# AFFORDABLE GROUND STATION EQUIPMENT FOR COMMERCIAL AND SCIENTIFIC REMOTE SENSING APPLICATIONS

James R. Chesney and Roger Bakos
TSI TelSys, Inc.

## ABSTRACT

The remote sensing industry is experiencing an unprecedented rush of activity to deploy commercial and scientific satellites . NASA and its international partners are leading the scientific charge with The Earth Observation System (EOS) and the International Space Station Alpha (ISSA) . Additionally, there are at least ten countries promoting scientific/commercial remote sensing satellite programs . Within the United States, commercial initiatives are being under taken by a number of companies including Computer Technology Associates, Inc., EarthWatch, Inc., Space Imaging, Inc., Orbital Imaging Corporation and TRW, Inc . This activity is due to factors including: technological advances which have lead to significant reductions in the costs to build and deploy satellites; an awareness of the importance of understanding human impact on the ecosystem; and a desire to collect and sell data some believe will be worth $1.5 billion (USD) per year within five years.

The success and usefulness of these initiatives, both scientific and commercial, depends largely on the ease and cost of providing remotely sensed data to value added resellers and end-users. A number of these spacecraft will provide an interface directly to users. To provide these data to the largest possible user base, ground station equipment must be affordable and the data must be distributed in a timely manner (meaning seconds or minutes, not days) over commercial network and communications equipment.

TSI TelSys, Inc. is developing ground station equipment that will perform both traditional telemetry processing and the bridging and routing functions required to seamlessly interface commercial local- and wide-area networks and satellite communication networks. These products are based on Very Large Scale Integration (VLSI) components and pipelined, multi-processing architectures. This paper describes TelSys' product family and its envisioned use within a ground station.

## KEY WORDS

High Performance Telemetry Processing, CCSDS, TDM, VLSI

## INTRODUCTION

Approximately 200 Earth observation and scientific satellites are projected to be launched within the next 10 years . Today, as many as ten countries (Brazil, Canada, China, France, Germany, India, Israel, Japan, Republic of China, Russian, and the United States) are sponsoring remote sensing satellite programs.

The recent commercial investment in the development of remote sensing satellites and payloads is due to technological advances which have lead to significant reductions in the costs to build and deploy satellites; an awareness of the importance of understanding human impact on the ecosystem; and an interest in participating in a market in which sales revenues from remotely sensed data product are projected to be worth over $1.5 billion (USD) annually within five years .

The success of planned scientific and commercial remote sensing programs is dependent ensuring that satellite data is accessible, inexpensive and easy to use . Historically, new applications are discovered to take advantage of accessible, inexpensive resources. Ideally, the art of transforming remotely sensed data into salable products must be reduced to the level of simplicity similar to retrieving information from the Internet.

TSI TelSys, Inc. (TelSys) was founded in 1994 to commercialize the telemetry processing technology and products developed by NASA at the Goddard Space Flight Center (GSFC), Greenbelt, Maryland . This technology is renown within NASA as the most comprehensive family of high rate CCSDS-conformant telemetry systems in the World. Since 1985, over 140 systems using this technology have been deployed on five continents.

This paper will succinctly describe the ground station equipment requirements and the attributes and capabilities of TelSys' ground station products .

# GROUND SUPPORT EQUIPMENT REQUIREMENTS

This section describes high-level ground support equipment requirements compiled from papers recently presented by commercial aerospace and government space agency representatives.

## Architecture Evolution

Currently, both NASA and the Department of Defense (DoD) are re-examining their ground segment architectures to make them more cost efficient and capable . Both are compelled to significantly change their traditional paradigms for supporting spacecraft. In developing a standard framework for satellite control, the DoD, for instance, has found that some of the satellite control functions originally believed to be unique can now be defined as generic telecommunications or information systems functions. In a similar exercise, NASA has discovered that it could reduce the complexity of its ground segment's infrastructure (a significant cost driver) by focusing on the similarities of functional requirements across programs, rather than differences.

The telemetry processing functions are increasingly being thought of as a traditional telecommunications application in which a gateway/bridge is required to join two dissimilar networks. Network equipment implementing these functions are highly autonomous, data driven and often simultaneously perform other network functions such as switching, routing or rate buffering .

