reminded of the explanation.

The nomenclature for the eight *Beyond Gridlock* pathways that I explain fully in Section 1.2 covering Global Gridlock Issues are referred to also by their respective number (1 to 8) throughout the thesis.

The three hypotheses explained in Section 2.3 are referred to, in parenthesis, both by their number (1 to 3) and their description throughout the thesis.

My own comments, for example when included in the abbreviation list or embedded in field work interviews or other text to add context and/or aid clarity, are always shown in [square brackets].

Wherever a figure or a table, is mentioned in the text, a hyperlink is provided to take the reader directly to the referenced object.

CHAPTER 1: LITERATURE REVIEW

This chapter provides a critique of four strands of relevant literature. The first section concerns the international relations theory with attention on nation state collaboration. This will be examined through the four sub-groups of realism, neo-realism, regime theory and international organisations. The second section examines the relatively new gridlock phenomenon. The review will cover the work of leading academics in the field including potential solutions that they have tabled together with literature that provides counter arguments to the standard views. The third strand is a review of the specialist sub-field of international relations concerning science diplomacy. I will briefly sketch the advancement of science diplomacy within world politics and how it has influenced societal issues in modern times. The final strand of literature concerns mega-project governance, leadership and performance and is divided into two parts, the first concerning general mega-project management issues and the second concerning the subject of this thesis, global SMPs.

This thesis purposively aims high to provide a systematic investigation into a problem of incomplete knowledge in a pressing field of international relations: global gridlock. The literature review is by necessity complex in that it combines analysis of the above four strands to set the broad context of the performance of SMPs in the international arena. The literature review will move on to recap three predominant themes: primacy of the state, science diplomacy and SMP leadership. Finally, I conclude the chapter by identifying a research gap within global gridlock studies and explaining the relevance of the literature for this thesis.

The libraries of Durham University, London University and Oxford University have been utilised in this literature review. The British Library PhD on-line archive was also accessed to examine previous work in related fields. The in-house documents of the three case-study IGO headquarters were accessed as follows:

- CERN: the CERN HQ library and archive in Geneva, Switzerland was visited, and material accessed on-line, the UNESCO library and archive in Geneva, Switzerland was visited, and material accessed on-line;
- ITER: the ITER HQ library in Cadarache, France was visited, and material accessed on-line and
- ISS: the NASA HQ library in Washington DC, USA was visited and accessed on-line, and the ESA and US Presidential libraries were accessed on-line.

The specialist librarians and archivists of all three SMPs and the archivist section of the UNESCO Library in Geneva provided expert assistance with respect to locating and accessing founding documents that included: the UN Economic and Social Council sessions and resolutions, SMP IGO treaties, conventions, MOUs, *common understandings*, multi and bi-lateral agreements and formal negotiation correspondence.

1.1: Theory regarding global collaboration and international organisations

This section provides evidence of considering and understanding the broad international relations field that sets the context to the emergence of the gridlock phenomenon. Comprising one of the four elements of the literature review and to maintain balance with the others, this section concentrates on the influential thinkers in each of the three fields of realism, neo-realism and regime theory. In addition, this section of the literature review will map out the international organisations that are central to the current global system and analyse where the IGOs that are tasked with delivering global SMPs fit in to that landscape.

1.1.1: Realism

This sub-sub-section will recap what realism theory is, outline the views of its key exponents and critics and lastly describe how it relates to the thesis topic.

Realism is not a single theory but a family of theories that have developed since the ancient times of the Greek writer Thucydides (471 – 400 B.C.) and have thrived in the past 75 years to the point where a single definition is elusive. Yet, Jeff Legro and Andrew Moravcsik (1999) point out that nearly all scholars who have voiced an opinion on the subject agree that what makes it possible and useful to speak about realism as a unified paradigm is the existence of a series of shared core assumptions. Paul Viotti and Mark Kauppi (1999) summarise that realism is based on four key assumptions: Firstly, states are the principal and most important actors. Secondly, the state is viewed as a unitary actor. Thirdly, the state is a rational actor seeking to maximise its own interest or national objectives in foreign policy and fourthly, that within the hierarchy of international issues, national security is paramount. Power and the exercising of that power by nation states is therefore a key concept in realism to the extent that security and strategic issues are sometimes termed *high* *politics* while economic and social issues are considered less important *low politics*. In the world of realism, the *high politics* dominates and sets the scene in which the *lower politics* is tolerated.

Traditional key exponents of classic realism and their major works include Hans J Morgenthau (1948) Arnold Wolfers (1962), Edward Hallett Carr (1951) and Raymond Aron (1966). There have been many detractors of realism and enduring critical analysis includes that from John Vasquez (1997) and the leaders of the main branches of the central concept such as Neorealism [Kenneth Waltz, Robert Keohane and Josef Nye; covered in the next sub-section], Offensive Neo-Realism [John Mearsheimer and Robert Gilpin] and Defensive Realism [Kenneth Waltz and Robert Jervis]. I will touch on the key writings of the exponents of realism and its critics at several points in the discussion that follows.

Given the precision of the assumptions that Viotti and Kauppi succinctly recap, it is somewhat surprising that there are diverse views on the definition of one of its key features: power. Three influential realism academics see power differently as:

- The capacity of an individual group, or nation to influence the behaviour of others in accordance with one's own ends, as defined by Organski (1968) in his work regarding the cyclical nature of war.

- Man's control over the actions of other men; the classical realism definition from Morgenthau (1948) in his seminal work *Politics Among Nations: The Struggle for Power and Peace*

- The ability to prevail in conflict and overcome obstacles; as defined by Singer and Deutsch (1964) in their work on the balance of power and system stability.

A fundamental difference in stance is whether power is considered as absolute and inherent (Morgenthau and Organski) or whether it is relative (Singer and Deutsch). When applied to states such as the USA the different attitude could manifest itself as an evaluation of the self-evident might of the US Military *or* an evaluation of that force in terms of its capabilities relative to other states. Another application would be an evaluation of the absolute fiscal power of the US Economy or its strength relative to other economies. In turn these different approaches lead to the question how do we measure the absolute or relative strength of that power? Are its resources (uniformed personnel and hardware) or their capabilities relative to other armed forces the right measure of military power? Is it a nation's Net National Income (NNI) or Gross Domestic Product (GDP) or an index showing these relative to other nations that is the correct measure of wealth?

For this thesis, what is important is the notion captured by Viotti and Kauppi that whichever realism stance is taken *the power of a state is dependent on the issue involved, the system in which power is exercised and its polarity*. The latter point being whether a system is: unipolar, as with the USA in the immediate aftermath of the cold war; bi-polar, as with the USA and USSR during the cold war period or multi-polar, as with the international system today [albeit still with a very powerful USA in several spheres such as security]. The systems are also often interrelated, for example military capabilities of states are affected by the strength or relative strength of their economies.

Another key defining characteristic of realism is the structural attribute of anarchy whereby there is no hierarchy of authority within the system in question. There is no body or central authority to whom states are accountable. In such a world, the realists would argue it is therefore logical to look out for number one and constantly update, upgrade and exercise power in all its forms to maintain national security. I will return to this assumption and challenge it in sub-sub section 1.1.2, Neo-realism. For now, it is enough to say that the hard-line realist stance - that there is no natural harmony in the world within a deeply anarchic system - is not supported by the SMP experience analysed in this thesis. Morgenthau's *Politics Among Nations: The Struggle for Power and Peace* (1948) position that state interests are more important than *any* other factor is reconciled by the reality that states must act rationally and collaborate when there is no go-it-alone alternative. I will investigate whether collaborating member states see SMP outcomes - albeit collectively attained – as improving the likelihood of increased national power, security and thereby, eventual stable autonomy.

A casual onlooker of the iconic case study SMPs may see them as utopian, self-governing and confident of their authority over states, this bluster masks the fact that basic realism theory still applies. The member states continue to be the controlling actors in the SMP model, allowing the central IGOs that authority they strictly need to deliver results but nothing more. For example, I will show that while SMP IGOs have design authority over the member states in key areas such as safety and operations, they have highly limited self-generating revenue powers, must adhere to strict guidelines on recruitment and workshare and are subject to continuous national oversight of performance.

The legalistic mechanism (protocols in the founding documents) that sets the boundaries of this granted authority mark the SMPs out as mature IGOs. Although there is a healthy debate regarding the authority of the central teams over the member states, the fundamental anarchic nature of the international system is maintained in that it is recognised that the SMP IGOs should not constitute a suprastate authority. The founding agreements [summarised in sub-section 1.3, Science Diplomacy and detailed in the separate case study chapters] *precisely* demarcate the limits on any granted authorities and define the protocols, governing bodies and voting mechanisms necessary to make any changes to them. The agreements are also carefully constructed to limit any mission creep that the leadership of SMP IGOs may wish to indulge in.

One example of the required submission to realism theory can be seen at the highest level of management that the SMP hierarchy models utilise. Governance documents show that an SMP IGO Director General is invariably appointed as a diplomat and enjoys the privileges and immunities that this status brings. However, the appointee reports to and is accountable to the governing Council that comprises voting representatives from the member states. The day-to-day running of the SMP ventures is entrusted to the Director General [true for CERN and ITER, not the case for the ISS as I explain in Chapter 5] who is granted considerable autonomous authority over the staff and operational matters; however, the final power rests firmly with the nations who approve Director General appointments and re-appointments.

Classic realism theory has had a series of critics including the champions of its numerous off-shoots including neo-realism (covered in sub-sub section 1.1.2), defensive realism (that argues that states are security maximisers) and offensive realism (that argues that states are power maximisers). The collapse of the Soviet Union emboldened critics as it seemed to highlight a general weakness in realism theory: an inability to foresee or explain change. This upsurge in criticism was swiftly rebuffed by the counter-counter argument that it was the realism of Mikhail Gorbachev and his advisors when he came to power that led the Soviet Union to the logical conclusion that it could no longer compete (philosophically and/or economically and/or militarily) with the USA and her allies and should therefore withdraw its forces from Central Europe.

Criticism has also been made that the theory has a fractured foundation in that there are major inconsistencies and disagreements amongst realists. Thomas Cusack and Richard Stoll (1990) for example suggest that in addition to confusion amongst realists as to the importance and distribution of power there are also diverse views on the significance of uneven patterns of growth amongst the actors in the system. To bolster their argument, they endeavour to link international relations theory with computer simulation within a realpolitik framework, their rationale being that no other rigorous models of realism exist. My position is that, while they try and play up the undeniable differences, they fail in undermining the veracity of the theory itself. Indeed, realism though having to be modified and adapted has seen off all manner of counter-arguments and survived the test of time as the main underling theory of international relations. This endurance is not least because we have its core arguments regularly reinforced in our psyche. For example, when we witness our nation's leadership navigate through turbulent global events on our behalf even if we do not independently agree with their proposed paths.

In summary, this sub-sub-section has shown that looking at the global SMPs that form the centre of this thesis through the lens of realism theory reminds us that states remain the primary actors in international affairs. Any global governance exercised by the SMP IGOs mandated to achieve their communities' goals is contingent on the power politics that the contributing members exercise. I will show that the central leadership teams of these massive projects operate within the degree of management authority that the nations tolerate and permit. Jason Charrette and Jennifer Sterling-Folker in the conclusion of their chapter on realism within Weiss and Wilkinson's *International Organization and Global Governance* (2014) sum up the condition thus: 'Realism provides a critical voice to the debate about International Organisations and global governance by drawing attention to power politics, reminding the discipline that despite the fluidity of international politics, some things never change.' This thesis will show that the governance and running of SMPs do not provide an exception to this firm realism footing.

1.1.2: Neo-realism

This sub-sub-section will first define what neo-realism theory is, then describe the views of its key exponents and critics before discussing recent developments of the concept and will end with an account of how this thesis relates to it.

While retaining many of the basic features of classical realism (e.g. states as key rational unitary actors and power as a central analytical concept), neorealism directs attention to the structural characteristics of an international system of states rather than to its component parts (Evans and Newnham, 1998). The system is still anarchical, and the units are deemed to be autonomous, but supporters of the modified theory argue that attention to the structural level of analysis enables a more dynamic, inter-connected and less restrictive picture of international relations to emerge.

Key exponents and their major works include the accepted founder of the neorealism movement Kenneth Waltz (1981; 1990), Robert Keohane (1986) and Joseph Nye who later with Keohane took a further step in thinking with a neoliberalist stance (1977). I will touch on their key works and that of other backers of neorealism during the discussion that follows.

Kenneth Waltz argued in his influential book *Theory of International Politics* that the international system functions like a market which effects the actors and the results they produce (1979). He asserted that this market, while structured, operated in an anarchic way which limited and explained the actions of nation states within it. Fundamentally, he wrote that democracies and dictatorships could not rely on the good will of others, so always had to be ready to fend for themselves. I would argue that the UK and France, by retaining independent strategic nuclear weapon capabilities despite both being NATO alliance members, are present-day examples of this. In other words, even in an ostensibly civilised world order of cooperation and structured alliances, anarchy and preservation of national security are the underlying forces that still often drive national administration decision makers.

Robert Keohane's *After Hegemony: Cooperation and Discord in the World Political Economy* contrasts the shift from realism to neo-realism (1984). This book is important to this research, particularly as it suggests why states - in a post-hegemonic world order - collaborate. Keohane's overall position is that states do have complementary interests, which make certain forms of cooperation potentially beneficial. Another strong theme is that institutions affect the patterns of cooperation that emerge. Both points, complementary interests and institutions, have direct relevance to the formation and operation of SMPs. I will develop this significance in the individual case study and research results chapters. The four post-hegemonic drivers for state collaboration that Keohane recognised in 1984 are still pertinent today:

1) *they reduce individual state costs.* Reducing state costs is often a predictor of cooperation, i.e. states must protect their self-interest and be confident that they are not over contributing to an endeavour. Keohane takes this further as he believes it can also be a predictor of the establishment of institutions, within the boundaries of the other driving factors described here. I will show in the Case Study Selection Justification, section 2.1, the very high development, construction and

operational costs of SMPs. The advantageous leverage that states enjoy by cooperating in such circumstances outweigh other concerns such as perceived lack of control or national esteem. I return to this theme and other advantages of SMP collaborations in the Results Chapter 6.

2) *there is bounded rationality in working together*. This notion is developed from Herbert Simon (1982) and is that states do not have the capability to maintain as high a degree of flexibility as would purely rational actors. The cooperation that is committed to does not require states to unquestionably accept common ideals or renounce sovereignty; limits are present even if they do not need to be openly stated. However, there is often an important longer-term commitment, beyond any state administration period, in that there is an innate anticipation of future need for continued cooperation. Given the long-term nature of global SMPs, described in section 2.2 (Case Study Selection Justification), this is a stance that has direct relevance to this thesis.

3) *regimes can help facilitate agreements and decentralized enforcement of agreements among states*. Keohane maintains that regimes are practical arrangements motivated by rational self-interested state actors to make mutually beneficial agreements. Keohane later (1986) edited *Neorealism and its Critics* that sought to reformulate the early thinking of Waltz. Keohane marshalled the various criticisms that had been levelled at the earlier work by the proposal of devising theories of new international institutions or regimes and challenging the validity of the state as main actor. I return to this notion in sub-sub section 1.1.3, Regime Theory.

4) *policies followed by one state are regarded by its partners as facilitating realization of their own objectives, as the result of a process of policy coordination*. This last point is utilised by Keohane as a formal description of when cooperation occurs and includes the idea that effective cooperation must be distinguished from utopian harmony. I discuss this further in the 'primacy of the state' part of sub-sub section 1.5.1., Analytical themes in the literature.

A distinguished critic of the importance of anarchy within the above neorealist description is Helen Milner who identifies the 'discovery of orderly features of world politics amidst its seeming chaos' as 'perhaps the central achievement of neorealists.' She goes on to assert that the whole idea of anarchy has been overemphasised while necessary interdependence has been neglected. The key word here is 'necessary' and its significance is more pertinent now than when Milner wrote it in 1991. In the ever-growing connectivity and interdependence that David Held and Antony McGrew describe in *Governing Globalization* (2002) there are a rising number of economic, environmental and political problems that cannot be addressed by a single actor. This is true even when some actors do not recognise it and irrationally try to operate alone or simply ignore the causal problem. I will show in sub-section 1.3.2 covering science diplomacy literature, that the acceptance of 'necessity' comes naturally to the SMP communities and is one of the central reasons for their success.

Robert Keohane and Josef Nye expanded neorealism into what they argued was the better theory of neoliberalism, encapsulated in *Power and Independence* (1977). In it they explored the politics of economic interdependence and their analysis contained three principal themes, which they later observed in *Power and Independence Revisited* (1987) their first work had not explicitly distinguished from one another. Firstly, a power-oriented analysis of the politics of interdependence, drawing on bargaining theory. Secondly, an analysis of an ideal type that they call *complex interdependence* and the impact of the processes that it encompassed. And thirdly, an attempt to explain changes in international regimes which they defined as 'sets of governing arrangements that affect relationships of interdependence'.

With these criticisms and their rebuttals, the debate on neorealism since Waltz has been on the boundary and interactions between the system and the unit level states. In the *Logic of Anarchy: Neorealism to Structural Realism*, Barry Buzan, Charles Jones and Richard Little (1993) point out that Waltz confines interactions to the unit level and that this diminishes the explanatory power of his theory. They credibly argue that interaction capacity stands as a third level of analysis, on par with units and structure; this thought weakens neorealism's original logic. Another flaw in Waltz's work that they reveal is that neorealism cannot explain the beginnings of an international system. It presupposes that a system exists with sustained, relatively sophisticated interactions spanning the globe, and why or how this communication arose is neglected. This does not match with what we see in the world and strengthens the case for the development of the structural realist paradigm.

James Dougherty and Robert Pfaltzgraff (2001) in their commentary of Buzan, Jones and Little effectively argue for the broadening of neorealist theory to cover competition and collaboration. In the political world system of today, nations develop alliances, coalitions, regimes, norms and institutions for a complex number of reasons including critical international collaboration. Sovereignty does not mean that anarchy is incompatible with cooperation when it is logical to do so; I discuss sovereignty issues further in sub-sub section 1.1.4., International Organisations. The expanded neorealist theory also introduces the idea that it is the domestic structure of states, together with the international systemic level of interactive capabilities that shapes the capacity of the system. I will show that this is directly supported with evidence from the case studies where the central IGOs must regularly take diverse approaches with different departments and ministries in the member nation states on the same topic.

These enhancements and the adding of needed complexity tolerate more change in the system than neorealism allows. Buzan, Jones and Little conclude that structural realism's foremost contrast with neorealism, therefore, lies in its renewed emphasis on the role of interactions wherever and between whoever they are necessary and occur in the system. Another interaction related development of neorealism that is relevant to this thesis is the proposition that states pursue goals in one arena that affect their pursuit in another arena. States may also attempt to solve domestic problems through actions at the international level. The combination of strategies is logical to leverage the best advantage possible for a given effort. This neoclassical realist theory acknowledges and seeks to explain the strategies of individual states and the fact that complex patterns of interactions can be in play in many arenas simultaneously (Lobell, Ripsman and Taliaferro, 2009).

The relevance here comes out of the reminder of a basic assumption of realism that 'states must constantly guard against actual or potential threats to their political and economic independence and that national security is always the principal concern' (Waltz, 1979). While national security is not directly the concern of nations in their agreement to participate in global SMPs, what *is* at stake is fundamental scientific *knowledge* that history tells us in many cases will in time affect economic and security issues. For example, in policy decisions that will help protect energy supply (ITER dependent) or superconducting materials know-how, computing expertise, hadron cancer therapy and the world-wide web that are all bi-products of high energy physics research (CERN dependent) or physiological findings, biotechnology techniques and advanced materials data that stem from lengthy micro-gravity exposure (ISS dependent). This is therefore a model example of the application of neoclassical realist theory: it is the need for *knowledge gathering* that is the driver for the collaboration. A need not borne out of unplanned interest but the inescapable facts that nations can only partly and/or more slowly achieve knowledge gathering alone and cannot neglect the area of concern or risk losing out in other fields that may in the longer term significantly affect national economic outcomes and thereby national security. I return to this notion of the nation state version of the social anxiety syndrome of the 'fear of missing' out when considering the political setting leading to nations agreeing to collaborate in each of the case study chapters.

When faced with long-standing, seemingly intractable and complex problems that the global SMPs must tackle, even the most powerful state, the USA, is governed by the multi-polar world that is eloquently described by Waltz. I will show, in sub-section 1.4.2., on SMP project management, that the SMP founding agreements are painstakingly negotiated. This is not least because of the need to accurately balance the sharing of power, economic risks/opportunities and reputational risks/opportunities with the state's financial commitments.

In summary, neorealism theory takes forward classical realist theory and its impact is pervasive and enduring. It has raised attention to the structural characteristics of an international system beyond the mere consideration of its component parts. However, scrutiny by leading critics has revealed several flaws including the focus on structure ignoring the formulation of systems and the limits of power. Recent neoclassical realist theory better matches real-world international relations, including SMP communities, by acknowledging domestic considerations, cooperation and competition between states. Relevant to this thesis is the notion that nations state's long term strategies mean efforts in one system are purposely undertaken to strengthen a nation's position in another. I will develop, in the case study chapters, how the SMP communities' science diplomacy systems interrelate with other international relations sub-systems such as energy policy, economics and national security.

1.1.3: Regime theory

This sub-sub-section will firstly outline what is meant by the term and identify its key exponents. It will then describe the arguments that have led many neorealist and neoliberal scholars to embrace regime theory before remarking on criticisms of the idea. The summary includes an appraisal of its relevance to this study.

International regimes encompass global issue areas as diverse as defence, trade, monetary policy, law, transport and the environment. Donald Puchala and Raymond Hopkins (1983) suggest that they can be categorised by function on specific issues through to multi-issue areas. This wide range of application demands a broad definition for international regimes which Stephen Krasner provides as principles, norms, rules, and decision-making procedures around which actor expectations converge in each issue-area (1982). Stephan Haggard and Beth Simmons point out that this form of words cleverly achieves a middle ground between order and explicit commitments while stressing the normative dimension of international politics (1987). Krasner obligingly expands on the terms as follows: principles represent ‘beliefs of fact, causation and rectitude’, Norms are ‘standards of behaviour defined in terms of rights and obligations’, Rules are ‘specific prescriptions or proscriptions for action’ and decision-making procedures are ‘prevailing practices for making and implementing collective choice’. Notably, this definition does not limit membership of regimes to states alone. I will show, in section 3.1 that this has direct bearing on this thesis where the CERN community invites organisations to have observer status in its central IGO.

The literature on international regimes significantly enlarged in the 1970s and 80s when scholars acknowledged that international collaboration was not limited to formal IGOs such as the UN but spread across several domains and constituent bodies. Key exponents and their major works include John Ruggie (1975), Stephen Krasner (1982, 2001 and 2009), Ernst Haas (1980) and Oran Young (1980) who later with Keohane took a challenging neoliberalism stance. Leading critics of regime theory include Susan Strange (1982) and followers of Hedley Bull’s interpretation of the international system (1977). Exponents’ and critics’ key works will feature in the following discussion.

Krasner delineates two differing approaches to regime significance within international relations. The first is the idea of regimes as ‘modified structural’ phenomenon whereby an international system of functionally symmetrical, power maximising states act in an archaic environment. In these circumstances, regimes arise only when individual state decision-making fails to secure desired outcomes. The basic causal variables for the formation of regimes therefore firmly remain power and self-interest. This position is well supported by respected international relations academics such as Arthur Stein, Robert Keohane and Robert Jervis. The second approach moves beyond the core realism perspective and introduces the idea that regimes do not form and operate by accident or by some short-term crisis-led need but are the inevitable consequence of a logical and predictable collaboration. Supporters such as Raymond Hopkins, Oran Young and Donald Puchala, point to the multi-faceted factors that play a role such as interest, power, diffuse norms, customs and knowledge. They maintain that elites are the practical actors operating in an interconnected net that embodies their own rules, norms and principles and most certainly transcends national boundaries. I will also show that elite networks also feature, to a limited degree, in epistemic groups at the centre of the SMP communities.

To see how the literature sits within this thesis it is useful to deliberate which of the above two approaches provide the most worth in explaining the regimes that host the case study IGOs. I will do this by considering in turn Krasner's five causal factors for regime development: 1) egoist self-interest, 2) political power, 3) diffuse norms and principles, 4) usage and customs and 5) knowledge.

The modified structural proponents cite the ***egoistic self-interest*** causal effect as the prevailing explanation of international regimes; it is a powerful argument as there are clearly times when rational self-interest calculation leads actors to abandon independent decision making in favour of a joint approach (Stein, 1982), the caveat being that the coordination need not necessarily be formalised or institutionalised and can operate in a semi-hidden way within already existing structural arrangements. The backers see regimes as the inevitable pervasive characteristic of the international system and that they are more common under conditions of complex interdependence that do not preclude self-interest but accommodate it within carefully crafted negotiated agreements (Young, 1982; Cohen, 1982). My thesis supports this argument and will show that it fits well with the SMP paradigm.

The second major causal variable for the development of regimes is that of ***political power*** which Krasner distinguishes between 'in the service of the common good' versus 'in the service of specific interests'. This is a complicated topic that involves leadership, markets and macro-economic factors amongst others. Stein, who is in the modified structural camp of regime theorists, provides a compelling argument that the international system more closely resembles an oligopoly than a perfect market (1982). State actors are aware of how their behaviour affects others as their foreign policy experiences will have either borne diplomatic acclaim or brickbats. Smaller states are also observant when a hegemon is no longer willing to offer a free ride within an existing collaboration and are likely to change behaviour and either become paying members or leave. This leads to a conclusion, supported by this research, that hegemonic decline can lead to stronger regimes where actors are more equally bound by shared costs and potential benefits. There is an important caveat however that Keohane describes in chapter 9 of *After Hegemony* (1984): the incomplete decline of hegemonic regimes. The US has observer only status at CERN and a low proportion of the workshare of the ITER project; nevertheless, I will show that its participation in both is key. The latent hegemonic status remains undimmed in the SMP governance arena, due to the strength and reputation of the US science and technology base, and this adds kudos and influence [for all the Members] to any collaboration it chooses to join. US involvement also reduces the perceived and/or real threat as a potent rival that could otherwise entice away scarce talent and resources.

The idea of ***norms and principles*** being a factor in the creation, persistence and development of regimes leads to an interesting argument that actors will invariably find ways of collaborating with other like-minded actors. Informed by the Grotian tradition the supporters of the pervasive characteristics of the international system, point to several examples where shared norms and principles have held sway. For example, John Ruggie's analysis of post-war economic regimes argues that it was founded on entrenched liberalism (1975). The modified structural approach to regimes would reason that sovereignty is the current overriding principle that influences the behaviour of actors (Bull, 1977) and that other actors' assertions lack principle, are temporary and subject to challenge. This causal variable has direct relevance to understanding the SMPs and I will take this up later in the sections on leadership in the individual case study chapters.

Usage and custom are considered by Krasner as not prevailing conditions for the development of regimes but rather supporting factors. 'We have always done things this way' can reinforce self-interest of dominant states over less powerful ones but would hardly be a convincing manifesto for any new relationships. Oran Young hints that transactional set-up costs in terms of the time and energy spent by negotiators are certainly reduced when the norms and customs of the actors are well known (1982). Once in operation, regimes can generate their own *usage and custom* protocols that become legitimized through longevity and positive outcomes. For example, informal arrangements regarding meetings can become formal protocols that support governance and voting rights in SMP community forums; this will also be expanded on in the governance sections of the case study chapters.

Ernst Haas positively asserts that ***knowledge*** can enhance the prospects for convergent state behaviour and transcend prevailing lines of ideological cleavage (1980). In an era when expert advice has been shunned by some politicians the reminder of the importance of knowledge is timely. Stein uses the example of international health regimes regarding quarantine regulations being led by consensus scientific knowledge. Benjamin Cohen points out that the fixed exchange rate mechanism central to the formation of the Bretton Woods financial institutions was based upon knowledge within the US domestic institutions who had learnt from the interwar economic experience (1982). In the same way as with usage and custom, knowledge may well not be the driving variable when considering regimes, but it will certainly affect the more prevalent variables of economic self-interest and political power. This variable also has direct relevance to SMPs as knowledge is seen by the communities as their main deliverable to the Members; indeed, they describe it as what they are in business to create. I will develop this further in Chapter 6, Research Results.

Regimes theory also has at its centre the concept of natural longevity once they are established; for example, Krasner maintains that regimes should be understood as more than temporary arrangements that change with every shift of power and interests (1982). Jervis agrees with this idea of the longer-term approach: 'the concept of regimes implies not only norms and expectations that facilitate cooperation, but a form of cooperation that is more than the following of short-run self-interest (1982)'. With this longer-term commitment to cooperation comes a need for changed behavioural considerations. For example, in security regimes Jervis raises the principle of reciprocity. Krasner recognizes that it is this infusion of behaviour with principles and norms that distinguishes regime-governed activity in the international system from more conventional activity guided exclusively by narrow and often short-term calculations of national interest. The notion of longevity applies directly to the SMP communities' model whereby they have been in existence borne out of a bottom-up need for collaboration between experts within epistemic groups. I will show, in the case study chapters, that they are therefore measured and mature in their dealings with each other and in their consideration of the tactics to take with those outside of their communities.

Susan Strange's criticism of regimes as an explanation for collaboration between states is that the core concept is too simplistic (1982). She argues that it ignores vast areas of non-regime behaviour in the world market economy where classic realism dominates states, NGOs and MNCs decision making. Her stance is that regime analysis is on the one hand too optimistic in overvaluing the positive aspects of international cooperation [for example in a few successful UN agencies] while on the other hand undervaluing the reality of there being more areas of nonagreement and controversy [for example in international migration and security issues]. Finally, she argues that the trend, driven by the integrated world economic system, is away from regimes being any kind of panacea to greater international collaboration and that a return to thinking along the lines of Hedley Bull's 'Anarchical Society' is more appropriate (1977). This research supports her analysis, but only to the extent that understanding the bargaining and trade-offs that nations reach is at least equally as relevant as understanding the form of the regimes in which they operate.

In summary, this sub-sub-section has provided the commonly accepted definition of regime theory and reminded us that membership is not exclusively for nation states. The leading exponents and notable critics and their respective sets of work have been recognised. The longevity of regimes with consequential changes in collaborative behaviour has been contrasted with classical realism theory. Stephen Krasner's two different approaches to regimes were described: modified structures and the ideas of regimes being an inevitable pervasive characteristic of the international system.

Krasner's five casual factors were then used as an analysis vehicle to see how this research sits within the two approaches of the overall theory, as follows:

1) It is understood that ***egoist self-interest*** is accommodated within the negotiated SMP agreements with work-share often based on relative contributions;
2) Hegemonic decline can lead to stronger regimes where the ***political power*** of SMP actors is more equally bound by shared costs, risks and potential benefits;
3) SMP actors find a way of applying their common ***norms and principles*** to overcome obstacles to collaboration;
4) SMP forums operate within formal and informal arrangements where the wider science based epistemic community's ***usage and customs*** hold sway and
5) The search for ***knowledge*** is the SMP's raison d'être and main deliverable to the funding members and their respective institutions.

Finally, a key criticism of the regime idea - as being too simplistic an explanation for the current state of the international system - was analysed. I concluded that understanding the, somewhat neglected, set-up arrangements were important, but this did not undermine regime theory having a role in understanding SMP communities.

1.1.4: International Organisations

This final sub-sub-section on theory regarding global collaboration considers the literature surrounding *International Organisations*. Firstly, I will outline which type of *International Organisations* are being considered for this study. Two parameters will then be used to examine the rise of *International Organisations* in the global system since World War II. Finally, I will then explain the general difficulty academics face when studying International Organisations together with how contingent realism theory can be regarded, through examination of sovereignty and globalisation themes, to assess relevance to the thesis.

For the purposes of this study I have limited the consideration of International Organisations to those that are established by treaties, agreements or conventions signed by states. In other words, *intergovernmental* institutions or *intergovernmental* organisations (IGOs). Also, I am considering here only IGOs that are inclusive (i.e. members are solely concerned about collaborating) rather than

IGOs that are exclusive (i.e. where members are equally concerned about who they will *not* collaborative with, as with military alliances such as NATO).

Even with the above delineations, the remaining sub-field of IGOs is vast. It includes the UN with its six principle organs and numerous specialised agencies and bodies, the Bretton Woods financial organisations, the EU and other regional political and trade collaboration IGOs, environmental IGOs, energy and nuclear power IGOs, educational and cultural IGOs and many other specialised IGOs. The field also covers scientific IGOs including the case study SMPs. As Samuel Barkin points out, when we then consider in a matric fashion the wide areas of human endeavour such as peace, security, human rights, economic, environmental, etc., that the multitude of IGOs cover, the task of analysis of this multifaceted tapestry is daunting (2006). To focus the analysis and given that I have already deliberated regime theory, the analysis in this sub-sub-section will consider the *accomplishments and failures* of IGOs and the *sovereignty and globalisation* issues affecting their performance.

Accomplishments and failures of IGOs will first be addressed by considering the foremost of them all. Critics of IGOs often point to the unqualified failure of the League of Nations, founded in the aftermath of the World War I. The ‘war to end all wars’ was marked by its immense scale of destruction and loss of life. Remarkably, in the aftermath of the second global conflict the League of Nations was disbanded only to be replaced with an even more ambitious United Nations whose primary goal was to deal with international peace and security issues; just as its predecessor had self-evidently failed to do (UN, 1945).

However, on this occasion, the catastrophic effects of total war led to widespread agreement that *comprehensive* international collaboration and global governance was required. The UN system, as it has become known, was set up to cover a range of activities that taken together the founders considered were essential to effectively tackle a panoply of pressing global issues. This study will not analyse the relative successes, failures and modest reforms of each of the UN organs and subsidiary agencies. I judge that the overall aim, of maintaining world peace, that the UN founders desired has been met. While there have been major proxy wars during the cold war stand-off (such as the Korean War, 1950-53 and Vietnam War 1954-75), regional conflicts that involved several states (such as Gulf War I, 1990-91) and several hard-fought conflicts such as the Ukrainian crisis that began in 2013 and lingers on today, there has been no outbreak of a World War III.

The Union of International Associations provide an annual yearbook (UIA, 2017) which records the inexorable rise in number of IGOs since World War II to the point where several thousand now operate in every area of human activity. The UIA data reveals that the creation of IGOs has levelled off since the mid-1990s. Hale and Held (2017) suggest this is due to a combination of factors including that global governance functions are now also performed by a wide range of actors and institutions beyond IGOs. Legro and Moravcsik (1999) argue that realists have struggled to reconcile their classic interpretation of rationality, prudence and self-interest with the emergence of harmony of state interests, epistemic cultures and the power of altruistic motivations that often lead to the establishment of IGOs. At best, realism has been stretched to fit inconvenient truths while ignoring more subtle explanations of nation's contemporary need for collaborations.

Realist and neo-realist theory have maintained that international institutions reflect existing structures including the relative power and capabilities of the state actors. Josef Grieco maintains that smaller states join international organisations to leverage their relative power compared to larger ones and that this is a self-interest accomplishment (1996). Contingent realism theory takes a more positive stance, for example Charles Glaser contends that international institutions can play an important role in reducing or minimizing security problems (1995). To understand which of these two stances better fits current practice, within the UN context and outside it, I will consider to what extent IGOs replace states when acting on global issues. In other words, to what degree - *if any* - is sovereignty forfeited by states to IGOs, especially set against increasing pressure from globalisation.

Robert Gilpin explains how the realist interpretation of IGOs makes several assumptions regarding the nature of international affairs (2002). The most basic of these is that the international system is anarchic and has no higher authority over states; *sovereignty* reigns supreme. Certainly, sovereignty's roots are strong, and the principle of sovereignty is embedded in state legal systems and even retained to a limited degree in ritualistic monarchies within democratic societies. Evans and Newnham highlight that the UN Charter explicitly acknowledges 'sovereign equality' of member states while exulting them to settle their disputes peacefully (1998).

The sovereignty concept has been steadily eroded in modern times by two main factors. Firstly, numerous failures of conventional sovereignty arrangements, through the four factors that extensive research by the CIA funded, Political Instability Task Force (PITF) identified: revolutionary war, ethnic wars, adverse regime changes and genocide, (Goldstone, et. al., 2010). The second eroding factor has been the rise in *globalisation;* a topic that I will limit here to consideration of the exercise of power. David Held, Anthony McGrew, David Goldblatt and Jonathan Perraton contend that globalisation concerns the expanding scale on which power is organised and exercised. In their introduction to *Global Transformations* they contend that the stretching of power relations means that sites of power and the exercise of that power become increasingly distant from the people and locales that experience the consequences. In other words, globalisation involves the accommodation of power relations at a distance (Held, et. al., 1999). This research will show that this has a high correlation to the experiences of global SMP communities and that their central team's mastery of this distance *vis-à-vis* real power arrangement is part of the reason for their success.

Despite occasional partial adoption [for example, as will be shown in the case study chapters where states in SMP communities only give up their power to a limited degree], overall the stubbornness of active supporters of the principle of sovereignty have repelled any telling breaches of national power by supranational entities. The success, to date, of national movements in Europe to curtail EU federalism is an example of this robust defence. Krasner (2009) explains the continued triumph of the sovereign state by two factors: the breadth of the state in terms of its links with other social entities and the depth of the state reflected in the concept of citizenship and national identity.

The limits of national jurisdiction and sovereignty are under constant debate in several international arenas including the demarcation of global commons such as the deep oceans, the atmosphere, outer space and the Antarctic (Stang, 2013 and UN, 2015). In this thesis I will show that the sharing of sovereignty only applies in the joint legal responsibility that the SMP agreements strictly require to make their communities work effectively together. I will provide evidence that the SMP IGOs are established as legal entities to allow contracting to be undertaken and regulatory responsibilities to be satisfied, but there is no broader or deeper constitutional independence granted from the member states. The SMP communities only transcend national sovereignties in a few essential operational areas even ironically in the highly globalised fields of work they undertake.

This absence of doubt regarding the level of delegated authority between the central organisation and member states is purposeful and well thought out. Theoretical opinions as to the nuanced levels of state control that are given up and those elements that are retained may be intellectually enriching but have no place in the real world of SMP construction sites. The nature of the detailed and complex tasks means that *there can be no ambiguity - as is the case with some political IGOs - over where the power lies.* This conclusion is in line with that of Krasner (2001) where he contends that globalisation is gradually changing the scope of state control but not undermining it completely.

In summary, this sub-section has outlined that it is IGOs that are established by treaties, agreements or conventions signed by states that are considered in this thesis. The resultant IGO field is vast and to narrow the focus I considered *accomplishments and failures* and *sovereignty and globalisation* issues when considering their performance. I briefly outlined the formation of the UN, the Bretton Woods Financial Institutions and the rise in IGOs up to the more recent plateauing of growth.

The erosion of the concept of sovereignty was examined together with the effect on IGOs of increasing globalisation. The discussion determined that the notion of sovereign state has endured even within the, some would claim, relatively utopian global SMP community's context. This thesis will reinforce the conclusion that while globalisation is undoubtedly changing the scope and boundaries of state control it is not undermining it completely. This conclusion will be supported in the case study chapters by my analysis of the specialist literature including founding documents, IGO conventions, treaties and agreements.

Section summary

By comparing the review of the literature in the four areas of realism, neo-realism, regime theory and IGOs with respect to this study, I will now draw out common themes and differences.

In common is that the power of states, as expressed within both the classic realism and more structural neo-realism frameworks, triumphs in the SMP community context. While there is certainly a surrender of sovereignty to the highest levels of management within the SMP IGOs, this is only to the basic limits necessary to exercise operational control over the projects. *Primacy of the state* is the first of the three predominant themes in the literature (summarised in sub-section 1.5.1).

A difference is that the operation of SMPs align much more with modified structural neo-realism than with classical realism theory. The seven members of the ITER project often interact and correspond, both at technical and managerial levels with an eighth entity: the central ITER IGO. I will show that this central body has a respected view and legitimacy around the table with the seven members but is ultimately subservient to them; for example, lingering disagreements may ultimately be referred up to the highest governing body, the ITER Council which the members control. Due to their size and reach, SMP IGOs often interact with different domestic departments within states. I will also show that state actions with SMPs can be to intentionally influence their competitive edge with other states in other domains. My position therefore is that we must go beyond neo-realism theory and consider modified structural neo-realism concepts to fully understand and appreciate the nuances of global SMP communities.

Another notable difference I will show is that SMP communities do not readily fit into either the conventional ‘modified structural’ or ‘inevitable evolution’ approaches to regime formation that Krasner describes. Global SMP IGOs are by no means predictable outcomes to address wicked problems. I will show that they are more often formed out of ripe political moments combined with visionary leadership within epistemic groups that have members with shared visions and values. They are structurally highly complex, with founding arrangements having to consider social, economic and power dynamics in addition to the scientific and technical challenges and workshare arrangements. The leadership provided by elites within SMP networks play a part in the founding processes, as predicted in the regime theory expounded by Puchala and Hopkins (1983). Crucially, this thesis will reveal that the global rules, norms and principles these elites, with the aid of other experts, agree are not limited only to their areas of scientific or technical expertise but also cover broader collaboration protocols.

There are several common elements between regime theory and IGO studies that the analysis using Krasner’s five regime casual factors exposed. The painstakingly negotiated SMP agreements accommodate self-interest and political power. I will show that these manifests themselves in the governing bodies voting arrangements and how valuable [in scientific communities this is often referred to as *noble*] work is fairly shared between the parties. Another common element is how the value of *knowledge* that is created within the SMPs is respected by the members and that its openness and distribution match best practice in IGOs in other fields.

A difference between regime theory and IGO practice also concerns *knowledge*. The search for knowledge is the SMP IGO’s *raison d'être* and core deliverable to the funding members. States understand that improved knowledge emanating from the SMP IGO’s may well have knock-on effects in other important national-interest areas. Performance in this knowledge gathering arena affects the relationship with the members and provides a positive and stabilising force that goes beyond more mainstream IGOs who must concentrate on their more subordinate coordinating role. I explain this idea - of the meaningful nature of SMP community activities - more fully in each the case study chapters when considering their organisational cultures.

1.2: Global Gridlock Issues

This section of the literature review examines the relatively new gridlock phenomenon; the topic that has particularly informed this study. The review will cover the work of leading academics in the field including plausible solutions that they have tabled together with literature that provides counter arguments to the standard views.

The wide range of topics that are confronted with these issues is illustrated by the *Beyond Gridlock* chapter headings: Finance, Monetary Policy, Trade, Investment, Energy, Humanitarianism, Human Rights, Health, Climate Change, Cyber Security and Weapons of Mass Destruction. They have different consequences in different settings where, as the subject matter expert authors explain, they also often overlap. However, the four pathways to gridlock that Hale and Held's earlier work in Gridlock (2013) identified: multipolarity, institutional inertia, harder problems and institutional fragmentation run through all the topics. Another common feature is that the difficulties stem at least in part from previous cooperation between states that perversely increase vulnerability to gridlock, in that when proven channels of communication and cooperation dry up, further routes are not readily available. The issues at hand in each topic are also complex and hampered by globalisation, stalled international negotiations, resurgent nationalism and growing differences in national interests.

In the introduction I highlighted the view of the world as 'overlapping communities of fate' that David Held demarcated in *Global Covenant* (2004). I pointed out that it is this world that needs effective GSNs if gridlock is to be combatted. Another aspect of this is that when GSNs are ineffective or late in being employed then the problems that they seek to address may deepen. This is because unmet challenges are prone to be exploited by leading populists who encourage anti-globalisation attitudes, a self-reinforcing cycle of negative events then ensues, captured by Figure 2:

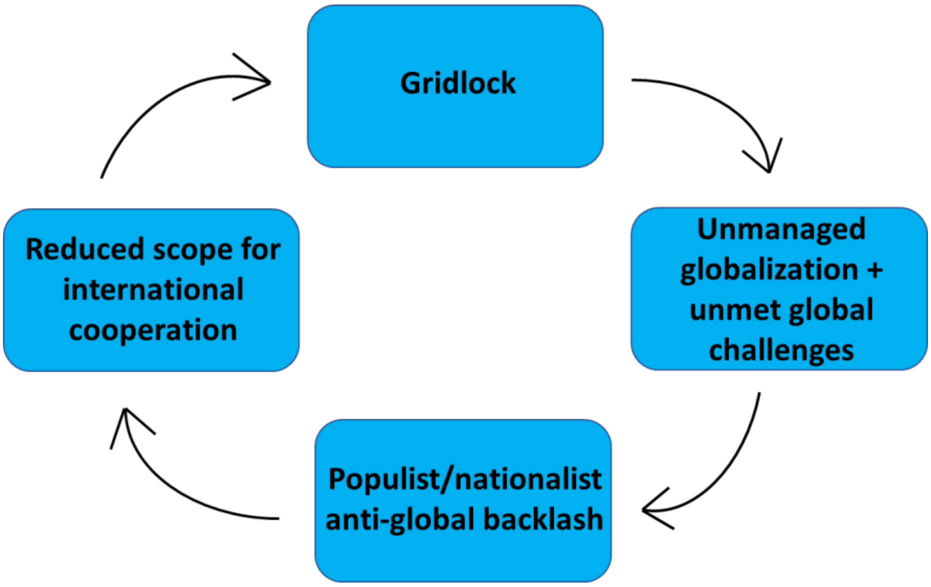

Figure 2; Self-reinforcing gridlock (Hale and Held et al., 2017)

Dissenting academic voices, such as Daniel Drezner, Professor of International Politics at Tufts University, have disputed the consensus gridlock view and argue that the global system *is* working (2014). Drezner maintains that the liberal financial world order system represented by the G20, WTO and IMF have many defects but is still performing not least by limiting damage to national economies during periods of crisis. The crux of his argument is that the great depression of the 1930s ended with no expert consensus regarding how to reinvigorate the global economy. In contrast, the aftermath of the 2008 financial crisis witnessed strong consensus on recovery steps and prevented a deepening of problems. While this has a certain logic, what cannot be denied is that the financial institutions, despite all their knowledge systems, inspection regimes and highly qualified and highly remunerated personnel, failed to predict and take preventative measures to the crisis itself. Counter-evidence, such as that espoused by Drezner, is collated and examined in section 6.1 of the Research Results chapter.

Equally troubling to the difficulty in finding pathway solutions is the fact that the detrimental effects of global gridlock are more pressing with each passing year and there is an urgent need for global coordinated actions that cannot be resolved by domestic actions alone. Gridlock studies then are undoubtedly of the moment and being pursued world-wide by both academics and practioners. In the UK, the University of Oxford and London University have leading scholars engaged in research as do the University of Massachusetts Amherst, Princeton University and Harvard University in the USA. Pascal Lamy former Chief of Staff for the President of the European Commission and former WTO

Director-General has been one of the leading practitioners involved in seeking to improve global governance through gridlock studies (Globalist, 2019).

Studies of potential pathways that the *Beyond Gridlock* authors analysis show the complex processes required to reach effective governance in each of their specialist areas. Their research is analytically sound, is based on robust reasoning and leads to recommendations on policy solutions that are operationalizable. Seven pathways and their mechanisms are explored: 1) Shifts in major powers' core interests, 2) Autonomous and adaptive international institutions, 3) Technical groups with effective and legitimate processes, 4) Multiple, diverse organisations and institutions coalesce around common goals/norms, 5) Mobilization of domestic constituencies for cooperation and compliance, 6) Civil society coalitions with reformist states and 7) Innovative leadership as a reaction to gridlock.

During this research a further pathway has emerged. As I mentioned in the introduction, the widespread *modus operandi* of science mega-projects is that they rely on Members' in-kind contributions as well as cash payments. The in-kind contributions system has several advantages to the Members, including keeping the majority of the spend in their own territory and enhancing the professional and social capital of the Member's companies, scientists and engineers. Consequently, I propose that 'Innovative Funding' be added to the seven above pathways as a new, eighth, pathway. The full argument for this is made in sub-section 6.3.8. of the Research Results chapter.

1.3: Science Diplomacy

This section concerns the relatively new sub-field of science diplomacy within international relations and is divided into two parts: firstly, I will outline how science's role and standing in society has developed since the emergence of modern science in the 19th century. Secondly, I will explain how the science diplomacy topic is organised and where this thesis fits in to that topography. *Science diplomacy* is the second of the three predominant themes in the literature that are summarised in sub-section 1.5.1., Analytical themes in the literature.

1.3.1: Science in society

This necessarily brief run through the history of modern science collaboration is to show how the interactions between science and broader society have led to the time being ripe for the former to contribute to the debate of how we find a way through the problems the global system faces. This section, in keeping with the basis of this thesis, will not examine scientific advancements *per se* but rather the means of collaboration that facilitated them.

Although the term *science diplomacy* may seem new, science has played an influential role in society beyond its important first-order results since the Age of Enlightenment. John Henry (2008) explains that European court entertainers of the middle ages fashioned impressive spectacles for their royal families. They often utilised mirabilia machines to disguise the true mean of surprises that left their audiences entertained and asking for more from the colourful protagonists. The upsurge in the systematic knowledge of nature throughout the 17th and 18th centuries resulted in entertainers being gradually replaced by more serious individuals who could provide explanations to natural events to affluent patrons including royalty who desired to be knowledgeable and desired to be seen as knowledgeable by the general population. These newly termed scientific advisors could then prosper in a privileged setting that allowed ideas to be shared and where they could inform their peers of progress through lectures and publications.

A wealth of history of science literature including Kuhn (1962) show us that during the Scientific Revolution the nature of scientific change that had begun as an argument to counter philosophical claims became one itself. For example, Malherbe shows that Francis Bacon (1643-1727) characterised the new science philosophy with an insistence that knowledge should be used for the benefit of mankind rather than exclusive individuals or even exclusive nations (1996).

Knowledge of science to quench curiosity and support military capability became increasingly accessible to monarchs, governments and wider society. This increased availability had a mixed reception: Hooykaas (1973) provides a study of the strained relationship between theology and early modern science where spiritual leaders often resisted new ideas. Olson (1991) on the other hand provides a survey of how discerning recipients, such as those dealing with the production of wealth via commerce, readily embraced what science could offer. As the fields of natural science (chemistry, astronomy, earth science, physics, and biology) explored ever more intractable problems the need for collaboration steadily increased; I will revisit this in the 'Diplomacy in Science' discussion below. The scientific community organised itself into networks of researchers who tackled progressively harder problems by sharing ideas, results and the investigative effort itself. The Royal Society of London spawned a succession of other societies who marshalled the efforts of specific scientific domains to form collaborations and perform research within their respective communities (Ornstein, 1938).

Spurts in scientific knowledge and influence were also borne out of major armed conflicts. From the mathematical models of catapult trajectories (middle ages), the chemistry of lethal gas weapons (World War I), the physics behind the atomic bomb (World War II), the geophysics of satellite surveillance (Cold War) and the energy science of laser weapons (today); scientific teams have often played leading roles. Setting aside moral dilemmas, national teams certainly delivered results that were then readily taken forward into fruitful peacetime collaborations when periods of conflict ended. For example, the US Jet Propulsion Laboratory in Pasadena, California employed several leading German scientists expatriated from the World War II V1 and V2 ballistic rocket projects (Bender, 2014 and Launius, 2018: 50).

This need for interaction between like-minded individuals and groups to tackle difficult issues was not unique to science. It was increasingly relevant in other fields where lone participants and even lone nations could not succeed. At first this inter-governmental cooperation was needed to facilitate growth and wealth with international bodies created to set and govern trade, trade routes and regularise the means of distribution. Nations collaborated where their national interests benefited from that alliance often to exploit lucrative markets by dividing up the spoils rather than fighting over them. As problems then emerged that also spanned national borders the need for intergovernmental collaboration to tackle them was also self-evident. Anne-Marie Slaughter (2004) takes this further with the idea that in the 21st century, inter-governmental networks are increasingly *required* to counter 'networked threats' to global issues. I will show that this theme of necessity to cooperate is a major driver to the formation of SMP IGOs.

Science ventures have repeatedly overturned the reluctance of Nations to cooperate and there are several tangible illustrations of successful scientific GSNs. Their routes to formation may vary but in common is the tight coalescence of national, international and non-governmental science groups around global issues of concern. Threats to global health posed by infectious diseases outbreaks such as the 2014 Ebola crisis are tackled by the WHO but only through the support of trans-governmental medical networks. The Medecins Sans Frontieres charity, International Red Cross and several other bodies cooperate in the field and share local and regional knowledge. They stay operationally up-to-date, effective and functional and have well proven associations with IGOs such as UNICEF and other UN agencies. Literature, such as the UN WHO Expert Panel Report *Protecting Humanity from Future Health Crises* (UN, 2016), shows us that in major medical emergencies more depth of knowledge and new solutions are often urgently needed but this is achieved through established and already functioning epistemic community networks rather than by the creation of any new entity. In the aftermath of such events it is also the joint conclusions of these community networks - rather than the WHO alone - that provide preventative strategy policy advice to governments; such as the US National Academy of Sciences Expert Group report on the optimal control of Ebola outbreaks (PNAS, 2015).

Kristen Lord of George Washington University and Vaughan Turekian of the American Association of Science co-authored a policy paper in Science (2007) that advocated it was *Time for a New Era of Science Diplomacy.* In it they argued that 'nongovernmental scientific organisations and individuals are more credible, nimbler and in many cases more respected than the US Government overseas'. They led a call to arms to the US scientific community in the wake of the recommendations of the 9/11 Commission Report to engage foreign public opinion through their actions. They cited three reasons why US scientists should be willing ambassadors at large. Firstly, they use the ITER Project as an example of how diplomacy benefits great science by forming iconic projects that could not be undertaken without the broader access they bring. Secondly, they asserted that as the health of the national scientific community depended on the willingness of foreign scientists and students to come to the US, every US scientist should play a part in ensuring that was an attractive prospect. Thirdly, they reminded readers that scientists are citizens too and share wider concerns about negative perceptions of the US abroad and were uniquely and fortuitously well placed, through widespread respect for American Science and Technology, to positively influence those perceptions.

1.3.2: Types of Science Diplomacy

The traditional Natural Sciences specialisations do not provide a ready fit when we consider *science diplomacy*. Appendix A, Selected Overview of SMPs and their Communities shows that global science projects feature in each of the classic natural science domains. Diplomacy scholars have long recognised that *science diplomacy* considerations span these domains and need fresh demarcations if they are to be understood, studied and enhanced. However, as Emmeline Ledgerwood and Sarah Bunn (UK Parliament, 2018) point out the term *science diplomacy* has become more common since the Royal Society and American Association of the Advancement of Science (Royal Society, 2010) joint paper *New Frontiers in Science Diplomacy*. The paper was the result of a joint conference which concluded that the concept of *science diplomacy* was gaining currency in the academic circles of the US, UK and Japan and needed to better organise its contributions if it was to be effective in exchanging views with wider fields of diplomacy. It helpfully provided three dimensions of *science diplomacy* that have become widely adopted and provide a co-home [with *Beyond Gridlock* theory] for this thesis. The paper concluded that while the full concept of *science diplomacy* and its definition were still fluid it was already being actively applied in three inter-related areas that I will now outline.

Firstly, *Science in Diplomacy* informs policymakers with up-to-date, impartial scientific advice on the range of problems facing the world. They were also needed to identify where uncertainty existed or where the evidence base was inadequate. Since 2005, the national academies of science of the G8 + 5 countries have met annually to produce joint statements relating to successive themes of the G8 Presidency. Similarly, the Inter Academy Panel on International Issues (IAP), representing over 100 of the world's national science academies of science, has published statements on ocean acidification and deforestation, as a contributor to the UN climate change negotiations with the member states (IAP, 2009).

Secondly, *Diplomacy for Science* was facilitating international science cooperation. The RA/AAAS joint paper challenged and dismissed the romantic notion of the scientist as a lone creative genius. In today's world to be alone in science means to be cut-off from ideas, concepts, funding and equipment that are all needed to tackle today's problems. Scientific enterprise is now premised on the need to connect with the best minds in each field; the emphasis being on the necessity to work in well-funded groups with cutting edge equipment. The RA/AAAS joint paper cites the CERN LHC as a leading example of this and argues that, due to the nature of the difficult fundamental problems, the instinctive impulse towards global scientific collaboration will invariably prove stronger than any defensive, national strategies. I do not agree that collaboration will *inevitably* win over national short-sightedness, but I will show in this thesis that the binding centripetal force for collaboration gets stronger as the underlying meaningfulness and need for knowledge increases.

The third dimension is *Science for Diplomacy* which draws on the soft power of science cooperation to improve broader international relations between states. This has several forms including science cooperation agreements (such as bi-lateral or multi-lateral treaties), new intergovernmental organisations and institutions (such as the ITER IGO), educational scholarships and science festivals and exhibitions.

The three dimensions described above are useful in providing boundaries to our academic thinking of *science diplomacy*. In real world applications they often overlap considerably. For example, informing foreign policy objectives with good science-based advice can lead to and be part of facilitating international science cooperation itself. It could be argued that this thesis falls into the second category of *Diplomacy for Science* in that it is examining iconic intergovernmental cooperation's, but that would be wrong. This study is about *how* global SMPs achieve their effective collaboration pathways with member states. Accordingly, it is firmly in the third category of *Science for Diplomacy* as I explore in what way science cooperation at the very highest global levels takes place and what pointers that may provide to improve international relations between states in other domains.

Professor Chris Llewellyn Smith was Director General of CERN from 1994 to 1998 and President of the SESAME Council from 2008 to 2017. SESAME is a physics mega-project based in Jordan. His article *Synchrotron Light and the Middle East: Bringing the Region's Scientific Communities Together through SESAME* provides an interesting example of this third type of science diplomacy (AAAS, 2012). Llewellyn Smith contends that 'CERN was conceived in the aftermath of World War II with the explicit twin aims of enabling science that the members individually could not afford and contributing to strengthening links between countries that had recently been at war. The SESAME project is also beyond the reach of individual science budgets and will require a range of skills that members do not possess on their own. The project has two aims: firstly, to 'foster scientific and technological capacities and excellence in the Middle East and the Mediterranean region (and prevent or reverse a brain drain from those regions to the west) by constructing an outstanding scientific device and enabling world-class research by scientists in a diverse range of fields including biology and medical sciences, materials science, physics and chemistry and archaeology'. Secondly, 'to build scientific links and foster better understanding and a culture of peace through scientific collaboration in the region.

