INTERNATIONAL PARTICIPATION IN AOS STANDARDS DEVELOPMENT

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ABSTRACT

During the current decade, international cooperation in space projects has become more and more popular and this trend is increasing. Initially, this involved only single missions with agencies flying payloads on other agencies' spacecraft. Later, this trend continued with international ventures, involving different agencies. In the immediate future, even more challenging scenarios are foreseen. The best known example and prime driver for such sophisticated missions will be the Space Station Freedom and its participating partners' spacecraft. Some of the international missions (ESA missions) are described briefly in this paper, in order to set the scene for a better understanding of the complex needs for standards within advanced orbiting systems. These ventures call for efficient means for cooperation and interoperability. Part of these requirements can be met by following international standards for space communications and space data systems.

The Consultative Committee for Space Data Systems (CCSDS) undertook the task of integrating the space data systems requirements and developing appropriate recommendations for data systems standards for these Advanced Orbiting Systems (AOS). All international partners in the Space Station Freedom Program participated in the definition, development, and review of the AOS recommendations. The need for better cooperation in space communications via data relay satellite prompted the formation of a three party international panel called the Space Network Interoperability Panel (SNIP).

An important aspect is the need for verification and validation of the concept and of the detailed technical recommendations. For the immediate future, special compatibility campaigns, involving the international

agencies are planned in order to ensure the smooth application and functioning of the AOS recommendations.

KEY WORDS

Consultative Committee for Space Data Systems (CCSDS), Advanced Orbiting Systems (AOS), Space Network Interoperability Panel (SNIP), Columbus, Hermes.

INTRODUCTION

All national space agencies had in the past established certain standards for their own missions in order to reap the benefits of standardization. Occasional cross support to other agencies normally meant specific implementation for a project, for one or both of the participating agencies. Typically this meant considerable investment, unless by coincidence or selected adaptations of existing industrial standards, the data systems of the cooperating agencies were at least partially compatible. The need for such cross-supported missions kept increasing over the years.

The spectrum of agency to agency support functions covered the following:

- hosting of payload of Agency A on Agency B’s spacecraft
- use of Agency A’s network to support Agency B’s spacecraft for data services (tracking, telemetry, and telecommand)
- cooperation of more than two agencies in aforementioned tasks
- joint spacecraft or payload development
- joint mission operations involving several spacecraft

These services or operations scenarios involved a range of missions including relatively straightforward support of conventional earth-orbit missions, support for planetary missions, as well as complex multiagency endeavors for manned spaceflight support, as will be the case for Space Station Freedom. As the trend towards more sophisticated missions continued, the danger of a diverging solution of space systems and standards became a real threat, mainly triggered by the growing complexity of space data systems. Consequently, space data systems experts and managers of leading agencies started discussing the systematic harmonization of space data systems with the goal of developing recommendations for standards. This eventually led, in 1982, to the foundation of the Consultative Committee for Space Data Systems (CCSDS). The CCSDS intends to establish recommendations for standards, in particular in those areas where interoperability between different space agencies is, or may become, an important issue in the years to come. The whole process of definition of concepts, development of recommendations and review is based on a consensus principle, as is current practice in other international standards organizations.

A similar need to cooperate in space communications via data relay satellites has prompted the formation of the international Space Network interoperability Panel (SNIP) and a similar international group is being set up for coordination of the networks and ground systems of the agencies supporting the Space Station Freedom.

The paper will briefly describe some of the international missions which will cooperate with the Space Station Freedom, the background for the international participation in the AOS recommendation development, and the main functions and goals of the two aforementioned international groups.

INTERNATIONAL PARTICIPATION

When finalized, the consensus technical agreement of the following member agencies in the AOS recommendations will be reflected:

- British National Space Centre (BNSC)/United Kingdom
- Canadian Space Agency (CSA)/Canada
- Centre National d'Etudes Spatiales (CNES)/France
- Deutsche Forschungsanstalt fuer Luft- und Raumfahrt (DLR)/West Germany
- European Space Agency (ESA)
- Indian Space Research Organization (ISRO)/India
- Institute de Pesquisas Espaciais (INPE)/Brazil
- National Aeronautics and Space Administration (NASA)/USA
- National Space Development Agency of Japan (NASDA)/Japan

It is foreseen that at the next CCSDS Plenary meeting in Autumn 1989, the AOS recommendation will be endorsed and agreed to by all the member agencies.

