Worldwide Satellite Magazine January 2009

SatMagazine

Micro

Mini

Nano

Pico

- A Small Satellite Revolution
- Expertise from Forrester, Near Earth, NSR...
- Ground Systems + Responsive Space...
- DMCii, Clyde Space, NASA + Parallel
- PLUS: 2009 Editorial Calendar

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A Smaller View...

The segment of the satellite industry garnering a great deal of attention is that of the small satellite. From previously taking the role of an engineering tool for higher education, the small satellite is becoming noted for its attractive cost factors, ability to launch within a shorter time frame, and on-orbit effectiveness. No longer are small satellites simply the bailiwick of universities — commercial and military projects are springing up around the globe to test the effectiveness of these smaller spacecraft to determine their viability for a variety of crucial projects.

Depending upon the wet mass of the satellite (the weight of the craft and its fuel), they are generally designated as:

- *Micro-, from 22 to 220 (100 to 500 kg)*
- *Mini-, from 220 to 1100 lb (100 to 500 kg)*
- *Nano-, from 2.2 to 22 lb (1 to 10 kg)*
- *Pico-, from 0.22 to 2.2 lb (0.1 to 1 kg)*

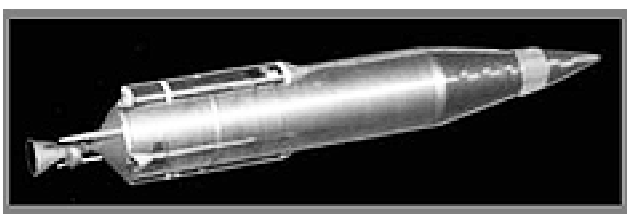
Considered by some to be a distinctive subgenre within the pico-satellite environs is the Cubesat, a craft that has the dimensions of 10x10x10 centimeters, which also happens to be the volume of exactly one litre of water, and a weight of no more than 1 kg. Although the majority of Cubesats have no propulsion systems, some are now incorporating ion thrusters into their designs. The photo below is of ***CP4***, one of **California Polytechnic**

University's educational Cubesats, was taken by ***AeroCube-2*** on April 17, 2007, after its launch via a Russian ***Dnepr*** rocket. AeroCube-2 is a pico-satellite built by **The Aerospace Corporation**. It was released from the rocket in a ***P-POD*** (*Poly Picosatellite Orbital Deployer*) built by Cal Poly, along with ***CP4*** and ***CSTB-1***, a satellite built by **The Boeing Company**.

The CP4's camera offers 640x480 pixel resolution.

Some extremely well versed experts will present their views of the small satellite segment in this issue of *SatMagazine*, and we believe their presentations will add fuel to the eagerness with which these craft are viewed as adjuncts and value-adds to current satellite endeavors. We also present a variety of other SatCom articles to assist all with growing their businesses, despite less than vigorous financial predictions.

There's content within ranging from Cubesats to codecs to net optimizations for managing satellite resources; the maritime Ku- challenges; the extremely popular and widely read columns from **NSR**, *Chris Forrester*, and **Near Earth LLC**; a most interesting examination of solar sails; ground systems to shark tagging; VSAT management to important UPLINK inclusions, such as the ESOA commentary on the 50th anniversary of satellite communications.



Project SCORE (*Signal Communication by Orbiting Relay Equipment — photo above*), the world's first communications satellite, was launched from Cape Canaveral on an ***Atlas*** rocket on December 18, 1958. This experiment was designed to test the feasibility of transmitting messages though outer space from one ground station to one or more other receiving centers. The satellite, which was in obit for only 12 days, was loaded with a tape recorder containing a Christmas message from the U.S. President *Dwight D. Eisenhower*. His voice transmission wished for "peace on Earth and goodwill toward men everywhere" and was successfully broadcast to the entire planet on a short-wave frequency.

On a more personal note, the publisher, editorial, production, sales, and development folk at **SatNews Publishers** wish our best to all of our readers, advertisers and subscribers. We offer a special thanks to those companies, organizations, associations, military commands, and hard working professionals with whom we forged new relationships during 2008. Plus, a huge "thank you" to the companies who have continued to support our publication efforts over the years. We look forward to supplying your critical information needs during 2009 and in assisting your SatCom endeavors with more interesting and relevant content to help ensure you enjoy profitable ventures.— *Hartley Lesser, Editorial Director*

ESOA is the Brussels-based trade association of all European satellite operators and their supporting members, which includes service providers, manufacturers, and launch service providers. Established in 2002, the association goals include raising awareness of the contribution of commercial satellite technologies to society and governments alike. ESOA also works to ensure satellites benefit from the appropriate political, industrial, and regulatory environment to fulfill their vital role in the delivery of global communications.

When the first communications satellite was being launched on December 18th 1958, it was very hard to imagine how significant that new technical invention would be to shape society as we know it. Now 50 years have passed and, although the idea behind this critical infrastructure remains unaltered, to connect distant points though a radio transmitter orbiting in space, the services and the reach of satellites has revolutionized global communications, thanks to HDTV, wireless Internet, emergency communications, and mobile phones, to name a few examples.

Today, satellites provide an invisible safety net, a global backbone, upon which most of our current communications services rely. And they may become even more relevant in the near future if the **European Union** (**EU**) wishes to accomplish the objectives set in the Recovery Plan that will be launched next year to stimulate our economies and mitigate the effects of the global financial crisis.

The plan calls for a timely, targeted, and temporary fiscal stimulus of around 200 billion euros, approximately 1.5 percent of the EU GDP, including many "smart investments." These are required to generate long-term growth through entrepreneurship, research, innovation, and access to technology. One of those concrete measures is the mobilization of 5 billion euros to improve energy connections and broadband infrastructure all across Europe.

Broadband Internet has gradually turned into an essential commodity to strengthen competitiveness and economic growth in the EU. The aim is to cover 100 percent of Europe by 2010. To do so, Commission and Member States will work with stakeholders to accelerate the upgrade and extension of networks. They are also planning to support that strategy with public funds in under-served and high cost areas where the market cannot and will not deliver.

