

# MINUTES – IOAG-11

Rev 12-20-07

## A. MONDAY, 18 JUNE 2007

Following a tour of ESA’s Cebreros station and lunch, Chairman, Dr. Manfred Warhaut, convened IOAG-11 at the European Space Agency’s (ESA’s) Cebreros, Spain complex. He introduced his colleague Mr. Klaus-Juergen Schulz who will become the Head of the ESA delegation at future meetings and will serve as Chairman for this one as well. The following persons attended some or all of the three-day meetings:

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### 1.0 MEETING ORGANIZATION

Dr. Warhaut explained the logistics of the meeting. The Chairman then asked if there were any changes to the Agenda. There being none, the Agenda was approved. A copy of the Agenda can be found in Annex 1. He then asked each delegate to introduce themselves.

### 2.0 ACTION ITEM REVIEW

Next followed a brief review of the Action Items assigned at IOAG-10.

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## IOAG-10 - Action Item Summary

Action Item	Action On	Disposition
10-1	Secretariat / Agencies	Secretariat: Sent list of standards to agencies on 10-18-06. Agencies: No responses received.
10-2	Secretariat / SFCG	Secretariat: Letter request SFCG advice sent on 10-18-06. SFCG: Response to be provided at this meeting.
10-3	W. Tai	Identified core services. CNES, JAXA, NASA provided inputs.
10-4	M. Warhaut	Architecture Review Group formed at ESOC. Action closed.
10-5	All Agencies	Tai: JAXA suggested ALOS for Service Management operations demo.
10-6	K. Narita	Latest version of framework on web site. Action item closed.
10-7	All Agencies	Proposed NASA Architecture to be discussed at this meeting.
10-8	All Agencies	Updates to tracking assets received. List placed on web site in 12-06.
10-9	M. Pilgram	Input received at this meeting. Action closed.
10-10	J-M Soula	Prepared report, received comments, results provided to CMC in 1-07.
10-11	All Agencies	No updates to IOAG Roadmap received.
10-12	All Agencies	Should only be one mission model for IOAG and SFCG.

Jean-Marc Soula raised a question regarding the Infusion Table and its relationship to the Roadmap. He explained that it was confusing because it is incomplete and should be removed from the web site. While the table might be of use to the IOAG and perhaps the CCSDS, persons on the outside would only become confused, because there is no indication as to the degree of implementation of the several CCSDS Recommended Standards. Following a brief discussion it was decided to return to the matter at a later time.

### 3.0 TERMS OF REFERENCE

Last update was in 2004 and there have been significant changes in which the IOAG operates since that time. A draft for the modified Terms of Reference, reflecting recommendations by several Agencies is currently on the web site. The two options are to consider the revisions now or alternatively, to ask everyone to read the draft on the web site and to discuss the matter later. The Chairman opted for the latter and the item was deferred.

### 4.0 AGENCY STATUS CHANGES SINCE IOAG-10

In this session, Agencies are invited to review organizational changes in their agency since the last meeting.

#### 4.1 ASI

Ms. Bruca stated that there have been no significant organizational changes since IOAG-10, except that there is a new president. However, she anticipates that there may be a new organization in the future.

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### 4.2 CNES

Mr. Soula reported that there are no major changes at CNES Headquarters. However Mr. Lafuma now heads the Procurement and Legal Affairs Office. With regard to the Centers, Mr. Pircher is replacing Mr. Moskwa as Director of the Toulouse Space Center and at Guiana, Mr. Barre is replacing Mr. Marce.

At the Toulouse Space Center, Mr. Goudy is now the Assistant Director for Orbital Projects and Ms. Campan has transferred from Development to Operations where she is Assistant Director. Mr. Soula went on to describe some of the CNES missions in the areas of space science, security and defense, and telecommunications. CNES has also developed an Automated Transfer Vehicle control center.

A world map with the CNES station locations was provided. Mr. Soula noted that CNES relies upon CCSDS standards and will conform to RF and Modulation, Coding and Synchronization, Telemetry and Telecommand, SLE, and others. Mr. Soula pointed out that strong, unambiguous positions of the IOAG help to convince projects to follow certain standards.

He cautioned that while Moon and Mars missions may be the focus of this meeting, we should not forget the other missions to L1, L2, Earth orbiters, and manned missions. Mr. Soula concluded that the IOAG should remember that it is an advisory group intended to provide management with high-level information. We have limited resources and should not try to produce detailed requirements because it may cause confusion with other organizations such as the CCSDS.

Mr. Struba asked how the IOAG could fulfill the Agencies' desire, expressed at the two Lunar-Mars Technical meetings, that it become responsible for ensuring Moon-Mars mission interoperability, if it could not establish requirements. Mr. Soula replied that the Agencies represented here also contribute the correct personnel to the SFCG and the CCSDS. It is the IOAG's job to see that these other organizations have the necessary resources, because here we do not have the resources to do this work.

Mr. Warhaut concurred that it would be impractical to duplicate the work of the CCSDS, SFCG, and other experts; however the IOAG should represent at a very high level the needs of the user community and we must make sure that what we do fits together.

### 4.3 DLR

Dr. Pilgram described DLR's facilities noting that a new Institute for Space Systems had been opened in Bremen in January 2007. Among other things, the Institute will be responsible for developing a concept for a German Moon mission. He went on to describe the DLR governing bodies and then focused on the German Space Operations Center (GSOC). Persons in the Center are the same as at the last meeting.

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Dr. Pilgram went on to describe several different types of missions being supported by GSOC. In response to Mr. Struba's question about the frequency bands used for military Earth Observation missions, Dr. Pilgram replied that the satellites will operate in the 8025-8400 MHz band. GSOC will also provide ground control center for Europe's Galileo mission.

DLR is planning for the operation of a German high-resolution lunar mapping mission that will launch in 2012. It will be a polar-orbiting spacecraft returning some 500 GB per day over a four-year mission lifetime. Mr. Brandel inquired about frequency band for the mission and its data rate. Dr. Pilgram replied that those questions are under discussion now. In response to Mr. Costrell's question about the approval process, DLR replied that it should be decided this year.

Dr. Pilgram described the DLR ground stations and noted that they are interconnected using SLE. For some missions that are not utilizing a CCSDS Packet Telemetry format, it is necessary to packetize the data stream before the SLE transfer service.

### 4.4 ESA

Klaus-Juergen Schulz gave the ESA presentation. He began with a description of the ESA tracking network, Estrack, its evolution, and a world map showing Earth station locations. Mr. Schulz provided the characteristics of several of these stations. He noted that ESA has used facilities of US Space Network, which are also utilized by NASA.

Villafranca 1 (15 M), used for the Cluster mission has been mothballed, but Villafranca-2 is being retained for pick-up purposes. Santa Maria, a small island belonging to Portugal has a new ESA 5.5 M, S-band uplink, S-band downlink station to be used for Ariane 5 launcher tracking. It will also support the ATV launch. The station will be operational in the fall of 2007.

After the Cluster-2 mission ends in 2010, ESA would like to keep the Maspalomas station for X-band Launch and Early Orbit (LEOP) support. In 2012, after the Integral mission, the station may be transferred to commercial interests. After XMM in 2012, ESA will use Kourou as an X-band LEOP station. ESA would like to establish a third deep-space site in either Chile or Argentina in time for the launch of ExoMars in 2012. A decision will be made in December 2007 regarding this new facility. ESA is now SLE Blue Book and Red Book compatible at all stations. ESA is in the process of removing a substantial amount of old equipment from their stations that they used during the past decade. ESA's X-band LEOP network (Kourou, Maspalomas, and Perth) will be completed in 2008. All but the Maspalomas stations and acquisition aids are complete at this time.

Mr. Schulz continued by describing each of the ESTRAC stations. ESA is experiencing some difficulty in obtaining the reliability on their deep-space X-band uplinks that they have experienced with their 15 M stations. Simultaneously, they are developing a European 30 KW X-band power amplifier.

Performance has been enhanced in the Kourou SX / SX station with the addition of a cryogenically cooled LNA. A Hydrogen MASER has been installed to improve the frequency and timing system. A new X-band acquisition aid is planned for installation in 2008.

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Maspalomas has a new SX / SX feed and a full X-band uplink X-band downlink installation is planned for January 2008. X-band electronics will be installed during the first quarter of 2008. Migration to the SLE services interface is complete.

The X / X-band system at New Norcia, the first ESA deep space station, has been improved. Migration of deep space mission to SLE is complete. Installation of an X-band acquisition aid is planned for 2008. Due to 2 GHz spectrum problems occasioned by the 3<sup>rd</sup> Generation Mobil companies, the Perth 15 M antenna will be moved to New Norcia and become New Norcia-2. Currently the move is planned for the 2010-2012 time period. The Australian Communications Authority has established 2018 as the point where 2 GHz operations at Perth must cease.

Redu has been upgraded with new with ESA's latest generation of frequency converters. It is the last station to receive SLE equipment, which will be installed during the fourth quarter of 2007. Redu-2 will be used to supply the ARTEMIS feeder link to support ATV.

Santa Maria is a new, small (5.5 M) S-band terminal used for Ariane-5, which will become operational at the end of 2007. ESA and the Portuguese authorities are considering use of the station as an X-band Earth Observation receiving terminal.

Villafranca-2 has had old equipment removed and new TMTCS equipment installed. Operations have been migrated to the SLE Services Interface.

This concluded Dr. Schultz's report.

### 4.5 ISRO

S.K. Shivakumar, Director of ISTRAC, gave the ISRO presentation. He began with an explanation of ISRO's position in the Indian Government. ISRO is under the Department of Space which reports directly to the Prime Minister.

Currently, India has several remote sensing satellites studying Earth and ocean resources. HAMSAT provides amateur radio operators with a satellite communication path. Additionally, there are geostationary satellites for telecommunications, TV broadcasting, weather forecasting, and search and rescue applications.

For the future, radar imaging and additional remote sensing satellites are planned. There will be a continuation of the GEOSAT series utilizing high power and high mass spacecraft. Science missions include Chandrayaan-2 and ASTROSA, an ultraviolet and high X-Ray mission. India has a cooperative program with French scientists called MEGA-TROPIQUES.

Mr. Shivakumar described TT&C ground stations for remote sensing, polar and geosynchronous mission launches. He provided a map of India showing station locations. There are also TT&C stations outside of India at Svalbard, Tromso, as well as in other locations. All ground stations are operated from ISRO's Network Control Center (NCC) in Bangalore. Since 1999, ISRO has been undertaking a modernization program for their Earth stations.

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Each ground station is operated from a single console in the NCC. Cortex receivers are a central part of ISRO's state-of-the-art Earth stations. CCSDS Standards are followed to ensure international compatibility. Communications with Earth stations are through INSAT if the stations lie within India and through INTELSAT if they are outside of India.

Mr. Shivakumar then described the 18M and 32M stations for Chandrayaan-1 and for missions beyond the Moon. Both are capable of providing 2 GHz uplinks at 2 and 20 KW respectively. Both can capture 2 and 8 GHz downlinks with G/Ts of 29.5 and 51 dB/K respectively. He then provided a summary of ISRO's tracking assets. Mr. Shivakumar concluded his presentation with a summary of non-ISRO missions supported by ISTRAC.

Mr. Shivakumar responded to several questions. ISRO is planning Chandrayaan 2, but that mission is in advanced planning and is not in his area at this time. He explained that some of the tracking assets listed in the tables were owned by other organizations, but that ISTRAC uses them frequently. Not all ISTRAC stations are SLE compatible; however DSN-32 in Bangalore and others may be similarly equipped at a later date. Dr. Warhant suggested that it would be of benefit to IOAG members to have a list of ISTRAC stations that are owned by ISRO and which are, or will be made, fully SLE compatible. The new 32M antenna is scheduled to begin testing in August 2008.

### 4.6 JAXA

Dr. Nakahara stated that there have been no organizational changes since IOAG-10. He noted that WTS-VIII was launched in December 2006 and that SELENE and WINDS are planned for launches later in the year.

With regard to tracking assets, 2 of the 6 "old" Ground Network (GN) antennas have been refurbished and transmitters, receivers, and baseband equipment are being replaced with the same types used in the "new" GN. Refurbishment of the remaining 4 "old" GN stations is "on hold" at this time. He provided a World Map showing the locations of JAXA's tracking assets.

He concluded by describing the current JAXA Mission Model. The Model subdivided JAXA missions into categories such as: Communications and Navigation, Earth Observation, Science, Moon and Planetary, LEOP, and Cross-Support missions.

### 4.7 NASA

James Costrell presented the NASA information. Mr. Costrell began with a description of NASA's organizational structure. Focusing on the Space Operation Mission Directorate (SOMD) he noted that Bob Spearing had retired and that the Agency was in the process of selecting his replacement. Within SOMD, Mr. Costrell is the Deputy Director of the Space Communications and Navigation Office (SCaN), which contains NISN, Network Services, Systems Planning, and Spectrum Management.

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Turning to the three networks within SCaN, Mr. Costrell described the antenna compliment in the Deep Space Network (DSN). The Ground Network (GN) consists of stations owned by NASA together with others owned by commercial organizations and other space agencies. The GN supports approximately 140 passes per day, about half of which are provided by non-NASA stations. Nine TDRS spacecraft comprise the Space Network (SN) together with the White Sands, New Mexico complex. A remotely controlled terminal in Guam augments the White Sands complex for spacecraft over the Indian Ocean.

Significant changes within the Networks include adding a 26 GHz receiving capability to DSN 34 M stations, closing the 26 M stations by the end of 2010, and replacing 70 M stations with an array. NASA is installing an 18 M antenna at the White Sands complex to support lunar missions. Two new TRRS satellites (K and L) are being procured with planned launch dates at the end of 2012 and the beginning of 2013. Mr. Costrell concluded his talk with a model showing missions to be supported by the three NASA networks.

### **5.0 STATUS OF CCSDS WORK IN RESPONSE TO IOAG RESOLUTIONS**

The CCSDS representative to IOAG, Mr. Adrian Hooke, began the presentation. This is the first meeting where the formal liaisons between CCSDS and IOAG will take place. He began by contrasting the membership of CCSDS with the IOAG. Additionally, CCSDS has several observer agencies, which IOAG does not.

CCSDS has six technical areas. Those of most interest to the IOAG are: the Space Link Services (SLS) area, which connects the spacecraft with ground stations, and the Cross-Support Services area, which exposes ground station services to other users in control centers or in other user facilities. Currently, there are 23 Working Groups

Several Resolutions at IOAG-8 were directed to the CCSDS, which Mr. Hooke assigned to three different groups. The first had to do with Cross-Support Service Architecture and a Framework for a Cross-Support Service Catalog. Mr. Hooke recommended deferring the report describing Cross-Support Service Architecture until tomorrow when there are several Agenda topics dealing with the subject.

There was a cluster of Action Items related to SLE, in particular the urgent need to get the SLE Service management work progressing properly to deliver some products together with some advice that there was too much effort being expended on Cross-Support Transfer Services to the detriment of the Management Services. Also, in the Space Link Services area, the IOAG felt that the RF and Modulation Recommendations needed some simplification and that the CCSDS needs to set up a group to handle High Rate Uplinks.

With regard to Service management, the deliverables are a Report [Green Book] describing the overall Service Management concept of operations and the Recommendation [Blue Book] representing the CCSDS standard. The Plan of Work includes a Best Practices document [Magenta Book].

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Currently, the Service Management Recommendation is a Red Book, version 2. It was concluded at a recent meeting that it is impractical to include Radio Metric Management in the version 2 document for lack of time, which is in accordance with IOAG Resolution 8.1.1. As of last week, the plan is for the Red Book to be submitted to the CCSDS Secretariat in December 2008. The problem has been resources because NASA is doing the majority of the work and it would be most helpful if other agencies could contribute more.

