SatCom For Net-Centric Warfare May 2009

MilsatMagazine

This Issue:

Command Center

Colonel Roger W. Teague, SMC

Priority Briefings

- >> Zachary Lemnios, Lincoln Laboratory
- >> Nexgen Soldier Support
- >> Military Access To Space

The Role of Baseband SATCOM
Taking Mobility To New Heights
Net Management For MILSAT
Tactical Use Of MILSATCOM

And More...

MILSATMAGAZINE MAY 2009

CONTENTS

Vol. 2 No. 9
May
2009

MILSATMAGAZINE
May 2009

THIS ISSUE'S AUTHORS

GUY ADAMS
JOHN DOUGLAS
GARY ECHO
JOS HEYMAN
FRED MCCLIMANS
JOSE DEL ROSARIO
DAN DIA-TSI-TSAY
KOEN WILLEMS

Published bimonthly by
Satnews Publishers
800 Siesta Way,
Sonoma, CA 95476 USA
Phone (707) 939-9306
Fax (707) 939-9235
Email: pattie@satnews.com
Web: www.milsatmagazine.com

INCOMING — MILSPACE

As I wrote in the May issue of SatMagazine, attending the National Space Symposium in Colorado Springs is an event I truly enjoy. Yes, the location is delightfully scenic and The Broadmoor Hotel is a magnificent stage set against a majestic backdrop — the Rockies. The real reason for SatNews attendance is the quality of the event, especially in regard to its military presence. These stalwart defenders of freedom and the commercial entities who support the warfighter come with proven product demos, new ideas for MILSATCOM, and an enthusiasm that is highly infectious, all in spite of a global financial environment that's rather recalcitrant, to say the least...

There is so much information imparted to attendees that one's synapses are firing on all neurons with new contacts, new technologies, and new solutions. The National Space Symposium is sponsored by the Space Foundation and that organization's CEO, Mr. Elliot Pulham, offers some thoughts regarding the current state of the space industry and its related business environs. He believes there may be lag before the full impact of the current economic doldrums are felt in our vital industry, with most business advancement to be experienced in the public sector. He definitely feels there will be an increase in collaborations of the international kind, as well as increased integration within the business sector. There is definitely available capacity, not necessarily with transponders, but for growth and advancement in this industry.

From a personal perspective, when economies are recalcitrant, forging forward with already committed projects, as well as activating aggressive marketing and public relations efforts, makes a great deal of sense. Due to any number of actors withdrawing from such activities, such is an opportunity for those with foresight to cement themselves into place as subject-matter experts. Their voices remain heard — their messages are more easily recognized due to a lack of competitive voices, not a bad thing when attempting to promote your product or message.

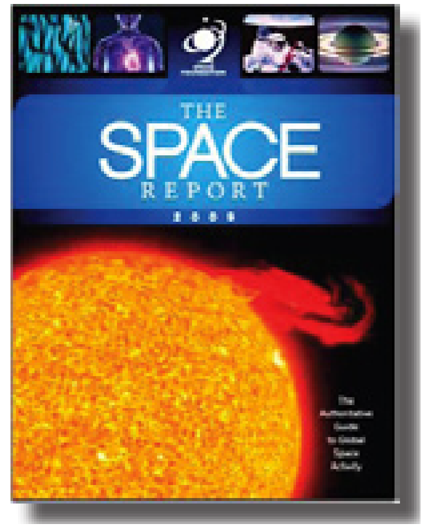
As economies improve, those who have weathered the storm and remain in place have no need to start from scratch, and seem to have "always been there," doing what is necessary to instill confidence with prospective customers, and assuring their well-established client base they are in the industry for the long term proving they can accomplish the job. This is also a good time for a new company to launch as more attention is paid to their announcements and products due to less clamor from an over-messaged industry.

I would wish to present excerpts specifically dealing with the military environs of our industry from the pages of the Space Foundation's magnificently produced annual, The Space Report 2009: The Authoritative Guide to Global Space Activity. For those who are interested in obtaining this publication, the annual is available at this direct link.

Military Space Activity

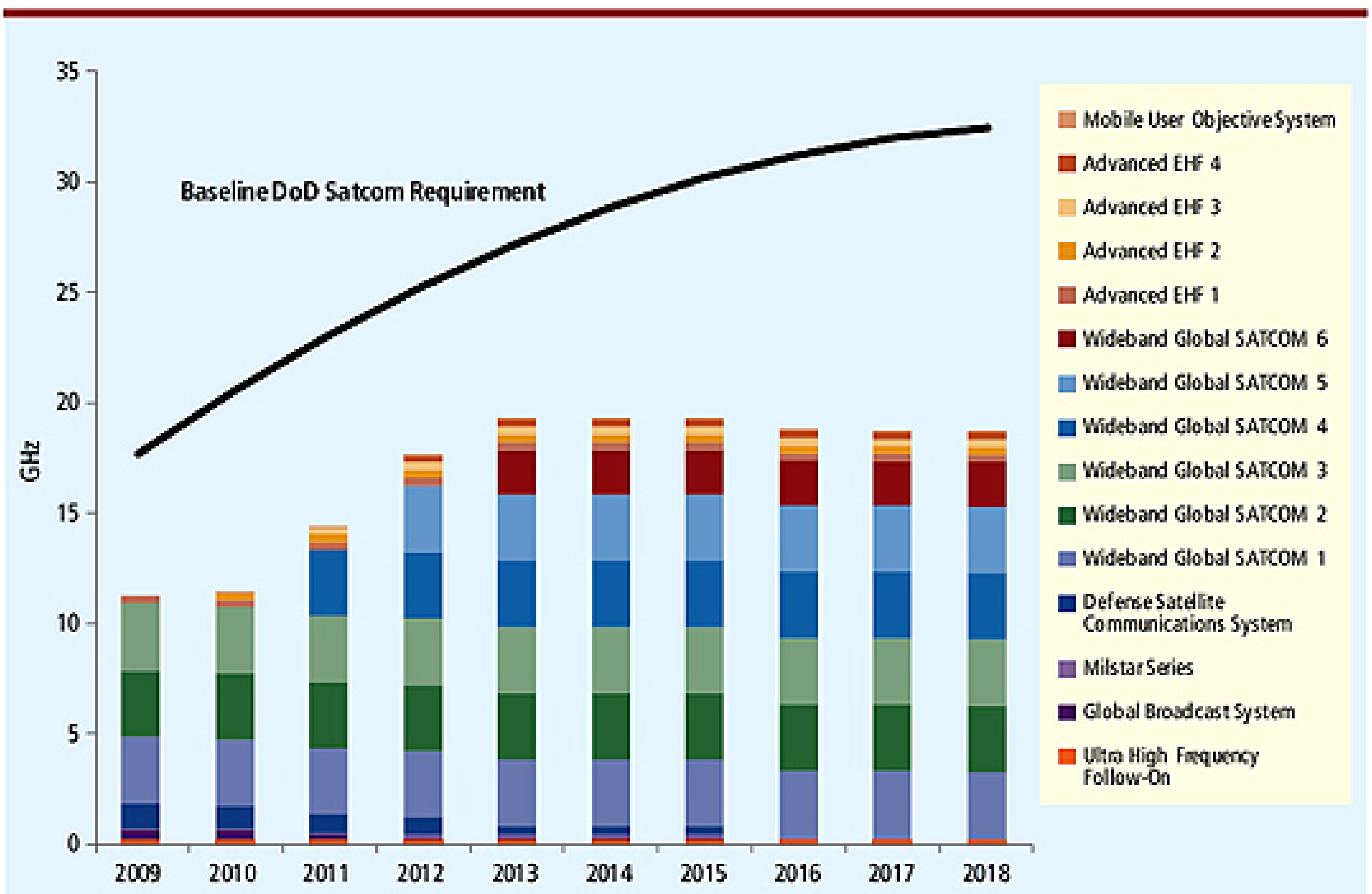
The United States, Europe, and Japan all took steps in 2008 that will affect the direction and prominence of their military space activities in coming years. The increasing reliance of governments on space-based capabilities makes military space systems valuable national assets. Demonstrations of anti-satellite weapons by China in 2007 and the United States in 2008 underscored the vulnerability of satellites and the need to develop systems capable of evading attack and constellations that can be replenished if they do sustain damage. Concern about orbital debris created by the Chinese exercise raised awareness of the challenge of maintaining a safe space environment.

In February 2009, the collision of a commercial satellite owned by Iridium with a non-operational Russian satellite illustrated the difficulty of operating in an environment where the precise location, speed, and direction of other objects is not always available. While there have been several accidental collisions of objects in space before 2009, this was the first time two large satellites destroyed each other. The debris from the incident is a potential threat to other satellites in similar orbits. ***Space Situational Awareness*** (**SSA**) efforts will grow in prominence in the near future as a necessary step toward better understanding of threats in space, whether malicious or unintentional.



United States Military Space

U.S. military and intelligence satellite constellations are being upgraded and replenished, as



Source: Futron

debate continues as to the most efficient and effective way to proceed. U.S. forces around the globe have become dependent on space systems, relying on them at every stage of operations. By the end of 2008, the U.S. military had achieved a record of 59 consecutive successful national security launches over nine years. Military planners are focused on how to maintain and expand space capabilities while addressing demands to cut costs and re-evaluate new programs.

The global deployment of U.S. forces requires an immense satellite communications infrastructure. Older systems in the ***U.S. Department of Defense*** (**DoD**) military satellite communications network have reached their life expectancy and a transition is underway as new satellites come into service. During the next decade, the ***Defense Satellite Communications System*** and first-generation ***Global Broadcast System*** (**GBS**) will cease operations entirely. The ***Milstar*** and ***Ultra High Frequency Follow-On*** systems are expected to be limited to one or two spacecraft. These systems are being replaced by the ***Wideband Global SATCOM*** (**WGS**), which includes new GBS capability, the ***Advanced Extremely High Frequency*** (**AEHF**) and ***Mobile User Objective System*** constellations. Even with these new systems a shortfall will exist between DoD capacity and baseline DoD satellite communications requirements, as shown in in the table at the bottom of *Page 4*.

As part of the Space Tracking and Surveillance System, this low Earth orbit satellite (as seen in this artist's drawing) will use a set of infrared and visible sensors to detect and provide tracking information about ballistic missiles globally. Credit: Northrop Grumman

To fill this gap, DoD users may rely upon a combination of commercial satellite communications capacity and the development of the ***Transformational Satellite System*** (**TSAT**) which could provide up to 30 gigabits per second of capacity. Both **Boeing** and **Lockheed Martin** have development contracts for TSAT, and the $11 billion program continues to undergo changes, including the likely elimination of key networking capabilities using inter-satellite links. The first block of five spacecraft is not expected to be operational until 2019.

Replenishment of the ***Global Positioning System*** (**GPS**) constellation operated by the U.S. Air Force is under way, with new models of GPS satellites planned for deployment over the next decade. These new satellites increase military capabilities and are interoperable with foreign systems. Greater interoperability reduces the need for multiple types of receivers to access individual navigation systems, thus improving global coverage. ***GPS Block IIF*** satellites are the next generation of GPS satellites and will provide new capabilities and an extended lifespan. The first GPS Block IIF satellite is scheduled to launch in

2009, with ***GPS Block III*** to follow beginning in 2014. ***GPS IIIA*** will transmit a new civilian signal compatible with the European Galileo satellite navigation system and Japan's Quasi-Zenith Satellite System. The first GPS IIIA satellites are projected to be available for launch in 2014 at a baseline cost of $4 billion.

The need to replace the aging U.S. satellites that perform the vital function of detecting and warning of missile launches in adversary states was underscored in November 2008 when a year-old ***Defense Support Program*** (**DSP**) satellite failed. The failure led some to warn of a potential gap in coverage beginning around 2014.The DSP satellite was the last of its constellation to launch. A new generation of missile warning satellites called the ***Space Based Infrared Satellite*** (**SBIRS**) system is to replace DSP. The Pentagon asked Congress for $117 million in funding in fiscal year 2009 to hedge against a potential gap in missile warning coverage. In November 2008, the ***SBIRS Highly Elliptical Orbit*** (**HEO-1**) payload was accepted for operation after a period of in-orbit testing. The second SBIRS payload, ***HEO-2***, will soon begin transfer from its development phase to U.S. Air Force operational control. The SBIRS system currently includes the two HEO payloads now in orbit along with two GEO satellites in development. The program is in early stages of planning for adding additional

Space Situational Awareness (SSA) seeks to form a comprehensive knowledge of the population of space objects, of existing threats and risks, and of the space environment. This artist's impression of objects in orbit around the Earth is based on actual density data, and illustrates the complexity of SSA. Credit: ESA

HEO payloads and at least two GEO spacecraft to the planned constellation. Estimates place the total cost of SBIRS at approximately $10.4 billion."

The new administration in Washington will be reviewing missile defense policy, deployment plans, and spending levels, but long-term financial support for U.S. missile defense spending appears likely to remain strong. The ***Center for Defense Information*** estimates an $8.8 billion investment in missile defense within the United States during fiscal year (FY) 2009. Missile defense spending is projected to increase annually to $9.7 billion by FY 2013. In February 2008, the U.S. military used a modified ***SM-3*** missile interceptor and a modified ***Aegis Weapon System*** aboard the *USS Lake Erie* to shoot down a defunct U.S. satellite that was re-entering the Earth's atmosphere. The military conducted the shoot down when the satellite was at a low altitude to ensure that the debris would burn up in the atmosphere instead of remaining in space as a hazard to other spacecraft. **MDA** is also developing the ***Space Tracking and Surveillance System*** (**STSS**) to enable worldwide acquisition and tracking of missile threats. The first two STSS satellites were scheduled to launch in 2009.

European Military Space

Until recently, European military space programs have been funded and operated primarily on a national level. In 2008, two key meetings resulted in the initiation of new programs for development of pan-European space systems with significant military applications. In October 2008, the **European Commission**, the ***European Space Agency*** (**ESA**) and the ***European Defence Agency*** (**EDA**) agreed to jointly develop critical space technologies in Europe for both civil and defense programs. The following month, ministers involved in space activities in ESA's 18 Member States and additional countries met to define the role of space in reaching Europe's global objectives. The security and defense initiatives discussed include a *Space Situational Awareness* network and a *European Data Relay System*. The plans could lead to development of military applications for the ***Galileo*** satellite navigation system and the ***Global Monitoring for Environment and Security*** systems.

Additionally, member governments are being asked to provide €400 million (US$564 million) for technology development that would reduce the dependence on U.S. space exports, which are controlled by the ***U.S. International Traffic in Arms Regulations*** (**ITAR**). Additional funding being sought would finance technologies for long-duration deep space missions. These efforts could have profound implications for European military space policy if they result in a shift towards pan-European military funding, development, and operations.

Evolving National Space Policies

The activities of spacefaring nations increased in 2008, and the policies of those and other countries continue to evolve. These policy changes often reflect the need to fund or authorize activities in response to steps taken by other national space programs, particularly when matters of national defense are involved. For example, it is likely that the increased space activity of China has been a factor in major space policy initiatives that have emerged in several neighboring countries such as Japan, Australia, and India.

On May 21, 2008, Japan's ***Basic Law of Outer Space*** was passed, for the first time allowing the country to use space assets for defensive military purposes. The bill modified the Japanese interpretation of using space "for peaceful purposes only." The new interpretation conforms with policies of other spacefaring nations and will allow Japan's government to develop military satellites for defensive purposes. In addition, the new law will place all space related projects into a unified program for better coordination.

The law encourages the government to spend more on space programs and thus increase Japanese competitiveness in the space industry. As this change could also allow Japan to export space-related military technology, Japan may use this flexibility to forge new international space defense ties. Japan may consider reducing joint defense system development efforts with the U.S. in order to develop its own systems.

Australia is considering the establishment of a specific space agency. The ***Australian Senate Standing Committee on Economics*** issued a report in November 2008 noting that Australia is the only member of the ***Organisation for Economic Co-operation and Development*** without a national space agency. The Senate committee called for the establishment of a ***Space Industry Advisory Council*** from industry, civil and defense agencies, and academia.

The focus of the council will be on development of more commercial programs such as Earth observation, satellite communications, and navigation. Longer-term priorities include defense as well as more civil and commercial programs addressing the environment, land management, disaster prevention and management, e-commerce, and telemedicine. With respect to international collaboration, the report recommends "that any Australian Space Agency reassess the case for Australia becoming more closely linked to an international space agency" in light of the benefits that often come from such linkages.

India acted in 2008 to develop integrated and cooperative programs both internally and with other countries. Internally, India has established an ***Integrated Space Cell*** jointly operated by the three armed forces and the ***Indian Space Research Organisation*** (**ISRO**) to protect India's satellites and enhance their capability for both military and civilian use.

On the international level, in addition to the collaboration on ***Chandrayaan-1***, India signed agreements in 2008 for space based disaster management with the ***Japan Aerospace Exploration Agency*** (**JAXA**) and for space exploration in cooperation with **NASA**.

All of these appear to support the development of the Indian space program across civil and defense fronts, and also to send strong signals to China that India intends to use space to promote government as well as commercial interests.

Other nations issued policy directives in 2008 outlining enhanced space programs, some military and others commercial. A French white paper on defense and national security, while noting that reliance on European cooperation will enable a range of budget cuts, stresses the importance of key space programs for intelligence gathering, and calls for the creation of a ***Joint Space Command***.

The United Kingdom also issued a space policy document focused on civil and commercial programs as the key to asserting a leading role for the U.K. in space. These actions indicate that governments are expanding space activities and encouraging commercial investment in programs for both government and commercial space ventures.

Thanks to the Space Foundation's Elliot Pulham and Janet Stevens as well as the editors and writers of the publication: Marty Hauser, Micah Walter-Range and Mariel John, with contributions from: Andrea Maléter, the Technical Director at Futron; Christopher Novak, Partner, Content First, LLC.; Charles Liu, Ph.D., of the City University of New York; Anita Antenucci, the Managing Director of Houlihan Lokey; and Kevin W. Leclaire, Managing Partner of ISDR Consulting, LLC. The Editor of the report is John M. Diamond and to **brandt ronat + co** ***for the superb design of the report.***

All have managed an exceptional job in presenting this annual. Believe me, there's so much more deep information and analysis within these pages that anyone involved in our various industries owe themselves a copy of The Space Report 2009. For further information, select the following graphic for the report's website. All images used in this article are located in the Space Foundation's book — Hartley G. Lesser, Editorial Director

From Transportable To Man-Portable: Baseband SATCOM

by Fred McClimans, DTECH LABS, Inc.

As long as our nation has existed, our military has been ready, willing and able to meet the various forces that have threatened our nation's interest, both here and abroad. And from the very beginning, information has played a critical role in our ability to meet these threats. From the first messages carried on horseback to today's global satellite and communications networks, the value, and need, for accurate and reliable communications has been clear. But far from its humble origins providing an often slow and one-way flow of information, the communications systems that we rely upon today have become both real-time and massive in nature, able to convey multiple forms of information between remote forward operating units and multiple levels of central command and control facilities.

As our communications infrastructure has grown in size and complexity, however, it has also become an often self-limiting system, becoming too big or complicated to handle the evolving mission roles that we ask our troops to undertake.

The Current Communications Package

When we look at the traditional "transportable" communications system that has been commonly deployed by mobile units, including larger forward operating bases, we are usually talking about systems that are designed to support 25 to 100+ warfighters, offering a complete suite of communications capabilities, including:

- ***LAN-based Data, VoIP and Video Services***
- ***Analog/FXS-based Secure Call Services (SCIP/STU/STE)***
- ***Embedded LMR (Land Mobile Radio) Gateways***
- ***VSAT-based IP Reachback***
- ***Full RED/BLACK separation***

To accommodate this set of services and functions, the typical transportable kit includes:

- ***BLACK-side Communications Rack: populated with a variety of rack-mount LAN hubs/switches, VoIP support systems, video support systems, traffic optimization/acceleration systems and network-side routers,***
- ***RED-side Communications Rack: populated like the BLACK-side racks and including Inline Network Encryption (INE) units,***
- ***Transportable VSAT equipment (anywhere from 2 to 6 cases), and***
- ***Accessory cases storing phones, radios, etc.***

In almost every deployment — and the current U.S. Military ***SNAP*** (**SIPR/NIPR Access Point**) VSAT offerings are a great example — each of the cases used for the various components are two-man transportable systems, often based on traditional "rack-mount" cases and equipment.

Existing Communications Package Issues

Over the past few years, we have seen a decrease in the size of deployed operational units to the point where traditional "transportable" **C4I** (***Command, Control, Computing, Communications and Intelligence***) systems are no longer practical. Communications systems that were designed to be transportable and support 100+ personnel are simply too large to meet many of the demands of today's rapid-deploy forces that often range from 5 to 20 personnel.

Existing Communications Package Shortcoming

- ***Too many "multi-man-lift" cases,***
- ***Overwhelming power requirements for "COTS in a box" racks of equipment,***
- ***Significant time of deployment/redeployment issues, and***
- ***Lack of flexibility in the configuration/reconfiguration of deployed systems.***

To address these issues, we need to rethink what it means to provide true network infrastructure to include the core "network" components as well as the inclusion of a new breed of forward-deployable systems that can adapt to the mission as well. Unfortunately, the missions themselves have become increasingly fluid.

While forward-deployed units have been a strong part of the Iraq effort, the mission parameters in Afghanistan will likely include a much stronger focus on smaller forward operating bases and highly mobile forward deployed units. Further, forward deployed units are now expected to be capable of seamlessly conducting missions that involve a mixture of urban, suburban and rural/remote locations. In fact, we have recently seen an increase in scenarios where vehicular-based missions now involve a much greater level of out-of-vehicle activities, either by design or in reaction to an encountered threat.

The net effect is that the traditional transportable communications system, one that required a vehicle for transportation and power, does not operate well in such a fluid operating environment — it lacks both the size and flexibility to adapt on the fly to changes in location, power availability, and "best-available" reach-back networks.

The Information Challenges

While the role of the forward deployed war-fighter has become more mobile and responsive, the level of communications required during this type of activity has increased. The same level of integrated communications that used to be required closer to central command and control has now been pushed out to the forward operating bases and is beginning to include individual forward deployed units. The result is a requirement for the simultaneous exchange of secure voice, data, imaging, telemetry, and video communications between mobile boots on the ground and their main base of operations as well as higher levels of central command and control. This is something that simply did not exist as an option ten years ago, but today has become an integral component of the war-fighter's arsenal.

Securing, powering, and connecting this level of communications in a highly mobile environment has its challenges — especially when you need to take into account true RED/BLACK separation requirements. The types of user devices that must be supported has expanded, including such items as laptops, PDA's, secure phones (**STU/STE/SCIP** as well as secure **V.150 VoIP** phones which will likely dominate the "voice" space within the next few years), fax machines, biometric systems, and video cameras.

Additionally, the requirement now is to properly secure the traffic (which, fortunately, has become almost exclusively IP-based). Of course, with the increase in the types and level of communications, there has been a corresponding increase in the requirement to selectively optimize/accelerate both specific types of traffic as well as specific application streams. This has been mainly in response to the physical size realities of high-speed satellite terminals. While such systems have become a bit smaller and lighter, the overall size has not decreased significantly, and achievements in bandwidth performance and utilization often come as a result of advanced electronics development and self-tracking .96 VSAT dishes.

Throughout this technology drive, the traditional limitations of mobile communications have continued to be present, including unreliable or unpredictable bandwidth, unreliable power, and fluid reach-back network availability.

Improving The "Transportable" Issue

There are certain constraints that are always going to dominate the information and communications infrastructure our military units must deploy. For example, there is a clear relationship between the size of a VSAT dish and how much data can be supported. Even the smallest of the new breed of mobile VSAT systems are still multi-case solutions. There are several key strategies that can be employed to increase the functionality of forward-deployed communications equipment and improve the mobility of our forces.

Size Reduction

Most importantly, we need to place an extremely high level of effort on the development of smaller "cases" required to make up a complete communications system. The advantages of replacing even one or two "multi-man-carry" cases with single-man-carry cases is significant.

This can come about through the implementation of newer **GOTS** (***Government Off The Shelf***) technologies that replace traditional COTS rack-and-stack systems with systems that integrate at the board level, not the component level — in essence, repackaging a rack-mount piece of hardware equipment into a hand-held sized version. This alone can result in a significant space/weight savings when applied to multiple components.

Power Reduction

By investing in the development of board-level integrated systems, we can also help significantly reduce the power requirements for the overall system. This is important in that many mobile missions operate in areas where reliable power is not always an option. Even operating using a vehicular power source, or portable generator, may not always be viable, or offer

enough power to support a trailer full of comms gear.

By developing communications systems from the "board up", rather than the "rack down", we can begin to think about the integration of embedded micro **UPS** (***uninterrupted power supply***) systems that can off-load at least part of the power requirement now supported by generators and massive rack-mounted UPS systems. Already we are seeing system appearing on the market that offer this type of embedded battery capability (some even offering hot-swappable batteries for extended operations).

Another side impact of compacting traditional rack systems into smaller GOTS systems involves thermal control. Cooling, for example, can be accomplished on the micro, and not the macro level. This is an important point, given that all signs point to a deployment strategy over the next few years where temperature extremes (both hot and cold) will stress any deployed equipment.

Improved Modularity

One of the shortcomings of a traditional rack-mounted communications system is the inability to quick configure, or reconfigure, a system to adapt to a change in mission operations. Rack-mount systems, by their very nature, are difficult to "hot-swap" components. However, if we take advantage of the development of smaller GOTS versions of traditional rackable components, we can start to think of these smaller components as being "modules" as part of a fully functioning system. If the modules are deployed in a "mobile chassis", we can easily deploy communications systems that allow for the quick removal/insertion of specific modules that provide the support for the mission at hand. For example, the benefits of being able to rapidly select and install user interface modules in a RED-side system (perhaps to accommodate an increased requirement for VoIP phones in place of FXS-based STU/STE/SCIP devices) could be invaluable.

Improved modularity can also be used to meet the changing requirements of network reachback. Given the varied deployment scenarios our troops now face, there is no standard "network" that can be considered available anywhere, anytime. The best available reachback network — especially for first-in or extreme forward-deployed units — may be a low bandwidth BGAN or even IP over ISDN GAN (or 3G cellular) network. Being able to select on the fly the appropriate "network module", along with the appropriate form of IP acceleration, greatly expands the flexibility of a mobile communications system.

The Emerging Tactical Package

The goal moving forward is to design a man-portable communications system that is capable of replacing the traditional multi-case, physically independent, RED/BLACK units presently deployed. An ideal package would include the following:

- ***Independent BLACK and RED-side communications modules (required for RED/BLACK separation) with sufficient user interfaces to support a mixture of PC, PDA, Secure Phones, etc.,***
- ***Multiple embedded reach-back technologies, allowing IP over anything (VSAT, BGAN, GAN and Cellular),***
- ***Sufficient IP or voice/VoIP optimization and acceleration technologies to improve the performance of critical applications over either high-latency satellite links or low-bandwidth cellular or BGAN/GAN links,***
- ***Embedded battery power sufficient to operate both the RED and BLACK modules, an INE unit and the reach-back interfaces, and***
- ***A packaged size that not only meets a single-man carry requirement but is also capable of being classified as airline carry-on (accepting that a satellite terminal will be a second component)***

The challenge in deploying such a unit is to ensure the unit can truly provide the same level of support as the traditional transportable unit (including features such as simultaneous multi-vector reach-back and embedded IP optimization/acceleration systems) in a package that is both small and sufficiently lightweight to be considered a real man-portable system under the harshest of circumstances.

Developing The Solution

There have been many attempts at creating smaller, lighter communications packages. Many, however, have sacrificed one or more key features in order to reach weight or size limitations. Others, in contrast, have been successful in achieving a "single RED/BLACK case" but have ignored weight or power considerations.

This does not mean such a system is not possible to implement. To the contrary, advances in the physical integration of traditionally stand-alone components into smaller, modular packages have allowed traditional rack-mounted systems to be replaced by lightweight, low-power alternatives that are now commercially available in the market. Featuring advances in power management technology and flexibility through increased use of modular component designs, these emerging systems offer the best promise for advancing the deployment of full-feature communications systems at the man-portable level systems that can offer the complete spectrum of data, imaging, fax, video and voice support that our forward deployed troops require to complete today's evolving mission requirement.

About the author

Fred J. McClimans is the Chief Information Officer for DTECH LABS.

COMMAND CENTER
COLONEL ROGER W. TEAGUE, SMC

Colonel Roger W. Teague is commander, Space Based Infrared Systems Wing, Space and Missile Systems Center, Los Angeles, California. He leads a government program team of more than 550 personnel and 2,300 contractor personnel to develop and deploy the nation's space-based infrared detection, targeting, and tracking systems for missile warning, missile defense, battlespace characterization, and technical intelligence. His $41 billion space systems portfolio includes the Defense Support Program and the next generation Space Based Infrared System (SBIRS). These systems are critical for protection against global and theater ballistic missile attacks against the United States, its deployed forces, and its allies.

Colonel Teague entered the Air Force in 1986 upon graduation from the U.S. Air Force Academy. His career includes a broad range of assignments primarily acquiring, supporting, and operating space control, missile warning, and communications systems. He has commanded at the squadron and group levels and is a fully-qualified joint specialty officer. Colonel Teague was formerly military assistant to the acting secretary of the Air Force. He commanded the 4th Space Operations Squadron, Schriever AFB, Colorado where he led his unit during launch, test and activation of three Milstar communications satellites. Colonel Teague also commanded the Space Based Infrared Systems Space Group, leading launch and operational testing of the final $400M Defense Support Program satellite. He led the developmental test and on-orbit checkout team for the first SBIRS highly elliptical orbiting sensor, capturing the Air Force's nomination for the 2007 Robert J. Collier Trophy as the greatest achievement in aeronautics or astronautics in America.

MilsatMagazine
Colonel, would you please tell MilsatMagazine readers about your background? How did you decide on an Air Force Career?

Colonel Teague
I am originally from Flagstaff, AZ and was a recruited high school football player. I selected the Air Force Academy as I then had the opportunity to obtain a great education and play on some outstanding teams. I decided to make the Air Force a career during my first assignment to Space and Missile Systems Center from 1991-1995. Over my 23-year career, I've worked in several space operations and acquisition related assignments and am thankful for the exciting journey I've experienced and the opportunity to contribute along the way.

MilsatMagazine
Colonel, what prompted your desire to become involved in satellite/space systems environs? Are you glad you took that path?

Colonel Teague
As many young boys, I grew up with a fascination for space. I remember watching Neil Armstrong's first steps on the moon and I used to build and launch model rockets as a Boy Scout. Early in my career, I was thrilled to be assigned to the Space and Missile Systems Center and the Defense Support Program (DSP) Office. DSP Flight-16 was launched aboard the shuttle Atlantis just after I arrived and it was a very exciting time. As a young Captain, I was given an opportunity to lead an important DSP ground processing upgrade program. It proved to be a springboard for my continued pursuits in the space business.

I am truly grateful for every assignment — the wonderful friends and coworkers I've known, the opportunity to mold and shape rising young leaders, the partnership I've experienced with our space industrial team, and strong support from great bosses who've inspired me at every step.

MilsatMagazine
To become the commander of the Space Based Infrared Systems Wing — that's a most important role for our country. How were you selected for this important position? What other commands have you held that have helped you in your current role? What command has been, or are, the most rewarding?

Colonel Teague
I am privileged to command this extraordinary Wing. As I mentioned, I've previously served in our heritage DSP Program Office and personally know all of the previous SBIRS leaders and several of the DSP directors. I am humbled to follow in their footsteps.

