INTERAGENCY OPERATIONS ADVISORY GROUP

IOAG-22 Meeting

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IOAG-22 Meeting Minutes
Ohio Aerospace Institute, Cleveland, OH, United States
25-28 June 2018

Attendance:
Chair**:** Michael Schmidt
Secretariat**:** Barbara Adde, Madeleine Bronstein

Members:
ASI: Fabio D'Amico
CNES: Jean-Marc Soula
CSA: François Alain, Ken Lord
DLR: Martin Pilgram, Rolf Kozlowski
ESA: Gian Paolo Calzolari, Klaus-Juergen Schulz, John Reynolds
JAXA: Tsutomu Shigeta, Hirokazu Hoshino, Kiyohisa Suzuki
NASA: Badri Younes, Bernie Edwards, Catherine Barclay, Dan Smith, Dave Israel, Eli Naffah, Jim Schier, Jim Stegeman, John Guidi, Les Deutsch, Nikki Desch, Phil Liebrecht, Wallace Tai

Observers:
KARI: Sangil Ahn
UKSA: Matthew Cosby

Liaisons:
CCSDS: James Afarin
ICG: Frank Bauer, James Miller
ISECG: Naoki Sato
SFCG: Enrico Vassallo, John Zuzek

Teleconference:
ESA: Marco Lanucara, Margherita Di Giulio
NASA: AJ Oria, Kathy Laurini, Marc Seibert, Sharada Vitalpur, Wendy Evans

Presentations are available at: www.IOAG.org.

IOAG-22 Meeting Minutes
Ohio Aerospace Institute, Cleveland, OH, United States
25 June 2018 – Day 1

Introduction: Michael Schmidt

The Chairman thanked the delegates for their participation and noted that he hoped there would be fruitful discussion in the week ahead. He thanked NASA for their hospitality and asked the delegates to introduce themselves. Following introductions and roll call, Mr. Stegeman introduced Ms. Janet Kavandi, the director of Glenn Research Center.

Welcome: Janet Kavandi

Ms. Kavandi welcomed everyone to Cleveland. She informed the delegates that Glenn Research Center is one of ten NASA centers and one of four research centers. Glenn Research Center has a history of working with NASA's international partners, such as through collaboration on the International Space Station. Ms. Kavandi then presented a video on current activities at Glenn Research Center. She further discussed Glenn's participation in activities, such as testing of NASA's Orion spacecraft, research on the Power and Propulsion Element (PPE) and solar electric propulsion, and supporting NASA's commercial crew and cargo projects. She noted, specifically, the support Glenn provides with research on space communications, including the SCaN testbed on ISS and integrating lasers in with radio frequency to enhance capabilities.

NASA's Next Generation of Space Communications Architecture: Badri Younes

Mr. Younes thanked the delegates for their participation and noted the importance the IOAG has for NASA's strategic objectives for interoperable space. He provided an overview of the NASA SCaN program and the NASA networks, which support human and robotic missions. SCaN's vision for the future of its networks includes upgraded capabilities and interoperability. Current initiatives include LCRD, DSOC, ILLUMA-T & O2O, RF/Optical Hybrid Antennas, and development of technology for a cognitive network. Mr. Younes outlined the development, demonstration, and operational timeline for near Earth and deep space technologies.

The Chairman inquired whether it is recommended for the IOAG to look further into cognitive. Mr. Younes responded that yes, if we have interoperability we will need to have standards established. Currently, NASA is working on the building blocks for cognitive, internetworking, and DTN. NASA has allocated $800 million to building out these capabilities and flying deep space missions with STRS, a building block for cognitive.

The Chairman also asked what kind of terminals can be considered for the optical network. Mr. Younes noted that there are several stations in place, but there would need to be hundreds of stations to enable industry. The architecture for deep space will be scalable and what NASA is doing can be replicated and duplicated. There will be an infusion of technology and operational capability with buildup alongside the customer community.

Mr. Kozlowski asked whether cooperation with industry should be a topic for discussion for the IOP. Badri encouraged cooperation with industry as a topic for IOP-4. He encouraged the IOAG to look at different ways of providing and integrating the commercial market into activities and modifying the agencies' behavior and services to align with industry and the user. He noted that we are dependent on the commercial sector being open with their architecture.

ESA ESTRACK Evolution: Klaus-Juergen Schulz

Mr. Schulz provided an overview of the ESA Tracking Stations network (ESTRACK). The core network of stations is owned, operated, and maintained by ESA and there is an augmented network of stations owned and operated by commercial providers and procured in support of routine operations and Launch and Early Orbit Phase (LEOP) execution. This will be implemented by the cooperative network of stations from partner Organizations, includes terminals from CNES, NASA, JAXA, CNSA, and RFSA.

ESTRACK evolution from 2018 through 2025 includes plans for approximately 20 LEOPs to be executed by ESA. Mr. Schulz emphasized ESTRACK's role as an ESA strategic asset, ensuring independent access to space. The ESTRACK load is projected to exceed by up to 50% of the current core network capacity. A very close partnership with ESA member states and industry is vital, allowing ESA to take stock of available infrastructure and know-how to satisfy ESA future missions.

For LEO and Near Earth missions, the ESA Kiruna station will continue to serve as the hub for ESA and EU Earth Observation missions. ESA is looking to expand the utilization of TT&C services from commercial providers in support to LEOP and routine phases. ESA is also pursuing the operational deployment of new capabilities for future LEO missions: X-Band uplink and K-band downlink. There is an experimental station deployed in Svalbard for operational validation of K-band downlink (26 GHz) using NOAA JPSS-1 and a new 26 GHz capability installed in Cebreros and Malargue for Euclid. Mr. Schulz also emphasized that ESA is promoting the adoption of innovative operational approaches including DTN, optical space-ground LEO communication in synergy with optical tracking (passive and active), and optical deep space communication.

ESA is completing a major upgrade of the current deep space network, including new modem (TTCP), new capabilities (Ka-band downlink, Ka-band uplink), refurbished amplifiers, and radio

science as well as deployment of additional 35m terminals over Australia and Argentina longitude in cooperation with international partners. ESA is also coordinating the setup of a European deep space communication solution over European longitude to foster the emergence of new commercial deep space services and enable the utilization of spare resources from existing institutional assets in Member States.

ESTRACK optical future ambitions include ongoing technology development activities and a European initiative to foster the gradual adoption of optical LEO-DTE communication network solutions in future missions.

Delegates suggested that the IOAG look into optical observation of space debris for tracking across agencies. Mr. Younes inquired whether there would be interoperability with NASA's ranging capabilities and Mr. Liebrecht answered that the laser ranging capabilities are interoperable, but the IOAG hasn't had a role in this. Mr. Younes suggested that the IOAG look into cooperation between agencies for debris tracking. Mr. Liebrecht furthered that this is on the list of items NASA is suggesting to be addressed at IOP-4. Mr. Younes also noted that he would like to exchange information with ESA regarding the 34m antenna as well as DTN implementation. He suggested further discussion on ground station specifications in the future.

Opposing opinions regarding standardizing uplink frequencies were discussed. The first option is to standardize three distinct uplink frequencies now rather than waiting longer for more options to materialize. The commercial sector moves at a faster pace than standardization bodies, so the IOAG should take initiative to create a solution, even if it's not the optimum solution. The opposing view is to standardize only one uplink frequency, otherwise there isn't interoperability. There was agreement between delegates to continue this dialogue. Once there is a solution, the IOAG will provide guidance to CCSDS.

Secretariat Report: Barbara Adde

The Secretariat provided a status update on actions and tables. Mr. Oria presented the updated mission model tables and Mr. Soula noted that the tables did not show input from all the observer agencies. The Chairman responded that agencies were reminded to provide input for IOP-4. The delegates approved updates to the following actions:

- 20a-01: Closed
- 21-01: One member and a few observers have not provided input. A reminder of the action will be sent to delegates.
- 21a-04: Closed
- 21a-05: Closed

Agency Reports

Each Member and Observer agency provided highlights of major changes to their programs during the past year. Presentations are available on the IOAG.org internal website.

1) ASI Report: Fabio D'Amico

Mr. D'Amico first noted that there have been no relevant changes to ASI's internal organization and the mandate of the ASI President and the ASI General Director have been confirmed for another four years. He also provided an overview of the new Italian Space Act. Mr. D'Amico then presented ASI's IOP-4 recommendations:

- Standardization (liaison with CCSDS & SFCG)
- Exploration (DSG & LCAWG recommendations, liaison with ISECG)
- Cross Support & Emergency Cross Support (SECSWG)
- GNSS (liaison with ICG)

He provided an overview of ASI's missions in operation and development, major updates on the Broglio Space Center (Kenya), and updates on the Sardinia Deep Space Antenna. The Sardinia Radio Telescope is now part of the NASA Deep Space Network (DSN) under ASI management and operations and there are plans to upgrade the antenna in coming years to implement Ka-band in the future. Mr. D'Amico concluded with a discussion on other ASI major programs with international cooperation: ESA EXOMARS 2020, ESA launchers VEGA-C and ARIANE 6, and several other ESA and NASA missions. Mr. Schier asked whether ARM is cancelled and whether ASI will participate in the Gateway? Mr. D'Amico responded that he will check on the answer to that question.

2) CNES Report: Jean Marc Soula

Mr. Soula reviewed the organization chart for CNES. He presented the list of recent and upcoming operations and the schedule of missions in operation and noted that the missions in the operations table include joint missions. Mr. Soula outlined specific recent spacecraft operations including Galileo LEOPs performed by CNES, as well as moving Jason-2 to a new geodetic orbit as a result of adapting its objectives to deliver complementary science products. He also provided updates on Venμs, the French/Israeli satellite which is now in operation and GAIA, an ESA astronomy mission with strong CNES involvement. Additional details were provided on the Space Climate Observatory (SCO), Mars exploration, COSPAS-SARSAT, and multi-mission operational facilities.

- *Space Climate Observatory (SCO*): The scope of SCO is to use space data, optimize products, and facilitate decisions. It is used to monitor climate parameters, track the potential impacts on climate, and for mitigating and adapting resources, population, and socio-economic development paths
- *Mars Exploration:* Updates were provided on the status of MSL – Curiosity, Insight, and Mars 2020/SuperCam

- *COSPAS-SARSAT:* It was noted that the transition to a MEO satellite is ongoing, the new Meolut Antenna at CNES Toulouse has been installed, and CNES was selected as the return link service provider for Galileo
- *Multi-Mission Operational Facilities:* An overview of the ground stations network enhancement and the next target missions was provided.

Mr. Soula reemphasized, on the topic of the Service Catalog and infusion plans to be discussed at IOP-4, we have catalogs and standards, but we do not plan to implement them. He asks how we can convince industry to participate if we do not have implementation plans. Regarding O3K standards, we may need more explanation on objectives. The message from IOP-3 was to have one standard in each category, not three. If there are three standards, there is no interoperability. At the end of any demonstration, we need to have a standard.

3) CSA Report: François Alain

Mr. Alain reviewed the CSA organization chart and the agency's strategic objective and mandate. An update on the following CSA activities was provided.

- *Space Astronomy:* Integration, testing, and launch preparation activities of Canadian instruments on the James Webb Space Telescope
- *Planetary Science:* Operation support for the APXS instrument on the Mars Curiosity rover and OSIRIS-REX Laser Altimeter encounter with asteroid Bennu
- *Human Spaceflight:* Deliver, launch, and commission of two elements of the Life Science Research System: bio-monitoring and bio-analysis and developing countermeasure protocols for effects of microgravity, radiation, and being in a stressful environment. It was further noted that the next Canadian in space will be in December 2018.

It was noted that the demand for robotics missions has drastically increased and Mr. Alain provided examples of CSA deep space exploration robotics. More information on CSA's exploration and science priorities can be found in the recently released report, *Canadian Space Exploration Science Priorities: Next decade and beyond*. In addition, Mr. Alain provided information on current CSA space utilization, which included details on the RCM improvements over previous RADARSAT missions and an animation of the RCM launch deployment. He noted that there was a recent directive on open government to maximize the release of government information and data of business value. The data acquired will be made available at no cost, subject to certain considerations.