XML Schema updates to Red-2 and the Prototyping activities are going well with the JPL prototype up and running in April 2007. JAXA's prototype should be online around September 2007 and ESA's prototype should begin interoperations in October 2007.

Mr. Costrell noted that only one part of NASA was mentioned in the prototyping report and he inquired if anything could be said about NASA as an entity. Mr. Hooke replied that there is only one part of NASA that is implementing SLE at this time and that is the DSN, so the prototyping is focused at JPL. Mr. Narita commented that the JPL prototype will support both Deep Space and Near Earth mission types.

There is concern regarding the Green Book and whether it will be produced in time for the review of Red-2. Presently, there are some limited resources coming from BNSC, but they are insufficient to do a good job on the document. Thus, there may only be a very basic Green Book available in December 2007. The Best Practices Book [Magenta Book], which defines the best ways of implementing and organizing the various Service Management interfaces, is also a concern. There are no resources from any agency allocated to producing this document.

Moving to the SLS area, particularly the complexity of the RF & Modulation Bandwidth Efficient Modulation Recommendations, the Working Group is currently considering their simplification. Pink Sheet modifications to 401 (2.4.17A) and (2.4.17B) are planned for November 2007. The RF & Modulation Green Book will be updated to reflect the changes. Warren Martin observed that the CCSDS web site currently has the 401 (2.4.17B) Recommendation containing only GMSK ( $BT_s=0.5$ ), so it appears to have already been modified. The IOAG Resolution resulted from the large number of modulation types permitted in 401 (2.4.17A) and that Recommendation is still being worked.

A High Rate Uplink Working Group has been formally chartered and has held its first meeting in January 2007. Unfortunately, they were unable to identify any requirements because neither the Constellation Program nor the Aurora Program were able to share their future needs, so the Working Group was unable to find a source of requirements. Accordingly, the CCSDS Secretariat sent a liaison message to the IOAG Secretariat requesting assistance. That message was transmitted to the IOAG Heads of Delegation on 4 April. At this point in time, the High Rate Uplink Working Group is blocked, there being no meaningful source of requirements.

Mr. Hooke passed the presentation to Nestor Peccia to report on Delta DOR and the Strategic Plan. A special group was created in CCSDS to consider which interfaces are affected by Delta DOR. Six interfaces were found: DOR Tones, Raw Data, Service to Transfer Data, Orbit Data Message, Reduced Data, and the Quasar Catalog.

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The two highest priority interfaces were deemed to be the Orbit Data Message and the Reduced Data. The Orbit Data Message is already a CCSDS standard and the Navigation Tracking Data Message is a Red Book currently under review and should be available toward the end of 2007. It already includes the Reduced Data needed for Delta-DOR. DOR Tones have high priority, but in the medium term. They are already partially covered by CCSDS Recommendation 401 (2.5.6B) and future updates will include the needed specifications. The Quasar Catalog has a low priority because JPL already has such a catalog.

Raw Data is not covered, but there is an activity between ESA and JPL where the agencies are trying to construct translators. When these results are available, the information will be made available for potential Birds of a Feather consideration. A service to Transfer Data will be part of the Cross-Support Area, but as has already been stated, this area is suffering from a lack of resources.

A Delta-DOR White Book will be submitted to the CESG in the next couple of weeks. The book will describe each of the six interfaces. The Book will be published toward the end of 2007; however, its color is yet to be determined.

Moving to the CCSDS Strategic Plan, the main comments from the IOAG to the CCSDS in Resolution 8.2.1 were:

1. The Plan should be more than a vision; it should be a driver for development for an architecture for cross-support services.
2. There are no clear connections to the forward-looking plans of the various space agencies.
3. Planning for standards is not covered well.
4. Member agencies are not engaged in the infusion of each new standard.
5. It is unclear how CCSDS Area objectives and goals are ascertained.

The CCSDS agrees that both the Strategic Plan and the Operating plan need to be reworked. With regard to the specific comments, the CCSDS:

1. Agrees with comment number 1.
2. Needs to discuss with the IOAG, because agencies' "forward-looking plans are sometimes vague or focused on a single area like the Moon or Exploration.
3. Agrees with comment 3, but believes that the IOAG must play a major role in the infusion process. Jean-Marc Soula commented that the IOAG had produced an infusion plan two years ago for this purpose and that document is on the IOAG web site. The IOAG Infusion Plan was intended to address the CCSDS comments in items 2 and 3. Mr. Peccia countered that there is a need for a longer term view that is found in the Infusion Plan. Dr. Warhaut commented that the IOAG should respond as a single entity stating the plans for infusion of CCSDS standards.

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4. Mr. Martin recalled that the original request for information about CCSDS Recommendation infusion in the IOAG agencies had come from the CCSDS Management Council (CMC). They were interested in knowing the extent of infusion by each agency, rather than by IOAG agencies as a single entity. Dr. Schulz clarified the matter by observing that the CMC interest was twofold. First they are interested in knowing the extent of implementation and operation of each agency. Second, it is desired to have the IOAG's strategic viewpoint as to where to spend their efforts in the standardization process. Dr. Warhaut agreed that information about the infusion of standards might be useful to the CCSDS. Mr. Martin noted that an Infusion Table summarizing the implementation status of each CCSDS Recommendation had been produced at IOAG-10 and that even if an agency did not have a specific Recommendation implemented at this time; they could insert a date when the capability would be available. Mr. Peccia observed that this would be of great value to the CCSDS. Dr. Warhaut cautioned that the Infusion Table was very summary in nature and could cause confusion, because CCSDS-recommended standards are complex and include many options, and a simple table cannot show which of these options have been implemented. Dr. Warhaut recommended deferring the matter until later, perhaps in a splinter session, because he found that completing the table was not straightforward.
5. With regard to item 4, the CCSDS feels that a Strategic Plan cannot guarantee the infusion of new Recommendations within an agency.
6. The CCSDS agrees with IOAG comment number 5, but seeks the help of the IOAG on providing user input.

Mr. Hooke took the floor to discuss a re-emerging issue. There will be a transition from the current point-to-point architecture, where a single antenna is pointed to a single spacecraft, to an architecture involving multiple elements. There appears to be a consensus that the community must evolve into an inter-networking architecture where there are protocols that allow messages to be sent to one vehicle which relays the information to a second vehicle, who then passes the message to a third vehicle and so on until it reaches its intended destination.

There is general agreement that that the internet protocol suite, the IP suite, will work in some environments such as those with short delays and strong signals. There is also general agreement that there is a new technology of disruption tolerant networking (DTN), which is now being developed. This would permit operation where there are disconnections, one-way links, long delays, etc. which will permit operations in environments where the current internet protocol would fail. However, at this time, there is no consensus as to how to achieve this evolution. Issues such as:

1. Where is the space link terminated?
2. Is IP the best choice of the long-term networking protocols for space use?
3. How will IP be transferred over the space link using current CCSDS standards? DTN is not an issue because it is being designed for compatibility with the CCSDS suite.

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### 4. What is the most general cross-support solution?

The IOAG needs to address these issues in the future. Mr. Hooke went on to summarize some simple scenarios that are available. Option 1 is similar to current practice. Information is sent from a spacecraft, via a radio link, to an ground station and then to a control center. CCSDS packets are used end-to-end. The problem with packets arises in multi-hop transfers where multiple-link connections are difficult. Option 2 replaces the CCSDS Packets with the internet protocol IP. Applications run over UDP are imbedded in IP packets which get routed around the on-board system. IP packets will fit directly into AOS Telemetry and Telecommand frames. When the message reaches the ground station the IP packets are extracted. Option 3 makes use of a capability which currently exists in AOS Recommendations, which, rather than taking IP datagrams and putting them in frames, one uses a private, bit stream interface by placing a serial bit stream in an AOS space-link frame. Today's ground system architecture can be used with this option. Several CCSDS agencies are opposed to this option. Option 4 terminates the space link at the ground station. There is no SLE. Several agencies dislike this option as well.

Mr. Soula expressed concern that the SLE is not even fully implemented throughout all agencies and already there is a proposal for some alternative system. He wondered how we can impose limitations on programs such as Constellation that just go off with some non-standard approach. Dr. Maldari commented that we must capitalize on the work done during the past 10 years. We cannot throw out the developments of the past 10 years. Dr. Warhaut did not believe that it was NASA's intention to drive the architectures of other space agencies. Rather, he observed that this is the present desire of a program which is still in a definition phase and the real issue is to what extent cross-support would be available to such a program. He noted that there are several options and the IOAG should review these to determine which is best, Dr. Wilk noted that there is a long list of issues to be addressed before IP in space could be used such as: is the spacecraft in the same subnet as the ground station? Does it imply IP 6? Do we do this with forwarding agents? How do we address security? Mr. Hooke agreed.

The discussion then returned to IOAG Resolution 8.7.1 requesting the CCSDS to study High Rate Uplinks (HRUs). A CCSDS HRU Working Group had been formed, but was unable to identify any requirements. They have requested assistance from the IOAG. Dr. Warhaut summarized the matter: the IOAG must determine whether there is a valid present requirement for an HRU. If so, it should forward the specifics to the CCSDS. If not, then it should advise the IOAG to terminate the effort. He further suggested going through all CCSDS responses to IOAG-8 Resolutions and agreeing upon the IOAG's positions.

Dr. Warhaut led the discussion. Resolution 8.5.1 should be discussed tomorrow. Resolution 8.1.1 was related to Service Management. Here it was acknowledged that the CCSDS did not have sufficient resources. ESA stated that they could not devote more resources to the work so the IOAG should advise the CCSDS to work on it as best they can. It was generally agreed that the Red Book was the highest priority and the Green Book and Magenta Book will have to be deferred until later. Mr. Hooke suggested deferring the discussions until after the presentations tomorrow. It was agreed to do so.

There being no further business today, the meeting was adjourned.

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### B. TUESDAY, 19 JUNE 2007

The Chairman, Dr. Klaus-Juergen Schulz opened the meeting. He opened the discussion on the Mission Model and whether should be a single model for the IOAG and SFCG or whether there should be separate ones. He specifically asked for comments by Mr. Struba and Dr. Vassallo, which also included feedback from the SFCG.

### 6.0 SFCG POSITION ON S-BAND FREQUENCY UTILIZATION

Dr. Vassallo began by explaining that the SFCG only meets once per year and, since they have not met yet in 2007, only a preliminary position on the 2 GHz band can be presented. The SFCG identified two questions:

1. Is the 2 GHz band necessary in the long term?
2. What is the level of threat to the usage of the 2 GHz bands by future users?

Considering the first question, the SFCG believes that the near-Earth missions have no real alternative to the use of the 2 GHz band; however, some agencies plan to use other bands in the future, particularly for Lagrange Point missions. For deep space (Category B) missions, there are other alternatives to the 2 GHz band.

Addressing the second question, there are two issues: Intraservice and Intranservice. With regard to Intraservice, the SFCG Data Base shows that each frequency slot is reused from 20 to 90 times and the SFCG Data Base only covers missions up to 2009. Reuse is not expected to decrease after 2009.

Mr. Costrell inquired about 2 GHz use for missions at the Lagrangian Point. Dr. Vassallo replied that it depends upon the application. For TT&C, 2 GHz may be adequate, but ESA has had problems with Lagrangian Point missions, such as SOHO, where link margins for payload data at 2 GHz have been low. They have experienced interference problems at least once a week. Dr. Warhaut observed that for many agencies TT&C includes the acquisition of scientific data as well as housekeeping. Mr. Martin commented that the ITU has a recommendation that TT&C and science data be accomplished in the same band, Drs. Warhaut and Vassallo agreed. Dr. Vassallo stated that ESA has no future plans to use the 2 GHz band for deep space.

Looking at the Interservice issue, the 2 GHz band is shared with other terrestrial services. The most difficult one is the 2110-2120 MHz uplink band for deep space which is shared with IMT-2000. Its use is forbidden in many countries in Europe and in Japan. In addition, there is increasing pressure from the terrestrial service users on space science users to vacate the entire 2 GHz band. Sometimes there are restrictions based on the use such as reduced emission power or limitations on emissions in a particular direction. These actions forced ESA to move their 15 M antenna at Perth, Australia to New Norcia, which is much more isolated.

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In conclusion, the SFCG believes that some missions may have no real alternative to the use of the 2 GHz band. However, when an alternative exists, the SFCG recommends using it. Typically, this would apply to payload data. Moreover, the SFCG believes that the 2 GHz band can be considered a prudent choice only when the following conditions are met:

1. The band is used only when strictly necessary.
2. When proper legal and political protection of the ground station is available.
3. When ground stations are placed in a suitably remote and shielded location.

Mr. Martin inquired as to the definition of “strictly necessary” because it sounds like a “compelling reason” is required. Dr. Warhaut replied: That for ESA, it will be legacy missions.

Mr. Struba commented that this entire band is requiring a greater overhead in making it useable. It requires dynamic ongoing coordination and vigilance. If one goes beyond 2009 there is good evidence that use of the 2 GHz band will go up. It will cost more resources to use in the future. It was decided to move to the NASA presentation on the subject.

### 7.0 NASA SPECTRUM PLANNING (B 007 23:30)

Dr. Brandel gave the NASA presentation. He focused on the non-deep space portion of the 2 GHz band. NASA spent about 2 years looking at the requirements for missions, both manned and unmanned, going to the Moon and on to deep space and Mars. These missions covered a time period from, 2010 to 2030. One of the assumptions was that there must be reliance on the bands allocated by the ITU-R in order to protect NASA’s investment. One issue was whether or not enough allocated spectrum exists.

Several assumptions were made prior to beginning the study. One such assumption was that new spectrum allocations require at least 10 years to implement because they require at least two ITU meetings. Another assumption was that continuous coverage is required. The study looked at meeting this need with relay satellites and multiple ground stations. A third assumption was that two bands are required for each user, one for low-rate critical data and another for high-rate mission data.

Dr. Warhaut questioned this third assumption based on the ITU Recommendation that payload and TT&C should be accomplished in the same band. Dr. Tai pointed out that some deep space missions are using 32 GHz for their high data rate telemetry while performing the TT&C in the 7/8 GHz bands. Mr. Struba stated that S-band will be used only for emergencies and that NASA is really going to the second band, K<sub>A</sub>-Band, for TT&C and for mission data. S-band is just for emergency (B 007 41:05). S-band is available worldwide.

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Dr. Brandel continued stating that continuous coverage is essential during Earth orbit assembly phases, as well as at the Moon and Mars. A fourth assumption is that in low Earth orbit TDRSS will provide all communications support, but once its altitude was exceeded, a transition to ground station support would occur. Exactly the same user hardware would be used to talk to both TDRSS and Earth stations.

There are only two allocations available and those are at 2 and 8 GHz. Of these the only band with an inter-satellite allocation is at 2 GHz. So, NASA cannot equip TDRS with 8 GHz links. S-Band also has a broader beamwidth than X-Band facilitating communications to a tumbling or spinning spacecraft. NASA is seeking a primary Space Research Service (SRS) allocation in the 22.5-23.5 GHz band.

7/8 GHz was selected for deep space low-rate missions and 34/32 GHz for high data rate missions. In the 2025-2030 time period the trunk lines around Mars may migrate to the 40/38 GHz bands.

In conclusion, we must retain and protect the 2 GHz band and obtain an uplink allocation for the 25.5 – 27.0 GHz band. Recommendations include retaining the 2 GHz band for interoperability, using the 26 GHz band for high data rate applications, utilizing bandwidth-efficient modulation, and we need to collaborate.

