**DRAFT**

**JOINT MEETING**

**Of the**

**INTERAGENCY OPERATION ADVISORY GROUP (IOAG)**

**And the**

**CONSULTATIVE COMMITTEE FOR SPACE DATA SYSTEMS (CCSDS)**

**MANAGEMENT COUNCIL (CMC)**

**15 November 2017**

**Darmstadt, Germany**

**European Space Operations Center**

Attendance:

Chair: Michael Schmidt/IOAG, James Afarin/CCSDS

Secretariat: Barbara Adde/IOAG, David Ross/CCSDS

IOAG Member Agencies:

ASI: Fabio D’Amico

CNES: Jean-Marc Soula

DLR: Rolf Kozlowski, Martin Pilgram, Osvaldo Peinado

ESA: Michael Schmidt, Michael McKay, Juan Miro, Nestor Peccia, Robert Daddato, Margherita di Guilio

JAXA: Tsutomu Shigeta, Kiyohisa Suzuki

NASA: Philip Liebrecht, David Israel, James Schier, James Stegeman, Les Deutsch, Wallace Tai

IOAG Observer Agencies:

CNSA: Shanbao He, Yonghui Huang

KARI: Sangil Ahn

Roscosmos: Dmitri Barannikov, Vladimir Yanik, Ivan Gulyaev, Andrey Dementyev (Eleonora Valodina – translator)

UAE: Adnan Alrais

UK-SA: Matthew Cosby

Other CCSDS Agency:

INPE: Eduardo Bergamini

Teleconference:

Josep Rosello/ESA, Catherine Barclay/NASA

*Agenda and presentations are available on the IOAG.org website.*

1. Gathering/Introduction: Chairs

The IOAG and CMC Chairs welcomed all participants to the first joint meeting of the two organizations in several years and attendees introduced themselves.

1. CCSDS Status Report: CCSDS Liaison/N. Peccia

Mr. Peccia provided a status report on the activities of the CCSDS since the last IOAG meeting, as well as the CCSDS vision on its relationship with IOAG. In this regard, he stated that the IOAG maintains an effective liaison to CCSDS, prioritizes its requirements relevant to space communications interoperability and cross support, and makes recommendations for standards development. The major challenge facing the CCSDS, he said, is achieving its goal within the current resource-constrained environment. Their approach is to comply with the IOAG requirements while also serving the needs of its different member agencies that the IOAG does not address.

In his overview of the CCSDS activities, Mr. Peccia stated that there are currently 147 active publications, 88 of which are normative and 59 of which are informative. These, as well as all their major publications since 1982 (approximately 336) are all available without charge from their website: [www.ccsds.org](http://www.ccsds.org).

The CCSDS last met at its Fall 2017 Technical Meeting in The Hague, Netherlands in the previous week, with over 210 participants from nine agencies and Eumetsat. Mr. Peccia reviewed the executive summary of the six subject areas: SE Area, CSS Area, SIS, SLS, MOIMS and SOIS. He noted that there will be a meeting near Washington, DC, in April.

An action is pending for review of the space packet protocol, which will result in a blue book but does not require any prototyping, he said. Mr. Peccia noted that the standard procedures will be distributed for agency review leading to publication of a green book; the working group has reached a way forward to include this in Service Catalog #1 (SC#1). The newly named Optical Communications Working Group has published many books within SC#1 and have finalized the draft for the high proton efficiency standard, which will be submitted to the CESG for agency review in the near future. It will be the first book requested by the IOAG that will start formal agency review, Mr. Peccia said.

Within the MOIMS area, the Mission Planning & Scheduling Working Group is working towards a blue book. The Navigation Working Group is continuing its work on eight navigation books; however, due to limited resources, they have decided to demote these to a draft project. The Spacecraft Monitor & Control Working Group still does not have an official product cycle, Mr. Peccia reported, but a work plan for the future has been established and promised. The Telerobotic Working Group is dormant and Mr. Peccia asked if there was a need for any standards in this area; there were none raised at this time. He also noted the achievements in the SOIS area, focusing on the interoperability test plan outline for EDS that was developed. This new standard will be important for cross support and interoperability.

Mr. Peccia cited the CCSDS new work items during the next six months and said that with 11 projects starting, there is a need for resources. He also provided the CMC poll statistics since May 2017, including published books and those under agency review, as well as approved charters and new projects since October 2017. He emphasized that CCSDS is doing its best to satisfy the requests from IOAG but that there are also mission requirements coming directly from various agencies.

Mr. Liebrecht thanked him for his efficient presentation and asked if first hop last hop was still needed. Both Mr. Peccia and Mr. Tai confirmed that it is still needed.

1. IOAG Status Report: IOAG Chairman/M. Schmidt

Mr. Schmidt began his presentation with a review of the IOAG organization chart, including the Interoperability Plenary as the guiding organization, and including both member and observer agencies, as well as several working groups and liaisons with other key international space organizations. Besides CCSDS, these include the Space Coordination Frequency Group (SFCG), the International Committee on Global Navigation Satellite Systems (ICG), and the International Space Exploration Coordination Group (ISECG).

Of the eight working groups that have been formed, two of them are currently dormant, the Coding & Modulation Working Group and the Space Internetworking Strategy Group. These should be revived in 2018 to provide a status report to IOP-4. The most recently formed working group, the Lunar Communications Architecture Working Group (LCAWG) is expected to provide a report in early 2018 to be used as an input for ISECG and for an ESA Strategy Paper on lunar communications, he said. The Low Earth Orbit 26 GHz Working Group (LEO26WG) is semi-active, originally created with the goal of enhancing the utilization of 26 GHz for the context of the LEO exploration missions to increase the data rate. This may evolve to include 22 GHz, he added. The Mission Operations Services Strategy Group is expected to finalize its report in mid-2018. The Optical Link Strategy Group is following the evolution of the optical links and will be reactivated in 2018 to prepare for IOP-4 and to follow the utilization of optical links in the Global Exploration Roadmap (GER). The Service Catalog Working Group, led by Mr. Soula and Mr. Calzolari, is maintaining SC#1 and SC#2 and interfaces to the relevant CCSDS groups. And finally, the Spacecraft Emergency Cross Support Working Group is an important activity, allowing cross support in relatively short notice for IOAG agencies.