Other recent activities include the STRATOS-2018 Campaign, CubeSat Mission Concept Reviews, and the QEYSSat Phase A SRR. The Chairman inquired about the coordination between CSA and the universities for the cubesat program. Mr. Alain responded that CSA provides the funding for the cubesats to universities. To conclude, Mr. Alain noted that CSA has not yet finalized any formal perspectives and goals for the IOP, but will be working on this as December approaches.

MOSSG Report: Dan Smith

Mr. Smith reviewed the purpose of the MOSSG and its membership. He noted that the challenge of a mission operations interoperability catalog is to address the wide range of needs of different mission types. In addition, trends in mission operations emphasize future increases in on-board capabilities, automation and autonomy, and increase cooperation across agencies. He listed the following scenarios:

- Coordinated Missions: Agencies operate their own spacecraft, but may share orbit information and schedule plans so that science activities can be coordinated. There are simple data exchanges.
- Partnership Missions: One agency has overall mission operations responsibility, but payloads may belong to other agencies. It is necessary to coordinate schedules, telemetry data, and command plans. This is a very common single-spacecraft model.
- Joint Operations Missions: Multiple agencies share operations responsibilities. This could be time-based sharing, device-based sharing, or full simultaneous mission operations. This is for large systems, such as the ISS.
- Future Large Enterprise Systems: There are multiple space assets and shared plans, communications, and data. It is deployed over an extended period of time.

Regarding CCSDS, Mr. Smith noted that MOSSG was directed not to assess CCSDS processes, priorities, or the ability to meet the MOSSG-identified service requirements. However, it is recognized that CCSDS has put a large effort into Mission Operations (MO) Services and other standards applicable to MOSSG needs. The CCSDS standards related to MOSSG needs are identified for reference through Service Catalog #3, but total compliance or adequacy is not meant to be implied. The MO services were designed for more than interoperability, which results in both potential benefits and shortcomings. To distinguish between Catalog #3 service needs and the CCSDS MO services, Catalog #3 uses the term "Mission Operations Interoperability Services" (MOIS). One difference is that the MOI approach is independent on the on-board design. Some MOIS needs can be met by MO services. The MOIMS area of CCSDS has a mix of service specifications and message formats covering the areas of interest to MOSSG. For example, nav is based on formats, SM&C is services, and Planning and Scheduling will be both formats and services. MOSSG sees value in both the formats and the services approaches.

The Chairman asked whether navigation data services were one of the topics that CCSDS was asking for guidance on and if MOSSG had given any guidance to streamline the direction. Mr. Lord commented that the MOSSG focus was on the data exchanges and that this was an independent assessment. The study group attempted to not be biased by CCSDS and instead, bring this information to the IOAG in order to decide on what should be sent to CCSDS. Mr. Lord furthered that experience with SC#1 and SC#2 had been taken into account. The delegates also suggested that CCSDS existing standards should be taken into account before new ones are made.

Mr. Smith presented the template for service description for Catalog #3. He noted that comments have been received on MOSSG use of the ABCD designations and work is needed to resolve confusion.

Following the description of SC#3, Mr. Smith reviewed the second document, including interoperability considerations and trends, the service catalog approach, service evaluation factors, and the roadmap to promote infusion. More details regarding the specifics of these topics can be found on www.IOAG.org.

1) **Interoperability Considerations and Trends**
   Mr. Smith began by noting that cross-agency joint missions, by definition, require some level of system interoperability and agencies must consider much more than just the definition of standard interfaces and standards to connect their systems.

   Infrastructure: A common global software system to promote interoperability is not practical and interagency boundaries must be established. Future multi-agency programs should agree on the infrastructure architecture before developing or adapting their mission operations systems. This may include voice and video systems, timing, networks, security, shared data storage systems, etc. It was noted by delegates that it is not stable enough to attempt interoperability based on global security standards, because standards for security are changing monthly.

   Systems Architecture: The following technology options can be considered as shared-mission and multi-mission architectures are developed: application sharing, client/server, service oriented architecture, remote access, and cloud. In general, the architecture should be independent of the interoperability standards selected.

   Development: Service quality should be built in at development. It is often not part of the data service standard. Additionally, interoperability should account for the use of legacy systems. Agencies can not be expected to "start from scratch" to develop interoperability systems. Legacy system adapters can be used to match individual components to a new format or service standards and a gateway can serve as a primary portal between dissimilar systems, supporting interoperable interfaces on one side and legacy interfaces on the other.

   Program: The program considerations MOSSG identified include: joint operations concepts and agreements (e.g. terminology, overall interaction concepts, data exchanges scaled to the mission type, processing responsibilities, access needs, etc.) to reduce dependency on extensive Interface Control Documents (ICDs); governance processes and agreements, due to the complexities of data distribution and ownership, the sharing of software and interfaces, and the longevity of many missions; documentation of technical support and commitment to assure service support for the duration of the mission and establish rules for how service, interface, or support changes are to be announced,

implemented, and transitioned; and awareness of competing priorities across the agencies to reap the benefits from standards-based interagency operations.

Trends: Mr. Smith listed current trends affecting mission operations systems and observed that these trends have the potential to significantly change how missions are operated in the future and how their mission support systems are developed and deployed. He noted that the format and service standards in SC#3 are compatible with all of the listed trends.

2) The Service Catalog Approach

Mr. Smith first reviewed the SC#3 context and the definition of interoperability. He then introduced the framework and functional services, as well as standard formats and standard services. The MOSSG recommends that the functional interoperability areas identified in SC#3 be addressed both by service specification standards and by format specification standards.

Mr. Smith included a visual graphic of the MOSSG Interoperability Model, which included 5 interoperability levels: extensive, high, moderate, minimal, and essentially none. The MOSSG primary focus is on level 2: moderate. Moderate interoperability is the "service level," including standardized interfaces, formats, and services. It is multi-program and multi-agency with standards developed collaboratively, but software may be developed independently. Agencies develop or adapt systems to satisfy standard interfaces. Lastly, Mr. Smith reviewed the SC#3 structure.

3) Service Evaluation Factors

The MOSSG suggests that careful consideration be given to the broad benefits of a new international interoperability standard prior to its development or adoption. In some cases, consistency between portions of a large international program may be handled best with mission-level "standards" instead of formal international standards that would apply to many other missions as well. The MOSSG has identified three categories of candidate evaluation factors against which service specifications and plans for future services can be evaluated:

1. Meeting Interoperability Objectives: common need, coverage of interoperability services, use of services, contribution to the larger plan, and compatibility with program integration requirements.
2. Ease of Adoption of Available Service or Data Exchange Standards: ease of adoption, compatibility with legacy systems, reuse of software capabilities across programs, and adaptability.
3. Service Quality: correct service orientation, standard support structure, compatibility with lower level standards, and resilience to IT evolution.

4) Roadmap to Promote Infusion

The MOSSG encouraged the IOAG member agencies to embrace and encourage (enforce) the implementation of Catalog #3 services and data exchanges. It was proposed that the

IOAG considers two paths to foster infusion: proof of concept demonstrations independent of missions and infusion by smaller missions, then by larger missions. The IOAG was asked to encourage member agencies to establish a demonstration environment in which service interoperability can be developed, tested, and demonstrated. Mr. Liebrecht noted that IOP-3 was interested in doing some sort of demonstration. Mr. Smith responded that time and budget didn't support the demo.

Mr. Liebrecht asked whether there is a mission or program in mind for the proof of concept. Mr. Smith responded that MOSSG would like to take the Gateway as a scenario, but that's not a commitment. He added that the IOAG could pick an existing mission to look at. Mr. Schulz responded that it's difficult to get funding for it if it's not a major mission. Mr. Schier added that the Gateway is a perfect target for infusion and there should be a conversation with Mr. Guidi regarding this. Mr. Smith responded that MOSSG believed the study group should meet through the IOAG and not directly from the study group.

The MOSSG concluded that a gateway approach is the most effective method to implement Catalog #3 services and data exchanges. It also supports the integration of legacy systems. Mr. Smith reviewed the gateway approach benefits and concept. He then identified potential barriers to the infusion of interoperability standards, an interoperable Proof-of-Concept Testbed (PCT), and a potential infusion timeline.

Mr. Smith noted that the MOSSG effort is scheduled to end following the acceptance of the report and SC#3 and the conclusion of IOP-4. Following IOP-4, the MOSSG could act as a mission operations resource for other IOAG activities and working groups as needed. He also identified the possibility for MOSSG work to be extended or for a new working group to be defined to accomplish additional mission operations interoperability activities. Mr. Smith concluded with a summary of statements from the MOSSG.

Dr. Deutsch noted that CCSDS needs two agencies to submit an implementation in CCSDS, but for this, they would like three. The Chairman asked whether there is any agency interested in this feature and function between agencies. Mr. Kozlowski responded that DLR has an HTC program ongoing. He would like to create well defined interfaces so others can communicate with them. Mr. Liebrecht noted that interfaces are a lot harder to achieve, so we should start with simple things that are more readily achievable. After that success, there could be more opportunities.

The Chairman asked whether there is an interest in defining common mission operations or leaving missions to determine the approach? Dr. Deutsch commented that there is a push towards standardizing operations for earth science missions. The Chairman recommended that the topic be discussed with Mr. Guidi as it relates to the Gateway. Mr. Liebrecht added that there should be another group of mission operations people that should be consulted, looking across the agencies.

Agency Reports: Continued

4) DLR Report: Rolf Kozlowski

Mr. Kozlowski provided the delegates with an overview of DLR organizational changes and a list of key events, including current and planned missions, launch updates, and an update on other missions with DLR involvement. He also provided a brief overview of communication assets.

Also highlighted in the DLR presentation, was the agency's approach to make optical communications operational through GlobeON. The GlobeON primary programmatic goal is economic utilization of optical direct-to-Earth communication from low Earth orbiting spacecraft, which requires establishment of a basic Optical Ground Station Network (OGSN) together with international partners and commodification of the OGSN. The secondary goal of the program is diversification of the service portfolio, which necessitates optical ground-to-space links. Technical objectives of the project include: development of a heavy duty Optical Ground Station (OGS) for routine operations, verification of fading mitigation strategies to ascertain customary service levels, and verification of data-defragmentation strategies.

Mr. Kozlowski noted that basic OGSN implementation could provide 24/7 coverage to satellite missions. Together, with commercial partners, an agency or agencies could develop a ground station network and it could then be expanded to move from an agency project to a professional service provider in a very short timeframe. He further clarified that DLR does not see itself as the operational provider of the worldwide service. The project could start with a demonstration of 2 to 3 optical ground stations, then move to a commissioning phase, and then commercialization. DLR has spoken with ESA and Mr. Schulz mentioned that ESA has a similar approach, so there is potential for a combined European approach. Lastly, Mr. Kozlowski presented a list of DLR's high, medium, and low priorities. The Chairman commented that the ground terminal network should be further discussed when the OLSG presents.

5) ESA Report: Michael Schmidt

The Chairman (Mr. Schmidt) presented ESA recent and near future operational events, as well as an overview of upcoming and medium/long-term missions. He highlighted Earth Explorers (EE) missions, provided an update on Copernicus Sentinels, and informed the delegates of ESA space weather monitoring from L1 and L5. Lastly, Mr. Schmidt gave an update on human spaceflight operations and an ISS schedule update.

6) JAXA Report: Tsutomu Shigeta and Hirokazu Hoshino

Mr. Hoshino provided a news update from JAXA, including that Dr. Hiroshi Yamakawa assumed the position of President as of April 2018 and Hayabusa2 is continuing to approach the asteroid Ryugu using optical navigation. He also provided a list of recent and upcoming launches.

JAXA is developing a new deep space station, GREAT, which will be ready for Hayabusa2 operations by the end of 2019. It will add a new Ka-band capability in the Asia region. Mr. Hoshino

gave additional details on capabilities and characteristics of GREAT and new Ka-band (26 GHz) data reception terminals being developed to be deployed in two sites.