Llewellyn Smith cites the success of CERN in inspiring and assisting in the creation of many other intergovernmental scientific organisations in Europe such as the European Molecular Biology Laboratory, the European Southern Observatory and the European Synchrotron Radiation Facility. He suggests that SESAME may not only emulate CERN's scientific and political success but will also in turn inspire and cultivate other collaborations. The common thrust is that as the language of science is universal, scientists and SMP leaders are uniquely placed to build bridges of understanding and crucially trust between states, their elites and their publics. They provide a back channel of communication that diplomats and practioners in other domains can exploit.

In summary, this part of the literature review has provided a précis of the major phases of the history of modern science collaboration to demonstrate that science has often led the thinking on the necessity for collaboration. The time is ripe for science [and as I will later explain the *organisation* of science mega projects] to potentially play a telling role once again in overcoming the wider gridlock problems the world now faces. The literature review has positioned this research in the category of Science *for* Diplomacy within the accepted three-part science diplomacy topography.

1.4: Mega-Projects Governance, Leadership and Performance Issues

Mega-projects are complex endeavours and the literature covering their governance, leadership and performance issues is large and driven from different research standpoints. This section of the literature review will focus on well-respected studies by leading academics from institutions in Europe and the USA. It is divided into two sections: general topic material which span management issues of different mega-project areas and material specific to the management and leadership within the SMP domain. *SMP leadership* is the last of the three predominant literature themes that are summarised in sub-section 1.5.1., Analytical themes in the literature.

1.4.1: Mega-project governance and management

Miller and Lessard (2000) provide an experience-based theoretical framework that allows managers to understand and respond to the uncertainty and complexity inherent in what they term as Large Engineering Projects (LEPs). LEPs have had a contested record of success, often defined as delivering the planned outcomes within budget and to schedule (Bruzelius et al., 2002, Flyvbjerg et al, 2003, Priemus, 2007). In such endeavours, project success may mean different things to different stakeholders (Shenhar et al, 2001); I will show in the case study chapters that this is also the case for SMPs but that practioners have found ways of accommodating these variations while working together to achieve their shared community goals.

LEPs are inevitable prone to some degree of uncertainty. During the construction phase, assumptions about the local geology, culture and climate that had not been anticipated may reveal themselves. SMPs often meet technical difficulties as they, by their very nature, develop and test new and unproven technologies. Mega-projects are also prone to political risks. Funding may be curtailed or withdrawn following a change to government priorities, long after the original funding has been approved. The shock decision to pull the UK out of the Gemini Observatory project being one example of an unforeseen change in government priorities (RAS, 2007). The sheer complexity of a mega-project poses challenges too. The design, planning and assembly of a complex piece of technical equipment require that all the components are designed so that the physical, mechanical, electromagnetic and electronic interfaces between them are clearly and accurately specified. Meticulous planning and specifications are invariably produced, but results show that they seldom survive intact from contact with project construction realities.

Stakeholders often have different views on their preferred mega-project outcomes and priorities. Allegiance to different baselines, differing preferences for efficiency and effectiveness, and general rivalry lead to competing performance narratives (Gil and Pinto, 2016). The geographical dispersion of stakeholders also contributes to project risk (Ivory and Alderman, 2005). If these issues are left unreconciled then problems may deepen and Lundrigan, et al., (2015) contend that LEP under-performance is often a result of organisational structural development issues, rather than any agency or competence related failure. The 'disappointing under performance' they describe is not due solely to how the organisational structure develops. Other factors such as individual and group competence failings and technical issues still do play a part. Miller, et al., (2016) focus on LEPs as 'games of innovation' where sponsors, experts, and stakeholders interact to form, design and deliver projects. Each project calls for different and multiple innovative management adaptions over time in the face of project events and design trade-offs. Bruzelius et al., (2002) frame mega-project underperformance as a problem of accountability and suggest four measures to raise it: transparency, performance specifications, explication of regulatory regimes, and involvement of risk capital. These respected LEP management study authors all have legitimate differing perspectives of what is taking place. Together they illustrate the necessary complexity that is involved and provide clues as to the wide range of knowledge, skills and practices needed to manage them.

Different academic studies in the management science field also reveals that the body sponsoring the work can insentiently affect the conclusion. A World Bank team led by Gerry Ingram in 1994 concluded the cause of poor big project performance lies not in planning errors but in the incentives facing sponsors and users (Ingram, 1994). The report emphasised that higher performance requires commercial factors rather than any managerial panacea and that competition instead of monopoly offered the best chance of success. Leonard Sayles and Margaret Chandler in their studies of major NASA programs concluded that to manage systems better the separate strands of management science, organizational behaviour and governance must be woven together. The crux of their concluding remarks was that managing LEPs involves political issues as much as it involves technical ones (Sayles and Chandler, 1971).

The conclusion that emerges from a study of mega-project governance, leadership and performance issues literature is that standard project controls and management best practice are well known; how they are respected and applied varies greatly by industrial sectors. This is a conclusion supported by Macintosh and Quattrone (2010) who showed the tights links between organisational and sociological issues when tackling project management in large-scale projects. Assorted management approaches are needed in different sectors. I will show, in the case study chapter sections dealing with organisational culture that this also applies to the SMP communities where a common approach that they all utilise has worked well.

1.4.2: Science mega-project management and leadership

SMP higher level management do not ignore accepted Management Science theory particularly with respect to LEP design and planning that I described in the previous sub-section. As I will explain in the separate case study chapters, their management approach does reflect the preponderant personality type that they employ. The situation is well summarised by Max Boisot, Marcus Nordberg, Saïd Yami and Bertrand Nicquevert in *Collisions and Collaboration: The Organization of Learning in the ATLAS Experiment* (2011): 'the leadership implications of a collaboration of nearly three thousand members… in the face of high levels of uncertainty, risk and ambitious scientific aims can be achieved by complex organizational networks characterized by cultural diversity, informality, and trust.' The CERN Management recognise [as it is where they largely come from] that the workforce is special in that it comprises highly educated, motivated and dedicated people drawn from varied backgrounds, age groups and cultural customs. Due to the way work is distributed many of this workforce are also located in the member states territories and remain under familiar cultural influences. The SMP leadership teams understand that their situation cannot be managed by pure management science, project controls, monitoring, risk registers and gateway decision gate meetings. Rolf-Dieter Heuer, the Director General of CERN in the critical period of building the Large Electron-Positron collider at CERN, agrees with Boisot, et. al., that a markedly more bottom-up and collective light-touch approach to decision making is needed (CERN/UNOG, 2015).

Leadership in these circumstances seems to be most successful when practioners recognise that the best leaders are not necessarily rounded but the best teams are. Tom Rath and Barry Conchie in a large study of strengths-based leadership conducted for the Gallup organisation showed that effective leaders of the world's largest projects surround themselves with the right people and create a working environment that allows those people to build on each person's strength (Rath and Conchie, 2009). Another consideration that influences our discussion on SMPs is the very problems they are tasked to deal with. Keith Grint's work on *Wicked Problems and Clumsy Solutions* (2008) shows the vital role that leadership plays in creating an organisational culture that succeeds. He frames wicked problems as persistent, tending to be insoluble and not presenting clear sets of alternative solutions. He summarises his position on the leadership approach that should be taken by quoting the Canadian academic Laurence Peter: 'Some problems are so complex that you have to be highly intelligent and well informed just to be undecided about them.' SMP leadership is a predominant theme in the literature [all three are summarised in sub-section 1.5.1.] and will be re-visited during the analysis of the case study governance arrangements and leadership.

Although there has been little published academic research on the overall management of SMPs, there have been several workshops and discussion papers of the administration and control of their funding mechanisms. For example, Ferrazzani (1997) provides a wide-ranging review of the European Space Agency (ESA) projects which have utilised in-kind deliverables (IKD) since the early 1970s. The members had prompted the review to re-examine their financial exposure to ESA's optional programmes, that predominately exploit in-kind deliverables, and to establish joint and clear guidelines. Ferrazzani, who is the Legal Counsel to ESA, highlights the complexity of the in-kind approach and focuses on what 'In-Kind Deliverables rules' he recommends be adopted; unsurprisingly, these are made from primarily a legal rather than project management perspective. Although over 20 years since publication, Ferrazzani's analysis is valuable as it covers in depth the ESA 'In-Kind Management System' assumptions. Some recommendations are internal such as those related to the Founding Convention, but others can be correlated externally, including cost control, industrial policy, contracts and intellectual property rights. Gordon (2003) provides the perspective of a contributing member on the day-to-day struggle between 'Consensus and Harmony versus Management' within ATLAS, an experiment undertaken on the LHC, supported by CERN. He explains the purposes of ATLAS financial management to be: minimising the amount of risk and cash held by the central administration, ensuring that attributed value of the in-kind contribution is in accordance with the agreed Cost Book value, clarifying the financial and contractual responsibilities and clarifying the technical and managerial responsibilities.

Despite this introspection within specialist scientific sub-domains, the reach and influence of SMP communities has come to the attention of governments not least because their success and growth has led to higher demands for funding. A European Commission Expert Panel (EC, 2010) report provides evidence of the governmental-level interest in SMP undertakings, the desire to share lessons learnt and to standardise approaches. Recommendation 9, states "best-practice systems for project control and risk management have to be fully embedded in the project management covering technical, financial and schedule issues." This was intimating - without saying directly - that while best-practice systems for project control and risk management were espoused by the project's higher management, the efforts of the central programme management offices to enforce them had mixed results. It also implied that insufficient rigour had been applied by stakeholders including Member State oversight bodies to check if the systems were well rooted.

SMP leadership literature has naturally focussed on detailed practitioners' needs to improve the management of these challenging projects, to overcome obstacles, and to re-arrange restrictive workshare arrangements to make them fit real-world realities. A further example is Ramila Amirikas and Pradeep Ghosh (2016) who focus on the legal basis of In-Kind Management in the context of the FAIR accelerator facility (based in Darmstadt, Germany) during the annual European Spallation Source International Workshop on In-Kind Contributions.

There are exceptions to the introspective SMP project management literature, where science authors try and break out of their communities to reach a wider readership: Boisot et. al., (2011) examines the management of the ATLAS experiment of the LHC at CERN and introduces topics such as procurement lessons, leadership issues and e-Science but does address the reasons behind the successful collaboration. Harry Collins (2017) a British sociologist who in the early 1990s embedded himself in the collaboration building the Laser Interferometer Gravitational-Wave Observatory (LIGO) experiment but provides a *who-done-it* rather than a *how-did-they-do-it* approach in describing their great success in detecting gravitational waves. Renee Rottner provides in *History of the Spitzer Infrared Telescope Facility (2013)* a basic analysis of the original international collaborations that enabled NASA's Spitzer project and the technical and funding challenges that the founders had to overcome; Rottner's main focus however is on the project management lessons learned (NASA, 2003).

One study that stands out is that of Karin Knorr-Cetina (1999) from Harvard University who investigated the role epistemic cultures play in explaining *How the Sciences Make Knowledge.* Her book is important to my thesis as it is the first to systematically compare two different scientific laboratory cultures (high energy physics and molecular biology) and touches on topics such as how expert systems and processes work and whether their organization, structures, and operations can be extended to other forms of social order. The work is also important as it raises the possibility that this research may have little or no applicability to other areas of international relations and thereby gridlock issues. It raises this prospect by labouring the fact that laboratories are unique reconfigurations of natural and social orders and that the reconfigurations even operate differently in different fields of science. However, her analysis while excellent in the level of detail conducted over many years is surprisingly limited in that it is was primarily set in one context. It was about what goes on *within* the epistemic communities of the modern scientific laboratories and the contrast in approaches to the discovery of knowledge between two different scientific communities. The weakness of the work is that it only touches briefly on why the nations agreed to form the laboratories or how the nations and the central organisation organise themselves to maintain those international collaborations.

In summary, this part of the literature review demonstrates that SMPs are more than just another class of LEPs, to be added to the category list of bridges, dams, highways, urban development's etc. They are distinctive because of their need for public funds with associated governmental oversight, their blending of many managerial cultures, tendency to utilise a bottom-up and collective form of management decision-making, their need to share risks, solve wicked problems and their provision of *knowledge* to the contributing Member States.

1.5: Themes in the literature, research gap and relevance to this thesis

In this last section of the literature review I will firstly ascribe three analytical themes. I will then argue why the thesis fills a research gap and will outline the relevance of the literature to the thesis.

1.5.1: Analytical themes in the literature

Three shared themes have been recognised in the literature as it relates to the research case studies: the primacy of the state, science diplomacy and SMP leadership. To examine synergies and note any major differences between these themes, I recap the analysis and set the SMP context of each one in turn.

It is in section 6.1. where I provide my response to all the counter-evidence, including the associated literature, to the hypotheses, that are central to explaining the thesis.

1.5.1.1: Primacy of the state

I concluded in the sub-section 1.1. on *realism* that any global governance exercised by the SMP IGO management teams is conditional on the power politics that the contributing members exercise. The top leadership teams of these iconic projects operate within the degree of delegated authority that the nations tolerate; but, no more. This thesis will show that the set-up and running of these SMPs do not provide an exception to this solid realism footing. SMPs also fit into recent *neoclassical realist* theory in that their set-up acknowledges domestic considerations, cooperation and competition between states and that complex stratagems may mean efforts in one system [science collaboration] are calculatedly undertaken to support and improve a nation's position in other systems [such as energy policy and national security].

Regime theory and international organisation literature showed that major steps have been made in global international cooperation often only in the wake of world catastrophes, such as The League of Nations post World War I and the UN, and its principle organs post World War II. The defensive characteristics of states alter in these periods; officials can relax the boundaries for compromise and a coming together of minds ensues. I will show that global SMP communities expertly ride such waves of change: CERN was formed in the immediate post World War II period; the ISS was born out of the end of the Cold War space race. The research will investigate if this was mere coincidence or a more calculated tactic of the SMP pioneers.

The final aspect of primacy of the state that Robert Keohane in *After Hegemony* prompts us to keep in mind is that effective cooperation must be distinguished from utopian harmony. This is true for SMPs, whose cooperation does not imply the absence of conflict but rather that without the risk of conflict there is no *necessity* to cooperate. They heed back to the basic human instinct of *necessity* for cooperation born out of dire circumstances. US President Truman in 1945, that I quoted in the introduction, articulated this perfectly: “if we do not want to die together in war, we must learn to live together in peace”. I echo this with these challenging statements, intentionally adding an emphasis to the first word of each: *If* we do not want to fail to understand the nature of fundamental physics, we must learn to make CERN a success. *If* we do not want to collectively suffer the collapse of the earth’s environment, we must learn to make an environmentally friendly commercial power source, such as ITER, a success. *If* we do not want to fail to master deep space travel and overcome harmful physiological effects of micro-gravity and cosmic radiation, we must learn to make the ISS a success. I will argue that the SMP communities revel in the meaningfulness of their endeavours and unshakably take on these massive challenges on behalf of us all. Once established, I will show that the communities have found a way of effectively channelling their collective efforts through IGOs that execute open actions, share risks and steadily build trust between states while always respecting the power and primacy of those states.

1.5.1.2: Science diplomacy

The literature review of the recent history of *science diplomacy* showed that science has often led the thinking on the necessity for collaboration. *Science diplomacy* has been present from Francis Bacon insisting that knowledge is for all to the formation by the Royal Academy of societal networks to tackle wicked problems right through to science communities bucking recent trends of national entrenchment by establishing iconic and successful SMP IGOs.

The literature review positioned this research in the category of Science *for* Diplomacy that draws on the soft power of science cooperation to improve broader international relations between states. This placement reinforces the idea that as SMPs have been remarkably effective in building a collective spirit and evolving complex processes and methods to enable global collaboration.

The connected nature of society and the threats to its welfare means that active clusters of scientific knowledge find themselves uniquely placed to use their influence for good. Despite recent rejection of experts from a minority of politicians and bi-partisanship influencing which science results to highlight, the *overall* trend has been for scientists to continue to be trusted across political divides. The literature review confirms that expert scientific working groups and bodies inform industrial conglomerates, governments and several UN agencies. The potency of science, as a real and/or perceived, impartial back channel for building trust and understanding between countries is gaining traction as its legitimacy is enhanced by self-evident successes that the SMP IGOs epitomise.

1.5.1.3: SMP leadership

There is a long historical association between science and international cooperation where the former has often led the way. Davis and Patman (2015) provide many examples where science cooperation has resulted in better international relations between states that I covered in the Introduction. Can science lead the way once more?

Modern management leadership literature emphasises the need for reflective management and develops the idea of the 'incomplete leader'. The industrial mega-projects, that I described in the introduction sub-section on global gridlock are no longer led by individuals who rely on hierarchy and authority. Shifting ideas about leadership described by management psychologist academics such as Derue, Nahrgang, Wellman and Humphrey (2011) have moved through three phases of 1) Hierarchy and Authority (early 20th Century), Involvement and Vision (Middle 20th Century), Empowerment (late 20th Century) and Networks and Value co-creation (21st Century).

I will show, through the data gathered in interviews that supports the literature covered in this Chapter that SMP community leadership and governance practices have been ahead of the three step shift of leadership approach described above. I will argue that although they are certainly not without fault, the SMP leadership teams have achieved a positive, fulfilling, work-related state of mind that is characterised by team members with vigour, dedication and absorption in the task (Schaufeli and Salanova, 2011). The reasons for this can be characterised by the collective management decision making observed by Markus Nordberg, Saïd Yami, and Bertrand Nicquevert in their study of ATLAS at CERN that I covered in sub-section 1.4.2.

The SMP community leadership have also trail-blazed advanced ways of coping with the varied needs of the participating states. I will develop this case in the governance, leadership and performance sub-sections of the individual case study chapters. My research has benefited from the leaders who agreed to provide first-hand insights into the diplomacy they have employed in working with the nations involved. I will show that distinct leadership qualities and diplomacies are an integral part of the SMP community's success story.

1.5.2: Literature gap

I have shown in this literature review that the set-up, collaboration agreements and operation of SMP IGOs are not outside of the international relations categories of theory; there is a reserved place for them. However, these collaborations of the world's leading industrial states and whose results will affect us all, have been a neglected area of enquiry by international relations scholars including those focused on global gridlock issues.

With a few notable exceptions that I highlighted in sub-section 1.4.2 (Science mega project management and leadership) the SMP community literature has predominantly and quite naturally been introspective within specific scientific domains. I have also shown that while both the European Commission and the United Nations have commissioned reports into global science infrastructures; these have been primarily to inform co-ordinated national investment decisions rather than to reveal any cooperation insights that the SMP IGO collaborations themselves may have.

The essence of the research gap argument is clear when considering the Abbot and Hale (2014) paper on *Orchestrating Global Solution Networks (GSN); a Guide for Organizational Entrepreneurs*. The paper has at its core the survey of 223 GSNs categorized into 10 groupings. There are no science GSNs in the survey. This is a conspicuous flaw but does not expose poor research practice; indeed, it is a landmark study of global web-based and mobile networks for cooperation, problem solving and governance. I believe the omission is because of the pervasiveness of an international relations academic blind spot whereby science collaboration is the giant sequoia tree in the wild forest that cannot be seen because of younger [more subject specific] trees that have grown around it.

The authors highlight four characteristics of successful orchestrator organisations. They contend they must 1) be seen as legitimate by those with whom it works, 2) occupy a central focal position in its issue area, 3) possess moral, subjective or material resources that it can offer collaborating organisations and 4) nurture an organisational culture of innovation and collaboration. I will employ the legitimacy and focality characteristics to assess the IGOs that lead the case study SMP communities.

1.5.3: Relevance of the literature to this thesis

I positioned this research in the category of Science *for* Diplomacy within the accepted three-part Science Diplomacy topography in the analysis in sub-section 1.3.2. I now turn to considering where it also fits in the 'pathways through gridlock' literature landscape.

In the same way that the original Bretton Woods organisations were formed from the needs of that time, it may now be apposite to re-mould those institutions and/or their working practices for the global needs of today. Milivoje Panić (2011) outlines radical development thinking that could be the framework for a new Bretton Woods global payments system for developing countries. Leading academic think tanks reason and urge diplomats that these types of sweeping changes are also needed to overcome the entrenched stalemate of global gridlock (BSG, 2016). This thesis aspires to provide new and novel notions to contribute to that 'sweeping changes' debate and therefore take its place in that cutting-edge part of the global gridlock literature.

CHAPTER 2: METHODOLOGY

This chapter will firstly set the scene for the research methodology by explaining the case study selection justification. It will then state the research problem and related sub-questions. The third section outlines the research strategy through a conceptual framework. The fourth section details the research design in five sub-sections: 1) the research philosophy, 2) methodological approach, 3) counterfactual evidence, 4) research limitations and 5) research ethical issues. The final section summarises the chapter.

Literature that has informed this chapter includes: David Dooley, *Social Research Methods* (1984); Peter Frost and Ralf Stablein, *Doing Exemplary Research* (1992); Catherine Marshall and Gretchen Rossman, *Designing qualitative research* (1995); Harvey Maylor and Kate Blackmon, *Researching Business and Management* (2005); Wayne Booth, Gregory Colomb and Joseph Williams, *The Craft of Research* (2008) and Marian Petre and Gordon Rugg, *The Unwritten Rules of PhD Research* (2010).

2.1: Case Study Selection Justification

The case study selection process has been a successive one, firstly covering the cost factors, then the international norms used for demarcating SMPs, the attributes and criteria for *global* SMP status and concludes with the rationale for the case studies that are the focus of this thesis taking into account the supporting and opposing attributes for testing the hypotheses that are detailed in table 1.

Full descriptions are provided in the first sections of each case study chapter; the titles, short descriptions and membership of each case study are as follows:

1. The CERN community. The main CERN laboratory is based near Geneva, Switzerland. It is a well-established global centre of excellence for fundamental high energy physics research. CERN has 23 European member states (detailed in section 3.1.1 for the founding Members and sub-section 3.3.3.1 for those that have joined since) and six associate member states: Croatia, India, Lithuania, Pakistan, Turkey and Ukraine. Observer states and organizations include the European Union, Japan, the Joint Institute for Nuclear Research (JINR) the Russian Federation, UNESCO and the USA. CERN's flagship infrastructure project is the Large Hadron Collider (LHC).

2. The ITER Project community. The project is based in Cadarache, France. It is arguably the largest collaborative scientific project ever undertaken with the aim of proving the commercial viability of nuclear fusion energy. ITER has seven members that together represent over half the world's population and over 80% of the world's GDP (OECD, 2018): the People's Republic of China, Europe (27 states bound together through the EURATON Treaty), India, Japan, the Republic of Korea, the Russian Federation and the USA.
3. The International Space Station (ISS) community. The ISS headquarters is in Washington DC, USA. The ISS is a unique achievement in human space exploration to conceive, plan, build, operate, and utilize a micro gravity research platform in a low earth orbit. The ISS member states are Canada, Japan, the Russian Federation, the USA, and eleven Member States of the European Space Agency (Belgium, Denmark, France, Germany, Italy, The Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom).

2.1.1: Cost factors

Miller and Lessard (2000) in their work at the Massachusetts Institute of Technology (MIT) use a practical construction cost threshold of greater than US$ 1B when defining Large Engineering Projects (LEPs). The figure does not consider inflation nor that there are different costs in different parts of the world, but it does provide an apt order of magnitude and has been widely accepted within academia researching mega-project management to denote LEPs. This thesis uses the same threshold as part of the SMP status criteria. Operating, decommissioning and disposal costs are not considered within the cost selection criteria but are addressed in the individual case study chapters.

2.1.2: International norms for demarcating SMPs

The role of the European Strategy Forum for Research Infrastructures (ESFRI) is to support European states in determining a coherent and strategy-led approach to science research policy-making. ESFRI comprises a well-respected body of experts from several fields who together facilitate multinational initiatives leading to development and/or better use of European science research infrastructures. ESFRI produce a bi-annual roadmap that demarcates between projects and landmark status projects; the category definitions run to several paragraphs (ESFRI, 2016).

The Group of Senior Officials (GSO) is the forum established by the G8 in 2008 to discuss and advance Global Research Infrastructures (GRIs). The group's *Framework for GRIs* received ministerial level approval in 2013 and set three broad categories of GRIs (EC, 2017): 1) Real single-sited global facilities that are geographically localized unique facilities whose governance is fundamentally international in character, 2) Globally distributed Research Infrastructures formed by national or institutional nodes, which are part of a global network and whose governance is fundamentally international in character and 3) National facilities of global interest with unique capabilities that attract wide interest from researchers outside of the host nation. The Framework also provides a useful checklist of the criteria to be considered in potential global GRIs.

2.1.3: Attributes and criteria for global SMP status

Utilising these the $ 1B construction threshold, the ESFRI roadmap methodology and the checklist from the GSO Framework for GRIs, results in a list of over one hundred SMPs. Despite the somewhat inflated claims of many science communities only a select few SMPs are *global* in that they have:

- taken decades to form into collaborations under intergovernmental treaty obligations;
- members that span continents and operate within a global expert community;
- a specially created central IGO or a specially created new entity within an existing IGO;
- construction budgets in the tens of $ B;
- funding mechanisms that comprise a combination of in-cash and in-kind contributions from the member states;
- highly complex technical challenges;
- results that are shared world-wide;
- ground-breaking respected iconic research status and
- high visibility within both the scientific and public realms.

A selected overview of global SMPs and their communities that fall within specific scientific domains is at Appendix A. It is also recognised that there are science related International Organizations that span science domains and/or provide a global service such as the UN Intergovernmental Panel on Climate Change (IPCC), the World Health Organisation (WHO) and the World Meteorological Organization (WMO).

2.1.4: Rationale for the case studies that are the focus of this thesis

The final justification in selecting the three case studies is when the following attributes are considered:

- all three case studies meet the global criteria bar outlined above;
- they are equal in the sense of all being in the foremost position within their domains;
- each is at a different phase within a project's life cycle and thereby in combination provide an overlapping complete picture: ITER is in final design / construction phase, the CERN main infrastructure LHC is in mid-life upgrade / operational phase and the ISS is the final stages of its working life. Although concentrating on physics global SMPs, I note the wealth of other natural science SMPs which also only have a select few projects in the global SMP category [as Appendix A attests] and the global IOs such as the IPCC which is one of five bodies considered as ripe for further research (see p 251);
- each have members who are also involved in other IGOs and/or other global communities that are functioning less well and therefore the analysis provides fertile ground to examine what the global SMP governance and leadership regimes are doing that the others are not;
- access to key interviewees - that will provide primary data for testing the hypotheses utilising the supporting and opposing attributes listed in table 1 (p 66) - is feasible and
- all three case studies provide ready access to founding documents, treaties, negotiation material, governance and leadership material including the minutes of governing organs that will provide reputable secondary data for testing the hypotheses utilising the supporting and opposing attributes listed in table 1 (p 66).

2.2: Research Problem and related questions

The thesis investigates the international collaboration agreements, set-up, governance and leadership aspects of three iconic global SMP Communities: the CERN Community, the ITER Project Community, and the ISS Community. The trans-border collaboration needed to address global scientific challenges highlighted by the G8 Science Ministers (G8, 2013) means that SMP Communities tackling the hardest problems are often led by bespoke IGOs requiring Ministerial level approval. This thesis analyses how the governance and leadership regimes of these IGOs, and their wider communities have found a way through global gridlock. Consequently, my research has been driven by the following research problem:

> ***How do global Science Mega-Project Communities achieve their effective collaboration pathways with Member States?***

There are two related research sub-questions: 1) do the subject SMP Communities utilise common diplomatic approaches in negotiating their founding arrangements and functioning in a collaborative way? And 2) What - *if any* - are the political lessons learned by the subject SMP Communities that may provide clues in advancing global collaboration to overcome gridlock in other domains?

Maylor and Blackmon (2005: 73) suggest that research problems have potential significance to a whole field of study when they link to larger theoretical constructs and/or to important policy issues. Leading research methodology theory of Booth, et al. (2008: 52) tells us that research problems stem from two places: a theoretical problem results from incomplete information or understanding, and a practical problem is a real-world problem with tangible costs. Booth goes on to explain that good research often meets both aspects. This thesis aims high as it purposively links to larger theoretical constructs in order to fill a gap [that I outlined in section 1.5.2.] in the international relations sub-field of global gridlock studies. The research has policy implications in that strategists should familiarise themselves with the full range of trans-border global institutions; particularly those that have apparently formed effective paths of collaboration.

2.3: Research Conceptual framework and research hypotheses

The research strategy can be viewed through the SMP conceptual framework; Figure 3. The first box 'Formal Agreement / Creation' is an external pre-cursor to the running of an SMP. It influences management in that it sets the scene, establishes the rules and provides guidelines on operational parameters. The second box 'External Constraints' comprises the myriad of constantly changing stakeholder aspirations, political and legal landscapes, regulations and foreseen/unforeseen events that the SMP leadership must navigate through and around. The third box comprises internal community governance and leadership aspects; the personnel involved in these activities are tasked with both the long-term viability and day-to-day running of the ventures. The conceptual framework allows us to see three key determinants that support the research:

1. Understanding how global SMPs negotiate and finalise their respective IGO formal agreements.
2. Understanding the external constraints that governing bodies, contributing members and the scientific community at large impose on the central organisation and how these constraints can affect overall performance.
3. Analysing methods and practices that global SMPs governance and leadership regimes utilise to operate within the boundaries of their founding agreements and overcome constraints, to identify differences and map common themes that may be applicable in other fields.

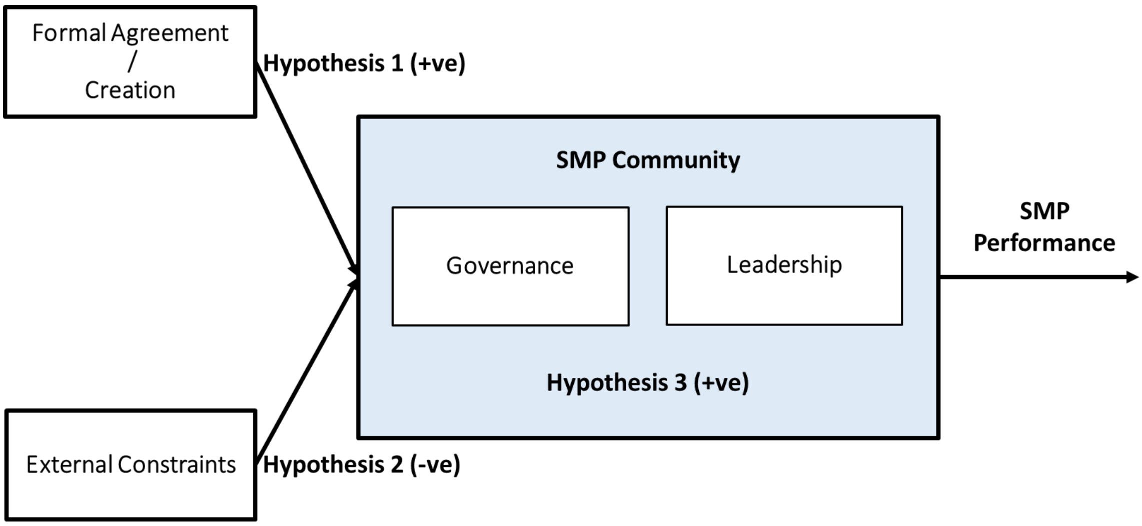

Figure 3; Global SMP Conceptual Framework

The framework comprises three hypotheses that I assert affect SMP performance either positively (+ve) or negatively (-ve). The hypotheses derive from three tributaries:

Firstly, my earlier Oxford MSc dissertation which included two hypotheses that were of a technical programme management nature concerning the funding aspects of the large projects by their communities. The MSc was grounded in literature and theorisation that included: Nils Bruzeliusa, Bent Flyvbjerg and Werner Rothengatter (2002) who studied *Big Decisions, Big Risks: Improving Accountability in Mega-Projects;* Ralf Müller (2009) who considered international *Project Governance*; Janet Smart (2012) who researched *Big science and big administration. Confronting the governance, financial and legal challenges of FuturICT*; Jay Galbraith (2014) in his work *Designing Organisations: An Executive Guide to Strategy, Structure and Process* and Ramila Amirikas and Pradeep Ghosh (2016) who studied *prosperous models for the procurement for Large-Scale Science Projects*. This MSc work was narrow and very different from the topic of thesis. The methodological approach, conceptual framework and hypotheses were wholly redeveloped and expanded with my supervisor, Professor David Held, during this research.

Secondly, the related theory underpinning the peer reviewed *Global Policy* article published during the development of the thesis that concentrated on the first of the three case studies, CERN (Robinson, 2018). Underpinning literature included: John Krige, et. al., (1987) *The History of CERN*; Henry Mintzberg and James Quinn (1988) in *The Strategy Process: Concepts, Contexts and Cases;* Kenneth Abbott and Thomas Hale (2014) in *Orchestrating Global Solution Networks; a Guide for Organizational Entrepreneurs;* Lloyd Davis and Robert Patman (2015) in *Science Diplomacy; New Day or False Dawn* and Marc Cogen (2015) in *An Introduction to European Intergovernmental Organizations.*

Thirdly, the hypotheses derive from the three analytical themes that emerged from the literature review (sub-section 1.5.1): the primacy of the state, science diplomacy and SMP leadership.

> I concluded in the sub-section 1.1. on realism that any global governance exercised by the SMP IGO management teams is conditional on the power politics that the contributing members exercise. The top leadership teams of these iconic projects operate within the degree of delegated authority that the nations tolerate; but, no more. The final aspect of primacy of the state that Robert Keohane in *After Hegemony* prompts us to keep in mind is that effective cooperation must be distinguished from utopian harmony (1984). This is true for SMPs, whose

cooperation does not imply the absence of conflict but rather that without the risk of conflict there is no necessity to cooperate. They heed back to the basic human instinct of necessity for cooperation born out of dire circumstances. I will argue that the SMP communities revel in the meaningfulness of their endeavours and unshakably take on these massive challenges on behalf of us all. Once established, I will show that the communities have found a way of effectively channelling their collective efforts through IGOs that execute open actions, share risks and steadily build trust between states while always respecting the power and primacy of those states. It is these sub-themes that help form the basis for Hypothesis 1.

The literature review of the recent history of science diplomacy showed that science has often led the thinking on the *necessity* for collaboration. The literature review positioned this research in the category of Science *for* Diplomacy that draws on the soft power of science cooperation to improve broader international relations between states. This placement reinforces the idea that the leadership of SMPs have been remarkably effective in building a collective spirit and evolving complex processes and methods to enable global collaboration and overcome and/or limit the many constraints that inevitably come their way over their long design, development, construction and operational phases [that will be detailed in figure 15]. It is these sub-themes that help form the basis for Hypothesis 2.

Shifting ideas about leadership described by management psychologist academics such as Derue, Nahrgang, Wellman and Humphrey (2011) have moved through three phases of 1) Hierarchy and Authority (early 20th Century), Involvement and Vision (Middle 20th Century), Empowerment (late 20th Century) and Networks and Value co-creation (21st Century). I will show, through the data gathered in interviews that supports the literature covered in Chapter 1 that SMP community leadership and governance practices have been ahead of the three step shift of leadership approach described above. I will argue that although they are certainly not without fault, the SMP leadership teams have achieved a positive, fulfilling, work-related state of mind that is characterised by team members with vigour, dedication and absorption in the task (Schaufeli and Salanova, 2011). The SMP community leadership have also trail-blazed advanced ways of coping with the varied needs of the participating states and the governance mechanisms that they collectively demand. It is these sub-themes that help form the basis for Hypothesis 3.

The supporting and opposing attributes (indicators of success and failure of the SMPs) for testing the validity of the hypotheses are explained in sub-section 2.4.2: Methodological Approach. Together the three hypotheses provide a vehicle to address the research problem, test the data and help to narrow down which *Beyond Gridlock* pathways apply:

- Hypothesis 1 is that IGO agreements and start-up conditions which are concise, fair, promote trust and mutual support, allow flexibility in problem solving, manage host state issues and emphasise the primacy of the State improve performance.
- Hypothesis 2 is that external constraints such as excessive stakeholder aspirations, changing political and legal landscapes, bureaucratic regulations, funding fluctuations and unforeseen events, while being mitigated as far as possible by IGO leadership actions, inevitably adversely affect overall performance.
- Hypothesis 3 is that sound governance and leadership dynamics improve global IGO performance.

2.4: Research Design and Methodology

The design needs to test the hypotheses, involve counterfactuals, offer a means of validation and deal with research limitations. Consequently, this section is split into four parts: 1) research philosophy, 2) methodological approach where the means of testing the hypotheses are addressed, 3) counterfactual evidence and finally, 4) ethical issues.

2.4.1: Research Philosophy

This research associates with two types of research philosophies advocated by Maylor and Blackmon (2005: 157): interpretivism and critical realism and both have therefore governed the research design described below. In *interpretivism* the goal of the research is not to explain human behaviour, but to understand it and analyse what we can learn from it. This is a mainstream epistemology for management research and fits well here where we will be examining the diplomatic, organisational and leadership approaches of three SMPs with data collection through interviews and observation visits. This subjectivist method does have some disadvantages that will be returned in counterfactual evidence and research limitations [sub-section 2.4.3 and section 2.5 respectively]. *Critical realism* developed by Roy Baskhar (1975) acknowledges that researchers cannot directly know reality, but that knowledge of reality is 'good enough'. This research philosophy is also apt here as it helps provide explanations to *hidden* generative structures particularly in the underlying political and economic patronage that the states provide to these projects. The SMP IGOs are formed from states desire to work together and they operate within rules and boundaries set and monitored by them. Critical realism accepts that this may be difficult to immediately draw out from empirical events which we can capture and record. Geoff Easton (2007) in *Critical realism in case study research* identifies that a critical realist approach involves developing a research problem and associated question that identifies a research phenomenon, in terms of noticeable events, and asks [in this study through the elucidation of these events by collection of primary and secondary data] what causes them to happen. The result is the identification of root causal mechanisms. In other words, this research has a completely open mind regarding what collaboration pathways the SMP Communities have and how they have been attained; interpretivism and critical realism will both be used to draw this out.

The research problem (section 2.2) lends itself to taking an ethnographic method. The root of this method meets the qualitative research criteria outlined by Marshall and Rossman (1995) and is the essence of why it is appropriate in this case; i.e. I have not only considered the case study organisations (the central IGOs and Member States' interfacing organisations) *but also the people in them*.

Other approaches were not dismissed. For example, the conduct of a quantitative survey of case study central organisation members and others in the wider science mega-project communities was also considered. The administrative burden of framing the survey, gaining necessary consents, testing and conducting it within time and budget constraints meant it was impracticable. It is not ruled out should an expansion of the case studies be undertaken in further research.

2.4.2: Methodological Approach

This sub-section covers the methodological approach which was conducted in three stages: desk research, field research and data analysis and validation. The three hypotheses include notions that are subjective in nature: Hypothesis 1 references agreements and start-up conditions that are *concise, fair, promote trust and mutual support, allow flexibility in problem solving*, *manage host state issues and emphasise the primacy of the State.* Hypothesis 2 introduces the idea of constraints such as *excessive* stakeholder aspirations and *changing* political and legal landscapes. Hypothesis 3 is that *sound* governance and leadership dynamics improve performance. To test the level of concepts such as *fairness, excessiveness or soundness* is problematic but not unsurmountable. For example, a matrix containing supporting and opposing attributes can be constructed, see Table 1. The nature of the research does not lend itself to simply checking off items revealed in the desk research or field work against this list of attributes. Instead it has been designed so that the complete body of evidence provides the basis for drawing a judgement, with the attributes in mind. The variation in success as seen by the practioners (collected through the primary data interviews) and literature (secondary data) is analysed and documented in the respective case study chapters and compared and contrasted in the research results chapter.

Collectively the hypotheses provide a way to understand the three key determinants that support the research and thereby help in answering the research problem (section 2.2): *how* do global SMPs negotiate and finalise their respective IGO formal agreements, *how* are external constraints dealt with and *how* are governance and leadership dynamics handled. Once the key determinants have been understood then this allows the research problem and associated questions to be answered in the research results chapter.

	Attibrutes for testing the vailidity of the Hypotheses	
	Supporting Attibutes	**Opposing Attributes**
Hypothesis 1	**Members have faith in each other underpinned by undisputed founding agreements and equitable start-up conditions** **Central IGO can autonomously adapt its structures/processes** **Central IGO respects the primacy of the state in all circumstances**	**Mistrust is rife amongst Members; founding documents are not fit for purpose and are regularly misinterprated** **Central IGO is inflexible and lacks autonomy** **Central IGO regularly tries to userp the primacy of the state to achieve results**
Hypothesis 2	**Members readily support each other during times of crises** **Potentially existential events are overcome; longevity is maintained** **Central IGO has legitimacy and authority to deal with external constraints** **Meaningful political/technical/cost risk sharing is practiced as well as espoused when dealing with constraints**	**Members quickly move to legal litigation to settle disputes** **Major problems lead to significant project de-scoping / cancellation** **Central IGO lacks authority and is not seen as having the legitimacy and/or means to deal with external constraints** **Constraints are left to adversely affect performance because of unbalanced approach to sharing political/technical/cost risks**
Hypothesis 3	**High level decisions are based on 'one Member one vote' consensus wherever possible** **Membership of representatives of advising organs is based solely on meritocracy selection by peers** **Light touch leadership approach is the predominant organisational culture** **Scientific outputs are universally considered worthy by peers** **Recognition of success is widely held**	**The dominant collaboration Member regularly imposes its views on other Members in highest level decision making body** **Membership of advising organs are political appointees of Members irrespective of meritocracy standing with peers** **A heirarchical management approach dominates organisational culture** **Value of scientific outputs are contested by peers** **Recognition of success is limited**

Table 1; Thesis hypotheses - supporting and opposing attributes

Hypotheses are unlikely ever to be formulated unless considered *potentially* valid and the first step in probing if the hypotheses in this research are plausible was during the case study selection process. The stepped selection method gradually ascertained – firstly at a rough cut level (Appendix A) - if *any* empirical instances can be found The rationale for selecting the case studies (sub-section 2.1.4) including ready access to documents and key interviewees that will provide data for testing the hypotheses listed in table 1 (p 65) then resulted in a selection that warranted the undertaking of the detailed analysis (as documented in the case study chapters) and the painstaking comparative study (as documented in the research results chapter).

It was not anticipated that the hypotheses could be readily falsified but rather that the detailed case study analysis would be where a judgement on the *level* of the hypothesis's validity be made. The collation and examination of counterfactual evidence in sub-section 6.1 emphasised that no data either primary (field work) or secondary (literature) has been dismissed as irrelevant or unreliable evidence. Opposing evidence to each of the hypotheses is analysed at the end of the respective sub-sub sections within sub-section 6.2 on testing the hypotheses. Examination of alternative hypotheses has also served to understand the problem better and identify any weaknesses or simplifications in the thesis hypotheses. Sub-section 6.1 will show that the balance of evidence is that SMP Communities are appropriate vehicles to investigate international collaborations.

The circumstance that the three cases are equal in the sense of all being in the foremost position within their domains provided a sound background to the comparative study. In section 1 of the results chapter I gather together the counterfactual arguments that span the three hypotheses and the case studies together with my response. In section 2, I analyse to what degree the *Beyond Gridlock* pathways have been utilised by the SMP communities to support the three hypotheses. The analysis is framed around the three boxed areas shown in Figure 3, the Global Conceptual Framework: 1) Formal Agreement and Creation where Hypothesis 1 is tested, 2) External Constraints where Hypothesis 2 is tested and 3) Governance and Leadership where Hypothesis 3 is tested. In section 3, I analyse the common and dissimilar diplomatic, governance and leadership mechanisms that have been used to implement the pathways.

The combination of *Beyond Gridlock* pathways that have been used by the case study communities in respect of each of the hypotheses are shown in section 6.2 tables 13 (p 206), 14 (p 208) and 15 (p 210). The common and different mechanisms that have been used in each of the *Beyond Gridlock* pathways are mapped out against the three case studies in table 19 (p 237).

2.4.2.1: Stage 1: Desk Research

The research began with a comprehensive literature review of the relevant academic material. This secondary data was collected through the academic and specialist SMP libraries described in the introduction to the Chapter 1 Literature Review. The result comprises academic literature including scholarly books and articles in peer-reviewed academic/managerial journals; the bibliography provides details of 262 items, all of which are cited in the main body of this thesis. Care has been taken to maintain a balance between well documented areas (such as international relations theory) and lesser known ones (such as science project leadership); I return to this in sub-section 2.5. Limiting Factors to the research and mitigating actions.

2.4.2.2: Stage 2: Field Research

Field data was collected via semi-structured interviews with world-leading SMP executives and academics. The full set of primary data was large with over 70 interviews; all conducted within the considerations of informed consent, confidentiality and anonymity, interviewee details are included in Appendix B. This data was supplemented by previous expert panel narratives from interviewees that were available on-line. The most fruitful of these was the *CERN Model, Science, Education, and Global Public Good - CERN / UNOG Symposium*, attended by the CERN DG designate, previous DGs, senior CERN Executives and leading UN figures, held in Geneva in 2015 over three days; all sessions being accessible through UN Web TV (CERN/UNOG, 2015).

Primary data was collected through SKYPE interviews and through field work face-to-face semi-structured interviews at the CERN HQ in Geneva, the ITER HQ in Cadarache, France, and the NASA ISS HQ in Washington DC, USA. Data was also collected at international conferences of the American Association for the Advancement of Science in Austin, Texas and Washington DC, USA., and at a symposium at CERN to celebrate 25 years of operation of the LHC, held in December 2017. Introductions and consent to interviews was achieved with the support of points of contact in each case study community.

The study design has at its core the research problem, related sub-questions and hypotheses that need to be tested (section 2.2 and sub-section 2.3 respectively). The questions were concise enough to reduce the problem space area but deep enough to address the fundamental issues at hand.

Resolving the questions this way helps keep fresh the original motivation of why it was an important topic (Petre and Rugg, 2004: 96). The *research analysis* needed to satisfy the test of 'answering the research questions' for a readership that could potentially include the wider international relations, global gridlock community. The data collection and analysis were therefore conducted and recorded in as jargon free style that the subject matter allowed. This effort is aided by the explanatory section in the Introduction on terms, nomenclature and notations and by the List of Abbreviations.

For the primary source data, Booth et. al (2008: 82) point out that striking a balance between not freezing the interviewee with too scripted questions while not questioning aimlessly can only be overcome by determining *exactly* what you want to know. Interviews were therefore conducted individually and in a straightforward manner. Information sheets were provided to all the participants, describing the nature of the research, why and how it was being conducted together with an explanation of why they had been asked to take part. This data capture successfully identified, in the way that Ives (2005) describes, contextual elements in the case studies' management that impacted on project success.

Pre-work with the points of contact in the case study IGO HQs showed how willing subjects were to take part. It was important to maintain this momentum while conducting the interviews as systematically and sensitively as possible. Maylor and Blackmon (2005: 243) describe this as 'controlled opportunism' whereby researchers take advantage of new themes to improve resultant theory. The few reticent interview participants were gently encouraged to relate their experiences of global SMP management and how they foresaw any improvements could be made and any potential read-across they could identify to other areas of international collaboration.

2.4.2.3: Stage 3: Data Analysis and Validation

The extensive British Library PhD archive was reviewed to see what analysis techniques had worked and what pitfalls to avoid in previous research that had elicited views and beliefs from international collaboration decision-makers. This review revealed that interviewees could be prone to answering research questions with lengthy answers. Therefore, to aid the process of combing the data for relevant themes and ideas, coding was applied during the analysis. A priori codes based on each of the three hypotheses that underpin the conceptual framework were used. The coding was useful in three ways; 1) helping to order and index the diverse data, 2) eliminating/minimising false correlations and irrelevant data, 3) allowing the data to be refined in groups, thereby making revisiting the data easy should the research be taken further. The possibility of the data revealing unexpected themes was not discounted; had that possibility occurred then grounded codes would have been created (Strauss and Corbin, 1998).

Validity of the research refers to how accurately it has been conducted and is notoriously difficult to measure in qualitative research. It is unlikely any researcher readily concludes they conducted themselves inaccurately with respect to data gathering and analysis. The research design has incorporated two internal and one external measure to gauge and improve validity.

Maylor and Blackmon (2005: 158), show that the main source of error in data is typically because of a flawed research method. They recommend *internal and external validity* checks to ask, 'do we have enough responses / data to justify the findings that are claimed?' In this research an independent measure was to confirm with the regular University thesis review panels that the number of case studies and the quantity of primary and secondary data met or exceeded that of similar studies that had been hitherto deemed by peers and supervisors to be 'valid' research.

A further internal validation measure was to learn from a pilot interview that was conducted to test if the design and approach were measuring what was sought [i.e. testing the research hypotheses] or inadvertently measuring another concept. The pilot produced respectable results and led to only minor adjustments to the wording of the reflective, open questions. This exercise also improved reliability of the data capture by aiding the uniformity of the interview procedure, documentation and conduct.

External validation utilised two well cited academic works to gauge how successful the collaboration was between the states and the central IGOs. If the results did not broadly fit within these academic constructs, then this casted doubts on the data and underlying research method:

Firstly, the results were mapped against two of the four characteristics of successful orchestrator organisations that are at the core of the Abbott and Hale (2014: 9) paper *Orchestrating Global Solution Networks; a Guide for Organizational Entrepreneurs*; [Section 1.2, Gridlock Issues form the Literature Review, Chapter 1]. The level and quality of 'focality' and 'legitimacy' is assessed within the governance and leadership sections of each case study chapter, drawing on evidence from field work interviews to supplement the available literature.

Secondly, as Claire Dunlop (2011: 5) points out getting to grips with the structure and power dynamics that may exist within an epistemic community is important if we are to understand their belief system formation. A sound belief system is a pre-requisite to effective collaboration and thereby results and legitimacy. The research ascertained to what extent the SMP communities embody a belief system around the four knowledge elements Peter Haas identified: 1) a shared set of normative and principled beliefs, 2) shared causal beliefs, 3) shared notions of validity and 4) a common policy enterprise. The external validation showed that the data did fall within the constructs of these two academic studies [evidence for this can be found in the Research Results, Chapter 6: sub-section 6.3.4 for Abbot and Hale and sub-section 6.3.3 for Haas] thus providing re-assurance of a sound research method.

2.4.3: Counterfactual evidence

The research conclusions have the potential to challenge existing ways of tackling an apparently intractable problem by suggesting innovative contributions to knowledge. Such conclusions would only have credibility if counter evidence had also been gathered, analysed and considered. Reasonable scepticism would also serve to reflect on and challenge the adequacy of the research problem and questions themselves.

Consequently, as David Dooley (1984) points out, rival hypotheses as plausible alternative explanations to observations and gathered data should not be ruled-out in the research design and methodology. The research design therefore has ensured that no data either primary (interviews) or secondary (literature) has been dismissed as irrelevant or unreliable evidence. The analytical methods of testing the hypotheses include counterfactual evidence, this has served to understand the problem better and identify any weaknesses/simplifications in the hypotheses.

The methods of dealing with latent interviewee bias and researcher bias are covered in Sub-section 2.5.1.4. of the Research Limitations Section of this Chapter. The collation and examination of all the counterfactual evidence is in Section 6.1 of the Results Chapter. The discussion in section 6.1 demonstrates that disagreement and alternatives to the three hypotheses have been gathered, analysed and recorded with equal veracity to any that support them.

2.4.4: Research Ethical Issues

The SMP points of contact indicated their readiness to assist by clustering interviews at opportune times to aid the participants [and thereby my efforts to conduct the interviews]. Consequently, research ethics approval was sought and achieved as soon as possible, this allowed pre-arranged interview appointments to be respected and fit in with interviewee schedules. The nature of the case studies means that interviewees were from varied backgrounds. Cultural customs and etiquettes were scrupulously followed in visits to their organisations and before, during and after the interviews themselves. Small details such as the correct respectful designation of the surnames of interviewees (e.g. adding “san” for Japanese interviewees and using Madam as the prefix for all French women interviewees) helped smooth the process.

The research was carried out in compliance with established social science ethical codes of conduct and data regulatory requirements including the best practice European Commission’s ‘Data Protection and Privacy Guidelines’ (EC, 2009). To faithfully capture the qualitative data, the interviews were recorded and transcribed later; all recordings were deleted after the submission of this thesis.

Careful consideration was given to the management of informed consent, confidentiality and anonymity. All interviewees were asked if they wished to exercise their right to anonymity and their individual choices have been respected; this is not seen as a problem for the research.

2.5: Research Limitations

In this section, I firstly describe four limiting factors have been identified as risks to this study including the mitigating actions that have been taken for each one: 1) lack of research focus, 2) skewed data, 3) unprincipled internet sourced material and 4) latent interviewee bias and researcher confirmation bias. Secondly, I outline four expected limitations of the thesis i.e., what it will not do and highlighting how far forward the research is taken.

2.5.1: Limiting factors to the research and mitigating actions

2.5.1.1: Lack of research focus

The field of International Relations is a broad one and there is increasing interest and literature on global gridlock issues. It was important therefore in this research to go from a broad area to a focused one. The subject matter is under researched but opportunely there was enough material available to avoid the risk of over specialising and narrowing the focus too much. Regular feedback from my supervisor and attention to detail in the collection of data was important in this respect.

2.5.1.2: Skewed data

When finding and interpreting other people's existing research, overcoming the skew of available data (sub-section 2.4.2.1., Stage 1, Desk Research) was necessary. The risk was that the research would re-visit well documented areas at the expense of lesser known ones. To mitigate for this, less well-known global SMP material has been sought out. This material has been peer-reviewed and published in established academic publications; albeit less mainstream ones. Indeed, the nature of the research problem meant that looking beyond predictable sources was vital as would be the need to carefully synthesise the diverse data during the analysis.

2.5.1.3: Unprincipled internet sourced material

Internet based data has been treated with caution to distinguish between reliable university library and UN on-line sources and indiscriminate web searches. Irrelevant and derogatory articles that are associated with high profile global SMPs were purposively avoided; for example, parody 'NASA' websites that accompany the official NASA website or tabloid paper articles predicting the end of the world during the start-up of CERN's landmark LHC infrastructure. Internet searches were systematic and predominantly used keywords that stemmed from the research key concepts that are outlined in the conceptual framework (section 2.3).

2.5.1.4: Latent interviewee bias and researcher confirmation bias

Latent interviewee bias

CERN is expanding human knowledge in fundamental physics that could help answer how our Universe was created and where we come from. ITER is endeavouring to provide a route to carbon-free, commercial power generation that could help save the planet from global warming and change geopolitics. The ISS is carrying out unique micro-gravity science and building the knowledge mankind will need for space travel to Mars and beyond. *Who would not be proud to be a member of these communities?*

Many SMPs compete with rival projects to gain formal go-ahead and be established. They have optimism bias and strategic misrepresentation [Flyvbjerg et al, 2003: 73 and 137, in the literature review section 1.4.1.] built into their founding genes as evidenced in their pre-approval phase bid documentation. Previous research confirmed that SMP managers are highly driven and prone to making hopeful programmatic decisions outside their reliable competence. Participants in Big Science projects are justifiably proud of their own contribution and that of the institutions and organisations that are addressing these types of global challenges.

With the above understandable pride comes the risk of excessive defensiveness when these individuals are faced with criticism. Sergei Krikalev is an icon of Russian space exploration and a current ROSCOSMOS Director. He provided this comment in a 2017 interview when asked to recall 'good and bad days' on the ISS: 'for sure, we had difficult days, probably it is a sign of human memory to remember more positive things than the negative one.' (Česká televize, 2017). I did not encounter this trait during the field work: pride in accomplishments was equally matched with acknowledgement of the failings. Indeed, it is the openness and insights into how difficulties and constraints have been overcome that are the key analytical material of this thesis.

The collection and analysis of data was conducted keeping this latent defensive bias in mind. Booth, et. al., (2008: 82) reveal that experienced researchers understand that for research of any substance, any one interviewee's version of the truth is complicated, usually ambiguous, and always contestable. That is why they argue a sufficiently large sample of interviews needs to be conducted in order to even out any bias; a recommendation that has been ardently followed in this research.

Researcher confirmation bias

Disadvantages associated with interpretivism include the subjective nature of the approach and the risk of confirmation bias on behalf of the researcher. The above risk of my own confirmation bias has been recognised and while it can never be eliminated it can be managed; in this research by implementing three mitigation actions.

Firstly, the research problem (section 2.2) is an open one, in that it asks *how* effective collaborative pathways have been achieved. In other words, the problem statement does not predispose that any SMP international relations collaborative pathways are 'good' or bad'; the research method is primarily designed to simply investigate what they are.

Secondly, the desk research included the analysis of a secondary data pool that included counter-evidence; see section 6.1. The breadth and quality of the literature was tested against similar PhD level studies that had been deemed to be 'valid' and with leading academics in the field including the research supervisor to ensure it surpassed this standard.

Thirdly, the field work interviewee information sheets included the research problem statement and related questions but *not* the three hypotheses underpinning the conceptual framework. This calculated omission was to remove interviewer bias from the process and maximise the opportunity for complete and accurate communication between the interviewer and the respondent (Cannel and Kahn, 1968: 526–595). A short series of broad and open questions were put to each participant to provide structure; see Appendix C Interviewee Questions. The tone of the interviews was an open one encouraging each participant to recount in their own way what *they* believed was important, thus revealing both supporting and opposing evidence for the hypotheses. This method eliminated the risk of distractive prompting of the respondents by the interviewer.

2.5.2: Limitations of the thesis

There are four expected limitations to this thesis.

Firstly, the purpose in presenting common features of the SMP Communities approach (Section 6.4) is to support the explanation of how the global Science Mega-Project Communities have achieved their effective collaboration pathways. In other words, the features serve to amplify my answer to the research problem stated in section 2.2. Although I go on to provide two suggested contributions the deeper analysis of these is outside of the scope of this thesis. Consequently, as I outline in the Conclusion to the thesis, the follow-up to the contributions is an area ripe for further research.

Secondly, I will make a case in this thesis for a novel pathway, concerning innovative funding for international collaborative ventures, to be added to *Beyond Gridlock* theory. While I provide strong evidence to support my case, and it features in the second suggested contribution to knowledge (Section 6.5), it is also not the primary focus in answering the research problem. Aspects of this new pathway raise the possibility of designing it into international collaboration start-up conditions and operations to improve performance. Although a thought-provoking idea the exposition of a potential new collaborative design is another feature ripe for further research.

Thirdly, this thesis examines in depth three case studies; the rationale for the choice was explained in sub-section 2.1. Although adding other Big Science projects, such as those listed in Appendix A, to the analysis could add supporting and opposing evidence to the results, time and resource limitations prevents this increase. As explained in the Conclusion, expanding the case study pool is a prime area for further research.