Mr. Schmidt then focused on eight issues of common interest between IOAG and CCSDS, including: 1) maintenance of the SCs; 2) maintenance of the IOAG-CCSDS Product Agreement (ICPA) database; 3) mission operations services; 4) optical communication; 5) evolution of certain frequency bands, e.g., 26 GHz; 6) standardization needs for future GER; 7) Interoperability Plenary (IOP-4); and, 8) future IOAG-CCSDS interaction.

Regarding the future GER, Mr. Schmidt noted that the IOAG is closely following the activities of the ISECG, particularly in its ongoing activities in cross support. He recommended that the IOAG study the evolution of communication scenarios to find where standardization efforts will be needed. Mr. Schmidt proposed the third quarter of next year for IOP-4 as many of the working groups are finishing their activities with good results to present to the IOP members. This would be good timing to receive a new mandate for future work as well, particularly in the area of exploration, the role of commercial providers, and cross support between the agencies.

Discussion followed regarding the exploration program, which comprises various elements in space and on the ground provided by various entities (both government agencies and industry), which will require close coordination. It was noted that Mr. Tai had provided a briefing on the IOAG activities to the ISECG. He added that while both the Moon and Mars are in discussion, the Moon may be more immediate, with development that may be relevant for Mars. Mr. Liebrecht added that in this regard, the “near term” may mean multiple decades. Mr. Schmidt noted again the increasing role of commercial providers, and that the last IOP was held in 2013, before these issues were raised. He is interested in IOP guidance on the role of IOAG in coordinating future communication and cross support with commercial providers.

Mr. Schmidt closed by thanking Mr. Peccia for his excellent support as CCSDS liaison and interaction during the past 11 years, to which all agreed. He added that the IOAG is interested in maintaining the same kind of interaction with CCSDS (e.g., participation in IOAG teleconferences and meetings, and maintenance of the ICPA). Mr. Afarin joined the IOAG Chairman in his thanks to Mr. Peccia, and announced that as CMC Chair, he will now serve as the CCSDS Liaison to IOAG. Mr. Schmidt thanked him and welcomed him as liaison.

1. Service Catalogs: J-M. Soula

Service Catalog Working Group (SCWG) Co-Chairman Mr. Soula provided a status report on the two current IOAG service catalogs. He presented a list of team membership, reflecting eight participating agencies, and the IOAG organization chart, with technology drivers and requirements for international space mission interoperability. He said that the work of the SCWG requires coordinating with users on one side and with standards organizations, such as CCSDS. One of these activities is to define the service catalogs, which reflect the vision of the IOAG on how cross support can be managed between agencies in different configurations. He added that SC#2 is more complex than SC#1, with interfaces at the internetwork level. In the future, there will be a SC#3 under production, on which the Mission Operations Systems Strategy Group (MOSSG) will report later. Service Catalog #1 contains four general data services, he said, and the agencies rely on the CCSDS standards developed for them; the agencies are in agreement that all member agencies will use them. This is why the close relationship with CCSDS is so important for these service catalogs, and has led to the development of the ICPA to agree on architectures, interfaces, standards and their implementation. These catalogs are used within each agency as reference to develop new infrastructure. This discussion and vision works if we have a dialogue with CCSDS on the development of standard, he said.

Mr. Soula reported that the SCWG progressed with the discussion and update of both SC#1 and SC#2 during the past three years. An update to SC#1, version 2.1, was approved by eVote and issued on 28 February 2017. During the past year, five new services have been included for optical communication. He noted that the process in IOAG is to coordinate through infusion tables, in which all agencies report on their deployment of the services and associated standards. Each agency has the opportunity to deploy the new standards for the new services. The infusion tables have been updated and verified this year, and reflect the collection vision of the IOAG concerning the deployment and implementation of these standards to provide to the CCSDS as priorities for the next time frame. These are shared between the organizations through the ICPA.

The remainder of the presentation would be a joint IOAG-CCSDS presentation on the required standards and any challenges in meeting the need date for implementation, Mr Soula said. He added that IOAG will need to finalize its prioritization of standards during the meeting this week and consider the feedback, but that this meeting provides the opportunity of real-time feedback from CCSDS.

Mr. Soula noted that the core services in SC#1 are understood to be implemented by all IOAG agencies by 2020, while extended services will be considered for bilateral cross support. He followed with a review of the various services within the catalog and their priorities as established by the agencies’ planned use date. He strongly recommended that the agencies update their need dates so that the priorities can reflect actual requirements, which will enable the CCSDS to work towards those priorities. His conclusions for SC#1 infusion tables are: 1) no new core service could be identified; 2) the SC#1 infusion tables were considered mature enough to elaborate a revised version of the ICPA concerning those services; and, 3) the analysis of the infusion tables raised questions still to be discussed within the IOAG in order to update the ICPA.

Mr. Soula next addressed SC#2, noting that the updated SC#2 v 1.2 was submitted to IOAG approval before IOAG-20d teleconference. NASA comments received 12 November are still being analyzed. Mr. Tai clarified that NASA approved with its comments. The data for the SC#2 infusion tables were collected as Action Item (AI) 20f-08 but were received too late to update the ICPA in advance of the CCSDS Fall meeting. Mr. Soula stated that SC#2 identifies the cross support service types that should be provided by the ground tracking assets operated by the IOAG member agencies participating in the Solar System Internetworking (SSI) based on Disruption Tolerant Networking (DTN and/or Internet Protocol [IP]) technologies. It is intended to provide guidance to CCSDS with respect to the focus and priority of those standards that need to be developed, which are reflected as “to be written” in the tables. He then reviewed the status of the SC#2 infusion tables.

