Wideband Advanced Recorder and Processor (WARP) Summary

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As spacecraft instruments generate data at ever increasing rates, space systems must find ways to handle that data and transmit it to the ground stations. This challenge is especially evident on earth-imaging spacecraft employing multispectral and hyperspectral detectors. The Landsat 7 instrument data rate is 150 Mbps. The Earth Observing-1 (EO-1) instrument data rate is over 500 Mbps. The next generation Landsat is expected to have even higher instrument data rates.

EO-1 is a pathfinder to the next generation Landsat mission. A key goal of EO-1 is to pioneer and flight-validate technologies that will make that mission feasible. One of those technologies is the Wideband Advanced Recorder and Processor (WARP). The WARP is essentially a very high data rate solid-state recorder. It is computer-based and provides science and housekeeping data acquisition, storage, and transmission functions.

Figure 1 shows the WARP mounted in Bay 1 of the EO-1 spacecraft. Figure 2 shows the WARP's circuit boards.

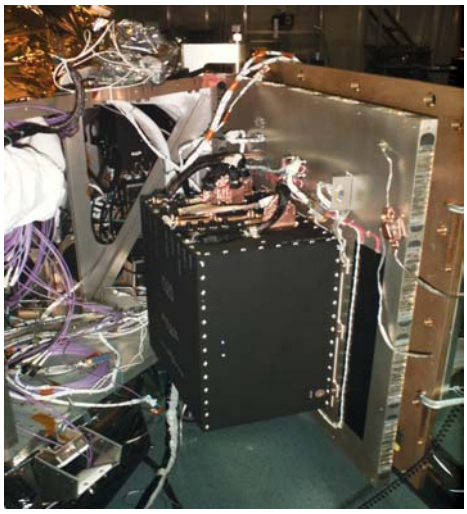

Figure 1. WARP Mounted in Bay 1 of EO-1 Spacecraft

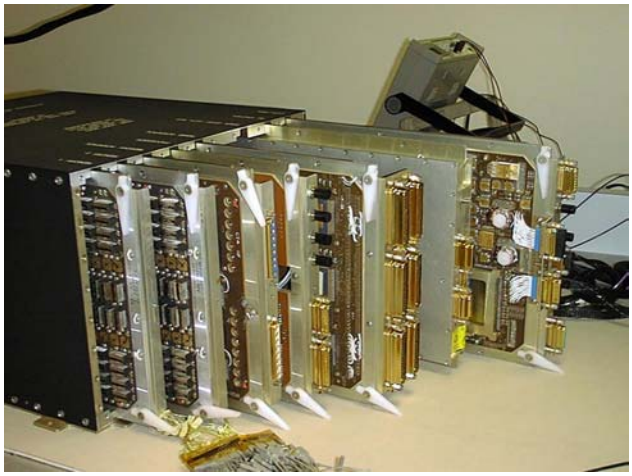

Figure 2. WARP Boards

Figure 3 shows the science data handling section of the EO-1 Flight Data System. The EO-1 Flight Data System is controlled and monitored through a MIL-STD-1773 Data Bus from an on-board command and data handling (C&DH) unit (not shown). When commanded by the C&DH unit, the instruments acquire ground images (scenes) and transfer those scenes at high rates to the WARP. The WARP stores the scenes as files in bulk memory. When in contact with the ground station, the spacecraft automatically transmits the recorded scenes to the ground station via an X-band downlink or an S-band backup downlink.

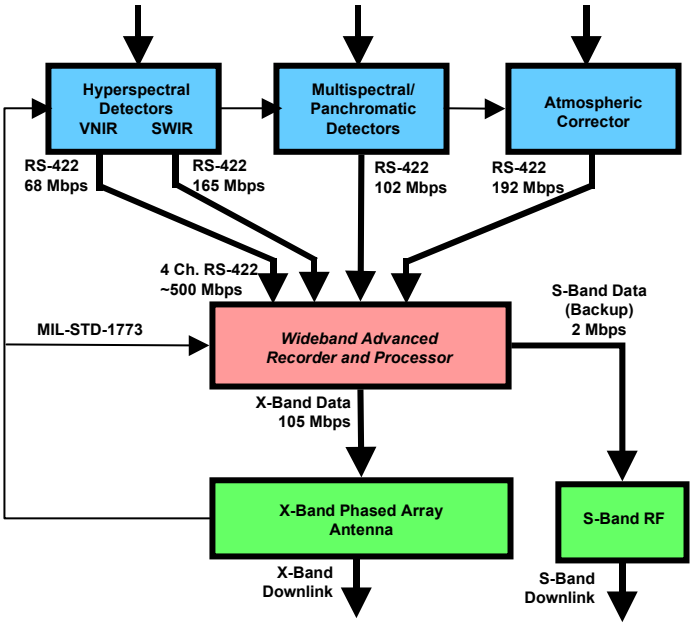

Figure 3. EO-1 Flight Data System Architecture

The primary downlink is through an X-band phased array antenna at 105 Mbps. The downlink has QPSK modulation with separate files being transmitted on the I and Q channels. The transmission is balanced at 52.5 Mbps per channel. EO-1 has a backup downlink through an S-band omni antenna at 2 Mbps.