Finally, although the thesis does make some deductions regarding aspects of project management, this characteristic is also not within the scope of this thesis.

Chapter summary

The series of steps that resulted in the cases studies being selected have been enumerated. Firstly, a recognised cost threshold, European research think tank roadmap and the output from a UN appointed set of experts regarding research infrastructure selection criteria were combined to produce a list of SMPs. The second gateway applied extra criteria (middle of page 58) that narrowed the field to truly *global* science community endeavours. Finally, the detailed research criteria (bottom of page 58) resulted in the selection of the three case studies.

The research problem - how do global SMPs achieve their effective collaboration pathways with member states - and associated sub-research questions were then stated. The case was then made that the research meets the test of helping to fill an incomplete understanding and addresses a practicable. This argument had two themes: firstly, that it linked to larger global gridlock theoretical constructs and secondly that strategists should familiarise themselves with the full range of trans-border global institutions, which the case study SMPs self-evidently are.

The research strategy was then described through the global SMP conceptual framework, showing three supporting determinants: firstly, the formal agreements leading to IGO creation; secondly, the external constraints affecting the projects and thirdly, SMP governance and leadership methods/practices. The framework mapped the three hypotheses against global SMP performance: better defined IGO agreements improve performance, external constraints adversely affect performance and sound governance and leadership dynamics improve performance.

The research design needed to test the hypotheses by adopting a research philosophy, following an accepted methodological approach, offering a means of validation, involving counterfactuals and dealing with identified research limitations and ethical issues. These requirements were then detailed through four sub-sections, summarised as follows:

1) while alternatives had been considered, a qualitative, ethnographic research method would be utilised to consider the case study organisations and the people in them. Interpretivism and critical realism research philosophies would govern the design.

2) a description of the methodological approach was then set out including the three stages of desk research, field research and data analysis and validation. Primary data would be collected

via semi-structured interviews with SMP executives and academics, secondary data comprised academic literature that would be gathered from University/Specialist Library resources. The data analysis included thematic coding, a pilot interview and internal/external validation to check that the data and underlying methodology were sound.

3) The need to include counterfactual evidence was then described together with the method of collection and an indication where the analysis could be found in this thesis.

4) Finally, the measures taken to ensure ethical issues were handled correctly were explained. These included scrupulous attention to cultural customs and etiquettes throughout the interview process and compliance with University and European Commission ethical codes of conduct. The overriding principle was the careful consideration and management of informed consent, confidentiality and anonymity.

Four research limiting factors and their associated mitigation actions were then outlined: a) lack of research focus, mitigated by ensuring sufficient material was available to avoid over specialising, b) skewed data, mitigated by seeking out less well-known peer-reviewed and published global SMP material, c) unprincipled internet sourced material, mitigated by avoiding irrelevant and derogatory articles that are associated with high profile global SMPs and d) latent interviewee bias and researcher confirmation bias, mitigated by having a high number of interviewees to average out and put in place any defensive optimism bias from a minority of interviewees, framing a problem statement that did not predispose any solution, including in the data pool counterfactual evidence and taking practical steps to obviate any distractive prompting of respondents.

Finally, four limitations of the thesis were then explained to indicate the scope boundaries, make clear what would not be covered and identify those areas that it was anticipated were ripe for further research.

CHAPTER 3: THE CERN COMMUNITY

Figure 4; CERN Community at IGO level as at March 2019

The purpose of CERN is to provide the world with knowledge of the fundamental laws of nature. The organisation also has a role in providing for collaboration among Member States (see Figure 4) in nuclear research of a solely scientific and fundamental character. Physicists use the world's most powerful and complex scientific instruments to study the basic constituents of matter. The instruments used at CERN are purpose-built particle accelerators and detectors. Accelerators boost beams of particles to close to the speed of light before the beams are made to collide with each or with stationary targets producing extremely high energy levels that release atomic particles (CERN, 2019). Detectors observe and record the results of these collisions. The data is shared through a world-wide distribution network of researchers as well as the central teams. The analysis process gives physicists clues about how the particles interact and provides insights into the fundamental laws of nature. The concept is encapsulated by Dr Markus Nordberg, Head of Resources Development at IdeaSquare: “CERN is an instrument to probe and interrogate nature itself…it is way for mere humans to talk to and listen to the power of nature.”

The term *World-Wide Lab* is used in CERN’s 62nd Annual Report (2016) to succinctly convey the confident camaraderie of purpose. The term naturally infers the prevalence of science at the heart of the CERN enterprise; but this is not wide enough for this study. As explained in the Methodology section 2.1, the CERN Community is an estimable example of an epistemic community that comprises knowledge-based experts in many sub-fields making its boundary difficult to define. For example, as Michael Lucibella (2014:2) points out, Member States are strategic in deciding where CERN funding comes from in their domestic budgets; therefore, it is not possible to generalise where individual financial knowledge-based experts, who support CERN, fit in. Member States may also change over time how they fund international projects to meet shifting domestic priorities. Consequently, the boundary of the CERN epistemic community, even in one sub-field such as Finance, varies from Member State to Member State and varies over time.

This first of the three case study chapters is organised into four sections that have been shaped by the main connections between elements of the Chapter 1, Literature Review and the separate hypotheses from the Conceptual Framework (Section 2.3: Research Conceptual framework and research hypotheses). While there is some overlap, by mapping out these associations I illustrate how the three hypotheses have been tested and where the results can be found:

> The first section will test Hypothesis 1 by examining the political contextual setting to CERN’s foundation, agreement of the CERN Convention and establishment of a range of favourable starting conditions. This relates mainly to section 1.1: Theory regarding global collaboration and international organisations of the literature review.
>
> The second section will test Hypothesis 2 by examining how three different types of constraints have been managed: a threat to its domain dominance, a political event that led to a funding crisis and a major technical set-back. This relates to section 1.2: Global Gridlock Issues of the literature review.

The third section will test Hypothesis 3 by examining governance and leadership dynamics. Three aspects are addressed: the organisational culture, focality and legitimacy and finally, plans for future developments and expansion. This relates to section 1.3: Science Diplomacy and section 1.4: Mega-Projects Governance, Leadership and Performance Issues of the literature review.

The final section evaluates the *Beyond Gridlock* pathways and associated mechanisms employed by CERN and acts as a summary of the chapter.

3.1: The CERN Convention

To test Hypothesis 1 (that IGO agreements and start-up conditions which are concise, fair, promote trust and mutual support, allow flexibility in problem solving, manage host state issues and emphasise the primacy of the State improve performance) four aspects are examined. Firstly, the political setting, CERN Convention (1953: 29) signature and ratification process. Secondly, the purpose of the CERN Organisation and its wider community including hosting arrangements are scrutinised. Thirdly, the Organs, Voting Rights, and the arrangements concerning the DG and Staff are examined. Fourthly, the special conditions and complex provisions that aid CERN's commercial, contracting and funding arrangements are outlined. Finally, a sub-section summary is provided.

3.1.1: Political Setting, Convention Signature and Ratification

The difficulties facing European nations' science communities in the early 1950s were many and multi-layered. Mainland Europe and large areas of the UK were re-building from the devastation of World War II. Their citizens were demobilising from a total war footing and gradually returning to civilian life. Mainland Europe academics were scattered and re-emerging from keeping a low profile. The only major European country whose science community had remained complete and indeed had blossomed during the war period was the UK, not only because of armament research related funding but because she had not been occupied and her Universities had survived largely intact. Germany was occupied by the Allies in four zones: three with the western allies and one with the Soviet Union. Leading German scientists were working for either the western allies or the Soviet bloc depending on their fate as the victors divided up the spoils of war. The USA, UK and France were arming themselves with nuclear weapons which all three were progressively developing and testing.

The cold war, which was to last 44 years, was just starting in earnest. The perceived threat of the Soviet Union with her communist doctrine embarking on its own nuclear weapons programme dominated world politics.

Against this grim backdrop, it is justifiable to ask how *any* effective international scientific collaboration could emerge. Part of the reason is the contrast between how the nations dealt with the aftermath of the two World Wars. Much has been written on the dissimilarity between the League of Nations that was formed in 1920 and the UN and its organs that were set up towards the end World War II and came into force in October 1945. Usually the analysis of the period centres on issues such as the 'big three' of the time (USA, USSR and UK) imposing their will on the world stage; a will they argued was necessary to overcome what Dan Plesch and Thomas Weiss (2015: 201) term as 'the general wreckage of the League of Nations'. Pierre Auger, who from 1948 to 59 was the Director of UNESCOs Department of Exact and Natural Sciences, provides an alternative rationale. He argues that as the League of Nations did not show any interest in science, no attempt was made to centralise or systematically coordinate the efforts of any of the national governmental institutions, and as a result their work was not brought together in any meaningful way (Auger, 1963: 10). One related non-governmental organisation, which still exists today, the International Council of Scientific Unions (ICSU) had been established in 1931. By the end of World War II, ICSU was recognised by UNESCO as effective in dealing with the national scientific unions. UNESCO duly signed an agreement with ICSU in December 1946 allowing it to distribute UN funds to the national unions. However, the scientific unions were under the influence of individual leading scientists, resulting in their actions being ineffective and they failed to set up committees on standardization or direct national projects into any international setting. Their actions were what Elisabeth Crawford, Terry Shinn and Sverker Sörlin (1993: 1-42) categorise as *spontaneous* rather than *bureaucratic*.

In contrast, the UN Charter was considered and was deliberately created before the end of the war and avoided the mistake of linking the new organisation with peace treaties. Fatefully, specialised intergovernmental agencies which were formed as part of the embryonic UN system such as UNESCO, FAO, WHO, etc., all at least had partly scientific aims. These IGOs were part of the second *bureaucratic* mode of science organisations that Crawford et al., had identified. UNESCO and its precursor body the UN Economic and Social Council (ECOSOC), provided a functioning vehicle which scientific communities could exploit to foster collaboration in their fields. An opportunity aided by a European Movement born out of the successes of the May 1948 Hague Congress that had a political will for growth and jobs and fostered various forms of European unity (CVCE, 2016).

A handful of visionary scientists, including Auger, Raoul Dautry and Lew Kowarski in France, Edoardo Amaldi in Italy and Niels Bohr in Denmark imagined creating a European atomic physics laboratory. They could see that such a laboratory would not only unite European scientists but also allow them to share the increasing costs of large scale facilities. It also meant they could compete with the US scientific community who were keen to retain their post World War II technological and scientific near hegemony. There was consensus that the time was ripe for Europe to move, and a risk that if it did not there could be a significant brain drain of the best fundamental physics talent to the USA.

The French ECOSOC delegation led the way with a draft resolution submitted for the establishment of UN research laboratories using an argument that 'many branches of science research connected with the promotion of human knowledge … would yield considerably more effective results if they were conducted on an international scale.' Their visionary document pre-dates the forming of UNESCO itself on 16 November 1946 and set in motion the chain of diplomatic events that led to the establishment of CERN; ECOSOC draft resolution E/147, dated 17 September 1946 (ECOSOC, 1946). The ECOSOC General Assembly debate and resolutions that led to the founding of international research laboratories under the auspices of UNESCO was another step forward (ECOSOC Resolution E/RES/22, 1946). The final piece of behind-the-scenes diplomacy resulted in the discussion paper *Question of Establishing United Nations research laboratories* that was the vehicle for agreement within the European nations of *how* to establish CERN (UN, 1948).

French physicist Louis de Broglie put forward the first official proposal for the creation of a European laboratory at the European Cultural Conference, in Lausanne in December 1949. A further push came at the 5th UNESCO General Conference, held in June 1950, where American physicist and Nobel laureate Isidor Rabi tabled a resolution authorizing UNESCO to 'assist and encourage the formation of regional research laboratories to increase international scientific collaboration.' Michael Krause (2014: 6) describes this moment as 'Rabi's smuggling of the idea onto the agenda.' Rabi was very well connected politically as he was a member of the US Atomic Energy Authority and had joined that organisation immediately following his involvement in the Manhattan Project that had developed the US atomic bomb. Rabi also, like many scientists who had been involved in the development of atomic weapons, was driven for the rest of his scientific career to the peaceful exploitation of atomic energy. He was the person the European high energy physics community needed in the international relations arena and he delivered. At an intergovernmental meeting of UNESCO in Paris in December 1951, a French resolution concerning the establishment of a European Council for Nuclear Research was adopted. Two months later at the 2nd session of the UNESCO intergovernmental conference, 11 countries signed an agreement establishing the provisional Conseil Européen pour la Recherche Nucléaire; the acronym CERN was born (UNESCO, 1952). The missing state, of the 12 who were to be founding members, was the UK.

CERN-UK bilateral correspondence reveals an underlying scepticism of the UK establishment as to why, given the advanced state of UK nuclear physics and close research links with the USA, any collaboration with European neighbours was needed. A negative position was led by Lord Cherwell the Paymaster General and scientific advisor to Winston Churchill. The UK reticence was only overcome by the determination and skills of the few UK scientists and engineers, such as John Adams [a future CERN DG], who could see the long-term benefits. The UK adroitly maintained payments to the fledgling pre-organisation to protect voting rights as an observer state. This meant that when Sir Ben Lockspeiser [a future CERN Council President] was finally authorised to sign the Convention, the UK seamlessly became a full member, narrowly avoiding missing out on being involved in the formation of the organisation, with influence on its structure and subsequent workshare (CERN, 1953).

Following signature of the CERN Convention and the associated financial protocol during the period July to December 1953, the national ratification processes started. The international treaty came into force when the instruments of ratification of seven Member States were deposited at UNESCO House in Paris. Switzerland, as the host state, had to be one of the seven and the final condition was that the financial contributions of the ratifying members had to be at least 75% of the organisations budget. The required number of ratifications with combined level of contributions were met, and CERN was created on 29 September 1954. Remaining national parliament ratifications were achieved by the end of 1954 and the founding 12 Member States were: Belgium, Denmark, France, the Federal Republic of Germany, Greece, Italy, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom and Yugoslavia. This grouping looks quite natural today but was the fall-out from a remarkable reconciliation that was taking place at the time. Former CERN Director General, Horst Wenninger highlighted that in the wake of World War II, “cooperation between European nations was simpler in science than in other fields” and helped play a part in the overall Franco-German rapprochement (Davis and Patman, 2015: 9). Werner Heisenberg, as a previous war time Director of the Kaiser Wilhelm Institute of Physics in Berlin, had worked on the Nazi regime atomic bomb project. With his signature on the CERN Convention, Germany regained its status as a coequal partner within the family of European nations for the first time since World War II (Krause, 2014: 21); the nature of this profound change within Europe is illustrated in Figure 5.

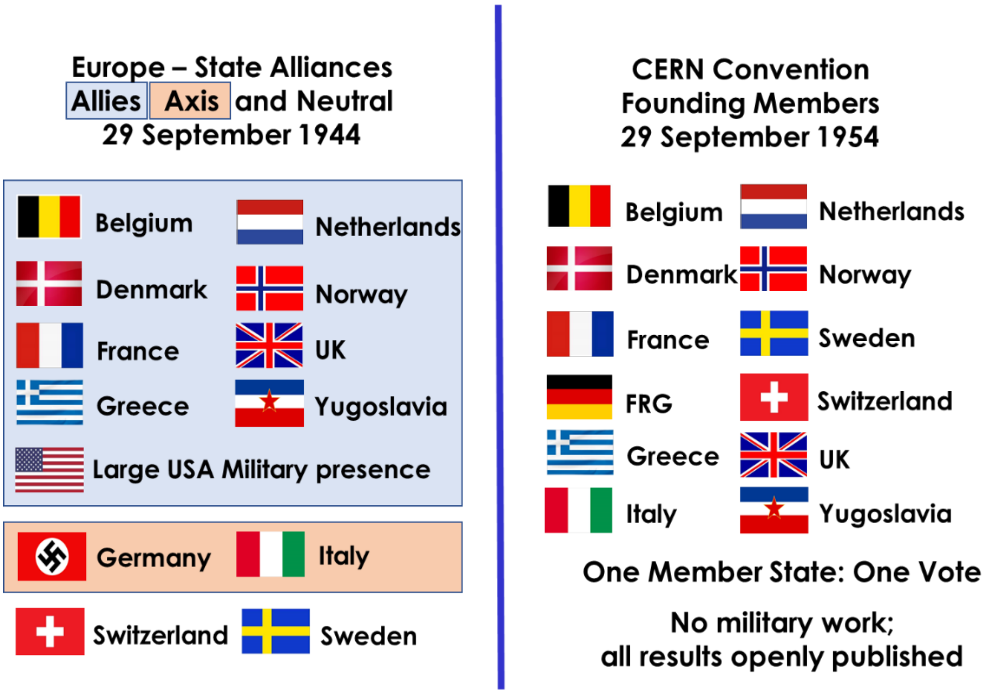

Figure 5; European State Alliances in 1944 compared to CERN Founding Member States in 1954

The unanimous national parliament ratifications are a testament to the efforts of the CERN founding fathers and the trust of the governments in both them and the project. Adapting Krause's (2014: 134) summary: consensus had been reached through the fateful, timely and powerful combination of two groups: European-minded politicians and single-minded European particle physicists. The politicians were looking for practical ways of reorienting Europe and the physicists were looking for their facility. Both were also determined to compete with the might of USA science and technology in fundamental science and wider contexts.

3.1.2: Purpose and hosting arrangements

The Convention makes clear that purpose of the organisation has two themes: firstly, to provide for collaboration among European States in nuclear research and secondly to describe what the central organisation will do from a facilities and experimentation point of view.

The first theme shows an acceptance by the Members of the necessity for collaboration and this permeates in all areas. It also explicitly makes clear that the 'Organisation shall have no concern with work for military requirements' and that all results will be published. This was included to combat unfounded criticism and public anxiety, particularly in the UK and some local Swiss elements, surrounding the formation of CERN. Paragraph 7 of Article II highlights the need for a co-operate spirit that also avoids duplication of effort. Nodes of excellence can exist and are encouraged outside of the central body but must fit-in to the overall plans that the centre leads on.

The second theme is to demarcate exactly what will be undertaken and thereby limit activities and the allocation of resources to just that, unless authorised by amendments to the Convention [the mechanism for doing this is described in Section 3.5.3]. This precision is a means for the Member States to immediately and effectively limit and manage any tendencies for the central organisation to indulge in mission creep. The only amendment to the convention was in 1971 to add a second laboratory administrative unit; a change that was reversed some 10 years later. The precision is enough to provide certainty of purpose but not too detailed to limit innovation and/or the means of achievement. Boisot et. al., (2011: 26) point out, given the technical uncertainties that must be dealt with, that this corresponds to what Mintzberg and Quinn (1988) label as a project adhocracy in that it leaves teams of experts to solve complex problems in whatever manner they see fit. This trust in the workforce is a crucial aspect of the management approach and relates directly to Hypothesis 3 concerning sound governance and leadership; it is analysed further in section 3.3.

The first two paragraphs of Article II ‘Purposes’ of the CERN Convention (1953) state the following:

1. ‘The Organisation shall provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto. The Organisation shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published or otherwise available.’ Herwig Schopper, Director General of CERN from 1981 to 1988, adds, in an interview for this research, colour to the Article: “the spirit from the beginning, was that we are not at CERN to profit we are there to help to achieve the common objective. A principle introduced by the founding fathers that still exists today.” Indeed, many long-serving senior staff voiced how proud they were of ‘their’ Convention, a sentiment summed up by Markus Nordberg the Head of Resources Development: “it is a very nicely written document and sets the scene for fostering international collaboration across the range of projects that comprise CERN… it provides a healthy balance between top-down and bottom up management approaches… we owe a lot to our founding fathers both on the scientific side and wise people in the ministries and governments at that time who made that happen.”

2. ‘The Organisation shall… confine its activities to the following:

(a) The construction and operation of one or more international laboratories (hereinafter referred to as ‘the Laboratories’ for research of high-energy particles, including work in the field of cosmic rays; each laboratory shall include:
   i. One or more particle accelerators;
   ii. The necessary ancillary apparatus for use in the research programmes carried out by means of the machines referred to in (i) above;
   iii. The necessary buildings to contain the equipment referred to in (i) and (ii) above and for the administration of the Organisation and the fulfilment of its other functions;

(b) The organisation and sponsoring of international co-operation in nuclear research, including co-operation outside the Laboratories; this co-operation may include in particular:
   i. Work in the field of theoretical nuclear physics;
   ii. The promotion of contacts between, and the interchange of, scientists, the dissemination of information, and the provision of advanced training for research workers;
   iii. Collaborating with and advising other research institutions;
   iv. Work in the field of cosmic rays.’

Paragraph 3 of the Convention deals with precise scientific requirements and paragraphs 4, 5 and 6 concern the CERN Council voting rights that I cover in sub-section 3.1.3. Paragraph 7 states that ‘The Laboratories shall co-operate to the fullest possible extent with laboratories and institutes in the territories of Member States … and seek to avoid duplicating research work’.

The first hosting ‘Agreement between the Swiss Federal Council and the European Organisation for Nuclear Research concerning the Legal Status of that Organization in Switzerland’ was signed despite some raucous local opposition to the venture (CERN, 1955). An unlikely coalition of the Swiss Communist Party and the International Red Cross opposed the site selection mainly due to concerns regarding nuclear safety and threats to the long-standing Swiss neutrality. Both objections were proven to be unfounded but did gain traction for a while during the public debate leading up to the referendum in the Canton of Geneva held on 27-28 June 1953. The vote had been called following the recommendation of the provisional Council's third session in October 1952, that the site of the future Laboratory be near Geneva; Figure 6.

Figure 6; CERN Provisional Council's third session, Geneva, Switzerland, October 1952 (picture courtesy of CERN)

The opposition debate was fuelled by the UK based *Economis*t Magazine that demanded re-assurances that CERN would not be a player in the evolving nuclear arms race. The CERN archive reveals that despite other pressing issues the first DG, Edoardo Amaldi, realised the need to respond immediately to the article. His reply was diplomatic but firm and included a reminder of an important concession that the local Swiss opposition groups had insisted was included in the Convention: ‘It has been emphasised … that the European Laboratory would be a *Maison de verre* and that all the work done in it would be published and freely available for everybody. This was a condition for participation of some countries like Switzerland, whose delegation had made clear was a ‘red-line’ for them at the first inter-governmental conference…’ (CERN Archive, 1952, Document Number 390). The Swiss had also ensured that no part of the Convention precluded eastern European states from membership thereby protecting Switzerland’s neutral stance to the widening east-west divide, a position that served CERN well in the years following the collapse of the USSR at the end of the cold war in 1991 when four former satellite states joined as full members. In the end the referendum resulted in an overwhelming two-thirds majority in support of site construction going ahead (CERN, 1953).

Host state personnel employed in the central organisation do not qualify for privileges and immunities that other Member State personnel enjoy. On the corporate level, the relationship also allows the Organization to have a legislative home for safety and regulatory topics that permit legal operation. Worthy of separate consideration is the constraint due to delicate in-kind arrangements for the 'host state'. John Womersley, ex-UK STFC Chief Executive and current DG of ESS in Lund, Sweden, commented that "the risk perceived by host states is that there will not be enough noble work for them." In this context, noble work means 'high technical value and/or high scientific value and/or high monetary value.' Womersley added that "this risk has to be adeptly managed to avoid resentment between the parties."

All IGOs publicly declare they are dedicated to fostering good host state relations and many strive to keep host states content. The importance of examining CERN's host state relations to this thesis, is to demonstrate that it is another feature that the Community has always, from DG Amaldi's letter to today with a dedicated host state relations team, recognized is crucial to its success.

3.1.3: Organs, Voting Rights, the Director General and Staff

The CERN Council is the highest decision-making body and is composed of two delegates from each Member State; accepted practice is that one is a leading physicist and the other represents the national government. The Council meets at least once a year in both open [allowing participation of observers] and closed sessions. Each Member State have one vote. Today, this arrangement seems predictable and self-evidently fair. In the late 1940s, there were those who argued, in relation to the establishment of the UN and its organs, that there were other possibilities. With what today would be correctly seen as cultural prejudice American Professor Harold Urey the Nobel Prize (Nobel, 1934) winning chemist, argued in 1948 that 'the inclusion of illiterate, poverty-stricken, over numerous masses of the far East' constituted the major problem for the world state. The American theologian Reinhold Niebuhr commented at the time that what Urey was proposing was a system of weighted votes in favour of nations with high literacy and abundance of raw materials and industrial production (Niebuhr, 1949: 5). The CERN founding members were clearly in Urey's view from the latter group that he favoured. This erstwhile forgotten debate reminds us that nothing is inevitable with the set-up of bespoke IGOs created by specific communities. There is no common rule book that they must follow. It is to the credit of CERN's founding leadership and her Member State statesmen that they resisted prevailing societal prejudices and unanimously adopted the one vote per member arrangements for the highest decision-making body (CERN Convention, 1953; Article V).

The Convention required the Council to establish two subsidiary bodies, which it duly did at its first meeting in 1954: a Scientific Policy Committee and a Finance Committee. The role of the Scientific Policy Committee is an important one in how the community governs itself and I cover this in detail in sub-section 3.3.2: Focality and Legitimacy.

The Finance Committee consists of representatives of all Member States and meets five times a year, to address budgetary, procedural, personnel and commercial matters. In June each year it discusses and recommends Council to approve the Annual Accounts of the preceding year, as well as the Medium-Term Plan, which includes the Budget for the following year. In the second half of the year, the Finance Committee advises the Council on the cost-variation index and the scale of contributions that member states need to pay. The Finance Committee has weighted voting whereby a 2/3rds majority [minimum of 15 of 22 states] must agree to a resolution *and* their combined contributions must be at least 70% of the total. There is a long-standing protocol whereby no Council decision related to key financial elements such as the budget, medium term plan and annual contributions is reached without a prior positive recommendation by the Finance Committee.

Two other committees, not addressed within the Convention, have subsequently been set up by Council to advise themselves and the Finance Committee. The Tripartite Employment Conditions Forum, where the Staff Association, the management and the Member States consider measures relating to the Organization’s social and employment conditions. Finally, an Audit Committee provides independent, objective advice and guidance on the adequacy and effectiveness of the Organization’s governance structure, risk management, values and ethics and provides oversight of the internal and external audit.

In contrast to a golden period when the budget was increasing, Herwig Schopper, Director General of CERN from 1981 to 1988, took over when the funds from the contributing members were being reduced. Tough decisions had to be taken to close existing projects and concentrate on securing funding for the LEP. He provided first-hand insight into how members voting was managed during this challenging period: “what I introduced was before each Finance Committee and each Council meeting there was a dinner of all the delegates and my team, where we could openly discuss serious questions and we asked delegates, do you have instructions to vote against something? They would say yes; I have these instructions and we would then ask if you are overruled by a majority then would that create serious problems in your country or not? Then delegates would say either if you overrule me, yes, it would create serious problems, or they would tell us it is manageable. If the answer was the first, then we would try hard to find another solution acceptable to everyone ahead of any closed sessions of Council. This pre-meeting dinner forum continues to this day. There was then and is now an active spirit of fairness in the collaboration that we always try and maintain."

The Convention at Article VI is thorough in the terms for the appointment of the Director General (DG). The DG is a diplomatic appointment and enjoys the privileges and immunities that this status brings. This standing is also needed as the DG represents the Organisation in contractual, safety and operating legal contexts. As discussed in sub-section 1.1.1: Realism of the Literature Review, while SMP DGs are granted considerable autonomous authority over the staff and operational matters, the final power rests firmly with the nations. A two-thirds majority of the Council is required to appoint the DG for a fixed term of 5 years. At CERN, the DG is exceptionally extended for 1 or 2 years but has never been appointed to a further full 5 years term. This contrasts with younger Science IGOs, such as the European Southern Observatory, where a DG can be re-appointed for a full second term. Similarly, another crucial role, the CERN Council President, is limited to a 3-year term allowing the Member States, who elect the President, to have regular input into how governance is operationally exercised.

On the 5th November 2014, at its 173rd Closed Session the CERN Council selected a long-standing distinguished Italian scientist and previous leader of ATLAS, Dr Fabiola Gianotti, as DG. The Council Press Release stated that the Members had rapidly converged in favour of Dr Gianotti and that she would be the first woman to hold the position; her five-year mandate began on 1st January 2016 (CERN, 2014). As with all DGs, Gianotti used her prerogative to decide on the number of Directors and proposed appointees including, for the first time, a Director of International Relations. The 'DG elect' is chosen one year before taking office to allow a smooth transition including the identification of his/her immediate team. Council then ratifies the incoming DG's organigram and Directorate level appointees. In the case of Gianotti, she was an 'inside CERN' person having led the ATLAS project; the established protocol is that her immediate direct reports then be from 'outside CERN.' This process enables a regular freshening up of the top-level management and allows the DG to be immediately at ease with the team he/she has formed. An attendee vividly recalled the first Directors meeting chaired by Gianotti: "I remember the first meeting when all five [the DG plus 4 Directors] of us were together, it is extremely demanding and a huge responsibility, but it [the appointment process] also instils a level of confidence because we were all unanimously confirmed by Council."

Paragraph 4 of Article VI makes a noteworthy statement that 'the responsibilities of the DG and the staff in regard to the Organisation shall be exclusively international in character'. It goes on to say 'in the discharge of their duties they shall not seek or receive instructions from any government or from any authority external to the Organisation. Tellingly, it concludes with 'Each Member shall respect the international character of the responsibilities of the DG and the staff and not seek to influence them in the discharge of their duties'. Many industrial JV arrangements aspire to similar standards whereby the central management team has both autonomy and authority over the JV companies but are often hampered by commercial considerations and company loyalties. Interviewees consistently attested that the CERN community crucially achieves this through living the principle in a combination of everything the DG and his/her staff do together with everything the Member States and their respective Institution's leadership and staff do. The decisions made in the centre are genuinely respected as being for the good of the whole community and not any single element.

3.1.4: Commercial, Contracting and Funding Arrangements

3.1.4.1: Commercial and contracting arrangements

Following on from the hosting agreements with Switzerland and France, CERN formalised the *Protocol on Privileges and Immunities* with the Member States (CERN, 2004). Legal disputes between CERN and its suppliers and contractors are not submitted to national courts but to international arbitration. CERN as a distinct legal entity can negotiate favourable terms and conditions for purchases of equipment and services. The commercial advantages of this arrangement are twofold. Firstly, for the organisation itself and include 1) exemption from value-added tax payments, 2) the opportunity for standardisation of procedures, 3) where appropriate, economy of scale savings, 4) the prospect of being an intelligent buyer with high reputation and 5) the chance to accumulate expert market knowledge over decades of construction, operation and maintenance. Secondly, there are also advantages for Companies and Institutions in bidding and being awarded CERN contracts, including: prestige in being associated with the research coupled with building long-term relationship and winning follow-up work with the Organisation and its Member States Institutions.

CERN is not bound, as with other SMPs such as the European Space Agency (ESA) where a strict *juste retour* principle is applied. For example, in their portion of the ISS (Chapter 5) whereby about 85% of ESA's budget is spent on contracts with European industry. ESA's published industrial policy is to ensures that Member States get a fair return on their investment. The aim is to improve the competitiveness of European industry, maintain and develop space technology and exploit the cost advantages of competitive bidding (ESA, 2018).

For CERN, more flexibility in the process is allowed to aid higher management in maintaining fairness in the nations' workshare. During competitive tendering, if the second lowest bidder company, who is compliant in all other ways and is within 20% of the lowest bid, is from a 'poorly balanced' or 'very poorly balanced' member in terms of its procurement share of CERN contracts then it is given an opportunity to 'align' with the lowest bid. Technology transfer and spin-off's, such as hadron therapy medical scanners, are another vehicle that keep nations content with their return on financial investment. These spin-offs also help foster a collective pride in improving the fabric of society.

The construction of CERN's physical infrastructure and experiments is an industrial scale undertaking similar in size to the largest civil engineering projects, such as commercial power stations. The LHC construction costs were in the order of US$ 4BN with an approximate annual operating budget of US$ 1B. Standard project control methods for cost-control, quality assurance and schedule adherence are employed by CERN and the large instrument project teams. The 'DG elect, Gianotti, explained in the 'CERN Model, Science, Education, and Global Public Good Symposium', that these control methods are applied with a light and sensitive management touch (CERN/UNOG 2015); I return to examine this management approach in Section 3.3: Governance and Leadership Dynamics.

The experiment projects and other major collaborations such as for the 'Deployment and Exploitation of the Worldwide LHC Computing Grid' are not legal entities but are bound together through MoUs (ATLAS, 1998; CERN, 2015). Boisot, et. al., (2011: 116, 135) describe 'buying under conditions of uncertainty: a proactive approach' and 'learning and innovation in procurement.' Their conclusions can be summarised by saying that there is untapped potential for SMPs to act as lead users to speed up and leverage the conversion of new scientific knowledge into exploitable industrial knowledge. A practical example of this is the Knowledge Transfer Group whose goal is to accelerate innovation and maximise the global positive impact of CERN on society. Interviewees confirmed that, as with many aspects of CERN, this Group is not just a name but a well-staffed, effective and high-profile part of the central organisation and plays a respected role in the wider community.

3.1.4.2: Funding arrangements

CERNs funding has two strands: that for the central organisation (infrastructure and personnel) and that for the embedded instrument projects. The complete picture is complicated, here I only consider the overview of both situations. The Director for Finance and Human Resources, Martin Steinacher, explained that “we do every year the exercise to calculate what the contributions will be, based on net national income, reflecting the economic strength, this is already in the Convention and was a very, very wise provision.” Each Member State contributes annual cash payments both to the capital expenditure and to the operating expenses according to the formula of Article VII of the Convention and the Financial Protocol. This means that while the LHC was built by CERN using the money contributed to the central fund, the four giant detector experiments were funded, designed, and built by independent international collaborations. Michael Lucibella (2014) recognises that this has the advantage that if one instrument project falls behind, it does not necessarily mean the entire endeavour will suffer. John Krige, identifies that “For some governments, the infrastructure of CERN is funded from the foreign policy budget, not the science budget.” (Hermann, et al., 1987: 106). He added that the UK is one of the few countries to use money solely from its science ministry, inevitably pitting scientists against each other over whether to support the international program or unrelated domestic research. Krige goes on to say, “That led to incredibly bitter fights in Britain on how much it can afford for CERN that were avoided in other States who funded international projects differently.” I return to this when considering US funding to the ITER Project (Chapter 4).

The ATLAS and CMS MoUs allow funding commitments from the participating Members States that include large scale in-kind contributions. Procurement, development, production and unit testing is carried out nationally before items are shipped to CERN, assembled and system tested. This arrangement has two major benefits to the contributing nations, making IKM a feasible route to participation in Science Mega-Projects. Firstly, it helps maintain alignment whereby a contributing nation obtains a benefit corresponding to the value of contribution that they make. It does so by keeping the majority of spend for the experiment collaborations in the Member State territories. Secondly, it enhances the professional and social capital of the member’s scientists and engineers who are participating in the project, leading to enhanced status for those nations and national institutions in the global science community.

A senior, long serving Manager provided an analogy to explain the CERN funding model: “it is like an airport; the runway is the LHC and there is a control tower where the wise CERN management keep an eye that it is not too crowded, and the airport resources match the demand. Then you have the crazy pilots and the airlines, they fly in the happy customers who are the physicists who love the airport because there is so much going on and everyone collaborates. But the funding of the two is separate, you have the infrastructure and everything that goes with that and you have the brains in the experimental projects that operate within it."

Section summary

Hypothesis 1 is supported (see checklist of supporting and opposing attributes at Table 1) in that the Convention clearly sets the scene, establishes workable rules and provides sound guidelines on operational parameters; the Convention Articles provide a solid base from which the organisation and its community have benefited. This relates to three *Beyond Gridlock* pathways: Pathway 1, 'shifts in major powers core interests' present as the driving force for the coalition that created CERN; Pathway 2, 'autonomous and adaptive institutions' that included granting governing bodies the capabilities to adapt to emerging issues and Pathway 3, 'technical groups with effective and legitimate processes' being free to solve problems without being overburdened by hierarchical bureaucracy.

3.2: Managing Constraints

To test Hypothesis 2 (that external constraints such as excessive stakeholder aspirations, changing political and legal landscapes, bureaucratic regulations, funding fluctuations and unforeseen events, while being mitigated as far as possible by IGO leadership actions, inevitably adversely affect overall performance) I examine how the CERN Community leadership has handled three potentially constraining events. The first concerns its scientific domain dominance, the second a political event that quickly threatened its funding and the third, an unforeseen technical issue. Finally, a sub-section summary is provided.

3.2.1: Domain Dominance

The first event to test Hypothesis 2 concerns one rival project that had the potential to challenge CERN's domain dominance. While much of this thesis discusses the collaborative facets of science, it is also a highly competitive field. There is a worldwide competition between groups and institutions to discover knowledge and to secure funds. Healthy competition is also encouraged and indeed essential to the way CERN operates internally, typified by the rigour employed in the detection of the Higgs boson. The findings were only made public when the results from the ATLAS team were independently confirmed by their counterparts in the CMS team. While there was a need for the dual confirmation there was also keen competition as to which investigational group would be first.

There is also fierce competition for the best scientific and technologist talent, and this is often related to which organisation has the best facilities, consistent funding and reputational kudos. Here I will focus on one rival project that had the potential to challenge CERNs domain dominance and how the community countered this threat. The rival Superconducting Super Collider (SSC) being planned in Texas in the 1980s was so large and ambitious with construction costs, even in the conceptual design stage in the multibillion-dollar order, that it could only be built by the USA finding collaborating partner states (Riordan, Hoddeson and Kolb, 2015: 172). The scientific and technical successes of CERN had political consequences for the SSC. Each triumph reinforced the political will of the European Member States to continue patronage and encouraged individual scientists, technologists, research groups, and new states to join.

An early CERN Device, the Super Proton Synchrotron, enabled Simon van der Meer and Carlo Rubbia to lead two-detector experiments that proved the existence of the W and Z boson particles. These particles are responsible for weak sub-atomic interactions, and the discovery substantiated the basic structure of the Standard Model of particle physics, an accomplishment for which they were jointly awarded the Nobel Prize for Physics (entry 3 in Table 2). This success reinforced the scientific and technical kudos allowing the CERN Council to push on to the next step device in the knowledge that it would have been unthinkable for European states to collaborate on any project other than the new CERN LHC they were then considering. Riordan, Hoddeson and Kolb (2015: 173) convincingly argue that prioritising on CERN meant there were little, or no funds left available for the Europeans to become involved in other international collaborations.

With Europe ruled out and Russian and Indian fundamental physics scientists already having access to CERN through Protocols first agreed in 1967, the US fundamental physics community courted Japan. US-Japan trade war tensions proved too big an obstacle to progress and pressure mounted on the project. US President Clinton (American Presidency Project, 1993) offered his public support with an open letter to the Chair of an influential Budget Committee of Congress that included: 'As your Committee considers the Energy and Water Appropriations Act for Fiscal Year 1994, I want you to know of my continuing support for the SSC... Abandoning the SSC at this point would signal that the United States is compromising its position of leadership in basic science, a position unquestioned for generations. These are tough economic times, yet our Administration supports this project as a part of its broad investment package in science and technology... I ask you to support this important and challenging effort.' Despite this, mounting design and construction costs and pressure from rival US projects, persuaded Congress to officially cancel the SSC in October 1993. The US Science Historian, David Appell noted in 2013 in Scientific American: "although no one reason explains the cancellation, a few key aspects of the project stand out. The inability to secure any foreign sources of funding was pivotal…" (Appell, 2013).

Many interviewees contended that you need both collaboration and competition and that for the benefit of high energy physics the whole community needs to have a healthy mix of proficiencies that a strong counterbalancing US capability should contribute to. There was therefore no rejoicing in the European science community at the SSCs demise but CERNs status as the preeminent fundamental physics facility in the world was now unchallenged. CERN had triumphed over the SSC by a combination of two factors. Firstly, scientific success was not then or now seen as a one-off but as part of a continuous stream of positive outcomes; this reinforced good will with the members including their national internal non-scientific backers. Secondly, by carefully expanding scientific access through protocols with individuals and institutions, increased associated membership and full membership, potential partners were relentlessly detached from the SSC. The brain drain that CERNs pioneers had warned against was stemmed. US fundamental physicists joined those from around the world and increasingly flocked to CERN to conduct their research.

3.2.2: Funding Resilience

The second event to test Hypothesis 2 stems from the period following German reunification in 1990 when payments from Germany to all international bodies were reduced. Germany was then and remains now the largest contributor and news of the reduction came just at the time when the Council had to find extra funds for the new flagship infrastructure project: the LHC. Other nations, led by the vocal UK, while sympathetic that Germany's contribution would fall insisted that no unilateral reduction could be agreed. The Council adroitly decided to reduce contributions for all Members to align with the reduction needed by Germany. By acquiring distinct extra funding from the Host States (France and Switzerland) whose industry would gain the most from the construction, the funding gap was partially plugged and allowed the Council to give the construction go-ahead in December 1994. Chris Llewellyn Smith [a future DG] then led the efforts to convince non-Member States to join the LHC project with great success: Japan (1995), India (1996), Russia, Canada and the USA (1997) all came onboard. When Germany again reduced her contribution in 1997, the Council permitted construction finance through advantageous European Investment Bank loans.

Another external funding constraint that was dealt with was explained by Martin Steinacher who at the time, in 2015, was still delegate for Switzerland in the CERN Finance Committee: "nimble flexibility was demonstrated when the exchange rate of the Swiss Franc quite unexpectedly dropped from 1.20 to parity, immediately the CERN membership for the Euro countries became more expensive by 15-20%, because they contribute in Swiss Francs. The CERN management held a crisis meeting and decided they had to do something to help and to show good will and so in 2015 the contribution levels for all states was lowered by 6% to ease the pressure. The situation was managed to the satisfaction of the member states."

Even when under budgetary pressure, the solutions reached were scrupulously fair as enshrined in the Financial Articles of the Convention. A principle described well by James Gillies the Head of Communications at CERN for 13 years up to December 2015 and current member of the Strategic Planning and Evaluation unit noted that "one of the most significant factors that has led to the good collaboration between the member states and the central organisation is the simplicity of the CERN convention and the fact that it is all about collaboration between countries, mutual support when needed, there is flexibility and it is very, very fair, everybody pays according to their ability to pay, so Council sets the overall budget and then the global economic situation sets who pays what….it is a beautifully simple document."

Markus Nordberg the Head of Resources Development at IdeaSquare provided this analogy: "it is almost like a family business [with the member states] there is always some little scandal somewhere ….and the family effort is trying to keep this one individual at that time, happy." He added regarding the budget "running an operations annual budget of over IBN Euro through 23 governments is not a trivial matter and often there is one nation which for internal political reasons has difficulty in funding and that generates a little tension, but only in the sense that the other nations have to find a way to help; like a family. There is an understanding, built up over time, that things change, governments change, atmospheres change, and the majority always takes upon itself to help the one in trouble. The one needing help changes, not the will to help."

The field work confirmed the message from the literature that today CERN benefits from having the seamless mix of both in-cash and in-kind funding. Members make cash contributions based on net national income, reflecting the relative economic strength, to the 1 BN $ annual budget. Non-member states have made substantial in-kind contributions during periods of need such as the Russian and US contributions to the LHC. In-kind contributions also feature strongly within the multinational experiment collaborations.

Crucially, the mixture comprises just the right levels of each type of funding. It has enough cash contributions to allow the central organisation to make timely operational decisions but not too much to allow unnecessary mission creep. The community has enough in-kind work to keep its industrial, scientific and technological base content but not too much to hamper the central organisation in managing the entire facility.

3.2.3: Overcoming Technical Obstacles

The third event that will be utilised to test Hypothesis 2, occurred on 19 September 2008, just nine days after the LHC was commissioned and circulated its first beams of particles. A connector between segments of the superconducting magnets failed and the pressure of the released cooling helium inside the cryostats caused catastrophic damage. Safety features worked well and there was no risk to the work force or the local community; but given the media hype around the start-up there was reputational damage to the whole CERN Community that could easily have escalated if the investigation into the cause and recovery had not been handled sensitively. Repairs took over a year and a thorough investigation found the root cause as a combination of a design flaw and manufacturing defect that more rigorous quality controls, throughout the process, might have prevented. It would have been easy for recriminations to follow, but the CERN Community took the opportunity to make the particle detectors better prepared, shared the increased costs between all the parties and put in place protocols to prevent, as far as possible, any reoccurrence. Throughout the shut-down the management team released open updates on the investigation into the causes, the repair plans, costs and progress. It was a set-back that a strong team spirit adeptly dealt with rather than adopting a blame culture which would have exacerbated any reputational damage.

Following that event, the continued trouble-free running of the LHC since 2009 has provided a stable platform for ATLAS, CMS and other instrument teams. The stand-out achievement has been the discovery in 2012 of a new fundamental atomic particle consistent with the Higgs boson predicted by the Standard Model. This discovery led to the Nobel Prize in Physics being awarded jointly to François Englert and Peter Higgs, with citation including recognition of the part CERN played: "for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider." (Nobel Foundation, 2013). The CERN DG at the time, Professor Rolf-Dieter Heuer, commenting: "The discovery... marks the culmination of decades of intellectual effort by many people around the world. It is a global effort, it was a global effort, and it is a global success." (BBC, 2013). Although the prestigious Nobel Prize can only be given to an individual or up to three collaborating individuals, CERN handles all its scientific papers in a collective way. The scientific papers surrounding the Higgs boson particle discovery and subsequent refining of size of the particle were cited as co-authored by the entire detector teams. For example, the paper that announced the ATLAS team's observation of the Higgs particle in 2012 had 2,932 authors, of whom 21 were listed as deceased. This 'hyper-authorship' is intentional and commendable; it publicly recognises the collaborative nature of modern research and helps foster an espirit de corps. As Davide Castelvecchi (2015) reports in Nature Magazine this practice is not unique to CERN, but CERN has led the way in its adoption not just in physics research but in the broader scientific community. This collective approach has led to calls from many, including the editorial team of Scientific American, for the Nobel Foundation to change its position and recognise that “Whereas a century ago a patent clerk famously divined the theory of relativity in his spare time, discovering a Higgs boson requires decades of planning and the efforts of 6,000 researchers. No one person -no troika, even - can legitimately claim all the credit” (Scientific American, 2012).

A physicist from one of the experiment teams pointed out that “when we have secured our funding and we are up and running, everyone is on the [signed science] paper, we are then focused on the results and this helps with the collaboration and helps with building personal reputations on who contributes most to that collaboration. When you get arguments on major papers with big results, many may initially hesitate before signing their names… and there is very long peer review… and we have to maintain patience and flexibility which is supported by management who are on same page… and that maturity really matters as it means anyone can do a very exciting result and the originators will get the credit eventually, but we are not going to get mavericks publishing random results. Everyone benefits in the end”.

Section summary

These three diverse examples demonstrate that while external constraints will affect performance, the effects can be minimised by the community leadership navigating through and around them. CERN’s high reputation is borne out of its repeated scientific successes and its managerial ability to overcome threats, obstacles and set-backs. This capability to deal with crises as well as supporting Hypothesis 2, also serves to support Hypothesis 3 that ‘sound internal governance and leadership dynamics improve global IGO performance’; see the checklist of supporting and opposing attributes at Table 1. The capability relates principally to Pathway 7 ‘innovative leadership as a reaction to gridlock’ with regular, supporting use of Pathway 8 ‘innovative funding’ mechanisms.

3.3: Governance and Leadership Dynamics

To test Hypothesis 3 (that sound internal governance and leadership dynamics improve global IGO performance) I examine three organisational features. Firstly, the organisational culture; here the analysis has profited from the views that were expressed at all levels within the community during the field work interviews on those management approaches that have been most productive and how criticisms have been dealt with. Secondly, I examine two characteristics of successful orchestrators that Abbott and Hale (2014: 9) identify: focality and legitimacy. Thirdly, I explore upcoming developments for CERN in an international context including how future membership may be managed and the community's potential strategies regarding the next generation facility. A sub-section summary is also provided.

3.3.1: Organisational Culture

I investigate the CERN Community culture through examples of practice and excerpts from field work contemporary interviews. It would be wrong to imply that the CERN central organisation is beyond criticism. As with any large organisation it reflects the societies from which it draws its personnel. The organisation suffers from gender inequality issues that beset many STEM IGOs, NGOs and natural sciences academia. The problem is well recognised and is steadily being addressed by the central leadership. There is greater equality in the non-physics dominated areas, but the imbalance in physics areas, while improving, is still far from parity and lags progress made in the Member States. A few interviewees reported on the presence of a 'community within a community' in that some physicists saw themselves as above the others in the organisation. There was also within the physicist community an inherent hierarchy with the theoretical physicists at the top followed by the experimental physicists and then those involved in the LHC and other infrastructure. A stereotypical 'old-boys-network' whereby different groups looked after their own was suggested to still be in play by only one or two interviewees.

In any high pressure, high stakes organisation employing thousands of young people drawn from disparate cultural backgrounds and beliefs there will be episodes of friction and behavioural incidents. CERN established in 2010 an Ombudsperson whose role is to provide impartial and informal advice and guidance, to help resolve interpersonal disputes and to guide people in applying the CERN Code of Conduct (CERN, 2010). The incumbent is available to all staff and reports annually to the Tripartite Employment Conditions Forum which in turn reports to Council. Interviewees confirmed these matters are invariably dealt with internally and with the Member States promptly, firmly and fairly.

The prevailing organisational culture is best illustrated by direct quotations from interviewees; who were unanimous that CERN's governance and leadership regimes get the clear majority of important things right. A senior manager provided a high level context "… the successful collaboration comes back to this idea of science for peace, it is a bit of a cliché almost, but it sums up so much, we get people coming here that are motivated by the science, they meet people from other countries and cultures and they have this shared passion and they discover they have a lot more in common than they maybe thought they would have."

A young and award-winning post-doctoral physicist made a telling observation that "as a scientist you are trained to think that there is a fundamental truth and this helps unify people and many scientists come from a background of international experience, many people go abroad already as students … and so, when you bring people together at a place like CERN there is already a component that has had that exposure in the past and what they have been exposed in the field of physics has been the same regardless of where they come from. They already have the mindset that to collaborate internationally is normal."

Dr Fabiola Gianotti, speaking at the CERN / UNOG Symposium in 2015 as the then 'CERN DG elect' stated that in her experience as the Spokesperson for ATLAS, the main reasons for the success of the CERN model were that: "these experiments have a very light, a very loose organisational structure and the leadership has no contractual power over the members of the collaborations. The Members are affiliated and report to their home institutes…authority comes from the intellectual contribution not from the hierarchy. The youngest student has a bright idea to the solution of a problem then the collaboration follows. Everyone can contribute in a significant way to shape the strategy and course of the experiment. Managerial structure is light. Some structure is needed… but it must be light and nimble, not to repress initiatives and ideas and creativity of individuals. Because the ideas and creativity are the drivers of the research. The organisation is there to assist and help particularly the young people to blossom and not be impeded by bureaucracy. This would be the death of research and science." (CERN/UNOG, 2015).

This was a view echoed by all the field work interviewees and cited by many as the single most important element in CERNs success. Over-dominant project leadership is rejected in the same way that over-dominance of a single research perspective is rejected. Tokenism or 'non-inclusive inclusion' of team members is also not tolerated; everyone's contributions are respected. The leaders of the embedded experiment teams are termed 'spokes-persons'. The incumbents are elected to these positions by their peers, they have no contractual levers over the team members from the collaboration partner institutes. Given that these embedded projects are multimillion-dollar endeavours with the all the project control, risk and reporting pressures that this brings, the fact that they work demonstrates the importance of having a first-rate organisational culture.

Gianotti concluded her remarks at the UN conference with: "The key element is that people are animated by a strong common passion for the scientific goals of the experiments and this passion and the realisation that these goals can only be reached by working together is much stronger than the ambition and interests of the individuals, institutes and countries. Universal values like knowledge, transcend the political, social and economic interests of individuals and countries and as such are a very strong glue to bring mankind together and are a very strong ally of peace".

James Gillies the former Head of Communications at CERN believed that "one of the most important political lessons learned by the project governance and management regimes was that the Convention puts in place the structures that promote and allow mutual trust to be developed over time." Trust is either there or it is not in an organisational culture and must be maintained through the actions of all the players. Gillies added "for the Instrument projects the spokesperson will normally reach decisions through consensus… the lead times for big decisions are also very long and this adds to the idea of the collective agreeing what is best for each instrument project."

3.3.2: Focality and Legitimacy

Orchestrating Global Solution Networks; a Guide for Organizational Entrepreneurs (Abbott and Hale, 2014) provides a helpful checklist to gauge how successful a central body is in managing other actors in the community to achieve the orchestrators goals. It is not the purpose of this thesis to describe in detail the achievements of this or any of the other case studies. It is important, given the case study selection justification criteria described in Section 2.2., to place the actions of the community in a global collaboration context. This is now mapped out, for two characteristics of successful orchestrators that Abbott and Hale (2014: 9) identify: focality and legitimacy.

3.3.2.1: Focality

CERN is an anchor institution that acts as a well-established fundamental physics hub that people look to and converge around. Abbot and Hale suggest that an organisation's centrality can be measured in terms of the number of interactions or working relationships between its staff and those of other organisations in the field. The number of people who read its publications or attend its meetings are similar measurable indicators.

The 2016 user community figures confirm CERNs global reach with over 12 000 researchers from institutes in over 70 countries being actively engaged. CERN makes substantial efforts to communicate with the public and welcomes over 80 000 visitors each year to 'The Globe' visitor centre and runs a series of High School Physics Teacher Programmes aimed at bringing modern physics into the classroom. Connectivity within the Community is excellent with cutting-edge seminars and conferences attracting the best in the fields of science and technology (CERN, 2016). While these figures must be viewed with the latent optimism bias described in sub-section 2.5.1.4 in mind, the sufficiently large sample of third-party material bears out the undeniable focality that the CERN community has achieved in its central establishment.

The risk of fragmentation of the community is combatted by a continual renewal process at different levels within the central organisations that is illustrated by three examples: First, renewal, comes through the constant flow of new-blood eager scientists engaged in cutting-edge work at CERN. Interviewees confirmed that the infrastructure teams and embedded experiment teams have a healthy mix of experience, middle career and post-graduate membership where fresh ideas are actively encouraged. Second, renewal is provided by the example of those at the very highest levels where top level positions are regularly rotated; I explained this in sub-section 3.1.3 regarding Organs, Voting Rights and the DG and staff. The CERN executives interviewed for this research all agreed that this renewal process fosters vitality and inclusiveness and enables the DG to be rapidly at ease with the team he/she has formed.

3.3.2.2: Legitimacy

Abbot and Hale consider legitimacy as the belief among all the actors in a community that the central organisation and its bodies are appropriate to direct policy. The research evidence and derivation of this status derives from multiple sources, here I outline the most important five.

First, the focality provided by Council is legitimized by the advice it receives from the Scientific Policy Committee that makes recommendations on the priorities of programmes and the allocation of research effort both within the CERN Laboratories and extramurally. This task demands members of the highest calibre and a practice that has continued from its first meeting in 1954 to today is that it is composed of leading world experts appointed by Council without regard to nationality. The founding members of the Committee included the most distinguished European physicists of the time, four of its eight members being Nobel Laureates. The Council considers recommendations for committee membership provided by the Chair of the Committee and that have the support of at least two-thirds of the members. The transparency of this co-option process whereby when a member leaves the Committee it is scientific esteem with peers that is the sole factor concerning who will be the replacement, builds confidence in its deliberations and recommendations.

Second, CERN has the moral authority to orchestrate though the vastness of its membership. The CERN archive accession papers confirm that States view membership as essential to their global scientific standing. The growth in membership to the 23 states of today emboldens the Council to govern, or at least actively shape, the world-wide epistemic fundamental sciences research community.

Third, it has legitimacy due to its unprecedented track record of success. The nature of CERN’s integrated research facility is that their major achievements over the last 65 years are models of collaboration across many individuals, teams and nations; an achievement that the high energy physics community is proud of and which was articulated by interviewees during the field work. CERN’s legitimacy is aided by a succession of Nobel Prizes for Physics where the recipients have a direct link to CERN research as shown at Table 2.

NOBEL PRIZE in PHYSICS Year of Award	Award Citation	Recipients	Award relationship to CERN
1952	"for their development of new methods for nuclear magnetic precision measurements and discoveries in connection therewith."	Felix Bloch Edward Mills Purcell	Bloch was the first Director General
1976	"for their pioneering work in the discovery of a heavy elementary particle of a new kind."	Sam Ting Burt Richter	Ting was the LEP Spokesperson
1984	"their decisive contributions to the large project which led to the discovery of the field particles W and Z, communicators of the weak interaction."	Carlo Rubbia Simon Van der Meer	Both Rubbia and Van der Meer were CERN physicists
1988	"for the neutrino beam method and the demonstration of the doublet structure of the leptons through the discovery of the muon neutrino."	Jack Steinberger Leon Lederman Mel Schwartz	Steinberger was a CERN physicist
1992	"his invention and development of particle detectors, in particular the multiwire proportional chamber, a breakthrough in the technique for exploring the innermost parts of matter."	Georges Charpak	Charpack was a CERN physicist
2013	"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider."	François Englert Peter Higgs	The ATLAS and CMS teams at CERN confirmed the existence of the Higgs Boson

Table 2; CERN related Nobel Prizes for Physics (Nobel, 2019)

No evaluation of CERN's record of success is complete without mention of its most notable spin-off that not only demonstrates the frontier nature of its technical work but also its open culture. CERN has always had a need for very high computing power and by the 1980s the global user community demanded improved communications and information management. Tim Berners-Lee a British computer scientist working at CERN developed a new networking system that eventually became known as the *World Wide Web*. His core concepts are still in use today and he made his ideas freely available with no patent or royalties due. CERN management decided to put the invention into the public domain and the Internet, a global network of information and easy accessibility that was previously used by only a few scientists, military personnel and computer experts, was thus made freely available to all. Berners-Lee's altruism was fêted by Time magazine in 1999: 'He wove the *World Wide Web* and created a mass medium for the 21st century. The *World Wide Web* is Berners-Lee's alone. He designed it and more than anyone else he fought to keep it open, non-proprietary and free' (Time, 1999). It was the fact that he was a CERN employee that provided the environmental culture and tools to make the discovery and allowed the act of corporate as well as personal generosity that unleashed it. This is one of a series of scientific/technical achievements that have met and exceeded the expectations of its backers. Success has bred success and enhanced the reputation of the central organisation, its management team *and* all those in the wider CERN community.