Mr. Liebrecht stated that NASA’s requirements for the time synchronization service predated CCSDS and meets the needs of its missions, adding that these can also enable international interoperability in the area of human spaceflight. Mr. Soula said that the IOAG message to CCSDS needs to be clear and represent all the agencies, and that the current tables are not final. He concluded on SC#2 by stating that these services, like SC#1, still need to be discussed within the IOAG and then be derived into a revised version of the ICPA. The analysis of the SC#2 infusion tables raise questions about the delivery agency service (first/last hop) as a core service and what priority should be given to the development of standards supported by one agency only.

Mr. Lord raised a point of clarification regarding the use of white to indicate no plans to implement a specific service. Mr. Soula recommends red to indicate no plans.

1. Service Catalogs: N. Peccia

Mr. Peccia proceeded to present the CCSDS response to the IOAG presentation on Service Catalogs, focusing on the need dates as provided by IOAG for the new services in both SC#1 and SC#2. He noted that only NASA has a need date of 2020 for file transfer for CFDP. Based on CCSDS experience with implementation of CFDP, it is very difficult to have cross support, but there are political issues, which need to be taken in to consideration; further dialogue will be needed. The issue is the same for forward file packet service with a need date of 2024. Regarding optical communications, it will be impossible to publish books by January 2019; it will require one year of development in CCSDS. He asked that the IOAG consider updating SC#1 to show the two different approaches for the physical layer on low complexity and high photon efficiency with different need dates, possibly in the 2020-2021 timeframe. Mr. Peccia asked if it would be possible to get examples of missions that will request packet file for return file services, such as NASA’s James Webb Space Telescope. There is the possibility for cross support, he said, although both teams were skeptical about doing this at the mission level. For other services, he noted that the need dates were not within the possibility of CCSDS’s resources and that they will have consider proposing alternative options to implementing these services. One possibility would be a small blue book or annex. His clear message to the IOAG is that need dates in 2018 are not achievable by the CCSDS. Other observations on SC#1 that Mr. Peccia raised include to improve the process in how the IOAG derives its need dates and asked the IOAG if there was a preference for more security or space data link security extended procedures.

Mr. Peccia then discussed SC#2, which he said has no corresponding draft projects in CCSDS. The old CCSDS Birds of a Feather (BOF) group on time services was disbanded years ago due to lack of resources but may need to be resurrected. He said that the need date of the end of 2020 for the First Hope/Last-Hop service will not be possible. He recommended a discussion with IOAG regarding the necessity of SOIS EDS. Mr. Peccia also noted several requests for clarification and need dates.

Mr. Tai asked about the utility of the ICPA to drive the development of CCSDS standards in terms of priorities. If it is based only on resources, then the utility is very limited as an instrument of strategic planning. Mr. Liebrecht agreed, adding that the IOAG needed to think strategically to meet the needs of its agencies missions. Although not all of the IOAG agencies have spacecraft with humans, those standards need to be higher priority for those agencies who do, he said. NASA will use this standard even if it is the only agency that does because it’s very important. He noted that ESA and JAXA are also expecting cross support for crewed vehicles. This needs to be a high priority, he said, otherwise the discussion is irrelevant with ISECG. Mr. Soula responded that the priorities come from the IOP so that the IOAG can prioritize and are not derived just from the service catalogs. There are new challenges with internetworking and optical communication, he said, so that the IOAG needs to reprioritize if the objectives are different. Mr. Peccia said that there are IOAG priorities, but he sees them as opportunities. Each agency needs to consider which services it wants to deploy, such as DTN, and determine the necessary resources to develop them. Mr. Afarin suggested that the two groups need to discuss their priorities. If an agency comes to the CCSDS and says it needs a standard and will provide the necessary resources, then the CCSDS will create that standard. Mr. Liebrecht pointed out that the agencies’ strategic initiatives are going to be driven by human spaceflight, with the International Space Station (ISS) as an example of a crewed spacecraft that wants more bits per second. The exploration community is driving the need for cross support and the IOAG needs to approach this strategically.

The Chairman agreed with Mr. Liebrecht’s statement and thanked both Mr. Soula and Mr. Peccia for their informative presentations.

1. Mission Operations Systems Strategy Group (MOSSG): Mr. Lord

Mr. Lord began his presentation with a review of the history of the MOSSG, noting that the CCSDS has been developing standards for mission operations services for some time. The previous working group, the Mission Operations Study Coordination Group (MOSCG) polled the agencies and various missions to arrive at a list of services that the agencies want to have standardized and those not interested in. The IOAG decided along with the IOP to take mission operations one-step further. From the MOSCG, the IOAG formed the MOSSG to lead standardization in this area, particularly concerning control centers to foster interoperability. The MOSSG’s objectives are to foster cooperation and interoperability among the IOAG agencies, specifically leading to greater integration, capabilities, efficiency, adherence to standards, and recommendations to IOAG agencies on how to better support each other, focusing on the steps to foster integration of these systems between control centers, he said. The MOSSG is required to deliver SC#3 concerning mission operations interoperability services with recommendations, a roadmap, findings, etc. to achieve this level of interoperability, which will be focused on a user perspective. The other deliverable is a report containing recommendations, a roadmap, findings, etc., to achieve this level of interoperability. The goal of MOSSG is cross support from an emergency perspective; operators in two different control centers commanding and controlling one system and seeing the same thing. He noted that an optional simulation or demonstration of the benefits of the technical approach was not exercised, but they do recommend that such a demonstration should be conducted by the IOAG in the future.

Mr. Lord stated that the working group conducted a gap analysis and completed a draft SC#3 in late 2016. This draft was thoroughly reviewed by every IOAG agency and CCSDS. The MOSSG started rewriting the report to include the many comments they received. The plan is for completion in the April 2018 timeframe so that there is time for the IOAG agencies to review it and decide how to incorporate it and bring it forward to IOP-4, he said. The IOAG will determine if the MOSSG should remain active, go dormant, or if its scope of work should be extended for further studies. He noted in closing that other than himself, all the members of the MOSSG are also members of CCSDS.

