

**THE ADVANCED ORBITING SYSTEMS TESTBED PROGRAM:
RESULTS TO DATE**

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ABSTRACT

The Consultative Committee for Space Data Systems (CCSDS) Recommendations for Packet Telemetry (PT) and Advanced Orbiting Systems (AOS) propose standard solutions to data handling problems common to many types of space missions. The Recommendations address only space/ground and space/space data handling systems. Goddard Space Flight Center's (GSFC's) AOS Testbed (AOST) Program was initiated to better understand the Recommendations and their impact on real-world systems, and to examine the extended domain of ground/ground data handling systems. The results and products of the Program will reduce the uncertainties associated with the development of operational space and ground systems that implement the Recommendations.

1. INTRODUCTION

GSFC's AOST Program continues to provide a bridge between the development and widespread use of the CCSDS Recommendations. AOST Program activities include developing and using a Testbed, developing flight-qualifiable components, conducting a test program, performing studies, and actively disseminating the knowledge gained. This paper presents an overview of the Capability Two (C-2) AOST and the results and lessons learned through AOST Program activities to date (July 1994), including architectural issues, the proposed standardized test suite, and flight-qualifiable components. This paper also summarizes the correlation between the AOST and the Code 500 Renaissance effort, and AOST future activities, including implementation of the Space Communications Protocol Standards (SCPS) and the Mission Operations Control Architecture (MOCA).

2. AOST PROGRAM OVERVIEW

An overview of the C-2 AOST is presented in Figure 2.1-1.

2.1 FLIGHT SYSTEM ELEMENTS

The C-2 AOST flight system elements include an Instrument Simulator (IS), a Video Digitizer/Packetizer/Multiplexer (VDPM) and a Wideband Transfer Frame Formatter (WTFF). These elements have been developed by the GSFC Instrument Electronic Systems Branch (Code 738).

The Instrument Simulator creates simulated spacecraft instrument data. The IS is capable of simulating data for one to six instruments and uses the CCSDS Version-1 Packet format (Reference 1). The data generated by the IS are input to the WTFF via Fiber Optic Transmitter/Receiver Interfaces (FOXI).

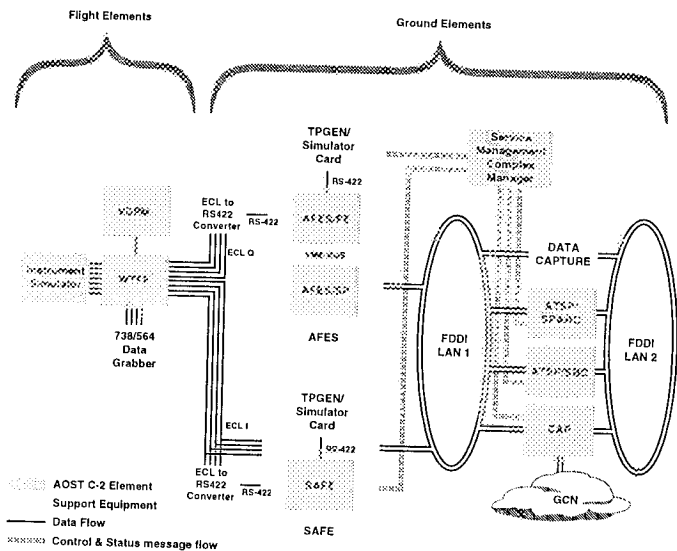


Figure 2.1-1. C-2 AOST Overview

The VDPM generates CCSDS Version-1 Packets and optionally multiplexes them into Multiplexing Protocol Data Units (M_PDUs) (Reference 2). The Packet data field contains either video data that have been converted to digital form by the VDPM or octet-aligned digital data input to the VDPM via a FOXI interface. The VDPM represents a standard interface for CCSDS Path Packet Service. The M_PDUs or Version-1 Packets are input as a single data stream to the WTFF using one of seven available telemetry user data input interfaces.

