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English only

Committee on the Peaceful Uses of Outer Space
Scientific and Technical Subcommittee
Forty-ninth session
Vienna, 6-17 February 2012
Item 14 of the draft provisional agenda*
Long-term sustainability of outer space activities

Long-term sustainability of outer space activities

The present conference room paper contains the full report received by the Secretariat from the Consultative Committee for Space Data Systems. A summary of the report is contained in document A/AC.105/C.1/103/Add.1.

* A/AC.105/C.1/L.310.

Report from the

Consultative Committee for Space Data Systems

Response to the request from the

Committee on the Peaceful Uses of Outer Space; Working Group on the Long-term Sustainability of Outer Space Activities

Prepared by the CCSDS Secretariat
Approved by the CCSDS Member Agencies
November 4, 2011

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I. Introduction

A. The purpose of this report

This short informal report is intended to respond to the request from the United Nations Office of Outer Space Affairs (OOSA). The response was solicited to support the work of the Committee on the Peaceful Uses of Outer Space, the Working Group on the Long-term Sustainability of Outer Space Activities. In the solicitation from the OOSA, it explains that "intergovernmental bodies and organizations, and relevant international organizations specified in the terms of reference, are invited to provide information on their experience and practices that might relate to the long-term sustainability of outer space activities, and on their experiences and practices in the conduct of sustainable space activities." The solicitation is included as Attachment A.

B. The purpose of the CCSDS

The Consultative Committee for Space Data Systems (CCSDS) was formed in 1982 by the major space agencies of the world to provide a forum for discussion of common problems in the development and operation of space data systems. It is currently composed of eleven member agencies, twenty-eight observer agencies, and over 140 industrial associates.

Since its establishment, it has been actively developing Recommendations for data- and information-systems standards to promote interoperability and cross support among cooperating space agencies, to enable multi-agency spaceflight collaboration (both planned and contingency) and new capabilities for future missions. Additionally, CCSDS standardization reduces the cost burden of spaceflight missions by allowing cost sharing between agencies and cost-effective commercialization.

The charter of the CCSDS is included as Attachment B.

C. CCSDS Membership

The currently active Member and Observer Agencies of the CCSDS are:

<u>Member Agencies</u>

– Agenzia Spaziale Italiana (ASI)/Italy.
– Canadian Space Agency (CSA)/Canada.
– Centre National d'Etudes Spatiales (CNES)/France.
– China National Space Administration (CNSA)/People's Republic of China.
– Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR)/Germany.
– European Space Agency (ESA)/Europe.
– Instituto Nacional de Pesquisas Espaciais (INPE)/Brazil.
– Japan Aerospace Exploration Agency (JAXA)/Japan.
– National Aeronautics and Space Administration (NASA)/USA.
– Federal Space Agency (FSA)/Russian Federation.
– United Kingdom Space Agency/United Kingdom.

<u>Observer Agencies</u>

– Austrian Space Agency (ASA)/Austria.
– Belgian Federal Science Policy Office (BFSPO)/Belgium.
– Central Research Institute of Machine Building (TsNIIMash)/Russian Federation.
– China Satellite Launch and Tracking Control General, Beijing Institute of Tracking and Telecommunications Technology (CLTC/BITTT)/China.
– Chinese Academy of Sciences (CAS)/China.