Discussion followed regarding the use of SC#3; Mr. Lord said that if the approach is format and messages, then the group could develop a converter/adapter/gateway and deal with it in that way. All those adapters be different for every agency, he said, adding that it would be better in the long term if the networks had defined gates that could be taken up in a hub, and then sent out. Mr. Liebrecht noted that when the MOSCG first started it, the mission being addressed was the ISS and its unique interfaces. He asked Mr. Lord what the IOAG can do to make it more efficient for projects of that magnitude in the future. Mr. Lord said the expectation is that it would be primarily bilateral and unilateral. In 2013, the focus was on a service-oriented architecture but a lot of agencies don’t want to be discoverable. That had been the intent but agencies aren’t comfortable with that. He said that the MOSSG is going to recommend setting up a mini-network with gateways to foster ease of connectivity. Mr. Liebrecht said that he thinks they would learn a lot by doing that. Mr. Peccia asked if SC#3 would be in the same format as SC#1 and SC#2, to which Mr. Lord responded that it was closely based on those catalogs.

1. Optical Communications Working Group (OCWG): Mr. Daddato

Mr. Daddato provided an update on the CCSDS Optical Communications Working Group (OCWG) on behalf of Mr. Edwards as the OCWG is attending meetings in Japan this week.

He began with a brief history of the IOAG’s Optical Links Study Group (OLSG) in 2010-2012, which studied interoperability for optical links. The group concluded with a recommendation for CCSDS to organize its own optical communication working group, which has been functioning ever since. This working group is now coming to the stage where it will start to produce output; its first set of blue books are now with the CCSDS editor in preparation for publication. The rationale behind this recommendation is to show the benefits of optical communication in relation to radiofrequency (RF) spectrum and to develop cross support between agencies, he said. Optical links are more susceptible to interference from the environment, such as clouds and aerosols, which can cause link quality to suffer. The driving idea behind this is to share the burden between space agencies by having multiple ground sites for various missions doing optical com downlinks to Earth, Mr. Daddato said.

The OCWG has two scopes: 1) physical, coding, and synchronization layer recommendations for the interoperability of flight and ground optical communication terminals; and, 2) recommendations for characterizing the atmosphere channel and for the concept of operations for space-to-ground links. The working group has been investigating the following three scenarios or “needs” for optical communication: 1) high data rate (HDR), 2) high photon efficiency (HPE), and, 3) low complexity (LC). The HDR concerns near Earth links, such as the European Data Relay Satellite (EDRS) and Japan Data Relay Satellite (JDRS), and direct to Earth links for low Earth orbit (LEO) satellites, he said. The HPE scenario is for deep space missions and could also entail miniature terminals on near Earth satellites or lunar satellites. The LC scenario is the most difficult to define in a way that all understand. The outcome from the CCSDS meeting is that the Optical Offkey Terminal is named now.

CCSDS has several books in work now; first are two blue books on the HPE scenario, one on the physical layer and the second on coding and synchronization. A green book has been completed and work has begun on a related magenta book. The original intention was to standardize the HDR in blue book standards, Mr. Daddato explained, but there was a difference of opinion, resulting in a decision to publish two experimental standards as orange books – one by NASA/CNES/JAXA/NICT and the other by ESA/DLR. Currently, it does not look like there will be consensus for a blue book. In discussing the architectural considerations of HDR throughput 1550 nm, he said that optical communications is mostly for interplanetary communication between planets over long distances. For a photon-starved channel, it is best to use direct detection. He noted pulse modulation, which was developed at JPL, and said that the maximum data rate of the link is no longer driven by technology, but by photon statistics. Different technical solutions are needed in HDR.

For HDR throughput 1064 nm, the book is based on ESA missions, DLR developments, and TESAT Spacecom LCT terminal developments. The key technical features are: 1064 nm wavelength, BPSK modulation, and 1.8 Gbps user data rate. The technical specifications ensure terminal compatibility and successful link operation. The future evolution of the orange book is foreseen to include: dual-wavelength terminals; increased data rates (3.6 – 7.2 Gbps); QPSK modulation, and novel coding schemes; and, WDM in the longer term for HDR, Mr. Daddato said. ESA and DLR consider the orange book to be a candidate for a future CCSDS recommendation providing interoperability with EDRS and complementary missions.

The LC scenario is the most complicated and has been a struggle, with one proposal having been re-written, Mr. Daddato said. He stated that the central idea of LC on-off-keying direct-to-Earth downlinks is to have small low-cost satellite terminals with minimum size, weight, and power. The idea is to reduce cost and development time by employing components used in terrestrial fiber communications around 1550 nm. The recommendation will allow a large range of data rates for various mission needs (1Mbps to Gbps). The intention is to implement standard coding for on-off-keying to mitigate interference. The green book for atmospheric characterization and prediction for optical communications is already in place. It includes a statistical study of weather at various sites, which can suffer from systematic effects, such as Sahara desert dust interfering with the ESA Optical Ground Station (OGS) on the Canary Islands. These techniques are used not only to operate links, but will also help decide how to handle links from one site to another, locations for sites, and how to coordinate between them. Characterization and prediction of the atmospheric channel are critical to inform space link handovers, select ground sites, and to maximize system availability, he said.

Mr. Daddato next reported on informing the magenta book through analysis of current atmospheric characterization data discussed in the green book. He presented a chart that reflects one study being conducted that compares concurrent infrared clouds and lidar measurement, and is attempting to establish a baseline between the two.

Mr. Daddato ended by saying that this is an exciting time for optical communications, and has the potential to enable new science and exploration missions throughout the solar system. International space agencies will come to rely on optical communication for high-bandwidth applications in the near future. International standards needs to be developed to enable interoperability and enable terminals built by one agency to use the infrastructure of another. International cross support of optical communications is the evolutionary next step to follow today’s radiofrequency cross support, Mr. Daddato concluded.