Quite naturally, during the definition process and the following reviews and detailed definition sessions, the international partners of the Space Station Freedom showed a very active role, including the French and German space agencies (CNES and DLR). The AOS “book” was derived in numerous working meetings in Europe and the United States. Many smaller workshops were required at national as well as international levels. The total manpower effort which went into that document is well beyond 30 manyears. As soon as the recommendation had matured from position papers to a concept, the more formal documents (Red Books) were produced which underwent formal reviews by the participating member agencies.

Clearly this major international effort has advantages and disadvantages, but the pro’s outweighed the con’s. More resources and more varied skills and special expertise were available than would normally be the case within one agency. Different groups of people tend to look at problems from different aspects and frequently find solutions which otherwise would not have been seen. Questioning a certain position called for rethinking of the concept, leading in most cases to an overall better and more acceptable product. The different schools of thinking in the international community furthered a more precise and less ambiguous definition of the recommendations. This was also necessary to some extent, since most of the participating experts did not have English as their mother tongue.

As a disadvantage, one could site the obviously longer turnaround time of position papers, replies, discussions, and necessary meetings. But, since conceptual solutions need a time to mature and cannot be hurried, this disadvantage has often not been a problem. The extremely good spirit of cooperation and understanding of one another’s position has been highly beneficial. Although in general the international process may be potentially slower than a purely national one, the international arena also necessitated strict adherence to agreed timescales and technical meeting schedules, with the end result being that the CCSDS recommendations were derived before the national standards. This is the course of action as it should normally occur; otherwise, all participating agencies would have to follow the agency which had first established a national standard on a topic. Since such standards would seldom reflect the requirements of all agencies, the outcome would likely be multiple non-compatible variations of the initial standard and would represent a costly duplication of effort.

PARTNERS FOR THE SPACE STATION FREEDOM

Presently it is planned that the international partners will contribute the following hardware elements which will be docked to the mainbase or to cooperate with the Space Station Freedom complex:

- Canada: the Mobile Servicing Centre (MSC)

- Europe: the Columbus Attached Laboratory, the Columbus Free Flying Laboratory, and the Columbus Polar Platform

- Japan: the Japan Experiment Module (JEM)

Corresponding Memoranda of Understanding (MOU) have been prepared and signed between the partners and the United States, defining the terms of agreement for cooperation. The elements to be provided by the international partners have specific requirements on the space data systems, which were reflected when preparing the AOS recommendations. In addition to these contributions, there are other missions which are designed to visit the Space Station Freedom and dock for a short duration, such as the European Space Plane Hermes. For a better understanding of the magnitude of the cooperative effort, it is worthwhile to describe some of these elements.

COLUMBUS ATTACHED LABORATORY

This European contribution is a pressurized laboratory module, where astronauts will be permanently available to carry out experiments mainly devoted to the microgravity dependent disciplines: material, fluid, and life sciences. In addition, the possibility exists for the control of payloads exposed to open space from the laboratory. The laboratory would be operated and utilized as an integral part of the Space Station Freedom. Its utilization would be shared by the partners as follows: ESA will retain the use of 51%, while NASA and Canada will use 46% and 3%, respectively.

The laboratory is cylindrically shaped, about 4 m. in diameter and 12.8 m. in length. The launch mass will be

14,700 kg. minimum, with a payload mass of between 3,000-10,000 kg. The payload volume will be 23 cubic meters. it will fill an entire Shuttle cargo bay. The data rate is 100 Mbps downlink and up to 25 Mbps uplink, including systems and payload data.

