INTRODUCTION

Since the late 60’s, the Grumman Automated Test System (ATS) has supported test data processing on almost all of Grumman’s test programs. Derivatives have been adapted to other DoD programs and installed at Air Force and Navy test installations. This technical paper will briefly describe the original system (1969-1983), the present configuration (1983-1986) and the future configuration (1986-1990’s) of the ATS. The ATS at Grumman, is one of the industry’s longest lasting operational system for real-time aircraft testing, and will continue to be operational through the 1990’s.

The ATS consists of a complement of hardware and software subsystems, which when combined with a central processor, form the integrated system capability required to perform real-time/on-line test analysis. The prime objective of the ATS is to provide real-time answers to test questions through interactive data processing of telemetered, range acquired, and data base generated test data. Utilizing extensive computer control and sophisticated interfaces between subsystems, the system provides data services in real-time, which, in the past, were not available until sometime after a test. The proven hardware and software characteristics of this facility promotes the successful and timely completion of the test program by:

a. display of engineering computations in a readily understandable form
b. on-line modification of test plans
c. optimizing batch processing

The ATS consists of the following:

a. A computer for system control, real-time analysis and other functions.

b. A preprocessor for in-flight formatting, processing, limit checking, and conversion to engineering units of FM and PCM formats.
c. An extensive CRT display subsystem for real-time monitoring, man-machine interface to hardware and software and devices.

d. Telemetry ground station equipment which provides for recording, demodulation, signal conditioning, conversion, and formatting of telemetry data.

e. Special purpose software system including statistical analysis, interactive telemetry input, control and data analysis language and complete hardware diagnostics.

ATS PAST (1970-1983)

Hardware Configuration

The ATS integrates a telemetry formatting subsystem, a telemetry preprocessor subsystem, a central computer subsystem, and a display subsystem into a real-time test analysis capability. From the Data Analysis Station (DAS) a Test Engineer can direct the system to acquire, condition, format and display the particular data parameters for real-time analysis. (Figure 1.0)

Telemetry Formatting Subsystem (TFS)

The TFS is modular and expandable telemetry data acquisition equipment that operates as a special purpose peripheral to the preprocessor system. Its purpose is to acquire and record the raw data from the telemetry receivers. The data is reformatted and synchronized before it is passed on to the preprocessor. Both analog and digital inputs are accommodated. The basic TFS was designed to accept telemetry data streams composed of PCM, FM and range time code signals. This subsystem, operating in conjunction with the preprocessor subsystem, performed all of the data handling functions necessary to permit real-time analysis and display of telemetry data.

Telemetry Preprocessor Subsystem (TMP)

The TMP provided the capability to process and display data from the TFS. The demodulated analog and digital data can be displayed for quick-look analysis on analog chart recorders. A multiplexer/A-D converter quantizes the analog data which along with the PCM data, will be input to the preprocessor for formatting, engineering units conversion, limit checking, data buffering and magnetic tape recording; simultaneously, and the transfer of selected data to the Central Processing Subsystem. Special peripheral devices perform the data handling tasks. They are:
a. Set-up and control functions and is a time input port.
b. Accepts, synchronized, and decommutates the PCM data input.
c. Stores programs, limit values, data sensitivity values and processing codes.
d. Performs required engineering units conversion, limit checking and assigns addresses.
e. Data transfer and interchange system.
f. Routes data destined for central computer transfer, 100% tape, or D/A output.

**Display Subsystem**

The display subsystem is the analyst’s communications link with the system. It contains a Data Analysis Station (DAS), an equipment status monitor section, and a hardcopy device. The analyst makes requests of the central computer to initiate a maneuver, set up parameters, or display data on the display console, brush records or hardcopy. The subsystem will consist of the following elements:

a. Data Analysis Station (DAS) - consists of an integrated unit containing:
   1. physical CRT size of 16 x 16
   2. plotting area of 11.3" x 11.3"
   3. light pen
   4. 1024 x 1024 addressable raster positions
   5. microfilm/hardcopy page print
   6. alphanumeric keyboard
   7. function keyboard

b. Analog display unit
   1. 8 traces, 60 HZ response
   2. 2 edge pens (i.e., time code event)

c. Hardcopy unit services the DAS areas with a one print/second output. Functions from buffered input such that simultaneous selection from the DAS areas will not cause a lockout.

d. Digital time display - provides time in days, hours, minutes, milliseconds. Capability to select either aircraft generated time or system generated time.

e. Small repeater CRT which displays the DAS image for review by the test conductor. Allows the Test Conductor to monitor critical manuevers as well as limit violations.