Dr. Schulz stated that his understanding of the NASA recommendations was that S-band should be retained for communications above and below 30,000 km for very important TT&C, while the routine mission would be conducted in K<sub>A</sub>-Band. Dr. Brandel replied that at the Second Technical Meeting in Japan several agencies expressed their desire to retain S-band for their lunar missions, but agencies are also using X-Band for lunar missions. NASA has no requirement for X-Band for lunar missions.

Dr. Schulz inquired again whether S-Band was only for emergency TT&C use. Mr. Costrell and Mr. Rush replied that S-Band is for primary use. Mr. Rush went on to say if a mission carried both 2 and 26 GHz communications, then it would appear prudent to rely primarily on 26 GHz for both TT&C and mission data to conserve the 2 GHz band. He noted that some missions having only low rate data requirements will not utilize 16 GHz communications.

Dr. Warhaut commented that we cannot rule out X-Band for missions going to the Moon. We should take note of the last slide in Dr. Vassallo's presentation stating the restrictive conditions under which S-Band should be used. We should also firmly support NASA's request for a new allocation in the 22.5-23.5 GHz band.

The Chairman then directed the discussion to the Mission Model.

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### 8.0 MISSION MODEL (B 007 1:11:11)

Mr. Struba stated that the mission model(s) must be accurate. Dr. Schulz summarized the IOAG position by saying that the Mission Model should be maintained by the IOAG and made available to the SFCG. Mr. Martin commented that the SFCG has certain requirements for a mission model that we must include for that model to be useful to them. Dr. Klaus said that we should frame an action to have the SFCG tell us what attributes must be added to make it useful to them. Mr. Costrell expressed reservations that other organizations may need detail far beyond that desired by the IOAG. Dr. Schulz replied that he would like to see what the SFCG comes up with and then we will consider the matter at the next meeting. Dr. Schulz concluded this portion of the meeting.

### 9.0 CROSS-SUPPORT SERVICE ARCHITECTURE (B 007 1:15:10)

Dr. Takahiro Yamada gave the JAXA presentation. At IOAG-10, an Action Item was assigned to JAXA to develop a framework for the *Cross-Support Architecture*. That framework document was prepared and circulated to IOAG members for comment. Since no negative comments were received, JAXA has proceeded to develop a document that defines the Architecture.

Dr. Yamada began by providing some basic concepts, such as the CCSDS definition for cross-support. He noted that the CCSDS also has developed standard protocols and services, termed SLE services, to enable this cross-support. Cross-Support Service Architecture establishes a basis for cross-support services. It also defines basic cross-support service types. This document provides guidance to: a) Service Providers and b) Service Users.

*Cross-Support Service Architecture* expands the conventional “service provider – service user” model to include both space and ground users. A *Cross-Support Service System* (CSSS) is defined as a set of cross-support service elements managed by a single authority with a single set of management policies. A *Cross-Support Service Element* (CSSE) is defined as a physical element that can provide one or more cross-support services to any space mission element of any space agency, proved that the customer element conforms to the technical interface. A *Cross-Support Service Element* can be an entity on a body, such as the Earth, Moon, Mars, etc. or an element cruising through space.

A *Cross-Support Service Element* has two “interfaces”:

1. The interface closer to the space user element is called the *Space Side Interface*
2. The interface closer to the ground user element is called the *Ground Side Interface*.

Mr. Hooke inquired if the CSSE was a lunar relay satellite and the users were on the surface of the Moon. What would one call those sides if both were in space? An example would be a JAXA relay satellite with a European astronaut on the moon talking to an American astronaut who was also on the Moon. Dr. Yamada replied that he had not included that type of link in his architecture.

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Dr. Yamada continued by describing a *Cascaded Configuration* in which a space user element and a ground user element are supported by two or more CSSEs. His presentation provided a diagram of such a configuration.

He then described four service views:

1. A *Service View* is used to describe services provided by CSSSs and CSSEs, together with their functional characteristics. He provided examples of service views. Cross-support Service Management is used to manage the interfaces. He noted that, for interoperability among agencies to exist, all agencies must implement that same set of services. Dr. Yamada recommended that the IOAG establish a basic set of services to be implemented. He provided an example set of basic cross-support services. He noted that networking services based on IP should not be included in this set because they only are required by a single agency. He concluded the Service View by providing a set of service attributes.
2. *Physical View* is used to describe the physical configuration of CSSSs and CSSEs as well as the topology and connectivity of the physical elements. An example showing a Mars landed element, communication through a relay satellite, to a ground control center was provided. These elements may or may not belong to a single agency.
3. *Communications View* is used to describe the communications protocols used for accessing cross-support services, including service management. Its focus is on the communications services interfaces between CSSEs and user elements. Dr. Yamada provided an example of a communications view together with its attributes.
4. *Enterprise View* is used to describe processes and rules governing the initiation, negotiation and agreement between supported and supporting agencies for the provision of cross-support services. This view focuses on the administrative and contractual aspects, rather than on the technical details. Dr. Yamada described a procedure for cross-support agreement, which included several templates for service agreements.

Dr. Yamada concluded his presentation with a series of steps and dates for generating a final document and a Cross-Support Catalog.

### **10 NASA SPACE COMMUNICATION & NAVIGATION ARCHITECTURE (B 008 14:30)**

Mr. John Rush gave the NASA presentation. In 2004 NASA formed a working group to formulate the architecture for its missions. The architecture has been reviewed by NASA management and accepted. There are four physical architectures: Earth based antenna element, Earth based relay satellite element, lunar based satellite element and a Martian based relay satellite element. Cross-cutting architectures are navigation, security, spectrum, navigation, and network.

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There will be a conversion from a large aperture antenna for deep space to an array of smaller antennas. The goal is to array the transmit function as well, but that will require further technology development. The Earth-based satellite element has been through a number of studies to determine if it is really needed and it was determined that it is needed. Two cases have been identified where a lunar relay element is required. For initial robotic missions, NASA would put a temporary relay system in place for communications with the back side of the Moon and for bottom of crater visibility. When the human exploration era arrives, a three relay satellite architecture is envisioned.

With regard to navigation, the architecture is pretty much what it is now except for low Earth orbit NASA will make more use of GN services. There will be technology development to make those services more accurate. Security architecture will permit missions to encrypt their commands. This architecture requires a “pass-through” communications system. The networking framework ties all of the elements together. The network architecture is layered; however, the specific layers are yet to be defined. The spectrum framework and the networking framework are the keys to interoperability. If we work in the same spectrum and use the same protocols, there will be opportunities for interoperability. Modulation was not included in the architecture studies, That work was undertaken by a separate group who will report later. Other on-going studies include Service Architecture Definition. Adrian Hooke will give that portion of the NASA presentation.

### 10.1 Service Architecture Definition (B 008 25:17)

Mr. Hooke gave the NASA presentation. Mr. Hooke noted that the work he will describe is outside the standards program. Rather, it is the product of the NASA Consolidated Networks Team comprising persons from the three NASA networks. These studies are just beginning, but the objective here is to expose the work to the IOAG and to request feedback.

The service architecture consists of a “backplane” of services consisting of different agencies who offer their services to each other. Missions can “plug into” those services to obtain the different layers needed. In response to a question, Mr. Hooke replied that there are two layers of security at the Application Layer and at the Network Layer. Cross-support would be at the Network Layer where either encryption or authentication would be required.

Missions will have three distinct phases over their life cycle:

1. *Formulation Phase*: where users discover the capabilities that are offered.
2. *Design Phase*: where the parties are negotiating the cross-support that will occur.
3. *Mission Operation Phase*: where the services are actually provided.

The first thing needed for the *Formulation Phase* is an international Service Catalog. This could be a web-based document that permits potential users to browse for details of services available. This Catalog should be completely open and anyone in the world should have access.

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At some point, prior to negotiation, the user must be authenticated in the *Design Phase*. A potential user will need to establish his credentials proving that he is an authentic user. The product will be a Service Agreement leading to a service profile. This process would be closed and only the user and the service provider would have access.

In the *Mission Operations Phase* the service profiles are used to configure the support and the actual support is provided.

NASA is in the process of bringing all of its tracking and data acquisition infrastructure back in centralized management. It is believed that the correct paradigm for this consolidated network is a serviced-based architecture. However, NASA does not want to get deeply into a serviced-based architecture without consulting with other agencies. NASA proposes that, as it brings its networks back together, they should be confederated and collaborated into an international infrastructure. That involves obtaining the agreement of the IOAG agencies in the architecture.

That infrastructure will probably start fairly simply but will evolve. It should start with a basic set of services and then increase the scope of those services eventually moving away from SLE into the generic transport cross-support services with cross-support service management becoming the more abstract evolution of the SLE services.

NASA will begin by focusing on its ground networks. Mr. Hooke presented a series of slides showing the different services and the status of implementation by each of the three NASA networks ranging from green (existing now) to orange (an emerging capability) to red (non-existent).

Currently, in the *Mission Design Phase*, the Service Management Red Book does define configuration profiles and a little pertaining to the service agreement, but there is no process for negotiating the content of the agreement. In the *Formulation Phase*, there is also nothing establishing a process for interrogating and discovering capabilities.

Looking at the Mission Operations Phase, Mr. Hooke proposed an initial, Earth based, service set. There are four batches of services: a) forward, b) return, c) radio metric, and d) a special class which includes positioning and timing.

Mr. Hooke concluded his remarks by outlining the next steps. Four things need to be undertaken now:

1. Need to obtain international consensus on the service architecture. It is proposed to add a new Working Group in CCSDS called the Cross-Support Architecture Working Group. The group would create three new books:
  - a) CCSDS Recommended Practice: *Cross-Support Service Architecture*
  - b) CCSDS Recommended Standard: *Cross-Support Service Catalogs*
  - c) CCSDS Recommended Standard: *Cross-Support Service Agreements*

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2. There is a need to complete the SLE Service Management Blue Book. Also there is a need to accelerate the generalization of SLE into cross-support transfer services. If there is international agreement on this course, then NASA will increase the resources available to work on this area.
3. It was recommended to formulate an IOAG Resolution to be transmitted to the CMC detailing the progress made in the Cross-Support Service Architecture area. Also the Resolution should ask the CCSDS to report the progress made after the Fall meeting.
4. The IOAG needs to agree to maintain the international Service Catalog. The IOAG must also agree on the minimum set of services that every agency will provide and it has to agree on a strategy as to how those services will be exposed. We will also have to agree on how those services will be infused.

In response to a question, Mr. Hooke replied that the Forward Space Packet (FSP) is an end-to-end network layer construct. Dr. Bobrinsky inquired whether FSP is implemented in the DSN. Mr. Hooke replied that it has not nor will there be an implementation plan unless there is international agreement with other agencies.

A question was raised as to how a Service Catalog could be a Blue Book. Dr. Hooke replied that the CCSDS Recommendation would only cover how the Catalog was structured. Dr. Hell commented that the IOAG would have to agree on the semantics as to what support for the various services really means. Dr. Tai replied that is in the Service Architecture specification. The service attributes characterize what each service provides. Dr. Hell commented that the Cross-Support Service architecture is a sort of living document. Dr. Tai agreed because new service types may be added from time-to-time.

Dr. Peccia commented that each agency should provide a list of the services it needs based on the mission model. Then the IOAG should provide a common view of which services are required to the CCSDS. If Bit Stream is only required by NASA, then IOAG cannot recommend that because it is only one agency.

Dr. McKay asked about the time scale, given the current architecture and current frequencies. Will we be using K<sub>A</sub>-Band and UHF on the proximity link? ESA is making decisions now for missions that will have consequences to 2015 to 2020. Dr. Warhaut commented that he had looked through Mr. Hooke's supplementary information and perhaps it would be good to go through the ESA presentation. He stated that the "rapid action" does not match what is contained in the supplementary material because the time frame appears to be 2017-2020 or beyond. Dr. Warhaut questioned why we should use IP when we currently have a properly functioning cross-supportable forward and return link capability. There appear to be other links that are disregarded (e.g., control center to control center, user to user). He acknowledged that it is a good start, but he did not see a pressing need for this new direction. In any event, NASA should wait for feedback from the IOAG.

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Dr. McKay asked again what time scale was foreseen because ESA has missions being designed that will operate until 2020. Mr. Hooke replied that from NASA's viewpoint, the most important item was to get rid of packets as an end-to-end construct. We need to bring in an inter-networking service. He stated that he did not say IP. Such an inter-networking service is going to be needed in the next 7 to 8 years and we are going to need to agree on an approach for that. We can already cross-support it if we do so at the SLE level, but if any mission comes along that wants internetworking support at the ground station, then there is a need to address it. Looking at the Constellation program for the period between now and 2014, it appears that things are pretty much the way they are now. He reiterated that the number one thing that we should look at now is how we begin transitioning from something based on the CCSDS packet to something that is based on a network-centric approach.

### **11.0 ESA SPACE COMMUNICATIONS ARCHITECTURE (B 008 1:15:05)**

Two presentations were provided for this session.

#### **11.1 ESA Space Communications Evolution**

Dr. Maldari gave the ESA presentation. ESA established a working group after the SCAWG report at IOAG-10 to consider the long-term evolution of the ESA tracking network. Its objectives were to:

1. Define a long-term science and Earth exploration mission model.
2. Derive a future ESA space communications architecture and associated protocols to meet the needs of the mission set.
3. Identify space and ground facility requirements and technologies.

The working group plans to:

1. Draft a conceptual architecture by mid-2007.
2. Consult with IOAG members at IOAG-11.
3. Develop final concepts and architectures by February 2008.
4. Reach agreement with European Partners in March 2008.
5. Present the plan to the international community in June 2008.

Progress of the working group thus far is:

1. Mission Model has been published covering a period to 2020.
2. Work on end-to-end architecture and protocols are progressing.

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Dr. Maldari described some of the missions on the model. Mr. Rush asked whether the optical links on Artemis were just for support of near Earth orbiters or whether they could also support deep space missions. Dr. Maldari replied that they were only for support of Earth-orbiting missions.

ENVISAT will be supported with a  $K_A$ -band antenna for transmission of payload data via Artemis. GMES has baselined S/S-X links; however, studies for  $K_A$ -Band and/or optical links have been initiated. ATV will be operated from the ground via Artemis. Interoperability with TDRS using the SNIP design has been adopted. Provision of a data relay capability for support of the rover is under discussion with ExoMars project

The first ESA mission that will use CFDP will be Bepi Colombo or ExoMars. Bepi Colombo will be the first ESA mission to use Turbo Coding. Herschel / Planck uses an advanced modulation scheme, GMSK, and will launch in 2008 or 2009. GAIA will also use GMSK and will have bit rates up to 9-10 Mbps. ESA has looked at potential missions in the 2020 to 2030 time frame, but that model is not clear at this point. In response to a question regarding the maximum data rate that could be handled by ESTRAC, Dr. Maldari replied that it would be 10 Mbps. Dr. Maldari provided several charts giving the characteristics of each mission.

ESTRAC architecture varies with time and snapshots of the 2007, 2010, and 2020 plans were presented. Architecture is very mission dependent and the charts reflect an evolution based on the mission set. Many missions that will be supported by the 2010 architecture are already flying. New missions include Herschel, Plank, and GAIA. In 2020 ESA will have ExoMars, a sample return mission, which will utilize X/X- $k_A$ -Bands and a Rover mission using a proximity link.

A preliminary conclusion is that ESA will not have a manned mission by 2020. Perhaps there will be such a mission in the 2030 time period. The focus of the ESA program until 2020, and possibly further, is on Earth observation, Lagrange point, and deep-space missions. Except for data relay feeder links from Earth observation missions, there are no data volume drivers for frequencies higher than 7/8 GHz. Use of  $K_A$ -band up to 2020 is likely to be only needed in unique circumstances such as for RSI in Bepi Colombo.

