The Development of a Military-COTS Mobile Satellite Earth Station

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ABSTRACT

The explosive development of a series of high bandwidth satellite constellations by 2006 coupled with the paralleled explosive growth of intranet/extranet networks will provide an opportunity to nonNATO countries to develop mobile C4I systems using Commercial-Off-the-Shelf (COTS) equipment. The systems can be semimilitarized by installing the C4I systems in military shelters and using military vehicles as transport platforms with the heart of the system is still being COTS. This paper describes key points in the development of just such a Military-COTS mobile satellite earth station, from design requirements to the actual build-out of the mobile system.

INTRODUCTION

An estimated $80 to $120 billion dollars of international funds that will be invested in the development of major satellite systems in the next 5-6 years. The end result is a shear explosion of satellites planned for launch by the year 2006; 61 GEOs, 65 MEOs, and 415 LEOs. These will, according to their respective owners, provide an aggregate bandwidth of about 3 terabits per second or the rough equivalent of about 2 million T1 lines. Accompanying these satellites will be the further development of low-cost earth station terminals to use the large bandwidth made available. These systems will be designed to provide such services as data delivery, global telephone, paging, broadcast and imagery.

As the satellite industry continues the development of these high bandwidth networks to meet the growing international bandwidth requirements the US Department of Defense (DoD) is also turning toward increased use of commercial satellite services for communications, intelligence, surveillance, navigation, and weather to meets its own growing needs. The Defense Department currently leases up to $200 million a year of wideband communications channels to augment DoD owned systems. The Pentagon's current "gapfiller approach" in buying communication services allows the agency to "buy time" before they commit to a specific satellite technology for communications services. The combination of a rapidly evolving commercial market coupled with military requirements such as security, encryption and radiation hardening are some of the factors that are being addressed as the US DoD considers high volume use of the new commercial systems. When DoD begins using the next generation of commercial satellite networks the Department will have access to state-of-the-art technology without funding the satellite and ground station IR&D effort.

This commercial focus has not been lost on the developing militaries of nonNATO countries. The timely combination of rapid advancement in space technologies with the establishment of large bandwidth networks, and the tumultuous growth in intranets /extranets hardware and software, allows communications engineers to piece together the pieces of the Military-COTS tapestry. These pieces can be fit to form low cost COTS mobile earth stations providing data, telephone and video teleconferencing services that can be used at the strategic and even the tactical level to enhance or augment current Command Control, Communications and Intelligence (C4I) capabilities of nonNATO armed forces. Realizing that COTS equipment is not radiation hardened or protected to the same degree as NATO militarized equipment, these same militaries are willing to trade off protection level for C4I capability. This trade off may be acceptable

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depending upon the military sophistication of their primary military threat.

A Military-COTS satellite mobile earth station system that utilizes the advancements discussed above is being developed for an Asian country. Their system augments a larger C4I system that is being employed for the country's military Supreme Commander; the Joint Staff; and the Army, Navy and Air Force Headquarters staff. The mobile earth station satellite system, referred to as the Mobile Command Post (MCP) Satellite System, provides connectivity for electronic file data transfers, electronic mail, secure/non-secure telephone, video teleconferencing, Over The Horizon (OTH)-Gold-type messaging, and "Common Operational Picture" Friendly /Enemy Force tracking system.

The paper will now consider the system overview, design requirements, design philosophy, system design, procurement realities, military standard constraint and finally future trends.