The roll-out of DSL and cable has steadily grown in cities, but in the remotest parts of the EU, the deployment of those technologies is, at best, not commercially attractive. At worst, it's substantially more expensive than other alternatives.

According to the last **i2010** mid-term review published in April, DSL, for example, is now available in 89 percent of all the telephone lines in EU25. However, this percentage has started to plateau while other alternative technologies still remain marginal. In the case of rural areas in countries such as ***Greece***, ***Czech Republic***, ***Malta***, or ***Cyprus***, there is no DSL coverage at all.

That is why *Giuliano Berretta*, chairman of ESOA, in a letter recently submitted to President *Barroso*, reminded him that existing satellites in orbit can help achieve this goal. This can be accomplished either

ESOA EUROPEAN SATELLITE OPERATORS ASSOCIATION as a stand-alone technology or by contributing to the deployment and performance of other land-based communication systems “to reach those citizens otherwise forgotten and unconnected due to their remote or rural location”.

Mr. Berretta encouraged Mr. Barroso to acknowledge the pivotal role that satellite communication can play in the Recovery Plan. “It is in the public interest to draw on a technological solution that achieves this objective in the most cost and time efficient way, satellites are already up in sky and able to offer those services, and in an ecologically friendly manner, satellites use solar energy for their entire lifetime of over 15 years,” Mr. Berretta wrote.

We availed ourselves of the opportunity to chat with some leaders involved in the small satellite industry. One such individual is the Executive Vice President and General Manager, Space, for **Comtech AeroAstro**, *Patricia A. Remias*.

SatMagazine
Ms. Remias, would be you please describe your Company’s role in the small satellite market segment?

Patricia Remias
Comtech AeroAstro was founded in 1988 on the premise that space could and should be more accessible to a wider number of users — and thus need not be either overly complex or enormously expensive. Over the ensuing 20 years, we have maintained our focus on finding simple solutions to space-based challenges in a wide variety of mission areas and applications.

We have built and launched four satellites in the <200kg class, and developed a wide range of associated technologies that support the functionality needed by those satellites, usually in very small packages. Examples of these include miniaturized star trackers, imagers, and radios. We provide our space system solutions and components to Government, civil, commercial, and international customers.

SatMagazine
Have you experienced growth within the small satellite segment of the market? If so, in what areas?

Patricia Remias
We’ve seen significant growth in the small satellite market over the last several years. There is growing recognition in the space community that many missions can be accomplished with much smaller, and more capable, spacecraft than has ever been possible before. Examples include initiatives in ***Operationally Responsive Space*** (**ORS**) that meet critical warfighter operational needs, replenishment of several commercial constellations of ‘small’ satellites, a variety of missions that use ‘plug-n-play’ technologies, and several **NASA** and **DARPA** programs. In an era of tough economies and shrinking budgets, customers want more for less. Small satellites are no longer strictly science demonstration and education missions, but rather an often faster-and-cheaper option to meeting critical needs for the space customer base.

SatMagazine
Have you witnessed more of a desire on the part of universities to now more fully involve the commercial side of the industry to help them “launch” their small satellite projects?

Patricia Remias
Comtech AeroAstro has always had close ties to the university community — it’s a win/win situation for all parties. We work together in a variety of ways; subcontracts for technology development, support of university space missions, co-sponsorship of workshops and conferences, employment of interns and graduates, and associations with university-based principal investigators. We always look for space experience in recent graduates that we hire as employees, they are our future. With the availability of smaller and cheaper technologies like the Cubesat kits, universities can accomplish space missions in shorter timelines that allow the students to experience the entire mission life-cycle. We anticipate continued support of the university community and their initiatives as the small satellite market continues to mature.

SatMagazine

Where do you see the small satellite segment moving over the next year or two in both the commercial and military side? What payloads seem to be garnering the most acceptance for incorporation with small satellites?

Patricia Remias

Small satellites continue to prove themselves in almost every mission area — communications, imaging, earth and space science, and a multitude of others in both commercial and military applications. Concepts like force enhancement — increasing the capability of already-existing assets by launching satellites that work with them — has great potential. S***pace Situational Awareness*** (**SSA**), the desire to understand what's happening around our assets in space, is another area that lends itself to small satellites.

SatMagazine

What are the most important reasons for those in the industry to consider small satellites for their various payloads? Are there any launch advantages?

Patricia Remias

There are few limits on what small satellites can accomplish, except on those missions where physically very-large payloads are required, and even some of those can be accomplished using constellations of small satellites working together. Missions that require very high reliability can be addressed by launching multiple identical vehicles, either together or in sequence, rather than building complicated, multiply-redundant single-platform systems. This approach also reduces mission risk due to any single launch failure.

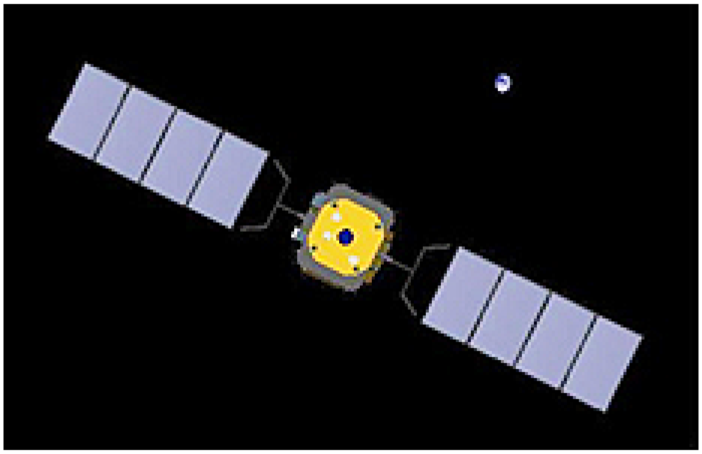
Small satellites can use secondary launch opportunities where the target orbit allows, greatly reducing launch costs, or allow multiple spacecraft to launch on a single rocket. On the first ***EELV Secondary Payload Adapter*** (**ESPA**) launch in 2007, Comtech AeroAstro was one of six spacecraft (from five different sponsoring organizations) on a single rocket. We look at requirements with an open mindset and the goal of meeting our customer's needs in the most efficient way possible, and presenting cost-saving alternatives at every opportunity.