- Chinese Academy of Space Technology (CAST)/China.
- Commonwealth Scientific and Industrial Research Organization (CSIRO)/Australia.
- CSIR Satellite Applications Centre (CSIR)/Republic of South Africa.
- Danish National Space Center (DNSC)/Denmark.
- Departamento de Ciência e Tecnologia Aeroespacial (DCTA)/Brazil.
- European Organization for the Exploitation of Meteorological Satellites (EUMETSAT)/Europe.
- European Telecommunications Satellite Organization (EUTELSAT)/Europe.
- Geo-Informatics and Space Technology Development Agency (GISTDA)/Thailand.
- Hellenic National Space Committee (HNSC)/Greece.
- Indian Space Research Organization (ISRO)/India.
- Institute of Space Research (IKI)/Russian Federation.
- KFKI Research Institute for Particle & Nuclear Physics (KFKI)/Hungary.
- Korea Aerospace Research Institute (KARI)/Korea.
- Ministry of Communications (MOC)/Israel.
- National Institute of Information and Communications Technology (NICT)/Japan.
- National Oceanic and Atmospheric Administration (NOAA)/USA.
- National Space Agency of the Republic of Kazakhstan (NSARK)/Kazakhstan.
- National Space Organization (NSPO)/Chinese Taipei.
- Naval Center for Space Technology (NCST)/USA.
- Scientific and Technological Research Council of Turkey (TUBITAK)/Turkey.
- Space and Upper Atmosphere Research Commission (SUPARCO)/Pakistan.
- Swedish Space Corporation (SSC)/Sweden.
- United States Geological Survey (USGS)/USA.

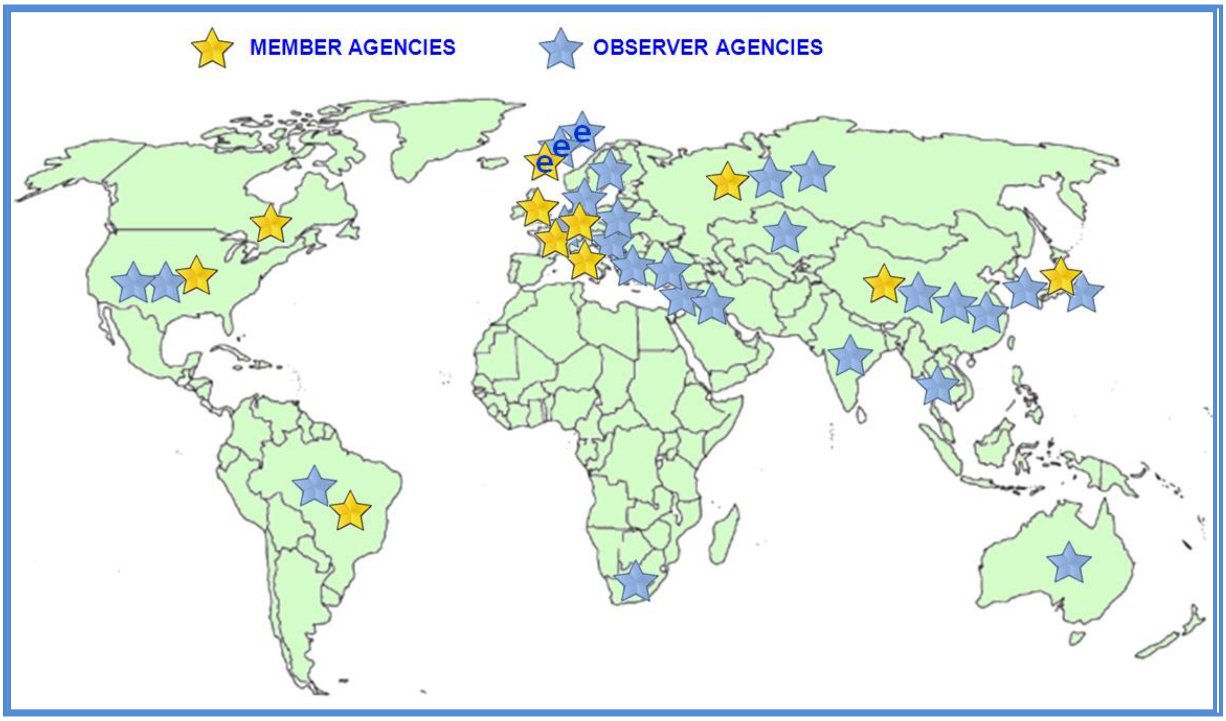

Figure 1: Global distribution of CCSDS participating agencies, by nation. Note "e" indicates European consortiums.

