Satellite Ground Station Cost/Performance Appraisal

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ABSTRACT

The proliferation of Low Earth Orbiting (LEO) science, earth resources and eventually global communications satellites either in orbit or planned, requires a much lower cost methodology for ground support. No longer is it economically feasible to consider a single, dedicated satellite tracking station to service a LEO spacecraft. An innovative approach is needed to lower the cost of LEO satellite data services thus contributing to the expansion of the commercial space market. This appraisal will cover the performance aspects needed for LEO tracking support and offer a unique and new solution to providing TT&C and payload services.

KEY WORDS

Satellite ground stations, Space communications, TT&C, Telemetry reception, Satellite telecommand.

INTRODUCTION

Historically, it has been required by a satellite program to arrange for or procure tracking station resources in support of Telemetry, Tracking and Command (TT&C) and payload data reception requirements. These ground station resources are extremely capital intensive in that adequate antenna, radio receiving, and data processing hardware costs could easily approach $1.5M. In addition to the initial cost of procurement and installation of the ground resources, the satellite program then has to provide manpower for maintenance, operation, continuing engineering, and the cost of ground station infrastructure. Annual maintenance and operation of “so-called” autonomous ground stations can be expected to cost in the neighborhood of $150,000 per year. In addition, the initial cost of the infrastructure required, such as a building, concrete work to support the antenna, power installations and communications equipment to state the obvious, could cost on the order of $200,000. If the project procures its own ground station, and assuming a satellite program of 3 years being typical for the scientific community, the total cost of ground support is summarized in the following table:

ITEM	TYPICAL COSTS	COMMENTS
GROUND STATION PROCUREMENT	$1,500,000	5 METER S-BAND ANTENNA, RECEIVING AND PROCESSING EQUIPMENT.
INFRASTRUCTURE	$200,000	BUILDING, ANTENNA PADS AND SECURITY
MAINTENANCE, OPERATIONS, COMMUNICATIONS, AND CONTINUING ENGINEERING	$450,000	$150K PER YEAR FOR 3 YEARS OF OPERATION.
TOTAL	$2,150,000.00	

The above table indicates that the cost of procuring, operating, maintaining and supporting a dedicated ground terminal for a satellite program of 3 years can cost in excess of $2.0M. Considering that the majority of the $2.0M (at least 1.5M for the station hardware and $0.2M for the facility), must be paid up front, the ground station is a significant expense in the operation of any satellite program. With the expected proliferation of Low Earth Orbiting (LEO) scientific satellites in the coming decade an alternate approach is needed to provide lower cost ground support. This paper studies the advantages of a fully commercial satellite tracking network to provide low-cost satellite TT&C services.

COMMERCIAL GROUND NETWORK

Now that the need for commercial tracking services has been identified, considerable attention must be paid to the implementation of the system. To effectively compete with stand-alone, project-owned ground station resources, the commercial service must be able to provide TT&C and payload data on a "shared" basis. Sharing resources provides the ability to amortize the capital cost of the station hardware and communications facilities, including the recurring cost of operations over several LEO satellite projects.

To maximize the commercial viability of this type of enterprise requires the ability to support as many satellite projects as possible. It is not economically feasible to provide a single station to each project on a no cost basis and then expect to charge that single project a "lease fee" for the station. This approach would require roughly the same investment from the project with the only advantage being the capital to procure and build the station would not be required. While this does offer some advantages to the project, it is not highly desirable because of the lack of long-term capital advantages.

LEO satellite orbits range from equatorial to polar in varying degrees. The following table contains a typical list of scientific satellites and their respective orbit inclination:

SATELLITE	ORBIT	ORGANIZATION	LAUNCH
FUSE	25 degrees	APL/JHU	NOV. 98
SWAS	65 degrees	NASA	FEB. 97
FAST	83 degrees	NASA	AUG. 96
LANDSAT - 7	98 degrees	NASA	MAY 98
TOMS - EP	99 degrees	NASA	JUNE 95

An innovative way to provide low-cost satellite tracking services to a wide variety of LEO spacecraft is to consider the use of a Commercial Ground Network (CGN) for tracking support. Envision a system where the satellite user (or Principal Investigator/Scientist) is seated at a computer terminal which is connected through a commercial telecommunication service to a Network Management Center (NMC) that provides him real-time access to his LEO satellite, such a system saves him many times the cost of traditional support. This CGN would allow the user to have unprecedented access to his LEO satellite regardless of its orbit inclination. In order to support both polar and equatorial LEO's in a variety of orbital inclinations the network must contain strategically located global resources.