ESA does see a need for enhanced modulation such as GMSK and for punctured, concatenated and Turbo coding to support high-rate downlinks. It does not see a need for a high-rate uplink at this time. File transfer protocols such as CFDP are needed for deep space missions. Delta-DOR is becoming a standard navigation tool for ESA.

The ESA mission model has no requirement for IP in space, although it may have certain technological merits. Studies are being initiated within ESA to define a roadmap for IP. These studies will examine the need for relaying data between multiple flight elements which are not in continuous contact. ESA finds CCSDS proposals for operating IP over HDLC to be destabilizing and believes that IP should only be used over existing CCSDS links using currently defined services.

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Cross-support services are well defined for the ground segment using SLE, but not for the space segment. This has caused problems in defining project-specific ICDs. While CCSDS is beginning to tackle the problem, ESA would like to see more effort placed in this area.

ESA's working group will be looking at the 2020-2030 time period with a particular emphasis on the Aurora program. It also needs to consolidate its work on services and protocols. The working group will look IP in space to identify its requirements and benefits together with a roadmap for implementation. Finally, the working group will derive the requirements on space and ground facilities.

Mr. Rush inquired about ESA's IP roadmap. He observed that if one is developing a roadmap it is because they have decided to implement a capability. He wondered if that were true here. Dr. Maldari replied that there have been some studies that show it would be worthwhile; however, ESA is not prepared to say either yes or no today.

### 11.2 ESA Service Architecture

Nestor Peccia gave the presentation for this segment. It became clear during Mr. Hooke's presentation that we must look for an end-to-end architecture extending from space, to ground station, to control center, to science operation centers, to PIs, and to the project. ESA agrees that a catalog for the entire mission lifecycle is required. ESA believes that the cross-support architecture must be cognizant of all parties involved including the manufacturer who supplies ground support equipment, who provides on-board software, and who is involved with flying the spacecraft. Then, there is communication with the ground station network, communications with the mission operations center that also must be considered. All of these entities are exchanging data. The service architecture must be the same when all parties are considered.

Considering Bepi Colombo, interfacing with the science operations center, with PI's, with the project, all of these require a service management agreement. Why can't we define a service architecture where the service management agreements for different entities follow the same standards?

Mr. Peccia addressed the different services that have presented and which of those are SLE and which are experiment data distribution. CFDP will be used on ExoMars for the first time by ESA. It will be implemented in the ground software in 2009. Forward Space Packet will be implemented in the ground software next year. Forward CLTU, Return All Frames, and Return Channel Frames are all operational. We need to discuss Delta-DOR.

Experiment distribution distributes data to other agencies or parties. Telemetry, Telecommand, predicts parameter, reports, catalogs, etc. are all distributed. Why should these catalogs be different from those for cross-support services?

In summary, the ESA architecture is trying to depict an end-to-end view covering all mission phases. Today, service architecture is treated differently, so we are studying a common future architecture where the principles of an architecture are the same for both services, SLE and Experiment Data Distribution. ESA believes that IOAG should take an end-to-end view and not only network centric operations. A full end-to-end view permits use of the same standards in the different phases of the mission and for space and ground.

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### 12.0 DISCUSSION OF ARCHITECTURE AND ORGR ITEMS (B 008 00:00)

Following lunch, Chairman Schulz called the meeting to order and asked: “Having heard the Space Communication Architecture presentations of NASA and ESA, what do you [the IOAG] want to do with these presentations and are there any particular actions that the IOAG would like to take?” Mr. Martin proposed that the group identify commonalities and differences and then look for ways to reconcile the differences. Dr. Warhaut agreed, but added that we should also take Dr. Yamada’s earlier recommendation and define a core set of IOAG cross-support services as well as “enhanced” and “optional” services. He proposed that Dr. Hell, Dr. Yamada, and Mr. Hooke form a splinter group and put together a list of “core services”. That report should be submitted tomorrow.

Mr. Soula commented that this must be an IOAG product, not merely that of a splinter group. It would be fine if the splinter group generated an exhaustive list of services, but then it must be up to each agency to assign each service to a category. Dr. Warhaut agreed that each agency should agree on the mandatory services. He also suggested that Mr. Soula join the group. Dr. Warhaut suggested that Dr. Hell chair the splinter group. He also restated the ESA position, which started from a real mission model, and from that model they generated a roadmap starting with what exists today and where ESTRAC needs to be at a point in time in the future. He would like to build on the cross-support capabilities that currently exist between ESA, JAXA, and the DSN.

Secondly, Dr. Warhaut also stated that enhanced modulation schemes and coding techniques are very important and cited several presentations to be given later today. Thirdly, file transfer is a very valuable tool. Unfortunately, in the absence of a CCSDS CFDP Blue Book, the Rosetta, Mars Express, and Venus Express missions have implemented a proprietary version of the file transfer protocol. ExoMars will go to the CCSDS version. Fourth, Dr. Warhaut was very pleased with the help ESA has received implementing Delta-DOR. With regard to IP, it appears to be the way to go in the future; however, ESA has no clearly defined user requirement at this time. Finally, the IOAG needs to focus on cross-support services for the space-to-space link.

Mr. Rush indicated his agreement with Dr. Warhaut’s comments, but raised a question about IP. ESA’s position is that something has to be done, but perhaps not as swiftly as suggested in the NASA presentation. ESA would like time to study the issue before selecting a specific architecture or implementation plan. Issues like IP-6 v. IP-4, security, control center-to-control center communications need to be studied. Dr. Warhaut suggested forming a working group of knowledgeable engineers from all IOAG member agencies and taking the next two years to investigate IP and how it should be implemented.

The Chairman inquired of the agencies about their plans for IP. Several agencies responded that they are planning Moon missions, but none had immediate plans to implement IP. Some agencies have not finished implementing SLE, so it is premature to discuss IP at this time. The consensus of all agencies, except NASA, is that we should consolidate the large investment in SLE. Mr. Hooke commented that in multiple hop applications where routing a communication is required, one can move the CCSDS packet to the Application Layer and put in a routing protocol, which is not necessarily IP.

## MINUTES – IOAG-11

The Secretariat asked about the Membership of the Core Service Working Group. It is as follows:

1. Wolfgang Hell – Chairman
2. Takahiro Yamada
3. Jean-Marc Soula
4. John Rush

Chairman Schulz returned to the High Rate Uplink discussion of yesterday and asked if any agency had a requirement. He poled the delegations. For NASA, Constellation was the only identified potential user and they are still in the process of establishing requirements. The rate identified was 1 Mbps and it was observed that a CCSDS standard already exists for this rate. No other agency identified a requirement. Dr. Warhaut asked that the following be reflected in the Meeting Minutes:

*In the absence of any firm user requirements, with the possible exception of Constellation, it was jointly agreed by IOAG members that there will be no specific request made to CCSDS to put efforts into development of a CCSDS High Rate Uplink standard. Nevertheless NASA may, in anticipation, of such a requirement, do internal work targeting this area.*

### 13.0 CMLP REPORT (B 009 38:16)

Dr. Leslie Deutsch gave the Coding, Modulation, and Link Protocols (CMLP) presentation. He pointed out that this is a work in progress and the purpose of this presentation is to engage the international community. The report is a product of a large Team effort co-led by Frank Stocklin of GSFC.

SCaN has defined a set of links to span the Solar system, maybe even the Universe and has recommended spectrum for these links. SCaN has also recommended protocols for the links; however, it has not as yet recommended how to implement the physical links.

This study recommends the entire set of link designs for the SCaN architecture to the extent that this selection is defensible. The scope covers every link in the NASA architecture through the year 2030, excluding only surface-to-surface links. The scope includes all reasonable coding, modulation, and multiple-access schemes. Dr. Deutsch stated that this scope covers a huge space so the team applied “common sense” to narrow the set.

The SCaN architecture is a major change for NASA. It involves not only coding and modulation, but also many other areas. CMLP is only one example. Legacy missions will have to be supported for many more years. Spectrum is another example; the Category A X-Band is not in the SCaN architecture, but it will take many years to phase it out. A SCaN transition plan will be prepared containing roadmaps, technology investment plans, infusion plans, strategies for international standards development, and policies for new missions. For example, at some point it will be necessary to tell new missions that they can no longer use X-Band near the Earth – that will need to be a policy.

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This Draft Final Report will be submitted in June 2007, with the Final Report to complete in the late summer of 2007. The Report includes a catalog of existing NASA links, a catalog of links in the Scan architecture, and a list of the coding, modulation, and protocols studied. A subset of recommended techniques has been generated.

Dr. Deutsch presented a table showing the list of tasks and the status of each. There are many stakeholders in this study. Some are SCaN, technologists, communications infrastructure engineers, spacecraft communications engineers, mission directorates, Constellation, and other persons from government, industry, and academia.

Dr. Maldari asked if this study considered what has been previously recommended by the CCSDS? For example, there have been substantial discussions in IOAG-8 about modulation and since that date, the CCSDS has reduced their recommended number of modulation types. Is that reflected in this study? Have you analyzed what has been done in the past or is this study unrelated to what the CCSDS has done?

Dr. Deutsch replied that the CMLP study is not totally independent of the CCSDS because it involved some of the same people that are involved in CCSDS. CCSDS documents were used in the study as background, but there were also people who were not involved in CCSDS, permitting us to give it a fresh look. The CMLP Report recommendations also indicate those that are also CCSDS recommendations.

The goal for modulations is to recommend those that are appropriate through 2030. Key “figures of merit” for modulations are: spectral efficiency, power efficiency, complexity, and standardization. Dr. Deutsch presented a table containing some 70 modulation types with CCSDS standard ones listed in blue and some non-standard NASA types shown in green.

Dr. Vassallo (Chairman of the CCSDS RF & Modulation Working Group) observed that the blue color was a bit misleading because the CCSDS specifies certain modulation schemes according to the channel type and the CMLP Report does not differentiate. Dr. Deutsch agreed, but stated that the report does differentiate later when specific links are named.

The same process was employed for codes, but the key attributes were: power efficiency, the encoding and decoding complexity. Whether the code is already a CCSDS standard and whether it is a mature technology. Three pages of codes were included in the report. The same color code used for modulations was applied for codes.

The presentation then turned to Multiple Access Techniques. This involves the simultaneous sharing a single physical link among several users. A catalog of multiple access methods was provided. The report also contains a catalog of link protocol functions. These are not protocols, but rather those things which are important to link protocols to the performance of coding and modulation.

## MINUTES – IOAG-11

Figures of merit used to down-select from the catalogs are:

1. Ability to support legacy missions
2. Spectrum utilization
3. Power efficiency
4. User burden (cost)
5. Infrastructure burden (cost)
6. Alignment with international standards
7. Ability to provide radio metrics
8. Robustness
9. Latency
10. Technology maturity
11. Capacity (bps)

Dr. Deutsch went on to show an example of the down-selection process for Category A missions. Links were divided into uplink and downlink.

Mr. Martin asked what services were included in Category A missions (i.e., Space Research, Earth Exploration Satellite, Meteorological, etc)? Dr. Deutsch stated that all were included, that the team looked at it from the physical link point of view (data rate, configuration) rather than what the use was. Mr. Martin then pointed out some typos such as the CCSDS Recommendation for Category A missions is GMSK ( $BT_b=0.25$ ). Additionally there is no CCSDS recommendation for 8-PSK, rather it is 4D 8-PSK TCM and that is recommended only for Earth Exploration Satellite Service missions.

Dr. Vassallo agreed, but apart from that the S-Band return link shows a 20 Mbps data stream in a maximum channel bandwidth of 10 MHz, whereas the actual 2 GHz band channels are only 5 MHz wide and that will not support a 20 Mbps link. Dr. Vassallo's second comment was that for K<sub>A</sub>-Band (26 GHz) there are no CCSDS recommended modulation types, so the color should be changed.

Dr. Deutsch continued with modulations for Category B missions. A table, similar to that for Category A missions, showing links and the recommended modulation types was provided. Someone commented that, "once more, 8-PSK is not recommended by the CCSDS for Category B missions." Therefore, it should not have a blue color. Dr. Deutsch responded that it may not be recommended by the CCSDS, but is recommended by the CMLP team.

Similar tables were presented for the different codes. A question arose as to whether the rationale for the selections will be in the report and whether the IOAG could have the report. Dr. Deutsch replied that the full report will be available, but not today.

Mr. Rush inquired that, after looking at all of the modulation types, has the team come down to discarding all modulation and coding types that are not CCSDS recommended? Dr. Deutsch replied no, the team has taken CCSDS recommended modulation types and extended them to other types of links and they have used non-CCSDS recommended modulation types on other links.

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With regard to navigation, Dr. Deutsch observed that many of the traditional radiometric data types are incompatible with the modulation types used for high data rate missions. The team is investigating new methods for collecting radiometric data when GMSK is used.

Multiple access has been identified in 5 major areas:

1. Near Earth Relay
2. Lunar DTE/DFE Relay
3. Lunar Relay
4. Mars DTE/DFE
5. Mars Relay

The team developed a driving scenario, representing the most stringent case, for each area. Important considerations are: the capacity must meet the needs of all the users; spectral efficiency must be sufficient to meet the needs, given the allocations available; user burden must be low; and technology maturity must be medium to high. Down-selection is in progress.

Future work of the CMLP team includes:

1. Respond to IOAG comments
2. Complete analysis and formulate recommendations
3. Draft Final Report
4. Review Report with international NASA partners
5. Undertake some post report work

Summarizing, the CMLP study has reached this intermediate point and the IOAG needs to comment and suggest changes. The team needs to complete technical work leading to recommendations as well as to resolve the multiple access standards effort. Finally, the team needs to complete the surface-to-surface link study.

Dr. Yamada asked if the mission requirements were documented and if so, where? Dr. Deutsch replied that missions currently flying have real requirements and documents containing these requirements. For missions flying in 2030, the team contacts the person formulating the mission concepts to obtain requirements. They are preliminary. For competed missions there are no requirements, so they try to contact the scientist working in the area for their views.

Dr. Schulz asked if optical communications had been considered. Dr. Deutsch replied that optical communications will be important in the future. Perhaps in the 2030 time frame, but that there are no current requirements. Mr. Soula asked if there are implementation plans for these tables and what is the weighting used for whether or not a standard exists. Dr. Deutsch answered yes there are implementation plans for near term needs but one of the purposes of this work is to identify what is needed in the long term. With regard to the weighting if there was or was not a standard, he replied that it depended on the link.

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Mr. Soula commented that the ratio of CCSDS Standardized to CMLP recommended (non-standardized) modulations and codes is not very low. It is not as high as the blue colors in the CMLP Report tables would indicate.

Chairman Schulz noted that Dr. Deutsch's presentation had mentioned resolutions related to multiple access. Mr. Soula stated that the matter had been discussed at IOAG-8 as a potential requirement on CCSDS, but that there was not a sufficient requirement nor was there a consensus to on how to proceed. Chairman Schulz then inquired whether anything had changed since IOAG-8. Dr. Maldari commented that the IOAG should avoid Liaison Statements to the CCSDS absent a compelling need because they may be returned for clarification as was the High Rate Uplink Resolution. Dr. Warhaut suggested deferring Resolutions and Liaison Statements to the end when we can concentrate on their wording as a group. All agreed.

### **14.0 ESA STATUS ON MODULATION SCHEMES AND CODING (B 009 1L33:22)**

Dr. Wolfgang Hell gave the presentation. Dr. Hell discussed ESA's current and planned use of modulation and coding standards. ESA's work in these areas is driven by the European Cooperation for Space Standardization (ECSS). Presently there is an ECSS Standard for RF and Modulation that is aligned with the CCSDS 401 Recommendations. However, the ECSS Standard is more restrictive than is the CCSDS when it comes to bandwidth-efficient modulations. ECSS includes:

1. GMSK
2. SRRC OQPSK
3. 4D 8-PSK TCM

All are intended for data rates in excess of 2 Mbps. CCSDS provides more freedom permitting an infinite set of filtered OQPSK modulations as well as FQPSK, and Shaped OQPSK. IOAG-8 submitted a Resolution to the CCSDS asking that the set of permitted modulation types be reduced to reasonable size.