## Remote Sensing Data Processing Requirements

The interaction between spaceborne and ground applications are established and maintained using telecommunications and data transfer services . Ground station equipment must perform both traditional telemetry/command processing and the bridging and routing functions required to interconnect commercial local- and wide-area networks and satellite communication networks . This interconnection is complicated by the necessity to ensure reliable space-ground communications, minimize mission operations costs and efficiently utilize critical spaceborne resources such as instrument duty cycle, data storage, processor power and communications resources.

Many of the modern scientific and commercial remote sensing satellites being launched generate enormous amounts of data resulting in telemetry data rates of many hundreds of millions of bits per second (Mbps) often using sophisticated layered packet-oriented communications protocols . For instance, EOS-AM generates an orbital average of 18 million bits of data per second and will require that over one terabyte of data per day is collected and processed . Ground data systems must have the ability to both capture and process the telemetry data as it is received and distribute the data over a network lower capacity than the space-ground link.

Cost and operational considerations dictate that ground station equipment must be automated to minimize the number of personnel required to support it, provide data to end-users in formats which are convenient to use and readily accessible and be able to support multiple missions. The NASA and the DoD are currently exploring ways in which ground stations autonomously receive, process, interpret, and respond to spacecraft telemetry. Towards this objective, NASA has found that, with appropriate security safeguards, non-critical data may be sent directly from the antenna complex to end users significantly reducing delivery time and cost .

The use of dedicated ground stations is becoming increasingly difficult to justify. Multi-mission support requirements dictate that ground station equipment must be flexible enough to capture and intelligently process various dialects of CCSDS-conformant and Time Division Multiplexed (TDM) telemetry streams at data rates ranging from tens of millions to hundreds of millions of bits per second, and nimble enough to process and distribute data quickly enough to prepare for subsequent passes.

Increasing the sophistication of the data processing performed at ground stations could be used to alleviate some of the complexities associated with using satellite data . NOAA, for instance, has developed a real-time satellite image processing capability for Geostationary Operational Environmental Satellite (GOES) data which performs a variety of functions including imagery calibration and enhancement, and gridding . In an unrelated project, NASA is developing a neural network which is capable of autonomously classifying Landsat images . These types of data processing are precursors to generating browse data and content-based metadata which would be valuable in subsequent data processing and archiving .

## Interoperability

The development of space systems requires rapid integration and deployment of ground and space segment equipment which meets increasingly demanding mission requirements and minimizes cost and development risk . Standardization and interoperability are widely seen as being indispensable towards achieving these goals . The development of common standards and operations concepts creates incentive for the development of commercial products, thereby minimizing the development costs and risks.

The adherence to Open System standards is an obvious prerequisite for commercial ground support equipment. However, as the degree of interoperability increases, it levies requirements for higher levels of application-specific service standards which imposes additional requirements on the network communications protocol at the Network Layer and above. For instance, the CCSDS AOS Path Service presently has no upper layer network support for the standard services and interfaces required to provide interoperability. Of course, the protocols and services developed to foster interoperability must conserve spacecraft data storage, processing and communications resources; be capable of supporting reliable data exchange during brief contact with the satellite; and account for bandwidth differences between space-ground and ground distribution networks.

Within the NASA community, there are three on-going efforts to define satellite operations services and communications protocols required for interpretability: grass roots efforts within NASA; NASA/DoD Space Communications Protocol Standards (SCPS); and the CCSDS Space Link Extension (SLE) services.

The degree of interoperability is increasing within NASA through the increased use of the Internet protocol suite in the ground segment. NASA is upgrading the Deep Space Network and Ground Network to use the Transmission Control Protocol/Internet Protocol (TCP/IP) for communications between ground stations and control centers and end users. The use of TCP/IP makes it possible to use commercial off-the-shelf network devices and transmission media to interconnect local and wide area networks to receiving ground station equipment. This activity has also contributed to the development of remote operation of ground station equipment.

The NASA/DoD Space Communications Protocol Standards (SCPS) provides the foundation for interoperability by defining a general cross support concept, reference model and service specifications. SCPS achieves the anticipated interoperability by running over the existing data link layer protocols, such as the OSI network protocols, CCSDS Space Link Subnet protocols and the U.S. DoD's Space-Ground Link System (SGLS) protocols. The U.S. Defense Information Systems Agency (DISA) has designated the SCPS as its lead candidate for the 'thin stack' data communications protocol for airborne, shipborne and in-field communications applications. Also, Teledesic, a commercial global satellite communications program, is evaluating the use of the SCPS.