Pertaining to the IOAG, Mr. Shigeta presented new content on the JAXA-CCSDS public website, JAXA participation in IOAG working groups focusing on optical communications activities, and DTN study and development. JAXA has also been participating in ongoing MOSSG and CCSDS mission operations studies, stating that the implementation of MO services depends on future mission requirements. Mr. Shigeta also noted that JAXA is in support of approving SC#3, while its applicability to the Gateway and JAXA's continued participation in this WG for Gateway, if necessary, were not clear at this stage. The Chairman commented that many of the points raised will be revisited during the rest of the IOAG.

7) KARI Report: Sangil Ahn

Mr. Ahn first presented organizational changes and an organization chart. Dr. Lim Cheol-Ho is the new KARI President, whose term is from 2018-2020. The new Director for Satellite Operation and Application Center is Dr. Lim Hyo-Suk. There have also been additional internal organizational changes implemented by the new president.

KARI is currently participating in two IOAG working groups: the SECSWG and LCAWG. Key events for KARI are the KSLV-II test launch in October 2018 and GEO-KOMPSAT-2A launch in November 2019. Mr. Ahn concluded with an overview of communication assets and current and future missions.

8) NASA Report: Phil Liebrecht

Mr. Liebrecht presented the updated NASA organization chart and noted that there have been significant changes to NASA leadership, including a new NASA Administrator, Jim Bridenstine. The National Space Council has also been reestablished and three Space Policy Directives have been signed. Mr. Liebrecht provided information on the NASA Exploration Missions and development of the Gateway, as well as updates on ISS international interoperability standards and the launch schedule of commercial vehicles to the ISS. An overview of the NASA missions GOES, TESS, InSight, GRACE-FO, ICON, the Parker Solar Probe, ICESat-2, IMAGE, and Juno was also provided.

Pertaining specifically to SCaN, Mr. Liebrecht presented the SCaN organization chart and updates on recent activities, including the launch of TDRS-M and the reconfiguration of the Sardinia Deep Space Antenna (SDSA) to support interplanetary and deep space missions for ESA and NASA.

Mr. Liebrecht presented NASA's IOP-4 meeting objectives and perspectives. He provided additional detail on NASA's goals for the IOP:

- The IOAG to communicate progress, challenges, and opportunities

- The IOP to reaffirm or provide updated guidance on the scope of the IOAG considering the success of IOAG in promoting cross-support
- The IOP to reaffirm or provide updated guidance on the IOAG architecture evolution approach
- The IOP to identify and provide guidance on potential future opportunities for engaging commercial and academic space, enabling future missions and facilitating future interoperability, space traffic management, and space weather event notification to space users

The Chairman noted that Mr. Liebrecht raised a lot of interesting topics and made good points regarding the scope for IOP-4 that the delegates should resume discussion on. A delegate asked how far along in the process the Gateway is to being financed and confirmed. Mr. Schier answered that it is in the President's Budget recommendation to Congress, so it is formally approved on the executive side. It still has to be approved on the legislative side. The agency is moving forward on it, so he is assuming it will be approved. He also noted that the draft BAA for the PPE was released to industry for a 30-day comment period. There are seven interoperability standards in the first solicitation and the Gateway is currently working with potential international partners on contributions. Mr. Liebrecht noted that it is likely to be as international as the ISS. The Chairman added that the other topics, such as space traffic management, are worth discussing. The IOAG should discuss ideas it would like to endorse to define for the IOP what the scope of work may be.

9) UKSA Report: Matthew Cosby

Mr. Cosby presented UKSA agency status updates, including that the agency has had a reorganization with the new Chief Executive Graham Turnock, current agency funding concentrations, and current agency representation. Additional details regarding how the UKSA operates and its plans for near-term activities was also provided.

Also presented was information on UKSA EO partnership missions SWOT, IASI-NG, and MicroCarb and updates on UKSA involvement in NovaSAR. The UK plans on continuing its commitment to responding to climate change and maximizing the benefits of space to the international climate change community through investments in the aforementioned EO missions, hosting the ESA Climate Change Office, continuing its involvement in the Climate Change Initiative (CCI), and participating in the Space for Climate group (S4C).

Mr. Cosby provided details on CCSDS compliant hardware and software in ground stations. He outlined the Pathfinder concept for the space, ground, and user segments and explained the mission concept. Mr. Cosby explained the International Partnership Programme (IPP) run by the UKSA, which funds partnerships between the space community and end users in developing countries using the UK space sector's research and innovation strengths to deliver a sustainable, economic, or societal benefit to developing countries. He provided additional details on the IPP Forests 2020

project, which uses Sentinel 1 and 2 data. Lastly, Mr. Cosby outlined the UKSA's current priorities.

IOAG-22 Meeting Minutes
Ohio Aerospace Institute, Cleveland, OH, United States
26 June 2018 – Day 2

Opening Comments from the Chairman

The Chairman noted that it is important to include cross support as a topic at the IOP, so that it is clear that what the IOAG is trying to do is practical to enable interoperability. An example of this is coding and modulation. The IOP does not have to give input on this, but it is important to be presented for informational purposes.

The Chairman also noted that delegates should double-check that the delegates invited to the IOP are the correct ones for the current list of topics on the IOP-4 agenda.

Liaison Reports

1) ISECG: Naoki Sato

Mr. Sato began with an introduction on the ISECG. The ISECG is a voluntary, non-binding forum where 15 participating space agencies continue to share information and work together on products with the goal of strengthening individual agency exploration programs and the collective effort. JAXA is the current ISECG chair. The ISECG updated the Global Exploration Roadmap in January 2018 to support the International Space Exploration Forum in Tokyo in March 2018 and provide momentum to participating agency efforts to secure funding for human and robotic lunar missions.

The IOAG is aware of these planned and conceptual missions through the Lunar Communication Architecture Working Group (LCAWG). It was noted that the communications standard is all one effort and the state of the LCAWG is in line with ISECG standards. The lunar communications architecture is also intended to apply to more systems than just the Gateway. There is close coordination being done by people in both working groups. Ms. Laurini concurred with this statement.

Mr. Sato outlined the ISECG work priorities for 2018-2019 and reviewed the key takeaways from ISEF2, including the importance of international cooperation on space exploration in LEO and beyond LEO. Mr. Sato provided an overview of the activities NASA and international partners are

pursuing to advance the Gateway architecture as well as a conceptual reference architecture for human lunar missions.

Regarding IOAG collaboration, the ISECG and IOAG have continued to work towards consistent assumptions and coordination, such as IOAG presentations at ISECG meetings and ISECG status at IOAG telecons. An interoperability communication standard, worked by ISS agencies, was developed consistent with IOAG standards and shared with the IOAG. It was provided to the IOAG for review and comment in addition to the involvement of IOAG representatives in agency efforts to develop the draft standards. The communications standard will be baselined in the summer of 2018. Spacecraft emergency and optical communications standards will be captured in the first or second baseline. The Chairman asked whether the IOAG is in line with the request for baseline by summer 2018. Mr. Cosby noted that the IOAG list of standards and consensus is in work, except regarding optical. It won't fully conclude in summer 2018, but there will be a draft. He asked what format the input should take. Mr. Tai commented that he believes it is the same input as what the IOAG provided to Gateway, ISECG also had the opportunity to review and provide comment. He thinks the IOAG has incorporated the overall comments.

The ISECG believes that presentation time is needed at IOP-4, but this would have to be something requested by the IOAG. Ms. Laurini supports a presentation, especially noting that there's a consensus on the roadmap. She noted that it doesn't need to specifically be given by ISECG, but it should still be presented. The conclusion is that the IOP-4 agenda will be adjusted accordingly to accommodate this.

2) ICG: Frank Bauer and James J. Miller

Mr. Bauer reviewed the space uses of Global Navigation Satellite Systems (GNSS), including real-time on-board navigation, earth sciences, launch vehicles range ops, attitude determination, and time synchronization. He noted that GPS capabilities to support space users will be further improved by pursuing compatibility and interoperability with GNSS.

Mr. Bauer presented a visual graphic on reception geometry for GPS signals in the space service volume (SSV) and explained that the SSV defines three interrelated performance metrics in the MEO and HEO/GEO regions: availability, received power, and pseudorange accuracy. High-altitude GPS early flight experiments demonstrated basic feasibility in the 1990s and it was employed operationally by MMS at 76,000 km in 2015 and by GOES-16/17 at GEO in 2016-2017. Current U.S. missions using GPS above the GPS constellation include the GOES-R weather satellite series, Magnetospheric Multi-Scale (MMS) mission, and in 2020, Exploration Mission 1 (EM-1). Mr. Bauer further explained the benefits of GNSS use in SSV:

- Significantly improves real-time navigation performance (from: km-class to: meter-class)
- Supports quick trajectory maneuver recovery (from: 5-10 hours to: minutes)

- GNSS timing reduces need for expensive on-board clocks (from: $100sK-$1M to: $15K–$50K)
- Supports increased satellite autonomy, lowering mission operations costs (savings up to $500-750K/year)
- Enables new/enhanced capabilities and better performance for High Earth Orbit (HEO) and Geosynchronous Earth Orbit (GEO) missions, such as earth weather prediction using advanced weather satellites, space weather observations, precise relative positioning, precise position knowledge and control at GEO, formation flying, space situational awareness, proximity operations, and beyond GEO/cislunar space.

Dr. Deutsch asked whether it is planned to be used on Orion? Mr. Bauer responded that we get significant availability from GNSS in the lunar orbit regime.

Mr. Bauer briefly discussed ICG-12 and the members of the ICG. The upcoming 13th annual meeting will be hosted by China in Xi'an in November. The current working groups of the ICG include WG-S: Systems, Signals, and Services; WG-B: Enhancement of GNSS Performance, New Services, and Capabilities; WG-D: Reference Frames, Timing, and Applications; and WG-C: Information Dissemination and Capacity Building.

Interoperable, multi-GNSS SSV coordination is accomplished under WG-B. Efforts currently underway include SSV booklet development, a companion SSV outreach video, a coordinated outreach initiative, and an ICG-approved recommendation to examine the use of GNSS SSV for exploration activities in cis-Lunar space. Additional WG-B discussion includes interoperable search and rescue (SAR) services and developing an interoperability and augmentation strategy to improve space weather observation, alerts, and prediction. NASA has also recently published two studies examining the feasibility of GPS navigation at lunar distances. These studies represent early GPS-only analyses that can be used as a basis for WG-B in-depth analysis. Study and simulation results from high-altitude and lunar GPS show that:

- GOES and MMS data have enabled the development of high altitude GPS simulation models that match flight data to within a few percent in overall visibility metrics
- These results show useful onboard GPS navigation at lunar distances is achievable now using currently-available signals and flight-proven receiver technology.
- A modest increase in gain or receiver sensitivity increases visibility significantly.
- Future work must extend these specific studies to full navigation analysis of cis-lunar spacecraft, including effects of DOP, and utilizing the full capability of multi-GNSS signals.

A potential future application is the Lunar Orbital Platform-Gateway (LOP-G). NASA will continue to provide updates to WG-B as plans develop.

Mr. Bauer outlined the NASA proposed path forward with the goal of conducting a WG-B-led trade study on options for future SSV concepts to support exploration needs in cislunar space and beyond. The U.S. is also proposing a workshop on future directions for the SSV under WG-B with the goal of the workshop being to collect international inputs on future directions for the multi-GNSS SSV in cislunar space and beyond. A plan will be agreed to and announced at ICG-13.

Mission areas currently supported by GNSS include precise orbit determination, time, relative navigation for rendezvous, formation flight, radio occultation, and oceanography. Mr. Bauer presented the number of missions by agency supported by GNSS, as of November 2017.

Mr. Bauer concluded by reemphasizing that the SSV, first defined for GPS Block IIF, continues to evolve to meet user needs. GPS has led the way with a formal specification for GPS Block III, requiring that GPS provides a core capability to space users. Current and future space missions in the SSV are becoming increasing reliant on near-continuous GNSS availability to improve their mission performance. Today, the ICG continues to work to ensure that the SSV keeps pace with user demands, including its use throughout cislunar space. Additionally, developing and evolving an interoperable multi-GNSS SSV is a critical space utility, improving on-board PNT resilience and ensuring wider capabilities are available as needed.

