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OPTICAL DATA TRANSMISSION TECHNOLOGY FOR FIXED AND DRAG-ON STS PAYLOAD UMBILICALS

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Executive Summary — January 1981

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EXECUTIVE SUMMARY

The objective of this study is to determine the feasibility of using optical data handling methods to transmit payload checkout and monitoring telemetry. The motivation for performing this study is the numerous reports of successful NASA, military, and commercial applications of optical communication systems, some of which, MDAC-St. Louis was a participant. These applications have shown optical communications to be superior to conventional communication systems for the following reasons: high data capacity optical channels, small and light weight optical cables, and optical signal immunity to electromagnetic interference. The study is composed of four tasks.

Task number one analyzed the ground checkout data requirements that may be expected from the payload community. The data lines were classified into two categories (1) stand alone payload telemetry checkout and (2) payload monitoring when the payload is installed in the Orbiter. The function of the payload checkout link is to transmit the maximum payload telemetry to the ground checkout equipment a distance of 200 meters; the maximum data rate for this link is limited by the TDRSS communication relay satellite which can accept up to 300 Mb/s. The function of the payload monitoring link is to transmit payload health and status. This data rate is limited by the data capacity of the T/O Orbiter circuits and is specified in the MLP/PAD/Orbiter Interface Document. The payload monitoring link is composed of several sections and is roughly 7.6 Km long.

Task number two selects the optical approach based on the interface requirements: the location of the interface, the amount of time required to reconfigure hardware, and the method of transporting the optical signal. The E/O interface for the payload checkout link is presently chosen to be at the test stand holding the payload. The E/O interface can be moved to the payload itself, as future payload designs and hardware become more amenable to this change. The E/O interface for the near-term payload monitoring link is chosen to be at the MLP, since only landlines are affects by this proposed change and KSC controls both sides of this MLP interface, the long-term payload monitoring link proposes an optical interface with the Orbiter. The Orbiter optical interface is a proposed option and is a recommended follow-up activity. Both air and optical fibers were examined as candidates for the transport media to carry the optical signals.

Optical fibers were chosen for both links because of their widespread use, their ability to enclose the optical signal and their flexibility in routing. The second part of this task was to select a method of multiplexing, modulating, and formating the optical signals. Time division multiplexing proved to be the most readily available and most efficient method for combining low data rate electrical channels into a single high-data capacity, optical channel. Optical components for wavelength division multiplexing are still in the research stage, but the concept offers the promise of transmitting a number of optical channels through a single optical fiber. The payload monitoring link was found to have several asynchronous PCM digital channels which were to be time multiplexed. Four candidate solutions were proposed; bit-stuffing, resynchronization, oversampling, and a packet telemetry method. The least efficient method, oversampling, added only one additional optical fiber, thus, it became the most cost-effective due to simpler design and fewer components. The direct modulation of input current/ voltage of the optical transmitter and external modulation of the output light beam are the two methods of modulating an optical transmitter. Since external modulators are not readily available and tested, and direct modulation meets our requirements and is implemented by well-known electronic components, then direct modulation was selected for both payload data links. Demodulation of the optical signal is accomplished by direct photon detection. The three modulation formats for intensity modulated optical signals are pulse code modulation, pulse position modulation, and analog modulation. Pulse code modulation was chosen since it provided the best combination of receiver sensitivity and wide bandwidth. The data format should be NRZ to meet the 300 Mb/s data rate for the payload checkout link and the maximum data transmission requirement for the payload monitoring link. The clock for the NRZ data should be transmitted on a separate fiber for the short payload checkout link and duplexed in a separate wavelength within the same optical fiber for the longer payload monitoring link.

Task number three surveyed and selected optical components for the two payload data link. Three types of optical components are surveyed: optical fibers are separated into single mode and multimode fibers (step and graded index); optical sources are divided into light-emitting diodes and semiconductor lasers; and optical detectors fall into the two categories of pin diodes and avalanche photo-detectors. Dispersion, pulse broadening of optical signals, and attenuation, pulse amplitude reduction, are the two main causes of signal distortion and are used in the discussion of performance parameters for each of the optical components. Then a quantitative analysis of the risetime (dispersion) and power margin (attenuation) is used to select optical components for each of the two payload data links. The analysis shows the optical payload checkout link can easily meet the 300 Mb/s maximum data rate requirement. It also shows the optical payload monitoring link is limited to roughly 100 Mb/s because of the influence of long length on attenuation and dispersion. Nevertheless this proposed data link is used in a quantitative comparison with the existing conventional method, demonstrating a major reduction in the communiction channels when optical data handling methods are employed in lieu of present metallic-wire channels.

Task number four makes a qualitative comparison of the conventional electrical communication system and the proposed optical communication system. The two communication systems are compared with respect to the growth capacity of the transmission system, the optical approach is clearly superior for two reasons: the capability of transmitting high data rates and reducing the number of transmission channels. Even though the distribution techniques and hardware for electrical signals are presently more developed off-the-shelf optical couplers are sufficient to meet the needs of the proposed options. The existing electrical transmission lines are heavier and larger since they are made of copper and require EMI shielding. In contrast, optical cables are composed of glass and require no EMI shielding. The lighter and smaller optical transmission lines are easier to handle by personnel and take up less room in existing ducts. A number of studies have shown a reduction of the cost of optical components can be anticipated as the volume of production increases. The same studies have shown, as the data rate increases it becomes more cost effective to use a fiber optic system than a metal wire system. For this application, it is obviously more cost effective to replace low data rate electrical cables with high data rate optical cables. Also, the reliability of optical components is now reached 10^5 hours (10 years), comparing favorable with electrical components.

This study recommends implementing the near-term options for each of the payload data links.

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