**Central Processor Subsystem**

The Central Processor Subsystem, which consists of the present CDC configuration, controls the entire realtime operation. The computer provides data analysis, and other subsystem services.
Software Configuration

Little attempt will be made in this section to provide an indepth definition of the various software routines, rather a presentation of their functional properties will be addressed. The basic of the central computer system software is the Grumman Tele-SCOPE 340 Operating System with extensive multiprogramming and multiprocessing capabilities. The Grumman Tele-SCOPE 340 operating system consists almost entirely of Peripheral Processor (PP) routines. All system overhead, such as servicing interrupts, scheduling facilities, providing operator communication, and driving peripheral equipment, if performed in the PPU’s without burdening the Central Processor Units (CPU’s). Tele-SCOPE 340 is a superset of the standard CDC Operating System. Among the modifications made were a software interrupt system, priority disk accesses for the writing of recall and plot files and a change to the job priority scheduler to assure proper allocation of resources for real-time execution. In addition Grumman Tele-SCOPE 340 includes:

a. Telemetry Compiler  
b. Real-Time Supervisor  
c. Display and Control  
d. Preprocessor Software

Capabilities

The ATS gave Grumman many capabilities required for real-time testing and include:

a. **User Software** - The system would allow for 10 application routines to be initialized and ready for execution. These programs would read/write data files, while merging it with real-time data. Software was controlled via keyboard, light pen and function keys.

b. **Data Files** - Several data files are generated through the test. Based upon pre-test planning these files could be defined such that data collected could be further processed in batch mode. Files generated included:

   - 100% raw data file  
   - E.U. converted file  
   - Plot files  
   - Re-call files

c. **CRT Displays** - Various displays, ¼ to full screen could be presented a CRT. Each real-time program would call 10 unique plot formats. Plot formats were defined at the DAS or predefined via a Plot Compiler. Plots were modified via keyboard or light pen inputs.

d. **Intermanuever Mode** - Between test points the analyst could direct data to batch online software. This gave the capability to do other processing while the test was still active.
ATS PRESENT (1983-1986)

As new requirements were defined by our Test and Instrumentation departments it became evident that the original ATS would have to be upgraded. This upgrade took place between 1979 and 1982 and was operational in 1983. This major reconfiguration of the ATS centered around a new Advanced Telemetry Preprocessor (ATP). Replacement criteria for the preprocessor function included a baseline of the capabilities of the current system and expansion capacity to meet future requirements based upon predicted testing and instrumentation systems. Among the future requirements were increased processing speed from 50,000 to 100,000 samples/second, capability for the preprocessor to be a standalone system, having both calculation and display capabilities. A critical goal for the ATP is the ability to handle formats from systems test aircraft which in the future are seen to be the bulk of the test work at Grumman. The ATP must be able to handle word lengths from 1 to 64 bits, intermixed word lengths within a format and programmability of EU conversion algorithms. A further set of goals was added over the required objectives of the ATP and included:

a. Provide as much excess machine power as possible (the design goal was 50%).
b. Strive for modularity in hardware and software for product growth.
c. Develop the nucleus of a design which would be used to satisfy other needs.

With this background, a preliminary design was conceived including tradeoff analysis between telemetry equipment and computer hardware and software. In a market search it became apparent that there was no product on the market at that time which fully satisfied Grumman’s needs. It was decided that for PCM inputs a unique ID rather than frame and subframe addresses would facilitate a table lookup scheme for data elements. Thus the Aydin-Monitor 1126B decommutator was chosen since it offered the ID tagging capability in a single piece of the equipment as well as the other necessary format handling abilities. The ability to process up to 50,000 5th order polynomials per second “on-the-fly” pointed to a choice between streaming data through an array processor, building some special purpose dedicated hardware or utilizing multiple mini-computers. It had been decided to build hardware where it was felt to be necessary to meet the overall design criteria rather than possibly sacrifice speed or cost to make use of off-the-shelf equipment. That decision coupled with the functional requirements of the preprocessor pointed to a blend of off-the-shelf and special purpose hardware to satisfy the architectural requirements as well as the goals set by Grumman.