SYSTEM OVERVIEW

The C4I system being developed in Asia and installed for the Supreme Commander and Joint Staff is a multi-network of four major networks: Office Automation (OA-LAN/WAN); a Unix based Common Operating Picture (COP) / OTH-Gold Application, Secure/Non-secure/ facsimile telephone system; and a Point-to-MultiPoint Video Teleconferencing (VTC) system. The C4I system combines these systems into a Joint Operations Center, a Joint Logistics Center, a Modeling and Simulation Center, and a Crisis Action Center. All of the divisions of the Joint Staff; the Minister of Defense staff; and the Army, Navy and Air Force Headquarters are part of the C4I system and are connected to these different centers. The system also ties in the Prime Minister and other key elements of the Government as well.
A key element of the C4I system is several MCPs. These MCPs have all of the same capability as the C4I network, but on a reduced scale. Examples are 140 Kbps for MCP WAN data connection versus E-1 C4I WAN links and 15 frames per second (fps) for MCP VTC versus 30 fps for large console versions at the Joint Operations Center. The mobile system uses satellite connectivity as one of its communication links to the C4I system. The architecture is shown in Figure 1.

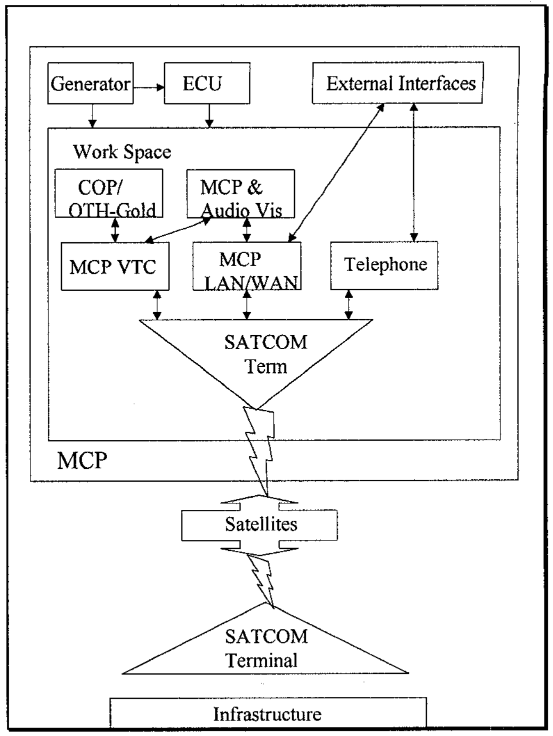

Figure 1. MCP System Architecture

DESIGN REQUIREMENTS

The design requirements and constraints can be divided into two major categories, those dictated by the client as stated requirements and those dictated by the system itself to meet the client's functional requirements. The impact of these design requirements dictates the COTS technology employed in the satellite system design. In terms of the MCP, the requirements below impacted the mobile earth terminal satellite system design.

Client Imposed:

- The MCP must
  - be fully self-transportable with all of its organic equipment. It is not required to carry passengers or their personal belongings. It must transport all electrical power and cooling support systems.
  - use minimal satellite bandwidth, but provide adequate capability to interact in near-real-time \ with command center staff.

- use current Military Communications (MILCOM) protocols and standards where available for establishing terrestrial connections to the main C4I networks.

- The command shelter transport vehicle must be a 5-ton military truck with associated trailer for electrical generator.

- Except for the environmental control unit (ECU), the electrical system must be 220 VAC, single phase.

- The MCP satellite system must provide communications connectivity between the four major networks that comprise the C4I System and the MCP Command Staff.

- The satellite system must use current satellite bandwidth available to the military. [Original requirement was Ku-Band. This was switched to C-Band during design by the Asian nation military.]

- A new import restriction on C-Band Transmit systems required that all imported antennas for C-Band will be no smaller than 3m diameter in order to be compliant with two-degree spacing.

System Imposed:

- The MCP will maximize commonality of network components to reduce training and maintenance requirements.

- All network and satellite equipment will be COTS.

- The satellite system will transport in duplex mode six voice channels, VTC, and a maximum of 256 kbps of data simultaneously.

- The satellite system will be digital SCPC in a star network design from a central hub site.

- Open standards, especially European standards, will be used to the greatest extent possible to ensure equipment compatibility.

- The VTC network switch hub will be located in a building on the same military compound as the MCP satellite hub.

- The satellite system will be able to withstand high velocity monsoon winds.

