REMOTE TELEMETRY CONCEPTS

R. STIERS - BOEING COMMERCIAL AIRCRAFT GROUP
T. LYDON - VEDA INCORPORATED

ABSTRACT

A Remote Telemetry Station (RTS) was developed to support Boeing's requirement to relocate its flight test telemetry range away from Seattle, Wa. As requirements to relocate the test range were investigated high level requirements were documented and various approaches were evaluated. The end result of the analysis and requirements definition was the procurement of the Remote Telemetry Station (RTS). The RTS is capable of supporting many sites, tracking and receiving up to 1024 Kbits/sec of telemetry data, providing fully redundant two-way radio communication in the UHF and VHF bands, linking all the data back to Seattle and appearing transparent to the users. The RTS was designed and developed by a Boeing/Veda Incorporated team. The end result of this joint design and development effort is a system that meets all Boeing requirements in a highly integrated, extremely efficient, and very flexible package providing for growth through the year 2000.

KEY WORDS:

Remote Telemetry
Telemetry Processing
Satellite Relay

INTRODUCTION

In 1989 Boeing concluded that it must move minimum crew flight testing (flutter) out of the Seattle area. A combination of three factors lead to this conclusion. First, in 1988, a Boeing commercial airframe undergoing dynamic testing in southwestern Washington state experienced a flutter event which resulted in a detailed procedures review. The second and third factors were increased commercial airline traffic and urban sprawl. These last two factors combined to cause the loss of a major portion of the previous test range area. The conclusion that Boeing must relocate its telemetry testing range was the driving force behind the Remote Telemetry Station (RTS) project.

Several relocation options were studied. The results of this study indicated the best solution was a mobile telemetry tracking and communications facility. In January 1990 after analyzing possible mobile configurations a Request For Proposal (RFP) was sent out. The RFP was for a two-stream mobile telemetry facility housed in a "motorcoach and trailer combination." This paper discusses requirements and solutions, final design requirements, and the RTS as built. The paper concludes with a brief discussion of how the system has performed since delivery in January 1991.

REQUIREMENTS

The requirement for the test range relocation project was investigated in two phases. The first phase dealt with broad concepts at a high level. The second phase added depth, detail and focus to the first phase concepts. One of the first areas of concern was where to move. No one site in the continental U.S. offered suitable year-round flight test conditions. The probability of having to support many different sites had to be considered.

The next area of concern was how much of the system to relocate. Two combinations were reviewed: a) ground analysis stations and the telemetry receiving hardware and, b) telemetry receiving hardware coupled with a highspeed data link to the existing ground analysis facility. During the review the existing ground analysis facility was deemed usable for the foreseeable future. When the expense of transporting the whole test team to a new site was added to this finding, the design focused on moving just the telemetry link hardware. The next consideration was operational. With the analysis staff, airplane, and telemetry link operators separated by hundreds or even thousands of miles, communications and link delays became critically important. These concerns and many others resulted in the following high-level design considerations:

- The system must be mobile so that it can support many sites with a minimum of capital investment.

- The system will include all hardware necessary to track and receive up to 1024 Kbits/sec of telemetry data.

- The tracking and receiving hardware must operate on L and S band.

- The system must provide fully redundant, two-way radio communications between the test director in Seattle and the test pilot.

- Both UHF and VHF radio frequencies must be supported.

- The data and communications link between the remote site and the Seattle analysis facility must be transparent to the operators.
- The data link must be compatible with the existing ground analysis facility.
- The maximum allowable delay in the link will be 500 m/sec one way.
- Target remote sites include Glasgow Mt, Moses Lake WA, and Edwards AFB CA.
- The maximum acceptable bit error rate is 1 bit in 1 million

Two of the above design considerations lend themselves to many possible solutions and require further refinement. The first design consideration to be refined deals with the mobile platform. There were several possible vehicle combinations capable of supporting this mission. Four combinations were reviewed. They were tractor trailer, satellite news gathering (SNG) truck with a trailer, cab and box (U-Haul) with a trailer, and motorcoach with a trailer. The tractor trailer combination could provide a stable platform with more than enough internal space. Its primary draw back is the special drivers license that is required just to move it. The SNG truck and trailer's strength is that it is custom built for mobility and easy set-up. It has two main negatives in this application, high cost and very limited operating space. A cab and box (U-Haul) truck with a trailer is readily available and the least expensive of the four platforms; however the structure of the box will not support the required loads. The last combination, motorcoach and trailer, is easy to drive, custom built (hence structurally sound), space efficient, and cost is only moderate. The main problem with this combination is detailing a specification since most telemetry integraters do not have an automotive engineer on staff. Any of the four platforms could have met the requirements; however, for this particular application the driveability, space efficiency, and moderate cost of the motorcoach and trailer made it the best choice.

