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NASA/GODDARD SPACE FLIGHT CENTER'S TESTBED FOR CCSDS COMPATIBLE SYSTEMS

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ABSTRACT

A Testbed for flight and ground systems compatible with the Consultative Committee for Space Data Systems (CCSDS) Recommendations has been developed at NASA's Goddard Space Flight Center.

The subsystems of an end-to-end CCSDS based data system are being developed. All return link CCSDS telemetry services (except Internet) and both versions of the CCSDS frame formats are being implemented. In key areas of uncertainty multiple design approaches are being carried out. In addition, key flight-qualifiable hardware components, such as Reed-Solomon encoders, are being developed to complement the testbed element development.

The Testbed and its capabilities are described. The method of dissemination of the Testbed results are given, as are plans to make the Testbed capabilities available to outside users. Plans for the development of standardized conformance and compatibility tests are provided.

Key Words: Aerospace, telemetry, data systems, CCSDS, testbeds

1. INTRODUCTION

The National Aeronautics and Space Administration's (NASA's) Goddard Space Flight Center (GSFC) has instituted a significant testbed effort in the area of end-to-end data communications for space generated data. This program, the Advanced Orbiting Systems Testbed (AOST) Program, provides a bridge between development and widespread use of the Consultative Committee for Space Data Systems (CCSDS) Recommendations. Although named The Advanced Orbiting Systems Testbed, the Testbed in fact has the capability of creating and processing data compatible with both the Recommendation for Advanced Orbiting Systems (Reference 1) and of the Recommendation for Packet Telemetry (Reference 2). NASA has been supporting the development of CCSDS Recommendations since 1983. The Recommendations, being used by most future NASA missions, offer the promise of significantly reducing mission life cycle costs by standardizing data handling interfaces and functions in both space and ground systems, and of significantly increasing the reliability of operations due to repeated use of well tested and established procedures. In addition, standardization greatly enhances the ability of the various NASA space oriented subnetworks to operate with one another, and provides a solid basis for such interaction on an international basis where needed for international programs. Standardization allows the reuse of hardware and software, and makes it easier to support agency interoperation in national and international programs.

The AOST Program systematically addresses current impediments to using the Recommendations. The multi-faceted approach to the AOST Program will reduce the remaining costs and risks associated with the implementation of the Recommendations within NASA. With one exception, it is not a prototyping program. It's goal is the accumulation and dissemination of knowledge.

2. THE AOS TESTBED PROGRAM

The AOS Testbed Program has five main thrusts: developing and using the testbed itself, conducting a test program, performing directly related studies, developing critical flight-qualifiable components, and disseminating the knowledge gained in all the above.

2.1 Development of the Testbed

Development of the AOS Testbed draws upon the personnel and experience base of several different organizations with the GSFC. The flight-side equipment and the flight-qualifiable components are being developed by the Electrical Engineering Division. The front-end systems are being developed by the Data Systems Technology Division, as is one implementation of the Service Processors. Two other implementations of Service Processors are being developed by the Information Processing Division.

Services and Network Management is being developed by the MITRE Corporation. "Back-end" communications is being provided by the NASA Communications Division's independent NASA Open Systems Interconnection Protocols (NOSIP) Testbed. A Production Data Processing (PDP) capability will be provided to the Testbed as software by the PACOR II Project. The entire Test Program, including test execution monitoring and test results analysis is the responsibility of CTA Incorporated, which is also the program support contractor, providing documentation, coordination, and other management functions.

Development and use of the Testbed is divided into four phases or "Capabilities". Capability One provides the "unadorned" data handling functions for validation, architecture comparisons, and cost/performance evaluation. This capability is basically achieved. Capability Two sets these functions into an initial operations environment to identify performance degradation and to test interface definitions, requirements, and specifications . Capability Three completes the "rapid prototyping" into an operations environment and provides an initial set of standards conformance tests and systems compatibility tests. Capability Four completes the development of conformance and compatibility tests and provides the flight qualifiable components for flight project qualification.