The launch is currently manifested as Shuttle flight 16 in the Freedom Station assembly sequence. The foreseen launch date is in 1996 and the design life calls for 30 years of operation, to be achieved via maintenance and servicing. The final position will be situated alongside the JEM and in line with one of the two U.S. pressurized modules -- the habitation and the laboratory module. The long axes of the pressurized modules are parallel to the orbital velocity vector in order to minimize microgravity resulting from gravity gradient forces. Once docked, it will remain permanently attached. It will receive basic resources such as power, communications, heat rejection, life support and waste removal, as well as crew habitation and safety from the Space Station Freedom.

The Attached Laboratory’s main function is to enable scientific astronauts to carry out experiments in a shirt sleeve microgravity environment. it must also support the participation of scientists on the ground in these experiments by telescience techniques. The payloads to be flown have not yet been finally negotiated with the user community and only “strawman” payloads have been assumed so far for interface definition studies.

COLUMBUS FREE FLYING LABORATORY

This element is dedicated primarily to the material sciences, fluid sciences, and compatible disciplines, together with technological missions. It will accommodate automatic and remotely controlled payloads which need a long duration, undisturbed microgravity environment. It consists of a pressurized module and an unpressurized resource module which provides the main utilities and services to the laboratory and its payloads.

The total length is about 12 meters with a diameter of about 4.4 meters. The mass at launch is 18,000 kg and 22,000 kg in nominal mission operation. Two solar arrays provide 10 kW of total system power. Communications links with a capacity of about 100 Mbps downlink and 2.5 Mbps uplink will be provided for which the ESA Data Relay System (DRS) is the baseline for communications with the Free Flyer and its payloads.

The Free-Flyer, together with an initial payload of about 2,000 kg., will be launched from the ESA launch facility in the Centre Spatial Guyannais (CSG) on a dedicated Ariane-5 flight, directly to an intermediate circular orbit at, typically, 450 km height and 28.5 degree inclination. After separation, it will deploy automatically and will be activated from the ground for initial verification of on board subsystems and payloads. Upon completion of this verification, a “boomerang” trajectory at an inclination of 28.5 degrees is initiated by the Free-Flyer’s own propulsion system. This trajectory is centered on the Space Station Freedom altitude, to achieve optimum microgravity conditions for the payloads and is flown in a solar inertial attitude. After a nominal free-flying unmanned mission of about 6 months, it either returns to the manned base of Space Station Freedom, or there is a rendezvous with the European Space Plane Hermes for servicing and payload exchange.

The launch of the Columbus Free-Flying Laboratory is nominally scheduled for 1998 and the in-orbit life-time will be up to 30 years.

COLUMBUS POLAR PLATFORM

This is an unmanned large platform permitting, jointly with similar platforms provided by the U.S. and possibly Japan, global observation of Earth for a great number of research application objectives such as weather and storm forecasting, prediction of long-term climatological changes observation of the solid earth for prediction of events such as earthquakes, vegetation yields, observation of the impact of man on the environment such as the ozone layer damage, the greenhouse effect of carbon-dioxide emissions and many others. There are two candidate payloads at the moment, several of the instruments will fly on both the ESA and NASA polar platforms. They must be operational at the same time, in order to make the global, simultaneous, and synergistic coverage of Earth possible. The platform will have a single solar array on the sun side, and must fly with its longest dimension in the direction of the velocity vector, in order to offer an undisturbed view of Earth and space to all of its payload instruments. More than five meters are needed on the preferred anti-sun side for the platform, with a free view across nadir and into cold space for cooling and calibration reference. The platform is designed with two major modules: the utility module with all platform systems, and the payload carrier which provides payload instrument mounting and platform services distribution networks.

The orbit will be sun-synchronous and near circular between 700-850 km altitude with an inclination of 98.8 degrees. It will be launched by Ariane-5 and have a life time of 4 years. The payload mass will be over 2,000 kg.

The prime data transmission system will be the DRS with up to three channels of ISO Mbps each (total capacity of about 450 Mbps). In addition, direct ground transmission in X-band will be used as well. Onboard data recording will be available with a recording and playback rate of up to 10 and 50 Mbps, respectively.