Spin-off's such as the *World Wide Web* and Hadron Cancer Therapy Scanners, are a practical vehicle that keep nations content with their return on investment. They help to foster a collective prestige and pride in accomplishment in improving the fabric of society. A 2014 OECD report *Impacts of Large Research Infrastructures on Economic Innovation and on Society: CERN Case Study* concluded that the series of global scale successes, such as the discovery of the Higgs boson, legitimise the mechanisms and procedures (informal and formal) that produced them (OECD, 2014: 64).

Fourth, the legitimacy stems from the expertise that CERN possesses and uses. It has unrivalled experience in the field carefully nurtured through corporate knowledge gathering and kept up to date by constant exchanges of personnel and their ideas with its Member States. Despite set-backs, its technical success in orchestrating the design, manufacture, assembly, commissioning and operation of some of the most intricate fundamental physics equipment in the world is impressive. Industrial Liaison Officers located in each of the Member States facilitate the flow of communication between CERN and its suppliers. CERN central staff collectively exemplify an intelligent customer free from national regulatory restrictions and able to manage risk by putting in place a contractual system of strong controls and oversight of its international supply chain partners.

Finally, another aspect of CERNs legitimacy is the increasing presence of the community leadership in international projects and forums outside of its primary domain. There are three stand-out examples: Firstly, the CERN Convention has been successfully adapted by several European IGOs and several former DGs have been instrumental in adapting it in the creation of the remarkable Jordan based SESAME alliance of Cyprus, Egypt, the Islamic Republic of Iran, Israel, Jordan, Pakistan, the Palestinian Authority, and Turkey (UNESCO, 2010). Secondly, the current DG, Gianotti was one of seven female co-chairs at the World Economic Forum 2018 in Davos; the CERN emblem flying alongside national flags. Thirdly, the granting of permanent observer status by the UN General Assembly (UN, 2012) confirms CERN as a world-leading independent and neutral IGO from outside of the UN system that has transcended fundamental physics research. CERNs views and experiences were sought on a wide range of issues including the effectiveness of the UN Working Group on Sustainability Goals and global STEM education initiatives.

3.3.3: Future Developments and Expansion

I now focus on two developments that field work confirmed are concentrating the minds of the CERN community leaders in the near to mid-term: Firstly, future membership and related innovative funding trends and secondly, planning for the next generation fundamental particle physics facility.

3.3.3.1: Management of future membership and innovative funding trends

The accession of a state to full membership has been achieved eleven times since CERN's foundation in 1954: by Austria (1959), Spain (1961, then leaving in '69 and re-joining in '83), Portugal (1985), Finland (1991), Poland (1991), Hungary (1992), the Czech Republic (1993), Slovak Republic (1993), Bulgaria (1999) and Israel (2014). The latest addition to full membership is Serbia (2019). The only non-reversed membership departure has been Yugoslavia which, due to a lengthy inability to pay its yearly contributions, left in 1961.

For this thesis, it is important to note that the community has managed this expansion in a measured and judicious way. Adding 11 full Members in 65 years has been a risk averse expansion through unanimous vote by Council respecting the primacy of Member States on every occasion. The reason is that this group which Nils Brunsson and Göran Ahrne term a *meta-organisation* [defined by as organization formed of other organizations] cannot be allowed to fail, as failure would endanger the higher organisational body (Brunsson and Ahrne, 2005: 132). The Council does not wish to recruit a member that may be problematic. The collective has to act in consensus, so everyone has to be comfortable that any new Member State will respect the responsibilities that go with that doctrine. Similarly, the Council has to protect the fairness of contributions that I covered in sub-section 3.1.4: Commercial, Contracting and Funding Arrangements. For example, it would be problematic in either the USA or China joining as full members. The Convention states that contributions are based on NNI and these superpowers would skew contributions too greatly and disturb the all-important existing balance. Two high level interviewees indicated that a natural limit may have been reached or is approaching. One of these two interviewees even expressed the view that to go above current levels of full membership may be counter-productive. Council meetings and pre-meetings would become too cumbersome and decision-making elusive.

The Council has found a way to circumvent the potential pitfalls of too wide a full membership and has designed other types of memberships and other types of funding for special projects. At the June

2010 Council Meeting the status of ‘Associate Membership’ was created, open to all states regardless of their geographical location, as an essential prerequisite to full membership: Cyprus and Slovenia are currently in this category. Other Associate Member States are Turkey, Pakistan, Ukraine and India. Croatia has also been accepted as an Associate Member State, subject to completion of its national ratification process. Associate Member States pay at 1/10th the rate of their contribution had they been full members and receive call for tenders and vacancy notices; they do not have voting rights on the CERN governmental bodies. Three intergovernmental organisations, the EU, the Moscow based Joint Institute for Nuclear Research (JINR) and UNESCO, have Observer status allowing them to attend Council meetings and receive Council documents, without taking part in decision-making. Figure 4 shows the complete CERN Community at IGO level as at March 2019.

In 2010 a notable resolution drafted by a Working Group on the Scientific and Geographical Enlargement was unanimously approved by Council: within boundary conditions that included applicant member states ‘guaranteeing democracy, the rule of law and human rights’ they would be considered for membership irrespective of geographical location. CERN had always been a global endeavour attracting the best minds regardless of nationality (birth or adopted), now the doors were truly open to all states in the world. Among the 58 Non-Member States collaborating with CERN are Australia, Brazil, China, Iran, Jordan, Kazakhstan, Qatar, Saudi Arabia and South Africa.

The innovative method of funding for the LHC that I briefly mentioned in the first paragraph of sub-section 3.2.2: Funding Resilience may provide a model for the future. Russia and the USA provide considerable in-kind contributions to the LHC infrastructure and Japan provides cash to the LHC budget. The go ahead for the USA in-kind LHC contribution, with a value of approximately US$ 0.5B, was made by Congress in 1996, the first time such a contribution would be sent overseas. The US Secretary of Energy, Federico Pena, commenting at the time of the CERN-USA agreement signature, on the 8 December 1997 that: ‘Today, we are embarking on an extraordinary scientific journey... I have no doubt that when the history of the next 50 years is written, the LHC and all of the science, new ideas and technologies its spawns will be a major chapter.’ (FNAL, 1997:1). This arrangement allows Japan, Russia and the USA to have Observer Member status and sit-in LHC deliberations of the Council and have hundreds of scientists and engineers on site during operations. Interviewees confirmed that this trend of expanded associated membership and tailored observer membership combined with carefully managed enlargement of membership is one way that a future facility may come to fruition.

3.3.3.2: Planning for the next generation facility

Recently, Council has approved two major infrastructure upgrades: the LHC Injector Upgrade (LIU) and the High-Luminosity Large Hadron Collider (HL-LHC) project. The HL-LHC project was announced as the top priority of the 2013 European Strategy for Particle Physics and its funding is enshrined in CERN's Medium-Term Plan. These upgrades will utilise once again the low interest European Investment Bank credit facility that will allow them to be financed within the agreed CERN budget without compromising or delaying the rest of the scientific programmes. However, at a symposium at CERN to celebrate 25 years of operation of the LHC, held in December 2017, it was noted by the keynote speaker that 'proof of the Standard Model is not Enough!' There are still many completely unknown areas such as Dark Matter and Dark energy that must be explored. While it was believed further LHC operation could provide glimpses of these areas through pioneering experimentation and major upgrades in the coming years that will increase performance, there is a growing scientific consensus that much more raw collision energy is needed to release the true picture. The concluding remarks at the symposium were that the approval of the LHC had depended on five factors: 'a robust science case, its uniqueness, unanimous support of the world particle physics community, technical success at CERN and no major budget bump'. Approval of future major CERN projects would also require a 'robust science case, unanimous support of the world particle physics community, continued technical success coupled with major discoveries at the LHC and a reasonable budget envelope'. The speaker added that public support might help and that this was previously not a factor as CERN was relatively unknown prior to the LHC.

There are two prime candidates for a European successor to the LHC: the Compact Linear Collider (CLIC) and the Future Circular Collider (FCC). These two projects are competing for the hearts and minds of the European fundamental research community. The European Strategy Group (ESG) for Particle Physics, a body set up by Council [under Article II 2b of the Convention as detailed in Section 3.5.1.] and other groups such as the International Committee for Future Accelerators (ICFA), which CERN staff participate in, will play key roles in recommending which path to take. The hope is that the LHC will reveal what the science case could be for whichever next step machine triumphs. Therefore, the continued success of the LHC and the associated instruments is part of the future and why CERN's pre-eminence gives her the advantage in shaping that future. The FCC with a foreseen circumference of between 80-100 km would be comparable to the SSC (whose demise I covered in sub-section 3.2.1: Domain Dominance) that the US cancelled in 1993. Had the SSC been built, commissioned and operated as planned then the chances of obtaining funding for a next generation European collider would have been critically weakened.

Technological ways of dealing with the ever-increasing volume of data, stem back to one of CERN's greatest spin-off successes: the creation of the *World Wide Web* [covered in sub-section 3.3.2.2: Legitimacy]. The current CERN Data Centre is a model of what computing will look like in the future, with very large quantities of data [about 1% of global data each day] being continuously analysed through seamless connectivity to 170 other data centres in 36 countries (Cogen, 2015: 189). A next generation collider would add to this already world record breaking daily data load and would need the latest state-of-the-art distributed computer facilities. Estimates are that up to 25% of the total costs of the next generation collider facility will be the associated world-wide computing complex.

For CERNs future, if we accept this need for a catalyst or vehicle for large scale changes, then it is possible to speculate what that might be. Could the threat, either real or perceived, of China developing its own facility be a 21st century version of the 20th century US based SSC 'threat'? One senior CERN executive thought there was potential for this but caveated that while this could perhaps gain traction in the political wings of the Member States it would not prevail as a telling argument within the more knowledgeable [of the technical advantages and disadvantages] global fundamental physics scientific community. The latter group would naturally focus more on when the facility could be built and its capabilities rather than its location.

For the reasons explained in the Literature Review, section 1.2: Global Gridlock Issues, the obstacles to international collaboration are becoming greater as nations become rooted in a cycle of self-reinforcing gridlock. National budget constraints are inevitably increasing as European politicians struggle with geo-political issues such as immigration and globalization. Consequently, robust, rational and convincing arguments will need to be developed to secure funding for the next generation particle physics research facilities. Solutions may be a hybrid of ideas including diverse in-kind contributions and other innovative funding streams. The trend of expanded associated membership and tailored observer membership combined with extremely carefully managed enlargement of full membership will surely feature.

As past performance is often the best indicator of future performance, it seems likely a way will be found to maintain CERN's research pre-eminence across her epistemic community. That way will have at its core the Member States continuing to exercise 'consensual governance' and the high level management group continuing with their ‘light-touch leadership’ approach. I contend that it is the combination of these two factors, over decades of operation, that have honed the international relations and organisational success story that is the CERN of today.

Section summary

Hypothesis 3 is supported (see checklist of supporting and opposing attributes at Table 1) through an analysis of ‘Science Diplomacy’ and ‘Mega-Projects Governance, Leadership and Performance Issues’, Sections 3 and 4 respectively of the Literature Review together with the data collected during the field work. Sound, consensual governance and effective, light-touch leadership can be seen to boost SMP performance. Analysis of GSN orchestration aspects such as focality and legitimacy have supported this argument. Focality is preserved by being a well-established, lively hub and by employing several measures in parallel to avoid fragmentation. Legitimacy is heightened through a combination of a meritocracy based main policy advisory body, the vastness of membership, continual success, deep domain experience and external recognition by world forums including the UN General Assembly. This governance and leadership sub-section relates to three *Beyond Gridlock* pathways: Pathway 3, ‘technical groups with effective and legitimate processes’; Pathway 4, ‘multiple, diverse organisations and institutions coalesce around common goals/norms’ and Pathway 7, ‘innovative leadership as a reaction to gridlock.

3.4: Evaluation of the *Beyond Gridlock* pathways and associated mechanisms employed by the CERN community

While *Beyond Gridlock* theory shows that there is overlap between which pathways are utilised by IGOs in different domains, it is possible to show which principally apply. This has been done at the end of each of the previous sub-sections and an overall cross-referencing to the *Beyond Gridlock* pathways is provided in Table 3:

Hypotheses	CERN Pathway
1. IGO agreements and start-up conditions which are concise, fair, promote trust and mutual support, allow flexibility in problem solving, manage host state issues and emphasise the primacy of the State improve performance	1, 2, and 3
2. external constraints such as excessive stakeholder aspirations, changing legal landscapes, bureaucratic regulations, funding fluctuations and unforeseen events, while being mitigated as far as possible by IGO leadership actions, inevitably adversely affect overall performance	7 and 8
3. Sound internal governance and leadership dynamics improve performance	3, 4, and 7

Table 3; Cross-reference between hypotheses and beyond gridlock pathway utilised by CERN

Hypothesis 1 does provide a solid base from which the organisation and its community have benefited. Pathway 1, 'shifts in major powers core interests' was utilised during the formation of CERN and has been maintained through a solid respect for the primacy of the state, exercised through Pathway 2 mechanisms including governing bodies being given capabilities to adapt to emerging issues. The principles of fairness enshrined in the Convention have allowed the technical teams to establish Pathway 3 type workable rules and develop a project adhocracy that enables experts to solve complex problems in whatever manner they see fit.

There are fewer pathways available to combat the Hypothesis 2 issues concerning external constraints and threats. The solutions rely on sound and innovative leadership and, where appropriate, employment of innovative funding; Pathways 7 and 8 respectively. Negative effects, such as program delays, persist but are much reduced from what would have occurred without effective interventions.

The sound governance and light-touch leadership dynamics central to Hypothesis 3 were articulated in the many field work interviews, a selection of which I have tabled earlier. This applies to Pathway 3 technical teams' performance, Pathway 4 enthusiastic participation in the global, connected research network that is the CERN of today and the employment of Pathway 7 innovative leadership.

Finally, the data cross-referencing confirms that two gridlock pathways do not feature for CERN, these are 'mobilisation of domestic constituents' (Pathway 5) and 'civil society coalitions with reformist states (Pathway 6).'

In Table 4, against each of the five *Beyond Gridlock* pathways that do apply and the new pathway [concerning funding] a commentary describing the 'mechanism for implementation' has been added to establish applicability to CERN.

Pathway	CERN Community Mechanism
1. Shifts in major powers' core interests	• Catastrophic World War II led to incentivisation for States through the European Movement and embryonic UNESCO to combine with visionary European particle physicists to create the Organisation
2. Autonomous and adaptive international institutions	• Governing bodies have been given inimitable capabilities to adapt to emerging issues and shifting constellations of power and interests • Member States have one vote each in Council; the primacy of the State is sacrosanct • Science Committee members are elected solely on merit by peers and are independent of national and/or other institutional affiliations
3. Technical groups with effective and legitimate processes	• Experiment team's authority comes from intellectual contribution and consensual decision making; project adhocracy and trust in the workforce leaves teams of experts to solve complex problems in whatever manner they see fit • The name 'CERN' is synonymous with the very best scientific research standards, execution and delivery
4. Multiple, diverse organisations and institutions coalesce around common goals/norms	• Unmatched global reach: over 12000 researchers from institutes in over 70 countries being actively engaged • World-wide connectivity with very large quantities of data being continuously analysed through seamless connectivity to 170 other data centres in 36 countries • Centre of excellence for holding of global fundamental physics seminars, conferences and events
5. Mobilization of domestic constituencies	The data confirmed that these two *Beyond Gridlock* pathways do not feature
6. Civil society coalitions with reformist states	
7. Innovative leadership as a reaction to gridlock	• Leadership is characterised by inclusivity and equality of contributing disciplines in terms of voice and status. • Leadership has an aura of invincibility within the global fundamental physics community. A reputation borne out of its repeated scientific successes and its ability to overcome obstacles, threats and set-backs by fair, timely and consensual governance • See (3) above for leadership of technical teams
8. Innovative Funding	• Scrupulously fair funding formula based on Member State economic strength for annual cash contributions • Procurement protocols help maintain alignment of work share to contributions but are not bound by strict *juste retour* • US and Russian LHC workshares and the Experiment projects are effective in-kind contribution collaborations

Table 4; Pathways though and beyond gridlock, CERN mechanisms for implementation (adapted from Hale and Held, et. al., 2017)

CHAPTER 4: THE ITER PROJECT COMMUNITY

Figure 7; ITER Community at IGO level as at March 2019 (logo courtesy of the ITER Organisation)

The goal of ITER is to prove that nuclear fusion can be the future, carbon emissions free, energy source that the world so urgently needs. It aims to do so by showing that magnetically confined plasmas can achieve the 'burning' state and thus produce more power than they need to operate. ITER is the essential experimental step between today's laboratory fusion machines, focused on plasma physics studies, and tomorrow's fusion power plants. Commercial fusion power generation once achieved will have a profound effect on the world-wide energy market. The importance of the project is captured by the statement of the current Director General, Dr Bernard Bigot when he was appointed: "The stakes are very high for ITER. When we prove that fusion is a viable energy source, it will eventually replace burning fossil fuels, which are non-renewable and non-sustainable… Providing clean, abundant, safe, economic energy will be a miracle for our planet." (ITER, 2016).

The project is headquartered at Cadarache, France where system design, project management and final construction and assembly takes place. However, the endeavour is a global collaboration on a massive scale arranged through an international agreement signed in 2006. Over 85% of the multi-billion-dollar cost is funded by the Member's through in-kind contributions and the remainder through cash. The EU (EURATOM states) contributes almost half, while the other six members, the People's Republic of China, the Republic of India, Japan, the Republic of Korea, the Russian

Federation and the USA, contribute equally to the rest. Together the members represent over half the world's population and over 80% of the world's GDP; Figure 7 shows the ITER Community at IGO level (OECD, 2018).

A term that is used on the project and in this research, is 'First Plasma' which can be seen in the same way that an aerospace programme has 'First Flight' of a development aircraft. ITER has two project defining milestones. The initial 'First Plasma' is when the device can hold a stable plasma within the magnetic confinement and heat it to the required extremely high temperatures; the later 'D-T Plasma' is with the addition of the crucial extra nuclear component as part of 'Deuterium-Tritium' operations. The predicted dates for these events have a political as well as technical dimension; I return to this in sub-section 4.3: Governance and Leadership Dynamics. Construction is very late to the original plan but is now well under way with achievement of 'First Plasma' currently forecast to take place in the middle of the next decade (ITER, 2017a).

ITER is completing its final detailed design and is mid-way through its construction phase, whereas CERN has been in full operation for decades and has undergone a series of upgrades. Consequently, this second case study chapter naturally focusses on ITER's early collaborative arrangements. It is again organised into four sections that have been shaped by the main connections between elements of the literature review and the separate hypotheses and supporting and opposing attributes from Table 1. While there is some overlap, by mapping out these associations I illustrate how the hypotheses have been tested and where the results can be found:

> The first section will test Hypothesis 1 by examining four aspects. Firstly, the political setting and finalisation of the ITER Agreement including establishment of the project starting conditions; secondly the purpose and functions; thirdly the organs, voting rights, the role of the DG and staff and finally the commercial, contracting and funding arrangements. This relates mainly to the literature review sub-section 1.1: Theory regarding global collaboration and international organisations.
>
> The second section will test Hypothesis 2 by probing how three constraints have been managed. Firstly, the political, logistical and collaborative implications following site selection; secondly, the handling of project delays and how funding has been maintained and finally how a regrettable development with respect to sharing project information is being addressed. This relates to the literature review, sub-section 1.2: Global Gridlock Issues.

The third section will test Hypothesis 3 by examining governance and leadership dynamics. Three aspects are addressed: the organisational culture, focality and legitimacy and finally, future national plans. This relates to two sections of the literature review: section 1.3 covering Science Diplomacy and section 1.4 covering Mega-Projects Governance, Leadership and Performance Issues.

The final section evaluates the *Beyond Gridlock* pathways and associated mechanisms employed by ITER and acts as a summary of the chapter.

4.1: The ITER Agreement

To test Hypothesis 1 (that IGO agreements and start-up conditions which are concise, fair, promote trust and mutual support, allow flexibility in problem solving, manage host state issues and emphasise the primacy of the State improve performance) four aspects are examined. Firstly, I analyse the political setting of the mid-1980s superpower summits and the lengthy negotiations that culminated in the ITER Agreement signature in 2006. Secondly, I scrutinise the purpose and functions of the central ITER Organisation. Thirdly, I examine the governing organs, member's voting rights, and the role and arrangements concerning the DG and staff. Fourthly, I outline the special conditions and complex provisions that aid ITER's commercial, contracting and funding arrangements. Finally, a section summary is provided.

4.1.1: Political Setting and ITER Agreement Signature

US President Dwight D. Eisenhower's 1953 *Atoms for Peace* speech to the United Nations General Assembly (UNGA) marked a turning point, following the use of the Atomic Bomb on two Japanese cities in 1945, in politicians publicly accepting the latent benefits of peaceful uses of nuclear knowhow: "… The United States would seek more than the mere reduction or elimination of atomic materials for military purposes. It is not enough to take this weapon out of the hands of the soldiers. It must be put into the hands of those who will know how to strip its military casing and adapt it to the arts of peace. The United States knows that if the fearful trend of atomic military build-up can be reversed, this greatest of destructive forces can be developed into a great boon, for the benefit of all mankind (IAEA, 2017a)."

The Eisenhower speech provide the impetus for the establishment, some four years later, of the International Atomic Energy Authority (IAEA) as an independent agency of the UN. While the IAEA had two purposes: to promote the peaceful use of nuclear energy and to inhibit its use for any military purpose, the organisations immediate focus was on the latter. Attention was paid by those few nations that possessed nuclear weapons to ensure that the IAEA led the efforts to limit nuclear proliferation and establish international safeguards and verification regimes for fission materials (IAEA, 2017b). The world in this period was divided into two distinct political, economic, military and social rival systems, divided by what UK Prime Minister Winston Churchill aptly described as an iron curtain. Because of the arms race to develop more powerful nuclear weapons, the opposing 'east - west' military industrial complexes worked under strict secrecy, any nuclear research was by default believed to have important military consequences. Eisenhower's speech excluded the word fusion, but interest in its possibilities for peaceful use had already begun in British, US and Soviet government undisclosed laboratories in the years following World War II (Chou, et. al., 2017: 29).

Scientists on both sides of the iron curtain soon quickly understood that there were no military applications for magnetically confined thermonuclear fusion. Although this message would fall on deaf ears of any non-expert of the period, there was a rising world-wide initiative by physicists to declassify fusion research. A turning point came after a lecture by the eminent Russian atomic scientist Igor Kurchatov at Harwell, UK in 1956. The lecture is remembered for its frankness which included rousing prose: 'Physicists over the whole world are attracted by this extraordinarily interesting and very difficult task of controlling thermonuclear reactions (Eurofusion, 2011).'

Two years later, at the 2nd Geneva Conference on the 'Peaceful Uses of Atomic Energy', 105 papers were presented, detailing work performed mainly in the Soviet Union, USA, UK and Germany. The papers revealed that, despite the officious security classification regimes in the authors home States, research had been conducted in practically identical paths (UN, 1958). With the inspiration of the 1956 Kurchatov lecture and academic unanimity as to the way ahead breaking out, the UK legislative secrecy finally gave way to openness. The Macmillan Conservative Government declassified magnetic confinement fusion research on taking office in 1957 and the USA did the same one year later. Since then there have been few veils of secrecy hampering the efforts to achieve the fusion commercial power vision. I will return in sub-section 4.2.3: Sharing of Project Information to show how this openness enhances cooperation and reinforces trust at all levels in the ITER Community.

Competing ideas as to the best form of fusion device continued to be developed at centres of nuclear research in several countries through the 1950s and 60s. Scientists in the Soviet Union led the way in 1968 when the two key criteria for fusion were achieved: remarkably high temperature levels and plasma confinement. The key to their success was a revolutionary device called a Tokamak [a Russian acronym for Toroidalnaya Kamera s Magnitnymi Katushkami; the English meaning is Toroidal Magnetic Chamber] invented by Igor Tamm and Andreï Sakharov at the Kurchatov Institute in Moscow. Once their results were independently confirmed by a UK team, the Tokamak quickly became the dominant concept for further research worldwide (New Scientist, 2009). Since then Tokamaks have passed several milestones, gradually edging towards the goal of producing more energy than they require to operate. The chronological list of leading Tokamaks aptly demonstrates the growing world-wide effort: the Joint European Torus (JET) in Culham, UK (operational since 1983), JT-60 in Naka, Japan (operational since 1985), T-15 in Moscow, Russia (operational since 1988), ADITYA at the Institute for Plasma Research in Gujarat, India (operational since 1989), NSTX in Princeton, USA (operational since 1999 and upgraded to NSTX-U in 2015), EAST in Hefei, China (operational since 2006) and KSTAR in Daejon, South Korea (operational since 2008). Behind each leading tokamak there is an extensive national programme on which the device rests and a community of people drawn from different disciplines dedicated to making them a success. The people in these communities gradually strengthened their connections with counterparts in other nations and the seeds of the tightly bound world-wide fusion community of today were sown.

Hand in hand with the early scientific and technical advancements came the realisation that the cost and complexity of a large device that could finally prove the viability of commercial fusion power were well beyond the reach of any nation acting alone. This awareness of the essential need for collaboration included the two superpowers. Leading figures in the fusion communities in the USA and Soviet Union began to apply pressure on their respective governments to join forces. In 1978 the Soviet Union proposed that an International Tokamak Reactor (INTOR) should be built, and the IAEA held a series of exploratory meetings. The very large estimated costs and immature international collaborative spirit hampered by deteriorating international relations following the Soviet invasion of Afghanistan in December 1979 meant the idea did not gain political traction. The need for collaboration persisted however and in March 1982, US President Ronald Reagan sent the following message to the US Congress: '…we also recognize that, while the United States retains international pre-eminence in many areas of science and technology, we are no longer in a position to dominate each and every field. Nor do we hold a monopoly on the world's supply of scientific talent… There are areas of science, such as high energy physics and fusion research, where the cost of the next generation of facilities will be so high that international collaboration among… nations may become a necessity. We welcome opportunities to explore with other nations the sharing of the high costs of modern scientific facilities (Reagan Presidential Library, 2017a).'

The catalyst for tangible progress was the appointment in 1985 of Mikhail Gorbachev as General Secretary of the Central Committee of the Communist Party and, by custom, Leader of the Soviet Union. Vast military expenditure coupled with bureaucratic central planning meant that by the time he took office the Soviet economy was in dire need of improvement. He quickly embarked on a radical reform programme and demonstrated a willingness for openness and dialogue with the West that his more elderly predecessors had shunned. His first international visit was to France to meet President Mitterrand. Accompanying Gorbachev was his chief scientific advisor and long-time friend, Evgeny Velikhov; they had met thirty years previously as students at Moscow State University. Velikhov was an ardent supporter of fusion research and was later universally accepted by the community as the 'godfather' of nuclear fusion. In an interview given in 2015 he recalled the political context of the times: 'It is important to remember that another collaborative project in fusion called INTOR, had started in the Brezhnev times during a thaw in relations with the West. When war in Afghanistan started relations chilled again. As a result of these complications, Europe and the USA moved forward on negotiations on fusion collaboration in the framework of the 1982 Versailles Summit without the participation of the Soviet Union. Negotiations had stalled again however; therefore, I decided to deliver this idea [of fusion] to Gorbachev who was going on a visit to Paris…. [he] took to the proposal and invited me to the meeting. President Mitterrand immediately picked up on the idea of international cooperation in fusion (ITER Newsline, 2015b).'

Mike Roberts of the US DOE at the time provided a first-hand account of one of the early approaches: "In September 1985, I led a US science team to Moscow as part of our bilateral fusion activities. Velikhov proposed to me at lunch one day his idea of having the USSR and USA work together to proceed to a fusion reactor. My response was 'great idea, but from my position, I have no capability of pushing that idea upward to the President.' Velikhov now realised that he had to find a high-level route to bring Reagan and Gorbachev together.

Reagan was a complex personality and a paradox: publicly a Cold War warrior but privately someone who hated 'the bomb'. His Strategic Defence Initiative (SDI) and election in January 1985 to a second term, meant that the peacemaker Reagan could come to the fore. Encouraged by Mitterrand and UK Prime Minister Thatcher, who had also met Gorbachev when he was Deputy General Secretary, Reagan considered the merits of a superpower summit. He faced opposition from hawks such as Defence Secretary Casper Weinberger and his deputy Richard Perle who both deeply distrusted the Soviets. Through careful management by US Secretary of State George Shultz and USSR Foreign Minister Eduard Shevardnadze, a reformer appointed by Gorbachev, the summit was kept on track and arranged for November 1985 in Geneva. The omens were not good and Weinberger, in a startling move at the time, made public his concerns regarding giving too much away on SDI in return for hollow promises of reductions in the Soviet nuclear arsenal (NYT, 1985).

Mike Roberts added: "Velikhov changed his strategy, now going up directly through Shevardnadze to Gorbachev and across to Reagan through Schultz, as opposed to through me." Meanwhile advocates including Alvin Trivelpiece (Director of the Office of Energy Research), Richard Stratford (President's Senior Scientific Advisor) and Charlie Newstead (State Department) worked on the US diplomatic establishment to encourage fusion cooperation. Newstead in an interview in 2009 recalled the hostile atmosphere and several 'shouting matches' prior to the Geneva meeting in the White House Situation Room, the only place that was deemed secure enough to hold meetings on the Soviet proposal. 'Once I had to close an argument saying that I had a PhD in physics, and they didn't!' (ITER Newsline, 2015a). The discussions were kept in high secrecy but gradually facts backed persistence and the argument for working with the Soviets on fusion gained traction. A key moment is documented by William Martin (Executive Secretary of the National Security Council (NSC) and Special Assistant to Ronald Reagan (1982 - 1986) in a 2012 letter to Alvin Trivelpiece: 'Let me recall our first meeting when I was serving as Executive Secretary of the NSC. You visited me in my office at the West Wing and brought to my attention a project with Russia involving cooperation in magnetic fusion. At this time, we had no positive relations with Russia…. Reagan had called the Soviet Union, the *Evil Empire*. You came to me to see what mischief I could do. Recently in my Reagan files I found a memo from Bob Gates – then number 2 at the CIA and future Secretary of Defense – that said: 'Bill, although our evaluation was hurried, we can find no good reason not to go forward with the magnetic fusion project.' I then gave my okay for the project…' (Martin, 2012).

The 19-20 November 1985 Reagan Gorbachev *fire side* summit in Geneva entered Cold War folklore. The world's media were primed to pass verdict on who had 'won' the encounter. While little was achieved in terms of arms reduction or SDI [this was to take another two summits] historians later concluded that the two men started a rapport and trust building that would ultimately lead to the ending of the Cold War some 6 years later. David Reynolds (2007: 178) summarises that it fostered a culture of negotiation right across the Cold War divide. While the New York Times special summit report noted improved science collaboration, there was no mention of the fusion agreement that had been reached (Apple, 1985). With little to show the world as tangible progress the final press conference included the release of joint statement that maximised the positives.

In contrast to previous US-Soviet summits, no pre-Summit draft statement had been prepared due to US concerns that it could unduly reveal negotiation positions. The final text was recorded in a joint letter from the Permanent UN Representatives of the USA and the USSR to the UN Secretary General dated 16 December 1985, ending with the same evocative words that Eisenhower had used in his address to the UNGA 30 years earlier: 'The two leaders emphasized the potential importance of the work aimed a utilizing controlled thermonuclear fusion for peaceful purposes and, in this connection, advocated the widest practicable development of international cooperation in obtaining this source of energy, which is essentially inexhaustible, for the benefit for all mankind' (UN, 1985:6). For the fusion community this marked the achievement of a long planned for political breakthrough, reinforced when Reagan, on his return to the US, even cited 'fusion energy' in his address to a Joint Session of the Congress on 21st November 1985 (Reagan Presidential Library, 2017b).

Two years later the IAEA, at its headquarters in Vienna, held the first meeting of the Quadripartite Initiative Committee (QIP) comprising Europe [EURATOM nations], Japan, USSR and the USA. The meeting's record shows the determination of the Member's representatives to find a way to collaborate on fusion despite the animosity between these states in other domains such as trade and defence (IAEA, 1988). Richard Pitts, a long serving ITER Science and Operations Team Section Leader identified that the causal driver for this is an international relations version of the social anxiety *fear of missing out*: "No-one [No ITER Member] can bet that this does not work. If you say I am not funding it as it may not work then you take a massive risk that it might have done, and you still have to find another solution." For the QIP group and others who were to join the negotiations the potential benefits were significant. The economic leverage was clear: by contributing a relatively small amount they would receive all of the results. The name ITER, standing for International Thermonuclear Experimental Reactor, was agreed on. The project rarely spells out the acronym on promotional material or its website [other than the history section]. The words Thermonuclear Experiential Reactor could conjure up a negative view of the project inconsistent with its aims. ITER, on the other hand rather upliftingly means *the Way* in Latin.

The conceptual design studies were launched, and the scene set for a landmark set of international negotiations that would see other Members join and some both join and leave again. Laborious negotiations covered three strands: firstly, Legal work on several topics included IPR, Non-Proliferation and Peaceful Uses of Fusion technology and material that needed 11 international conferences to resolve. Secondly, Decision Making protocols including the Organization Structure and Staffing that needed 12 international conferences and countless workshops to agree. The third negotiation strand concerned Site Selection where four technically compliant candidates emerged: Clarington (Canada), Rokkasho (Japan), Cadarache (Europe; France) and Vandellos (Europe; Spain).

Following high level interventions by the European Commission, it was decided to base the EURATOM consortium headquarters in Barcelona. Spain then backed Cadarache as the site and with no one else supporting the Clarington bid, Canada withdrew from the site selection process and left the project entirely in 2004. The stand-off between Japan and Europe on the two remaining candidates was fierce. Dr Michael Roberts, the Director of International Programs of the Office of Fusion Energy, US DOE and member of the US Negotiation Team, provided insight on the act that helped break the stalemate: "[it] was Rob Goldston's [the Director of Princeton and a member of the US negotiating team] suggestion to treat the decision from a practical point of view, namely instead of each side saying 'my site is better' turn the discussion into 'what we could give the other side to let us have our site'. Then it was just a matter of raising the stakes until one side said, 'OK, you can have it on these terms.' That then led to the Broader Approach Agreement to solidify the terms of the deal." The *Broader Approach* was an astute mechanism which I cover in sub-section 4.2.1. Some 21 years after the 1985 Geneva summit, the USA, USSR and five other Members, were finally ready to join forces to find a new, clean energy source for the world.

Figure 8; ITER Agreement Ceremony, Elysée Palace, Paris on 21st November 2006 (IAEA, 2007)

The formal *Agreement on the Establishment of the ITER International Fusion Energy Organization for the Joint Implementation of the ITER Project* [known as the ITER Agreement] was signed at the Elysée Palace in Paris on 21 November 2006 by Ministers representing each of the seven Members; Figure 8. Below I show the lead person, and national organisation affiliation, who signed on behalf of their respective Member State and provide a commentary to show the final positions and compromises necessary to reach agreement.

For the Government of the People's Republic of China the signatory was Xu Guanhua, Minister of Science and Technology. It was the formal entry of the People's Republic of China and Republic of Korea to the ITER negotiations in 2003 that helped strengthen the argument of supporters of the project in the USA that they should re-join after a gap of some 5 years. China, because of its population size and economic growth, has the greatest need of any Member to achieve commercial nuclear fusion.

For the European Atomic Energy Community (EAEC) the signatory was Janez Potočnik, European Commissioner for Science and Research. The EAEC was founded by the Treaty establishing the EURATOM Treaty on the 25 March 1957. EURATOM is a separate legal entity from the EU, but it is governed by the bloc's institutions and falls under the legal jurisdiction of the European Court of

Justice (ECJ). Fusion for Energy [known as F4E] a joint undertaking within the meaning of Article 25 of the EURATOM Treaty based in Barcelona was established in March 2007 to manage the European contribution to the project. F4E also has one Associate Member State: Switzerland. Europe had won the hard fought site selection battle but in doing so committed to a challenging set of long-term commitments that I cover in sub-section 4.2.1. The complexity was ably captured by Laetitia Grammatico-Vidal who put in context that the main European partner's legal arrangements were just part of the overall legal agenda that the negotiators had to settle (Grammatico-Vidal, 2009).

For the Government of Japan, the signatory was Takeshi Iwaya, Vice-Minister for Foreign Affairs. The final agreement of Japan to not oppose the EU site candidate was achieved after lengthy side discussion between EURATOM officials and the Japanese Government. The day after the ITER Agreement signing ceremony in Paris, representatives of these two parties re-convened at the headquarters of the European Commission in Brussels. They signed the Joint Declaration for the implementation of Broader Approach Activities. Following formal signature in February 2007, the *Broader Approach* established a framework for the EU and Japan to conduct R & D in support of ITER over a ten-year period. Three projects were set into motion (sub-section 4.3.3) that enabled Japanese industry to gain an advantage over and above what Japan's contribution to ITER would normally have warranted. Another part of the site location trade-off was the informal agreement that the ITER DG would be from Japan and the Japanese Government provided assurances to increase their efforts to find a suitable nominee. I return to this in sub-section 4.2.1.

For the Government of the Republic of India the signatory was Anil Kakodhar, Secretary to the Government of India, Department of Atomic Energy. India were the last of the seven members to join the project in 2005. This was achieved despite India being the only Member not to be a signatory to the UN Treaty for the Non-Proliferation of Nuclear Weapons (NPT); Table 5 (UNODA, 2018). In one sense India's inclusion helps to emphasise the fundamental non-military purposes of the project. There are no military advantages to participation, only strategic advantages by being part of the quest for safe, reliable and non-greenhouse gas emitting commercial power. I also return to India's non-signature of the NPT when considering the consequences of Site selection in sub-section 4.2.1.

For the Government of the Republic of Korea the signatory was Woo Sik Kim, Vice Prime-Minister, Ministry of Science and Technology. The Republic of Korea's close ties to the IAEA meant that it had an opportunity to hold bilateral meetings with the EU and the US in 2002. A letter of intent to join the ITER project was sent to all parties in 2003 and legal and technical experts visited Korea. Korea then joined the ITER Negotiations from June 2003 as a full partner.

For the Government of the Russian Federation the signatory was Vladimir Travin, Deputy head of the Federal Atomic Energy Agency (ROSATOM). The collaboration of the US with the USSR in the ITER Agreement is, as I have described in the earlier part of this sub-section, a remarkable feat of science diplomacy. As the evidence provided by Michael Roberts (lead US negotiator) and the letter of William Martin (Executive Secretary of the National Security Council provided on p 123 attest personal relationships between the principal political leaders and their aides were as important in reaching agreement as the science necessity. Other parts of ROSATOM [which at the time of signature was known as Ministry of Nuclear Engineering and Industry of the USSR] were then and remain today intrinsically involved in companies and programmes that support the Soviet nuclear military complex (ROSATOM, 2018).

For the Government of the United States of America the signatory was Raymond Orbach, Under Secretary for Science, Department of Energy. US participation in ITER continues to be a long running political saga; Government support during the negotiations for such an expensive and risky project that is based outside of the US has been patchy at best (Harding, Khanna and Orbach, 2012). Following disagreements on the cost outcome of the Engineering Design Activity the US withdrew from the process completely in 1998 only to re-join in 2003. In the years that followed, the main legal and political hurdles included financial obligations, liability, withdrawal provisions, dispute settlement and the type of agreement that the US could legally enter were endlessly debated. A way ahead was found in 2005 when a provision was added to the Energy Policy Act that meant the ITER agreement could be considered as a *congressional-executive agreement*. Congress could now review the agreement regardless of whether it was submitted to the Senate for advice and/or consent. In practice this meant that if Congress did not object it would amount to implicit congressional blessing and funding. This provided the US negotiators with extra flexibility to reach agreement on financial obligations, since the other Members firmly rejected any agreement in which the US signature would be conditioned upon ‘Annual Authorisation of Funds’. The final hurdle to US backing of the ITER Agreement was overcome when US President Bush signed an Executive Order in November 2007 designating the ITER Organisation a Public International Organisation. This allowed the US to implement the privileges and immunities commitments that Orbach had agreed to almost one year earlier. Since then, the US DOE has led the efforts for exceptional oversight and rigorous project management of ITER; I return to this in sub-section 4.2.2. (American Presidency Project, 2003).

Michael Roberts in his interview reflected that it had taken an extraordinary alignment of powerful personalities at the very top of the USA Administration to bring the US back into the Programme: "In the summer of 2002, Rob Goldston [the Director of Princeton] explained to John Marburger, the Director of the Office of Science and Technology Policy [and ex Director of Brookhaven National Laboratory], that fusion was 'no longer his father's fusion' but was a now real programme with diagnostics, theoretical support and computer calculations; it was 'known science'. Marburger was convinced and then went back and spoke to President Bush. The key was Goldston's good relationship with Marburger and that Marburger was the right kind of scientist both as a fellow physicist and someone who would listen, think and speak to the President who would also listen and think. President Bush then made a speech in January 2003 that included: 'we owe it to our children and grand-children to join ITER, an ambitious international research project to harness the promise of fusion energy'. This high-level support was as important as that of President Reagan back in the mid-1980s and led the way for the US to re-join at the same time that China was to join the project at a February 2003 negotiating meeting in St. Petersburg. Michael Roberts recalled the theatre of the occasion: "To show the displeasure of the negotiators in the meeting room over the five-year US withdrawal from the negotiation, I was left to sit outside for over an hour - nothing personal of course, I was told later - before finally, I was allowed to lead the three of us in the US delegation into the room in parallel with the Chinese delegation."

Table 5 shows the disparity between which lead government departments interface with ITER. These also change over time. As several interviewees pointed out, at the start of the project, the US State Department, due to ill-advised security concerns, was opposed and the DOE was a solid backer. A situation reversed today with the DOE, mainly due to budget pressures from other projects, struggling to support the project, whereas the State Department now fully backs the collaboration.

ITER Member	Lead Government Department			Accession to UN Non-Proliferation of Nuclear Weapons Treaty / Year
	Science/ Tehnology	Energy	Foreign Affairs	
People's Republic of China	✓			✓ 1992
EU	✓ (EC: Science and Research Directorate) varies by EURATOM State			✓ varies by EURATOM State (e.g. UK, 1962; France, 1992)
Republic of India		✓		No
Japan			✓	✓ 1975
Republic of Korea	✓			✓ 1976
Russian Federation		✓		✓ 1970 (as Soviet Union)
USA		✓	State Dept support also required	✓ 1970

Table 5; ITER Members lead governmental departments and details of accession to the UN NPT (as at the signature of the ITER Agreement in November 2006)

The negotiating teams also skilfully included a catch-all tie-in in the event of any Member wishing to withdraw, which was possible after 10 years, from the Agreement signature. Driven by the size and length of the task ahead, the Members were deliberately tough on themselves. Article 26 (IAEA, 2006: 19) includes the statement: 'Withdrawal shall not affect the Withdrawing Party's contribution to the construction costs of the ITER facility. If a party withdraws during the period of operation of ITER, it shall also contribute to the cost of decommissioning of the ITER facilities.'

4.1.2: Purpose and Functions

This sub-section analyses the purposes of the organisation from an international relations perspective and is based mainly on secondary data such as the ITER Agreement (2006) and associated documents. Article 2 of the Agreement states: 'The purpose of the ITER Organization shall be to provide for and to promote cooperation among the Members … on the ITER Project, an international project that aims to demonstrate the scientific and technological feasibility of fusion energy for peaceful purposes, an essential feature of which would be achieving sustained fusion power generation'. This single sentence provides clarity of purpose and helps to reduce any tendency for mission creep by the central team or the Members.

Article 3 goes on to elaborate the functions of the ITER Organization to:

a) Construct, operate, exploit, and de-activate the ITER facilities in accordance with the technical objectives and the general design presented in the Final Report of the ITER Engineering Design Activities… and such supplemental technical documents as may be adopted, as necessary, in accordance with this Agreement, and provide for the decommissioning of the ITER facilities;
b) Encourage the exploitation of the ITER facilities by the laboratories, other institutions and personnel participating in the fusion energy research and development programmes of the Members;
c) Promote public understanding and acceptance of fusion energy.

The Article 3 functions are again succinct and focused. At sub-paragraph 1a, the importance of following on from the exhaustive pre-work that all Members had contributed to is underscored by naming the Engineering Design Activities. I will show in Section 4.2 that the level of design maturity that this exercise had produced was grossly over estimated and that this led to the first crisis facing the project community. Sub-paragraph 1b returns to the importance of keeping the Members satisfied that their facilities were gaining from the collaborative experience; I return to this in sub-section 4.2.3 concerning the sharing of information. Sub-paragraph 1c recognises the need to promote public understanding and acceptance of fusion energy. Public knowledge of large science mega-projects that produce no tangible results until they are well into their operations phase is scant, and media attention spans short and prone to sensationalism as I described in Chapter 3 regarding the start-up of the LHC at CERN. In the era of fake news and vociferous opponents to all matters nuclear, repeated public re-assurances to help allay safety misconceptions are vital. The fusion community works hard through a mixture of public and private channels and local liaison committees to provide this. The need to put ITER in the public realm was not just for educational purposes but also to bolster the political will of the Members. A weekly flow of official, professional project community news, supplemented by Members public outreach, relentlessly fills any gaps that elements of the media or obstructive pressure groups might seek to exploit (ITER Newsline, 2018).

4.1.3: Organs, Voting Rights, the Director General and Staff

This sub-section analyses the principle organs of the central organisation, the role of the Director General (DG) and the ITER international staff and the organisation's governance arrangements.

While doing so I also provide a commentary, based on the primary interview data, on informal governance and accepted practice featuring those considered the least and most productive.

Council comprises up to four representatives from each Member; in practice, two formal representatives are supported by a posse of officials depending on the topics at hand. It self-appoints a Chairperson who serves for a maximum of 4 years. It meets twice per year and holds extraordinary sessions when needed. The representatives have a unique dilemma; on the one hand they are responsible for the delivery within specification, quality and schedule of their portion of the in-kind contributions while at the same time being the ultimate body that the central organisation can appeal to when a Member fails to meet those very obligations. I return to this juxtaposition in sub-section 4.3.2. It is advised by three bodies: the Management Advisory Committee (MAC), the Science and Technology Advisory Committee (STAC) and the Financial Audit Board (FAB).

The MAC advises the ITER Council on strategic management issues such as budget allocations, the effective application of privileges and immunities and recommends actions to help improve the conduct of the project. In practice this means that if any person, specialist group or Member wants to gain Council approval for a new management initiative they must first seek MAC endorsement or, at the very least, avoid MAC disapproval. This has the advantage of providing an expert filter to the Council deliberations but runs the disadvantage of making operational change cumbersome. The current DG has now established an Executive Project Board that includes the Heads of each Domestic Agency that provides effective operational control.

The STAC advises the ITER Council on both science and technology topics that arise during design, construction and operation. Members of the Committee are chosen on a basis of the combination of their qualifications and experience. One feature of the STAC has been to stalwartly resist cost-driven cuts to the scientific scope. There has been a continuous defence of several key elements that will feature in ITER's experimental phase such as the number of heating methods and the number of diagnostics tools. Finally, the Financial Audit Board oversees the audit of the annual accounts of the ITER Organization in accordance with Article 17 of the Agreement and the Project Resource Management Regulations. In practice the audit is carried out by companies appointed on rotation between the Members

The project is currently led by Dr Bernard Bigot a respected nuclear scientist who has been closely associated with ITER since the early years of France's hosting proposal in 2001. As DG he is responsible for strategic management planning and policies and represents the ITER Organization in all official instances; as such he is one of two project officials to have full diplomatic status; the other being the Principle Deputy DG [where one is appointed]. As with CERN, this status is needed as the DG is ultimately the responsible person for contractual, legal, safety and operational mattes. Each DG is responsible to the ITER Council and is appointed for a period of five years which may be renewed once. The DG is assisted by a Cabinet and all the ITER Organisation staff.

The ITER Organisation staff has grown in numbers from the 170 when it was established in 2007 to over 825 ten years later (ITER, 2017). The main reason for the large increase has been the need to complete design work that is then used as a basis for the Members Domestic Agencies to place contracts for the manufacture of the parts in their respective territories. The ITER Members decided not to place the project within a pre-existing organization with experience in successfully building complex infrastructure. Instead the organization has been steadily built up by a combination of recruiting experienced staff and by outsourcing. The latter has culminated in the appointment of a Construction Management Agent (CMA) in 2016 to handle the assembly and commissioning of the device. The organisational structure is top down, and many interviewees commented suffers from having too many management layers that has been compounded by the CMA appointment. ITER is a unique facility and the nuclear safety requirements for fusion components, buildings, and operating have needed to be developed with little read-across from other facilities. The French nuclear authorities and IAEA departments have had to gain experience themselves of what regulation and oversight is needed for this new type of machine. The entire fusion community is bound together in its story, from the fabricators in the Member State’s factories right through to the high officials in the IAEA who will ultimately authorise its use.

4.1.4: Commercial, Contracting and Funding Arrangements

4.1.4.1: Commercial and contracting arrangements

During the 21-year ITER Agreement negotiation period, *common understandings* were also agreed as to the projects design, work breakdown and costs. Linked to these were how the knowledge generated by the project, during the design phase, construction, commissioning and operation would be shared by the Members. The aim was to spread the work so as each Member gained knowledge through its industrial base of the processes and techniques involved. Noble high-quality work (CERN sub-section 3.1.2) would therefore be shared not just for cost sharing reasons but also for the good of the fusion community. Harry Tuinder, the former ITER Legal Advisor and at the time of the negotiations, the Chief Legal Advisor to the European Commission provided an explanation of the need for the *common understandings* and that, in practice, their usage may not be as intended: "they are interpretations that are too detailed to go into the Treaty [ITER Agreement] text because it would have been too restrictive on the Members… we came up with a model that is acceptable to all seven Members, that means there was a lot of fighting about words that in practice now have very little meaning." (ITER, 2012).

The negotiations regarding project intellectual property was intense and resulted in a lengthy Article 10 of the Agreement (IAEA, 2006: 12). The key position was that the implementation of the Article and a supporting Annex on Information and Intellectual Property Rights (IPR) would be equal and non-discriminatory for all the Members and the ITER Organisation itself. This principle of openness, given the nature of the information and impact for future development of commercial fusion power, is a landmark of international trust building and an undoubted credit to the tenacity of the Member's negotiating teams. I return to the practicalities of sharing IPR in sub-section 4.2.3: Sharing of Project Information.

The ITER Agreement, at Article 13, also specified that Field Teams of ITER Organisation staff would be hosted by each Member to exercise the central organisation's functions and fulfilment of its purpose. In other words, a means of having the DG's own people on the ground to check what each Member's organisation and supply chain were doing especially with respect to Quality Assurance. In the event, no Field Team Agreements were ever concluded [or even started] between the ITER Organisation and any Member. Every Member decided it would conduct its part of the *common understandings* in their own way and saw no added value in having central ITER Organisation staff embedded in their organisations; I return to a consequence of this stance in sub section 4.2.3.

4.1.4.2: Funding arrangements

The Broader Approach Agreement (F4E, 2018) allocates some of Europe's share of work to Japan detailed in sub-section 4.3.3. The final Member's funding positions are shown in Table 6:

ITER Member	In-Cash Contribution (%)	In-Kind Contribution (%)	Notes (in-cash contrbutions are fixed) (in-kind contributions vary slightly in any given year by project contractual/schedule demands)
People's Republic of China	9.08	11.21	
EU	45.6	32.73	In-Kind reduced by EU-Japan Broader Approach Agreement
Republic of India	9.08	5.38	
Japan	9.08	25.88	In-Kind increased by EU-Japan Broader Approach Agreement
Republic of Korea	9.08	7.81	
Russian Federation	9.08	9.43	
USA	9.08	7.57	
Total	100	100	
Approximate % of Total Value over Project Life-Cycle	15	85	Total Project Value is combination over the Project Life-Cycle of In-Cash (provide each year in Euros, but valued in IUA) In-Kind Contrbutions (valued in IUA)

Table 6; ITER Member's Contribution Summary (ITER, 2017b)

Approximately 85 percent of the total value of contributions will be delivered 'in-kind.' In the place of cash being provided to the central organisation for it to carry out procurement, the Members deliver components, buildings, research results and secondee personnel. The in-kind contributions are divided into over one hundred Procurement Arrangements that are recorded in the *common understandings*. These Procurement Arrangements include technical specifications and management requirements. They are the method for the central organisation to exercise a degree of control over the Members by agreeing with them the terms under which the various elements will be procured, manufactured, inspected and delivered to the main site.

The series of Management Reports and many interviewees point out that the main disadvantage of the dispersed supply chain is that the central organisation does not have direct control or contractual levers to influence performance. While true, this inherently inefficient arrangement has within it the motive for the project's survival: over 85% of the value of the project is led by and directly benefits the Member States.

The dominance of the in-kind funding feature can mask the cash contributions that the central organisation also needs. The remaining 15% of the project value is required to be paid by the Members in cash during the construction phase and is a considerable annual commitment. This funding set-up is complicated by design and I will explain in sub-section 4.2.2: Project Delays and Funding Resilience that while it adds resilience to the project it has inherent operational flaws that the management team must continually deal with.

Section summary

Hypothesis 1 is supported in that the ITER Agreement does provides a concise and fair vehicle to promote trust and mutual support, allows flexibility in problem solving, deals with the arrangements to manage host state issues and emphasises the primacy of the State. Primary interview data has also shown that while the Articles provide a solid base from which the organisation and its community have benefited, they over prescribe in some areas that have necessitated work arounds.

The creation of a formal IGO collaboration between the ITER Members, given their rivalry in other domains, is remarkable. To have created an Agreement that covers intellectual property rights, export controls, peaceful uses and non-proliferation of nuclear materials is miraculous. Fusion pioneers such as Evgeny Velikhov of the USSR and Charlie Newstead of the USA worked tirelessly in bringing together their respective national leaders for the 'benefit of mankind' and, as this section has explained, for the benefit of their own community.

The ITER Agreement, while an iconic piece of international science diplomacy, is not flawless. The field work has highlighted that the immaturity of the Engineering Design Activities cited in the Agreement are obvious in hindsight. The difficulties that the founder's optimism bias produced was exacerbated by decisions such as the Member's deciding not to implement central staff field teams in their own national organisations. Also, the failure of top-level leadership to firmly and collectively address the issues and conflicts that then arose added more strife to an already serious situation; I cover the mitigation efforts to combat these circumstances in section 4.2.

The funding arrangements means that each Member can produce in their home territories most of their contributions to the project. This together with the punitive withdrawal penalties that the founders set, have kept the Members embraced on the project despite significant and unexpected delays and the political turbulence that has adversely affected them in several other domains.

This relates to two *Beyond Gridlock* pathways. Firstly, pathway 1, ‘shifts in major powers core interests’ where towards the end of the Cold War a set of well-placed advocates overcame gridlock in superpower international relations. This bi-lateral rapprochement was the catalyst for the remarkable seven Member coalition that created ITER. Secondly, pathway 8, ‘innovative funding’ mechanisms that took decades to negotiate and have both helped preserve the project and led to significant project management, quality control and logistical constraints that the community must continually wrestle with.

4.2: Managing Constraints

To test Hypothesis 2 (that external constraints such as excessive stakeholder aspirations, changing political and legal landscapes, bureaucratic regulations, funding fluctuations and unforeseen events, while being mitigated as far as possible by IGO leadership actions, inevitably adversely affect overall performance) I examine how the ITER Community leadership has handled three events. The first concerns the consequences of the site selection including hosting arrangements, the second the measures taken to combat funding fluctuations and the third the handling of an unforeseen set-back with respect to sharing project information. A section summary is also provided.

4.2.1: Consequences of Site Selection/Hosting Arrangements

Optical astronomy mega-projects are only sited after painstaking studies of the local observing conditions; hence the cluster of facilities in high altitude, dry humidity and remote low light interference locations such as the Atacama Desert in Chile (ESO, 2018). Beyond these practical considerations, site selection on SMPs is typically fraught with political overtones. The considerations that led to the USA choosing a green field site in Texas for the SSC (Section 3.2.1), rather than a location nearby to an existing high energy research facility, had two distinct threads: 'technical and political' (Riordan, Hoddeson and Kolb, 2015: 104).

As analysed in sub-section 4.1.1 on 28 June 2005, after more than four years of complex negotiations, Cadarache in southern France was selected as the ITER site. Akko Maas, the current science engineering officer in the ITER cabinet of the DG, who at the time was responsible for representing the European Member site candidates pointed out the consequence of the lengthy site selection process: 'several detailed areas of the main Treaty [ITER Agreement] could only be progressed once the Site was known (ITER, 2012)'. Without a decision on the Site, progress on the main agreement stalled. The choice was far from straightforward and the implications persist until today. I will consider three consequences: the first concerns political appointees to the central organisation and the second concerns logistics. The third relates to workshare and I cover this in sub-section 4.2.2 when considering funding resilience.

Part of the trade-off in Japan giving up its Site candidature was the agreement that Japan provide the DG. Kaname Ikeda was duly appointed by Council and he was succeeded by Osamu Motojima in 2010. Both were respected Japanese nuclear scientists but took markedly different approaches to the role. Ikeda had been Japan's ambassador to Croatia, and he relied heavily on a seasoned German

‘Big Science’ manager, Norbert Holtkamp, who he appointed as Principal Deputy DG and Project Construction Leader. Ikeda led the project in a diplomatic sense dealing with the Members and international, regional and local relations aspects and delegated day-to-day running of the organisation to Holtkamp. On taking over, Motojima took a more hands-on approach and Holtkamp departed to be the Deputy Director of the US National Accelerator Laboratory at Stanford, USA.

The risks of political appointees in large scale national projects is widely accepted and well researched (Kelman, 2010 and Dahlström & Holmgrem, 2015). These risks are magnified in IGOs that have high delegated powers of the DG and his/her immediate team. Also, to change the top-level positions in IGOs is often more laborious than in national institutions due to the consensus needed from the international partners. ITER suffered from the consequences of political appointees to its early high-level management team. An ITER Director typified the views of many involved at the time: “In a sense you could imagine that the DG could be a political appointment; that is OK as it is a political facing role. That is reasonable. The problem has also been the next level down; there is still some of it left in place, but it is not as bad as it was in the first round of appointments. The next level are department heads and therefore should be operational managers but, in the beginning, they were mainly political appointees that had little appropriate skills.” The constraint of these political appointees has been steadily mitigated by recruiting suitably experienced replacements.

