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EUMETSAT-NOAA Collaboration in Meteorology from Space

Review of a Longstanding Trans-Atlantic Partnership

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Executive Summary

The application of remote sensing technologies to operational meteorology has profoundly impacted the accuracy of weather forecasting. Meteorological satellite data is currently used by many different parts of society to ensure safety of the population, to protect property and to increase economic performance and scientific knowledge. The collaboration between the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and the United States' National Oceanic and Atmospheric Administration (NOAA) has played an important role in the establishment of these capabilities. This study assesses the various dimensions of partnership between EUMETSAT and NOAA and shows how this particular trans-Atlantic collaboration has produced tangible and strategic benefits for both organisations, their user communities and the governments that provide their funding.

In its first part this study chronologically describes the evolution of the record of collaboration between both organisations in their fields of engagement. This starts with an outline of the historical foundations that preceded the first collaborative activities between EUMETSAT and NOAA. Awareness of these developments is essential to grasp the structure and unique features of the global meteorological community and the surrounding geo-political environment in which this partnership is so strongly embedded. Subsequently the negotiation processes and legal agreements of joint activities in the fields of geostationary, polar orbiting and ocean altimetry missions are documented. A theoretical framework on the key elements required for success in international collaboration in space missions is applied as a narrative throughout the first part of the study. The first systemic basis of working together occurred in 1993, when the organisations formulated a set of contingency conditions under which they agreed to provide mutual back-up support. The result was increased robustness of the observation capabilities in geostationary orbit. Two years later they signed an agreement that acknowledged and regulated the reciprocity of their exchange of data. Still in effect today, these agreements ensure a higher reliability of their geostationary satellites and data access continuity for their user communities.

In the field of polar orbiting satellites the agencies have been able to establish a state-of-the-art observing constellation that supports a broad range of environmental monitoring applications and weather forecasting. The seeds for this joint undertaking were sown in the margins of the G7 summit in 1983. Although the negotiation processes preceding the signing of the Initial Joint Polar System agreement in 1998 were challenging, the eventual results substantially exceed the political ambitions that were formulated at the outset of this endeavour. Besides the division of responsibilities in the mid-morning and afternoon polar orbits the organisations have implemented a sharing of infrastructure and an exchange of instruments that currently guarantees timely data access and homogeneous data sets for their user communities. Latest developments in this field are concerned with the follow-up activities required for the implementation of their Joint Polar System. The Jason missions are the most recent field of activity brought under the umbrella of the partnership. What initially started out as a successful ocean altimetry mission between the U.S. National Aeronautics and Space Administration (NASA) and the French space agency "Centre national d'études spatiales" (CNES) has now translated into a long term operational service provided under the auspices of EUMETSAT and NOAA in collaboration with the founding partners. The Jason missions are fully integrated platforms that make use of critical American and European technologies. Moreover, the performance of ocean altimetry will be even further optimised in the future "Jason Continuity of Service".

The collaboration record analysis reveals that the road towards these achievements has been complicated by various internal and external factors. Nevertheless EUMETSAT and NOAA have shown that even organisations with different industrial policies, technologies and data policies can establish long term successful collaboration based upon principles of reciprocity, mutual understanding and sense of partnership.

The second part of the study takes a more analytical approach. The partnership assessment in the study analyses how the two meteorological operational agencies work to-

gether from a more structural point of view. To this effect a theoretical framework is applied which distinguishes different forms of collaboration based upon their structural characteristics in terms of focus, commitment and resource deployment. This reveals that each field of joint activity displayed in the EUMETSAT-NOAA partnership is particular and, that the organisations have gradually increased their commitment over time as the joint undertakings turned out to be successful and beneficial for both partners. Over time this has resulted in a full spectrum partnership that is characterised by strong interdependency and mutual levels of trust. In this sense the cemented partnership as it exists today has become a keystone element in fulfilling the user requirements defined for the Global Observing System in the World Meteorological Organization's framework.

A cost-benefit impact assessment in the final chapter of the report analyses the impact of the collaboration on the organisations' overall costs and performance. It reveals that EUMETSAT and NOAA have been able to get a double win out of their partnership. The agencies have been able to establish state-of-the-art observing system at a lower cost. This has been possible because the approach with respect to resource pooling was based upon comparative cost advantages that resulted from existing experience and fields of expertise on both sides of the Atlantic. In their polar orbiting programmes this has taken the form of divided orbital responsibilities and an exchange of instruments. In ocean altimetry, both sides provided complementary technologies that are critical for mission success. In turn, this specialisation has also translated into considerable improvements in performance. In short, differences in remote sensing technologies have yielded unexpected synergies that were to a large extent the result of serendipity. In the Initial Joint Polar System, the combination of EUMETSAT and NOAA expertise has given rise to new forecasting skills that currently benefit user communities and decision-makers. In the Jason missions the merging of American and European technology onto fully integrated platforms has increased the accuracy and reliability of the data they provide. Over time both organisations have experienced an increased pace of technological innovation due to their partnership. Elements that have brought about this long term performance optimisation include an interwoven dynamic of collaboration and competition and resource reallocation in the data processing chain of meteorological products. Together these two elements have a considerable impact on the benefit-to-cost ratios of both organisations and their funding governments that go well beyond mere cost sharing. The economic benefits derived from meteorological data in comparison to the investment costs required to establish polar orbiting and ocean altimetry operational programmes have very likely more than doubled compared to the scenario where the organisations would have duplicated full systems by themselves.

EUMETSAT, NOAA, their funding governments and the meteorological community should take note of the value of this partnership. It has enabled their user communities to benefit from more data products, increased accuracy and a better timeliness and robustness of the observing systems, all at a lower cost. Together these elements have translated into an increased ability to protect human life, property and infrastructure and added value to the American and European economies. In addition the partnership has created positive spill-over effects in the context of the World Meteorological Organisation in terms of example-setting, scientific research and the facilitation of development aid applications.

The unique combination of different added values displayed in this partnership raises the questions as to how it can be maintained, further optimised and even leveraged to other activities in the future, especially in times of tightening budgets. The strong dimension of international collaboration in operational meteorology as exemplified in this report would merit further consolidation in a political sense. In the United States the value is already acknowledged as a principle in the National Space Policy of the Obama Administration. In Europe, however, this formalisation still needs to be undertaken. Given that it could give this long-term partnership a stronger political foundation on both sides of the Atlantic, it should be definitely considered during the reiteration of the European Space Policy.

1. Introduction

The application of remote sensing technologies to operational meteorology has profoundly impacted the accuracy of weather forecasting. Today, data provided by geostationary, polar orbiting and ocean altimetry satellites is used by many different parts of society to ensure the safety of the population and to protect property. In addition, accurate weather forecasting helps to increase economic performance as estimations have shown that about one third of the gross domestic product generated in developed economies is sensitive to weather fluctuations.[1, 2] Furthermore, the data is used by the science community to increase our knowledge of the environment and to monitor the effects of planetary climate change.

Collaboration between the European Organisation for Meteorological Satellites (EUMETSAT) and the United States' National Oceanic and Atmospheric Administration (NOAA) has significantly contributed to achieving the state-of-the-art observing system capabilities currently in orbit. The operational agencies have jointly built up a longstanding and diverse record of working together in a number of fields that allow their user communities to reap social and economic benefits that would not be obtainable by a single agency under the same conditions. This study assesses the various dimensions of partnership between EUMETSAT and NOAA and shows how this particular trans-Atlantic collaboration has produced tangible and strategic benefits for both organisations, their user communities and the governments that provide their funding. Finally also the spill-over effects of this partnership in the framework of the World Meteorological Organization are addressed.

Although the joint undertakings between EUMETSAT and NOAA are the main focus of this study, it is important to note that this collaboration needs to be placed in a wider context. Not only does this help clarify the reasons behind the establishment of the collaboration, its structure and strengths, but it also sheds light on the political ambitions that were at the foundation of this partnership.

1.1 The Global and Political Context

Many external developments in Europe and the United States have directly and indirectly given shape to the evolution of the EUMETSAT-NOAA partnership and its form as it exists today. In fact, the foundations for this partnership were laid well before the first experiences in meteorological satellites. International coordination among meteorologists and weather centres had begun already in the 19th century, and really took off after the Second World War when the World Meteorological Organisation (WMO) was established in the United Nations framework. The WMO, having established dedicated programmes and mechanisms to stimulate coordination, has continuously offered a context that facilitates data exchange and the working together of its members. As a result, NOAA and EUMETSAT were immediately embedded in the networked structure of the global meteorological community following their creation, in 1970 and 1986 respectively.

Yet, the first direct incentives for the partnership emerged on a national level in the United States. After a series of promising technology demonstrations and successful proof-of-concept missions in the 1960s and 1970s, it became clear that American efforts in polar orbiting meteorology would translate into a truly operational service, in addition to the already established service of geostationary coverage. This idea started to self-reinforce when the meteorological offices – typically adopting a conservative approach with respect to innovation in order to guarantee the reliability of their services – became more familiar and comfortable with the use of satellite data in their Numeral Weather Prediction (NWP) models throughout the 1980s. At that time, however, the Reagan administration was implementing structural budget savings to address the economic consequences of the oil crises and the related budgetary deficits. The U.S. federal government felt that if meteorological observations from the polar orbits were becoming a long

[1] Lazo, Jeffrey K., Lawson, Megan, Larsen, Peter H. and, Waldman, Donald M. "U.S. Economic Sensitivity to Weather Variability." Bulletin of the American Meteorological Society 92 (2011): 709 – 720.

[2] EUMETSAT, The Case for EPS/MetOp Second Generation: Cost Benefit Analysis, 2012.

term operational service, this should take the form of an international collaboration. Therefore, the U.S. in 1983 declared its intent to downscale the civilian American polar-orbiting programme from two orbit coverage to one, announcing it would only guarantee coverage of the afternoon orbit after the mid-1990s. Not only would this opening up of the mid-morning polar orbit to other partners result in cost savings for the American government; it would also ensure a more balanced input in the WMO's Global Observing System. Because the first bilateral contacts with different international partners yielded no concrete results, the project was brought into the context of the G7. By doing so the United States aspired to give the project more political impetus, while at the same time the scientific nature of meteorology could bring a positive dynamic of international collaboration into a trans-Atlantic political scene that was mostly dominated by the prevalence of the Cold War and economic turmoil. In the margins of the G7 summit held in Williamsburg in 1983 the political representatives decided to set up a panel dedicated to remote sensing. The discussions in the panel revealed that the European states were in favour of supporting a Europeanised initiative to achieve meteorological coverage in the mid-morning polar orbit. European states had taken a similar approach when the geostationary Meteosat satellites of the European Space Agency (ESA) were translated into an operational service to be executed by the newly formed international organisation EUMETSAT. This pointed the way towards EUMETSAT involvement in polar orbiting satellites. In this sense it is considered the immediate cause of the initiation of the partnership.

In the period following Europe's agreement in principle to share the burden of the meteorological polar service with the United States, EUMETSAT – still a small organisation at the time – was endowed with the resources to take up this commitment. The European Space Agency took up the role of development and acquisition agency for new series of satellites, which ensured that critical European expertise was leveraged into the young organisation. This enabled EUMETSAT to achieve observation capabilities conforming to the set of requirements of its user communities in a relatively short time.

Shortly after the initiation phase both organisations started working together directly, based upon their own agreed conditions. In the first part, this study will thoroughly describe those negotiations and the resulting achievements of the partnership in the fields of geostationary, polar orbiting and ocean altimetry satellites. It will also show that direct working together between the operational meteorological agencies on both sides of the Atlantic has not evolved in a vacuum. On the contrary, it has been shaped by different driving forces such as domestic politics, institutionalism, economic motivations, changing technologies and evolving user requirements. Although some of these elements have sometimes complicated progress in negotiations between EUMETSAT and NOAA, their mutual interest in fulfilling their missions and satisfy their user communities' requirements beckoned them further in the spirit of collaboration. In a second part the partnership will be analysed from a structural point of view. It reveals that the partnership has come a long way since its beginnings. Over time, the collaboration between both organisations has widened and intensified; and as a result, the partnership consolidated, becoming an integral part of the ecosystem of space-based operational meteorology. The final chapter presents an assessment of its impacts on NOAA's and EUMETSAT's expenditure and performance which sheds a light on the value of this partnership.

1.2 The Space Policy Context

The range of the activities jointly pursued by EUMETSAT and NOAA has increased considerably over time. What started out as a modest form of working together based upon technical, operational and political needs in the late 1980s has now resulted into a solid partnership that produces strategic and tangible benefits in Europe, the United States, and beyond.

Only recently has this transatlantic partnership started receiving attention and consideration from policy makers. This lag is due to the fact that it took some time before the strategic importance and the value of this partnership were fully understood on both sides of the Atlantic. The benefits resulting from EUMETSAT-NOAA collaboration, and the realisation that this partnership is to be a long-term given, have grown as the collaborative activities increased and intensified. Moreover, on the European side, the full policy dimension to this partnership was only enabled when the European Union (EU) was given an explicit mandate for space activities following the entry into force of the Lisbon Treaty in 2009.[3]

[3] Treaty of Lisbon amending the Treaty on European Union and the Treaty establishing the European Community, Lisbon, done 13 December 2007, entered into force 1 December 2009, C306/01 (2007).

In the United States, the use of international partnerships in operational satellite meteorology is considered as a guiding principle in the National Space Policy of the Obama Administration.[4] On the European side, however, this partnership merits further consolidation from a policy perspective. In spite of the fact that the transatlantic dimension of Earth Observation programmes is recognised in the dialogue on civil space cooperation between the European Union and the United States, it is not yet included as one of the principles in the European Space Policy.[5] [6] Acknowledgement of this partnership on space policy level would however be a sensible thing to do from a strategic point of view. The need to match space competences to strategic goals is currently stimulating the European Union to seek to develop a coherent, widely shared approach to space activities. In doing so the EU has an interest in making sure its activities and programmes are embedded in a cohesive overall policy that truly links space utilisation to its other competences and policies. Earth observation data, because of its diverse usability, already has an indispensable support function in the daily execution of a number of EU policies, including but not limited to: agriculture and fishery, environmental policy, scientific research and innovation, climate change, internal market, transport, and energy. In addition, some data resulting from the EUMETSAT-NOAA partnership might become strategically more relevant as the EU further deploys its Common Security and Defence Policy. If the EU acknowledges the trans-Atlantic dimension of the space based meteorological capabilities it makes use of, this might further anchor the partnership and demonstrate that the EU is a major stakeholder in the process. The latter is especially relevant considering that the ties between the EU and EUMETSAT have been strengthening over the last years, partially because of the implementation of the Copernicus programme. Finally, a recognition in the European Space Policy would close the policy loop supporting the partnership, giving it a stronger political foundation on both sides of the Atlantic. For these reasons, recognition of the partnership should definitely be considered in the next iteration of the European Space Policy.

1.3 Structure of the Study

As indicated above, this study will be structured around two main parts, each with a slightly different focus. This makes it possible to distinguish the description of the establishment and evolution of collaboration from the more analytical chapters that seek to give interpretation to the implications of the partnership. In this sense the twofold approach creates a more holistic perspective on the partnership and a balance between description and analysis.

The first part of this study is a collaboration record analysis. The chapters in this part cover the pre-collaboration phase and an extended history on the collaboration activities in the programmes of geostationary, polar orbiting, and ocean surface topography satellites. These chapters describe the major milestones in the development of collaboration in these fields, and in parallel shed light on the driving forces steering this evolution. In this regard, a theoretical framework will be applied as a narrative to review the conditions for success in international space missions. This distinguishes those conditions for success in the EUMETSAT-NOAA partnership that are universal and those that are more specific to the EUMETSAT-NOAA partnership in particular.

The second part of this report, the inter-organisational assessment, looks at the underlying dynamics in the collaboration. The first chapter in this part is a partnership assessment based upon a theoretical framework for different collaborative strategies. It is applied to reveal the structural differences between the three fields of collaboration as a function of their degree of integration. This assessment yields information on how the partners have become mutually dependent on each other for the satisfaction of the requirements of their user communities and how they have been able to achieve this strong partnership. The final chapter of the study is a cost-benefit impact assessment. It demonstrates how the collaboration has affected both organisations in terms of cost structures, performance and efficiency.

Finally, the conclusion reflects on the findings of both parts and draws a picture of the overall structure and value of this partnership for the different parties involved.

[4] "National Space Policy of the United States of America" 28 Jun. 2010 The White House 12 May 2013 <http://www.whitehouse.gov/sites/default/files/national_space_policy_6-28-10.pdf>.

[5] Commission of the European Communities. Communication from the Commission to the Council and the European Parliament: European Space Policy. COM(2007) 212 final of 26 Apr. 2007. Brussels: European Union.

[6] Commission of the European Communities. Communication from the Commission to the Council, the European Parliament The European Economic and Social Committee and the Committee of the Regions: Towards a Space Strategy for the European Union that Benefits its Citizens. COM(2011) 152 final of 4 Apr. 2011. Brussels: European Union.

Part I. Collaboration Record Analysis

The theoretical framework of the key elements in international collaboration in space missions is elaborated below and then later applied on a continuous basis as a narrative throughout the various chapters of Part I of this study. This framework is based upon the findings of the Joint Committee of the U.S. National Research Council and the European Science Foundation. In the study "*U.S.-Europe Collaboration in Space Science*", the Joint Committee identified eight key elements that it believes are essential to success in international collaboration in space missions.[7] Although these elements are by no means exhaustive and, the particular case of EUMETSAT-NOAA collaboration has more special features to it, they form a good starting point, allowing further specifications to be added. All eight are described in the following:

1. *Historical foundation.* A partnership will have more chances of success if the agencies have a shared context within which the nature of their collaboration project fits. This context encompasses a common understanding of the science and engineering required for the project. In case of EUMETSAT and NOAA, or rather the wide field of satellite meteorology, the history and basis started in the International Meteorological Organisation and was taken further in the framework of the World Meteorological Organisation when the United States and later Europe developed their first meteorological satellites. Given that this element is an integral part of developments in the pre-collaboration era, the second chapter will focus on the historical foundations of the relationship.

2. *Scientific support.* To establish compelling scientific justification of a mission and its components, review by international experts is appropriate. Experts can determine whether the science is of excellent quality and meets high standards and whether the methods proposed are cost effective. From a financial and political point of view, strong support by the scientific community is a way to overcome budget restrictions and administrative delay. In terms of scientific support, NOAA and EUMETSAT can count on the expertise and experience provided by their development agencies NASA and ESA, respectively for implementation expertise. More importantly, however, the user communities of the organisations are an integral part of the global scientific community in meteorology and climate monitoring, ensuring strong bottom-up scientific support in the definition of user requirements and scientific instrumentation.

3. *Shared objectives.* Some shared goals and objectives for international collaboration should be agreed by all parts of the organisation. This includes scientists, engineers, administrators and the management level. In addition, the organisation has to receive a specific mandate to engage in this commitment, either from the political level or from its Council. Again, this element is of a particular nature in the NOAA-EUMETSAT relationship. As both are operational organisations with end-to-end systems and a long-term perspective, it is easier to align the views of the scientific and engineering staff. In addition, for both organisations the user communities are the central stakeholders for whom the continuity and quality of service is assured. The latter is an element of key importance in the strategy documents of both organisations.

4. *Clearly defined responsibilities.* The Joint Committee stated that cooperative programs must involve a clear understanding of how the responsibilities of the mission are to be shared among the partners, a clear management scheme with a well-defined interface between the parties, and efficient communication. Hence, successful missions require that each partner has a clearly defined role and a real stake in the success of the mission. It is clear that this part becomes more critical in more integrated collaboration strategies; this is definitely reflected in the processes of negotiation addressed throughout this study. In legal terms, this element is guaranteed by means of memoranda of understanding, formal agreements and exchange of letters at managerial level; all of them that have had an impact on defining of responsibilities between the parties will be described throughout part I.

[7] National Academy of Sciences, European Science Foundation, eds. U.S.-European Collaboration in Space Science. Washington D.C.: National Academy Press, 1998.

5. *Sound plan for data access and distribution*. Similar to the need for clearly defined responsibilities, cooperative ventures should have a well-organised and agreed-upon process for data calibration, validation, access, and distribution. As EUMETSAT and NOAA have specific agreements on data policy and data denial, they treat this part of their collaboration as a separate component.

6. *Sense of partnership.* According to the joint NRC–ESF committee, the success of an international space scientific mission requires that collaborative efforts reinforce and foster mutual respect, confidence, and a sense of partnership among participants. Each partner's contributions must therefore be acknowledged in the media and in publications resulting from joint missions. In the EUMETSAT–NOAA case, this manifests itself in recognition of the other partner in policy documents and in the global meteorological space community, for example.

7. *Recognition of importance of reviews*. The study states that periodic monitoring of science goals, mission execution, and the results of data analysis is necessary to ensure that international missions are both timely and efficient. Particularly in the event of unforeseen problems in mission development or funding, this is vital for minimising delays or the updating of scientific imperatives throughout the programme development. Ensuring this requires an appropriate protocol for reviewing ongoing collaboration activities. As the need for clearly defined responsibilities, this element becomes more critical in more integrated collaboration strategies, especially when more than two partners are involved. NOAA and EUMETSAT have set up specific structures to manage and guide review processes, such as their High Level Working Group. These bodies and procedures will be described with respect to the different collaboration areas.

8. *Beneficial characteristics.* This element is crucial to initiate collaboration in the first place. Although the beneficial characteristics must not be exactly equal for both partners and there might be a shift of benefits over time, the overall structure should deliver benefits on a fairly even basis. Typically, the shared benefits go beyond exchanges of scientific and technical data, know-how and access to training. According to the Joint Committee of the ESF-NRC, successful collaborations have had at least one – but usually more – of the following characteristics: (1) unique and complementary capabilities offered by each international partner, such as expertise in specific technologies or instruments, or in particular analytic methods, (2) contributions made by each partner that are considered vital for the mission, such as providing unique facilities like launchers, instruments, spacecraft subsystems, or ground receiving stations, (3) significant net cost reductions for each partner, which can be documented, leading to favourable cost-benefit ratios, (4) international scientific and political context and impetus and, (5) synergistic effects and cross-fertilisation of benefits.[8] The beneficial characteristics of the EUMETSAT-NOAA partnership in the various collaboration areas are one of the focal points of this study. They will further described and assessed in Part II.

[8] Ibid.

2. Historical Foundations

The first historical foundations that influenced later developments in the EUMETSAT-NOAA partnership date back to well before the first meteorological satellites were launched in outer space. This chapter will review developments in the global meteorological community that took place before the first collaboration between EUMETSAT and NOAA, even before these organisations were established. The first development was the process of internationalisation – and later globalisation – of the meteorological community, which dramatically changed its modus operandi.

2.1 Processes of Internationalisation and Globalisation of Meteorology

In the 1850s, telegraphy permitted meteorologists for the first time to create and share so-called '*synoptic weather maps*'[9]. In a relative short time, scientists were offered the opportunity to watch the development and movement of weather phenomena like storms, and warn those downwind. Although these empirically based findings did not achieve great accuracy at the time, these dramatic '*God's-eye views*' brought new visibility to meteorology and offered opportunities for the military and agricultural services of the industrialised nations in Europe and North-America.[10]

Further increasing the usefulness and accuracy of these weather services by means of international data sharing, however, posed some challenges. For a long time national weather services were primarily concerned with the collection and charting of data, using existing networks of military, astronomical and amateur observers. First, there was a need for additional professional observers and operational data networks. Second, all this data from various sources needed to be centralised on national level. In order to address both challenges properly, data had to be collected by instruments calibrated to a single standard, and recorded in similar units. The establishment and enforcement of standards, however, proved to be remarkably difficult, even on national level and whenever national standards differed, the use of data exchange systems posed problems. To address this standardisation issue, national weather services throughout Europe and the United States founded the International Meteorological Organisation, or IMO.[11]

2.1.1 The International Meteorological Organisation

Founded in 1873, the IMO was born from the realisation that weather systems move across boundaries and that forecasting thus required upstream and downstream collection of weather data. A major milestone in this process was the decision of the 1905 IMO Conference of Directors to develop a telegraph-based worldwide weather station network. It was decided that this network should collect, calculate, and distribute monthly and annual averages for pressure, temperature, and precipitation from a well-distributed sample of land based meteorological stations, in effect a global climatological database. The distribution standard was two stations within each ten-degree latitude/longitude quadrangle. In the end, the network comprised about 500 land stations between 80°N and 61°S. In the year 1917, the first annual data set, for 1911, appeared.[12]

Despite these first steps of internationalisation in the meteorological community, the results turned out to be rather unsatisfactory. One of the reasons was the structure of the IMO which, in retrospect, has been described as a typical pre-World War II scientific form of internationalism. For 75 years, the organisation was limited to a cooperative association of national weather services without intergovernmental organisation status. The principle of interaction was explicitly voluntary and as a result, IMO policies functioned merely as recommendations. National identity, sense of independence and cultural practices lead nations to refuse or simply ignore proposed standards. Moreover, data sharing

[9] Synoptic Weather Maps are snapshots of simultaneous observations taken over larger areas.
[10] Edwards, Paul N. "Meteorology as Infrastructural Globalism„ OSIRIS 21 (2006): 229 – 250.
[11] Ibid.
[12] Ibid.

and bartering were for a long time limited by the telegraph networks' technical capabilities, while in the pre-computer era the collecting and integrating of data from different channels and media remained slow, labour intensive, and error-prone. These factors led to significant delays in the publication of what were in the end mediocre annual datasets.[13]

The IMO leaders were aware of this endemic institutional weakness. In an attempt to regain central control of standard-setting processes, they came to agree on the need for an intergovernmental standard-setting authority, and posted a letter to governments with a request for such mandate in 1929. Largely because of the impact of the Great Depression, the proposal was neglected and only revisited by the IMO at its 1935 meeting in Warsaw. It was decided that future meeting invitations would be sent directly to governments, asking them to appoint each weather service director as an official government representative. In parallel, the organisation began drafting a World Meteorological Convention, which was presented to the 1939 meeting in Berlin. The conferees forwarded the draft convention to a committee for refinement. The plan called for final approval at the 1941 IMO Conference of Directors, but of course, the Second World War intervened.[14]

From a historical point of view, the creation of the IMO was the first step in the process of internationalisation of the meteorological community. Although in many aspects the standard-setting and thus harmonising role of the IMO was limited, it created an environment in which networking and modest forms of collaboration were encouraged. The organisation reflected and consolidated the idea that meteorology by definition transcends the national level; states and their national weather services are reliant upon each other. This feature seemed so strongly embedded in the nature of meteorology that it has ever since determined the path-dependency of further developments in this scientific field.

2.1.2 The World Meteorological Organisation

After World War II, the 1946 IMO Conference of Directors acknowledged the need for an organisation supported by governments. Preparations continued with a conference in 1947 in Washington DC. The convention entered into force in early 1950, and one year later the World Meteorological Organisation (WMO) was officially created as one of the 'specialised agencies' of the United Nations, in direct succession from the IMO.

[13] Ibid.
[14] Ibid.

Unlike its predecessor, the members of the WMO are representatives of their respective countries, not their weather services. Although the WMO convention carefully avoided any claim to absolute authority – and hence the WMO, in principle, could not produce binding standards – it was stated that members were required to 'do their utmost' to implement WMO decisions. This intergovernmental structure, founded in a post-war atmosphere of optimism, has eventually enabled the WMO to play a unique and powerful role in contributing to the safety and welfare of humanity.[15] It achieves this through several methods. First, it promotes collaboration in the establishment of networks for making meteorological, climatological, hydrological and geophysical observations, as well as the exchange, processing and standardisation of related data, and assists technology transfer, training and research. In addition, the WMO fosters collaboration between the meteorological and hydrological services of its member-states, and furthers applications for meteorology, agriculture, aviation, shipping, the environment, water issues and the mitigation of the impacts of natural disasters, in addition to classic public weather forecasting.[16]

An important milestone in the historical trans-Atlantic relationship in satellite meteorology was the establishment of the WMO's World Weather Watch (WWW) Programme. This programme was developed together with the Global Atmosphere Research Programme (GARP), in response to a United Nations Resolution, adopted in 1962, to develop "meteorology and atmospheric sciences for the benefit of all mankind". While GARP, sponsored by the International Council of Scientific Unions and the WMO, had the aim of improving the quality of Numerical Weather Prediction and to extend the forecast range, the WWW coordinated space- and ground-based observations from all the world; overseeing the actual gathering and distribution of meteorological data and products to WMO member states. One of the major mechanisms to provide continuous and reliable observational data world-wide in the WWW Programme is the Global Observing System (GOS). Although the GOS started with a relatively narrow set of observational requirements[17], it was recognised early on that

[15] Ibid.
[16] "WMO in Brief" 12 Nov. 2012. World Meteorological Organization <http://www.wmo.int/pages/about/index_en.html>.
[17] These were in support of mainly synoptic, mesoscale and short-term weather forecasts. See "Evolution of the Global Observing System" World Meteorological Organization 12 Nov. 2012 <http://www.wmo.int/pages/prog/www/OSY/GOS-redesign.html>.

space-based observation from satellites was to be an important component, next to observations from land, sea and aircraft. This awareness was raised by the impact of TIROS-1, the first meteorological satellite placed in orbit by the U.S. National Aeronautics and Space Administration (NASA) in 1960.[18] The images of TIROS-1 brought forecasters all over the world a better understanding of the state of the planet's atmosphere. European meteorologist made use of the data made available by the Americans and as a result, European involvement in satellite meteorology began to form in the minds of meteorologist and space scientists.[19]

Under the WWW and GARP framework, consensus grew that in order to ensure global space-based coverage, the space component of the GOS should include four or five geostationary satellites and two or three polar orbiting satellites. Hence, already in September 1967, D.A. Davies, then Secretary-General of the WMO, officially put the challenge of a joint European effort in space meteorology before the Commission for Science and Technology of the Council of Europe.[20]

The WMO, by means of its global membership and the deep-rooted culture of working together and sharing of information, was able to establish a solid global overall framework for meteorology, the crowning attainment of which was the establishment of a coordinated international meteorological satellite programme in the form of the GOS. This global development in turn had repercussions on local level, as the United States and Europe had to develop dedicated structures to establish and maintain these space-based capabilities, and to guarantee the long-term continuity of the services they provided.

2.2 Establishment of NOAA

The National Oceanic and Atmospheric Administration (NOAA) was founded within the United States Department of Commerce in 1970. In line with the rise of the environmental movement at the time, NOAA was designed to unify the nation's widely scattered environmental activities and provide a rational and systematic approach to improve understanding and stewardship of the total environment. Next to its specific responsibility for the development and conservation of marine fisheries, one of the missions of NOAA was to lead the development of consolidated national oceanic and atmospheric research and development program and provide a variety of scientific and technical services to other U.S. Federal agencies, private sector interests and the general public.[21] This included a responsibility to predict changes in the oceanic and atmospheric environments and living marine resources, and to provide related data, information, and services to the public, industry, the research community, and other government agencies.

NOAA works towards this mission through six major line offices[22] and with the support of more than a dozen staff offices. Most relevant in the context of space and collaboration with EUMETSAT is the National Environmental Satellite, Data and Information Service, or NESDIS. This line office was established when NOAA's operational meteorological satellite program became a reality, as the experimental geostationary satellite experiment was transformed into a continuous, operational program in 1974/5. NASA's Synchronous Meteorological Satellites (SMS) 1 and 2 were the prototype for NOAA's Geostationary Operational Environmental Satellites (GOES). GOES-1, the first NOAA-owned and operated geostationary satellite, was launched on 16 October 1975. A few years later, in June 1979, the first NOAA-funded satellite in the NOAA system of polar-orbiting environmental satellites was launched. Endowed with a clearly-defined mandate and sufficient funding, NOAA was able to transform itself into a world leader in application of space-based observing systems for operational environmental forecasting and related services during the 1970s.