Mr. Miller added that he thinks it is necessary for the ICG liaison to present at the IOP. There is high-level interest, so it is necessary for leadership to be aware of the work going on and have their engineers attend the proper meetings. Mr. Werner furthered this. There are actions in place for how the second generation Galileo can support the SSV. Representatives are taking this very seriously and putting requirements in place.

Mr. Liebrecht asked whether there is any discussion within the MMS community on going further out once the science mission is met. Mr. Bauer responded that yes, it could keep going from an engineering perspective. The challenge is that the satellites are spinning, but this is an opportunity for the future. Currently, 7 satellites are in view, but they only need 1 signal (although 4 is better).

The Chairman confirmed the ICG presentation at the IOP and asked for the presentation to be provided by the end of September so delegates may receive it ahead of time.

3) CCSDS: James Afarin

Mr. Afarin provided the organization chart for CESG and an overview of CCSDS accomplishments. CCSDS currently has 150 normative (blue and magenta) and 92 informative (green) active publications and has published approximately 366 major publications since 1982. 1,094 space missions have adopted and used various CCSDS standards. In the presentation, it was stated that 58 of the active publications are downloadable for free. It was clarified that all active publications are downloadable for free from www.ccsds.org. Mr. Afarin also provided a list of the publications, reconfirmations, approval of charters, and approval of new projects since IOAG-21.

Other achievements since IOAG-21 include those related to spacecraft on-board interfaces, cross support services, system engineering, SANA registries, space internetworking, space link, and mission operations.

Mr. Liebrecht inquired about whether CCSDS has considered 4G LTE? Mr. Cosby recognized terrestrial protocols as the route to take. Mr. Tai commented that 4G LTE is a long term evolution and would like for them to go through SFCG for the waiver process. Hopefully, there will be a true international commercial standard. Dr. Deutsch asked whether there is a problem with the protected zone of the moon? Mr. Cosby replied that there is not a recommended band.

Mr. Afarin provided an update on the IOAG service catalogues and status of ICPA. The IOAG updated Service Catalogue #1 and Service Catalog #2 and checked the status of projects in ICPA, referencing SC#1 and SC#2. For the projects not yet in ICPA, the IOAG shall provide the relevant priority and for the projects already in ICPA, the IOAG shall check and update the priority. Lastly, the Service Catalogue #3 draft is available and waiting to be submitted so implications to ICPA can be seen.

Delegates inquired about projects that are not in ICPA – will CCSDS put them in and establish priority for them? Mr. Afarin responded that he will see what CCSDS can do based on available resources. Mr. Calzolari commented that this is addressed in the SCWG presentation.

Key issues outlined were:

- *SANA registries:* There is a management concern about the significant amount of work envisioned for the development and administration of the SANA registries. Are these registries truly necessary? Can we afford them?
- *Publication of books:* Over the past few years, the increase in document production rate has overwhelmed the reviews process and technical writing/editing. How to resolve the backlog in the book production queue remains a challenge.
- *High-rate uplink coding:* The need for the high-rate uplink (i.e., AOS uplink) coding standard by the international Lunar exploration missions is pressing us to come up with a more expedited solution.
- *Infusion of SMC MO services:* The lack of clear consensus among CCSDS member agencies on the infusion path for SMC MO services seems to be a persistent phenomenon. Is this a problem?
- *Loss of key talents:* we suffered from the loss of some key talents, e.g., security and delta-DOR.
- *Resources and prioritization of work items:* A continued shortage of resources has forced us to delay the progress for certain standards, such as CFDP V2 prototype and DTN First hop/Last Hop, and a continued resource constraint requires us to resort to more dynamic prioritization/re-prioritization of projects.

The Chairman asked Mr. Afarin to expand on the problem with the SANA registries. Mr. Afarin expanded on the issue by noting that a lot of documents are overwhelming the technical writers and this is why the cue is larger and there have been delays. The registry keeps growing and it needs to be more productive and efficient. Reducing the load on SANA will make it more focused.

Mr. Afarin concluded by outlining the CCSDS presentation for IOP-4. Topics include key mission drivers for standards development since the IOP-3, a summary on standards developed since the IOP-3 that have contributed to the interoperability and cross support for missions of the IOAG member agencies, and the states of the standards related to the various key initiatives identified at the previous IOPs:

- Space internetwork per DTN
- Optical communications
- Ka-band
- Spacecraft Emergency Cross Support Services
- Mission operations
- Cross support services
- Service Catalog 1 and 2

Delegates brought up the point of putting focus on commercial providers and noted that if we adopt the commercial standards or help develop standards for industry, this may be a better philosophy than us developing a standard and trying to educate industry. Mr. Afarin noted that CCSDS does invite industry for discussion and holds a webinar that 9 companies participate in, give comments, and receive updates.

A delegate noted that in reference to the number of blue books, all space missions refer to only 4 blue books out of the 92 that exist.

The Chairman asked if cubesats are looking for lighter versions of the standards. Mr. Afarin responded that if the cubesat wants agency support then they must use standards. If nothing is done through the agency, then it is up to them. It is very dependent on what is supporting the cubesat. The Chairman asked whether there is too much burden on networks for missions not under control of the agencies. Mr. Tai noted that lunar cubesats did not have a problem with adopting CCSDS standards for telemetry, command, and radiometrics. The standards have not imposed any undue burden to those missions. Mr. Cosby commented that commercial missions often pick out what is needed. Ms. Di Giulio noted that CCSDS tries to encourage participation from commercial providers, but it’s not always possible to impose standards on commercial missions who need a quick return on their investment.

It was asked whether there is a minimum requirement in order to be added to the usage list. Mr. Afarin replied that if a mission is using a standard, they are on the list, but that doesn't make them interoperable. It was also noted that each standard is going to have different options.

Mr. Schulz asked whether it would be beneficial to give industry red books for review. Mr. Afarin responded that he wasn't sure what the value would be to give them a book that wasn't approved yet. Industry is able to receive an update anytime.

4) SFCG: Enrico Vassallo and John Zuzek

Mr. Zuzek first reviewed the ITU WRC-19 agenda items of concern and interest to the IOAG:

- AI 1.13: Bands for terrestrial component of IMT-2020 (5G mobile phones)
- AI 1.14: Bands for High Altitude Platforms (HAPS), fixed-satellite service applications providing "IMT-like" services in rural areas
- AI 1.16: RLANs between 5150 MHz and 5925 MHz
- AI 1.2: Feasibility to establish in-band power limits for earth stations in the EESS and MetSat in 401-403 MHz, and the MSS in 399.9-400.5 MHz. Meant to protect the current operations of low-power satellite-based Data Collection System (DCS) in this band.
- AI 1.3: Upgrading of the secondary allocation to the MetSat service (space-to-Earth) to a primary status and a primary allocation to the EESS (space-to-Earth) in 460-470 MHz, while maintain the relative priority between the 2 services.
- AI 1.7: SOS (Space Operation Service) allocation for non-GSO satellites with short duration missions within 150.05-174 MHz, 400.15-420 MHz. Meant to try accommodating the growing number of nanosatellites/cubesats outside the already crowded 2 GHz band or the Amateur Satellite bands.

Mr. Zuzek outlined the proposed way forward for the IOAG on the agenda items and noted that SFCG would like support on actions that support our assets.

Mr. Liebrecht asked about Mr. Zuzek's confidence in space relay links with the assumptions made for analysis on 5G. Mr. Zuzek responded that he believes we are okay based on the assumptions, but he's not extremely confident in the assumptions.

Mr. Schulz asked about 26 GHz for exploration and trying to promote it for space agencies. He asked if this is a wrong assumption because we don't know if mobile will be deployed first, and we will be secondary. Mr. Schulz mentioned that this is certainly a difficulty because we haven't implemented many 26 GHz stations yet and it is difficult to determine deployment for 5G from what we've seen. Only two borders with other nations in the U.S. can be unaffected by them, but in Europe, the coordination zone would cross many borders. Getting a recommendation on how to correctly calculate this will be critical. He would like to get everyone on the same page and get

into the regulations so we can still deploy new Earth stations within reason. The concept of who is there first does matter in most countries. Mr. Schulz asked whether there is an issue with 26GHz uplink for future lunar communications, because large investments are being planned in that domain, and he wants to be sure of protection for that band. Mr. Zuzek replied that studies in respect of 32 and 37 indicate less of a problem than the 26 GHz band. Some are going full speed ahead of 26 GHz, even though the WRC hasn't occurred yet. 40-42.5 is another band that probably won't affect our plans and we are probably okay at the moment on 37-38. We will have to see what comes out of the conference prep meeting. 26 GHz seems exceedingly likely to be identified. Ms. Barclay recommended to continue to protect the band, because it will have a significant impact. Mr. Schulz again noted that missions are being told to go to 26 GHz, so perhaps building more stations to protect the band is the answer. The Chairman asked which bands we need to protect. Mr. Zuzek replied that 25.25-27.5 is the first priority. Crosslinks overlap with downlinks and it is the most critical based on WRC agenda items. It is a little easier to defend deep space bands, but he's not as worried about those. The Chairman asked what the IOAG can do to help. Mr. Zuzek said that from an agency standpoint, the frequency managers need to be active in the regional activity for the WRC. 5G is important, but we need to protect very large investments and future investments for space exploration. From a technology standpoint, he is unsure of anything the delegates can do. Mr. Liebrecht suggested providing money to the ground stations with this capability.

Mr. Liebrecht asked if there is anything the agencies can do to make missions more robust against interfering sources. Mr. Zuzek responded that everyone needs to do a better job in mitigating interfering signals and being more efficient. In filing NASA signals domestically, some of what we see is not the best decision based on spectrum. Sometimes, it's financial. It's a balancing act.

The Chairman asked whether the SFCG would be a good mediator towards ITU to obtain special regulations regarding satellites in emergencies. Mr. Zuzek said this should be possible. Ms. Barclay noted that one of the main concerns is the lead time to authorize to transmit. There is an ITU rule that in the event of spacecraft emergency with life or property loss at risk, there is an exemption that allows operators to do what they need to do to transmit and can follow up afterwards to gain approval. Delegates discussed whether this is the right approach and can be exercised. Mr. Zuzek confirmed that there are international radio regulations, duplicated in domestic regulations, that say in an emergency you can do what needs to be done to save a spacecraft. It was noted that it may be helpful for the SFCG to come up with a resolution or recommendation that outlines what you can do in spacecraft emergencies. Mr. Zuzek said he would take this back to Mr. Vassallo. Ms. Barclay clarified that the U.S. has a national policy, but she is unsure about other countries, so something overarching would be helpful. Mr. Zuzek noted that most countries don't contradict international radio regulations that they sign on to, but they do have the sovereign right within their country to do what they want. We can make the exemption more clear in our documentation.

Mr. Shigeta asked whether the above regulation was applicable to both the downlink and uplink, because the uplink is a domestic issue while the downlink is an issue of ITU filing. Mr. Zuzek responded that this is for both downlink and uplink. In a lot of cases with near Earth spacecraft, the U.S. will look at getting systems certified for anomalies or emergencies. Most of the time, they violate rules. Uplink is usually less of a problem, but we still see that a lot at NASA. The Chairman thanked the presenter and noted that the conversation could continue later in the meeting when spectrum is revisited.

Working Group Reports

1) C&MWG: Les Deutsch and Gian Paolo Calzolari

The co-chairs reviewed team membership and stated the problem that during the years, the number of coding and modulation schemes available in CCSDS standards has grown significantly. Currently, the expectation is that all core standards in the IOAG service catalog should be implemented at applicable participating ground stations, but this approach would require a large investment by agencies. Moreover, there is currently no incentive, beyond their superior performance, to use newer (better) standards. The purpose of the C&MWG is to identify a subset of preferred modulation and coding that pertains to these core standards. The WG encourages missions seeking cross-support services to choose coding and modulations from the preferred list, but this does not place any restrictions on missions using any other standard codes or modulations as long as they do not expect to receive international cross-support standard services.

The "Recommendations on Preferred Coding and Modulation Schemes" were approved at IOAG-19d and consequently, the IOAG Service Catalogs were updated to refer to the C&MWG Report, CCSDS was informed of the preferred list, and the IOAG encouraged adherence to the preferred list for missions requiring international cross-support services.