DESIGN PHILOSOPHY

The basic premise of the MCP design is to build a system that is capable of operating independent of the main C4I system networks yet is capable of becoming an extension of the main networks with satellite or terrestrial connectivity. The MCPs deploy stand-alone capability in office automation, telephone, and COP/OTH-Gold applications, but are required to use satellite connectivity to conduct video teleconferencing due to the lack of ISDN outside the capital city.

The stand-alone method of operation was deemed critical from both an operational standpoint and in defining the type of data being transmitted over the satellite link. Due to the long time delay caused by the use of geosynchronous satellites, approximately 500 milliseconds from the time an Internet Packet /Transmission Control Packet (IP/TCP) is sent and the subsequent acknowledgement (ACK) returns, real time applications are not easily employable without complicated TCP spoofing. Data transmission in the MCP system is limited to file transfers, e-mail transfers, and OTH-Gold database record transfers, which are less time sensitive than network-based applications. As the Internet Engineering Task Force (IETF) develops a satellite transmission compatible TCP standard, other TCP standard mechanisms are available such as Path MTU Discovery, TCP Windows Scaling, and Selective Acknowledgements (SACKs) to maximize IP/TCP packet flow over satellite communication links.

Another premise of the MCP earth station terminal design is to keep it as simple as possible for operational use and system management. This is achieved by using the lowest possible number of connections and least network equipment possible to operate and connect the systems to the main C4I networks. This is possible due to the flexibility of the latest COTS network equipment, which offers a wide array of interfaces and protocols, as slide in modules. Determining and finding the appropriate equipment with the correct serial and network interfaces for the time division multiplexer became a driving factor in the design. A side benefit of this flexibility is the capability to add new features to the system as new requirements arise.

The MCP must transport all provided equipment as organic equipment and provide adequate electrical power and cooling for the equipment and staff in the command shelter when deployed. The size, shape, weight, electrical power draw and heat produced by the COTS equipment in conjunction with maintaining space for operator consoles was a driving consideration in COTS equipment selection. This was especially crucial in determining the antenna type and stand since they must be transported on the same trailer as the electrical generator.

SYSTEM DESIGN

Figure 1, MCP System Architecture is a high-level overview of the major systems in the MCP and how these systems interact. MILCOM is the primary means of communication for transporting telephone and data traffic. The satellite system is the secondary method for these two systems when MILCOM connectivity is unavailable in forward-deployed positions. In conducting video teleconferencing, the satellite system is the only communications channel available. Figure 2, MCP Satellite and VTC System Schematic further highlights this at the component level.