As is the case with other Air Force wing commanders, I was competitively selected by a board for this position based on my record, past assignments, and other related experience. I've previously commanded twice at the 4th Space Operations Squadron (4 SOPS), and as Commander of the Space Based Infrared Systems Space Group. While my group command experience helped me to grasp the broader SBIRS program issues more quickly, my time as 4 SOPS commander was invaluable. It reinforced the importance and wide-variety of the day-to-day challenges our operational mission partners face and showed me how I can better help support our combatant commanders today. Both command assignments were very rewarding, not only from a mission standpoint, but most-importantly, from a people standpoint. Our nation is well-served in both the protected communications and missile warning mission areas by teams of patriotic professionals who are dedicated to excellence in all they do.

MilsatMagazine
Why is your Wing so important our Country? What are the various responsibilities for your personnel? How many separate divisions are within your Wing? How does your work improve the efforts of our warfighters?

Colonel Teague
The Space Based Infrared Systems Wing is the U.S. Air Force's activity responsible for developing, acquiring, fielding and sustaining infrared space systems in support of combatant commanders and other users. We are the only organization in the country that develops space systems that provide early warning to our Nation and fielded forces in the event of a ballistic missile attack. We manage a portfolio of $41 billion in developmental and operational assets. Personnel perform their daily jobs at 5 different locations in California and Colorado. Our systems contribute to four distinct mission areas: missile warning, missile defense, technical intelligence, and battlespace awareness.

The Wing is organized principally in support of two materiel product groups for space and ground system acquisition. There are five different staff organizations that provide program management, contracting, financial management, engineering, sustainment, and security functional expertise in support of our programs. We have a detachment located in Boulder, Colorado, responsible for test and evaluation support of fielded products and an operating location in Sunnyvale, California, that resides in-plant with our contractor teammates to support satellite development activities.

The Defense Support Program (DSP) replaced the space-based infrared Missile Defense Alarm System (MiDAS) in 1970. The first DSP launch occurred 6 November 1970, the system has provided global missile warning coverage for 39 years. The satellites have continued to evolve over their long history by increased power output, increased infrared sensitivity, and subsystem improvements. This has increased their design life from 3 to 5 years with many satellites living past 15 years of operations.

DSP-23 satellite (courtesy U.S.A.F.)

During DESERT STORM the DSP early-warning satellite imagery quickly located fixed sites of SCUD attacks. The detected information provided an asset to the warfighter, beyond what they had received in the past. DSP continues to provide accurate and reliable missile threat detection for the strategic and theater allies.

The final DSP satellite known as DSP-23 launched on 10 November 2007. The constellation will continue to be the backbone of the U.S. missile warning detection until the Space Based Infrared System (SBIRS) augments and eventually replaces the system.

Currently, SBIRS has two Highly Elliptical Orbit (HEO) payloads on orbit. "eye watering views provided by these sensors provided capability well beyond DSP performance.

The SBIRS system performs all its mission requirements, sees targets earlier, longer, and more frequently than other sensors. Its flexible tasking ability provides new ways of collecting mission data, thus enhancing current missions and spawning new missions.

MilsatMagazine

Two of the programs for which you are responsible include the Defense Support Program and SBIRS. Would you please describe each program and their importance to our national security? Were you involved in the Milstar program? How will Milstar be used as new Systems come on line?

Colonel Teague

SBIRS and DSP have as a primary mission to provide timely, reliable, and accurate missile warning information to combatant commanders and other users. SBIRS and DSP have both global and theater functional requirements to support strategic and theater ballistic missile warning, and as an emerging

Milstar satellite (image courtesy USAF)

SBIRS satellite (image courtesy Lockheed Martin)

capability, to support national and theater missile defense. SBIRS and DSP accomplish these missions by providing sustained global infrared surveillance of the earth, detecting and tracking a variety of missile classes to include Surface to Range Ballistic Missiles (SRBM), Infrared Ballistic Missiles (IRBM), Intermediate Ballistic Missiles (ICBM), Space Launch Ballistic Missiles (SLBM), and SLVs. In general, detection occurs early in the missile's boost phase and the missile is tracked throughout powered flight.

During my command at the 4th Space Operations Squadron, we oversaw launch and activation of Milstar Flights 4, 5 and 6, formed the first protected communications "ring" around the earth using the Milstar crosslink antennas, and stood up the 148 SOPS at Vandenberg AFB, California, to provide a more robust command and control capability. At the time, there was significant pressure on Milstar Flight 4 launch success and eager anticipation of the new capabilities the medium data rate system would provide. In some aspects, we are experiencing a similar period as we bring SBIRS online.

We're ushering in the SBIRS-era with the two new sensors now on-orbit for polar warning and we're on-track for our first SBIRS geosynchronous satellite launch next year. While the Milstar and SBIRS systems support different mission areas, both are essential to combatant commanders and provide "game changing" capabilities. Over the past 10 years or so, we've learned how to best maximize the inherent capabilities within the Milstar system. We will be doing the same with SBIRS as we continue to field this impressive new system.

MilsatMagazine
You must work with a variety of military and government organizations that govern product acquisition. It seems, sometimes, the pathway from RFP reply to contract award takes forever. How can private firms better interface with these environs to supply needed product more quickly?

Colonel Teague
While there can sometimes be a lengthy path from Request for Proposal (RFP) to contract award, it is important to note that we follow the Federal Acquisition Regulations to the best of our ability. To support a better government-industry interface, it is very important that government and industry establish and maintain clear communications regarding expected contract award and process steps along the way. It is also important that contractors become involved at the beginning for the draft RFP process. One of the main delays in letting an RFP is the fact the request for proposal sometimes has to be amended multiple times due to lack of contractor's involvement in helping to clearly define the proposal requirements at the beginning of the process.

MilsatMagazine
How many service and civilian personnel are required to perform the activities? And, how are you handling the budgetary necessities given the federal cutbacks on programs?

Colonel Teague
Our Wing currently has a total of 454 personnel working at five different sites in support of our mission. There are 102 military, 94 civilian and 258 contractors. Lockheed Martin has 1,800 persons supporting the SBIRS Engineering Manufacturing and Development (EMD) program of which 500 workers are Northrop Grumman employees, the remaining 1,300 are Lockheed Martin employees. For the SBIRS Follow-on Production Program, Lockheed Martin currently employs about 600 folks, of which 200 are Northrop Grumman personnel. Finally, Northrop Grumman also employs 100 persons performing sustainment support for the Defense Support Program. Addressing the budgetary necessities given cutbacks, we work in accordance with our approved program budget authorization and adjust workload and schedule consistent with the funding received.

MilsatMagazine
What do you believe are the most important considerations for Space Systems' programs through the USAF in the near future? How do you see such being implemented?

Colonel Teague
I view three areas as most important.

#1. Adequate, consistent funding. In today's budget environment, adequate funding may be hard to come by for many programs. Defense acquisition programs need predictable budgets. I know President Obama's administration is looking at these issues very carefully and will provide the policy and programming guidance needed for our defense (and space) capabilities.

#2. Stable requirements. The national security space community must resist adding new requirements to on-going acquisition programs. Air Force Space Command Commander, General Bob Kehler has noted several times that we have too many competing requirements and too many capabilities that lead to increased complexity. We need to simplify our requirements and define them clearly.

#3. Protection for our systems. Recent events clearly demonstrate that we need to pay more attention to systems protection (space and ground site). Going forward, we may need to mandate that programs fence funds for system protection. The cost of a catastrophic loss of on-orbit capability is too high — we must act now.

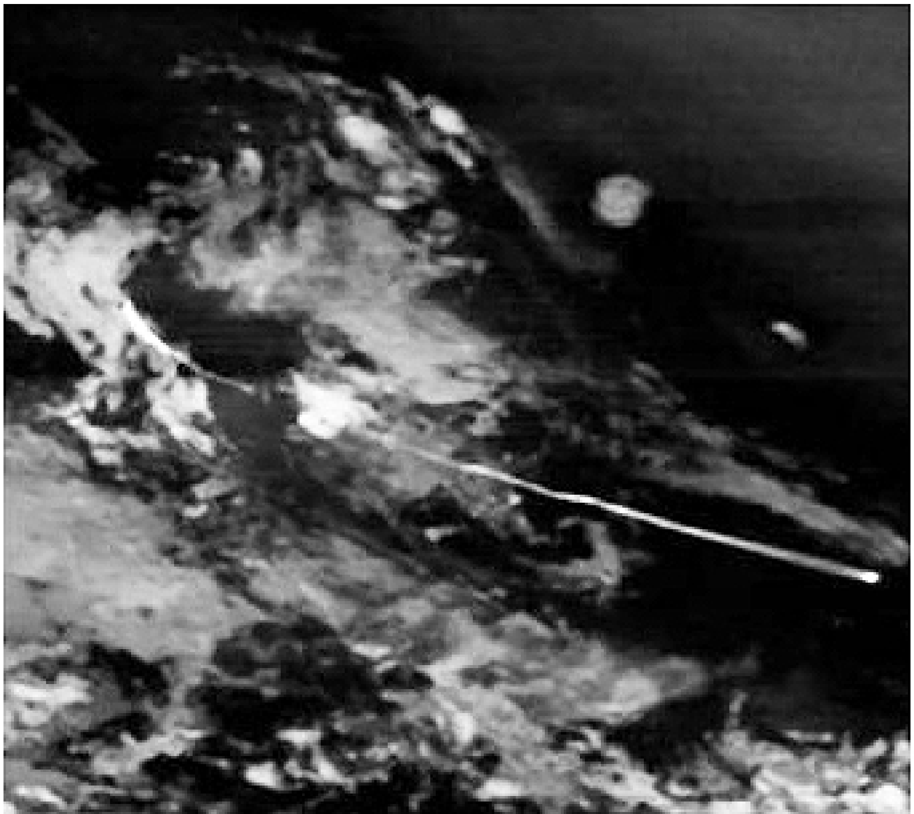
MilsatMagazine
What are the most crucial challenges facing our nation, and the Air Force, over the next few years in regards to MILSATCOM and space systems?

Colonel Teague
Over the next few years, I believe the Air Force will face multiple space-related challenges.

First, we must find a way to sustain excellence in space-related science, engineering, acquisition and operational disciplines. We should continue to improve the way we utilize our currents assets and successfully accomplish our jobs without burning out our workforce. Several career fields and organizations have an extremely high operations tempo and we need to find ways to ease the stress on our forces.

We should continue to seek improvements in space system development and acquisition. The primary goal of space system development and procurement must be mission success. There must be an understanding of realistic and stable requirements, setting and maintaining realistic and stable funding and providing acquisition program managers with the tools, responsibility, budget flexibility and authority to achieve this goal. Given the long timelines typically associated with space acquisition, it is important to strike a balance between requirements creep and extended system fielding timelines.

Finally, we need to continue to find ways to ensure we'll have a healthy space industrial base for the future. During a previous assignment at the National Security Space Office in the Pentagon, I was fortunate



Infrared satellite imagery from the Space Based Infrared Systems Highly Elliptical Orbit-2 sensor depicts a missile launch through the clouds. (U.S. Air Force photo)

to work on many issues associated with the critical need to maintain a robust U.S. science, technology and space industrial base. We're making progress towards this objective. Longer term, we have a serious growing concern with the Nation's math and science workforce. Fewer students have been entering these fields of study, and as baby boomers retire, we need to replace them with new talent. It is important to cultivate the next generation of space professionals.

Regarding MILSATCOM, I am very happy to see the Advanced EHF and Wideband Global System programs making steady progress. These systems provide essential communication capabilities for our joint forces worldwide, and along with commercial systems, are critical to our success in Iraq and Afghanistan. It is important that both programs continue to receive strong support as they are fielded.

I am thankful for the exciting journey I've experienced along the way and the many opportunities I have had to contribute to our missions There is a very exciting time ahead for us in the missile warning business as our first SBIRS geosynchronous satellite continues integration in preparation for launch. We're also working hard to exploit the outstanding new capabilities provided by our two new HEO sensors. We are poised to fulfill our commitments to the Nation.

MilsatMagazine

Thank you for your valuable time, Colonel. And for our readers, just recently, the U.S. Air Force Space and Missile Systems Center awarded United Launch Alliance a contract modification to perform the launch services for the Space Based Infrared Systems (SBIRS) GEO-2 satellite aboard an Atlas V Evolved Expendable Launch Vehicle. The anticipated launch period is between December of 2010 to March of 2011 from Space Launch Complex 41 at Cape Canaveral Air Force Station, Florida.

The SBIRS GEO-2 space vehicle will provide missile warning quick reaction messages to National Command Authorities and missile defense data to destroy missiles and launchers. SBIRS will also provide wideband data to technical intelligence analysts and battle space characterization of the battlefield to the warfighter. Lockheed Martin Space Systems Company, Sunnyvale, California, is the SBIRS prime contractor. Northrop Grumman Electronic Systems, Azusa, California, is the payload subcontractor. Both companies are developing SBIRS. United Launch Alliance program management, engineering, test and mission support functions are headquartered in Denver, Colorado and are supported by transition employees in Huntington Beach, California. Launch operations are located at Cape Canaveral Air Force Station, Florida, and at Vandenberg Air Force Base, California.

WAVESTREAM: SOLVING COMM-ON-THE-MOVE CHALLENGES

by Gary Echo, Wavestream

Whether land-mobile, maritime or airborne, military or commercial, the need to communicate on moving platforms at increasing data rates is becoming more and more critical. These "disadvantaged" platforms present difficult challenges to be solved. Platforms incorporating Wavestream amplifiers have dramatically improved the solutions being deployed.

The Army's vision of a rapidly advancing military force capable of remaining in constant communication with commanders and other services became a key driver for satellite terminal development. **Wavestream** amplifiers have been at the heart of many deployed on-the-move terminals. These systems are operating in some of the most demanding conditions of very high temperatures and the continual shock and vibration of wheeled and tracked vehicles.

Systems deployed on maritime and airborne platforms present similar challenges. Satellite communications on ships and aircraft is not a new concept. But there is an evolving need for much higher data rates and lower profile solutions. Wavestream amplifiers are allowing sub-meter terminals to transmit at T1 (1.544 Mbps) and above while at sea or in flight.

News gathering, disaster recovery, and homeland security are applications that are benefitting from having *communications on-the-move* (**COTM**), allowing personnel to be much more effective and safe.

The Challenges

System engineers tasked with developing satcom systems for COTM applications have many challenges to overcome. These are impacted greatly by the amplifier and its performance. The challenges boil down to five key categories: thermal, mass, vibration, power source, and reliability. All of these categories are inter-related; and gains in one area can lead to gains in other areas with a cascade effect.

Thermal

COTM terminals have one thing in common: the antenna system is in a sealed enclosure. As a result, heat exchange to ambient air is not direct. Unless thermal loading is controlled, a runaway condition can occur. The most significant heat source in the system is the power amplifier, and its efficiency directly drives the required thermal solution.
Today's systems are moving to smaller and smaller antennas to reduce terminal height. This change has doubled or quadrupled the RF output power required to keep data rates constant. But demand for data rates has increased in most cases by a factor of four or more. Combined, these two changes have increased the required RF power by a factor of 8 to 16 times.

Wavestream has responded to this challenge with high-efficiency amplifiers in small packages. Efficiency gains typically remove one-half the heat dissipation of other amplifiers. Additionally, in most terminal designs, Wavestream amplifiers are able to be mounted directly on the feed of the antenna, minimizing (or eliminating) the loss between the amplifier and the feed found in prior systems. Mounting on the feed also eliminates costly (and lossy) RF rotary joints capable of handling high power and replaces them with low-power Intermediate Frequency (IF) designs.

Improving the system equation is the superior linearity of Wavestream amplifiers. Spectral regrowth and intermodulation performance define the operating point of the amplifier. Wavestream amplifiers deliver 1 or 2 dB better linear performance to comparable ***Solid-State Power Amplifiers*** (**SSPAs**) and up to 4 or 5 dB better linear performance over ***Traveling Wave Tube Amplifiers*** (**TWTAs**).

Mass

COTM applications require gimbaled, high-speed tracking antennas. Analysis of instrumented vehicle dynamics shows that tracking rates of up to 200 degrees per second, and tracking accelerations of 400-600 degrees per second are required to maintain communications performance while in motion. These requirements place a premium on reducing moving mass in the antenna's gimbaled assemblies.

Further, in many designs, mass that is placed on final antenna axis must be offset to maintain balance.

Mass savings in the amplifier often leads to mass savings in counterweight.

Overall, mass savings lead to simplified antenna designs with minimized motor requirements; which lowers thermal load, improves cost, and provides better tracking performance.

Vibration

Land-mobile, maritime, and airborne applications impose varied and difficult shock and vibration requirements on the amplifier. Many commercially available amplifiers will not stand up to the harsh environment presented by these platforms. Wavestream's amplifier architectures are inherently robust — spatial power combining yields compact amplifiers that are less susceptible to shock and vibration. Wavestream designed amplifiers use only high military/industrial-grade components and processes. No matter if the application is military or commercial, Wavestream applies the same design heritage to its amplifiers.

Power Source

Often overlooked is the power supply. It can be the Achilles' heel of any system and often is the cause of system failures. Wavestream has recognized this challenge and applied design methodologies used by space programs where power supplies must be efficient and completely trouble-free (once you launch you don't see it again). Wavestream power supplies typically have 90 percent or better efficiency and are designed with the highest grade capacitors and other components to meet high *Mean Time Between Failures* (**MTBF**) in the challenging, high-temperature environment of COTM platforms.

Reliability

A significant challenge in COTM applications is repair and replacement. COTM systems, as the name suggests, are not fixed. Systems deployed with the warfighter, or used covering a news story, can be miles (of land or ocean) away from a depot or major city. Furthermore, the radome and mounting position of these systems present additional complications. The bottom line is the system MTBF must be high as the cost to diagnose and repair a failed unit is costly in time and in money.

As mentioned earlier, all the factors in the system design are inter-related. Improvements in each category lead to an overall improvement in reliability. Similarly, deficiencies in one category can undermine the overall reliability of the system.

A driving factor to MTBF is temperature. A decrease of 10 degrees in the operating temperature inside the radome can yield a 10-fold increase in the MTBF of a component, perhaps taking a component from 100,000 hours to 1,000,000 hours MTBF. The key heat source is the amplifier. The mass, efficiency and linearity improvements Wavestream provides work together to decrease the thermal load by up to a factor of four. This is huge — it can be the difference between a design with thermal runaway and a high MTBF design that meets the objective requirements.

The Solution

While several approaches for building high-power transmit amplifiers exist, many do not meet the particularly demanding needs for COTM applications. Conventional amplifier approaches use binary combining of several solid-state MMICs to build low-power modules and then binary combining of these modules into high-power amplifiers. The size and mass of these amplifiers preclude mounting them on the moving portion of the tracking antenna. The inefficiencies in this method of combining result in power dissipations that cannot be handled inside the radome.

Spatial Power Combining

Wavestream uses a different technique for combining the transistor outputs. Spatial power combining is the means for advancing solid-state solutions to the next level and the basis for the ***Powerstream***™ amplifiers. Rather than combining in multiple steps, increasing loss and size with each combining stage, all transistor outputs are combined in a single step. Many amplifying elements synchronously amplify the input signal, and outputs are combined in free space for very high efficiency.

Wavestream's patented ***Grid Amplifier***™ chip couples the output from a grid of hundreds of transistors in free space with very low combining loss. *Figure 1* shows a Grid chip and the individual unit cells. The

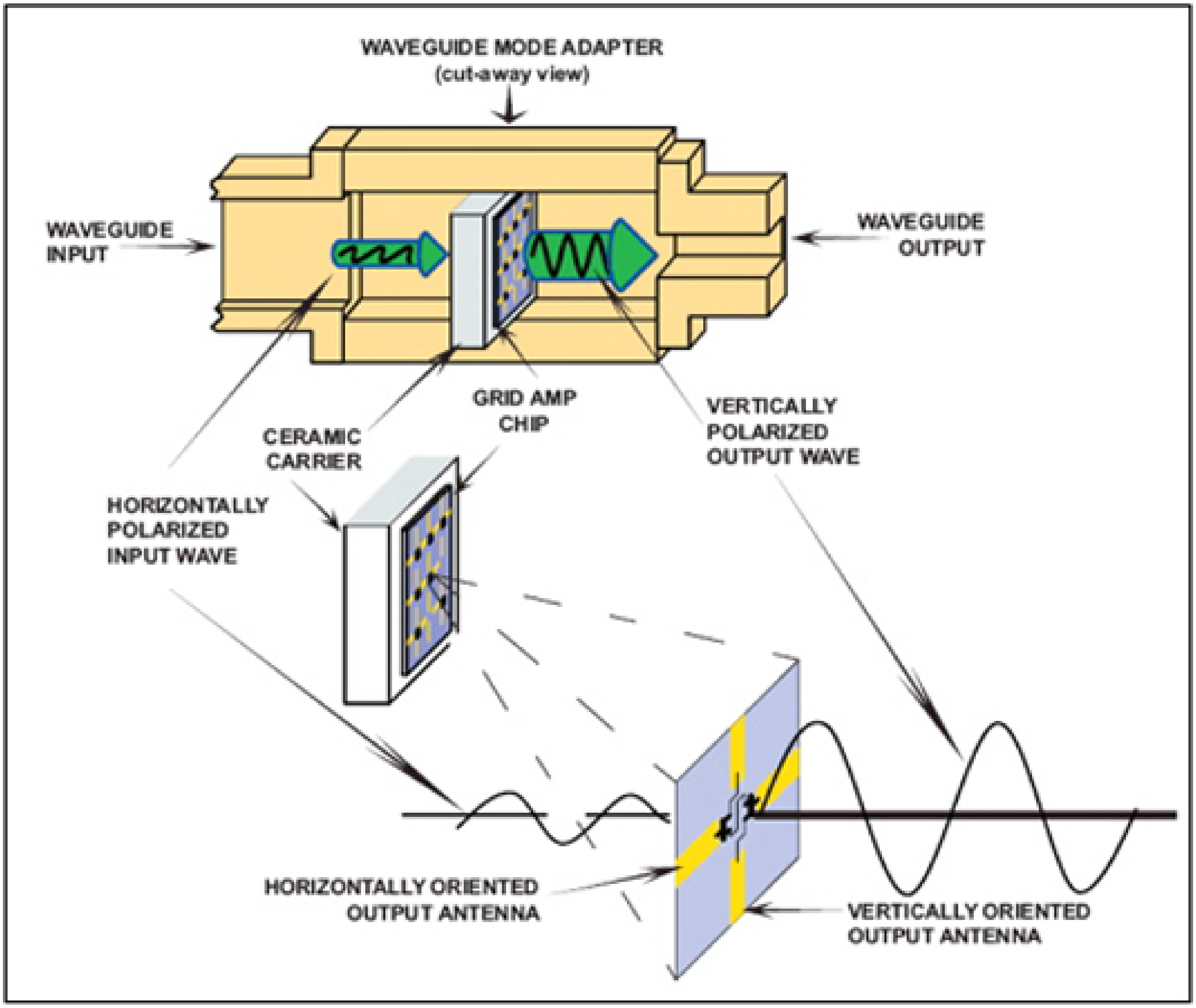


Figure 1
Grid Amplifier combines the outputs of many transistors in free space.

resulting *power-added efficiency* (**PAE**) is a 2-4x improvement over traditional amplifier designs.

Simple Design

Each of the amplifier components is manufactured using standard techniques and these are assembled in a straight-forward manner. The signal passes directly through the chip, never touching a bond wire or other tunable element. No post-assembly tuning is necessary. The amplifiers can be manufactured in very high volume.

Heat from the amplifier chip is removed radially in a nearly optimal configuration significantly reducing junction temperatures and therefore leading to higher MTBFs. *Figure 2* on the next page shows the assemblies of a two-stage Grid amplifier.

The Total Package

The result is an amplifier that is compact and much lighter than the traditional amplifier. Figure 3 is a picture of a 12W Ka-band amplifier, which measures a mere 2.25"L x 2.0"W x 1.25"H and weighs approximately 16 ounces. With power supply and integral

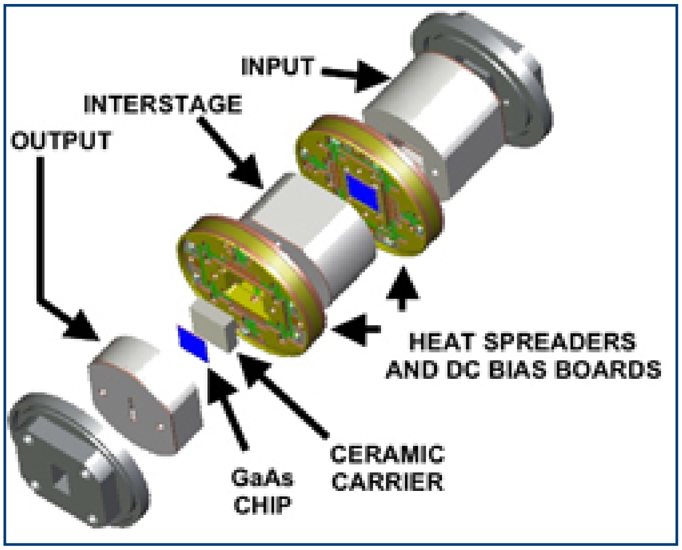


Figure 2
Components in the Grid amplifier assembly

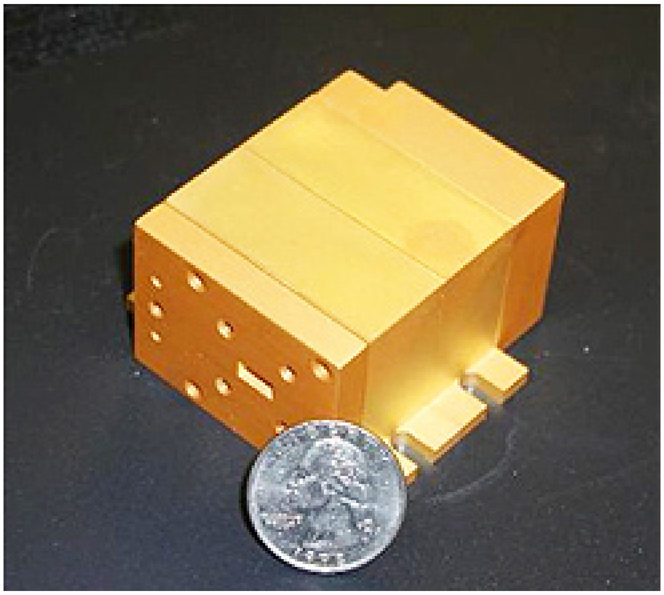


Figure 3
Wavestream amplifier providing 12W at Ka-band

driver, the power draw is only 125 watts.

The results at Ku-band are similarly impressive. *Figure 4* is a picture of a 40W Ku-band amplifier, which measures 3.75"L x 2.5"W x 1.5"H and weighs 1.5 lbs. With power supply and integral driver, the power draw is only 275 watts.

These core amplifier modules are used directly in many COTM terminals with smaller apertures. On larger platforms, packages integrating the SSPA and Block Upconverter (BUC) with thermal management are used. Wavestream offers a wide range of frequency bands and output power levels.

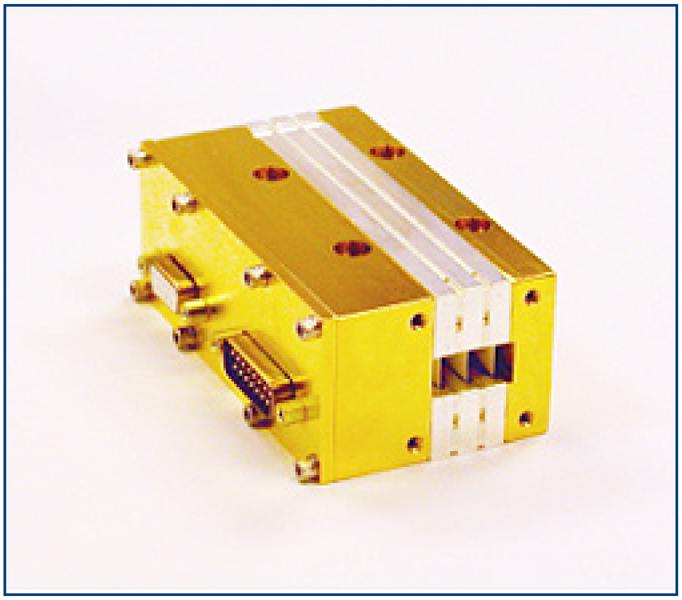


Figure 4
Wavestream amplifier providing 40W at Ku-band

Mission Effectiveness Enhanced

The new generation of COTM terminals enabled by Wavestream amplifiers is greatly enhancing mission effectiveness for land-mobile, maritime and airborne users. The challenges have been met. High data rates and high reliability are being deployed in the most demanding environments.

About the author

Gary Echo, Vice President Business Development at Wavestream, has spent his career in satellite communications. At Tachyon, Inc., a pioneer in IP-based satellite networking, Gary was Director of Product Marketing and General Manager of Mexico operations. He also served as Director of Business Development for Titan Wireless, a leading provider of satellite-based rural telephony. Gary was an early employee at ViaSat, Inc., where he filled various roles building leading-edge, military and commercial satellite communication systems. Gary started his career at Linkabit, where he worked on advanced modulation and coding algorithms. He earned his bachelor's and master's degrees in electrical engineering from Rice University.

PRIORITY BRIEFING
ZACHARY LEMNIOS, CTO, LINCOLN LABORATORY

Zachary Lemnios is responsible for coordinating Lincoln Laboratory's technology strategy. He spoke recently with Lincoln Laboratory Journal Editor in Chief *Herb Brody* about the Laboratory's strengths and challenges.

Lincoln Laboratory Journal (LLJ)
How have the changes in the nature of the threats to U.S. security affected what Lincoln Laboratory does?

Zachary Lemnios
As the 9/11 attacks showed, a new set of asymmetric threats has emerged — threats that aren't well characterized and that are not necessarily driven by nation states so it's hard to assign where they've come from. The U.S. doesn't have the tools or the experience and understanding of how to work through that.

LLJ
What are the ramifications of that shift for technology development?

Zachary Lemnios
The first issue is thinking through how an adversary uses commercially available technology. After all, we are a country that publishes freely and puts an awful lot up on the Web for anyone to read. We see that today in IEDs [improvised explosive devices]. The triggering mechanisms are exploitations of what's available commercially. We need to be thinking through how an adversary exploits open source understanding of technology and adapts it to their means.

LLJ
Broadly speaking, what does Lincoln Laboratory contribute to this effort?

Zachary Lemnios
The Laboratory has a keen role here — probably a unique role — in understanding how an adversary adapts and works in an environment that is entirely open, where the barriers to entry are very low, where the consequence is very high, and where the fingerprints are hidden. How do we understand that environment technically? How might we build countermeasures—tools to identify these threats or to mitigate their effects? The Lab does that very well because we are one of the few places where field testing, state-of-the-art development, prototyping, and an understanding of the application space and threat space come together.

LLJ
What's the most important area of technology that you think the Lab ought to become more deeply involved in?

Zachary Lemnios
One thing that worries me a lot is this: how do we understand the enormous amounts of data that the Department of Defense now collects on emerging and operating threats? How do we find salient features, such as targets and signatures that aren't well characterized? The second is how do we make this information more clearly accessible to the end user.

LLJ
So this would be kind of data mining?

Zachary Lemnios
Yes. And, in particular, social network analysis, which means not just looking for a single target but looking for networks of targets—people, places, or things that have some relationship. Rather than finding the single IED, for example, you want to look for the network of the bomb maker, the emplacement team, the trigger team, and the team that broadcasts the attack. This is a particularly urgent problem as our young men and women in service are under attack this very moment.

LLJ
How might you go about doing that?