The Chairman thanked him for his presentation and asked if the need for standardization has been discussed at CCSDS. Mr. Daddato said that there has been a great deal of discussion in the working group, as well as work on two orange books. He said that specific technical implementation does not appear to be possible for HDR at this time. The Chairman asked if the standard is needed to implement some scenarios in the GER. Mr. Liebrecht responded that he believed a standard is needed for exploration vehicles, which are extremely mass- and power-challenged. It should be reasonable to implement one, he said, and the good news is that the international community is converging on a standard. Mr. Daddato agreed, saying the fundamental work is being done and proves that selective modulation is the optimum.

1. Low Earth Orbit 26 GHz Study Group: Mr. Rosello

Mr. Rosello reported on the work of the Low Earth Orbit (LEO) 26 GHz Study Group (LEO26GHzSG). They have had two releases of its report – one in June 2013 and one in November 2018. The IOAG tasked them in late 2012 in its Terms of Reference to: 1) facilitate the utilization of 26 GHz K-band (i.e. 25.5-27.0 GHz) direct space-to-Earth data downlink for future LEO missions, in the context of cross support; 2) develop high level Concept of Operations (CONOPS) and preliminary architecture inputs for a 26GHz K-band system for LEO; and, 3) determine the business case for cross support at 26 GHz for LEO applications.

He provided the table of contents for the latest report, noting that the focus is to facilitate its utilization in the context of cross support. Two main points he raised were the importance of propagation from one station to the next, and steerable antennas is a change with respect to x-band. The appendices are being updated; all these missions are very important today, he said. The first satellite using this frequency is JPSS; the launch was delayed but is expected today. Mr. Liebrecht clarified that the Joint Polar Satellite System (JPSS) is the first LEO satellite using Ka-band; there are others at the Moon. Mr. Rosello concurred, saying that the concern is that the International Telecommunication Union (ITU) models for preparation are well established for high elevation angles. He will address this in more meeting in the IOAG meeting tomorrow.

Regarding Appendix I, Mr. Rosello clarified the availability of three standards, noting that the Study Group (SG) can’t agree; the decision goes beyond the SG and IOAG. Mr. Liebrecht said he is familiar with the second standard, which is used extensively by industry. The third is used at the NASA Goddard Space Flight Center. Is the SG going to look at applicability and service, and develop recommendations on which is most effective? Mr. Rosello responded that other groups are doing just that. Dr. Deutsch said that he is working in both groups and the recommendation is to use VCN scheme; it is not the purview of this group to recommend which one but rather the CCSDS needs to solve this problem. Mr. Liebrecht suggested that the IOAG discuss this because it would be valuable to have agreement on just one of these three standards.

Mr. Rosello reported the next steps for the IOAG, as approved by IOP-3 in 2013 are to: 1) recommend its member agencies expand the propagation knowledge of the 26GHz band, and 2) request the CCSDS complete relevant standards. The part that has not been completed is the further development of the ACM/VCM protocols to guarantee interoperability. The complication of uplink can reduce all downlink information in CVM, which can improve in the operation and in particular with simultaneous transmission of commands and updating; therefore, space link extensions in that area could work. Interoperability for missions of different agencies with mission control center of another brings to issue if commands will be accepted, security aspects, etc. Mr. Cosby noted the example of Planet, operating in LEO, which presented at Smallsat conference in Utah, USA last year. Mr. Rosello agreed that this would be very interesting to study. Mr. Soula said that using a standard coming from the telecommunication community and making it compatible with all protocols and modulation of CCSDS would be one way to make New Space products from industry compatible with CCSDS standards. Mr. Rosello strongly agreed. After further discussion, Mr. Peccia said that they would return to this topic in the next presentation.

Mr. Rosello closed with the SG’s recommendations to IOAG-21. They intend to update their report with: 1) an updated missions inventory; 2) update Appendix H (propagation campaigns); 3) a new Lessons Learned appendix from expected launched satellites; and 4) a new Check List addressing decision aspects both on-board and ground. Mr. Liebrecht stated that this band can be used by commercial space entities and US government because the bands are totally different. Mr. Rosello answered that it is irrelevant to whether for government or commercial service, to which Dr. Deutsch agreed. Mr. Rosello said that they will also continue to focus on the IOP-3 recommendations and will expand to CCSDS, in particular the Variable Coded Modulation (VCM) protocol. Ms. Barclay added that they will be working with the agencies’ missions to develop the Lessons Learned to find any real or perceived issues for implementing.

Mr. Liebrecht suggested that before the IOP-4, the IOAG should conduct a case study regarding how many contacts it takes to get data from a mission using Ka-band and lower frequency bands to motivate them towards using Ka-band. There is a factor of five or ten improvement, which saves money for the agency. Mr. Rosello said that this is in Appendix G, which will be addressed in tomorrow’s meeting. With signal rates and power change there are many options, which can bring down 10 GB/sec; lower elevation angles have lower speed. It can be compared in Svalbard with what can be achieved with x-band, he said. Mr. Peccia added an important clarification that there is no additional recommendation for ACM; the additional tasks are agency specific. He asked if an Agency A would allow an Agency B to perform these steps, taking into account that ACM is real-time. If two agencies are using ACM that require an interaction at the ground station, this could have ITAR issues. Mr. Rosello responded that mission managers would ultimately decide if they want to operate through another station.

Both IOAG and CMC chairs thanked everyone for the excellent presentations of the morning.

Mr. Schmidt noted that the remainder of the day would focus on the GER and then discussed a conceptual lunar communication architecture diagram provided by Mr. Schier. It shows the complexity of the potential needs, different frequencies, and connections. Based on a proposal by Mr. Cosby, the IOAG created a Lunar Communication Architecture Working Group.