Table 1 shows the WARP key specifications. Figure 4 shows the WARP hardware architecture.

Table 1. WARP Key Specifications

Data Storage:	48 Gbits (Easily Expandable to Tera-Bit Range)
Record Rate:	>1 Gbps Burst, 900 Mbps Continuous
Playback Rate:	105 Mbps with built-in X-Band RF Exciter
Data Processing:	Post-Record Capability
Size:	25 x 39 x 37 cm
Mass:	18 kg
Power:	45 W orbit average, 110 W Peak
Thermal:	0-40 °C minimum operating range
Mission Life:	1 year minimum
Radiation:	15 krad total dose, LET 35 MeV

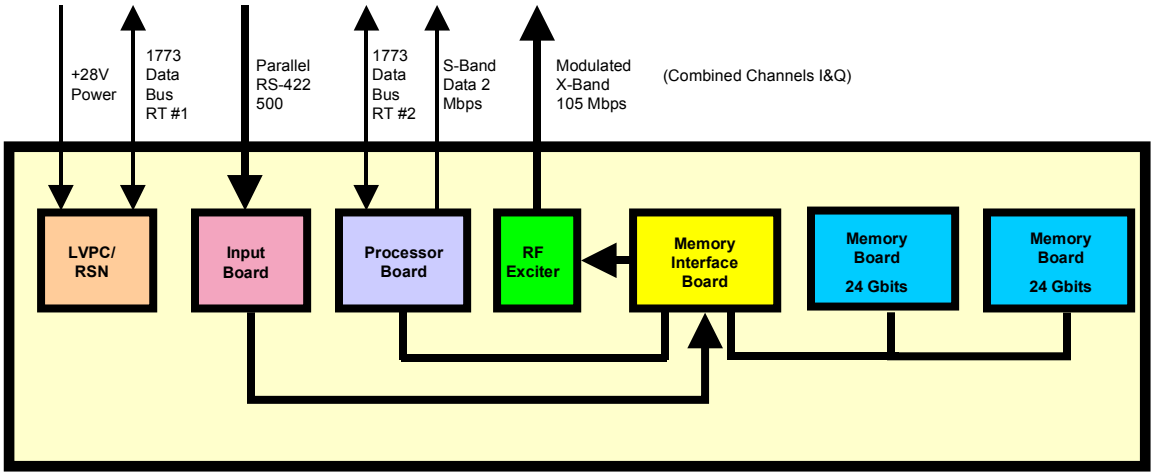

Figure 4. WARP Hardware Architecture

Prior to the initiation of the Data Record Mode, the WARP Processor Board sends commands to the Input Board that select which channels will be recorded. The Processor Board also sends commands to the Memory Interface Board that defines where the scene data will be stored in the Memory. Upon receiving the appropriate MIL-STD-1773 command, all the instruments transmit pixel data in bursts across their respective parallel RS-422 interfaces.

The Memory Interface Board receives the input data and breaks the data stream up into fixed length code blocks. It then appends a short Reed-Solomon Error Detection and Correction (EDAC) field to the end of each code block, interleaves the data, and transmits the data stream across the 1 Gbps Memory Data Bus to the Memory Boards.

The Memory Boards receive the data stream, generate detailed address locations, and store the data. Each scene of each instrument detector channel is stored in a separate file. Each Memory Board has 24 Gbits of data, organized as six 4-Gbit arrays.

In addition to science data recording, the WARP also records full-resolution instrument housekeeping data across the MIL-STD-1773 Data Bus. The housekeeping data is stored in a memory buffer on the Processor Board until after the science data record is complete. The Processor Board then transmits the housekeeping data across the 250-Mbps Processor Bus to the Memory Interface Board, which then performs the same operations as it did with the science data stream.

The WARP performs X-band data playback by transferring files from the Memory Boards to the Memory Interface Board. The Memory Interface Board de-interleaves the data, performs EDAC on the data using the short Reed-Solomon Decoders, formats the data, appends long Reed-Solomon EDAC coding, and transmits the data to the RF Exciter. Two data streams are transmitted to the RF Exciter, an I channel and a Q channel.

The WARP successfully completed a series of ground tests to verify that the WARP performed to its design specification. The WARP was not subjected to any explicit on-orbit tests to validate its performance. Rather, it was put into operational service and monitored for the occurrence of any errors. The WARP performed over 3,000 error-free record and playback operations since the launch of EO-1 in November 2000 to the end of the baseline science mission in November 2001. Its performance was nominal over that period with the exception of one anomaly that occurred on June 21, 2001. The cause and resolution of this anomaly is described in the full WARP validation report.