Lincoln Labs Microelectronics Laboratory

Zachary Lemnios

There are many signatures — communications is one, imagery is another — and there may be cultural cues. Our understanding of the Soviet Union was based upon a published set of operations and a published set of capabilities. They published it, we verified it, and we trained against it. We had a very-well-understood schema of how the Soviets would employ forces, what their strategic approach would be, what their tactical engagements might look like. This is a different world. The real challenge now is finding the indications and warnings and signatures of events when you don't have a lot of history on what that person or what that group might do. One of the challenges is trying to understand from this enormous data collection these very diverse set of sensors, how we cohere a picture of what's going on strategically and tactically. The Laboratory is developing the fundamentals in that space.

LLJ

You also mentioned user interfaces. Why is that so important?

Zachary Lemnios

We need to do a better job at presenting information so that the end user understands things in a natural way. A person looking at a photograph can pick out the salient features. We need computer systems that do that with sensor data. The human-machine interface hasn't yet scaled to the level of complexity of the systems that we're building. We need to be able to convey the information so that the user really understands it.

LLJ

It seems you have defined two separate but interrelated problems: one, how to abstract out salient features from huge amounts of data; and two, how to then convey this higher level of abstraction to the end user. What are the specific approaches that Lincoln Laboratory is pursuing?

Zachary Lemnios

The first question is, how do you build algorithms to look for salient features? This is all about building networked sensors, building a schema for storing data, data retrieval, putting in place Bayesian filters or hidden Markov model filters. There's a body of science that's helping us understand how to do that. The second piece is, once you've done that, how do you convey lots of information in a way that doesn't overload the user? While there are a few examples of good human-machine interface, the fundamentals are not well understood.

LLJ

What specific capabilities would you like to see developed?

Zachary Lemnios

Well, right now users have to learn about their computers. I'd like to see it the other way around: computers should learn about their users and adapt themselves accordingly. Why is it that when I sit down at my keyboard, I have to type the same things over and over again—login, password, pulling up

Lincoln Space Surveillance Complex

certain screens? I do that every day. Why doesn't my system just do that for me? It knows that when I come in, the first thing I do is check e-mail, and I look at a particular website. The operating system should build a model of a user and tailor its interaction to the user. We do this socially all the time. When you have friends over for dinner and they are interested in a topic—gardening, say, or fine wine—you'll end up having a discussion about that.

LLJ
Advanced information technology can also be used against us, though, right?

Zachary Lemnios
Yes. In fact, the Laboratory has been working for many years to understand the cyber threat. A team of four can do enormous damage. An individual can basically shut down a city. It's a problem set that the Lab has resources to address, and we're starting to do so.

LLJ
On this, and other national security issues, what do you think sets Lincoln Laboratory apart from the many other institutions focusing on similar work?

Zachary Lemnios
Well, we have very bright people, of course. But there are bright people everywhere. More uniquely, Lincoln Laboratory has access to the right data sets—that's the heritage of Lincoln Lab. A lot of other organizations are trying to solve these problems in the abstract. But here, we have access to user data and an understanding of threats that have been identified. We have access to not only the worm or virus itself but also to information as to how it was inserted into the system.

LLJ
How would you characterize the Laboratory's place in the defense technology ecosystem?

Zachary Lemnios
We have a dual role. On the one hand, we are a gold standard for data and analysis; that is, we provide the independent assessment of ideas and technologies developed by others. In other cases, we are a pioneer of new concepts. The Laboratory takes on projects that have enormous technology risk, far more than the private sector would take on.

LLJ
You are on R&D management side of things and spent several years at the Defense Advanced Research Projects Agency [DARPA], which funds a lot of cutting-edge technology development. If you could have all the scientists and engineers at the Laboratory understand something better than they do now, conceptually, what would it be?

Zachary Lemnios
I'd like to see a more consistent ability to think beyond technology into the application space and into the countermeasures space. The Laboratory does that

Experimental Test Site at White Sands Missile Range

RF System Test Facility

really well. That's because we live in field sites, we collect data, we do the data analysis, and we own the data sets. We have many people here doing analysis not just on the data that we collect, but also on systems that the U.S. operates and on systems that will counter our systems. So we're really thinking all the time about countermeasures.

LLJ
So what tends to guide the Laboratory's activities more—"technology push" or "applications pull"?

Zachary Lemnios
There's both. Part of our job in this office is to balance the two—that is, to find the right connections between innovative technology and compelling applications. In some cases, a systems engineer will pose an application that absolutely demands a technology and we connect those up. But it's that intersection that is so rich. And there are a lot of people at the Lab who live in that intersection.

LLJ
What Laboratory programs do you think exemplify the Laboratory's main strengths in this regard?

Zachary Lemnios
There are a few. One is the Air Force red team. Threat assessment, technology development, countermeasures assessment—that's exactly their game. The same is true for the work that we're doing in counter IED work. And then there's the ERSA [Enhanced Regional Situation Awareness] activity, which is all about threat assessment. You build a core capability, drive it with what's available commercially, add where you need to, but don't be overly aggressive about technology development. Another good example is a program we have for analyzing patterns of communications to help predict what actions a terrorist group is going to take. It's called CT-SNAIR, for counterterror social network analysis and intent recognition.

LLJ
How did this effort originate?

Zachary Lemnios
Several years ago, when the Laboratory started building a counterterrorism program, the first thing that we did was take a close look at the threat network and how it might evolve, and try to understand where the vulnerabilities were in the kill chain. Take the threat of improvised explosive devices, or IEDs, for instance. While many organizations are looking at defeating the trigger of the IED, we have been doing a lot of work to try to understand the operation of the network of people that are responsible for IEDs. How are these networks structured, and how do they evolve? Where are the vulnerabilities in the process of designing, building, and placing of IEDs, as well as in the filming and subsequent reporting of the attacks?

LLJ
Isn't this what intelligence organizations do all the time? How is CT-SNAIR different?

Reagan Test Site on Kwajalein Atoll

Zachary Lemnios
Conventional intelligence operations certainly do help identify people and where they are on the ground. The capability that is emerging—which CT-SNAIR is a part of—is to analyze the communication network amongst those who pose the threat so that we can better understand what they might be doing.

LLJ
Even though the information could be in any number of languages?

Zachary Lemnios
Yes. In fact, the ability to do natural language translation is an important piece. The Laboratory has a lot of strength in that technology. So language understanding, coupled with social networking analysis, is really what the CT-SNAIR effort is all about. CT-SNAIR uses tools that build upon the language processing work the Laboratory's been doing for many years. This effort couples well to work on MIT campus. We're also collaborating with Carnegie Mellon and with the University of Massachusetts, Amherst, in particular, on the front-end social network analysis tools. This effort entails more than just word spotting; we are also trying to identify phrases, disambiguate aliases, and understand cultural context, all of which are really hard research problems.

LLJ
How far along is CT-SNAIR toward being a deployable system?

Zachary Lemnios
It's not anywhere near close to that stage yet. At this point, we're trying to understand the underlying science of the problem and validate the algorithms that are being used.

LLJ
What are some key areas with this system that need to be worked on?

Zachary Lemnios
Well, right now the false-alarm rate is a big problem. Getting false-alarm rates down to acceptable levels is key. It won't be very useful if the system keeps triggering alerts in situations when the communications being analyzed are benign. There's a huge area here of research on how to get a system like this to do machine learning in very dynamic environments with unstructured data. This is an area that the Laboratory is very interested in.

LLJ
Is the goal of CT-SNAIR more to monitor the activity of a known group or to identify new groups that we didn't previously know existed?

Zachary LemniosFor now, we are focusing on improving our understanding of existing networks. Eventually you'd like to be able to identify networks that aren't yet known, but this would give rise to enormous false-alarm rates. So at best I think these will be tools that cue an analyst rather than replace an analyst. And if we could provide some insight that the analyst hasn't yet seen, that would be a win.

LLJ
One common theme to describe work at Lincoln Laboratory is that it would seem important for there to be in place a culture and a structure that encourages interaction among different disciplines.

Zachary Lemnios
Yes, it is all about that. In fact, most of problems that we take on are so interdisciplinary that it's far more important to have a team with great technical depth across a number of domains than a single individual researcher with twice as much depth in his or her own specialty.

LLJ
How does the Laboratory foster this kind of innovation?

Zachary Lemnios
We have a couple of mechanisms to help launch new ideas. The first is the Advanced Concepts Committee, or ACC. The ACC is all about finding a way to get the young, bright staff member with a glowing idea enough money to prove his or her thesis. This program gives a staff member enough money to run an experiment and collect the first data set. All the ACC work is internally funded, and the consequence of failure is low. We're basically betting on people and betting on good ideas.

LLJ
So that's more at the component level. What about systems level thinking?

Zachary Lemnios
That's where the other mechanism—the New Technology Initiatives Program [NTIP]—comes in. The NTIP is the first opportunity to start integrating a number of concepts into a systems picture. The level of funding is higher than that of the ACC and the time horizon is closer. With an NTIP project, we assume that the enabling technologies are mature enough. The bet that we are placing on these efforts is the integration concept. We want make sure that technical developments hang together from the system perspective. It's also the first time that we start thinking about measures and countermeasures. If somebody comes up with a new radiofrequency tag, say, and wants to demonstrate it against some sort of aircraft, the NTIP might also look at what the countermeasures to that tag might be. The NTIP might think through what's the concept of operations. That is, how would you actually use this, and how does that compare with the existing concept?

LLJ
What are some examples of NTIP successes?

Zachary Lemnios
Well, one is CT-SNAIR, which we've already talked about. Another is MASIVS [Multi-Aperture Sparse Imager Video System], a system concept to build a very-wide-area imager from a number of commercial imagers. Whereas the ACC would be funding the actual device, the NTIP is looking at how we take that and start integrating it. It really takes a different mindset; we have different types of people in each of these two groups. The ACC largely funds work by people who love to spend time at the lab bench, whereas the NTIP projects are more for system thinkers. Both are absolutely vital.

LLJ
Lincoln Laboratory has traditionally shunned the spotlight. When you talk to people in government, academia, and industry about the Laboratory, what's the most common misperception that you encounter?

Zachary Lemnios
A lot of people confuse us with the Department of Energy labs—the national labs such as Los Alamos and Sandia. Of course, we are not a DOE lab. And in fact, I would argue that while those national labs are good in certain selective areas, Lincoln Laboratory has a deeper foundation in a broader set of topics that are of interest to the DoD—as well as the agility to take on new problems in lots of areas. Another way a lot of people have the wrong idea about Lincoln Laboratory is that they still regard us as a radar house. While that was the heritage of the Laboratory, we really are now an information technology organization in the sense that much of the work here is really about target identification, discrimination, and understanding, and the flow of that information across very complex systems. Radar is one sensor. We work with many other sensors.

LLJ
What effect do you think the Laboratory will feel as the new administration takes the reins in Washington?

Zachary Lemnios
We just don't know. I suspect that missile defense work might scale back a bit, but there will be other areas that increase. Homeland protection, for instance, is an area that I think we'll be seeing a lot more interest in. Counter-terrorism work will grow. And we're starting a small effort and trying to understand where the Laboratory can make contributions in the energy space. Energy, after all, is now correctly viewed as a national security problem and so it is entirely consistent with the larger mission of Lincoln Laboratory.

LLJ
What aspects of energy technology do you see the Laboratory focusing its efforts on?

Zachary Lemnios
Well, you can divide up the energy space into two major pieces. First, there's a supply side that deals with fuels, distribution, and power conversion at the megawatt level. Then there is the consumer piece, which pertains to making sure that appliances and other energy-consuming systems are efficient in their use of electricity. I suspect most of the work we do will be on the usage piece—building low-power electronics, say. I could see our involvement in building systems that have power management schemes that go beyond what is available commercially, and maybe new technologies that allow for more efficient dc-to-dc conversion. We have also talked with some professors at

the University of California, Davis, about developing a smarter electrical grid that could take advantage of the energy storage and load-management that could be provided by a large fleet of plug-in electric hybrid vehicles. We are primarily interested in what the system architecture might look like. And we have a significant effort in collaboration with MIT campus to build a thermoelectric power generator (see "Power to Go," Lincoln Laboratory Journal, vol. 17, no. 1, p. 9). That's a good example as one of the first projects that puts the Lab in this space. The Solid State Division is doing a lot of work to extend the low-power operation of conventional CMOS and CMOS SOI [silicon-on-insulator] technology. These efforts could lead to much lower power consumption as we build systems with large numbers of processors, and processors with higher and higher transistor counts.

LLJ
What impact do you expect the present economic crisis to have on Lincoln Laboratory?

Zachary Lemnios
There's going to be a lot of budget pressure on all elements of DoD, including the Laboratory, to propose the best ideas.

LLJ
The Laboratory is also less reliant on DoD than in the past, right?

Zachary Lemnios
Yes, we've got a portfolio that's richer than we had a few years ago. We have a large number of sponsors and more of a diverse assortment of sponsors. We're moving into some new areas. We may thin down other areas within the Laboratory; missile defense, as I said, may be an area that has some sponsor pressure. During past downturns, we've been fortunate and we've had sponsors continue the work here. I suspect that's going to happen this time as well. Generally, we weather these kinds of things out; we try to reduce the overhead expenses as best we can. Now, as has been the case historically, we have had an over-commitment of sponsors—that is, we have more work that we can possibly do. But fundamentally, technology remains key to many of the problems that DoD has, and the Laboratory is in a unique position to provide a lot of those key technologies. That's not going to change.

Editor's Note
We thank Lincoln Laboratory Journal, the original publisher of this interview, and their Editor-in-Chief, Herb Brody, for allowing us to reprint this informative interview. For further information, please access their website

All photos and images used in this article are courtesy of Lincoln Labs. For more information, please select the Lincoln Labs Headquarters image below.

PROCUREMENT POTENTIAL
IGT: TAKING MOBILITY TO NEW HEIGHTS

Currently, one of the biggest trends in military and government communications is mobility. Soldiers and first responders across the globe are turning to high-speed satellite broadband to support voice, video and data connectivity in the field to better fulfill their missions, whether that's on the ground, in the air, across sea or anywhere they serve.

To date, *communications on-the-move* (COTM) technology has provided reliable satellite communications for a variety of standard military and government vehicles in some of the world's most demanding and hostile environments. While COTM represents a significant advancement for satellite communications, the size of the equipment has limited it to larger vehicle applications — until now.

iDirect Government Technologies (**iGT**) has recently launched a new small form-factor DVB-S2 satellite router board to power a new standard of high portability, low profile mobile applications. At half the size of current product standards, the ***iConnex e850mp*** packs iGT's full suite of mobility and advanced platform features into a compact, portable board for systems integrators.

Emerging Applications

The e850mp is designed to integrate into a portable VSAT solution that can easily be transported by a single person or mobile vehicle. That makes it ideal for Comms on the Move, emergency response, and command and control applications in the field.

When combined with a bidirectional satellite antenna, the e850mp extends high-speed connectivity to a wide range of small form-factor portable and mobile solutions. This has led to the development of some exciting and innovative new applications, including:

- ***Personal mobile broadband: Individual soldiers utilize compact satellite communications systems to expand battlefield awareness, identify potential threats, transmit situational video back to base, receive command and control information, and enable telemedicine***
- ***Expanded aerial applications: One of the latest applications for Comms on the Move technology is equipping medium- and small-size aircraft, cargo planes and Uninhabited Aircraft Systems (UASs) where space constraints demand smaller communications equipment.***
- ***Deeper maritime coverage: Satellite communications has emerged in the maritime industry to support shipboard applications for deep water fleets, manned and unmanned submersible vehicles, and Coast Guard shallow water fleets.***
- ***First Response: Fire and forestry units benefit from greater portability to deploy mobile command centers on the front lines of a spreading wildfire in dangerous zones where vehicles can only get so close.***

Key Product Features

The iConnex e850mp is engineered to meet the most rigorous demands for mobility, security and flexibility

iConnex e850mp DVB-S2 satellite router board

from military and government organizations. Key features of the e850mp include:

- ***Compact and lightweight size:** The e850mp measures only 10.35 in x 6.675 in x 1.24 in, weighing in at a mere 2 lbs.*
- ***Two-way satellite IP routing:** The e850mp features high carrier data rates: up to 156 Mbps outbound and 6.5 Mbps on the inbound, as well as a choice between iNFINITI TDM or DVB-S2/ACM on the outbound, providing even more flexibility for network design and bandwidth optimization.*
- ***Spread spectrum waveform technology:** The e850mp features iGT's proprietary Direct Sequence Spread Spectrum technology, enabling use of ultra-small mobile antennae on aircraft, ships and land-based vehicles.*
- ***Military-grade Security:** The e850mp was engineered to be compliant with the highest military security specifications, including AES encryption, TRANSEC, FIPS 140-2, and X.509 digital certificate encryption and automatic over-the-air key exchange.*
- ***Advanced Quality of Service (QoS) and traffic prioritization:** With iGT's state-of-the-art Group QoS, network operators can prioritize mission critical traffic and applications over their networks, ensuring the highest quality transmissions where needed.*
- ***Global network support:** The e850mp is fully enabled for iGT's Global Network Management System (GNMS) and automatic beam switching technology allowing for a seamless network with truly global coverage while on the move.*
- ***Intuitive network management:** Service providers can easily configure and centrally manage each individual unit though the iVantage network management system, a complete suite of software-based tools for configuring, monitoring and controlling networks from one location.*

From front lines of the battlefields to disaster scenes closer to home, the **iDirect Government Technologies *iConnex e850mp*** is bringing new applications for mobility to military and government organizations around the world.

NSR: PRIORITY BRIEFING IN SUPPORT OF THE NEXGEN SOLDIER

by Jose Del Rosario, Sr. Analyst & Regional Dir., ***NSR***

Satellite communications, whether on commercial or proprietary systems, are at a crossroads when looking at military markets. Issues that come to mind given the changes in policy, in warfighting capabilities and in the enemy itself, are leading to questions that include:

- ***Is the military market sustainable for commercial players over the long term?***
- ***Are current space assets adequate in terms of supply and in terms of capabilities?***
- ***What changes, if any, are required to support future warfighting?***

New weapons systems are moving away from Cold War capabilities, and rightly so, given that the enemy has and will continue to change. For future warfighting, technical capabilities need to be developed today in order to tap the military market of the future. More importantly, it would appear that current satellite capabilities are a long way from the vision of the nexgen soldier, which could present opportunities for companies that are willing to invest in systems development for future use.

Policy & Budgets

Before R&D funds are allocated, it is useful to examine the vision of the globe's Defense Departments, specifically the **Pentagon** when considering the future landscape. In April 2009, U.S. Defense Secretary *Robert Gates* continued to reiterate his position that the U.S. should cease funding $billions into futuristic, highly-expensive, F-22 jet fighters and new presidential helicopters (among others) and, instead, pour taxpayer dollars into systems U.S. soldiers can use against actual adversaries on the ground. The plan or the shift in policy calls for the Pentagon to procure systems for smaller and more direct battlefield conditions that the military is currently facing and is likely to face in future conflicts.

If Secretary *Gates* gets his way, does the major overhaul that would slash several weapons programs mean less funds for future warfighting? Gates' proposed $534 billion budget for the coming year is actually an increase from $513 billion for 2009. Thus, despite talks on budget cuts, current policy calls for discontinuing outdated systems conceived during the Cold War and spending more funds for new systems that directly support the warfighter. The goal is to tap or reflect what future defense capabilities should be such that current and future weapons systems address programs aimed at an evolving enemy, which is becoming highly sophisticated. And here, the administration is not asking for less but for more funds. It is also probably not asking defense plants in the U.S. to shut down but to re-tool.

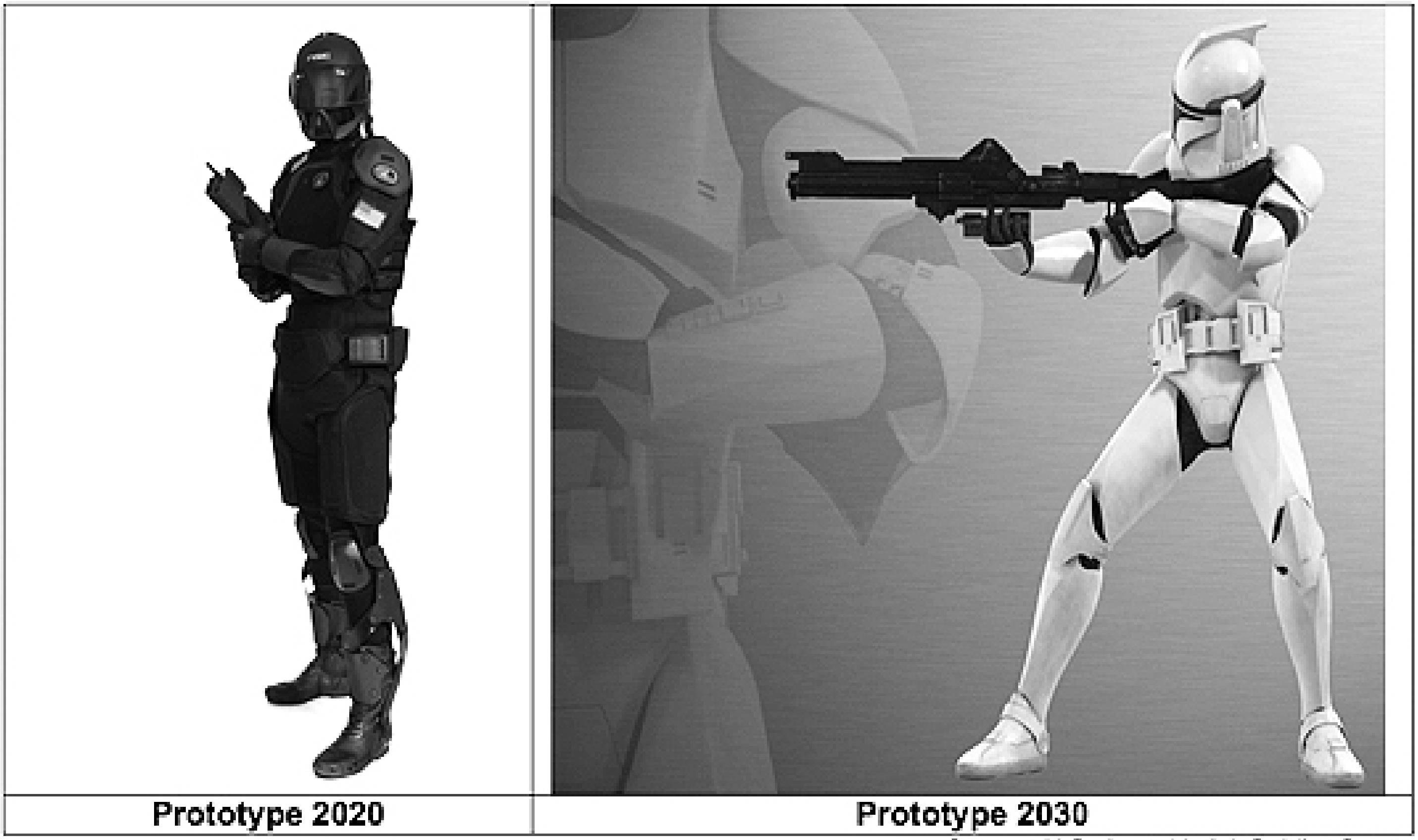
The new spending thrust reflects the policy change. For instance, instead of the highly expensive $140 million ***F-22 Raptor***, current policy would add $2 billion to fund surveillance and reconnaissance equipment, specifically for 50 new ***Predator*** drones. The argument is that the Raptor is ill-suited for deterring roadside bombs or hunting insurgents that vanish into mountains and urban enclaves, whereas UAVs are more useful for reconnaissance and tactical purposes under such conditions.

Many other initiatives and program priorities are outlined by the Pentagon, but the overarching policy is to start building for the next form of warfighting. The priority is to move towards the next step in warfighting evolution. And here, the trend is towards more automation via greater use of UAVs and UAS'.

The Next Warfighter: Aim for the Head

That is not to say, however, that the soldier (or, for that matter, the fighter pilot) will begin to have a decreasing role in warfighting. Indeed, it is *Gates*' vision that the soldier who is engaged in the field, who is in harms way with roadside bombs, and who is chasing insurgents in mountains and urban enclaves, need to be protected and better equipped. As such, the soldier itself will have to evolve to face an evolving enemy. And this is a useful place to begin studying the market prospects for the nexgen soldier and where new market opportunities exist.

The prototype of the next warfighter is already on the drawing boards for 2020 and 2030. These soldier prototypes in terms of equipment are a vast improvement in terms of protection, mobility, situation-



Source: U.S. Army Natick Soldier Center

al awareness (SA) and communications capabilities compared to today's soldiers currently patrolling Iraq and Afghanistan.

Future technical capabilities include developments for the soldier's:

- ***Weapon***
- ***Helmet***
- ***Physical Attributes where "Super Human Strength" is achieved***
- ***Smart Cloth Body Armor***

The most pertinent for satellite communications lies in the warfighter's helmet, or what the U.S. Army describes as "Information Central." Plans for capabilities include:

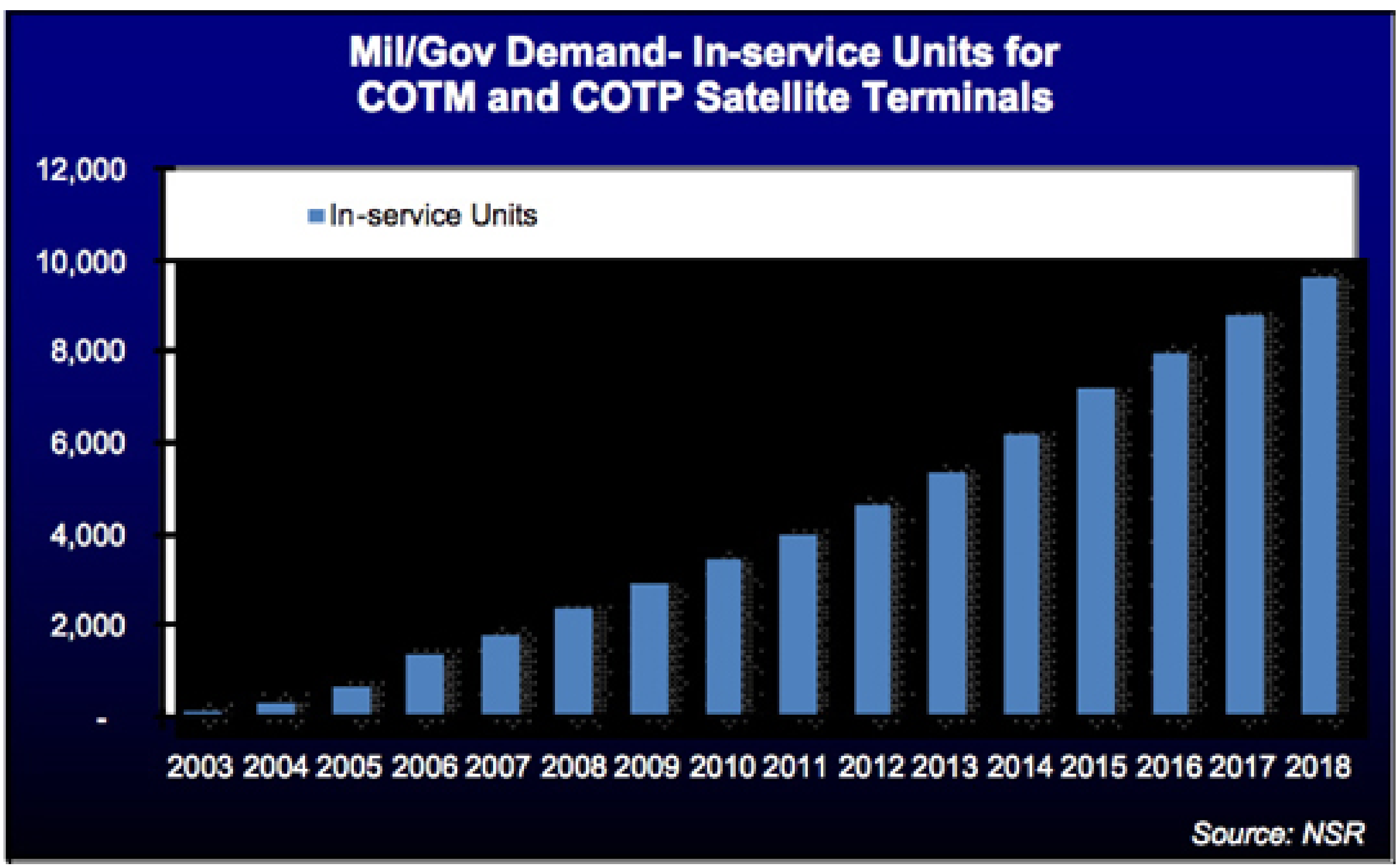
- ***All around protection with built-in gas mask***
- ***180° emissive visor display***
- ***Stereoscopic night-vision cameras with images and incoming tactical data projected onto or inside of visor***
- ***Integrated tactical processing (e.g., maps, routes, SA data)***
- ***High data rate (GB/sec) communications***
- ***Microelectronic/optics combat sensor suite that provides 360° situational awareness***
- ***Integrated small arms protection in selected locations***
- ***Satellite communications***
- ***Voice activated commands for various suit systems***
- ***Instant voice translator lets soldiers "speak in" various languages***

In terms of where current capabilities are, most of the systems outlined above are said to already exist in helmets worn by pilots of fighter jets, while computer voice translation is currently in development. As the priority set by *Robert Gates* decreases the procurement of fighter jets in favor of UAVs, the number of helmets where SATCOMS will have a market base will rest with the soldier on the ground rather than the pilot in the sky. This is good news for helmet manufacturers since the addressable market will rise given that there are more U.S. Army and the Marines ground soldiers compared to fighter pilots.

Future SATCOM Requirements

In tapping the future market, SATCOM systems in the space and ground segments will have to incorporate these features:

- *Small antenna systems and other military frequencies that support small antenna systems. — L-band is a natural fit, and there may be a play for Ku-band, Ka-band and X-band. Reconnaissance data from UAVs that run on Ku-, Ka- and X-band will have to re-transmit on frequencies supporting small antennas or these frequencies will have to develop small and lightweight antenna systems that fit the soldier's back. The antenna systems should likewise seamlessly point to the satellite. The nexgen soldier will have a computer embedded in his/her suit located at the base of the soldier's back, which will be connected to a local and wide-area network for data transfer. Small antenna systems in L-, Ku-, Ka- and X-band, as well as military frequencies that are housed in the computer itself, will be quite compelling.*
- *Broadband Capability — Sensor and tactical data will (at a minimum) take the form of video files, maps and other high-bandwidth content. The helmet will combine rapid information transfer, accelerate and improve situational awareness that "sees all, hears all, and can relay this information to all." The system is envisioned to be equipped with a 17" internal virtual reality display viewed by the soldier, a hologram projector viewed by others, and satellite and video communications available for view to all, including both field and command garrison staff.*
- *In-building and Foliage Penetration — As mentioned above, the enemy disappears into mountains, caves, urban enclaves and jungles. The nexgen soldier has to be able to engage the enemy under such conditions. MUOS, a planned narrowband military satellite system, will have the capability to penetrate foliage and buildings. The drawback when looking at the future warfighter is that MUOS is a narrowband system, but communication links for the Future Force Warrior are envisioned to reach Gbps of throughput. Moreover, although most capabilities in jet pilot helmets already exist today, conditions in the sky for communications are vastly different from communications on the ground where buildings, foliage and other conditions prevail. It is thus technically complicated to re-apply fighter pilot helmets to ground troop helmets.*
- *Real-time — Tactical data in theater has to be real-time, or at worst near real-time. The nexgen soldier is envisioned to be part of a small netted unit/team with robust team communications. Capabilities and assets will include state-of-the-art distributed and fused (thermal and image intensification) sensors, organic tactical intelligence/collection assets, enhanced situational understanding, embedded training, on-the-move planning, and linkage to other Future Force assets.*



- ***Redundancy** — Given the sophistication and collaboration of activities and capabilities, redundancy will have to be integrated in the entire communications system or network architecture. This means that military and commercial satellite assets should be able to seamlessly switch signals when one system is down or overloaded.*

It would appear that a system that features "small antenna/broadband capability/able to penetrate foliage, buildings, caves and jungles" is still not in existence today. Current systems as well as the upcoming MUOS military system offer a combination of features, specifically "small antenna/broadband" or "small antenna/able to penetrate foliage, buildings, caves and jungles", but not all three features are currently available or currently planned.