The second design consideration was the data link between the remote site and Seattle. There are two primary trade-offs relating to this issue: cost and availability. The two options are fiber-optic land lines and a satellite data link. Leased fiber-optic lines are far cheaper than satellite time; however, availability is a problem since fiber-optic lines do not go to many remote sites. Although more expensive per hour, the satellite data link is still cost effective and can provide true remote operation capability.

Distilling the ten listed high-level design consideration and the above discussion on mobile platforms and data links yielded the more detailed and focused second phase requirements:

- The vehicle consisting of a motorcoach and trailer must contain all tracking, receiving, communications, and satellite link equipment.

- A T1 satellite link will be employed for the remote site to Seattle data link.

- Operational at -20 to +50 C with wind load requirements exceeding non-operational winds of 100 mph.

- A master control computer will interface with and control all components within the system.

- Positive bit sync, frame sync, and when appropriate subframe sync lock must be indicated both with panel lights and on the microprocessor controller system.

- Bit sync inputs must accept NRZ-S data at up to 512 Kbits/sec.

- Frame synchronizers must accept classical PCM and message formatted PCM data. (For a description of Message Formatted PCM data please see the paper on ADDAS elsewhere in this ITC proceedings).

- Status information will be provided from the RTS to Seattle via the satellite link.

- The system must require no more than two persons for set-up and operation; furthermore they must be able to set-up the system in less than one day.

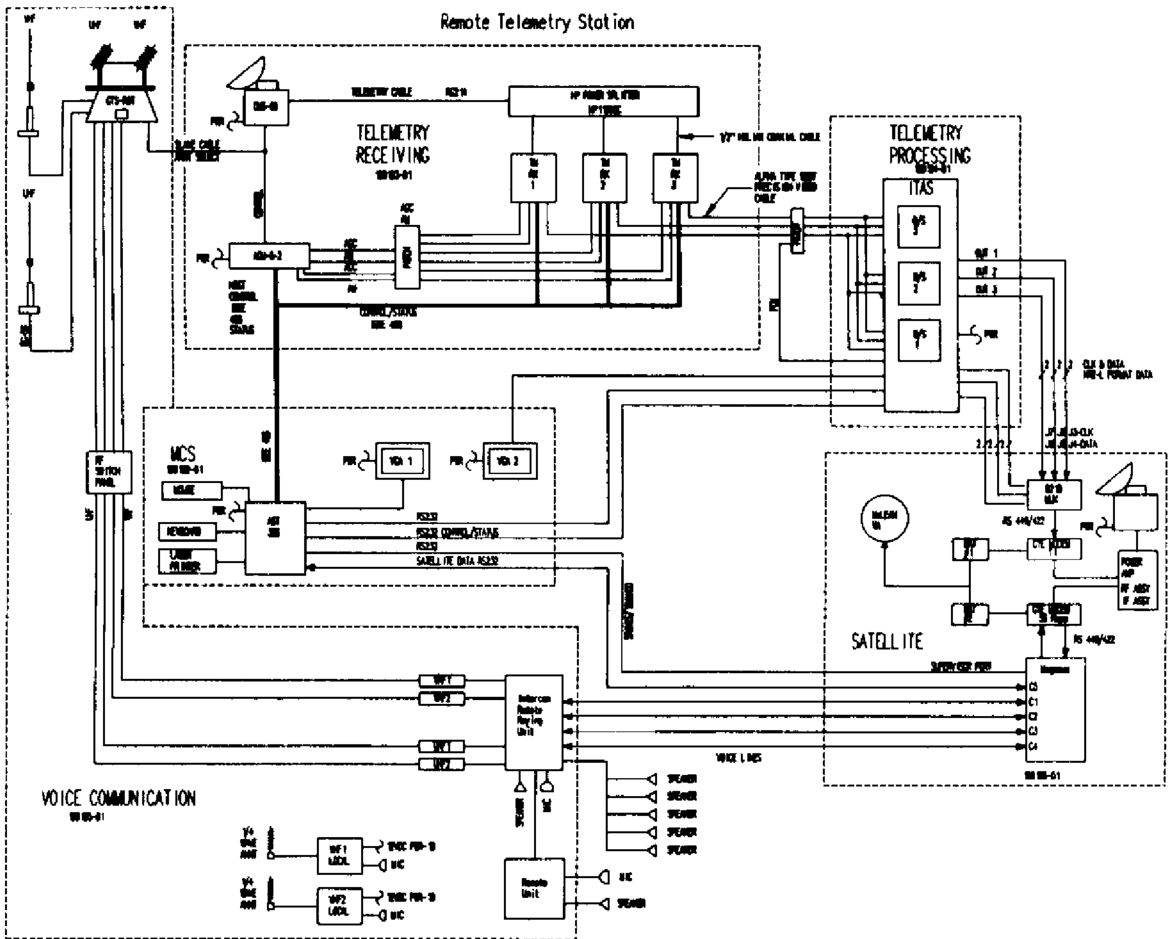
- The RTS shall be compatible with commercially available power.

