Experience with Collaborative Space Projects

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International cooperation in space is becoming more and more important in these very days. The human exploration of the Solar System being the next logical step in Astronautics, there is the need of combining the efforts and sharing the same goals among nations in terms of destinations in the Solar System. To be taken then in duly account, each space fairing nation must keep its own goals and respect its own requirements in terms of research&development, national pride, political situation, financial availability. This is what I'm referring to as "Autonomy for cooperation" which calls for a strong worldwide cooperation scheme and at the same time, guarantees the autonomy of each and every country involved on a voluntary basis. The paper is addressing several very important programs as examples of different schemes of cooperation. The International Space Station, the greatest achievement of collaboration in space so far, the ESA scientific programs, being an example of good cooperation at European and International level, the Global Exploration Strategy, one of the broadest scientific experiment in space ever, the Alpha Magnetic Spectrometer (AMS), the international activities on space safety, dealing with space debris, asteroids threats, and commercial human spaceflight, pushing the idea of creating an "ICAO for Space".
The paper is addressing the various programs and their collaboration models in an innovative way, due to the uniqueness of its content and the personal experiences of the author, reporting on all the various aspect of international cooperation in space from inside, underlining lessons learned and indicating the right path to a worldwide cooperative approach in space activities.

Introduction

The various programs presented in the paper represent a very good set of models and experiences, and it would be possible to grasp pros and cons of any of them to stratify a set of "lessons learned" which in reality have been

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implemented naturally in the more recent programs. The Global Exploration Strategy, as an example, gained since the beginning from the ISS experience, even if the participants are different and the two programs are in two different phases in their respective lifecycle.
In this paper, a brief historical summary will be provided for very important cooperative programs, underlining their success stories and what I have personally learned from working deeply inside them. Each program will encompass various aspects which will allow, in the conclusions, to answer to the following key questions:

- **What** is cooperation about?
- **Why** cooperation is so important in space?
- **How** different experiences can shape the future of space activities?

A chapter will be devoted to the concept of Autonomy for Cooperation, and on how this concept can probably represent the way of approaching cooperation in space in the future.

I The International Space Station

The International Space Station (ISS) is currently the greatest accomplishment in space as a human achievement as well as technological. Cooperation has been dealing and will continue to deal with planning, coordinating, and monitoring the number of activities of the Program's many organizations over the decades of its operations. As of today, the ISS is a huge international laboratory in space, result of the work of 15 different countries, five space agencies, with a total living space of a five-bedroom house (or the equivalent of a Boeing 747 jumbo jet) and an extension of a football field.
The program started in 1984, when President Reagan, at his State of the Union Address, said: "*Tonight, I'm directing NASA to develop a permanently manned space station and to do it within a decade…….We want our friends to help us meet these challenges and share their benefits. NASA will invite other countries to participate so we can strengthen peace, build prosperity, and expand freedom for all who share our goals*". Since then, it has been a very intense period of time, with important negotiations on-going, tragic events, stop and go events which characterized the entire life of ISS. The five partners, which have been responsible for the ISS development and are now responsible for its operations, are the space agencies of the United States, Russia, Europe, Japan, and Canada. Assembly complete was declared in 2011, at least for the "non-Russian" side, when the last element was brought up in orbit with the last but two shuttle flights STS133, after 13 years from the launch of the ISS first element, the Russian module Zarya launched in November 1998, for a total construction cost of about 100 billion dollars. As of July 2012, we can count a total of 125 launches (81 Russians, 27 shuttle, 1 U.S. commercial, 3 Europeans and 3 Japanese), and a total of about 1000 hours of extravehicular activities for 162 spacewalks. This implies that as of 9 September 2012, the ISS has been in

orbit 5042 days, for a cumulative crew time of 4329 days. With the Expedition 1 leading the phase of a permanent presence of humans on board the ISS starting in the year 2000, the participating agencies have been able to reach the "crew of 6" steady-state in May 2009. In a nutshell, the ISS can be defined as the first exploration, international and permanently manned outpost in space; it's a unique laboratory for performing unique research benefiting society and life for further exploration missions both for astronauts and technologies. ISS will be operated at least until 2020 and possibly beyond, providing a long-term perspective to microgravity research and studies.
It's important to underline that the same international partnership of space agencies, which provided the various elements of the ISS, also allows its operations and the activities on board. The ISS can be easily considered the most politically complex space exploration program ever undertaken. In fact, the ISS is very demanding in terms of operations, due to the fact that it brings together international flight crews, multiple launch vehicles, several launch complexes, not to mention communications and, extremely important, a worldwide international scientific community.
But how the ISS collaboration is organized? The partnership is based on a multilateral Inter-Governmental Agreement (IGA) and bilateral Memoranda of Understanding (MOUs) signed between the US agency NASA and the partners, all signed in 1998 as being in force today. In this bilateral Memorandum, ESA represents the 10 Member States which participated in the development phase of the European contribution to the ISS. Further so-called Implementing Arrangements have been continuously put in place between the Space Agencies (i.e. barter arrangements) considering that the MOUs call for a non-exchange of fund principle.
The ISS shows also a very complex mechanism for operations cost sharing among the partners, for resource access on board and utilization of the facility.