II. Preface

A. Overall CCSDS Objectives; what we do.

The ability of nations, agencies and companies to have spacecraft and ground facilities with compatible communications and data systems is the first and foremost lynchpin of sustainability. Enabling joint missions, lower costs and more efficient missions with greater return is clearly a major step towards long-term sustainability.

The CCSDS contributes to the long-term sustainability of Outer Space Activities by virtue of the technical standards documents which it produces. These standards, when adopted by spaceflight programs and projects around the world, enable, in summary:

- International cooperation in spaceflight activities
- Efficient development and operations between the elements of a large organization (such as the centers or contractors supporting an agency)
- Lower cost through greater commercialization of components
- Efficient operations, such as rapid contingency operations when one agency must unexpectedly provide communications for another agency's spacecraft.

All of these benefits contribute directly to improvements in the sustainability of outer space activities. The primary objective, however, of the CCSDS member agencies is the first item, the ability of the agencies of CCSDS to join together in internationally cooperative spaceflight missions. This means that CCSDS standards will first and foremost provide capabilities that promote regional and interregional cooperation, one of the central objectives of COPUOS.

Of all of the potential "touch points" where spaceflight systems interface in cooperative missions, (mechanical systems, fluid systems, data systems, etc.) the single greatest benefit to cooperation comes from interoperability between communications and data systems, both flight and ground. This has been widely recognized by the Space Agencies of the world for a long time, and this was the reason for the formation of CCSDS. While CCSDS initially addressed only basic packet communications, the technology goals have expanded to include the entire scope of the ISO communications stack from the physical layer to the application layer, space-to-space, space-to-ground and ground-to-ground. And while CCSDS is Agency-led, it has strong participation from commercial organizations. Currently there are 142 Commercial Associates participating in CCSDS.

Unlike many standards organizations, CCSDS distributes its standards free of charge.

B. Why this is important to COPUOS and its Working Groups.

The Report of the Committee on the Peaceful Uses of Outer Space, Fifty-fourth session (1-10 June 2011) stressed the need to support regional and interregional cooperation in the field of space activities. Active promotion by COPUOS of the adoption of interoperability-enabling standards, including CCSDS standards, would certainly cause progress towards that objective. Further, greater participation by technology experts in development of the next generation of CCSDS standards would accomplish that to an even greater extent in the future, and pave the way for a cooperative space infrastructure that will benefit the spaceflight missions of all the agencies of the world. CCSDS would welcome support from COPUOS to recruit strong technical participation by additional agencies

Most of the benefits from CCSDS standards only indirectly support the UN's Millennium Development Goals. For example, Environmental Stability is supported by Earth-sensing missions that use CCSDS standards for communications and data exchange. However, the Millennium Development Goal of Global Partnership includes Target 8.F: *In cooperation with the private sector, make available benefits of new technologies, especially information and communications.* This is directly supported by ongoing work in CCSDS and the Internet Research Task Force (IRTF) addressing the development of Delay/Disruption Tolerant Networking (DTN) which supports both in-space and terrestrial internetworking. DTN provides network layer communications protocols that are specially adapted to work in distressed or disrupted communications networks, as are often found in developing regions. The CCSDS has been on the forefront of development of DTN technology and standards, and it has become a "spinoff" that was picked up by the IRTF for the terrestrial internet. Of course, this will benefit the terrestrial internet in both developed and developing regions. But a case can be made that the developing regions will probably see the most benefit, because of their typically disrupted network environment.

III. The scope of ongoing CCSDS work

Figure 2 illustrates the overall scope of the CCSDS architecture. The names listed under each technical area are the names of active or forming working groups.