With the Americans having covered two geostationary slots and their polar orbiting satellite system in pre-operational proto-type flight status[23], the European meteorological community started to further elaborate the idea of a joint European contribution in the form of a geostationary satellite programme. After all, many European states - being active

[18] The Television Infrared Observation Satellite or TIROS-1 was launched on 1 April 1960.
[19] EUMETSAT, 25 Years of EUMETSAT – 25 ans d'EUMETSAT, 2011, 320 p.
[20] Ibid.

[21] "A History of NOAA" 8 Jun. 2006 National Oceanic and Atmospheric Administration 14 Nov. 2012 <http://www.history.noaa.gov/legacy/noaahistory_12.html#operational>.
[22] The National Marine Fisheries Service (NMFS), The National Ocean Service (NOS), The National Weather Service (NWS), Office of Oceanic and Atmospheric Research (OAR), Office of Program Planning and Integration (PPI), and finally the National Environmental Satellite, Data and Information Service (NESDIS).
[23] TIROS-N was launched on 13 October 1978, and was the first satellite in the fourth generation operational environmental satellite system. Serving as a proto-type flight for the operational follow-on series (NOAA-A trough NOAA-N´ spacecraft), the satellite was deactivated in 1981.

members of the WMO - could not fail to take up their role in the establishment of the Global Observing System. This process was not an isolated spontaneous undertaking, on the contrary, American representatives at the time were actively looking for possible partners to implement the space component of the GOS in the networked community meteorology had become.

2.3 Establishment of EUMETSAT

Subsequently, the challenge of a joint European undertaking in satellite meteorology started to become clear. Initially, it was France that had the idea of establishing a national geostationary satellite programme that they called Meteosat. As the nascent idea of a European contribution conflicted with the French plans, in December 1970 the Director of the French National Meteorological Service expressed his concerns in a letter to Hermann Bondi, Director-General of the European Space Research Organisation (ESRO). The Ad Hoc Meteorology Group initiated by ESRO gathered half a year later in Zurich to discuss this issue. The Group decided that ideally the European system would consist of following elements: (1) a geostationary satellite able to provide cloud cover images in the visible and infrared spectrum, (2) one polar-orbiting satellite for atmospheric soundings and, (3) a communications package to collect and relay the meteorological data from ground-based platforms.[24] Some weeks later, after having reflected on this issue, France proposed to the Chairman of ESRO's Council that their Meteosat concept be implemented on European level, by ESRO and the European meteorological community. After internal assessment and consultation with meteorological experts, ESRO considered Meteosat ready for adoption as a European project.

Following this decision, the meteorological community in Europe started defining the technical features of the mission. In addition, an Ad Hoc Group opted for a centralised approach, keeping raw satellite and meteorological data processing together. With the structure put forward, the eight ESRO Member States that were participating in the project[25] signed the Meteosat Agreement in July 1972. The gathering of funds and the pre-operational programme of the first Meteosat satellites, however, were characterised by heated discussions on the approach with regard to its translation into an organisational structure and the allocated budget for operational satellite meteorology. The Meteosat Agreement was eventually translated into a pre-operational programme by the European Space Agency's Programme Board for Meteorological Satellites in the mid-1970s.[26] Following the successful procurement, launches and operations of the first three Meteosat satellites, it became clear that this service had become a long term operational commitment and as such, did not really fit into the scope of the European Space Agency.

It was not until the Intergovernmental Conference in Paris in 1983 that it was officially decided to create EUMETSAT, and to make this newly formed international organisation responsible for three satellites in the Meteosat Operational Programme (MOP) series. EUMETSAT's founding convention was opened for signature on 24 May 1983 and entered into force on June 1986. The organisation officially took over responsibility for the operational Meteosat series on 1 January 1987, the first operational satellite, MOP-1, being launched in March 1989. During the inaugural Council Meetings, the delegates decided to select Germany as the location for EUMETSAT's headquarters, and John Morgan was appointed as the organisation's first director. With the European meteorological collaboration now finally translated into a working structure with an operational programme, the basis was laid for further developments and collaboration at international level.

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[24] EUMETSAT, 25 Years of EUMETSAT – 25 ans d'EUMETSAT, 2011, 320 p.

[25] These countries were Belgium, Denmark, France, Germany, Italy, Sweden, Switzerland and the United Kingdom.

[26] In 1975, the European Space Agency was founded as a single integrated organisation to take over the responsibilities of ESRO and ELDO.

3. Geostationary Satellites

This chapter will focus on the forms of collaboration between EUMETSAT and NOAA in the field of geostationary satellites. This type of satellite is placed in an orbit at about 36,000 km above the Earth's surface, in the equatorial plane. As the orbital period in this particular position takes as long as it takes the Earth to revolve around its axis – one day – the satellite appears to be fixed with respect to the Earth's surface, providing a constant view of the region beneath it. In this position, geostationary meteorological satellites are able to provide very frequent observations in the infrared and the visible spectrum.

What started out as a case-based form of support between EUMETSAT and NOAA later evolved into a formal form of collaboration, formalised by a back-up agreement and geostationary data agreements. This transition ensured that the benefits of collaboration in the field of geostationary satellites were mutual and on a transparent, continuous basis.

3.1 Formalisation Process of Back-Up Support

The first trans-Atlantic geostationary collaboration predates EUMETSAT's establishment. In 1985 NOAA repositioned its GOES-4 satellite to cover the observation gap over Europe created by the partial loss of service of Meteosat-2 whose Data Collection Service (DCS) for in-situ observations failed. Although this function could be continued by Meteosat-1, the latter ran out of hydrazine propellant in 1985.

This arrangement for support was facilitated by the Coordination on Geostationary Meteorological Satellites, an international group whose name was later changed into Coordination Group for Meteorological Satellites (CGMS) to include low-Earth orbit satellites. At the time of the malfunction, ESA was still operating the meteorological satellites and the agency had strongly networked with NOAA on the American side. This strong connection – resulting from the coordinated implementation of the GOS – was an enabler for a more committed form of collaboration between the two agencies, as shown by the fact that the American partners were willing to reposition one of their GOES-satellites to ensure global meteorological coverage from the geostationary orbit. This back-up of Meteosat-2 lasted until 1988 and so NOAA directly supported EUMETSAT in its mission upon its establishment in 1986. The American side regarded this support as part of its commitment to its partnership with the European meteorological community, but at the same time deemed it useful in case one of their GOES satellites failed in the future because of a technical malfunction or reaching the end-of-lifetime without having a spare one available. Europe could be expected to come to its aid in this case. All the while, global coverage in the GOS was ensured through the GOES re-positioning.

3.1.1 GOES Satellite Back-Up

In January 1989, EUMETSAT Director John Morgan received a letter from Thomas N. Pyke, NOAA NESDIS Administrator, with a request for support in helping to maintain geostationary coverage for North and South America. NOAA was faced with a failure of its GOES-6 satellite, which brought the number of U.S. operational imaging geostationary satellites back to one, instead of the nominal two. With only one satellite, the back-up operational scenario of NESDIS was for the satellite to cover the Atlantic and Pacific sectors alternately, according to season. This scenario, however, caused a decrease in coverage, not only for North and South America, but also for the areas of the Atlantic Ocean that were of direct interest to Europe. Moreover, it was understood that the launch of the next geostationary satellite, GOES-I, could not take place before November 1990. NOAA was afraid of a further delay in the launch of GOES-I combined with a premature failure of GOES-7, particularly because the confluence of such situations would lead to full loss of coverage of the Americas; a serious discontinuity of GOES service.

For this reason, NOAA requested that the Meteosat-3 satellite be moved to a position at 50° west to facilitate coverage of the U.S. and the Western Atlantic. After all, Meteosat-4 was already in place, covering Europe and Africa and so Meteosat-3 served as a hot stand-by satellite. This, however, required the assent of ESA as the owner of the satellite, and EUMETSAT as one of the funding partners. The issue was addressed at EUMETSAT's Policy Advisory Committee (PAC) meeting in March 1989 and received a very positive response. Given the longstanding tradition of collaboration in meteorology and the fact that NOAA had previously helped EUMETSAT by repositioning its GOES-4 satellite, this willingness to help out the American partner did not come as a surprise.

Although there was a strong willingness to contribute to possible solutions of the GOES-6 failure, the exact implementation was troubled by disagreement among the European partners. EUMETSAT's Scientific and Technical Group (STG) reviewed two proposals. One was suggested by ESA's European Space Operations Centre (ESOC), which was at the time still responsible for satellite operations in the EUMETSAT Meteosat Operational Programme (MOP). Specifically, ESOC proposed to keep control over the satellite and also take responsibility for the dissemination of the data to the United States. The second proposal was put forward by France, and entailed that ESOC would retain the ground control function, but that France would take care of data processing and image dissemination. Although the French proposal was cheaper – and this was also acknowledged by the majority of the STG – there was a strong preference for the ESOC proposal because it would require the least reconfiguration of METEOSAT operations.

The issue was taken up at the 10th EUMETSAT Council meeting in June 1989. Many delegations were in favour of encouraging the use of national facilities, but feared that in this particular case, the data processing and image dissemination might be a task too big for a national institute to perform, with possible risks of delay. In addition, the Italian delegation raised questions about the completeness of the stated motivations for repositioning Meteosat-3 to 50° West, stating that the title "GOES Back-up" might be misleading, as this action would benefit Europe as well, given that most weather systems affecting Europe form over the Atlantic. This convincing point – supported by other Council members – led to the then freshly coined designation of "Atlantic Data Coverage" (ADC), which has been used ever since.

3.1.2 Atlantic Data Coverage

Finding a Mandate within EUMETSAT

Ironically, the consensus for the new designation reinforced the argument raised by the French delegation that moving Meteosat-3 was a departure from the Meteosat Operational Programme and therefore constituted a new programme. Since a new programme required unanimous approval and possibly another scale of contributions compared to the existing MOP, the timely implementation of ADC was endangered. As the majority of EUMETSAT Member States were anxious to accommodate the American request as soon as possible, they were willing to accept an interpretation that ADC would be considered to be part of MOP. A resolution to this effect was prepared by the EUMETSAT secretariat and put to the vote. Fourteen Member States were in favour; the Netherlands abstained because they wanted more information on the costs related to the ADC, while France did not participate in the vote. The French delegation challenged the legality of the ADC resolution and was therefore not willing to pay for its implementation. The disagreement led to a serious impasse between the EUMETSAT Member States.

It is important to note that this deadlock was not related to the willingness to help out the American partner. France – just like the other EUMETSAT Member States – was eager to facilitate NOAA's request. The issue was caused by an internal organisational dispute on the European side, highlighting also a fundamental disagreement on the nature of the EUMETSAT Convention, more specifically its interpretation. In this respect, the shortcoming clearly reflected a common feature of newly formed organisations, namely the poor adaptability of their legal frameworks to unforeseen circumstances, accompanied by the lack of organisational experience to address them in an appropriate way. Moreover, in this particular case the debate was intensified due to time pressure.

Following further consideration in PAC the ADC issue came before the EUMETSAT Council again in December 1989. France pointed out that Annex 1 of the EUMETSAT Convention described the MOP as consisting of one operational satellite and a second one "not in use". Giving Meteosat-3 an operational role in parallel to Meteosat-4 hence conflicted with the description as drafted in the annex, which meant that the required amendment of the annex would involve a time-consuming process of parliamentary approval in some Member States. Other delegations argued that the annex as drafted in the convention did not preclude further developments and that therefore approval could be granted by only a two-thirds majority. Nevertheless, the French did not change their position and consequently, the deadlock remained unresolved.

Eventually, a breakthrough solution was found. After a period of informal discussions in the PAC, a new resolution was prepared and presented. In this compromise, which still did not resolve the fundamental constitutional issue, the French contribution to the ADC was to be calculated at the lower GNP rate, while other member states contributed on the MOP basis. Also, it was agreed that the financial ceiling of the MOP – the cost-to-completion – would not be exceeded. This resolution was approved unanimously, enabling EUMETSAT to use Meteosat-3 at 50 degrees West in August 1991. Although clearly a success it was still two and a half years after the initial letter of Thomas N. Pyke.

ADC – Implementation

The next step in the ADC was its practical implementation, which was a joint effort between EUMETSAT, ESA and the *Centre de Météorologie Spatiale* (CMS) of the French National Meteorological Service. The WMO was also involved in the coordination of the ADC dissemination schedule. ESOC was at the time still responsible for the operations of the satellites of the MOP.[27] It was requested to move the Meteosat-3 satellite to 50 degrees West and to provide pre-processing of the satellite data and dissemination of high resolution image formats for a period not exceeding three years, starting from the date the satellite was operable in its new position. All the while, EUMETSAT, being responsible for the Meteosat Operational Programme, remained under full control of the satellite. This included the right to move the satellite – with assistance of ESA – back to its previous position if needed.

The necessary technical preparations at ESOC were completed by October 1990. A complete set of additional telecommunication links between the ground stations and ESOC had already been implemented in 1989. The Phase 1 installations included the splitting of redundant equipment, installation of an independent imagery chain, hard- and software modifications at the Meteosat Ground Computer System, and the installation of an additional dissemination chain for digital dissemination formats. New mission controllers to operate Meteosat-3 were recruited and trained.

At the CMS station at Lannion, France, preparations included updates of the GOES/METEOSAT Relay Computer system and extensions of the local ground facilities of the site. More specifically, the uplink antenna was modified to allow frequent pointing between the two METEOSAT spacecraft at 0 and 50 degrees West during ADC operations.

Despite the organisational challenges resulting from a multiple agency involvement, the practical implementation of the ADC turned out to be successful, and Meteosat-3 was in place and operational as of August 1991, before the Atlantic hurricane season started. Not only was the execution of the ADC beneficial for both the American and European meteorological community; the investments in infrastructure resulted in a strategic capacity that would prove to be useful for the further collaboration between the two trans-Atlantic partners in the field of geostationary satellites.

ADC – Extension

During the implementation of ADC, it was already apparent that the American GOES-NEXT satellite programme, the follow-up to the GOES programme, was hampered by development problems. The United States was faced with the possibility that GOES-7, in orbit since 1987, would cease to provide any services at some point, leaving it without any geostationary image data after the end of the ADC. Obviously, this situation would severely impede hurricane and storm monitoring over the Western Atlantic, an area of such vital importance for the United States.

To bridge the gap until the operational phase of the GOES-NEXT, various options for continuing data coverage on a contingency basis were considered by the U.S. The option of prolonging the use of Meteosat-3 was eventually selected as the primary contingency plan. NOAA informed EUMETSAT that it was internally authorised and endowed with sufficient financial resources to continue Meteosat-3 operations. From a technical point of view, this option was feasible for the satellite had sufficient on-board fuel to support normal operations until mid-1994.

To provide a pan-optic view of the Americas with only one geostationary satellite – recall that GOES-7 was nearing its end of lifetime – it was proposed to move Meteosat-3 to a new nominal position further West, at 75 degrees. In this new position the satellite would be out of range of the Odenwald, Germany ground station normally used for the control and operations of EUMETSAT's geostationary fleet, and therefore the NOAA CDA station at Wallops Island would be used to route data transfer, telemetry and telecommanding, while central control would remain with ESOC. This is the so-called bent pipe configuration.

EUMETSAT's then director, John Morgan, addressed the delegates of the EUMETSAT Council, stressing the gravity of the situation. He argued strongly that EUMETSAT should respond favourably to the NOAA request. Despite some technical anomalies observed in Meteosat-4 and Meteosat-5, it was ex-

[27] In fact, ESOC remained responsible for all EUMETSAT satellite operations until 1995, when the EUMETSAT control centre tool over the operations.

pected that full services over Europe and Africa could be guaranteed, and that it was therefore acceptable to further provide the services of Meteosat-3 to NOAA. Moreover, NOAA was ready to take over all the costs incurred in the extension of the ADC and willing to examine if it could contribute to the deficit in contributions that had occurred in the ADC implementation.

The EUMETSAT Council, in support of the request, authorised the Director to establish and sign the necessary agreements with NOAA and ESA to implement the proposal as outlined. A tripartite exchange of letters between EUMETSAT, ESA and NOAA was signed in February 1992, covering the installation required for the bent-pipe operation at the NOAA CDA station at Wallops and the X-ADC operations, which would expire at the end of the life of Meteosat-3. As agreed, the cost of activities under the exchange of letters was funded by NOAA. Moreover, EUMETSAT and ESA agreed to keep open the possibility of considering in due course the further extension of collaboration with NOAA beyond the lifetime of Meteosat-3, should NOAA still have the have need for support and should capacity still be available on the European side.

Operational support under the Atlantic Data Coverage Extension further fostered the sense of partnership between the organisations, and in this sense paved the way for the first structured formal form of collaboration: the Back-up Agreement.

3.1.3 Back-Up Agreement

The emergency situations that had occurred both in Europe and the United States showed that despite a relative conservative satellite delivery schedule, a robust launch policy and adequate funding, launch and premature satellite failures or delays in satellite deployment could threaten continuity of coverage. The Atlantic Data Coverage, followed by the X-ADC, was not the first example of collaboration on back-up between EUMETSAT and NOAA, as it was preceded by the NOAA repositioning of its GOES 4 satellite between 1985 and 1988. These activities showed that in addition to internal contingency plans, international collaboration is vital of emergencies.

These experiences and considerations led EUMETSAT and NOAA to discuss the possibility of making common contingency plans to be in a better position to solve such emergency situations. Bilateral discussions eventually led to the draft Agreement on Back-up of Operational Geostationary Meteorological Satellite Systems (further referred to as “the Back-up Agreement”). It defines long term collaboration activities required in order to reduce the risk to both parties of losing system coverage. This is done by providing each other with emergency back-up coverage under certain conditions.

The provisions for back-up activities were based on the state of infrastructure in geostationary orbit. In this regard, a baseline system was defined for both organisations. For NOAA, this consisted of two operational GOES satellites operated at 75° and 135° West longitude. The configuration for EUMETSAT consisted of one operational Meteosat satellite operated at 0° longitude. If an operational GOES or Meteosat satellite failed, it was agreed that both parties would carry out back-up arrangements until the baseline system had been restored. The conditions for this back-up agreement are listed in table 1.

EUMETSAT	NOAA
One operational GOES fails and there is no other operable GOES in orbit	One operable Meteosat fails and there is no other operable Meteosat in orbit
A GOES launch is not possible within the next 4 months	A Meteosat launch is not possible within the next 4 months
At least two operable Meteosat are in-orbit.	At least two operable GOES are in-orbit.

Table 1: The Requisites for Back-up Arrangements between EUMETSAT and NOAA.

From a structural point of view, the Back-up Agreement is structured around following four premises: (1) the collaboration between EUMETSAT and NOAA under the agreement is based on reciprocity; (2) both organisations seek to balance their respective measures over time; (3) there is no exchange of funds; (4) carrying out the respective responsibilities under the agreement is based upon a best efforts approach. The general provisions clearly reflect the idea that the balance of responsibilities for geographic coverage of both parties should be unchanged. The agreement was designed to improve the reliability of the global geostationary meteorological satellite system and to diminish the risks of loss of coverage in the event of emergency situations. Furthermore, the agreement set out the mechanisms for management and coordination, information transfer and release, data policy, liability, settlement of disputes and taxes and customs.

It should be noted that from an analytical perspective, the signing of the Back-up

Agreement[28] in August 1993 fundamentally transformed the nature of the relationship between NOAA and EUMETSAT. Until then, mutual support of back-up activities had taken place on a case-by-case basis and was reactive in nature. The coming into force of the Back-up Agreement, however, introduced a proactive component to the collaboration between the organisations. After all, the nature of future collaboration was anticipated and translated into a formal legal framework and implementation protocol. Finally, it should be noted that the Back-Up Agreement is based on a non-exchange of funds basis. Whereas NOAA paid for the technical preparations and lease of the equipment required for the repositioning of Meteosat-3 under the ADC and X-ADC activities, the idea for the future was one of balanced input and hence it was agreed that no more funds would be exchanged. The signing of the Back-Up Agreement was one of the first key milestones in the EUMETSAT-NOAA partnership.

3.2 Data Policy on Geostationary Satellites

The necessity of a sound plan for data access and distribution had already been stressed in the theoretical framework of this study, since it was one of the key elements for successful collaboration in space missions as identified by the Joint Committee of the U.S. National Research Council and the European Science Foundation. In the case of meteorology, this feature is even more relevant considering that data are used by downstream user communities for weather forecasting.

In this respect, a major challenge for the collaboration between EUMETSAT and NOAA was the difference in philosophies upon which the principles of the European and American data policies are based. The United States apply the so-called "full and open" data policy, which is in line with the idea that civil meteorological data should be freely available to citizens and the private sector because they are paid by taxpayers. With a free and open data policy the U.S. government also intends to support the development of commercial meteorological sectors. In Europe, the production of meteorological data is also financed by tax revenue, but most of the governments considered that data should be made available at some cost for use for commercial purposes. This seeks recognition of the economic value of the data through a price, assuming further that the price of input data cannot be a barrier to business development, and that revenue will somewhat reduce the contributions from taxpayers. The conflicting positions were resolved in the framework of the WMO, with the adoption of Resolution 40, which identifies essential data available free of charge without restriction and allows WMO members to identify non-essential and other data which is subject to restrictions, e.g. through licensing. EU directives have further established that meteorological data shall be available under the same conditions, including price, to the private sector and the commercial arms of those National Meteorological Services entitled to have commercial activities. The latter are ensured a level playing field by introducing a degree of cost recovery vis-à-vis commercial providers. Not surprisingly, these basic differences were reflected in the respective data policies applicable to NOAA and EUMETSAT satellite date and products, in particular for geostationary orbit data.

Although data policy and data denial are treated as separate components in the collaboration between the two organisations, their negotiation and implementation will be discussed separately for geostationary and polar orbiting satellite programmes. This is done not only to ensure consistency with the overall structure of this study, but it also facilitates a better distinction between the specific issues of concern in both fields of collaboration. This is especially helpful in the analysis of the crisis that occurred during the negotiations on data policy and data denial in the Initial Joint Polar System (IJPS), an issue that will be addressed thoroughly in chapter four.

3.2.1 The Geostationary Agreement

The need for an agreement on data policy arose as of 1995 when EUMETSAT started to prepare encryption of its geostationary High Resolution Images (HRI). The possibility of encryption enabled EUMETSAT to have secure control of access to data at individual file and individual user level. EUMETSAT's access to American geostationary satellite data from the GOES-system did not pose any particular problems or changes because of the application of the "full and open" data policy in the United States. To maintain access to the EUMETSAT data, the American partners stated they would appreciate a mutual agreement on data use rather than a unilateral license given to them by EUMETSAT. Such an agreement would also emphasise the reciprocity of their collaboration, which would be less clear should a unilateral license be granted.

[28] The EUMETSAT Council voted in favour of the Back-up Agreement at the 23rd Council in June 1993, which gave the Director the authorisation to sign it.

The EUMETSAT Council started to reflect on the proposal for an agreement with the U.S. on geostationary (and polar) data use in May 1994 and used its data policy – as agreed in 1991 – as a legal reference. The organisation's Working Group on Data Policy (WGP) and its Policy Advisory Committee (PAC) recommended basing the HRI data agreement upon four major principles:

- The agreement ensures that both parties make their data available to the other partner under certain conditions on a no-exchange of funds basis.
- U.S. governmental authorities can use EUMETSAT data worldwide for official duty purposes. NOAA shall provide EUMETSAT with a list explaining what kind of EUMETSAT data is used by U.S. Governmental Authorities and for which purposes.
- EUMETSAT data is freely available for research purposes in the USA. However, this shall be carefully monitored to avoid commercial use of the data received at no cost.
- A subset of EUMETSAT three-hourly data may be redistributed by NOAA to American commercial users. Hourly and half-hourly data, however, shall not be accessible without a prior licence to be granted by EUMETSAT. The latter is granted on a non-discriminatory basis against a fee in accordance with general EUMETSAT tariffs.

Following authorisation by the 25th EUMETSAT Council, a draft agreement containing the above elements was consequently proposed by the EUMETSAT Secretariat to NOAA in the summer of 1994. After initial discussions NOAA informed the Secretariat in September that year that the U.S. had decided to undertake a general review of its data policy and that therefore no formal negotiations could take place with EUMETSAT until this review had been completed. The secretariat, taking note of the situation, drew attention to the fact that Meteosat HRI data would be encrypted from September 1995 onwards and that it would be in the interest of NOAA to have an agreement on data access as early as possible, given that some technical adjustments of receiving facilities would become necessary for data decryption.

In July 1995 – a few months before the encryption was to go into effect – NOAA indicated that the internal review of data policy issues on the American side had nearly been completed. On this basis, informal negotiations between the trans-Atlantic partners proceeded, resulting in a draft agreement on "Access to Images from the EUMETSAT Geostationary Meteorological Satellites", referred to as the "Geostationary Agreement". Shortly after, the Geostationary Agreement was signed and entered into force.[29] The provisions were in line with the principles defined by the EUMETSAT Council.

Extension of the Geostationary Agreement

The duration of the 'initial' Geostationary Agreement was stipulated to be five years, which meant that is was due to expire on 20 July 2000. Given the wish of both parties to continue collaboration in geostationary meteorology, a new agreement had to be drafted. Consultation between the partners resulted in a draft proposal for the Extension of the EUMETSAT-NOAA Geostationary Agreement. Although the spirit of this proposed 'Extended Geostationary Agreement' was similar to its predecessor, some changed were made, as it was necessary to incorporate new developments. For example, NOAA was interested in being granted access to Meteorological Data Dissemination (MDD) material from the Meteosat satellites. This request was granted; access to MDD was added to the Image Data made available without fee to NOAA and was provided for official duty use without territorial restriction. NOAA also proposed rephrasing the liability clause because of an ongoing policy debate within the U.S. Government on the use of language in international agreements. It was deemed that the notion of wilful misconduct was not sufficiently defined and thus its use would weaken the parties' commitment to cross-waiver of liability.

In contrast to the Geostationary Agreement, the duration of the renewed agreement was linked to the end of life of the EUMETSAT satellites under the Meteosat Transition Programme (MTP), instead of a fixed period. The MTP program was established to ensure operational continuity between the end of the successful Meteosat Operational Programme in 1995 and Meteosat Second Generation (MSG), which eventually came into operation at the start of 2004 using improved satellites. The MTP provided an overlap with MSG by continuing the current Meteosat system until the end of the year 2005.

Access to Meteosat Second Generation Geostationary Data

By 2002, the run-up to the Meteosat Second Generation was taking place, and so both partners started to prepare a draft agreement that would guarantee NOAA access to images and MDD material from EUMETSAT's new and improved generation of geostationary satel-

[29] The Geostationary Agreement was signed by EUMETSAT and NOAA on the 12th and the 20th of July 1995, respectively.

lites. The eventual result – not surprisingly – was very much in line with the spirit of the Extended Geostationary Agreement. After all, the structure and stipulations in the previous agreements had proven to be a solid basis for collaboration in the field of data exchange, therefore all clauses were altered only to include references to the MSG Image Data and MDD Material. Further, the agreement also stated that the free access granted to NOAA was given in recognition of its contributions to the WMO's GOS and the meteorological satellite data provided to EUMETSAT, its Member States and user communities. Signed in June 2003 for a period of five years, this agreement too was followed up by an Extension Agreement in July 2008, which automatically renews itself after five years, unless either party objects by providing 60 days written notice to terminate to the other party.

3.3 Geostationary Satellite Activities and the Theoretical Framework

Now that all collaborative activities between EUMETSAT and NOAA in the field of geostationary satellites have been described, they can be linked to the theoretical framework on the "key elements to success in international collaboration in space missions" presented at the beginning of the study.

The historical foundations preceding the first pursued geostationary undertakings were already described elaborately in the second chapter of the study. In addition to those foundations laid before the establishment of NOAA and EUMETSAT, the collaboration record revealed that both organisations initially started collaborating on an ad hoc and case-based basis, as illustrated by the repositioning of the GOES-4 satellite and later the Meteosat-3 satellite. These developments paved the way for the structural, pro-active joint activities deployed later: the Back-Up Agreement and the Geostationary Agreement. In terms of scientific support, the second criterion, both organisations can internally and externally count on a wide range of expertise from scientists, management and engineers. In addition, the user-driven structure of the meteorological community creates an open and very science-oriented context that facilitates the decision-making process and implementation of both NOAA's and EUMETSAT's activities.

In terms of shared objectives, it is very clear that the two partners are closely aligned: i.e. both are operational agencies with a similar mission and modus operandi regarding time horizon, risk-avoidance, requirements and user-communities. With criteria four and five, the definition of responsibilities and plans for data access and distribution were guaranteed by the stipulations in the Back-Up Agreement and the Geostiaonary Agreement. Although the joint geostationary activities were among the first direct bilateral forms of collaboration between EUMETSAT and NOAA, the fledging sense of partnership was demonstrated by the willingness to help out each other by reposition satellites and the executed activities, both legal and technical, related hereto. Moreover, the non-exchange of funds basis of the Back-Up Agreement shows that there was sufficient trust and confidence between the partners that over time efforts would be more or less balanced and mutual. In other words, EUMETSAT and NOAA regarded each other's technical capabilities as more or less of the same quality and reliability; otherwise, the non-exchange of funds basis would have been detrimental for one of the parties. Reviews take place through the renewals of the legal agreements that are intended to prolong them and at the same time keep them up-to-date.

Finally, beneficial characteristics of these first collaborative undertakings are definitely present. Although they will be addressed in much more depth in the final chapter of the study, it is clear that the stipulations of the two agreements guarantee a more secure data access and, increased continuity of data providence for the user communities in cases of performance anomalies or premature satellite failures.

All these elements demonstrate that the working together in geostationary satellite meteorology entails all elements essential for successful collaboration and while some criteria – such as the historical foundations and shared objectives – were intrinsically fulfilled, others were guaranteed by the choices made in their collaboration record.

4. Polar Orbiting Satellites

Unlike geostationary satellites, the ground track of polar orbiting satellites moves with respect to the Earth's surface. Passing close to the poles at approximately 800 km above the planet, these satellites cover a different ground swath on each successive orbit. Generally, polar-orbit meteorological satellites are given a sun-synchronous orbit that ensures that the satellite ascends or descends over any given Earth latitude at the same local mean solar time. This time consistent position facilitates the comparability of the detailed and specialised data on the Earth's surface and atmosphere their instruments provide. This data supports a broad range of environmental monitoring applications including weather analysis and forecasting, climate research and prediction, global sea surface temperature measurements, atmospheric soundings of temperature and humidity, ocean dynamics research, volcanic eruption monitoring, forest fire detection, global vegetation analysis and many others.

4.1 The First Developments in Polar Orbiting Collaboration

4.1.1 The American Meteorological Polar Satellite System

The United States has been experimenting with polar orbiting satellites since the beginning of its space programme in the 1950s. The ninth Television Infrared Observation Satellite (TIROS-9), developed by NASA, was the first to provide a complete daily coverage of the entire sun-illuminated portion of the Earth. It was launched into sun-synchronous, near polar-orbit in 1965. Throughout the 1960s and 1970s a period of phenomenal discovery and development in remote sensing characteristics occurred as a result of the symbiotic and productive relationship between NASA, the U.S. Department of Defence (DoD) and NOAA. As an heir to this environmental satellite technology, NOAA was able to establish its own programme of operational 'second generation' polar orbiting satellites in the early 1970s, the TIROS-N series.[30]

An important step in the process of polar orbiting satellite collaboration was the authorised declassification of the previously secret Defense Meteorological Satellite Program (DMSP) in the United States. This decision, made by President Nixon in 1973, led to a restructuring in order to avoid the danger of partial duplication and the related redundant development cost of funding two similar series. As a consequence, NOAA was directed to use the DoD spacecraft design for the next generation of polar-orbiting satellites. An important element in this second generation series was the choice of using a two spacecraft NOAA system to cover the morning and afternoon orbit.[31] In the 1980s, however, NOAA needed to balance the high cost of space systems and the growing need to provide a complete and accurate description of the atmosphere at regular intervals as input to numerical weather prediction and climate monitoring support systems. This implied NOAA was considering the option of covering only one orbit in the future. As this restructuring would have repercussions on the balance of input of the Global Observing System, intergovernmental discussions were initiated to guarantee the continuity of service of the GOS in the long term.