All modulation types, except 4D 8-PSK TCM, are currently implemented in ESA stations. 4D 8-PSK TCM will be implemented in one dedicated station at Villafranca. The IOAG-8 Resolution to CCSDS recommended reduction of modulations. ESA proposes removing FQPSK, Shaped-OQPSK and a number of the filtered options.

There is a further task in CCSDS to identify modulation schemes suitable for 25 and 32 GHz, as well as into the 22 GHz bands where there is hoped will be a new Space Research allocation. Also, there is a need to look into 2 GHz modulation schemes for the Moon including spread spectrum techniques, based on the SNIP agreement.

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There is also an ECSS book for coding standards, entitled: *ECSS Telemetry, Synchronization and Channel Coding*, which is largely based on CCSDS 131, but is somewhat more restrictive. The ECSS Standard only permits Reed-Solomon codes, which can correct up to 15 bit errors. It also does not include rate 1/3 or rate 1/6 Turbo Codes. ESA has implemented the following codes in its stations:

1. Reed-Solomon (up to 16 bit errors)
2. Convolutional (rate = 1/2)
3. Concatenated Convolutional / Reed-Solomon
3. Punctured Codes (being implemented)
5. Turbo Codes (rates – 1/2, 1/3, and 1/6 are being implemented)

The ESA mission model does not require any new modulation or coding schemes. NASA believes that, for the new K-Band (26 GHz), existing modulation schemes can be reused.

Chairman Schulz stated that after having listened to the NASA presentation with its large number of modulation and coding options, whether these were all needed. Can't you identify a minimum subset in order to cross-support each other? From Dr. Hell's presentation it appears that ESA is trying to limit the set of standard options, whereas NASA appears to be doing the opposite. Can NASA live with minimum subset, because I have not seen a justification for this large group of options?

Chairman Schulz then asked NASA "Is the SNIP agreement important because it is used on TDRS? What is NASA's position regarding standardizing SNIP via the CCSDS? Mr. Rush replied that was an excellent suggestion. Dr. Warhaut observed that, in principle if we [ESA] were asked to be SNIP compatible we could do it, but we have no requirements, so we don't do it. Dr. Maldari noted that ESA is somewhat compatible because it has one ground station that is compatible, since it is used for Artemis and TDRS, but the ESA ground network is generally not compatible.

Mr. Rush suggested that the IOAG should review the SNIP material and make a decision at the next meeting as to whether further action is warranted. Dr. Warhaut agreed and noted that ESA does not have a backup scenario. He stated that those interested in making the SNIP agreement a CCSDS standard should make a proposal. Mr. Rush stated that, with the large number of relay systems envisioned for the future, there should be some standards to ensure interoperability. Dr. Warhaut recommended that NASA should come to IOAG-12 with an evolved SNIP, which they propose to make a CCSDS standard, the present SNIP will not make it. (B 009 1:44:15)

Dr. Warhaut summarized his understanding of the conclusions reached at the previous session: NASA will take an action to investigate the present SNIP, or a modified SNIP, or a completely new multi-access protocol should be recommended to CCSDS to become a standard. It was agreed by IOAG.

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Dr. Warhaut continued turning to the modulation schemes identified in the BMLP Report. He would like to have the full report. Dr. Deutsch replied that the report does not now exist. However, there is a large amount of backup material, which he will provide. Dr. Warhaut reiterated that he would like an official report from NASA stating that these are the modulation methods and the coding schemes that we need for our missions so the IOAG members can assess how far they subscribe to your findings.

Dr. Deutsch stated that there is no final report, it can and will be written, but he wanted to understand how technical experts from the international community could be engaged before writing the final report. Mr. Rush noted that NASA does not want to issue a final report only to find out that the international community has a large number of questions and comments. Mr. Hooke commented that the technical experts reside within the CCSDS and these reports will be sent to them for comment. The problem is that they do not have enough information yet on which to base comments.

Mr. Costrell inquired as to what the proper path is to obtain the necessary technical review. There was general agreement that it is the CCSDS RF and Modulation Working Group. Mr. Soula remarked that it was his impression that the IOAG should review the document in terms of requirements first and compare with the existing infrastructure. Only then can the IOAG determine whether standards should be generated. Dr. Warhaut saw the IOAG as a second step determining which modulation and coding types should be implemented only after a CCSDS determination that the proposed modulation types are worth of standardization. Following a polling of the IOAG delegations a consensus was reached that the Report should be sent first to the CCSDS for comment.

### **15.0 CNES STATUS OF IMPLEMENTATION OF INTEROPERABILITY STANDARDS (B 010 16:33)**

Mr. Jean-Marc Soula gave the CNES presentation. Mr. Soula reported on some activities initiated by CNES including thematic (why?), infrastructure (what?), and technology (how). Two roadmaps have been completed: a) mission segment infrastructure and b) control segment infrastructure.

A new Ground Network to Achieve Internal and External Interoperability roadmap has just been initiated. Internal Interoperability means that all of the ground assets will be compatible with all of the CNES flying missions. External Interoperability means compatibility with all IOAG members' missions particularly Category A missions. Existing sites could be closed and new ones may be opened. Future mission profiles will require a review of S-, X-, K<sub>U</sub>- and possibly K<sub>A</sub>-Bands. Coding will also be studied along with ground communications, and management operations. All will be considered in light of CNES missions and also the mission of CSES partners.

The evolution of CNES ground station will depend upon the proper standards being in place as well as the cost for new capabilities. CNES will look at COTS products as well as new technologies that can be used.

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The evolutionary process will depend upon the mission model, both present and future. These include Polar, Equatorial, Geostationary, and Highly Elliptical orbit satellites. CNES will analyze the requirements presented by the missions in the model for:

1. Frequencies and Spectrum
2. Ground-to-Satellite interfaces
3. Ground-to-Ground Communications
4. Security
5. Navigation
6. Monitor and Control of Mission Operations
7. Mission Operations Interfaces

In conducting these studies, CNES will be cognizant of SFCG and CCSDS Recommendations.

Ground Network architecture four elements have been identified for analysis:

1. Network Management
2. Ground Stations
3. Communications Network
4. Flight Dynamics

CNES will rely on CCSDS standards as well as upon IOAG decisions. Mr. Soula provided a mission model, mainly containing CNES satellites. The roadmap relies heavily on the mission model, particularly on main missions like SPOT, Helios, and Pleiades. CNES is developing a new, generic platform that may go as high as one ton. It may be used in as many as 12 missions starting in 2012. At this time, CNES cannot cover missions going to deep space. CNES will also implement a GMSK receiving capability in their stations.

Mr. Soula presented a chart showing the different types of orbits around the Earth, together with the frequency bands and the modulation types used for the different classes of missions. Previously, CNES did not have a highly elliptical Earth orbiting mission. S- and X-Band will be used for this new mission class, with X-band reserved for downlink payload data.

Dr. Tai inquired as to the CNES schedule for implementing a GMSK receiving capability. Mr. Soula replied that, based on the mission model provided, it would probably be 2014; however, the new platform being developed by CSES may accelerate that schedule.

Mr. Rush inquired about the ground interface. Mr. Soula replied that CNES will use TCP/IP and SLE. All future missions, starting with Pleiades, have adopted SLE, using TCP/IP.

A question was asked whether there are any future CNES missions that cannot be satisfied with existing CCSDS Recommendations. Mr. Soula replied that none have been identified to date; however, there are questions pertaining to modulation schemes for the new platform. The main issues that have been identified thus far apply to formation flying spacecraft.

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### 16.0 INTERNET PROTOCOL IN SPACE (B 010 38:35)

Nestor Peccia gave the presentation. Mr. Peccia started with some “facts”. First, no ESA mission has a requirement for an internet in space. The need to study and analyze this potential use of IP is recognized, mainly for technology trends and for potential cost reductions on the ground. IP can compliment CCSDS standards

Mr. Hooke commented that IP should run over UDP, because it has been substantially demonstrated that TCP will not work. Mr. Peccia responded that there are only proposals to study and analyze.

Second, ESA would like to discuss IP in space at the CCSDS and in the IOAG. Third, an evolutionary approach is always applied to the adoption of new technology in ESA. That means that a new technology must be backward compatible so that it can support legacy missions. Finally, ESA prefers to move forward in a controlled manner in response to real requirements.

Short-term IP activities in ESA include a study at Demokritus University in Greece. TRP/GSTP studies have been submitted for completion in 2008-2010. Examples include use of CFDP, DTN, and IP for both flight and ground applications. Internet-connected ground station cluster, Uses for an IP stack, Enhanced operation of satellite networks.

The university study in Greece will asses the impact on ESA ground stations of several scenarios proposed by ESA. Issues included are security, denial of service, how to synchronize Doppler and ranging measurements with UTC time. When the results are available, they will be shared with other agencies.

In summary, ESA has no firm requirements for IP in space. There is a need for a more networking centric model for space operations. A roadmap will be developed for such future operations. A roadmap approach should be adopted by the CCSDS to develop a common understanding as to how to develop future protocols.

Mr. Rush noted that one of the lessons learned from the space station is that technically we can distribute data directly from the ground station; however, when the operations people were consulted it was found to have problems. Will this study consider the operational aspects? Mr. Peccia responded that in ESA, ESCOC has the responsibility to distribute data.

In answer to a question: Does your study look at the advantages and disadvantages of using IP on the spacecraft for end-to-end routing of data? Mr. Peccia replied that this study focuses more on the ground. However a future study may look at the end-to-end application of IP.

### 17.0 USN DEBRIEFING (B 010 52:00)

Dr. Klaus-Juergen Schulz gave the presentation. A meeting was held at ESOC on 24 April 2007. Participants were CNES, DLR and ESA representing customer together with SSC and USN representing the providers. The meeting was triggered by the recent poor performance on Metop-A during LEOP for ESA and by the experiences of CNES and DLR.

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The experience is from two LEOPs in 2002 by DLR where initial acquisition and ranging difficulties resulted from hardware failures. As a result it was recommended to: a) Improve compatibility testing, b) Improve Monitor and Control to provide better visibility of station operational status, and c) Apply stricter configuration controls.

CNES also reported experiences with two LEOPs, one in 2004 and the other in 2007. Here, a variety of problems were encountered including: a) Problems with auto-track, b) Improper acquisition sweep procedure, c) Voice loop outages, d) Many telemetry data drops, e) Telecommand losses, and f) Poor ranging performance. A variety of recommended changes resulted from these anomalies.

ESA's problems with Metop-A LEOP in 2006 resulted from the fact that USN stations are remotely operated, even during LEOP. During Metop-A launch, a person was assigned to be at the station, but there was no ESA-station voice link, only an ESA-Network Management Center (NMC) voice link. NMCs remotely operate USN stations. ESA policy requires operators to be at stations during critical phases. There was very little hot redundancy and intervention, by local maintenance personnel, made only at the request of the NMC. A single point of failure was discovered in the communications with Kiruna. As a consequence, Svalbard was added to the LEOP support to mitigate risk.

Generally speaking, ESA finds USN's operational concepts to be more suitable for routine support than for critical event coverage. ESA's Materials Review Board found that: *Until evidence is provided that reliability and availability requirements for supporting LEOP and other critical operations are now met satisfactorily, further use of USN PioraNet stations for such activities is not recommended.*

Several suggestions for improvement were forthcoming from the providers. More emphasis will be placed on LEOP support as an entry to routine operations. PioraNet enhancements will include: a) Improved redundancy via multi-station coverage, b) Radio frequency compatibility testing to be done at the spacecraft manufacturer's facilities with representative station equipment, c) Harmonization of pointing data as well as with Cortex receivers at the stations, d) Provide a formal quality assurance process, and e) An improved escalation management process.

PioraNet improvements include: a) X-Band uplinks at Australian station, b) Increased S-X/S-X capacity at Hawaii station, c) Cortex baseband receiver outputs are not currently SLE compatible, but could be requested from In-Snec by customers, d) Diverse communications link routing through INMARSAT,

Dr. Schulz provided a list of potential future customer requirements and recommendations. Recommendations included a) USN should upgrade all stations to SLE and b) Expand capacity in the Pacific Ocean and in Australian regions to meet future European needs.

Mr. Hooke inquired about USN's reaction to ESA's recommendations. Dr. Schulz replied that USN responded that "in principle" they have the capability, but they are requesting a specific customer demand, because it is a software option. Mr. Rush commented that the more space agency users of commercial services that request SLE from USN, then the easier it will be to get.

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Mr. Rush then asked Mr. Liebrecht if NASA has conveyed this message to USN. Mr. Liebrecht replied that it had been discussed but that the missions that the GN is supporting do not use SLE. We would have to modify the mission control center to use SLE. That is not a huge deal; it is just some extra work. Mr. Rush reiterated that the more agencies that request SLE the more likely it is to be there. Chairman Schulz added that CNES, DLR, and ESA already have control centers that are SLE compliant. And that all future missions and most legacy missions have been migrated to SLE. Mr. Hooke suggested that the IOAG formulate an advisory communiqué to USB conveying the direction of the agencies, whether that would help to get things moving. Mr. Soula commented that USN received the message during the European meeting, but that vigilance will be needed to ensure that changes are actually made. He added that, with regard to SLE, NASA's opinion will carry a great deal of weight.

### **18.0 ESA GROUND STATION TECHNOLOGY (B 011 00:00)**

Nicolas Bobrinsky gave the presentation. ESTRACK is a combination of 15M and 35M stations operating in S- and X-Bands. It has undergone a 40-year evolution and is now technically sophisticated. ESTRACK stations support all ECSS modulation types, except 4D 8-PSK TCM, which as noted in a previous presentation, comprise a subset of those in the CCSDS 401 document. Stations also support the codes contained in the ECSS Telemetry Synchronization and Channel Standard. These too, were named in a previous presentation. Turbo and punctured codes should be available to users in 2008.

With regard to communications, X.25 has been substantially replaced by TCP/IP. CCSDS SLE User Services are operational in the control center and SLE Provider services have been deployed at the ESTRACK stations. Migration to SLE services over TCP/IP is complete, fulfilling ESA's commitment made during the 1999 IOP meeting. ESA is now fully interoperable with all international agencies having made the same transition.

For the future, ESA plans several upgrades including:

1. Adding an X-Band acquisition aid.
2. Implementation of  $K_A$ -Band downlink receiving capability at 26 and 32 GHz.
3. Addition of a third 25M antenna for X- and  $K_A$ -Bands.
4. Development of a new TT&C processor.
5. Provision of Cryo-cooled LNAs.
6. Development of a new tracking system.

Dr. Bobrinsky then provided details for each of the new initiatives. For specific details, readers are referred to his presentation, which can be found on the IOAG web site.

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Dr. Tai inquired why the 26 GHz receiving capability would only be implemented on 35M stations. Dr. Bobrinsky replied that one must consider the architecture of the antenna. First, 35M stations were designed to operate at 32 GHz, so the surface will clearly support 26 GHz. Second, the 35M antennas are Beam Wave Guide (BWG) making it much easier to add additional frequencies, such as 26 GHz. This does not preclude the future acquisition of a smaller aperture specifically for 26 GHz operation.

Mr. Liebrecht asked if the plan was for non-simultaneous support of both  $K_A$ -Bands. Dr. Bobrinsky replied that ESA is studying the possibility of simultaneous support of X and  $K_A$ -Bands, but they are not sure whether this is feasible.

Dr. Bobrinsky concluded with photographs of several of the technology developments.