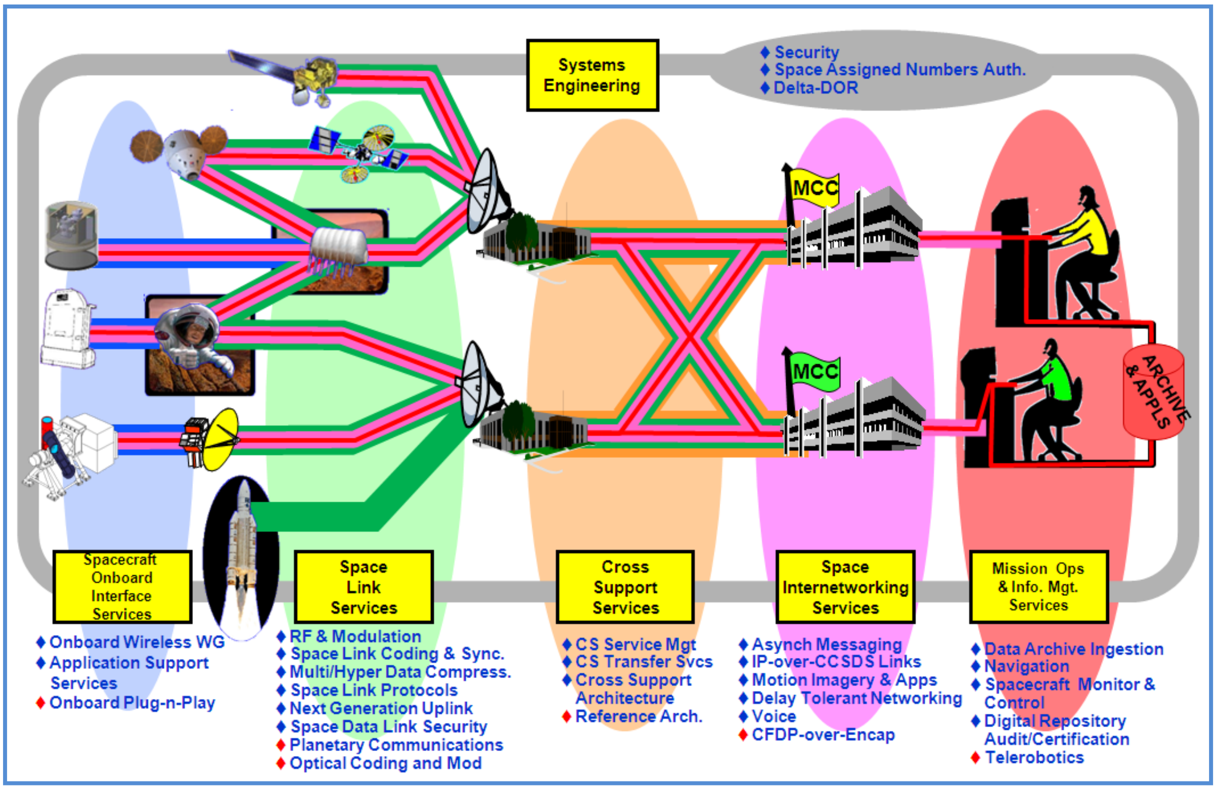

Figure 2: CCSDS Architectural Overview. The yellow boxes are the technical areas.

While this brief report does not allow for the full expansion of the technical description of the technical areas being addressed within CCSDS, the names of the working groups should illustrate for the reader the broad scope, the technical depth, and the critical advancements in interoperability that the CCSDS technical teams are making.

Further details are available online at www.ccsds.org. By entering the "Collaborative Work Environment", one can view public descriptions of the ongoing work in greater technical depth.

CCSDS produces voluntary consensus standards. The final products are actually called "Recommended Standards" and "Recommended Practices" in order to make it clear that they do not carry the weight of treaty or law. CCSDS agencies are not required to comply with these "Recommendations", but by agreement within the committee, they agree not to produce competing standards. The success of CCSDS stems from the technical quality of the standards and the CCSDS processes that insure that they are implementable for interoperability. CCSDS standards have been adopted by 533 missions (as of this writing).