The C-2 WTFF is designed to serve as a gateway providing transfer frame generation using PT and AOS services for up to seven user virtual channels (VCs). Data arriving from any of the seven user data input interfaces are buffered and inserted into Version 1 Transfer Frames (VITFs) or Virtual Channel Data Units (VCDUs). WTFF processing of the data consists of: Reed-Solomon (R-S) header, R-S frame, and bit transition density encoding; multiplexing of the frames into a single physical data stream; and appending of a frame synchronization marker to each frame. The WTFF also provides the interface to the ground system elements. The WTFF can selectably output data on one or two physical output channels.

2.2 GROUND SYSTEM ELEMENTS

AOST ground system elements include two Front Ends (FEs), three types of Service Processors (SPs), a Communications Address Processor (CAP) and service management elements. The CAP provides a connection to a ground communications network (GCN). A network and service management system controls, configures, and monitors the AOST ground system elements.

The Microelectronics Systems Branch (Code 521) is developing the Advanced Front End System (AFES), which provides a multiprocessing environment based on a VMEbus open architecture. The AFES uses cards based on custom Very Large Scale Integration (VLSI) controllers to achieve a low cost, high speed, and highly reliable implementation. Each custom card has a 32-bit microprocessor. AFES components

are being developed for generic applications and are being used in other systems such as the Small Explorer (SMEX). Commercial off-the-shelf (COTS) cards such as Ethernet and Fiber Distributed Data Interface (FDDI) cards and disk modules are used wherever possible.

The AFES provides return link processing services, configuration management services, and testing and verification services. The AFES comprises a front end (AFES/FE) and one of the SPs, the AFES/SP, housed in a single VME enclosure. Frame synchronization, bit transition density decoding, R-S header and frame error detection and correction, and VC sorting are provided by the AFES/FE. The AFES/FE outputs data formatted as Space Operations Service Data Units (SOSDUs) (Reference 3), a data unit defined by the AOST Program. The SOSDU provides a mechanism for ground transportation and identification of data types consistent with the CCSDS Recommendations. The AFES/FE transfers SOSDUs to the SPs or to the CAP for routing to their user destination(s). The interface to the AFES/SP is internal to the AFES; the data across this interface are formatted as VC Frame SOSDUs. The interface to the ATSPs and to the CAP is accomplished using a FDDI LAN.

The AFES/SP is an integral part of the AFES. The AFES/SP performs CCSDS PT and AOS processing on the SOSDUs received from the AFES/FE, creating Virtual Channel Access (VCA), Bitstream, or Path Packet SOSDUs. The resulting SOSDUs are transferred to the AFES FDDI network interface function for transmission to a predetermined destination address.

Code 521 has also developed a Stand-Alone Front End (SAFE) that is identical to the AFES/FE; these redundant FE systems enable the AOST to process two simultaneous data streams from the WTFF. The SAFE also uses FDDI interfaces to transfer data to the ATSPs and to the CAP.

The Data Systems Engineering Branch (Code 564) has developed two ATSP implementations using solely COTS hardware and operating systems. One implementation is using a "Single Board

Computer" (ATSP/SBC) and a real-time operating system (VxWorks). The second implementation is using a SPARC workstation (ATSP/SPARC) and a UNIX-based operating system. Both the ATSP/SBC and the ATSP/SPARC use Reduced Instruction Set Computer (RISC) technology. The input, output, and management interfaces are identical for both ATSP implementations. The ATSPs receive SOSDUs from the AFES/FE or the SAFE via the FDDI LAN and process these SOSDUs, providing VCA, Bitstream, or Path Packet service processing consistent with Reference 2. The goals of the ATSP developments are to take advantage of and evaluate the potential of the latest technological advancements that industry has produced.

The CAP provides a gateway function for the AFES, SAFE, and ATSPs, translating the global CCSDS identifiers contained in the SOSDU Header to the appropriate user destination address(es), and providing protocol translation between the AOS Testbed and the GCN. The CAP was developed by the NASA Communications Division's Advanced Development Branch (Code 541.3).

The GCN provides communications interfaces to systems external to the Testbed.