2.2 The Test Program

The AOS Testbed test program is viewed as the primary means of obtaining the knowledge which is the objective of the Testbed. Testbed internal testing is performed to validate the achievement of each "Capability". Specific test periods (the majority of the Testbed development lifetime) are set aside for testing. The tests are formal and conform to a Master Test Plan and a Capability Test Plan; however, flexibility in schedule and sequence of testing is maintained in order to derive the greatest knowledge from the testing. Specific test program objectives are to:

- define and validate internal and external data and system management interfaces for AOS systems
- capture and disseminate knowledge gained in the implementation and testing of CCSDS Recommendations in an actual system
- raise issues associated with the implementation and testing of CCSDS Recommendations and communicate these issues to the CCSDS
- develop standard conformance tests and systems interface tests for use in acceptance testing by both flight and ground systems complying with the CCSDS Recommendations
- establish cost/performance curves for various configurations

The AOS Testbed Test Program distinguishes five levels of testing complexity. These are:

- Element Tests - performed by implementors to ascertain a unit is ready for integration into testbed
- Compliance Tests - to determine that a unit does what it is supposed to do
- Interface Tests - to determine that two units operate properly together
- String Tests - to determine that three or more units operate properly together
- End to End Tests - to determine that the entire system operates properly

The Test Program has four types of tests. These tests may be conducted at any of the five test levels. The four types are:

- Functional Tests - to determine that the system/subsystem does what it is supposed to do
- Performance Tests - to determine that the system/subsystem performs at the speed or capacity or reliability, etc., that it is supposed to
- Regression Tests - to determine that the system/subsystem, after modification or upgrading, still performs properly
- Research Testing - includes investigations of choke points, influence of architectures on performance, cost-performance curve measurements, etc.

It is already clear that one of the most important products from the AOS Testbed will be the suite of tests that is being developed. The AOS Testbed is beginning a program for the development of standard test suites for "CCSDS Compatible" systems. The currently developed test suites will be restructured and enhanced to become standard test suites. It is planned these test suites will be made available to organizations that wish to do their own testing of existing or new systems. Both conformance and compatibility tests will be developed. Efforts are being made to accomplish this work in cooperation with the European Space Agency and possibly other international agencies. All results of this development effort will be provided to the CCSDS.

In addition to the AOS Testbed's internal test program, the Jet Propulsion Laboratory (JPL), the European Space Agency (ESA), the Canadian Space Agency (CSA), and the National Space Development Agency of Japan (NASDA) have expressed interest in cooperative testing. A specific plan for testing with ESA is in its final preparation stage.

2.3 Related Studies

By far the most significant study effort being supported by the AOS Testbed is its participation in the ad hoc inter-Center Space Operations Service Infrastructure (SOSI) working group. Most of the members of this group are also members of CCSDS Panel 3. The SOSI group is developing a top-down, end-to-end graphical model that can be used to:

- Develop service concepts
- Develop operations concept
- Identify cross support points, protocols, and formats
- Discuss cross support issues and interfaces
- Be a basis for CCSDS Panel 3 work

The CCSDS Packet Telemetry, Telecommand, and AOS protocols are tuned to operate across the space link, terminating in a ground station. The CCSDS space link protocols conserve bandwidth (and allow high speed data processing) by using managed information instead of in-band signaling and by minimizing redundancy. The Ground System must extend the services provided by these space link protocols to user application processes. Usually the user applications are in a Ground-based End System (GES) that is provided data from several distant Ground-based Spacecraft Access (GSA) systems over commercial or private data networks. The GSA is an intermediary between the space link and various end systems on the ground. GSAs typically provide services to many missions. The scheduling, management, and reporting necessary to allow multiple missions to receive services from multiple GSAs -- efficiently and correctly - is a key aspect which the SOSI model is intended to illustrate. A key function of the GSA is to apply annotation information before the data unit leaves the GSA. The annotation information is of two types:

- SDU Information which is specific to each sublayer of the service:
  - -information not known prior to ground receipt (e.g., loss of sync; Reed-Solomon Corrections; Sequence Discontinuities, ground receipt time)
  - -information carried in one sublayer but needed in another sublayer (e.g. Spacecraft ID)
  - -known prior to ground receipt but lost if the service were to be extended beyond the RF terminal.
- Managed information: distributed systems will be easier and cheaper to operate if information which is managed over the space link subnet due to bandwidth limitations, is signaled over the ground system.

In addition, an agency implementing a GSA may wish to attach agency specific annotation information for purposes of accounting and fault isolation (e.g., system IDs).

The SOSI model and related concepts are being developed in cooperation with the AOS Testbed. Both architectural issues and data format development are worked between the "top-down" approach of the SOSI and the "bottom-up" experimentation within the Testbed. A more detailed discussion of the SOSI work may be found in Reference 3.

A key element in this cooperative work is the content and format of the annotation information. The annotation information is applied to each data unit to be delivered by the GSA. The annotation mechanism as so far developed by the AOS Testbed, is called a Space Operations Service Data Unit (SOSDU) header (when the header is added to the data unit, the combination is called a SOSDU). The SOSDU header currently contains a generalized label, a SOSDU label which is the same for all SOSDUs, a set of Service specific parameters which are different for each of the Services, and possibly optional agency and/or network unique fields. The SOSDU header is a relatively early stage of development and is expected to change significantly over the next several months. A major revision to the format is expected to be completed within the next month.

2.4 Flight-Qualifiable Components

The objective of this part of the AOS Testbed Program is to generate key products to promote flight project use of CCSDS Recommendations. These products were planned to include flight qualifiable coding components, flight qualifiable frame level components, and flight qualifiable packet generators/buffers. A good foundry run has already been achieved of a single chip, high speed Reed-Solomon Encoder. The chips will be made available through the University of New Mexico. Unfortunately, the current budget situation has required a halt in the funding of this activity. It is hoped that some FY93 funds can be found to continue the work at a lower level of activity, or that it can be re-started in FY94.

2.5 Dissemination of Knowledge Gained

The primary vehicle for the dissemination of the knowledge gained through the various activities of the AOS Testbed is the annual "Workshop for CCSDS Implementors". The first of these was held on November fourth and fifth of this year at the Goddard Space Flight Center, and was very successful. Over 300 persons attended, representing 44 companies, 2 universities, 4 NASA Centers, NASA Headquarters, and the Department of Defense. The attendance was far in excess of our expectations, demonstrating a very broad interest in CCSDS implementations. (A reason for this wide-spread interest can be seen in Table 1, Spacecraft/CCSDS Compatibility.) The attendance was so large that we found it impractical to actually have a "workshop", and it was in fact a seminar. We will change the format for the next workshop, at least part of the time breaking up into interest groups, thereby providing a true workshop environment.

3. AOS TESTBED ARCHITECTURE

There are two major architectural drivers considered within the AOS Testbed Program. First is the distribution of functions due to network and facility drivers. Second is the allocation of functions to subsystems within a major "infrastructure" facility. The first is being addressed by the Space Operations Service Infrastructure (SOSI) group (see above). So far, the two drivers seem to lead to a highly compatible allocation of functions. The testbed architecture was selected to expose potential cross support (inter-network) points, provide easy access to inputs and outputs of major functional blocks, and to allow easy and standardized (serial) interconnection among the elements. The testbed elements, shown in Figure 1, represent all of the subsystems of the return side of an end-to-end data system (forward link capability is not presently included or funded). The rate performance target for the ground side is 20 mbps peak, and for the flight side, 80 mbps peak. Simulators are used for the end users systems, both onboard and on the ground.