One technical area warrants special attention, namely, in the Space Internetworking Services Area, the work on Delay/Disruption Tolerant Networking. A consortium of Space Agencies known as the Interagency Operations Advisory Group (IOAG) has defined a vision of future Space Internetworking, and framed it as the Solar System Internet (SSI). The SSI brings to spaceflight programs an adaptation of the terrestrial approach to internet which can deal with the unique environment of spaceflight (as terrestrial Internet Protocols cannot). Because the SSI uses Delay/Disruption Tolerant Networking (DTN), the IOAG has asked CCSDS to take the next step to realize the SSI; development of the SSI architecture and the supporting DTN protocols that will enable collaborating nations to support each other with this networked infrastructure. This follows the same paradigm of automated routing that the terrestrial internet uses, wherein many organizations support other organizations by providing packet and message routing through their systems. However, this internet is adapted to the disrupted communications and long lightspeed delays that are inherent in the Outer Space environment. Clearly, such capability will support the goals of COPUOS by enabling regional and interregional cooperation in space activities, a correlation to similar benefits that are realized on Earth because of the terrestrial internet.

IV. Addressing the major points of the Scope of the Terms of Reference (ToR) of the Working Group on the Sustainability of Outer Space Activities (Annex II, Section IV)

The major points of the Scope of the ToR, as provided by the UN OOSA, are addressed below. The major points are transcribed in bold, and the CCSDS responses are the numbered items below them.

(a) Sustainable space utilization supporting sustainable development on Earth:

1. Compliance with CCSDS standards allow lower cost exploitation of space by developed countries because of joint collaboration and mission cost-sharing. Lower cost translates to more sustainability.

2. Compliance with CCSDS standards allows developing countries to enter into the exploitation of space with systems compatible with those of developed countries, and the sustainability benefits such as lower costs, joint mission capability, and overall equitable access to communications functions like the developed countries.

(b) Space debris:

1. The CCSDS Navigation WG provides a discipline-oriented forum for detailed discussions and development of technical flight dynamics standards (e.g., representation of the

trajectories of orbiting objects, representation of spacecraft attitudes, exchange of tracking data, design of maneuvers, predicted orbital events, etc.). In the area of space debris, these discussions and development are heavily focused on the development of a standard that will be used to communicate information about a conjunction of objects in space once it has been predicted. Space conjunctions represent potential collisions that can exacerbate conditions in the space debris environment. The CCSDS Navigation Working Group combines the resources of the CCSDS member space agencies, the United States Air Force (USAF) Joint Space Operations Center (JSpOC), the United States Strategic Command (USSTRATCOM), and the ISO Technical Committee 20 (Aircraft and Space Vehicles) Subcommittee 14 (Space Systems and Operations) Working Group 3 (Operations and Ground Support) on the development of a standard called the "Conjunction Data Message" (CDM). The CDM standard establishes a common format that may be utilized to communicate information about a predicted conjunction to satellite owners/operators. An individual conjunction data message will contain information about a single conjunction between two space objects, each of which could be an active satellite, passive satellite, rocket body, and/or debris. Conjunction information includes data such as the identities of the objects, predicted time of closest approach, miss distance, relative position and velocity at closest approach, collision probability, and covariance information that helps to establish the uncertainty of the predicted conjunction. This information may be used by satellite owner/operators to evaluate the risk of a collision and plan maneuvers if they are deemed necessary. The CDM draft standard has made rapid progress since its inception in Fall 2010, and should soon be available for public review and comment (currently planned for mid-2012).

2. Use of the CCSDS CDM standard will promote long-term sustainability of the space environment by contributing to efforts to prevent collisions before they happen. Several organizations have already indicated an interest in using their space surveillance network facilities to produce Conjunction Data Messages.