The Service Management (SM) system developed for the AOST allows users of a CCSDS service-providing network to interact with that network in terms of services rather than equipment configurations. The service management system manages equipment configuration information, generates periodic reports about the quality of services, and monitors ground system elements for fault isolation. The AOST SM function provides fault detection, isolation, and recovery capabilities for CCSDS data services. The MITRE Corporation is developing the Network and Service Management elements.

The current management hierarchy for SM comprises a Complex Manager that manages the AFES, the SAFE, the ATSP/SBC, the ATSP/SPARC, and the CAP. Each managed system comprises two conceptual components: the data

processor, which performs the actual processing and presents the agent with a local representation of managed parameters; and the agent, which translates the management information from the local representation to a global representation understood by the Complex Manager. The agent presents the Complex Manager with a view of the processor as a collection of abstract functions and system operation parameters. The CAP has an agent that is integral to the CAP development; the AFES, ATSP/SBC, and ATSP/SPARC have SM proxy agents.

Proxy agents are separate modules that reside on the Complex Manager workstation, and are not integral to the development of the associated ground element. These agents translate the Management Information Base (MIB) parameters received from the Complex Manager into configuration setup tables that are then transmitted to the appropriate AOST elements.

The AOST has developed and tested a demonstration version of a standard MIB for CCSDS services and protocols (Reference 4). The MIB allows the Complex Manager and managed systems to exchange management information using a common, standard language. The Simple Network Management Protocol (SNMP) was chosen since it is a well-supported standard protocol for managing network elements and allows the use of public-domain and COTS software for the implementation of the agents and Complex Manager.

3. ACTIVITIES TO DATE

The C-2 AOST development effort is complete, and the testing program for C-2 is nearly complete.

The C-2 AOST provided five CCSDS AOS services: VCA service, VC Frame service, Path Packet service, Bitstream service, and Insert service. The C-2 AOST also support a non-CCSDS service called Space Link Channel (SLC) service. The C-2 AOST supports both conventional CCSDS data units, VITFs, and AOS CCSDS data units, VCDUs.

A completely new test program was implemented for the C-2 AOST (Reference 5). The test program implements the Master Test Suite (Reference 6) to provide a system-independent series of tests that can be implemented to verify any systems' compliance with the CCSDS Recommendations.

Functional testing associated with the C-2 AOST is completed, and research and performance testing is in progress. The C-2 program has produced a number of results, some related to implementation issues associated with the development of AOST elements, and others related to the CCSDS Recommendations themselves. A selection of these results are presented in Section 4.

Flight-qualifiable components have been produced from the equipment in the AOST and additional flight-qualifiable components are currently being manufactured.

A library of AOST Program and related documents continues to serve as a central repository of knowledge gained and products for the AOST Program. A second AOST Workshop has been scheduled for November 1994 to disseminate AOST results.

4. RESULTS

4.1 ARCHITECTURE

4.1.1 Service & Network Management

AOST SM has greatly facilitated the operation of the AOST ground elements, and has streamlined the testing and analysis process within the Testbed. SM controls, configures, and monitors all Testbed ground elements from a single workstation, providing a focus for AOST ground system activity. The SM graphical user interface allows the operator to highlight AOST elements, select predefined configurations, create new configurations, and download these configurations to appropriate AOST element(s). SM is also able monitor the results of data processing by obtaining status information from each element either on

demand or on a periodic basis. These status data can be displayed in real-time either numerically or in graphical format; periodic data can be graphed over time to monitor data processing history.

The AOST SM mitigates sources of error in the comprehensive configuration of the AOST by centralizing and streamlining configuration and control. The service-level specifications manipulated at the Complex Manager workstation concisely define the comprehensive Testbed configuration, and mitigate configuration errors often experienced in the past when local system-level configurations were used. The simultaneous configuration and coordination of several Testbed elements via SM has reduced the number of configuration mismatches, and has allowed for spontaneous development of new scenarios and what-if analyses.

By acquiring and displaying status information from multiple ground elements simultaneously, SM expedites the analysis of AOST data processing activities. The ability to display and graph data from multiple sources in near-real time has been an invaluable tool to developing a comprehensive view of AOST data processing activities. SM also maintains log files that permit more comprehensive post-test analysis.