- The system must be designed with redundant operating modes wherever possible.

- The system must be designed to be easily modified to accept future changes as required.

REMOTE TELEMETRY STATION DEVELOPMENT

With the exception of an Interphone and Remote Keying (IRK) device and custom software, the system represents a complete off the shelf approach, and is divided into six distinct groups: 1) the Tracking and Receiving Subsystem (TRS) 2) the Telemetry Processing Subsystem (TPS) 3) the Monitor and Control Subsystem 4) the Voice Communication Subsystem (VCS) 5) the Satellite Communications Subsystem (SCS) and 6) the Vehicle and Power Distribution Subsystem. A detailed block diagram of the RTS is depicted in the following diagram and the remaining sections of this paper discuss the overall approach in detail.



TRACKING AND RECEIVING SUBSYSTEM

At the input to the system is the Tracking and Receiving Subsystem (TRS) which consists of a dual axis telemetry tracking antenna and associated dual axis controller which in turn feeds three dual L and S band TM receivers. The TRS features both a high and low gain antenna to accomplish long-range acquisition and high resolution auto tracking. Outputs from the feed assembly are split to the three telemetry receivers, two of which provide AGC and AM control loop feedback to the antenna controller. The third receiver serves as a hot spare.

Since space and weight considerations were paramount in system design, special care went into the selection of the telemetry receiving antenna, since it was the single largest piece of equipment. To further reduce equipment, it was decided that directional UHF and VHF radio antennae would be mounted on an azimuthally-slaved pedestal. That was driven by the azimuth servo control of the telemetry tracking antenna. This scheme allows for continuous tracking for voice communication even through brief periods of telemetry blanking (using rate memory servo control).

The chosen telemetry tracking antenna system was a CMS-05 designed and developed by EMP Incorporated. It provides hemispherical coverage with conical beamwidths of up to + /- 8 degrees at L band and + /- 5 degrees at S band. Using a radially scanning feed assembly reduces the system weight and, therefore, the load-bearing requirements to support a roof-mounted assembly. As noted above, the azimuth axis is supplied with a second synchro to provide slave command data to a communications antenna rotor. For typical telemetry subbands, the antenna can provide 24 dBi gain at L band and a minimum 27 dBi gain at S band. Antenna control is accomplished using a microprocessor-based Antenna Control Unit with autotrack, remote, hold, stow, and manual modes of operation via IEEE-488 (GPIB).

The Microdyne 1400MRA telemetry receivers are microprocessor-based dual conversion type receivers which meet IRIG Standard 106.86. To provide the greatest possible flexibility, the receivers were outfitted with dual L/S band tuners, as well as plug-in wideband conversion modules. This allows remote selection of a desired band on a given receiver, thereby eliminating module swapping time and, hence, down time for reconfiguration. The receivers are capable of processing telemetry signals with data rates to 15 Mbps in FM/PM/BPSK and QPSK formats. The receivers are completely remote controllable by the MCS through an IEEE-488 bus interface, and outputs from the receivers are routed to all three bit synchronizers.

TELEMETRY PROCESSING SUBSYSTEM

The telemetry processing subsystem (TPS) consists of a single Integrated Telemetry Analysis System (ITAS) designed and developed by Veda Systems Incorporated. Receiver output is directed to the appropriate ITAS bit synchronizer via the setup and control software. Once setup, complete intact data streams are processed and retransmitted via the SCS (discussed in a following section) to the ground station at Boeing in Seattle, Wa.