The complexity of the ISS and its management in the operational phase in a cooperative way is also linked to:

- The long duration of the program before assembly complete, due to the need to maintain political support in all the countries involved over decades, coupled with some solutions adopted becoming obsolete (i.e. Space Shuttle retirement);
- The size of the program, consuming in some cases a large fraction of national space budgets;
- The articulated cooperation scheme, which brought up to the partners, with different perspectives, very important lessons learned which, as well described in chapter III, have also been very useful in understanding what to do better, what not to be done in a cooperative program, what has to be considered as a value for the future. The Global Exploration Strategy has been conceived to avoid the same issues encountered in the ISS program, with a more cooperative approach since the beginning of the cooperation, with a different leading role of NASA, and enlarging the number of countries/space agencies working on it since the very first moment.

The ISS provides a couple of very positive lessons learned, from which future cooperative endeavors can build on and benefit from. In fact, it provides an excellent example how different management cultures can successfully interact; at the same time, to assure robustness to an international program, a strong political commitment is essential, and it must be a politically binding agreement, even if usually in space, agreements are based on the "best effort" basis, to take into account unexpected events.
The ISS in reality shows also some weakness in the consideration that the robustness of the program and redundancy in key elements have not been considered in building up the program, and we could define the ISS as a program based on "dependency" and not on "cross-support". At the moment, since the Shuttle retirement in mid
2011, the only vehicle able to bring astronauts to the ISS has been the Russian Soyuz, until NASA will succeed in its action of enlarging to the commercial private world the access to Low Earth Orbit with private manned vehicles starting to visit the ISS on a regular basis, which will not happen before 2015 at the earliest. Here it comes the strategic importance of the "Autonomy for cooperation" concept.

II The Global Exploration Strategy

The Global Exploration Strategy success story started with the creation of a proper set-up to support initial dialogues on "International Collaboration for Sustainable Exploration". This was done thanks to a couple of workshops co-organized by ASI and ESA in 2005 and 2006 in Italy (Spineto). A similar topic was discussed in Washington D.C. in 2006 too. In August 2006, 14 Space Agencies began discussing a "vision for globally coordinated space exploration", namely ASI (Italy), CNES (France), CNSA (China), CSA (Canada), CSIRO (Australia), DLR (Germany), ESA, ISRO (India), JAXA (Japan), KARI (Republic of Korea), NASA (USA), NSAU (Ukraine), Roscosmos (Russia) and UKSA (United Kingdom).
The goal was twofold:

1. articulate a compelling case for exploration to gain broad public support for globally coordinated exploration involving the Moon, Mars, and other destinations;
2. set the stage for future international discussions on coordination mechanisms and on initial lunar exploration architectures.

These discussions led to the finalization of a document, which became then a masterpiece, a milestone in the history of cooperation in space exploration: The Global Exploration Strategy: a Framework for Coordination", jointly released in May 2007 at the time of the 3rd workshop in Spineto by all the participating space agencies. The Framework document, in fact, represents an important step for the participating 14 agencies in an evolving process, which is also open to other space agencies keen to "join the club" , toward achieving a global, strategic, coordinated and comprehensive approach to space exploration.

Which are the main features of the Framework for coordination? Easy in their complexity:
– it articulates a shared vision of human and robotic exploration focused on solar system destinations where humans may someday live and work;
– provides an extended rationale for exploration;
– identifies a common set of exploration themes and values;

and:

– is not a proposal for a single global program but it recognizes that individual space exploration activities can achieve more though coordination and cooperation;
– calls for a voluntary, non-binding coordination mechanism among interested space agencies globally.