The co-chairs discussed the future of the C&MWG and presented a summary of the C&MWG report. Further details on the report can be found on www.IOAG.org.

Mr. Calzolari's message to the IOP is that the group was appointed and completed the work. It may need some review since some recommendations were not mature at the time of usage, but the C&MWG can revisit the report if needed in the next one to two years, or when needed. The co-chairs noted that recommendations are not able to be provided before IOP. They will be ready next year. With finalization on work of the LOP-G, the group could take into account what the LOP-G is deciding and update the report, however, it is difficult to say something is not preferred if it's already been selected. There was additional discussion from delegates on how often updates of the report will be needed to add, update, or remove items from the preferred list.

Approval of Minutes

The delegates voted to approve the IOAG-21 and IOAG-21b minutes.

Working Group Reports: Continued

2) Service Catalogs Working Group (SCWG): Jean Marc Soula and Gian Paolo Calzolari

Mr. Soula reviewed the status of SC#1 and SC#2 and SCWG membership. He reminded the delegates of the definitions of priorities in the evaluation process. Mr. Soula also reminded the delegates that the IOAG need date should be understood as not as the date when the new standard "should fly," but as the date when the new standard should be published so that its implementation is possible on a first customer project of one of the IOAG Members. A status of each of the action items was given.

- AI 21-05: NASA noted that there was no input from NASA incorporated in the infusion tables, except for near-Earth. Mr. Liebrecht noted that that was incorrect and there was missing information pertaining to the DSN and optical. Mr. Soula noted that it was difficult to set priorities, so assumptions were made on the priorities that SCWG could assign for the different categories for optical considering the replies that were received. This can be adjusted based on NASA input.
- AI 21-06: Question on Delta-DOR priority. The Chairman agreed to an e-vote to determine priority for DDOR.
- AI 21-07: Priorities yet to be confirmed.
- AI 21-08: Only NASA plans to implement in 2022.
- AI 21-25: LCAWG was given the action after there was no response from the agencies.
- AI 21-30: No comments.
- AI 21a-01: The due date of this action was extended.

Mr. Soula noted that the SCWG could show the full infusion tables for all services in both the service catalogs. The question for the IOP is whether we want to show no plans for what to put in the service catalogs for interoperability. It's almost completely red right now. There is only some green on DTN. Mr. Schulz asked the question of whether it's necessary to develop so many standards for data transport and there was further discussion on CCSDS priorities. Mr. Afarin commented that CCSDS priorities come from agencies who ask for standards to be developed when they have funding for an activity.

<u>IOAG CCSDS Product Agreement (ICPA) Report to IOAG-22</u>

Mr. Soula reviewed the ICPA report to the IOAG. Delegates accepted the delays presented and discussed the missing standards to the ICPA. There was further discussion on the prioritization of

standards between the IOAG and CCSDS. The Chairman suggested that the conversation be revisited.

Cross Support Metrics: James Afarin, Phil Liebrecht, and Tsutomu Shigeta

Considerations about Cross-Support and Involvement of Commercial Providers/Industry

Mr. Afarin noted that CCSDS and the IOAG will improve outreach with commercial providers in its long-term strategy to consider/infuse their main requirements. He outlined potential obstacles with engaging industry, as well as ways that CCSDS can be more efficient.

Mr. Liebrecht asked how many individuals from industry typically attend CCSDS workshops. Mr. Afarin responded that they make up approximately 3-5% of attendees and have heavier attendance at specific working groups, primarily optical. Mr. Schulz asked Mr. Afarin to clarify what he meant by "commercial providers." Does this include equipment providers or also the tracking station providers? Tracking service providers invest where they see a market, which is different from equipment providers. Mr. Afarin responded that we want commercial providers to help CCSDS with standard development, not just use it. The Chairman added that not just standards should be coordinated with the commercial provider, but also the development of resources. He asked whether the charter should be opened to receive guidance on openness to commercial providers. Dr. Deutsch proposed that the IOAG go to the IOP with a recommendation after discussing internally. Mr. Shigeta asked whether the IOAG should encourage CCSDS to conduct outreach activities for communicating with the commercial side. Mr. Afarin asked what the goal of this would be. Mr. Israel responded that part of working with commercial is to leverage their investments to help solve problems. Mr. Liebrecht noted that there any many ways to interact with industry, either country by country or collectively.

Tracking Network Cross-Support: IOAG Role and Issues

Mr. Liebrecht presented the results of the IOAG in promoting Cross Support -1 and -2. He discussed the recent trends with CS-1: the number of commercial service providers is increasing, which is expected to continue, and the number of new users is increasing. Current trends of CS-2 include: the number of CubeSat/SmallSat launches by private companies, institutions, and universities has been rapidly increasing, while the adoption of CCSDS in their missions is limited; and commercial tracking service providers are expanding their services, but the CCSDS standards are not always being utilized. He noted that CCSDS is considering outreach activities for how it may encourage industry to adopt its standards and join in the development of CCSDS standards.

Mr. Liebrecht discussed what the future role of the IOAG should be. On the point of outreach to industry, the Chairman noted that ESA is already coordinating with industry on two aspects: standardization and development of operational resources. The Chairman recommended illustrating and highlighting the matrix on cross support at the IOP. On the topic of industry, there would need to be more discussion on ideas before a concrete proposal. Mr. Liebrecht agreed that

there was not consensus yet. Mr. Soula commented that he was confused about what "commercial" really meant in the context of the conversation, because it doesn't apply to deep space. Additionally, the IOAG can not present a table that only a few agencies have filled in with information. The Chairman clarified that the table is the most important output of the IOAG, because it was set up to do cross support. The table shows what level the agencies are set up to do and how many missions and agencies are participating. Mr. Schulz noted that the IOAG has been a success story over the last 20 years. Mr. Liebrecht agreed that CCSDS and IOAG have contributed a lot to what is happening by establishing standards.

Databases: AJ Oria

Mr. Oria provided a summary of the reference tables. He noted that there are many more missions, so the more information delegates can provide, the better. He would like if China and Russia could provide input, so their inputs can be included in the table at the next IOAG meeting. The Chairman noted that he had contacted CNSA and Roscosmos and sent them directions on how to do this and they hadn't provided input. Mr. Liebrecht asked Mr. Oria to include a chart showing the growth in missions depending on compatible GNSS with the cross support tables.

Working Group Reports: Continued

3) LEO26SG: Catherine Barclay

Ms. Barclay noted that the co-chair position is being handed to Philip Baldwin, so this will be her last time presenting. The Chairman added that Mr. Rosello would also be replaced with a new co-chair. Ms. Barclay reminded the delegates that there have been two prior releases of the report – June 2013 and November 2016. She reviewed the study group terms of reference and provided an overview of the report including the introduction, concept of operations, mission and business considerations, missions and networks using 26 GHz, architecture considerations, and technology and system development. The study group made recommendations for resulting IOAG actions and provided recommendations to the IOAG to update the study group for IOP-4. Ms. Barclay also emphasized that there is a need to protect the 25.5 to 27 GHz from Mobile 5G. The lessons learned overview pulled lessons learned from different Ka-band missions and propagation studies, including TESS, MetOp-SG and SNOWBEAR, NASA propagation studies, and other propagation activities.

Ms. Barclay concluded by presenting the IOP-4 resolutions, next steps, and conclusions. The Chairman asked if the study group could be more specific referencing "coordination" in the resolution, "The IOP encourages coordination between users to reduce interference." Ms. Barclay responded that there is potential for mutual interference, for example, with LEO missions at Svalbard. Mr. Liebrecht suggested showing current and planned Ka-band capabilities on a world

map. Ms. Barclay responded positively that this would be a good way to show how far and wide the band would need protecting. Mr. Liebrecht asked whether there was any discussion on whether missions should fly certain antenna shapes. Ms. Barclay said that was a topic the group could address.

The Chairman noted it would make sense to continue the working group in order to collect more information. The future scope could widen to include other areas, such as Lagrange, lunar, and GEO. He noted that delegates should nominate people who can continue in the group or new people who can contribute.

Mr. Soula added that where we are in respect to high data rates should be included in the report. Mr. Rosello replied that the group would like to report on that. Ms. Barclay added that the group could look at more coordination with the C&MWG.

Open Discussion

Frequency Bands

The Chairman asked if there were any frequency bands that needed additional discussion besides optical and 26 GHz. Mr. Liebrecht noted that defending S-Band was successful in the U.S. The Chairman asked if there should be a frequency report to the IOP outlining bands that need protection as per the SFCG presentation. Mr. Schulz asked about infusion plans of X-Band uplink for Earth. The Chairman asked whether there should be an action or group to look at this. Mr. Liebrecht noted that if you don't use it, then you're at risk of losing it, and it's very useful for uplinks. The Chairman revisited the bands and priority levels listed in the SFCG presentation and asked whether Enrico should give one or two charts of input on critical issues for the IOP. Mr. Liebrecht cautioned that once a band is lost, it's near impossible to get it back. Mr. Alain asked whether the issue should be addressed in the SFCG. Dr. Deutsch noted that this is for the SFCG, not IOP audience, because it should be discussed at the lower-level between scientists. Mr. Alain concurred.

Infusion Table

The delegates discussed the cross support infusion table and whether standards which are not implemented impact cross support and interoperability. The response was that nothing is blocking it and we are doing global cross support today. It was suggested that the IOAG look at service catalogs to see what is actually needed and what the IOAG can do without. A possible solution suggested by Mr. Liebrecht is to limit or reduce service catalogs. The most fundamental things are already in place to make the standard, since cross support is currently happening. He added that standards allow us to offer more services and do cross support in more efficient ways, but there are also always backup options. Which service catalog is the core and how does it evolve over time? Mr. Tai added that cross support seems to be focused on the physical and data link layer and

is now about how to move to space internetworking. There needs to be a complete picture of where we are today to have a discussion on each of the services and get to standards that are useful. Mr. Calzolari noted that the delegates also need to remember the definition of core services. Delegates noted that priorities have changed over time, so a review of the core services and agency priorities needs to be initiated.

Interface Between IOAG and CCSDS

The Chairman asked whether a mismatch between the IOAG and CCSDS is a problem or not and what the relevance of this mismatch in the ICPA is. Mr. Soula noted that the SCWG used the priorities which resulted from the IOP-3 to determine what is needed first for standards. Mr. Afarin noted that the CCSDS standards were prioritized by the agencies who asked for the standard. Mr. Liebrecht noted that some fraction of the standards should have guidance from the IOAG, but others have nothing to do with what the IOAG is doing. Mr. Soula added that some standards are based on the technical aspect and the goal of them isn't cross support. Delegates suggested that there is the need to gain understanding of the IOAG standards for cross support vs. the CCSDS standards that the agencies want.

Commercial Providers

The Chairman noted that this topic is still too high level and the IOAG should further discuss it. The IOAG can bring it up to the IOP, but his impression from the earlier discussion is that it's not a priority anymore to bring to the IOP. The group can continue to follow this topic, but there's nothing to conclude as of this moment.

Cross Support Tables

Mr. Soula commented that the cross support table that includes commercial providers was not giving the correct picture (the other table is fine). If considering commercial, only a few agencies reported using them. The Chairman asked about looking at them without commercial providers on cross support. Mr. Liebrecht replied that the tables are missing an important point by doing that and the IOP should understand whether commercial providers are using CCSDS standards. Mr. Schulz recommended presenting the information using qualitative instead of quantitative statements. The delegates agreed to continue the discussion later in IOAG-22.

IOAG-22 Meeting Minutes
Ohio Aerospace Institute, Cleveland, OH, United States
27 June 2018 – Day 3

Opening Comments

The Chairman began by saying that Mr. Cosby proposed for IOAG-23 to be held in Cornwall, UK in September 2019. Mr. Soula asked whether it would be possible to advance the meeting date to be able to discuss the outcome of the IOP. Mr. Cosby noted September was a better time to travel to Cornwall considering availability of hotel rooms and costs. The conversation on finalizing the date of IOAG-23 will continue. The Chairman suggested to organize a small IOAG meeting at the end of the IOP meeting. This proposal was accepted.
Mr. Liebrecht noted that IOAG leadership change should be discussed. The Chairman responded that this would be a good topic to discuss the next day during IOP discussions.