John. J. Webb, Jr., the CEO and Founder of **Instarsat LLC**, was kind enough to contribute his time to answer our queries regarding small satellites. When asked about what his company's involvement was, he answered...

"**Instarsat** is a privately held, innovative space technology company that is developing a new generation of small and medium class satellites for commercial, civil,and military space markets. To meet the growing demand for a new generation of smaller space platforms, Instarsat is developing ***ExpressBus*™**, which is intended for use in academic and research missions. ExpressBus™ is a microsatellite class platform that offers customers greater mission planning flexibility, responsive operations, higher return on mission investments and a lower cost access to space."

Regarding this market segment, John sees significant growth potential in small satellite missions for "university and commercial research payloads, in part because of the emerging launch services that are enabling affordable access to space." And will higher educational centers more readily accept commercial firm involvement? "Many university programs I am aware of would most likely welcome private sponsorships, commercial partnerships, and other forms of technical assistance. However, I do not see those programs abandoning traditional forms of government funding."

We asked John where he expects the small satellite segment moving over the next year or two. "Near term, within two to three years, I see a continuing shift in the commercial and military sectors to smaller space systems. In particular, smaller missions that can repeatedly deliver schedule and performance benefits. On the commercial side of the equation, smaller missions with microgravity research, Earth observation, space weather, and communications payloads will continue to see an increase in mission frequency. On the military side, smaller missions that meet the war fighter's needs, such as, situational awareness, communications, and threat monitoring are all in the realm of possibility for future smaller missions.



"Based on my observations of the market, there are three reasons for potential customers and their end-users to consider the value in small satellites for their missions. These include improved quality — efficient production techniques that lower costs and produce repeatable results — a rigorous and continuous development and testing program that enables predictability, while substantially mitigating technology risk — and performance, thanks to a proven hardware heritage that increases the prospect of a longer operational life and ensures higher returns on mission investment."

Regarding the company's ongoing development projects, Instarsat focuses on supporting its markets by "executing a rigorous and continuous product development and testing program. Called ***DemoStar™***, this delivers on our core value proposition and substantially mitigates customer risk. Proven heritage hardware combined with our competitive advantages and high customer confidence will result in our spacecraft products and subsystems doing exceedingly well in all of our targeted markets."

Other product families under development by Instarsat include ***ScienceBus™*** (minisatellite class spacecraft), ***CommercialBus™*** (small class spacecraft), and ***DefenseBus™*** (large class spacecraft). These space platforms afford a broad range of product choices for mission planners and encompass breakthrough improvements in cost, quality, reliability, performance and scheduling.

The **European Space Agency** will present the ***Second European CubeSat Workshop***, to be held at **ESA/ESTEC** in January of 2009.

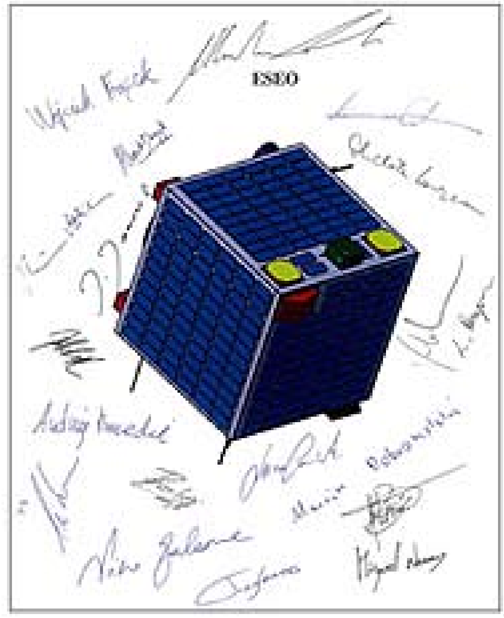
Already, the first workshop to be conducted during the **B2** development phase of the ***European Student Earth Orbiter*** (**ESEO**) was held from December 15th through the 19th of 2008 and was organised by the ***ESA Education Office***. The workshop took place in the *Concurrent Design Facility* (**CDF**) at the *European Space Research and Technology Centre* (**ESTEC**) in the Netherlands.

In the early stages of Phase B2, the ESEO project studied the implementation of some important changes in requirements, in order to comply better with launch opportunities to fly the satellite to low Earth orbit as a secondary payload on one of the VEGA qualification flights. This, essentially, involved a redesign to reduce the dry mass of the satellite and its payload from about 120 kg to a target of 75 kg, while at the same time maintaining an architecture that will support the key systems and functions of the satellite.

The ESEO reconfiguration activity is led by **Carlo Gavazzi Space**, the Industrial Contractor for **ESEO Phase B2** and **Phase C/D**, supported by their university coordination team.

The workshop involved the direct participation of 11 students from seven different universities, who attended the ESTEC CDF in person. Five other students (representing subsystems to be designed by three additional universities) were involved via teleconference.

The workshop was also supported by **AMSAT**, an international group of amateur radio operators that is participating in ESEO by providing some of the satellite communication functions. AMSAT will enable the ESEO flight operations to access the *Global Educational Network for Satellite Operations* (**GENSO**) and the worldwide amateur radio network.