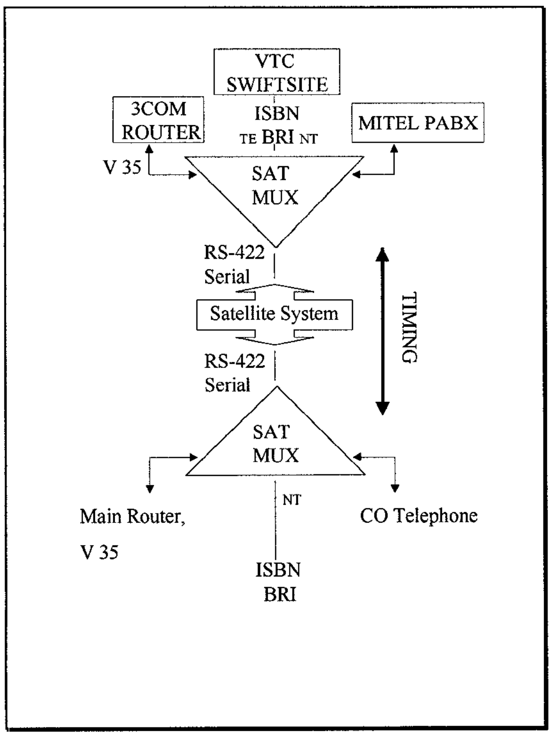

Figure 2. MCP Subsystem Architecture

Figure 2 also raises an issue that will become more complicated as satellite systems carry additional switched digital services on single carriers: conflicting network clocks. Strict attention is required in the design of COTS satellite systems in the source and flow of network clocks. However, the emergence of telephony and data on single networks is leading to the development of switched network COTS equipment that is capable of supporting multiple network clocks. This is evident in the development of switched routers capable of integrating data, ISDN and voice services all in the same chassis. As a result, the satellite modem becomes just another clock source for the switched service to handle. In the current MCP design, two COTS capabilities were leveraged to avoid conflicting clocks: RAD Kilomux 2100's capability to accept ISDN BRI directly and its capability to accept or give network clock. This is delineated in Figure 2 as Terminal Equipment (TE) or Network Terminal (NT) respectively. The second COTS capability leveraged is the capability of the VTC Conference Server to act as a switched router and accept network clock on several ISDN BRI ports. Thus, the Datum GPS clock generator becomes the network master clock and all timing is passed from the satellite system hub modems to the rest of the MCP and hub earth station systems.

PROCUREMENT REALITIES

Gathering and updating databases of the vendors developing new products and capabilities in data and voice networks is a monumental task. Finding the features you require at the data rates you require, and in the appropriate interface standard are even harder. This is not due the lack of products, but rather the difficulty in finding the right combination. For instance, the RAD Kilomux 2100 multiplexer supports V.35 for data, E1 CAS for telephone, and Integrated Services Digital Network Basic Rate Interface (ISDN BRI) for VTC. Other COTS equipment had the appropriate data rate, but an inappropriate standard, such as ISDN Primary Rate Interface (PRI) instead of an ISDN BRI.

With the development of new products come more selection, but also the requirement for additional "test driving" prior to purchasing. Multifunctional COTS equipment requires more thorough test than single functional COTS equipment. In the rush to market,

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incompatibilities or limitations may exist between chassis modules. Case in point again is the RAD Kilomux 2100. With the use of the ISDN BRI module, the main network link is limited to a maximum throughput data rate of 384 kbps, even though this link has a maximum system rate of 768 kbps.

As Military-COTS systems are developed and built, the availability of in country COTS warranty and product support becomes critical in the procurement process. Sending products out of the region for repair coupled with phone calls back to the US for technical support greatly impacts repair time. Overseas shipping and import duties become maintenance cost increases.

MILITARY STANDARD CONSTRAINTS

COTS equipment seldom, if at all, meets any of the US-NATO Military Specifications for shock, environmental or other pertinent requirements for militarized equipment. Attention must be provided in the design and procurement process to ensure that the selected COTS equipment can be integrated into a mobile system, if that is required. Equipment placement in equipment racks, the shock isolation of those racks and the locations of the racks determine the MCPs configuration, which in turn defines the end user usability. Vehicle integrators must be familiar with both military specifications and COTS equipment durability. They must design and build mobile systems that have military functionality but use COTS based hardware. The development of smaller and more reliable COTS equipment with increased functionality coupled with military capable system designs will allow for smaller and more functionally capable COTS based military mobile systems in the future.

FUTURE TRENDS

The development of this MCP system with its solely COTS-based data, voice and VTC networks is a forerunner of other such systems to be developed for other nonNATO and even possibly NATO countries for non-nuclear threat response forces. For nonNATO military forces the complexity and capabilities of future systems will be determined by the perceived long-term threat; the degree to which they are willing to rely on a 3rd party for strategic and even tactical satellite communications; and the long-term budget available to implement the satellite system requirements.

In summary, the combination of the following factors will only increase the pressure on nonNATO governments to seriously consider COTS-based satellite systems using leased bandwidth: satellite networks providing large bandwidth capability; rapid growth in intranets and extranets; development of Ka-band to reduce dish size; satellite friendly IP/TCP protocols; increased COTS equipment functionality; competitive pricing by vendors on all fronts; and reduced military budgets.