Working Group Reports: Continued

4) SISG: Dave Israel and Klaus-Juergen Schulz

Mr. Israel reviewed the SISG charter and membership. He also reminded the delegates of the recommendations from IOP-3.

Regarding DTN, the CCSDS DTN WG has published several documents, including recommended standards of the core DTN protocols. Mr. Israel included the standards that are the minimum required for interoperability operations. The Internet Engineering Task Force (IETF) DTN WG is strongly attended and is gaining momentum on the commercial side, so we need to maintain interoperability on the IOAG side. Members of the CCSDS team are also participants in the IETF activities. Mr. Israel noted that commercial interest is more for activities, such as emergency responder communication support and bringing network connectivity to remote locations. Mr. Cosby furthered that the UK is using DTN for its rural counties for connectivity. Mr. Israel also reviewed DTN implementations, including Interplanetary Overlay Network (ION), DTN2, and others. He noted that demonstrations have proven interoperability of the aforementioned implementations. JAXA also has implementations. Mr. Schier noted that there is a more comprehensive list than Mr. Israel included in his presentation. He will send Mr. Israel a contact for Northrop Grumman – Air Force ISR. Mr. Israel noted that we also need to make sure we're interoperable with commercial uses.

Mr. Israel outlined space internetworking demonstrations and infusion progress since the last IOP, including current work, as well as planned space internetworking demonstrations and infusion activities from ESA, JAXA, and NASA.

The SISG has made progress in the last five years (standards published, DTN operational on ISS, other demonstrations by multiple agencies), but not as much as they had hoped. Part of this is the lunar and Mars exploration focus. The value of DTN for a single LEO mission was underestimated, but the role of DTN for high-rate communications for weather-sensitive links (optical and Ka-Band) is better understood. Standardized high-data-rate transmission technology in a standardized network-centric communications architecture with Bundle Protocol enables the overall next-

generation productive space communications solution. The introduction of DTN standard products will decrease development costs and increase mission operations productivity. Mr. Israel concluded with the SISG proposed IOP resolutions.

Mr. Shigeta asked when the earliest opportunity to conduct flight DTN is. Mr. Israel replied that 2019 is the earliest launch for ESA and NASA. Mr. Liebrecht added that it's difficult to get the processing power necessary on flight components for high rates. Mr. Israel responded that if you already have the software power to be running DTN, it may not be that much of a change to the building blocks already flying. It is already found within NASA. Mr. Liebrecht noted that for the IOP members who are not as familiar with what the importance is of this, there needs to be more motivation about why this is important for operations concepts. This is something we should all do before the IOP. The Chairman commented that he agreed delegates should receive a pre-brief and data pack for IOP background information. Mr. Schulz added that the main message should be the shared hope of higher productivity of missions. Mr. Afarin added that there are spinoff returns on investment, such as what the UK is doing with using DTN for ground systems. What are other applications? Mr. Liebrecht concurred.

Mr. Soula noted that many missions today are accustomed to losing data. We need to be prepared to answer questions at the IOP regarding the data rates achieved using optical links or 26 GHz, where is data stored, etc. Mr. Israel responded that NASA is currently working on those arguments to show there is standard implementation. When the motivation charts are put together, SISG should add this. There are parts beyond reliable data distribution, such as reliable, standardized ways to manage storage. The delegates further discussed pros and cons pertaining to Ka-band and optical links from ground stations.

Mr. Shigeta asked about opportunities on reporting to the IOP on a possible plan of flight testing for the NASA cubesat (SUDS) in 2019 and about interagency demonstrations for the ground segment? Mr. Israel responded that there is not only a node at ground stations of different agencies, but also cubesats of different agencies. There is interoperability from both sides. He will work on the wording of this.

It was also noted by Mr. Ahn that KARI is working on DTN implementation and the delegates noted that there should be further conversation on these activities.

5) OLSG: Bernie Edwards and Klaus-Juergen Schulz

Mr. Edwards reviewed the OLSG IOP-3 resolutions and the WG achievements following the IOP-3. He noted that when working towards international standards there was progress in some areas and setbacks in others. The OLSG asked CCSDS for guidance prior to the standardization process and some were accepted. Collaboration was urged on demonstrations and that was accomplished.

In addition, achievements were shared in various forums with lessons learned. Lastly, HPE was recommended for any future architecture for deep space optical communications. However, for near-Earth intersatellite links of data relay systems, a common wavelength and signaling format could not be defined, which has led to an agreement to prepare two High Data Rate Orange Books.

The CCSDS Optical Communications Working Group has investigated High Data Rate, High Photon Efficiency, and Low Complexity scenarios. Mr. Edwards listed the current efforts from the WG on optical communications and outlined the current optical communications activities and ten year vision from: CSA, CNES, JAXA, NICT, ESA, and NASA. DLR later noted that they do not have inputs because they had a change in representation and there was no feedback due to that. DLR can provide input in the future on current activities.

Mr. Edwards also reviewed the NASA/ESA recommended lunar optical communications architecture based on the CCSDS HPE recommendation. There was additional discussion on the pros and cons of photon counting and pre-amplified with the following considerations: longevity, cost, future support, complexity of technology. Mr. Edwards confirmed that HPE was the recommendation after all considerations. Regarding the assumptions, Mr. Tai asked whether SCPPM will be used for Earth to Moon? Mr. Edwards confirmed this, as well as for intersatellite links and the return links.

Mr. Edwards reviewed the OLSG conclusions, issues, and recommendations and presented the proposed IOP-4 resolutions. Delegates had conflicting opinions regarding O3K for LEO DTE. Some delegates suggested that the number of concepts be increased while another delegate recommended to not rush and develop only one. Mr. Liebrecht suggested a compromise that there are multiple wavelengths, but the IOAG agrees to all 3. NASA, CNES, JAXA, and NICT all say 1550, but there is significant pushback from other members of the working group. All agreed with 3 as a compromise. Mr. Schulz noted that the Gateway declined to use HPE for direct to earth, because there were too many standards and recommendations with no consensus. NASA and ESA now propose to use HPE for both direct to earth and intersatellite links, and confirmed that there is WG consensus on this. The WG will work on wording for the IOP presentation, including making the IOP presentation less technical.

The Chairman asked whether there is any proposal to the IOP for a network of ground terminals. Mr. Edwards responded that putting stations in the U.S. gives NASA easier access to control high speed and cost, however, the relay will use the international standard. The Chairman asked about the worldwide network initiative. Mr. Liebrecht noted that this was a good point to mention at the IOP, because it was brought up at the IOP-3. Mr. Schulz noted that if there is agreement on O3K, a tech agreement to do a demonstration of implementation is the logical next step. A real network could exist not only between agencies, but also commercial operators. Commercial operators have shown interest from European and American companies. Mr. Shigeta added that JAXA, together

with NICT, is proposing Ethernet tech for O3K. He asked the Chairman how this proposal has been discussed in the WG and whether it is appropriate to mention the industry involvement in the report to the IOP? Mr. Edwards encouraged JAXA and NICT to come forward regarding this. Using commercial standards and protocols and technology as much as possible will reduce costs. If the CCSDS model is being broken, however, there needs to be good technical reasons. Mr. Schulz noted that HPE and O3K transport is fully inside the CCSDS boundary at this moment in time. Mr. Edwards responded that the concept was to move Ethernet frames rather than CCSDS. Mr. Soula noted that when DLR adds its comments, we can see if there is hope for convergence in the longer term. He also brought up the issue of eye safety, which was critical in the IOP. Has there been evolution in the perception of this issue? Mr. Edwards noted that NASA had to modify pointing and tracking to allow the ISS terminal to be eye safe. ESA responded that the higher power level is eye safe for them, so this is a good example of different standards between the agencies.

6) SECSWG: Catherine Barclay and Thomas Beck

Ms. Barclay provided an overview of the SECSWG and its membership, scope, and deliverables. She noted that this year the group focused specifically on how to establish a procedure from a technical perspective. Challenges with management wasn't an original focus on the working group, but it's necessary to address to enable the goals.

Mr. Reynolds provided an overview of the demos performed by the SECSWG and the status of the preparatory work.

Ms. Barclay presented the Standard Operating Procedure (SOP) document outline and reviewed each of the sections: introduction, services available for emergency cross support, cross support information exchange, standard operating processes and procedure, participating communications assets in the spacecraft emergency cross support, and example SECS services scenarios. Mr. Afarin asked why the SANA registry is recommended if it's too cumbersome. Ms. Barclay clarified that this is not a final decision or recommendation and there has only been preliminary discussion on registries. The Chairman asked whether the list of SECS services is offered by all agencies. Ms. Barclay answered that the engineering services, yes, but not for TT&C.

Ms. Barclay presented the proposed levels of preparation and services delivered. She noted that the definitions are currently under discussion for "committed," "acknowledged," and "non-registered." Comments on the Hayabusa-2 demonstration and upcoming TerraSAR-X demonstration were that HYB2 was closed loop only and typical of a non-registered support. The latest ongoing demonstration will be typical of a committed support. The target is to have everything "in-situ" for IOP. The Chairman asked about the group's impression of cooperation and whether training was needed. Ms. Barclay replied that there were no problems.

Ms. Barclay reviewed drafted options for implementing SECS services and proposed IOP-4 resolutions. Mr. Tai asked about whether the group should include having "no agreement in place" as an option for implementing services, because the point of the group is to legitimize the approach and avoid not having an agreement. Ms. Barclay responded that sometimes it's unavoidable and agencies prefer different options.

She concluded by presenting the group's accomplishments and next steps. The delegates inquired about permission to radiate without an RF license during an emergency. There were conflicting opinions about whether this was legal and whether an emergency had to be authorized. The group was advised to seek additional information regarding this. The delegates further discussed the types of agreements presented. The Chairman created an action for the agencies to check with their management to determine which type of charter is preferred.

Gateway Overview and Plans: John Guidi

Mr. Guidi began with an overview of U.S. Space Policy Directive-1, emphasizing the United States' goal of returning humans to the Moon for long-term exploration and utilization. He provided an update on the NASA exploration campaign and reviewed budget request highlights, which emphasize NASA priorities under the current administration. Mr. Guidi also called special attention to the focus placed on growing the commercial space sector and provided further information on updates pertaining to ISS utilization and LEO transition activities to develop the domestic LEO space economy. Regarding deep space transportation, Mr. Guidi provided an overview of EM-1 and EM-2 and updates on Gateway functionality, development, architecture, concept investigations, PPE studies, and utilization.

Mr. Guidi provided information pertaining to the Gateway communications planning, noting that the Gateway is preparing for an increased role as a relay service provider. A top takeaway from recent workshops is that there is a lot of data for human missions in particular and the far side of the moon is RF silent, and Gateway wants to keep it that way. Pertaining to PNT, an atomic clock on board is a good option. GPS didn't fit into PPE programmatically, but it's still on the agenda for somewhere else on the Gateway, and it's the goal to have it up there. Gateway communications will follow ICSIS standards and protocols with using IOAG and CCSDS/International standards. The draft standards, including those for communications, were released for public comment on March 1, 2018.

Mr. Afarin asked what current thoughts about integration were. Mr. Guidi replied that government will be the overall integrator. The Chairman asked about uplink and downlink requirements. Ms. Vitalpur responded that for uplink, it depends what you are looking at. For command data, it would be 4 MB/sec and for high rate data, 10-25 MB/sec. Mr. Schier and Mr. Guidi emphasized that the

Gateway is an operations and logistics change from ISS. The Gateway will be crewed for one month, maximum two. 85% of the time, it will be empty and conducting automated science systems. One of the main focuses is how to allocate crew time. The Chairman asked whether other agencies are involved in the operations concept. Mr. Guidi responded yes, other agencies are looking at draft conops, but it's not mature enough on daily ops. Mr. Guidi and Mr. Schier also noted that adding commercialization upfront would be a problem. There is a difference in scope of partnerships with interoperable standards than ISS. The Gateway team is trying to be inclusive, but they are starting with the partners they currently have and moving on from there. Ms. Sharada noted that from a communications and navigation standpoint, some of the conops are implicit in writing the interface there. Gateway is expected to be much more autonomous, so providing navigation onboard and in the lunar system and not relying so much on tracking from earth stations. This could be applied to Mars in the future, so there is a lot of opportunity there to build on.