(c) Space weather:

1. Traditional CCSDS protocols provide capabilities and benefits as described earlier to solar research spaceflight missions that improve space weather prediction capabilities.

2. New advanced space internetworking protocols, which are in development in CCSDS working groups, has the potential of providing “sensorweb” capabilities to automate the reaction of multiple orbital research spacecraft for faster responses to space weather events.

(d) Space operations:

1. Compliance with CCSDS standards can enable short –notice contingency support. Missions in trouble can rapidly configure unplanned communications sessions with other agencies’ communications assets. There have been two incidents where compliance with standards allowed one agency to “rescue” another agency’s mission (The UK’s STRV mission and ESA’s XMM-Newton mission).

2. Operations efficiencies are achieved when standards are used because operations and maintenance teams become familiar with the characteristics of the protocols, and those protocols and the associated experience and training carries over to new missions. This enhances operations capabilities and ground crew performance with lower cost, hence contributing further to sustainable space missions.

(e) Tools to support collaborative space situational awareness

1. As described in (b) above, the CCSDS Navigation Working Group has standardized several navigation message formats, intended to be exchanged between Mission Control Centers. When these messages are exchanged between control centers, they increase situational awareness by spacecraft flight control teams (for all missions) as well as by onboard crews (for human spaceflight missions).

2. While several message formats have been completed and are in operational use, the WG is now focusing on the Conjunction Data Message, a communications capability that totally focuses on collision avoidance (as mentioned above).

3. Enhanced communications between Mission Control teams using other CCSDS ground-to-ground standards (Such as service interfaces in the Mission Operations standards from the Spacecraft Monitor and Control WG) will naturally increase the level of space situational awareness for parties on both sides of the service interfaces. These standards will allow the exchange of realtime command and telemetry, planning data, and eventually other functions such as simulations and training. The experience from the ISS program has shown that large collaborative programs have a need to exchange an extensive variety of specialized data (command history, antenna management, payload health and status, etc.). For the ISS program, these data formats were the “proprietary” internal formats of the agencies that “owned” the data, and the result was that either expensive format conversions (multiple conversions per data type per agency) were required, or else the operations concept had to change to deal with the inability to exchange the data. CCSDS efforts, if successful, will prevent this obstacle for future programs. The ability to more freely and efficiently exchange these complex data types will result in increased situational awareness among collaborating control centers.

(f) Regulatory regimes

1. CCSDS teams perform technology development and standardization. This is conducive to the transfer of approved technologies from one agency to another as part of the standard development process. It also effectively provides technology transfer to agencies who use the standards, because they benefit from the technology development that was part-and-parcel of the development of the technical standard.

2. For the upcoming age of the Solar System Internet (SSI), a loosely-coupled volunteer-oriented governance framework will be needed by the collaborating space agencies, to enable cooperative internet-style automated routing across multi-agency assets, as is done on the terrestrial internet. The same coordination functions will be needed (address assignments, etc.) as are provided by the Internet Engineering Task Force (IETF) for the terrestrial internet. Of course, with the initially low population of SSI-enabled spacecraft, a full governance model will not be needed for some time.

(g) Guidance for actors in the space arena

1. Technical standards development and compliance is an asset that all agencies need and many project/program managers shun. The COPUOS should actively promote standards for specific technology touch-points where they most enable cooperative missions. As cited at the beginning of this report, of all the potential technology areas employed for

spaceflight, interoperability in the area of communications and data exchange provides the greatest benefit to collaborating entities. COPUOS should promote that guidance to actors in the space arena, as mankind begins in earnest to explore the Solar System.

V. The Current Environment

As noted earlier, there are two distinct phases of the standard life-cycle:

(1) Development of the standards, and;

(2) Adoption of the standards by spaceflight missions.

Each phase has unique challenges.