The second consequence of the site selection is the effect on project logistics. The agreement of Spain to the rival Cadarache site was reached when it was agreed to establish F4E in Barcelona (sub-section 4.1.1). F4E would handle over 40% of the project value contracts and manage the Japan-Europe *Broader Approach*. It would have aided project communications if F4E had been co-located with the ITER HQ in France. Following the adoption of the French site, Europe acts as the Host Member. Highly Exceptional Loads (HEL) manufactured in the Members supply chain will need to be shipped to the French harbour of Fos-sur-Mer, west of Marseille on the Mediterranean Sea and then, via a specially prepared 104 km itinerary that winds its way through rural Provence, hauled by road to the construction site. Some 250 HEL road convoys, the heaviest of which will weigh approximately 800 tonnes (including the 200-tonne, 352-wheel transport vehicle), travelling at night to minimize disturbances to the local communities will navigate this tortuous route (ITERCAD, 2018). These topographical constraints have been largely mitigated by the Host Member’s planning and French State’s logistics efforts but still add a degree of difficulty that a coastal site could have avoided.

4.2.2: Project Delays and Funding Resilience

The ITER project is very late compared to the original plan. Soon after appointment, Holtkamp supported by the international staff and independent Management Assessors identified and made known to the Members that they had grossly overestimated the maturity of the design. It is not possible to ascertain as to the strategic misrepresentation that may have occurred and whether an alternative more realistic schedule was known to insiders, as the sparse evidence is contested. What is beyond dispute is that soon after ITER Agreement signature a significant adjustment to schedule and thereby costs had to be made. A long-serving ITER Science Team Section Leader described the underlying reason: "The project started on the false pretence that everything was ready. The people who were hired quickly discovered that things were not ready, and we had a situation where we had a management team that was not optimised to deal with that situation. The first step was to realise that it was nowhere near ready, so they had to go back to the drawing board and there was a big design review. As a result of the design review lots of things changed and there was a delay in getting going and at that point the communications between the DA [Member State organisations] and IO [central organisation] was poor. People who do not work in this environment do not realise how hard communication is."

Lack of credibility of the schedule to harness fusion energy for commercial power generation has been a feature of the fusion landscape from the onset of pioneers raising expectations to gain backing and funds, all adding to common semi-serious quip that *fusion is always 10 years away and 10 US$ BN away*. Efforts by the first two DGs in tackling – albeit difficult schedule issues - were unsuccessful in changing this perception. A report on the 2008 Management Advisory Committee (sub-section 4.3.1) deliberations reveals the prevailing mood. Holtkamp pointed out that 'The clock ticks and the money runs…. it is as simple as that.' For the first time the heads of the Domestic Agencies have joined together to explain where some of the reasons for their difficulties lie. Didier Gambier, the Director of the European Domestic Agency in Barcelona, is the first to take hold of the microphone. 'The ITER Organization has the responsibility for the ITER design, but the Domestic Agencies have the money, and money talks!' Ned Sauthoff, head of US ITER, agrees with his European colleague: 'This is not a normal project. The ITER principle foresees significant in-kind contributions and the Domestic Agencies hold considerable resources. We thus have to find the right balance (ITER Newsline, 2008a)'.

The most telling indicator of the unexpectedness of the delay is the ten-year limit included in several Articles of the ITER Agreement and the *Broader Approach*. For example, the provision for any Member to withdraw from the project at ITER Agreement Article 26 only come into force after 10 years. Ten years was the original estimate for the combined length of the construction, commissioning and initial operation phases. The basic first plasma is now forecast for the mid 2020's almost twice that original estimate. Even considering the traits of optimism bias and strategic misrepresentation that Flyvbjerg, Bruzelius and Rothengatter have described (2003: 73 and 137 and Oxford University, 2006) no-one foresaw that the delay would be of this magnitude. This has placed a considerable strain on all the Members due to the prolonged funding that the delays have caused.

Overcoming global political turbulence in the period 2006 to today and broadly maintaining funding has taken skill and determination. For example, Tim Luce, a veteran fusion scientist and current Head of ITER Science and Operations noted that "When the Crimea Crisis happened in 2014 the Russian currency devalued by a factor of three, yet they kept up all their commitments at a considerable cost to their internal Fusion programs. They are understandably upset when others do not meet their obligations."

The problem Member currently receiving the wrath of Russia, the other Members and the Central Organisation is the USA that has missed a series of annual cash contributions. The US domestic political reasons for these missed payments are complex. Field work confirmed that the DG, Bernard Bigot, has taken several diplomatic steps to reach out to the US Administration including urging President Macron to raise the matter directly with the US President Donald Trump. Bigot pointed out to the Subcommittee on Energy of the US House of Representatives that 'The United States, as the most scientifically and technologically advanced country on earth, is a highly valued ITER partner' he went on to say: 'The U.S. contribution to the ITER Project is 9.1% of the total. In return, the U.S. has access to 100% of the scientific and technological advancements resulting from the project. This leverages the US investment by a factor of more than 10: a solid investment by any measure (US Congress, 2018)'. The US DOE Report on US Participation in the ITER Project to the US Government in May 2016 was more positive than previous assessments of programme progress. One year later during another trip to brief the US House Appropriations Committee, Bigot also astutely met with the US Secretary of Energy Rick Perry.

Bigot updated the US Congressional Hearings of the Space and Technology Subcommittee of Congress on March 6, 2018 on project progress. In the face of the missing payments, his testimony emphasised the interdependencies between the Members: 'a shortfall in the contributions of any single member … will have a cascading, strong effect on delays, cost and the disruption of fusion research for every other member. It is why I would like to urge the US to timely comply with its contribution commitments. We at ITER are committed to working day and night to make this project the model for international collaboration in complex science and technology. We are committed to make ITER a sound investment for the US and all the other members.' He was supported in this request by leading figures in the US Fusion Community: Dr James Van Dam, the acting associate director, Fusion Energy Sciences, Office of Science, Department of Energy and Dr Mickey Wade, director of the Magnetic Fusion Energy Division, General Atomics (US Congress, 2018). Diplomatic efforts continued when Mr Perry visited the site to review first-hand project progress in July 2018. A way to resolve the matter is still in work at the highest diplomatic levels. The US contributions are currently being examined by the US Administration as part of an overall national energy review.

The USA with its annual budgetary appropriations of funds is more susceptible to an oscillatory cycle of boom and bust and therefore more captive to political and instantaneous public opinion pressures. In contrast, a positive outcome of the Site selection is the stability provided by Europe which has markedly longer timescales to act on their commitments. The EU through the European Commission (EC) operates on a 6 or 7-year timeframe. No other Member, except China (who did not offer a site candidate), could have provided this level of supportive medium-term funding. Given the significant delays, this beneficial situation regarding EC funding cycle, in combination with the advantages of in-kind procurement for all the Members (sub-section 4.1.4.), has helped prevent project cancellation.

The Joint European Torus (JET), situated at Culham near Oxford is the largest operational tokamak in the world and contributes to the ITER project research community; it is governed under EURATOM arrangements. Several UK nationals serve in the ITER Organisation either as EURATOM secondees or on individual contractual basis as citizens of a EURATOM state. The consequences of the UK notification to leave the EU and thereby leave EURATOM, are currently open to speculation (Fernando, 2016:1). The impact is being assessed by EURATOM, the UK authorities, the DG and ITER HQ Management Team, the F4E Management Team and the wider fusion science community.

4.2.3: Sharing of Project Information

Attractive features that made the governments make such a large investment decision in the ITER project was the assured excellent return on investment and the sharing of knowledge and know how. The ITER Agreement enshrines the principle of sharing when two conditions are met: firstly, if the information is *Generated* Intellectual Property (GIP) rather than *Background* Intellectual Property (BIP) which companies retain, and secondly if it is for fusion research and development. The companies involved must declare when these conditions are met and then licence the sharing with the other parties involved. DG Bigot underlined this benefit while hosting the US Secretary of Energy, Rick Perry, on his 2018 site visit 'it is ITER's ambition to serve as a model of successful international collaboration and as a smart deal and positive return on investment for the US and all ITER Members.'

In practice it is proving hard to collect this GIP. The experienced companies who own it are many in number and operate under a contractual relationship to each Members Domestic Agency (DA). The contract between the DA and the suppliers are confidential, so the central IGO, with no Field Team representatives (sub-section 4.1.4) does not know the exact IPR clause involved only that the requirement is included. Early signs were good, and Members were content with both the volume and quality of the GIP they were seeing. More recently declarations have slowed and there is growing discontent among the Members. Reasons for the change are contested, the most common one, cited by three interviewees being: 'The main difficulty that the central organisation has in convincing suppliers to declare is that the contractual levers to encourage them to do so rest solely with the national domestic agencies.' The inference here is that national considerations may be hampering either intentionally or unintentionally GIP declarations.

One of the Directors tasked by the DG to raise the number of GIP declarations reminisced that lobbyists sold the project to their governments at its inception by the argument: "this is a wonderful project: we invest 9% but in return we get 100% of the shared Intellectual Property" and the Director pinpointed the bigger picture consequences should performance in this area not improve: "The total financial capability in the world for fusion development is limited, if we do not share the IP as originally intended then you could theoretically spend seven times the needed investment for any one new technology. The aim is a total global fusion saving. Global saving means that the whole Fusion community can have more money to overcome the big challenging technical barriers such as the plasma facing materials or the tritium plant. If you spend the same money on each part by not sharing, it will be a disaster for the global Fusion Community. Also, as the production devices will be built much later the Members taxpayers will rightly ask what tangible things have been delivered? You said on the way to the final goal you can deliver many spin-offs, where are they?"

Mitigation in this area is difficult and the Fusion Community reputation is on the line. The matter is receiving high-level attention from the ITER Council and the conclusion is still to be determined. Every technical responsible officer has been tasked to identify areas of their work that are GIP sharing candidates. Annual targets have been set by Council on each Domestic Agencies to declare GIP. The European Member has a strong team in Barcelona to manage their IP. Other DA are finding it a difficult task with some interviewees commenting that suppliers sometimes fail to respond to requests or even threaten to leave the project if coerced to declare.

Section summary

The operations of the ITER community tightly support Hypothesis 2 in that 'external constraints such as excessive stakeholder aspirations, changing legal landscapes, bureaucratic regulations, funding fluctuations and unforeseen events, while being mitigated as far as possible by IGO leadership actions, inevitably adversely affect overall performance.'

Managing constraints on the ITER project is not easy and this section has highlighted three areas that typify the depth of problems that have had to be overcome and in some instances are still being combatted. Firstly, the consequences of the site selection have included the negative aspects of political appointees and logistical hurdles of a site situated over 100km from the sea. Secondly, the effects of project delays caused by a combination of circumstances including immature design at start-up and ineffectual leadership to deal with the conflicts, that potential fixes demanded were a potent combination that almost led to the projects' cancellation. The community did act to address these constraints, and the project is now on a more secure footing. Thirdly, the effects of Member's suppliers not adequately declaring intellectual property has been shown to be misplaced self-interest; a problem that the Member States are now making major efforts to address.

This capability to deal with these constraints as well as providing support of Hypothesis 2, also serves to support Hypothesis 3 that 'sound internal governance and leadership dynamics improve global IGO performance.' It relates to two *Beyond Gridlock* pathways. Firstly, Pathway 2, autonomous and adaptive international institutions, that has been stretched to its limits in the herculean efforts to overcome the technical and scientific obstacles in putting ‘A Star in a Bottle’, as termed by Raffi Khatchadourian (2014), while keeping the diverse Members together. I provide further examples of these efforts in sub-section 4.3.1: Organisational Culture. Secondly, Pathway 3, ‘technical groups with effective and legitimate processes’ being free to solve problems without being overburdened by hierarchical bureaucracy is true for this case study but gains have been agonizingly slow to materialise.

The steady success of the Pathway 2 and Pathway 3 efforts have allowed the Council to rise above the turmoil that has engulfed its members in other political fields since 2006. The numerous working level mini- epistemic communities that comprise the ITER Community have positively contributed to the whole. Nevertheless, this section has shown that the depth and seriousness of the constraints has adversely affected overall performance, demonstrated by the almost doubling of the original estimate for construction and achievement of ‘first plasma.’ This has allowed criticism to mount that will only be fully abated when the scientific results bear fruit in the later 2030’s. The Pathway 2 and Pathway 3 efforts have also been strengthened by Pathway 7 ‘innovative leadership’ with regular use of Pathway 8 ‘innovative funding’ mechanisms that I now move on to in the next section.

4.3: Governance and Leadership Dynamics

To test Hypothesis 3 (that sound internal governance and leadership dynamics improve global IGO performance) I examine three organisational features. Firstly, the organisational culture where the analysis has taken account of the views that were expressed at all levels within the community during the field work interviews on those management approaches that have been most productive and how criticisms have been dealt with. The analysis has also benefitted from the availability of the bi-annual Management Assessors Reports that provide a regular barometer of performance and, through the results of extensive staff surveys, moral. Secondly, I examine two characteristics of successful organisational orchestrators: focality and legitimacy. Thirdly, I explore upcoming developments for ITER in an international context including how collaborations on the future DEMO devices may be managed and the community's potential strategies regarding commercial exploitation of fusion. A section summary is also provided.

4.3.1: Organisational Culture

To grasp the rate of progress on a project of the magnitude of ITER is not straightforward and the need for independent oversight was foreseen by the founding negotiators and detailed in Article 18 of the ITER Agreement (IAEA, 2006: 16). The importance of establishing the compulsory, regular and independent nature of these reviews was emphasised by a leading US negotiator, Michael Roberts who revealed detail of the arguments concerning its periodicity: "the US originally advocated an annual assessment while China thought four years more sensible." All those interviewed agreed that the appointment of a Management Assessor every two years has proven to be about right: frequent enough to provide meaningful oversight while giving the central management team enough space to get on with operations.

Although sensitive and/or business confidential information is not released, the Management Assessors reports, and executive summaries of independent review groups commissioned by the Council to investigate specific matters are available. This secondary data supports the primary research interviews in pointing to two underlying reasons behind the delays: Firstly, the 2001 design was incomplete as shown in the evidence in sub-section 4.2.2. Secondly, a lack of appropriate top-level leadership in the early years failed to effectively address the first issue. DG Motojima was struggling to lead the project through the deep and diverse difficulties it was faced with and his position was progressively seen as untenable culminating in the 2013 Management Assessors report including at number two of its eleven recommendations to ‘Accelerate the Director General Transition” (Madia and Associates, 2013: 7). Great expectations were therefore placed on Bigot when the Japanese agreed with the other Members that he should replace Motojima earlier in his five-year term than was originally planned. Evidence of the improvement in project culture following the change in leadership is best illustrated by primary data quotations from within the Community:

A current ITER Division Head, with over 10 years on the project: “In Bigot’s dealing with the US, I think he has made magic. He has managed to communicate and convince major players in the US; which was the complete opposite before he came”.

A respected veteran of the central team, who joined at its foundation in mid-2007: “What I see has happened is that when Bigot came in he said to the workforce that one of his conditions in being appointed was the amount of control including funding that he would have. Previously and restricting my comments to the institutes rather individuals, because of the power struggle with F4E, it was very difficult for the Directors to do want they wanted to do.”

A long-serving and respected ITER Science and Operations Team Section Leader: “And what is good now is that Bernard Bigot has insisted on more central team control over the DA and much more dialogue, so things are clearer. How things are written is clearer, the way documents are reviewed and assessed is getting better and so communication channels are much improved. It also helps when you see that the project has come to life in the last few years. Now you hear good things, not just bad things. That inertia is very important and that has come from the very top… Bigot is so well connected that he has opened up influential contacts everywhere. Something his predecessors just could not do.”

A current ITER Head of Department noted: “One of the things Bernard Bigot is very good at is ‘ask what you want’ and ‘say what you think’. Do not play political games on the project as it is viewed differently in different cultures”.

Dr James Van Dam, the acting associate director, Fusion Energy Sciences, Office of Science, Department of Energy in his testimony to Congress: “The ITER Organisation has significantly improved its project management performance under DG Bigot and we thank him for that.” Realistic action plans, detailed schedule reviews and national recovery activities resulted in the US DOE 2016 overall recommendation to stay in the project. The DOE final report stated that in coming to the endorsement, the review team had ‘considered the program strategy, project management, foreign policy and international relations and the anticipated national budget conditions’ (US DOE, 2016).

Finally, the 2016 Management Assessors report, some 13 months after the changeover, concluded that: ‘the creation of an engineering project culture had been instituted and was improving, re-structuring efforts were taking place, the new DG was effective and communication and general cooperation between the central organisation and the Members had dramatically improved’. Evidence of the positive effect of innovative leadership can be seen in the reports survey of 28 senior ITER Organisation staff who were asked seven questions including “Are you supportive of the new management?’: all 28 responded positively (ICRG, 2016: 51).

The 2013 Management Assessor (Madia and Associates, 2013: 4) pointed out the difficulties in establishing a shared project culture between fusion systems designers, scientists and nuclear industry construction engineers. The groups have differing backgrounds, personality types and priorities. For example, the design groups are stereotyped as having difficulty in embracing the concept of ‘this is good enough.’ This view was supported by a highly experienced ITER Division Head: “We talk a lot about cultural differences and conflicts and people like to relate this to nationalities. In my opinion this is completely wrong. We do have a big cultural problem but that is between the Science Community and the Nuclear Industry Community which are two extremes, and everything is different in these two worlds and we continually have conflicts. So, scientist work one way which may be extreme chaotic and nuclear industry work in complete opposite way, which is bureaucratic, slow and blocking. It does not matter if we make progress as long as we complete the right excel sheet! The Nuclear Industry is big strong and blocking, but it is less blocking than it used to be. The Science Community on ITER has adapted and become a little stronger to push back. For example, Operations has never been a player, but is now becoming a player”.

A long-serving ITER Director, noted with respect to analysing the project culture that: “There is not a single relationship. Every Procurement Arrangement Responsible Officer in the central organisation has a relationship with their counterparts in the Domestic Agencies; each one has a plus or minus that contributes to the overall depth and quality of the central organisation to domestic agencies relationships”. This telling observation has read across to a series of specialist mini epistemic communities that are led by the central organisation staff who have counterparts in the DA depending on their specific circumstances. For example, the mini-community led by long-serving ITER team leader: “I organised annual meetings and ITER became the leading entity in an emerging specialist field of technology. People attended to find out what to do and went and did it, this has benefited everyone in the end. What we have seen is that the less experienced countries see the collaboration as a possibility to learn. An example is China where they have learned. It is a win-win for our community as they learn, and we get the work done cheaply, well and on time."

This long serving ITER team leader also supported the view of the ITER Division Head above regarding project culture: "People talk about the problems due to different national cultures being involved, I have not found this to be an issue. There is worldwide team and there is a community of Fusion neutronics people and we all know what must be done. In the neutronics community, I have no authority and a little money. It works because everyone has a common interest in progress. Everyone wants to be the best. For neutronics this is the best project in the world and if participants can hold their own here, they can hold it anywhere. The team works well because it has some very good people; it would have been difficult with mediocre people."

4.3.2: Focality and Legitimacy

This sub-section benchmarks the case study results against two characteristics of successful orchestrations that Abbott and Hale (2014: 9) outline within their Guide for Organizational Entrepreneurs: focality and legitimacy. While doing so it examines the unusual dilemma facing the participants that I highlighted in sub-section 4.1.3., namely, that at ITER Council level the representatives are responsible for the delivery of their portion of the in-kind contributions while at the same time being the ultimate body that the central organisation can appeal to when a Member fails to meet those very obligations. A Member in these types of scenarios would declare a conflict of interest if Council deliberations stepped that way and may even exclude themselves from part of a meeting or a vote; the dilemma is manageable due to its limited scale. On an industrial JV the members would also be the first-tier suppliers but would ultimately be accountable and responsible to the client and his/her separately appointed central management team. What is different here is that, due to the way the project is set-up and funded, the Members play a significant role in all aspects: firstly, they provide representatives to the Council and therefore have ultimate governance responsibility; secondly, they are responsible for the Domestic Agencies who place contracts with and oversee the supply chain with respect to schedule, quality and costs of the in-kind contributions and thirdly, they provide the cash contributions to the central organisation who manage the project including, setting design requirements, exercising configuration control, oversee safety and carry out quality assurance all of which have an impact on costs.

Focality and Legitimacy concepts are therefore intertwined in a convoluted embrace throughout the ITER community. To aid the analysis of both features, Figure 9 provides an Overview of ITER Community Contributions Focality and Legitimacy of Common Enterprise:

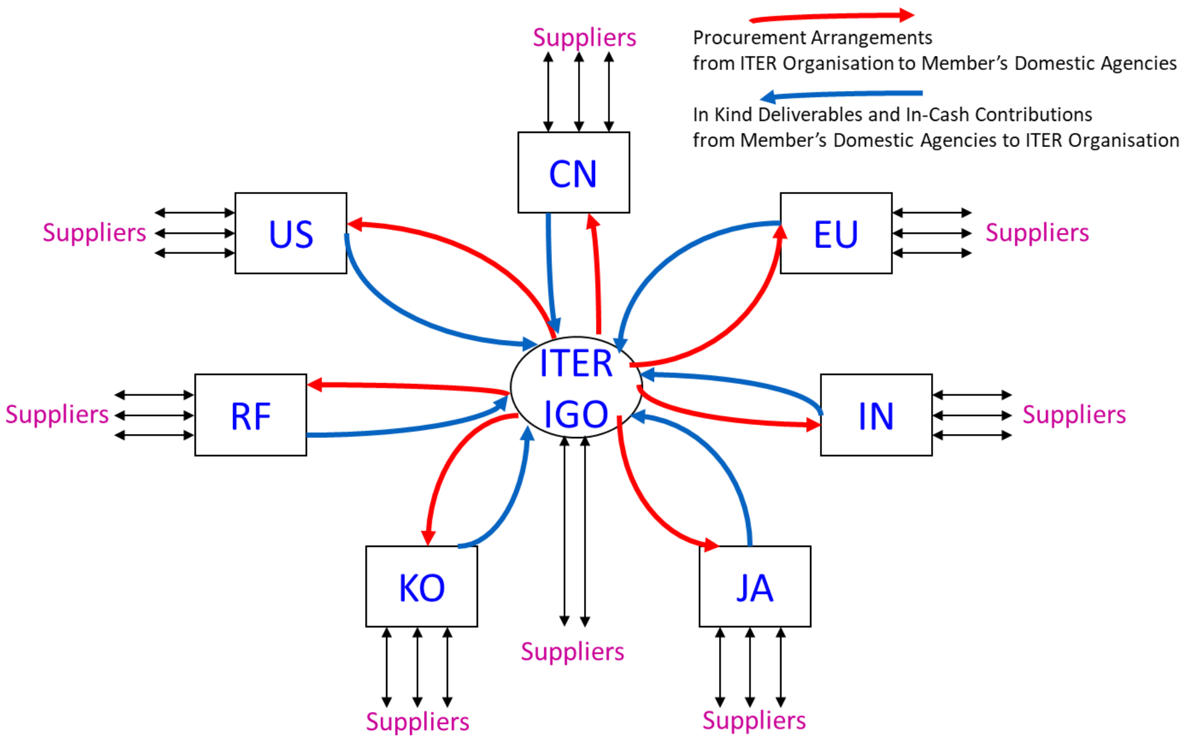

Figure 9; ITER Community Contributions - Focality and Legitimacy of Common Enterprise

4.3.2.1: Focality

The ITER central IGO HQ acts as a hub for its epistemic community but people perceive it from a different perspective to the way CERN acts as hub for its community (sub-section 3.3.2). Richard Pitts captures the difference: "This project is the absolute culmination of the world-wide fusion community; this tokamak design is based on the biggest body of knowledge that we have. All our eggs are in this one basket and there is naturally pressure that we must get it right". He added the existential threat to the community that the focality of the project represents: "most people are on board as they see it as our only chance, for better or for worse, we have decided to go down this route. Some scientists still believe it is not the right way to go, but they have to support it because if the project goes down it takes with it the entire community. This is not the case in other larger research communities."

Secondary data support for this position is widespread including the series of Management Assessors Reports, scientific journals and national assessments such as the US Congress Subcommittee on Energy Hearing Report, the Future of U.S. Fusion Energy Research (US Congress, 2018). They all emphasise the focality of the project and add to the pressure on the community to deliver. There is a realisation that the set of circumstances that established this nuclear collaboration (see section 4.1: The ITER Agreement) would be impossible to repeat in today's political climate. There will therefore be no ITER 2.0 project, no second chance for generations; failure is not an option for the planet or the fusion community. A counter-argument to this analysis is that, should the collaboration fall apart, then Europe would continue to build the device alone; a supposition that no-one in the community wants to test.

The arrangement shown in Figure 9 also bolstered the domestic magnetic confinement fusion areas in the Member States which are burgeoning. The distributed supply network has meant that domestic agencies have had to learn to be intelligent hubs to control the vast amount of work that they are responsible for. The scale of the central design has primed specialist research and development activities to begin in Member States. This research suggests that this is a - albeit limited – use of the *Beyond Gridlock* pathway 5 'mobilisation of domestic constituencies for cooperation and compliance' mechanism. Examples include Plasma Disruption Studies in Europe at the EURATOM JET facility near Oxford in the UK and at the Oak Ridge National Laboratory in Tennessee, USA. ITER is like CERN in that it acts an anchor institution that acts and directs.

4.3.2.2: Legitimacy

It is vital that there is a belief among all the actors in a community that the central organisation and its bodies are appropriate to direct policy. At times that belief has wavered in the ITER Community. In sub-sections 4.2.2 on project delays and funding resilience and 4.3.1 on project culture I analysed the problems with the first round of appointments to the central organisation's high-level leadership. Faced with unexpected incomplete design, the central team's authority to direct events (if not its very legitimacy to exist) was challenged by Members. The Members in this period were also establishing their Domestic Agencies and were hard pressed to place the contracts needed to get components under construction. Having the DG and central teams to take the blame for the majority of the delays and indecisiveness was a not too hidden tactic for the Members who themselves were behind schedule with their elements of the enterprise.

Today, like with CERN, the ITER central IGO has an unchallenged legitimacy and enjoys a shared set of normative and principled beliefs, shared causal beliefs, shared notions of validity and a common policy enterprise with its wider epistemic community. This standing has had to be earned and fought for. I have already described the change in leadership and improvement in project culture that has helped bring this improvement in legitimacy about. Further evidence of this status derives from multiple sources. Here I outline the most important two, in doing so, I will include counter-factual evidence that reveals the unyielding high stakes the ITER Community must constantly deal with.

First, the Council is legitimized by the expert support it receives from two of its subsidiary governing bodies: the MAC makes recommendations on the management arrangements and the STAC on both scientific and technical issues. These tasks demand members of the highest calibre and experience. These requirements also highlight an inherent weakness in the arrangement that can be illustrated by an example from June 2008: the ITER Council asked the former Operations Director of the UK's fusion centre at Culham, Frank Briscoe, to set up an independent panel of experts to assess the project. The review group, termed the 'Briscoe Panel', consisted of 17 experts, with at least one from each ITER Member, plus three advisers. Briscoe commenting at the time that 'Some of the panel members are fusion scientists, some have no scientific background at all, but they all have good knowledge of big projects.' The 'but' exemplifies the belief that to adequately determine how an organisation set up and performing you really need to understand [fusion] science. In one aspect, this is self-evidently true due to the complexity and special ground-breaking nature of the project. It is an issue other SMPs face, such as ESO in the Astronomy epistemic community and DUNE in the high energy physics community. However, the very high focality exacerbates the risks for ITER. Field work confirmed that the inherent flaw is that a group within an epistemic community that are themselves dependent on the success of the key component of that community's flagship project are unlikely to be free of optimism bias (either deliberate or subliminal). The same applies to deliberations of the STAC and its specialist panels with one veteran team leader commenting: "We should avoid the Council being incestuous with respect to the project itself. There should be more external scrutiny. We should have had members on the Council and the other bodies where their welfare is not linked to the project welfare. We should bring in five top business executives, they will find things you are not doing right". In providing this counterfactual evidence I am not purporting that the supporting governing bodies and their many expert panels over the years of ITER's construction have been in any way unprofessional; without them the project would undoubtedly be in a worse position. I do contend that any community as passionate and committed about fusion energy being the key to our collective energy needs cannot impartiality assess itself. If you are part of the wider magnetic confinement fusion community, you are by default a believer in that approach. What DG Bigot has achieved is to reassert the moral authority of the central organisation to exercise the necessary project management and controls despite these types of constraints.

Second, the central organisation has legitimacy due to the expertise that ITER possesses. The technical and scientific mini-epistemic communities are led by world-leading experts in their respective fields such as super conducting magnets, neutral beam, cryogenics, neutronics, etc., The central organisation sets the pace in these areas as it must continually make the best decisions that the project and thereby the community needs. This expertise has deepened as the project has moved - albeit slower than anticipated - forward. Secondary supporting data includes the list of fusion conferences that the central organisation chairs (both by hosting at the HQ and at the Members facilities worldwide) and the large number of peer reviewed papers that its staff have published (ITER, 2019a and 2019b).

The undisputed focus in key domains that Figure 9 illustrates means that any deficiencies markedly affect project performance and therefore must be addressed quickly and decisively. I have outlined some steps such as the establishment of the Executive Project Board, the employment of the CMA and the gradual professionalisation of the second tier of leadership to match the task (sub-section 4.1.3). The added legitimacy that these steps has fostered is currently backed by the whole community as evidenced in sub-section 4.3.1. Interviewees emphasised that it is crucial that those improved results sustain this momentum.

4.3.3: Future developments and expansion

There are three reasons why it is unlikely membership will be expanded. Firstly, the amortisation of a proportion of the costs borne to date by the founding seven members, that would need to be included in any joining fee, would be prohibitive; secondly, the Members believe that the long-negotiated *common understandings* on workshare already covers all that is required and thirdly, there is no desire to share the foreseen benefits too widely other than on a commercial basis. Nevertheless, since its formation the ITER organisation, with the unanimous approval of the Council representatives, has entered into a series of bi-lateral agreements with states, other international organisations and institutions. A 2015 proposal to collaborate with Iran, on mainly diagnostics research, has been put on hold following the US withdrawal in 2017 from the Joint Comprehensive Plan of Action (JCPOA). None of the collaborations have been undertaken by either party for a single reason. For the fusion community there tends to be one or more of four main drivers: strategic/financial, sharing of the research load, to help fill a specific technical/scientific capability or scarce resource and finally, for outreach/educational purposes; Table 7 provides a summary with the foremost collaboration category shaded:

State / International Organisation	Year	Collaboration Category from Fusion Community Perspective (principal category shown highlighted in green)				Main Driver/Focus of Collaboration
		Strategic/ Financial	Research	Specific Capability and/or Scarce Resource	Public Outreach/ Educational	
IAEA	2008			X		Regulatory oversight
Principality of Monaco	2008	X			X	PostDoc Fellowships
CERN	2008		X	X		Research in Superconducting Magnets
Australian Nuclear Science and Technology Organisation	2016	X	X			Fusion research
National Nuclear Center of the Republic of Kazakhstan	2017	X	X	X		Mineral Resources and Research
UKAEA	2017		X	X		Research in Remote Handling
16 National Laboratories (worldwide)	varies		X			Fundamental Fusion Research
32 Universities (worldwide)	varies				X	Education
4 National Schools	varies				X	Education
Local Community Groups	varies				X	Public Outreach

Table 7; Summary of the ITER Organisation's main bi-lateral Cooperation Agreements (with the foremost collaboration category shaded)

Future expansion into commercial power generation is the long held fusion community vision. The pressure on ITER staff (sub-section 4.3.1.) to get things right is replicated in each of the national programmes. The future demonstration fusion power station (DEMO) devices in each of Members territories will be simpler than ITER as they will draw of the technical and scientific lessons learned. They will mark the penultimate step before the construction of thousands of commercial fusion power plants.

Section summary

Hypothesis 3 that sound governance and leadership dynamics improve IGO performance is supported (see checklist of supporting and opposing attributes at Table 1) through the field work testimony and the analysis of 'Science Diplomacy' and 'Mega-Projects Governance, Leadership and Performance Issues'; Sections 3 and 4 respectively of the Literature Review.

Field work interviews and secondary data including management assessors reports and national independent review groups commissioned by the Council have stressed the importance of sound leadership on a project such as ITER. One person, even a DG, cannot single-handedly extinguish a project of such magnitude or lead it, cult like, to a promised land. I have shown that one person's influence can quickly affect the community culture and thereby markedly change performance. Thankfully for ITER [and the world] DG Bigot has done this in a positive sense. I have shown that focality and legitimacy, two characteristics of successful IGO orchestrations are both well-established on ITER. Indeed, the project and its community are focused in their efforts not only to make a success of the project but also to preserve the community itself. Failure of the project is widely seen as highly likely to bring down the entire community. With the caveat that I outlined in sub-section 4.3.2., regarding the complications in assessing your own work in a highly specialised field of endeavour, the legitimacy is strengthened through a combination of a meritocracy based advisory committees and the expertise of the central teams.

The explanation of future developments and expansion serve to emphasise the importance of the project for the environmental health of the planet. The leadership within the Member States to develop their own fusion communities upon which their national devices sit has been given further impetus by the shared international experience. Direct examples being the three joint Europe-Japan elements of the Broader Approach Agreement (sub-section 4.3.3), the Neutral Beam Test Facility in Padova, Italy (sub-section 4.1.1) and the major EURATOM facility at Culham in the UK (sub-section 4.2.2). These national communities and their ITER related facilities all contribute to the wider fusion community knowledge sharing envisaged by the founders.

This governance and leadership dynamics section relates to four *Beyond Gridlock* pathways: Pathway 3, 'technical groups with effective and legitimate processes'; Pathway 4, 'multiple, diverse organisations and institutions coalesce around common goals/norms'; limited use of Pathway 5, 'mobilisation of domestic constituencies for cooperation and compliance' and Pathway 7, 'innovative leadership as a reaction to gridlock'.

4.4: Evaluation of the *Beyond Gridlock* pathways and associated mechanisms employed by the ITER community

As predicted by *Beyond Gridlock* theory this research shows that there is overlap between which pathways are utilised by ITER. It is nevertheless beneficial to support the three Hypotheses to show which principally apply. Table 8 cross-references the pathways that have been identified in the summaries of the preceding sections.

Hypotheses	ITER Pathway
1. IGO agreements and start-up conditions which are concise, fair, promote trust and mutual support, allow flexibility in problem solving, manage host state issues and emphasise the primacy of the State improve performance	1 and 8
2. External constraints such as excessive stakeholder aspirations, changing legal landscapes, bureaucratic regulations, funding fluctuations and unforeseen events, while being mitigated as far as possible by IGO leadership actions, inevitably adversely affect overall performance	2 and 3 (aided by 7 and 8)
3. Sound internal governance and leadership dynamics improve performance	3, 4, (limited 5) and 7

Table 8; Cross-reference between hypotheses and Beyond Gridlock pathways utilised by ITER

Hypothesis 1 is supported through the employment of two pathways. Firstly, pathway 1, 'shifts in major powers core interests' where towards the end of the Cold War a set of well-placed advocates overcame gridlock in superpower international relations. This bi-lateral rapprochement was the catalyst for the remarkable seven Member coalition that created ITER while maintaining a solid respect for the primacy of the state. Secondly it is supported by pathway 8, 'innovative funding' mechanisms that have both helped preserve the project and led to significant project management, quality control and logistical constraints that the community must continually wrestle with.

The section on Managing Constraints shows the pathways used to combat Hypothesis 2 issues have been steadily strengthened since the project's inception. Pathway 2 mechanisms including giving the central organisation increased authority to tackle project construction and integration challenges and pathway 3 initiatives that allow technical groups to gradually develop a project adhocracy that enables sets of mini-epistemic communities to solve complex problems and navigate constraints have both had a positive effect. Although negative effects such as program delays persist, I contend that there are good reasons to deduce that they are mitigated from what would have occurred without effective interventions. For example, had the ITER Community leadership delayed dealing with the multiple consequences of site selection, analysed in section 4.2: Managing Constraints, this would have stored up problems. I have shown that implementation of the pathway 2 and 3 solutions relies on sound and innovative leadership and, where appropriate, employment of innovative funding; Pathways 7 and 8 respectively.

The governance and leadership dynamics section relates to four *Beyond Gridlock* pathways. Firstly, Pathway 3, 'technical groups with effective and legitimate processes' where they have developed legitimising expertise. Secondly, Pathway 4, 'multiple, diverse organisations and institutions coalesce around common goals/norms' where focality and legitimacy are knotted together in such a way that the community depends on the success of the central entity. Thirdly, Pathway 5, 'mobilisation of domestic, constituencies for cooperation and compliance' whereby the vastness of the project means that research and development studies are carried out world-wide to support the central goals and national follow-on devices (in most cases) complement the central efforts. Finally, albeit quite late as explained in sub-section 4.2.1, Pathway 7 innovative leadership is employed.

Finally, table 4 confirms that the gridlock pathway 'civil society coalitions with reformist states (Pathway 6) does not feature for ITER. Table 9 provides a summarising commentary of the mechanism in use for each of the seven pathways that do apply.

Pathway	ITER Community Mechanism
1. Shifts in major powers' core interests	• Thawing of Cold War at US-USSR Summits in Geneva (1985) and Reykjavik (1986) provided opportunity for determined and shrewd advocated to add the fusion vision as a balance to nuclear weapon issues in Summit protocols. Led to 7 party 'ITER Agreement' Paris (2006) • Aligns with post WW II, 'Atoms for Peace' concepts
2. Autonomous and adaptive international institutions	• Although ITER Agreement allows weighted voting in Council, consensus unanimity has always been practiced; the primacy of the Members is sacrosanct • MoUs have been agreed with other nations for specific needs: e.g. Kazakhstan (mineral resources)
3. Technical groups with effective and legitimate processes	• The central team's authority comes from ownership of the Project Baseline, Design Authority, Nuclear Operations Licensee and guidance to Council on balancing of in-cash / in-kind contributions • ITER device is the world's most complicated man-made object; its design, assembly and operation demand strict adherence to Systems Engineering standards • In-Kind workshare means control of majority of supply chain rests with dispersed Member Domestic Agencies
4. Multiple, diverse organisations and institutions coalesce around common goals/norms	• Extensive global collaboration: 7 members comprise 35 developed nations that together represent over half the world's population and over 80% of the world's GDP • Recognised centre of excellence for Nuclear Fusion
5. Mobilization of domestic constituencies	• Central funding primes limited specialist R & D activities to begin in Member States (e.g. Disruption Studies)
6. Civil society coalitions with reformist states	Research confirmed that this *Beyond Gridlock* pathway does not feature
7. Innovative leadership as a reaction to gridlock	• Early leadership was problematic culminating in a 2013 Management Assessors Report calling for an earlier than planned preparation for succession of the second DG • Current DG (Bernard Bigot, France) has strong backing from Members and staff; he has introduced a more open approach to problem solving and teamwork • Diverse locations of technical teams continue to present problems in systems integration
8. Innovative Funding	• 85% of the project is funded by in-kind contributions whereby detailed design activities and manufacturing are carried out in members home territory. This helps 'lock-in' to the project despite schedule/cost overruns • The in-kind arrangements have also contributed to difficulties in the central organisation exercising, through the Members, the required level of project controls. • Scrupulously fair funding formula for cash contributions; but currently two Members are behind in payments

Table 9; Pathways though and beyond gridlock, ITER mechanisms for implementation (adapted from Hale and Held, et. al., 2017)

CHAPTER 5: THE INTERNATIONAL SPACE STATION COMMUNITY

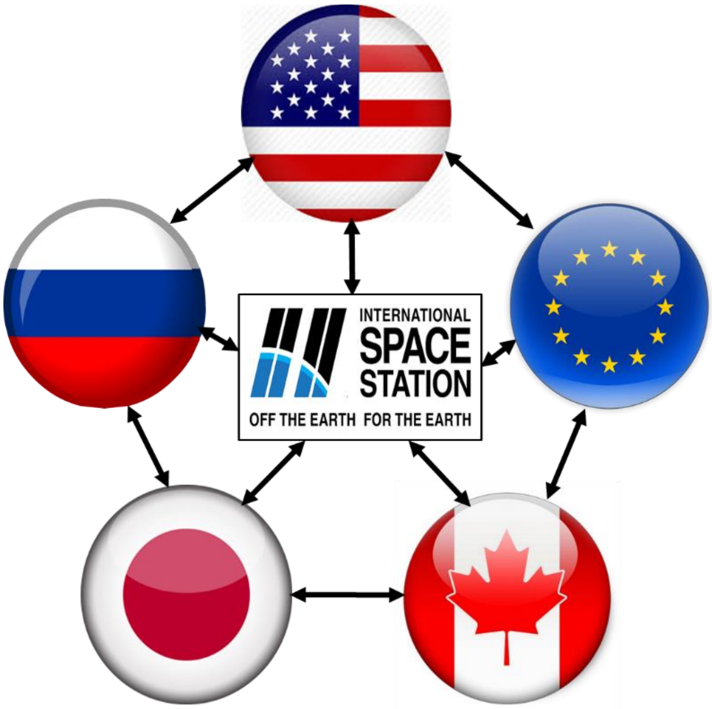

Figure 10; ISS Community at IGO level as at March 2019 (logo courtesy of NASA)

The goal of the International Space Station (ISS) is to provide a safe, common environment to carry out science experiments in a microgravity environment. The facility is therefore unique in that it has operated with a continuous human presence in low earth orbit since the Expedition 1 crew boarded the station in November 2000 (NASA, 2018). Construction started in 1998 and was painstakingly slow, requiring 37 US Space Shuttle flights, 4 Russian assembly launches and over 155 spacewalks by astronauts to complete. The ISS of today is a colossal structure made up of multiple interconnected modules that are provided by the Members respective Space Agencies. The project has captured the public imagination as an iconic example of international collaboration overcoming national boundaries by metaphorically and literally rising above them. John Holdren, an American scientist who served as the Director of the Office of Science and Technology Policy in the Executive Office of President Obama, captures that spirit: 'The international partnership that built and maintains the station is a shining example of what humanity can accomplish when we work together in peace.' (AAAS, 2018)

The project has a central Multilateral Coordinating Board that I address in sub-section 5.1.3. However, there is no IGO or even a unitary operational mission control; each Member manages their respective operations from their own facilities. The US Mission Control is permanently operated by

NASA at the Johnson Space Center in Houston, Texas. The Russian Mission Control is permanently operated by the Russian Federal Space Agency (ROSCOSMOS) at Korolev just outside Moscow. The other Space Agencies exercise their control as required by technical and science operations. The Canadian Mission Control is operated by the Canadian Space Agency (CSA) at Saint Hubert, Quebec. The group of European nations Columbus Control Center is operated by the European Space Agency (ESA) and is located at Oberpfaffenhofen, Germany. The Japanese Mission Control is undertaken by the Japan Aerospace Exploration Agency (JAXA) in Tsukuba Science City sixty kilometres northeast of Tokyo. The ISS Community at IGO level is shown at Figure 10.

While the ISS hardware is qualified for space operation until 2028, the end of operations is increasingly in sight. Consequently, this third case study chapter will focus on how the ending may be managed and what follow-on international space collaborations are being considered. Like the previous case study chapters, it is organised into four sections:

> The first section tests Hypothesis 1 by examining the political setting that led to the USA and USSR (now the Russian Federation) agreeing to effectively end the Cold War fuelled Space Race and enter into a partnership. The broad terms of the governing organs, voting rights and role of the central ISS administration will be examined. This section relates to Section 1 of the Literature Review regarding global collaboration and international organisations.
>
> The second section tests Hypothesis 2 by examining three types of constraints that have been tackled by the ISS Community. Firstly, the Space Shuttle accidents that beset the technical construction programme; secondly, the political events that strained relations between the Member States and thirdly funding shortfalls from all the Parties. This relates to Section 2 of the of the Literature Review that covered global gridlock issues.
>
> The third section tests Hypothesis 3 by examining governance and leadership dynamics. Three aspects are covered: the organisational culture, focality and legitimacy and finally, national and international plans for ISS related follow on space exploration. This relates to Section 3 of the Literature Review covering science diplomacy and Section 4 that examined mega-project governance, leadership and performance issues.
>
> The final section assesses the *Beyond Gridlock* pathways employed by the ISS and acts as a summary of the chapter.

5.1: The ISS Intergovernmental Agreement

To test Hypothesis 1 (that IGO agreements and start-up conditions which are concise, fair, promote trust and mutual support, allow flexibility in problem solving, manage host state issues and emphasise the primacy of the State improve performance) four aspects are examined. Firstly, I analyse the political setting that culminated in the ISS IGA signature in 2006. Secondly, I scrutinise the purpose and functions of the ISS. Thirdly, I examine the governing organs, member's voting rights, and the operational arrangements concerning the ISS astronaut cadre. Fourthly, I outline the complex provisions that govern the ISS's commercial, funding and legal arrangements. Finally, a section summary is provided.

5.1.1: Political Setting, Convention Signature and Ratification

The scientific drive for international collaboration in space is long established. The event that marked the beginning of the age of space exploration was the International Geophysical Year (IGY) that ran between July 1957 and December 1958. Conference delegates collectively called for the gathering of global geophysical data from satellites. The plan was to do this in the same way that international polar expeditions had all contributed to geophysical knowledge up until then. Roger Launius, 2018: 88) explains that both the US and USSR readily took up the challenge to develop and launch satellites that could gather IGY type data. High level common scientific goals were equally matched by nationalistic driven rivalry; the Space Race start flag had been waived.

Early Russian successes were notable: although highly rudimentary the Sputnik mini satellite caused alarm in the USA and led to a great outpouring of pride in the USSR when it was first to enter earth orbit in October 1957. The US response was threefold: firstly, efforts to launch the US IGY satellite were re-doubled, secondly, President Eisenhower established a Science Advisory Committee and thirdly, Congress passed legislation leading to the establishment, in 1958, of NASA. Another consequence was the establishment by the UNGA in 1959 of the UN Committee on the Peaceful Uses of Outer Space (COPUOS), which is still in existence today, to 'govern the exploration and use of space for the benefit of all humanity: for peace, security and development' (UNOOSA, 2019).

The Cold War space race rivalry continued throughout the 1960s and 70s with US Astronauts and Soviet Cosmonauts pushing the boundaries of aeronautical design and their own skills and bravery.

Yuri Gagarin made history in 1961 as the first man in space and Valentina Tereshkova became the first woman in space in 1963.The Salyut Space Station was the first in orbit in 1971, two years before the US achieved the same with SKYLAB. Although national spending on space was climbing fast, there was strong sentiment in the US that it was lagging Soviet efforts. When President Kennedy challenged NASA, in a speech to at Rice University in 1962, to 'land an Astronaut on the moon within this decade', it was therefore as much a national public spending call to arms as a highly challenging technical goal (JFK Presidential Library, 1962).

Despite the Cold War entrenched attitudes of the US and USSR in other domains such as economics, military power and politics, there were voices at the highest levels within the US administration, including the President himself, calling for the Moon Landing effort to be an international one. Kennedy made approaches to the Soviet Leader Khrushchev and in September 1963 in a landmark speech to the UNGA he closed with 'Space offers no problems of sovereignty…why, therefore, should man's first flight to the moon be a matter of national competition?' (JFK Presidential Library, 1963). Any prospects of a joint effort ended with his assassination three months later and Khrushchev, who it was later revealed had carefully examined Kennedy's proposal, fell from power the following year. The US national programme continued and led by a well-funded NASA, all the required elements (other Federal Government Agencies, affected States, the industrial supply base and the science community) worked together to make it happen including. The Apollo 11 moon landing on 16 July 1969 did not mark the end of the Space Race but it did graphically underline US superiority over its technological rivals.

Following the Moon landings, the US and USSR expanded their space programmes with ambitious missions to observe other planets and the Sun. They were gradually joined by other nations including, Japan, Canada, India and China. Two European IGOs were established in 1964: the European Space Research Organisation (ESRO) and the European Launch Development Organisation (ELDO). In the early 1970's ESRO and ELDO were merged into the European Space Agency (ESA) that was formally established in May 1975.

The penultimate piece in the geopolitical puzzle to enable the ISS collaboration was provided by President Reagan in his State of the Union Address on 25 January 1984 where he set NASA high goals: 'America has always been greatest when we dared to be great. We can reach for greatness again. We can follow our dreams to distant stars, living and working in space for peaceful, economic, and scientific gain. Tonight, I am directing NASA to develop a permanently manned space station and to do it within a decade…. We want our friends to help us meet these challenges and share in their benefits. NASA will invite other countries to participate so we can strengthen peace, build prosperity, and expand freedom for all who share our goals (NASA, 2007).' Consequently, NASA's leadership concentrated their initial efforts on courting contributions from the Space Agencies of countries that were traditional Cold War allies such as Europe, aided by the formation of ESA, Canada who had gained experience in early space robotics, Brazil and Japan. With these plentiful 'Friends and Allies' and the growing capability of NASA through the development of SKYLAB, the understandable question is why the US then agreed to involve the Russians in the ISS at the end of the 1980s. This thesis confirms that the reason was twofold:

Firstly, the Russians through their long operation of the Salyut and MIR space stations had invaluable technical and operational experience that could be tapped. The pre-amble to the IGA (US State, 1998: 2) spells out the argument: 'Convinced that, in view of the Russian Federation's unique experience and accomplishments in the area of space flight and long-duration missions, including the successful long-term operation of the Russian Mir Space Station, its participants in the partnership will considerably enhance the capabilities of the Space Station for the benefit of all the parties.' I will return to this Russian capability when considering the management of project in section 5.2.

The second reason concerns US strategic policy. John Logsdon is the founder and from 1987–2008 was the Director of the Space Policy Institute at George Washington University. In 2003, he was a member of the Space Shuttle Columbia Accident Investigation Board and is a former member of the NASA Advisory Council. At the start of his interview for this thesis he explains the background to the US decision: "One distinction that we should make is the station before Russia and the station after Russia. The international partnership was in being from 1988 and then the parties decided to invite Russia to join and all the original agreements had to be re-negotiated. If we go back to the very basics at the beginning, there was in 1993 the one vote in Congress when the super collider was also up for a vote and probably the main thing that kept the station alive in that era was that it was an international project. Had it just been a domestic project then it would have been in trouble. One of the factors that helped keep it going was not being seen as letting the others down." Logsdon went on to explain the particular aspect that applied to the involvement of Russia: "There was a growing opposition to the project within the Clinton administration from 1993 on to even cancel participation. Members of Congress proposed amendments to cut funding and one of those amendments was defeated by one vote. But, almost in parallel Russia was brought into the partnership and one year later the same amendment was approved with a 125-vote margin. There was a strong desire to have Russia involved because of the technology transfer issue. They needed hard currency and launches of other satellites and the US sought to limit [technical know-how] transfers that could have taken place to rogue nations [*rogue states*; see section on terms at the end of the Introduction]. There were politically potent arguments at the time within the US for bringing Russia in. Allowing Russia into the ISS limited not only the money they had available for other projects but also the spare technical expertise they would have available for other endeavours involving Iran, Iraq or North Korea. In this respect having them join was highly successful." The NASA Administrator, Daniel Goldin led the US team during the final negotiations that coincided with the height of revolutionary strife in central Moscow. He later summed up why the time was ripe for union of adversaries: 'On that day of revolution, we negotiated the Russian entry into the ISS… in reality, both sides needed each other' (Garan, 2015: 18).

With the last piece in the political puzzle in place the International Multilateral Treaty between the USA [State Department] and the Government of Canada, Governments of Member States of the European Space Agency [eleven nation states: Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland and the UK], The Government of Japan and The Government of the Russian Federation concerning cooperation of the Civil International Space Station was duly signed in Washington on 29th January 1998 (US State, 1998); Figure 11.

Figure 11; Commemorative Plaque presented by NASA
to all other IGA signatories on 29th January 1998 (picture courtesy of NASA)

5.1.2: Purpose

Paragraph 1 of Article 1 of the IGA (US State, 1998: 3) emphasises the solely peaceful purposes of the collaboration: 'The object … is to establish a long-term international cooperative framework among the Partners, on the basis of genuine partnership, for the detailed design, development, operation, and utilization of a permanently inhabited civil international Space Station for peaceful purposes, in accordance with international law. This civil international Space Station will enhance the scientific, technological, and commercial use of outer space.'

The dominant role of the USA in the arrangements and the key role of the Russian contribution are made immediately clear in Paragraph 2: 'The Partners will join their efforts, under the lead role of the United States for overall management and coordination, to create an integrated international Space Station. The United States and Russia, drawing on their extensive experience in human space flight, will produce elements which serve as the foundation for the international Space Station.'

The modular nature of the ISS construction and operation is a feature of Paragraph 3: ‘The permanently inhabited civil international Space Station [hereinafter "the Space Station"] will be a multi-use facility in low-earth orbit, with flight elements and Space Station-unique ground elements provided by all the Partners.” This modularity aids the evolutionary nature of its construction and future enhancement as can be seen in this statement at the end of Article 1: “The Space Station is conceived as having an evolutionary character... This Agreement lists in the Annex the elements to be provided by the Partners to form the ISS.’

Logsdon describes the tiered structure of the founding arrangements: ‘The set of agreements that are the foundation of the partnership are at two levels. Firstly, there is the government to government, one single Intergovernmental Agreement level agreement that has treaty status in most countries but not in the US. To have it a treaty in the US requires Congressional ratification of two thirds of the Senate and that is always an issue. Also, one Congress cannot commit the next Congress to spend money. Therefore, the US is only the Executive Branch as a party to the IGA. Secondly, there is next level down MoUs that describe the understandings [and detail the deliverables] between the space agencies that are parties to the agreement.’

The IGA Annex provides an overview of the required in-kind contributions. The four bi-lateral MOUs between NASA and the respective space agencies of Canada, Europe, Japan and Russia provide the details of what those comprise and therefore act as the project technical and funding baselines. This is examined further in sub-section 5.1.4.

5.1.3: Organs and Voting Rights

The ISS management structure is distributed between the contributing Member States Space Agencies. There is therefore no prescribed IGO nor a Director General. However, there are elements that an IGO HQ would have if it existed, John Logsdon explains the main one: “The agreements established what I call “the international organisation for Space Station’ it is formally called the Multilateral Coordinating Board. The MCB is the governing body for the station. It meets two or three times per year at the programme director level and once or twice a year at the Head of Agency level. It is based in Houston and has representatives of all the partner agencies sitting there on a day-by-day basis”. Henry Hertzfeld is the Director of the Space Policy Institute at the Elliott School of International Affairs, George Washington University, added a caveat to that description: “It is important not to overestimate the significance of the MCB. It is more the operations management board for the facility. The people on that are the heads of human space flight and once or twice a year the Heads of the Agencies come to discuss and check plans”.

Article 7 of the IGA (US State, 1998: 6) describes the intention of the management arrangements: “Management of the Space Station will be established on a multilateral basis and the Partners, acting through their Cooperating Agencies, will participate and discharge responsibilities in management bodies established in accordance with the MOUs and implementing arrangements as provided below. These management bodies shall plan and coordinate activities affecting the design and development of the Space Station and its safe, efficient, and effective operation and utilization, as provided in this Agreement and the MOUs. In these management bodies, decision-making by consensus shall be the goal. Mechanisms for decision-making within these management bodies where it is not possible for the Cooperating Agencies to reach consensus are specified in the MOUs.” In practice, regarding voting rights of the ISS partners, Hertzfeld pointed out that: “Voting rights are that all decisions are supposed to be by consensus. There was a sticking point in the original negotiations because, although the US does not have a formal veto, in practice, the US retains a veto on grounds of safety and effectiveness.” There is no official record where the US has exercised that veto in the deliberations of the MCB or in any other areas; the skill of the ISS community members has been to resolve their differences in closed sessions and maintain the public persona as a model of consensus intergovernmental diplomacy.

5.1.4: Commercial, Funding and Legal Arrangements

Articles 5 of the IGA describes the thorny issue of jurisdiction and control of the various ISS elements and Article 6 covers ownership (US State, 1998: 5). The key here is that each Member retains legal jurisdiction over all their in-kind contributions and over their nationals that operate and maintain that equipment. Sole ownership of the various modules is therefore retained by the party that has contributed it. The public view of a harmonious, fully integrated *World Space Laboratory* is somewhat at odds with the legal realities of its operation. I return to this when considering organisational culture in sub-section 5.3.

The required resources for a project of this magnitude and one that is by design evolutionary in nature have been a moving target and needed renegotiating throughout the ISS lifecycle. Article 15 of the IGA (US State, 1998:10) proscribes the funding arrangements and the final paragraph encourages the employment of a system of 'barter': 'The Partners shall also seek to minimize the exchange of funds in the implementation of Space Station cooperation, including through the performance of specific operations activities as provided in the MOUs and implementing arrangements or, if the concerned Partners agree, through the use of barter.'

These bartering arrangements have become the norm and allowed for limited central autonomy in an important operational aspect. How it works was summarised by Hertzfeld: "There is no central cash contributions; all is in-kind. There are all kinds of ongoing bartering of exchange of resources that goes on in operating the station where if a Japanese experiment requires more power than the Japanese module has available then it barters to get it. A tally is kept, if Japan wants something then the US wants something back; the staff of the MCB keep the tally. This goes back to the percentage contributions they started with and set up in the original negotiations. What is important is that the partners have learned how to work these things out. It is more a good marriage partnership than global governance. We have learned how to operate effectively within an operational partnership."

As I showed for ITER in Chapter 4, the US funding of an international endeavour of this scale is always difficult given the other pressing demands on public funds. Like ITER, the saving feature is that most ISS funds are spent in individual States that dutifully support the programme and fiercely defend their part of the supply chain. Logsdon recalls a typical funding scenario: "NASA leads as a government agency and there are members of Congress who represent NASA sites. When the Trump administration in its most recent budget said we are going to cut [NASA] funds in 2025, Senator Ted Cruz said like hell you will, and Congressman Bannon said like hell you are. Unlike most other government systems, it is a set of people sharing power. It is a distributed executive." Hertzfeld added more detail: "NASA people are the technical people, but you have the Office of Science and Technology and the National Space Council, the executive at the White House level and the Office of Management and Budget; it is a fragmented system with NASA in the lead to push for funds."