The closest market that approximates the future warfighter lies in the *communications-on-the-move* (**COTM**) and *communications-on-the-pause* (**COTP**) market. However, it is quite limited today, given the technological hurdles that exist. The COTM and COTP markets are projected to grow at steady levels; however, the market potential, particularly if or when the nexgen soldier can be tapped, is expected to be at much higher levels. In a sense, an offering that can incorporate all the capabilities outlined above will be a "game changer" that transforms the market dynamics.

Coming To A Head

At the heart, so to speak, of the nexgen warfighter will be his/her head. And this is where SATCOMS will be most pertinent in terms of establishing a unique value proposition. Current satellite systems fall short in supporting the nexgen soldier as envisioned by the Pentagon. The good news is the funds to support nexgen capabilities will be available given the budget request of the *Obama* Administration.

More importantly, the policy to support such capabilities for the nexgen warfighter is beginning to be firmly established. Current and planned technical capabilities for satellite systems, including MUOS, still fall short of the requirements of the prototype soldier for 2020. As such, a golden opportunity exists today in developing and enabling the ***Future Force Warrior***. The initiative can come in the form of a unique satellite deployed by a commercial player, a hosted payload agreed to by the military and commercial operator, or via a partnership between the satellite manufacturer, the satellite operator and the military entity.

Whichever form of payload is contracted, procured and launched will dramatically change market demand for space capacity as well as developments in ground terminals, software and application suites.

About the author

Mr. del Rosario covers the Asia Pacific region and is a senior member of the consulting team where he focuses his research on quantitative modeling, data verification, and market forecasting for the wireless industry and satellite communications sector. He conducts ongoing research with specialization in policy analysis, regional economic indicators, regulatory initiatives and end user demand trends. In addition to authoring numerous syndicated reports in his areas of focus, Mr. del Rosario has been involved in a wide range of strategic consulting projects. He has advised clients on market trends, implications, and strategies on such diverse topics as WiMAX, mobile communications, mobile video, 3G offerings, terrestrial microwave services, IPTV, and more.

NETWORK MANAGEMENT FOR MILSAT VSAT TECHNOLOGY

by Guy Adams, CTO, ***Parallel Ltd****.*

This article discusses the key issues of monitoring and the management of Very Small Aperture Terminals (VSAT) networks and whether a network is either military or commercial, exactly the same issues apply with the exception of a greater emphasis on security for a military application. All forms of satellite communications (SATCOM0 are covered, but for convenience, the term VSAT will be used throughout to equate to SATCOM.

Military or civilian applications using VSAT are overwhelmingly the most prevalent mechanism for two-way data satellite communications. This is the case for point to point SCPC links, TDM/TDMA or other multiplexed type of data communication systems. The satellites these networks operate over that provide the space segment capacity may be provided either via military or commercial satellites. The issues discussed here relate to VSAT operations over dedicated military or commercial geostationary satellites, which dominate military communication networks. However, it should be noted that many aspects of network management discussed in this paper also apply to polar or inclined orbit satellites.

Plusses

The advantages of two-way VSAT communications are widely accepted and understood. VSAT networks face different challenges whichever operational frequency band is used, whether it be Ku-, C-, Ka- or X-bands. For network management, the choice of frequency is not an issue. However, customer and operations department management requirements for VSAT networks have been increasing rapidly, to an extent propelled by developments in terrestrial network management. Additionally for satellite networks, the requirements for higher bandwidths combined with increased commercial space segment scarcity and therefore cost, have driven VSAT manufacturers to develop and implement more and more sophisticated systems to squeeze every bit per hertz from satellite capacity.

These changes benefit the military market even though capacity availability on military satellites is not such an issue. These increasing requirements have created some of the most complicated management issues in any networking technology. This is compounded by the generally poor acceptance by most VSAT vendors of the need to provide adequate network management.

Generally, but understandably, VSAT vendors concentrate on the VSAT satellite element of their networks that includes the central satellite NOC systems and remote sites, but ignores the remainder of the network elements that comprise a total operational VSAT network. For military applications in particular, this is insufficient. What was evident from the outset was that a *Commercial Off-The-Shelf* (**COTS**) *Network Management System* (**NMS**) for a hybrid VSAT network was not available.

VSAT Technology

VSAT technology has been in use for more than 20 years for a wide variety of applications for military deployed systems for troops on the ground together with ship-board and land based mobile communications networks as well as for commercial, rural telecoms, distance learning, disaster recovery, to name but a few. When deploying a VSAT network, there are a number of unique characteristics to be considered, particularly with reference to the provision of network monitoring and management.

Network Management

Historically, network monitoring and management are not generally considered during a VSAT network design phase. Designers concentrate on providing the customer with a network configuration that meets the criteria for end to end connectivity. As contentious as this may be, it is rare that network design engineers consider the operations department and how they will monitor the network to meet the contracted *service level agreement* (**SLA**) figures and how they will provide the required customer network statistics reports. Designers generally assume network operations will simply add a new network to their portfolio to look after, but not consider whether their systems can achieve what is required to satisfy these customers. Customers will undoubtedly have requirements based on SLA's and may require significant numbers of reports about network performance including for example, per virtual circuit availability, monthly network availability, quarterly rolling average availability and a host more technical information about satellite link performance.

In addition, the support for remote sites and the availability reports for terminals are also crucial in providing the highest possible network availability. VSAT manufacturer proprietary NMS's are unlikely to provide the capability to satisfy all these requirements. Network management must accommodate the VSAT infrastructure as well as the other significant elements of the implementation that, together, forms the communications network.

Network management is the process of monitoring and controlling a network to increase efficiency and productivity. This is achieved by gathering, processing, and interpreting data about a network and then performing fault-finding and IT planning on the basis of that information. It also covers change control, security, access and management of all other aspects of network usage. Demand on network performance has never been greater. Network management ensures that high availability and fast network speeds are being met, or can alert staff to developing issues before they affect the network. The cost of having ineffective network management can spell disaster for an organisation. Prolonged or frequent network downtime can result in serious operational and logistical issues particularly for a military operation. For commercial organizations outages can result in a loss of reputation, productivity, revenue and a consequent decrease in financial performance.

Added Complications

There are literally hundreds of NMS designed for terrestrial networks. These tools are designed to work on LANS and terrestrial WANS, typically characterized by:

- ***Low latency. Response times that are less than 100ms***
- ***Symmetric bandwidth. Upstream bandwidth is the same as downstream bandwidth. There are a few notable exceptions to this such as ADSL***
- ***Discrete failures. A link is generally working or not working; there are generally no partial failures (congestion is user generated and is therefore not a failure of the link)***
- ***Accessible equipment. Network equipment is generally easy to access***

- ***Management Traffic. Network management traffic can be carried either on the network it is monitoring or on a separate network***

These tools will not be referred to as 'terrestrial' network management tools and their vendors will boast support for any IP network, which in principal is true. If all that is needed are simple on/off status shown by red/green icons and a couple of pre-generated graphs, these proprietary tools may be adequate. However, they are not adequate to satisfy ever more demanding VSAT network users.

Network Management + VSAT Technology

VSAT network management is in the middle of three opposing forces:

1. Rapidly increasing customer demand for online, real time and historical reporting with huge levels of detail, SLA Reporting, QoS Monitoring and many other complex requirements

2. Increasing sophistication and complexity within the VSAT technologies that make even simple monitoring difficult

3. VSAT technologies which are still primarily designed to be standalone and managed only using vendor proprietary tools. This is changing with some manufactures now actively supporting upstream integration and access by other management systems

This presents a 'perfect storm' scenario: customers are demanding more, the technology advancement is making it harder just to stand still, and VSAT manufacturer support in many cases is limited.

Increasing Customer Requirements

As much as ten years ago, most network owners were happy to be told whether their circuit was up or down and relied totally on the network service provider to ensure their network was operated effectively and efficiently. Five years ago, with more technical expertise in their organizations, customers now like to know total traffic volumes, latency, and perhaps even EbNo/SNR at the remote sites and at the central hub site. Two years ago, the range of metrics they wanted a report on had expanded greatly and incorporated packet loss, jitter, and started to breakdown traffic into more detailed component parts. Customer Operations Management teams were no longer satisfied with one set of reports for the VSAT part and another set for their terrestrial elements. What was needed was full end to end monitoring. Today, the trend is for clients to have the level of reporting they required on a per circuit basis, but to have this replicated down to Virtual Circuits or Service Classes.

Increasing Technology Sophistication

The nature of VSAT communications necessarily implies a certain amount of technical sophistication. To get a packet through a shared frequency band from one point on the Earth to another via a satellite and back again requires some complexity and is also driven for the need for higher performance, lower latency, and substantially increased bandwidth efficiency.

Automatic power control, advanced acceleration and compression, dynamic QoS and CIR changes plus Adaptive Coding and Modulation are well known examples of these developments. Each one brings with it greater management complexity. This complexity extends far beyond being able to simply measure and store additional data series. Many of these techniques fundamentally change the nominal values of several other metrics. What may be perfectly healthy circuit/network performance one second may be very poor the next. Keeping track of tens or hundreds of metrics and how they compare to nominal ranges which are constantly changing as would be expected over a satellite system is a nearly unique challenge to SATCOM and one totally beyond any terrestrial management system.

The great challenge with VSAT technologies is the lack of a friendly and efficient management interface as well as a lack of management standards. Many organizations believe that by adding a standard management stack, such as **SNMP** (***Simple Network Management Protocol***), their management responsibilities have been met. It is widely accepted that as SNMP has been a de facto standard for management of terrestrial networks and components, it is a perfect solution for all networks. With the very high cost of satellite bandwidth, this is rarely the case for satellite networks. As an example, to get data that can only be obtained from the remote device (*e.g.,* transmit and receive traffic, temperature, buffer fill levels, and so on) could occupy significant bandwidth. In a typical management scenario there could be 15 of these metrics to collect every 60 seconds. Each of these would likely be a 4 byte counter. However, under SNMP, typical packets sizes are around 70 bytes, requiring 70*15=1050bytes per minute (140 bps) both upstream and downstream per circuit.

This is as compared to a theoretical minimum limit of 8bps, or even lower if only changes are transmitted. An additional 130bps per circuit may not seem like a lot but on large networks this can very quickly become significant (126kbps on a 1000 circuit network).

The second problematic situation is where a useable system exists but is not standards based in terms of network management. This usually means an efficient and comprehensive integration is possible but requires complex and customized integration into a management system. In practice, these systems are usually possible to integrate into 'standard' network management systems as they generally only support standards based integration.

The final situation is that neither option is available — neither a useable nor a standards based management interface. Fortunately, on modern VSAT systems this is rare, although it still exists. There are many legacy systems in use and it may be many years before these are retired. For the military in particular, the issue of legacy equipment and non-standards based systems makes the ability to integrate even more important.

Another issue worthy of note is with the increased sophistication of many VSAT systems and the ability to provide more extensive centralized fault finding of remote terminals, with the intent of improving link SLA's and reducing the cost, delays, and downtime associated with engineer visits to site. Additionally, remote control of sites can also be achieved to reduce the requirement for skilled VSAT engineers to be deployed to install and/or maintain these VSAT remote sites.

A Viable Solution

Parallel Ltd. has many years of experience in designing and developing a comprehensive suite of software features and has overcome the aforementioned problems —***SatManage***™. The diagram below demonstrates the diversity of inputs that ***SatManage*** can accept.

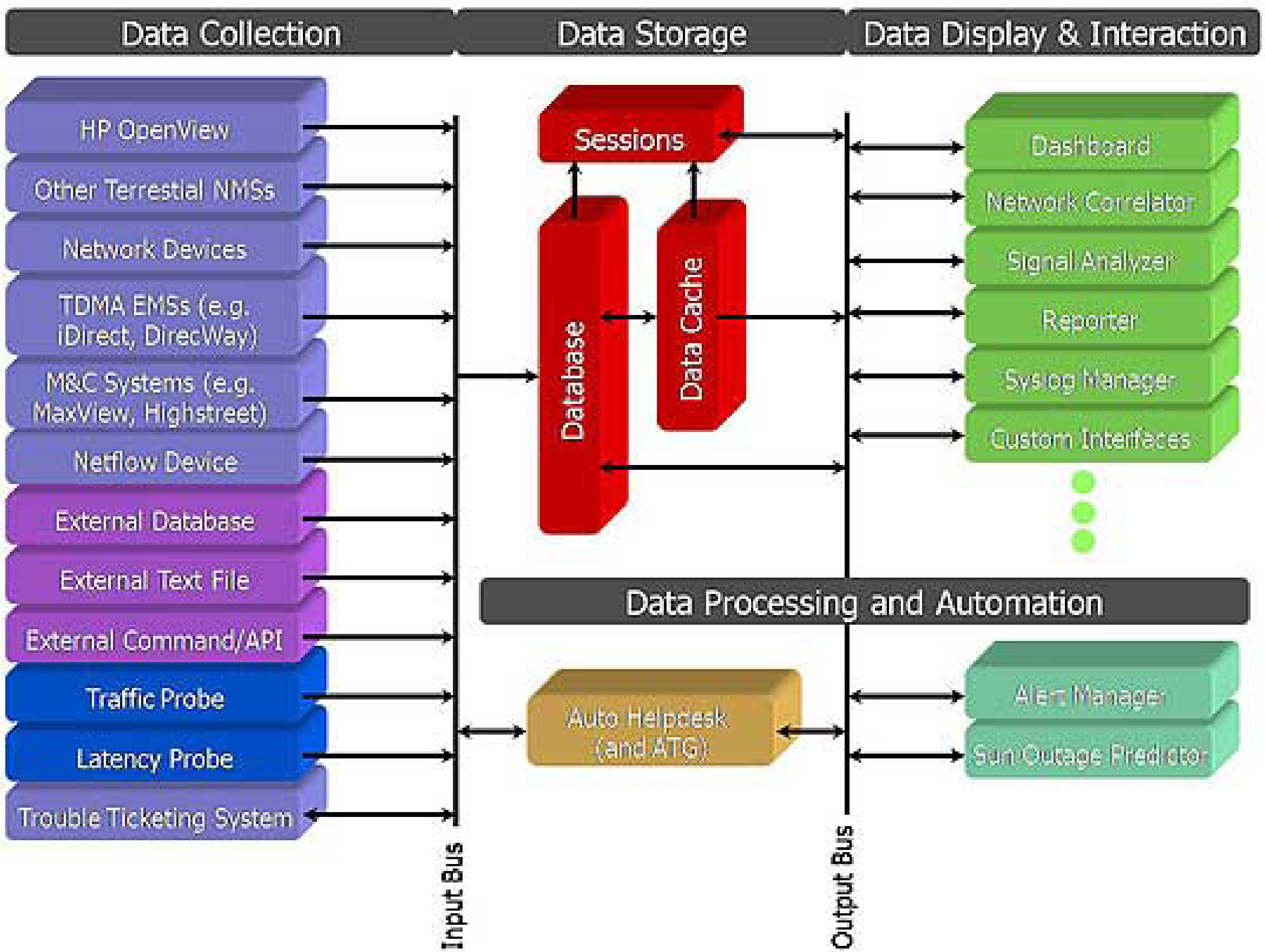
SatManage is designed around this modular framework and the main reasons for this are:

- ***The Modular architecture allows an implementation to exactly fit the existing customer NOC infrastructure ensuring no wastage in unwanted investment***
- ***The solution is scalable - it can be installed onto one or spread across many computer systems depending upon the network sizing, user base, performance and redundancy requirements • Because Parallel publish all the application APIs, it means that customers or third parties can make modifications to existing code and can build their own modules. This means that customers are not tied to Parallel for ongoing development***
- ***Custom modules can be more easily created and plugged into the architecture enabling easier integration with other equipment and applications***

All this information and functionality from SatManage is web based, in real time, plus it has the ability to go back months or years for historical reporting and can be made available from anywhere in the world. This provides the ability for Management and/or Operations to be notified proactively via, say, a smart phone regarding anything affecting service, not just outages, but also congestion, VoIP chop, overheating equipment and more.

For a military application, security is vitally important. The SatManage system connected over the Internet is secure as it runs over https and restricted access is provided by user authentication. SatManage runs a hardened Operating System based on ***CentOS 5.2*** (a binary compatible release of **Red Hat Enterprise *Linux 5.2***). All extraneous and unrequired services are stopped. All inter-system communication is locked down to the specific SatManage IP addresses. Generally, the only port visible to the outside world is port 443 on the SatManage front end server, which is the SSL port of the web server. U.S. **NSA** standards can be implemented, which further hardens the operating system and provides additional privilege separation.

At the remote terminal, it is also possible to implement a solution that separates Red/Black traffic to further enhance overall security. SatManage provides a wide variety of software features that will provide



all the information and reports that are generally required. These features have been developed by Parallel over the last 10 years, based on their varied customer base. The basic SatManage modules that are available, but not limited to, are summarized as follows...

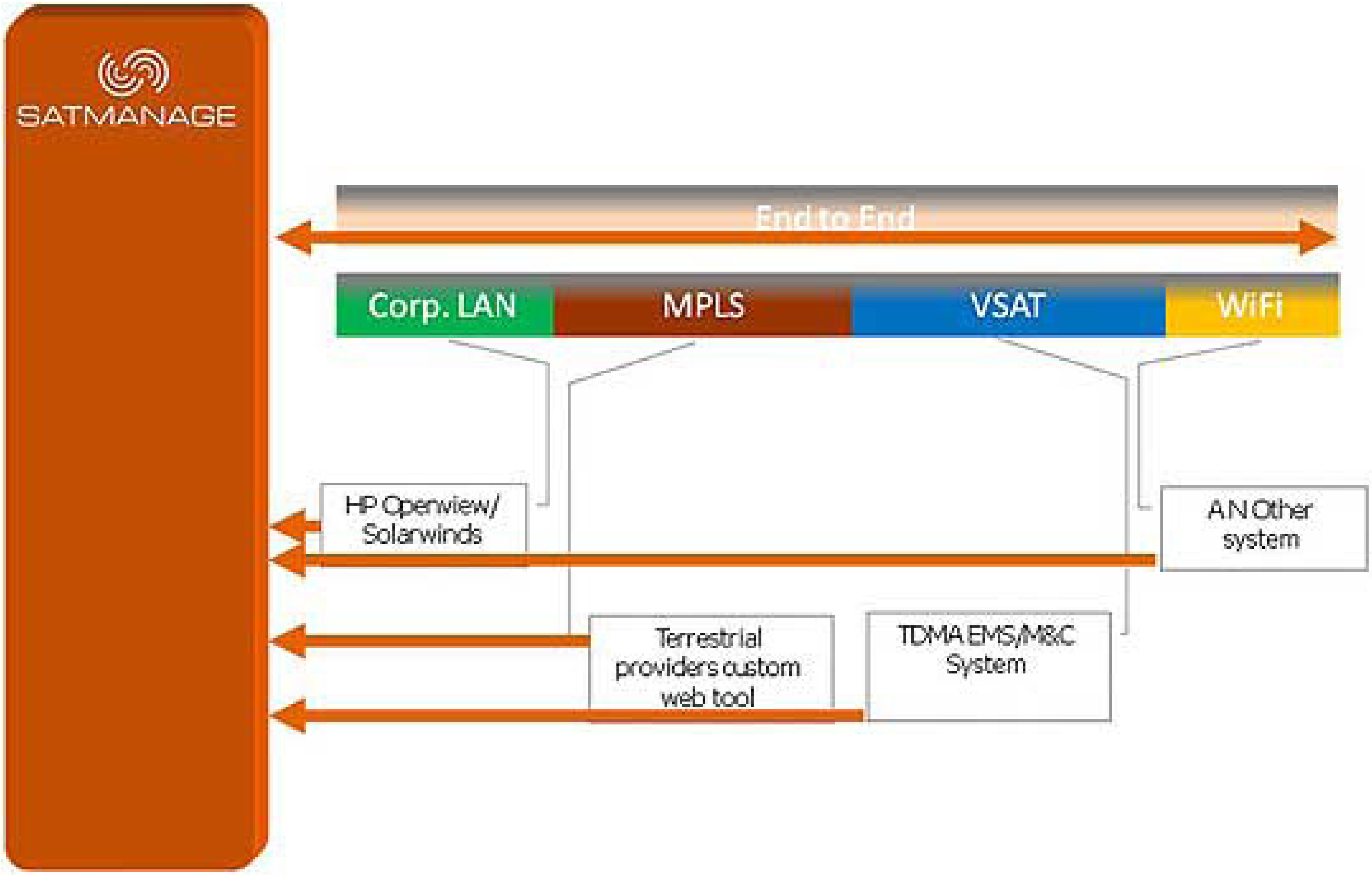
- ***Dashboard***
- ***Network Correlator***
- ***Circuit Manager***
- ***Signal Analyser***
- ***Reporter***
- ***Documentation Portal***
- ***Remote Application Connectivity***
- ***Mobile Tracker***

An important feature of SatManage is the application's capability to be used remotely via a web interface. Also, by virtue of the API interface, customers can develop and integrate their own applications into SatManage.

These issues are VSAT specific — however, realize there are very few pure VSAT networks. Most WAN networks are hybrids using a wide range of technologies including ATM, Frame Relay, ISDN, VPN, MPLS, Ethernet, as well as standard networking equipment such as routers, switches, hubs, firewalls, and servers.

Net Know How

As has been discussed above, end to end management of a network, whether it is a military or a commercial network, is a critical requirement. The ability to intelligently manage the VSAT component, while cleanly integrating with management systems for other components and providing full end-to-end class based monitoring, is the ultimate challenge.



This can also provide great opportunities for improving efficiency by time saving through increased automation which in turn improves customer satisfaction.

Although SatManage can now be categorized as a COTS system, by the nature of diverse VSAT network implementations that range from a single central hub with a few associated remote terminals to multiple central VSAT NOC's, multiple terrestrial networks connecting them and widely dispersed remote terminals, a bespoke SatManage NMS configuration is normal. With the SatManage suite of software modules, system tailoring is now considerably easier. Originally, VSAT operations teams with their proprietary NMS's were capable of providing only reactive network management. Today, with Parallels SatManage system, pro-active network management is possible. Parallel's SatManage system has proven it can accommodate all these variables, making it a unique product in today's market for VSAT systems network management. Details of SatManage can be found on the web site ***www.satmanage.com***

About the author

Guy Adams is the Chief Technical Officer at Parallel Ltd. In 2004, he was named the UK's Network Professional of the Year. He has overseen the development of a satellite network management system now used in many of the world's largest and most prestigious organizations. His software's groundbreaking data correlation, visual displays and trouble ticketing automation now form the basis of SatManage, a comprehensive satellite network management suite. This system also won the prestigious British Computer Society Technology Award in 2005. An experienced speaker, Guy regularly addresses university students in the UK and key industry events globally, as well as writing many technical white papers and magazine articles.

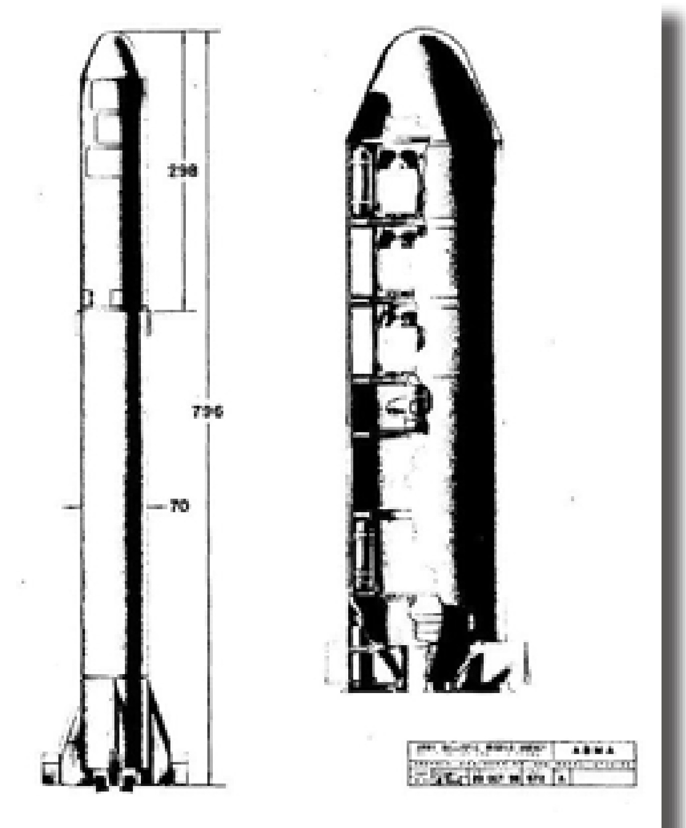
by Jos Heyman, Columnist

The United States Air Force (USAF) had always considered space as a logical extension of the air space in which it has its operations and it sought to achieve this in several ways.

In the early days, this belief resulted in several projects that concerned the long range delivery of bombs, such as expressed through the ***Project Bomi*** (Bomber Missile) project that was commenced by the **Bell Aircraft Co.** for the USAF in 1951. This project was supervised by Dr. *Walter Dornberger*, one of the **Peenemunde** engineers. The design consisted of two rocket powered winged aircraft. The mothership constituted the first stage with a crew of two and would have had five rocket engines, which would fire for 130 seconds after lift-off. The first stage would then separate and return to base.

The second stage, or space plane, with a single crew member, was to have three rocket engines and would maintain a speed of 13,600 km/h. Initially, it was intended that, after dropping a bomb, the spaceplane would make a 180 degree turn and return to base. However, later it was considered more practical for the spaceplane to continue in orbit until closer to the landing site. Development did not proceed, but the ideas led to several programs that lead toward crewed spacecraft in the format of spaceplanes.

One of these ideas was a concept to transport troops and cargo quickly to the battlefield using basic Redstone missiles be fitted with a passenger/cargo pod. They would be sent on a ballistic trajectory before landing suspended from a parachute. Needless to say this idea never got much further than being an idea.



Redstone troop transport version (Army Missile Command)

A Boeing ad for Dyna-Soar in TIME magazine, November, 1961

Dyna Soar

A more serious effort to develop a space plane was commenced on October 14 , 1957, a mere 10 days after the launch of ***Sputnik-1***. On this day, the USAF issued preliminary directives for a manoeuvrable space plane. The project, with the military designation ***X-20***, was an attempt to combine the best features of two approaches: high speed flight in space and the capability to return with airplane like control.

In March of 1958, eight aerospace companies submitted proposals. In June of that year, **Boeing**, as well as a **Bell/Martin** consortium, were awarded contracts for further studies into the project. By December 9 , 1959, it was obvious that the Bell/Martin proposals relied heavily on unproven technology and Boeing was awarded a development contract.

Known also as ***model 844 Dyna Soar***, the proposed craft was a delta-winged glider. It was to be rocketed into space by a powerful booster and, once in orbit, the pilot would be able to fly to any point on the globe at speeds of more that 27,000 km/h. When the pilot completed his mission, he would fly his craft back into the atmosphere and land at an airfield of his choice.

The term ***Dyna Soar*** was derived from 'dynamic' and 'soaring', meaning the vehicle was to use both centrifugal force and aerodynamic lift. Centrifugal force was to sustain the craft at orbital speeds when it would be flying just fast enough to off-set the pull of the Earth's gravity. The aerodynamic lift would be afforded by the wings and would be used for flight in the atmosphere.

During re-entry, the craft would encounter severe surfaces heating. To resist the heat, ceramic materials were to be used in addition to high nickel alloy steel, molybdenum, and columbium. The heat resistant materials were to radiate the heat from the surfaces of the craft back into the atmosphere. Nevertheless, the surface of the

Dyna Soar would be so scorched, it would have looked like an old fashioned wood stove. However, it would have been a simple task to prepare the craft for re-launch.

The design also incorporated many other unusual features, including a main landing gear which was to consist of landing skids with wire brushes mounted on the them and a nose gear designed to resemble a shallow kitchen pan. This unusual combination was dictated by the fact the high re-entry temperatures ruled out rubber tires and lubricated bearings, and subsequently, conventional brakes.

X-20 (Boeing)

By 1961, the design was frozen and the Air Force formally ordered ten production vehicles. At that point of time, it was planned to fly seven scale models of the ***X-20*** on top of ***Scout*** rockets into sub-orbital trajectories to test high speed flight as well as thermal protection. It was further envisioned that air drop tests would commence in 1963 using a B-52 mothership. These flights, which would be unmanned as well as manned, would take place over **Edwards Air Force Bas**, in California.

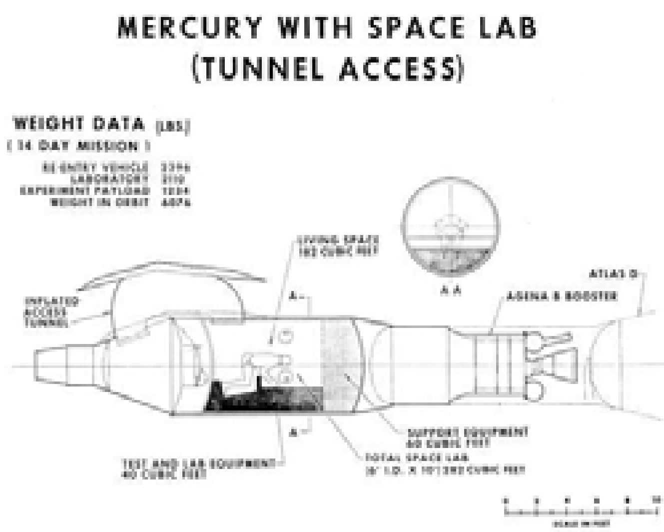
In 1964 the first unmanned sub-orbital flight was to take place, with the first unmanned orbital flight to occur in late 1965. After two such flights, the first manned orbital flight was scheduled for early 1966, after which flights at three months' intervals were planned. At that point in time, funds would be made available for a total of 12 flights. All orbital flights were to be launched by a modified **Martin *Titan*** launch vehicle.

But in mid-1961 the government, in the embodyment of the Secretary for Defense *McNamara*, began to question the project and delays crept into the program, leaving only the pure space flight aspect as viable. When it appeared that this was adequately being met by the other crewed space projects of the United States, eventually the entire ***Dyna Soar*** project was cancelled. By then, Boeing had built a full scale mock-up of the ***Dyna Soar*** and some material for production had been cut, although no construction had commenced. The Air Force had already selected a number of potential pilots for the project's initial phase and subsequent 'operational' phase.

Like the later MOL program, the ***Dyna Soar*** project was not directly connected with the lunar effort which dominated the United States' thinking in those days. It is further doubtful whether the project had any significant direct impact on the ***Space Shuttle*** project. Nevertheless, had the project been completed, it would have provided the United States with an alternative means to space and, as such, the cancellation of the ***Dyna Soar*** program must be considered an unfortunate occurrence.