But how this was then implemented? Based on the following four principles:
1. openness and inclusiveness;
2. flexibility and evolutionary approach;
3. effectiveness;
4. establishment of mutual interest,

a mechanism was found to provide participating agencies with a forum to discuss their interests, objectives and plans in space exploration, and a forum to promote space exploration at the same time. Such mechanism, through which then nations can collaborate, could help to strengthen both individual projects and the collective effort when we come to Exploration overall. As a result, the International Space exploration Coordination Group (ISECG) was set up in Berlin in 2007, with the goal of working collectively toward the further development and implementation of the Global Exploration Strategy, helping also participating agencies to identify gaps, overlaps and synergies in their space exploration plans. The benefits of such a group are the increase of robustness, safety and cost effectiveness of individual and collective exploration goals, facilitating at the same time the ability of participating agencies to engage in productive bilateral or multilateral discussions, while preserving their autonomy. This process, in the end, will contribute to strengthening the sustainability of global space exploration.
As of today, ISECG is realizing its ambition to contribute to the implementation of the Global Exploration Strategy following its founding principles. ISECG is a very interesting experience in worldwide cooperation in space, taking also into account that its creation is the result of a bottom-up process whose momentum is due to the global nature of exploration, and its uniqueness resides in its capacity to deal with the interests of all its members on a voluntary and non-binding basis. The broadness of the collaboration which ranges from the USA to China, from Canada to India, from Europe to Japan and Republic of Korea, from four European national space agencies to Australia, has a meaning per se' and shows that collaboration worldwide is possible, at the least at this stage. The next challenge will be to put in place

the implementation mechanisms to move from studies and architectures to a global program development phase.

III The European Space Agency

European space activities, conducted through the management of the European Space Agency, are a matter of international cooperation per se'. Since 1975, and even before with ESRO and ELDO (then merged to form ESA in 1975) European States (growing in number) are pooling their resources to define and implement space activities at European level, with the principle of "juste retour", the guaranteed industrial return, which is considered as a major driver for this successful cooperation.
ESA programs cover the whole spectrum of space activities, with the 25% of its budget referred to Mandatory activities (based on GNP) and the remaining part made of Optional Programs, which Member States subscribe at their convenience.
European cooperation in space is articulated in several different levels:

- National space agencies – some of which are retaining an important part of their budget for national programs, also through bilateral agreements with other national space agencies;
- On a cooperative basis through ESA, but also through Eumetsat (funded in 1986, currently 25 members and associated States), Eutelsat (48 member States), the European Union through the European Commission, which has established already important organisms/agencies like the European Defence Agency (in which space programs are becoming more and more important), the GSA (Galileo Service Agency) and the GNSS (Galileo) Supervisory Authority.

The Lisbon Treaty addresses in its art. 189 that "*1 - To promote scientific and technical progress, industrial competitiveness and the implementation of its policies, the Union shall draw up a European space policy. To this end, it may promote joint initiatives, support research and technological development and coordinate the efforts needed for the exploration and exploitation of space. 2 - To contribute to attaining the objectives referred to in paragraph 1, the European Parliament and the Council, acting in accordance with the ordinary legislative procedure, shall establish the necessary measures, which may take the form of a European space program, excluding any harmonization of the laws and regulations of the Member States. 3 - The Union shall establish any appropriate relations with the European Space Agency…..*". Since its entry into force, at the end of 2009, the cooperation and governance scheme has been characterized by clear sign of evolutions in the relationship between ESA and the EC, not yet clear in which direction. From the comparison of the two methods of implementation adopted up to now, and the growing interest of the Commission on space exploration and technology development (see also the FP7 Call 6, Theme 9 Space for a total of 126 million euros), European observers consider 2013 a key year to shape the future for Space in Europe.

Coming back to the European Space Agency, it is evident from the above that European Space Programs are the result of intense international cooperation with many players and several national objectives, interests and resources. ESA, which is now close to 20 Member States plus the agreement with Canada has been demonstrating since its inception its ability to manage international cooperation as the basis of all its programs and activities, with a long score of achievements and successes. Some lessons learned can be derived also from the analysis of the ESA functioning which can be used to work on a well customized model for international cooperation, to be adapted to each and every program of reference.
A very interesting additional model of cooperation in space in Europe is the way in which the Science program is managed at ESA. The Science program, mandatory, is supposed to fund, for each mission, the development of the spacecraft, the procurement of the launcher and to cover the operations, but not the scientific activities per se'. This approach implies that national space agencies are supposed to provide financial coverage to their scientists who get and maintain a position as Principal Investigators (PI), co-PI, team member, etc. including the hardware development and the scientific data analysis when the spacecraft is in orbit and performing its scientific observations, who have been approved by ESA to be on board the mission in question. Also in this case, some lessons learned have been quite useful to be brought up, when the SPC – Science Program Committee – claimed for the set up of a team of experts to review the Science Program, the SPRT (science program review team). One of the main results outlines in the report provided in 2006, focused on the need for the national agencies to continue funding the various instruments on board a selected mission and on the other side, to allow to provide more rewarding rights and opportunities to the national agencies contributing a lot to each and every science mission, also in terms of visibility and communication. As a consequence, the MLA (Multi-Lateral Agreement) was proposed as the solution and it has been implemented since then. It has been proven, then, that a more binding and formal mechanism prevents national agencies from discontinuing their financial support and at the same time, provide them with the formal responsibility, and therefore proudness and visibility, on the development and scientific results of the overall mission. In addition, ESA has been working more and more in cooperation with international partners, and European scientists too. In particular, the increasing need and desire for multinational collaboration has been a characteristic of the Science Program (and it's increasing in other areas too) at ESA. SPRT, then, recommended "*that an appropriate system of consultation and planning be set up to achieve a more effective harmonization with national agencies in Europe and with other, non-European entities, such as NASA, JAXA, Roscosmos and CNSA*".