A more detailed drawing of the Flight Elements of the Testbed is shown in Figure 2. The digital video equipment string is not yet completed, but is expected to be added in late spring of 1993. A detailed drawing of the ground side configuration is given in Figure 3. It is in this Figure that the major architectural features are discernible. The Local Area Networks (LANs) of the Testbed may, in real-world implementations, be Wide Area Networks (WANs). The same is true of the second Testbed LAN. The multiple implementations of the Services Processors allow for experimentation in both the geographical distribution of Services Processors and in the maximization of resources utilization in a heterogeneous multi-user ground facility.

Results from testing and study in the AOS Testbed may be found in Reference 4.

4. ACKNOWLEDGMENTS

The author wishes to express his sincere thanks to the members of the AOS Testbed implementation team. Their dedication and hard work is producing invaluable information which will influence the design of space data systems for years to come. And while doing this, they have also made this a most enjoyable and personally rewarding project.

Special thanks are due to Mr. Charles Fuechsel, of NASA Headquarters, whose original idea and consistent support has made the AOS Testbed a reality.

And last, my gratitude to Ms. Penny Newsome, head of the Program Support Contract, whose unflagging efforts and exceptional management abilities have made a major contribution to the success of this program.

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TABLE 1 SPACECRAFT/CCSDS COMPATIBILITY

SPACECRAFT	LAUNCH	FRAME	R-S CODING	PACKETS	PKT TIME CODE	FWD LNK
EUVE	92	NO	NO R-S	YES		
SAMPEX	92	YES	CCSDS CONV	YES	YES	YES
FAST	94	YES	CCSDS CONV	YES	YES	YES
SWAS	95	YES	S	YES	YES	YES
SOHO	95	YES	YES	YES	YES	YES
XTE	96	YES	YES	YES	YES	YES
TRMM	97	YES	YES	YES	YES	YES
ACE	97	YES	YES	YES	S	S
SMEX 4	96	YES	S	YES	YES	YES
SMEX 5	97	YES	S	YES	YES	YES
SMEX 6	98	YES	S	YES	YES	YES
EOS-AM	98	YES	YES	YES	YES	YES
EOS-PM	99	YES	YES	YES	YES	YES
SSFP	96	YES	YES	YES	S	YES
MARS OBSRVR	92	YES	YES	YES	YES	NO
CASSINI	97	YES	YES	YES	YES	YES