Working Group Reports: Continued

7) LCAWG: Matthew Cosby and Wallace Tai

Mr. Cosby reviewed the LCAWG members, purpose, and current work items. The LCAWG generated recommendations for the down-selected frequency, modulation, ranging, and coding for the future lunar architecture for input to the Gateway project. For reference, the LCAWG included a list of potential lunar missions to be launched during the 2018-2028 decade. Mr. Tai emphasized that the list included commercial vehicles and missions. Mr. Cosby noted that it did, but did not include *all* commercial missions. He then provided a list of the factors taken into account for the selection of CCSDS standards. The WG started with all CCSDS recommendations with the idea that they would not create anything that was not needed and would work around CCSDS input.

Mr. Cosby presented charts on the selection of each of the down-selected items. Regarding selection of frequency bands, Mr. Cosby and Mr. Lanucara discussed WG consensus on the downselection of one or two bands. Mr. Cosby noted that it was the only outstanding issue of the WG. In the Frequency Bands Table, Mr. Tai noted, in response to Mr. Lanucara's question on why GMSK was not included, that the LCAWG will update the table following final coordination and the WG may have GMSK rather than filtered, or both. Mr. Schulz asked about 37 GHz. Mr. Tai responded that the LCAWG did not pursue that and ESA agreed with that. However, how to protect 37 and 42 GHz is an item that could potentially be brought to the IOP. The cost ramification for hybrid Ka-band is very sensitive collectively. Mr. Cosby also noted that the time scale of the work is near-term (2020-2025) and that band isn't implemented in that timeframe. The task of the WG is to come up with architecture and not which frequencies to protect.

The WG reviewed CCSDS and SFCG specifications and CCSDS standards at the network layer and application layer. Action item 21a-05 was closed with the response that from the working

group's preliminary assessment, first hop/last hop services are not a core service and should not be maintained as a core service in SC#2.

Mr. Cosby defined relay services, service types, Lunar-Earth Space Internet, and the Lunar Relay Network and noted the constellation of 3 orbiters (2 polar frozen, 1 equatorial circular). Mr. Calzolari commented that the lunar relay service as defined is a network service. Mr. Cosby responded that that is the point. He understands that it may be contentious. We are moving away from the approach of moving nodes to the ground stations. Mr. Cosby also noted that the final report on lunar relay services will identify what is missing for standardization and will present this to the delegates to accept or reject the WG recommendation. Regarding Mr. Tai's chart on lunar relay orbiters, it was emphasized that further information from China was needed on their orbiter, because it is not using an SFCG frequency for that relay service and X-Band is not allowed within the recommendation. It is unknown whether they asked for a waiver. Mr. Tai furthered that it is not clear whether it's been approved by SFCG and there is some disconnect, because China is a member of the SFCG. Mr. Lanucara flagged that this is a problem to be discussed later on.

Mr. Cosby presented the preliminary summary, conclusions, and recommendations of the WG. He noted that the WG would complete this for the final report by September. Mr. Liebrecht noted that he thinks the WG is moving in the right direction and the information adds a lot of flexibility for missions to work within the constraints and framework. Mr. Guidi added that he liked the diversity of capabilities. Mr. Schier added that the work is consistent with NASA studies for the last several years and applauded the WG. He was pleased with the degree of consensus and for fellow agencies to be moving in the same direction. He furthered that the 12 hour frozen orbit is the best option we have going and it's a good long term strategy which allows for incremental buildup, which is exactly what is needed. The delegates also discussed the far side of the moon relay and whether S-Band or Ka-band would be selected. Dr. Deutsch noted that there is no prohibition for optical at all and Mr. Tai noted that only one violates the RF requirements.

There was additional discussion on the final report and discussion that need to take place within the WG. Mr. Cosby noted that the final report will be made available to the ISECG. For the IOP, the WG will propose a resolution for the agencies to adopt the architecture. The co-chairs noted that they will further discuss the draft resolutions the next day. One of the main points Mr. Cosby noted is that navigation is a key driver for the architecture and the agencies need to accept that. This came out of the WG as a top-level resolution. Mr. Lanucara concurred.

Mr. Liebrecht proposed that besides socializing the information with stakeholders, all agencies ought to make sure to socialize this inside the agencies with their IOP delegates. He asked the co-chairs what they would like to present at the IOP as the path forward. Is it to endorse the architecture at some level and who do they need to coordinate with? The Chairman noted that the WG should take the outcome of the WG and present it to CNSA at the workshop in mid-July. Mr.

Soula asked whether there would be a lot of commonalities for Mars. Mr. Tai answered that some of the work done so far in the WG is applicable to Mars. Therefore, some of it could be exported to the Mars network architecture eventually. Whether something should be done right now is up to the IOAG to decide. Mr. Soula asked when this would be discussed with the IOP. Mr. Cosby responded that the Mars infrastructure is already there and a study would be the first step, then the WG could review what the output could be. Mr. Tai wanted to note that the WG is currently only for lunar. Dr. Deutsch added to the discussion that he agreed with Mr. Cosby and Mars would be different. Relays are needed at the moon for visibility and relays at Mars would mostly be to reduce the onus of communications on the user spacecraft. The constraints and requirements will be different. The overall philosophy can be applied to Mars, but the exact design would need to be worked. Mr. Tai added that in terms of service types – interspace networking based on DTN, in situ tracking, and in situ navigation – is already encountered in Mars missions. At that level, there are strong similarities, but it is completely different in detail.

Gateway & IOAG: John Guidi and Jim Schier

The Chairman noted that there was no formal agenda and this discussion should be an open dialogue and exchange of ideas. Mr. Schier began by giving an overview of the responsibilities of the IOAG and ISECG. The ISECG is responsible for exploration architecture and the IOAG is responsible for communications and navigation and coordinating consistency across exploration activities. Mr. Guidi added that the ISECG is a collaborative group to work between agencies, but if there is something formal being requested of them, there is not a lot they can do beyond alerting their agencies. The IECST is the strongest way to be involved right now. The Chairman asked who the ESA representative to IECST is. The answer was unknown, so ESA will look further into this.

Mr. Liebrecht asked how concepts could be brought forward. Mr. Guidi replied that he could brief Mr. Crusan (NASA). Mr. Liebrecht responded that he would brief Mr. Crusan to come to a determination of whether teams would look at information or bring information directly to the control board. Mr. Liebrecht asked if there were other groups information should be socialized with. Mr. Guidi noted that the ISECG is all government, but commercial plans ought to be included in government strategic planning, however, people are struggling with how to do that. He suggested going to the IAC to get feedback from industry, perhaps setting up time at the IAC to set up a mechanism to receive feedback.

Mr. Tai noted that he wasn't able to obtain very much information on commercial lunar aspirations and asked Mr. Guidi and Mr. Schier whether they have any insight on interoperability and cross support as far as communications is concerned. They noted that formal feedback normally happens in one-on-one meetings. A lot of the information is proprietary as well.

Mr. Schulz asked how likely a 22 GHz uplink or Ka-band inter-satellite links would be. Ms. Vitalpur confirmed that the uplink is specified. Mr. Schier confirmed that the upgrades and implementation for ground stations is planned. The same approach was taken with international communications systems standards. There was an explicit expectation that partners would be implementing capabilities consistent with the standards. The SC is directly related to what was committed to previously and is now falling short. There needs to be some reexamination between the SC and ICSS and the lunar communication architecture and what is being committed to. Ms. Vitalpur commented that the ESA team was included on discussion on the ICSS. Mr. Guidi added that the ESA study lead is Bernhard Hufenbach.

Mr. Schier emphasized that the Gateway will be a phased approach – it's not a one launch mission. It will take over five years and multiple launches to assemble. He also noted that more partners are needed. SCaN and the Gateway are working the phasing of capabilities, such as for optical communications. The PPE will have accommodations for an optical communication payload, even though it will fly up later – timed to when the robotic arm flies – because the arm is required to install the optical payload. So, it may be helpful to look at the lunar communication architecture on when some capabilities are really required and potentially feed this back to the SC. The Chairman added that regarding infusion, delegates should look at whether a specific mission need can push and change infusion on the IOAG side. Mr. Liebrecht asked about data rate constraints. Ms. Vitalpur answered that the Gateway will live within data rate constraints. Mr. Schier added that the assembly sequence should be tracked, because it changed hundreds of times on the ISS. Mr. Guidi noted that that may be simpler, because the Gateway will be smaller than the ISS.

The Chairman asked about interest in the SECSWG. Ms. Vitalpur answered yes, and she wanted to discuss this. For the ICSS, the major outstanding work items are emergency contingency communications, how to interface between mission systems, and addressing what changes, if any, need to be made to address protocols for deep space missions. Mr. Tai noted that the IOAG recommends X-Band for TT&C for spacecraft contingency mode support and recommended adding S-Band at an additional cost. Ms. Vitalpur responded that this is something to think about. X-Band will be there and S-Band could be revisited. Mr. Schier noted that there is currently no S-Band use in the PPE and adding S-Band would add cost, so there needs to be a compelling reason to add it. The principle reason for X-Band is because the Gateway needs to be as "Mars forward" as possible. Mr. Schulz noted that ESA would not like to go to S-Band, because its assets are all X-Band and Ka-band. They'd like to leave S-Band and decommission it.

Mr. Liebrecht noted that there are no standards between different ground stations and suggested a demo for ground to ground interoperability for the Gateway. Ms. Vitalpur responded that that would be helpful. Gateway is updating the ICSS document based on comments received by the end of June. After that, they will look at forward work items for mission ops and ground stations. Mr. Liebrecht suggested establishing contact with Mr. Smith, NASA/GSFC. Mr. Guidi asked if

there is a point of contact to review concepts for implementation? The Chairman answered that the chairs of the WGs would be the appropriate points of contact. Mr. Guidi and Ms. Vitalpur noted that they would follow up with the appropriate contacts for future work.
Possible areas of interest are:

- Emergency Contingency Communications
- Audio & Video Standards
- Optical Resolutions / Recommendations
- Mission System Interfaces
- Change of Protocols.

Mr. Schulz commented on the need to collaborate on the assembly sequence for phasing into the technology development process. He noted that ESA would need to prioritize in line with the assembly sequence. The Chairman responded that the gap assessment was not addressed in that level of detail in the technology working group. Mr. Guidi commented that the ISECG looks at the plans of agencies, compares, and looks for gaps. Mr. Schulz replied that every agency needs to look at those gaps and other potential gaps that could be relevant to the IOAG apart from communications. Mr. Liebrecht and Mr. Schier agreed that navigation would be relevant. Mr. Schulz proposed for agencies to share their development roadmaps for distribution in order to identify maturity levels.

IOAG-22 Meeting Minutes
Ohio Aerospace Institute, Cleveland, OH, United States
28 June 2018 – Day 4

Opening Comments

The Chairman noted changes in the agenda and called for Mr. Liebrecht to reintroduce the change of IOAG leadership. Mr. Liebrecht reminded the delegates that long term chairs were established with the understanding that changes in leadership would occur at IOPs. NASA is happy with how Mr. Schmidt has managed the IOAG and doesn't have any complaints. NASA is not looking for a change, but would like the opportunity for the agencies to discuss the topic. The agencies voiced their opinions and there was consensus that Michael should remain the chair. Mr. Soula agreed, but noted that the topic may have to be raised again before the next IOP (i.e. IOP-4). The Chairman noted that he will retire in approximately 3 years (in 2021), so he suggested that a new chair be installed in 2020, with discussion in 2019 for volunteers and preparations to be made by an agency to take over. He accepts the delegates' nomination to continue serving as chair until then.

The delegates discussed and confirmed the dates for the IOAG-22 follow-up telecons, reflected on www.IOAG.org.