A. The development phase.

CCSDS agencies who contribute to the development of the standards are seeing declining budgets applied to standards development, because as the economy contracts, agencies focus on their core mission capabilities, and mere "standards work" takes a back seat in funding priorities. Much of the work (systems engineering, interface negotiations, etc.) required for those missions could done in the standards community with "more eyes on the problem", however mission project managers are risk-averse, and prefer to have those tasks done in their own controlled environment rather than in the international standards development environment. Keeping a standards development focus requires top-down management sanction and adequate resources to keep the work on track.

Right now, CCSDS standards development teams (and likely other standards organizations) are in a fragile state. Declining budgets have caused the closure of several standards development working efforts over the last few years. While CCSDS requires prototyping of new standards by independent organizations to verify interoperability before publication, some CCSDS working groups are having difficulty finding resources for the required prototyping. It is difficult for CCSDS Agency representatives to promote from within their agencies. Advocation of standards development efforts by external organizations may have a positive effect. This could promote a heightened awareness of the benefits of standards development for cooperative spaceflight endeavors.

B. The adoption phase.

The same risk-averse nature of mission project managers contributes to resistance to adoption of new standards. The standards community refers to the phase after a new technology standard has been released and before it is successfully adopted by spaceflight mission projects as the "valley of death". If a new technology standard makes it to the adoption phase for several missions, it will generally be successfully adopted by project teams that perceive a lowering of risk. If it does not make it through that phase, it will likely never succeed and proprietary or local agency approaches will prevail.

Again, heightening awareness of the benefits of standards will help, and advocates that are external to the standards community are in the best position to place top-down emphasis on standards among the spaceflight agencies of the world.

C. *The conflict between standardization and innovation.*

Concern has been raised, even by many in the CCSDS community, that standardization can stifle innovation. As new technology arrives on the scene, the existence of a very powerful, widely adopted standard using the older technology can make it difficult for the new technology to gain acceptance. This concern has also been cited as the reason that some missions, agencies or communities have resisted adoption of standards.

The CCSDS community believes that we can strike a balance that accepts new innovative technologies into the standardization community, choreographing transitions that are acceptable (although not always painless) for the participating agencies. Evidence of this is in the ongoing efforts right now for standardizing new technologies in CCSDS at the Link Layer (Serially Concatenated Convolutional Code, Low Density Parity Check Code), at the Network Layer (Delay Tolerant Networking) and at the Application Layer (Service Oriented Architectures, Asynchronous Message Service).

The CCSDS has adopted a philosophy of "***Adopt, adapt, develop***".

- First, if at all possible, ***adopt*** an existing standard, such as a commercial standard.
- Second, if necessary when an existing standard does not work for the space environment, ***adapt*** it with minimal modifications.
- Third, as a last resort, when existing standards do not exist or fail in the space environment, only then do we ***develop*** a new standard.

As new communications and data technologies emerge in the marketplace, this approach allows CCSDS to infuse innovation into the tool set of standards used by our agencies' spaceflight missions.

VI. Recommendations

CCSDS recommends that COPUOS and its working groups should broadly advocate the adoption of interoperability-enabling standards by the spaceflight missions of the developed and developing nations of the world.

While the CCSDS agencies are engaged in communications and data system standards because we believe it is the most critical area for enabling interoperability, we recognize that there are other technology areas that also impact interoperability. COPUOS and its working groups should promote the adoption of such standards, including, but not limited to, CCSDS standards.

CCSDS recommends that COPUOS and its working groups should encourage broader participation in the development of new standards that enable interoperability, but only by those organizations that have technical skills in the technology area.

CCSDS welcomes participation in standards development by any nation or organization in the world that endeavors to promote cooperative spaceflight missions. However, track records indicate that participants must have genuine technical skills in the technology area, otherwise they hamper the already difficult process of internationally interoperable standards development.

Any organization that can contribute resources and technical skills to these difficult but rewarding tasks is invited to first browse the CCSDS website and CWE at www.ccsds.org to familiarize themselves with the current technology efforts, and then contact either the working group chairs of the area that they are interested in (contact info on the website), or the CCSDS Secretariat at Secretariat@mailman.ccsds.org.