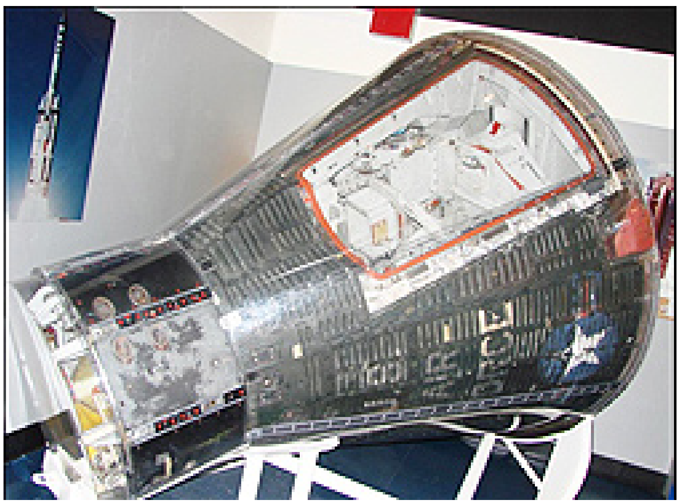
Mercury Developments

When **NASA** developed the ***Mercury*** manned spaceflight project, the USAF showed great interest in potential applications of this spacecraft for military purposes. One of those possibilities studies involved the use of a Mercury capsule with a small, one crew space laboratory with a 280 cubic feet interior space. Access from the Mercury spacecraft to this 'miniature' space station was to be through an inflatable tunnel.



Blue Gemini

In a similar way as the USAF was interested in Mercury development, they also displayed an interest in a crewed Earth orbital facility based on NASA's ***Gemini*** spacecraft. ***Blue Gemini*** was the name given to an Air Force proposal to continue Gemini flights after ***Gemini-12*** for Air Force research purposes and the development of a satellite inspector. The program envisaged seven flights, which were to land with a paraglider wing and skids, rather than in the sea. But in 1963, Congress refused to fund Blue Gemini and the proposal lapsed.



MOL

The ***Manned Orbiting Laboratory*** (**MOL**) program was commenced in 1963 as an alternative to the Dyna Soar project. The objective of this program was to demonstrate the functioning of a crew performing military functions in space. This knowledge was deemed essential before any specifications of an operational nature could be drawn up and, as such, the program was more scientific and engineering in nature than directly of a military nature.

It was anticipated that during a series of 30 day duration flights, a range of scientific, technical, and biological experiments could be conducted while a number of EVA's would evaluate the ability of an astronaut to work outside the spacecraft.

Given the go-ahead on August 15, 1965, ***MOL*** was to comprise of the ***Gemini B***, a Gemini spacecraft with the original Service Module removed and an access hatch cut through the heat shield, and a new, non-recoverable, *Laboratory Module* which could accommodate the two crew members during their mission. The latter would have an aft section with living quarters and a forward section for the mission experiments. The dimensions of the Laboratory Module, which was to be built by **Douglas**, have been quoted as 3.05m in diameter and 12.8m in length. The weight was 9100 kg.

The program envisioned seven flights, the first two of which would be automated, with the remaining flights being crewed and taking place at six months' intervals. The ***MOL*** was to use the ***Titan IIIM*** version of the ***Titan IIIC*** launch vehicle, which was to be fit-

ted with two larger solid fuelled strap-on boosters. All flights were to be launched from **Vandenberg AFB** in California, into a polar orbit, which would ensure that any sensitive instrumentation would not fall over foreign territory should a mission fail.

Commencing in November of 1965, 17 military astronauts were selected for the program. By 1964, 12 primary and 18 secondary experiments had been selected for the ***MOL*** project.

However, from the start. the MOL project was bedevilled by the twin problems of development delays and a perception that the project was a duplication of NASA's plans for the ***Apollo Applications Program*** and the ***Manned Orbital Research Laboratory*** (**MORL**). The latter was a study of the feasibility of adapting a ***Saturn 1B*** stage into an orbiting laboratory and eventually materialized as ***Skylab***.

On November 3, 1966, the one and only ***MOL*** research flight was launched using the ***Gemini*** that had been recovered from the unmanned ***Gemini-2*** mission. The flight was not identified as ***MOL*** but rather by the designation of one of its three payloads: ***OV4***. The 9661 kg *Orbiting Vehicle* (OV)4 3 was a boiler plate model of the Manned Orbiting Laboratory to which the reconditioned Gemini-2 spacecraft was attached. The objective of the flight was to test the launch vehicle configuration as well as to qualify the MOL heat shield. By 1969 the first launch date had slipped to 1972 and the MOL project was eventually cancelled on 10 June 1969.

Space Shuttle

The ***Space Shuttle***, in its initial plans, offered the military a means to gain quick access to space for pure military purposes and a series of military flights were planned of which most were to be launched from a separate launch facility at **Vandenberg Air Force Base**, in California.

A first flight from the Vandenberg launch site was scheduled for March 20, 1986, and was to be flown by the orbiter ***Discovery*** as the ***STS-62A*** mission. However, less than two months earlier, the demise of the orbiter ***Challenger*** on January 28, 1986, had suspended all flights of the Space Shuttle. Before that, two Space Shuttle flights (***STS-51C*** and ***STS-51J***) had been two dedicated military flights conducted from the Kennedy Space Center.

In the wake of the Challenger disaster, a comprehensive review of the Space Shuttle program saw the use of the launch vehicle for scientific purposes only. It was, in principle, no longer to be used as a launch vehicle for commercial satellites or military application flights. Also, all flights from Vandenberg, for which at least another seven had been planned for the 1986 to 1988 time frame, were cancelled.

Name	Int.Des.	Launch	Payload
STS-51C	1985 010A	24-Jan-1985	Magnum-1
STS-51J	1985 092A	3-Oct-1985	DSCS III-2, DSCS III-3
STS-27	1988 106A	2-Dec-1988	Lacrosse-1
STS-28	1989 061A	8-Aug-1989	USA-41, A.Jumpseat-1
STS-33	1989 090A	23-Nov-1989	Magnum-3
STS-36	1990 019A	28-Feb-1990	KH 12-1
STS-38	1990 097A	15-Nov-1990	KH 12-3
STS-39	1991 031A	28-Apr-1991	IBSS, CRO-A, CRO-B, CRO-C, MPEC
STS-44	1991 080A	24-Nov-1991	IMEWS-16
STS-53	1992 086A	2-Dec-1992	A.Jumpseat-2

Dedicated military Space Shuttle flights

A number of military flights were still conducted from the **Kennedy Space Center** between 1988 and 1992, but the use of the Space Shuttle as a ready access to space vehicle, had lapsed.

Dedicated Military Space Shuttle Flights

Expendable launch vehicles

With the loss of the Space Shuttle as a ready launch vehicle for military as well as civilian payloads, military space users again turned their attention to the use of expendable launch vehicles. But the usual time it takes take to get a *Delta* or ***Atlas*** launch vehicle ready for launch was considered too long for some military applications and the search for a quick response launch vehicle that could place payloads in orbit within a few days of a launch request remained a priority for the U.S. military.

Four current launch vehicles are perhaps best capable to meet the U.S. Air Force's requirement for quick response vehicles.

In 1990, **Orbital Sciences Corp**. and **Hercules Aerospace** introduced the ***Pegasus*** winged launch vehicle as an inexpensive way of launching small payloads. The vehicle is propelled by three solid fuelled stages and is air-launched by a ***Tristar*** launch aircraft, thereby avoiding the usual first stage. The initial flights were air-launched from a ***B-52***.

The basic ***Pegasus***, which also has the military designation ***ASB-11A***, had a small, delta-shaped wing with a span of 6.70m attached to its first stage and the entire vehicle had a length of 15.50m. The payload bay had a length of 1.83m and a diameter of 1.22m. It had the capability to place a 375 kg payload into low orbit. The first flight of the Pegasus was on April 5, 1990 and up to June 7, 2002, there were nine flights.

Pegasus XL

The current version is the ***Pegasus XL***, an improved version with increased propellant and a length of 17.60m. It has a capability to place a 443 kg payload into low orbit. The first flight of the ***Pegasus XL*** was on June 27, 1994 and the launch vehicle remains in use.

Orbital Sciences also developed the ***Taurus*** series of launch vehicles by matching the three stages of the Pegasus vehicle (less the wings) with a new upper stage. The first flight was on March 13, 1994, and to date there have only been eight flights, of which two, including the latest flight on February 24, 2009, were a failure. The Taurus rocket has a proven 'gestation' time of just a few weeks, thanks to the simple launch site that's devoid of a large gantry or other major infrastructure need.

The use of redundant ***Minuteman II*** missiles as space launch vehicles has been the subject of a number of proposals. Only one of these proposals resulted into an actual launch vehicle when Orbital Sciences combined the modified first and second stages of the Minuteman II missile with the Pegasus upper stages and avionics. Named the ***Minotaur 1***, it offered the combination a

Taurus II launch vehicle
(image courtesy Orbital Sciences)

Falcon launch vehicle (image courtesy of SpaceX)

launch capability of 640 kg into a low orbit. The first launch was on January 27, 2000, and to date only six flights have occurred.

Developed by **Space Exploration Technologies** (**SpaceX**), the ***Falcon*** series of launch vehicles will provide a low cost launching facility through the use of standardized engines, which are clustered to achieve a desired launch vehicle. Its objective is to provide low cost launch vehicles and it is intended that the first stage be re-usable after a return to Earth via parachute and into a water landing. The launch vehicle makes use of existing materials and components, but the liquid fuelled ***Merlin*** and ***Kestrel*** rocket motors are newly developed. The first flight was on September 28, 2008.

Future launch vehicle developments include the ***Hybrid Launch Vehicle*** (**HLV**) proposals by **Northrop Grumman**, **Lockheed Martin** and **Andrews Space** that envisage a launch vehicle consisting of a reusable airplane as the first stage with expendable upper stages. The first stage would use a rocket engine for boosting the payload up to an altitude of 45 km where the upper stage would separate and send the payload into orbit. For the return to the launch site (or any other site for that matter), the first stage would use jet engines. The HLV would include medium-lift and heavy lift configurations.

The use of ***C-17*** military transport aircraft as a vehicle for air launches has been tested in the joint

Artistic rendition of HLV, courtesy of Lockheed Martin

USAF-Defense Advanced Research Projects Agency '*QuickReach*' program to evaluate the air launch techniques for a low-cost, rapid-reaction small satellite launcher. On September 29, 2005, a dummy rocket was successfully released from the cargo bay of a C-17. At an altitude of about 10 km, the dummy rocket was pulled away from the cargo bay by means of gravity. On June 14 and July 26, 2006, further tests were conducted, again using a dummy rocket. The operational QuickReach will have a length of 20m and a diameter of 2.50m.

It is clear for any of these launch vehicles to be used as a 'quick launch vehicle', with a limited preparation time, a range of requirements still need to be met. In particular, the hardware (*i.e.*, rocket and spacecraft) required for a quick response launch requires time to manufacture and, unless a stockpile of launch vehicles and spacecraft are established, a quick response space vehicle will remain elusive.

About the author

*Jos Heyman is the Managing Director of Tiros Space Information, a Western Australian consultancy specializing in the dissemination of information on the scientific exploration and commercial application of space for use by educational as well as commercial organisations. An accountant by profession, Jos is the editor of the **TSI News Bulletin**.*

MAJOR TRENDS IN THE TACTICAL USE OF MILSATCOM

by Dan Dia-Tsi-Tay, Regional Manager Asia Pacific, ***SWE-DISH Satellite Systems***

While Military Satellite Communications (MILSATCOM) has been used for strategic communications as reachback between field command posts and headquarters for decades, recent technology advances in the satcom field is enabling faster deployment of highly mobile forces capable of adapting quickly to changing conditions in the field.

Worldwide, military organizations are in the process of transforming into network-centric, information-based forces. New requirements are re-defining the need and use of communications. Innovations are shaped by new operational concepts and weapon and sensor trends. In the new paradigm, communication is not only an enabler but is directly affecting the outcomes of wars. Tactical use of MILSATCOM play a pivotal role in providing the interoperable, robust, "network-centric" communications needed for future operations.

Experiences From Operation Iraqi Freedom

Operation Iraqi Freedom (**OIF**) validated some of the expected benefits of a joint and fully networked force — massing of effects rather than force, high force exchange ratios through better situational awareness, and coordinated engagements. OIF achieved a 70-90 to one exchange ratio, meaning that for every coalition force soldier, there were 70 to 90 Iraqi soldiers.

A hidden factor underlying these success factors was the far superior communications capability of the U.S. forces as compared to those of the Iraqis. U.S. forces were able to maintain close coordination, disseminate sensor and intelligence information, and enable coordinated strikes over an expanded theatre of operations.

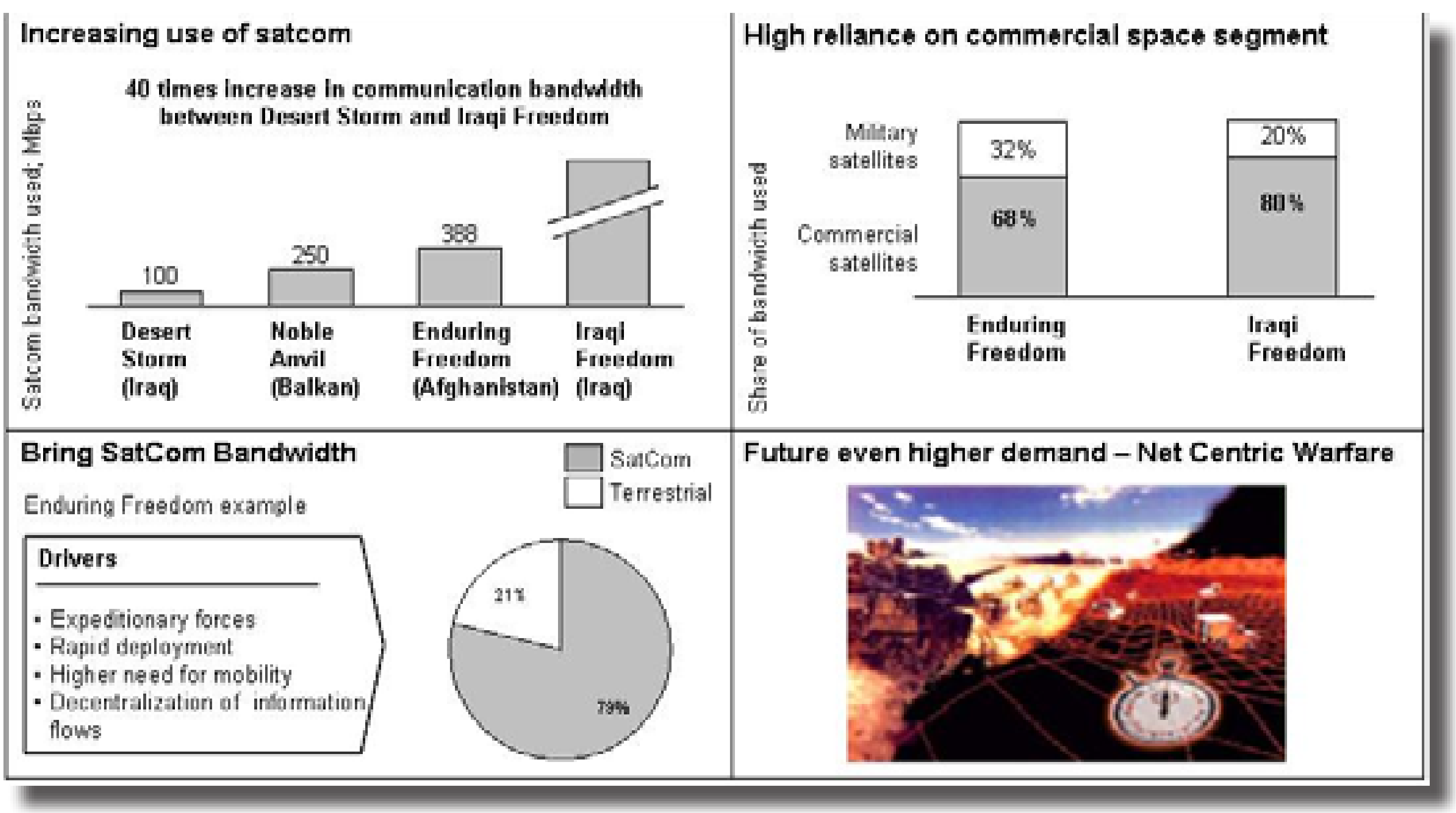


Figure 1
Use of MILSATCOM during recent conflicts
The same trend could also be seen in the ground segment, where Commercial-Of-The-Shelf (COTS) terminals in military use outnumbered dedicated military-built terminals.

While the deployment of troops and application of munitions have dropped drastically, the demand for communications has increased dramatically. The number of troops deployed in OIF was roughly 300,000, compared to the 500,000 troops in ***Operation Desert Storm***, while the bandwidth used for satellite communication increased from 100 Mbps to almost 4 Gbps — 40 times more bandwidth for a 40 percent smaller force. The increased bandwidth allowed coordinated use of UAVs, which improved situational awareness. Voice communications increased by 40 times and secure data communication 6 times. It also allowed Video Tele Conferencing (VTC) and desktop collaboration tools to be extensively used for *Communication and Control* (**C2**).

This massive increase of satellite bandwidth could not be catered for by dedicated military satellites — as a matter of fact, all but 20 percent of the used capacity came from commercial satellites.

"It helped us speed up the operational tempo significantly". The quote is from a high ranking U.S. military official discussing the broadband satellite communications network used by the **US V Corps** in OIF. The network used a new generation of lighter, easier to use, more rugged broadband satellite systems. Its successful performance in combat operations gave a hint both on the future role of MILSATCOM and on the ground equipment that will be used.

U.S. V Corps' Assault Command post, Western Iraq, 2003. A SWE-DISH DA150K satellite antenna mounted on top of LTG Wallace's Command and Control Vehicle. Satellite communications enabled him, as the first US commander in modern history, to lead his troops from the front.

General *Tommy Franks*, the Commander of the **U.S. Central Command** during OIF, stated that "the most important lesson from Operation 'Iraqi Freedom' is that networked forces rule the battlefield."

A Force In Transformation

The end of the Cold War era has changed the nature of threats and conflicts around the world. What used to be a West vs. East standoff between two superpowers has changed into a world with scattered regional and ethnical conflicts and a global threat from terrorists and insurgents. The switch from the Cold War era territorial defence to modern expeditionary warfare also affects the military organizations.

Today's forces are not only deployed for war fighting. They are involved in counter-insurgency operations and global peace keeping mission. The military also often play an important role in disaster response and recovery operations. Apart from territorial defence many of these missions take place on foreign grounds.

The traditional hierarchical organization is not suitable for the new environment. The key to the flexibility required by the military to meet the new challenges is to have an organization that can adapt to the different operational needs — a task force organization. The task force is tailored to be best equipped to fulfill a certain mission, and that accounts for its competencies and resources - both human and equipment.

One example of this is the creation of the ***European Union Battlegroup*** (**EUBG**) organization. Not only the military organization, but also the soldiers themselves are affected by the changes. The soldiers have many roles to fulfill — war fighters, peace keepers, relief workers, and so on. As part of a global security community, they also have to be prepared to work together with people from other nations, cultures, and backgrounds in places far from home.

Their roles as war fighters have also changed. From previously being specialized in one area, they are now required to be more multi-functional, which brings demands on new competencies and equipment. Apart from weapons and body armor the soldiers are also required to carry various sensors and communication equipment — all on which they have to be properly trained.

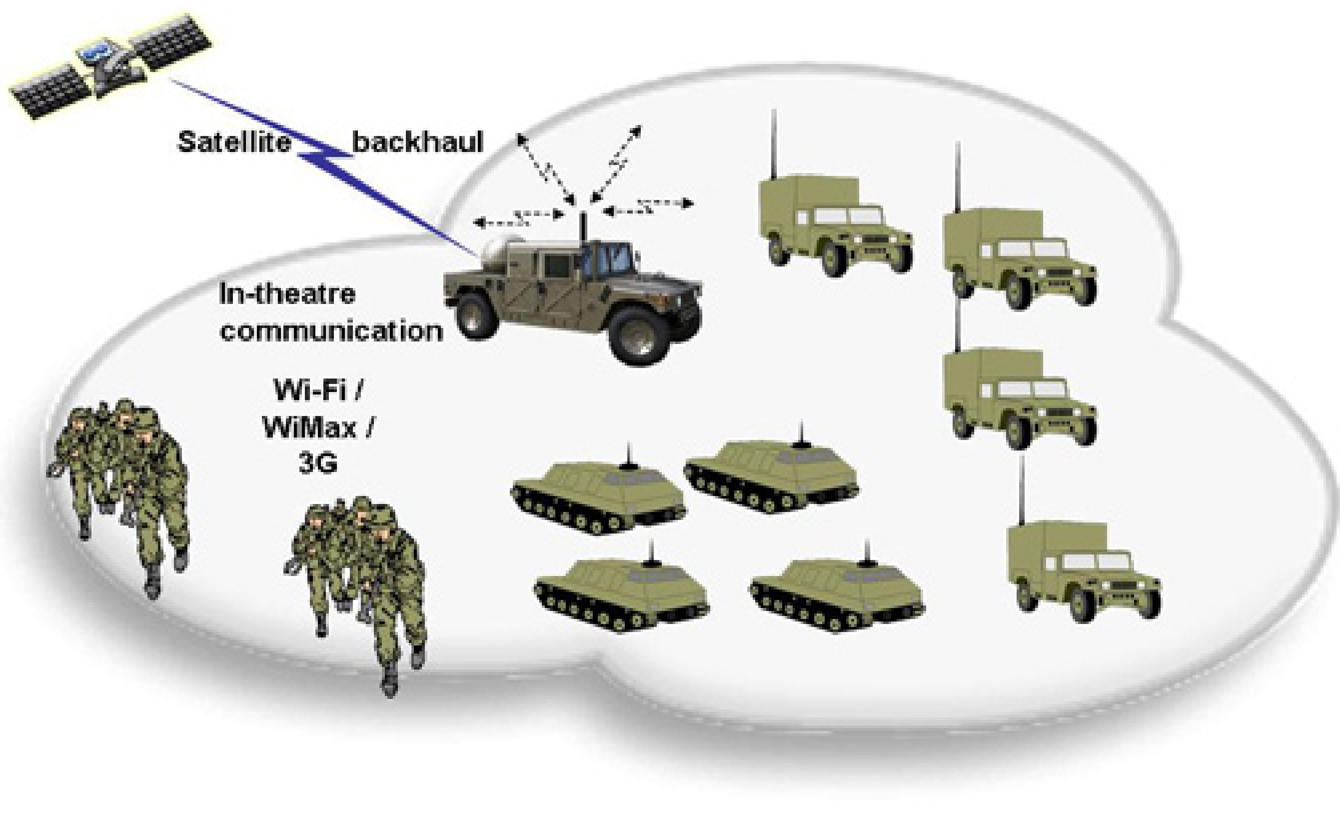
Tactical MILSATCOM

Strategic MILSATCOM is traditionally used on a division or brigade level and operated by specialized satellite engineers from the Signals Corps. The introduction of MILSATCOM into tactical use puts new requirements on the terminals as well as the users. Its use at lower echelons puts strong demands on size and operability of the terminals as the users are mobile units with limited space to spare and operates under constant time constraints.

Three typical operational modes of tactical MILSATCOM are commonly described as ***COMMUNICATIONS*** or ***SATCOM-ON-THE-HALT*** (**C/SOTH**), ***COMMUNICATIONS*** or ***SATCOM-ON-THE-PAUSE*** (**C/SOTP**) and ***COMMUNICATIONS*** or ***SATCOM-ON-THE-MOVE*** (**C/SOTM**).

C/SOTH

This is defined as when terminals are in one, fixed position for several days up to several months in duration. The terminals are typically larger transportable systems (from 2.4m and upwards) operated by communication experts and used as temporary anchor stations for reachback communications from field command posts to headquarters for various applications, such as: Command and Control (C2); Intelligence, *Surveillance and*



Example of extending C/SOTM reach down to the soldier level

Reconnaissance (**ISR**); remote specialist functions; and soldier welfare (communication with home).

C/SOTP

This is mainly used by company level and below and the terminals are deployed during short stops — minutes/hours/days. The terminals must be compact and easy to use as mobility and quick deployment is critical. They are commonly used for in-theatre communication to support VTC and battlefield planning collaboration, operated by soldiers with limited training in comms.

C/SOTM

These systems provide real-time communication while on the move. They must provide continuous connectivity and be able to automatically and rapidly recover from signal blockages, due to man made objects, terrain/foliage, weather and other atmospheric effects.

C/SOTM are deployed on various types of vehicles serving as mobile command posts, reconnaissance teams, missile and artillery units etc covering a wide range of applications including: Command and Control, which tends to be asymmetrical with most bandwidth to the remote terminal; and Intelligence, Surveillance and Reconnaissance (ISR), where data is generated on the remote platform, so while also asymmetrical, most bandwidth is from the remote terminal. New applications also include soldier-system interoperability where individual warfighters have wireless connectivity to the SOTM vehicles and back into field or headquarters command centres.

The biggest issues for implementation and growth of SOTM services include: interference and regulatory compliance; compatibility with legacy networks and systems; limited power from satellite beams that may have been designed for larger antennas; limited bandwidth; and the need for terminals to operate across multiple platforms — on the ground, sea, or in the air.

Requirements On Tactical MILSATCOM Terminals

The current and future operational requirements of tactical MILSATCOM for expeditionary forces sets a number of conditions the terminals must fulfill. To support truly global operations all terminals must:

- ***Support true broadband connectivity - Mbps and upwards***
- ***Be compliant with all satellite operators (including requirements for 2° orbital satellite spacing)***
- ***Support multi frequency band operation***
- ***Be compatible with legacy protocols and nets***
- ***Provide seamless communication with existing portable, mobile & fixed assets***
- ***Operate on same family of satellites as existing ground terminals***
- ***Support both star and mesh networks***
- ***Be operational in SCPC, TDMA and DAMA nets***
- ***Support quick and automatic deployment — no operator intervention***
- ***Be easy install, operate and maintain***

Additional requirements for C/SOTM terminals are:

- ***Instant re-acquisition after blockage***
- ***Support pole-to-pole operation without keyhole effects (requires 4-axis stabilization)***
- ***Support platform independence (land/sea)***

By using terminals built on common modular system architecture the users can easily adapt the systems to rapidly evolving operational needs, thereby significantly reducing the total cost of ownership. Field replaceable antenna-, transceiver- and modem modules provide maximum flexibility and minimum unavailability.

About the author

Dan Dia-Tsi-Tay *is Regional Manager for Asia Pacific of SWE-DISH Satellite Systems,*

a world-leading supplier of mobile satellite communications equipment and related services for broadband applications, recently acquired by DataPath. He has more than 20 years of experience from the communications field from several senior management positions in the communications sector in the region. Mr. Dia-Tsi-Tay has a Master of Science in Electrical Engineering from the Royal Institute of Technology in Sweden.

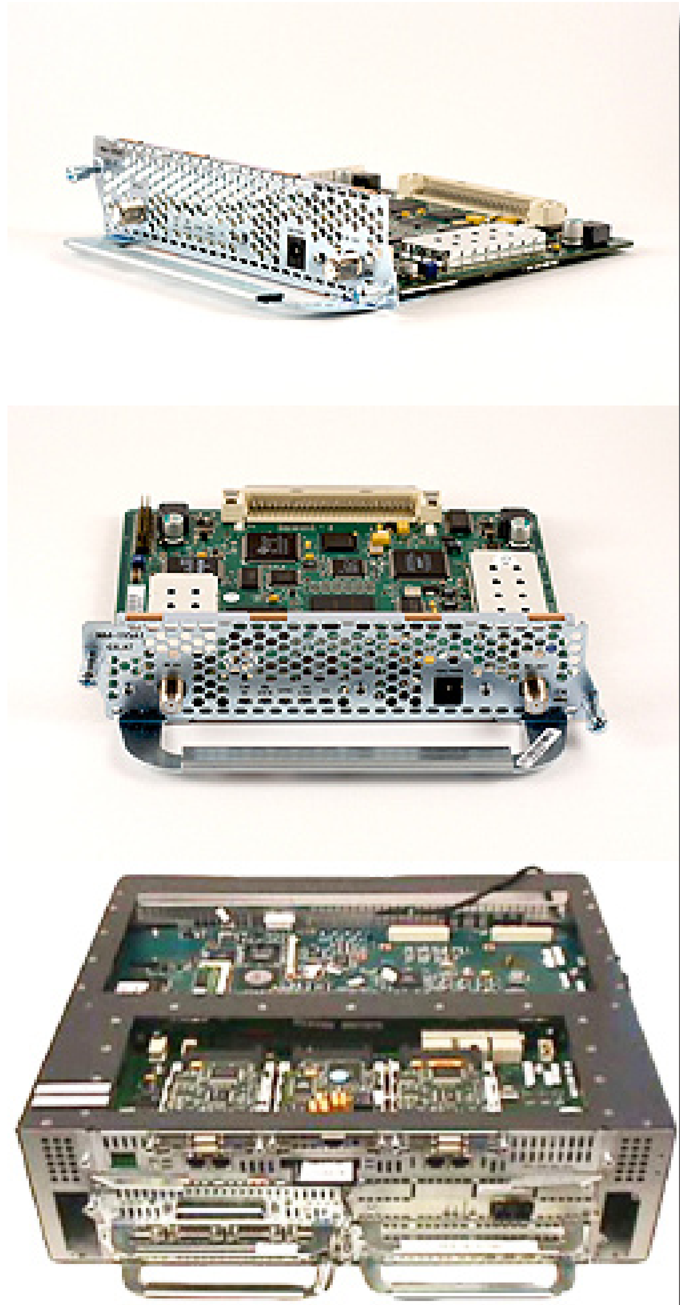
PROCUREMENT POTENTIAL
CISCO INTEGRATED FIPS SOLUTION OVER SATELLITE

*by Jon Douglas, Director of Marketing, **Spacenet***

Satellite networks have long been a key technology used by federal, state, and local government agencies to provide a variety of communications solutions. The satellite's unique ability to provide simultaneous, multicast data to thousands of sites over a huge geographic footprint, independent of terrestrial networks, provides a variety of flexible solutions for government agencies. Satellite is an ideal technology to support primary networks in mission-critical applications and offers transportable solutions for rapid deployment and disaster recovery as well as a continuity of operations (COOP) solution.

Satellites posses a high level of adaptability for a variety of situations — government organizations deploying satellite networks must account for a variety of requirements and options to ensure their communications network infrastructure is fully capable of supporting an agency's mission-critical applications. Some of these considerations include coverage, cost, bandwidth efficiency, mobility, ease of integration, reliability, and, of course, security. The challenge is to find the correct balance of all the requirements, ultimately providing a network infrastructure that enables an organization to successfully fulfill its mission without going over budget or requiring too many resources.

For example, front line military users might have a higher requirement for physical security, mobility, and higher encryption needs for highly classified data. Civilian agencies might have a high requirement for security, but this must be tempered with the practical need to balance against cost, reliability, and the supportability. State and local agencies may require mobility, but must be willing to sacrifice some network security. The one element agencies have in common is a push to use "off the shelf" solutions whenever possible. Government security standardization, particularly the FIPS 140-2 standard, has enabled government communication providers to ensure security validation for their sensitive but unclassified data, while providing greater standardization and economics.