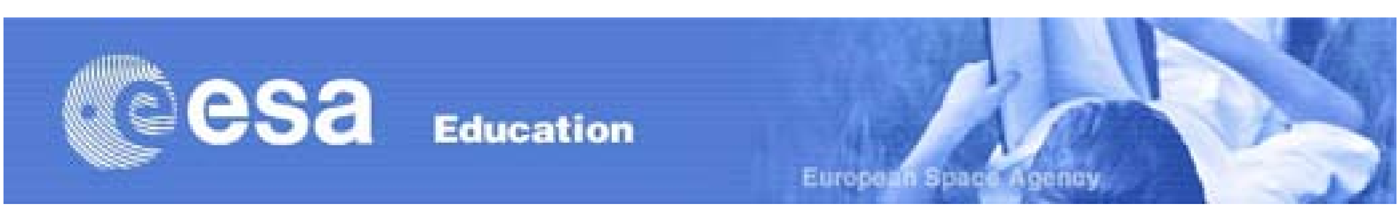
ESEO preliminary design courtesy: ESA

The end results? The successful completion of the preliminary definition of the new ESEO configuration and the definition of the corresponding preliminary system budgets (mass, power, data links), as well as the identification of potentially critical areas that will require further attention at a later date.

ESEO is the second micro-satellite mission within the ESA Education Office's *Satellite Programme*. It builds upon the experience gained with the ***SSETI Express*** micro-satellite, launched in 2005, and the ***YES2*** student experiment flown in September 2007. The project schedule foresees Phase B2 lasting one year, then a two year-long Phase C/D, followed by the launch campaign, with launch expected to occur in 2012.

Additionally, the ESA Education Office is pleased to announce the ***Second European CubeSat Workshop***, which will take place in **ESA/ESTEC**, *Noordwijk*, The Netherlands, from *January 20th through the 22nd*, 2009.

Since the first workshop, the ESA Education Office in the *Directorate of Legal Affairs & External Relations,* in conjunction with the *Directorate of Launchers,* has selected nine CubeSats (plus two backups) from European universities for launch on the maiden flight of the ***Vega*** launcher, now scheduled for November 2009.



Arianespace' Vega launch vehicle (image: ESA)

The nine CubeSats will be deployed from three different deployment systems mounted on the support structure of the main payload, ***LARES*** (*LAser RElativity Satellite*), into an orbit of *350 km by 1450 km at an inclination of 71 degrees*.

The launch opportunity is offered by ESA to the selected CubeSats free of charge, and recognizes the growing importance of the CubeSat as a powerful, hands-on, space education tool. This is but the first step to boost student hands-on development of CubeSats in Europe, providing a suitable and qualified space workforce for the future in complement with other education project activities.

The main aims of the workshop are to:

- *Report upon on the development status of the CubeSats selected for the Vega maiden flight*
- *Outline ESA's long-term strategy for supporting CubeSats, including plans for cooperation/ coordination and the prospects of future flight opportunities, for instance on the first and sub sequent VERTA flights of the Vega launcher*
- *To facilitate information and data exchange between CubeSat teams, ESA and commercial suppliers on lessons learned, best practices, mission applications, technologies and instrumentation, cooperative space/ ground networks, and future mission plans/concepts.*

The workshop consists of invited papers and contributed papers selected from a *Call For Papers*, and will include both oral presentations (20 min.) and a poster session over a period of three full days in room **Newton 1+2**. Invited papers will include status reports from the 11 CubeSats associated with the Vega maiden flight.

In addition, a Round Table discussion is planned. This event will feature key members of the CubeSat community within and outside Europe in an interactive session with the workshop participants. The Round Table will address themes related to current issues and future evolution of the CubeSat field. Following the Round Table, all workshop participants will be invited to a workshop buffet dinner.

Professors and their students inspect a CubeSat kit and P-POD from Stanford Uni/CalPoly
Photo: ESA

The ESA Education Office plans to sponsor up to three students from each participating CubeSat team (from an ESA Member or Cooperating State) to attend the event. There will also be a tour conducted of the ESTEC test facilities.

The ESA has a number of educational and professional opportunities for learning and implementation at their education website. Select the ESA banner logo on ***Page 9*** for additional information.

Lastly, here's an open letter to President-Elect ***Obama***, authored by *Hoyt Davison*, the Founder and Managing Partner of **Near Earth LLC**, a New York-based satellite industry investment banking consultancy.

Ideas for a Space Legacy

First of all, congratulations on a brilliantly run campaign. We add our hopes to that of our fellow citizens that this same degree of enthusiasm, optimism, organization, planning, intellect, and civility can be infused top down into all of Washington, D.C.

We have also been impressed with the thoroughness of your transition team's efforts in relation to reviewing NASA and its goals and challenges. It will indeed be a daunting task to maintain our country's lead in space on a $20 billion budget and we offer no advice on the many complicated budgetary trades between completing the International Space Station and perhaps extending its life, accelerating development of the Ares and Orion programs to lessen any gap in our independent access to space, or alternatively extending the Shuttle fleet's life. There are enough experts of differing opinions and no shortage of interested parties to make these decisions quite difficult. Good luck.

What we really want to address is your legacy in space, because your legacy will be our legacy, too. It is, of course, highly unlikely (though certainly not technically beyond our means) that any country will send people to the Moon, and certainly not onto the surface of Mars, within the next eight years. So, all audacious hope aside, that is unlikely to be your legacy. But like JFK, a clearly stated goal to boldly move forward on one, or both, can be your legacy and we would strongly suggest it should be.

Do we really want to explain to our children and grandchildren in 2020 or 2025 how we landed on the Moon in 1969, but somehow lost the ultimate space race to China, India, Russia, Europe or all of the above? At the very least, let's find some partners and go back together.

As for the difficult decisions mentioned above, in 25, 50 or 100 years the world will little note whether the International Space Station was operated a few more years or not. What the world will remember is what wonderful new drugs or materials were first created there.

So far the track record of investment and achievement is underwhelming. In the future, the world will not care so much as to whether we used Ares, Soyuz, or the Shuttle to get into space during your Administration. They are all just upgrades of varying degrees of German rocket technology from WWII.

The world will, however, be impressed if, during your Administration, new reusable launch vehicle technologies and systems are finally developed that allow us to gain the order of magnitude reduction in cost per kilogram we so desperately need. The world will remember if space tourism becomes a reality, or if any country can add its citizens to the ranks of astronauts.

