HIGH-RATE OPTICAL COMMUNICATIONS LINKS FOR VIRTUAL PRESENCE IN SPACE

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Abstract

As man continues the exploration of space, either from platforms in Earth-orbit or from missions to the bodies of our solar system, there will be an on-going need to keep the public engaged in the process so that the general populace can share in the excitement of discovery and the inquisitive (professional or student) can participate in the data mining. To do this will require the development of high-data-rate communications links for data return and dissemination. However, the cost constraints on future missions will require tl~attl~cscl~igt~-rate links be smaller and lighter-weight than even the lower-capacity systems that have been used in the past. NASA has been developing free-spfice optical communications technology for just such missions. This paper will discuss the technology developments and system demonstrations that have been accomplished to date, and will describe preparations for the space demonstrations that will validate the performance of this new technology.

INTRODUCTION

Past space missions have typically been limited in their data collection abilities by the available sensor technologies. As gr-cater data collection needs were met, the sizes of the spacecraft continued to expand. This was particularly (rue for the communications systems required to transfer that data to the final user. Today, the technologies for sensors can enable enormously large data collection volumes. However, the economics of space flight have forced significant reductions in the sires of the platforms on which such sensors must fly. In today's environment, there is a need for much more capability to support those sensors, while, at the same lime, requiring less impact (in terms of mass, size, power) on the host spacecraft.

To satisfy this "more for less" requirement, NASA has been developing optical (laser) communications technology. This technology has the ability to enable enormous gains in the available link capacity with systems (hat are only a fraction of the sizes of the conventional rf systems. This enhancement comes from the narrow "pencil" beams associated with laser beam propagation. This gain dots come, however, at a cost of requiring a more precise control of the transmitted optical beam. Such systems in the past were both bulky and required substantial amounts of electrical power. Recently (Chen 1994; US Patent 1997) a very simple implementation of the beam control system was developed at JPL. This system, called the Optical Communications Demonstrator or OCD has become the basis of a number of planned flight demonstrations of laser communications technology, and for the development of much more capable systems for extending this technology to the far reaches of the solar system.

THE OPTICAL COMMUNICATIONS DEMONSTRATOR

The primary reason fur the size, complexity and power consumption of past beam control systems was the number of detectors and steering elements required to track a beacon signal from the target receiver and to point the data-modulated beam back in that direction. The OCD architecture is based on a simplified structure for that process utilizing only one detector array and onc steering mirror (past designs used as many as four of each). Figure 1 shows the concept for this system.

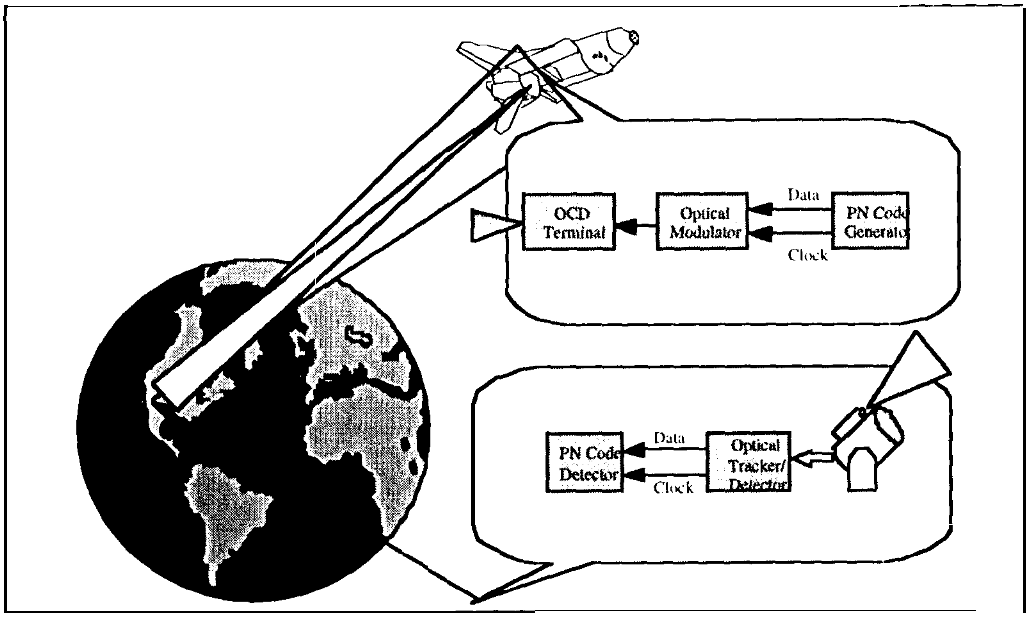
The bands represent the hounds 01 capabilities resulting from an aggressive, and a conservative, investment in the technology. To the right of the figure are indicators of the kinds of service provided to the missions based on reasonable assumptions on coding nd dala compression. Clearly, IMAX-quality video could be ret urned fi om Mars by the 2020 time period.