S = UNDER STUDY

FIGURE 1 AOS TESTBED ELEMENTS

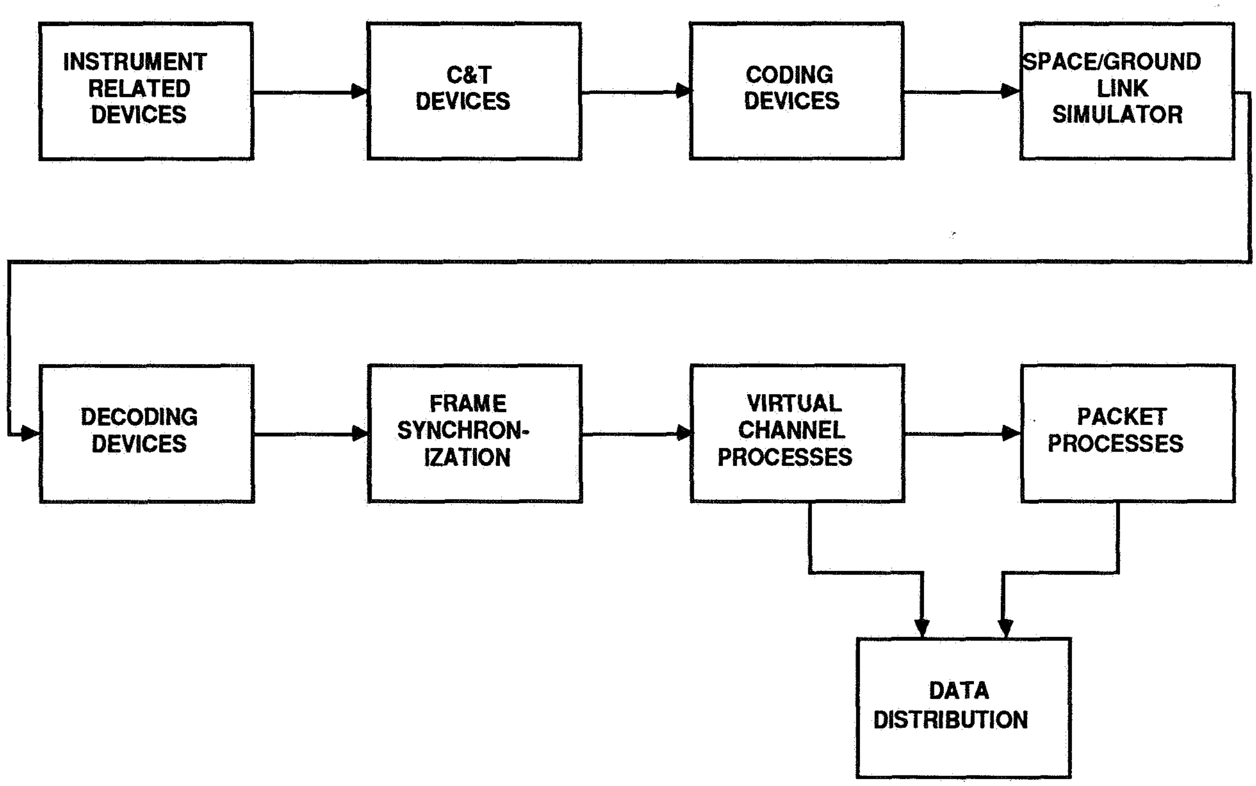

FIGURE 2 AOS TESTBED FLIGHT SIDE CONFIGURATION

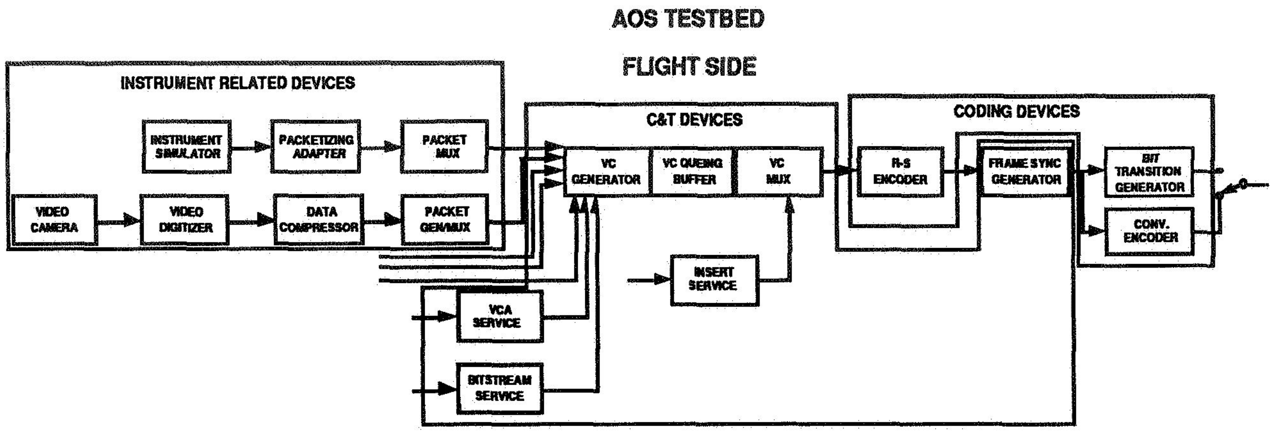

FIGURE 3 AOS TESTBED GROUND SIDE CONFIGURATION