1. Lunar Communication Architecture Working Group (LCAWG): Mr. Cosby

Mr. Cosby presented on behalf of the LCAWG, which he chairs jointly with Mr. Tai. He reported that the LCAWG created an overall mission architecture for lunar orbit, with input from all IOAG agencies. They consolidated the requirements as their starting point to downselect frequencies, coding & modulation, and network layer to provide a simplified architecture that all IOAG agencies could support.

Following on from the Lunar Mars Working Group, the LCAWG prepared a series of tables for the IOAG agencies to populate. The IOAG has taken up the lunar architecture only for this working group because that is most pressing going forward, Mr. Cosby explained, with human spaceflight to Mars as the next stage. He presented charts that reflect the agencies’ planned lunar missions in the near term, approximately the next decade. The changes in these charts reflect S-band and x-band uplink and downlink from ISRO. He noted that the working group has excellent representation from across IOAG, and expressed the need for input from ISRO and Roscosmos. Mr. Tai added that Roscosmos provided good input as of this week, which is reflected in the spreadsheet. This exercise is to collect mission requirements. Mr. Cosby also discussed the commercial UK-SA mission, which uses CCSDS standards for both uplink and downlink.

The Deep Space Gateway (DSG) will be driving all development and frequency selection, Mr. Cosby stated, and the frequencies selected for DSG aren't in the SFCG’s recommended frequency list. This is an important issue that the working group identified. Mr. Tai stated that the DSG violated the SFCG recommendations in regard to proximity link, having selected near band x-band for low rate and K-band for high rate (instead of Ka-band). He said that he raised this during the review at the DSG international communications standards meeting. Mr. Cosby reiterated that DSG will drive the architecture through 2024-27; it is clear in the trend analysis that it dominates the changes. As an international endeavor, cross support will be critical, so we need to do this properly.

Mr. Cosby presented a graph representing all the planned cubesats and missions for NASA’s Space Launch System (SLS) and Orion, noting that Exploration Mission-1 (EM-1) is scheduled to take cubesats from NASA, ASI, and JAXA. These will require standards that can interact with NASA’s Deep Space Network (DSN) stations. Another graph provided a snapshot of requirements from the agencies’ missions. The LCAWG brought all of these requirements together, but it is not a proposal for architecture. The top three rows show a large number of frequencies, coding and modulation. He then discussed different scenarios, including communications from lunar orbit or the surface of the moon, including terrestrial commercial protocols, such as IP on the surface up to Disruption Tolerant Networking (DTN) around the moon. He said that there may also be an orange book for a few forward links which are not in CCSDS because NASA requires them. Mr. Cosby said that there is clear consensus regarding the network layer; all agencies have adopted DTN, there are no alternatives.

The next task of the LCAWG is to ensure the table is complete and accurate, he said, and then they can begin the work of down-selecting. The Lunar Missions chart reflects a very crowded environment with a high number of vehicles present as well as requests for cross support; the right architecture to allow this cross support is critical. He stated that ground based and other CCSDS link layers have been adopted by the agencies, which is good news.

He closed with a review of the next work items for the working group over the next few months, including down selection of frequency bands from collected mission requirements, and the definition of: relay service(s), Lunar Relay Network, Lunar Surface Network, Lunar-Earth Space Internet, and all service types. The LCAWG will next meet in the January timeframe to develop a proposal.

Mr. Schier posed several questions to Mr. Cosby, including a request for the inclusion of commercial entities in these tables, which he noted could be difficult to collect for a shared table. Mr. Schmidt said that ESA’s commercial sector representative has meeting with various commercial entities; some have made clear that they will not share what they are doing but will adopt whatever they need to in order to use the assets available. They won't invest in ground infrastructure, he said, and they will rely on cross support to enable their missions. This may not be true for all industry, he said. Mr. Tai stated that he had interaction with industry also; the challenge will be a requirement for these companies to be CCSDS compliant if they want DSN support. This is very hard for them to do, so they back off. For example, an Indian lunar mission approached NASA for DSN support because they don't have equivalent communication capabilities; they did not respond after that requirement was levied. He recommended that the IOAG should “contain our appetite” on including commercial participation. Mr. Schmidt noted that public-private enterprises are of keen interest in the current political environment and recommended that we work with industry so that communication in different directions can be standardized as much as possible.

Mr. Schier agreed and added that the DSG Request for Information (RFI) should be available for release in a couple weeks; there is a delay due to a translation issue. The RFI will be open for eight weeks, with responses due in the January timeframe; this input can be used as a source of information. Mr. Cosby suggested that January might then be well timed for the LCAWG to incorporate that input. Mr. Schier said that the DSG is one mission with four launch dates, similar to the ISS. The first element is power and propulsion, which is under intense schedule pressure to build and launch by 2022, so there will be minimal mission requirements. From our standpoint, the necessary standards already exist today. Mr. Cosby said that a stable architecture is good news and Mr. Schier added that testing new capabilities is an important part of success. Mr. Tai said that it is important to look at the overall DSG architecture to ensure that it is the right lunar communication architecture. Mr. Liebrecht agreed, adding that NASA’s three communication networks developed separately and have largely evolved for different communities over time. “We need to think how to do this more efficiently,” he said. Mr. Cosby agreed, saying that this provides robustness, offering the ISS as an ideal example of how not to approach the architecture.

The Chairman asked if they had identified standardization needs, to which Mr. Tai responded that the LCAWG will provide that information to the IOAG tomorrow and hopes that the IOAG reach a conclusion about including Ka-band 22GHz as well as 37-38 GHz. Mr. Liebrecht concurred, saying that these strategic decisions need to be taken by the IOAG at this meeting.

1. IOP-4 Overview: Mr. Schmidt

Mr. Schmidt began his discussion of the Interoperability Plenary (IOP) with a review of the IOAG organization chart, which was updated to reflect the seven member and seven observer agencies. Next, he discussed three drivers for holding IOP-4: to report on achievements since IOP-3 held (held in 2013); to clarify the future role of the IOAG, in particular regarding the GER; and, to clarify the future interaction with industry/service providers.