**Hardware Overview**

A block diagram of the ATP is presented in Figure 2.0. To provide simultaneous testing of two projects, there are two identical ATP's which share common peripheral not utilized in
support of tests. Data flows in from the left and has already been conditioned by an IRIG compatible front end which includes telemetry reception and demodulation equipment, wideband tape recorders/reproducers, bit synchronizers, analog discriminators, cross-connection facilities and various calibrators, simulators and monitoring equipment for setup and checkout. The PCM and Analog stage processors differ in the first stage but have identical second stages. Stage I of the PCM receives data/ID pairs from the decommutator which is programmed to pass only the data of interest. Under software control the ID is used as a vector into a list which points to the addresses of previously linked list of algorithms to be used for each measurement.

Data then is converted to engineering units (up to a 5th degree polynomial), or passed raw, then DAC’d out before passing to Stage II. The second stage performs limit checking and fills various buffers (real-time, tape, out-of-limits, critical). Time is tagged to each full buffer through an interface to a time code generator/translator.

Software Overview

An overview of the ATP software is presented in below. The software is divided into four areas:

1. Micro-computer programs (Plessey).
2. Real-time Operating System supervisor in the mini computer (SEL).
3. Modifications made to the existing software executing on the central process.
4. Telemetry compiler/utilities.

All software with the exception of the modifications made to TeleSCOPE™ 340 were built to run and be supported on the SEL computer to facilitate the standalone capacity of the preprocessor and the move toward a new distributed architecture at the ATS.

Descriptive Telemetry Acquisition and Input Language (DETAIL) is a compiler which interfaces to the system user in terms familiar to test analysts and telemetry users. It produces a set-up file which consists of groups of object codes to load each of the boxes and computers with the format information, parameter lists, algorithms, coefficients data descriptors, etc. required for specific tests. Written in FORTRAN the compiler accepts format descriptions and lists of active measurements from an instrumentation file as well as lists of desired outputs (real-time, tape, DAC, etc.). Using keyword directed, free-format style, input is syntax checked and divided into tables. Patching lists, decommutator programs, MUX/ADC sampling programs, measurement algorithm processing lists, DAC assignments and data descriptions are all produced automatically by DETAIL. Included is the capability to support concurrent analog and digital processing, multi-syllable words, multiple asynchronous subcoms, supercommutation, in support of IRIG formats. Several
utilities are also included such as a translator which converts source statements. The translator permits all old test to be played through the ATP using only those resources of DETAIL and the ATP which are pertinent.

The Real-Time Operating System (RTOS) is an executive program which resides beneath the Operating System and which directs the operation of the preprocessor in real-time mode where directives are received from and data transferred to the central computer. In standalone mode the same software is used except that directives are input directly and data is output to local computer compatible tapes. Upon request, RTOS supervises peripheral connection, downloads the decons and micro with the specified setup files, and in real-time mode uploads the central computer with descriptions of all parameters which are to be transferred. The present command set allows such operations as loading boxes, dumping boxes, turning data on and off, turning computer tapes on and off changing the assignment of DAC’s and coefficient values while data is being transferred.

Programming in the micros is supported by a cross-assembler written on the SEL. All supervisory programming, drivers and algorithms were developed by Grumman to specifically support the ATP. The overriding consideration was speed of execution, thus programming at the assembly level was indicated. Programs and algorithms are modularized permitting changes and additions.

Modifications to Tele-SCOPE™ 340 on the central computer were necessary mainly to accommodate the HYPERchannel interface which was not used on the old system. Since the same buffering strategy was used as in the older system, the changes required were at the I/O driver level and did not propagate very far in the system. Several other areas were changed in the initialization of the system but these were not time critical. Because of a difference in philosophy of the system, where the central processor now requests loading from the ATP, rather than downloading to the preprocessor, changes were necessary in the commands given and ability to receive data descriptors from another machine. With the philosophical change of removing the central computer from the role of master in its relationship with the ATP a further step was taken away from emulation. Although the ATP still puts out data in formats compatible to the central processor, the command preprocessor, file system and compiler were all moved to the preprocessor machine.

**ATS FUTURE 1987-1990’s**

**Background**

It was recognized in the later part of the 1970’s that major ATS subsystems would need to be upgraded and or replaced in the 1980’s. It was a management decision based on technical advice to deal with the preprocessing subsystem as first priority. But the display
and control subsystem was by no means ignored. Scores of meetings, at every level, were held to agree on general broad requirements that the replacement/upgrade had to address. Included were:

a. One DAS per telemetry stream. In effect only one flight test discipline could be “on-line”.

b. The complexity of the applications software versus the available compute power.

c. Limited data base display capabilities. This was not a problem earlier as storage media was expensive and our test groups were concentrating on developing their processing algorithms. Today we see two things, first storage media costs are dropping, and second, there are requirements that call for plotting answers against a grid that already shows such things as: contract envelopes, tunnel predicted envelope, math-model predicted envelopes as well as the actual built-up points collected from earlier flights.

d. It was and is difficult to rapidly support applications software changes while supporting a heavy test schedule. All of us have seen the effects of “one card changes” on a system. Changes are done off shift or on weekends but not at the expense of the test schedule. A goal of the subsystem is to alleviate this constraint.