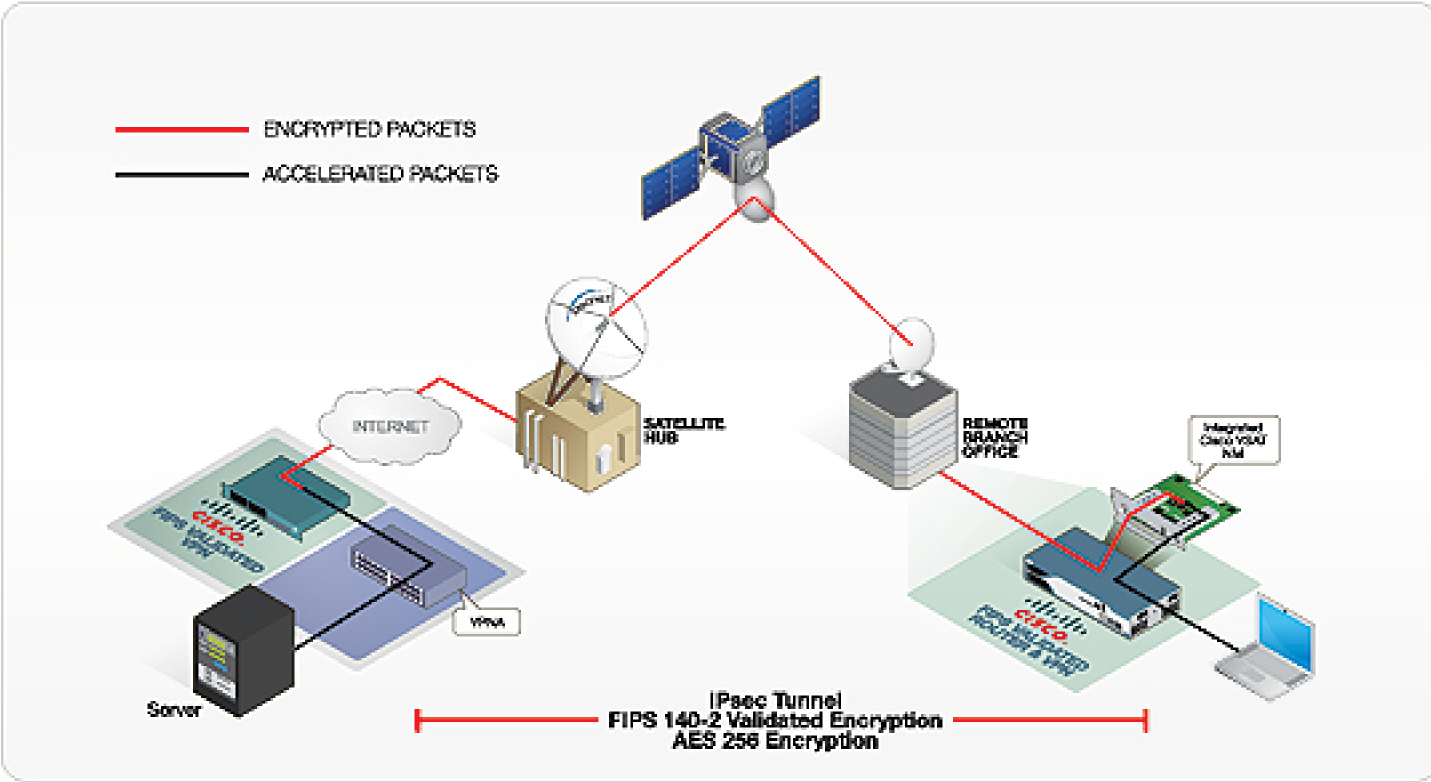


FIPS is published by the ***National Institute of Standards and Technology*** (**NIST**) and defines the security requirements that must be satisfied by a cryptographic module used in a security system protecting unclassified information within IT systems. The **FIPS 140-2** standard is an information technology security accreditation program produced by private sector vendors who seek to have their products certified for use in government departments and regulated industries that collect, store, transfer, share and disseminate "sensitive, but unclassified (SBU)" information.

By law, U.S. government purchasing agents must purchase the product that is certified for FIPS 140-2 (or FIPS 140-1), over one that is not so certified. FIPS 140-2 is also required in Canada and is also recognized in Europe and Australia.

FIPS compliance has become an integral part of network communications, including common carrier and satellite technologies. Today, new solutions, including the **Spacenet** and **Cisco FIPS 140-2** certified encryption solution over satellite, provide new options to government organizations that need to meet strict security options and meet their full range of network requirements in a format they can support. By integrating this solution with the Cisco platform, the Spacenet solution delivers ease of implementation, uses existing infrastructure, and simplifies the ongoing management of the platform. For customers, this means less initial training required and fewer platforms for the IT group to support.

The Spacenet and Cisco FIPS certified encryption solution over satellite provides government agencies expanded satellite communications options, including services for CONUS based Department of Defense agencies and backhaul services between EMEA and the U.S. The solution supports mission-critical disaster recovery, backup networks, and other on-demand applications that are integrated directly into existing infrastructure. The ***Cisco VSAT Network Module*** helps enable easy deployment of satellite networks integrated directly with an organization's existing Cisco router equipment and enables overall simplified network management. Competitive solutions use multiple devices, which increases the complexity of the system and adds components that may fail. Satellite services combined with the Cisco VSAT Network Module reduce complexity and eliminates the problem of multiple points of failure by using the Cisco router.



"The combination of Spacenet's fully managed service, with industry-leading SLA's and Cisco's integrated FIPS 140-2 certified module delivers a whole new level of flexibility to government agencies as well as the ability to use their existing Cisco platform and investment," said Spacenet Vice President of Government Services *Mike Mazza*. "This ability to take advantage of existing infrastructure should also reduce the training required by agencies to deploy the service or to maintain it."

Spacenet's integrated VSAT Cisco solution supports FIPS 140-2 and also supports acceleration of the encrypted traffic without the need to install additional devices at the remote location. The solution uses the Spacenet and Cisco codeveloped *Integrated Acceleration and Encryption* (**ITAE**) technology to provide end-to-end accelerated FIPS 140-2 certified encryption over satellite. The ITAE feature provides an integrated single box solution at the remote office that combines encryption and acceleration. It enables optimized support for site-to-site VPN and secure voice over satellite while providing efficient utilization of the satellite link, increased throughput, reduced latency and increased cost efficiencies. The ITAE solution enables organizations to deliver applications securely without the need to sacrifice user experience or to modify the method of application delivery.

FIPS Security

Government agencies rely on their networks to transport mission critical application data to and from multiple locations. FIPS certification over satellite insures network security to protect sensitive information through data, voice, and video transmissions. The Spacenet and Cisco FIPS solution expands the satellite options available for government organizations to support mission-critical applications including emergency response and continuity of operations, and provides assurance that it meets strict government security and testing requirements.

In addition, the Spacenet and Cisco FIPS certified encryption offering provides a more cost effective solution for meeting the security requirements of government agencies that don't require the higher levels of more extensive security options. At the same time, it provides the flexibility of leveraging existing Cisco infrastructure, providing a better solution that meets an organization's network size, cost and throughput requirements.

About the author
Jon Douglas is Director of Marketing for Spacenet and brings more than 18 years of marketing communications expertise in the telecommunications and IT sectors. Email: jon.douglas@spacenet.com.

PROCUREMENT POTENTIAL
KEEPING UNMANNED SECURITY VEHICLES ON TRACK

Frontline Robotics' GRUNT AUGVs (*Autonomous Unmanned Ground Vehicles*) are robots that perform perimeter patrols and other security tasks to enhance the efficiency within airports, container yards, and other critical security locations, as well as improving overall safety for soldiers or guards.

The **GRUNTs** (short for ***unmanned GRound UNiTs***) rely on **Frontline**'s ***ROC***™ (*Robot Open Control*) operating system, which enables multiple AUGVs to collaborate and further improve security and reconnaissance over large areas. **KVH Industries**' ***CNS-5000 Continuous Navigation System*** is a key component of the GRUNT, providing critical navigation and position data via a combination of KVH's *fiber optic gyro* (**FOG**)-based inertial measurement technology and **NovAtel**'s global positioning system (GPS) technology.

Challenges

Navigation and position are critical to **AUGVs** for successful autonomous decision-making and plan implementation. As each vehicle in a team of vehicles is preprogrammed to complete missions and achieve conditional goals, it is important that the vehicle knows precisely where it is and where it is going at all times. This can be difficult, especially in areas where terrain is unpredictable or GPS is fully or partially blocked.

The Continuous Navigation System

The ***CNS-5000*** combines FOG-based inertial measurement technology with NovAtel's GPS technology to provide higher reliability and improved performance compared to other navigation solutions. Its deeply coupled design affords superior bridging capability between the two technologies when GPS reception is obstructed or unavailable. This allows the CNS-5000 to switch effectively between an optimal combination of GPS and inertial measurements when GPS is available, and reliable inertial data when it is not (for example, in urban settings or heavily wooded areas). The CNS-5000 can rapidly reacquire the satellite signal when it becomes available after an outage, and can continuously deliver the most accurate and precise position, velocity, and attitude information possible in any situation.

"Frontline Robotics has been building turn-key autonomous unmanned ground vehicles using KVH and NovAtel sensors for four years," says *Jeremy James*, President and CEO of **Frontline Robotics**. "The data from these separate sensors was fused by algorithms executing in our proprietary control computer. The fused data provide localization for the automatic navigation software. The CNS-5000 physically integrates the functional capabilities of the KVH inertial and NovAtel GPS sensors into a single package. Furthermore, the CNS-5000 fuses the data from these sensors internally and provides this information directly to the control computer of an autonomous UGV. The combination of these fundamental sensing capabilities along with data fusion is a cost-effective solution for our autonomous unmanned ground vehicles."

Critical Attributes

Integrated navigational tools allow multiple GRUNT units to work in robotic synergy, using a "hive mind" that is controlled by the ROC. This can double or even triple perimeter reconnaissance or security capacity, replacing soldiers or guards and keeping human security forces out of harm's way in the event of a breach or assault on the facility. GRUNT units use navigational data from the CNS-5000 in conjunction with input from optical platforms to resolve "safe" structures and landmarks from possible intruders or foreign objects. This provides maximum efficiency in perimeter patrols and monitoring while maintaining full and efficient perimeter coverage, regardless of the environment.

In critical and dangerous situations, GRUNTs can be equipped with both lethal and non-lethal payloads. When an intruder is identified, the CNS-5000's navigation technology works in conjunction with data

KVH's CNS-5000 Continuous Navigation System

from optical sensors to help the GRUNT identify the exact position of the threat and allow for accurate assessment in determining the appropriate action, using force only as necessary to secure the area or await support personnel. The combination of inertial measurement and GPS provides continuous location and position information, contributing to 100% situational awareness. This information is invaluable in rapidly developing critical situations where security is compromised and the safety of the facility may be at risk. The CNS-5000's rapid signal reaquisition means that the GRUNT uses the most accurate location information available in real time, while constantly maintaining precise navigation.

"Frontline Robotics' core capabilities are in algorithms for autonomous and collaborative behaviors of unmanned vehicles. We rely upon the expertise of sensor manufacturers such as KVH to provide quality sensor data," Mr. *James* explains. "If sensors are made more intelligent, there are significant benefits for Frontline because we can leverage the investments in sensor technology that KVH and NovAtel have made and will make to support our client base and market. The result is fused data that is smoother and more reliable than the data from our own data fusion algorithms. Therefore, Frontline AUGVs deploying the CNS-5000 will have more reliable location-based positioning data. Furthermore, the CNS-5000 offloads data fusion algorithmic computations from our own control computer so that the vehicle's control computer can do more application-specific work."

Results/Impact

By integrating KVH's CNS-5000 into the design of the GRUNT AUGV, Frontline Robotics was able to build 100 percent situational awareness into each AUGV, along with outstanding reliability when GPS is partially or completely unavailable. The CNS-5000's rugged, small form-factor design simplified the integration into the larger structure, which is a key benefit as Frontline Robotics often builds custom platforms to suit their customers' security needs.

"The CNS-5000 is commercial-off-the-shelf technology integrated into a compact, robust enclosure that is well suited to the demands of 24/7 operation in a variety of environmental conditions on a vehicle. In the existing form, the CNS-5000 meets current and future requirements for our target market which is AUGVs for the perimeter security of critical infrastructure," says Mr. *James*. "These include, for example, the perimeters of airports, borders, nuclear power stations, and military bases."

About the company

Frontline Robotics is committed to keeping people out of harm's way with intelligent, mobile robots. If the task is dull, dangerous or dirty, robots should be in the front line. The company's mission is to elevate the robotics industry to address the serious threats faced by our society, addressed with integrity, imagination, and a sense of adventure.

COMM-OPS
DIGITAL TERRESTRIAL + MOBILE TV DEPLOYMENT OVER SATELLITE

by Koen Willems, Newtec

"The beginning of wisdom is to call things by their right names," a Chinese proverb states. Indeed, when it comes down to a Digital Terrestrial or a Mobile TV deployment, the money-question drops in eventually. A logical first reaction by broadcasters could be to request lower equipment prices to reduce the overall investment. Fair enough. But one might question whether such a short term measure could influence costs in the long run. Looking beyond the horizon, items such as operational issues, performance, maintenance, satellite bandwidth and quality quickly come to mind, each one of them nicely delivered with a price tag at the expense of the broadcaster.

This article takes a look at the cost considerations a broadcaster could face during a deployment over satellite and explains how technologies such as DVB-S2 multistream and regionalization can reduce the total cost picture. Some use cases will be added to illustrate an alternative approach to design Digital Terrestrial or Mobile TV installations.

Current Market Conditions

A quick browse through the news confronts us with topics on financial crisis, cost reductions, inflation levels — a bit more than we actually would like to know. We do not need to understand the root causes of the economic downturn to realize the market is reacting to major bank reorganizations, company reorgs, and governments manipulating their budgets.

As for the broadcast market, the financial resources obviously are not infinite. The economic slowdown may affect the media sector progressively as financing new satellite projects could become more complicated, resulting in fewer launches and satellite bandwidth capacity reduction. Due to the reduced bandwidth over satellite, it becomes increasingly important for new technology to obtain more 'bits per Hertz' over the same bandwidth. On the other hand, broadcasters and governments could choose to postpone new projects in order to optimize their current networks in a cost-effective way.

Some long term projects might not be directly exposed to the current economic crisis as they are bound to the regulatory environment and to government projects. One example is the Analog switch off in an increasing number of markets that needs to be completed before 2013 in Europe and North America. In times of financial crisis, governments tend to start up large projects to stimulate internal economics and to ensure employment. Still, there seems to be quite an interest in the satellite business as the financial injection of 10 billion Euros from the European Union (EU) towards the European Space Agency (ESA) clearly illustrates.

Low Cost Approach

With the installation of new projects, or the review of current projects, a natural reaction is to select low-cost equipment to fit the tight budgets available to deploy broadcast networks. This reaction towards financial harder times and budget restrictions for deployments is to purchase low cost material instead of best of breed equipment. The risk in purchasing lower cost equipment is easily identifiable, but sometimes forgotten by the price tag's blinding effect. Some examples are:

Quality

A first important consideration is quality. Broadcasters cannot afford to have downtime or to have bad picture quality because it will drive away dissatisfied customers (viewers), which could impact advertising revenues. Poor quality implies more service costs and more employee hours to recover broken signals. As some DTT (Digital Terrestrial TV) and Mobile TV towers are located on remote sites service engineers need to travel to these locations, or extra investments in communication lines need to be made to enable multiple and fast remote management control.

Internal parts consistency inside products

Another issue with low cost equipment is the tendency to replace internal parts during the product life cycle according to the market availability and price fluctuations, such as in the PC market where internal parts are changed every six months. As DTT and Mobile deployments mostly are planned over longer stretches of time a broadcaster could end up with equipment that has different internal parts, when discovered, increasing the difficulty of maintenance. Additionally it provides headaches in terms of spare parts supply after deployment.

Technology

A final consideration is that low cost equipment tends to stick with old technology, whereas new technology could bring features that have a big impact on other cost lines next to equipment cost. The switch for example from DVB-S equipment towards DVB-S2 already saves up to 40 percent bandwidth or 570k Euro per year (market average) on a transponder.

Price negotiations and comparison of different suppliers are natural steps in a purchasing process. This white paper tries to hold up a warning sign not to be blinded by short term price reductions, but, instead to look at long term impacts behind a purchase. What could be the Return-on-Investment behind acquiring new equipment? This aspect will be investigated further along in this article.

Why Satellite?

Satellite links have the advantage of not having to depend on any telecom infrastructure on the ground, and they certainly are the fast track option to deploy a digital terrestrial TV network over entire countries. With the right technology and equipment, satellite ensures a very economical way to perform the primary distribution of TV content. The operational costs do not increase with the number of towers and repeaters in the network, and last, but not least, satellite also provides very efficient methods to synchronize and manage towers remotely.

Technology To The Aid

Considering the cost issues broadcasters are faced with, new satellite network technology ideally focuses on aspects that touch the broadcaster operational issues on a daily basis. Some major cost issues are:

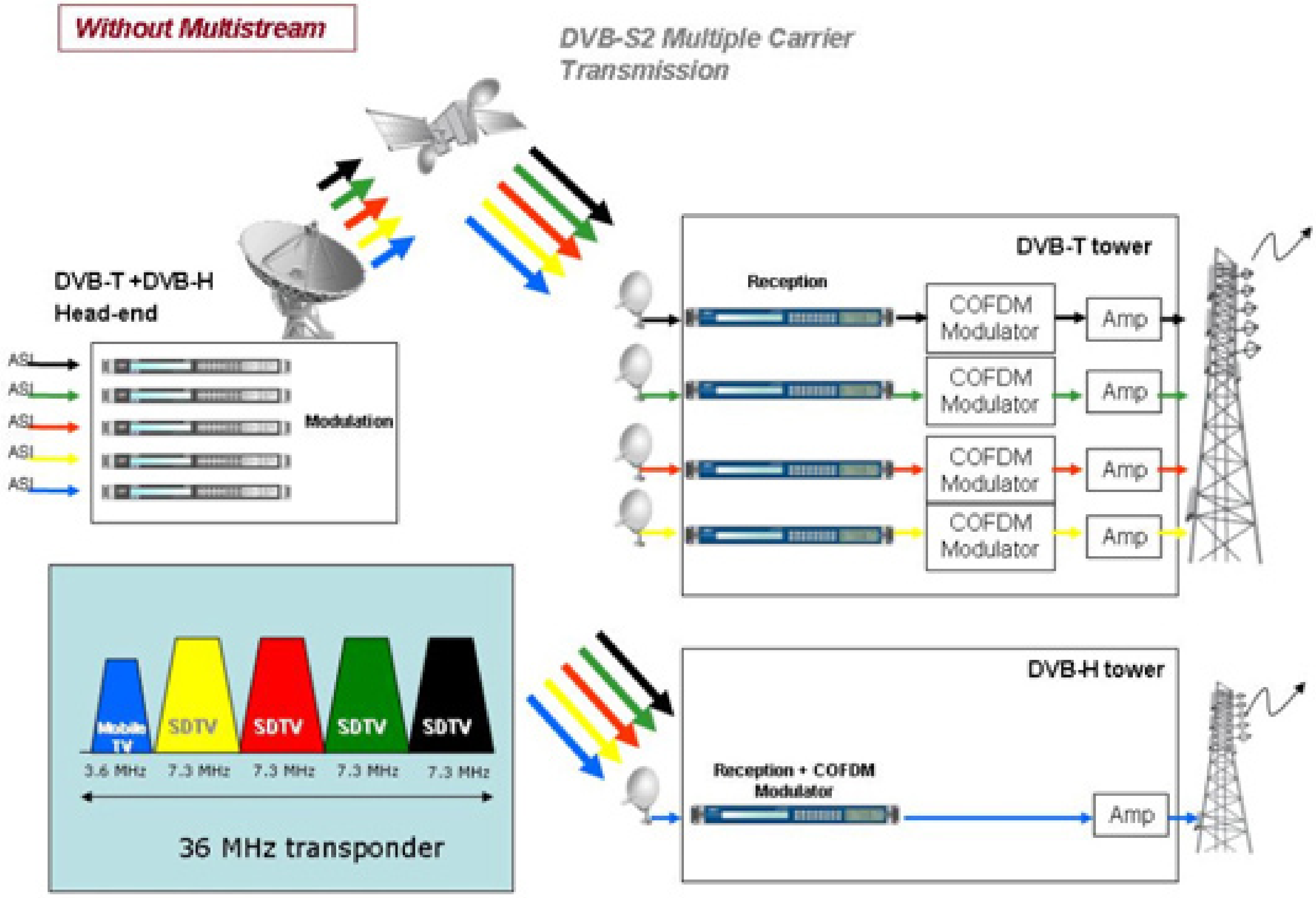


Figure 1
DVB-T/H Broadcast network with Multiple Carrier Transmission

- ***Cost of equipment: new satellite network technology should check whether it can reduce the amount of equipment that is needed to install an improved network.***
- ***Cost of operation: new satellite network technology should investigate how to put multiple services on the same carrier, and how to save bandwidth over a satellite link.***
- ***Cost of service: new satellite network technology should be easily installed/deployed and have a good reliability/MTBF.***
- ***Cost of content: new satellite network technology should protect the content of the satellite link in order to prevent piracy and (news) scoop hijacking.***

From DVB-S To DVB-S2

Currently we see the transition from the DVB-S standard towards the DVB-S2 for satellite links in the broadcasting market. DVB-S2 (*Digital Video Broadcasting - Satellite - Second Generation*) is an enhanced specification to replace the DVB-S standard. DVB-S2 is closely linked to the increased demand for High Definition Television (**HDTV**) over satellite. HDTV typically requires three times the bandwidth required for Standard Definition Television (**SDTV**) signals.

From a cost perspective, DVB-S2 has a performance gain over DVB-S around 40 percent, or 570k euros, on a yearly basis (market average) on a transponder. Alternatively, up to 2.5dB less power is needed to transmit the same information in DVB-S2 which reduces the energy costs.

Multistream

Multistream is a main advantage in satellite communication for Primary Distribution of Digital Terrestrial TV and Mobile TV and is fully complaint with

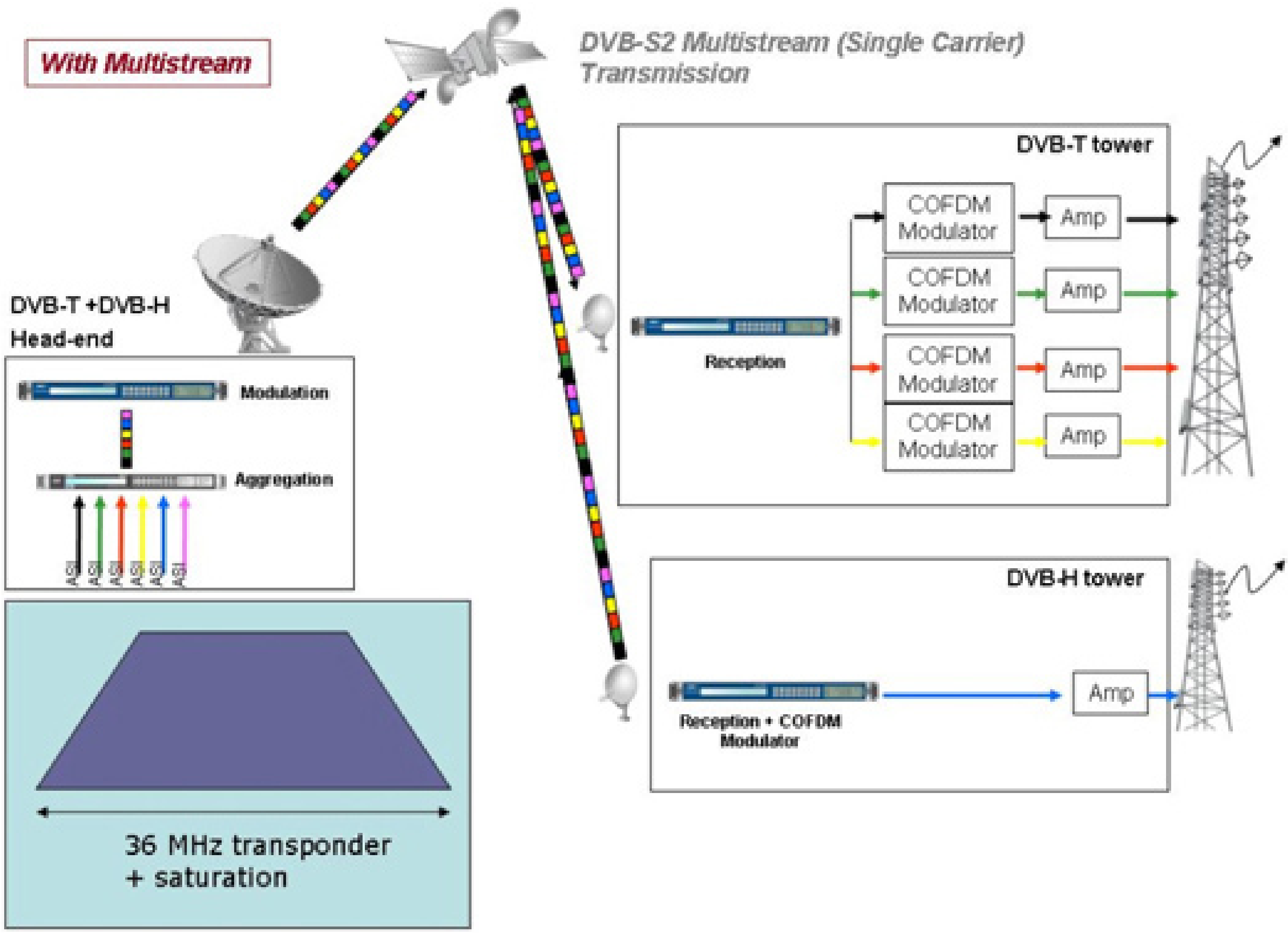


Figure 2
DVB-T/H Broadcast network with Single Carrier Transmission (Multistream)

the DVB-S2 standard. Multistream in short allows users to aggregate (combine) a number of transport streams, or IP streams, into one satellite carrier in a fully transparent manner, maintaining the integrity of the original content.

The application of Multistream within Primary Distribution of Digital Terrestrial and Mobile TV via satellite will be displayed in the following examples. The network examples have been simplified for clarity sake. In the first example (*Figure 1 on previous page*) a DVB-T/H network with multiple carriers is displayed. Each ASI input stream (can be a multiplex) is modulated separately and sent in different carriers over the satellite link. At the receiver end, separate devices (IRD's or demodulators) receive a selected carrier and send it through to the COFDM modulator in order to be amplified and transmitted to the end-user's (mobile) TV set. Looking closer at the 36 MHz transponder, five different carriers can be identified. Four carriers for standard TV signals at 7,3 MHz and one Mobile TV carrier at 3,6 MHz. Due to the risk of inter-modulation (explained later in the white paper) the satellite transponder cannot be saturated.

When compared to the previous example, some interesting differences can be noticed when building a Primary Distribution Network for Digital Terrestrial and Mobile TV over satellite with Multistream (*Figure 2*).

First, the amount of equipment has been drastically reduced. The different ASI input streams coming from terrestrial and mobile TV bouquets are aggregated (combined) and injected into the modulator. At the receiver end, a multi ASI output satellite receiver is preferred above multiple single ASI output receiver devices (*e.g.*, IRD's). Instead of 4 IRD's a single satellite receiver unit with multiple ASI outputs does the

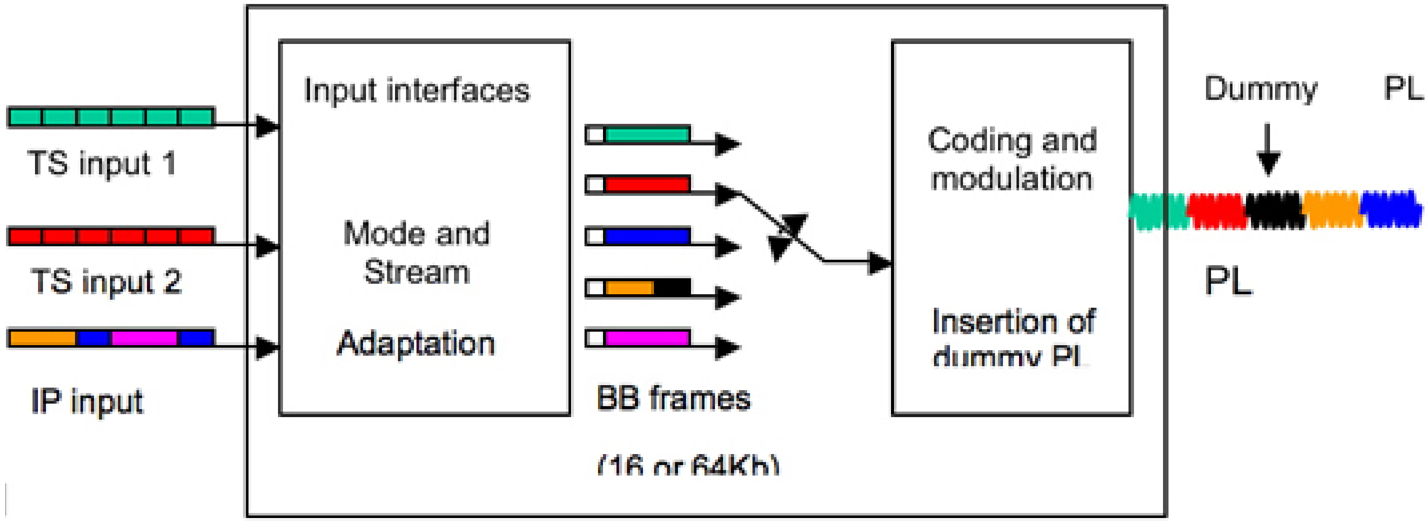


Figure 3
Multistream encapsulation and aggregation

trick. If we multiply this tower installation over a total deployment a drastic reduction in CAPEX can be achieved. In a network with 300 towers, only 300 satellite receivers (in this example) are required instead of 1.200 IRD's.

A second difference can be found in the transmission over satellite. Instead of sending different carriers over satellite, all the digital terrestrial and mobile TV bouquets or multiplexes are combined into one BaseBand stream before the modulator. A single carrier is sent over the satellite link towards the different towers. This Multistream operation allows saturation of the transponder. Additionally the compatibility with SFN operation is ensured through demodulating multiple transport streams from a single satellite carrier guaranteeing the integrity of the content.

Multistream In Detail

If we have a look at Multistream in a more technical sense (*Figure 3*), we see that transport streams (coming from encoders or multiplexers), and/or IP streams, are divided into a chain of packets. The packets in transport streams and IP streams are encapsulated into **Base Band Frames** through stream aggregator equipment. These Base Band Frames consist of a header and a payload (content). Into the header the *Input Stream Identifier* (**ISI**)-value is inserted to restore the streams' position at the receiver's end. The header also bears the ***Modulation and Coding*** (**MODCOD**) information for each Base Band Frame. Multiple packets out of a similar initial transport stream can be stored in a Base Band Frame (16 or 64Kb). The Base Band Frames on their part will be multiplexed (combined) into a multiple input stream, which is called the Multistream. The Multistream is injected into the modulator in order to be sent over the satellite link.

At the receiver end of the satellite link, the Multistream is demodulated. The Base Band Frames that are required for that specific location will be taken out of the Multistream and separated again into the different Transport and IP streams. The modulation and coding information is checked per base Band Frame. Once the transport streams are restored in their original ASI format they can be inserted into the COFDM modulator and amplified in order to send through DTT and Mobile TV transmitter sites to the end-user's (mobile) TV sets. As an additional benefit Multistream is SFN-compliant which is necessary for the distribution of digital terrestrial and mobile TV content in *Single Frequency Network* mode.

Multistream in more human comprehensible terms could be described as multiple similar packets that are put into a box. Each box is labelled with a destination address, address of origin and how it should be sent. The resulting boxes containing different content are organised and put onto a means of transport that carries the payload from one location to another, or to multiple locations. Having arrived at destination the boxes are selected and unpacked. The packets are then put into their original state and in their original sequence.