Mr. Schmidt then described the IOAG’s interaction with other related multi-national space coordination organizations: CCSDS, SFCG, ICG, and ISECG. He stated that the close cooperation with CCSDS is good with various results that can be presented (e.g., service catalogs, coding and modulation schemes, etc.) The cooperation with SFCG is also very successful, he said, with various results that can be presented to the IOP. The cooperation with ICG has increased in the last year; at the most recent annual meeting, the ICG formally adopted the IOAG’s database on GNSS payloads. There is a great deal going on with the ISECG, Mr. Schmidt said. The involvement of the IOAG in the ISECG has increased significantly this year. Mr. Tai provided a presentation to the ISECG on the IOAG’s related activities and Mr. Schmidt said that he is following the activities of their Technical Working Group and other working groups. In addition, the results of the LCAWG will be taken into account by ISECG for the Exploration Roadmap. He added that Mr. Liebrecht and Mr. Schier have established a close link with both groups, including with Ms. Laurini of NASA. He asked for feedback from the delegates.

Mr. Afarin asked if examples of the cooperative activities between these organizations and IOAG should be included in their presentations to the IOP. The Chairman answered that the four liaison organizations will be asked to make these presentations at IOP-4, as they did at IOP-3.

Next, Mr. Schmidt presented the status of the IOAG’s six working groups. The Space Internetworking Working Group is currently limited, but there is some progress that can be reported to the IOP. The Optical Communications Working Group has made progress with many ongoing activities. The IOAG can play a role in coordinating some activities regarding the utilization of optical communications, he said; for example, in the context of the future GER. The utilization of the K-/Ka-Band for Earth observation and deep space is growing, and the 26 GHz Working Group will have information to present to the IOP in the context of the future GER. Mr. Liebrecht added that the working group has met for the past two days during the IOAG meeting under the direction of Mr. Jon Walker of NASA, and can expect good results. The Chairman continued noting that the Mission Operations Services Study Group has had less progress in this field than expected, but can nonetheless provide a good report to the IOP as well. In the area of the Spacecraft Emergency Cross Support Working Group, they have achieved valuable results. The Chairman suggested that it would be extremely useful if the basic principles of cross-support could be demonstrated by a test mission before the IOP-4 is held. Finally, the most recently formed working group, the LCAWG, could have very important results that form the basis for a wider role regarding the coordination of communication activities.

Finally, Mr. Schmidt discussed two key initiatives that the IOAG continues to address – coordination with industry and the GER. He reported that there are currently some steps in the direction of a closer cooperation with commercial providers of communications services. This topic requires further discussion but could be an area where the role of IOAG will increase. He also stated that it is important to endorse the role of IOAG in the context of the GER. This is the right time to get a confirmation of the IOAG mandate as the corresponding activities are starting now (e.g., DSG communications). The IOP should clarify whether a coordination with industry should be followed up and what the role and mandate of the IOAG is in the context of the future GER, Mr. Schmidt said, and asked for any objections or comment from the participants.

Mr. Liebrecht said that he agreed that the IOP is the best opportunity to obtain IOP agreement on IOAG’s role in the GER. Mr. Tai added that it’s important to make the IOP aware that the global exploration community is not focused on communication and navigation; the IOAG has a complementary role to the ISECG to ensure common approaches for so many vehicles. Mr. Soula asked if the goal of clarifying the future role of IOAG to the GER was achieved already at IOP-3; the IOAG has made progress since then in this area. The Chairman agreed, but noted that other groups have been created since then and require coordination. Mr. Afarin said that he agreed that this was the right way to go forward but that dedicated resources will be needed, stating that “vision without budget is illusion.” Mr. Liebrecht suggested that with a year before the IOP-4, the IOAG should work to solve this internally first; the funding required is relatively low in perspective of the entire GER, but is critical to ensure mission success. The Chairman stated that the IOP can’t be used as a call for funds. Mr. Peccia responded that CCSDS would continue with its program of work with the resources in place. It is unclear if any new standards will be needed for GER.

1. CCSDS – Involvement of Commercial Providers/Industry: N. Peccia and W. Tai

Mr. Peccia gave a presentation regarding CCSDS’s interaction with commercial providers, saying that this issue was discussed at the last CMC meeting. With regard to participation of industry in CCSDS review, ESA has improved the future participation of industry during the CCSDS Standards Agency Reviews through EUROSPACE (the trade association of the European Space Industry), who will be the prime point of contact for CCSDS space industry contacts (both in space and ground) in Europe. They will distribute CCSDS documents under international review and will coordinate their reviews on behalf of ECSS. He noted that NASA added that CCSDS should be careful with how many people are introduced from commercial industry to the CCSDS, as the organization should not be overrun by standards developers whose focus is profit oriented.

CCSDS is also conducting outreach activities with industry, Mr. Peccia, reported, including an industry webinar NASA recently held to invite new commercial participants to join the CCSDS as associates. The plan is to continue to have these kinds of presentations annually. There is a strong campaign from the OMG Space Domain Task Force for infusion of their standards into the enterprise ground system (EGS) for the US Air Force (USAF); CCSDS does not have a similar program for infusion.

Mr. Peccia said that the CMC also discussed the issue of universities working on the development of smallsats/cubesats, primarily without CCSDS protocols and they don’t promote CCSDS. The on-board CCSDS compliant components are expensive. Dr. Deutsch noted that for deep space smallsat/cubesat missions, most come to NASA or ESA for communication services; therefore, more of them are using CCSDS standards. Mr. Peccia said that cubesat missions need to comply. This is an emerging private sector, he said, noting that OneWeb started using CCSDS standards in space and ground early in the process and were able to find a best value for the money solution. He said that CCSDS recognizes the related issues regarding the availability of CCSDS compliant products; there is not an open source suite of CCSDS standards and a strategy or combination of standards is needed to improve private sector services when using CCSDS standards. The private sector is overtaking the LEO/MEO market of non-CCSDS standards, he said.