4.1.2 The Choice of a European Meteorological Polar Satellite System

The official U.S. announcement declaring the intent to downscale the American polar-orbiting programme from 1995 onwards was made by the Reagan Administration in 1983, coincidentally also the year in which the EUMETSAT convention was opened for signature. More precisely, American morning and afternoon orbit satellites were to be launched

[30] These second generation satellites provided day and night viewing of the Earth's cloud formulation with visible and infrared scanning radiometers, simultaneous direct readout broadcasts, and data storage for later playback to a central processing ground station. They also measured snow and ice extent, sea surface temperatures, and gathered vertical atmospheric temperature and moisture profiles over the entire globe on a daily basis.

[31] A major aim in the second generation of polar orbiting satellites in the U.S. was to achieve daily, day and night global atmospheric sounding coverage.

in 1994 and 1995, respectively, and thereafter, only the afternoon orbit would have continuity within the NOAA responsibility. It should be recalled that this decision was driven by cost savings in the United States and by the will to get a more balanced global input in the WMO's GOS framework. It was generally understood that Europe was expected to take over coverage in the morning orbit. Following this declaration, the issue of global Earth observation was taken up by the G7 summit in 1983. The political leaders at the G7 forum held in Williamsburg, Virginia, decided to set up a dedicated panel of experts on remote sensing from space to take up the matter. This panel, attended by representatives of the G7 Member States[32], along with ESA and the European Commission, met one year later in Washington DC to discuss the possible contributions they could make to a polar-orbiting mission.[33] In response to one of the recommendations from the panel, the permanent coordination platform 'Committee on Earth Observation Satellites' (CEOS) was established. Although ESA envisaged a polar-orbiting mission by the mid-1990s, it took a somewhat cautious approach in the discussions regarding operational meteorology from the mid-morning orbit. It considered that additional support for meteorological satellites would prove difficult given its relatively recent involvement in geostationary meteorological satellites. Some of the European states present were in favour of a European initiative as a contribution to the international polar-orbiting system, analogue to the Europeanised structure of the Meteosat programme. This pointed the way towards future EUMETSAT involvement, however, many obstacles impeded a fast final decision.

A major barrier at the time was the scope of the International Space Station (ISS). NASA was strongly in favour of having an array of operational meteorological instruments on board the ISS, as this would have the advantage of on-board maintenance and upgrading through human involvement. Meteorologists on both sides of the Atlantic, however, had reservations as to its effectiveness for operational meteorology. EUMETSAT acted as a focal point for the general European requirements and after a while it became clear there were serious shortcomings in terms of continuity, reliability and affordability in the ISS solution. Eventually, in early 1989, NOAA finally abandoned the ISS option in favour of independent polar-orbiting satellites. As a consequence, the specifications on implementation were now to be elaborated further on the European side only. Nonetheless, ESA and EUMETSAT were confronted with a different mind-set regarding the set-up and structure of this venture. The EUMETSAT Council approved a resolution that stated that EUMETSAT was prepared to consider a fixed financial contribution to the polar-orbiting activity and to prepare a follow-on programme that would ensure long-term commitment. In parallel, ESA was developing the Polar-Orbiting Earth Mission (POEM) as a follow-up to its European Remote Sensing (ERS) satellites, and these parallel paths resulted in lack of clarity on the further deployment of a European polar system.[34] This lasted until the EUMETSAT Council meeting in June 1992, where it was decided that ESA should formulate a revised plan based on the splitting of the POEM concept into two parts, the Environmental Satellite (Envisat) and the Meteorological Operational Satellite programme (MetOp). This milestone set the scene for the preparation of a new polar-orbiting programme for EUMETSAT, which together with ESA, would be jointly responsible for the procurement of the MetOp satellites. The Preparatory Programme for the EUMETSAT Polar System (EPS), the European component of the Initial Joint Polar System, had commenced.

4.1.3 Towards the Initial Joint Polar System

Before the Initial Joint Polar System (IJPS) was established by NOAA and EUMETSAT, both organisations had the intent of sharing infrastructure and exchanging instruments in the field of polar orbiting satellites. Although eventually only the infrastructure was shared and the instruments were only later exchanged under the IJPS agreement, these prior actions stimulated the sense of partnership between both organisations, and as such they paved the way for the later deployment of the IJPS.

Sharing of Infrastructure

In 1987, the French Meteorological Service asked EUMETSAT to consider the possibility of taking over NOAA equipment it had been using at the CMS site at Lannion, France. The

[32] These countries were France, West Germany, Italy, Japan, the United Kingdom, the United States and, Canada.

[33] EUMETSAT was not present because its convention was still open for signature, but it would later become a member of the International Polar Orbiting Meteorological Satellite group (IPOMS), a specialised body proposed by the panel to focus – among other things – on the implementation of the polar orbiting component of the GOS.

[34] It should be noted that ESA offered EUMETSAT a free flight on its polar platform. This offer, however, carried no commitment to any launches after that flight. Thus, this offer did not meet the long term operational requirements of EUMETSAT.

equipment and ground facilities at Lannion were initially given for exploitation to the French Met Service to support NOAA polar-orbiting satellites (TIROS-N series) in 1981.[35] The major driving force behind the request to EUMETSAT was a new superseding EEC-regulation that would end the tax and VAT exemption this material had been subject to for many years. Acquisition by EUMETSAT would avoid this impending taxation, and at the same time offer a European perspective for the use of this equipment. The latter was especially relevant in the context of expanding EUMETSAT data processing activities. Moreover, the support of EUMETSAT would be a small contribution as it increased the European input regarding meteorological observations by satellites, thus decreasing the total imbalance of input on the EUMETSAT side that had developed in the late 1980s. It should be recalled that at the time, NOAA was still providing back-up support by repositioning its GOES-4 satellite and no back-up support provided by EUMETSAT to NOAA had yet taken place. In this regard, the take-over of equipment helped EUMETSAT gain some political impetus at a time when the organisation was still small and had to prove its capability to build solid partnerships and to live up to its international commitments. Finally, this takeover would be beneficial from a purely meteorological point of view as well, since the operation involved acceleration of the acquisition of data on Western Europe, an essential element in weather forecasting.

It was understood that the allocation of the equipment from CMS to EUMETSAT would take place without any exchange of funds, and that CMS – together with NESDIS – would provide, at its own cost, the facilities and personnel necessary to fulfil its responsibilities under the agreements. After agreement by EUMETSAT's STG and AFG, the Secretariat prepared two draft arrangements, one between France and EUMETSAT and one between NOAA and EUMETSAT. Eventually the signing of the Memorandum of Understanding (MoU) and exchange of letters between EUMETSAT and NOAA/NESDIS in November 1988 made official the allocation of the Lannion equipment to EUMETSAT.

Exchange of Instruments

Part of the EUMETSAT Polar System (EPS) Preparatory Programme was to procure two instruments that would be provided to NOAA. Until then this Advanced Microwave Sounding Unit B (AMSU-B) had been developed, through industry, by the U.K. Meteorological Office, which had provided this instrument for the previous NOAA-K, NOAA-L and NOAA-M satellites. AMSU-B was designed as a multi-channel microwave radiometer intended to examine several bands of microwave radiation from the atmosphere to perform humidity soundings in cloudy conditions. The procurement of the AMSU-B for the NOAA-N satellite would consist of purchase through a dedicated EUMETSAT contract. Eventually, however, this instrument was exchanged as part of the activities defined in the IJPS agreement.

The other instrument, a Microwave Humidity Sounder (MHS), was to be provided to NASA for the purpose of its Earth Observation System Programme (EOS). Initially conceived as a large undertaking, the EOS was put through a restructuring process after reduction in funding levels by the U.S. Congress. Structurally, this meant that the instruments had to flown on a series of intermediate-sized and smaller spacecraft instead of a series of large platforms. More specifically, the Microwave Humidity Sounder (MHS) instrument was a successor to the AMSU-B and was designed to provide and improve continuity with the polar sounding capabilities aboard the EOS-PM spacecraft scheduled for launch in December 2000.[36] Although this provision was initially hard to reconcile with the EUMETSAT Convention, later amendments expanded the objectives of EUMETSAT to include contributing "to the operational monitoring of the climate and detection of global climatic change". The basic assumption for the provision of these instruments was that the synergetic sounding data from AMSU-A, MHS and AIRS, installed on the NASA EOS platforms, could be made available to EUMETSAT and its users via NOAA. The advantage of this pre-operational demonstration of the Advanced Infra-Red Sounder AIRS was that it would enable the major forecast centres in Europe to assess the value of hyperspectral infrared soundings, which EUMETSAT deployed on the MetOp satellites in 2006, based on different technology developed in Europe by CNES.[37] Although eventually this instrument was not delivered to NASA due to programme restructuring, exchange of instruments would become one of

[35] The ownership of the equipment, however, remained in the hands of NOAA all the time, CMS was responsible for the exploitation.

[36] Technically, the instrument was replaced by a similar microwave humidity sounder called HSB. The spacecraft was later renamed Aqua and was eventually launched on May 4, 2002.

[37] The CrIS instrument flown on the Suomi NPP satellite launched by the U.S. in 2011 was based on the same technology as IASI, and the NOAA National Weather Center benefited from the operational use of IASI data to prepare for using similar CrIS data.

the keystones of collaboration between the partners in the future IJPS constellation.

4.2 The Initial Joint Polar System

This section describes the establishment of the Initial Joint Polar System or IJPS. Conceptually, the IJPS comprised two series of two polar orbiting satellites and respective ground segments. The two series consist of a morning service fulfilled by the EUMETSAT Polar System (EPS) programme, providing MetOp-A and MetOp-B and an afternoon service fulfilled by NOAA providing the NOAA-N and NOAA-N' satellites, including an exchange of instruments for flight on each other platform. Figure 1 illustrates the IJPS constellation, showing the different satellites, ground systems and facilities for data dumping, both domestically and for the blind orbits.

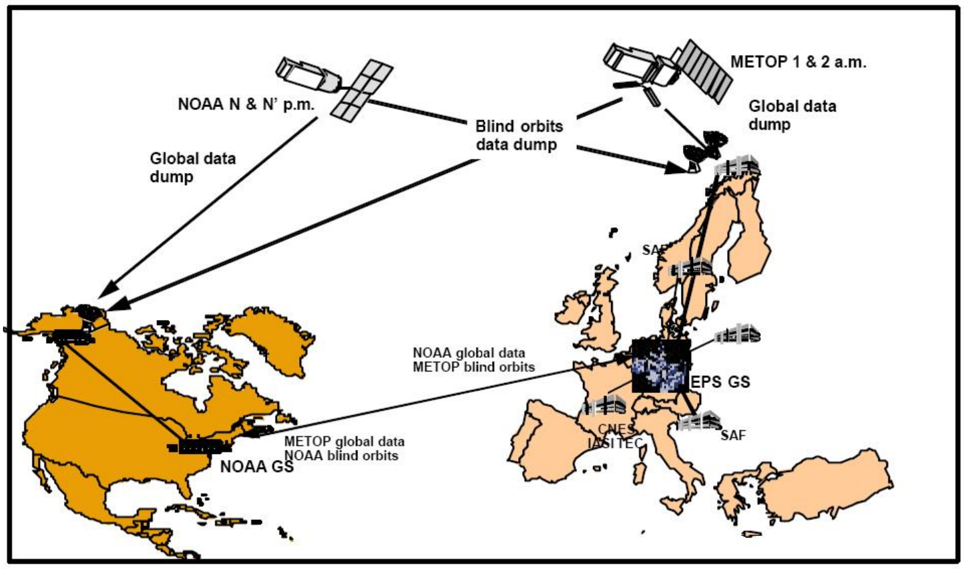

Figure 1: The Initial Joint Polar System Configuration.

In retrospect, the IJPS turned out to be the most complex and challenging achievement so far of the EUMETSAT-NOAA relationship in terms of effort and achieving progress and results. Issues of data policy and data denial turned out to be two of the major obstacles in the negotiation phase, and will be addressed thoroughly in this chapter.

4.2.1 Negotiation Phase

On the European side, negotiations with NOAA on what was coined the Initial Joint Polar System were accompanied by intense internal debates on the exact nature of the EUMETSAT Polar System. The EPS was conceived as a three satellite programme over 14 years, including the satellites MetOp 1, 2 and 3. The nomenclature in the series was later transformed into A, B and C, respectively. This confluence of internal programme development with an international dimension proved to be a challenging undertaking. Internally, the complexity of the MetOp missions gave rise to conflict with ESA on the payload and on the nature of the procurement process to be followed for the instruments. Eventually, ESA and EUMETSAT edged closer to harmony on the EPS programme and it was agreed that ESA would provide most of the funding for the first satellite in the series (MetOp-A) and would, with EUMETSAT, oversee the procurement of the remaining two satellites (MetOp-B and -C). ESA would also take responsibility for the storage of the satellites and would be involved in the preparation for launch in all cases. EUMETSAT would contribute to the cost of the first MetOp satellite and would fund the recurring satellites' ground segments, launch services, the launch early orbit (LEOP) phases. One of the policies that EUMETSAT adopted in the EPS programme was the insistence on firm fixed price contracts that sought to avoid the risk of cost overruns. This has worked very much to its advantage and increased the political support for the EPS programme.

At the same time, EUMETSAT and NOAA were in full negotiations on the intended IJPS joint-venture. The EUMETSAT Council was developing a proposal for the treatment of polar orbiting data. This was necessary to proceed in the negotiations with the American partners.

Some developments in the United States, however, radically changed the expected course of the negotiations.

The Impact of U.S. Convergence

On the American side, convergence turned the existing civil and military operational meteorological satellite programmes into a single, integrated, end-to-end satellite system. This joint programme was formed in 1994 by a Presidential Decision Directive under the Clinton Administration. The U.S. government had traditionally maintained two operational weather satellite systems, each with an over 40-year heritage of successful service: NOAA's Polar-orbiting Operational Environmental Satellite (POES) covering the afternoon orbit, and the U.S. Department of Defence's (DoD) Defense Meteorological Satellite Program (DMSP) covering the early-morning orbit. At the time, however, changes in world political events and declining agency budgets prompted a re-examination of the two systems and a consideration of combining them. In 1992, a U.S. National Space Council study recommended convergence of the two separate weather satellite systems. Following further recommendations and influenced by increased interest of the U.S. Congress, NOAA, DoD and NASA initiated studies in 1993 to determine how to converge the two systems. A completed study revealed that a converged system could reduce agency duplication and bureaucracy, substantially reduce costs, and satisfy both civil and military requirements for operational, space-based, remotely sensed environmental data. This tri-agency study formed the basis for the development of the implementation plan for what would later become the National Polar-orbiting Operational Environmental Satellite System, NPOESS. An Integrated Program Office (IPO) was set up to provide each of the participating agencies with lead responsibility for one of three primary functional areas. NOAA was given overall responsibility for the converged system and was also responsible for satellite operations. NOAA was also the primary interface with the international and civil user communities. DoD was made responsible for supporting the IPO for major systems acquisitions, including launch support. NASA had primary responsibility for facilitating the development and incorporation of new cost-effective technologies into the converged system.

In the negotiations between EUMETSAT and NOAA, this element entered very late and without prior consultation and hence the negotiation process was fundamentally transformed in a very short time. The late announcement was due to the United States government's wish to keep the confidentiality of the decision-making process intact vis-à-vis industry until a final decision had been made. Given that DoD would occupy one orbital slot and that IJPS was conceived as a two orbital slot satellite system – recall one morning orbit foreseen for EUMETSAT and one afternoon orbit to be continued by NOAA – there was a risk of EUMETSAT becoming redundant in the deployment of the overall polar observing system. Moreover, approval for the MetOp polar satellite system had not yet been completed internally, which meant it became very hard for EUMETSAT to convince its member states to provide the required funding. EUMETSAT officials involved in the negotiations at the time recall it took a lot of negotiation effort and appealing to NOAA to convince the U.S. to speak of a three satellite system, and to include EUMETSAT in the mid-morning orbit[38]. Eventually this was accomplished although it was not an easy exercise as the military dimension in the converged American system brought in new requirements fundamentally different from the civilian modus operandi characterising NOAA and EUMETSAT. In this respect, EUMETSAT officials experienced difficulties because DoD seemed reticent to rely on international partners.

Eventually, with EUMETSAT confirmed as an integral partner in the polar satellite system, negotiations on the specifications of the deployment proceeded. The negotiation phase on the issues of data denial and data policy for the implementation of the IJPS was initiated by the convergence on the American side in the early 1990s and ended when a final compromise was reached on all specifications as formalised in the final IJPS agreement signed in 1998. Spanning many years, different incidents throughout this period had seriously tested the solidity of the partnership that had grown between NOAA and EUMETSAT. In retrospect, this tumultuous period can be divided into a first phase of dissension, following a phase in which compromise-seeking held the upper hand. The main reason for this equivocal course were the envisaged underlying principles for the to-be-applied data policy and data denial in the eventual agreement, for which the solution lay in a compromise rather than convincing the other partner to change its respective data policy. After all, the specific data policies applied by both organisations went back to their organisational structure and working environment and hence could not be changed that easily. The following two sections de-

[38] The early morning orbit with an equatorial crossing time at 5.30 a.m. fell under the responsibility of the Department of Defence.

scribe the parallel negotiation processes and outcomes for the IJPS on data policy and data denial, respectively.

Negotiations on Data Policy

Around 1994, the initial EUMETSAT proposal for the use of polar satellite data was structured around three points. The organisation's Working Group on Data Policy (WGP) and Policy Advisory Committee (PAC) recommended an agreement based upon following principles:

- Low Rate Picture Transmission (LRPT) data from both the European and the American polar satellites would be available without any restrictions.
- Global data and High Rate Picture Transmission (HRPT) data from the American satellite would be available without any restrictions.
- The EUMETSAT satellite would be built with an encryption capability. Concerning global data and HRPT data from that satellite EUMETSAT reserved the right to encrypt and control the data at a later stage if necessary to protect the rights of its Member States. In any event there would be no restrictions for official U.S. governmental authorities' use worldwide.

In abovementioned principles, there is distinction concerning the availability of the high rate picture transmission in the NOAA and EUMETSAT satellites. In the EUMETSAT case, the technical possibility for data encryption served a functional purpose that was based upon the specific data policy of the organisation. Obtaining observations from meteorological satellites is expensive. This was one of the reasons why different European states had come together to share resources through their participation in EUMETSAT. This voluntary collaboration however implied that free riding behaviour could be possible if all data was available at no cost. If any country not a member of EUMETSAT could receive all high rate transmission data for free there would be no incentive for any country to apply for membership and pay contributions. In this way, the data policy of EUMETSAT was – in addition to the reasons relating to WMO Resolution 40 – also shaped by its governance structure. This required that a compromise be found with organisations that operate on a national agency basis, like NOAA.

The converged satellites would satisfy both military and civil requirements, and conforming to American practice, data from the converged system NPOESS would be openly distributed under normal conditions. The U.S., however, would have the possibility of restricting access to data from certain of its instruments over restricted areas during times of conflict for reasons of national security. The EUMETSAT Secretariat informed the U.S. representatives of its reservations about data denial in general because of its exclusive civilian character and that if data denial should be debated by the EUMETSAT Council then it could only be considered on the basis of a proposal which fully respected an equal partnership between the organisations involved. Consequently, data denial was treated as a separate topic in the negotiations on the IJPS and hence will be discussed subsequently.

Following a discussion on this item at the 25th EUMETSAT Council in June 1994, the Council deferred agreement on the proposal for polar orbiting satellite data pending the outcome of further discussions on convergence of U.S. programmes. The main open point between both partners was the question whether EUMETSAT's data control would apply worldwide or only with regard to Europe. One year later, at the 27th EUMETSAT Council in 1995, the negotiation efforts had resulted in a draft agreement on the establishment of an Initial Joint Polar System comprising of two series of 2 polar orbiting satellites and their respective ground segments, including the exchange of instruments for MetOp-A, B and NOAA-N and NOAA-N'. The EUMETSAT Secretariat intended to conclude the agreement but a consensus had not yet been reached on articles dealing with data policy. EUMETSAT believed it should have the right to control access to HRPT and Global Data from the EUMETSAT satellites and that this control should not just apply to U.S. Government Agencies and other U.S. users. Access to HRPT and Global Data from EUMETSAT satellites for non-U.S. users would be granted on a non-discriminatory basis according to defined data policy principles.[39] In the American view, however, the right for EUMETSAT to control access to IJPS data disseminated from the EUMETSAT satellites would only be possible within European territory, and not on a global basis. It was agreed that the EUMETSAT PAC would review the issue and

[39] Certain data and types of use are subject to a fee, any user may obtain a license plus decryption key and is subject to license conditions. All National Meteorological Services of Members of the WMO are provided a set of data free of charge. For data sets beyond this "basic" data set, the following applies: All National Meteorological Services in countries with a Gross National Product of less than 2000 U.S. $ per capita may receive all data without any fee. Other National Meteorological Services are only subject to fees for this additional data. Commercial users have full access; however, there is a fee depending on the kind of use intended. Research and educational use is free of charge and access is provided at no more than the marginal cost.

several options were subsequently put on the table:

1. *Platform provider's policy applies.* All data from all instruments is subject to platform operator's policy. Encryption capability may be used at a platform operator's discretion to implement this policy. For the EUMETSAT platform, this involves use of data control (encryption), licensing and fees. For the NOAA platform, data would be distributed without restriction consistent with U.S. data policy.
2. *Instrument provider's policy applies.* Access to all data from any instrument is subject to the policy of the party that provides the instrument. Data from NOAA satellites is distributed without restriction to all users consistent with U.S. data policy. Data from EUMETSAT instruments is distributed in accordance with EUMETSAT data policy.
3. *Regional approaches:*
    1. EUMETSAT applies its policy and controls data from the entire MetOp payload within a defined region and the U.S. establishes policy for the rest of world from its instruments. For the EUMETSAT platform, this entails use of data control (encryption) within the region. For the NOAA platform, data are distributed without restriction consistent with U.S. data policy.
    2. EUMETSAT applies its policy and controls data from the entire MetOp payload for all regions except the United States, including official United States Government duty use worldwide. For the EUMETSAT platform, this entails global use of data control (encryption). For the NOAA platform, data are distributed without restriction consistent with U.S. data policy.
4. *Procurement approach.* EUMETSAT procures the necessary U.S. instruments and thus applies its policies to the entire payload. NOAA procures the necessary EUMETSAT instruments and thus applies its policies to the entire payload. Data from NOAA satellites is distributed without restriction; data from EUMETSAT instruments is distributed in accordance with its policies.

Based upon these different approaches, both organisations put forward their preferred options. Ideally, the U.S. preferred there to be no restrictions placed on IJPS data at all, but as this option would be impossible given EUMETSAT's data policy it had a preference for option 2, as this would ensure that no restrictions would be placed on data from U.S. instruments except during crisis or war. For EUMETSAT this option was hard to accept, as it would entail that each potential instrument provider could come to the platform operators and propose to fly a new instrument with a completely new data policy. This could lead to conflict and to consequent lack of progress because potential instrument providers would lack a clear understanding of what the technical and legal constrains of flying with a particular partner are. In the light of long term development of increased international collaboration, EUMETSAT could not support this option as a general principle.

Ideally, EUMETSAT preferred to apply its policy to all its satellites in the IJPS constellation, thereby enabling users to recognise the immense value of the satellite data while providing a mechanism to ensure a direct benefit to those countries which provide the actual funding, namely its Member States. In the context of the negotiations on data policy for the integrated IJPS system, EUMETSAT had a preference for option 1 because of its clarity; it would give an agency direct control over the data from the platform that it operates and ensure that there is only one data platform for a given platform. For the U.S. this option would only be politically viable if EUMETSAT did not apply restrictions to data beyond those identified as acceptable in 3.1. Moreover, option 1 would imply that the U.S. could be unable to ensure access to U.S. instruments data by NMSs globally even though these data are to be considered part of a single data set, which would be in contravention of U.S. policy directives.

EUMETSAT		NOAA
Assessment	**Option**	**Assessment**
Preferred option	1	Politically unviable under most conditions
Not preferable because of risk of conflict	2	Preferred option
Second best option / Compromise	3.1	Second best option / Compromise
Complexity of licensing	3.2	Politically not viable
Politically not viable	4	Risk of divergence and complexity in IJPS

Table 2: Overview of the IJPS Data Policy Options and their Attributes.

Further, U.S. officials stated they would be able to accept option 3.1 as a compromise, with some greater understanding on the nature of the regional control EUMETSAT would exercise. Interestingly, this option combined features of option 1 and 2, the EUMETSAT and NOAA preferences, respectively. Having regard for the U.S. policy, EUMETSAT also considered option 3.1 as a possible compromise. In this regional option the U.S. policy would apply worldwide for all instruments except for use with Europe, while the EUMETSAT policy would apply worldwide for all EUMETSAT instruments except for use within the U.S. It is this symmetry that made this option acceptable as a compromise solution.

Options 3.2 and 4 were not really favoured by either partner. For EUMETSAT option 3.2 would entail a huge deal of complexity because there would be licensing of the use of data from U.S. instruments over the entire world, while users could get free and unrestricted access to the same data from the American satellites. For the United States, this option was politically unviable for essentially the same reasons that were problematic in option 1: it would restrict the world community's access to data from U.S. instruments and at worst, even restrict the use of the data itself. Option 4 was not preferred by the U.S. because it would basically avoid the compromise required for a common approach to a shared platform. It would imply significantly divergent data policies for separate elements of the joint system. In fact, it would even reduce the cooperative and joint aspects of the IJPS constellation as a whole, increasing the risk of divergence between both partners because of the lack of historical precedents for collaboration. The latter was problematic because it could have serious impacts on system optimisation and the ability of the U.S. to rely on the EUMETSAT element for national security purposes. EUMETSAT considered this option politically unrealistic because it implied that the U.S. would procure instruments in Europe and EUMETSAT would procure instruments in the U.S. Moreover, because of duplication of instrument development cost, this option would have decreased one the most substantial benefits of IJPS undertaking: economies of scale.

Further elaborating the compromise solution, in line with the WMO Resolution 40[40], regional option 3.1, the EUMETSAT Council defined the conditions of access to so-called "non-essential" that would be subject to use within the EUMETSAT-zone. As opposed to the essential data set from EUMETSAT polar satellites, the non-essential data is subjected to licensing and encrypted. The EUMETSAT Council endorsed the view that, regarding the non-essential data from U.S. instruments aboard MetOp, EUMETSAT regulations would only apply for the use of these data in the EUMETSAT zone. It also stressed that in order to enforce such regulations, it was necessary that the direct reception of this non-essential data be controlled by encryption on a global and permanent basis. The Council unanimously agreed that the Secretariat should further negotiate with the United States officials in order to finalise the agreement on this basis. Following the mandate given to the Director by Council, a meeting was held in January 1996 with U.S. representatives. In order to avoid a deadlock situation, a possible compromise approach was explored at the meeting. In addition, in the EUMETSAT PAC meeting of March 1996 it was agreed that for the IJPS the MHS data would be treated as essential data on both the U.S. and EUMETSAT platforms and that the EUMETSAT Council would need to agree the terms of any conditions of use of the non-essential data. In essence, the compromise refers to the following key issues:

- The U.S. accepts that certain data from their instruments on MetOp may be categorised as "non-essential data" by EUMETSAT.
- EUMETSAT accepts not to control access to data from U.S. instruments on MetOp. This means that no encryption would apply to U.S. instruments during the Initial Joint Polar System period.
- The U.S. accepts that non-essential data from U.S. instruments on METOP may be subject to conditions on use (e.g. licensing and charging) within the EUMETSAT zone.

In the period following, discussions between EUMETSAT officials and the United States representatives progressed well and by mid-1996, most issues regarding IJPS data policy had been resolved.

Negotiations on Data Denial

In parallel to the discussions on data policy, negotiations proceeded on the implementation of data denial for U.S. instruments on MetOp-A and B. Data denial was one of the fundamental principles of the converged system; it must ensure the ability to selectively deny critical environmental data to an adversary during crisis or war, while enabling the

[40] Secretariat of The World Meteorological Organization, Resolution 40: "WMO Policy and Practice for the Exchange of Meteorological and Related Data and Products Including Guidelines on Relationships in Commercial Meteorological Activities" during The Twelfth World Meteorological Congress (1995) (Cg-XII).

use of such data by U.S. and allied military forces. It was envisaged that the full converged system would come into effect after NOAA-K, L, M, N and N'. The U.S. indicated that while full convergence of instruments and spacecraft would not occur before the construction of MetOp-A and B, there would be a high possibility that MetOp-B would fly during a time-frame in which it would be the only mid-morning satellite and that MetOp-A would still be in orbit during this time frame. The U.S. therefore required that the data denial capability be included in the NOAA-EUMETSAT IJPS Agreement for the American instruments flying aboard MetOp-A and B. This way, data denial would begin to be applied to U.S. instruments on both the U.S. converged system and the EUMETSAT platforms at the time of the launch of the first afternoon converged satellite. This decision to develop an integrated structure suddenly introduced a military component into the negotiations between EUMETSAT and NOAA, organisations that until then had been cooperating on a civilian and user community oriented structure.

Initially, the EUMETSAT Secretariat had reservations about the general concept of data denial and its implementation because of the civilian character of the organisation.[41] Further, it informed the U.S. representatives that if data denial should be debated by the EUMETSAT Council it could only be considered on the basis of a proposal that fully respected an equal partnership between the organisations involved. This meant that data denial could not just be imposed in a unilateral manner and without prior consultation. The United States agreed and negotiations were initiated to elaborate the further implementation of data denial on the EUMETSAT satellites. A first issue that required further clarification was the procedure and process for decision making to be followed and the exact implementation for data denial on U.S. instruments. Both parties put forward their initial views and ensuing negotiations between the EUMETSAT Secretariat and the United States yielded following common approach:

a. *The Criteria for Decision* are intended to serve as a framework used by NOAA to explain its intention to the EUMETSAT Director:

   - whether a condition of crisis or war exists or is developing and whether the crisis or war poses an immediate and serious threat to the U.S. and/or Allied national security objectives – e.g., whether it affects the lives of U.S. and/or Allied personnel and resources;
   - an adversary's ability to receive and exploit environmental data from U.S. sensors for military purposes;
   - an adversary's ability to receive and exploit similar environmental data from other sources for military purposes;
   - what advantage the U.S. instruments' data would provide an adversary, given that similar data may be available from other resources;
   - the impact of denying data to non-adversaries who may also be affected by data denial;
   - the U.S. would consider its international obligations, include those with EUMETSAT and its members, in making a decision on data denial.

b. *The Process for Decision* would need to reflect the equal partnership nature of the collaboration by timely and reliable consultation in the process leading up to a decision to deny data.

   - the EUMETSAT director would be the focal point for consultations with the U.S. and be empowered by the EUMETSAT Council to act on its behalf, which implies no concurrence is required by all EUMETSAT Member States individually;
   - the United States would inform the EUMETSAT Director at the earliest possible time that it was considering data denial; this would ensure that the views of EUMETSAT would be integral to the overall U.S. decision-making process;
   - the United States would use the abovementioned criteria to assess the situation and inform the EUMETSAT Director. Since the criteria would be pre-agreed by the EUMETSAT Council, the Director would be able to authorise implementation to proceed data denial on a timely basis;
   - if more partners were part of an international coalition including the United States, a broader consultation process will take place.

c. *The Implementation* of data denial would be performed by EUMETSAT on the following basis:

   - to a specific user;
   - to a group of users;
   - to a geographic region; or

[41] Note that some of the EUMETSAT Member-States are not members of NATO, such as Austria, Ireland, Finland, Sweden and Switzerland.