### 19.0 JAXA CCSDS IMPLEMENTATION UPDATE (B 012 00:00)

Dr. Narita gave the JAXA presentation. JAXA adopted the CCSDS AOS Blue Book for both Telemetry and Telecommand. Dr. Narita provided a mission model showing missions from 1997 through 2008. With regard to the Space Link Service, JAXA is developing a Turbo decoding capability for deep space missions that will be installed at the Usuda ground station. Two antennas have been refurbished, one at Katsura and one at Okinawa.

There is an SLE gateway at Sagamihara, which is supporting MUSES-C and will support SELENE when it is launched. There is also an SLE gateway at Tsukuba. An SLE Service Management prototype is being developed for demonstration purposes. A feasibility study is underway for implementation of service management at Tsukuba.

JAXA Flight Dynamics has adopted the ODM model for SELENE. The agency has also participated in the CCSDS Delta-DOR White Book development with ESA and NASA to ensure interoperability. Dr. Narita concluded with a table summarizing JAXA's interoperability status.

Dr. Warhaut asked if the Interoperability summary table is consistent with the presentation by Dr. Yamada. Dr. Narita replied that it is, but that the table covers both the Sagamihara and Tsukuba capabilities. Dr. Yamada clarified the matter by stating that the table he showed represented the core set of services that all agencies should provide whereas Dr. Narita's table shows only what JAXA has.

A question was asked as to JAXA's plans to provide specifications for JAXA Delta-DOR cross-support in the next 6-months to 1-year. Dr. Narita replied that studies are now underway as to how to mutually develop the translator and correlator. Unfortunately, he could not assign a date.

### 20.0 NASA NEAR EARTH NETWORKS CCSDS IMPLEMENTATION (B 012 4:18)

Philip Liebrecht gave the presentation. One of the problems has been how to obtain more bandwidth. Currently TDRS 8-10 have a 300 Mbps capability. However, that is a receiver limitation and the rate could be as high as 1 Gigabit if they were replaced. TDRS K and L will add  $K_A$ -Band and will launch in the 2012-2013 time period.

## MINUTES – IOAG-11

Three new 18M  $K_A$ -Band antennas are being implemented at White Sands, New Mexico. Two are dedicated to SDO and one to LRO. QPSK will be added to the GN to improve spectral efficiency. The SNIP agreement will be enshrined as a NASA standard. The 18M antennas will have S and  $K_A$ -Band and they are being designed for SLE compatibility. Obsolete receivers at Wallops and McMurdo will be replaced in February 2008 and that will provide SLE compatibility. The upgrade to the 5M antenna at Wallops, discussed at IOAG-10, is now on hold because it seems likely that it will be deactivated in the future.

SLE is being implemented on the Space Network (SN) uniquely for space station. That capability should be operation in September 2007. A test bed has been created for protocols, modulation schemes, and other things important to exploration and science missions. SLE benchmark tests will be conducted in the test bed only. There is no funding to install a generic SLE capability in the SN.

Tests are underway at JSC to evaluate link margins with rate =  $\frac{1}{2}$  and rate =  $\frac{7}{8}$  LDPC codes. GSFC is also planning tests on the same codes at White Sands at  $K_U$ -Band and  $K_A$ -Band for TDRSS, trying to get as much link margin as possible for Constellation. At this point only demonstrations are funded.

With regard to Service Management, there will be a unique opportunity in about two years. The present system is unsustainable and GSFC would really like to implement Service Management, provided that the CCSDS standard is sufficiently mature. Implementation in the SN is rather more complicated and will have to come at a later time.

A question was asked as to what will be the data rate of the LDPC decoder and whether it is both uplink and downlink. Mr. Liebrecht replied that it was both forward and return. He thought that the rate =  $\frac{7}{8}$  decoder's data rate was around 300 Mbps. Dr. Tai thought that the rate =  $\frac{1}{2}$  decoder, which is only an engineering model, was working around 50 Mbps.

### **21.0 DSN INTEROPERABILITY AND IMPLEMENTATION PLAN (B 012 12:30)**

Dr. Tai gave the presentation. All DSN interoperability capabilities will be based upon CCSDS standards, that has been the case and it will continue to be the case. He provided a table summarizing various services and the solutions selected. There are two problems with the DSN's implementation of SLE in terms of CCSDS standards compliance: a) The DSN's API implementation was early and was based on a Red Book and b) DSN implementation of the Telemetry Return All Frames service is at the network control center, rather than at the station where it belongs. Unfortunately, there is no current plan to upgrade the system for compliance with the CCSDS Blue Book. The earliest date that the All Frames and Return Channel Frames services can be migrated to the station appears to be October 2009.

Work has been in progress on a Service Management prototype since 2003. The plan is to work with JAXA and ESA using targeted missions such as Hayabusa, Rosetta, and ALOS. At this time, there is not a specific plan for Service Management implementation in the DSN.

## MINUTES – IOAG-11

For Radio Metric Tracking services, we must wait for the Tracking Data Messaging standards. At this point there is no CCSDS standard to comply with. The DSN has completed some testing of the draft CCSDS Tracking Data Messaging standard, but nothing more. Delta-DOR is being standardized and JPL has been very active in working with other agencies in sorting out interoperability issues.

Significant headway has been made with the CCSDS File Delivery Protocol (CFDP). Two additional missions have agreed use CFDP and they are Mars Science Laboratory (MSL) and JUNO. The list is now:

1. Deep Impact
2. Messenger
3. MRO
4. MSL
5. Juno
6. JWST
7. Space Interferometry Mission

In terms of Predicted trajectory, the DSN supports the CCSDS Orbit Data Message, which includes the Orbit Ephemeris Message and the Orbit Parameter Message. The DSN prefers the full ephemerons, but can accept just the state vector.

MRO will be the first mission carrying the Electra proximity link package. Currently, there are no plans to implement GMSK because no NASA missions are planning to use it. Higher data rates and spectrum congestion has accelerated a move to 32 GHz. By 2008, all 34M BWG stations will be equipped to receive 32 GHz. MRO, Kepler, and SIM will use K<sub>A</sub>-Band. The DSN is also committed to provide 26 GHz support to JWST.

Turbo decoding is implemented and is used by most NASA deep space missions. The maximum throughput is limited to 1.6 Mbps. No increase in this capability is foreseen before a decision is made on the use of LDPC codes. We would like to see LDPC codes become a CCSDS standard.

Dr. Bobrinsky asked about the data rate supported at 26 and 32 GHz. Dr. Tai replied that the DSN is being implemented with a 150 Mbps receiving system. At 32 GHz, MRO is currently 6 Mbps and SIMM is planned for 5-10 Mbps.

Dr. Warhaut had several questions:

1. Are you phasing out 26M stations? Answer: 26M stations are currently scheduled for retirement by October 2008.
2. What SLE Services are being moved to the stations? Answer: The Return All Frames and the Return Channel Frames will be moved. Eventually, the Tracking Service will be at the stations also.

## MINUTES – IOAG-11

3. When the SLE services are migrated to the station, will ESA have to have lines to each DSN tracking complex or is the route still through JPL? Answer: The communication is still to JPL, even though it is routed directly to a station. At the physical Link Layer, the routing is not evident. At the Network Layer and above, the difference is apparent.
4. Did you say that you do not have a formal statement that ExoMars can be supported by MRO although by a CCSDS Proximity-1 link? Is this correct? Answer: Yes.
5. What happens if MRO fails? Answer: MRO will not fail, but in that event, Odyssey would take it.

Another question was asked whether the Proximity-1 link will support CFDP. Dr. Tai replied if a spacecraft is cross-supported by a NASA relay satellite and by NASA's DSN, then you will get the files. Proximity-1 and CFDP are not linked, they are different layers.

Another question was: For ExoMars, would you like to use CFDP? Dr. Tai replied in the affirmative. Doing it that way permits cross-support at a higher level.

Dr. Warhaut asked if NASA still planned to have direct links to landed assets. Dr. Tai replied yes, MSL will have a direct X-Band link.

### **22.0 SLE SERVICE MANAGEMENT DEMO (B 013 00:00)**

Dr. Narita gave the presentation. The objective of this demonstration is to validate the SLE Service Management prototyping and to demonstrate interoperability among agencies. The demonstration should validate the message exchange protocol, gain experience in security techniques, help to identify best practices, and validate that the technology is mature. NASA/JPL and JAXA/ISAS have been cooperating in this effort.

A plan for the prototyping was introduced at IOAG-10. The following tests are included in that plan:

1. Interface Test: To verify interfaces between provider and users
2. Shadow Testing: To verify end-to-end interfaces and procedures of SLE Transfer Service utilization

Dr. Narita provided diagrams showing test configurations. A schedule was given showing concurrent prototyping by JAXA and NASA/JPL with ESA joining a few months later. Mr. Peccia commented that ESA will have a prototype completed in January 2008. JAXA and JPL will complete a test plan in July 2007. Shadow Tracking tests are planned for mid October 2007.

The Chairman adjourned the meeting for the day.

## MINUTES – IOAG-11

C> WEDNESDAY, 20 JUNE 2007 (C 013 00:00)

Chairman Schulz called the meeting to order. The meeting began with a discussion of several items from the prior day's meetings.

Dr. Warhaut wished to return the IOAG's Liaison Statement inquiring about the future use of the 2 GHz band and the Mission Model parameters. He specifically wanted to know if the Liaison Statement was acceptable to NASA. He read the Liaison Statement. The Liaison Statement also asked the SFCG to provide the mission model parameters needed. It was found acceptable by all agencies.

Dr. Warhaut complimented NASA on its detailed future architecture presentations; however, he wondered how many of the requirements presented for Constellation were based upon real versus anticipated needs. He acknowledged that we must consider IP in space as a future technology which will be needed; however, he thought the pace suggested by NASA might be a bit too challenging, considering that the European program will not be defined until the Council meets in November 2008. He recommended using the next two years during which time all agencies should study the applications and meet in mid-2009 to reach a joint conclusion.

Mr. Hooke responded that it now appears clear there will be a need to move to an Internet type environment in space. Moreover, European Industry is one of the most vocal proponents of this position. Dr. Warhaut responded that he agreed that there will be a need for an internet type capability in space; it is only the pace with which he is concerned. ESA's future plans will only become clear after the Council meeting next year.

Mr. Hooke proposed that on a two-year horizon, the Mars Working Group takes on the task of how to internet across the solar system. They would produce a recommendation on a two-year horizon. For the immediate future, SLE is quite capable of providing what Constellation needs. We have the ability, at the SLE level, to cross-support what Constellation wants to do. The interface will be at the frame level. Several agencies have said, if we want to deal with IP over those frames, then it should be done using the CCSDS standard way of putting IP in those frames. That statement needs to be formalized. Dr. Hell and others expressed reservations about this approach saying that it would compromise many of IP's benefits and that it may become enshrined as the only way to handle IP. Mr. Costrell stated that NASA will continue to study IP and report its findings at the next meeting.

Mr. Hooke commented that we currently have layered standards and between each layer there is a clean, well defined, accountable interface. Serial interfaces are neither clean nor well defined nor accountable. They are just streams of bits. If we allow missions to start introducing "dirty interfaces", which is what serial streams are, we are going to lose future accountability. One of the problems with CCSDS standards is that they allow these "private interfaces". That is done for good reasons, but it precludes the CCSDS from regulating these "private uses". Therefore, for potential cross-support situations, the IOAG must take a position.

It was agreed to create an IOAG subgroup to study Internet in space issues and report back in approximately two years. All agencies are welcome to participate. The product will be a consensus strategy for space internetworking. Chairs are Mr. Maldari and Mr. Rush.

## MINUTES – IOAG-11

The discussion then turned to the proximity link. Mr. McKay commented Proximity-1 is basically a serial interface and that is causing substantial problems. Dr. Yamada commented that ExoMars is basically end-to-end Packet Delivery service. The problem is that there is no infrastructure that supports that service and he believes there should be. We should add that service to our catalog. Dr. Tai said that we should focus on a reliable packet delivery service over the proximity link first. The Electra proximity link does not have that capability. First we should work on that deficiency and then upon end-to-end packet delivery. Thereafter, we can address the file delivery service

### **23.0 SPECTRUM ISSUES IN AUSTRALIA (C 015 00:00)**

Manfred Lugert gave the presentation. He presented the spectrum problems that ESA has experienced with 2 GHz in metropolitan areas of Australia. The Australian Communications Management Authority (ACMA) has received denial of service complaints over many years forcing it to re-plan locations of spacecraft tracking facilities. Additional services will be entering the 2 GHz band over the next three years. ACMA has also told ESA that there is an absolute deadline to cease transmissions from the Perth, Australia station by the end of 2015. ACMA suggested relocating the Perth station to New Norcia. ESA will move its Perth station to New Norcia.

There is an embargo on any new frequency assignments at S-band frequencies. News gathering systems are being relocated into the Space Research bands. Wide-band access systems will be entering the 2 GHz band. This increases the risk of interference with spacecraft communications. Mr. Struba pointed out that there is an ITU-R Recommendation not to put high density systems in the 2025-2110 and 2200-2290 MHz bands. Dr. Vassallo pointed out that Australia is putting these high density systems in the 2.5 GHz band and, to make room, they moved the News Gathering systems to the Space Research service bands.

There is also an embargo on a portion of the 26 GHz band that is being auctioned for commercial purposes. ESA also raised concerns about the 23.6-24.0 GHz band, which is a passive band, because ACMA has automotive radar systems in that band. Mr. Struba pointed out that NASA has met with the ACMA and described NASA's needs for the 26 GHz band.

Dr. Narita pointed out that JAXA is facing the same situation in Australia. JAXA would like to work with ESA on this matter.

### **24.0 LUNAR-MARS EXPLORATION (C 015 30:30)**

Three presentations are included in this session. One is by ESA and two are from NASA.

#### **24.1 NASA LUNAR EXPLORATION PLANS (C 015 30:30)**

Scott Greatorex gave the presentation. A Constellation manifest was provided. NASA has selected a contractor and they are going through the design phase for the crew vehicle (CEV). It will carry up to six persons.

## MINUTES – IOAG-11

Lunar robotic exploration has been somewhat curtailed, but still has two missions: LRO, which orbits the Moon for about a year, and LCROSS, which is an impactor. LRO will utilize 26 GHz for science data return and 2 GHz for TT&C. Laser tracking will also be included.

LCROSS consists of two elements. The booster impacts the Moon and releases a mass to excavate the surface. A second element then flies through the ejecta to sample for water.

A lunar communication satellite is envisioned; however, since NASA is in the process of defining its architecture, the concepts presented here are somewhat outdated. It includes orbiting communications satellites and an infrastructure on the surface. It also includes a package for communications between the Earth and the Moon.

For human exploration of the Moon, a heavy booster would place the crew in lunar orbit. Thereafter the entire crew would descend to the lunar surface using a Lander/Assent vehicle. To return, the same strategy would be used.

Mr. Costrell added that the expected time period for a Moon landing is 2019-2024.

### **24.2 NASA MARS EXPLORATION (C 015 42:00)**

Wallace Tai presented the material. Dr. Tai provided the Mars mission model consisting of Mars Odyssey, ESA's Mars Express, MRO, and Phoenix. MSL will launch in 2009. Two Mars Scout missions are competing for selection. The winner will launch in 2011. Mars Science Orbiter will launch in 2013 as will ESA's ExoMars. Mars Scout is an ongoing program and will have additional missions in the future. A Mars Sample Return mission will take place some time after 2020.

MER uses 7/8 GHz (X-Band) for communications with Earth. And UHF is employed for the proximity link. A "beacon mode" set of tones will be used for entry, descent, and landing.

Mars Reconnaissance Orbiter (MRO) carries Electra, which provided the Proximity-1 protocol. AOS frames and CFDP are used on the deep space link. After its primary mission is complete, MRO will serve as a relay link.