One of the issues related to the development of SM was the coordination of the proxy agent development with that of the data processors. It was necessary to maintain a constant dialog between the proxy agent developer and the data processor developer during the development process to ensure that the system-level configurations performed by the proxy agent matched the system-level specification within the data processor. On several occasions, small software changes were made to a data processor that required corresponding changes to the configurations being managed by the proxy agent. SM functionality is predicated on a successful communication process to coordinate agent-system interaction.

In the next version of the AOST, the Testbed may develop a Network Management Integration and Coordination workstation that manages a set of Complex Managers. Also, SM may be extended to flight elements, either via a direct link or across a ground-space forward link.

4.1.2 Data Latency

The AOST has been addressing latency issues associated with the AOST elements and the interfaces between the AOST elements. Low data latency is desirable, constant data latency is required, and data loss is unacceptable. The AOST test program is currently attempting to vary the transmission approach across the LANs in the AOST to best meet these three criteria. The AOST is being subjected to a series of performance tests designed to measure and improve data throughput. A FDDI LAN analyzer is being employed to assist in the analysis of the FDDI LAN components and AOST elements.

Data losses have been experienced on the FDDI LANs used to transmit data between AOST ground elements. The AOST test program is currently investigating these data losses, employing strategies to analyze and eliminate these data losses.

The FDDI LAN packet size in use for the AOST is predetermined to be 4136 octets in length, with 4096 octets dedicated to data. A ground rule established for AOST regarding the FDDI LANs and designed to facilitate low data latency was that a single FDDI packet would contain no more than one SOSDU. With the exception of Path Packet SOSDUs (which vary in length in proportion to the packet length) the length of all the SOSDU data types handled by the AOST are significantly shorter than the FDDI LAN packet length. Non-Path Packet SOSDUs use no more than 32% of the FDDI LAN packet capacity.

The AOST will "pack" SOSDUs into FDDI packets in an attempt to increase the effective

FDDI LAN utilization. The challenge is to ensure low data latency and data delivery without substantially compromising constant data latency. Once hardware and software modifications are made to effect this change in FDDI LAN utilization, tests will be conducted to measure the resulting data latencies and the data throughput capability.

Future ground systems that transport data consistent with the CCSDS Recommendations should consider data transmission methodologies that better facilitate the rapid transfer of variable-length data units. For example, the use of variable-length FDDI LAN packets that more closely accommodate the varying SOSDU sizes would improve AOST FDDI LAN utilization while maintaining constant and low data latencies. The equipment currently in use in the AOST does not facilitate using variable FDDI LAN packets.

4.1.3 Data Distribution

Equipment designed to support data processing consistent with the CCSDS Recommendations should manage and control each VC data stream separately. As built, AOST ground elements do not always regard each VC as a separate channel, limiting data management and distribution capabilities. Furthermore, the inability to manage each VC separately impacts other ground elements in the Testbed.

The CAP was implemented within the AOST to route data, based on VC, to destinations outside the AOST. The CAP is the only AOST ground element that can route data to multiple output destinations by VC. During the C-2 design phase, a decision was made to route the output of the AOST FEs and SPs to a single destination by Internet Protocol address. The implementation of testing scenarios has been limited by the inability to route data between the AOST ground system elements by VC. For example, scenarios were developed to use separate service processors to process different VCs emanating from a single front end system. It was not possible to selectively route data from a single front end to more than

one service processor. To implement this scenario, the front end system was set to “broadcast” data, that is, send all the data to all the active service processors. While introducing obvious security concerns, data broadcasting forces each service processor to examine each incoming data unit to determine if it should be processed. A service processor not designed to perform this query as the initial data processing step will suffer certain performance degradation as it partially processes data before rejecting it.

A fundamental change in the approach toward data transmission is being instituted in the AOST to enable each AOST front end system to transmit each VC data stream to a separate destination. The extra processing required to route each VC to a specific destination will have some effect on the performance of the front end processors, but should result in better service processing performance. Implementation and testing are necessary to determine the aggregate AOST performance improvement.