- to all users except the pre-defined list of users (incl. EUMETSAT and its Member States' national meteorological services) on the understanding that none of these users would redistribute data; and
- within a specific time frame.

This common approach was translated into a draft '*Procedure and Process for Decision Making and Implementation of Data Denial on U.S. instruments*' that further defined all elements of data denial as described in the negotiations more precisely: crisis or war, critical data, adversary. In addition, this draft procedure stated that both parties agreed that, in due course, reciprocal arrangements could be established between the U.S. and EUMETSAT to meet possible EUMETSAT data denial requirements. This draft document was reviewed at the 19th EUMETSAT PAC Meeting in November 1995. Here, the United Kingdom suggested that also European non-member states co-operating with EUMETSAT should be treated as Member States for data denial, as this would be consistent with the proposal to include them in the EUMETSAT zone in the data policy negotiations. Also, the PAC recommended that the provision for reciprocity in data denial should be stipulated in a legal article rather than in the implementation procedure. With the understanding that these changes would be made to the draft agreement, the EUMETSAT Council unanimously agreed to the inclusion of data denial as an integral element of the collaboration agreement with the United States for the IJPS.

Both organisations set up a common Data Denial Working Group (DDWG) that was mandated to further elaborate on the issue. One year prior to the launch of the first MetOp satellite, the DDWG completed a comprehensive Data Denial Implementation Plan (DDIP), which was reviewed and signed by both parties in 2004. Structures like the DDWG can be seen as a form of review as they ensure continuous monitoring and implementation of collaboration activities. Among other things, this ensures compliance with each organisations' operational needs and is therefore vital for programme development in a solid cooperative framework. The theoretical framework presented at the beginning of this study has already made clear that sound plans for data access and distribution and reviews are indispensable for mission success in international collaboration. For operational meteorology these elements are even more critical as it operates on longer timescales.

4.2.2 The Initial Joint Polar System Agreement

By June 1996, most issues had been resolved and NOAA was authorised to sign the Agreement. In a vote, the EUMETSAT Council unanimously approved the collaboration agreement with NOAA on an Initial Joint Polar Orbiting operational Satellite System. This agreement took into account the modifications requested by NOAA and those presented by the EUMETSAT Secretariat. Apart from a number of editorial corrections and clarifications, modifications included provisions on a geographically separate back-up Command and Data Acquisition (CDA) ground station and a geographically separated back-up Spacecraft Control Centre, in accordance with the EPS Programme Proposal. The approval was given on the understanding that the Agreement would only enter into force after formal approval of the EPS Programme, and that the application of the EUMETSAT data policy by possible future Cooperating States could be addressed with NOAA in a separate exchange of letters. The latter guaranteed the equal treatment of current and future Cooperating Non-Member States of EUMETSAT.

The IJPS Agreement in Detail

At the 38th EUMETSAT Council in July 1998, EUMETSAT Director-General Tillmann Mohr was pleased to announce that NOAA confirmed that the U.S. inter-agency clearance process had been completed, and thus that NOAA had obtained the authority to sign the Agreement as soon as EPS entered into force. This major achievement illustrated that the United States had confidence in the imminent full start of the EPS Programme and EUMETSAT's capability to set up its operational polar orbiting satellite system. The agreement was eventually signed by both parties in November 1998.

The preamble to the IJPS Agreement outlines the general context and major milestones in the historic records of EUMETSAT and NOAA. Also, it recalls the longstanding and fruitful collaboration between EUMETSAT and NOAA in the field of Earth Observation and indicates the usefulness of polar-orbiting collaboration for research on climate change and other sectors of the global Earth observation and science user communities. Following Article 1 describing the purpose of the IJPS in function of WMO and its GOS objectives, the Agreement addresses the future ambitions of this initiated collaboration. It states that the parties shall continue planning to extend the respective satellite series and to continue the interrupted availability of data from the system; generally improving polar observations beyond the satellite system as described in the overall agreement. This long term commitment is also reflected by the fact that IJPS – as the name indicates – concerns an initial operational system, implying the establishment of a follow-up system in the future.

The general system configuration and the responsibilities of NOAA and EUMETSAT are covered in articles 3, 4 and 5, respectively. These include the spacecraft NOAA-N and NOAA-N' on the American side and MetOp-A and 2 on the European side, the instrumentations carried by and exchanged between both parties and the ground segments for spacecraft control and, command and data acquisition (CDA). In this respect, there are four CDA sites that are active to support IJPS services. NOAA operates one at Wallops Island (Virginia) and a second one for data capture and satellite telecommanding at Fairbanks (Alaska). Those operated by EUMETSAT are located in Fucino (Italy), and in Svalbard (Norway). One of the unique aspects of IJPS is the ability for EUMETSAT to command MetOp satellites through the Fairbanks station, and NOAA to command its IJPS satellites through the Svalbard site.

Similar to the approach taken in the geostationary collaboration, there is no exchange of funds foreseen; each party will bear the costs of fulfilling of its respective responsibilities. The financial obligations of both parties are subject to the funding procedures and to the availability of the appropriated funds. Because NOAA – unlike EUMETSAT – must rely on yearly appropriations from the U.S. Congress, it agreed that the funds required to meet its obligations under the IJPS Agreement would be included within the highest possible priority in its annual budget request. This expressed strong recognition of the importance of the IJP System to U.S. missions and a strong sense of partnership towards the European partner.

In terms of data policy, the regional approach was integrated with the platform provider approach. This means that all data from NOAA satellites would be provided to other users in accordance with U.S. data policy and mutatis mutandis the same reasoning was applied to data from EUMETSAT satellites. However, EUMETSAT agreed not to control access to the data from the NOAA instruments on the EUMETSAT satellites in the sense that it would limit the application of its data policy concerning use of data from such NOAA instruments to the territories of its Member States only. In other words, the use of data from NOAA instruments on EUMETSAT platforms was not subject to EUMETSAT data policy outside the EUMETSAT zone. The stipulations regarding data denial for military purposes were included in an annex as described in the previous section.

To ensure a smooth IJPS implementation and operations, structures for management, coordination and consultation were established. Although both IJPS management structures remained independent, each party would consult as necessary with the other party on any matters under its control that might affect the Agreement's implementation. To this effect, both organisations agreed to develop and approve a Programme Implementation Plan (PIP). This PIP set forth the points-of-contact and management structures, all details required for the technical and managerial components of the IJPS deployment and the services and technical documents to be exchanged by both organisations. In addition, each party nominated a programme manager responsible for the implementation of its own programme and ensuring close coordination between the NOAA and EUMETSAT responsibilities. These programme managers alternately chair a committee in charge of facilitating consultation and coordination on the right level. Furthermore, the Agreement included general articles on: liability, based upon a cross-waiver of liability clauses, title and risk, settlements of disputes and, taxes and customs.

Finally, the last Articles stipulated the circumstances in which the Agreement could be amended and terminated. Noteworthy here is that in the event of major technical schedule or funding difficulties and if despite all reasonable efforts the difficulties cannot be resolved, either Party may terminate the Agreement. In doing this, however, it would have to consider any major disadvantages for the other party. If a party gave notice of termination, both organisations had to reach agreement as soon as possible concerning the terms of condition of termination, with a view to ensuring the orderly reorganisation or termination of the IJPS.

In addition to the Agreement, a number of issues related to the interpretation of specific provisions of the Agreement had been raised both by EUMETSAT and the United States. Several exchanges of letters took place to cover the exact implementation of the CDA back-up ground station, the application of EUMETSAT data policy for future EUMETSAT cooperating states, the non-discriminatory basis for the application of the IJPS Agreement and agreement not to protect eventual IPR resulting from the IJPS.

4.3 Evolution of the IJPS Collaboration

4.3.1 The Need for Flexible, Continued Collaboration

All along, the implementation of the IJPS collaboration was accompanied by negotiations and discussions on the nature and baseline of future collaboration activities. To ensure timely follow-up, NOAA and EUMETSAT needed to accelerate their discussions on post-EPS collaboration shortly after the signing of the IJPS Agreement. The reason was that the Integrated Programme Office (IPO), in charge of the U.S. Converged Programme, had already established requirements for the upcoming NOAA Polar-orbiting Operational Environmental Satellite System (NPOESS) and was planning to develop new sounding and imaging instruments which could be seen as duplicating European assets of the MHS, IASI and GOME-2 instruments. Although in principle such requirements and developments were specific to the NPOESS system – to be operated in the METOP-C timeframe – they were also expected to form the American assets for the systems to be flown after EPS. In this context, EUMETSAT needed first to establish an agreement for the U.S. payload to be flown on MetOp-C, because the provision of these instruments was not covered by the IJPS Agreement with NOAA. Secondly, both organisations had to discuss options for future collaboration in the post-EPS era. EUMETSAT felt such discussions were needed to avoid that U.S. decisions a priori curtail the possibilities for collaboration or result in a 'fait accompli' situation as regards the possible European role in the definition, design, development and operation of a Joint Polar System. The general objective for EUMETSAT was to reach agreement with NOAA and their U.S. partners on the basic principles for future co-operation.

Initial Developments

The EUMETSAT Policy Advisory Committee (PAC) agreed on the importance of EUMETSAT being actively involved in the definition of the overall strategy for collaboration with the USA on the post EPS satellite system and that to this effect a meeting would be organised with NOAA in 1999. In parallel, the PAC requested the Secretariat to pursue mechanisms for post EPS user requirements. At the same time, the PAC produced a set of basic principles upon which future collaboration would have to be based. The conclusions were that Europe should have a clear and valued role within a balanced collaboration while keeping its own data policy, European industry should maintain autonomy in strategic areas and, an economic solution should be implemented. For the latter there was strong support for small satellites, providing they could be delivered in a cost effective way.

The EUMETSAT Secretariat prepared a policy document that reflected the principles of future collaboration and stipulated the long term objective of having a joint series of small missions, with each partner looking after one orbit (morning and afternoon) for particular observation. For the short term, it was necessary to agree on a balanced exchange of instruments with the flight of European instrumentation on NPOESS and Europe considering implementing the morning mission through a series of small satellites.

Regarding the exchange of instruments required for the MetOp-C, the NOAA Assistant Administrator for NESDIS and the Director of EUMETSAT reached the conclusion in 1998 that the only feasible and affordable solution would be to fly the identical instruments AMSU-A and AVHRR, just as on MetOp-A and -B. There are a few reasons why the instrument package remained the same. The IPO – responsible for the procurement of the NPOESS programme – had embarked on parallel phase B studies for new instruments it was expecting to select for NPOESS platforms between 2000 and 2001, dates which could not be made compatible with the MetOp-C need dates. Also, the new complex imaging instruments driven by the U.S. Department of Defence requirements were not going to be compatible with MetOp-C capabilities in terms of data rate or physical accommodation. Moreover, information on the design of such instruments could not be made available due to legal constraints in the context of parallel competitive studies. Unlike the case of MetOp-A and -B, no HIRS/4 would be flown on MetOp-C, as the EUMETSAT instrument IASI would have proven its value by then.

The EUMETSAT assumption was that all other instruments as part of the American IJPS contribution would be supplied at no cost to EUMETSAT by the United States. Following discussions between EUMETSAT and the American partners, this was seen as the only viable way forward by both sides. The EUMETSAT PAC recommended that the Director be given by the Council the mandate to finalise the negotiations with the U.S., noting that the preferred option regarding the legal framework would be an extension of the current IJPS Agreement.

In parallel to the negotiations on the exchange of instruments, informal discussions were held in 1998 and 1999 between the JPL AIRS project Team and the EUMETSAT Secretariat. It became clear that NASA, EUMETSAT and CNES had a common interest in cooperating on some activities relevant to AIRS and IASI[42]. More precisely, the NASA AIRS instrument and the IASI instrument are in many respects comparable and collaboration between the procuring organisations could deliver risk reduction. European activities in support of AIRS calibration and validation would benefit NASA and would offer Europe the possibility of collecting expertise on the post-launch pre-operational activities to the benefit of IASI afterwards. After the initial negotiations which outlined the scope of the collaboration, the duties foreseen for the respective partners were agreed and formalised shortly after by means of a Letter of Agreement signed by the different partners.

4.3.2 The Future Collaboration Taking Shape

The Baseline for Further Collaboration and IJPS Extension

An important milestone for the baseline of future collaboration in Low Earth Orbit Programmes was the discussion meeting held in Darmstadt on 21 January 2000 between EUMETSAT and NOAA, represented at administrator level by Jim Baker. It was structured around six main elements:

- A first point was the reconfirmation of the collaboration between the agencies. It was agreed that the parties would develop a Memorandum of Understanding (MoU) setting out the basis for long-term collaboration. That way, the MoU would allow NOAA and EUMETSAT to jointly plan future cooperative programmes covering issues such as realisation of joint studies on technical issues, common experiments, observer status for NOAA in the EUMETSAT Council and EUMETSAT being represented as an observer on relevant NOAA boards[43];
- The U.S. proposed establishing a high-level working group tasked with preparation for future collaboration. This idea was unanimously accepted;
- The possibility of involving other international partners in the undertaking of a joint polar system such as Japan, China, India, Russia and others. This general policy to broaden collaboration in terms of participation would also be addressed in the MoU. The idea that more concrete activities and discussions on broader collaboration with other satellite operations could easily take place within existing informal groups was also supported;
- It was proposed to extend the current IJPS Agreement to MetOp-C on the assumption that it would fly the American instrumentation AVHRR, AMSU-A and the SEM instruments. NOAA officials confirmed that NOAA would be ready to provide these instruments to EUMETSAT;
- Regarding the potential way forward, the potential use of small satellites was considered. Participants agreed that, despite the fact that small satellites provide an optimum route for additional missions with specific orbit requirements, it was still not clear whether they could offer a cost-effective way to replace the current system with state-of-the-art technology. Therefore, the high-level group was tasked to propose an action plan to prepare a study on small satellites technology;
- There would be an exchange of staff between EUMETSAT and NOAA and also here, the high-level working group was tasked to prepare a relevant statement of work.

Also at the meeting, NOAA representatives suggested that consideration should be given to the possibility of a joint altimetry mission. It was noted that, viewed from the United States, EUMETSAT would be a logical partner with NOAA to carry the NASA/CNES Jason mission into operational status by means of follow-up missions. This proposal was not left unaddressed as both organisations successfully established this venture later on. This further broadening of the set of collaboration activities between the organisations will be discussed thoroughly in chapter five of this study.

The high-level working group established by the partners elaborated on the nature of future working together, which resulted in a proposed baseline for the exchange of instruments. It was stated that NOAA agreed to provide AVHRR, AMSU-A, SARSAT and SEM instruments for MetOp-C in a timeframe consistent with the schedule of the MetOp industrial contract and the overall IJPS schedule. Attention was drawn to the fact that these instruments also serve as spares for NOAA-N, NOAA-N' and MetOp-A and B. This meant that under certain circumstances reshipping to the U.S. could be required for use on

[42] Recall that the IASI instrument to be flown on the EUMETSAT MetOp platforms was developed by CNES in the framework of a collaboration agreement.
[43] Eventually this did not happen, but a similar baseline plan for future collaboration was signed on 27 August 2013 in the office of the Delegation of the European Union to the United States in Washington DC.

NOAA-N and/or NOAA-N'. If one or more spares had to be used for these satellites, then a solution would have to be found by the partners. Unfortunately, this scenario became reality as will be explained later in this chapter. Further, the instruments were to be provided to EUMETSAT on a non-exchange of funds basis and under the same terms as those applicable to the U.S. instruments on MetOp-A and -B. NOAA, however, could not commit to full technical support beyond the NOAA-N' launch, which was scheduled for 2008. Additional support therefore would potentially require a separate agreement. To avoid a complete redraft of the IJPS Agreement in order to extend it to apply to MetOp-C, it was agreed to cover this extension through an exchange of letters, and to resolve all details of a technical and programmatic nature through amendments to the IJPS Programme Implementation Plan.

The exchange of staff between both organisations was seen as a good opportunity to facilitate the implementation of the IJPS and to prepare future LEO programmes. After formal unanimous agreement, EUMETSAT and NOAA each appointed a liaison engineer, located in Washington DC and Darmstadt, respectively. The extension of the IJPS Agreement was formalised through an exchange of letters in May 2000. This was, however, only the first step in the era of post-IJPS collaboration.

4.3.3 Joint Transition Activities

The JTA Agreement

After further reflection the high-level working group suggested that it would be better to cover both the elements of collaboration foreseen for the transition phase and the baseline for future collaboration under one umbrella agreement. Normally, this joint planning for future cooperative programmes would take place through a Memorandum of Understanding but the United States stated that it would be difficult to process this MoU in an election year. Therefore both aspects were subsumed into a proposed '*Joint Transition Activities regarding Polar-Orbiting Operational Environmental Satellite Systems*' Agreement. The drafting of this so-called JTA Agreement started in autumn 2001. Further discussions took place in EUMETSAT in February 2002, a few months later in Washington in June and by teleconference in September that year. These preparatory discussions led to a final negotiation meeting in EUMETSAT on 26 September 2002. The draft JTA Agreement defined all the terms of collaboration between NOAA and EUMETSAT during the transition from the IJPS Agreement to a future Agreement for a joint polar system. Also, it would replace the existing extension of the IJPS Agreement, as all relevant provisions for the exchange of instruments and agency representatives were also included.

In the initial draft, the Joint Transition Activities as defined involve elements of three polar-orbiting satellite systems: POES, EPS, and NPOESS. New in this agreement was the reference to the six satellites in the NPOESS series, C-1 through C-6, covering the early morning, mid-morning and afternoon orbit. Structured around MetOp-C satellite activities and the provision of NOAA POES instruments, the sharing of data and data products from MetOp-C and the NPOESS Series, and additional transition activities, the draft agreement defined the responsibilities for NOAA and EUMETSAT, both individually and jointly. Also, it stipulated that both parties would work together on a long-term basis to define a joint polar system based on common user requirements, based upon all reasonable efforts, within 8 years of signature of the JTA Agreement. This was done in order to ensure continuity of data services from the systems, a major driving force in operational satellite meteorology. In terms of funding, data policy, data denial and other standard provisions, the content and structure of the draft JTA Agreement was similar to the IJPS Agreement.

From a partnership point of view, the interesting thing about the JTA Agreement is that it was amended several times, once during the drafting process and four times after it was signed. These amendments occurred as a response to incidents that affected the availability of instruments and a restructuring of the NPOESS Programme on the American side.

Amendments to the Draft JTA Agreement

For EUMETSAT one particular development raised questions and concerns regarding the balanced relationship it had established with NOAA. When the United States Government awarded a contract for the implementation of the NPOESS satellite system, it included a – for EUMETSAT unexpected – procurement for both advanced imaging and sounding instruments to be flown on the mid-morning satellites. This meant that, if equipped with a full package of sounding instruments, the satellites would entirely duplicate EUMETSAT EPS capabilities of the MetOp satellites and this based on a unilateral U.S. decision. Not only would this conflict with the agreement reached in the margins of the G7 summit, which highlighted the importance of sharing responsibilities for observations in the Low Earth Orbit between Europe and the USA, but it could also raise internal problems for EUMETSAT. After all, a significant factor in obtaining support for and commitment to the EPS Programme had been the strategic partnership with the American partners. The unilateral action taken by the U.S. implied that EUMETSAT had to identify a way forward to maintain the overall integrity of the partnership that was built upon reciprocity. EUMETSAT noted that if this were not possible, its Member States might question the continued funding of the EPS/MetOp programme. EUMETSAT feared that if no solution to this turf-issue was found it might be detrimental to the willingness of the European states to join in future partnership programmes. Also there could be implications on a wider front, as international efforts through the Integrated Global Observing Strategy Partnership to achieve more integrated strategy for observations could suffer. In an international context, the NOAA-EUMETSAT strategic partnership was seen as a model for implementation, and if the international community received the message that the United States and Europe could not work together in this area, then the ability to forge new partnerships would have been in jeopardy.

After informing NOAA through a letter co-signed by the EUMETSAT Director-General and the EUMETSAT Council Chairman, U.S. Navy Vice Admiral Lautenbacher said that MetOp high level specifications might fulfil NPOESS sounding requirements for the mid-morning orbit and therefore the U.S. decided not to fly these capabilities on this orbit. This would mean that the capabilities of MetOp would not be duplicated and the strength of the NOAA - EUMETSAT collaboration would continue to show. After this confirmation was formalised by the U.S., including the proposed amendments by NOAA to the draft JTA Agreement to express this position, the EUMETSAT Council authorised the Director-General to sign. It was proposed to have an exchange of side letters as well which would formalise the mutual understandings reached by the parties on points raised by the U.S. in the answer of Vice Admiral Lautenbacher to the letter co-signed by the EUMETSAT Director-General and the EUMETSAT Council Chairman. This included recognition by NOAA that the IASI sounder, as specified, was expected to meet or exceed the NPOESS requirements. NOAA confirmed that it would not fly an advanced sounding package in the mid-morning orbit as long as EUMETSAT would be providing advanced atmospheric temperature and humidity sounder data. The JTA Agreement and its side letters were signed in Darmstadt in June 2003.

First Amendment: Impact of NOAA-N' Recovery

A few months after the JTA Agreement was signed, an unfortunate incident occurred in the assembly room of Lockheed Martin Space Systems in California. As the NOAA-N' satellite was being rotated from vertical to horizontal position, it fell, causing considerable damage to the spacecraft. The instruments had to be removed from the spacecraft for an assessment that had to determine whether they remained flight qualified or required replacement. In this process, NOAA received assistance from its partners EUMETSAT and CNES. The problem was that if instruments were damaged, this could severely affect the implementation of the EUMETSAT Polar System. Two different Agreements were applicable in this case. For MetOp-C it was foreseen in the JTA Agreement that NOAA would provide to EUMETSAT the AVHRR, AMSU-A1 and A2 and SEM instruments. Recall, however, that these instruments served as spares for the IJPS satellites, and given the fact that NOAA-N' was damaged because of the accident NOAA could no longer warrant the readiness of these instruments for flight on MetOp-C. The IJPS Agreement, which was still valid, stated that EUMETSAT would provide a MHS Flight Model 2 Instrument for NOAA-N'. In other words, EUMETSAT was in a position where the American instruments for MetOp-C could not be provided in the timeframe foreseen, while at the same time, EUMETSAT had to ensure the provision of an instrument to replace the one that might have been damaged.

EUMETSAT Instruments for NOAA		NOAA Instruments for EUMETSAT	
To be flown on NOAA-N' (IJPS)		To be flown on MetOp-C (JTA)	
MHS	Microwave Humidity Sounder	**AVHRR**	Advanced Very High Resolution Radiometer
		AMSU-A 1/2	Advanced Microwave Sounding Unit 1 and 2
		SEM	Space Environment Monitor

Table 3: Instruments Subject to Exchange that were Affected by the NOAA-N' Incident.

Shortly after the incident, NOAA assured the EUMETSAT Council that its collaboration with EUMETSAT in MetOp-C was receiving due consideration and that it was developing options to deal with the NOAA-N' accident. EUMETSAT received a written proposal on 30 September 2004. In this communication, NOAA confirmed its intention to extend its support for the two AMSU-A units, designated for integration on MetOp-C, from 2010 to 2014, at no cost to EUMETSAT. This prolonged service would be offered in return for EUMETSAT's agreement to deliver to NOAA a retested MHS by November 2005. If for some reason EUMETSAT discovered a major problem during the testing of the MHS instrument, both parties would agree to consult of possible ways forward. Also, as these undertakings altered the agreement of the JTA Agreement, NOAA proposed to amend it at the earliest convenience. Finally, NOAA asked EUMETSAT to confirm whether it would be able to deliver an MHS instrument for integration on NOAA-N' by November 2005.

The assessment revealed that the AVHRR, the AMSU-A1 and A2 units and the SEM instrument were damaged and needed replacement. NOAA would use the complete set of spare instruments nominally allocated for MetOp-C for use on NOAA-N', and decided to fund the rebuild of the instruments damaged during the accident. More precisely, it would provide flight models for AVHRR, AMSU-A1 and A2 instruments for MetOp-C. The SEM instrument, however, would not be provided to EUMETSAT.

In order to comply with NOAA's request regarding MHS, EUMETSAT needed to place a Contract Change Notice with the MHS contractor by the end of 2004. The EUMETSAT Council – supported by the findings of the PAC –decided to supply a re-tested MHS for NOAA-N', providing that the support for AMSU-A1 and A2 instruments from 2010-2014 would be included in an amendment to the JTA Agreement. These amendments were agreed and entered into force as of January 2005.

Second Amendment: MHS FM2 Repair

The MHS FM2 Re-test programme was started in January 2005 and the instrument successfully completed all environmental testing and characterisation tests. Unfortunately, on 15 September EUMETSAT was informed by Astrium-Portsmouth about an anomaly that was observed on channel H1 during the final functional test[44]. In subsequent discussions between the EUMETSAT Secretariat and NOAA, NOAA proposed a similar mechanism to cover the repair of the MHS FM2 instrument by assuming responsibility for some of the long-term maintenance of the AVHRR instrument for Metop-C. That way, EUMETSAT would have guaranteed maintenance for both the AVHRR and AMSU-A1 and A2 instruments. Just like the previous arrangement, this cooperative effort required a further amendment to the JTA Agreement.

In May 2005, the first flight model of the Microwave Humidity Sounder (MHS) instrument was successfully launched aboard the NOAA-N satellite. This represented the first ever space hardware procured directly by EUMETSAT and launched into space in polar orbit. The MHS was intended to replace the AMSU-B instrument as it delivered strong improvements in radiometric performance and therefore in the accuracy of the final product.[45] Through this collaboration, under the IJPS programme, EUMETSAT had a fully operational and accurate MHS instrument in orbit generating the expected meteorological products. The users were expected to benefit from the improvements that the MHS instrument offered over its predecessor. It was proposed the damaged MHS FM2 instrument for the NOAA-N' satellite would be repaired and when done the repaired FM2 instrument would be returned to NOAA in March 2006, in line with NOAA's needs. The JTA Agreement was amended for a second time in November 2005 to incorporate these changes.

Third Amendment: SEM Instrument on MetOp-3

Originally, the MetOp industrial baseline stated that each of the three MetOp satellites would embark a 'Space Environment Monitor' instrument or SEM. During the negotiations for the first amendment to the JTA Agreement, NOAA indicated that in view of the payload complement embarked on their mid-morning NPOESS satellite, the SEM instrument would no longer be required on MetOp-C and hence, the spare instrument used for NOAA-N' would not be rebuilt for MetOp-C.

After that, however, some restructuring took place in the American NPOESS Programme. Due to severe technical problems on NPOESS and consequential financial issues, the U.S. had delayed the launch of the first NPOESS by 3 years. They also changed the order of launch and there would be no mid-morning NPOESS platform until 2016. This meant the United States would rely upon MetOp data for

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[44] Channel H1 was observed not to function and to provide flat counts over all scenes.

[45] It should also be noted that the AMSU-B instruments suffer from electromagnetic interference from the spacecraft S-band transmitters, which requires on ground correction of the science data. The MHS PFM instrument does not suffer from such interference.

the period 2007-2016. In further discussions, the United States even indicated that they might propose to scrap the mid-morning USA platform altogether. As part of the restructuring, the U.S. Authorities required NOAA to investigate with EUMETSAT the possibility of re-integrating the SEM instrument on the MetOp-C satellite. NOAA, in its request, proposed to deliver an instrument similar to the one flying on the first two MetOp satellites and indicated that the lead time to acquire this new instrument was estimated to be 18-24 months. On the European side, industry confirmed there would be no technical problem to re-integrate the instrument onto the MetOp-C satellite and that this could be arranged by a contract change involving some cost impacts to be borne by EUMETSAT.

Similar to the former two amendments to the JTA Agreement, NOAA and EUMETSAT worked on a solution whereby the transfer of funds between the two partners would be avoided. In return for bearing the re-integration costs, EUMETSAT would receive maintenance of the AMSU-A units until the launch of MetOp-C, then foreseen for October 2015 and maintenance of the AVHRR instrument covered by NOAA until 3,5 years after the planned launch date of the last IJPS satellite, foreseen for September 2004. The EUMETSAT Secretariat was convinced these modifications would bring a fair solution to the issue of the SEM instrument on MetOp-C. This third amendment to the JTA Agreement was approved by the EUMETSAT Council in 2008.

Fourth Amendment: Impact of NPOESS Restructuring

In the United States, the NPOESS Programme continued to suffer from cost overruns and schedule delays. The status of the programme was reviewed and it turned out that the joint execution of the programme between three agencies (DoD, NOAA and NASA) of different size with different objectives and acquisition procedures was troublesome. An Independent Review Team concluded that the programme, in the absence of managerial and funding adjustment, had a low probability of success and that data continuity was at extreme risk. Therefore, in February 2010, the White House announced that NOAA and the Air Force would no longer continue to jointly procure the polar-orbiting satellite system NPOESS and thus the ambitious American programme was fundamentally restructured in its preparatory phase. In terms of balanced input, this meant that Europe would remain on the critical path for the implementation of the polar orbiting satellite system.

It was noted, however, that the termination of the NPOESS programme would not have a negative impact on the collaboration between EUMETSAT and NOAA under the JTA Agreement. Rather, as part of the restructuring, a satellite would be available on the NOAA side for the afternoon orbit. More precisely, the NPOESS Programme was replaced by the Joint Polar Satellite System Programme (JPSS). As in the past, NOAA was given responsibility for the afternoon orbit, while environmental measurements from early morning orbit would be obtained from the Defense Weather Satellite System (DWSS). The NPOESS Preparatory Project (NPP) – originally proposed as a proof-of-concept satellite – was repurposed to support NOAA operations after the decision on restructuring. The divergence of the U.S. civil and military operational meteorological programme significantly increased the strategic importance of the MetOp satellites covering the mid-morning orbit. The vital role of EUMETSAT in covering the mid-morning orbit was also explicitly stated in the report that described the impacts of the Nunn-McCurdy Certification[46] of the NPOESS programme on the climate programme goals of NASA and NOAA.[47] The latter was a clear sign of the mutual and balanced input-based relationship between both agencies and as such it can be seen as a key milestone in the recognition of partnership between both trans-Atlantic partners.

In view of the increased strategic importance of the MetOp satellites, NOAA agreed to remove the obligation of EUMETSAT to maintain the U.S. instruments on Metop-C. Instead, the maintenance of these instruments would now be undertaken by NOAA in a similar way as for Metop-A and -B, with the assumption of a launch date of Metop-C before 2017. This restructuring of the organisations' responsibilities had to restore the balance of input in the overall polar system. A fourth amendment to this effect was signed in 2011. Table 4 presents an overview of the satellite constellations as they were eventually estab-

[46] The Nunn-McCurdy Act requires the DoD to report to the U.S. Congress whenever a major defense acquisition programme experiences cost overruns that exceed certain thresholds. See: Schwartz, Moshe. "The Nunn-McCurdy Act: Background, Analysis, and Issues for Congress." 21 Jun. 2010 <http://www.fas.org/sgp/crs/misc/R41293.pdf>. Following this notification and further evaluation, the U.S. Congress can decide to approve budget overruns or to restructure and eventually terminate the programme. In the case of NPOESS, the programme was substantially restructured.

[47] "Impacts of NPOESS Nunn-McCurdy Certification on Joint NASA-NOAA Climate Goals" 11 Dec. 2006. A Joint Document of The National Aeronautics and Space Administration and The National Oceanic and Atmospheric Administration <http://www.climatesciencewatch.org/file-uploads/NPOESS-OSTPdec-06.pdf>.

lished and delivered, based upon the IJPS and JTA Agreements.

