**CCSDS Optical Communications (OPT) Working Group**

**Revision 2 of the Optical Communications Blue Books**

**White Paper**

**Section 1: Background**

Several space agencies are working on space-based optical communications. The primary motivation for these efforts stems from the expectation that optical communications will enable substantially higher (at least 10 times) data rates than Radio Frequency (RF)-based solutions with similar user spacecraft onboard terminal burden (mass, volume, and power). In addition, optical communications can be used at data rates comparable to RF to lower an onboard communication system’s required mass, volume, and power. Use of optical communications is also appealing since RF spectrum availability is becoming an issue for high-data-rate applications.

Optical communications systems can operate in space, e.g., via inter-satellite links and between space and Earth. The latter must operate through Earth’s atmosphere, and can be severely impacted by weather (clouds, optical turbulence, and other atmospherics); the result is that a typical spacecraft using optical communications to communicate to/from Earth must be supported by several ground stations to overcome weather-related link outages. Thus, international cross support is vital to enable optical communications.

The CCSDS Optical Communications Working Group was formed in January 2014 and is developing the following:

* Standards for wavelengths, modulations, coding, interleaving, synchronization, and acquisition that are best suited for free-space optical communications systems
* Standards for definition, exchange, and archiving of weather data for predicting and operating optical communication links among optical ground stations and their network operations centers

To guide standards development, the working group has been considering various applications of free-space optical communications, including Earth relay satellites and Low Earth Orbit (LEO) direct-to-ground, lunar direct-to-Earth, and deep space direct-to-Earth communications. Just as different RF systems are required to support such very diverse applications, different optical communications systems will be needed as well.

To date the working group has developed the following CCSDS books:

* Blue Book on Optical Communications Physical Layer
* Blue Book on Optical Communications Coding and Synchronization
* Green Book on Real-time Weather and Atmospheric Characterization Data
* Orange Book on Optical High Data Rate Communications – 1064nm
* Orange Book on Optical High Data Rate Communications – 1550nm
* Magenta Book on Atmospheric Characterization and Forecasting for Optical Link Operations

The working group is currently developing Revision 1 of the Blue Books to include recommendations for Optical On/Off Keying (O3K). While the O3K recommendations can be used for numerous applications, they were developed with LEO direct-to-Earth optical communications in mind. The working group has reached consensus on the recommendations to be incorporated in Revision 1 and is waiting for completion of the two independent prototypes before Revision 1 is submitted for official publication. The working group members would like Revision 1 to be published as soon as possible and it will take some time to create Revision 2 as proposed below.

**SECTION 2: Revision 2 of the Blue Books**

The working group members have reached consensus to begin work on Revision 2 of the Blue Books. Revision 2 will build upon the work done to develop both Optical High Data Rate Communications Orange Books. The working group is motivated to revise the Blue Books because several space agencies are considering the deployment of optical communications terminals in lunar orbit to provide dates rates in excess of 1 Gbps from the Moon to Earth. NASA, for example, is targeting a data rate of 5 to 10 Gbps from lunar orbit. The Moon is located close enough to Earth to allow the use of either coherent signaling or the CCSDS High Photon Efficiency (HPE) optical communications recommendations. With today’s technology, however, the HPE maximum data rate is limited to approximately 1 Gbps; coherent signaling, on the other hand, can support the desired higher data rates.

In addition, the Moon is far enough away to warrant the use of 1-meter class or larger optical ground stations to support the expected data rates. Not only will these ground stations require significant resources to implement, they must be globally located to enable communications with the Moon. Thus, the effort to provide high-data-rate optical communication from the Moon could benefit greatly from international cooperation. Consequently, the CCSDS Optical Communications Working Group proposes to produce a revision of the Blue Books to incorporate coherent signaling.

**SECTION 3: Tentative Work Plan**

The following tentative work plan is established.

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | **Start** | **End** |
| 1 | Revision 2 of the Blue Book for Optical Communications Physical Layer | May 2022 | June 2024 |
| 2 | Revision 2 of the Blue Book for Optical Communications Coding & Synchronization | May 2022 | June 2024 |

**ANNEX A**

**CCSDS Optical Communications (OPT) Working Group**

**Projects**

**1) Revision 2 of the Blue Book for Optical Communications Physical Layer**

**Title: Optical Communications Physical Layer**

**Document Type:** Blue Book

**Issue: 2**

**Description of Document:** This Blue Book defines the physical layer parameters and techniques required for interoperability of optical communications. It addresses low and high signal photon flux scenarios for space-Earth and space-space links to standardize one or more techniques for these scenarios.

**Contents of the Blue Book:**

* Wavelength(s) / Frequency(ies)
* Modulations for low and high signal photon flux scenarios

**Book Editor (estimated resources + Agency Volunteering):** 10mm + NASA

**Prototype 1 (estimated resources + Agency Volunteering):** 8mm + NASA

**Prototype 2 (estimated resources + Agency Volunteering):** 8mm + ESA

**Expected Contributing Agencies:** CNES, DLR, ESA, JAXA, NASA, NICT

**Expected Monitoring Agencies:**

**Schedule: May 2022 – June 2024**

|  |  |  |
| --- | --- | --- |
| **Schedule Milestones** | **Forecast** | **Comments** |
| Project Approved | 1 May 2022 |  |
| Internal WG Review | | |
| - First draft circulated to WG | 30 Oct 2022 | After Fall 2022 Meeting |
| - First draft comments due | 1 Dec 2022 | Before Fall 14 Meeting |
| - Second draft circulated to WG | 30 March 2023 | Before Spring 2023 Meeting |
| - Second draft comments due | 30 April 2023 | Before Spring 2023 Meeting |
| - Final WB submitted to AD for further processing | 1 July 2023 | After Spring 2023 Meeting |
| Secretariat Document Processing | 1 Sep 2023 | Start of Review after CESG + CMC Polls |
| First Agency Review | 1 Nov 2023 | End of Review |
| RID Resolution | 31 Dec 2023 |  |
| Secretariat Document Processing | 1 Feb 2024 | Start of 2nd Review (if needed). No Polls. |
| Final Agency Review | 30 Mar 2024 | Before Spring 2024 Meeting |
| RID Resolution | 30 April 2024 |  |
| First Prototype Development | 31 Dec 2023 | NASA |
| Second Prototype Development | 31 Dec 2023 | ESA |
| CMC Approval | 1 June 2024 | Includes Final Secretariat Document Processing + CESG Poll + CMC Poll for Publication |

**Revision 2 of the Blue Book for Optical Communications Coding and Synchronization**

**Title: Optical Communications Physical Layer**

**Document Type:** Blue Book

**Issue: 2**

**Description of Document:** This Blue Book defines the coding and synchronization layer parameters and techniques required for interoperability of optical communications. It addresses low and high signal photon flux scenarios for space-Earth and space-space links to standardize one or more techniques for these scenarios.

**Contents of the Blue Book:**

* Coding
* Synchronization

**Book Editor (estimated resources + Agency Volunteering):** 10mm + NASA

**Prototype 1 (estimated resources + Agency Volunteering):** 8mm + NASA

**Prototype 2 (estimated resources + Agency Volunteering):** 8mm + ESA

**Expected Contributing Agencies:** CNES, DLR, ESA, JAXA, NASA, NICT

**Expected Monitoring Agencies:**

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