4.1.4 Interactive Determination of Grade of Service

In an attempt to achieve a more “data driven” system (Reference 7), the C-2 AOST was prepared to implement the dynamic model given in the “AOS Green Book” (Reference 8), section A.4.1, Option-B, for determining Grade of Service. Figure 4.1-1 presents a flowchart representing the referenced algorithm. The AOST has identified three issues associated with the interactive determination of Grade of Service. The first issue is related to R-S header decoding (Grade 3), the second related to R-S frame decoding (Grade 2) when the data zone is populated with an octet-repetitive data pattern, and the third is related to performing R-S decoding on a VC basis.

4.1.4.1 R-S Header Decoding (Grade 3)

The algorithm illustrated in Figure 4.1-1 initially attempts to perform R-S frame decoding; the presence of the R-S header encoding and CRC fields are not considered in this portion of the

algorithm. If the frame fails R-S frame decoding, R-S header decoding is then attempted. There is a 31% chance that a frame that is not R-S header encoded will pass R-S header decoding with two “correctable” errors (see *R-S (10,6) Header Decoding Analysis*, next page). When the frame is falsely identified as being R-S header encoded, the “errors” are corrected changing values in the header. The changed header values can result in misidentification and misrouting of the frame. As the algorithm checks for R-S header encoding only after R-S frame encoding has failed, the actual probability of a frame being altered due to false determination of the presence of R-S header encoding is 0.31(probability of an uncorrectable R-S frame encoded VCDU).

The AOS Green Book, section A.4.1, Option-A specifies a dynamic model for determining Grade of Service in which header decoding is performed first. Using this same analysis, there is a 31% chance that a frame that is not R-S header encoded will pass R-S header decoding with two “correctable” errors when Option-A is implemented.

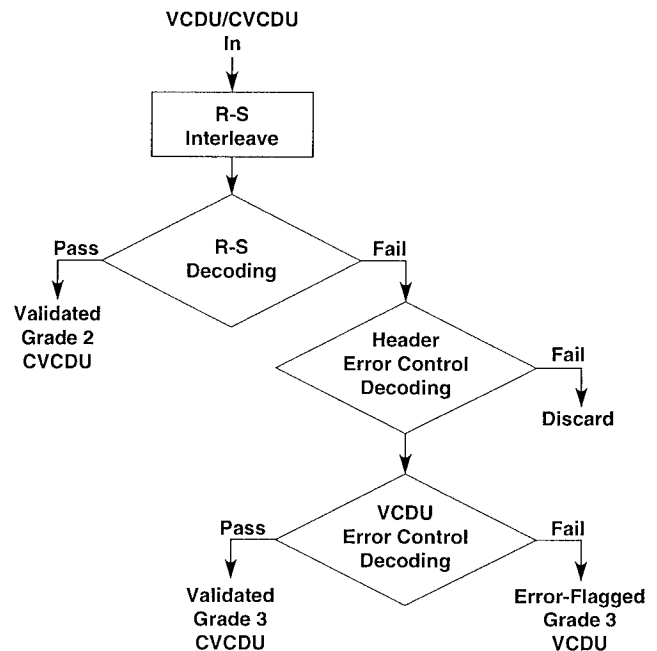


Figure 4.1-1. Option-B Error Control Decoding

4.1.4.2 (255, 223) R-S Frame Decoding of Octet-Repetitive Data Zone Patterns

The data used in the AOST is usually simulated data that contains octet-repetitive data patterns in the data zone portions of the packets and frames, e.g., the data zone of a frame would be populated with "A5A5A5A5A5A5..." (hexadecimal). Tests reveal that a frame containing a high percentage of octet-repetitive data patterns will be decoded and "corrected" when the dynamic model for R-S decoding is applied using the (255,223) R-S code, whether or not the VCDU is R-S frame encoded. An invalid correction can alter header values resulting in misidentification and misrouting of the frame.

R-S (10,6) Header Decoding Analysis

CCSDS R-S encoded headers consist of 3 octets of header data and 2 octets of parity. The code can correct up to 2 errors in the 5 octet pattern. Since parity is derived from the 3 octets of header data, there are $2^{(8)(3)} = 2^{24}$ possible codewords, and $2^{(8)(5)} = 2^{40}$ possible 5 octet patterns. Since parity of the R-S (10,6) code is 2 octets in length, a 5 octet pattern has a $1/2^{(8)(2)} = 2^{-16}$ probability of being a codeword with no error.