The IJPS constellation achieved double orbit coverage when MetOp-A started operations in the mid-morning orbit in 2006, as NOAA-N, launched in 2005, was already covering the afternoon orbit. The second American and European satellites were added to the system in 2009 and 2012, respectively. Because of the restructuring of the NPOESS programme into the JPSS, the American polar-orbiting programme is to be spread over the time-frame of the JTA and the JPS. The NPP satellite was renamed the Suomi National Polar-Orbiting Partnership (SNPP). It was the first

EUMETSAT		NOAA	
Initial Joint Polar System (IJPS) Constellation			
Mid-morning Orbit		**Afternoon Orbit**	
Satellite	**Launch Date**	**Satellite**	**Launch Date**
MetOp-A	October 2006	NOAA-N	May 2005
MetOp-B	September 2012	NOAA-N'	February 2009
Joint Transition Activities (JTA) Constellation			
Mid-morning Orbit		**Afternoon Orbit**	
Satellite	**Launch Date**	**Satellite**	**Launch Date**
MetOp-C	2016 (expected)	Suomi / NPP	October 2011
		JPSS-1	2016 (expected)

Table 4: Satellites in the IJPS and JTA Constellations.

next generation polar-orbiting satellite and boasts five instruments, which will be the same payload and main instruments carried on JPSS-1. Its design life is five years and was launched with a Delta-II launcher from Vandenberg Air Force Base, California. JPSS-1, the second spacecraft within NOAA's next generation of polar orbiting satellites, is scheduled to launch in 2016. The satellite will take advantage of the successful technologies developed through the Suomi NPP satellite and has a design life of seven years.

4.3.4 Antarctica Data Acquisition

The latest development in the IJPS – JTA context was the Antarctica Data Acquisition (ADA) for the MetOp satellites. This recently established capability connects the U.S. McMurdo Station in Antarctica to EUMETSAT's ground facilities in Darmstadt, decreasing the latency of MetOp satellite data by fifty percent; from 130 minutes to 65 minutes. The ADA capability was the first operational system to provide half-orbit polar orbiting satellite data.[48]

The need to further improve the timeliness of IJPS data and product delivery to end users was already recognised in the Joint Transition Activities agreement between NOAA and EUMETSAT. To that end, both partners examined potential solutions to add ground stations in the southern hemisphere. In October 2007, EUMETSAT's then Director General, Lars Prahm, received a letter from NOAA Assistant Administrator Mary E. Kicza proposing a joint solution that NOAA saw as an efficient means of establishing downlink capability for the MetOp satellite series in Antarctica within targeted timelines for operational readiness. At that time NOAA was procuring high-bandwidth satellite communications services from McMurdo station designed for three polar orbiting satellites. Because of the restructuring of the NPOESS programme, however, only two orbits would be occupied by the American polar meteorological programmes. Because of this the bandwidth could comfortably accommodate MetOp data, decreasing the latency of the MetOp satellites. As NOAA had budgeted for these activities, no funding from EUMETSAT was required other than modifications to its data recovery and processing infrastructure and the "last-mile" communications costs near the

[48] Valenti, James M., Monham, Andrew, Keegan, Conor, Mungley William G. and Smith, Patrick D., "Metop's Antarctic Data Acquisition Project: An International Partnership Success." 29 May 2013 <http://www.spaceops2012.org/proceedings/documents/id1275309-Paper-001.pdf>.

EUMETSAT headquarters in Darmstadt, Germany. Because of the many advantages and relative low costs in the ADA solution, the proposal was very well received at the EUMETSAT Council of June 2008.

For the practical implementation, NOAA and EUMETSAT could count on key support and experience provided by the American NSF and NASA, who performed the technical installations and updates required for this capability. The final terms were agreed to in 2009, and the formal agreement, known as the Supplement to the Program Implementation Plan (PIP) for the Cooperation between the NOAA and EUMETSAT on MetOp Data Downlink at McMurdo Station, Antarctica was signed in 2011.[49] Today, the improved latency of the MetOp satellites in orbit provides both European and U.S. weather services more frequent environmental observations for near-real-time mesoscale and mid/long-range global weather forecasts.

4.4 The Road towards a Joint Polar System

In spite of the many internal and external developments that have challenged the course of polar orbiting collaboration between NOAA and EUMETSAT, continuous efforts have delivered considerable tangible benefits for both organisations, making it the flagship achievement of their partnership. Because of these benefits – which will be further described in Part II of the study – the follow-up programme of the IJPS is currently taking shape.

4.4.1 Future Outlook: The Joint Polar System

In terms of collaboration intensity, the main difference between the IJPS / JTA Agreements and the constellation of the JPS will be the absence of exchange of instruments. Therefore, the future potential of the Joint Polar System will be mainly at the level of data and services and the integration of ground segments and operations.

EUMETSAT		NOAA	
Joint Polar System (JPS) Constellation			
Mid-morning Orbit		Afternoon Orbit	
Satellite	Launch Date	Satellite	Launch Date
EPS-SG	2020s (TBD)	JPSS-2	2019 (expected)

Table 5: Satellites expected to be provided under the JPS Agreement.

Even though the lack of instrument exchange might increase the autonomy of both organisations in terms of technological capabilities, it will also involve higher development costs because of duplication of efforts. Although the EPS-SG programme is still to be approved, it is very likely that it will be conceived as a two-satellite programme as to avoid going through the time and energy consuming decision-making process twice.

The American Joint Polar Satellite System – JPSS

Although not the first satellite under the American JPSS programme, the JPSS-2 will be the first satellite to be part of the trans-Atlantic JPS venture. The JPSS programme will provide operational continuity of the POES programme, the SNPP and ground systems. Except for an updated version of the CERES instrument, the payload will be identical to that of the JPSS-1. Table 6 lists all instruments and describes their function.

In terms of ground infrastructure on the U.S. side, the JPSS Common Ground System (CGS) converges the NOAA-NASA civil polar environmental satellite programme, NPOESS Preparatory Project (NPP), and the Air Force's Defense Weather Satellite System (DWSS) ground systems into a single, common system that will satisfy both the U.S. and its partners' international environmental monitoring satellite needs from polar orbit.

[49] Ibid.

Instruments		Function
VIIRS	The Visible Infra-red Imaging Radiometer Suite	Takes global visible and infrared observations of land, ocean, and atmosphere parameters at high temporal resolution.
CrIS	The Cross-track Infrared Sounder	Will produce high-resolution, three-dimensional temperature, pressure, and moisture profiles. These profiles will be used to enhance weather forecasting models, and will facilitate both short- and long-term weather forecasting. Over longer timescales, they will help improve understanding of climate phenomena such as El Niño and La Niña.
ATMS	The Advanced Technology Microwave Sounder	A cross-track scanner with 22 channels, provides sounding observations needed to retrieve profiles of atmospheric temperature and moisture for civilian operational weather forecasting as well as continuity of these measurements for climate monitoring purposes.
OMPS	Ozone Mapper Profiler Suite	An advanced suite of three hyperspectral instruments, extends the 25-plus year total-ozone and ozone-profile records. These records are used to track the health of the ozone layer. OMPS products, when combined with cloud predictions, also help produce better ultraviolet index forecasts.
CERES	Clouds and Earth's Radiant Energy System	Senses both solar-reflected and Earth-emitted radiation from the top of the atmosphere to the Earth's surface. Cloud properties are determined using simultaneous measurements by other JPSS instruments such as the VIIRS and will lead to a better understanding of the role of clouds and the energy cycle in global climate change.

Table 6: U.S. Polar Satellite System Instruments in the JPSS Programme.

The EUMETSAT Polar Programme Second Generation – EPS-SG

In Europe, activities are on-going for the definition of the follow-on EUMETSAT Polar System, to replace the current satellite system in the 2020 timeframe and contribute to the Joint Polar System to be set up with NOAA. This follow-on programme has been coined EPS Second Generation (EPS-SG) and its corresponding satellite development programme was approved by the ESA Ministerial Council in November 2012. Through consultation with users and application experts, requirements have been defined for a range of candidate missions mainly in support of operational meteorology and climate monitoring. Currently a number of on-board instruments, satellite platforms and ground support infrastructure are under study in coordination with ESA, NOAA, DLR and CNES. EUMETSAT has decided on a twin satellite configuration and payload. The full programme will be presented to the EUMETSAT Member States in 2014 and its approval is expected by the end of that year.

4.5 Polar Orbiting Satellite Activities and the Theoretical Framework

The collaboration record in this chapter revealed that the negotiations and resulting joint activities in polar orbiting satellites were much more elaborate and complex than those displayed in the field of geostationary satellites. As a consequence the challenges related to the fulfillment of the eight criteria for successful implementation of space missions in an international context were also greater. Nevertheless, the IJPS is now implemented successfully and the planning activities for the JPS are taking shape. Various factors have helped the challenging execution of polar orbiting collaboration activities.

First, in addition to the historical foundations already present, the implementation of the IJPS benefitted from the experience and trust gained in the existing joint geostationary satellite activities. This made both organisations more accustomed to each other’s structure and ways of operating. Because of the exchange of instruments, the scientific support provided was much more comprehensive. Also the flows of information and support were more mutual and inter-agency based compared to before. The shared objectives on the other hand were again very closely aligned, given that polar orbiting satellite programmes had taken a similar position in both partners' portfolio of meteorological programmes. The Initial Joint Polar System Agreement and the Joint Transition Activities Agreement, approved and signed after lengthy negotiation processes, set forth the division of responsibilities and plans for data access and distribution, while the conditions for data denial for U.S. military purposes are described in an annex.

Perhaps the most interesting criterion in the IJPS venture was the sense of partnership and its influence on the developments in the negotiation processes. Although the sense of partnership between NOAA and EUMETSAT has eventually helped reaching the breakthroughs required for progress in certain deadlock situations, it has nevertheless proved to a critical factor in the discussions regarding the data policy and data denial, and the duplication of MetOp capabilities in the to-be converged NPOESS system before it was restructured. Fortunately, the two partners have showed genuine sense of partnership by being flexible when unforeseen circumstances required amendments to the JTA Agreement in order to safeguard the balanced input on the system. For review purposes, dedicated structures were established to guarantee continuous follow-up of activities such as the Data Denial Working Group and the structures for management, coordination and consultation as defined in the IJPS and JTA agreements.

Finally, the IJPS and JTA constellations have generated considerable benefits for EUMETSAT, NOAA, their funding governments, and their user communities. These will be thoroughly assessed in the final chapter of the study.

5. Ocean Surface Topography Missions

Seventy-one percent of the planet Earth's surface is covered by water, making the world's oceans a key dimension in the complex and interactive system that determines global weather and climate. For this reason oceanographers and climatologists use oceanic models to investigate large-scale ocean circulation, ocean dynamics and their interaction with the atmosphere.

An important element in oceanic modelling is ocean surface topography. Being influenced by ocean circulations and variations in water temperature and salinity, the surface of the ocean displays certain topography with "hills" and "valleys".[50] Data on these variations in ocean surface topography – which can be as much as two meters – are useful for two reasons. First, they help us understand how the ocean and its circulations move heat around the globe, which in turn increases the accuracy of both short term to seasonal weather forecasts and climate change models. Second, long term observations of the average ocean surface topography reveal changes in global sea levels as a result of climate change.

5.1 First Ocean Altimetry by Satellites

Historically, ocean surface topography was derived from buoys and measurements by ships of temperature and salinity at depth. However, the data obtained was mostly fragmented in both space and time, putting limits on the oceanic models that were derived from it. It was only recently that satellites radically changed the act of oceanic modelling.

More precisely, an ocean altimetry satellite measures sea height by sending a radar signal down to the sea surface and analysing the return signal. In doing so it takes into account the imperfect spherical shape of the planet and atmospheric conditions. Satellites can now deliver data within an accuracy of one centimetre and can deduce other important information such as wave height, wind speed over the ocean, surface roughness, ocean currents etc. In this respect ocean altimetry data is applied in a wide series of products and services varying on both spatial and temporal scales.

5.1.1 Prior Missions

The first real successful ocean altimetry mission to be launched was the TOPEX – Poseidon mission[51] , jointly developed by CNES and NASA. Launched in 1992, it was originally designed to have a lifetime of three to five years but the satellite went on to perform for over thirteen years, providing extensive information on sea levels, currents, ocean circulations and tides.[52] The mission was praised[53] and proved that – given enough accuracy – satellites can sample adequately and globally, offering a "*God's-eye"* view on our oceans and their dynamics that other measurement could not deliver. For this reason, the development space agencies CNES and NASA decided a follow-up mission would be pursued.

Its follow-up, Jason-1, was eventually launched in December 2001. This mission, the direct predecessor of Jason-2, continued to supply the research community with valuable oceanic data. Even before its launch, CNES was interested in ensuring continuity of

[50] Actually, the ocean surface, even if undisturbed by waves or tides, is not a perfect sphere. The Earth's geoid is a calculated surface of equal gravitational potential energy that represents the shape the sea surface would be if the ocean were not in motion. The ocean surface topography is then calculated as the difference between this reference ellipsoid and the actual surface height as measured.

[51] Actually, some other proof of concept missions have preceded the TOPEX – Poseidon mission. The first one, GEOS-3, was launched by NASA in 1975. A few years later the NASA SEASAT mission, launched in 1978, demonstrated the feasibility of global satellite monitoring of oceanographic phenomena. However, it only operated for 105 days because of a payload failure. GEOSAT, launched by the U.S. Navy in 1985 operated until 1990 and was decisive in the follow-up process of ocean altimetry from space.

[52] EUMETSAT, 25 Years of EUMETSAT – 25 ans d'EUMETSAT, 2011, 320 p.

[53] Influential oceanographer Walter Munk stated that he considered TOPEX – Poseidon as the most successful ocean experiment ever performed. See: Sullivant, Rosemary. "Topex/Poseidon Sails Off Into the Sunset" 1 May 2006. National Aeronautics and Space Administration 22 Mar. 2013 <http://www.nasa.gov/vision/earth/lookingatearth/topexf-20050105.html>.

service beyond Jason-1. NASA, however, was less enthusiastic in sharing the cost of what essentially becoming an operational service. In searching for possible partners for the initiative, CNES approached EUMETSAT. On the other side of the Atlantic, for similar reasons, NOAA was also considering an involvement in what would now become a long-term operational activity. Meetings between both organisations were held to discuss the outline of a possible joint programme. What eventually emerged was a proposal for a partnership of four organisations: CNES and EUMETSAT on the European side and NOAA and NASA on the American side. The idea emerged to set-up an Ocean Surface Topography Mission (OSTM) of which Jason-2 would be the space segment.[54]

5.2 The Ocean Surface Topography Mission/Jason-2

5.2.1 A Four Agency Approach

EUMETSAT's First Optional Programme

Involvement in an ocean altimetry mission was slightly more challenging for Eumetsat than for NOAA, given that the organisation had no prior experience in this particular field of earth observation. Also, because altimetry was not part of its 'core responsibilities' as described in the EUMETSAT convention[55], it would be conceived as the organisation's first optional programme.

The possibility of optional programmes, open for participation by Member States that agree to do so, was put on the table during the discussions on the Atlantic Data Coverage in the early 1990s. At the time, the French delegation proposed amendments to the convention so as to make decision-making procedures more efficient, the possibility of allowing optional programmes, and a possible role for EUMETSAT in climate monitoring. Although the proposed amendments to the convention could count on wide support among the EUMETSAT Member-States, it took several years until all of them had ratified them.[56] Shortly after sufficient ratifications had been received, the new amended convention was acknowledged by a EUMETSAT Council resolution, entering into force in November 2000.[57] This paved the way for EUMETSAT involvement in ocean monitoring.

It was at the 48th Council meeting in June 2001 that the ocean altimetry programme first appeared on the EUMETSAT Council agenda. Conforming to the procedure for optional EUMETSAT programmes, the Secretariat outlined the role the organisation would play in this mission and adopted an "initiating resolution". Subsequently, potential participating states would be invited to adopt a programme declaration and programme definition which would then approved by the Council. After this, the programme declaration would be opened for signature. An optional programme only takes effect once at least one third of all EUMETSAT Member States have signed the Declaration within an established timeframe and the subscriptions of the participating states have reached 90% of the total financial envelope for the programme.

The response around the Council table was generally positive and so the procedure as described to establish the optional programme was initiated. Throughout this procedure, the composition of the group of potential participants slightly changed because of internal decisions of the different Member States. At the 53rd Council meeting in June 2003, the necessary 90 per cent figure had been attained and so the Jason-2 programme entered into force.[58]

Structure of the Ocean Surface Topography Mission

Given that the Ocean Surface Topography Mission (OSTM) - with the Jason-2 satellite as the space component - would be a quadripartite project between EUMETSAT, NOAA, CNES and NASA, cost and responsibilities would be shared. The main responsibilities would be shared as follows:

- NASA would provide the launcher, a Delta rocket and the radiometer instrument.

[54] EUMETSAT, 25 Years of EUMETSAT – 25 ans d'EUMETSAT, 2011, 320 p.
[55] Mandatory programmes were described as "basic programmes required to continue the provision of observations from geostationary and polar orbits" and they would require a unanimous vote from the Council. Satellite programmes could be adopted as optional if there was not unanimous support for them.
[56] A major driving force in this ratification process was the fact that no polar programme could be established before the amendments were signed, as this would be concerned with climate monitoring.
[57] By the beginning of the year 2000, all EUMETSAT Member States of that time had ratified and signed it, except for Italy and Greece.
[58] In the end, after additional subscriptions following the programme initiation, 17 EUMETSAT Member States participated in the Jason-2 programme: Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, and The United Kingdom.

- NOAA would have responsibility for operation of the satellite.
- CNES would provide the satellite bus PROTEUS and the other instrumentation and have responsibility for the advanced processing of the data.
- EUMETSAT would be responsible for the dissemination of data and near-real-time products to users through its telecommunications facilities and for archiving the data for further use by researchers.

The satellite would be launched into a circular, non-sun-synchronous orbit at an inclination of 66 degrees to Earth's equator. Orbiting at an altitude of approximately 1340 kilometres, it would be in a position to monitor 95 percent of Earth's ice-free ocean every ten days. The instruments to be provided by CNES and NASA were based upon the expertise established by both partners in ocean altimetry and location technology. An overview of the instrumentation, its function and provider is presented in Table 7.

Payload Instrumentation	Provider	Description
Poseidon-3 Altimeter	CNES	The mission's main instrument, derived from the Poseidon-2 altimeter on Jason-1. Poseidon-3 is a radar altimeter that emits pulses at two frequencies and analyses the return signal reflected by the surface. The signal round-trip time is estimated very precisely, to calculate the range after applying corrections. The primary goal of the dual-frequency operation is to provide a precise ionospheric correction.
Advanced Microwave Radiometer (AMR)	NASA	Measures radiation from the Earth's surface at three frequencies. These different measurements are combined to determine atmospheric water vapour and liquid water content. Once the water content is known, it is possible to determine the correction to be applied for radar signal path delays.
Location Systems	**Provider**	**Description**
Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS)	CNES	Uses a ground network of 60 orbitography beacons around the globe, which send signals to a receiver on the satellite. The relative motion of the satellite generates a Doppler shift in the signal's frequency that is measured to derive the satellite's velocity. These data are then assimilated in orbit determination models to keep permanent track of the satellite's precise position in its orbit.
Global Positioning System Payload (GPSP)	NASA	GPSP uses the Global Positioning System (GPS) to determine the satellite's position by triangulation. At least three GPS satellites are needed to establish the satellite's exact position at a given instant. Positional data are then integrated into an orbit determination model to continuously track the satellite's trajectory.
Laser Retroreflector Array (LRA)	NASA	The LRA is an array of mirrors that provide a target for laser tracking measurements from the ground. By analysing the round-trip time of the laser beam, we can locate where the satellite is in its orbit and calibrate altimetric measurements.

Table 7: Payload Instruments and Location Systems on the Jason-2 Satellite.

The OSTM Memorandum of Understanding

A Memorandum of Understanding (MoU) was drafted to set fort the detailed respective responsibilities and the terms and conditions under which the four partners had agreed to collaboration on the OSTM. The MoU has a strong heritage from the previous MoUs signed between NASA and CNES on TOPEX/Poseidon, Jason-1 and the CALIPSO environmental satellite mission. The OSTM MOU took the shape of a 'three parties, four partners' agreement. Although it was signed by four Partners, the two U.S. agencies, NASA and NOAA, acted jointly as one Party to the MoU representing the United States government. This arrangement was necessary for formal reasons, but the obligations set out in the MoU text were defined individually for each of the four partners.

The mission description in the MoU explicitly refers to the heritage of the TOPEX/Poseidon and Jason missions and highlights the importance of bringing high precision altimetry to full operational status. More precisely, the aim is to provide data products for a period of five years to the operational and research communities in the fields of marine meteorology and sea state forecasting, operational oceanography, seasonal and climate forecasting and general ocean, Earth system and climate research. Subsequent articles in the MoU list all respective responsibilities of CNES, NASA, EUMETSAT and NOAA in detail. The lists reveal a substantial amount of inter-agency contact and follow-up to secure the smooth implementation of the four partners' different responsibilities in the OSTM. To this effect the partners agreed to establish an OSTM Joint Steering Group (JSG). The JSG comprises of up to two senior representatives from each partner that meet at least once a year. The JSG will be co-chaired by NASA and CNES during mission development until handover of the satellite operations, and by NOAA and EUMETSAT following handover of the satellite operations and control functions. This body is also responsible for approving changes that may impact other partners in terms of cost, mission performance, schedule and end of life of mission. In parallel, it is also authorised in the area of conflict resolution and to review project status. The data policy for the OSTM is much less differentiated and complex than the model established in polar orbiting satellite collaboration. The partners agreed to make available to each other all telemetry and data products in a timely manner and without any conditions as to the partners' use of telemetry and data products. Also, as the OSTM would be a joint contribution to the world-wide exchange of meteorological data and related data and products under the auspices of the WMO, the partners agreed to consider all data products in the OSTM as "essential data and products". The latter implies that they are made available as such to other users on a free and unrestricted basis. Interestingly, the MoU also includes an article on the provision of future collaboration, after the Jason-2 end of lifetime, as it is noted that "all partners will consider working together, as appropriate, on a long-term basis to help define the research and operational requirements for implementation of future ocean surface topography missions involving Europe and the United States, with the objective of ensuring fitness for purposes of research and continuity of data and services for all applications". This clearly reflects confidence and determination among the partners with regard to mission success and the governance model conceived as a four partite undertaking with shared responsibilities and balanced input.

By July 2005, the final draft – including all principles as explained above – was nearly complete and the MoU was agreed by the four partners. Shortly after, the U.S. State Department gave final clearance, which meant the MoU was ready for signature, pending EUMETSAT Council approval. The latter took place at the 58th EUMETSAT Council meeting in November 2005. Following this approval, the OSTM MoU was signed by all four partners in April 2006. The launch date for the Jason-2 satellite was targeted for June 2008 and with an estimated satellite life time of five years, the mission would last at least until mid-2013. This target was eventually met, as the satellite was launched successfully on June 20, 2008 aboard a Delta II 7320 rocket at the Vandenberg Air Force Base in California.

5.3 Jason Follow-On

Because of the requirement of continuity in operational altimetry services beyond Jason-2, discussions regarding a follow-on programme to the OSTM were held during its implementation phase and, in fact, the need was even recognised earlier. EUMETSAT and NOAA had already formally identified this perspective in the Joint Transition Activities agreement signed in 2003, which explicitly refers to the implementation of a Jason-3 satellite. It is important to note that planning for a Jason follow-on mission was embedded in a context of international coordination. One of the reasons is that for nowcasting and Numerical Ocean Prediction, at least three – but preferably four – altimeter missions are needed to monitor mesoscale ocean circulations. Partially for this reason the global implementation for ocean surface topography is being coordinated in the framework of the Committee on Earth Observation Satellites' Constellation for Ocean Surface Topography (OST). In this framework the Jason missions – given their high accuracy and medium inclination orbits – are considered as the reference missions for global ocean altimetry (see figure 2).

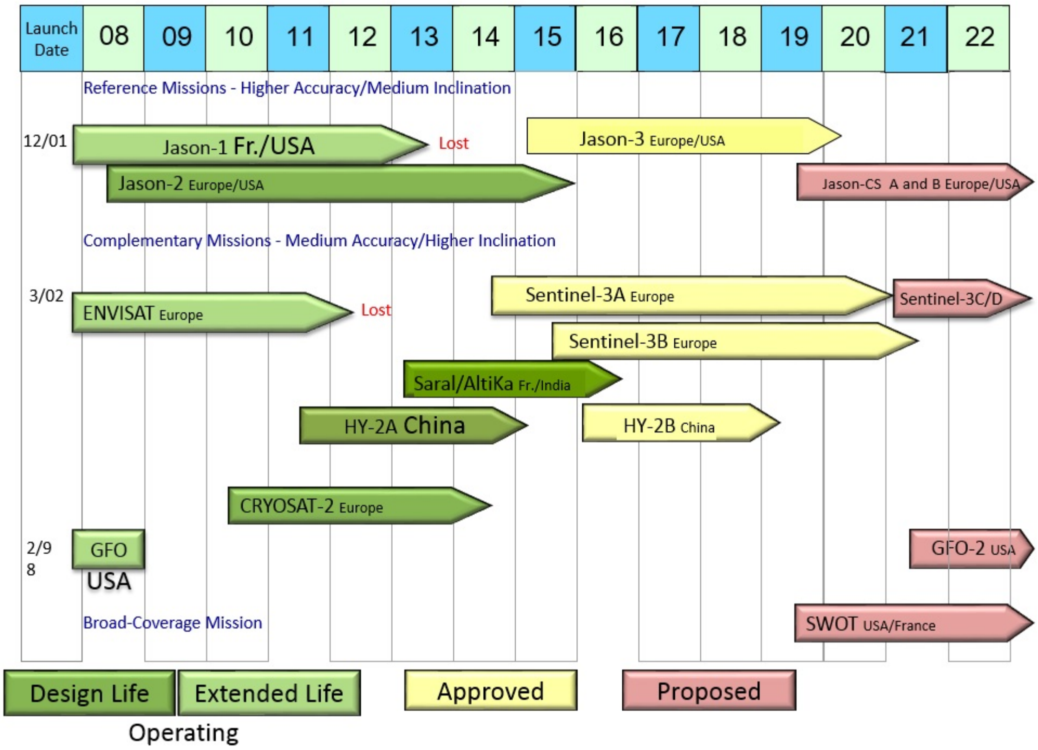


Figure 2: Overview of Global Altimeter Missions as Coordinated by the CEOS Constellation for Ocean Surface Topography.[59]

In this context of international coordination, a Jason-3 mission would be an excellent complement to the Sentinel-3 satellites in the planned Global Monitoring of Environment and Security programme (GMES - hereinafter referred to as Copernicus, its new name). Unlike Jason-3, the Sentinel-3 satellites will be launched into a sun-synchronous, high inclination orbit. This way the Jason-3 mission would not only ensure continuity with its predecessors, the synergy and commonalities with the Sentinel-3 satellites would also augment sampling capabilities on a global scale. Because the latter would benefit user communities, the planning for Jason-3 was strongly highlighted as a priority in the European Commission's Copernicus programme. More precisely, the Copernicus 'Working Group on Space Infrastructure' for Marine Core Services (MCS) identified Jason-3 as a critical component for space based ocean monitoring. In turn, this European Commission involvement changed the financing structure of the mission, which would be divided among three partners on the European side instead of two: CNES, EUMETSAT and the European Commission.

5.3.1 Jason-3

In March 2006, a series of informal discussions was held at the Symposium on 15 years progress in altimetry in Venice, Italy. Following these talks, NOAA and EUMETSAT proposed an approach for Jason-3, which was afterwards endorsed by the management of both partners. It was agreed to establish a joint NOAA-EUMETSAT Focus Group with overall responsibility for preparing a conceptual approach and, consistent with the OSTM/Jason 2 MoU wording, to invite NASA and CNES to participate as members. The Focus Group then established two joint groups: an Applications Working Group, and an Implementation Working Group. The Applications Working Group was tasked to identify overall needs, both operational and research, for satellite altimetry and the basis for those needs. The Implementation Working Group was tasked to identify options for the implementation of a system capable of meeting the needs identified by the Applications Working Group.

Based upon the findings and recommendations of the Application Working Group, the Implementation Working Group – gathering representatives from NOAA, NASA, CNES and EUMETSAT – focused on two main aspects: the sharing of responsibilities between Europe and the United States and, the cost estimation for such a mission. At the time two main options were considered by

[59] "Global Altimeter Missions" 24 May 2011. Committee on Earth Observation Satellites 3 Apr. 2013 <http://www.ceos.org/index.php?option=com_content&view=article&id=106:ceos-virtual-constellations-ost-test&catid=65:ost&Itemid=108>.

EUMETSAT. The first one considered Jason-3 as a gap filler with a strong heritage of the Jason-2 mission, and not as a new series. For this type of mission, the main constraint would be a launch as soon as possible, at lowest cost possible. The second option would see Jason-3 paving the way for the next decade of ocean altimetry. In this option most choices for who provides what would be open, one major exception being the altimeter because of the synergies with the altimeter proposed for the Sentinel-3. EUMETSAT addressed these two options in a position paper that elaborated all further implications. This paper was handed to the European Commission DG Enterprise and Industry, which would convene a meeting of the European partners in the project, including ESA as the implementing agency of the space component of Copernicus. Also, the issue of Jason-3 conceptualisation would be addressed by the Copernicus Space Component High level Coordination Platform jointly set-up by the European Commission and ESA.

After having reviewed several options for Jason-3, the Implementation Working Group converged on the idea that a Jason follow-on with a strong heritage from past missions would be the best way to ensure continuity and avoid data gap, while minimising the risks inherent to such a programme and optimising its costs. This would be the only way to be compliant with the need for continuity of observation required by the Copernicus Marine Core Services (MCS). It was the opinion of the Working Group that the implementation of a new and more expensive scheme for a one-shot mission should be avoided because of the complexity of a new scheme and risk of delay detrimental for the MCS.

As consultation was taking place in the framework of the joint Focus Group, internal programme development needed to be initiated on the European side to ensure timely progress. In order to start the formal approval procedure for optional programmes, it was essential for EUMETSAT to get confirmation of the U.S. commitment to continue the partnership. For this purpose, the EUMETSAT Director General held exploratory talks with the Assistant Administrator for NOAA NESDIS in July 2006. Later that year, in November, EUMETSAT received a letter sent by NOAA Administrator Conrad C. Lautenbacher confirming NOAA's interest in strengthening the collaboration in satellite altimetry by means of the Jason-3 mission. At the same time, the EUMETSAT Secretariat received a letter from the President of CNES to indicate the interest of the French space agency in developing a Jason follow-on programme. These events comforted the Secretariat on the need to explore possibilities of developing a Jason follow-on mission through a CNES, NOAA and EUMETSAT partnership, with the objective of responding to the needs expressed by the Copernicus Marine Core Service. At the 62nd EUMETSAT Council in June 2007, the Secretariat was authorised to work on the preparation of a Jason Follow-on Preliminary Proposal and Initiating Resolution, to be submitted to the EUMETSAT Council in December 2007.

In the meantime, the discussions in the framework of the High Level Coordination Group on Copernicus Space Component (HLG-GSC) led to the formulation of three options for a Jason-3 mission. The first two were very much in line with the options EUMETSAT proposed; one being a Jason-2 recurrent spacecraft based upon the established U.S.-European collaboration, the other one would be a more advanced mission based on technology that was being developed for Cryosat. The third option proposed by the HLG-GSC, however, was a downscaled Sentinel-3 mission, disembarking the two instruments that were not required for ocean altimetry[60]. The chairman of the HLG-GSC proposed that ESA and EUMETSAT would converge on a single proposal to be discussed at the HLS-GSC meeting of January 2008 and that users would be consulted through the Copernicus Marine Core Services Implementation Group. At the same time, CNES would perform a detailed technical analysis of the proposals and the views of EUMETSAT Member States would be sought at the next EUMETSAT PAC meeting in October 2007. Eventually, the discussions and negotiations translated into a sharing of responsibilities similar in structure to the one displayed in the implementation of Jason-2. A detailed overview is provided in Table 8.