Please consider how you might smartly invest in these new technologies and how access to space can be expanded for all. Looking back from the future, we suspect the world will also want to say that during your Administration we finally took Earth monitoring seriously and put in place new satellite constellations to measure, predict and better understand our global climate. We should really not be guessing when and where hurricanes will form and what direction they will head. That is so 20th century.

Your Administration could also mark a renaissance in mankind's quest to explore and use space. To date, other than for some notable commercial applications from Earth orbit, space has been almost exclusively the domain of governments. With recent and continuing advancements in technology that no longer has to be the case.

The world is full of space enthusiasts and entrepreneurs, as we are sure you have discovered, and many are quite willing and able to risk their lives and their own capital. But operating in space is expensive and what they need are government incentives to attract additional capital. This has been talked about for years, but nothing major has ever happened. What we have received are X prizes of $10 or $20 million to accomplish things costing 10x to 100x more money.

What we need are XXX Prizes, meaning amounts large enough to spur the private sector forward with realistic hopes of just rewards for accomplishing tasks the government would otherwise spend considerably more to achieve.

Lastly, as you contemplate a potential trillion dollar stimulus package, please keep in mind that we need more than just bridges and roads and the temporary construction jobs they entail. In fact, we would argue the jobs we really want to create for our country's long term competitive advantage are jobs in science and technology.

We know you understand as your green technology, alternative energy, and terrestrial broadband initiatives are exactly along these lines. What we humbly suggest is that a significantly increased investment in space also be considered. We need to do more than just maintain the "high ground" of space for our military and intelligence communities. We need to recommit ourselves to aggressively lead the world in exploring and using space for commercial, scientific and peaceful purposes for the benefit of all mankind.

To achieve these gains we will, of course, need more home grown scientists and engineers. Sadly, we are falling woefully behind our important competitors in this regard. You, as President, can use your bully pulpit to make science and math cool and important to our youth and there is no better stimulus for that than Space, the Final Frontier.

Very respectfully,
Hoyt Davidson, Near Earth LLC

About the author

Mr. Davidson is the founder and Managing Member of Near Earth LLC. Previously, he was a Managing Director in the Telecomm Group at Credit Suisse First Boston. Mr. Davidson's investment banking career began in 1987 as an associate and one of only approximately 100 bankers at Donaldson, Lufkin & Jenrette. He was part of the phenomenal growth and success of DLJ to over 1,000 bankers by the time of its acquisition by CSFB in 2000. At DLJ, Hoyt Davidson was a co-founder of the firm's Space Finance Group, Wall Street's first dedicated industry coverage group for the satellite industry. Mr. Davidson was one of two Managing Directors of the Space Finance Group. The group raised over $25 billion for satellite related entities and held a number one market share for several years.

NEAR EARTH LLC

Israel's AMOS: Ready for #4 + #5

by Chris Forrester

"We have managed to pull some very interesting rabbits out of the hat,'' says *Omri Arnon*, V.P. of business development at Spacecom, operators of the growing Amos fleet of satellites. Amos has just won a new DTH platform from Germany's T-Telekom, that operates over Hungary. ''It is a highly competitive area and we have won some good business against some tough competition,'' adds Arnon.

But **Amos**, like other satellite operators, is also looking closely at winning new business out of Central Asia, which he describes as "a hidden gem" of a region. "We have looked closely at this whole region and it is a primary target for our ***Amos-4*** craft and possibly for ***Amos-5*** as well.

"Amos-4 is slated for launch in 2012 and Amos-5 is planned for launch in December 2010. People may be confused that Amos-5 will arrive before Amos-4, but it's simply because we ordered Amos-4 and then had an opportunity to acquire a fast-track satellite in Amos-5 with ISS which is large compared to the existing Amos fleet with 36 transponders, quite powerful and it was a good deal that we couldn't refuse. Amos-5 will come from **JSC-ISS** with the payload coming from **Thales** in France."

ISS is the **Russian Reshetnev Co**., and better known to readers as the former **NPO-PM** satellite builders of the ***Express-1000*** system. The satellite will be integrated and tested in Krasnoyarsk, Russia.

"We see Central Asia as a fast-developing area," says Arnon. "There is already considerable VSAT activity there and everyone recognises that it is growing quite fast and with good demand from countries like Kazakhstan and Azerbaijan which are, in some cases, looking to launch their own satellites, which some outsiders may question as to the economies."

> *"We see Central Asia as a fast-developing area,"*
> ***Spacecom*** *Israel*

Some people might question why **Israel**, a tiny country with a modest population, would want its own satellite fleet.

"For us it was a technology project and it has proved to be a good investment for Israel," says Arnon. "We are helped by having a major customer in Israel in the ***YES*** platform and this helps enormously. While some satellite operators can make a business out of VSAT, ISP and occasional use traffic, this has never been our intention. We want a strong video presence. While none of us know where these countries are headed, and we have to recognise that each of them have their own national requirement in terms of national broadcasting as well as their own security, that sort of market does not interest us. Kazakhstan has its own satellite [currently with major problems, ED]. Azerbaijan has stated they want their own craft. The countries in Central Asia might also be compared to Africa where the regions are so large that satellite distribution is a logical choice. Contemplating fibre or cable delivery would be a significant cost.

"We see these new emerging markets very much like those of Central and Eastern Europe and our focus is very much on video and we see them as being good potential customers. It would be wrong to overstate the opportunities because the region is very much emerging. Disposable income in some cases is extremely modest but we do sense there is more activity in the last year or two in this area in the satellite arena generally, mostly that activity is based on communications but video is also coming on. Channels in their

Amos wins Hungarian DTH

On November 25 Amos added Hungary's latest DTH platform, T-Home Sat TV and transmitting from Amos-3. Deutsche Telekom, the German telco giant, owns the DTH bouquet. The bundle of channels on offer includes four in HDTV. The new bouquet brings to three the number that Amos is now handling (Israel's 'YES', as well as Romania's BOOM.)