IOP-4 Agenda & Logistics

Real-time edits were made to the IOP-4 agenda after delegates, liaisons, and working groups were given time to discuss their time allocations. Mr. Kozlowski presented logistics for the IOP, which can be found on www.IOAG.org and reminded the delegates that invitations for visas have been sent out electronically and through regular postal mail. The delegates continued discussion on the agenda and suggested that IOAG delegates further discuss the potential topics with their senior leadership and IOP delegates.

IOAG Top Priorities

The delegates discussed the IOAG top priorities drafted by the Chairman and real-time edits were made to the document, which can be found on www.IOAG.org.
Some topics that are relevant in this context were discussed:

- Protection of frequency bands
- Coding & Modulation recommendations
- Outcome of the Emergency Cross-support WG activities
- Harmonize process for 26 GHz
- Mission Operations Core Services & Application Services
- DTN (Delay Tolerant Networking or Disruption Tolerant Networking)
- Data Link Security Layer
- Exploration Communications Architecture
- Optical Communications.

IOAG Presentation to the IOP

The Chairman presented the draft IOAG presentation to the IOP and real-time edits were made as the delegates discussed the content. The Secretariat was asked to provide hardcopy briefing binders for the IOP. Delegates agreed to put the WG definitions in backup. The delegates also concurred that the IOP-4 issues should highlight the interface between the IOAG and ISECG and important findings. It should also highlight the interface with CCSDS and include the guidance and the prioritized list. The Chairman noted that presentations will be circulated ahead of time to allow time for review before the IOP. Time allocations for presentations in the IOP-4 agenda can also be adjusted if it is determined that resolutions will be included in the both the executive summary as well as the presentations.

Working Group Presentations to the IOP

The working groups presented their draft presentations, including executive summaries and resolutions to the IOAG. The delegates also reviewed the CCSDS draft presentation and Mr. Afarin approved the IOP-4 CCSDS resolutions.

IOP-4 Communique & Agenda

Delegates reviewed the Chairman's draft IOP-4 communique. Real-time edits were made to the document and the Chairman asked that any additional proposals be sent to him. The delegates revisited the draft agenda and allocated timing for liaison reports. The chairman will adjust the scope and timing of the agenda accordingly.
One open issue concerned the Director's Forum on the 1st day of the IOP. The delegates should propose topics that could be relevant. Depending on the inputs it will be decided whether the Director's Forum will take place and in which form.
Another open issue that was identified is the interface to the commercial providers and how this aspect should be addressed in the IOP. This topic is to be discussed further.

IOAG-22 Conclusion

The Chairman thanked all the delegates for their participation and thanked NASA for hosting. The meeting was adjourned.

Appendix A: Actions

AI 22-01: MOSSG to provide updated draft of Catalog #3 to the Secretariat for further distribution to all agencies. [Assigned to: MOSSG/Smith. Due date: 13.07.18]

AI 22-02: All agencies to review MOSSG report and SC#3 and provide comments on clear approach for IOP-4. [Assigned to: All Agencies. Due date: 24.08.18]

AI 22-03: All agencies to provide comment regarding interest in a Mission Operations Interoperability (MOI) demonstration. [Assigned to: All Agencies. Due date: 20.08.18]

AI 22-04: All agencies to provide input to ICG liaison regarding missions that use Global Navigation Satellite System services, such as Galileo, GPS, GLONASS. [Assigned to: All Agencies. Due date: 31.08.18]

AI 22-05: All agencies to respond to SFCG liaison recommendations for defense of space communication-related spectrum at World Radiocommunication Conference (WRC-19). [Assigned to: All Agencies. Due date: 31.12.18]

AI 22-06: SFCG liaison to provide insight to WRC regulations regarding emergency support as it relates to the Spacecraft Emergency Cross Support activities. [Assigned to: SFCG. Due date: 31.08.18] Note: This action was later cancelled. Mr. Vassallo noted that the item was discussed at length in many teleconferences and physical meetings and the procedure to be used agreed by the relevant WG. There is nothing new to add.

AI 22-07: All agencies to determine their agency's position on the preferred agreement approach for spacecraft emergency cross support management. Select one or more that are acceptable:

1. Bilateral (generic)
2. Multi-lateral
3. Establish agreement at the time of the request (if not pre-existing)
4. Agreements are not needed to support emergencies.
5. IOAG Policy statement would be acceptable to serve as the agreement for emergency cross support.
6. Propose another method

[Assigned to: All Agencies. Due date: 24.08.18]

AI 22-08: All agencies to determine agency's interest in extending the mandate of 26GHzWG to beyond LEO. [Assigned to: All Agencies. Due date: 24.08.18]

AI 22-09: All agencies to report on the status of optical communication standardization, first operational use, in-orbit demonstrations and future cross support possibilities. [Assigned to: All Agencies. Due date: 24.08.18]

AI 22-10: All agencies to provide lunar communications roadmaps in order to find any gaps. [Assigned to: All Agencies. Due date: 24.08.18]

AI 22-11: Chair and Secretariat to work with ISECG liaison to determine if an ISECG presentation is required at IOP-4. [Assigned to: Chairman and Secretariat. Due date: 24.08.18]

AI 22-12: All agencies to brief IOP participants on the proposed open forum on day one of IOP-4 and determine if interested, and if so, topics for discussion. [Assigned to: All Agencies. Due date: 24.08.18]

AI 22-13: All agencies to prepare written input for IOAG top priority themes with concrete objectives. [Assigned to: All Agencies. Due date: 24.08.18]

AI 22-14: All WG co-chairs to develop one-page executive summary for IOP delegate briefing package. [Assigned to: All WG Co-Chairs. Due date: 24.08.18]

AI 22-15: All WG co-chairs to develop 2-3 bullets to describe WG for IOAG org chart within Chair's IOP presentation. [Assigned to: All WG Co-Chairs. Due date 24.08.18]

AI 22-16: All agencies to review draft charts for Chair's IOP-4 presentation and provide comment. [Assigned to: All WG Co-Chairs. Due date 24.08.18]

AI 22-17: Secretariat to provide presentation format template to all presenters. [Assigned to: Secretariat. Due date: 31.07.18]

AI 22-18: SFCG liaison to propose IOP-4 resolution for protection of space communication-related spectrum. [Assigned to: SFCG Liaison. Due date: 24.08.18]

AI 22-19: NASA SN and DSN to provide their infusion plans on optical communications (slide 8/17 of SCWG report). [Assigned to: NASA. Due date: 23.07.18]

AI 22-20: SCWG co-chairs to coordinate with the CCSDS liaison to update the ICPA with IOAG missing standards and new/revised inputs, based on the outcomes of the related e-votes (no answer to the e-votes will be accepted). [Assigned to: SCWG Co-Chairs and CCSDS Liaison. Due date: 31.08.18]

AI 22-21: SCWG co-chairs to organize within the SCWG a critical review of the SC#'s to revisit the needs (core/extended/to be removed) and solutions (to be developed by CCSDS or legacy solutions to be used), in view of the global picture established with the agencies' infusion plans, the ICPA and the IOAG Top Priorities. Out of this analysis, to make recommendations for SC#'s modifications to the IOAG and, wherever required, to propose the creation of new strategy groups in IOAG to formulate and provide BoF input to CCSDS (model on the SISG and OLSG examples; especially for new areas or areas where there is no active project nor consensus to initiate work in CCSDS). [Assigned to: SCWG Co-Chairs. Due date: 04.10.18]

AI 22-22: SCWG co-chairs to revisit as required the proposed ICPA optical communication priorities and to send the outcome to the Secretariat for a subsequent e-vote. [Assigned to: SCWG Co-Chairs. Due date: 30.07.18]

AI 22-23: SCWG co-chairs to update Service Catalog 2 according to the results of AI 22-26. [Assigned to: SCWG Co-Chairs. Due date: 04.10.18]

AI 22-24: Approve, or disapprove and provide input on the attached proposal for prioritization of service management functions. [Assigned to: All Agencies. Due date: 06.08.18]

AI 22-25: Confirm that CSTS Forward Frame should be P2 for 2022 in the ICPA. [Assigned to: All Agencies. Due date: 06.08.18]

AI 22-26: Confirm that First/Last hop should not remain a CORE Service in SC#2. [Assigned to: All Agencies. Due date: 06.08.18]

AI 22-27: Each Agency to approve/disapprove the following changes in IOAG inputs to the ICPA:

- Space Data Link Security (SDLS) protocol: extend procedures 355.1 - change the current need date (12/30/2018) to 05/31/2019. [+5 months]
- Cross Support Service Management: File Transfer, Ground Segment, Recommended Profile 927.1 - change the current need date (11/30/2018) to 11/01/2019. [+11 months]
- Bundle Security Protocol for CCSDS 734.5 - change the current need date (12/31/2018) to 12/31/2019. [+12 months]

[Assigned to: All Agencies. Due date: 06.08.18]

AI 22-28: Approve the new IOAG inputs to the ICPA relative to the file transfer services. [Assigned to: All Agencies. Due date: 06.08.18]

AI 22-29: Approve the new IOAG inputs to the ICPA relative to the SC#2 services. [Assigned to: All Agencies. Due date: 06.08.18]

Appendix B: Acronyms

LEO26SG	Low Earth Orbit 26 GHz Study Group
ARM	Asteroid Redirect Mission
ASI	Agenzia Spaziale Italiana
C&MWG	Coding & Modulation Working Group
CCI	Climate Change Initiative
CCSDS	Consultative Committee for Space Data Systems
CESG	CCSDS Engineering Steering Group
CNES	Centre National d'Etudes Spatiales
CNSA	China National Space Administration
CSA	Canadian Space Agency

DLR	German Space Agency
DOP	Dilution of Precision
DSOC	Deep Space Optical Communications
DTE	Data Terminal Equipment
DTN	Disruption Tolerant Networking
EO	Earth Observation
ESA	European Space Agency
ESOC	European Space Operations Centre
ESTRACK	ESA Tracking Stations Network
EU	European Union
GEO	Geosynchronous Orbit
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEO	High Earth Orbit or Highly Elliptical Orbit
ICD	Interface Control Documents
ICG	International Committee on GNSS
ICPA	IOAG CCSDS Product Agreement
ICSS	International Customer Service Standard
IECST	ISS Exploration Capabilities Study Team
IETF	Internet Engineering Task Force
ION	Interplanetary Overlay Network
IOP	Interoperability Plenary
IPP	International Partnership Programme
ISECG	International Space Exploration Coordination Group
ISS	International Space Station

ITU	International Telecommunication Union
JAXA	Japan Aerospace Exploration Agency
KARI	Korea Aerospace Research Institute
LCAWG	Lunar Communication Architecture Working Group
LCRD	Laser Communications Relay Demonstration
LEO	Low Earth Orbit
LEOP	Launch and Early Orbit Phase
LOP-G	Lunar Orbital Platform – Gateway (also known as “Gateway”)
MEO	Middle Earth Orbit
MO	Mission Operations
MOIMS	Mission Operations and Information Management Services
MOIS	Mission Operations Interoperability Services
MOSSG	Mission Operations Systems Strategy Group
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
O2O	Optical to Orion
OGS	Optical Ground Station
OGSN	Optical Ground Station Network
OLSG	Optical Link Study Group
PCT	Proof-of-Concept Testbed
PNT	Positioning, Navigation, and Timing
PPE	Power and Propulsion Element
RFSA	Russian Federal Space Agency
SANSA	South African National Space Agency
SAR	Search and Rescue

SC	Service Catalog
SCaN	Space Communications and Navigation
SCO	Space Climate Observatory
SCWG	Service Catalogs Working Group
SDSA	Sardinia Deep Space Antenna
SECSWG	Spacecraft Emergency Cross Support Working Group
SFCG	Space Frequency Coordination Group
SISG	Space Internetworking Strategy Group
SM&C	Spacecraft Monitor & Control
SOP	Standard Operating Procedure
SRR	System Readiness Review
SSV	Space Service Volume
STRS	Space Telecommunications Radio System
TT&C	Telemetry, Tracking, & Command
TTCP	Technology Transfer Control Plan
UAESA	United Arab Emirates Space Agency
UKSA	United Kingdom Space Agency
WG	Working Group
WRC	World Radiocommunication Conference