The R-S (10,6) code operates on 4 bit "nibbles"; for a 5 octet pattern, there are 10 nibbles. For each nibble, there is 1 correct value and 15 possible incorrect values. The code will correct for any of the 15 possible error patterns in any one of the 10 nibbles. Therefore, there are $15 \times 10 = 150$ possible single error cases that will be corrected for each codeword.

A 5 octet pattern has a $150 \times 2^{-16} = 0.0023$ probability of being a codeword with one correctable error.

The code will also correct for any of the 15 possible error patterns in any one of the other 9 nibbles for each of the 150 single error cases. Therefore, there are $150 \times 9 \times 15 = 20,250$ double error cases that will be decoded correctly for each codeword. A 5-octet data pattern has a $20,250 \times 2^{-16} = 0.309$ probability of being a codeword with two correctable errors.

The source of this invalid correction is the fact that 255 octets containing octet-repetitive data represent a valid R-S codeword. Thus, if any set of 255 octets has 239 or more octets that are repetitive, a R-S frame decoder will "correct" the set to have 255 repetitive octets. A R-S header encoded VCDU with an octet-repetitive data zone will contain only 10 octets not equal to the data zone octets. The following 10 octets will be "corrected" to match the repetitive octet pattern:

- frame primary header - 6 octets
- header parity - 2 octets
- frame CRC - 2 octets

For a VCDU of Interleave 5 containing CCSDS Version 1 Packets, the R-S frame decoder will "correct" the frame first header pointer (2 octets) and the packet primary header (6 octets per packet) for up to 6 packets in the frame data zone, assuming all the packet source data zones share the same octet-repetitive data pattern.

4.1.4.3 R-S Decoding by VC

The AOS Blue Book (Reference 2), paragraph 5.4.9.2.1.5.a states, "The presence or absence of [R-S frame encoding] is an attribute of the Virtual Channel and is pre-specified by management." The system performing R-S decoding and correction must look at the VC to determine whether to perform R-S header or R-S frame decoding. Prior to decoding, the value in the VC field is potentially erroneous and is therefore not a reliable value upon which to base Grade of Service determination.

4.1.4.4 R-S Decoding Conclusions

The AOST has addressed these three issues by prespecifying a Grade of Service for the entire physical channel, and limiting the physical channel to a single Grade of Service. This approach resolves the issues associated with R-S specification per VC, and the potentially erroneous decoding of both R-S headers and R-S frames associated with "on-the-fly" Grade of Service determination. While prespecifying a Grade of Service for a physical channel is a compromise of the Recommendations, it is currently the only reliable alternative presently identified.

4.2 TEST SUITE

The Master Test Suite (MTS) for New AOS Implementations, (Reference 6) has been used to implement the tests for the C-2 AOST Test Plan (Reference 5). The functional test cases used for C-2 testing have a one-to-one correspondence to the tests identified in the MTS, and the structure of each test case is as close to the specifications in the MTS as possible.

There was no single AOST data generator that could implement the entire MTS. A combination of the C-2 AOST flight elements and a data simulation tool developed by Code 521, the Test Pattern Generator (TPGEN), were used to implement portions of the MTS for the C-2 AOST. A portion of the MTS could not be implemented by any test tool available in the AOST; the error patterns identified in some of the MTS test cases could not be created. The next iteration of the AOST may provide a test tool based on TPGEN that provides the full complement of tests in the MTS.

The portion of the MTS that was implemented provided a rigorous and thorough test of the functionality of AOST elements. The AOST data generators did not always provide a sufficient amount of data, however. Some problems with functional production occurred when the systems were tested with large data volumes, for longer periods of time, from a few minutes to 24 hours, and at higher data rates. Systems that successfully passed functional tests with brief test data sets, composed of only a few hundred frames each and processed within 1 to 5 seconds, developed anomalies after processing more continuous data sets and/or data transmitted at a higher data rate. An analysis of the test cases identified in the MTS will be performed to ensure that each test case requires a sufficient amount of data.

