10 Gbps Shuttle-to-Ground Adjunct Communication Link Capability Experiment[1]

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ABSTRACT

A 1.2 Gbps space-to-ground laser communication experiment being developed for use on an EXpedite the PRocessing of Experiments to the Space Station (EXPRESS) Pallet Adapter can be adapted to fit the Hitchhiker cross-bay-carrier pallet and upgraded to data rates exceeding 10 Gbps. So modified, this instrument would enable both real-time data delivery and increased data volume for payloads using the Space Shuttle. Applications such as synthetic aperture radar and multispectral imaging collect large data volumes at a high rate and would benefit from the capability for real-time data delivery and from increased data downlink volume. Current shuttle downlink capability is limited to 50 Mbps, forcing such instruments to store large amounts of data for later analysis. While the technology is not yet sufficiently proven to be relied on as the primary communication link, when in view of the ground station it would increase the shuttle downlink rate capability 200 times, with typical total daily downlinks of 200 GB - as much data as the shuttle could downlink if it were able to maintain its maximum data rate continuously for one day.

The lasercomm experiment, the Optical Communication Demonstration and High-Rate Link Facility (OCDHRLF), is being developed by the Jet Propulsion Laboratory's (JPL) Optical Communication Group through support from the International Space Station Engineering Research and Technology Development program. It is designed to work in conjunction with the Optical Communication Telescope Laboratory (OCTL) NASA's first optical communication ground station, which is under construction at JPL's Table Mountain Facility near Wrightwood, California. This paper discusses the modifications to the preliminary design of the flight system that would be necessary to adapt it to fit the Hitchhiker Cross-Bay Carrier. It also discusses orbit geometries which are favorable to the OCTL and potential non-NASA ground stations, anticipated burst-error-rates and bit-error-rates, and requirements for data collection on the ground.

INTRODUCTION

The optical communications system designed for use on an EXPRESS Pallet Adapter (ExPA) as part of the International Space Station Engineering Research and Technology Development (ISSERT) program has a maximum downlink data rate of 2.5 Gbps into the 1 meter OCTL receiver. This paper will discuss the necessary modifications to upgrade the flight terminal to 10 Gbps and interface it to a shuttle Hitchhiker double bay pallet. Modifications to the flight terminal include laser power, mast size, thermal design, electrical interface, and data interface. Modifications in the ground terminal include the detection process and the storage medium.

SPACECRAFT TERMINAL MODIFICATIONS

Transmitter

A wavelength division multiplexing (WDM) scheme will be used to increase the data rate. Four wavelengths, each transmitting 2.5 Gbps, would achieve a 10 Gbps aggregate downlink data rate. This enhancement involves adding three master oscillator lasers to the laser transmitter assembly (LTA) and

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upgrading its power amplifier to 800 mW; 200 mW for each of the four WDM channels. This design retains the per-channel power and involves only the LTA; the design of the rest of the flight terminal would remain unchanged.

Thermal

The difference in orbit inclination between the shuttle and International Space Station results in different temperature ranges. The largest temperature swing for the EXPRESS pallet is from -110°C to +40°C [1], whereas the cargo bay of the shuttle swings from -160°C to +95°C while on orbit with the doors open [2]. These changes in thermal environment plus increased thermal load from the three master oscillators and a more powerful amplifier will require a change in the thermal design specified for the ISSERT mission. The thermal design for the ISSERT mission uses blankets and heaters to keep the telescope optical assembly (TOA) in the preferred operating range of +10 to +30°C. All other electronics are placed on a radiator with louvers attached to a mirror radiator surface for the hot case, and a heater for the cold case. The changes to this thermal design necessary to support a shuttle mission depend strongly on the shuttle orbit of interest.

Interfaces

Interfaces for the Shuttle Hitchhiker Carrier and the ISS EXPRESS pallet adapter share few similarities, although both provide two 28 VDC power supplies. The Hitchhiker can provide 10 Amps and up to 1600 Watts of simultaneous total customer power, while the ExPA has a configurable current supply, which can be 5, 10, 15, or 20 Amps and is limited to 1000 Watts. In any case the power capability is ample compared to the estimated 135 W total power for the ISSERT mission.

The payload envelopes of the ExPA and the Hitchhiker double bay pallet are similar. The ExPA can accommodate a payload weight of 227 kg and size 86.4x116.8x124.5 cm [1] , and a double bay pallet Hitchhiker carrier can accommodate a payload up to 272 kg with a size of 83.8x139.7 cm [2]. The height of the shuttle payload is limited by a center of gravity that must not exceed 38.1 cm in height [2]. The approximate size of the telescope optical assembly and gimbal is 54x33x31 cm. The estimated volume and mass of 62 kg would easily be accommodated by either platform.

Data interfaces for the ISS EXPRESS pallet adapter and the Shuttle Hitchhiker are a point of dissimilarity. While the EXPRESS pallet uses a MIL-STD-1553B command and control data bus, the Shuttle Hitchhiker uses a RS 422 asynchronous interface. A complete redesign of the data interface would be necessary to modify the ISSERT design for interface to the shuttle.

RECEIVER MODIFICATIONS

The receiver telescope focuses the downlink signal onto the data detectors. To accommodate the four wavelength channel, the receiver telescope design must be modified to separate the four wavelength channels using either prisms, gratings or specially designed long-pass filters. The spatially separated wavelengths would then each be focused on their own data detector receiver, requiring the addition of three data detector channels and data recorders.

ORBIT GEOMETRIES

Obits which have a long contact time with one of the potential ground station sites are favorable. Potential ground stations include the OCTL at the JPL Table Mountain Facility near Wrightwood, CA, the Air Force Maui Optical Station (AMOS) in Maui, HI, the ESA station in the Canary Islands, and the NASDA station in Tokyo, Japan. The ESA and AMOS ground stations are favorable for the normal 26 degree inclination orbit. While the other locations would not have contact times for this orbit, they would be favorable for orbits at 35 degrees or more.

ERROR RATES

Atmospheric fades dominate the error rate in optical communication channels, typically lasting 8-10 ms. The burst-error-rate depends on the elevation of the shuttle above the horizon, the ground wind speed, and the degree of turbulence in the atmosphere. The burst-error-rate is estimated to be typically < 10^{-5} when the shuttle is only 20 degrees above the horizon and reduces to < 10^{-8} when more than 30 degrees above the horizon. When fades are not present, the bit error rate is expected to be 10^{-9}.

REFERENCES

[1] Expedite the Processing of Experiments to Space Station (EXPRESS) Pallet Payloads Interface Definition Document, SSP 52000-IDD-EPP Working Draft, NASA, March 8, 1999.

[2] Hitchhiker Customer Accommodations & Requirements Specifications (CARS) document, HHG-730-1503-07, Goddard Space Flight Center, Greenbelt Maryland, 1994.