An important feature of the ISS Treaty is the legal liability framework that the Parties operate within. The IGA details this in a lengthy Article 16 covering Cross-Waiver of Liability and Article 17 Liability Convention (US State, 1998: 12 and 13). A summary of what the negotiators achieved is provided by the UN Committee on the Peaceful Uses of Outer Space Legal (COPUOS) Subcommittee that in 2013 comprised legal experts from the five ISS space agencies (NASA, CSA, ESA, JAXA and ROSCOMOS). The key task of the negotiators being 'to establish a cross-waiver of liability … in the interest of encouraging participation in the exploration, exploitation, and use of outer space through the Space Station' and that 'The purpose of a cross-waiver of liability is to prevent claims by a Partner against the other Partners and their 'related entities' for damages arising out of ISS-related activities' with carefully prescribed exceptions. So, the cross-waiver elegantly creates a legal safety barrier between the Partners, their Space Agencies and related entities. This novel arrangement has been designed to co-exist with applicable UN space Conventions such as the Outer Space Treaty (UN, 1967), the Rescue and Return of Astronauts Agreement (UN, 1968) and the Space Liability Convention (UN, 1972). The welcome outcome is that the Partners can collaborate to further the peaceful exploration and use of outer space through the ISS, without fear of legal claims that could arise out of the risks that are inherently present in such a multipart endeavour (UN, 2013). The Member States took the advice of their respective national legal colleagues but did not burden the project with an unworkable legal straight-jacket which could easily have hampered progress (Wilman and Newman, 2018: 143 and Wessel, 2012)

The IGA Withdrawal Article 28 (US State, 1998, p19) is typically hard-hitting for the period (see my analysis of the ITER Agreement Withdrawal Article at the end of Section 4.1.1). The ISS community negotiators imposed a one-year notice period on all the parties, bound ESA to deliver all the European deliverables even if one or more European nations withdrew and bound Canada to punitive conditions due to the special and integrated nature of the Canadian in-kind contribution [remote arm needed throughout assembly]. It also made clear that any party that did decide to withdraw would lose all rights and privileges to Intellectual Property and exchange of Data and Goods and that any bi-lateral ISS agreements in force with the USA at the time of withdrawal would immediately be terminated. Unsurprisingly, no partner to the IGA - at least in the public record or ascertained through field work - has ever suggested withdrawing.

Section summary

Hypothesis 1 is supported in that the IGA does provide a concise and fair vehicle to promote trust and mutual support, allows flexibility in problem solving, deals with legal issues and emphasises the primacy of the State. The Treaty had to sit within the existing UN Space Conventions at the time of signature and be future proofed to allow for the development of the station over a long timescale; constraints the negotiators dealt with despite the political turmoil of the period.

The decision to involve the Russian space community after the intense rivalry of the Cold War Space Race was a bold move. I have explained that the US leadership could see the value of the age-old adage: 'keep your friends close and your enemies closer.' Concerns regarding Congressional ratification has resulted in the exceptional position of the US acting as the only Executive Branch party to the IGA; this has allowed the US to carry out its project leadership role. The inherent fairness of the IGA is borne out by it never having been amended and all the Member States remaining in the collaboration. The bi-lateral MoUs that detail the in-kind deliverables between the supporting Space Agencies and NASA form the technical and funding baseline. This innovative funding together with the legal framework allowing litigation free progress and the punitive withdrawal penalties that the negotiators set, have kept the Members involved despite significant and unexpected delays, political turbulence and funding cut-backs.

Three *Beyond Gridlock* pathways have been utilised by the ISS community in their set-up phase. Firstly, pathway 1, 'shifts in major powers core interests' where at the end of the Cold War the US political leadership sought to build bridges with the Soviet Union rather than take undue advantage of the other parties' weakened position. Albert Holland, a psychologist and a key member of the US negotiating team tasked to bring the Soviets on board through a series of visits to Moscow, recalled some personal approaches in the early 1990s: 'We brought over to our counterparts whatever they needed which caused the Russians to reconsider their relationship with us in a positive way. (Garan, 2015: 43). Secondly, pathway 3 where the respective US, Soviet and other Member's Technical, Scientific and Astronaut groups, following a period of lack of mutual respect, mis-understandings and suspicion, gradually established effective and legitimate processes that are the *modus operandi* of the station of today. Thirdly, pathway 8, 'innovative funding' mechanisms have preserved the project's national base support and allowed for significant bartering arrangements that the community has successfully exercised.

5.2: Managing Constraints

To test Hypothesis 2 (that external constraints such as excessive stakeholder aspirations, changing political and legal landscapes, bureaucratic regulations, funding fluctuations and unforeseen events, while being mitigated as far as possible by IGO leadership actions, inevitably adversely affect overall performance) I examine how the ISS Community leadership has handled three events. The first concerns the consequences of the Columbia Space Shuttle disaster in 2003, the second concerns the political turmoil amongst the Member States following the Russian invasion of Crimea in 2014 and the third concerns funding shortfalls by all the Member States. A sub-section summary is also provided.

5.2.1: Technical Set-Backs

Space exploration has frequent occurrences of nature reminding participants that leaving and returning through earth's thin atmosphere is inherently perilous. The Space Shuttle Columbia disintegrated on re-entry in 2003 killing all seven crew members. The entire fleet was grounded, and a wide-ranging enquiry was established to investigate the cause or causes. In a collaborative project such as the ISS, a set-back for one party immediately effects all the others.

In the immediate aftermath the Russians stepped up with ROSCOSMOS undertaking fourteen re-supply and crew rotation missions. In order to complete construction, there was a need to restore NASA's technical reputation and get the Space Shuttle missions back on track. John Logsdon describes the consequences to the ISS project from a US perspective: "There are very specific moments in time where the international nature has helped preserve the project and its supporting elements. One was that the Space Shuttle was not terminated after the Columbia accident in 2003 because we had not yet flown any of the partner modules. Each of the partners made it very clear how unhappy they would be – given their modules were already built – if they were left undelivered. There was no other way of getting them into space. When the Space Shuttle returned to flight in 2005 there was major problem with the first post-accident flight and further considerations made on the future and the modules were still on the ground. The Head of NASA at the time Mike Griffin went to President GW Bush and pointed out the international agreements that were in place. This international collaboration glue has saved the project at these pinch points."

The estimated number of Space Shuttle flights to complete construction, at the time of the Columbia tragedy, was thirty and Griffin was told by officials at the US Office of Management and Budget that there were only funds available for fifteen, some of which popular science sources report also had a non-ISS related, partial military payload [official records only show DoD related payloads up to the end of 1995; NASA History Office, 2019]. In addition to the high-level political canvassing described above. Griffin commented later how he dealt within NASA with the constraint: 'I took money from science and other places, and I got yelled at for that, but I did it. Because I made the decision quickly, we stuck to it, and the actions that followed were obviously in support of the decision, it engendered a lot of trust on the part of the partners, for the United States and for NASA' (Garan, 2015:21).

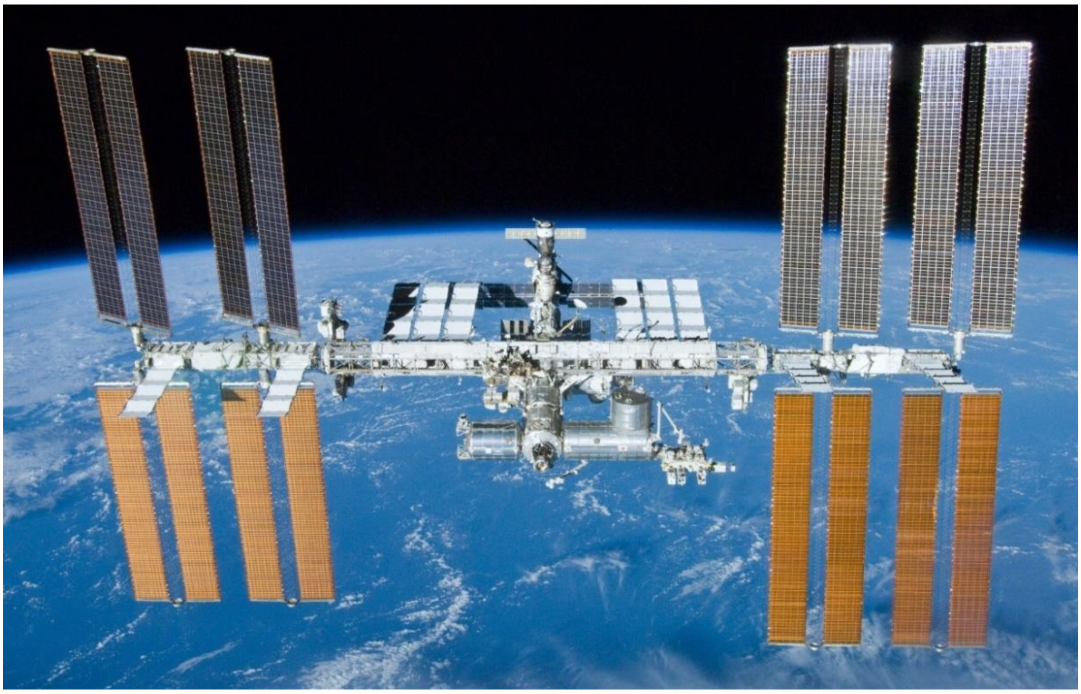

Figure 12; ISS in its final constructed configuration, photographed by the Crew of the Space Shuttle Atlantis after undocking on 23rd May 2010 (picture courtesy of NASA)

The collaboration survived, and although much later than originally planned and reduced from the original aspirations of the Members, the ISS was declared 'construction complete' by the Space Shuttle Atlantis Commander when it departed for the last time in the summer of 2011. The combined launch manifests demonstrate the vast array of in-kind contributions and their importance to the respective national industrial supply base (NASA History office, 2019). I summarise the Modules and other major equipment here as it serves to underline the arguments drawn together in sub-section 6.3.8. regarding the case for inclusion of an 8th pathway to *Beyond Gridlock* theory (Smithsonian, 2018); Figure 12:

- Canada through the CSA: CANADARM 2 robotic arm, DEXTRA robotic servicing device and a Mobile Base System to ease the external movement of equipment and astronauts;

- Europe through the ESA: COLUMBUS Science Laboratory and logistics and supply provided by the Automated Transfer Vehicle system;

- Japan through JAXA: KIBO Science Laboratory including an exposed exterior platform and logistics transport vehicles;

- Russia through ROSCOSMOS: ZARYA which was the first ISS module and is a functional cargo block, ZVEZDA Service Module, RASSVET a mini-Research Module, PROGRESS spacecraft cargo flights and the Soyuz spacecraft for crew transport to the station and return;

- The USA through NASA: LEONARDO Multipurpose Module, DESTINY Science Laboratory, UNITY, TRANQUILITY & HARMONY connecting nodes, Solar Arrays, Truss Segment and Mating Adaptors.

5.2.2: Political Turmoil

In the ITER sub-section 4.2, I highlighted that overcoming global political turbulence from the ITER Agreement signature in 2006 to today while broadly maintaining funding took skill and determination by all the ITER Community Member States. This is also true for the ISS, but over an even longer period: 1998 to today. The same severe pinch points have applied to the ISS collaboration as with other long-running Big Science projects, but for the ISS they have needed different solutions.

One example is the Crimea Crisis of 2014 where on the ITER project the Russians, when their currency devalued by a factor of three, acted internally by making cuts to other national projects in order to maintain their cash contribution. The effect on the ISS was potentially existential as the Russian in-kind contribution was vital to the collective effort. John Logsdon describes the high-level US space policy thinking that was necessary to circumvent this threat: “When the troubles with Russia started in Crimea and Ukraine [in 2014] there was a very conscious policy decision on behalf of the White House to build a wall around the station and not let our unhappiness with Russia in these other areas have an impact on the integrity of the station collaboration including the access needed to get there. To be excluded from any restrictions, reparations or sanctions that might be put in place. The President agreed that as failure of the project at that point was not acceptable. We had put ourselves in a position both in the architecture of the station itself and by our failure to have a replacement for the shuttle where we had become mutually dependent on Russia."

The UK's direct involvement in ESA is unaffected by the consequences of the UK notification to leave the EU as the ESA Convention is separate to EU membership (ESA, 1980). Indirect negative consequences on the general UK science and innovation landscape, and the effect on the UK's ESA partners, are currently open to speculation.

5.2.3: Partner funding shortfalls

I have explained that the perception that the ISS is one integrated facility does not match the reality imposed by its modularity and national operational controls. This applies also to the Science work that is carried out by the crews during, what the community terms as their collective 'Expeditions'. An unwelcome feature has been the steady failure of the parties to meet their original planned capacity to conduct science. Logsdon summarises the position: "The research done in the station is sponsored by the national space agencies. These have been subject to great budget constraints. The amount of science has changed a lot over time. NASA built the station but did not have the money to fully utilise it. Japan being Japan has delivered exactly what it promised in 1984. Europe had very ambitious plans and those shrunk over time. Canada has done what it said it would do and the US followed through on its commitments, but Russia did not. One of the disappointments if not disagreements has been the inability of Russia to follow through on its commitments. Russia originally was going to contribute laboratories and they never have."

Significant research has been achieved despite these funding squeezes in many science sub-domains including high energy particle physics, earth remote sensing, geophysics, protein crystallisation, human physiology, radiation, plant and cultivation experiments, fluids and combustion, materials science and biology (AAAS, 2018). Many experiments conducted on the ISS have applications to terrestrial medicine and the partners work hard to maximise the positives, nurture public good will and develop worthy spin-offs in areas such as immunology and DNA and RNA sequencing. However, there have been no major breakthroughs like the 'Higgs Boson' moment that CERN enjoyed. Logsdon summarises a common view held by several other non-attributable interview sources: “There are a lot of peer reviewed published papers coming out of ISS research but very few of them represent social or economic benefit anywhere commensurate with the cost of getting the results. The proponents of the station will say that is because we have not been able to do full utilisation and the best years of the station are ahead”.

The need to mitigate the science capability shortfalls have been known within the ISS Community since the start of the operational phase in 2000. With pressure mounting from the projects external critics and national leaders seeking results, the US Congress passed the NASA Authorization Act of 2005 that designated the US ISS Scientific module as a National Laboratory (US Congress, 2005). This legislation directed NASA to increase utilization and to foster commercial interest in conducting research. Subsequently, the NASA Authorization Act of 2010 required NASA to enter into a cooperative agreement with a non-profit organization to manage at least 50 percent of the Agency’s available research capacity. In August 2011, NASA signed a cooperative agreement with the Center for the Advancement of Science in Space (CASIS) to manage non-NASA ISS research. A 2013 Office of the Inspector General Audit report confirmed that while progress had been made there was lingering push-back from some within the ISS community who questioned the approach and suggested that re-booting internal efforts could be more fruitful. The Audit Board noted this view but maintained that the success of CASIS was the best mitigation possible to improve utilisation and set NASA the task of identifying metrics to help manage that improvement: ‘In order to better assess the performance of CASIS, we recommended that the NASA Associate Administrator for the Human Exploration and Operations Mission Directorate work with CASIS to develop precise annual performance metrics that measure CASIS’s success at fostering private research on the ISS… we continue to believe that CASIS’s success is critical to maximizing the research capabilities of the ISS.’ These initiatives mean that the project may be on the cusp of providing uncontested and improved value-for-money results. Efforts to improve utilisation rates will be given a boost when future US Space Policy decisions (sub-section 5.3.3) crystallise and bring a better research focus to the remaining ISS Expeditions.

Section summary

Similarly, to CERN and ITER the ISS Community has had to deal with several severe technical, political and funding crisis. The negative consequences have been mitigated through a combination of actions that support Hypothesis 2. Three examples were cited: Firstly, the most notable technical set-back surrounded the Space Shuttle Columbia disaster on re-entry in February 2003 that threatened to terminate the ISS project. In the immediate aftermath the Russians filled the capability gap. This gave time for the US to deal internally with budget pressures and maintain its commitments to the programme thereby bolstering its technical and collaborative reputation with its international partners. Secondly, the Crimea crisis had the potential to end Russian involvement. The essential nature of the Russian in-kind contributions meant that there was a mutual dependency that could not be jeopardised. Only through the ring-fencing of the project from political, economic and social sanctions that were being imposed on Russia was the constraint mitigated. Thirdly, the failure of ISS Members to fully deliver on their start-up commitments for Science capacity had been a long running problem for the project. While results have been steady there is a common sense of unfulfilled potential. Mitigation actions have included emphasizing the positives, employing an intermediator to boost utilisation and nurturing public good will.

This ability to counter these constraints strongly supports Hypothesis 2 and serves to support Hypothesis 3 that 'sound internal governance and leadership dynamics improve global IGO performance.' It relates mainly to two *Beyond Gridlock* pathways: Firstly, Pathway 2, autonomous and adaptive institutions, the central MCB, national Space Agencies and their dispersed Mission Control centres have been severely tested during the challenges of constructing a highly complex structure in low earth orbit. Secondly, Pathway 3, 'technical groups with effective and legitimate processes' where like-minded groups, such as scientists, meteorologists and administrators, dispersed throughout the members space agencies have worked together to overcome obstacles.

This thesis has also shown that these constraints have taken their toll on the project. The construction period was longer and costlier than even the most pessimistic early estimates foresaw; the budgetary constraints have resulted in tension between the Partners that I have shown has even encroached in the two-sided nature of the on-board science operations. This has increased criticism of the project and is why the future of the collaboration is intrinsically bound up in the overall space policy and strategic policy of the Member States. The Pathway 2 and Pathway 3 efforts that have protected the project have been aided by Pathway 7 'innovative leadership' that I will move on to in the next section and by comprehensive use of Pathway 8 'innovative funding'.

5.3: Governance and Leadership Dynamics

To test Hypothesis 3 (that sound internal governance and leadership dynamics improve global IGO performance) I examine three organisational features. Firstly, the organisational culture where the analysis has taken account of the views that were expressed within the ISS community field work interviews. Secondly, I examine two characteristics of successful orchestrators: focality and legitimacy. Thirdly, I explore upcoming developments in the ISS collaboration in the context of international space policy and how the assessment of alternatives is connected to the Member States national interests.

5.3.1: Leadership and Organisational Culture

5.3.1.1: Leadership

When considering leadership on a project as large as the ISS, it is important to distinguish between the leadership of the main contributing Member States together with all their governmental apparatus and the individual leaders who manage the endeavour on behalf of all the Members. In the case of ITER, the main Member was *Europe* whose group of Nations under EURATOM contributed most of the funds, enjoyed the largest workshare and hosted the project in France. For the ISS as I explained in sub-section 5.1.1 the dominant role of *the USA* in the management arrangements was accepted by all the parties when they agreed to Paragraph 2 of article 1 of the IGA: 'The Partners will join their efforts, under the lead role of the United States for overall management and coordination, to create an integrated international Space Station.'

The reputation of the US to deal with its partners fairly has therefore been under scrutiny from the outset. The ex-astronaut Ron Garan points out that some within the US ISS management hierarchy see the endeavour as a US project with international partners, others views it more as a multinational egalitarian concern (Garan, 2015: 38). When considering what the most significant factor has been in the long-standing, good collaboration between the member states and their respective agencies, Logsdon is clear: "The most significant factor that has allowed the project to be on a firm basis has been the US leadership. The US is clearly the managing partner of the enterprise, responsible for around 75% of the funding. Another influencing technical issue is that it could not be built without the shuttle. Others did not so much recognise the US lead; they had no choice. If they wanted to join the project, they had to essentially accept US dominance in the project." The main reason that the other member states could so readily agree to this compliant role is precisely the same as that driving the collaboration on CERN, ITER and other international Big Science projects: the advantages of contributing a portion but receiving the benefits of the whole.

All the ISS interviewees cited that the community has been privileged in having remarkable individual leaders that have both provided internal examples of what it takes to be successful in international collaboration and have been excellent communicators to the wider public. Here I provide three examples, one from the USA (NASA), one from Canada (CSA) and the third from Russia (ROSCOSMOS):

Dr Ellen Ochoa, a veteran US astronaut with over 1000 hours is space has a PhD from Stanford University in Electrical Engineering and became the 11th director of the Johnson Space Centre in 2012. Her leadership style has been highly appreciated resulting in numerous awards including NASA's highest, the distinguished service medal and the President's Award for outstanding leadership by a Senior Executive in a Federal Agency. Ochoa even has five Californian Schools named after her. Ochoa was on three ISS Missions and therefore commanded authority in the decisions she made in her later high-level management career. In a speech made at the American Association for the Advancement of Science (AAAS) Annual Meeting in Austin, Texas in 2018 she readily points out that international collaboration is not easy: "Maintaining that International Partnership is not easy, it requires constant cross-cultural diplomacy and negotiations at all levels, for example all parties have to agree to extend the life of the ISS…another manifestation of the peaceful cooperation is the world-wide control network that operates continuously twenty four hours a day, seven days a week, every day of the year, coordinated by our Mission Control Centre at the Johnson Space Centre and includes all the other parties Mission Control Centres."

The number of followers that Yuri Gagarin may have had if twitter had been available in the 1960's is open to speculation. What is known is that he was the first serving Russian military officer to make the cover of Time Magazine (TIME, 1961). Neil Armstrong's 'small step for man; giant leap for mankind' commentary on stepping onto the lunar surface in 1969 was heard by an estimated global TV audience of over 600 Million (Telegraph, 2012). The use of popular media to bolster a current Big Science project was expertly demonstrated by the Canadian ISS Commander Chris Hadfield. His 2013 rendition of David Bowie's Space Oddity song in the weightlessness of the ISS attracted over 7 million views across all social media platforms. The importance of this in international relations should not be underestimated. In a world of 24/7 global news coverage, the attention span of the public is fleeting. Keeping the project in the public's consciousness is important in promoting environmental issues and the linked sub-agenda of the ISS Science programme (ISS US National Laboratory, 2019). Hadfield used the platform of his 2.4 million twitter followers and his book An Astronaut's Guide to Life on Earth (2013) to promote global collaboration and to fiercely defend Canada's Space budget: 'Many people object to 'wasting money in space' yet have no idea how much is actually spent on space exploration. The CSA's budget, for instance, is less than the amount Canadians spend on Halloween candy every year, and most of it goes toward things like developing telecommunications satellites and radar systems to provide data for weather and air quality forecasts, environmental monitoring and climate change studies. Similarly, NASA's budget is not spent in space but right here on Earth, where it's invested in American businesses and universities, and where it also pays dividends, creating new jobs, new technologies and even whole new industries.'

Sergei Krikalev is an icon of Russian space exploration and became later in life a leader within ROSCOSMOS and the wider ISS Community. Following his early cosmonaut career that included the final days of the MIR space station he was the first Russian to fly the Space Shuttle in 1994 and was a member of Expedition 1 to the ISS in 2000. He was unique in straddling the two eras of space exploration when he was then selected to be the Commander of ISS Expedition 11. His calm leadership style was praised by all who served with him. His many honours include being a Hero of the Soviet Union and later the Russian Federation, a recipient of the French Legion of Honour and the NASA Distinguished Public Service Medal. As the Director of the Yuri Gagarin Cosmonaut Training Center he has championed inter-operability with the ISS partner Space Agencies. He has an accumulated time in space of over 2 years and he provided the following insight on international space collaboration in a 2017 interview: 'There are many angles to look at what we achieved [on the ISS], engineering experience for sure… physiological lessons for sure…but the main achievement has been learning how to trust and understand each other, how to collaborate in a difficult environment to achieve a common mission' (Česká televize, 2017).

5.3.1.2: Organisational culture

Like other Big Science endeavours, the ISS Community comprises several mini-epistemic communities of experts that are geographically dispersed but united in delivering their elements of the myriad of project tasks. Typical groups include: Scientists, Engineers, Programme Managers, Administrators and uniquely for this community, Astronauts. Haas (1992: 29) shows that the cultural differences are more likely to be between these groups than on traditional national boundaries. While the latter differences unquestionably linger and may surface during pressure points such as funding rounds, the day-to-day cultural differences are of a different type. It is one where the *science group* may have an issue with the *technical group* on the best way to implement a project solution or the 'programme management group' may be in conflict with the 'administration group' on a reporting issue.

This research shows that the international astronaut cadre has found a way to navigate through national constraints and formed an effective expert community while building on and respecting their national space exploration heritage. In effect, they lead the project operationally as they represent the Member States through their presence and actions in space. The Apollo-Soyuz Test Project culminated in an Apollo spacecraft with a crew of three docking with a Soyuz spacecraft and its crew of two in July 1975. This mission can too easily be seen as one-off political event that served both the US and the USSR little tangible benefits. For this thesis, it is an important episode as it illustrates both, 1) the idea of a community 'riding a wave of change' that I recap when considering Pathway 1; Shifts in major powers core interests in sub-section 6.3.1 and 2) the limits of that idea.

The mid-1970s saw a period of improved relations between the USA and the USSR. Henry Kissinger was US President Nixon's national security advisor (from 1969 to 75) and Secretary of State (from 1973 to 77) and introduced the concept of détente which led to an easing of strained relations between the superpowers; a controversial policy which he describes as having both avid supporters and discontents (Kissinger, 1994: 733). Successes included signing the Strategic Arms Limitations Treaty in 1972 and Willy Brandt's West German government, pursing a détente off-shoot policy of *Ostpolitik* and formally recognising East Germany in the same year. However, criticism that the US was giving too much away for too little in return and was therefore naïve appeasement remained widespread in the US Congress. US State Department officials were also particularly resentful that back-channels of communication, that Nixon and Kissinger had set up as part of a twin-track negotiating strategy with several world leaders, bypassed the accepted way of doing diplomacy

(Berridge, et al., 2001: 200). Détente was therefore struggling to gain traction in official circles in the US long before it formally ended with the Soviet invasion of Afghanistan in 1979.

So, the window of opportunity for a community to take advantage of a shift in major power core interests was both narrow (in time) and lacking depth (in the number of proponents). Nevertheless, far-sighted individuals on both sides of the Space Race Cold War divide such as Anatoli Blagonravov, a scientist and diplomat who represented the Soviet Union on the UN Committee on the Peaceful Uses of Outer Space (COPUOS) and the NASA Administrator Thomas Paine and his deputy Hugh Dryden, took the opportunity and made the Apollo-Soyuz mission happen. Both the US and USSR space communities did what they could to maximise the event and termed the astronauts and cosmonauts as a *Joint Crew*; see Figure 13. The reality was that their ethos, operating procedures, spacecraft and training regimes were separate. The only common feature was the [NASA designed] mechanical docking mechanism itself. The political wave of change had simply been too short for the community to make further immediate joint gains, but the event certainly made an important statement and paved the way for future international space collaborations (Launius, 2018: 212).

Figure 13; Joint US-USSR Apollo-Soyuz Test Project - Crew Portrait (picture courtesy of NASA, 1975)

Several ISS astronauts have been inspired by their experiences to reach out globally, amplified by social media, on environmental topics and science diplomacy. Kofi Annan, the ex UN Secretary General commented that US Astronaut Ron Garan's book *The Orbital Perspective* 'reminds us of our common humanity and that the pressing challenges we face, we must face and resolve together through tolerance, dialogue and cooperation.' Garan's, NASA backed, video *What kind of world do we want?* captures this spirit of togetherness in tackling the world's problems. Through the power of sharing on social media, the importance of these ISS inspired initiatives is advanced with widespread public support. The 'Fragile Oasis' project has the strapline: 'Guided by the unique orbital perspective of men and women who live and work in Space, our vision is for Fragile Oasis to help people and organizations work together to overcome the challenges facing humanity on Earth.' It is an example of the type of egalitarian, young people centric initiative that the Astronaut Corps have enthusiastically championed (Fragile Oasis, 2019). The astronauts embody, through their actions when they return, the idea of being a 'global citizen', ironically accentuated by journeying out of the earth's atmosphere.

Every safety incident ranging from the Space Shuttle disasters to less severe accidents in and around the ISS itself have led to improvements in management systems, quality control, launch escape system design, development of joint procedures and improved inter-operability (Foust, 2018: 2, NASA, 2003: 205; Reuters, 2018: 1). Overarching these improvements has been the steady engendering of trust; an essential ingredient to any successful collaboration. In addition to expert astronauts, the ISS crews now comprise a wide range of disciplines including geologists, engineers, teachers and medical doctors. Seven paying space tourists (5 Americans, 1 Canadian and 1 South African) have even made the journey. The training regimes use common procedures and interchangeable safety equipment and their work schedules are as integrated as the modularity of design allows. Every procedural document used in the station opens to a set of instructions in English on the left-hand page and Russian on the right-hand page.

A welcome development is that the cadre now draws members from a wide variety of disciplines more familiar to the public than the five ex-military fast-jet test pilots, typical of the early space exploration years, shown in the Apollo-Soyuz Test Project Crew Portrait; Figure 13. The ISS Expedition Crew 56, Figure 14, typifies the transformation in crew composition that has taken place in the 43 years since then, comprising: a US geophysicist, two Russian Cosmonauts, an American educator, a US physician and a German geophysicist (the Expedition Commander):

Figure 14; International Space Station Expedition 56 - Crew Portrait (picture courtesy of NASA, 2018)

Regarding the set of arrangements that govern the ISS, Henry Hertzfeld pointed out that "One agreement that is not often published in the same way [as the IGA and MoUs discussed previously in sub-section 5.1.3] is the Code of Conduct for the astronauts and the mechanism for dealing with ground control and decisions in space; this has been agreed to by all the partners and works well. There is a de facto recognition of rotation of command. An example is the ESA astronaut Alexander Gerst took over the role of ISS commander from NASA astronaut Drew Feustel on 3 October 2018 for a three-month period. His background is as a Geophysicist and he has recently reflected on his experience in space: 'Humans relate to Humans and that is the secret success of [space] exploration….One of the most important things that we do in space is look down on our planet to get a perspective of our home from the outside … and it is clear that it is very fragile and we could destroy the conditions that allow us humans to live comfortably and that is something we often forget…. If we use up our resources, we do not have a Planet B and that is a view that every astronaut I guess realises and it is in our nature to try and bring that perspective home' (BBC, 2019).

In contrast, Logsdon explained that the day to day cultural environment on the ISS is not as rosy a picture as news media may sometimes portray: "There is almost in a real sense two stations joined at the Functional Cargo Block. The Russians have their own food, their own supplies and basically spend most of their time in the Russian segment. The other original partners have the other side. On a day-by-day basis there is not that much interaction between the two sides. They meet for dinner!"

Motoko Uchitomi, the Head of the Legal Affairs Division at JAXA provided data, in a Legal Framework presentation to the UN Committee on the Peaceful Uses of Outer Space Legal Subcommittee that confirms the starkness of this 'old/new' partners divide: the US Laboratory is shared between NASA and CSA, the European Laboratory is shared between ESA, NASA and CSA and the Japanese Laboratory is shared between JAXA, NASA and CSA. The Russian Laboratory, on the other hand, is solely for use by ROSCOSMOS (UN, 2013: 25). Despite this a common ethos and trust has built up between the astronauts themselves that is reflected in the many first-hand accounts of life in orbit by ex-ISS astronauts. Nevertheless, Logsdon captures the essence of the difficulty that the lack of full integration has produced: "They [the Russians] help a little with the others' experiments but spend a lot of time on maintenance of their area. The overriding environment is cooperation but there is a soupçon of tension because unlike CERN it is not an integrated facility."

Building trust takes time and includes overcoming difficulties. Ron Garan cited one notable episode from the ISS construction period: "During the period immediately following the [Space Shuttle] Columbia tragedy, I too felt the solidarity of the Russians and other international partners. We mourned and grieved together, and through that dark period we became something more resembling family. We came to realize that being able to count on each other's support when it's needed is more important than trying to agree on things all the time. That is true collaboration". (Garan, 2015: 44).

Professor Mark McCaughrean, the Senior Advisor for Science & Exploration at ESA, provided a European perspective on the ISS in a follow-up provided for this research to an interview he gave to the BBC on 1 January 2019: "Space is very expensive of course, but we spend all of the money on the ground in our industrial companies, not actually in space, so there is always that national investment dimension. In the European Space Agency, we have 22 Member States [11 involved in the ISS] who give money to the Agency, but that money is then spent back in the countries according to the proportion in which it is given. As a result, there are national statements to be made about certain components, and yes, you can get to wave flags in your small sector, but the whole point of the Space Station is that is an international collaboration and it would not be there if we did not work together very actively. You do not shut separate chunks of the space station off and say this is our part and you cannot go in there."

The overarching effect reflected through the astronaut accounts of life in space has been the steady building of respect for what each party brings to the whole and the establishment of an espirit de corps. In 2014, the influential German Economic Society for Westphalia and Lippe awarded the Peace of Westphalia Prize to the ISS Community in recognition of the station's demonstration that *peaceful international cooperation of partners from very different cultures has proven to be possible* (Muenster, 2019). There were even calls leading up to the 15th Anniversary of continuous operations in 2015, from some within the space science community and popular press, for the ISS collaboration to be awarded the Nobel Peace Prize (Azriel, et. al., 2014 and Telegraph, 2015). The community has managed to embed in the public consciousness this model of collaboration despite the reality being, as this thesis has shown, somewhat less than ideal.

5.3.2: Focality and Legitimacy

This sub-section benchmarks the case study results against two of the characteristics of successful orchestrations that Abbott and Hale (2014: 9) outline within their Guide for Organizational Entrepreneurs: Focality and Legitimacy.

5.3.2.1: Focality

There is a manifest focality provided by the ISS edifice. However, as I have shown, it is an integrated product through the ingenuity of its modular component interfaces rather than a single tailored design. As I described in sub-section 5.1.3., there is no central IGO and no delegated authority to a dedicated Director General as in the previous two case studies. There are central features however, such as the MCB that carries out two main tasks. Firstly, it acts as an operations management board for the facility whereby it undertakes reviews of the project such as in 2010 when it reported on efforts underway to increase efficiency and further enhance the use of the ISS through standardization of interfaces (such as docking mechanisms), definition of common transportation requirements, and cost reduction strategies (NASA, 2010). Secondly, it keeps a tally of the results of the bartering deals regarding changes to the in-kind contributions that Members may propose and/or project circumstances may demand.

These tasks help provide a focus to the project management through seconded staff still employed by their respective contributing agencies rather than a self-sufficient IGO executive management team. The primacy of the Member States is sacrosanct as demonstrated by them retaining the right to accept, decline or modify any MCB recommendations; the aim always being to reach a consensus.

5.3.2.2: Legitimacy

The legitimacy of the ISS should be viewed from two perspectives: firstly, its standing in the worldwide public including the citizens, pressure groups and political class of the Member States and secondly within the ISS community including the space policy-makers, supplier base and customer communities. The two perspectives are interweaved firstly because enhancing public support is crucial in securing extra funding and building resilience when setbacks delay results and secondly because much of the dispersed ISS community is in competition with counterparts on other projects also seeking to bolster their legitimacy and thereby secure funds. Ellen Ochoa reminded the plenary session audience of the AAAS 2018 Annual Meeting that the ISS has been in the US public consciousness for a generation and any 18-year-old high school student has always lived with people in permanent space habitation (AAAS, 2018). This millennial generation and their children will expect space exploration to be a routine part of their national landscape. This *legitimacy by presence* naturally boosts the space study aspirations of youth in all the Member States as witnessed through the global uptake of the Space Station Explorers education programme. Space Station Explorers is funded by a range of US based educational institutions including NASA's Office of STEM Engagement and has a community of educators, learners, and organizations whose aim is to ‘make STEM learning fun and exciting through connections with the ISS’ (Space Station Explorers, 2019)

The argument for legitimacy from science results is contested and dependent on which expert group is asked. All would agree it has carried out unique and valuable microgravity science in many fields, what is disputed is whether the results are commensurate with the huge costs. The difficulties in estimating costs, vital to providing any sense of ‘return on investment’ were considered in sub-section 5.2.3: Partner funding shortfalls.

A durable case for legitimacy is the collaboration itself which draws together parties that are adversaries in many other domains. *Meaningful purpose* means different things to different people and this research has shown that their perspective is closely linked to which mini-epistemic group they are a member of. For some, that the IGA exists at all and has survived the types of constraints I have analysed is good enough legitimacy to justify the costs. This view is captured by the recent ISS Commander, Alex Gerst: ‘Science is not the main purpose of why we fly to space and use the ISS, we are explorers, humankind has always been that way … in our planet we have looked in to almost all nooks and crannies … now we do the same in our cosmic surroundings, the Moon and Mars are not that far away and the Moon is only half a days' worth of trip on the ISS … and it is important for us to continue to learn more (BBC, 2019).'

The legitimacy has been hard fought for including the human costs to the ISS community and significant financial costs to the Member States. It is consequently there to be lost if the project takes the wrong steps in the future. This is something the field work revealed the ISS community is aware of and why it is taking its time to consider the next steps while continuing to carefully nurture its network of public and private backers.

5.3.3: Future developments

The unipolar position of the US in Space exploration and exploitation that it enjoyed at the height of the Apollo era, has long passed. Recent examples of rival agencies catching up and even overtaking NASA's capability, in limited cases, include the ESA Rosetta 2014 mission being the first to deliver a lander to a comet's surface (ESA, 2014) and China landing a probe on the far side of the Moon in January 2019 (CNSA, 2019a). Nevertheless, I have shown that the US is still in a leading position in the domain, is trusted by its ISS Community partners and with development of the Space Launch System (SLS) is positioning itself to re-exert its power (NASA, 2019). The world's space powers are therefore waiting for a robust US Space Policy to emerge from the options currently being debated, so as they may judge where they could and should fit in.

The ISS Member States have conflicting visions of the future in space both internally and between each other and have been examining potential follow-on collaborations since operations began in 2000. Ellen Ochoa, the 11th director of the Johnson Space Centre believes that the fate of the ISS will, like all major decisions, be decided by consensus: "the life of the ISS which has now been extended out to at least 2024, from its original termination date of 2020, was agreed unanimously by all the partners. Future developments will be decided the same way (AAAS, 2018)." The next steps are certainly difficult to forecast and as Henry Hertzfeld outlines even the next collaborative agreement type is open to conjecture: "The general sense is that the next round of international collaboration may not use the same type of agreements as we have learned what works and what does not in both the IGA and the MoUs." There is a desire within the US to widen international membership of a future ISS like community at least from a funding standpoint. This builds on the reasons I outlined in Partner Funding Shortfalls, sub-section 5.2.3, and is an area for potential improvement on the current IGA as Hertzfeld explains: “it has proved very difficult to add participants and there is a desire to at least engage countries like India, maybe the Emirates as they have resources. These decisions are political acts and the trickiest question is what about China.”

The opening statement of the ranking Democrat member, Donna Edwards, of the US Congressional Subcommittee on Space in September 2016, emphasised the parallels between the US-Russia Space Race and emerging rivalry posed by China: ‘How different would today’s world be if NASA had not responded to Presidents Kennedy’s challenge [to land a man on the Moon within the decade of his May 1961 Congressional speech]. Now, almost 50 years since that historic event, some are asking if we are again in a space race, but this time with China…. I look forward to hearing the panel’s views on whether the US should seek greater cooperation with other space-faring nations, including China, and what challenges we face if we choose to do so.’ (US Congress, 2016: 10)

The militarisation of Space is at odds with the ISS Treaty, but is not immune to its affects. The expert evidence provided to the Subcommittee including the following from Dennis Shea, the Chairman of the US-China Economic and Security Review Commission which had reported to Congress in 2015: ‘Unlike the US, China does not have distinctly separate military and civilian space programs… even ostensibly civilian projects, such as human space flight, directly support the development of People’s Liberation Army space, counterspace and conventional capabilities.’ (US Congress, 2016: 19)

Any future link up with China by the US or other current ISS Member States would inevitably have to address this dual-use posture and the lack of transparency from China that surrounds it. The testimony of Dr James Lewis, Senior Vice President and Director Strategic Technologies Program, Center for Strategic and International Studies, emphasised the difference between science goals and strategic decisions with respect to the US-China space competition: ‘The US is focused on the manned exploration of Mars, and from a scientific perspective, going to Mars makes sense, but it does not make sense strategically…. In the US and Soviet space race, the objectives were prestige and global influence. Having won the race, the US largely lost interest in space. In contrast, China uses its space programs to gain political advantage. Its human space programs serve important domestic and foreign policy purposes. (US Congress, 2016: 56)

Despite these difficulties and the growing enmity between the US and China, the subcommittee agreed in its concluding statements with Ed Perlmutter, the Congressman for Colorado, regarding the positives that Science Diplomacy can bring to parties that are adversaries in other domains: ‘… to have a back channel for diplomatic purposes sometimes is very important if the political systems between two countries are not working. So, scientists sometimes lend us that back channel.' (US Congress, 2016: 78). Certainly, the Chinese Space Agency publicly backs the opening of such channels of collaboration. The CNSA used the world attention of their Chang'e-4 probe landing on the far side of the Moon, on 3rd January 2019, to announce at a press conference that 'China is open to international cooperation in all its future space missions… so far, China has carried out cooperation in manned space mission with Russia, Germany, France and the ESA… [in the future] all member states of the United Nations are welcome to cooperate with China to jointly utilize the Chinese Space Station.' (CNSA, 2019b).

Whatever overall US space policy decisions do emerge the future of the ISS will need to be dealt with. Logsdon emphasises its importance in that debate: "The ISS has become the number one space policy issue; what to do with the station since we have declared we want to resume exploration. Many would now say the issue, frankly for the US Government is how do we get out of it gracefully or indeed can we? The right question is more a sense of how much of what we have done on the station collaboration can be applied to the next step… how much of it is applicable to going deeper into space. That justification also depends on whether you will carry through and do that."

Igor Porokhin, the ROSCOSMOS delegate to Legal Subcommittee of the 2013 UN Committee on the Peaceful Uses of Outer Space Legal (COPUOS), reminded the ISS community that Article 1 of the IGA includes as one of the objectives: '[the] ISS will enhance the scientific, technological and **commercial use of outer space'** [Porokhin's highlighting]. He went on to suggest four new fields of commercial activities in space. Firstly, transportation services for delivery of people and cargo; this is now well established with private companies such as Space X providing an increasingly reliable service. Secondly, space tourism but Porokhin points out that, the ISS cross-waiver of liability for any space tourists, even if they were nationals of Member States would not apply and such persons would have to procure a liability insurance; this is one reason why take up to date has been limited to the world's super-rich class of space enthusiasts. Thirdly, space advertising which has not yet been developed beyond the strictly controlled national logos that adorn Members in-kind contributions (e.g. the Canadian Maple Leaf flag on the CANADARM). Fourthly, space commercial experiments where there has been some take up through the non-profit intermediator CASIS has great potential to fill national public funding gaps (UNOOSA, 2013: 28-32).

Private, commercial flights to replenish the ISS, such as the SpaceX Falcon 9, have helped fill the gap left by traditional US national launch capability, fostered innovation and driven down costs. They have also allowed NASA to concentrate efforts on the future SLS that will take manned space flight to new frontiers; perhaps Mars. Henry Hertzfeld: "The Gateway project [The Lunar Platform Orbital Gateway] is being actively discussed, but the number of partners is still unknown. Even if we had the same partners the level of partnership and percentages and all of that details are to be negotiated and almost by definition would be different. When we actually come down to writing a new agreement, if we have one, for space exploration the one thing lawyers like is precedence. You are going to look at these ISS agreements and you are going to heavily negotiate… but I cannot see them not being a model for moving ahead."

Logsdon agreed that the lessons learnt form the ISS collaboration will continue: "The fact that the collaboration has persisted 34 years since Mr Reagan invited friends and allies to participate stands as a kind of example. You would need to argue, why not do it that international way. It stands as an example of the ability to do things cooperatively. There have been no high-level negatives of the collaboration program." (Logsdon, 2019)

Regarding the future of the ISS, the veteran cosmonaut Sergei Krikalev commented: 'in the future, the involvement of Governments will reduce, and the involvement of private industry will increase. This provides an opportunity as Governments can then put all their collective resources on exploration beyond earth orbit…. the most interesting days [for space exploration] are in the future. Our future destiny is in space and for sure we will do this together [with our international partners]' (Česká televize, 2017).

Section summary

Hypothesis 3 that 'sound governance and leadership dynamics improve IGO performance' is supported through the field work testimony and the analysis of 'Science Diplomacy' and 'Mega-Projects Governance, Leadership and Performance Issues'; Sections 3 and 4 respectively of the Literature Review. Secondary data has included independent audit review reports commissioned by the ISS Member States' national Space Agencies.

The leadership of the main contributing Member, the USA was accepted by the other Members during the IGA negotiations and, despite set-backs has proven to be successful. The on-board organisational culture has been affected by the failure of many Members to deliver on science laboratory commitments. However, the collective collaborative spirit is epitomised by the cadre of international astronauts who train, work, eat, sleep and even space-walk together. This group has been affected by their time looking at the earth from space with several in later life, entering politics and leading initiatives to foster global collaboration. The project has also benefitted from a succession of inspirational individual leaders who have vigorously promoted the project.

I have shown that focality and legitimacy, two characteristics of successful IGO orchestrations are present in the ISS and its community. I have explained that focality is present but is weakened due to the paradoxical governance structure whereby there is no classic Big Science IGO HQ and Director General but features that must be centrally coordinated are present. This arrangement leaves within the bailiwick of the Member States the operational control of their respective ISS assets and governance authority over the limited central bodies.

The projects legitimacy is deep-rooted with a wide-ranging professional customer community and admiring global public. The ISS has a life of its own within each Members' Space Agencies and arguably is now entering a golden period when it will bear greater results – particularly when focused by a clearer US space policy – and thereby further enhance its legitimacy.

How US space policy should address the growing global US-China rivalry will be pivotal in steering the space policy of the other ISS Member States; the outcome is currently uncertain. I have shown that the ISS, and by inference its wider community, has a unique place in world perception of what good international collaboration looks like. In a world of relentless bad global gridlock news, the legacy of the project as a beacon of collaboration may be considered by future scholars as being broader than its science results. It is likely its IGA and MoUs will be heavily modified in any future projects, but key features such as legal arrangements and the separate Astronaut Code of Conduct will continue to provide a model for future negotiators.

This governance and leadership dynamics section relates to three *Beyond Gridlock* pathways: Pathway 3, 'technical groups with effective and legitimate processes'; Pathway 4, 'multiple, diverse organisations and institutions coalesce around common goals/norms' and Pathway 7, 'innovative leadership as a reaction to gridlock'.

5.4: Evaluation of the *Beyond Gridlock* pathways and associated mechanisms employed by the ISS community

As predicted by *Beyond Gridlock* theory this research shows that, like the previous two case studies, there is overlap between which pathways are utilised by ISS community. It is nevertheless again useful to show which principally apply: Table 10 cross-references the pathways that have been identified in the summaries of the preceding sections with the eight pathways set out in the Methodology Chapter.

Hypotheses	ITER Pathway
1. IGO agreements and start-up conditions which are concise, fair, promote trust and mutual support, allow flexibility in problem solving, manage host state issues and emphasise the primacy of the State improve performance	1, 3 and 8
2. External constraints such as excessive stakeholder aspirations, changing legal landscapes, bureaucratic regulations, funding fluctuations and unforeseen events, while being mitigated as far as possible by IGO leadership actions, inevitably adversely affect overall performance	2 and 3 (aided by 7 and 8)
3. Sound internal governance and leadership dynamics improve performance	3, 4, and 7

Table 10; Cross-reference between hypotheses and beyond gridlock pathways utilised by the ISS

Hypothesis 1 is supported through the employment of three *Beyond Gridlock* pathways. Firstly, pathway 1, (shifts in major powers core interests) where the US decided to involve the Russians in the ISS IGA in addition to the original 'Friends and Allies' that had been invited to participate. The two driving reasons being that the Russians had invaluable technical and operational experience that could be tapped, and their participation would help limit technology transfer to what the US Administration and wider international community considered to be *rogue states*. Secondly, pathway 3 where the varied ISS epistemic groups gradually established effective and legitimate processes that are the *modus operandi* of today. Thirdly, pathway 8, (innovative funding) mechanisms that have as their baseline the bi-lateral MOUs between the US and Canada, Europe, Russia and Japan that detail the respective ISS modules and major equipment in-kind contributions. The fairness of the funding has been maintained through the central MCB keeping tally of the

Members in-kind contributions as project changes come into effect. The primacy of the state has been protected through the required national endorsement of MCB recommendations.

The section on Managing Constraints shows that the ISS community has had to deal with significant technical set-backs, political turmoil and persistent partner funding shortfalls. While these have taken their toll on schedule, strained relationships and added to criticism of the project the employment of Pathway 2 (autonomous and adaptive international institutions) and Pathway 3 (technical groups with effective and legitimate processes) efforts have mitigated the consequences. These efforts have been aided by Pathway 7 (innovative leadership) mechanisms such as the acceptance of US leadership and dispersed operational control. There has also been a wholehearted use of Pathway 8 (innovative funding) mechanisms through Members' in-kind contributions being the constituent parts of the modular design.

This Governance and Leadership Dynamics section relates to three *Beyond Gridlock* pathways. Firstly, Pathway 3, (technical groups with effective and legitimate processes) where legitimising expertise has been developed in the dual challenging environments of low earth orbit and earth-bound politics. Secondly, Pathway 4, (multiple, diverse organisations and institutions coalesce around common goals/norms) where focality is manifested in the completed edifice space station is re-enforced by the behaviour and conduct of the astronaut corps A solid legitimacy also stems from a broadly satisfied scientific customer community and a high reputation with the public. US leadership has delivered results despite national adversities such as wavering Congressional backing and unforeseen technical set-backs. Finally, a series of inspirational individuals have provided strong leadership to maintain momentum at key points in the project's history.

The cross-reference Table 10 confirms that gridlock pathway 5 (mobilisation of domestic constituencies) and pathway 6 (civil society coalitions with reformist states) do not feature. Table 11 provides a summarising commentary of the mechanism in use for each pathway that does apply.

Pathway	ISS Community Mechanism
1. Shifts in major powers' core interests	• The US originally only invited Cold War 'Friends and Allies' to join the project • At the point of break-up of the Soviet Union, US strategic considerations to limit Russian technology transfer to rogue states, combined with unquestioned Russian technical and operational experience in space led to decision to extend offer of membership to Russia
2. Autonomous and adaptive international institutions	• There is no prescribed IGO HQ and no DG; the management structure is distributed between the Member States Space Agencies that exercise day-to-day operational control of their respective elements • Despite having no IGO HQ, a Multilateral Coordinating Board has been established to provide central functions • Primacy of the State is ensured through the MCB recommendation endorsement process
3. Technical groups with effective and legitimate processes	• Shared procedures and rescue protocols provide a vehicle for effective, dispersed operational authority • The Astronaut Corps enjoys common training regimes and non-partisan crew selection albeit within a de-facto agreement to rotate the selection of the Commander • In-Kind workshare means control of the supply chain rests with Member State national Space Agencies
4. Multiple, diverse organisations and institutions coalesce around common goals/norms	• Extensive global collaboration: the 5 members comprise 15 developed nations • Recognised unique centre of excellence for Micro-Gravity research in several science domains
5. Mobilization of domestic constituencies	Research confirmed that these *Beyond Gridlock* pathways do not feature
6. Civil society coalitions with reformist states	
7. Innovative leadership as a reaction to gridlock	• All IGA signatories accepted US leadership that has delivered despite technical set-backs, political turmoil and funding limits, thereby improving trust in the US • A series of inspiring individuals have occupied key decision-making roles and helped foster public support • Serving and retired Astronauts have championed global environmental initiatives gaining mass public support
8. Innovative Funding	• The project is funded by in-kind contributions whereby Member States provide their own modules, operating personnel, national Mission Control Centres and communication networks. • MoUs detailing in-kind deliverables between NASA and the other supporting Space Agencies provide the technical and funding baseline • The MCB keeps a tally of in-kind contributions that are bartered by the Space Agencies as project changes occur; subject to Member State endorsement

Table 11; Pathways though and beyond gridlock, ISS mechanisms for implementation (adapted from Hale and Held, et. al., 2017)

CHAPTER 6: RESEARCH RESULTS

The research problem (section 2.2) is: *How do global Science Mega-Project Communities achieve their effective collaboration pathways with Member States*? There are two related research questions: *1) do the subject SMP Communities utilise common diplomatic approaches in negotiating their founding arrangements and functioning in a collaborative way?* And *2) What - if any - are the political lessons learned by the subject SMP Communities that may provide clues in advancing global collaboration to overcome gridlock in other domains?* In this chapter, the answer to the research problem and related questions are addressed through five sections.

In section 1, I gather together the counterfactual arguments that span the three hypotheses and the case studies together with my response.

In section 2, I analyse to what degree the *Beyond Gridlock* pathways have been utilised by the SMP communities to support the three hypotheses. The analysis is framed around the three boxed areas shown in Figure 3, the Global Conceptual Framework: 1) Formal Agreement and Creation where Hypothesis 1 is tested, 2) External Constraints where Hypothesis 2 is tested and 3) Governance and Leadership where Hypothesis 3 is tested.

In section 3, I analyse the common and dissimilar diplomatic, governance and leadership mechanisms that have been used to implement the pathways. It is also in Section 3 where I make the case for the inclusion of an 8th pathway, innovative funding, to be added to *Beyond Gridlock* theory. This section serves to answer the first of the two related research question.

In section 4, I summarise four common features of the SMP Communities that have emerged during the research. These features, while admirable [in the sense that they have been part of the SMP's success] do not reach the bar as organisational structures or characteristics that would necessarily be recommended to be emulated elsewhere. Nor are they appropriate for me to suggest that they are contributions to fill a gap in knowledge. They are, however, worthy of separately distilling and discussing as they serve to provide the closing part of the answer to the research problem.

Finally, in section 5 I propose two contributions to knowledge that the analysis of the three case studies has revealed. These contributions should benefit global gridlock academics and those involved in fostering effective international collaboration in other domains. This section serves to answer the second of the two related research question. .

6.1: Collation and examination of counterfactual evidence

The three stages of research described in Chapter 2 (Methodology) are: desk research of literature (secondary data); field research interviews (primary data) and finally the analysis and validation of the data. During each of these stages and in parallel to the evidence that supports the thesis, three strands of counterfactual evidence emerged. Firstly, literature that challenges *Beyond Gridlock* theory, secondly literature and sporadic field work data that suggests SMP communities are atypical of international collaboration with little read across to other domains and thirdly the risk of optimism bias from some interviewees combining with confirmation bias from the researcher to slant the analysis to inapt conclusions. Here I examine and respond to each of these counterfactual arguments.

6.1.1: Response to the argument that *Beyond Gridlock* theory is flawed

Literature that challenged the notion of the global gridlock phenomenon, 1) questioned that the problems existed at all or 2) suggested that if there were examples of the phenomenon then these were exaggerated. As global gridlock affects many domains the criticising literature was spread across theses domains and was led, in some instances, by those who it could be argued had vested interests in playing down any impacts. Here I consider two domains that have attracted significant counter-evidence: climate change and global finance and provide a response to each.

It is too convenient to dismiss climate change deniers as deluded or driven by ulterior motives. It is more pragmatic to recognise that 1) the denial movement is persistent in their opposition 2) they are well funded and 3) they have allies in the highest political offices. Indeed, a concern of the Trump Presidency is that he ignores, such as in his February 2019, State of the Union Address, widely held concerns on the climate more as a ploy to maintain backing from his domestic political base rather than any wider thought through alternative policy (Whitehouse, 2019). For this thesis, it is sufficient to place this denial movement and their literature within the framework of the self-reinforcing gridlock that I described in section 1.2. The climate denial movement is a high profile example of the many elements that add fuel to the negative cycle of events depicted in Figure 2. By keeping this perspective, the actions of the climate denial movement [and associated literature] actually strengthens the case that gridlock theory is sound in that it is *part* of the problem rather than representing a compelling argument that the problem does not exist.

The converse way of looking at the global gridlock argument is to ask a series of questions as to why the blocking primacy of the state in combination with institutional inertia seem to prevail even in the aftermath of global calamitous events. Why was there no major reform of the IMF or World Bank after the 1980's financial crisis? Was Daniel Drezner (2014), whose work I reviewed in sub-section 1.2: Global Gridlock Issues, correct in his analysis that the financial system had worked in that the mid-1980s crisis had not resulted in a depression, so no major changes were deemed by the global order to be necessary? Drezner's position crystallises the idea that critics of gridlock theory centre on, which is that they contest the underlying phenomenon itself. If we take this stance as correct and consider the situation across other domains such as security, migration, trade, etc., then the inference could be promulgated as: security crisis? What security crisis? Migration crisis? What migration crisis? Trade crisis? What trade crisis? I contend that these suppositions appear even more unlikely when viewed together.

Another aspect of the counter evidence to gridlock theory is that crises are nothing new and indeed are to some extent an expected, if not welcome, correction to the global order. Kahler and Lake (2013) argue that the Great Recession is only the latest in a long history of international economic crises that, as the 1980's events prove, were unlikely to be the last. They go on to argue that the networks of professionals tasked to oversee the system found a way to overcome the problems because of institutional as well as individual learning. Michael Clarke argues in Weapons of Mass Destruction: Incremental Steps (*Beyond Gridlock:* Chapter 12) that one plausible way forward in addressing the need to reduce the stockpiles of nuclear weapons is reform of the current WMD control regime rather than seeking to install any new regime. In other words, while Clarke does not go as far as Drezner in suggesting that the current system 'works' he suggests that reform of existing structures is the only practical basis for making progress (Clarke, 2017).

These types of argument are powerful and could, if accepted, be logically applied to other domains. My response is that we need to try harder, given the scale of problems that the world faces, than pinning our hopes that crises are inflated and/or that what we already have in place today to deal with them is adequate. Addressing Drezner's argument I would counter that while the basic argument [that the crisis was ultimately dealt with without the world going into recession] is true, it also cannot be denied that the institutions, despite their knowledge systems, inspection regimes and qualified personnel, failed to predict and take preventive measures to the financial crisis itself. Stewart Patrick supported Drezner's position with his 2014 essay *The Unruled World; The Case for Good Enough Global Governance* (Patrick, 2014). In it he dismisses the idea of any United Nations based solutions to the world's problems ever emerging and argues that realistically the most that we can strive for is a multilateral sprawl of solutions. The crux of my position aligns with that of Dan Plesch and Thomas Weiss (2015) that acceptance of this 'good enough' type of failure is no longer good enough. The negative effects of not tackling the problems more systematically demand more efforts to find a way through the gridlock effect. All methods of international collaboration need to be explored to ensure that collectively we have not missed any better way of dealing with wicked problems.