REMOTE GROUND STATIONS

A Commercial Ground Network of remote ground stations (RGS) would have to support Low and Medium Earth Orbiting (LEO and MEO) satellites. The RGS must be true multi-mission support systems with a high degree of tunability and programmability built in. Baseline stations would be built in strategic locations such as Hawaii (for equatorial) and Alaska (for polar) to provide support for "S" band TT&C and "X" band. The remote ground stations (RGS) must have a high degree of autonomous operation and must be fully remotely controlled. The stations must be controlled by a centrally-located Network Management Center (NMC) to provide single-point access to the global RGS's. Figure 1 shows the high level topology of the network.

To provide a cost-effective, reliable and secure operation the network must be connected with Public switched Internet services (T1/Frame relay) and PPP telephone circuits. Each RGS should have, as a minimum, 128Kbits/second data service to and from the NMC. Additional bandwidth to 1.544 Mbits/second can be obtained on an "as needed" basis to support higher data rate operations in real-time. The user always connects to the NMC for telecommand and real-time telemetry data. Future availability of higher rate, commercial telecommunication services will allow cost-effective enhancements to the CGN increasing the real-time bandwidth available for mission support.

The NMC will validate all telecommands before forwarding them to the appropriate remote ground station (RGS). All RGS's will have the same complement of backend equipment and will communicate using the same protocols. Users may connect via PPP (modem or Integrated Services Digital Network (ISDN) dialup) if extra security or

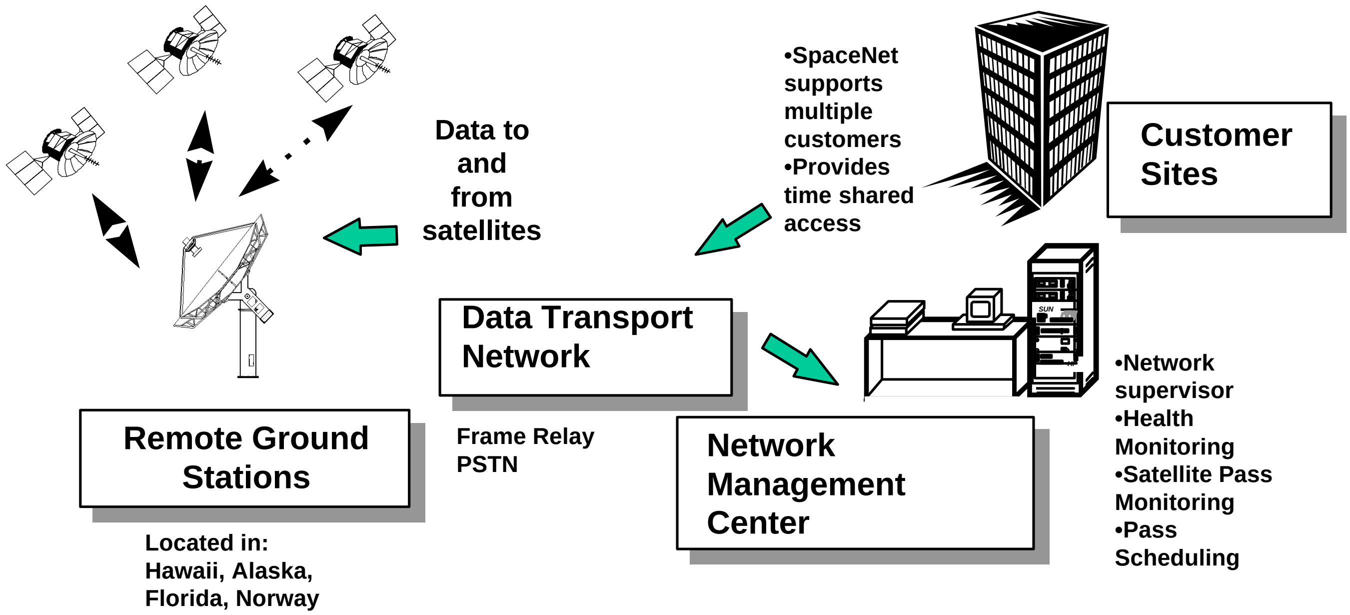

Figure 1 - CGN Network Architecture

promptness (deterministic routing) is needed. The NMC always connects to the RGS's with PPP for secure telecommands and reception of real-time housekeeping data. Use of the PPP allows for fast connectivity with no delays in service. The user with appropriate authorization can obtain data files directly from the station. The frame relay connectivity allows for large data file dumps to the NMC and users as well as system reconfiguration and maintenance . The user may also temporarily install specialized equipment at the RGS site for specific missions.