In the RTS, the dual data streams are handled in two ways. First, ITAS bit synchronizers process and signal condition the data for use by the TM multiplexer, which sends the data over the satellite link unchanged. Secondarily, the data is decommutated to provide the positive frame lock indication and processed for use in a mapping program that has a number of utility functions. The flight map program displays basic aircraft flight parameters (altitude, airspeed, heading, etc.). In addition, the flight map program positions the RTS relative to the aircraft and local latitude and longitude. A God’s eye view of the flight test area can be displayed from a range of 50 to 400 mile radius, anywhere in the continental U.S., in real time.

To facilitate ease of use, setup files, which were previously stored, can be recalled and downloaded to ITAS from the MCS completely and swiftly reconfiguring the system. EU conversion, tabular and graphic data displays, and data extraction and archival processes may all be created and used via the ITAS menus. If required, the user may perform statistical analyses on the data, or may choose to process the data with functions from extensive libraries of mathematic and engineering or custom applications programs. However, in most applications once ITAS has been configured to decommutate data, only the mapping functions will be required. The result is a system that can be completely operated by a user with no special knowledge of the ITAS software or hardware architecture, but easily supports custom display, application programming and independent control by advanced users.

MONITOR AND CONTROL SUBSYSTEM

The Monitor and Control Subsystem (MCS), hosting the Veda developed software, is the central control of the RTS. All major components of the RTS can be initialized, monitored, and controlled from a single user console. Written in C code and running the OS/2 operating system, the MCS mouse-driven menus access and control all but a few RTS functions.

This central control system is essential in the scheme of RTS since the majority of the test personnel will be at the local control center where flight test parameters might change up to the last minute. Operationally, the Seattle flight test engineers can build and download the most current set-up for the RTS via the satellite link using a second MCS on the Seattle side. Once RTS setup parameters are established, the Seattle MCS "wakes up" the RTS MCS and downloads the configuration of the day. This function greatly reduces the workload of the team in the RTS. The beauty of the system is its ability to be configured from either local or remote sites.

The MCS initializes and controls the telemetry tracking antenna, telemetry receivers, telemetry processor, and the voice and status mulitplexer. This subsystem can be configured for a majority of uses including complete data processing and control. Physical interfaces are provided to each subsystem via IEEE-488 (GPIB) or RS-232 interfaces.

VOICE COMMUNICATION SUBSYSTEM

The Voice Communication Subsystem (VCS) designed jointly by Boeing and Veda consists of a bank of UHF and VHF radios along with intercom and remote keying circuitry. The VCS allows communications between the Flight Test control center, the RTS, and the flight crew in the "open mike" or "local intercom" modes. This will allow the test director to communicate directly with the aircrew while they are in flight or with the RTS test personnel. As part of the VCS, local VHF radios are installed to allow the RTS personnel to communicate with local control towers.

There are four VHF and two UHF receiver/transmitter pairs. The receivers and transmitters are single-channel ground station receiver/transmitter pairs designed for aeronautical radio telephone communications service. A crystal controlled synthesized frequency generator forms an integral part of the receivers, providing for selection of any standard aeronautical frequencies in the range of 118 - 135.975 MHZ for VHF and 225 - 400 for UHF. Modern all solid-state circuit design is featured providing current state-of-the-art techniques for optimum spurious and intermodulation performance. The receivers are specifically designed for use in the typical modem airport environment with 25 kHz channel spacing and the resulting frequency congestion. Modular construction is employed together with conservatively rated components for simplicity of maintenance and excellent long term reliability.

In addition to the receiver/transmitter, a custom Interphone/Remote Keying device was specifically developed. The only developmental item in the system, this unit is used to interface the DataMux with the radios and provides the required interphone capability between Seattle and the RTS. A unique feature of the unit is its ability to pass voice data directly to the aircraft without coach personnel assistance or relay. Speakers are located in strategic RTS locations to provide spatial separation, thus allowing coach personnel to determine which radio is being used without actually monitoring indicators.

SATELLITE COMMUNICATION SUBSYSTEM

The system is configured to transmit telemetry data, voice data, and status/control data over commercially available satellite systems. Furnished by GTE Spacenet, the Satellite Communication Subsystem (SCS) is also a dual stream system, telemetry data, and voice and control commands are up-linked separately. The SCS consists of a transportable satellite earth station, a fixed site earth station, satellite network access controllers, two different types of multiplexers, and satellite modems. The SCS accepts telemetry data from the telemetry data multiplexer and accepts voice from the DataMux. This system effectively puts the data analysis team on range.