My other position in tackling the counter-arguments to gridlock theory is that we must step up and respond to the commonly held view epitomised by the Nobel laureate Joseph Stiglitz that existing global institutions have not kept up with and adapted to shifts in power politics. Stiglitz in *Globalisation and its Discontents* (2002) points out that it is no longer the USA or any group of advanced countries that now 'set the rules' of global governance, but rather corporate and financial interests within that set of nations led by those in the USA. It is outside of the scope of this thesis to examine if this interpretation is true, but it serves to demonstrate what is uncontested: the global governance landscape is dynamic. Consequently, our response to gridlock needs to keep up with the changes and design solutions that are nimble if they are to be reliably effective.

6.1.2: Response to the case that SMP Communities are atypical examples of international collaboration

There are three strands of argument that support the idea that the SMP Communities are uncharacteristic examples of global collaboration: firstly, that their Member States are an elitist club with the world's nuclear powers at their core who therefore do not provide a model for other domains; secondly, that the individuals who comprise the key scientific staff are an elitist group who reach agreement through long-standing peer-to-peer networks rather than any shrewd collaborative method and, thirdly, that the projects themselves are given special preferential treatment which other domains cannot easily replicate. I provide a response to each of these arguments during the analysis that follows.

6.1.2.1: SMP Member States are an elitist club, with the world's nuclear powers at their core, who therefore do not provide a model of collaboration for read-across to other domains

The proposition that the Member States are an elitist club of the most powerful developed nations who work to their own hidden agenda does have supporting *circumstantial* evidence from the research. The case study SMPs all fail to include developing nations, and field work revealed that they have no meaningful plans to include any. Also, it is true that at the core of each project's memberships are the world's nuclear powers who certainly have strategic reasons for staying close to each other, including working within the bailiwick of the IAEA on safeguards and verification programs. The counterfactual argument continues with the reasoning that the case for nuclear powers to stay close to each other is weaker in other non-strategically relevant domains and therefore the same states do not make sufficient efforts to achieve meaningful collaboration in these other domains.

This rival hypothesis also looks plausible if we simply cross-reference the nuclear powers to SMP membership, see Table 12. However, the situation is more complicated and fragmented than its premise assumes. India is a member of the ITER project even though it is a nuclear power that is a non-signatory of the Nuclear Non-Proliferation Treaty. It is involved due to the nuclear fusion research knowledge it brings and the prowess of the design and manufacture of its in-kind contributions. The achievement of commercial nuclear fusion will have major implications for world energy provision and geopolitics. The ITER Community therefore does ring fence project IP to its Members and their industrial base; nevertheless, the grouping represents over half the world's population many of whom include underdeveloped regions of their respective territories. For the ISS, while certainly trying to disrupt technology transfer from Russia to rogue states was part of the reason for extending the membership invite to Russia, it was not the only consideration.

This research also showed that CERN and the ISS consistently reach out far beyond the national boundaries of their Member States in global scientific and educational initiatives.

Nuclear Power	Accession to UN Non-Proliferation of Nuclear Weapons Treaty / Year	Case Study 1	Case Study 2	Case Study 3
		CERN	ITER	ISS
People's Republic of China	Yes / 1992	No	Yes	No
French Republic	Yes / 1992	Yes	Yes, as a member of EURATOM	Yes, as a member of ESA
Republic of India	No	Associate Member	Yes	No
Islamic Republic of Pakistan	No	Associate Member	No	No
Russian Federation	Yes / 1970 (as Soviet Union)	Observer Status	Yes	Yes
United Kingdom	Yes / 1962	Yes	Yes, as a member of EURATOM	Yes, as a member of ESA
United States of America	Yes / 1970	Observer Status	Yes	Yes

Table 12; Nuclear Power States membership of the case study SMPs (shading means state is a full member)

6.1.2.2: The scientific staff of SMPs are members of an elitist group who reach agreement through long-standing peer-to-peer networks rather than astute collaborative methods

The second strand of the counterfactual argument is that scientists, who are the main group of the SMP communities and are at the core of the IGOs (for CERN and ITER), are part of a global old boys' network: a network of people who have had privileged educational opportunities, get special treatment in the international job market, enjoy lucrative renumeration packages and bask in the attention of an admiring public. They are therefore atypical when considering if their collective approaches reveal anything worthwhile in matters of collaboration.

Circumstantial evidence for this emerged in sub-section 4.3.2: Focality and Legitimacy, where I examined the legitimacy of one aspect of the ITER Communities external review system that could be viewed as a too intramural community arrangement. Another isolated example came from the literature concerning the series of management studies conducted at CERN to assess the LEP project in the 1980s. SMPs, through conditions set in their founding documents, are subject to independent external management assessor scrutiny. In practice they have little choice, due to the nature of the specialist areas under review, but to include in these bodies individuals who may have a vested interest in positive outcomes. The purpose in mentioning these here is not to comment on the veracity of the results of the reviews but to highlight that *critics* say that they may be influenced by those conducting studies due to their backgrounds and remits. The implication that critics make is that a group within an epistemic community that are themselves dependent on the success of the key component of that community's flagship project, as may be the case with ITER and CERN, are unlikely to be free of optimism bias (even if subliminal) when assessing progress.

While it is unquestionably true that no specialist group, organisation or SMP can impartially assess itself, the research revealed that the SMP communities are aware of this and design in checks and balances to their governance systems to counter it. Measures include the rotation of which Member State is responsible for the external review arrangements to keep the process fresh and authentic. Another response to this counterfactual argument is the high competency of CERN's governance regime, which I analysed in sub-section 3.1.3., to show that the accepted protocol on the appointment of a DG is that if that person is a CERN 'insider' (i.e. an existing member of the central IGO staff) then his/her direct reports will then be from 'outside' CERN. The reverse would apply if the DG was an 'outsider' appointee. I explained that this process enables a regular freshening up of the top-level central management and helps break up any cliques that may form. Similarly, the CERN Council President, is limited to a 3-year term allowing the Member States, who elect the President, to have regular input into how governance is operationally exercised. For the ISS, Scientists are one of the key epistemic groups involved and have influence but were not, as I explained in sub-section 5.1, the sole driving group in the founding negotiations.

As explained in each of the SMP 'organisational culture' sub-sections, it would be wrong to imply that the SMP communities are beyond criticism. They reflect their members' societies. All suffer from the same gender inequality issues, particularly at the highest levels of management, that blight many STEM IGOs, NGOs and natural sciences academia. Field work confirmed that they are all aware of the issue and are actively tackling the problem albeit, too slowly for many equality reformers. The SMP communities are also accused of tolerating a 'community within a community' sub-culture with a few interviewees describing the hidden hierarchy within the physicist community. A stereotypical 'old boys' network' whereby closely linked groups looked after their own advancements and careers was suggested to still be in play by only one interviewee.

These minority reports need to be seen in the context of the overwhelming positive reports of the prevailing organisational culture in my field work interviews. The SMPs comprise broadly content, well-educated, well-motivated, well-paid and hard-working individuals. Further evidence for this was in the 'Organisational Culture' sub-section 4.3.1. where 28 senior ITER Organisation staff who, when asked 'Are you supportive of the new management?', all responded positively (ICRG, 2016: 51). The organisation culture of each case study was encapsulated by the young, award-winning post-doctoral physicist that I quoted in sub-section 3.3.1.; here I provide an abridged version of the full quotation: "as a scientist you are trained to think that there is a fundamental truth and this helps unify people… and so, when you bring people together at a place like CERN there is already a component that has had that exposure... they already have the mindset that to collaborate internationally is normal." I repeat this here as I witnessed this mind-set throughout the field work. While the point is that scientists' educational background and operational best practice when dealing with international papers helps foster the right cross-cultural attitudes, it does not mean that this skill of accepting other people's views may not be transferable to other domains. To the contrary, it provides an important clue as to a feature that that could be transferred. Similarly, the counter-factual accusation that agreements are reached in the SMP communities primarily because those involved are members of an epistemic community of experts who all know each other and have long standing personal relationships is a self-defeating argument. If these connections do indeed produce results and help keep powerful states bound together, despite the global turbulence that buffets them, then that, in itself is a positive factor not a negative one.

6.1.2.3: SMPs are one-off endeavours, benefiting from preferential set-up and governance conditions operating in distinct domains

CERN is often cited as a model of good collaboration for solely peaceful purposes. Examples include Herwig Shopper (2009) in *The Lord of the Collider Rings*, Boisot, Nordberg, Yami and Nicquevert (2011) in *Collisions and Collaboration: The Organization of Learning in the ATLAS Experiment* and Hale, Held and Young (2013) in the Introduction to *Gridlock*. Countering arguments to the string of positive citing are few and tend to emerge to feed in to public concerns on safety such as during the start-up of the flagship LHC infrastructure. These narratives are often from unreliable tabloid newspaper sources, that I explain in sub-section 2.5, are purposively avoided and therefore were not within the scope of the literature review or the thesis as a whole. While the ISS is held in high regard as a model of collaboration its scientific results and the validity of spin-offs are contested. As I analysed in sub-section 5.2.3., lack of breakthrough results led to Congress passing the 2005 NASA Authorization Act (NASA, 2009 and US Congress, 2005). As I explained further in that sub-section, to look purely at the economic return on investment fails to appreciate the Member States' core strategic reasons for establishing the space station.

It is when considering ITER that the levels of criticism of its community mount. The counter evidence is of three types. Firstly, ITER has had severe programmatic criticism not least from its own Member States independent management reviews. Secondly, the project has been also been subject to consistent criticism from those who doubt that fusion will ever bear fruit such as Charles Seife (2008) in *Sun in a Bottle: The Strange History of Fusion and the Science of Wishful Thinking* and Daniel Jassby (2018) with his derisive critique in *ITER is a showcase … for the drawbacks of fusion energy.* Finally, there have been persistent vocal demands from environmental pressure groups that scarce Members resources would be much better spent on other renewable sources of clean energy such as solar power or wind turbine technology. Examples include regular statements from Helga Trüpel, a prominent and influential Green Party Member of the European Parliament from Germany and the Green Group's Energy adviser Michel Racquet (Euractiv, 2011). These criticisms increase in volume after notable set-backs in semi-related areas of nuclear power generation such as the Fukushima nuclear *fission* reactor disaster of March 2011.

This third strand of counterfactual case is encapsulated by the notion that the research question could have been better phrased 'why are SMPs not *more* successful than they already are?' Indeed, they do enjoy preferential circumstances. CERN has an annual budget of over $1 BN and has negotiated an advantageous *Protocol on Privileges and Immunities* with the Member States (CERN, 2014). Legal disputes between CERN and its suppliers and contractors are not submitted to national courts but to international arbitration. CERN as a distinct legal entity can negotiate favourable terms and conditions for purchase of equipment and services including exemption from value-added tax. ITER has an entire scientific community's resources at its disposal. Many interviewees also echoed the recent US DOE report that ITER is both a *first-of-a-kind machine* and a *first-of-a-kind organisation* (US DOE, 2016). The ISS benefits from resources including launch complexes that up until quite recently, with the arrival of commercial platforms such as SpaceX (2019), only government agencies such as NASA, ESA and ROSCOSMOS could provide. Another tack to this line of thinking is that perhaps the projects were just blessed by some good fortune and do not warrant scrutiny as exemplars of collaboration.

I contend that the counter evidence across the case studies of their unsuitability as exemplars of international collaboration paradoxically adds weight to the core message of this thesis, the twist being that *despite* these issues the communities have developed what Boisot and Nordberg (2011) term as a 'coherent legitimizing discourse and achieved results that continue to appeal to the contributing Member States more than competing alternatives.' It is *how* the global SMP Communities achieve their effective collaboration pathways with Member States, including achieving these preferential starting conditions, substantial funding and advantageous operating conditions, that is the 'answer to the 'problem' that this thesis addresses. The first step in seeing whether communities in other domains may profit from adapting some of the SMP pathways is to firstly understand what they are and how they have been implemented; either through brilliant planning, consummate negotiation skill, inspirational leadership, blind luck or any other mechanism.

The literature review reinforced the idea that one action that academics can and should take is to thoroughly investigate and explain all possible paths through gridlock. I contend that this is true even if individual research results merely rule routes out. I demonstrate this last point in the collation of my evidence in Table 19 that shows the low usage of Pathways 5 (mobilisation of domestic constituencies) and the non-usage of Pathway 6 (civil society coalitions with reformist states) by SMPs.

Section summary

No data either primary (field work) or secondary (literature) has been dismissed as irrelevant or unreliable evidence. I have demonstrated that the data pool contained counter-evidence and the collation and examination of counter arguments has been done with equal rigour to that which supports the three hypotheses. Examination of alternative hypotheses has also served to understand the problem better and identify any weaknesses or simplifications in the thesis hypotheses.

I have shown that there will always be an intransigent group who deny, in a particular domain, that a problem exists despite their being overwhelming evidence to the contrary. There will therefore be a group of climate-change deniers who will vociferously oppose efforts (academic and/or practical) to overcome gridlock issues in climate change negotiations as they see no need for the measures that would be agreed. Similarly, there will always be those who fervently believe that a market based economic system will find its own way of overcoming global financial crisis without intervention from well-meaning academics or practioners, that they would term as meddling. Their own version of realism theory dominates their thinking and they therefore see no need for gridlock theory.

I have also shown that while it may be comforting to critics to label the SMP leadership as a spoilt elite, it is a disparaging comment that does not pass scrutiny of the majority evidence collated during this research. On projects of this magnitude there will always be sporadic events where counterfactual evidence rings true; for example, where field work revealed that despite self-reflection by the project communities, the commendable efforts to embrace peer review impartiality needed to be re-doubled. However, I have shown that these are minority cases only. While acknowledging the concerns regarding the preferential conditions that the SMPs enjoy, I made the case that it is the investigation of these very factors that adds credence to the thesis.

The difficulty in maintaining impartiality in management reviews, difficulties in addressing gender imbalance and isolated occurrences of remnant old boys club behaviour are all regrettable, but they do not singularly or collectively disqualify the verifying of the hypotheses and the response to the research problems and associated questions. The balance of evidence is that SMP Communities *are* appropriate vehicles to investigate international collaborations.

6.2: Testing the Hypotheses

6.2.1: Testing Hypothesis 1

Hypothesis 1 (sub-section 2.4) is that *IGO agreements and start-up conditions which are concise, fair, promote trust and mutual support, allow flexibility in problem solving, manage host state issues and emphasise the primacy of the State improve performance*. Table 13 summarises which *Beyond Gridlock* pathways have been used by the case study communities in respect of Hypothesis 1.

	***Beyond Gridlock* Pathways employed**		
	Case Study 1	**Case Study 2**	**Case Study 3**
	CERN	**ITER**	**ISS**
Hypothesis 1	**1, 2 and 3**	**1 and 8**	**1, 3 and 8**

Table 13; Beyond Gridlock pathways used by the case study SMPs supporting Hypothesis 1

For case study 1, CERN, I have shown that the organisation and its community have benefited from the solid foundation that the 1953 CERN Convention provides. Pathway 1, 'shifts in major powers core interests' was utilised during its formation in the period of European political rapprochement in the aftermath of World War II and have been maintained through an unwavering respect for the primacy of the state enshrined in the Convention. Pathway 2 mechanisms have included governing bodies, such as the Council, being given capabilities to adapt to unforeseen issues. The principle of fairness in the CERN Convention financial protocol and dispute resolution articles have allowed teams to establish Pathway 3 type workable rules and develop a project adhocracy. This has enabled expert groups of scientists and engineers to legitimately and effectively solve complex problems in whatever manner they see fit. This meaningful delegation of authority has aided the attraction and retention of the best scientific and technologist talent.

For case study 2, ITER, Hypothesis 1 is supported through the employment of two pathways: Firstly, pathway 1, 'shifts in major powers core interests' whereby at the end of the Cold War a set of well-placed nuclear fusion advocates overcame gridlock in superpower relations to push their niche science domain onto the world stage. The breakthrough at the 1985 Reagan-Gorbachev *Fireside Summit* in Geneva was the catalyst for the seven Member coalition of world powers that created

ITER in 2001. These powerful Members committed to the project, re-assured by the legal Articles respecting the primacy of the state and equitably sharing the effort, costs and risks. Secondly, the negotiating teams extensively used pathway 8, ‘innovative funding’ mechanisms that were embodied in the long negotiated *common understandings* which detail the Members’ in-kind contributions.

For case study 3, the ISS, the research showed that a combination of two powerful factors led to the use of Pathway 1, shift in major powers (US and other original ISS participants) decision to extend an invitation to Russia to join the project in 1998. The first factor was the accepted experience that the Russians could bring to the endeavour and the second was the hidden agenda of seeking to limit Russian technology transfer to *rogue states*. Pathway 3 mechanisms, whereby the varied ISS epistemic expert groups gradually established workable and legitimate processes across national boundaries, led to the effective *modus operandi of* today. Finally, pathway 8, innovative funding mechanisms have as their baseline the bi-lateral MOUs between the US and the four other Member States that detail the respective in-kind contributions. The fairness of the funding arrangements was maintained through a bartering system, foreseen by the negotiators and encouraged in the IGA, to manage changes to those contributions.

Opposing evidence to Hypothesis 1 centred around the argument that the SMPs are one-off endeavours, benefiting from preferential set-up and governance conditions. I addressed these concerns and provided a detailed response to each of them in sub-section 6.1.2.3.

6.2.2: Testing Hypothesis 2

Hypothesis 2 (sub-section 2.3) is that *external constraints such as excessive stakeholder aspirations, changing political and legal landscapes, bureaucratic regulations, funding fluctuations and unforeseen events, while being mitigated as far as possible by IGO leadership actions, inevitably adversely affect overall performance.* Table 14 summarises which *Beyond Gridlock* pathways have been used by the case study communities in respect of Hypothesis 2.

	***Beyond Gridlock* Pathways employed**		
	Case Study 1	**Case Study 2**	**Case Study 3**
	CERN	**ITER**	**ISS**
Hypothesis 2	**7 and 8**	**2 and 3 (aided by 7 and 8)**	**2 and 3 (aided by 7 and 8)**

Table 14; Beyond Gridlock pathways used by case study SMPs supporting Hypothesis 2

For case study 1, CERN, the solutions to combat external constraints and threats have relied on sound leadership and the employment of innovative funding; Pathways 7 and 8 respectively. The CERN Community has progressively delegated authority to the centre from the Member States. This has enabled a succession of eminent DGs and their management teams to seamlessly guide the Organisation and its wider community through sixty five years of political and funding turbulence. Examples include 1) how CERN has masterfully maintained fundamental physics domain dominance without jeopardising the will of other, potentially rival, states and organisations to make in-kind contributions to key infrastructure, 2) how it dealt with technical set-backs through actions that did not generate acrimony between the parties, and 3) how it has scrupulously preserved fairness in cash contributions. The field work confirmed the findings from the literature analysis that negative effects, such as program delays persist but are much reduced from what would have occurred without the effective interventions that I detailed in section 3.2. The strength of the CERN Convention has led to it being adapted by several other science communities when they are forming IGOs; the Astronomy Community using it for the formation of ESO being one example.

For case study 2, ITER, the pathways used to combat constraints have taken time to be put in place since the project's inception in 2006. The major hurdles to progress outlined in Chapter 4 all had the potential to seriously impede or even trigger project cancellation. A continual challenge has been how to keep the global powers that are the ITER Members together when they openly contest each other in other domains. Pathway 2 mechanisms included granting the central organisation increased authority to tackle project construction and integration challenges. Pathway 3 initiatives have allowed expert groups to gradually develop a project adhocracy to solve complex problems and navigate constraints. Although program delays persist, there is strong and independent evidence that these mechanisms have had positive influences. For example, had the ITER Community leadership delayed dealing with the multiple consequences of site selection (analysed in section 4.2.) this would have stored up problems. Another key supporting factor has been the dominant reliance on Members' in-kind contributions. Although these have disadvantages such as the difficulty in controlling the dispersed supply chain, without the national support that they engender the project could have been cancelled at any of several pinch-points.

For case study 3, the ISS, the Chapter 5 research shows that the ISS community has had to deal with significant technical set-backs, political turmoil and persistent partner funding shortfalls. These have taken their toll on schedule adherence and served to embolden critics. The employment of Pathway 2 (autonomous and adaptive international institutions) and Pathway 3 (technical groups with effective and legitimate processes) efforts have been utilised to mitigate the consequences. The efforts have been aided by Pathway 7 mechanisms such as adept US leadership at critical points such as the loss of the Space Shuttle Columbia in 2003. There has also been a wholehearted use of Pathway 8 (innovative funding) mechanisms through Members' in-kind contributions being inherent in the ISS modular design and the central MCB keeping a tally of the value of Member's contributions as changes are bartered.

Opposing evidence to Hypothesis 2 centred around the argument that the SMP Member States are an elitist club, including the world's nuclear powers, that overcome external constraints in the SMP communities mainly because of strategic concerns. Concerns that are much less of a factor in other domains where the Member States do not make the same high efforts to overcome the constraints. I addressed these concerns and provided a detailed response to each of them in sub-section 6.1.2.1.

6.2.3: Testing Hypothesis 3

Hypothesis 3, described in sub-section 2.3, is *that sound governance and leadership dynamics improve global IGO performance.* Table 15 summarises which *Beyond Gridlock* pathways have been used by the case study communities in respect of Hypothesis 3.

	***Beyond Gridlock* Pathways employed**		
	Case Study 1	**Case Study 2**	**Case Study 3**
	CERN	**ITER**	**ISS**
Hypothesis 3	**3, 4 and 7**	**3, 4, (limited 5) and 7**	**3, 4 and 7**

Table 15; Beyond Gridlock Pathways used by the case study SMPs supporting Hypothesis 3

For case study 1, CERN, an analysis of 'Science Diplomacy' and 'Mega-Projects Governance, Leadership and Performance Issues', Sections 3 and 4 respectively of the Literature Review together with the evidence collected during the many field work interviews, showed that CERN's governance and management teams consistently take timely and apposite actions. Sound governance is demonstrated in how the Member States' representatives respect and help each other during periods of difficulty. Employment of light-touch leadership helps keep the workforce motivated. Analysis of GSN orchestration aspects such as focality and legitimacy have supported this argument. Focality is preserved by being a well-established, lively hub and by employing several measures in parallel to avoid fragmentation. Legitimacy is heightened through a meritocracy-based main policy advisory body, the vastness of membership, continual scientific and technological success, deep domain experience and external recognition by world forums including the UN General Assembly. These features correspond to Pathway 3, technical teams' performance, Pathway 4, enthusiastic participation in the global, connected research network that is the CERN of today, and the employment of Pathway 7, innovative light-touch leadership.

For case study 2, ITER, the governance and leadership dynamics relate to four *Beyond Gridlock* pathways. Firstly, the IGO leadership has developed, Pathway 3 type, legitimising expertise and exercised regulatory design authority over the project community. Secondly, the community has combined focality and legitimacy in such a way that the community depends on the success of the central entity and vice versa. This is a form of Pathway 4: 'multiple, diverse organisations and institutions coalesce around common goals/norms.' As I explained in section 4.1 the magnetic confinement fusion community and the ITER project are inexorably linked when addressing any issues that they must jointly tackle. Field work also showed that the IGO leadership and the Heads of the Member States Domestic Agencies are aware of this interdependency; they succeed or fail together. Thirdly, the community uses Pathway 5, 'mobilisation of domestic, constituencies for cooperation and compliance' processes whereby the close interdependence of the community and the project means that research and development studies are readily carried out world-wide to support the centre. Similarly, the national follow-on DEMO devices complement and learn from the central efforts. Finally, Pathway 7 innovative leadership was employed in the wake of the independent management assessor process that I analysed in sub-section 4.3.1. (Organisational Culture). This led, with eventual unanimous Member State support, to the earlier than previously planned replacement of the Director General and some of the first-order IGO management tier. As evidenced in my analysis, DG Bigot then led several initiatives to gain more central control from the Member States. This was innovative as it needed the Member States to accommodate measures that abated, to the extent necessary for the project, the natural situation that occurs whereby the power over the supply chain is predominantly with them.

For case study 3, the ISS, the Governance and Leadership Dynamics, section 5.3., research has revealed three *Beyond Gridlock* pathways. Firstly, Member States have successfully developed and supported Pathway 3 type 'technical groups with effective and legitimate processes' in the dual challenging environments of low earth orbit and earth-bound superpower politics. Examples include the US Administration leadership ensuring the project was ring fenced and unaffected by sanctions being imposed in other domains on Russia in the aftermath of Crimea Crisis in 2013. Secondly, Pathway 4, 'multiple, diverse organisations and institutions coalesce around common goals/norms' where focality is manifested in the completed edifice space station re-enforced by the behaviour and conduct of the astronaut corps. A solid legitimacy also stems from a broadly satisfied scientific customer community and a high reputation with the public. US project leadership has delivered results despite national adversities such as wavering Congressional backing. Finally, a series of inspirational individuals have provided strong Pathway 7 type leadership to maintain momentum and bolster vital public support. They have had to be innovative in their style and actions as none of them have been afforded the delegated authority or supporting international staff that would come with Director General status. Evidence for how difficult this has been is provided in the field work interviews in sub-section 5.3.1: Leadership and Organisational Culture.

Opposing evidence to Hypothesis 3 centred around the accusation that the leadership and staff of SMP IGOs and the corresponding staff in the SMP Community Member State organisations are members of an elitist club who reach agreement with each other through long-standing personal contacts rather than any astute collaborative methods. I addressed these concerns and provided a detailed response in sub-section 6.1.2.2.

Section Summary

In the preceding three sub-sections I have mapped out how the utilisation of the *Beyond Gridlock* pathways supports the three hypotheses (section 2.3) as follows:

Firstly, I showed in support of Hypothesis 1 that *all* three case studies needed a shift in major powers' core interests to aid their foundation. This aid to their foundation was not taken up by chance; the communities were primed and ready to exploit it; I will develop this argument in section 6.5. This essential base pathway was then supported by a combination of other pathways. These included the central organisation being granted autonomy and the means to adapt its institutions, giving its technical groups effective and legitimate processes and utilising innovative funding to engage the Members and help keep them on-board (Pathways 2 and 3 respectively).

Secondly, in support of Hypothesis 2 I showed that the SMP Communities shrewdly grant the central organisation sufficient authority to tackle problems and combat external constraints. For CERN there has been a mature devolvement of authority to the centre over decades of operation. I showed that for ITER and the ISS, the central delegation is less deep, but the techniques used to overcome constraints are similar. It is the resilience and fairness of the ITER Agreement that has enabled states such as China, Russia and the USA to continue to share project data without interruption despite the external political turmoil that has affected them. For the ISS, the ring-fencing of the project during the Crimea Crisis, when US and other aligned states exercised sanctions against Russia in other spheres, was critical in shielding the project schedule from severe slippages.

Thirdly, I showed in support of Hypothesis 3 that sound governance stems from, what are now widely seen (sub-sections 3.1., 4.1., and 5.1.) as, first-class founding documents that enshrine the primacy of the state while at the same time allowing the central organisation to perform its role. Multiple, diverse organisations and institutions then keenly and without fear of legal impediment coalesce around common goals and norms. This allows the project communities to step up and get behind the technical groups who steadily establish effective and legitimate processes. These groups are backed up by leadership which supports and encourages a meritocracy-based organisational culture. For example, the light-touch leadership approach epitomised by the current CERN DG Gianotti has consistently been seen by staff and external collaborators as the optimal one to maintain delicate collaborations. Innovative funding is used whereby fairness in cash contributions is supplemented by in-kind contributions that bolster industry and institutions in Members' territories.

Counterfactual evidence to the three hypotheses was examined and responded to in Section 6.1. For Hypothesis 1 this examination and response was in sub-section 6.1.2.3, for Hypothesis 2 this was provided in sub-section 6.2.2.1 and for Hypothesis 3 it was provided in sub-section 6.2.2.2. As I have shown in this section the weight of evidence strongly supported each of the thesis Hypotheses.

6.3: Common and different diplomatic, governance and leadership mechanisms that have been used to implement the *Beyond Gridlock* pathways

6.3.1: Pathway 1; Shifts in major powers core interests

A common feature of the formation of both CERN and ITER is that both sets of advocates were primed and ready to ride momentous waves of change as major powers shifted their core interests (sub-sections 3.1.1 and 4.1.1. respectively). Hindsight shows that the timing to step onto each wave was also flawless. For the ISS the take-up of shifts in major powers' core interests were subtler.

For CERN, a consensus in the fundamental physics community, led by several Nobel laureates emerged for the need for a world-class fundamental physics facility dedicated, as I described in Section 3.1, to 'nuclear research of a pure scientific and fundamental character'. This call was matched by the 1950s European movement of reconciliation after World War II. forward thinking scientists, such as Pierre Auger, Raoul Dautry, Lew Kowarski, Edoardo Amaldi and Niels Bohr, aided by the establishment of UNESCO, strove to build bridges between nations in education, science and culture. The appreciated support of leading US scientists, such as Isidor Rabi, to a high energy physics 'global laboratory' being based in Europe also fell in line. The timely cooperation between the fundamental physicists and the politicians provided an opening that led to the CERN Convention. Nations were bound together in peaceful research that 10 years earlier had been at war; Figure 5 shows the dramatic improvement in international relations that the community had worked together to achieve.

For ITER, the wave was the mid-1980s rapid thawing of the Cold War between the two global superpowers of the period: the USA and USSR. I have shown that the magnetic confinement nuclear fusion community had influential advocates in the very highest levels of both the US (Michael Roberts, Charlie Newstead, Alvin Trivelpiece and Richard Stratford) and Soviet (Vladimir Travin and Evgeny Velikhov) political establishments. They expertly nudged the negotiating teams in the 1985 Reagan-Gorbachev Geneva Summit to include in the final protocol a commitment to jointly develop fusion energy. As others joined the idea of an international fusion project it was the determination of the EU to host the facility and the ensuing acquiescence of other Members to this offer that provided the necessary breakthrough surge for the Governments to enter the final negotiation stages. The research showed that national mechanisms also contained 'mini waves' of opportunity for funding that needed to be exploited if activities were to proceed smoothly. Evgeny Velikhov commented in 1990 on the quirks of the USA annual budgetary cycle: 'the US system was akin to a sine wave that had to be overcome by rising with the up-side to hop over obstacles before readying for the next one' (ITER Newsline, 2015b).

US technological pre-eminence in space had been underlined by the Moon Landing in 1969. The peak of the period of US-USSR *détente* led to a false start in space collaboration with the Apollo-Soyuz joint mission in 1975. Although this was a one-off event, it did provide a tantalising glimpse to the respective national space agency communities of what might come. Leading advocates in the US such as Daniel Goldin and Albert Holland were ready when the Cold War Space Race finally ended to lead the effort for an international approach. The ISS community has been led by the USA since US President Reagan in January 1984 invited 'Friends and Allies' to join the challenge and share the costs, risks and rewards. The motivation to involve the Soviets at the end of that decade was different. The Russian experience in space was certainly seen as valuable but there was an indubitable lingering Cold War inspired mistrust, from both parties. The strategic argument to involve the Russian space technological and science teams was partly to wrap them in a collaboration that would allow little spare capacity for anything else. There was a desire to limit any science and technology transfer to former Warsaw Pact states and *Rogue States*. In hindsight it was a masterful decision as it not only helped to achieve this restriction but was also vital in preserving the pace of the project when US launch capability was lost with the second Space Shuttle disaster in 2003 and Russia stepped in to fill the gap.

Figure 15 provides an overview of the SMP project timings and shows [in yellow highlighting] the major waves of opportunity that helped provide the necessary breakthrough surge:

- The establishment of UNESCO in 1946 and the birth of the first European Movement in 1947 for CERN (Convention signed in 1953);

- The period of US-USSR détente, 1967 to 1979 and US invitation to potential partners in 1984 for the ISS (IGA signed in 1998) and

- The collaborative stance taken by the US and USSR leaders at the *Fireside Summit* in Geneva in 1985 for ITER (Agreement signed in 2006).

Figure 15 shows the increasingly long negotiation periods were needed to bring the world's major powers together: 7 years (1946 to 1953) for the European Nations that formed CERN, 14 years (1984 to 1998) for the five major powers that were to collaborate on the ISS and 21 years (1985 to 2006) for the seven world powers that were to form the ITER project to reach agreement. Literature and field work point provided a rationale for this growth, including: Member States negotiators being more knowledgeable and warier of contractual commitments than in the 1950s, the problems being tackled by the projects being increasingly wicked in nature, and laborious talks being required to agree higher proportions of in-kind contributions.

Figure 15 also shows the longevity of the three case studies since their respective start dates of 1954 for CERN, 1998 for the ISS and 2008 for ITER. This longevity has been achieved despite the series of significant constraints that have beset them and fall within three categories (cross reference to this research detailed analysis is shown in brackets):

Financial: the German Funding crisis following reunification in 1990 (p 99), the Global Financial crisis of 2008 (p 225) and the Swiss Franc crisis of 2015 (p 99);

Political: the Afghanistan crisis of 1979 (pp 122-123 and p 182) and the Crimea crisis of 2014 (p142, p172, p174, p177 and pp 212-213) and

Technical: the Columbia Space Shuttle Accident of 2003 (p 172, p 177, p 188 and p 210), the LHC Incident (pp 99-100) and the Fukushima Accident of 2011 (p 204)

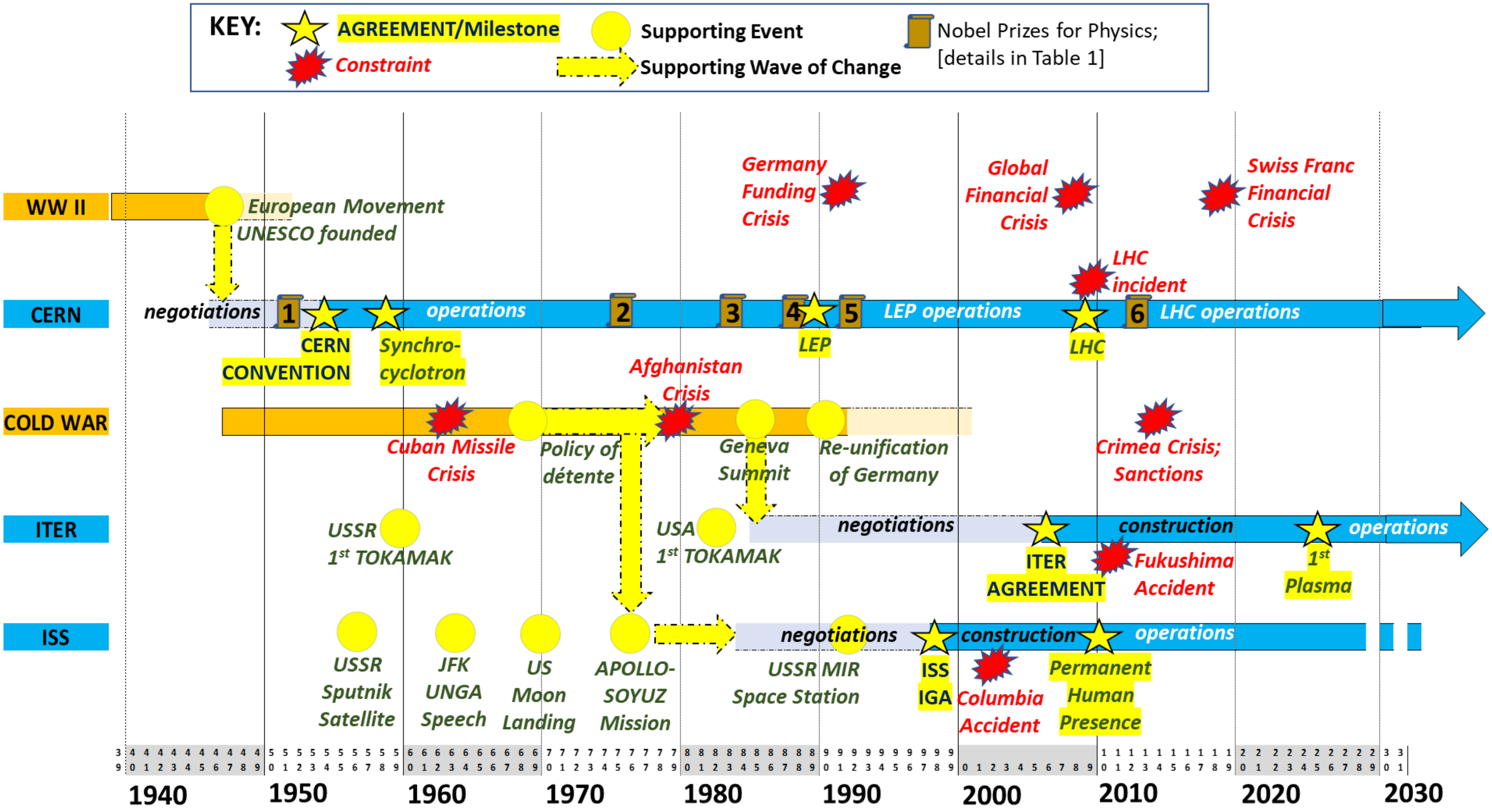

Figure 15; Timing of establishment and major milestones of case study SMPs set against major political events and constraints affecting the Member States

6.3.2: Pathway 2; Autonomous and adaptive international institutions

In the Methodological Approach, sub-section 2.4.2. I referred to the work of Claire Dunlop (2011: 5) who highlights that understanding the structure and power dynamics that exist within an epistemic community is important in understanding their behaviour. In this thesis, these dynamics can be viewed by the degree that the Members grant the central element autonomy and the performance of the community to adapt to shifts in organisational structure as more power is delegated to the centre as the project matures. The differing dynamics for each case study are summarised as follows.

For CERN, the structural arrangement is that the embedded experiment instrument programs and core LHC infrastructure form one integrated research facility. The larger LHC complex provides the high energy beams that the experiment programmes need, and no results would be produced if they did not act in a fully integrated manner. However, as I showed in sub-section 3.1.3., the two elements are independently managed. The recognised management teams of the former do not overbear the more recently established teams of the latter.

The early CERN management teams quickly established an international institution that commanded global respect and consistently drew funds from the Member States. The community has encouraged the embedded experimental projects to exercise autonomy in deciding how they tackle science enquiry. Interviewees from both the central teams and the Member States confirmed that this helps to attract and retain the world's best scientific and technological talent.

For ITER and the ISS there is less autonomy granted to the centre by the Member States than for CERN. However, I have shown (in Section 3 of both the ITER and ISS case study chapters) both management teams nevertheless actively manage the ensuing multi-polarity into good outcomes.

For ITER, the central team is hampered in making autonomous decisions of substance beyond its legal obligations due to the interdependence of the in-kind management system. Design decisions reached by the IGO staff ripple through to all the participants. The impact on costs and resources then needed to be individually negotiated and agreed right down through the Member States supply chain. Central autonomy has therefore been hard fought for and only granted by the Member States in areas where it is seen to be necessary. For example, the project adapted to the special needs of the construction phase by the appointment of the central Construction Management Agent that manages and supervises the myriad of companies on site.

Similarly, for the ISS, central autonomy is controlled and limited to only those areas where it is strictly necessary. In the view of some (such as John Logsdon) the central MCB is the governing body for the station. For others (such as Henry Hertzfeld) is merely an operational necessity. I explained the full case for both positions in sub-section 5.1.3: Organs and Voting Rights. What is undisputed is that the ISS has no central IGO and no DG and accompanying international staff. The Members retain control of their programme elements through their national space agencies and retain full budgetary control of their science programmes. The ISS structure is an iconic emblem of what international collaboration can produce when major powers work together in peace, but the ISS research facility is far from being an integrated one. The US has adapted its operations within its own autonomous area by designating the US ISS Scientific module as a National Laboratory (US Congress, 2005). In August 2011, NASA entered into a cooperative agreement with the Center for the Advancement of Science in Space (CASIS) to manage and boost non-NASA ISS research.

In summary, the SMP Community's Management Teams exercise autonomy and adapt their structures through intelligent strategies to achieve results to the level that their set-up conditions, governance and funding regimes allow.

6.3.3: Pathway 3; Technical groups with effective and legitimate processes

For CERN, the infrastructure and experiment teams work seamlessly within an integrated research facility. They are managed separately but need each other for the collective effort to deliver results. Both sets of technical groups have devised legitimate and effective processes that the other groups respect. There is naturally competition between the experimental groups - as with events such as the Higgs Boson confirmation - but as I explained in sub-section 3.2.1 (Domain Dominance) it is a healthy rivalry. CERN also benefits from this healthy internal organisational culture when dealing with the outside world; it has a reputation as a centre of excellence and an intelligent buyer of goods and services that speaks with one voice. Four interviewees confirmed that industry has learned that it cannot play one element of the organisation off against another.

For ITER, two interviewees believed that at the start of the project there was a power struggle between the central IGO HQ team based in France and the main Member (Europe) Domestic Agency team based in Barcelona and, to a lesser extent the six other Members Domestic Agency teams based worldwide. While the overall design authority rests with the DG and thereby his staff and is respected for areas such as nuclear safety, there has been a reluctance from the Members to provide project control levers to the central organisation in other areas. Evidence for this was discussed in sub-section 4.3.3 in the analysis of independent Management Review Reports such as that provided by Madia and Associates in 2013.

When DG Bigot took office in 2015, he set as one of his conditions of appointment that he and his team needed to be given more executive authority. While this has been done to some extent, three interviewees indicated that there is a lingering tension between the central team and the ring of supporting Members. This is one of the draw-backs of the in-kind funding system whereby the control of the supply base is not with a central team [who would need to be given the cash to place all the contracts] but remains with the contributing Members. What has emerged is sets of mini epistemic communities that have effective and legitimate processes within their expert areas; an example of this was Fusion neutronics mini-community that I analysed in sub-section 4.3.1. These then combine with similar groups to collectively form the engine room needed to deliver the project for the community.

For the ISS the range of specialist groups needed to design, manufacture, construct and operate the station is vast; see sub-section 5.3. Added to this, the management structure is distributed between the contributing Member States' Space Agencies with only a central coordinating administration based in Houston. I explained in sub-section 5.1.3. that this results in a project fragmentation that has taken monumental efforts to overcome. Remarkedly this has been done despite significant funding constraints. Like CERN and ITER, what has emerged is sets of mini epistemic communities that have effective, legitimate and respected processes within their expert areas. The most noteworthy group is the astronaut corps who I examined in sub-section 5.3.1. and will return to when covering Innovate Leadership in sub-section 6.3.7.

The key to success of this pathway as a route through gridlock has been the emergence of epistemic communities of experts who have their own norms and expectations and operate within a shared belief system. As I stated in the Research Framework (sub-section 2.3), this belief system can be seen through the four knowledge elements that Peter Haas (1992) identified: 1) a shared set of normative and principled beliefs, 2) shared causal beliefs, 3) shared notions of validity and 4) a common policy enterprise. Interviewees invariably demonstrated a deep holding of these beliefs. They have overcome national boundaries [albeit with occasional set-backs usually because of national funding shortfalls] by working in their specialist areas to establish effective and legitimate processes to deliver their portion of the work.

This effective collaboration does not mean the total lack of conflict. To the contrary it means groups being passionate and caring about their areas. The groups have learned that, if they are to be effective, they must articulate and defend their position with other peer groups and with higher management. Crucially, the prevalent organisational culture also means that they have respect for each other and know when to compromise. It is *constructive conflict* which DG Fabiola Gianotti, described when speaking at the CERN / UNOG Symposium in 2015 as follows: "… Decisions are taken by consensus. Consensus does not mean that everyone agrees; this is impossible. Consensus means that problems, issues, strategy and plans are discussed all together in an open manner." (CERN/UNOG, 2015). It is a form of the *interaction capacity* that Buzan, Jones and Little (1993) [that I featured in the Literature Review] suggested needs to be analysed on the same level as *units* and *structure* in order for the neorealism of Kenneth Waltz (1979) to fit the world we see before us. It is then all these groups operating to a single goal that form the reliable core of the projects.

6.3.4: Pathway 4; Multiple, diverse organisations & institutions coalesce around common goals/norms

In order to analyse the appropriateness of this pathway, I re-visit the focality and legitimacy analysis sub-sections from each case study.

6.3.4.1: Focality

In sub-section 3.3.2., I showed that CERN is a well-established fundamental physics hub that people look to and converge around. The scale of operations marks it out as a genuinely global collaboration with over 12 000 researchers from institutes in over 70 countries being actively engaged (CERN, 2016). The risk of fragmentation is combatted by a constant renewal process at different levels within the CERN central organisations that is illustrated by three examples: first, through the constant flow of new-blood eager scientists engaged in cutting-edge work, second, by the regular change of the Council Chair and the DG and third by the accepted practice whereby the first reports of the DG when changeover takes place should be outsiders if the appointee is an insider and *vice versa.* Field work showed that the higher management respecting these processes helps foster vitality and a sense of inclusiveness throughout the community.

In sub-section 4.3.2., I highlighted the dilemma that the ITER Council faces when trying to provide a focal point for the project. On the one hand, the representatives are responsible for the delivery of their portion of the in-kind contributions while on the other hand they are collectively the highest body that the central organisation can appeal to when a Member fails to meet those very obligations. A Council Secretariat interviewee's evidence was that if Council deliberations stepped that way then a Member's representative would recuse themselves from that part of a meeting or vote. Despite this, the nature of the construction means that all roads lead to Cadarache in France. Figure 9 (sub-section 4.3.2) illustrate that the project is therefore an exemplar of *focality by presence.*

In Chapter 5 on the ISS I showed that there is a manifest focality provided by the ISS edifice. However, it is an integrated product through the ingenuity of its modular component interfaces rather than a single tailored design. As I described in sub-section 5.1.3., there is no central IGO and no delegated authority to a dedicated DG as in the other two case studies. A limited central focus is provided by the Multilateral Coordinating Board (MCB) but power and influence remain firmly with the national space agencies with NASA leading in all important operational decisions.

6.3.4.2: Legitimacy

As I concluded in sub-section 3.3.2., CERN has a high legitimacy built up over decades of success, that can be summarised in five areas. Firstly, legitimacy is reinforced by the transparency of the co-option process for the word-renowned experts that it uses for the its sub-organs such as the Scientific Policy Committee that advise Council. Secondly, legitimacy is bolstered by the moral authority to orchestrate events though the vastness of its membership. Thirdly, it has legitimacy due to its series of scientific discoveries given further kudos by the award of a succession of Nobel prizes for physics that are detailed in Table 2 and shown on the timeline in Figure 15. Fourthly, the legitimacy stems from the expertise that CERN possesses and uses in its commercial arrangements and contracting as I analysed in sub-section 3.1.4. Lastly, it has an increasing global legitimacy in domains outside of its scientific remit by its Convention being the model for other alliances, the granting of permanent observer status by the UN General Assembly in 2012 and its DG co-chairing sessions at the 2018 World Economic Forum.

As I explained in sub-section 4.3.2., it is vital that there is a belief among all the actors in a community that the central organisation and its bodies are appropriate to direct policy. The field work interviews confirmed that, at times, that belief has wavered in the ITER community. The early days of the project saw a power struggle between the main Member, Europe, and the central organisation both of which were going through their own organisational forming process. Today, the ITER IGO has increased its legitimacy through three features: Firstly, like CERN, its Council is legitimized by the expert support it receives from two of its subsidiary governing bodies: the MAC makes recommendations on the management arrangements and the STAC on both scientific and technical issues. Secondly, it has legitimacy due to the expertise that ITER possesses through the many scientific and technical mini-epistemic communities that contribute to the whole and which are led by renowned world experts in their respective fields. Thirdly, the legitimacy stems from its *science diplomacy* success in achieving the ITER Agreement in 2006 and surviving the international political disorder that has engulfed its global power Members since then.

In sub-section 5.3.2. I proposed that the legitimacy of the ISS project should be viewed from two perspectives: its public standing and its standing within the ISS professional community. I explained that the two perspectives are closely linked. Firstly, because enhancing public support is crucial in securing extra funding and building resilience and secondly because much of the dispersed ISS community is in competition with counterparts on other space related projects that also seek to strengthen their legitimacy and access to funds. The facility being in space since 2000 has given it, certainly in the consciousness of the millennial generation who have known nothing else, a *legitimacy by presence.* I showed that for many, that the IGA exists at all and has survived the types of constraints I have analysed is good enough legitimacy to justify the costs. This view is strongly supported by the Astronaut Corps whose intrinsic message, from their numerous personal account books, is that while national agendas will always be present in projects of this magnitude, the notion that trumps these is the collective higher-level goal of the advancement of knowledge.

In summary, I have shown that focality and legitimacy concepts are closely intertwined throughout the three case study SMP communities and that both concepts are vital in gaining the support of Members. By measuring the degree with which community actors look to and converge around the central teams and the quantity and quality of the connectivity of the centre with the dispersed project elements, it was possible to assess the level of focality. By analysing the track record of science results, moral authority within the community and standing with the public, the sense of achievement in legitimacy could be made. Table 16 provides a summary of both features.

		Case Study 1	Case Study 2	Case Study 3
		CERN	ITER	ISS
Focality	Actors look to and Converge Around the centre	VERY HIGH accepted global hub for fundamental physics	VERY HIGH Project and Community are united in achieving one aim	VERY HIGH self-evident unique global lab for micro-gravity research
	Connectivity of the centre with the community	VERY HIGH world-wide community share data through landmark comms network	HIGH Connectivity has improved since early days of the project	MIXED national operational communication paths work alongside central coordination
Legitimacy	Track record of Science Results	VERY HIGH several Nobel Prizes and meaningful spin-offs	LOW meaningful results only available in operations phase but potential is VERY HIGH	CONTESTED differing views of worth to date versus cost; commercialisation may bear fruit
	Moral Authority: Professional Community	VERY HIGH infrastructure and embedded experiment projects work seamlessly together	MEDIUM meaningful control of supply base rests with Members; central authority in some areas is contested	MEDIUM limited central authority; national space agencies run operations
	Moral Authority: Public perception	VERY HIGH well developed community, education and public outreach programs	LOW broadly unknown to the public despite public outreach programs	VERY HIGH well developed community, education and public outreach programs

Table 16; Attributes of focality and legitimacy across the case study SMPs (adapted from Abbott and Hale, 2014)

6.3.5: Pathway 5; Mobilization of domestic constituencies for cooperation and compliance

Examples of Pathway 5 type mechanisms from the *Beyond Gridlock* literature include the human rights domain where international initiatives often have the intent of mobilising domestic constituencies. Such efforts are often targeted on those states that have a poor track record in defending human rights. International pressure on Member States regarding combatting climate change, through the UN Sustainable Development Goals, No 13, (UN, 2019b) or the Paris Agreement on Climate Change (UNFCCC, 2016), are other examples of this pathway in action. The underlying aim, through initiatives at the international level, is to support the establishment of domestic movements and/or to help them overcome national impediments in existing efforts.

All three case studies' central organs encourage healthy domestic constituencies. CERN takes strength from its Member States fundamental physics facilities which carry out important research and development activities. Similarly, it needs, encourages and supports the personnel within these facilities and educational institutions, many of whom come to work at CERN and then return to their host institutions. The ITER IGO and the Member States' Domestic Agencies are the major players in the management of the project. It is the capabilities of the Member States industrial base that provide the components to the central construction site. The ITER international staff are recruited through the Member States' Domestic Agencies who need a good knowledge of this job market. I showed in sub-section 5.3.3: Future developments, that the ISS Member States' space agencies have diverse and emerging agendas outside of the project. The station itself is operationally controlled via those national space agency control centres and the project needs these dispersed assets to be capable, well managed and seamlessly connected to the US operational control centre in Houston.

The above SMP interdependencies are natural given the scale of the projects and the geopolitical nature of the communities that support them, but they are not within the meaning of this pathway that I outlined in the first paragraph of this sub-section above. There are a few exceptions (such as research and development studies carried out world-wide to support the central goals; see sub-section 4.3.2.) that do fall within the remit of this pathway but overall, the mobilisation of domestic constituencies is not a pathway that any of the central teams have used for the purpose of their establishment (Hypothesis 1) or overcoming their own constraints (Hypothesis 2) or improving their governance or leadership dynamics (Hypothesis 3). It is, therefore, other than in the highly linked ITER IGO - ITER Community case, not a pathway of *direct* relevance to this thesis.

6.3.6: Pathway 6; Civil society coalitions with reformist states

This pathway concerns routes through global gridlock that come about through concerted civil society efforts. CERN has a history of dedicated staff who have strongly advocated for the advancement of human knowledge through fundamental physics research, ITER has nuclear fusion advocates who have devoted their professional lives to achieving the promise of commercial fusion power generation and the ISS has an active public network of supporting space exploration groups. All these individuals and groups contain activist members, but they operate firmly within the accepted establishment of the respective communities.

There is no 'occupy Wall Street' type movement involved in these substantial projects. *Beyond Gridlock* (2017: 43) illustrates that the occupy movement was born out of low growth and justifiable resentment of inequality in society exacerbated by the 1980's financial crisis. There is no such deep-seated rage within the SMP communities; one reason being the high status in the world order of the Member States involved. The membership of these projects (see sections 3.1, 4.1 and 5.1) does not include any developing nations; nor is there a gateway that a pressure group in a reformist state could readily use to gain access. I addressed this question of limited, elitist Membership of SMP Communities in the examination of counterfactual evidence in sub-section 6.1.2.

It can be argued that civil society coalitions including eminent pressure groups could work more closely with Big Science projects. For example, environmental organisations such as Greenpeace could view the ITER Community positively in that it strives to bring long-awaited sustainable energy sources to the world. They could perhaps find the door more open in these broad-minded, long-term international project environments than has been the case with the more short- and medium-term conservative thinking of individual Member States. To date, for reasons known to them and outside the scope of this thesis, they have chosen not to do so (Greenpeace, 2019). The outcome of the analysis is that this pathway does not apply to the SMP Community case studies.

6.3.7: Pathway 7; Innovative Leadership

Here, I highlight two aspects of leadership that have strongly emerged from the research: Firstly, the concept of consensual governance by the lead entity and secondly an adept light-touch style of leadership being exercised by individuals in high management positions.

6.3.7.1: Leadership by lead-entity

Governance features when considering the leadership provided by lead entities in the SMP Communities. It concerns the *approach* taken by the central organisation leadership (as in the CERN case study) or by the principal Member's leadership ('Europe' for the ITER project and the USA for the ISS) to other Members:

- I explained in the sub-section 3.2 (Managing Constraints) that when Germany was forced to reduce its cash contribution to the central capital funds, just at the time when the organisation needed more funds for the LHC infrastructure, the decision reached was to reduce the cash contributions of all the Member States by the same proportion. The central management team realised that the overriding need was to maintain fairness, a judgement that was then endorsed by the Council.

- For ITER, the main Member is ‘Europe’ whose group of EURATOM states contribute most of the funds, enjoy the largest workshare and host the project in France. An ongoing advantage that this has provided to the whole community is financial stability (see sub-section 4.2.2., Project Delays and Funding Resilience). Europe operates on a 6 or 7-year funding cycle rather than a 1 or 2-year funding cycle as is the case in most of the other Member States.

- For the ISS as I explained in sub-section 5.1.1 the dominant role of the USA in the management arrangements was accepted by all the parties when they agreed to Paragraph 2 of Article 1 of the IGA: ‘The Partners will join their efforts, under the lead role of the United States for overall management and coordination, to create an integrated international Space Station.’ I have shown in the evidence of sub-section 5.2. that the US has consistently provided sound leadership and thereby gained the respect of the other Members in this domain.

The lead entities (central organisation or principal Member) have found a way to maintain progress by acting fairly in times of crisis, providing funding stability and exercising sound leadership. This has been most strongly evident in potentially gridlock-inducing moments that could have otherwise de-railed the projects.

6.3.7.2: Individual Leadership

The idea of individual leadership sits incongruously with the other *Beyond Gridlock* pathways. The others rely, to varying degrees, on collective actions by groups of players: *major powers* (Pathway 1), *international institutions* (pathway 2), *technical groups* (pathway 3), *diverse organisations and institutions* (pathway 4), *domestic constituencies* (pathway 5) and *civil society coalitions* and *reformist states* (pathway 6).

Nevertheless, the field work data showed that the projects have benefited from individual leaders who I contend have exercised, to varying degrees, the required light-touch management approach that their environments demand. The best example of this is CERN, whose leadership have had longer to develop the approach. As I explained in sub-section 3.3.1., the present DG Gianotti fully embraced the concept as one of the key drivers for the success of the CERN model. This innovative approach is coupled by the way the leaders (known as ‘spokespersons’) of the embedded experiment teams are appointed by their peers not least because of their personal leadership abilities.

I showed in section 4.2 that early high-level appointments to the ITER IGO were political. One of the reasons that Japan had agreed to the project being hosted in Europe was that the IGO DG would be provided by Japan. I explained in sub-section 4.2.2., that the second incumbent was not seen as having all the necessary attributes to deal with the problems the project faced in its set-up phase. The current DG Bigot has restored faith in the IGO leadership through personal example and by a series of apposite and timely decisions. As all the field work interviewees attested, the central team have gained authority over the whole community; the improvement in morale being evidence by the executive staff survey results that were analysed in sub-section 4.3.1.

Examples of effective leaders on the ISS project, that I provided in sub-section 5.3.1., included those from the USA, Canada, Germany and Russia. They come from different professional and cultural backgrounds: Ellen Ochoa, the first Hispanic woman to go into space; Chris Hadfield, a former fast-jet military test pilot from Canada; Alexander Gerst, a German geophysicist and Sergei Krikalev a veteran cosmonaut. Three of them have commanded the ISS: Krikalev (Expedition 11), Hadfield, (Expedition 34) and Gerst (Expedition 56). The way that the project selects its ISS Commanders is based on a de facto agreement that the lead position should be rotated. These examples demonstrate that the USA does not exclude other Members from the lead person on ISS Expeditions. The USA could have used its pre-eminence in the project to not share or severely limit these types of appointments; it has chosen not to do so. Many large ventures pronounce that their organisations are a meritocracy, only those within these structures know if it is the case; ISS interviewees confirmed that there is a belief that this is so in their community. This confidence in each other is also something the community does not want to lose. It is one of the reasons why the US space policy, as I covered in section 5.3.3: Future developments, is taking time to finalise.

In summary, pathway 7 has two applications for the case study SMPs. Firstly, in the *approach* taken to other Members by the central organisation (as with the CERN IGO) or to other Members by the principal Member (as with 'Europe' for ITER and the USA for the ISS). Sound governance was consistently exercised through the lead entities consistently acting fairly and openly and thereby gaining the other Members' respect. This leadership has been strongly evident in times of crisis that could have otherwise de-railed the projects. Secondly, by the approach taken by individuals in leadership positions where the projects have benefitted from a series of inspirational individuals who have exercised the required light-touch management style that their settings demand. A meritocracy-based decision-making is demanded at the technical and science team level by the nature of their specialist operations.