In this scheme, CNES would play the role of system prime for the customers EUMETSAT and NOAA. The funding formula was slightly different to the approach taken in Jason-2. Because of the Copernicus context and the fact that the Copernicus Marine Core Service group identified Jason-3 as a top priority, the European Commission would also contribute to the mission.

NOAA secured its participation in the Jason-3 programme and has given it top priority for securing climate-related measurements. On the European side, the Jason-3 Programme

[60] These instruments are the Ocean and Land Colour Instruments and the Sea and Land Surface Temperature instrument.

Europe	Shared	United States
Use of the PROTEUS platform which was already used on Jason-1 and 2, as well as some other missions. The element was procured by CNES as part of 6 platforms that were contracted to Alcatel.	The use of a ground segment, both for satellite and instrument command control and for product generation, based on a maximum re-use of existing elements.	The provision of a radiometer and of the other precise orbit determination elements (similar to the LRA, GPSP instruments).
The use of an Altimeter based on Poseidon 3 flying on Jason-2.	The use of an operations scheme based on the Jason-2 one. NOAA would be in charge of routine satellite operations. Processing and data dissemination to be ensured by EUMETSAT and NOAA.	The provision of a launcher and launch support activities to achieve a more balanced cost sharing between Europe and the United States.
The provision of the DORIS location instrument.		

Table 8: Sharing of Responsibilities between NOAA and EUMETSAT for Jason-3.

was approved in 2010 by the participating EUMETSAT Member States.[61] The Jason-3 satellite is currently scheduled for launch in March 2015.

5.3.2 Preparations for Jason Continuity of Services

Throughout the conceptualisation and procurement of Jason-3, the long-term perspective for ocean altimetry – beyond the Jason-3 timeframe after 2020 – was given consideration. In this respect, the EUMETSAT Secretariat was actively triggering discussions with the partners in order to define the nature of a future global altimetry system. These discussions were mainly held in the frame of the CEOS Ocean Topography Constellation (OST), which is co-led by NOAA and EUMETSAT. The advantage of discussing this issue in the CEOS OST context was that it ensured that all potential partners around the world would be involved. The OST requirements were elaborated in a report following the CEOS workshop of January 2008 that took place in Asmannhausen, Germany.[62]

The eventual way forward will be a continuation of the existing partnership between the United States (NOAA and NASA) and Europe (EUMETSAT, ESA, CNES) and industry. In the distribution of responsibilities in Jason CS EUMETSAT is leading the system definition and is responsible for the Jason-CS ground segment development; operations preparation and operations of both satellites, and will co-fund the recurrent Jason-CS-B satellite together with the European Commission. The European Space Agency on the other hand is responsible for the development of the first Jason-CS-A satellite; the prototype processors; delivery of the LEOP services, and procurement of the recurrent satellite on behalf of EUMETSAT and the European Commission subsequently, given that ESA is responsible for the development of the Copernicus space component. The European Commission will co-fund the recurrent Jason-CS satellite with EUMETSAT and funds the operations of Jason-3 and both Jason-CS satellites, including the LEOP service for the second Jason-CS-B satellite. Finally, NOAA is expected to provide launch services for both Jason-CS satellite, the U.S. payload instruments and ground segment support, and will contribute to the operations.[63] CNES will support EUMETSAT and NOAA in their mission design. This approach, combining the operation of Jason-3 with the development and operations of two Jason-CS satellites, is known as the Copernicus High Precision Ocean Altimetry activity.

Given that Jason-CS will serve as the future reference mission of the Ocean Surface Topography constellation, a same or better level of performance as the earlier Jason series will be guaranteed. The spacecraft will be based on a platform derived from CryoSat-2, but adjusted to the specific requirements of the Jason-CS mission and specific orbit. Currently the development process for Jason CS is in phase B2 and the proposed design is composed of the following instruments:[64]

[61] These are: Belgium, Croatia, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Romania, Slovenia, Spain, Sweden, Switzerland, Turkey and, the United Kingdom.
62 “CEOS Ocean Surface Topography Constellation Strategic Workshop.” December 2008 EUMETSAT 11 Apr. 2013 <http://www.ceos.org/images/OST/2008_Strategic_Workshop.pdf>

[63] “Jason-CS (Jason Continuity of Service) is the second component of the hybrid solution (Jason-3 + Jason-CS) agreed in 2009.” 20 Jun. 2013 EUMETSAT 27 Jun. 2013 <http://www.eumetsat.int/website/home/Satellites/FutureSatellites/Jason3/JasonCS/index.html>.
[64] Ibid.

- A radar altimeter, developed by ESA, based on the heritage from the Sentinel-3 SARL instrument, but with a design adopted to allow the interleaved mode combining the SAR and the LRM modes;
- An AMR-C Microwave radiometer, provided by NOAA;
- GNSS Precise Orbit Determination Receiver, developed by ESA and derived from the GNSS Receiver on Sentinel-3;
- The same DORIS Receiver as on Jason-3 and Sentinel-3;
- The same Laser Reflector Array as on Jason-3, provided by NOAA;
- A radio-occultation instrument based on a Tri-G receiver, provided by NOAA.

5.4 Ocean Altimetry Missions and the Theoretical Framework

The Jason missions are the last joint activities to be linked to the theoretical framework on the eight key elements for success to international space missions. Not surprisingly, in this field of collaboration the criteria for successful implementation also are met.

In terms of historical foundations, the collaboration in ocean altimetry could count on the extensive inter-organisational experience gained throughout the implementation of the IJPS constellation. In addition the Jason missions and their implementation approach were already given shape by CNES and NASA. The latter also brought leverage into the EUMETSAT-NOAA partnership in terms of scientific support by engineers, scientists and management practices. The shared objectives were of course again very closely aligned, as the operationalisation of ocean altimetry for meteorology had the same impact, position and significance for the agencies on both sides of the Atlantic. As opposed to the legal agreements used to define the responsibilities and plans for data access and distribution in the geostationary and polar orbiting satellite activities, memoranda of understanding were used to set forth the legal stipulations in the Jason missions. Given that the Jason missions are fully integrated platforms that make use of American and European technology, recognition to the other partners is always given in policy documents, presentations and in other sources such as on the internet. These elements clearly constitute a sense of partnership aligned with the overall partnership exhibited in the EUMETSAT-NOAA relationship.

Thorough review is somewhat more critical in the Jason missions as they are implemented by four different agencies instead of two: EUMETSAT, NOAA, CNES and NASA. To this effect, the MoU defined a substantial amount of interagency contact and follow-up to secure the smooth implementation of the four partners' different responsibilities. Measures include the establishment of a Joint Steering Group responsible for the follow-up during mission development until hand-over of satellite operations and any changes that may impact other partners in terms of cost, mission performance, schedule and end of life of mission.

Finally, the benefits of the collaboration in the Jason missions go beyond the mere cost sharing, as both sides of the Atlantic have provided technologies critical for mission success. These benefits in terms of cost and performance will be addressed in more detail in the final chapter.

Part II. Inter-Organisational Assessment

The Collaboration Record Analysis, Part I of the study, focused on the historical context, the different negotiation processes and the resulting formal agreements and constellations between NOAA and EUMETSAT. The eight key elements required for international space missions were applied as a framework for interpretation. The aim of the Inter-Organisational Assessment, Part II, is to analyse the partnership and its benefits from a more structural point of view. In the first instance the structural changes that have occurred and intensified the partnership will be assessed by means of a theoretical framework on collaborative strategies. This is accompanied by a summary of all physical established systems and segments. Finally, the strategic benefits of the partnership will be assessed. This chapter will demonstrate that the benefits for both partners are tangible and considerable and, that the partners have sometimes delivered particular and unique leverage to each other.

6. Partnership Assessment

So far this study only briefly touched upon the structural changes that have occurred throughout the evolution of the EUMETSAT – NOAA relationship. Supported by a theoretical framework on the progressive continuum of collaborative strategies, this section of Part II will offer a more comprehensive and analytical overview of the structural underlying dynamics in the partnership. The information upon which this analysis is based was acquired by means of interviews with EUMETSAT and NOAA staff[65] and by analysing the structures of the physical constellations they have jointly established.

6.1 Collaboration: Definition and the Progressive Continuum of Collaborative Strategies

In a general sense collaboration has been be defined as "*a process to reach goals that cannot be achieved by one single agent*".[66] In this regard, the concept 'collaboration' is used as an umbrella term and includes following components: (1) jointly developing and agreeing on a set of common goals and directions; (2) sharing responsibility for obtaining those goals and, (3) working together to achieve those goals, using the expertise and resources of each collaborator.[67] The three major constraints in the establishment of collaboration are time, trust and turf. All three are necessary to engage in more committed forms of working together. Moreover, they often influence each other:

- Time is a necessity in the evolution of working together between organisations and although collaboration takes more time and effort than providing services independently in the long-term it will save time.
- Trust is influenced by factors such as prior working experience, lack of understanding of the other organisation's operational mode and even personal relationships between agency representatives.
- Turf is the range of the authority or influence exerted by an entity. It is also related to the perceived position of the other partner in the collaboration. Turf issues, for example, may arise when one agency perceives that another agency reaps more benefits from the collaborative efforts, or takes on a lesser degree of responsibility, or has more decision making power.[68]

The degree to which agencies are able to overcome these three main barriers to a large extent determine what kind of collaboration they can engage in. In this regard, five different forms have been described in the literature. Ordered as a function of increased commitment, these are: (1) networking, (2) coordination, (3) cooperation, (4) collaboration and, (5) integration. In this categorisation, the term collaboration is a more specific form of the same-named umbrella term that has been used so far to cover all forms of working together, this should be kept in mind throughout the rest of this chapter. Together these different forms of working are called "the progressive continuum of collaborative strategies". In the EUMETSAT-NOAA case, especially the first four forms matter, as none of the systems established entail a merging of the two organisations or their branches. Table nine lists the four relevant forms of working together and describes their major features.

[65] On the NOAA side this includes Charles Wooldridge, Mike Haas, Peter Wilczynski, Jim Silva, Laury Miller and, Jim Yoe. In EUMETSAT information was provided by Paul Counet, Francois Parisot, Pierre Ranzoli, Gökhan Kayal, Silvia Castañer, Tillmann Mohr and Marc Cohen.

[66] Himmelman, A.T. Collaboration for a Change: Definitions, decision-making roles, and collaboration process guide, Himmelman Consulting, Minneapolis, 2002.

[67] Ibid.

[68] Ibid.

	Networking	Coordination	Cooperation	Collaboration
Relationship	Informal	Formal	Formal	Formal
Intensity	◉○○○○	◉◉○○○	◉◉◉○○	◉◉◉◉○
Definition	• Exchange of information for mutual benefit.	• Exchanging information for mutual benefit. • Altering activities to achieve a common purpose.	• Exchanging information for mutual benefit. • Altering activities and deployment of resources to achieve a common purpose.	• Exchanging information for mutual benefit. • Altering activities, deploying resources, and enhancing the mutual capacity to achieve a common purpose.
Characteristics	• Information exchange is the primary focus. • Minimal time commitment, limited levels of trust.	• Making access to services or resources more user-friendly is the primary focus. • Moderate time commitments, moderate levels of trust.	• Sharing of resources to achieve a common purpose is the primary focus. • Substantial time commitments, high levels of trust.	• Enhancing each other's capacity to achieve a common purpose is the primary focus. • Extensive time commitments, very high levels of trust.
Resources	• No mutual sharing of resources necessary.	• No or minimal mutual sharing of resources necessary.	• Moderate to extensive mutual deployment of resources. • Some sharing of risks, responsibilities and rewards.	• Full-scale deployment of resources. • Full sharing of risks, responsibilities and rewards.

Table 9: The Progressive Continuum of Collaborative Strategies.[69]

It is important to emphasise that each of the strategies can be appropriate for particular circumstances. This is because a trade-off has to be made between the efforts and benefits that are associated with each type of collaboration. Although intense forms of working together can bring great leverage and generate synergies that translate into considerable benefits, their initiation and maintenance also tend to be associated with more complex challenges in terms of, for example, political feasibility, engineering requirements and management. In other words, moving up one progressive stage is not an improvement per definition. The optimal form of partnership for a specific activity depends on many factors, like the strategy of the organisations in question, the nature of the joint activity concerned, the organisations' technological capabilities and the financial resources required.

In order to get a realistic and consistent overview of the NOAA-EUMETSAT partnership one has to consider the long term development and dynamics of these different collaborative strategies and link them to the constraining factors time, turf and trust. First, this helps clarify why some issues were easily overcome, while others have – as it goes – posed challenges to the progress in the relationship between EUMETSAT and NOAA. Second, it serves as measure of solidity and strength of the partnership that has grown since the first networking contacts in the mid-1980s. The latter is important to grasp the value of the benefits this partnership has produced. This will be addressed in the sub-

[69] Ibid.

sequent chapter, the cost-benefit impact assessment.

6.2 Geostationary Satellite Activities as a Form of Coordination

In the field of geostationary satellites the partnership has resulted in two crowning achievements that are still in force today: the Back-Up Agreement and the Geostationary Agreement. It should be recalled that the first was signed in 1993 to proactively regulate the requirements and procedure for back-up assistance in the event of loss of coverage from geostationary meteorological satellites. The second, signed in 1995, was conceived as a plan for data access and distribution following encryption of High Resolution Images by EUMETSAT.

In the theory of the progressive continuum of collaborative strategies, the joint geostationary activities correspond to a form of coordination. This means they are more committed and formal than just networking, but at the same time less integrated than cooperation activities. This becomes clear when the definition, characteristics and resource deployment of coordination are applied. Here, the information exchanged for mutual benefit takes the form of the organisations' core product: the data as made available under the Geostationary Agreement. User communities on both sides of the Atlantic incorporate the data obtained from both GOES and METEOSAT satellites in their models and eventually products and services. The alteration of activities on the other hand is reflected by the Back-Up Agreement and the technical preparations related thereto. Defining the protocol for satellite back-up events, it ensures that the common purpose of continuity of coverage in the Global Observing System framework is guaranteed. At the same time, the amount of time and levels of trust required to establish and maintain this coordination are relatively limited. Data exchange under the Geostationary Agreement takes place on an automatic basis, while the Back-Up Agreement only involves activities under relatively rare circumstances. Both organisations also retain total independence in the development and operation of their own satellites. Taken together, the main focus of the geostationary coordination activities is increasing the user friendliness of both the American and European systems. This takes the form of trans-organisational data access by means of data exchange and, improved chances of data access continuity in times of loss of coverage. Also, unlike cooperation activities, the coordination in geostationary activities does not involve a deployment or sharing of resources. Actually, the Back-Up and Geostationary Agreements are explicitly structured around the premises of no exchange of funds and a best efforts approach.

Turf has never really been a restraining factor in the field of geostationary satellites, mainly because turf issues are more prone to arise in more complex forms of working together than mere coordination. These are typically characterised by stronger commitments, higher integration and critical sharing of risk and responsibilities. One reason for this lack of complexity is the clearly geographically separated slots in the geostationary orbit with their fixed area of coverage and related lack of incentive for integrated platforms and exchange of instruments. On the operational side, the transparent and clear stipulations of the Back-Up Agreement assure equal commitments under similar circumstances, which assure a certain balance between input and gains, given that both organisations have more or less some consistency in their programmatic development. Luckily, the American partners felt they could rely on the European partner's capabilities for the Back-Up Agreement. Reasons for this include the prior working experience under the Atlantic Data Coverage and the leverage of ESA meteorological expertise into EUMETSAT at the time of its creation. In this sense the first real achievements were indirectly supported by the historical foundations in the networked community, which had created sufficient trust for coordination activities. When all these elements are taken together, there was intrinsically not much room for turf issues to arise. As will be explained further, this was slightly different in the evolution of polar orbiting satellite joint activities.

Overall, the constraining factors shaping this coordination were at the time very much influenced by their timing and sequence in the overall cooperation record. Not much time had passed since the establishment of EUMETSAT and the organisation was still small, undergoing a process of maturation. Table 10 schematically maps the structural elements of the geostationary activities to the corresponding form of working together as identified in the progressive continuum of collaborative strategies.

<table>
<tr><th colspan="4">Geostationary Satellites</th></tr>
<tr><th colspan="4">Legal Agreements and Constellation Characteristics</th></tr>
<tr><td colspan="4">Back-Up Agreement (1993)</td></tr>
<tr><td>Definition</td><td colspan="3">• Altering activities by means of satellite back-up under certain predefined conditions.
• Common purpose is the achievement of the goals in the WMO GOS Framework.</td></tr>
<tr><td>Characteristics</td><td colspan="3">• No time commitments to maintain this coordination of back-up.
• Organizations remain fully independent and autonomous in development and operations.
• Making access to satellite data more user friendly (i.e. robust) is the main focus.</td></tr>
<tr><td>Resources</td><td colspan="3">• No sharing of resources in nominal scenarios; only for a limited time when necessary. Resources are thus shared but not on a systematic nor full-time basis.
• Best effort approach in case of emergency.</td></tr>
<tr><td colspan="4">Geostationary Agreement (1995)</td></tr>
<tr><td>Elements</td><td colspan="3">• Exchange of information for mutual benefit by full exchange of data between EUMETSAT and USG in the interest of their user communities.</td></tr>
<tr><td>Characteristics</td><td colspan="3">• Low time commitments because of the automated exchange of data.
• Moderate levels of trust, mainly in the quality and continuity of data provided.</td></tr>
<tr><td>Resources</td><td colspan="3">• No sharing of resources, only data.</td></tr>
<tr><th colspan="4">Structural Form of Working Together</th></tr>
<tr><td>Networking
⦿⊙⊙⊙⊙</td><td>Coordination
⦿⦿⊙⊙⊙</td><td>Cooperation
⦿⦿⦿⊙⊙</td><td>Collaboration
⦿⦿⦿⦿⊙</td></tr>
</table>

Table 10: Structural Overview of the Achievements in Geostationary Satellite Activities.

6.3 Polar Orbiting Satellites as a Form of Cooperation

Throughout Part I, the Collaboration Record Analysis revealed that a substantial degree of negotiation effort was required to eventually achieve an operational Initial Joint Polar System constellation and plan activities under the Joint Transition Activities Agreement. This can be explained by situating these activities in the continuum of collaborative strategies and considering the peculiarities of the constraining factors in this specific case.

Whereas the organisations worked together through relatively loose coordination in the geostationary field, the joint polar satellite activities as executed under the IJPS and JTA Agreements are an example of cooperation activities. In addition to the elements that constitute coordination activities, the IJPS and JTA constellations also entail an explicit resource component. The latter is displayed in two ways. First, there is a clear deployment of resources to achieve a common purpose. The operational activities in the mid-morning and afternoon orbit constitute a real integrated and joint system, which is even expressed in the name. Activities in the geostationary field – although properly coordinated – do not display a similar degree of systemic integration. This means that by fulfilling their operational responsibilities in the different orbits by means of their own resources, the organisations guarantee the performance of the overall cooperative system. Second, notwithstanding the non-exchange of funds basis of the agreements, there is also a component of sharing resources. This has taken the form of an exchange of instruments and sharing of infrastructure. In fact, this component is so critical that the entire premise of the cooperation is based on the sharing of resources, rather than increasing user-friendliness of the system.

By virtue of their structure, the IJPS and JTA constellations entail sharing of risk, responsibilities and rewards. Although NOAA and EUMETSAT are responsible for their own satellites and their operations, the performance of their joint system is dependent upon the exchanged instruments and shared downlink facilities in Svalbard and the Antarctic. In case of satellite or data access anomalies, for example, the implications would be particularly troublesome for the operator in question because it falls under his responsibility, but the actual impact for both partners in terms of data providing to their user communities will be similar. At the same time, successful implementation and operation of the cooperation produces shared rewards that more or less equally beneficial for both partners. This feature is intrinsically more present in systems that display a higher degree of integration and therefore the interests to be defended and safeguarded during the negotiation process are more critical. This became very noticeable for the first time during the lengthy and complex negotiation efforts on data policy and data denial for the IJPS Agreement. The major issue during the data policy negotiations related to the type of data policy to be applied to the different platforms and or their instruments. The discussions were clearly complicated by the exchange of instruments as it was not clear whether the data policy should apply to the platform provider, the instrument provider, the region receiving the data or the procurer. Eventually a compromise was found because both organisations were aware of each other's sensitivities and hence willing to accept a solution that was not their preferred one, but one that respected the integrity of both organisation's visions on data policy. The fact that some reciprocal data policy familiarity had grown during the realisation of the Geostationary Agreement probably spurred the sense of partnership and trust to come to the compromise solution reached.

In terms of turf, the issues were not so much related to the deployment of the EUMETSAT MetOp satellites in the mid-morning orbit as such. In fact, the whole idea behind the IJPS constellation was precisely to get a European contribution to polar orbiting satellites, and the American partners were actively involved in this process in the context of the G7 discussions during the 1980s. If anything, the taking up of the MetOp programme by EUMETSAT was meant to reduce an existing historical turf issue that had grown at the overarching level; the Global Observing System framework. The main turf issues related to the implementation specificities of the system. A critical point was the foreseen duplication of EUMETSAT EPS capabilities of the NPOESS system in the mid-morning orbit. EUMETSAT felt this would have reduced its strategic importance in the partnership to an extent that it would risk becoming obsolete. For the data denial capability, some turf issues arose because of the sudden involvement of both civilian and military authorities at the highest level on the U.S. side. Due to the implications of the planned converged civilian/military U.S. polar programme NPOESS, the negotiation process became somewhat more rigid almost resulting in a deadlock situation. Finally, potential turf issues were avoided during the implementation of the Joint Transition Activities. Although the JTA Agreement was initially conceived as an interim agreement between the IJPS and the JPS, its significance in the cooperation between both organisations increased because of the consequences of the NOAA-N' incident and, the restructuring of the NPOESS Programme into the JPSS Programme on the American side. These events required further amendments that guaranteed the balance of input and responsibilities in the overall set of polar system activities.

Although the future Joint Polar System will not entail an exchange of instruments between NOAA and EUMETSAT as in the Initial Joint Polar System, the Agencies' ground systems for polar orbiting satellite data will be more integrated. In this sense, the degree of systemic integration will partially shift from instruments towards ground facilities.

Taken together, these responsive actions have demonstrated that the trans-Atlantic partnership is flexible and has been able to evolve continuously throughout the cooperation period. Reasons for the successful operations in the IJPS and JTA constellations today include the availability of sufficient time to force breakthroughs in the negotiation processes, the prior working experience and trust built up in the preceding geostationary coordination activities and a vast will to succeed and match the political ambitions set out in the G7 framework. Table 11 applies the structural elements of the IJPS and JTA constellations to the characteristics of cooperation activities as defined in the theoretical framework.

<table>
<tr><th colspan="4">Polar Orbiting Satellites</th></tr>
<tr><th colspan="4">Legal Agreements and Constellation Characteristics</th></tr>
<tr><td colspan="4">The Initial Joint Polar System Agreement (1998);
The Joint Transition Activities Agreement (2005).</td></tr>
<tr><td>Definition</td><td colspan="3">• Sharing of data products for mutual benefit
• Altering of programmes, deployment and sharing of resources</td></tr>
<tr><td>Characteristics</td><td colspan="3">• Primary focus is the fulfilment of user community requirements and achievement of GOS goals by means of sharing resources
• Substantial time commitments and high levels of trust required as indicated by the negotiation processes and legal agreements</td></tr>
<tr><td>Resources</td><td colspan="3">• Extensive mutual deployment of resources, sharing of infrastructure and exchange of satellite instruments.
• Operational IJPS and JTA constellations that entail some sharing of risk, responsibilities and rewards</td></tr>
<tr><th colspan="4">Structural Form of Working Together</th></tr>
<tr><td>Networking
◉⊙⊙⊙⊙</td><td>Coordination
◉◉⊙⊙⊙</td><td>Cooperation
◉◉◉⊙⊙</td><td>Collaboration
◉◉◉◉⊙</td></tr>
</table>

Table 11: Structural Overview of the Achievements in Polar Orbiting Satellite Activities.

6.4 Ocean Altimetry Satellites as a Form of Collaboration

Compared to the activities in polar orbiting satellites, developments in ocean altimetry have taken a huge practical step forward in a relative short time span. One of the reasons for this smooth implementation is that the taking over of the Jason programme by NOAA and EUMETSAT can be seen as a consolidation phase of the operationalisation of space based ocean altimetry, whereas the IJPS venture entailed a longer and more substantial programme development process. In this respect NOAA and EUMETSAT significantly benefitted from the prior experience gathered in CNES - NASA partnership. The latter has leveraged critical technologies, a balanced division of responsibilities and an appropriate legal framework into the Jason-2 and 3 programmes.

From a structural point of view, the working together in ocean surface topography is the most integrated form of working together displayed in the EUMETSAT – NOAA relationship. Whereas cooperation characterised the relationship between both organisations in polar orbiting satellite programmes, the relationship in ocean surface topography displays clear features of collaboration. It should be recalled that in the G7 context, cost sharing by means of pooling resources was the main driving force behind the cooperation in the IJPS and JTA systems. After all, before the cooperation was initiated, polar orbiting satellites were already a proven technology and even an established operational service in the United States. The Jason missions on the other hand found their origin in a technological maturation process that was made possible by a combination of American and European expertise and instruments. In this sense the primary driving forces for working together in ocean altimetry activities were capacity building and capacity enhancement, rather than deployment or resources. An overview is presented in table 12 below.

<table>
<tr><th colspan="4">Ocean Altimetry Satellites</th></tr>
<tr><th colspan="4">Legal Agreements and Constellation Characteristics</th></tr>
<tr><td colspan="4">Jason-2 Memorandum of Understanding (2006);
Jason-3 Memorandum of Understanding (2010).</td></tr>
<tr><td>Definition</td><td colspan="3">• Sharing of data products for mutual benefit
• Altering of programmes, deployment and of resources and enhancing the mutual capacity by merging different fields of expertise</td></tr>
<tr><td>Characteristics</td><td colspan="3">• Primary focus is enhancing the mutual capacity
• Extensive time commitments and high levels of trust, mostly leveraged from the CNES – NASA partnership and previous EUMETSAT – NOAA partnership</td></tr>
<tr><td>Resources</td><td colspan="3">• Full scale deployment of resources for the missions
• Jason-2 and 3 missions entail full sharing of risk, responsibilities and rewards</td></tr>
<tr><th colspan="4">Structural Form of Working Together</th></tr>
<tr><td>Networking</td><td>Coordination</td><td>Cooperation</td><td>Collaboration</td></tr>
<tr><td>⦿○○○○</td><td>⦿⦿○○○</td><td>⦿⦿⦿○○</td><td>⦿⦿⦿⦿○</td></tr>
</table>

Table 12: Structural Overview of the Achievements in Ocean Altimetry Satellite Activities.

The collaboration aspect is also reflected in the associated resource features. Whereas in polar orbiting satellite cooperation the overall system consisted of a two orbit constellation with a clear division of organisational tasks and responsibilities, the Jason programme consists of fully integrated one-satellite missions, which implies a full sharing of risks, responsibilities and rewards. If full mission accomplishment were not achieved, the implications would be indivisible and identical for both partners. Obviously such a degree of mutual dependency for mission success requires extensive time commitments and high levels of trust. In this respect, both agencies have not only benefitted from the NASA – CNES heritage and leverage, but also from their own partnership which had solidified significantly throughout their cooperative efforts in geostationary and later, polar orbiting programmes.

In addition, some constraining factors that have thwarted negotiations in other fields were less present in ocean altimetry. Being very user-community driven, collaboration in ocean altimetry missions entails fewer traditional barriers and restrictions. Unlike polar orbiting satellite data, ocean altimetry data lacks the strategic/security dimension and hence no data denial requirements had to be negotiated. Furthermore, the input provided by the four parties for the Jason missions was balanced and, took into account the strategic expertise on both sides of the Atlantic required for mission success. Although there is no duplication of efforts, engineering tasks as well as operational activities are conducted on both sides of the Atlantic. All these elements have diminished the intrinsic risk of turf issues.

6.5 Overall Structure Analysis

When the results of the three structure analyses are put together they reveal a picture of the overall evolution and state of partnership between NOAA and EUMETSAT. This is illustrated in figure 3 below. It shows that the working together has been subject to two dynamics. First, there has been a trend of widening through which ever more fields of space based meteorology have become part of the joint activities. Operating in a networked global meteorological community, both organisations started with geostationary coordination and subsequently widened the partnership into polar orbiting activities and eventually into ocean altimetry from space. Second, the partnership has been characterised by an accompanied process of deepening, in which every newly added field also displays a higher degree of integration and commitment. Since the different fields of partnership have not structurally changed since their initiation, the overall result is a broad range partnership consisting of different fields and intensities. Moreover, the collaboration record shows that the nature of the agreements and memoranda of understanding are really tailored and optimised to fit the needs and the nature of the joint activities pursued.

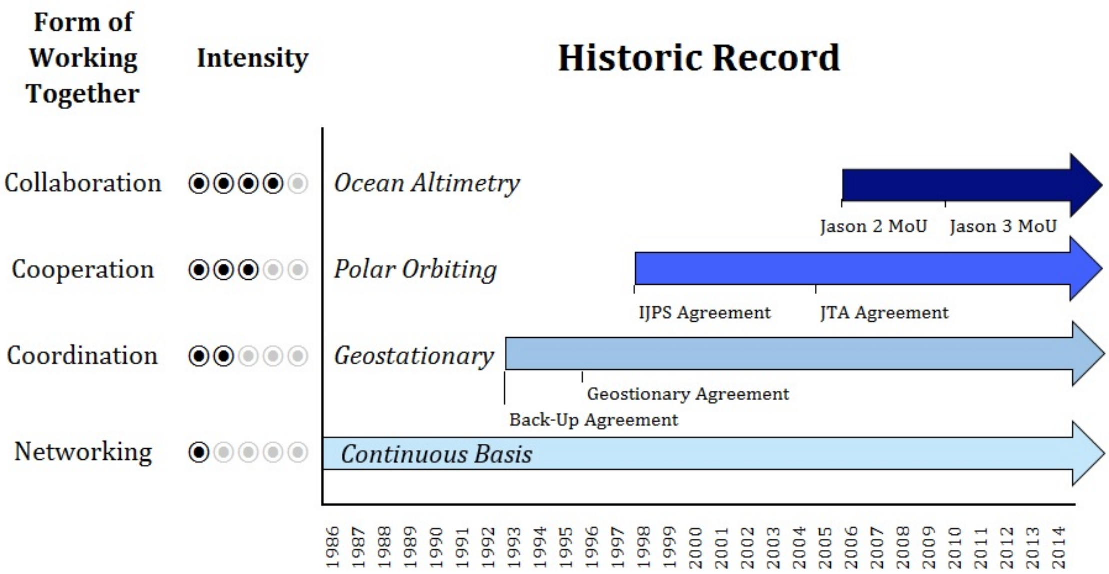


Figure 3: Overview of the Achievements and Related Collaborative Strategies.

6.5.1 Implications of the Partnership

The various forms of working together as displayed in the EUMETSAT – NOAA partnership today have some structural implications for both agencies. Interdependency has now become an essential keystone from the organisations' point of view. In fact, this trans-Atlantic relationship displays three different forms of interdependency between its inter-organisational branches.