IV The Alpha Magnetic Spectrometer

The **Alpha Magnetic Spectrometer** (AMS-02) is a state-of-the-art particle physics detector which is operating as an external module on the International Space

Station. The unique environment of space is key to study the universe and its origin by searching for antimatter, dark matter while performing precision measurements of cosmic rays composition and flux. Fundamental questions AMS is dealing with, such as "What makes up the universe's invisible mass?" or "What happened to the primordial antimatter?" could get an answer hopefully soon. AMS is a result of a huge international collaboration of 16 countries in 3 continents, for a total of 56 institutions and 600 scientists, who have been working together for 16 years to develop and get it launched to the ISS.
The AMS collaboration represents a very successful model of cooperation in space. It's "*a partnership of scientists and engineers belonging to Institutes, Universities, Laboratories and Research Centers (the Participating Institutions) supported by Funding Agencies…… The Participating Institutions have secured the support of their Funding Agencies to enable them to contribute to the AMS experiment. The Funding Agencies approved the AMS experiment…..*" including the AMS-01 precursor flight, and the development and launch to the ISS for AMS-02. The experiment is conducted under the leadership of Prof. Samuel C.C. Ting, the AMS Collaboration Spokesperson, under an agreement between NASA and the US Department of Energy (DOE). Participating Institutions also encompass *Participating Research Centers and Agencies that provide special services and expertise to the Collaboration. These include CERN, NSPO, ESA, etc.* NASA is supporting the AMS collaboration through JSC, providing technical support in the design, construction, safety and integration of the entire AMS-02 detector into the Space Shuttle and the International Space Station. AMS, as per today, is not only the largest scientific instrument installed on the ISS, but it is also the result of the largest international collaboration for a single experiment in space. The AMS collaboration has been successfully able also to go through the dramatic experience of seeing the shuttle flight assigned to it for its launch and installation on the ISS cancelled from the Shuttle Manifest and work collectively to get it back. STS134 was the last but one flight in the history of shuttle flights (STS135 in July 2011 marked the retirement of the Shuttle fleet) when in May 2011 brought finally the AMS-02 to the Station.
The AMS collaboration shows that a worldwide cooperation is feasible and works well, allowing exchange of approaches and methods for the benefit of science, and gaining from cross-cultural connections ranging from China to the US, encompassing most of the main space fairing nations scientists in the world.

V International Space Safety

In 2004, in recognition of a urgent need to advance safety in all areas of space activities, the International Association for the Advancement of Space Safety (IAASS) was created. Objectives were to pursue research activities, publishing relevant books, and began to work with institutions and academia in the field. In 2008, then a group of safety experts from government, industries and other organizations understood that USA had to make a choice in this