The MTS defines tests to be implemented at the system module level. For example, the test case for frame synchronization tests only the part of the system that performs frame synchronization. The MTS approach of testing system modules is

analogous to the testing performed by a programmer during integration and development. The C-2 AOST Test Program is analogous to an independent system verification and validation. The C-2 Test Program provided at least one data set to test each function identified in the MTS.

Providing one data set to test each function identified in the MTS created significant redundancy in the complement of tests. For instance, the first test performed, frame synchronization, also succeeded in testing processing for R-S header decoding, CRC decoding, and VC Frame creation. Some streamlining of the MTS is appropriate when testing is performed at the system level. The next iteration of the MTS may provide a streamlined set of test cases for testing performed at the system level.

4.3 FLIGHT-QUALIFIABLE COMPONENTS

Two CCSDS-based and one non-CCSDS flight-qualified components are being developed:

- Reed-Solomon Encoder
- Reed-Solomon Decoder
- Lossless Data Compressor

The flight-qualified R-S Encoder features a selectable interleave depth (1 to 8) and supports a sustained data rate of 200 Mbps. This Encoder is currently available for flight project use, and has been delivered to the Tropical Rainfall Measuring Mission and the X-ray Timing Experiment.

The flight qualifiable R-S Decoder is designed and currently scheduled for production at the NASA Microelectronics Research Center at the University of New Mexico. This chip will perform 1 to 16 symbol error corrections at a sustained data rate of 150 Mbps. The flight qualifiable R-S Decoder will incorporate technology allowing the production of flight-qualifiable components by a commercial foundry.

The flight-qualified lossless data compressor has been developed and manufactured. This compressor chip is available for flight project use, and has been delivered for use on Landsat 7.

4.4 KNOWLEDGE TRANSFER

The knowledge gained through the AOST Program is disseminated to a wide audience that includes flight projects, users, and ground system developers, among others. Workshops provide a forum for the exchange of knowledge between AOST participants and other interested organizations. A library and knowledge database have also been created. An AOST workshop is scheduled for November 1994.

4.5 AOST AND RENAISSANCE

The GSFC Code 500 Renaissance effort is an approach to data systems development designed to improve quality and lower development life cycle cost through the implementation of standards, modularity, and reusable components (building blocks) supporting varying classes of missions and complexity.

Should the Renaissance effort chose to implement a Testbed for the prototyping of building blocks, the AOST architectural approach is a effective model. The concept of well defined functional building blocks on a distributed communications network that supports commercial protocols is central to both the AOST and Renaissance. The redundant front end processors are developed from a set of Code 521 modular components. The front end processors used in the AOST are easily reproducible from both COTS and custom components. Two of the service processors developed in the AOST are also software based; one is developed using the C programming language on a UNIX platform, making it easily transportable to a large number of commercial workstations. The FDDI LAN connecting the AOST ground system elements can incorporate

other components developed either within or external to the AOST. The AOST has the potential to easily incorporate and/or test new components.

5. AOST FUTURE PLANS

The next iteration of the AOST, Capability Three (C-3) will incorporate a forward link capability to demonstrate, validate, and verify future implementations of the CCSDS Telecommand (TC) and AOS (forward link) Recommendations. Specifically, the forward link capability will be designed to support the SCPS and MOCA. Implementation of the TC and AOS Recommendations, SCPS, and MOCA will necessarily be incremental, since SCPS depends on the underlying Layer 1 and 2 services provided by the CCSDS Recommendations, and MOCA depends on the upper layer services provided by SCPS. The incorporation of the forward link will require the addition of new ground elements to the AOST, as well as enhancing existing ground and flight elements.

6. SUMMARY

The AOST continues to provide a key source of findings and information related to the implementation of the CCSDS Recommendations. The AOST work will continue through 1995 with a Testbed that supports the AOS and TC forward link command and uplink data generation and processing, SCPS, and MOCA. The AOST remains available to support testing of flight elements and ground system data processors.

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