The stations are controlled via Transmission Control Protocol/Internet Protocol (TCP/IP) in a client/server architecture, Figure 2 shows a typical station block diagram. Each RGS is constructed using well known commercially available telemetry equipment. The stations are controlled via client/server software remotely from a network management center. Using well known commercial equipment adds reliability and modularity to each RGS. The ability to upgrade performance is built into the system, the latest ground support equipment can be interfaced with a minimum of effort. The RGS will also contain "hot" redundant spares that can be switched into the system if needed. Each station will be remotely controlled from the NMC for routine and stable mission support, but will be manned for powered flight operations, injection, and special mission support. The stations should, at a minimum, support all the requirements and protocols in the following list:

1) "S" and "X" band receive
2) "S" band transmit
3) Subcarrier demodulation
4) Transponder support for NASA, CNES, DOD, etc

5) CCSDS data processing
6) QPSK, BPSK, PM, FM, AM modulation types
7) IRIG telemetry codes
8) Viterbi decoding
9) Reed Solomon error detection/correction
10) TCP/IP data and command transport

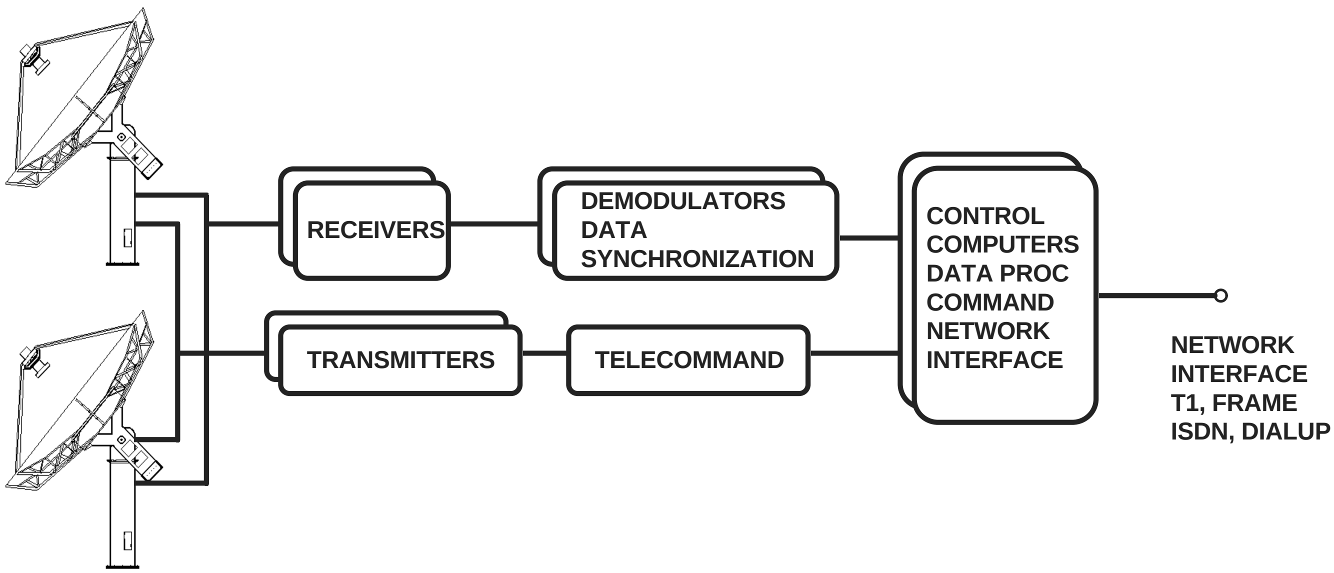

Figure 2 - RGS Block Diagram

TYPICAL APPLICATION

Assume that The University of Space Sciences is building a small satellite for a 12 month mission, for the purpose of this paper we'll use the name Atmosphere Monitor (AM). The AM satellite will be launched from the Kennedy Space Center by the "Intrepid" expendable launch vehicle headed for an altitude of 800 KM at an orbit inclination of 25 degrees. The satellite requires 2 contacts/day, the Principal Investigator must find a way to support this mission within his budget. The entire budget for the mission operations including flight ops, staff, science and ground station support is under $1.0M, which is considerably less than would be needed to purchase the ground station hardware alone." A CGN can provide support for this mission on a per/pass basis, with a cost savings of an order of magnitude over the mission life, compared with procurement and operations of a dedicated ground station.