field, and created the International Space Safety Foundation (ISSF), becoming the only organization in the US to be fully dedicated to furthering policies of international cooperation and scientific progress in the field of space safety. It's a non-governmental organization operated by an independent board of Directors, and supported by a think-tank of experts, the Advisory Council, who the author of this paper has the honor to chair. Main cooperative effort has been already the establishment of the International Institute for Space Safety (IISS). Becoming more and more evident is also the need for an Integrated Regulatory for Aviation and Space. Considering the increasing number of vehicles reaching the Low Earth Orbit, the flourishing of suborbital and orbital commercial endeavors, the requirement for an international regulatory framework for a coordinated space traffic management, launch and re-entry safety, plus new services such as space weather forecast and orbital debris monitoring is calling for more attention. In the year 2000, Assad Kotaite, ICAO President of the Council, mentioned in the September 2000 ICAO Journal: "..*The time seems ripe to begin formal discussions on how best to harness the extraordinary potential of the frontier we call outer space. Contrary to the drafters of the Chicago Convention, we have a model at our disposal. We should not ignore this precious lesson of history. By acting expeditiously, we can tackle these issues before we are forced to do so*". ICAO (International Civil Aviation Organization) is the organization, created in 1944 as a specialized agency of the United Nations, which allowed the civil aviation to become safe and reliable over the years. ICAO serves as a forum for cooperation in all fields of civil aviation among its 190 contracting states. The case for extending ICAO to Space is based on the evidence that air and space are becoming more and more interconnected, especially in the area of suborbital flights, but also on the experience and lessons learned from the civil aviation history and how ICAO adapted during the past 50 years or so to the dramatic transformation of civil aviation. ICAO proved that a global forum of nations is essential for a common approach to the management of civil aviation activities and already exists since decades, having proven it works. The next logical step could be to expand its mandate amending the Chicago convention. However, even if the idea was brought up already since years, for the time being, a proper international treaty has not been established yet.

With this goal in mind, the International Association for the Advancement of Space Safety is organizing a conference in May 2013 in Montreal, "Safety is not option" and in conjunction with it a discussion on ICAO on Space will be brought forward. IAASS also sponsored the publication of a book "The need for an integrated regulatory regime for aviation and space – ICAO for Space?" in which the topic is addressed extensively.

The cooperation model addressed here with IAASS&ISSF is different from the other cases mentioned in this paper. In this specific case, in fact, we witness a bottom-up approach, as safety and space experts worldwide are contributing to increase the awareness of the importance of safety in space activities, more and more in this very phase, where the need for safety certification and regulations is increasing dramatically.

VI A Focus on Autonomy for Cooperation

Year by year, Autonomy for cooperation became a motto, because the experience shows clearly that, in a global endeavor, autonomy for co-operation is nearly mandatory. Increasing the autonomy of a participating country in a cooperative space program allows increasing the robustness of the partnership. In 2008 the concept of Autonomy for enhanced cooperation has been brought on stage, referring to the need al least for Europe to develop and master key technologies for the future operations of the International Space Station, and beyond for Moon and Mars exploration.
As mentioned in chapter II, this is a lesson learned quite important from the experience we have with ISS. On this basis, a new standard approach shall be considered for the future, assuming the autonomy of each participating country as a must for its participation to a given international program, with the understanding that its contributions shall be decided all together by the partnership, based on the requirements of the country in question on one side and the requirements of the entire collaboration on the other one. In the light of the evidence that both the approaches (i.e. top-down and bottom-up) work well for a given international cooperation program, the best of the two approaches shall be kept. This new way of doing, i.e. a mixture of the top-down and bottom-up approaches in the same program, is also in the essence of "Autonomy for enhanced cooperation", allowing in fact flexibility, robustness, inter-operability, national satisfaction and global success.

VII Conclusion

The paper illustrates several different models of cooperation and explain lessons learned and how the international community could get benefit from the experience gained in decades of cooperative programs. But the fundamental questions on cooperation still have to be answered, and the answers represent the proposed way of doing for of future of space. Here we are.

What is cooperation about?

Bringing together expertise, common objectives, different technological assets and capabilities, avoiding duplication, maximizing results and the economic burden on each country participating, cross-cultural interactions providing a boost, for a proper management of an international endeavor at the frontier of new discoveries;

Why cooperation is so important in space?

All the programs and cooperative activities described in this paper are, with their peculiarities and characteristics, the evidence per se' that international cooperation works well, and in a way, it's mandatory in space. We are really entering in a new era for astronautics, since we learned on a global scale how

to develop satellites, launchers, space infrastructures, and how to operate them internationally. For access to LEO it's now time for the commercial market to take it over, and at least in the USA, that's the trend in these very days. Government space agencies have therefore to focus on new technologies, at the frontier of innovation, experimenting new methods and approaches, with the goal of exploring the Solar System and enhancing at the same time the quality of life on our planet Earth. International cooperation, on a global scale, is therefore the only possible choice. Human exploration of the Solar System is a humankind endeavor, to be decided and managed, in a politically binding way, on a global scale. Science and discovery are not belonging to anyone in particular, but is the heritage of humankind.

How different experiences can shape the future of space activities?

Experiences in cooperative programs will allow to prepare the future in the right way. Other models exist and could be added, or models which have been repeated or slightly modified. Success is depending from an high degree of interactions, and readiness to understand each other requirements and constraints in a partnership. We, the space community, now know how to do that.

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