Interdependencies

Pooled dependency occurs when collaborating organisations share and use certain common resources that nevertheless remain independent.[70] This moderate form of interdependency is reflected in the back-up agreement and the sharing of infrastructure and the ground stations McMurdo and Svalbard. Sequential dependency on the other hand arises when the output of one organisation becomes the input of the other.[71] This has taken place in the exchange of instruments in the IJPS and JTA constellations and the procurement of instruments for the integrated Jason platforms. As a result of sequential dependency the other partner is included in the critical path, which comes with some development and cost risks because of the non-exchange funds basis of the agreements and memoranda of understanding. Finally, both organisations have also become reciprocally dependent upon each other in fulfilling the requirements of the GOS and the needs of their own user communities. The division of responsibilities in terms of operational activities and polar orbits is such that data continuity would be endangered if the partnership ceased to exist in its current form, the element of data exchange is especially critical here. In this sense the interdependence and close relationship between NOAA and EUMETSAT indirectly impacts the other stakeholders in the data delivery chain: the weather forecasting centres, the user communities and, the governments that expect state-of-the-art observing systems in return for their investments.

Consequences

As a consequence of the interdependencies agencies are exposed and subject to various internal and external events and risks that impact their partner. This has clearly happened in this trans-Atlantic relationship. While some impacts were caused by decisions on a higher level, other were due to 'force majeure'. Examples in the first category include the U.S. decision to converge military and civilian meteorological programmes in space and, budget savings that currently obstruct partners from exchanging instruments in the upcoming Joint Polar System. Unforeseen circumstances that have im-

[70] Kumar, Kuldeep, and van Dissel, Han G. "Sustainable Collaboration: Managing Conflict and Cooperation in Inter-organizational Systems." MIS Quarterly 30.3 (1996): 279-300.
[71] Ibid.

pacted the working together occurred for example because of the NOAA-N' incident that ultimately required four amendments to the JTA agreement. In the implementation of Jason-3, NOAA was responsible for the procurement of launch services at a time when its budgetary situation was less flexible due to the financial crisis and the implications following the restructuring of the NPOESS programme. Partners have had to take these elements into account when planning of future activities is conducted. Despite the fact that NOAA's yearly contribution to Jason-3 was reduced, it was never cancelled and the agency was capable of placing a contract in time, guaranteeing a Jason-3 launch securing data continuity after Jason-2. In this sense, the value of the collaboration and the international commitment it entails can help secure funding in times of financial austerity. Finally, the roads that have been followed in the past also have an influence on which future actions are likely to be taken; introducing an element of path dependency in the partnership as well. The agencies should be well aware that the elements of risk and cost sharing resulting from interdependencies typically do not play out in a symmetric way. Although successful partnerships produce win-win situations for the partners involved, the gains for each partner can be different and will eventually depend on many factors. Moreover, long term collaboration characterised by interdependencies will have repercussions on the organisations' areas of specialisation, their cost structures, performance and innovation practices. Awareness of these dynamics and their influences on costs and opportunities cements the partnership and therefore these dynamics will be assessed in the cost-benefit impact analysis in the final chapter of this study.

7. Cost-Benefit Impact Assessment

This final chapter will assess the cost-benefit impacts of the partnership for EUMETSAT and NOAA. The idea behind the approach is that collaborations give rise to many more dynamics than just programme cost sharing. By assessing these other dynamics the cost and benefit impacts that result from the partnership can be applied to a theoretical framework on the cost-benefit structure of observing systems. Major elements that were introduced because of the partnership include cost efficiency implications and the synergies and technological innovation that have had positive effects on EUMETSAT's and NOAA's performance. These were identified in interviews with scientists, engineers and management personnel during multi-week on-site residences in NOAA and EUMETSAT Headquarters.[72] When all elements are taken into consideration, they reveal that benefits in terms of cost and performance have resulted in increased profitability of the observing systems in polar orbiting satellites and joint ocean altimetry missions. In addition many strategic capacities have emerged and although these have had a lesser impact on profitability, they have considerably benefitted both organisations and their user communities.

7.1 A Cost-Benefit Framework for Analysis

Cost savings are typically stated as one of the major advantages of collaboration in observing systems. They occur when operational agencies establish an observation capacity fulfilling certain user requirements by pooling resources instead of preferring the 'go-alone' option. However, the benefits of this partnership go far beyond the mere sharing of costs. The long-standing practice of working together between NOAA and EUMETSAT has impacted the benefits resulting from their observing systems more than anticipated. Therefore, it makes more sense to assess the impacts of the partnership from a benefit-to-cost approach. A benefit-to-cost ratio captures the relationship between the delivered benefits for society and the investment cost of an observing system. It is given by the following formula:

$$Benefit-to-Cost\ ratio = \frac{Delivered\ Benefits\ for\ Society}{Investment\ Cost}$$

Interestingly, all the outcomes and changes introduced by the collaboration between EUMETSAT and NOAA can be grouped into two categories, according to whether they have an impact on benefit or cost. This premise is the starting point of this cost-benefit analysis and it offers a number of advantages. First, such an approach better incorporates the various dynamics displayed in this relationship, which in turn yields a more all-embracing interpretation of the partnership's impact on both organisations. Moreover, the benefit-to-cost dynamics can be assessed in a model that reflects the economic specificities of observing systems. This sheds light on the partnership's influence on the profitability of observing systems as perceived by the governments that fund the meteorological operational agencies. The latter is important because the profitability of a system – though hard to quantify precisely – is typically something that will be considered by governments and other decision-makers seeking to optimise their return on investment. After all, observing systems serve a functional purpose; they are intended to translate technological capabilities into benefits for their user communities: the weather services and the scientific community, and the economy and society at large.

Unfortunately, the overall benefit-to-cost is not directly perceived by any partner involved in the delivery chain of meteorological products, nor by the governments that provide funding. This is because the benefits of observing systems are dispersed and propagated throughout the entire socio-economic realm over longer time scales. Although this feature is one of the strengths and strong potentials of observing systems, it also makes it harder for NOAA and EUMETSAT to make a case for their programmes. This has

[72] The dynamics described in the cost-benefit analysis came about thanks to the helpful information provided by staff members with diverse fields of expertise. On the NOAA side this includes Charles Wooldridge, Mike Haas, Peter Wilczynski, Jim Silva, Laury Miller and, Jim Yoe. In EUMETSAT information was provided by Paul Counet, Francois Parisot, Pierre Ranzoli, Gökhan Kayal, Silvia Castañer, Marc Cohen and former Director Tillmann Mohr.

repercussions on the benefit-to-cost impact assessment of the partnership.

Assessing the cost savings and positive benefits resulting from this partnership in monetary terms is obstructed by many factors that would make the eventual result an educated guess at most. In terms of cost, it would require case-based and hypothetical scenarios with which to compare cost. For polar orbiting satellites a previous system already existed on the American side, but because of the different technology requirements and structural differences between the systems any cost comparison would lack consistency. In the case of ocean altimetry this is ever more unclear, as the Jason missions have always been a result of international collaboration; there would be no 'go-alone' option to compare the procurement and operational costs in the first place. In terms of benefits a monetary assessment would require that all synergies and impacts of the collaboration on technology development be quantified. The latter is practically infeasible and therefore the user requirements will be used as a proxy for derived benefits. For these reasons, the cost-benefit assessment will focus on the dynamics of the opportunities in this partnership rather than their estimated monetary value.

To begin with, the cost-benefit dynamics of observing systems will be explained by an economic framework. Subsequently, the consequences of the NOAA-EUMETSAT collaboration on this model will be described and illustrated with concrete examples of cost and benefit impacts. Finally, these will be applied to the cost-benefit model to show how they give rise to considerable opportunities for both agencies.

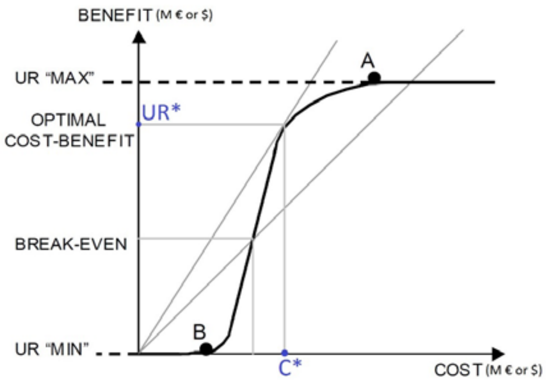
7.1.1 Generic Cost-Benefit Dynamics in Observing Systems

The cost-benefit structure of observing systems as used by the World Meteorological Organisation is based upon the positive non-linear relationship between fulfillment of user requirements and economic benefits. This approach makes it possible to use user requirements as a proxy indicator for derived benefits. Before this relationship is plotted against cost, the structure of user requirements and derived benefits will be considered. It should be recalled that the formulation and evaluation of observing system user requirements takes place on a global level in the WMO context. More specifically this is done in the Rolling Review of Requirements (RRR), which is applied to each application area covered by WMO programmes such as global NWP, atmospheric chemistry, ocean applications, hydrology, climate monitoring and others.[73] According to the RRR, for each application there is no abrupt transition in the utility of an observation as its quality changes; improved observations are usually more useful than degraded observations but even though the latter are less useful, they are usually not totally useless. Therefore, a gradual relationship exists with the following boundary conditions:[74]

- The "goal" or maximum requirement is defined by the RRR as the value above which further improvement of the observation would not cause any significant improvement in performance for the application in question. In other words, the cost of improving the observations beyond the target would not be matched by corresponding benefits in economic terms. Naturally, targets evolve as applications progress and develop capacities to make use of better observations.
- The "threshold" or minimum requirement is the value that has to be met to ensure that data are useful. Below this minimum, the benefit derived does not compensate for additional costs involved in the observation. Threshold requirements for any given observing system cannot be stated in an absolute sense and assumptions have to be made concerning what other observing systems are likely to be available.
- In the range between threshold and goal requirements, the observations become progressively more useful. According to the RRR the "breakthrough" is an intermediate level between threshold and goal which, if achieved, would result in significant improvement for the targeted application.

Given that the benefits can be seen as a function of user requirements and that these can be expressed in financial terms, the cost-benefit curve of observing systems has a typical s-shape defined by the following general characteristics:[75]

[73] "Rolling Review of Requirements and Statements of Guidance" World Meteorological Organization 10 Jul. 2013 <http://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html>.
[74] Charpentier, Etienne and, Eyre, John. "Requirements for Observational Data: The Rolling Review of Requirements" World Meteorological Organization 11 Jul. 2013 <http://www.wmo.int/pages/prog/www/OSY/Documentation/RRR-process.pdf>.
[75] Ibid



Graph 1: Generic Cost-Benefit Curve for an Observing System.[76]

- A significant cost must be incurred before any significant benefit is derived. That is why the curve is flat until a point where a certain critical mass is reached. Beyond this threshold point (B), additional costs result in increasing benefit and the cost-benefit curve goes up. However, when the maximum user requirement is met (point A), additional expenses (e.g. for more accurate instruments) will not result in increased benefits.
- Typically, a cost-benefit curve will intersect the line of equal cost-benefit (radius vector of 45°) twice at the break-even points. Beyond the lowest point of intersection the observing system becomes profitable as the benefits are higher than the investment cost, beyond the second intersection it turns loss-making again because the investment costs are much higher than the economic benefits.
- The point where the vertical distance between the cost-benefit curve and the radius vector at 45° is the longest is the optimal cost-benefit point. Mathematically, it is the tangent point of the radius vector on the cost-benefit curve. From a policy perspective, this is the optimal point in terms of decision-making.

In a situation where governments seek to maximise the return on their investment, they will establish an observation system with a set of user requirements of UR* at a corresponding cost of C* (see graph 1). At this point the benefit-to-cost ratio is at its maximum and overall profitability is optimised. If a government spent less, for example by procuring instruments with lower performance, the benefits would decrease more than proportionally. If a government spent more than the optimum, the benefits would increase but less than proportionally. In other words, any point other than the optimum would be detrimental to the societal profitability of an observing system.

When working together is introduced, the typical cost-benefit curve will be subject to transformations. This occurs because collaborations will have an impact on the indicators of both axes. When resources are pooled, the curve will be compressed horizontally since a certain set of user requirements can be met by spending less individual organisational funds. If performance is impacted by the partnership, it will stretch or compress the curve vertically. These transformations will also move the optimum, because the tangent line of the radius vector from the origin will be displaced. As a result the overall benefit-to-cost ratio perceived by EUMETSAT and NOAA will be affected. Before the impacts of the EUMETSAT-NOAA partnership on cost and performance are applied to the initial cost-benefit curve, they will be assessed based upon the information acquired from interviews with scientists, engineers and management staff of both organisations.

7.2 Cost Impacts of the Partnership

Pooling resources will diminish the expenses to be paid by a single agency to fulfil a given user requirement. The NOAA–EUMETSAT partnership has demonstrated that this can take many forms. The cost of establishing an observing system can be diminished by exchanging instruments for different satellites as in the IJPS and JTA constellations, or by pooling instruments on one integrated platform as in the Jason missions. Another way is to divide responsibilities in a constellation by appointing specific orbits to be covered by each agency. All these forms of pooling resources will result in significant cost-sharing and as a result programme costs will be shared while at the same time, the derived benefits remain indivisible. This occurs because like all digital information, meteorological and ocean altimetry data are so-called '*non-rivalrous*' goods that once produced can be copied and distributed an infinite number of times at near zero cost. This means that – as opposed to many other goods and services produced in the economy – their value in terms of delivered benefits does not decrease as a function of the number of users.[77] This

[76] Ibid

[77] In fact, meteorological data are a truly common good in the United States, whereas they are a club good in the EUMETSAT zone; only accessible by those who pay a fee. This distinction, however, has no impact on the fact that the data are a 'non-rivalrous' good in both Europe and the United States.

implies that programme cost can be divided without dividing or even diminishing benefits.

In reality it is very unlikely that the investment costs that would occur in single agency execution will be split exactly into two when collaboration is introduced, given that there are both deliberate and unavoidable elements in the partnership that introduce scale effects.

Although it is practically impossible to calculate the overall scale effect of the collaboration in exact numbers, it is possible to look at the different elements in the partnership that exert an influence on it. Interestingly, scale effects of opposite tendencies can be found. Some features in the collaboration have the tendency of introducing resource deployment inefficiencies, these are called diseconomies of scale. Economies of scale, on the other hand, have a tendency to make the collaborative execution of an observing system more cost-efficient than a 'go-alone' scenario.

7.2.1 Diseconomies of Scale

Diseconomies of scale arise when the sum of the individual organisation's resources spent on a common programme exceed the sum that would be required for a single agency to establish an observing system meeting certain user requirements. Phrased differently, it is the efficiency loss that results from multi-agency involvement, leading to a deterioration of the – still favourable – cost-benefit ratios. In the EUMETSAT-NOAA partnership there are two elements that constitute diseconomies of scale: (1) transaction costs and, (2) duplication of efforts.

Transaction costs are the expenses and opportunity costs that incur as a result of partnership initiation and maintenance. Although in economic theory, transaction costs were initially conceived as the cost of using the price mechanism[78], more recent literature has focused on its applicability to partnerships.[79] In this context, transaction costs have been divided into two groups: on the one hand there are ex ante costs of drafting, negotiating, and safeguarding an agreement, on the other hand there are ex post costs that emerge when a contract's execution is misaligned with the costs of running the economic system as a result of gaps, omissions or unanticipated disturbances.[80] The negotiations on data policy and data denial that preceded the establishment of the IJPS constellation are a clear example of ex ante transition costs for NOAA and EUMETSAT. Ex post transition costs occurred in the renegotiation of the JTA Agreement, when it was amended four times following the implications of the NOAA-N' incident. Because of the non-exchange of funds basis of the collaboration transaction cost can also increase as a result of external factors, for example when a launch has to be rescheduled because of delay in an instrument's delivery. Although transaction costs are intrinsic in every kind of partnership and some elements are unavoidable, they can be assessed and minimised in the interests of the partners involved. One example of transaction costs that can be addressed are the ITAR regulations that sometimes impede efficient technical assistance by EUMETSAT engineers and scientists. Taken together, however, the transaction costs for NOAA and EUMETSAT are probably quite low, especially in comparison to the substantial budgets required for their mission fulfilment. This is attributable to different factors. First of all the legal agreements were custom-made to fit the varying intensities of working together, with each of them specifying a clear division of responsibilities and the dedicated structures that would be set up for management, coordination, consultation, settlements of disputes, etc. Second, there is a strong person-to-person and team-to-team interaction between EUMETSAT and NOAA engineers, scientists and management. Over time this, and the fact that the community is relatively small and networked, has created social capital within both organisations. Social capital has been ascribed an important role in the performance of partnership and bringing down transaction costs since it smoothens interagency communication, brings down the time required to get specific information and accelerates decision-making processes.[81] Third, the risk aversion characterising space technology and operational services such as meteorology in particular, has decreased the risk of uncertainty, which is shown to have a positive relationship with transaction costs.[82] Moreover, uncertainty aversion benefitted from knowledge and expertise leverage from third parties involved such as NASA, CNES and, ESA.

Duplication of efforts in joint activities takes place when certain tasks are performed twice, or when both organisations maintain a

78 Coase, Ronald Harry. "The Nature of the Firm." Economica 4.16 (1934): 386-405.
79 Williamson, Oliver Eaton, ed. The Economic Institutions of Capitalism. New York: Free Press, 1985.
80 Ibid.

81 Jobin, Denis. "A Transaction Cost-Based Approach to Partnership Performance Evaluation." Evaluation 14.4 (2008): 437-465.
82 Artz, Kendall W. and, Brush, Thomas H. "Asset Specificity, Uncertainty and Relations Norms: An Examination of Coordination Costs in Collaborative Strategic Alliances." Journal of Economic Behavior & Organization 41 (2000): 337-362.

parallel capacity in certain domains. As opposed to transaction costs, duplication of efforts are an explicit form of diseconomies of scale. This means that these costs are the result of an explicit choice or motivation, for example to maintain a certain capacity in order to retain strategic independence. As such, it could be argued that these expenses should not be considered as diseconomies of scale; rather they are the price paid for certain political decisions and operational requirements. Interestingly, also here the EUMETSAT-NOAA partnership seems to score very well. In the Initial Joint Polar System and Joint Transition Activities constellations duplication of efforts were very much limited by the exchange of instruments. In the Jason missions the instruments and technologies that were provided by the partners were non-overlapping because they concerned an integrated platform. In terms of supporting infrastructure, the organisations utilise and share their ground segments in a way that doubles the downlink capacity per orbit, rather than serving as duplicates. In terms of satellite operations and data storage, the partnership with its full data sharing has introduced a contingency aspect. In this way, some parallel capacities are not only an investment in strategic autonomy, but indirectly also increase the robustness of the established systems, ensuring the continuity of data access to their user communities. In this sense the redundancy in the constellations and ground segments serve an operation-driven purpose. Moreover, a certain degree of duplication of efforts tends to introduce interesting features such as specialisation and technological competition to achieve outstanding performance.

7.2.2 Economies of Scale

Economies of scale are cost synergies that make a joint programme less resource-demanding than it would be on a single agency basis. These efficiency gains can result from various dynamics and processes and while their causes are typically universal, they have played out quite strongly in this partnership. This is mainly due to the fact that space based operational meteorology is very much technology-driven and thus also technology-constrained. Because of this, the resources related to technology development are one of the major budget expenditures of EUMETSAT and NOAA. This means that if they can be reduced, it will profoundly impact both agencies.

One of the major driving forces in many collaborations is specialisation, which is mostly linked to comparative cost advantages. If for a given observing system a set of user requirements has to be met, collaborating partners will automatically try to divide the distribution of responsibilities to conform to their areas of expertise and specialisation. This tendency has a positive effect on cost, as components will typically be delivered by the partner who is able to deliver in a cost-efficient way. This has played out very visibly throughout the Agencies' collaboration record. Especially in the establishment of the Initial Joint Polar System, the United States leveraged its experience in demonstrated advanced microwave sounding technology by delivering the AMSU-A 1 and 2 units also for the MetOp platforms. At the same time, this offered the opportunity of embarking technology demonstration instruments on the platforms in parallel; the strategic advantages of which will be elaborated further in section 7.3. In the Jason missions a similar process took place thanks to technology leverage from CNES and NASA. The Poseidon Altimeter and the Orbitography beacon technology used by the DORIS instruments were provided as contributions from the French space agency CNES. The American contributions were based upon expertise matured by NASA in the form of the GPS payload and the Advanced Microwave Radiometer used to determine the corrections to be applied in modelling. If NOAA and EUMETSAT had developed all the critical technologies required for mission success in these areas, it would have required substantially higher levels of resource deployment.

In addition to economies of scale, the partnership has also delivered advantages in terms of performance and technological progress. Although these also significantly improve the performance of the systems NOAA and EUMETSAT have established, they cannot be considered as economies of scale because they have no direct cost implications. Therefore, they will be discussed separately.

7.3 Benefit Impacts of the Partnership

EUMETSAT and NOAA are both operational agencies that provide data products to their user communities. To ensure the continuity of services to their user communities the organisations have adopted a relatively conservative approach with respect to technological innovation. New technologies are embarked upon as principal instruments once they have proven performance from a technical point of view and, once it has been verified that they actually correspond to the requirements of the user communities. Since the partnership spans many different fields and is especially integrated in polar orbiting and ocean altimetry satellites, two positive dynamics impacting performance have arisen: short term synergies and an increased rate of technological innovation in the long haul.

7.3.1 Synergies in Remote Sensing Capabilities

Typically, synergies arise at least partially as a result of serendipity and as such, they are bound within a specific mission or constellation. Once beneficial synergies arise and have been discovered, they become subject to user requirements and engineering planning processes. Therefore they will very likely translate into long term technological progress in follow-up missions or next generation instruments. This long term dynamic will be discussed subsequently.

The exchange of instruments in the Initial Joint Polar System, in particular, has brought considerable synergies between American instruments and European technology. The fact that NOAA and EUMETSAT are flying a common set of instruments on different platforms is a big advantage for the user communities because the data is more homogeneous and consistent as a result of similar technologies and better options for cross-validation. Particular synergies have also arisen between instruments from both parties. Probably the most tangible one resulted from embarking the AMSU-A units[83] and IASI instruments[84] together on the MetOp platforms of the Eumetsat Polar System programme. The AMSU-A units perform atmospheric sounding of temperature and moisture levels by means of microwave sounding and their data is used extensively in numerical weather forecasting. Their spatial resolution of approximately 40 kilometres at nadir is, however, not accurate enough to provide useful information on small storms and other local weather phenomena. The IASI instruments, developed by CNES, provide atmospheric emission spectra that enable scientists to derive temperature and humidity profiles with a higher vertical resolution and accuracy. Although there was some reticence at first with regard to the utility of the IASI instrument from the American side, the results turned out to be very positive. When the observations of both instruments are combined in the models, these yield an accuracy that puts forecasters in a position to make predictions on storm trajectories and precipitation patterns. It goes without saying that the emergence of new forecasting skills like these offer huge advantages to the user communities and society at large since they help protecting property, infrastructure and eventually, human lives.

In the Jason missions, a point of discussion on the to-be-embarked orbit determination system resulted in a synergy that increased the reliability of the data. Although this discussion occurred in the context of the Jason-1 satellite, the synergy was leveraged into the Jason-2 and 3 missions. The United States used its GPS satellites to provide ephemeris data of satellites in orbit, whereas European technology relied on a ground network of orbitography beacons based upon the Doppler shift principle. There was a discussion as to exactly which system would be used, until it was realised that merging both estimations would yield a more precise result than taking individual measurements from one system only, as both systems do not have the same errors and have particular strengths and weaknesses. Currently, the best orbit that is released is a concatenation of three systems: GPS, DORIS and, the Laser Retroreflector Array (LRA) instrument developed by NASA. This synergy improved the reliability of the data, considering that precise orbit determination is critical in a mission that is intended to measure sea surface altitude differences within the millimetre range.

The previous section on profitability of observing systems already pointed out that synergies translate into a user requirement standard that goes beyond what was initially envisaged in the establishment of an observing system. As they do not directly affect the cost of establishing an observing system they are not a form of economies of scale. This is exactly what happened in the events described above. Although synergies are not reflected in the programme cost, they have a tendency to increase the quality of the data and the usability and applications of the data by the user communities for a given cost.

7.3.2 Increased Pace of Technological Progress

An increased pace of technological progress typically spans over more than one mission or programme. It is the process that increases the normal ‘baseline rate’ of technological innovation typically displayed in remote sensing capabilities. From a structural point of view, this acceleration dynamic is driven by three driving forces: collaboration, competition and resource reallocation to address the maximum capacity constraint.

Collaboration Dynamics

In collaboration the underlying goal is improving the overall systemic capability by enhancing the capabilities of the other part-

[83] Advanced Microwave Sounding Unit-A.
[84] Infrared Atmospheric Sounding Interferometer.

ner. NOAA and EUMETSAT have an interest in doing so because the mutual capacity reinforcement coincides with self-interest. When one partner is able to meet the user requirements, the other partner will equally benefit because of full data sharing.

Moreover, the collaboration dynamics for technological innovation goes beyond the mere exchange of scientific and engineering expertise. In fact, it also includes the strategic capacities that are leveraged from one partner to another. This was very present in the exchange of instruments under the IJPS and JTA agreements. Without the exchange of instruments and expertise from the United States, EUMETSAT would have faced more challenges in getting its own proper polar system developed and implemented in the same timeframe, especially given that the organisation had no historic experience in polar orbiting satellites. Although the direct technical benefit for EUMETSAT was relatively limited because of compliance with the International Traffic in Arms Regulations (ITAR), a lot of knowledge was leveraged in terms of management processes, and Europe could use existing capacity, while at the same time test new and innovative instruments with higher resolutions. These opportunities gave European industry the time to develop its own strategic capacities in the field of meteorological instruments. In this sense, assistance from NOAA has served as a catalyst for EUMETSAT's expertise and capacity building. In turn, this leverage has benefited NOAA after the NOAA-N' incident and the restructuring of the NPOESS Programme, as it could count on EUMETSAT for the provision of instruments as outlined in the JTA and, could continue to rely on its European partner for high quality observations from the mid-morning orbit, respectively. Finally, the sharing of infrastructure with the downlink station at Svalbard, Spitsbergen (EUMETSAT) and the American McMurdo Station on Antarctica has enabled the NWS and other user communities in Europe and America to obtain environmental data twice as fast as before, since data are dumped to ground for processing every half orbit, instead of one time per orbit.

In the Jason missions the collaboration dynamics that foster innovation are very complementary for both partners. There has been an exchange of expertise on exploitation for retrieving and processing of ocean altimetry data products. Increasing scientific knowledge also takes place by sharing young talent such as post-doctoral researchers. In this sense the scientific collaboration in the Jason programmes seems to be more interwoven and open then in polar orbiting cooperation. The fact that ocean altimetry is really driven by the global scientific community has played a major role in this dynamic.

In addition to these advantages, the collaboration has unconsciously also introduced a form of peer review between NOAA and EUMETSAT. Both organisations are typically aware of each other's activities because of planning meetings and operational review meetings. These continuous forms of (semi)formal interagency review at the different levels help the scientists, managers and engineers of both organisations keep a fresh eye on their actions and decisions.

Competition Dynamics

Dynamics with a certain competition aspect play out when a partner focuses on improving its own capabilities. Also in this case, the impact is in the end typically beneficial for both partners given the full data sharing. Because of the close collaboration, many of the innovations and technological improvements resulting from internal innovation practices actually also find their origins in the close interaction with the other partner. In this sense the competition dimension is intrinsically linked to the collaboration, which is uncommon and unique compared to the competition dynamics typically displayed in commercial markets.

Direct effects of the partnership in this respect result from learning opportunities and unexpected synergies that have arisen in the execution of previous collaborative efforts. Indirect effects arise often transcend the NOAA-EUMETSAT partnership in the strict sense. However, they are often to some extent influenced by the partnership, since it has enhanced the networked structure of the meteorological community.

The direct effects can take various forms because there are different factors that can affect the pace of technological innovation. For example, partners can learn from performance issues or anomalies in instruments that were developed and initiated by the other partner on previous missions. These learning experiences typically shorten the technology innovation process as it will be less subject to trial-and-error optimisation. This has happened with the VIIRS[85] instrument, where EUMETSAT learned from some failures in terms of performance degradation and software optimisation.

As stated in the previous section, the pace of innovation also increases when individual synergies with a proven track record are

[85] Visible/Infrared Imager Radiometer Suite.

translated into a long term reconfiguration of satellite instrument packages on a continuous basis. This process increases the rate of technology innovation because synergies are more likely to arise when systems and instruments are developed in parallel and later merged onto platforms. Interestingly, this process will optimise itself since user communities have a good overview of the impacts of synergies and new instruments on the accuracy of their models' forecasts. The operational agencies, being aware of these impacts, can subsequently make cost-benefit trade-offs in their follow-up programmes. This dynamic has pushed the United States to develop an instrument with hyper spectral observation capabilities in line with the IASI technology and to embark the Cross-track Infrared Sounder (CrIS) instruments on the Suomi/NPP satellite.

Indirect effects often find their origins in the development of new technologies that were incubated by development agencies on both sides. This happened with the Radio Occultation instrument which derives temperature and humidity profiles by limb sounding[86] of GPS signals. The validity of this concept was first proven with the launch and operation of the GPS/MET instrument by the Jet Propulsion Laboratory in 1995.[87] Further capitalising this technology with ESA expertise eventually resulted in the GRAS[88] instrument which flies aboard the EUMETSAT MetOp satellites. The applications of GRAS observations benefit user communities in different ways. Currently GRAS observations are assimilated into NWP models because of their global sampling ability, stability and high vertical resolution in combination with high absolute accuracy. This has a positive impact on regional and mesoscale forecasting as they provide information about sparsely observed ocean areas. In climate modelling, GRAS data seems to be a very good starting point for building up and archiving radio-occultation data once more satellites equipped with this sensing technology are in orbit.[89] Finally, GRAS data will enable verification and further study of many atmospheric theories and models.[90] This makes the data particularly interesting for the Earth science community.

The 'Maximum Capacity' Constraint

The maximum capacity constraint is a bottleneck issue that emerges when the information potential generated by an observing system is not fully translated into benefits because of limitations in data processing capacity. In meteorology this is one of the causes of the non-linear relationship between user requirement standards and derived benefits which results into a 'flattening' of the cost benefit curve beyond certain programme expenses. In the long term, however, the maximum processing and modelling capacity is not fixed, but variable. This implies that if the modelling / forecasting capacity is improved, the cost-benefit curve of observing systems will stretch vertically because increased accuracy will be accompanied by corresponding benefits. When the entire cost-benefit curve is transformed it gives rises to a new optimal point with higher user requirements.

Here the partnership has provided opportunities as well. In terms of software there is already an exchange of algorithms between the European Centre for Medium-Range Weather Forecasts (ECMWF) and the NOAA National Weather Service (NWS) of the United States. Moreover scientists are engaged for particular fields of expertise and there is a strong interaction with academia and the Center for Satellite Applications and Research (STAR); the science arm of NESDIS. These actions increase the capacity of the models and as a consequence positively influence the accuracy of the forecasts for a given computational capacity. Economically, this means that the benefits of meteorological data are not only indivisible, it also seems that they are subject to positive network externalities because the utility of the data increases as a function of the number of users. The latter is quite unique and an intrinsic driving force for collaboration between NWP centres. In addition to software optimisation, the presence of partnership can also indirectly affect the physical processing and modelling capacity of forecast centres. This occurs as a result of an internal resource reallocation process initiated by the increased budgetary leeway the organisations experience because of cost sharing.

Assuming that budgets are considered as a whole, some of the programme development savings resulting from the collaboration might

[86] Radio Occultation instruments measure the phase delay of GPS signals that occur as they pass horizontally through the atmosphere.
[87] Loiselet, Marc, Stricker, Nico and, Luntama, Juha-Pekka "GRAS – Metop's GPS-Based Atmospheric Sounder" ESA bulletin 102 (May 2000): 38–44.
[88] Global Navigation Satellite Systems Radio Occultation Receiver for Atmospheric Sounding.
[89] Interestingly, NOAA is currently partnering with the Taiwan's National Space Organization (NSPO) on a programme that will launch six satellites into low-inclination orbits in late 2015, and another six satellites into high-inclination orbits in early 2018. This programme, when operational, will match the needs of climate change science community.