At an altitude of 800 KM, the Atmosphere Monitor (AM) spacecraft completes roughly 13 orbits every 24 hours. Figure 3 shows AM coverage provided by two Universal SpaceNet, Remote Ground Station (RGS) elements with 5 degree elevation contours drawn around each site. In this case, the use of a CGN provides coverage of 9 of the possible 13 daily orbits of the AM spacecraft. The PI may choose the 2 best passes of the day for scheduling and on a priority-basis could have access to 7 more if needed for contingency. Also, if a problem occurs with a given pass, the PI has another opportunity to “see” the AM spacecraft at the other site on 3 of the 9 passes. This built-in redundancy is provided automatically by the Commercial Ground Network at no additional cost to the PI.

Atmosphere Monitor
Inclination = 25 degrees
Altitude = 800 KM
Pass Duration, 8-13.6 minutes

Pass #	Uncovered	Hawaii	Florida	
1			X	
2			X	
3		X	X	
4		X	X	
5		X	X	
6		X		
7		X		
8		X		
9		X		
10	X			
11	X			
12	X			
13	X			

13 PASSES/DAY MAXIMUM

- **Hawaii Covers 7/13 Passes/Day**
- **Florida Covers 5/13 Passes/Day**
- **Together, Hawaii and Florida cover 9/13 Passes/Day.**

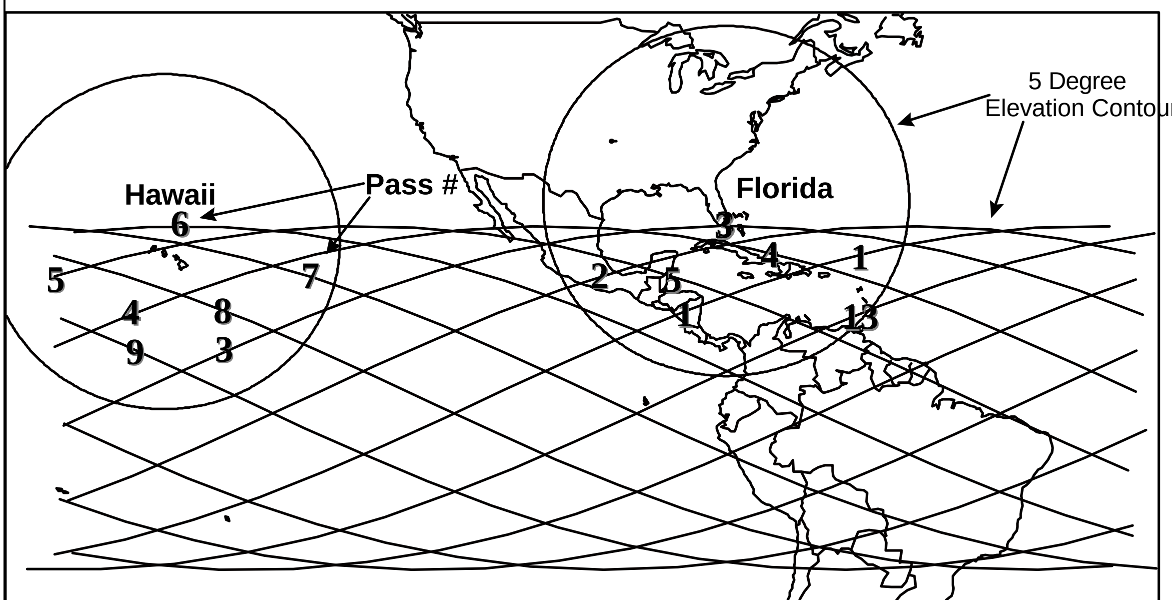

Figure 3 - Atmosphere Monitor (AM) Ground Coverage

CONCLUSION

In conclusion, if a satellite program is considering obtaining their own ground station in order to support a mission or if “true cost” accounting and amortization must be adhered to using an existing resource, a CGN will save great effort and considerable expense while offering a significant increase in redundancy and reliability.

ACKNOWLEDGMENTS

The author wishes to thank Mr. Thomas M. Pirrone for his invaluable contributions and assistance in the preparation of this paper.

ACRONYMS

CCSDS	Consultative Committee on Space Data Systems
CGN	Commercial Ground Network
IRIG	Inter-Range Instrumentation Group
ISDN	Integrated Services Digital Network
LEO	Low Earth Orbiting
LEO-T	Low Earth Orbiting satellite tracking Terminal (NASA)
NMC	Network Management Center
PPP	Point to Point Protocol
PSTN	Public Switched Telephone Network
RGS	Remote Ground Station
TCP/IP	Transmission Control Protocol/Internet Protocol
TT&C	Telemetry, Tracking, and Control

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