The CCSDS is defining Space Link Extension (SLE) services to enable remote science and mission operations facilities to access the ground station equipment which terminates the AOS and Packet Telemetry /Telecommand Space Link services. It is anticipated that the SCPS and SLE development efforts will merge.

# TELSYS' VISION AND PRODUCT CAPABILITIES

TelSys' family of Telemetry Gateway products were engineered to meet the evolving requirements of modern remote sensing missions . Its broad range of performance and functional capabilities are intended for use throughout a program's development cycle, from test, integration and training to program operation . Individual products are tailored to a particular user's requirements by configuring various combinations of standard hardware and software components (i.e. building blocks such as card subsystems) which can be augmented with project unique software or hardware as required.

## Functional Components Architecture

TelSys' Telemetry Gateway products are optimized for high data rate applications using TelSys' modular, pipelined Functional Components Architecture (FCA). This architecture allows an individual product to be configured as a standalone system or as a core processor in a larger scale ground data system . FCA consists of a standard board and chip level hardware and object oriented software components . The interfaces and performance characteristics of the Telemetry Gateway Equipment is summarized in Table 1 .

TelSys Telemetry Gateway products support data rate to 500+ Mbps for both TDM and CCSDS telemetry formats through the use of a pipelined architecture and highly integrated system designs . TelSys' modular, standalone products have standard network interfaces to minimize development costs and risks by simplifying the integration of TelSys' systems into ground support facilities. To minimize operations costs, TelSys Gateway products are designed to be highly autonomous and reliable, and can be remotely scheduled and configured to support data acquisition, processing and distribution requirements for multiple missions. The Telemetry Gateway Equipment compiles comprehensive statistics documenting telemetry data acquisition and processing and has the ability to perform system self-tests and diagnostics.

TelSys' Telemetry Gateway products support the processing of TDM and CCSDS Transfer Frames/Virtual Channel Data Units to 500+ Mbps . The CCSDS packet service is supported to 300 Mbps for average packet lengths of 1000 bits . Telemetry Gateway products also provide NASA Level Zero Processing (data sorting, aggregation and deletion of redundant data) data services, protocol conversion or encapsulation for data distribution, over 2.4 Terabits of redundant data storage, and standard network interfaces. The telemetry systems are capable of recognizing and prioritizing data and distributing it appropriately.

## Multi-Mission Support

The individual elements of the Functional Component Architecture were engineered to anticipate the requirements for a wide variety of spacecraft, including the International Space Station Alpha, the EOS constellation, ADEOS, Radarsat, TRMM, TOPEX/Posiden and Landsat.

The functional components architecture easily accommodates mission unique hardware and software. The FCA is an open architecture which conforms with Open Systems and industry standards . The Telemetry Gateway application software is written in either C or C++ and resides within a VxWorks environment .

## Autonomous Operation

TelSys' Gateway Management Software is intended to provide remotely managed, fully automated operations . Its functionality includes:

- Control and monitor Telemetry Gateway Equipment
- Schedule automated operations
- Provide comprehensive histories of system events
- Provide real-time, graphical system status displays
- Create catalogs of telemetry processing configurations and control parameters
- Automatically distribute data sets to remote users

The Gateway Management Software is an object-oriented software package written in C++ and runs in a UNIX environment with X Windows and OSF Motif .

The Gateway Management Software functionality is made possible by the comprehensive accounting of all system events compiled by the Telemetry Gateway Equipment and components . In compliance with industry network management standards and to facilitate the integration of ground station equipment into commercial local and wide area networks, the Telemetry Gateway Products will soon begin to use Simple Network Management Protocol (SNMP) for network management functions . However, the management features which automate the Telemetry Gateway Equipment are inherent to the Gateway Management Software .

## Mission Specific Production Data Processing

TelSys is currently investigating the feasibility of performing higher level image processing to the telemetry data collected . The Telemetry Gateway' Functional Components Architecture easily accommodates customization required to meet mission unique requirements not addressed by TelSys' standard hardware and software components.