6.3.8: Pathway 8; Innovative Funding

The case for a new pathway to be added to *Beyond Gridlock* theory is set out below and draws on evidence from all three case studies. Firstly, I provide supporting evidence for the inclusion and I then outline the opposing evidence. The sub-section summary weighs up both sets of evidence and provides the rationale why the former argument prevails.

6.3.8.1: Evidence supporting the inclusion of the new pathway Beyond Gridlock theory

Mark Uhran was the Assistant Associate Administrator for the ISS at NASA HQ in Washington DC from 2005 to 2012. He is currently the Head of Strategic Communications at Oak Ridge National Laboratory, USA and during field work for this thesis he stated: "For the first time in history, we find industrialized nations forming partnerships to design and build complex, technological assets for which no nation alone can bear the cost, or the risk. By partnering together, the effort and cost is shared; the risk distributed, and; the benefits accrue to all." I included this quote in the preamble to the thesis (*at page v*) because Uhran, succinctly sums up the case for Big Science collaboration. When he rightly says that *the effort and cost is shared,* he also touches on a key point of the case for the inclusion of this new pathway to gridlock theory.

Member States need persuasive reasons to provide large cash contributions to Big Science projects on the scale of CERN, ITER or the ISS. Even regional grouping of nations, such as the EU, may provide cash support to major projects but only when linked to *juste retour* terms and special conditions such as those in the EC Framework Programmes (EC, 2019). This situation applies to many domains and their IGOs. For example, Jan Beagle, the UN Under-Secretary-General for Management reported to the Fifth Committee of the General Assembly at its 73rd session on 16 October 2018 that cash funding by Member States to the plethora of UN Agencies is ever more strained (UN, 2018). Secretary General António Guterres raised the detrimental effects of the negative trend in cash funding in an internal memorandum to all UN employees in the same year (Gladstone, 2018). Kenji Nakano, the Chief of the UN General Assembly Branch at the Department for General Assembly and Conference Management provided evidence to this research regarding adopting in-kind contributions to help fill the funding gap. The policy of Contingent Owned Equipment (COE) was adopted by the UN in 1996 to simplify the means by which countries are reimbursed for providing in-kind contributions (equipment, personnel and support services). In that period this primarily related to urgent contributions for peacekeeping missions (UN, 1996). Nakano highlighted that these measures have been repeatedly updated and reformed culminating in a COE Working Group being set-up to advise the Secretary General on suggested improvements including where the concept could be used more widely. The Working Group's initial conclusions are scheduled to be presented in New York in January 2020 (UN, 2019c).

Given the increasing scarcity of cash contributions the SMP founding negotiators also looked to in-kind contributions as an *essential* additional element of funds. I provided evidence in Section 3.1, the CERN Convention, Section 4.1, the ITER Agreement and Section 5.1 the ISS Intergovernmental Agreement that the SMP founding documents enable fairness and promote trust and mutual support through their precision, aptness and depth of detail. In support of my argument for an 8th pathway, I draw attention to the fact that *all* of these principal founding documents also have supporting papers that detail the Members' in-kind contributions, see row 1 of Table 17:

- For CERN, Russia and the USA provide parts of the LHC accelerator ring as contributions in-kind in return for a voice in LHC operations. I provided details of this in sub-section 3.2.2: Funding Resilience and sub-sub-section 3.3.3.1: Management of future membership and innovative funding trends. In-kind contributions are also the means of funding the embedded experimental programs such as ATLAS and CMS.

- For ITER, the in-kind contributions are detailed in the *common understandings* that are attached to the ITER Agreement and was one of the last documents to be agreed. I provided details of these in sub-section 4.1.4: Commercial, Contracting and Funding Arrangements.

- For the ISS, in-kind contributions are detailed in four MoUs between NASA and the other Space Agencies: CSA, ESA, JAXA and ROSCOSMOS. I provided details of these in section 5.1.4: Commercial, Funding and Legal Arrangements.

Big Science projects cannot function with in-kind contributions alone. CERN and ITER have dedicated IGO HQs with a DG and his/her staff who need resources to carry out their management and coordinating roles. I have shown that even the ISS, with its distributed control centres needs a central MCB to, amongst other tasks, keep tally of the changes to members in-kind contributions. For all three case studies, Members make cash contributions based on indices that reflect their relative economic strength such as Net National Income (NNI) or Gross Domestic Product (GDP).

The share of in-kind and in-cash is dependent on the detailed workshare negotiations that take place and the level of authority that the Member States grant to any central entity. More delegated authority means a higher proportion of in-cash contributions and vice versa; see rows 2 and 3 of Table 17.

Founding Documents/ Funding Type	**Case Study 1** **CERN**	**Case Study 2** **ITER**	**Case Study 3** **ISS**
PRINCIPAL DOCUMENT plus ***Collaborative Documents***	**CERN CONVENTION** plus ***CERN IGO Bi-lateral MoUs: with Japan, Russia and USA*** plus ***Embedded Experiment Agreements***	**ITER AGREEMENT** plus ***Common Understandings***	**INTER GOVERNMENTAL AGREEMENT** plus ***NASA bi-lateral MOUs with: CSA, ESA, JAXA and ROSCOSMOS***
Share of Total Funds provided *In-Kind*	**MEDIUM** (USA and Russian elements of the LHC and high proportion of embedded experimental projects)	**VERY HIGH** (85% of the Project Value is provided by the 7 Members in kind deliverables)	**VERY HIGH** (all ISS Modules and major components are provided by the 5 Member's Space Agencies)
Share of Total Funds provided *In-Cash*	**HIGH** (Approximately 1 BN USD Annual Budget provided by all 23 Members, based on Net National Income, to central IGO)	**LOW** (15 % of project funding is provided by Annual cash contributions of 7 Members to the central IGO)	**LOW** (some cash and seconded personnel are provided to central MCB administration body

Table 17; Case Study SMP's founding documents and summary of share of funds provided in-kind and in-cash

There are two appealing advantages to Members of funding Big Science projects by mostly in-kind contributions rather than solely cash and one advantage that also applies to the entire Community.

Firstly, it keeps the majority of the spend in the Member States own territories and thereby embodies a practical structural realism. It fits in well with the neo-realism theory (sub-section 1.1.2), where Buzan, Jones and Little (1993) raise the importance of interactions between States to understanding how the modern world works. While there is no US Senator for Provence, France there are Senators for the 44 US States that benefit from over 300 ITER related contracts (Congress, 2018). The US has consistently maintained its in-kind contribution commitments, not least the crucial Central Solenoid manufactured by General Atomics in California. This type of arrangement is replicated in the other six Member States. The local, actual real cost to a Member of designing, procuring, testing, accepting and delivering an item to the central organisation is a matter solely for them. Similarly, the contracting details are a matter for each Member within the overall provisions set out in the Procurement Arrangements that the central organisation sets. Effective control and power therefore rests with the Members; this all adds substance to the principle that the primacy of the State is sacrosanct even in the camaraderie type atmosphere of SMP Communities.

Secondly, it helps develop and maintain the Member's industrial base and boosts the professional and social capital of the member's scientists and engineers. This leads to an enhanced status for their respective national institutions that are part of the global communities. This distribution inherently recognises that it is the Members who 'own' and benefit from the project rather than a single all-powerful central organisation that could limit the sharing of these features. The very nature of these projects is that they push the boundaries of science and technology, therefore the distribution of the work to the Members is a major driver in fostering a community of innovators.

A final advantage to the communities that embrace the in-kind management system is that they make the cancellation of the projects, once established, much less likely.

- For CERN, the Russian and US in-kind contributions helped plug the funding gap left by the European funding crisis following the re-unification of Germany. Without it, in conjunction with the other measures that were employed to mitigate the Constraint which I covered in section 3.2.2: Funding Resilience, the flagship LHC project could have been in jeopardy.

- For ITER, the US had already withdrawn for a five-year period (1998 to 2003), during the 21-year negotiation phase. There was strong field work evidence from all the US interviewees (sub-section 4.1.4: Commercial, Contracting and Funding Arrangements) that, without this funding method, the US would almost certainly have withdrawn again, probably permanently. Congressional records show that it is the stalwart support of representatives of States with ITER-related contracts - together with recent improved performance and expert lobbying of DG Bigot - that have influenced the specialist committees to recommend continuance.

- For the ISS, I provided evidence in sub-section 5.2.1: Technical Set-Backs, that the Russian's providing greater frequency and access to their in-kind contribution elements, when the US launch capability was lost, was instrumental in preserving the project.

6.3.8.2: Evidence opposing the inclusion of the new pathway Beyond Gridlock theory

The model of how the in-kind contributions system should work is met in practice by some harsh realities. These came particularly to the fore in interviewees in the ITER Community where many believed that the result is that the ITER device will be built in an unprecedentedly inefficient way. Collectively, they cited five issues that hamper progress. Firstly, the original *common understandings* valuations were too optimistic, and the Member States ended up having to pay far more than anticipated to produce components. Secondly, changes to the overall design meant that Members had to make only partly compensated changes to their components. Thirdly, there was waste in that many components could have been more easily produced by not duplicating some of the work share. Fourthly, despite the best efforts of the negotiators and technical teams who authored the specifications some items were missed and/or interfaces were unclear, and lengthy disputes resulted as to which Members were responsible for providing them. Finally, integration and testing on site meant that some components needed re-work the liability for which was disputed.

This field work evidence confirms that there is greater mutual dependency between the participants when in-kind contributions are the main source of funding. This means that Member States must be more engaged than is often the case when only cash contributions are provided. A side effect of this arrangement is that 'free riding' by Members whereby they can appear to contribute or contribute to the minimum level necessary [for example to retain voting rights in an organ of governance] is more difficult. All the contributions are necessary for the whole entity and thereby the whole community to work; there is therefore no place to hide in a disciplined in-kind management system. Hiding that would, somewhat paradoxically, be easier if Members simply had to provide cash contributions. Providing in-kind contributions is harder for the Member States than simply donating cash. The in-kind management system needs a high interaction capacity from the Members who must raise their diplomacy skills, as well as their technical and scientific capacities, to make it work.

Another underlying strain that permeates across the above Member State relations, that four ITER interviewees commented on, is that the long negotiated in-kind contributions procurement agreements are not nimble. The original commitments are carefully guarded by Members who wish to protect their hard fought for national interests. The research signposts that the in-kind arrangements give the Members - if they choose to exercise it - more power to limit the availability of noble scope (described in sub-section 3.1.2) than a regular Large Engineering Project joint venture community would tolerate.

The regular ITER Configuration Control Board agrees changes to the technical baseline and the effect on associated systems and the contributing Members' in-kind deliverables. As I explained in sub-section 4.1.4., the associated value of the change is often long and hard negotiated and ultimately must be balanced against the Members' in-cash contribution. This balancing is to preserve the overall sharing ratios enshrined in the ITER Agreement (see Table 17). This effort consumes the energy of the central organisation staff and the Members' teams. The ISS MCB carries out the same balancing function when it keeps tally of the changes to the ISS Members' in-kind contributions. The large administrative burden is not carried out lightly; it is an *essential* feature of the contemporary Big Science international collaboration process.

This inherent lack of central control and overhead costs mean that the in-kind management system has several vocal critics within the Big Science project management communities. Maria Spiropulu, a physicist at Caltech and vice-chair of the American Physical Society (APS) Forum on International Physics sums up the frustration: 'of all the current international physics projects under development now, ITER receives the most comparisons to CERN, but the fusion project is years behind schedule and projected to be billions of dollars over budget…it tried to [carry out] the dream where there is an equal division of the responsibilities… the politics became more important than the project' (Lucibella, 2014:1). The inference is that construction of the reactor was split up among the Member States who picked different components to build, based largely on national interests, rather than collective efficiency. A criticism that can be countered by the notion that the Members intentionally shared the work in order to learn lessons from the design and manufacturing processes that they would all need for the follow-on national programmes. The recollections of Akko Maas and Harry Tuinder (ITER, 2012), that I covered in sub-section 4.2.1., indicate that the truth was somewhere between the two positions and was one of the reasons why the *common understandings* that underpin the ITER Agreement took over 20 years to finalise.

A note of caution was even applied to the idea of researching the entire topic by Tim de Zeeuw, the European Southern Observatory Director General from 2007–2017. In an interview for this research he emphasised the advantages of staying with an empowered central team approach: "while the science community could undoubtedly benefit from a study of in-kind and its consequences, we may not necessarily want to create guidelines or strategies that makes it easier to adopt given the weaknesses of IKM. The goal always should be to run projects with in-cash contributions."

Sub-Section summary

Given the range of difficulties it is reasonable to question the supposition that innovative funding should be included as an 8th pathway through and beyond gridlock. The overriding reason is straightforward and is the final one cited in sub-section 6.3.8.1: the in-kind arrangements have been pivotal in connecting and holding the Member States together. There is strong evidence (for example in sub-section 4.2.2. for ITER and sub-section 5.2.1 for the ISS) that it has been essential to the international collaborations both being established and surviving the project, economic and political turbulence that the long time-scales of SMPs inevitable span.

Inherent in provision of the in-kind contributions means that the Members also share the technological and financial *risks.* The Members must weigh up these extra responsibilities against the benefits to their home industries and research institutions. This research has shown that Member States generally decide that the latter prevails. Exceptions, where in-kind contributions are not taken up a Member State may be when that Member State assesses that it already has expertise in that area or where it considers the technological or programmatic risks of late delivery too high.

Evidence from the three case studies shows that the judgement on how much of each type of funding to provide will vary over time. For example, as trust builds within the community then the Member States may decide (as is the case with CERN and belatedly with ITER) to provide more authority to the centre with commensurate extra cash funding required to enable more autonomy in functions such as leadership, design authority, safety and host State regulatory matters.

Table 18 illustrates the key factors that participants must consider when embarking on large international SMP collaborations that involve contributions -in-kind and in-cash. It is possible to map on the table where the three SMP case studies fall across the three categories of 'High level of contributions in-cash to the Central IGO' (the left column), 'Appropriate blending of contributions in-cash and contributions in-kind to the Central IGO' (the middle column) and 'High level of contributions in-kind to the Central IGO' (the right column):

> *CERN can be seen as predominantly being in the central column* due to its start-up conditions being correct for the times and its expansion being judiciously managed by the Member States. Today, CERN benefits from having the appropriate mix of both cash and in-kind funding. It has enough cash [some critics would say an overly generous amount; see sub-section 6.1.2.,

Collation and examination of counterfactual evidence] to run the autonomous central functions that the CERN Council has granted it and enough in-kind contributions to get it through cash shortfall periods and keep non-Member states engaged.

ITER has been set-up to operate in the circumstances summarised by the right hand column. Currently, ITER is highly dependent on in-kind contributions, a situation which I have shown in sub-section 4.2.2. has advantages and disadvantages that both have to be actively managed. However, it is gradually moving to the centre ground as the Member States [interviewees would say grudgingly] allow more central autonomy to be established.

The ISS is also in the right hand column as it is a *de-facto* conglomeration of Members' in-kind modules and major equipment (text below Figure 12); an arrangement that has been managed with aplomb by the dispersed operational centres.

Tellingly, no case study is in the left column or has plans to try and move to that circumstance. The period when mainly cash funding is provided to a large international SMP Community collaborative endeavour of the scale of CERN, ITER and the ISS are long over.

In sum, this research, through the compilation and analysis of evidence from all three case studies has established a compelling case to add 'Innovative Funding' as a new, eighth pathway to *Beyond Gridlock* theory.

COMMUNITY ELEMENT	High level of contributions in-cash to the Central IGO	Appropriate blending of contributions in-cash and contributions in-kind to the Central IGO	High level of contributions in-kind to the Central IGO
INTER-GOVERNMENTAL ORGANISATION/ CENTRAL PROJECT TEAM	• More autonomy and nimbleness in decision making • More potential for unauthorised [by the Member States] mission creep	• Sufficient authority to tackle problems and combat external constraints is delegated to the centre • Sufficient project control levers are provided to the centre to work with Member States to control the project	• Increased project resilience; less likelihood that the project could be cancelled • Less central autonomy • Cumbersome decision making • High administrative burden to manage changes
MEMBER STATES	• Harder to receive national go-ahead and regular re-authorisation from home national funding agencies • Simpler collaborative effort required • Free riding easier [although responsible Member States will not take up the opportunity]	• Primacy of the Member States is sacrosanct protected in voting rights being retained in highest decision making body • Improved project performance and thereby better and more timely accrued results to the Member States	• Easier to receive national go-ahead and regular re-authorisation from national funding agencies • Increased benefits to home industry and institutions • More interfaces with central organisation and other Member States is challenging for configuration control and schedule adherence

Table 18; SMP Community, Central IGO Team and Member State factors positively and negatively affected by the level and blending of contributions provided in-kind and in-cash

Section Summary

The common and different mechanisms that have been used in each of the *Beyond Gridlock* pathways are mapped out against the three case studies in Table 19. The overview shows those pathways that are used extensively (Pathways 1, 4, 7 and 8), those that are used more by some than others (Pathways 2 and 3) and those that are not applicable or used sparingly (Pathways 5 and 6). Two pathways emerge as core requirements for major international collaborations to be initiated, maintained and delivered: firstly, shifts in major power core interests (Pathway 1) and secondly, the need for common shared goals for multiple diverse organisations and institutions to coalesce around (pathway 4). These are aided by use of Innovative Leadership and Funding (Pathways 7 and 8 respectively). This thesis has shown that it is through the *combination* of these pathways that substantial progress through gridlock can be made. This finding will now be taken forward into the next section of the Results Chapter covering common features of the SMP Communities.

Beyond Gridlock Pathway	Case Study 1	Case Study 2	Case Study 3
	CERN	ITER	ISS
1. Shifts in major powers core interests	Yes	Yes	Yes
	All collaborations were long prepared for and advocates successfully rode timely waves of political and strategic opportunity		
2. Autonomous and adaptive international institutions	Yes	Partly	Partly
	Highly autonomous and adaptive	Member States control/limit central autonomy	
3. Technical groups with effective and legitimate processes	Yes	Partly	Partly
	Infrasructure and Experiment Teams work seamlessly	Central design authority hard fought for and interface management achieved despite difficulties	
4. Multiple, diverse organisations and institutions coalesce around common goals/norms	Yes	Yes	Yes
	All have high focality and legitimacy		
5. Mobilization of domestic constituencies	No	Partly	No
	Central organs do actively encourage healthy domestic constituencies but not in the sense of application of this *Beyond Gridlock* pathway		
6. Civil society coalitions with reformist states	No	No	No
	This pathway does not apply to SMP Communities		
7. Innovative Leadership	Yes	Yes (Belatedly)	Yes
	Sound governance and light-touch leadership	Slow establishment of effective central leadership	Collaborative operational leadership
8. Innovative Funding	Yes	Yes	Yes
	All use a combination, at different levels, of contributions in-cash and in-kind to fund the project		

Table 19; Summary of Beyond Gridlock pathways and their mechanisms applicability to the case study SMPs (adapted from Hale and Held, 2017)

6.4: Common Features of the three SMP Communities

Here I summarise four common features of the case study SMP Communities that have emerged during the research. They are not lessons learned *per se*, but rather collectively, they help explain how the SMP Communities have overcome gridlock and delivered results. In doing so they serve to complete the answer to the research question.

Feature 1: Each SMP has at its core a meaningful endeavour that generates and maintains strong binding forces between the major powers and the individuals involved.

The case study SMPs are tackling some of the most difficult problems that face the world: increasing fundamental physics knowledge; providing an important step in developing carbon-free, nuclear fusion commercial power generation and undertaking space habitation, experimentation and exploration.

The benefits of these endeavours are not necessarily seen early on; these are long term considerations. For example, scientifically, the field of fundamental physics research is important because it provides knowledge, whose immediate consequences are unknown, but which is foreseen to be potentially momentous. This makes the projects harder to sell to a political class who crave short term results to bolster popularity and to a sceptical public who can easily point to other more pressing immediate societal needs.

Long term vision is needed to reach the decisions to back these projects. Although the idea of developing a large international collaboration in fusion research was the last agenda item in the Reagan-Gorbachev *Fireside Summit* in 1985 Geneva summit and the last entry to be agreed by the parties for inclusion in the joint *communiqué*, in the end it was the one with the farthest reach (ITER Newsline, 2015a). This thesis has shown that the SMP advocates appreciate that this long-term vision needs to be expertly nudged into the mainstream policy decision making process. They have learned that sustained backing will not be achieved by the sudden seizing of political agendas.

I showed in sub-section 5.3.2., that while national agendas will always be present in projects of this magnitude, the driving factor that trumps these is the collective higher-level goal. Interviewees were unanimous that these are ventures which generate high emotions with one or two even suggesting that the projects have a soul of their own. One Executive level interviewee and veteran of the cause to bring the vision into reality stated: “there are many great science projects; but this one is mine.”

An example of the passion that these projects generate is the way that the Communities mark their project inaugurations. Like LEPs they may plant a tree or lay a foundation stone; or in the case of the ISS deliver a first module in low earth orbit! What sets them apart is that they also feel the need to emphasise and celebrate the meeting of minds between major powers. At the signature of the ITER Agreement on 21st December 2006 the host of the event, President Jacques Chirac of France, noted that the occasion marked a memorable moment in the history of science: ‘Exceptional for its scientific ambition to harness the sun´s power to take up the challenge of ecological energy, and exceptional for its international scale: the unprecedented association of seven major partners from the North to the South. It is the hand held out to future generations, in the name of solidarity and responsibility’; rousing rhetoric that I contend would have seemed embarrassingly out of place for something of less importance. In this research I have cited similar speeches by President Kennedy in his address to the UN General Assembly calling for a joint Moon Landing mission with Russia (JFK Presidential Library, 1963) and President Reagan in his address to a Joint Session of the Congress on 21st November 1985 where he extolled the benefits of fusion energy and urged international collaboration (Reagan Presidential Library, 2017a). These moments matter, they help legitimise the projects, raise their profile beyond the ordinary and, as the field work revealed, are cited by the project participants to this day.

The fact that these events linger in the minds of those involved is exemplified by William Flynn Martin, who served as Special Assistant to President Reagan for National Security Affairs in the mid-1980s. He wrote in 2012 to Alvin Trivelpiece, the former Director of the Office of Energy Research at the US DOE, evoking the spirit of the times: ‘I then gave my okay for the project and it was the only tangible product agreed upon at the first and historic Geneva Summit of 1985 between Reagan and Gorbachev. I was at the meeting, as you know, and I recall meeting Velikhov who was wearing a Princeton tie. Interestingly, the resulting joint *communiqué* concludes with the sentence "The two leaders emphasized the potential importance of the work aimed at utilizing controlled thermonuclear fusion for peaceful purposes and… advocated the widest practicable development of international cooperation in obtaining this source of energy, which is essentially inexhaustible, for the benefit for all mankind." By the way, I enjoyed our celebration with Velikhov years later (with Nick and Chris pouring the vodka) when Velikhov toasted us as the “fathers of ITER.” Indeed, the three of us were the fathers of ITER – especially the two of you!’ (Martin, 2012).

The notion of high meaningfulness in the mission is also encapsulated by Maria Spiropulu, a physicist at Caltech, vice-chair of the American Physical Society (APS) Forum on International Physics and a member of the CMS collaboration at CERN: 'Being a fundamental physics lab inherently played a big role in pushing competing nations to work together…the goal is the same, and it's very clear that it is fundamental research …. That alleviates a lot of the conflict…because we're all going towards the same fundamental goal and the same dream (Lucibella, 2014:1).' The astronaut, Ron Garan also summarised the situation well: 'If you create something meaningful then the inevitable bumps in the road do not derail the partnership' (Garan, 2015: 43).

Feature 2: The SMP's benefit from having creditable start-up conditions

Lord Browne of Madingley (2013: 3), points out that time spent on start-up considerations for major projects is never wasted: 'the lowest standards that are set at the start of a project are the highest standards that can be expected for the rest of the project. As one contracts and procurement interviewee put it [regarding a lengthy negotiation] "the pain was worth the certainty gain." Here I highlight two start-up areas that were seen across all the case studies as vital in achieving and maintaining a successful international SMP collaboration: first-class founding documents and choosing the site wisely.

Founding Documents

Big Science project negotiators certainly need to agree clear and succinct technical specifications. A need amplified by the fact that they have to distribute the work amongst themselves and allow the complex parts to be integrated and tested in the construction phase. The achievement of a technical baseline is far from easy in these ground-breaking endeavours. The problems with a grossly overestimated maturity of design was attested by ITER interviewees in Section 4.2.2. This optimism in the baseline certainly contests the position that the SMPs are invariably exemplars of first-class start-up conditions. However, these types of problems, though painfully time-consuming to address were solvable.

Negotiators of major international collaborations need to also provide a series of pseudo political assurances to Members in order to gain their support. These assurances are very difficult to correct once the agreements are signed as often, they have been reached in partisan trade-off's with other Members. The belief that 'nothing is agreed until everything is agreed' certainly applies to SMP founding agreements. That is why Member States are highly reluctant to re-open the CERN Convention, the ITER Agreement or the ISS IGA. Indeed, the only amendment that has been made to any of these was to the CERN Convention when in 1971 a second laboratory administrative unit was added; this change was reversed some 10 years later.

Member States need certainty on these issues not least in order to sell the founding documents to their domestic constituencies. Domestic harmony is needed to achieve national ratification. Essential areas include cast iron certainty that the primacy of the state will be respected [through equal representation and voting rights enshrined in cogent legal articles], that protection of background intellectual property is protected [through adherence to international standards] and that that there is unambiguous legal jurisdiction, dispute resolution and cross-waiver liability provisions. For ITER (and the Canadian contribution to the ISS), the negotiators also set punitive withdrawal penalties. Crucially, attachments to the main agreements also need to entice the Members with the prospect of good quality, contributions in-kind (that will create and/or protect home based industries and institutions) and show in the financial agreements that there will be scrupulously fair, NNI or GDP based, sharing of contributions in-cash.

The SMP Communities have learned that there is no need to start from scratch; successful IGO collaboration documents are available that can be tailored to new circumstances. As James Gillies, former Head of Communication for CERN points out: “The governance model is one of the things that really makes CERN work… There are several more [such collaborations] now, and they’ve based their models on CERN.” The project to build a synchrotron light source in Jordan has brought together nations normally hostile to one another, including Israel, Iran and the Palestinian Authority. Chris Llewellyn Smith, a previous CERN DG and President of the SESAME Council commented that: “SESAME is modelled on CERN conceptually… the SESAME statutes are modelled on the CERN Convention, as is the governance structure. They have worked very well in the circumstances.” The International Linear Collider (ILC) is in the very early stages of development. The Nobel Laureate Barry Barish is the Director of the global design effort for the ILC and pointed out, in a lecture at the 2018 annual conference of the American Association for the Advancement of Science, that this project also uses CERN as a guide. ‘For something like a new international collaboration, this serves as a well-made model that all we have to do is tweak.’ (ILC, 2019).

Site Selection

Geographical features such as low susceptibility to earthquakes and high availability of natural resources play an important part in the selection of SMP sites. In astronomy there are clusters of ground-based observatories that are in remote areas such as the Atacama Desert of Chile (Domain 2 in the selected overview of SMPs at Appendix A). I have shown for the case study SMPs that political considerations also feature in deciding which Member will host the concern. The ramifications of this start-up decision are many due to the trade-offs that have to be made for other potential hosting Members to give way (ITER site selection negotiations at sub-section 4.2.1). Other tangible factors emerged during the research that have impacted on the selection of a site. Reliable international air travel links, a safe welcoming environment and a good international school, can all improve Member buy-in through attracting and retaining key staff and their families. It is no chance co-incidence that both Geneva (CERN) and Provence, France, (ITER) are eminently suitable locations to attract the best scientific and technological talent (Ecole International PAC, 2018).

Feature 3: The Member States in all three SMPs consistently exercise consensual governance

As I have shown in the three case study sections (3.2, 4.2 and 5.2) on managing constraints, fairness to all parties must outweigh any short-term political or economic gains in order to keep the collaborations intact. Particularly during times of project stress, consensual governance exercised through respect for the primacy of the state is vital. Dominant members have shown leadership in foregoing weighted voting wherever possible and seeking agreement by consensus on all major issues; the overriding priority being to keep the collaboration itself intact.

A shared mission alone cannot sustain a laboratory for sixty-five years, and CERN's administration is designed to accommodate the Member States' scientists and politicians as much as possible. The ultimate authority for the laboratory rests in CERN's governing Council. Each Member State gets two seats: one reserved for a scientist and the other reserved for an administrator (sub-section 3.1.3.). One Member, one vote has been maintained throughout CERN's existence and the Member States have appropriately empowered the central management team. The former DG, Llewellyn Smith summarised the position: "The governing structure was pretty hands-off… there was never a tendency to micromanage; they let the CERN management just get on with it."

For ITER (sub-section 4.1.3.) the Members are both Stakeholders (through the Council) and Suppliers (through the in-kind contributions they are responsible for). This is a dilemma that must be sensitively handled if the legitimacy of the Council is to be maintained. The project delays that the Council has also had to deal with have added to the pressure on them to collectively keep the project on track. All ITER interviewees agreed that the situation in this regard has improved since the early days of the project. Publicly at the very least, consensus has prevailed as without it the project's critics would have exploited any major conflicts between the Member States.

For the ISS (section 5.3) Governance of the project is inexorably linked to the leadership that the dominant Member State has provided. As I explained in sub-section 5.1.1 the lead role of the USA in the management arrangements was accepted by all the parties when they agreed to take part. The international reputation of the US to deal with its partners fairly has therefore been under scrutiny from the outset. Interviewees attested that reaching consensus with the other Space Agencies has been at the centre of NASA's approach to ISS operations throughout the project's life-cycle (sub-section 5.3.1.). The success of the US in doing so has elevated the ISS to become an iconic beacon of what can be done when there is a collective will for peaceful collaboration.

A further reason for the members states tendency to exercise consensual governance stems from the supporting arguments for the new pathway through gridlock detailed in sub-section 6.3.8: Innovative Funding. The need to maintain the institutions and industries in their own territories bound by the project's detailed in-kind contribution commitments is an important consideration for the member states. Consensus decision making to maintain the long negotiated balance of contributions embodies a practical structural realism. It fits in well with the neo-realism theory (sub-section 1.1.2), where Buzan, Jones and Little (1993) raise the importance of interactions between States to understanding how the modern world works.

Finally, consensus is maintained through a need for community survival. As explained in sub-section 4.3.2.1., ITER interviewees all emphasised that the project's focality added to the pressure on the community to deliver. There is a realisation that the set of circumstances that established this nuclear collaboration (section 4.1: The ITER Agreement) would be very difficult to repeat in today's increasingly nationalistic political climate. There will therefore be no second chance for generations; failure is not an option for the planet or the fusion community. National interest from non-European ITER member states also features whereby they want to avoid the possibility of Europe taking over the remnants of the project should the international collaboration collapse.

Feature 4: The management teams in all three SMP communities exercise a light-touch leadership approach and inspire an inclusive organisational culture

The SMP communities are a product of complex social interdependencies and reflect ongoing relationships between their aims and the constraints of the everyday world. Consequently, the IGOs that manage the projects are estimable examples of an epistemic community of knowledge-based experts. They comprise groups of motivated people who are highly employable in their SMP Communities and in the broader science and technology sectors. It would be unfair to label them as high maintenance employees, but they are certainly a group who need special considerations with respect to working conditions and being given the freedom to solve problems as they see fit.

The IGO leadership employ a light-touch leadership management style with international staff and visiting external collaborators. All ideas and contributions are considered regardless of what level they have originated from, whatever nationality the person is or which Member State organisation or institution the person has originated from. Nurturing staff to accept the principle that international collaboration is normal and fostering the right cross-cultural attitudes is essential in the international environments that the SMP Communities occupy.

6.5: Contributions

This thesis has been driven by the research problem detailed in sub-section 2.2: *How do global SMP Communities achieve their effective collaboration pathways with Member States?* Chapters 3, 4 and 5, addressed this question for each case study and in section 1 of this chapter, I summarised, using the framework of the three hypotheses, the findings. In section 2, I addressed the first of the two related research sub-questions: *do the subject SMP Communities utilise common diplomatic approaches in negotiating their founding arrangements and functioning in a collaborative way?* by showing to what degree each of the *Beyond Gridlock* pathways are used by the case studies.

In this section, I consider the second related research sub question: *what - if any - are the political lessons learned by the subject SMP Communities that may provide clues in advancing global collaboration to overcome gridlock in other domains?* In answering this question, I will suggest two contributions to knowledge.

Ron Garan in his 2015 book *The Orbital Perspective* asks a number of searching rhetorical questions of his readers: 'How did we go from those early days of mistrust and suspicion to building and operating the ISS? What was the secret ingredient that enabled a coalition of fifteen nations to work together systematically, in a fully integrated manner, to construct and operate the most complex structure ever built in space? Is there something we can learn from how the members overcome differences and cultural misunderstandings in order to accomplish remarkable things together? And can we use these same techniques to reach agreement on things such as alleviating poverty, mitigating climate change, or achieving peaceful solutions to long-term conflicts?' He also somewhat challengingly suggests that you do not have to be in orbit in the ISS to have the orbital perspective he espouses.

Garan, in answer to the questions he posed, suggests several lessons learned from his ISS experience (Garan, 2015: 35, 39 and 42), here I collate them and add a short note in parenthesis of where my research has revealed similar cases:

- "Be in for the long run" [use of Pathway 1; shifts in core interests where nation states agreed to make long-term legal commitments through international conventions, treaties and agreements];
- "Plan for incremental collaboration" [use of Pathway 2, autonomous and adaptive international institutions];

- "Establish relationships and build trust. This is made more difficult by changes in staff, ROSCOSMOS is more stable than NASA in that respect" [use of Pathway 3, technical groups with effective and legitimate processes showed the importance of fostering expert mini communities who are the backbone of the communities];
- "Effective information sharing, and communications is important" [use of Pathway 4, the focality sub-sections of each case study chapter echoed the importance of this];
- "Check pride at the door, solutions can come from anywhere" [use of Pathway 7, innovative light-touch leadership that is particularly prevalent at CERN where scientific and/or technological solutions are encouraged from anyplace and any level in the organisation];
- "Live up to commitments" [use of Pathway 8, innovative funding that helps provides resilience in overcoming external constraints].

This cross-refencing to Garan's worthy list of lessons learned is reassuringly coherent but is general in nature. I will now suggest two contributions that have emerged from this thesis that are worthy of consideration by academics who study global gridlock. The suggestions should also be of interest to diplomats, negotiators and management teams involved in major international collaborations in other domains. In doing so, it is not anticipated that they provide a universal panacea to the wide-ranging phenomenon of global gridlock, but nevertheless are thought provoking ideas.

Contribution number 1: Global communities need to exploit any opportunities provided by a change in major powers' core interests to establish their endeavours

Advocates of major international collaborations need to take advantage of political waves of change, when major powers shift their core interests to advance their agendas. Communities need to have allies of the necessary calibre in key positions in order to influence policy makers and maximise the timing advantage. Ingenious preparation by the SMP Communities included positioning key respected individuals within influential circles of policy makers.

I showed in section 3.1 that CERN was first conceived in the late 1940s as Europe was still recovering from World War II. Fascism and war had depleted most of the continent's resources and many of the top scientists had fled to the United States. CERN did not triumph over rival science laboratory concepts by chance; the fundamental physics community made their own luck. As I showed in sub-section 6.3.1. a series of scientists joined forces, put aside national interests and made it happen.

French physicist Louis de Broglie first proposed a multi-national European lab in 1949. After years of lobbying spearheaded by Isador Rabi, a Nobel laureate and the U.S. envoy to UNESCO, twelve European nations came together to sign the convention, officially forming CERN in 1954. “The physicists needed CERN to work in order to be able to participate in frontline particle physics; so, they felt compelled to make it work,” said Christopher Llewellyn Smith (CERN DG from 1994 to 1999) in an interview for this research. At the time of CERN’s founding, the United States was emerging onto the global scene as a major leader in scientific research. European physicists wanted to compete, but no single country could match the resources of the emerging superpower. “If Europe wanted to do high energy physics, the only way is by having governments collaborating with each other because it’s such an expensive field…pooling resources is the best way.… That’s the only way they’re going to be able to afford it.” said John Krige (a historian at Georgia Institute of Technology who specializes in the history of CERN) in an interview for this research. It was high-level strategic lobbying by like-minded individuals who had personal relationship developed over decades that held the key.

For ITER, as I showed in sub-section 4.1., the nuclear fusion community had passionate advocates who could directly influence the US administration and the USSR leadership. Evgeny Velikhov had long-standing good relations with counterparts such as Michael Roberts (DOE) and Charlie Newstead (State Department) in the USA and was instrumental in establishing a joint approach with them. The ITER Agreement took 21 years to negotiate from the Reagan-Gorbachev *Fireside Summit*, but it would never have gotten under way without the expertise of Velikhov and his US counterparts to have the joint commitment to develop fusion included in the final summit joint *communiqué*.

For the ISS, sub-section 5.3., contacts between US and USSR space exploration practioners had been steadily increasing from the, détente inspired, first joint Apollo-Soyuz mission. Personal relations between the US and USSR space communities developed and trust between the two camps was steadily reinforced. This trust gave credibility to the idea of inviting Russia to take part in the ISS when the opportunity came along in the late 1980’s. ISS advocates successfully canvassed the cautious officials in the US State Department to, somewhat counterintuitively, collaborate with the Russians in a domain that had seen fierce Cold War rivalry.

Contribution number 2: For a meaningful global collaboration to be agreed and maintained, contributing Member States must agree the correct balance of contributions in-cash and in-kind

The case for inclusion of Innovative Funding, to *Beyond Gridlock* theory was made in sub-section 6.3.8. What is important to stress here is that the set-up phase needs to take as long as necessary to stipulate the in-kind deliverables, time-scales and relative value. As I showed in Table 17 the suite of high level documents of all three case studies include those that detail the sharing of the Member States' contributions. The funding of major international collaborations needs a balanced mixture of in-cash and in-kind contributions. The skill of the negotiators is to ensure that there are enough cash contributions to the central entity to let it function effectively and enough in-kind contributions to allow the Members to maintain backing for the project in their home territories. I also showed in Table 18 that the degree of one type of funding versus the other depends on the level of autonomy that the community wishes the central entity to have.

For CERN, Members contribute to a central fund for the infrastructure of the Laboratory as a whole. However, the embedded experiments are not funded from central cash funds but rather by in-kind contributions of those taking part in that research. This means that while the LHC was built by CERN using the money contributed to the central fund, the four giant detector experiments were funded, designed, and built by independent collaborations of nations. This way, if one falls behind, it does not necessarily mean the entire high energy research effort will suffer. Many interviewees attested that CERN has developed the optimum balance between the two types of funding.

The task of providing for and promoting cooperation among the diverse group of ITER Members was a challenge during the negotiations that continues to this day. Not least in the difficulties facing the central ITER Organisation was the balancing act of keeping Members content with their respective work-share and project progress while exercising actions to maintain that progress through the Members' own dispersed organisations.

For the ISS, the nature of the construction is that the Members provide their respective modules to the central entity. It is a consummate in-kind jigsaw puzzle assembled and operated in space by remarkable co-ordinated efforts, not least of the universally respected astronaut corps. As I showed in sub-section 5.1.4., there are central cash contributions for the coordinating MCB body but only to the level necessary for its limited functions. There is no IGO, DG or large international staff to fund. It is to the ISS Communities credit that despite this imbalance they have made the collaboration work.

The three SMP communities have exercised consummate *power relations at a distance* that David Held highlighted as one of the requirements of managing globalisation (Held, et. al., 1999). The figures at the start of each case study chapter (Figure 4 for the CERN Community, Figure 7 for the ITER Community and Figure 10 for the ISS Community) illustrate the breadth of membership of the communities at IGO level. The Member States involved are the power houses of the industrialised world; power houses who fiercely compete with each other in many other domains.

The in-kind management system that the SMP Communities employ demands close cooperation between the Member States. There is a need for constant dialogue and tight interface management. There is no room for ambiguous political positions or free riders. The mastery of the in-kind management system is far from easy and adds a level of effort to the Member States that they would not need with a simple delivery of in-cash contributions. However, once mastered and under control it is an important reason for them staying bound together.

CONCLUSION

Today, the world news, amplified by social media, is dominated by continuing armed conflicts, migration and environmental problems that span borders. Many of these grave problems are also insidious in nature: climate change inexorably threatens the populations of low lying geographic areas and increases the frequency and depth of extreme weather events; higher resistance to antibiotics raises the prospect of a future global pandemic being an existential threat to human life, and tensions between the populations of global developed nations and those of developing nations adds to the number and ferocity of regional conflicts.

The urgent and essential need to make progress in several domains means that advocates of progress run the risk of jumping at any solution or struggling through painful workarounds, both of which courses of action will no longer do. There is a desire from diplomats, subject matter experts and the public to improve performance and to find a way through these impasses. There can be no more important question in this field than what could work to improve global collaboration.

Looking up at the ISS provides a welcome respite to this gloom and offers inspiration to many as a beacon of higher level collaborative human behaviour. Similarly, CERN inspires people that there is a better way to collaborate in peace on the fundamental questions of nature. ITER provides hope of a carbon-free commercial power source for the benefit of mankind.

Robert Keohane in *After Hegemony* (1984: 12) makes the point that, once the arguments have been won and the effort has been made to bind major powers and establish a collaboration, then hegemony is less important for the continuation of cooperation than for its creation. I would contend that the case study SMPs show that if we can create a global collaboration of major nations around meaningful endeavours, knowing the strength of a free and broad international collaboration of people with common beliefs and sharing a powerful vision, then anything is possible. Keohane was also correct when he said: ‘cooperation is not easy’ and this thesis confirms that this is certainly true for Big Science projects. The technical and engineering challenges of designing, constructing and operating facilities that are at the outer limits of what today’s technology can achieve by multiple partners working together make them extraordinarily difficult to manage. This degree of difficulty is present even before factoring in the international relations considerations of major nuclear powers who comprise the core of the membership. All of this makes their self-evident success even more noteworthy.

In this thesis I have described how SMPs achieve their collaborations amongst states that are adversaries in other domains. I have shown where they share common features including having at their core a meaningful endeavour that generates buy-in, binds the major powers together and sustains their collaborative spirit through major political and programmatic constraints. This sense of meaningfulness also transfers to the individuals who take part and gives them a sense of pride in themselves and their communities. Utilising science diplomacy approaches in negotiating credible founding arrangements is also a common feature, together with exercising consensual governance. All of this does take time and leadership, and it requires the use of multiple *Beyond Gridlock* pathways to keep on track.

Two contributions emerged for consideration by others in the International Relations field. The first shows that communities should be primed and ready to exploit shifts in major power core interests in order to launch new endeavours and the second is how an ingeniously designed funding system allows Member States to commit to projects, permits the central IGOs to operate effectively and, at the same time, maintains support in the Member States' homelands.

Further Research

There are four areas that are ripe for further research:

First suggestions arise out of the factors covered in Research Limitations (section 2.5). As Appendix A, Selected Overview of SMPs and their Communities shows, a suitable area for further research is to add SMP case studies for detailed analysis. With more time, a quantitative survey of SMPs could also be conducted to strengthen the available data (Booth, Colomb, and Williams, 2008: 81). This expanded pool of data could help answer the question of whether a new type of SMP structure could fundamentally change the science business landscape for the better.

Secondly, the hypotheses could be tested in other domains. Initial candidates for non-science related case studies include:

- The Universal Postal Union which coordinates global postal policies in addition to the worldwide postal system. It was founded in 1874 and incorporated into the UN in 1945 and is based in Bern, Switzerland;

- The International Civil Aviation Organisation which is responsible for implementing the principles of the Convention on International Civil Aviation to ensure the safe and orderly development of global civil aviation. It was founded in 1947 and is based in Montreal, Canada;
- The Intergovernmental Panel on Climate Change (IPCC) which is the UN body for assessing the science related to climate change. The IPCC was created by the UN Environment Programme and the World Meteorological Organization (WMO) in 1988 and has 195 Member countries;
- The International Maritime Organization which is responsible for managing and regulating international shipping. It was founded in 1948 and is based in London, UK and
- The Arctic Council which is the IGO forum promoting cooperation, coordination and interaction among the Arctic States [Canada, Denmark; representing Greenland and the Faroe Islands, Finland, Iceland, Norway, Russia, Sweden and the United States] and was formally established by the Ottawa Declaration of 1996. An agreement on Enhancing International Arctic Scientific Cooperation was signed in 2017.

Thirdly, the applicability of the eighth pathway, concerning funding, to other domains outside of this research is unknown. A thorough systematic investigation of the advantages and disadvantages of the in-kind management system as it applies to intergovernmental collaboration is needed. For example, could academics and practioners combine to design an in-kind management system to help overcome constraints and improve collaborative performance for the United Nations?

Fourthly, if the premise of the first contribution is accepted, that *“Global communities need to exploit any opportunities provided by a change in major powers’ core interests to establish their endeavours”* then it is worth considering what the next major wave may be. I would argue that, given the urgency of addressing the wicked problem that face the very existence of humankind, to simply await the next wave of change that may galvanise global collaboration is too complacent. Instead, research could be focused to determine how an *artificial wave* of change could be designed in each domain to provide a tailor-made plan to overcome global gridlock that major powers, expertly nudged by strategically placed advocates, could then rally behind.

APPENDICES

Appendix A: Selected Overview of SMPs and their Communities

An overview of international SMPs within their broad science community domain is shown below. The selection criteria for SMPs, together with the case study selection justification is described in Section 2.1. The three case studies are highlighted in yellow. The nomenclature used in this overview is the project title, usual abbreviation and (where applicable) the host State and/or leading State.

Domain 1: High Energy Physics Community

- European Organization for Nuclear Research (CERN), Switzerland/France; (CASE STUDY ONE)
- Deep Underground Neutrino Experiment (DUNE), USA;
- International Linear Collider (ILC), Japan;
- Future Circular Collider (FCC), Switzerland/France;
- Synchrotron-light for Experimental Science and Applications in the Middle East (SESAME), Jordan;
- Facility for Antiproton and Ion Research GmbH (FAIR), Germany and
- European Spallation Source (ESS), Sweden.

Domain 2: Ground Based Astronomy Community

- European-Extremely Large Telescope (ESO – E-ELT), Germany/Chile;
- Southern African Large Telescope (SALT), Namakwa, South Africa;
- Square Kilometre Array (SKA), UK, South Africa and Australia;
- Atacama Large Millimetre/submillimetre Array (ALMA), Germany/Chile;
- LIGO/VIRGO; USA and Europe (Italy) and
- Five-hundred-meter Aperture Spherical Telescope (FAST), China.

Domain 3: Global Health/Life Sciences/Genome Mapping Community

- International Human Cell Atlas Initiative, US and worldwide;
- Global BRAIN Initiative, US and worldwide;
- Human Genome Project, worldwide;

- European Life Sciences Infrastructure for Biological Information, worldwide;
- European Molecular Biology Laboratory, Germany;
- International Health Partnership, UK and worldwide;
- International Mouse Phenotyping Consortium, worldwide and
- National Ecological Observatory Network, USA.

Domain 4: Nuclear Fusion Community

- International Thermonuclear Experimental Reactor (ITER); IGO HQ, France; (CASE STUDY TWO)
- High Power laser Energy Research facility (HiPER), UK;
- EUROFusion JET, UK and
- National Fusion Devices worldwide.

Domain 5: Space Science/Earth Observation Community

- International Space Station (ISS); US (NASA), Canada (CSA), Europe (ESA), Japan (JAXA) and Russia (ROSCOSMOS); (CASE STUDY THREE)
- Copernicus; EU-EC;
- European Organisation for the Exploitation of Meteorological Satellites, EU-EC;
- Galileo; EU-EC and
- In-Service Aircraft for a Global Observing System; EU-EC.

Domain 6: Oceanography/Antarctic Studies

- Antarctic Treaty; 12 original Members States from 1959 that retain voting rights: Argentina, Australia, Belgium, Chile, France, Japan, New Zealand, Norway, Russia (Soviet Union at time of signature) South Africa, UK and the USA plus 41 other, non-voting, Member States that later acceded to the Treaty;
- Ocean Observatories Initiative, USA and worldwide;
- 'Citizens' Observatory for Coast and Ocean Optical Monitoring/EyeOnWater, worldwide;
- Deep Sea Scientific Drilling Vessel, Japan;
- Ocean Networks, Canada;
- International network for scientific investigation of deep-sea ecosystems, worldwide and
- Naval Enterprise Partnership Teaming with Universities for National Excellence, USA.

Appendix B: Interviewee Details

The methodology for field data collection is described in sub-section 2.4.2. Data was gathered through over seventy field work interviews: around twenty for each of the case studies and around ten from the general field of Big Science projects and *Science Diplomacy*. This data was supplemented by previous expert panel narratives from interviewees that were available on-line.

This project has been reviewed by, and received ethics clearance through, the Durham University Research Ethics Committee. All interviews were conducted within the considerations of informed consent, confidentiality and anonymity. Any participant that has exercised the right for anonymity has had that view respected and complied with. In circumstances of anonymity the quotations have been included with agreed descriptions of the role of the person. Recording were made of some interviews for transcription purposes only. In accordance with the agreements on the handling of data, *all* recordings have been deleted on submission of this thesis.

The alphabetical list below contains those interviewees who have agreed to be named and/or already have their comments publicly available, where the latter is the case the data is cited in the bibliography. The list shows the interviewees current position and/or former role or affiliation to a case study community. Some interviews have no direct affiliation to a case study community but have been interviewed because of their overall SMP and/or science diplomacy knowledge; in these cases, they are recorded as 'other' in the case study column. The details of the remaining interviewees are retained confidentially, and their names and affiliation are shown as *Anon* (to indicate the entry has been anonymised).

	Name		Case Study	Role	Comments
1	Anon	Anon	Anon	Departmental Safety Officer	Field Work interview
2	Anon	Anon	Anon	Member State Audit Team Member	Field Work interview
3	Anon	Anon	Anon	Scheduler	Field Work interview
4	Bernard	Bigot	ITER	Director General	Archive Video Testimony to US Congress (see bibliography)
5	Ken	Blackner	ITER	Deputy Head of Department for Operations	Field Work interview
6	Anon	Anon	Anon	Head of Systems Functional Integration	Field Work interview
7	Maurizio	Bona	CERN	Senior Advisor for Relations with Parliaments and Science for Policy	Field Work interview
8	Micheline	Calmy-Rey	Other	Former Foreign Minister of Switzerland (2003 to 2011)	Archive Video contribution to UNOG/CERN conference (see bibliography)
9	Laban	Coblentz	ITER	Head of Communications	Field Work interview
10	William	Colglazier	Other	Fourth Science and Technology Adviser to the US Secretary of State (2011 to 2014)	Field Work interview
11	Anon	Anon	Anon	Former Ombudsperson	Field Work interview
12	Anon	Anon	Anon	International Relations Team Member	Field Work interview
13	Anon	Anon	Anon	Member State Legal Advisor	Field Work interview
14	Anon	Anon	Anon	Project Management Consultant	Field Work interview
15	Tim	de Zeeuw	Other	Former Director General of the European Southern Observatory (2007–2017)	Field Work interview
16	Anon	Anon	Anon	Technical Section Leader	Field Work interview
17	Anon	Anon	Anon	Public Outreach Team Member	Field Work interview
18	Alexander	Gerst	ISS	Geophysicist and Former ISS Commander (Expedition 56)	Archive BBC Radio Interview (see bibliography)
19	Fabiola	Gianotti	CERN	Director General	Archive Video contribution to UNOG/CERN conference (see bibliography)
20	Anon	Anon	Anon	Head of Contracts and Procurement Division	Field Work interview
21	Anon	Anon	Anon	Council Member	Field Work interview
22	Anon	Anon	Anon	Project Officer	Field Work interview
23	James	Gillies	CERN	Strategic Planning and Evaluation Former Head of Communications (2003 to 2015)	Field Work interview
24	Sabina	Griffith	ITER	Senior Communications Officer	Field Work interview
25	Henry	Hertzfeld	ISS	Director of the Space Policy Institute Elliott School of International Affairs, GW University	Field Work interview

	Name		Case Study	Role	Comments
26	Rolf	Heuer	CERN	Former Director General (2009 to 2015)	Archive Video contribution to UNOG/CERN conference (see bibliography)
27	Anon	Anon	Anon	Member State Negotiator	Field Work interview
28	Anon	Anon	Anon	SMP Archivest	Field Work interview
29	Norbert	Holtkamp	ITER	Former Deputy Director General (2006 to 2009)/ currently Deputy Director at SLAC, California	Field Work interview
30	Anon	Anon	Anon	Council Secretary	Field Work interview
31	Anon	Anon	Anon	Project Management Consultant	Field Work interview
32	Anon	Anon	Anon	Member State Negotiator	Field Work interview
33	Anon	Anon	Anon	Member State Advisor	Field Work interview
34	Anon	Anon	Anon	SMP IGO Director	Field Work interview
35	John	Krige	Other	Science Diplomacy Historian and Author	Field Work interview
36	Sergei	Krikalev	ISS	ROSCOSMOS Cosmonauts Director	Archive Video Interview to Česká televize (see bibliography)
37	Don	Lessard	Other	Emeritus Professor of International Management MIT Sloan School of Management, Cambridge, USA	Field Work interview
38	Chris	Llewellyn Smith	CERN	Former Director General (1994-1998)	Field Work interview
39	Anon	Anon	Anon	US Science Diplomacy Academic	Field Work interview
40	Anon	Anon	Anon	Head of SMP Member State Organisation	Field Work interview
41	Anon	Anon	Anon	Science Advisory Committee Member	Field Work interview
42	John	Logsdon	ISS	Director of the Space Policy Institute, DC/ Former member of the Columbia AIB	Field Work interview
43	Michael	Loughlin	ITER	Co-ordinator for Nuclear Analysis and Shielding/ Deputy Leader of the Nuclear Integration Unit	Field Work interview
44	Timothy	Luce	ITER	Head of Science and Operations Directorate	Field Work interview
45	Akko	Maas	ITER	Science Engineering Officer	Archive ITER Video Interview (see bibliography)
46	Mark	McCaughrean	ISS	Senior Advisor for Science & Exploration European Space Agency	Field Work interview
47	Anon	Anon	Anon	Head of External Relations	Field Work interview
48	Michael	Møller	Other	Director-General of the United Nations Office at Geneva	Archive Video contribution to UNOG/CERN conference (see bibliography)
49	Kenji	Nakano	Other	Chief General Assembly Affairs Branch Department of the General Assembly	Field Work interview
50	Markus	Nordberg	CERN	Head of Resources Development Development and Innovation Unit	Field Work interview

	Name		Case Study	Role	Comments
51	Ellen	Ochoa	ISS	Former Director of the Johnson Space Centre/ ISS Commander	Archive NASA Video Interview (see bibliography)
52	Anon	Anon	Anon	Council Secretariat Member	Field Work interview
53	Patrick	Owen	CERN	Physicist and sub-group leader within the LHCb experiment team	Field Work interview
54	Alexander	Petrov	ITER	Head of Communications Russian Federation Domestic Agency	Field Work interview
55	Richard	Pitts	ITER	Science and Operations Team Section Leader	Field Work interview
56	Michael	Roberts	ITER	Former Director of International Programs Office of Fusion Energy, US DOE/lead US negotiator	Field Work interview
57	Ned	Sauthoff	ITER	Head of USA ITER Domestic Agency	Archive Video Testimony to US Congress (see bibliography)
58	Herwig	Schopper	CERN	Former Director General (1981 to 1988)	Field Work interview
59	Anon	Anon	Anon	Collaboration team member	Field Work interview
60	Janet	Smart	Other	Reader in Operations Management Saïd Business School, University of Oxford	Field Work interview
61	Anon	Anon	Anon	IGO Director	Field Work interview
62	Anon	Anon	Anon	Senior Project Officer	Field Work interview
63	Carl	Strawbridge	ITER	Deputy US ITER Project Office Oak Ridge National Laboratory, USA	Field Work interview
64	Harry	Tuinder	ITER	Legal adviser EC Research & Innovation Directorate Fomer ITER Head of Legal Affairs	Archive ITER Video Interview (see bibliography)
65	Anon	Anon	Anon	Operations Division Team Member	Field Work interview
66	Anon	Anon	Anon	Personal Assistant	Field Work interview
67	Anon	Anon	Anon	Sub-section Leader	Field Work interview
68	Mark	Uhran	ISS	Former Assistant Associate Administrator for the ISS NASA HQ in Washington DC (2005 to 2012)	Field Work interview
69	Anon	Anon	Anon	Member of the G8 Science Ministers Group of Senior Officials	Field Work interview
70	James	Van Dam	ITER	Acting associate director, Fusion Energy Sciences Office of Science, US DOE	Archive Video Testimony to US Congress (see bibliography)
71	Anders	Wallander	ITER	Head of Control System Division	Field Work interview
72	Anon	Anon	Anon	Head of Department	Field Work interview
73	John	Womersley	Other	Director General of the European Spallation Source (Lund, Sweden)	Field Work interview
74	Ryuji	Yoshino	ITER	Head of Japanese Domestic Agency (2007 to 2009) Former Head of ITER Project Office (2009 to 2015)	Field Work interview

Appendix C: Interviewee Questions

INTRODUCTORY QUESTION PUT TO ALL INTERVIEWEES

Q1. You work as part of the senior management team here, please tell me about your role and responsibilities.

CORE QUESTIONS PUT TO ALL INTERVIEWEES

Q2. This project has reportedly long-standing, good collaboration between the member states and the central organisation, what would you say is the most significant factor that has led to this?

Q3. What would you say have been the greatest disagreements and difficulties with the members states on this project and are there any lingering, unresolved problems?

Q4. Given that this is a science related project to what extent has this affected international relations with the member states?

ELECTIVE QUESTIONS PUT TO CERTAIN INTERVIEWEES DEPENDING ON CIRCUMSTANCES

Q5. What would you say are the most effective diplomatic approaches that have been used with the member states to negotiate the founding arrangements and support the project operations?

Q6. What new measures would you say could be introduced to the project management that would improve schedule and cost performance?

CONCLUDING QUESTION PUT TO ALL INTERVIEWEES

Q7. What - *if any* - are the political lessons learned by the project governance and management regimes that may provide clues in advancing global collaboration more generally?

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