Amos-4 will have governmental/commercial roles

AMOS July 7, 2007 said it had signed an agreement to build and launch AMOS-4, the newest addition to the AMOS constellation, with Israel Aerospace Industries (IAI). IAI will construct the satellite for approximately US $365 million. AMOS-4 is scheduled for launch in 2012 with a 12-year lifespan. "This is a tremendously important achievement for Spacecom. AMOS-4 vaults us forward dramatically with its new capabilities," said David Pollack, Spacecom president and CEO. "It will enable us to offer enhanced services, reach new regions and drive business expansion. The agreement strengthens IAI's already proven advanced space capabilities adding to the AMOS series they have constructed."

Spacecom will pay US $100 million for AMOS-4, with a US $22.5 million first payment scheduled for January 2010 and a $6.25 million final payment upon the satellite's delivery. The Israeli government will pay Spacecom US $265 million generated from a pre-launch deal to supply it with services on AMOS-4 over the satellite's full life span. After pre-sold capacity to the Israeli government is utilized, AMOS-4 will have available eight Ku-band transponders of 108 MHz and four high power Ka-band transponders of 218 MHz with steerable beams.

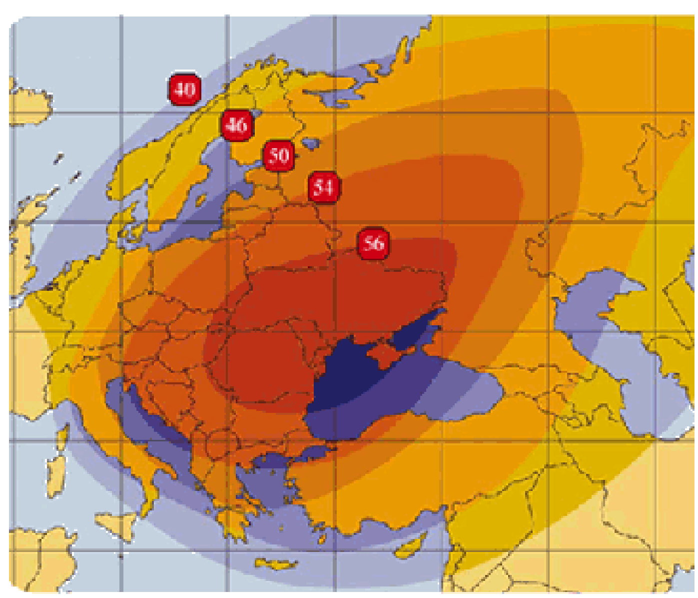
local languages also need to be important and ready for distribution and a portfolio of willing international channels would also be useful, whether in English, French, Arabic or Turkish."

"Our Amos-4 craft has steerable beams so is well able to embrace parts of the region and we are including the area in our potential marketing plans. Amos-4 will be positioned in the mid 60 ° locations [between 64 ° E and 76 ° E] and Amos-5 will be in a completely new location for us. The positions we are looking at are quite crowded but we believe we have found a niche, which will give us entry to the market. The challenge of opening a new position means that potential customers do not get the benefit of our existing broadcast neighbourhood. We don't see this as a problem but it means we have to work harder to develop the new position and you start with a single satellite.

"While 4 ° West will continue to be our main video neighbourhood, we hope that we will be in a position to develop similar bundles of channels for the new neighbourhoods. Our long-term strategy is to have two satellites at least in each of the locations, but today we admit we only have that capacity at 4 ° West. We all recognise that we cannot turn the clock back, but the past few years have seen very good business come out of Central Asia, purely based on governmental demand, and we could have easily filled up a satellite. There is so much demand out of the Middle East, out of Afghanistan, and prices, even for communications-only satellites, have been robust these past few years.

"Video for TV attracts a higher fee per transponder, but if you are not too greedy, you can make a nice profit out of communications"
—Omri Arnon

"Video for TV attracts a higher fee per transponder, but if you are not too greedy, you can make a nice profit out of communications. But Occasional Use traffic takes a great deal of administration, but we do offer it and while we very much would like more video, and we are very hopeful that Amos-5 will give us good coverage over this region as well as over Africa, but it would



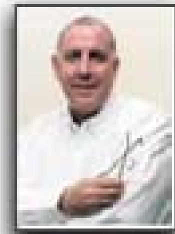
AMOS footprint

be wrong of us to expect levels as high as 70 percent of video, maybe it will be 70 percent communications.

"We recognise that the likes of **Astra** and **Eutelsat** are increasingly getting into Value Added Services at a wholesale level and this is an area that is possibly interesting to us, we are talking about it but have yet to agree a solid strategy on how to achieve this. We look at what **SES**, **Eutelsat**, **Telenor**, and others have in terms of a complete solution for their clients where they have fibre as well as satellite communications and this could be interesting for us.

"Our view is that if you combine fibre with satellite, then you can make a good return on the overall investment. But it requires significant investment, measured in the tens of millions of dollars, but if we act smartly, perhaps leasing fibre capacity there are ways to do this efficiently. But we also know that we have a lot of work on our hands already and we are only a modest company," says Arnon.

"We are very pleased to have added the Hungarian DTH platform to our overall portfolio and we are hopeful of adding another, similar bundle. Our goal was always to have two to three DTH platforms as part of our portfolio and we have achieved those goals. We still hope to add another."



About the author

London-based **Chris Forrester** *is a well-known entertainment and broadcasting journalist. He reports on all aspects of the TV industry with special emphasis on content, the business of film, television and emerging technologies.*

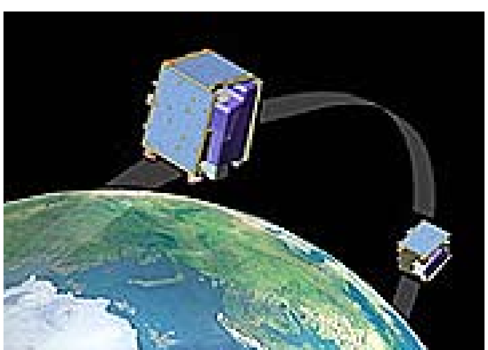
Satellites—Bigger Or Smaller? Yes!

by Ian Fichtenbaum, Associate, **Near Earth LLC**

Go big or go small? Rarely have we had such an opportunity to witness the contrast in evolution of the size and scale of satellite systems in such a short time span. Nearly three months ago, and, coincidentally, merely a week apart from each other, we witnessed the launch of two new ways to observe the world and, indeed, two ways to see the future of satellites.