NEAR-TERM DEMONSTRATIONS

The importance of the OCD terminal architecture cannot be underestimated. 11 is the basic starting point for both near-earth terminal designs, as well as those for deep-space, It is therefore important that an early demonstration of the OCD principles and performance predict i ns be carried out in space. Two such demonstrations arc under study and preliminary design; one on the Space Shuttle and the onther on the International Space Station.

Space Shuttle Demonstration

The first demonstratic on is the Free-space Optical Communicatic ons Assessment Link (FOCAL). It would use the OCD engineerin g model as the flight terminal which would fly on the Space Shuttle. As the Shuttle flies over an appropriately-equippcci ground telescope, a beacon laser signal would be transmitted from the ground to the Shuttle. The flight terminal would use that signal as a pointing beacon against which to direct its downlink beam. The downli nk data rate could be as high as several Gbps and still provide 10's of dB of demon stration link margin. While such a link mar-gin is excessive for operational systems, it is felt prudent to keep a large margin for the first several space link demonstrations to cover any uncertainties in the atmospheric beam propagation. Figure 5 depicts the FOCAL demonstration. The FOCAL flight could take place in early-mid 2000.



Figurrc5. Concept diagram for the FOCAL Shuttle demonstrat ion.

Space Station Flight Demonstration and Facility

The Space Shuttle provides a convenient opportunity to test out equipment in space for a modest cost. However, the durations of most Shuttle flights do not permit extensive testing of the equipment, especially if such tests arc restricted to overflights of a ground station. For more in-depth testing, a longer presence on orbit is needed. One such opportunity was recently realized by an award from the International Space Station (ISS) experiments program office. The ISS demonstration is depicted in Figure 6.

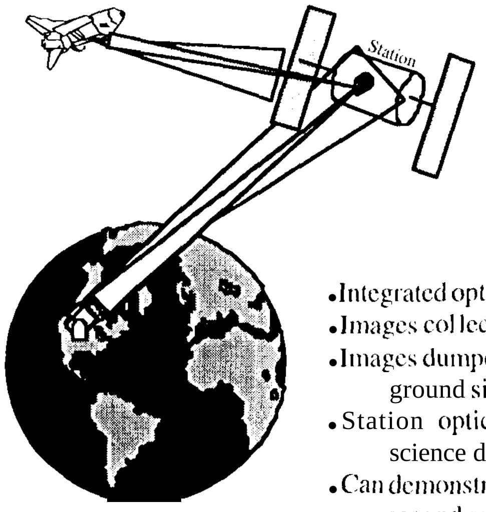


Figure 6. Space Station demonstration (with future extension to space-space demo)

In this program, the OCD engineering model will again be flown, this time on the ISS. Like the FOCAL demonstration, the flight terminal will utilize a beacon laser signal from the ground for pointing and tracking. Because the terminal will be on orbit for an extended period of time, a more thorough set of experimental measurements can be made. Additionally, the longer time on or-hit will also allow reliability data to be collected on the flight terminal.

After the experimental testing has been completed, the flight terminal will be left in place on the station. At this point, it will become a station Facility instrument and will be made available for use by other stati uon experimenters. Flight demonstrations of instrument (like high-resolution multispectral imagers or synthetic aperture radars) that produce larger amounts of data than can be handled by the normal ISS communications infrastructure will be able to use the optical communications link to download their data.

A follow-on demonstration is also being considered. Given that there is an operational OCD terminal on the Station, it would only be necessary to mount a second unit on the Space Shuttle in order to conduct a space-space optical communications demonstration. At this point, the space-space demonstration is only at the conceptual discussion stage.

CONCLUSIONS

The technology and subsequent demonstrations described above will have a major impact on the architecture and the performance capabilities of future space communications networks. The results of these programs will be useful to both government and commercial space communications needs. The bandwidths afforded by this technology will be important enablers for man's virtual presence in space in the next millennium.

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