SPACE PLANE HERMES

The primary missions of the European manned delta-wing spaceplane will be servicing, maintenance, and re-supplying of the Columbus Free Flying Laboratory and of the Columbus Attached Laboratory of the Space Station Freedom. The technical features include two main parts:

- the re-usable spaceplane itself and
- the resource module subject to destructive re-entry.

The total length is 15.5 meters with a wing span of 10.5 meters. The dry mass in orbit will be 23,000 kg. The orbit will nominally be at 463 km height and have an inclination angle of 28.5 degrees to permit visits of the Space Station Freedom and the Free-Flyer. The maximum cargo mass to be lifted up to the Free-Flyer will be 3,000 kg. and 1,5000 kg. can be returned to Earth. Hermes will have a crew of three (commander, pilot, and mission engineer). A typical mission will last 12 days. Crew safety will play a major role in the design and development of the Hermes system and a crew escape system is planned, with an ejectable cabin as the reference baseline. The final decision will be taken later when several options have been compared against each other. The servicing capacity will permit module servicing by shirtsleeve crew members and external servicing by robotics and Extra Vehicular Activity (EVA). The data rate will be 3 Mbps down and up to 300 Kbps up with the prime communication system again being the European Data Relay System. The first unmanned launch by Ariane-5 from Kourou is scheduled for 1998 with a first manned launch foreseen in 1999. For landing it will use a runway either in southern Europe or in Kourou.

THE SPACE NETWORK INTEROPERABILITY PANEL

The three space agencies operating or planning data relay systems, namely NASA, NASDA, and ESA, formed an international three-partite Space Network Interoperability Panel (SNIP) in order to coordinate plans and capabilities of the relay systems. The main objective is to achieve a certain degree of interoperability of the envisaged system with obvious advantages for users and operators. The benefits provide operational enhancements and, at the same time, international cooperation will be promoted. Since, as a minimum, compatibility at S-band can be achieved and it is likely that the future systems will also include K-band cross support capabilities, the following can be expected:

- increased capability in total system communication capacity
- offloading of peak workloads to other agencies
- use of other agency system to close the zone of exclusion, not accessible to own relay system
- backup emergency support for manned and unmanned missions
- backup support required due to a malfunction in one agency’s data relay system.

As far as international cooperation is concerned, several specific benefits are also envisaged. If the networks of the three agencies establish space and ground interoperability, the data requirements of the participants can be much more easily and efficiently fulfilled. Joint international missions such as the polar platforms and the Space Station Freedom would have obvious connectivity advantages.

There are clear economic benefits to this international cooperation since spare relay satellites could be stored on ground until they are really needed, rather than launching them as a kind of insurance against the failure of a primary relay satellite. The lifetime of relay networks could be extended by levelling out loads and stretching the spare capacity since the mission models of the three agencies for user support are not completely certain. Finally, the data distribution for international users could be improved and optimized scheduling of international science payloads would permit more efficient data acquisition. Thus, by advocating an international minimum capability for standardization of the operational data relay systems, the world wide data coverage and exchange capability would be considerably enhanced.

VALIDATION OF RECOMMENDATIONS

The need for validation and consistency checks has to be seen as a crucial element of the standardization activity. This activity is carried out on several levels. During the development phase, formal checks and simulations by computers are made. For the AOS recommendations, a special situation exists, since there will be no actual implementation for some time. Consequently, the major agencies involved plan to execute validation campaigns on existing recommendations and implementations of standards for the “conventional” systems on which the AOS recommendations are based. In addition, it is planned to prepare test-beds which can perform end-to-end validation, involving international participants. This will initially be done between NASA and ESA, and will later involve other participants as well.

CONCLUSIONS

International participation in the derivation of the Advanced Orbiting Systems recommendation was clearly necessary since they will apply to the internationally used Space Station Freedom. The participation was also extremely useful since it provided new capabilities and expertise and permitted a better understanding of the requirements of all participating groups.

REFERENCE

CCSDS 701.00-R-3, “Recommendation for Space Data Standards, Advanced Orbiting Systems, Network and Data Links: Architectural Specification,” CCSDS Red Book, Issue-3, June 1989.