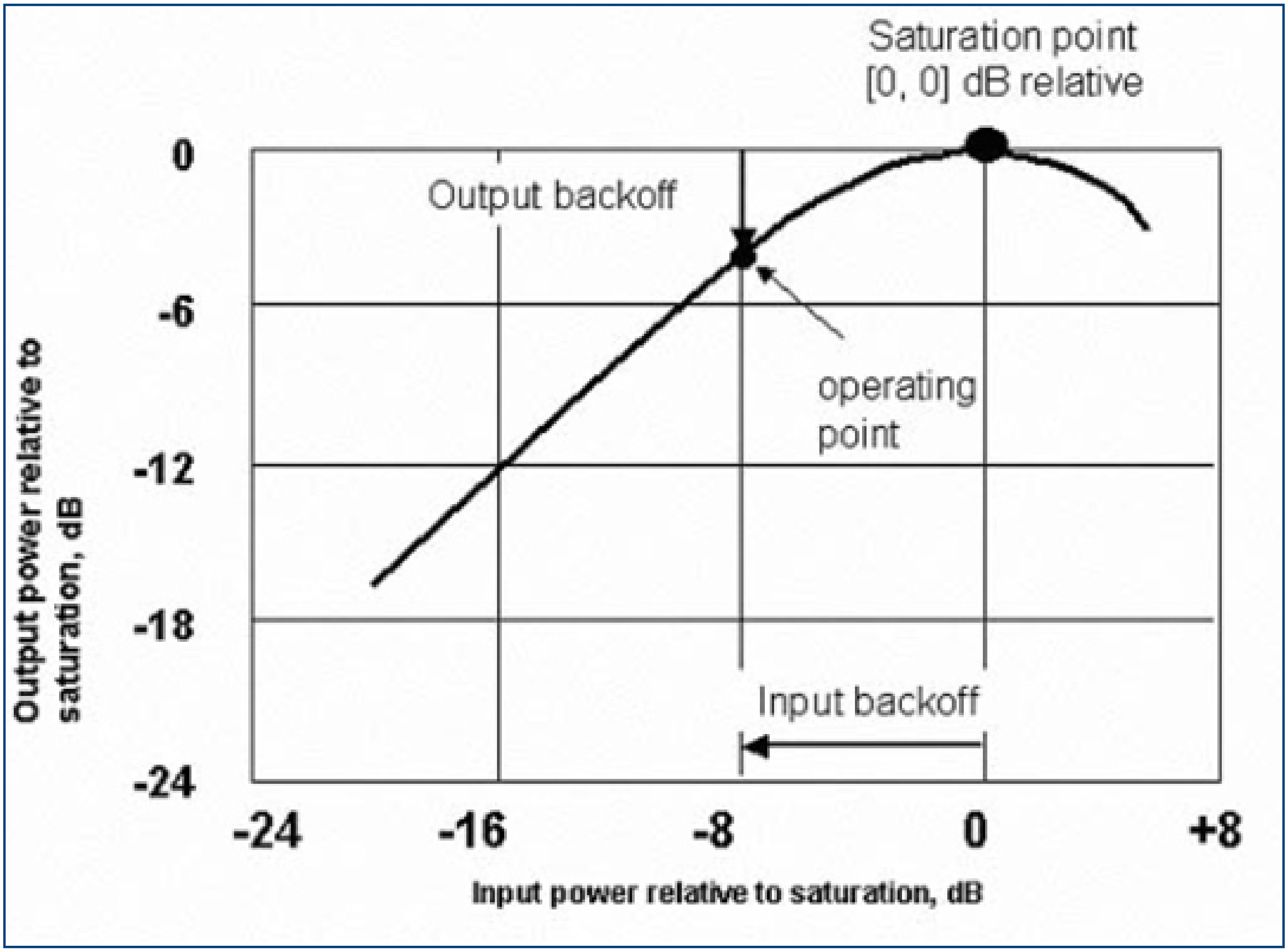


Figure 4
Transponder back-off

Multistream is fully in touch with the broadcasting operational reality as several services (Terrestrial TV, Mobile TV, Direct-to-Home and IP data distribution) can be combined onto one carrier. The combination facilitates the saturation of a transponder and thus achieves a more efficient and economic use of satellite bandwidth.

Returning back to the cost topic, Multistream can reduce the **OPEX** (bandwidth cost) by filling up a transponder to full capacity in a single carrier operation. Single carrier operation (Multistream) does not need the so-called 'back-off' and can saturate the transponder to its maximum. The 'back-off' is used in multi-carrier operations (one multiplex per carrier) in order to reduce the risk of 'shadows' or inter-modulation between the different carriers, which could compromise the quality of the received signal.

Multi-carrier operations are not able to use the full output power of the transponder. When compared to (currently mostly used in the market) multi-carrier operation, Multistream saves up to 4dB resulting in more "bits per Hertz" of bandwidth (5 percent to 12 percent of bandwidth gain).

To avoid jitter and time lapses in the television signals at the receiver's end, DVB-S2 includes an 'Input Stream Synchronizer' (ISSY) operation mode to be used with Multistream. Better implementations of Multistream do not require ISSY which is a big advantage as ISSY creates up to 2 percent overhead in the bandwidth.

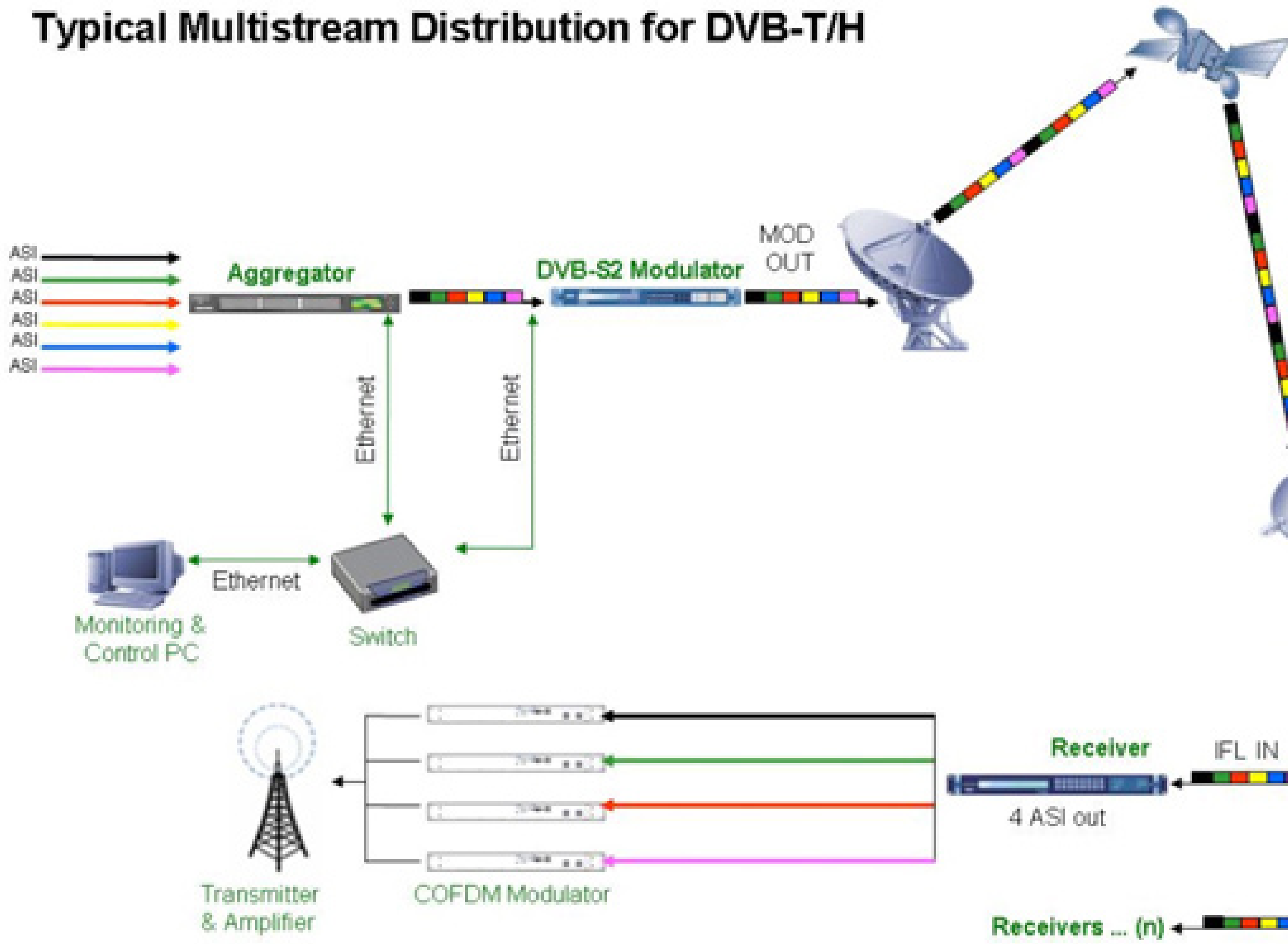


Figure 5
Multistream network equipment

SFN Requirement

Analog TV broadcasting had to face the problem of co-channel interference, prohibiting the re-use of the same channel over considerable distances. In addition, echo's (multi-path propagation) by buildings and natural obstacles resulted in receivers capturing the sum of the original signal, some delayed replicas and channel noise. To compensate this physical degradation, the traditional method was to increase the transmitting power, thereby increasing signal to noise ratio. Unfortunately, this also increases the frequency occupancy over a larger area as well as operational cost (power consumption).

New digital transmission standards make use of the so-called **SFN** (***Single Frequency Network***) technique to overcome those problems. Under certain conditions, some 'positive' echo's in a COFDM broadcast can reinforce the original signal and the negative effect of other echo's and/or channel noise can be bypassed.

Single Frequency Network operation can be obtained only if all transmitters radiate the same digital signal at any point of the service area. Therefore, each transmitter within one SFN must radiate the same data bits, on the same frequency, at the same time. SFN requirements have a direct impact on the way to set up the transmitter network and the primary distribution network. Through Multistream equipment multiple transport streams can be demodulated from a single satellite carrier in a way that guarantees the integrity of the content in order to be compatible with SFN operation.

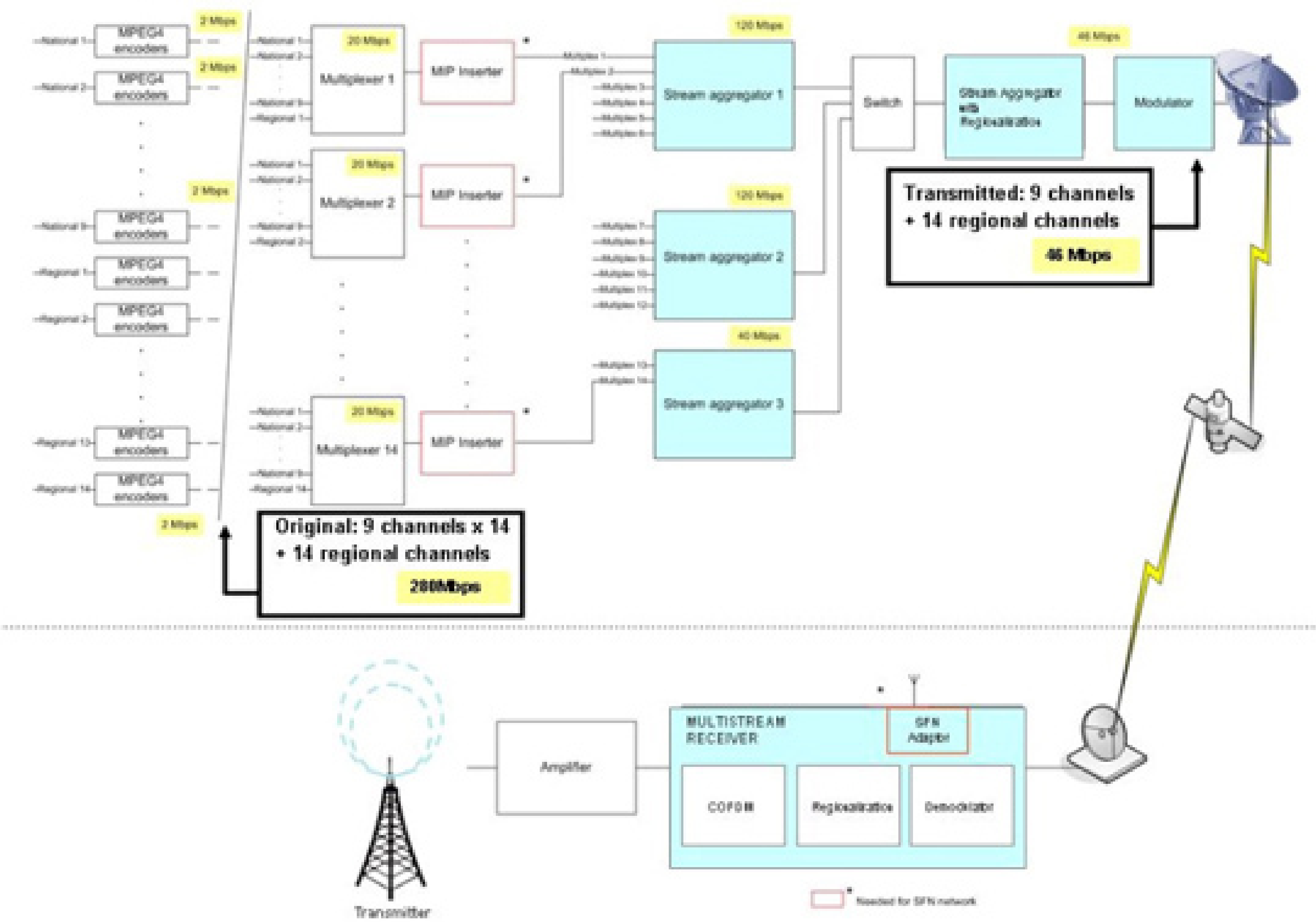


Figure 6
Multistream distribution with regionalization in a SFN network

Multistream Equipment

In order to enable Multistream in DVB-S2 some adapted equipment is required. The use of the ***Stream Aggregator*** is a specific **Newtec** implementation. The content received from broadcasters is encoded in MPEG2 or MPEG4 streams. The different channels are inserted into the aggregator. The aggregator supports multiple ASI inputs and combines the different multiplexes in one baseband stream that is inserted into the modulator. In case of large number of ASI Transport Streams other aggregators can be placed in parallel in order to feed the modulator. The cascading of several Aggregators yields to the creation of subgroups that can be routed to different modulators. The modulator sends the signal over satellite to the required locations.

At the other end of the satellite link, the Satellite Receiver is capable of demodulating multiple MPEG streams in Multistream mode. The transport streams are separated again based on their DVB-S2 Input Stream Identifier (ISI).

Another strong point in Multistream can be identified as a means to reduce the **CAPEX**. Instead of multiple Integrated Receiver-Decoders or IRD's (typically one IRD per carrier) in the transmitter towers, one unit can receive and distribute multiple streams over ASI and IP. This saving is multiplied by the number of towers, where multiple multiplexes need to be delivered for transmission. If we translate these findings into numbers, we see that for a deployment of 300 transmitter towers with 4 multiplexes, up to 45percent can be saved in hardware cost through the use of Multistream receivers with multiple outputs.

Combining multiple outputs in a receiver adds advantages that do not come to mind directly but which should equally be considered, as they are delivered with a price tag at the end of the ride. If less units are used (*i.e.*, 1 Multistream Satellite Receiver in stead of 4 IRDs) the consumption of electricity will be lowered, the air-conditioning only needs to consider one receiver and the rack-size can be reduced to fit in space-limited cabinets.

Regionalization

If we are in a cost saving mode, why not go all the way? By means of an example, the case for Multistream and regionalization will show that even more bandwidth can be saved on the transponder.

The regionalization functionally in short allows the operator to distribute all 14 regional and 9 national content undoubled on the same satellite carrier. The content of the terrestrial bouquets will be composed locally by the satellite receivers with regionalization functionality. In other words, the equipment inside the transmitter towers will pick the correct channels (nine national channels and one regional channel) out of the satellite signal that are linked to their region. The rest of the regional channels are left disregarded. The content will then be transferred to the COFDM modulator to be amplified and transmitted to the (mobile) TV devices. Without this feature each local bouquet would need to be composed centrally and distributed separately, increasing the satellite bandwidth cost dramatically.

Multistream with regionalization does not jeopardize the quality of signal. The integrity of the content is guaranteed. If not the SFN operation requirement would not be valid anymore.

In this real-life example, nine national channels and 14 regional channels need to be distributed over satellite. In total, 280 Mbps content should be transferred simultaneously. Without considering Multistream or regionalization, three transponders would be required with a market average price of 2.5 million euros a piece a year. To avoid the multiple transmitting of national content in our example, some specific regionalization technology must be used on top of the Multistream, keeping SFN requirements in scope. The big cost reduction using Multistream with Regionalization is captured through the requirement of only one transponder instead of three to send the same information over satellite. In a whisker, a broadcaster saves 5 million euros on average per year. On top of that, some other services can be added to the transponder or rented to other parties, as in this example the transponder capacity is not entirely filled. Return on Investment? On the fly.

Security

However earnestly companies and governments try to secure their networks and content, the risk that unwanted parties will intrude upon the network and/or abscond with vulnerable content remains high. Is security related to cost saving? It certainly is.

In the broadcaster market, content is key and represents a big financial value in terms of revenue. If content is pirated or hijacked, the investment costs to create the content will be much more difficult to recover. Still, only a minority of the primary satellite distribution links are secured at this point.

Two different security solutions emerge: **BISS** because it is a standard compliant technology and **AES** because it is a simpler yet more powerful propriety scheme that can support the high bitrates of DVB-T bouquets.

In The Long Haul

With the financial crisis hitting hard, and broadcasters in search for means to complete their Digital Terrestrial TV and Mobile TV networks projects, the exercise to find the correct technology and equipment becomes an essential consideration in order to fit restricted budgets.

Broadcasters should look into reducing their initial investment as well as consider how the technology will affect their investments in the long term. The dimension beyond the price tag needs to be closely investigated. This is especially true when you consider new technologies as HDTV and 3DTV are popping up over the horizon, requiring additional transponder bandwidth over satellite.

The DVB-S2 Multistream solution has a proven Return-on-Investment track record both on CAPEX and OPEX domains. Stream aggregators and multiple ASI output demodulators help broadcasters to get more bits per Hertz over their satellite link. A first reaction for a broadcaster whenever adapting or installing a new network over satellite should be to consider best price solutions… more precisely best price solutions in the long term.

About the author

Koen Willems started his career in 1998 with Lernout & Hauspie, as project manager in the Consulting & Services division. He then joined Toshiba as a Product Marketing Manager for the Benelux and later for the European market. For six years, Koen contributed to all major Toshiba Retail IT product releases. Mr. Willems is, at present, Product Marketing Director Mobile TV and Digital Terrestrial TV Equipment for Newtec, a Belgium-based specialist in satellite communications. Koen holds a degree in Germanic Languages (University Ghent, Belgium, 1997) and he completed a Master in Marketing Management program at the Vlekho Business School in Brussels (1998). He acquired a Six Sigma Black Belt for product development and process improvement in 2006.

PRIORITY BRIEFING
STPSAT-1: TWO YEARS OF SUCCESSFUL OPERATIONS

by Richard Barnisin, Patricia Remias, and Frank Scalici

STPSat-1 was launched on March 8, 2007 as one of the payloads on the maiden flight of the *EELV Secondary Payload Adapter* (ESPA) ring. This Class "C", single-string satellite is currently on orbit and exceeding the per-orbit data collection requirements of the two active experiments onboard: the *Spatial Heterodyne Imager for Mesospheric Radicals* (SHIMMER) and the *Computerized Ionospheric Tomography Receiver in Space* (CITRIS). The Air Force/Comtech AeroAstro (CAA) team completed the *STPSat-1* Launch and Early Orbit checkout (LEO) activities within three weeks after launch, supporting an early start of the nominal operations phase and experiment data collection. On multiple occasions STPSat-1 has shown robustness in software and hardware implementation, allowing the satellite to continue its mission while dealing with issues that would have stymied a less robust design.

The ***STPSat-1*** mission parameters specified an on-orbit life of one year. On March 8, 2009, STPSat-1 completed its second year of successful on-orbit operations and, to date, continues to perform well against the requirements set forth by the customer. For the first year on-orbit, the project was sponsored by the ***DoD Space Test Program***. The second year on-orbit has been sponsored by the ***Navy Research Laboratory***. The Naval Research Laboratory, which built the ***SHIMMER*** and **CITRIS** payloads, operates STPSat-1 from their Blossom Point facility near LaPlata, Maryland, in southern Charles County.

Missions such as STPSat-1 prove that the "small" satellite class has established itself as a credible alternative to traditional, high-cost, long-duration missions. By providing mission success in a smaller, less expensive package — micro and small satellites make it possible to launch many more important payloads that have otherwise been grounded due to the escalating costs associated with larger space vehicles. By utilizing robust, single-string systems and components specifically designed (in-house) for small satellites, CAA is uniquely qualified to remain at the forefront of this burgeoning space market.

The ***Space Test Program*** (**STP**) STPSat-1 mission was initiated in 2001 as the first space vehicle explicitly designed to launch on the ESPA as a secondary payload (*Figure 1*). The space vehicle (SV, satellite bus plus payloads) weighs 164 kg, and carries two active experiments on board: SHIMMER (*Spatial Heterodyne Imager for Mesospheric Radicals*) is a deskjet printer-sized rugged spectrometer designed to measure solar resonance fluorescence of hydroxyl (OH) in the Earth's middle atmosphere; while CITRIS (*Computerized Ionospheric Tomography Receiver in Space*) investigates and characterizes ionospheric radio scintillations that can seriously degrade the performance of space systems providing communications, navigation, and geolocation. CAA is the prime contractor for the STPSat-1 space vehicle; both experiments were provided by the Naval Research Laboratory.

The satellite bus design was intended to be as simple as possible with a minimum of non-recurring engineering. Although there was no mission requirement specifying a quantitative probability of success, STPSat-1 was required to provide a mission life of one year, beginning after Launch and Early Orbit checkout (LEO). As a Class C satellite, all critical bus components were single string, and only selectively redundant. Shortly before launch, the final calculated reliability prediction showed only 75 percent probability of success to meet the one year goal. However, over

Illustration of fully-deployed STPSat-1 SV on orbit, with CITRIS antenna on SV front, and circular standard separation adapter on back.

the course of the first year of on-orbit operation, the design proved to be highly robust, which permitted continued performance to mission requirements in the presence of on-orbit anomalies.

STPSat-1 was launched on the STP-1 ***Atlas V*** from Cape Canaveral on March 8, 2007, with ***Orbital Express*** as the primary payload and several other ESPA secondaries. After a complex series of engine burns and maneuvers, STPSat-1 was successfully released into its target orbit (**35.4° inclination, 560 km circular**).

LEO TEST PHASE

The Launch and Early Orbit (LEO) checkout phase of operation began immediately after STPSat-1 separation from the ESPA ring into the target orbit, and was scheduled to be completed in four weeks. Successful conclusion of the LEO phase would mark the beginning of the first year of normal satellite operations, and collection of scientific data by both payloads.

The objectives of this LEO were to verify spacecraft subsystems performance, characterize individual payload's functionality, identify acceptable fixes (or work-arounds) to all anomalies, and successfully demonstrate and characterize combined spacecraft/ payload operation. For this extensive testing, CAA provided 24x7 on-site support at the RSC including CAA experts from each of the major satellite subsystems, system engineers, and the mission operations lead.

All available data indicates that the STPSat-1 Space Vehicle (SV) successfully withstood the launch environment and arrived on orbit without any launch-induced anomaly to the satellite. The separation system operated as expected in separating the STPSat-1 SV from the ESPA ring, with low tip-off rates observed.

The STPSat-1 Power Subsystem is a direct-energy-transfer system utilizing shunt regulation to shed excess generated power. Tests on the power subsystem proved nominal performance for the solar arrays, battery, and shunts. Comparisons were made for on-orbit performance of the power subsystem against the pre-launch power simulation. *Figure 2* shows the pre-launch power simulation output for the solar arrays, battery and shunts over 11 orbits.

When comparing this data to the actual on-orbit performance during LEO shown in *Figure 3*, similar peak values and trending are apparent. The "double-peak" of the solar array output during an orbit is caused by direction of the sunlight moving over the solar panel edge from the front to backside of STPSat-1's double-sided deployed solar arrays. The simulation not only tracks the on-orbit data well, but comparison of the peak values illustrates the conservative approach used in the simulation.

The ***Attitude Determination and Control Subsystem*** (**ADCS**) met and largely exceeded mission requirements for attitude pointing (≤ 0.10° error in all three axes). LEO analysis of ADCS on-orbit performance showed strong correlation between real orbit data, and the pre-launch ADCS simulation tool. The on-board GPS receiver, an SSTL SGR-05, initially performed well enough during LEO that transponder-based ranging by ground assets was discontinued after one week due to the high quality of GPS position and velocity data downlinked in telemetry.

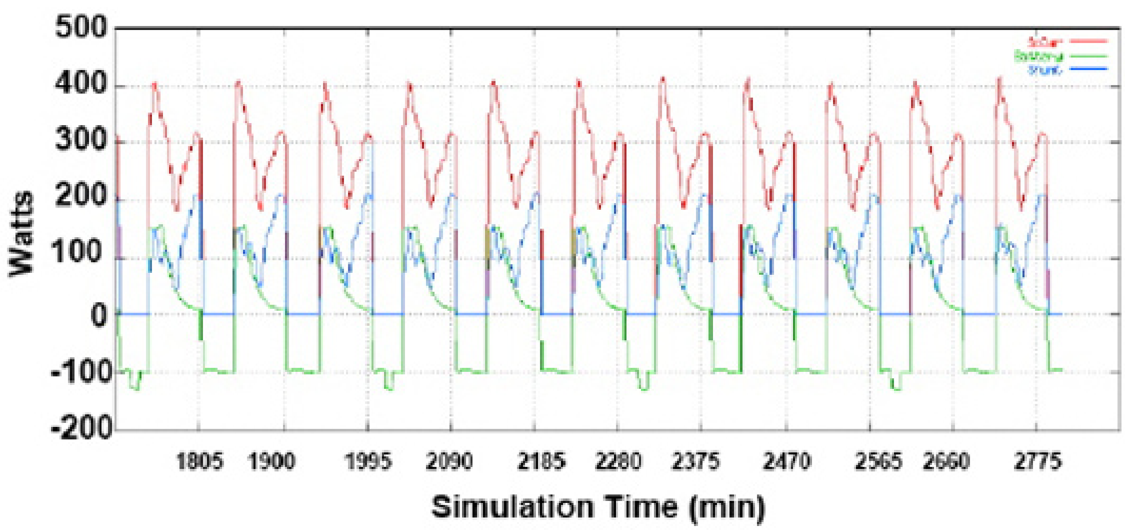


Figure 2.
STPSat-1 Power Simulation Output of Bus Power – Solar Array Output (red), Battery (green), & Shunts (blue) – for 11 orbits.

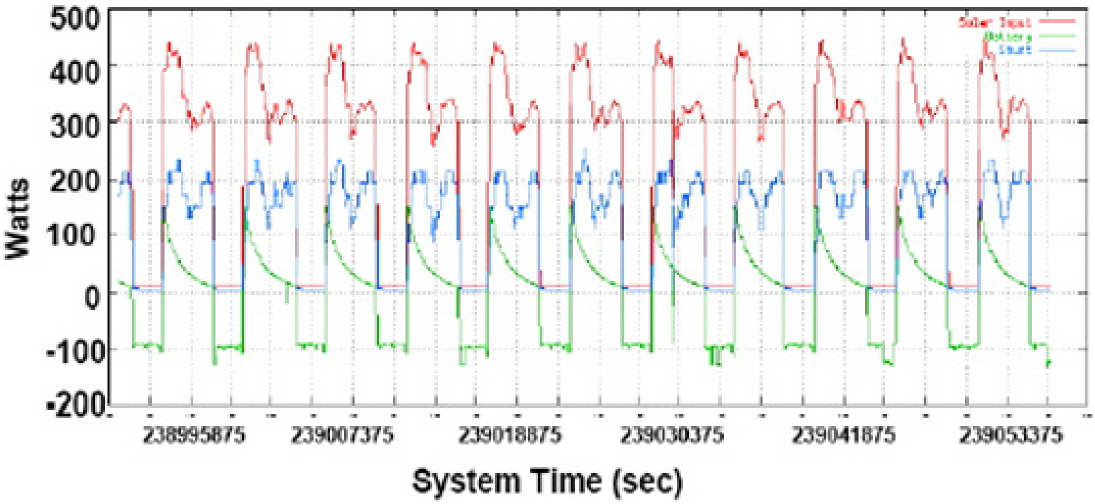


Figure 3.
STPSat-1 On-Orbit Bus Power – Solar Array Output (red), Battery (green), & Shunts (blue) – for 11 orbits.

During this phase, some transient hardware anomalies caused by ionizing radiation were discovered that affected both STPSat-1's star tracker and GPS. However, mitigation approaches were identified during LEO, and later proved successful.

Payload testing for CITRIS, including testing of the ***Coherent Electromagnetic Radio Tomography (CERTO) Satellite Beacon Mode***, the ***Doppler Orbitography and Radiopositioning Integrated by Satellite*** (**DORIS**) ***Ground Transmitter Mode***, and noise floor measurements showed the antenna and receiver electronics were operating as expected.

SHIMMER payload testing during LEO indicated the interferometer was not damaged during launch, the moving parts (door and shutter) were performing well, and the detector (CCD) temperature and electronics temperatures were well within the operational limits. No indication of any significant contamination could be detected. Judging from the LEO data, SHIMMER was working as expected.

SHIMMER Shuttle Re-Pointing

STPSat-1 is a three-axis stabilized, nadir-pointing satellite. Prior to launch, the only specific slewing maneuvers planned were a SHIMMER calibration that pointed the instrument to the Sun for several minutes, and a 180-degree yaw maneuver once every six months to avoid sun incursion into the star tracker's field-of-view. STPSat-1 does perform active roll slewing each orbit to compensate for Earth oblateness, but this small change to the roll angle was designed, tested, and extensively analyzed prior to launch. However, CAA designed an additional capability (that was originally not required) for a small attitude adjustment (constant bias) to the satellite pointing in each axis should it be required after launch. This robust capability was later utilized to further the scientific return on the SHIMMER payload by providing the ability for SHIMMER to observe the altitudes of the thermosphere in which a significant part of the Space Shuttle exhaust plumes are deposited during the Shuttle's launch.[1]

Liquid hydrogen and oxygen are used to fuel the main engine of each Space Shuttle. At launch, the exhaust from the shuttle's main engine deposits about 300 metric tons of water vapor between 108-114 km altitude.2 By pointing the SHIMMER instrument slightly higher to include the altitude region around 110 km, SHIMMER observations are potentially able to include the Shuttle plume. These observations could give additional information about the dynamics of this altitude region and the temporal development of the plume. Furthermore, these measurements could lead to a better understanding of plume related mesospheric cloud formation.[2]

On June 7, 2007, one day before the launch of STS-117, STPSat-1 was successfully rolled to observe the plume from this shuttle launch. The SV remained in that orientation for approximately one week to allow the SHIMMER instrument to collect data. This SHIMMER Shuttle Re-Pointing was also accomplished for several subsequent launches over the past year including ***STS-118***, ***122*** and **123**.

ADCS Performance

The required ADCS space vehicle attitude pointing error is defined in the STPSat-1 Mission Requirements Document to be no greater than +/- 0.10 deg (3-sigma). SV pointing is controlled with a combination of three momentum/reaction wheels (procured from RoBi Controls) with momentum unloading accomplished by magnetic torque rods (from **Microcosm, Inc.**), to provide stable, momentum-biased, three-axis pointing.