Table 1 - Telemetry Gateway Product Performance and Interface Characteristics

| | |
|---|---|
| Telemetry Interface | |
| Telemetry Protocols | CCSDS AOS/ Packet Telemetry; TDM |
| Data Rates | to 500+ Mbps |
| Telemetry Frame Lengths | 128 - 32K bits |
| Error Detection and correction | CRC; Reed-Solomon (255, 223), (10, 6) |
| CCSDS Path Service Performance | 300 Mbps/100,000 PPS |
| Input Formats | NRZ-L, NRZ-M, NRZ-L PCM |
| Input Interfaces | ECL, TTL, RS-422 |
| Input Telemetry Data Format | bitstream, CADU, Nascom Block |
| Time Code Standards | NASA36, IRIG-B |
| Telecommand Interface | |
| Output Command Protocols | CCSDS AOS/Telecommand; COP-1 |
| Output Command Data Formats | bitstream, CLTU, CADU, Nascom block |
| Mass Storage | |
| Mass Storage Capacity | to 2.5 Terabits |
| Mass Storage Data Rates | 400+ Mbps |
| User Network Interface | |
| Physical Layer | Ethernet, FDDI, HiPPI, TAXI, FOXI |
| Data Link Layer | IP, ATM |
| Network/Transport Layers | FTP, TCP, UDP |

## CONCLUSION

TelSys' Telemetry Gateway products are engineered to provide cost effective solutions to the sophisticated, high performance telemetry processing requirements of modern remote sensing missions which can be summarized as follows:

- Perform routine contacts automatically.
- Operate at minimum cost.
- Provide a graphical/simplified operations interfaces
- Perform highly reliably and have a self-test and diagnostic capability

- Use of open systems architectures .
- Minimize development cost and risk

## REFERENCES


Aviation Week and Space Technology, January 16, 1995, vol. 142, no. 3, p. 55.

Space News, March 6-12, 1995, vol. 6, no. 9, p. 9.

Earth Observing System Reference Handbook, NASA, 1993.

Martin, Fredric W., Distributed Architecture for a Global TT&C Network, Naval Satellite Operations Center, International Telemetry Conference, San Diego, Ca, October 1994.

Lide, David A, and Stephen Talabac, The Use of Digital Signal Processors in Front-End Weather Satellite Telemetry Processing, International Telemetry Conference, San Diego, Ca, October 1994.

Markely, Richard W., et al., Economical Ground Data Delivery, Jet Propulsion Laboratory, Third International Symposium on Space Mission Operations and Ground Data Systems, Greenbelt, Maryland, November, 1994 .

Heuser, W.R., Open Solutions to Distributed Control in Ground Tracking Stations, Jet Propulsion Laboratory, Third International Symposium on Space Mission Operations and Ground Data Systems, Greenbelt, Maryland, November, 1994.

Nakayama, K., et al., A System Study for Satellite Operation and Control in Next Generation, National Space Development Agency of Japan, Third International Symposium on Space Mission Operations and Ground Data Systems, Greenbelt, Maryland, November, 1994.

Hornstein, R., et al., Reengineering NASA's Space Communications to Remain Viable in a Constrained Fiscal Environment, Third International Symposium on Space Mission Operations and Ground Data Systems, Greenbelt, Maryland, November, 1994.

Golden, C., A Standard Satellite Control Reference Model, U.S. Air Force Space and Missile Center/CWI, Third International Symposium on Space Mission Operations and Ground Data Systems, Greenbelt, Maryland, November, 1994.

Jefferies, A., and Adrian Hooke, The Space Communications Protocol Standards Program, Third International Symposium on Space Mission Operations and Ground Data Systems, Greenbelt, Maryland, November, 1994.

Stallings, W., and Jean-Francois Kaufeler, Cross Support Overview and Operations Concept for Future Space Missions, Third International Symposium on Space Mission Operations and Ground Data Systems, Greenbelt, Maryland, November, 1994.

Perkins, D., and L. Zeigenfuss, Renaissance Architecture for Ground Data Systems, Third International Symposium on Space Mission Operations and Ground Data Systems, Greenbelt, Maryland, November, 1994.

Harris, J., et al., A Second Generation 50 Mbps VLSI Level Zero Processing System Prototype, Third International Symposium on Space Mission Operations and Ground Data Systems, Greenbelt, Maryland, November, 1994.

Campbell, W., et al., Distributed Earth Science Validation Centers for Mission to Planet Earth, NASA Goddard Space Flight Center, 8th International Symposium, ISMIS, Charolotte, North Carolina, USA, October, 1994.

Chettri, S.R, and R.F. Cromp, The Probablistic Neural Network Architecture for High-Speed Classification of Remotely Sensed Imagery, Telematics and Informatics, 10(3), 1993.