[90] Loiselet, Marc, Stricker, Nico and, Luntama, Juha-Pekka "GRAS – Metop's GPS-Based Atmospheric Sounder" ESA bulletin 102 (May 2000): 38–44.

be used to increase funds for data exploitation and modelling. This reallocation aspect is less visible on the European side because EUMETSAT does not perform weather and climate predictions itself. Nevertheless the effect of the collaboration does indirectly affect the organisation's resource requirements and thus this effect is indirectly perceived by the EUMETSAT Member-States. Yet this effect is clearly noticeable on the American side since forecasting is performed by the NOAA Center for Weather and Climate Prediction (NCWCP). It seems that there is still room for improvement in this part of the data processing chain. Latest developments in computer science are yielding novel concepts such as scalable supercomputer clustering. Because this technology tackles many of the traditional error detection and bottlenecks in communication and computation in supercomputers, it is an important step forward in the development of ultra-precise simulations.[91] Although the concept is still being matured it is thought that these new simulation architectures can be applied to areas of weather forecasting and climate modelling.[92] In this sense, the partnership is serving indirectly as a catalyst for innovations in the modelling and forecast capacities of the weather centres. If the modelling capacity goes up, this will in turn have an impact on the requirements of the user communities and thus on NOAA and EUMETSAT as well. This is a consequence of the spiralling dynamic between the user communities, the operational agencies and, the NWP centres and services.

7.4 Cost-Benefit Impact: Results and Interpretation

Now that the cost and benefit impacts of the EUMETSAT-NOAA partnership have been described and illustrated, their dynamics can be applied to the cost-benefit curve of observing systems. First, the general dynamics of collaboration will be applied to the initial model. Subsequently, they will be described with respect to the NOAA-EUMETSAT collaboration in particular.

[91] SC '12, ed. Proceedings of the International Conference on High Performance Computing, Networking, Storage and Analysis, 10-16 Nov. 2012, Salt Lake City, United States. IEEE, 2012.
[92] Carla Osthoff, Roberto Pinto Souto et al. "Improving Atmospheric Model Performance on a Multi-Core Cluster System" Atmospheric Model Applications. Ed. Ismail Yucel. Rijeka: InTech Europe, 2012: 1-24.

7.4.1 Cost-Benefit Dynamics in Collaboration

In this chapter, all the implications of the collaboration have been divided into two categories. The first comprises all the changes that have repercussions on the cost for a single agency to achieve a certain observation system fulfilling a set of user requirements. These have been expressed in terms of resource deployment scale effects. The second category includes all the performance changes that have resulted from the partnership. In order to demonstrate what their effects will be on the original cost-benefit curve they have to be translated into factors that can be included in the benefit-to-cost ratio.

Scale Effects

Scale effects occur in a partnership when the sum of resources spent on collaboration is not equal to what an individual agency would have to spend in order to achieve the same set of user requirements. If scale effects are represented by factor a, it can be expressed by the following formula:

$$a = \frac{\text{'Go Alone' cost}}{\text{Sum of individual agency costs in collaboration}}$$

If collaboration leads to overall economies of scale the value of factor *a* will be greater than one. If diseconomies of scale are the dominant feature in resource pooling, factor *a* will be less than one. Compared to the scenario where cost can be split straightforward into two, a value of factor a different from one will lead to a further horizontal compression and stretching of the cost-benefit curve, respectively. As a result, every point of the original cost-benefit curve will be moved closer or further to the y-axis with the same proportional factor. Given that any value of a different from one will transform the cost-benefit curve, it will give rise to a new optimum point that will correspond to a change in the benefit-to-cost ratio for an agency. The impact of scale effects in collaboration on the benefit-to-cost ratio is given by the following formula:

$$\text{Benefit-to-Cost ratio} = \frac{\text{Delivered Benefits for Society}}{\dfrac{\text{Investment Cost}}{2a}}$$

It shows that the investment cost for a given observing system will now be divided by a factor of two in combination with the scale effects displayed. The number two in the formula represents an equal sharing of cost. If resources are pooled in a balanced way, the impact of scale effects and cost sharing on the benefit-to-cost ratio will be comparable for both organisations. For these reasons, the value of the scale effects *a* in the collaboration is a critical parameter for partnership efficiency.

Performance Efficiencies

The impact of the collaboration on performance in terms of user requirement satisfaction will affect the benefits that are derived from observing system capabilities. This effect can be expressed by factor *b*:

$$b = \frac{\text{System performance in collaboration}}{\text{System performance in the 'go alone' option}}$$

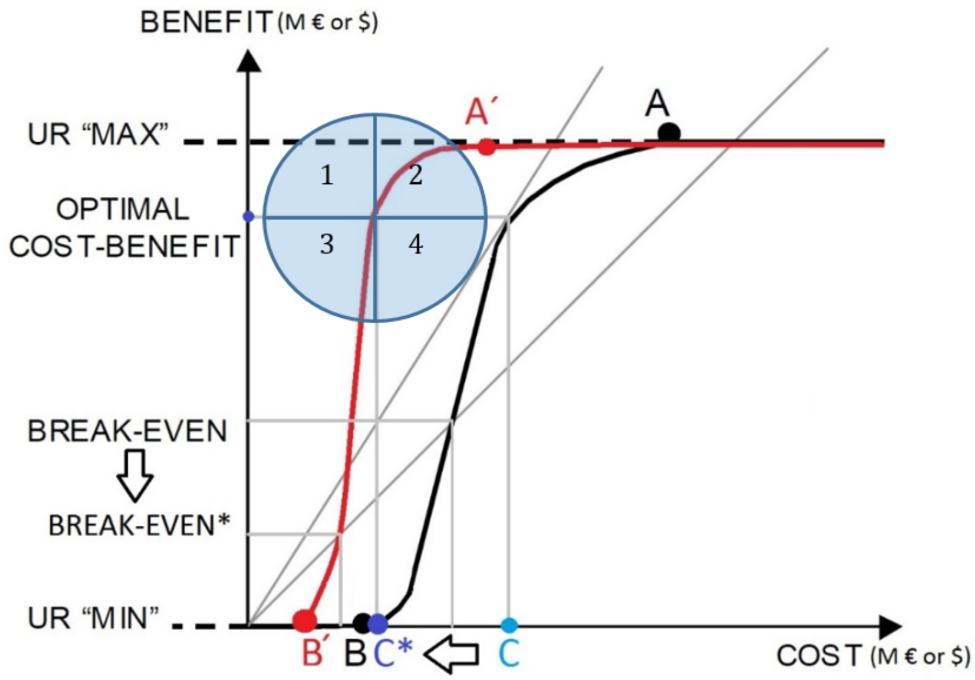
If the partnership translates into increased performance compared to the go alone scenario, factor *b* will be greater than one. If the partnership results in performance efficiency loss, factor *b* is smaller than one. Graphically, factor b will stretch the cost-benefit curve vertically because factor b only exerts influence on the benefits and not costs. The impact of changing performance *b* on the benefit-to-cost ratio of an agency that collaborates is given by the following formula:

$$\text{Benefit-to-Cost ratio} = \frac{\text{Delivered Benefits for Society} * b}{\text{Investment Cost}}$$

The joint impact of those transformations will eventually give rise to a new optimum on the cost-benefit curve. The position of the new optimum depends on the value of factors *a* and *b*.

Impact on the Cost-Benefit Curve

To illustrate this, a new reference curve is drawn in red with factors *a* and *b* equal to one. This is depicted in graph 2 below.



Graph 2: *Cost-Benefit Curve for the Joint Observing Systems.* (A new red cost-benefit curve emerges when the original curve is compressed along the x-axis with factor 2 conforming to a scenario with no economies of scale (a=1) or synergies in performance (no vertical stretching, b = 1).[93]

The original curve is only subject to a compression by factor two as a result of pooling resources. The novel cost-benefit curve represents the cost-benefit curve perceived by a single agent in a collaboration without performance synergies or scale effects. This red reference curve is now calibrated to show the effects of *a* and *b* and as such it serves as a good starting point to show the cost-benefit dynamics introduced by the partnership other than just cost sharing. The optimal point in the transformed reference curve lies left of the previous one; costs are shared in two (from C to C*), while the benefits remain unaltered.

When the values of *a* and/or *b* differ from one, they will give rise to a new cost-benefit curve with a novel optimum point. The new reference optimum in the centre point gives

[93] Own transformation based upon Charpentier, Etienne and Eyre, John (2013). Remark that the entire curve has been compressed by factor two and thus not just has been moved. Every point of the new curve has a new x-coordinate in the Cartesian coordinate system. As a result the new red cost-benefit curve has a sharper inclination than the black parent curve.

rise to four scenarios with regard to the values of *a* and *b*. Economies of scale and diseconomies of scale prevail left (quadrants 1 and 3) and right (quadrants 2 and 4) of the reference point, respectively. Performance synergies resulting from the partnership are positive in the fields above the reference point (quadrants 1 and 2) and vice versa (quadrants 3 and 4). Table 12 below gives a brief overview of the different scenarios corresponding to the different values.

Quadrant	Value *a*	Value *b*	Scenario
1	$a > 1$	$b > 1$	Economies of scale in resource deployment combined with a performance efficient partnership.
2	$a < 1$	$b > 1$	Diseconomies of scale in resource deployment combined with a performance efficient partnership.
3	$a > 1$	$b < 1$	Economies of scale in resource deployment combined with performance inefficiency.
4	$a < 1$	$b < 1$	Diseconomies of scale in resource deployment combined with performance inefficiency.

Table 12: Different Scenarios for Different Values of Factors *a* and *b*.

It is important to note that although scenario number one is clearly preferential, especially when compared to scenario number four, collaborations in all of them can make sense from an economic point of view. This is because the values of *a* and *b* smaller than one are the result of relative efficiency losses, not absolute ones.

7.4.2 Cost-Benefit Dynamics in the NOAA-EUMETSAT Partnership

Now that the implications of the dynamics of *a* and *b* have been applied to the economic model, the particularities of the EUMETSAT-NOAA partnership can be applied. Although the values of a and b for the collaboration between EUMETSAT and NOAA in the polar orbiting and ocean altimetry satellites cannot be calculated exactly, the cost and benefit impacts of the partnership reveal useful information on their substance.

Cost Efficiencies in the EUMETSAT-NOAA Partnership

It should be recalled that the value of *a* is determined by the aggregated effect of diseconomies and economies of scale in resource deployment. The partnership cost impact assessment in this chapter has shown that the diseconomies of scale in resource pooling have turned out to be rather limited. Transaction costs have stabilised following negotiations on data denial and data policy the IJPS agreement and JTA amendments. In fact the overall transaction costs in the partnership are quite low compared to the resources of the organisations. Reasons for this include risk avoidance and the sensible approach taken in the evolution of the overall partnership, where increasing commitments were made on a gradual and long term basis. In addition different interagency communication channels between engineers, scientists and management have ensured that information exchange proceeds smoothly. At the same time duplications of efforts was limited because of the exchange of instruments and sharing of infrastructure and the duplication of efforts that has occurred has served as additional redundancy for the two operational systems. Moreover, the exchange of instruments in the IJPS and JTA constellations and the provision of instruments for the Jason missions were outlined conform to the specialisations of expertise that had grown historically on both sides of the Atlantic. The importance of the latter should not be underestimated. User requirements are typically formulated in a technology-free manner while their fulfillment is very much constrained by the technological capabilities that can be obtained by the given resources. If specialisations exist and are leveraged into a partnership they will give considerable economies of scale because of comparative cost advantages. In addition the exchange of instruments has allowed both agencies to decrease the cost per unit of instruments, given that capital equipment amortisation is spread across more units.

When all these elements are taken into account as a whole, it is very likely that the factor *a* is in the proximity of one or even higher than one. This means that the cost-benefit curves for EUMETSAT and NOAA will be in the proximity of the red reference curve in graph 2, or left of it.

Performance Synergies in the EUMETSAT-NOAA Partnership

The performance changes introduced by the collaboration are definitely positive. In the short term synergies have arisen in the implementation of the IJPS and JTA constellations. The merging of American and European technology on the MetOp satellites has even enabled NWP centres to develop new forecasting skills that can be used by decision-makers for warning and evacuations. In the Jason missions the performance synergies have translated into higher accuracy and reliability of the data these ocean altimetry satellites provide. Synergies are very valuable in collaborations for a number of reasons. First, they prove that the benefits of partnership and intense collaboration go far beyond cost-sharing. Second, their serendipity aspect makes their impact often exceed expectations and as such, they add a positive feature to the partnership that exceeds the political ambitions formulated at the outset of the partnership. Finally, they further steer the technological development process in remote sensing capabilities. The latter has a positive impact on the long term. Both operational agencies have seen their pace of technological innovation increased thanks to an interwoven dynamic of collaboration and competition and, a higher degree of budgetary freedom that allows the processing and modelling capacity to be improved. Therefore the overall value of *b* is definitely higher than one.

Benefit-to-Cost Ratio

The benefit-to-cost ratio is an indicator that represents the overall value for money for, in this case, an observing system. Although this ratio is hard to measure because of the propagation effects of meteorological data throughout society, funding governments seeking to optimise the return on their expenditure spent should be aware that when collaboration is introduced, the scale effects and synergy performances will impact this ratio. The assessments of the values of *a* and *b* yield the following operating constraints:

a ≅ 1 or > 1
b > 1

This means that the optimal cost-benefit point achieved by NOAA and EUMETSAT in polar orbiting satellites and ocean altimetry will be situated in the first or perhaps in the second quadrant. As a function of the 'go-alone' scenario it is given by the following formula:

$$\text{Benefit to Cost ratio} = \frac{\text{Delivered Benefits for Society} * b}{\left(\dfrac{\text{Investment Cost}}{2a}\right)}$$

It should be recalled that the value of two supposed a balanced way of recourse pooling. In the case of NOAA and EUMETSAT it is safeguarded by a long term balanced input from in <their collaborative undertakings. The collaboration record and partnership assessment demonstrate that this assumption is legitimate. The inputs in the GOS are balanced in terms of constellations responsibilities, as in the IJPS and JTA systems and in terms of strategic capabilities provided. The latter is very clearly present in the Jason missions. Moreover, when imbalances arise – as happened after the NOAA-N' incident – there are mechanisms to restore the balanced input by means of revising the agreed input and responsibilities. From this it follows that the benefit-to-cost ratio for the joint undertakings NOAA and EUMETSAT have established compared to go alone scenario's is the following:

$$\text{BTC Collaboration (per partner)} = 2 * a * b * \text{BTC 'Go alone}$$

$$(\text{with } a \cong 1 \text{ or} > 1\ ;\ b > 1)$$

Factors *a* and *b* will affect the benefit-to-cost ratio proportionally. Given the yielded constraints of these values for NOAA and EUMETSAT, it shows that the benefit-to-cost ratios for both organisations have most likely increased by a factor of more than two. Interestingly, a study performing a cost-benefit analysis for the EPS/MetOp Second Generation programme yielded results that display a similar degree of synergy regarding the relative impact of American and European polar orbiting meteorological satellites on the accuracy of numerical weather prediction and the related socio-economic benefits.[94] Unfortunately, because the benefit-to-cost ratios are not directly observable by any party involved, efficiency gains that go beyond mere cost sharing are underexposed. The organisations and their funding governments, however, should be well aware of this value of the partnership in the interest of user communities. After all, the values of *a* and *b* represent considerable benefits in terms of data product quality, timeliness and cost. These added values should not be taken for granted. The fact that the values of *a* and *b* are currently so favourable has taken a lot of time and energy to achieve, as illustrated throughout the collaboration record analysis in part I of the study.

[94] EUMETSAT, The Case for EPS/MetOp Second Generation: Cost Benefit Analysis, 2012.

These added values of the partnership raise a question as to how they can be maintained, further optimised and even leveraged to other activities in the future, especially in times of significant financial constraints. So far, the synergies that have emerged have been mainly due to serendipities under the exchange of instruments and pooling of instruments on integrated platforms. This indicates that there is probably more fruit to be picked. If EUMETSAT and NOAA were to pursue joint innovation on a systematic basis, this could even yield more beneficial outcomes for user communities in the United States, Europe and elsewhere. Currently the U.S. International Traffic in Arms Regulations is impeding this interagency innovation dynamic for reasons of national security. Yet scholars have argued that "provisions of ITAR that are too strong in preventing knowledge transfer can eventually even be detrimental for national security by hampering innovation and preventing the free exchange of knowledge that is essential to space research in a global society".[95] If negotiations regarding a free trade agreement between the United States and the European Union address the ITAR issue and eventually result in an agreement, a new trans-Atlantic innovation dynamic in remote sensing capabilities for civil use can be stimulated.

Regarding future leverage of the current added value of the EUMETSAT-NOAA partnership, there are some potential opportunities as well. It is possible that in the mid- to long term a new activity will become part of operational meteorology for NWP purposes. The ESA Aeolus satellite, which is an integral part of the planned Atmospheric Dynamics Mission (ADM), will be launched in 2014 to record and monitor wind velocities and atmospheric pressure patterns in different parts of the world. Given that Aeolus will improve knowledge of all kinds of weather phenomena it will allow scientists to build more complex models of our environment. Aeolus is seen as a mission that will pave the way for future operational meteorological satellites dedicated to measuring the Earth's wind fields.[96] On the American side, expectations and enthusiasm for this mission is also present. If the mission is successful and operational follow-up activities are initiated, it might point towards a potential new field of collaboration between EUMETSAT and NOAA in space based meteorology, similar to what has happened in ocean altimetry. In the long term this would imply that the synergies between different operational activities in terms of NWP, could also be expanded to atmospheric wind monitoring.

7.4.3 Spill-Over Effects

Finally, the partnership has also created some spill-over effects that cannot be expressed in economic terms. Nevertheless, these have created added value and should therefore be taken into consideration in parallel to the cost-benefit impacts.

Because of the technological capabilities established, user communities have been able to come up with data applications that have opened new and unexpected possibilities. The performance synergies that have emerged during the implementation of the IJPS and JTA agreements have benefitted applications that do not directly affect just the American and European societies. Many of the instruments embarked currently provide data that is used for epidemiological and agronomical models to help protect people and agriculture in regions vulnerable to droughts and floods in Africa and other parts of the world.

From a political point of view, the polar orbiting cooperation – by means of the IJPS and JTA – has set a positive example vis-à-vis other partners. More precisely, NOAA and EUMETSAT have shown to the world and the global meteorological community that even organisations with different technologies, industrial policies and data policies can overcome all these hurdles and deliver satellites that have a homogeneous suite of instruments with continuity between the orbits. This has enabled the partners to deliver seamless observations from a set of four satellites in the interest of their user communities. In ocean altimetry the collaboration has even taken the form of integrated platforms equipped with complementary technologies provided by both partners. What is more, EUMETSAT and NOAA have shown that such undertakings can bring about unexpected synergies for the parties involved. If this feature could be valorised in other partnerships it would be a huge stimulus for collaboration in the networked meteorological community. Because of its success the structure of this partnership could spur other operational meteorological institutes to pursue similar mechanisms. The structure of the partnership and its approach of gradual increasing commitment can even serve as a blueprint for future collaborative efforts between other agencies in operational meteorology and possibly even in other domains that are characterised by similar conditions.

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[95] Broniatowski, David A., Jordan, Nicole C., Long Andrew M. et al. "Balancing the Needs for Space Research and National Security in the ITAR" Cambridge: American Institute of Aeronautics and Astronautics, 2004.
[96] "ESA's Living Planet Programme" 8 May 2013 European Space Agency 20 Jun. 2013 <http://www.esa.int/Our_Activities/Observing_the_Earth/The_Living_Planet_Programme/ESA_s_Living_Planet_Programme>.

Conclusions

The collaboration between the European Organisation for Meteorological Satellites (EUMETSAT) and the United States' National Oceanic and Atmospheric Administration (NOAA) has played an important role in the establishment of the various state-of-the-art observing systems currently in orbit. The meteorological satellite data provided by geostationary, polar orbiting and ocean altimetry satellites is used by many different parts of society to ensure safety of the population, to protect property and to increase economic performance and scientific knowledge. The aim of this study was to assess the various dimensions of partnership between EUMETSAT and NOAA and to show how this particular trans-Atlantic collaboration has produced tangible and strategic benefits for both organisations, their user communities and the governments that provide their funding.

The first part this study chronologically described the evolution of the collaboration record between both organisations in their different fields of engagement. This started out with an elucidation of the historical foundations that preceded the first collaboration activities between EUMETSAT and NOAA. This was done because awareness of these developments was essential to grasp the structure and unique features of the global meteorological community and the surrounding geopolitical environment in which this partnership is so strongly embedded. It turned out that the context of this partnership was very much influenced by the processes of internationalisation and globalisation that have reshaped the meteorological community. The World Meteorological Organisation in particular, by means of its global membership and a deep-rooted culture of working together in the Global Observing System framework, has played a vital role in this respect. Subsequently the negotiation processes and legal agreements of the joint activities in the fields of geostationary, polar orbiting and ocean altimetry missions were documented. A theoretical framework on the key elements required for success in international collaboration in space missions was applied as a narrative throughout the first part of the study.

The first systemic basis of working together occurred in 1993 when the organisations formulated a set of contingency conditions under which they agreed to provide mutual back-up support. Although this first collaboration was initially driven by the need for a case-based form of support, it was later formalised and the result has been an increased robustness of the observation capabilities in geostationary orbit. Two years later, in 1995, they signed the Geostationary Agreement that acknowledged and regulated the reciprocity of their exchange of data. Still in effect today, these agreements ensure a higher reliability of their geostationary satellites and data access continuity for their user communities.

In the field of polar orbiting satellites the agencies have been able to establish a state-of-the-art observing constellation that supports a broad range of environmental monitoring applications and weather forecasting. The seeds of this joint undertaking were sown in the margins of the G7 summit in 1983. The negotiations preceding the signing of the Initial Joint Polar System agreement in 1998 were challenging because of disagreement on the data policy to be applied and the specifications for the possibility of data denial. Nevertheless, continued efforts resulted in a balanced agreement that takes into account the interests and operational needs of both organisations. Eventually the Initial Joint Polar System constellation substantially exceeded the political ambitions that were formulated at the outset of this endeavour. Besides the division of responsibilities in the mid-morning and afternoon polar orbits, the organisations have implemented a sharing of infrastructure and an exchange of instruments that currently guarantees timely data access and homogeneous data sets for their user communities. Noteworthy in this respect is also the common use of the McMurdo and Svalbard data acquisition facilities, which has cut in half the data latency of EUMETSAT's and NOAA's polar orbiting satellites. The latest developments in this field are concerned with the follow-up activities required for the implementation of their Joint Polar System, which will entail further integration of the European and American ground segments.

The Jason missions are the most recent field of activity brought under the umbrella of the partnership. What initially started out as a successful ocean altimetry mission between NASA and CNES is now translated into a long term operational service by EUMETSAT and NOAA. The Jason missions are fully integrated platforms that make use of critical American and European technologies. Moreover, the performance of ocean altimetry will be even further optimised in the future Jason Continuity of Service.

The chapters in the collaboration record analysis revealed that the road towards these achievements was complicated by various internal and external factors such as programme restructuring on the American side and some unexpected events like the NOAA-N' incident. Nevertheless EUMETSAT and NOAA have shown that even organisations with different industrial policies, technologies and data policies can establish a long term successful collaboration based upon principles of reciprocity, respect and sense of partnership. The fact that both organisations have a similar mission and comparable operational requirements has definitely played a role in this process.

The second part of the study took a more analytical approach. The partnership assessment in the study analysed the working together between the two meteorological operational agencies from a more structural point of view. To this effect a theoretical framework was applied which distinguishes different forms of collaboration based upon their structural characteristics in terms of focus, commitment and resource deployment. This revealed that each field of joint activity displayed in the EUMETSAT-NOAA partnership is particular and, that the organisations have gradually increased their commitment over time as the joint undertakings turned out to be successful and beneficial for both partners. The geostationary joint activities are characterised by the relatively loose form of coordination. The IJPS and JTA constellations display features of the more integrated form of cooperation. Finally, when both agencies started to procure fully integrated platforms in the Jason missions, collaboration also became a form of working together in their partnership. Eventually this resulted in a full spectrum partnership that is characterised by strong interdependency and mutual levels of trust. In this sense the cemented partnership as it exists today has become a keystone element in fulfilling the user requirements defined for the Global Observing System in the WMO framework.

The cost-benefit impact assessment in the final chapter of the report analysed the impact of the collaboration on the organisations' overall costs and performance. It revealed that EUMETSAT and NOAA have been able to get a double win out of their partnership. The agencies have been able to establish a state-of-the-art observing system at a lower cost. This has been possible because the approach with respect to resource pooling was based upon comparative cost advantages that resulted from existing experience and fields of expertise on both sides of the Atlantic. In their polar orbiting programmes this has taken the form of an exchange of instruments. In ocean altimetry complementary technologies that are critical for mission success were provided by both sides. In turn this specialisation has also translated into considerable improvements in performance. In short, differences in remote sensing technologies have yielded unexpected synergies that were to a large extent the result of serendipity. In the Initial Joint Polar System, the combination of EUMETSAT and NOAA expertise gave rise to new forecasting skills that currently benefit user communities and decision-makers. In the Jason missions the merging of American and European technology onto fully integrated platforms has increased the accuracy and reliability of the data they provide. Over time both organisations have experienced an increased pace of technological innovation due to their partnership. Elements that have brought about this long term performance optimisation include an interwoven dynamic of collaboration and competition and resource reallocation in the data processing chain of meteorological products. Together these two elements have a considerable impact on the benefit-to-cost ratios of both organisations and their funding governments that go well beyond mere cost sharing. The economic benefits derived from meteorological data in comparison to the investment costs required to establish polar orbiting and ocean altimetry operational programmes have very likely more than doubled compared to the scenario where each organisation would have done this on its own.

EUMETSAT, NOAA, their funding governments and the meteorological community should take note of the value of this partnership. It has enabled their user communities to benefit from more data products, increased accuracy and better timeliness and robustness of the observing systems, all at a lower cost. Together these elements have translated into an increased ability to protect of human life, property and infrastructure and added value to the American and European economies. In addition the partnership has created positive spill-over effects in the context of the World Meteorological Organisation in terms of example-setting, scientific research and the facilitation of development aid applications.

Because of the unique combination of different added values displayed in this partnership, some questions were raised as to how it could be maintained, further optimised and even leveraged to other activities, especially in times of tightening budgets. This shows that there are still partnership opportunities to be considered in the future. The trans-Atlantic innovation dynamic in remote sensing technologies has the potential of being further increased. In terms of other activities, the monitoring of wind velocities will very likely be translated into an operational service in the mid- to long-term. The strong dimension of international collaboration in operational meteorology as exemplified in this report would merit further consolidation in a political sense. In the United States the value is already acknowledged as a principle in the National Space Policy of the Obama Administration. In Europe, however, this formalisation still needs to be undertaken. Given that this would generate strategic benefits for the EU and could give this long-term partnership a stronger political foundation on both sides of the Atlantic, it should definitely be considered during the reiteration of the European Space Policy.

List of Acronyms

Acronym	Explanation
ADA	Antarctic Data Acquisition
ADC	Atlantic Data Coverage
ADM	Atmospheric Dynamics Mission
AIRS	Atmospheric Infrared Sounder
AMR	Advanced Microwave Radiometer
AMSU	Advanced Microwave Sounding Unit
ATMS	Advanced Technology Microwave Sounder
AVHRR	Advanced Very High Resolution Radiometer
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CDA	Command and Data Acquisition
CEOS	Committee on Earth Observation Satellites
CERES	Clouds and Earth's Radiant Energy System
CGMS	Coordination Group for Meteorological Satellites
CGS	Common Ground System
CMS	Centre de Météorologie Spatiale
CNES	Centre national d'études spatiales
CrIS	Cross-track Infrared Sounder
Cryosat	CRYOgenic SATellite
DCS	Data Collection Service
DDIP	Data Denial Implementation Plan
DDWG	Data Denial Working Group
DG	Directorate-General
DLR	Deutschen Zentrums für Luft- und Raumfahrt
DMSP	Defense Meteorological Satellite Program
DoD	United States Department of Defence
DORIS	Doppler Orbitography and Radio-positioning Integrated by Satellite
DWSS	Defense Weather Satellite System
EC	European Commission
ECMWF	European Centre for Medium-Range Weather Forecasts
EEC	European Economic Community
ELDO	European Launcher Development Organisation
Envisat	Environmental Satellite
EOS	Earth Observation System program
EPS	EUMETSAT Polar System

Acronym	Explanation
ERS	European Remote Sensing satellites
ESA	European Space Agency
ESF	European Science Foundation
ESOC	European Space Operations Centre
ESRO	European Space Research Organisation
EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
GARP	Global Atmospheric Research Programme
GMES	Global Monitoring of Environment and Security programme
GNP	Gross National Product
GNSS	Global Navigation Satellite System
GOES	Geostationary Operational Environmental Satellite
GOME	Global Ozone Monitoring Experiment
GOS	Global Observing System
GPSP	Global Positioning System Payload
GRAS	Global navigation satellite system Receiver for Atmospheric Sounding
HIRS	High resolution Infrared Radiation Sounder
HLG-GSC	High Level Coordination Group on GMES Space Component
HRI	High Resolution Images
HRPT	High Rate Picture Transmission
IASI	Infrared Atmospheric Sounding Interferometer
IJPS	Initial Joint Polar System
IMO	International Meteorological Organization
IPO	Integrated Program Office
IPOMS	International Polar Orbiting Meteorological Satellite group
ISS	International Space Station
ITAR	International Traffic in Arms Regulations
Jason CS	Jason Continuity of Services
JPL	Jet Propulsion Laboratory
JPS	Joint Polar System
JPSS	Joint Polar Satellite System
JSG	OSTM Joint Steering Group
JTA	Joint Transition Activities
LEO	Low Earth Orbit
LEOP	Launch and Early Orbit Phase
LRA	Laser Retroreflector Array
LRPT	Low Rate Picture Transmission
MCS	Marine Core Services
MDD	Meteorological Data Dissemination

Acronym	Explanation
METEOSAT	Meteorological Satellite
MHS	Microwave Humidity Sounder
MOP	Meteosat Operational Programme
MoU	Memorandum of Understanding
MSG	Meteosat Second Generation
MTP	Meteosat Transition Programme
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NCWCP	NOAA Center for Weather and Climate Prediction
NESDIS	National Environmental Satellite, Data and Information Service
NMFS	National Marine Fisheries Service
NMS	National Meteorological Services
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
NRC	United States National Research Council
NWP	Numerical Weather Prediction
NWP	Numerical Weather Prediction
NWS	National Weather Service
OAR	Office of Oceanic and Atmospheric Research
OMPS	Ozone Mapper Profiler Suite
OST	Ocean Surface Topography
OSTM	Ocean Surface Topography Mission
PAC	Policy Advisory Committee
PIP	Programme Implementation Plan
POEM	Polar-orbiting Earth Mission
POES	Polar-orbiting Operational Environmental Satellite
PPI	Office of Program Planning and Integration
RRR	Rolling Review of Requirements
SARSAT	Search And Rescue Satellite Aided Tracking
SEM	Space Environment Monitor
SMS	Synchronous Meteorological Satellites
SNPP	Suomi National Polar-Orbiting Partnership
STAR	Center for Satellite Applications and Research
STG	Scientific and Technical Group
TIROS	Television Infrared Observation Satellite
TOPEX	Ocean Topography Experiment
U.S.	United States of America

Acronym	Explanation
VAT	Value Added Tax
VIIRS	Visible Infrared Imaging Radiometer Suite
WGP	Working Group on Data Policy
WMO	World Meteorological Organization
WWW	World Weather Watch
X-ADC	Atlantic Data Coverage Extension

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