Like the telemetry link analysis, satellite links perform differently in different environments and geographical locations. The satellite communication subsystem consists of a “matched pair” of satellite earth stations. Each earth station system provides a setup and control computer suite, a satellite modem, and an antenna. One end of the equipment is housed and deployed on range, and the other is installed at Boeing field. The following figure depicts the mobile satellite link design for the system.

The satellite subsystem consists of two Network Access Controllers (NAT) facilities connected through combiners and splitter to an outdoor IF/RF assembly for satellite interface in full duplex mode. The NAT facility consists of a rack mounted personal computer for monitor and control of the system. A set of satellite modems interface between the data from the two multiplexers and the IF/RF assembly. The IF/RF assembly consists of an IF/RF converter with 15 watt SSPA and receiver LNB. It provides conversion of the modulated transmit 70 MHZ IF signal to Ku-band (14GHz) signal. It also provides conversion of the modulated receive Ku-band (12 GHz) signal to 70 MHZ IF signal.

The outdoor equipment is located on a 22 ft. transportable trailer. The antenna is fully adjustable with elevation over azimuth position drive assemblies. All outdoor electronics are mounted on the backside of the antenna assembly and are interfaced to the NAT terminals from the trailer via two Inter-Facility Link (IFL) cables which carry the modulated 70 MHZ signal. Set-up of the whole system is done in such a manner that all speeds can be selected automatically with software and the transmit levels will be correct.

VEHICLE AND POWER DISTRIBUTION

The vehicle and power distribution completes the RTS picture. A custom manufactured motorcoach houses the entire RTS facility, and acts as a platform for deployed operations. The motorcoach receives power from an external source. Once power is applied to the coach, all connections to the satellite trailer and other equipment are realized from internal power distribution circuits. The interior laboratory space is designed to be outfitted with modular, movable (and removable) components to allow reconfiguration at any time. All electronic equipment is installed into heavy duty enclosed racks with sufficient air circulation for cooling. All cable troughs are recessed under the vehicle floor to provide an unobstructed floor area. Basic human comforts such as chairs/work stools, a small refrigerator, microwave oven, and water cooler are installed in the vehicle.

The entire installation takes into account that space is a premium concern in the laboratory area, and minimizes wasted floor and wall space. The laboratory floor is designed and built so that it is raised to yield a straight-through floor (no wheel well obstructions). Recessed cable troughs are installed in the floor of the laboratory area with transverse connecting trough runs. The cable troughs are completely accessible from above by means of removable cover plates. Additionally, the cable troughs are accessible from both sides of the exterior of the vehicle via weather resistant access hatches.

The unit is designed to operate in varying environments and weather conditions. Heat is primarily provided by below-floor fan-forced electric heat capable of maintaining comfortable conditions in sub-zero degree weather. Six tons of air conditioning is provided by roof mounted heat pumps which also serve as dehumidifiers and auxiliary heat sources.

Electrical power is provided by two external busses, one used for environmental and the other used for instrumentation. The environmental bus powers the air conditioners, heaters, and laboratory outlets, and is supplied via a 110/220 volt single-phase, 100 amp power cable connected to the vehicle with a weatherproof cannon type plug. External termination of the cable may be with similar connectors, with power bus lugs, or left stripped for bolting to a commercial power bus. Power for the telemetry processing instrumentation is supplied by the other external 110/220 volt single phase, 100 amp power cable, also connected to the vehicle with a weatherproof cannon type plug.

CONCLUSIONS

In the world of decreasing test range availability the RTS concept offers one possible solution. The solution chosen by Boeing for the RTS, and developed by Veda Incorporated, has met all of the requirements for a dual stream telemetry system with satellite relay capability. In its first few months of operation the Boeing/Veda RTS has already proven its worth by successfully supporting two flight test flutter programs. During these tests, while based in Glasgow Montana, the RTS operated successfully in winds up to 40 mph and temperatures as low as -5C and acquired telemetry data at or beyond the RIF horizon, approximately 250 miles @ 30,000 ft. There are many aspects of the RTS concept that could easily be expanded to accommodate changing requirements in the future. This “designed-in” flexibility gives the RTS an expected life cycle well beyond the year 2000.