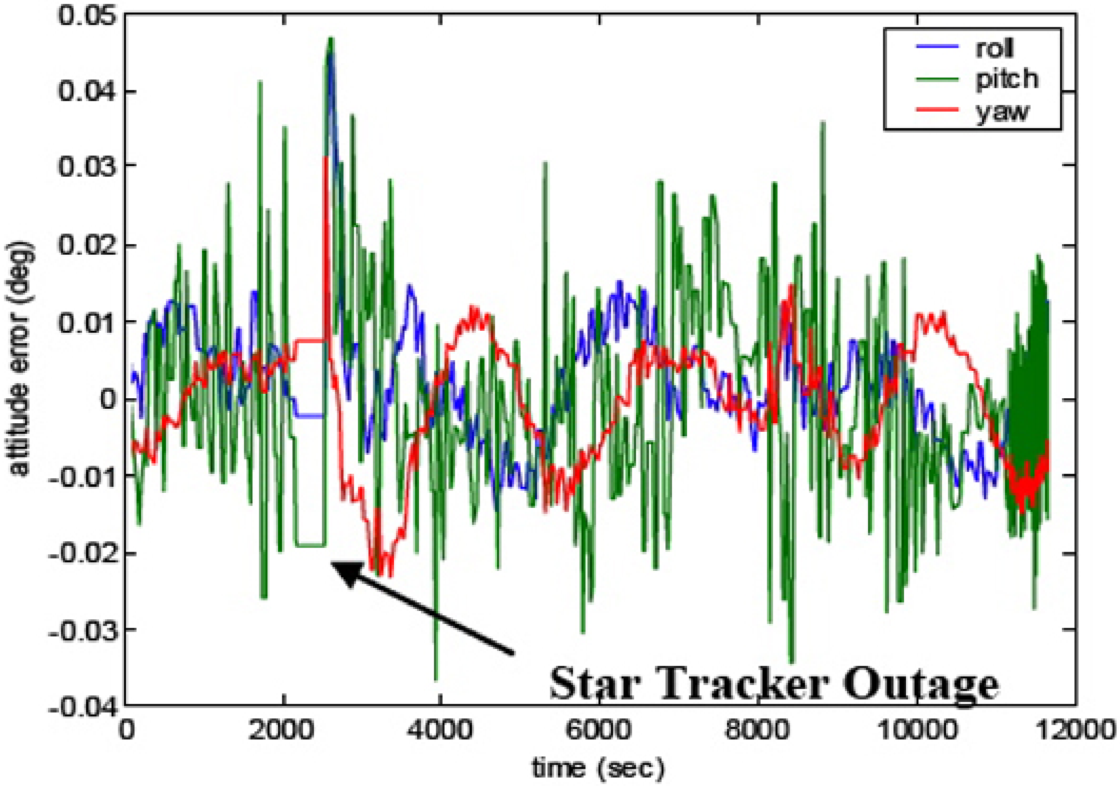


Figure 4.
STPSat-1 Attitude Pointing Errors in Roll (blue), Pitch (green), and Yaw (red) axes during a three-hour time span in LEO.

Pre-launch ADCS performance simulations predicted attitude pointing excursions not to exceed +/- 0.10 deg error, and generally center about +/- 0.05 deg error. *Figure 4* on the previous page trends the on-board calculated attitude pointing errors during the LEO phase, indicating close agreement with the pre-launch ADCS simulations. In fact, from this data, one can see that the attitude error in all three axes does not exceed +/- 0.05 deg error, resulting in a performance margin of (0.10 / 0.05) = 2, or twice better than required. The "three-sigma" aspect of the requirement permits occasional violation of the pointing requirement, but no more than 0.25% of the time. However, as can be seen from this graph, STPSat-1 holds this pointing margin consistently.

Nearly one-year after LEO, the ADCS performance was still twice better than required. *Figure 5* shows attitude errors over a two week period from 12-Feb-2008 to 26-Feb-2008.

Star Tracker Radiation Hits

The main factor contributing to the out-of-spec attitude excursions is caused by an ionizing radiation effect on the star field imaged by STPSat-1's star tracker, the primary attitude determination hardware. Most precision-pointing spacecraft that use star trackers are relatively costly (compared to most microsatellites) and may have several attitude sensors (*e.g.*, star trackers plus gyros, multiple star trackers, etc.). As a Class C spacecraft, STPSat-1 is single string and only selectively redundant. There is only one star tracker aboard STPSat-1 from which the ADCS software can calculate spacecraft attitude. Further, there are neither gyros nor secondary ADCS hardware of sufficient accuracy to provide attitude knowledge in the event of short-term star tracker outage. The decision to use this approach was made in the design phase of STPSat-1 not only for cost considerations, but also for mass and volume constraints on this ESPA-class satellite. This aspect of STPSat-1 design was extensively discussed and

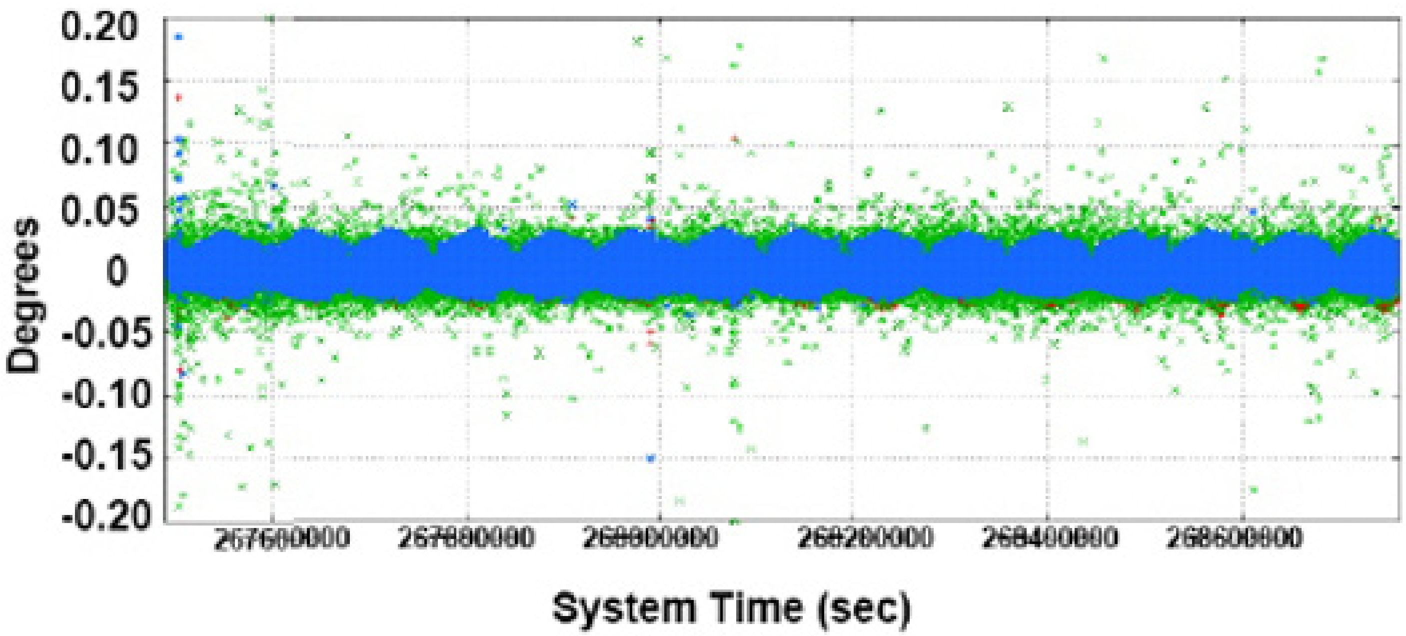


Figure 5.
STPSat-1 ADCS Performance One Year after Launch. Attitude Pointing Errors over two weeks are shown in Pitch (green), Yaw (blue), and Roll (red, but largely not visible due to overlapping blue and green data).

agreed upon between CAA and the customer.During the LEO phase of on-orbit operation, it was discovered that the CCD imager of the CT-633 star tracker would occasionally lose star lock, and hence, stop output of attitude data. These occurrences were most prominent over the ***South Atlantic Anomaly*** (**SAA**), see *Figure 6*.

It is well known that various electronic devices (CCDs in particular) are susceptible to ionizing radiation hits, and that such hits are common in the SAA, where STPSat-1's orbit has substantial exposure. Analysis of STPSat-1's on-orbit raw star tracker pixel data telemetry by the star tracker manufacturer indicated radiation transients as the cause of these loss-of-lock events. Further, there were instances of simultaneous hits on both the star tracker CCD, and the SHIMMER CCD, further corroborating ionizing radiation as the initiating event for the attitude disturbance.

When the star tracker would lose star lock, the onboard ***Failure Detection & Correction*** (**FDC**) strategy implemented in the ADCS software "froze" actuator commands to the most recently commanded value (*i.e,*. repeated torque commands to wheel and mag torque actuators) until the star tracker regained star lock. The purpose behind this technique is to take advantage of low body rates (typical of 3-axis stabilization) prior to loss-of-lock, and so minimize attitude excursions. This approach to reaction wheel commanding permitted the wheels to remain close to their set speed, while the (repeated) torque commands overcame bearing friction - zero-torque commands would have eventually led to wheel spin-down. This highly effective approach is illustrated in *Figure 4*, where a star tracker loss-of-lock of approximately eight minutes caused an attitude excursion of less than 0.05 deg (within spec). However, STPSat-1 later experienced some radiation hits that caused longer outages, resulting in larger (out-of-spec) attitude errors, and in some cases forcing the FDC to initiate SV safing actions. Although the star tracker manufacturer studied the raw on-orbit data and determined there was no long-term impact to the lifetime of the star tracker, mitigation of this issue was necessary because the loss-of-lock events could impact mission performance.

To mitigate against future radiation hits, the star tracker's manufacturer provided CAA a star tracker software patch which lessened the effect of these occurrences. CAA's robust on-board flight software design permitted software patch uploads directly to the star tracker so that the on-board star tracker may update its internal software. Interestingly, this is a software feature that was not required — CAA simply implemented this feature to provide capabilities. This feature has proved very useful in a number of instances, and helped in closing this anomaly.

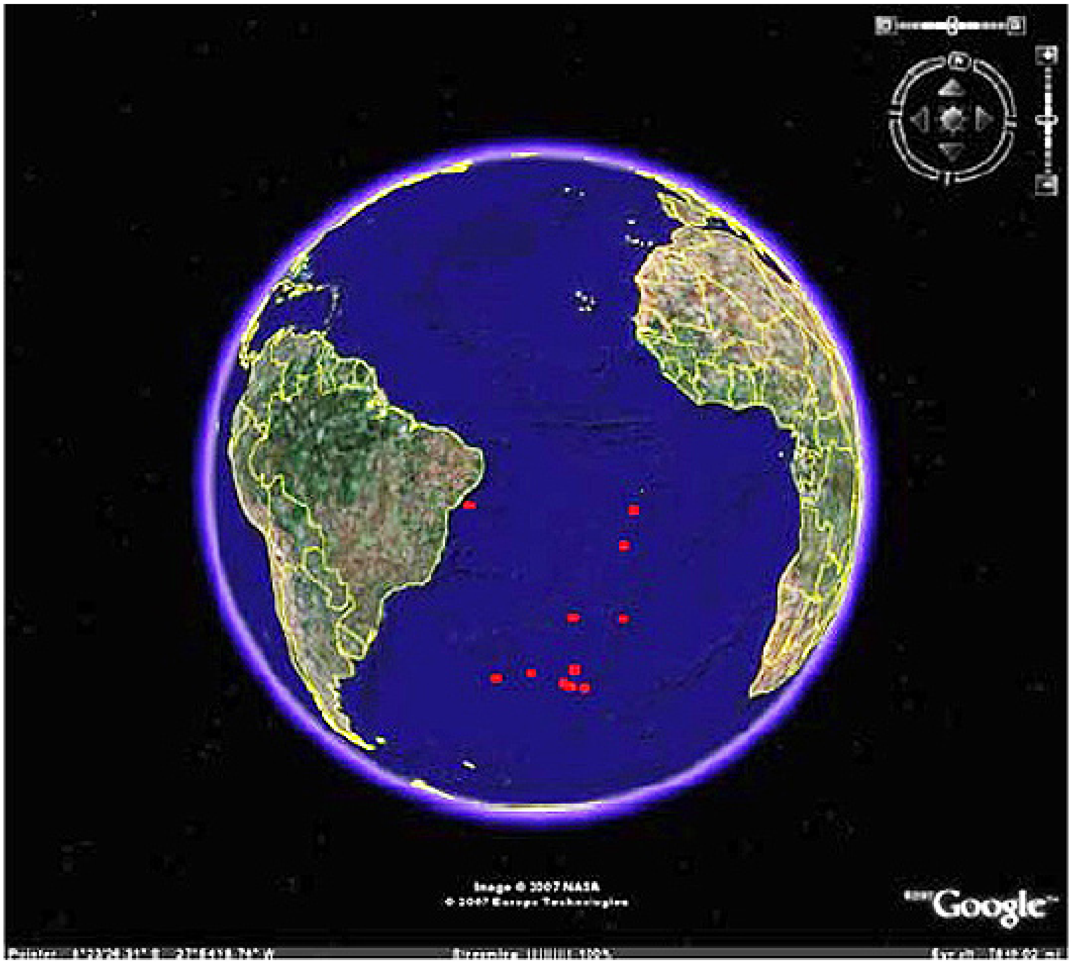


Figure 6.
Geo-location of several attitude disturbances during LEO initiated by Star Tracker Loss-of-Lock, identified in this illustration as red dots.

GPS Radiation Hits

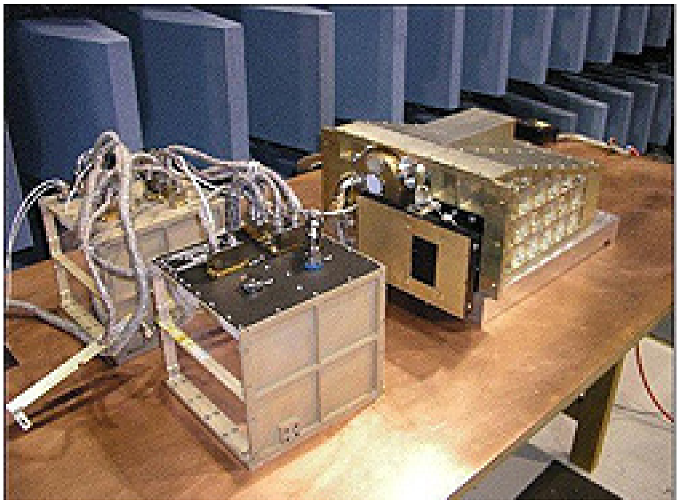
STPSat-1's GPS receiver provides orbital position and velocity data as well as accurate time pulses for the numerical attitude integration software. In the first few months of on-orbit operation, it was discovered that ionizing radiation affected two aspects of GPS operation. First, the ***pulse-per-second*** (**PPS**) output of the GPS would unexpectedly become disabled, preventing output of the once-per-second GPS time tick, used for on-board time synchronization. Second, the GPS would output position and velocity data with higher than expected residuals (noise-related error). These effects were predominant during periods of elevated space weather (higher than normal background-radiation).

The PPS anomaly was quickly remedied by limit checking in telemetry the PPS enable flag, warning satellite operators to send the re-enable command when the PPS autonomously became disabled.

The position and velocity residuals issue was successfully analyzed by the GPS manufacturer (Surrey Satellite Technologies Ltd) who provided a simple power-cycle solution. Periodic trending of the GPS position data indicates timeframes when residuals may impact mission performance, and a power-cycle of the GPS receiver corrects this situation (this occurs approximately monthly). The robustness of the ADCS software permits extended dropouts of GPS data without impact to mission performance, including those dropouts (several minutes in duration) that occur when there is a power-cycle of the receiver.

Yaw Maneuver

Since STPSat-1 has only one star tracker, and does not possess alternate ADCS sensors to provide accurate attitude knowledge in the event of star tracker outages, it was necessary for STPSat-1 to perform a predefined 180-degree yaw maneuver every six months



The SHIMMER instrument (credit: NRL)

to avoid star tracker "blinding" by the sun. This ADCS maneuver uses a combination of momentum wheels and magnetic torquers to perform this slew.

This maneuver can only be executed at certain times during the year, when SV pointing to either orientation can be tolerated by the star tracker (*i.e.*, no blinding). This aspect of SV operation made testing of this maneuver during LEO impossible, since only one of the two 180-deg-orientations of the SV could be tolerated by the star tracker at that time. When the slew was performed on-orbit for the first time in October 2007, the satellite unexpectedly transitioned into Detumble (safe-hold) Mode shortly after the satellite executed the slew command. This was due to an incorrect command parameter used in the upload to define the direction of slew. The parameter used in the command was from the satellite command and telemetry database, but the database was in error - the ADCS software required a parameter not present in the database.

Recovery of the satellite into the original orientation was relatively straightforward, but was time-consuming due to repeated sun interference in the star tracker during the detumble recovery process. Due to cost and potential operational impacts of making a database change at the RSC, CAA developed an alternate yaw maneuver approach that did not require use of the omitted command parameter. Instead, this maneuver used the incremental slew described earlier to accomplish the SHIMMER Shuttle Re-pointing. However, in this case, successive ten-degree yaw slews were performed sequentially. This maneuver resulted in finally achieving the correct 180º yawed orientation, after several attempts were thwarted by star tracker / sun interference. A subsequent yaw maneuver performed in April 2008 accomplished the correct yaw slew via the original yaw maneuver.

Power Performance

Power System Description

STPSat-1 has a direct energy transfer system that utilizes approximately 5.3 square meters of solar panel area with Triple Junction Gallium Arsenide solar cells (by **Spectrolab, Inc**.) positioned in a 0.9 to 0.95 packing factor. In addition to the four body-mounted solar panels, there are four deployed solar arrays, each of which is populated with solar cells on both sides (double-sided).

The power subsystem handles voltage regulation, battery charging, and the shunting of excess power. Mounted panels, and the deployable arrays, are populated with solar cells on both sides. In the CITRIS-Ram attitude, the four body-mounted panels and the forward side of the four deployed panels are illuminated at sunrise. By sunset only the rear of the deployable panels are directly illuminated, giving the array output the distinctive non-symmetrical double-peak signature shown in *Figures 7* and *8*.

In CITRIS-Ram the first peak is the larger of the two peaks resulting from the sunlit portion of the orbit, but battery charging consumes most of the excess array current during this first peak, reducing shunting requirements in this orientation.

Almost immediately after achieving the desired CITRIS-Wake orientation, internal shunt load temperatures rose dramatically to undesirable levels. The satellite was temporarily commanded to a 'rotisserie' mode — a pre-defined safe mode — while the situation was studied. This rotisserie mode results in lower orbit average power and reduces temperatures.

Analysis revealed that the deployable shunt loads were not drawing any current and therefore the remaining internal loads were carrying the entire excess array capacity. The internal loads were built to shunt the entire array, but only for very brief periods of time — seconds during eclipse-to-sun transitions — hence, the dramatic temperature increase. The issue with the external loads was not evident

The CITRIS instrument (credit: NRL)

in CITRIS-Ram due to the battery charging occurring coincident with the larger array output peak. Reduced shunting requirements during the larger peak masked the failure of several shunts. However, when STPSat-1 was commanded into CITRIS-Wake, the larger of the two peaks occurred in the later portion of the sunlit portion of the orbit, after the initial battery charging had occurred. Excess array current during this half of the sunlit period required much greater shunt operation — with several shunts failed, the effect was evident.

Further analysis indicated that previous recoveries from *Detumble Mode*, caused by star tracker loss-of-locks resulted in SV geometries (*e.g.*, inertially fixed attitude) where sustained sunlight would overheat the epoxy affixing the external shunt loads (heaters). Delamination of any load would prevent adequate heat sink of that load to the array panel. Excessive heat causes the shunt current to burn through the heater wire resulting in an open circuit, rendering the heater useless for excess current dissipation.

Fortunately, the pre-launch STPSat-1 power budget was proven to be very conservative in comparison with actual on-orbit performance. Pre-launch estimates permitted SHIMMER operation for its required 40 minutes per orbit, and CITRIS operation for 40 minutes per day. Further, the SGLS transmitter was only allowed to operate a total of 35 minutes per day. A power study just prior to the anomaly confirmed the observations of the on-orbit performance and concluded that all these time restrictions could be relaxed - permitting longer duty cycles and enhanced payload operations. After the anomaly occurred, the mitigation strategy was obvious - a strategy beneficial to both payloads permitting longer operation. Further mitigation was possible by longer transponder operation (to download the additional payload data). As the main purpose of the (failed) shunts was to consume excess power, extended use of satellite loads (e.g., payloads and transponder) accomplishes the same purpose - consuming excess power. As a result, CITRIS was left powered on, as was the SGLS transmitter. SHIMMER operation was increased from 40 minutes per orbit to 70 minutes (the command database prevented longer than 70 minutes per orbit). Additional mitigation was provided by heater operation. Heaters which otherwise would have remained power off, were instead enabled, and were operated without detriment to any hardware since thermostatic control prevented over-temperature. These strategies not only maintained the internal shunt temperatures within design limits, it also allowed the scientific payloads the opportunity to collect more data on orbit than originally planned.

Further illustrating the robust thermal design is the fact that the internal Shunt Power Board, which was only designed to handle the full load for a short period, and a nominal load of 40 watts, instead handled loads in excess of 90 to 100 watts for extended periods and continues to operate nominally. It is important to note that at no time during this anomaly did bus voltage regulation suffer in any way. Bus regulation in sunlight remained controlled at 33.6 volts continuously.

Experiments' Successes

Both SHIMMER and CITRIS have performed as expected since completing the LEO phase of the STPSat-1 mission, returning valuable science data during the first year of operations.

SHIMMER has already returned several hundred thousand atmospheric OH measurements, contributing to our understanding of mesospheric hydroxyl. Moreover, the experiment's unprecedented local time coverage allows investigation of how atmospheric dynamics influence Mesospheric Clouds (MCs) and their environment, and thus potentially bias the interpretation of multi-decadal cloud frequency and brightness trends. To date, SHIMMER data have already led to three significant science results.

- ***Mesospheric clouds show a systematic daily variation; the dynamic range of this signature is unexpectedly large and will help reconcile exist-***

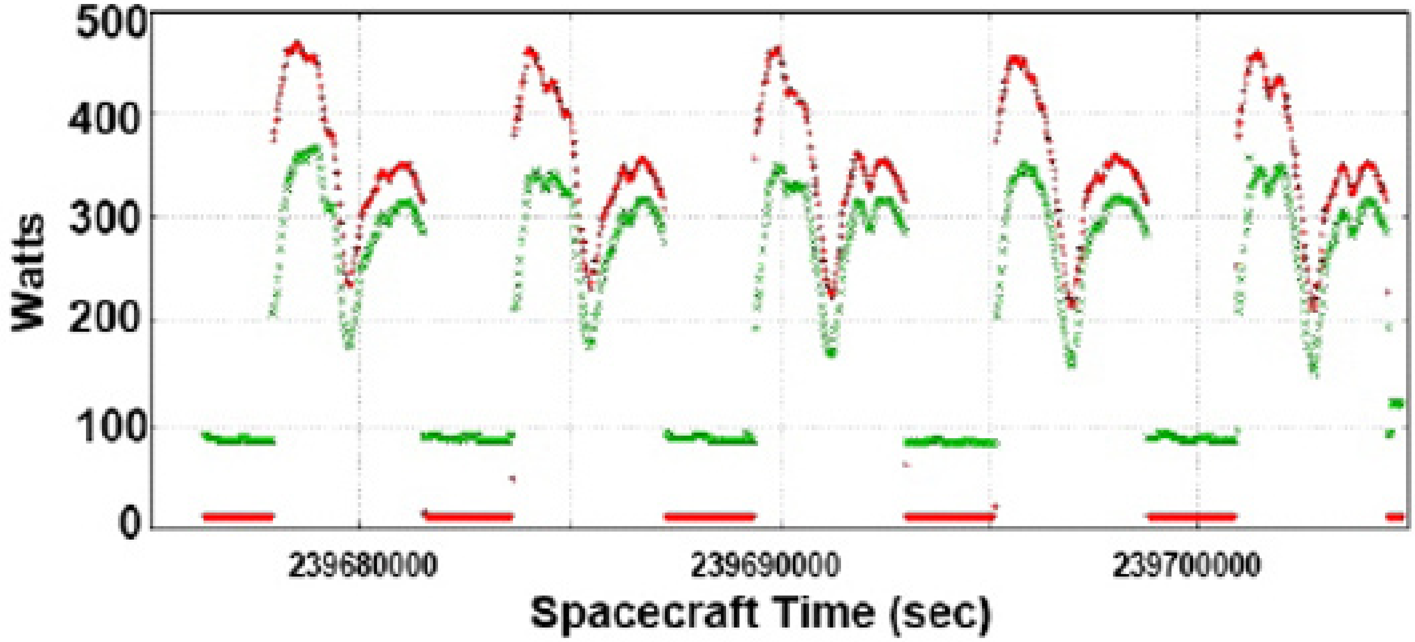


Figure 7.
Five orbits of BOL solar panel power (red) and bus power (green).

ing satellite data sets that consist of observations at discrete local times;[3]

- *Identification of discrepancies in the expected diurnal variation of OH, which will help to update current standard models;[4]*
- *Unusual SHIMMER cloud observation consistent with Navy weather models, potentially supporting forecasting of MCs much as tropospheric clouds are forecast.[5]*

The CITRIS receiver supports study of the ionosphere using data obtained from radio transmissions from ground and space beacons. The data from CITRIS is helping to update and validate theories on the generation and effect of ionospheric irregularities known to influence radio systems. By using simultaneous beacon transmissions from the DORIS ground network and from low-Earth-orbit (LEO) beacons in space, observations of ionospheric total electron content (TEC) are being obtained in remote regions over the ocean and land with unprecedented accuracy.[6]

CITRIS is designed to lock onto LEO beacons on the COSMIC, DMSP/F15, NIMS, and the recently-launched C/NOFS spacecraft, as well as the 56 ground radio beacons that are part of the French DORIS network. CITRIS operates in radio frequency bands near 150, 400, 1066 2/3 MHz, and 2036 ¼ MHz to obtain TEC and radio scintillation parameters. Using the satellite to satellite measurement technique, up to 48 independent TEC scans over 7000 km range can be obtained from the CITRIS data set; using DORIS, separate scans of TEC and UHF scintillations are obtained continuously through the day. These measurements are providing valuable data to improve the accuracy of space weather models on a global scale; in addition, the amplitude and phase fluctuations recorded by CITRIS can be used to determine the locations of ionospheric irregularities that disrupt radio systems used by civilian, Navy and other DoD agencies.[7, 8]

Acknowledgments

The authors wish to thank Mr. Tony Bachta whose insight, dedication, and hard work contributed greatly to STPSat-1's successful first year of on-orbit operation. His contributions in supplying data for this paper were invaluable. We also wish to thank the STPSat-1 mission operations team at KAFB, and the SHIMMER and CITRIS experiment teams at NRL.

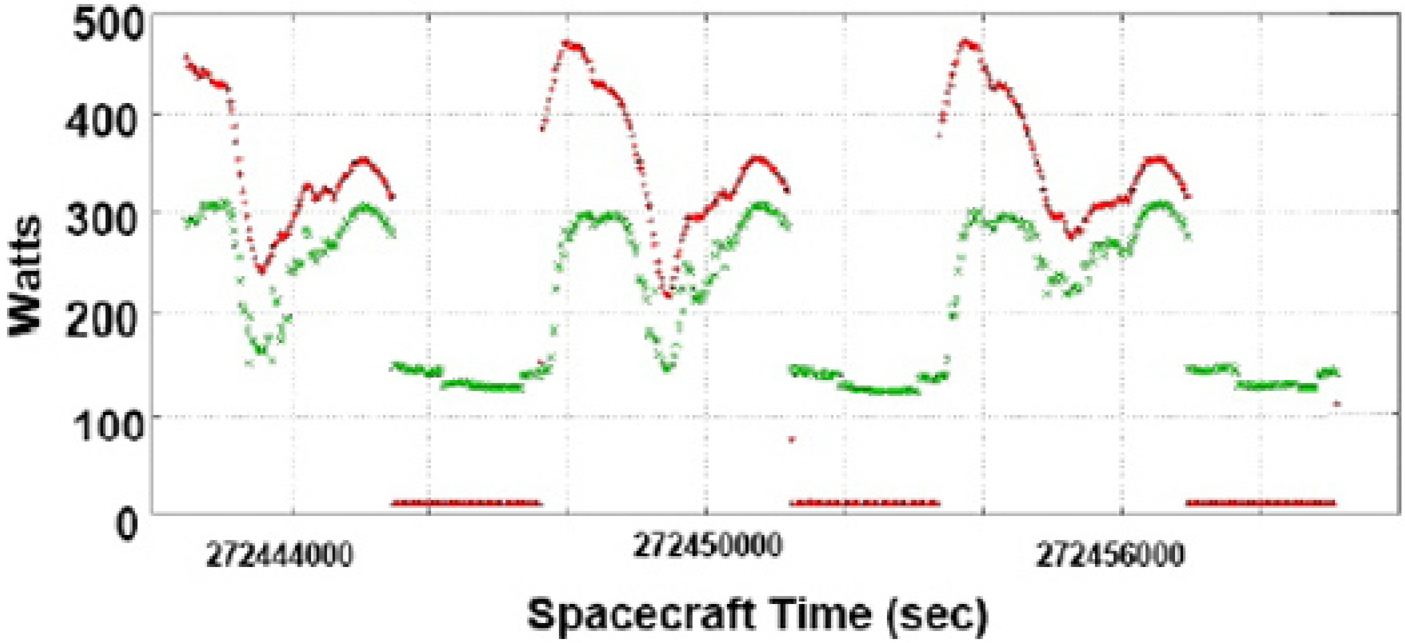


Figure 8.
Three orbits of SV power after one year of operation from the solar panels

References

1. Stevens M.H., C.R. Englert, J. Gumbel, OH Observations of Space Shuttle Exhaust, Geophysical Research Letters, 10.1029/2002GL015079, 2002.
2. Stevens M.H., J. Gumbel, C.R. Englert, K.U. Grossmann, M. Rapp, P. Hartogh, Polar mesospheric clouds formed from space shuttle exhaust, Geophysical Research Letters, 10.1029/2003GL017249, 2003.
3. Stevens M.H., C.R. Englert, S.V. Petelina, W. Singer, K. Nielsen, The diurnal variation of noctilucent cloud frequency near 55°N observed by SHIMMER, submitted to Journal of Atmospheric and Solar-Terrestrial Physics, 2008.
4. Englert C.R., M.H. Stevens, D.E. Siskind, J.M. Harlander, F.L. Roesler, H.M. Pickett, C. von Savigny, A. Kochenash, First Results from the Spatial Heterodyne Imager for Mesospheric Radicals (SHIMMER): The Diurnal Variation of Mesospheric Hydroxyl, submitted to Geophysical Research Letters, 2008.
5. Eckermann S.D., K.W. Hoppel, L. Coy, J.P. McCormack, D.E. Siskind, K. Nielsen, A. Kochenash, M.H. Stevens, C.R. Englert, M. Hervig, High-Altitude Data Assimilation System Experiments for the Northern Summer Mesosphere Season of 2007, submitted to Journal of Atmospheric and Solar-Terrestrial Physics, 2008.
6. Bernhardt P. A., C. L. Siefring, I. J. Galysh, D. E. Koch, First Results from the Scintillation and Tomography Receiver in Space (CITRIS) Mission, Submitted Geophysical Research Letters, 2008.
7. Bernhardt, P.A., C.L. Siefring, I.J. Galysh, T.F. Rodilosso, D.E. Koch, T.L. MacDonald, M.R. Wilkens, G.P. Landis, Ionospheric Applications of the Scintillation and Tomography Receiver in Space (CITRIS) used with the DORIS Radio Beacon Network, J. Geodesy, 80, 473-485,2006.
8. Bernhardt, P.A., C.L. Siefring, New Satellite Based Systems for Ionospheric Tomography and Scintillation Region Imaging, Radio Science, 41, RS5S23, 2006.

Index of Advertisers