Mr. Peccia closed with a discussion on the way forward in this area through improved CCSDS/IOAG outreach with commercial providers, large private sector projects, universities, etc. He asked if this is enough or is there more that is not being considered. Perhaps missions will adopt sooner if development time of standards could be improved from the current five to seven years. The problem in achieving that improvement is the availability of resources and long internal processes. In response to a question from Mr. Liebrecht regarding the OMB, he responded that the OMG started with goal of deploying standards in two years but is now four to five year. Mr. Schier said this is not out of line; the bigger the group, the broader the technology area, the more players, the harder it is to bring to consensus. New cubesat developers can help move them in the direction we want them to go and help broaden people's awareness, he said, adding that the IOAG and CCSDS need to develop a cubesat philosophy. Mr. Afarin added that CCSDS standards are developed by consensus, whereas OMG standards are approved by majority vote. Mr. Schier recommended that CCSDS could take better advantage of its orange (experimental) status and use it more strategically; Mr. Peccia responded that half of the books CCSDS is producing today are orange books. Mr. Liebrecht asked if suppliers participated in CCSDS; Mr. Peccia answered that KSAT and others participated once for cross-support interests but have not returned. OMG is active in Brussels, where ESA’s Mario Merri met with them recently. Mr. Liebrecht suggested that this topic be raised with SFCG liaison Enrico Vassallo at the IOAG meeting tomorrow. Mr. Afarin stated his strong belief that industry should pay their own way and not ride on the agencies’ work.

The Chairman closed the discussion saying that this will be further addressed within the IOAG tomorrow. He suggested that perhaps a workshop with service providers and IOAG would be of value, enabling access to different facilities and assets worldwide. The workshop could include a “CCSDS Lite” presentation as well.

1. Future Interactions: Mr. Afarin

CMC Chairman Mr. Afarin announced that during yesterday’s CMC meeting, it was decided that going forward, he will serve as CCSDS liaison to IOAG, saying it will be difficult to fill Mr. Peccia’s shoes. The IOAG Chairman and all participants thanked Mr. Peccia for his dedicated service to CCSDS and IOAG. Anything technical issues will be addressed by the CCSDS Engineering Steering Group (CESG) Chair, Margherita di Guilio. Mr. Afarin will be responsible for all reports, and he will consult with the CESG Chair before his presentation to the IOAG. The IOAG Chairman noted the technical details that arise during IOAG meetings periodically, and Mr. Afarin said that the CESG Chair can participate in teleconferences and meetings, as needed. Mr. Schmidt said that during the IOAG meetings tomorrow the frequency of these joint meetings would be discussed. Mr. Afarin responded that joint meetings are welcome but with the CMC Chair serving as liaison and the CESG Chair’s participation as needed, there is no need to increase the frequency of joint meetings of both groups. Mr. Liebrecht noted that with the upcoming IOP-4, another IOAG meeting before the IOP might be necessary, with close collaboration with CCSDS.

The participants discussed the upcoming schedule of meetings in order to determine a possible schedule for another IOAG and IOP-4 meeting. DLR will probably host IOP-4 in Germany in the last quarter of 2018.

1. Wrap-Up: IOAG and CCSDS Chairmen

Mr. Afarin began by thanking the IOAG for the opportunity to present to the IOAG on behalf of the CMC and CCSDS; his key message to the IOAG is that the CCSDS works very hard to produce the many verified standards needed. He tipped his hat to all the people, who complete a great deal of work outside of the budget on their own hours because the team is dedicated to standards in all the agencies. He thanked Mr. Peccia for his fantastic work as CCSDS liaison, following in the footsteps of Mr. Adrian Hooke. As CCSDS liaison in the future, he is always available when needed, he concluded.

Mr. Schmidt thanked Mr. Afarin for the CCSDS status report, and said he recognizes there are not enough resources for them to complete all their work. It is the IOAG’s task to balance the requirements put on them to meet the priorities. He acknowledged Mr. Soula’s effort to establish realistic need dates and asked all the agencies to support Mr. Soula and Mr. Calzolari’s efforts with input so they can align the priorities. He also noted the organizational institution of standards created by the CCSDS, with a tremendous list of standards adopted by the missions. Regarding cooperation with commercial providers, it remains to be seen how far this can develop. In the context of exploration, with new players, institutional and commercial resources need standards to avoid chaotic space communications.

Mr. Liebrecht added that IOAG agencies contribute 90 percent of resources to CCSDS. “We should be able to work amongst ourselves to make sure resources are available for our priorities,” he said, and asked that each agency ensure that their standards budgets are consistent and stable. Mr. Soula emphasized the importance of determining how priorities are established and the role of the IOAG-CCSDS Product Agreement (ICPA) database, developed by Mike Kearney and Adrian Hooke in 2010.

Mr. Lord noted that the work of the MOSSG is almost completed, with a SC#3 to be aligned with the other two service catalogs. The Chairman said that the optical communication area has also had a great deal of evolution and shows potential, with work to be done on standards and technology. Dr. Deutsch said that the 26GHz Working Group has completed its work and is updating its database and making the case for ACM at some point. The Chairman turned to Mr. Cosby, noting that the work in the LCAWG is one of the biggest challenges for IOAG. Mr. Cosby responded that coordination is key, particularly with the other related working groups so they can develop an architecture for input to the DSG and other relevant organizations.

The Chairman stated that there weren’t any objections to begin planning for IOP-4 and concrete planning would begin the next day. Regarding work with commercial providers, Mr. Peccia said that the CCSDS and IOAG need to reflect how we think our way forward – e.g., workshops, more outreach, contact the commercial providers separately, whether there is a need to do more in standardization, etc. Mr. Afarin suggested that there needs to be an objective that all can agree to on interaction with industry. Mr. Shigeta said that this will be further discussed tomorrow and will report to CCSDS.

The meeting was closed with a final welcome to Mr. Afarin as incoming liaison, a round of applause for retiring Nestor Peccia and Juan Miro.