The unacknowledged mode of CFDP is used on MRO. Dr. Warhaut wondered whether the CCSDS standard should be modified to indicate that this is not a preferred mode of operation. Mr. Hooke predicted that in two years the group formed earlier will come back with a plan to have CFDP as an application running over DTN, running over LDP, which provides reliability across the link, in turn running over AOS TM and TC.

Phoenix will carry a Cincinnati Electronics transceiver to communicate with an orbiter to relay information to and from Earth. There is no Direct-to-Earth (DTE) link, once the spacecraft has landed.

MSL is a lander that will rely on MRO and Odyssey as relay satellites; however, it will also be equipped with a DTE capability. It also utilizes CFDP, but in an unacknowledged mode.

## MINUTES – IOAG-11

Dr. Tai went on to describe missions for the next decade, but little is known about their communications plans at this time. Readers are referred to his presentation on the IOAG web site for the details. Current NASA policy requires all Mars Orbiters to carry a relay package.

Forward and return links, which are relayed through an orbiter using the Proximity-1 protocol, utilize the reliable bit-stream mode. These data are encapsulated into a series of CFDP PDUs, stored on the orbiter, and then relayed to their destination.

Dr. Tai identified four interoperability issues:

1. Electra only implements a bit-stream mode, making it incompatible with ESA's packet mode.
2. A method is needed for end-to-end data accountability for frames and packets.
3. Use of CFDP for reliable data transfer (operation in the acknowledged mode).
4. There is a need to define a security standard.

### **24.3 ESA LONG-TERM STRATEGY FOR SPACE EXPLORATION (C 015 1:16:39)**

The presentation was made by Michael McKay. ESA desires to extend human, real and virtual access, in the Earth, Moon, and Mars. The approach within Europe is to align European goals and aspirations with political goals and aspirations into one strategy.

Mr. McKay presented a chart showing different destinations and ESA experience in each. He also presented a slide containing strategic principles, such as:

1. Avoiding single points of failure.
2. Limit dependence on single partners.
3. Build European competence.
4. Utilize existing infrastructures.

He noted that cross-support from the DSN has increased the data return from Mars Express by a factor of nearly five times that originally expected. He observed that is what cross-support provides and why it is so important.

ESA objectives are to secure the investment made in the space station, to launch Columbus, and to achieve European human access to space with the development of a crew exploitation or exploration vehicle. ESA wants to be a significant participant in the exploration of Mars, not only with Mars Express, but also ExoMars.

## MINUTES – IOAG-11

With regard to space station, ESA is looking forward to the launch of ATV early next year. ESA is also looking at a cruise transportation system, which is in the definition phase, hopefully in cooperation with the Russians.

There is a lot of interest in going back to the Moon. Many agencies are planning missions. ESA has no Moon missions identified at the moment, but ASI and DLR do. Currently ESA is focusing more on Mars. ESA is looking at a Mars Sample Return mission in the 2020 time frame. ESA is examining strategies for identifying technologies needed for human exploration of Mars. No time frame for such missions exists today.

ExoMars will be launched with an Ariane 5, as an alternative to a Soyuz-Fregat launch. Doing so would permit a direct transfer using an Ariane 5, a later launch and an earlier finish for the mission. There is an Ariane 5 for interplanetary escape transfer in 2013 with a backup in 2016. This is a lander so it is most important that a relay be available. It is a six month mission with a potential for a six month extended mission.

A question was asked about a potential problem with the proximity-1 protocol. Both ESA and NASA have implemented the protocol legally and yet their services are not compatible. There needs to be a guideline to ensure cross-support is possible. There was wide agreement on this matter.

### **25.0 IOAG WORK PLAN (C 015 1:30:25)**

Wallace Tai gave the presentation. He began by providing some background on the action item. A question was raised at IOAG-10 as to what work is needed to achieve interoperability at the Moon and Mars. Some questions need to be addressed before defining a plan. First, should the work plan be limited to interoperability at the Moon and Mars, or is it broader than that?

When no agency responded, Dr. Warhaut suggested that all member delegations look at the presentation and decide to what extent such a work plan is needed. The questions are:

1. Do we need such a work plan?
2. If the answer is yes, is this the correct list of topics?

Mr. Costrell asked to review the need expressed at IOAG-10 for such a work plan. Mr. Martin responded that there were two Technical Meetings held at the recommendation of the U.S. State department to:

1. Develop a spectrum plan.
2. Define a roadmap to achieve interoperability.

## MINUTES – IOAG-11

Following the Second Technical Meeting, several agencies proposed:

1. Spectrum matter be handled by the SFCG. They established a separate group for the task.
2. Interoperability should be handled by the IOAG.

The focus at the time was lunar Mars.

Mr. Costrell commented that the IOAG is handling the task in a different way. NASA's opinion was that it was premature to set up a working group. Dr. Warhaut agreed. Mr. Struba disagreed, saying this is an excellent opportunity to: a) establish the needs of an exploration program and b) have sufficient time to examine the issues to ensure that there will be interoperability at the Moon and Mars.

Considerable discussion followed and it was concluded that a work plan specifically for the Moon and Mars is not needed at this time. Several items of work have been identified as at this meeting and that work will apply to Moon and Mars missions as well.

### **26.0 Remainder of Wednesday Session (c 016 99:00)**

The remainder of the late Wednesday afternoon session was spent in discussions about the:

1. Mission Model
2. Tracking Assets
3. ISEO Membership
4. IOAG Terms of Reference
5. Liaison Statements
5. Next Meeting
7. A.O.B.

The results are embodied in a series of resolutions and Action Items appended to these Minutes or on the IOAG web site.

Mr. Costrell stated that his view was that the Mission Model and Tracking Assets documents are on-line and are updated separately from IOAG meetings, obviating the need to discuss them at this meeting.

Chairman Schulz polled the Agencies regarding ISRO's admission to the IOAG. There being no objections, ISRO was unanimously elected as a full member to the IOAG.

The Terms of Reference were discussed and modified.

A discussion of the Standards Infusion Table followed. Mr. Soula suggested agreeing to 2-3 terms indicating the current status. Two terms were agreed upon *Existing (E)* and *Partial (P)*. *Blank* indicates the capability does not exist, but may be added at a future time. Remove the "available for cross-support" under Note 1.

## MINUTES – IOAG-11

Dr. Hell presented his recommended list of Cross-Support Services generated by a team consisting of Dr. Hell, Mr. Hooke, Dr. Yamada, and Mr. Soula.

Liaison statements were discussed:

1. SFCG
2. Space Internet Strategy Group (SISG) Charter

		
<p data-bbox="701 743 1495 818"><b>IOAG-12 AGENDA</b></p> <p data-bbox="617 1101 1579 1240"><b>8 – 10 SEPTEMBER 2008 OBERPFAFFENHOFEN, GERMANY</b></p>		

# ANNEX 1: AGENDA

	<h2>IOAG-12 AGENDA</h2>	
<h3>MONDAY, 8 SEPTEMBER 2008</h3>		
14:00	MEET AT WEILHEIM TRACKING STATION GATE	DLR
14:15 - 16:30	TOUR OF WEILHEIM TRACKING STATION	DLR

## ANNEX 1: AGENDA

	<h1>IOAG-12 AGENDA</h1>	
<p><b>TUESDAY, 9 SEPTEMBER 2008</b> (DLR; Building 124, Second Floor)</p>		
09:00 - 09:30	WELCOME, OPENING REMARKS, LOGISTICS	M. PILGRM
09:30 - 10:00	ACTION ITEM REVIEW	SECRETARIAT
10:00 - 10:30	REVIEW OF WGSB UNDEXTAMEN AT IOAG-12 SFCG LIAISON REPORT <small>RELEVANT MATTERS OF INTEREST TO IOAG GOVERNING AT SFCG</small>	E. VASSALLO / W. MARTIN
10:30 - 11:00	CCSDS LIAISON REPORT <small>RELEVANT MATTERS OF INTEREST TO IOAG GOVERNING AT CCSDS</small>	A. HOOKE / N. PECCIA
11:00 - 11:15	BREAK	
11:15 - 12:45	SISG REPORT (INCLUDING 2010-2025 ROADMAP)	P. MALDARI / J. RUSH
12:45 - 14:00	LUNCH	

# ANNEX 1: AGENDA

	<h2>IOAG-12 AGENDA</h2>		
<p>TUESDAY, 9 SEPTEMBER 2008 (CONT.) (DLR; Building 124, Second Floor)</p>			
14:00 - 15:30	<b>AGENCY PLANS FOR LUNAR / MARS MISSIONS</b> <i>(OPTION - EACH AGENCY TO DESCRIBE PLANS FOR LUNAR AND/OR MARS MISSIONS)</i>	ALL AGENCIES	
15:30 - 16:00	SPACE EXPLORATION STRATEGY GROUP - POTENTIAL LIAISON	J.J. FAVIER	
16:00 - 16:15	BREAK		
16:15 - 17:15	MODULATION AND CODING (DRAFT RESOLUTION TO CCSDS)	L. DEUTSCH / W. HELL	
17:15	ADJOURN		

ANNEX 1: AGENDA

	<h2 style="margin: 0;">IOAG-12 AGENDA</h2>		
<p>WEDNESDAY, 10 SEPTEMBER 2008 (DLR; Building 124, Ground Floor)</p>			
<p>09:00 - 10:00</p>	<p><b>NEAR TERM MARS RELAY INTEROPERABILITY (SPACE &amp; GND)</b> <i>(DESCRIBE AND DISCUSS DRAFT RESOLUTION FOR IGIN2)</i></p>	<p>C. TAYLOR / W. HELL / W. TAI J. RUSH</p>	
<p>10:00 - 10:30</p>	<p><b>SLE CROSS SUPPORT SERVICE CATALOG</b></p>	<p>W. HELL</p>	
<p>10:30 - 11:00</p>	<p><b>SLE RADIO METRIC / DELTA-DOR SERVICES</b> <i>(PREPARE DRAFT RESOLUTION FOR IGIN2)</i></p>	<p>W. TAI</p>	
<p>11:00 - 11:15</p>	<p><b>BREAK</b></p>		
<p>11:15 - 11:45</p>	<p><b>SLE SERVICE MANAGEMENT</b></p>	<p>W. TAI</p>	
<p>11:45 - 12:15</p>	<p><b>IOP-2 BRIEFING</b> <i>(IGIN2 THRUST - NASA OBJECTIVES FOR IGIN2 MEETING)</i></p>	<p>J. COSTRELL / B. ADDE</p>	
<p>12:15 - 13:30</p>	<p><b>LUNCH</b></p>		

## ANNEX 1: AGENDA

	<h1>IOAG-12 AGENDA</h1>		
<b>WEDNESDAY, 10 SEPTEMBER 2008 (CONT.)</b> (DLR; Building 124, Ground Floor)			
13:30 - 14:00	FINALIZATION OF IOAG-12 RESOLUTIONS TO CCSDS	ALL	
14:00 - 14:30	FINALIZATION OF IOAG-12 RESOLUTIONS TO SPOG	ALL	
14:30 - 14:50	FINALIZATION OF IOAG-12 RESOLUTIONS TO CIO P-2	ALL	
15:30 - 15:45	BREAK		
15:45 - 16:15	IO P-2 AGENDA PROPOSAL	ALL	
16:15 - 16:45	IOAG MEMBERSHIP	ALL	
16:45 - 17:00	A.O.E.		
17:00	ADJOURN		

## ANNEX 2: ACTION ITEMS

1. **Provide Liaison Statement to SFCG regarding their preliminary findings regarding the long term use of the 2 GHz band.**

**Actionee: Secretariat  
Due Date: 30 June 2007  
Complete:**

2. **SFCG representatives to convey the desire of the IOAG to maintain the IOAG Mission Model for both the IOAG and SFCG. IOAG agrees to consider such modifications to the Mission Model as needed for SFCG purposes.**

**Actionee: W. Martin  
E. Vassallo  
Due Date: 30 Sep 2007  
Complete:**

3. **Provide draft copy of NASA CMLP Report for study/comment to CCSDS RF Modulation WG and IOAG Delegates explaining modulation and coding selection criteria and rationale.**

**Actionee: L. Deutsch  
Due Date: 31 August 2007  
Complete:**

4. **NASA to review SNIP Standard with a view to identify whether it can be used as is, or modified, or replaced by a new standard that includes Multiple Access; propose its adoption to other agencies as a CCSDS Recommended standard.**

**Actionee: L. Deutsch  
Due Date: 31 August 2007  
Complete:**

5. **Provide additional details regarding 32 GHz transponder problems occurring on MRO to IOAG delegates.**

**Actionee: W. Tai  
Due Date: 30 November  
Complete:**

## ANNEX 2: ACTION ITEMS

6. **Include updated Organizational Relationship diagram in IOAG Terms of Reference and post on IOAG web site.**

**Actionee: Secretariat  
Due Date: 30 June 2007  
Complete:**

7. **ISRO and JAXA should provide updates for the IOAG Cross-Support Mission Model and the IOAG Cross-Support Tracking Assets to the IOAG Secretariat for inclusion in the relevant tables.**

**Actionee: Mr. Shivakumar  
Mr. Narita  
Due Date: 31 July 2007  
Complete:**

8. **IOAG member agencies should review Mr. Yamada's Cross-Support Service Architecture Framework document. Priority should be given to the review of the template definition.**

**Actionee: IOAG Agencies  
Due Date: 30 Sept. 2007  
Complete:**

9. **Define what shall be on private IOAG web site portion.**

**Actionee: M. Pilgram  
Due Date: 30 Sept. 2007  
Complete:**

10. **IOAG member agencies to provide a list of those persons who need access to the private web space to the Secretariat.**

**Actionee: Heads of  
Delegation  
Due Date: 30 Sept. 2007  
Complete:**

## ANNEX 2: ACTION ITEMS

### 11. The following A.I. results from Resolution 11.1.1

- a) Update the Cross-Support Service Architecture to reflect presentations made by ESA and NASA at IOAG-11 and circulate to IOAG and CCSDS for review and comment.
- b) Create a baseline IOAG Service Catalog, indicating the “core” services that all Agencies agree to cross-support together with a phasing plan that indicates when new cross-support services will be added by Agencies in the future, and obtain IOAG and CCSDS review and comment.

Actionee: W. Hell  
Due Date: 14 Sept. 2007  
(issue-1)  
Complete:

### 12. The following A.I. results from Resolution 11.2.1

Provide IOAG with interim status reports relative to the IOAG goal of a Service Management Blue Book by the end of CY 2008.

Actionee: A. Hooke  
CCSDS Liaison  
Due Date: October 2007,  
May 2008  
Complete:

### 13. The following A.I. results from Resolution 11.3.1

Provide the IOAG with interim status reports relative to IOAG goal of finalizing the simplification of CCSDS RF & Modulation Recommendations CCSDS 401 (2.4.17A), 401 (2.4.17B), and 401 (2.4.18) by the Spring of CY 2008.