On September 6th, a powerful new geospatial imaging system, the ***GeoEye-1***, was launched from California's **Vandenberg Air Force Base**. Only a week earlier, on August 29th, the ***RapidEye*** constellation of five satellites blasted off from Baikonur, Kazakhstan, to form the newest entry into the commercial, multispectral, remote sensing market. The contrasts were striking indeed. Each of the RapidEye sats is less than a tenth of the size (by mass) of the GeoEye system — only 150 kg each. As has held true in the electronics industry, is smaller the future of satellites as well?

GeoEye-1 satellite



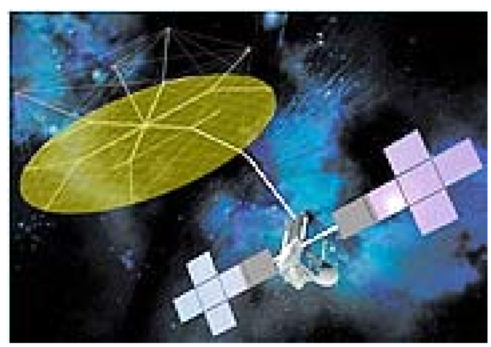
RapidEye constellation

It is always a pleasure to see a successful launch of new space-based services. We offer our congratulations to all players involved. One particularly proud participant in all of this should be **Surrey Satellite Technology Limited** (**SSTL**), the U.K.-based organization that built the highly compact buses for the RapidEye constellation. Having grown out of a university project in the early 80s, SSTL has been a force in the development of small satellites for the last two decades, pushing the limits in satellite size and capability in dozens of systems.

> *The biggest thing to watch will be not so much the size of the satellite but the functions they will serve and the potential for the opening of new markets.*

Along the way, many fellow travelers have joined them — enthusiasm for building satellites as small as a single kilo has exploded among academic institutions, in scientific missions, and even in military circles. A small satellite can now be built for a few million dollars each — compare that to the standard quarter-billion dollar telecom sat. The idea of building low-cost satellite systems assembled on rapid schedules appears to be an economically attractive one.

On the other hand, commercial space systems have been less likely to trend towards smaller and, in fact, have been going directly in the other path. Commercial telecom satellites have been growing ever larger, due to increased demands for ever larger and more powerful antennas, more transponders and spot beams, and more power from larger arrays of solar panels.



Terrestar-1 satellite

Telecom satellites routinely weigh in at over 5 metric tons and some now weigh over 6 metric tons. Soon-to-be-launched mobile services satellite ***Terrestar-1***, with a record 20-meter deployable antenna, will weigh in at about 6700 kg — more than almost any other commercial satellite ever launched. If there is an economic argument for going small, the commercial market certainly has other ideas.

	RapidEye	GeoEye
Size	5 satellites	1 satellite
Mass per sat	150 kg	1955 kg
System costs	€160 million	$209 million

Some of this is the inevitable result of engineering requirements emanating from market demand. Telecom satellites are getting bigger because consumers demand smaller handsets and more bandwidth. Physical constraints demand that nothing less than bigger satellites to satisfy that requirement. Remote sensing sats, such as GeoEye-1, are also getting bigger as higher resolutions demand larger aperture sizes.

Orbcomm satellite

The argument can go the other way, as well. RapidEye, for instance, trades resolution for faster revisit times and greater coverage. The Company positions itself as the conduit for clients who need more dynamic demand, such as for weather events, natural disasters, and seasonal land use surveying. Another small satellite system, **Orbcomm**, focuses exclusively on low data-rate *machine to machine* (**M2M**) communication, a market that argues for the low capital cost of deploying small satellites.

How do small and large satellite systems measure up economically for their sponsoring businesses? So far, direct comparisons between small satellites and their larger brethren are hard to come by in direct commercial markets. ***The chart at the top of this page compares the most recent example.***

Both the RapidEye constellation and GeoEye-1 had roughly equivalent costs, with both having a degree of government participation. Are the five sats of RapidEye the rough equivalent of one GeoEye-1? The market will tell the story.

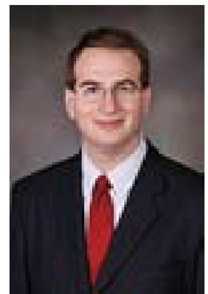
A possible comparison would be the various competing mobile satellite systems deployed in the mid-90s. The chart below compares the first generation Orbcomm and Iridium systems with the Inmarsat-3 satellite system, all launched within a few years of one another. Subscribers are based on the most recently available data. Revenues and EBITDA are annualized for 2008, based on the most recently available information. Readers should note that Inmarsat financial numbers reflect the operation of the newer ***Inmarsat-4*** system.

	ORBCOMM	iridium	inmarsat
System	Orbcomm	Iridium	Inmarsat-3
Size	28 satellites	66 satellites	5 satellites
Mass per sat	45kg	689kg	2068kg
System costs	$330 million	Approx. $6 billion	Approx. $1 billion
Subscribers	420,000	305,000	235,400
Revenues (m)	27.2	312.0	623.2
ARPU	$64.76	$1022.95	$2647.41
EBITDA (m)	(2.5)	107.0	435.4