VII. Summary

The CCSDS welcomes the interest of COPUOS and the Working Group for the Long-term Sustainability of Outer Space Activities in the promotion of standards that enable interoperability between spaceflight missions (the primary CCSDS objective), cost efficiencies, operational flexibility and the improved ability for developing regions to cooperate in spaceflight activity (a COPUOS objective).

The CCSDS recommendations above are offered in the spirit of promoting the common interests of CCSDS and the COPUOS community. We sincerely hope that they are helpful in raising the awareness of this work in the COPUOS community, and that we have provided the appropriate background information to support the recommendations.

In the area of communications and data standards, if COPUOS or its working group have a need for any further information or support from CCSDS, please notify the Secretariat and if agency resources permit we will be pleased to support.

Attachment A: Solicitation from COPUOS

UNITED NATIONS
Office for Outer Space Affairs

Reference: OOSA/2011/14
CU 2011/148

6 September 2011

Dear Madam/Sir,

I have the honour to refer to the recommendations of the Committee on the Peaceful Uses of Outer Space at its fifty-fourth session (*Official Records of the General Assembly, Sixty-sixth Session, Supplement No. 20* (A/66/20) (to be issued), relating to the work of the Working Group on the Long-term Sustainability of Outer Space Activities at the forty-ninth session of the Scientific and Technical Subcommittee, to be held from 6 to 17 February 2012.

In accordance with the provisions of the terms of reference and methods of work of the Working Group on the Long-term Sustainability of Outer Space Activities, adopted by the Committee at its fifty-fourth session (A/66/20, annex II, para 16 and 17) United Nations entities, intergovernmental bodies and organizations, and relevant international organizations specified in the terms of reference, are invited to provide information on their experience and practices that might relate to the long-term sustainability of outer space activities, and on their experiences and practices in the conduct of sustainable space activities.

Annex II to document A/66/20 is attached as an advance copy for your reference.

I would be grateful to your organization if it could submit its contributions to the above-mentioned requested reports and information, for translation into all the official languages of the United Nations for the Scientific and Technical Subcommittee at its forty-ninth session, to the Office for Outer Space Affairs, United Nations Office at Vienna, P.O. Box 500, 1400 Vienna, Austria, before **4 November 2011**. In addition to a hard copy of the submission, an electronic version (Word document) should also be sent to the Office or via e-mail (submissions@unoosa.org).

I look forward to hearing a positive response from you at your earliest convenience.

Yours sincerely,

Niklas Hedman
Secretary of the Scientific and Technical Subcommittee

Chairman and General Secretary
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Attachment B: The CCSDS Charter

Preamble

The major space agencies of the world recognize that there are benefits in using standard techniques for handling space data and that, by cooperatively developing these techniques, future data system interoperability will be enhanced. In order to assure that work towards standardization of space-related information technologies provides the maximum benefit for the interested agencies, both individually and collectively, an international Consultative Committee for Space Data Systems (CCSDS) is established as a forum for international cooperation in the development of data handling techniques supporting space research, including space science and applications.

Purposes

The purposes of the CCSDS are as follows:

1. to provide a forum whereby interested agencies may exchange technical information relative to the development or application of standards for space-related information technologies;
2. to identify those common elements of space data systems which, if implemented in a standardized way, will result in significant enhancements in the operation of future cooperative space missions, or in the sharing of mission products;
3. to develop through consensus appropriate Recommendations that will guide the development of agency infrastructure so that interoperability is maximized;
4. to facilitate and promote the use of software and hardware developed under the CCSDS program by all participating agencies;
5. to promote the application of the Recommendations within the space mission community; and
6. to maintain cognizance of other international standardization activities that may have direct impact on the design or operation of space mission data systems.

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1 The CCSDS Charter was originally approved in 1982. It was updated in May 1999 and again in September 2004.