Actionee: A. Hooke  
CCSDS Liaison  
Due Date: October 2007  
Complete:

**ANNEX 2: ACTION ITEMS**

**14. The following A.I. results from Resolution 11.4.1**

**Notify CCSDS of IOAG decision to withdraw IOAG Resolution 8.7.1.**

**Actionee: A. Hooke  
CCSDS Liaison  
Due Date: October 2007,  
May 2008  
Complete:**

**15. The following A.I. results from Resolution 11.5.1**

**Provide IOAG with interim status reports relative progress on Delta-DOR standardization.**

**Actionee: A. Hooke  
CCSDS Liaison  
Due Date: October 2007,  
May 2008  
Complete:**

**16. The following A.I. results from Resolution 11.6.1**

**Provide CCSDS with IOAG Cross-Support Services Catalog and IOAG Infusion Matrix**

**Actionee: W. Hell  
Due Date: 1 Dec. 2007  
Complete:**

**17. The following A.I. results from Resolution 11.6.1**

**Provide IOAG with interim status reports relative to progress on the CCSDS Strategic Plan update.**

**Actionee: N. Peccia  
CCSDS Liaison  
Due Date: October 2007,  
May 2008  
Complete:**

## ANNEX 2: ACTION ITEMS

### 18. The following A.I. results from Resolution 11.7.1

**Notify the CCSDS that the IOAG does not approve the mode whereby IP datagrams are encapsulated within a private serial bit stream during transfer across CCSDS space links. Clearly state that the IOAG does not endorse this option, that it will not be cross-supported, and for future cross-support purposes then IP data transfer should be implemented using existing CCSDS mechanisms of encapsulation or direct IP multiplexing.**

**Actionee: A. Hooke  
CCSDS Liaison**

**Due Date: October 2007,  
May 2008**

**Complete:**

### 19. The following A.I. results from Resolution 11.8.1

**Establish detailed Terms of Reference and initial meeting schedule for Space Internet Strategy Group**

**Actionee: J. Rush  
P. Maldari**

**Due Date: 31 August 2007  
May 2008**

**Complete:**

## ANNEX 3: IOAG-12 RESOLUTIONS

Several Resolutions were adopted at IOAG-8. Many pertained to work of the CCSDS and were directed to the CCSDS Management Council (CMC). At IOAG-11, those Resolutions directed to the CCSDS were updated and actions were levied on IOAG members. The new Resolutions appear below.

- 11.1.1 IOAG-11 resolves to retire Resolution 8.5.1 and agrees to provide future guidance to CCSDS with respect to the desired Cross-Support Architecture and Cross-Support Service Catalog. IOAG thanks JAXA for assuming the leadership of this work and resolves to ask JAXA to work with the CCSDS to continue to develop the architecture. IOAG also resolves to create and maintain an agreed inter-agency Cross-Support Catalog.
- 11.2.1 IOAG resolves to retire Resolutions 8.1.1 and 8.4.1 and notes its satisfaction with the current CCSDS progress in developing standards for Cross Support Service Management and Cross Support Transfer Services. IOAG further resolves to ask CCSDS to report progress with a view towards finalizing a CCSDS Recommended Standards (Blue Book) for Service Management by the end of CY 2008.
- 11.3.1 IOAG resolves to retire Resolution 8.3.1 and notes its satisfaction with current CCSDS progress in simplification of CCSDS 401 (2.2.17B) and 401 (2.2.18). IOAG further resolves to ask the CCSDS to report progress with a view towards finalizing CCSDS 401 (2.4.17A) as Recommended Standards by the Spring of CY 2008.
- 11.4.1 IOAG resolves that no requirements for future high rate uplinks are currently foreseen and therefore resolves to withdraw Resolution 8.7.1,
- 11.5.1 IOAG notes its satisfaction with current CCSDS progress in standardization of Delta-DOR and therefore resolves to retire Resolution 8.3.1. IOAG further resolves to ask CCSDS to report progress on a regular basis.
- 11.6.1.1 IOAG notes that CCSDS intends to update its Strategic Plan and resolves to supply CCSDS with the IOAG Cross-Support Services Catalog and IOAG Standards Infusion Matrix as a contribution towards that update. IOAG further resolves to retire Resolution 8.2.1 and asks CCSDS to report progress on the new CCSDS Strategic Plan on a regular basis.
- 11.7.1 The IOAG takes note of indications from NASA that the transmission of IP datagrams across CCSDS space links has been proposed in a mode whereby the IP datagrams are encapsulated within a private serial bit stream. This operational mode is currently being considered as an implementation option in the “IP-over-CCSDS Links” Draft Recommended Practice (CCSDS 701.1-R-2 IP).

The IOAG does not endorse this option and it will not be cross-supported. Such an implementation is a private Agency matter and should not be documented by CCSDS. For future cross-support purposes, IP should be implemented using existing CCSDS mechanisms of encapsulation or direct IP multiplexing.

## ANNEX 3: IOAG-12 RESOLUTIONS

- 11.8.1 The IOAG resolves to form a Space Internetworking Strategy Group to reach international consensus on a recommended approach for transitioning the participating agencies towards a future “network centric” era of space mission operations. The group will focus on the extension of internetworked services across the Solar System, including multi-hop data transfer to and from remote space locations and local networked data interchange within and among the space end systems. In developing this strategy, the group will consider future mission requirements, projected technology trends and the current installed base of inter-Agency cross support capabilities. The final deliverable, which is due by the Spring of 2009, is a report that:
- a. Identifies a concept of internetworking operations and associated user scenarios;
  - b. Analyzes and recommends potential profile(s) of existing CCSDS standards necessary to implement future space internetworking;
  - c. Provides a road map for how Agencies will evolve to support the new capabilities

## **ANNEX 4: IOAG-12 LIAISON STATEMENTS**

### **Liaison Statement to the SFCG**

#### **Long-Term Use of the 2 GHz Band**

At the request of the IOAG, the SFCG has investigated the question of long-term use of the 2 GHz Radio Frequency (RF) band. The preliminary result of the SFCG survey was presented at IOAG-11 and the IOAG members concluded that:

*Acknowledging:*

- a). That 2 GHz (S-band) frequency re-use is expected to remain at the same level, except for deep space which will decrease;
- b). Allocations are not available in X-band for near Earth space-to-space links, and that such allocation is also unlikely to be obtained in the future;
- c). The need for proper coordination to minimize interference utilizing the SFCG recommendations and resolutions

*The IOAG invites the SFCG to:*

- 1) Firm-up their preliminary recommendations (attached hereto) at their September 2007 meeting
- 2) Take such action as is necessary prior to WRC-11 to secure an Earth-to-space Space Research service allocation of at least 500 MHz contiguous width in the 22.55 – 23.55 GHz frequency band to be utilized as necessary by space agencies.

In addition, the IOAG stressed the importance of using IOAG mission model as a single mission model to be used at high level for strategic planning purposes, and asked the SFCG to specify those parameters which the IOAG mission model would need to consider. This shall avoid different models being used with conflicting information.

The SFCG is invited to report back to the IOAG when its preliminary recommendations have been further studied and concluded.

## **ANNEX 4: IOAG-12 LIAISON STATEMENTS**

### **Charter:**

#### **IOAG SPACE INTERNETWORKING STRATEGY GROUP**

Co-Chairs: Paolo Maldari/ESA  
John Rush/NASA

The IOAG resolves to form a Space Internetworking Strategy Group to reach international consensus on a recommended approach for transitioning the participating agencies towards a future “network centric” era of space mission operations. The group will focus on the extension of internetworked services across the Solar System, including multi-hop data transfer to and from remote space locations and local networked data interchange within and among the space end systems.

In developing this strategy, the group will consider future mission requirements, projected technology trends and the current installed base of inter-Agency cross support capabilities. The final deliverable, which is due by the Spring of 2009, is a report that:

- a. Identifies a concept of internetworking operations and associated user scenarios;
- b. Analyzes and recommends potential profile(s) of existing CCSDS standards necessary to implement future space internetworking;
- c. Provides a road map for how Agencies will evolve to support the new capabilities

## ANNEX 5: IOAG-12 CROSS-SUPPORT SERVICES

Cross Support Service Type	Basic Cross Support Service	Function	Cat	ASI	CNES	DLR	ESA	ISRO	JAXA	NASA DSN	NASA GN	NASA SN
Forward Delivery Services <sup>1</sup>	Forward Bitstream Delivery Service	Deliver bitstream received from the ground user element to the space user element <sup>2</sup>	F									
	Forward CLTU Delivery Service	Deliver Communications Link Transmission Units received from the ground user element to the space user element <sup>3</sup>	C									
	Internetworking	Encapsulate IP datagram into SL-DU	F									

<sup>1</sup> What about dedicated AOS forward services as defined in the SLE Reference Model or is the CLTU service deemed sufficient?

TY: I didn't think the AOS forward service will be required by many projects, but I may be wrong.

<sup>2</sup> Does this refer to AOS bitstream over the spacelink?

TY: It is a service for transferring undelimited bit streams (not the AOS bitstream), but I'm not sure whether it will be required by many projects.

<sup>3</sup> I feel that the CLTU service specification is deficient in the sense that the PLOP and the associated behavior is in essence undefined.

TY: JAXA has been using the CLTU Service with three networks without any problem. Information on which of the two PLOP's is used should be transferred by Service Management.

## ANNEX 5: IOAG-12 CROSS-SUPPORT SERVICES

Cross Support Service Type	Basic Cross Support Service	Function	Cat	ASI	CNES	DLR	ESA	ISRO	JAXA	NASA DSN	NASA GN	NASA SN
	Forward Space Packet Delivery Service <sup>4</sup>	Deliver Space Packets received from the ground user element to the space user element	O									
	Forward File Delivery Service	Deliver files received from the ground user element to the space user element with CCSDS File Delivery Protocol <sup>5</sup>	F									
Return Delivery Services <sup>6</sup>	Return Bitstream Delivery Service	Deliver bitstream received from the space user element to the ground user element <sup>7</sup>	F									

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<sup>4</sup> This service is also required as tunnel for IPv6.

TY: That's true. But it's also true for any packets that are encapsulated in the Space Packet.

<sup>5</sup> Shall that include a reliable uplink? Where shall be the service access point? Where the loop shall be closed?

TY: My assumption is that files are delivered hop-by-hop and the loop is closed in each hop. But I'm not sure whether this is a good assumption.

<sup>6</sup> Where shall we capture the different flavors of delivery modes? Which of them shall be basic/optional service modes?

TY: If you are talking about the Online/Offline modes, they appear as a service attribute in Annex A of my document.

<sup>7</sup> Does this refer to AOS bitstream over the spacelink?

TY: It is a service for transferring undelimited bit streams (not the AOS bitstream), but I'm not sure whether it will be required by many projects.

## ANNEX 5: IOAG-12 CROSS-SUPPORT SERVICES

Cross Support Service Type	Basic Cross Support Service	Function	Cat	ASI	CNES	DLR	ESA	ISRO	JAXA	NASA DSN	NASA GN	NASA SN
	Return Unframed Telemetry Service	Deliver telemetry data blocks, if possible frame synchronized <sup>8</sup>	F									
	Return Frame Delivery Service	Deliver frames of the TM or AOS Space Data Link Protocol received from the space user element to the ground user element	C									
	Internetworking	Extract encapsulated IP datagram	F									
	Return Operational Control Field	Extract the CLCW and deliver it to the ground user element	O									
	Return Packet Delivery Service <sup>9</sup>	Deliver Space Packets received from the space user element to the ground user element	F									
	Return File Delivery Service	Deliver files received from the space user element to the ground user element with CCSDS File Delivery Protocol	F									
	Telemetry Catalog Service	Delivers from the return service provider to the ground user element the list of available 'telemetry trains'	F									

<sup>8</sup> What shall be the implications in terms of delivering symbols only?

TY: I don't know. JAXA doesn't need this service.

<sup>9</sup> This service is also required as tunnel for IPv6.

TY: That's true. But it's also true for any packets that are encapsulated in the Space Packet.

## ANNEX 5: IOAG-12 CROSS-SUPPORT SERVICES

Cross Support Service Type	Basic Cross Support Service	Function	Cat	ASI	CNES	DLR	ESA	ISRO	JAXA	NASA DSN	NASA GN	NASA SN
Tracking Services	Radio Metric Data Service <sup>10</sup>	Perform radio metric measurements for the space user element and deliver validated radio metric data to the ground user element <sup>11</sup>	F									
	Delta-DOR Service	Perform delta-DOR measurements for the space user element using multiple tracking stations and deliver validated delta-DOR data to the ground user element <sup>12</sup>	F									

<sup>10</sup> Do we have to be more specific here in terms of which types of radio metric data shall be collected (as basic service / as optional service (antenna angles, Doppler (1-way, 2-way, 3-way), ranging (tone, code, hybrid, regenerative), meteo, other data required for calibration / correction). What types of ranging shall be supported? Which characteristics can be assumed regarding to the transponder? Should CCSDS be requested to work on a ranging recommendation?

**TY:** [These things should be described as service attributes in Annex A of my document.](#)

<sup>11</sup> Shall we really exclude delivery of raw data? In practice, we are doing that, but this will typically be based on bilateral agreements in terms of data format. Nonetheless, a standard delivery mechanism could be used.

**TY:** [OK. It is included in NASA's proposal.](#)

<sup>12</sup> Delta DOR has different flavors to it. If the service interface shall be on the basis of final products, the data volumes are small and we have little issues with data format. The draw back is that in this case we limit ourselves to baselines covered by one agency. If we strive for more flexibility, we also need to have a standard raw data format or suitable translators. The other question is, if we shall expand this service also to capture open loop receiver data, which implies the need to agree on raw data format or translator outputs.

## ANNEX 5: IOAG-12 CROSS-SUPPORT SERVICES

Cross Support Service Type	Basic Cross Support Service	Function	Cat	ASI	CNES	DLR	ESA	ISRO	JAXA	NASA DSN	NASA GN	NASA SN
	Trajectory Determination Service <sup>13</sup>	Perform radio metric and/or delta-DOR measurements for the space user element and deliver its positions and velocities to the ground user element	O									
Monitoring Service	??? <sup>14</sup>	Deliver monitor data related to service production and space link status	F									
Time Service	Spacecraft Time Correlation Service	Receive information on the onboard clock from the space user element and deliver to the ground user element correlation coefficients to convert the onboard clock time to UTC <sup>15</sup>	F									

TY: These things, as long as they are recognized by the CCSDS Delta DOR WG, should be described as service attributes in Annex A of my document.

<sup>13</sup> Is there a need for such service? Typically, the agency operating a space vehicle has the best knowledge (drag, mass properties, etc) that are needed for a precise trajectory prediction.

TY: JAXA has used this service provided by NASA many times.

<sup>14</sup> Do we need a monitoring service in its own right or is the standardization of the private annotation in RAF/RCF good enough?

TY: I think this should be included here when CCSDS has developed a standard for that.

<sup>15</sup> Such capability is certainly required, but I feel that we are lacking a standard within CCSDS on how the necessary data are captured.

TY: I think the only thing missing is a standard format for the Time Packet.

## ANNEX 5: IOAG-12 CROSS-SUPPORT SERVICES

Cross Support Service Type	Basic Cross Support Service	Function	Cat	ASI	CNES	DLR	ESA	ISRO	JAXA	NASA DSN	NASA GN	NASA SN
Voice and Video Services <sup>16</sup>	Voice Service	Relay two-way voice signals between the space and ground user elements	F									
	Video Service	Relay one-way or two-way video signals between the space and ground user elements	F									
Service Management	Service Production and Provision Management	Configure service production and provision <sup>17</sup>	F									

Do we also need to consider / specify additional services:

- Launcher services
- Beacon detection and tracking
- Automation of station operations
- Security
- RF Compatibility Tests

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<sup>16</sup> We had pertinent recommendations in the context of AOS that I believe have been withdrawn. Why was that done? Is anybody working on replacement recommendations?

TY: I don't know.

<sup>17</sup> Service management needs to be adapted to the scope of services that need to be managed.

TY: I agree. But I don't think service management should be an independent service. It should be included in each of the services as much as possible.

## ANNEX 5: IOAG-12 CROSS-SUPPORT SERVICES

- System / Station Performance Tests
- Simulations
- Rehearsals

Legend:

Cat: C = Core, O = Optional, F = Future (no service specification available to date.

supported

no plans to support

likely to be supported, when standard available

function supported, but 'private' service