**Systems Requirements**

To correct shortcomings is never sufficient reason to embark on a costly improvement plan. Indeed the ATS changes are and will include upgrades other than simple replacements. The mission of the ATS in the mid to late 1980’s bear little resemblance to the mission addressed in the late 1960’s. The chart below clearly shows the differences.

<table>
<thead>
<tr>
<th>Item</th>
<th>Late 60’s</th>
<th>Late 80’s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Object</td>
<td>Vehicle Flight Testing</td>
<td>Vehicle plus extensive on-board system flight testing (avionics)</td>
</tr>
<tr>
<td>CRT Displays</td>
<td>1 Per Telemetry Stream</td>
<td>Multiple CRT displays</td>
</tr>
<tr>
<td>Display Subsystem</td>
<td>Shared Computer</td>
<td>Dedicated computer per DAS</td>
</tr>
<tr>
<td>Simulation</td>
<td>Not Required</td>
<td>Extensive simulation requirements in support of real-time testing</td>
</tr>
<tr>
<td>Data</td>
<td>Telemetry</td>
<td>- Telemetry, Range Sensors</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Engineering Dev’l. Centers,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Data Bases</td>
</tr>
</tbody>
</table>
Discipline | 1 Per Telemetry Data Stream | Up to 8 stream in parallel
--- | --- | ---
On-Line dbms | Not Required | Extensive requirements in support of real-time testing
Test Conductor | UHF, VHF, Intercom | RF links plus a requirement for a standalone DAS
DoD Security | Unclassified | Mixed including secret

**System Configuration**

The architecture has been selected and is currently being designed. Final design is still several months away, however we will briefly discuss the candidate architecture shown in Figure 3.0. The solution is a distributed architecture, centered around a local area network (LAN), that will meet growth in both a horizontal and vertical direction.

Ease of expandability can be seen by noting the possible vertical movement in the DAS hosts. Without changing the system software one can progress upward through the extensive VAX product line. Horizontal growth can be accommodated by simply adding DAS stations to the LAN. The final design will allow for up to 24. Yet another growth dimension is possible by adding communications trunks, additional preprocessors, other vector processors, additional mass memories and other special devices to the LAN. The LAN (HYPERchannel) allows us to “integrate” several different computers (CDC, SEL, VAX) into one system. The LAN and its interface hardware allow us to select the right machine for the right job. By carefully planning the network, the traumas associated with a multi-vendor system are easily eliminated. These growths are not at the sacrifice of reliability. In fact single-points of failure are minimized and even with the sudden loss of an asset, the system may be rapidly reconfigured with minimal risk as each asset may be independently and rapidly re-assigned from one stream to another.

Test data enters one of two data streams and is passed to the telemetry preprocessor for engineering unit conversion. Selected parameters are passed to the central computer for further processing. Data also is passed directly from the preprocessor to the strip chart recorders and to a magnetic tape for recording. The single data stream allowed only one CRT display per stream and relies on the main frame computer for all complex problem solving. The new system, channels data from the preprocessor through a communications bus supporting up to four separate data analysis stations per data stream. Each data analysis stations uses a minicomputer for most of its computations, allowing the central computer to be located off the main data stream. The layout eliminates several possible single-point failure areas associated with the current system. The new system will be able
to handle the increase number of discrete parameters and bit checks associated with the
digital flight controls of the X-29A forward-swept wing aircraft, while also being capable
of supporting the diverse aircraft being tested at Grumman.

SUMMARY

Grumman has kept their computerized telemetry ground station operational for 15 years
and intends to extend this to 25 years. Careful planning and coordination between various
departments supporting testing was critical and time consuming. This prevented us from
“starting from scratch” whenever new requirements or test programs appeared at
Calverton. The system is modularized and will now easily accommodate expandability and
technology insertion without any significant architectural changes.

FIGURE 1.0
ATS CONFIGURATION
1970-1983
FIGURE 3.0
ATS CONFIGURATION
1987-1990's