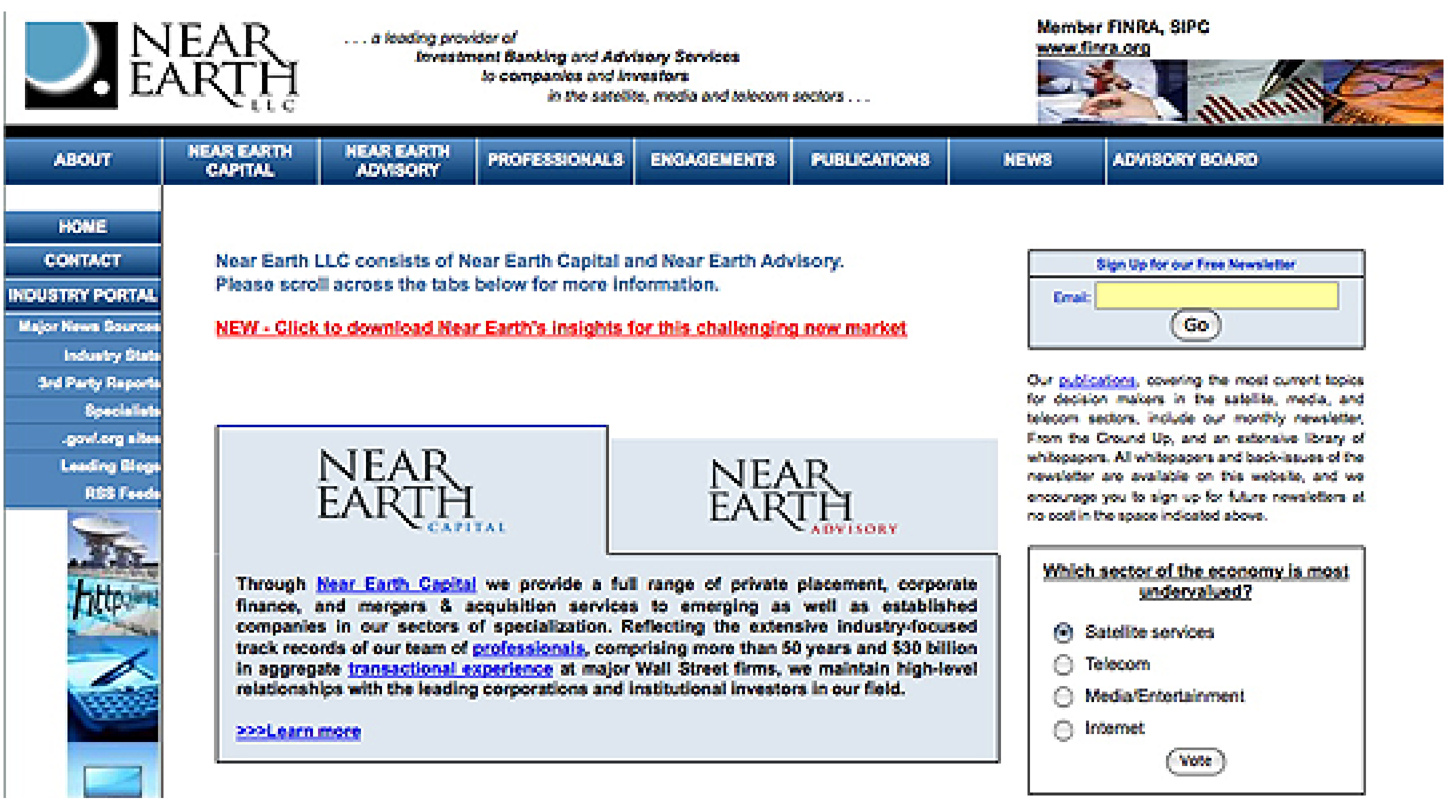
Of the three, Orbcomm was certainly the least expensive to build out, but its limitations to low data rate communications has meant that it must overcome much lower *average revenue per user* (**ARPU**) than its competitors. Iridium and Inmarsat were much more expensive systems, yet garner far more revenues due to their increased capabilities in voice and high data rate communications. They also have positive EBITDA, an indicator of maturing companies. On the other hand, Iridium can boast a model few businesses can — after the original company went bust on low subscriber growth buried under huge capital costs, private investors bought the whole system for $25 million. When you can get that kind of a deal, who needs small satellites?

Where do we go from here? Will new technologies allow small satellite systems to gain the capabilities of larger systems? Will the business case to go smaller be compelling? The biggest element to watch will be not so much be the size of the satellite, but the functions they will serve and the potential for the opening of new markets. What systems will be used to finally bring mobile satellite communications to regular handsets? What systems will be used to deliver high-resolution real-time earth imaging around the globe, or to provide robust technology demonstration services? Will they be big or small? **Yes**.

About the author



Mr. Fichtenbaum is an Associate for Near Earth LLC. Hailing from Canada, he is a graduate of the Master of Management program at the University of British Columbia as well as a Bachelors of Engineering at McGill University. Since graduation, Ian has built a variety of business experience in both the satellite and financial worlds, having worked at the financial firm, Divine Capital Markets, and advised the Montreal-based small satellite startup, CANEUS NPS. He also worked at UBC's Center for Operations Excellence, providing quantitative analysis and decision support tools to industry clients. He is fascinated about the intersection of business, finance and advanced telecom and aerospace technologies and the ties between these fields. In addition to his undergraduate and graduate studies, Mr. Fichtenbaum is also a proud alumnus of the International Space University, having participated in the 2006 Space Studies Program in Strasbourg, France. Contact Ian @ 646-290-7794 or at his email address ***ian@nearearthllc.com***



by Carlos Placido, Analyst, **NSR**

Citing difficult market conditions and slow adoption of IPTV by small U.S. telcos, SES Americom announced it will cease IP-Prime operations by July 31, 2009. While SES has made progress in the number of telcos using the service (37), the number of end subscribers totals 10,000, implying (on average) single-digit TV service penetration in the telco markets.

As ***IP-Prime*** has been leading wholesale linear satellite IPTV offerings, and has always provided a positive outlook for the service, the announcement surprised most in the sector, most notably SES clients that now need to make other plans. **NSR** does not view this service disruption as shadowing the market for telco-satellite hybrid offerings or the viability of other HITS offerings, but rather as a sign that the combo of satellite C-band and DSL delivery for telco-packaged live video channels fails to pass “the audience test” necessary to justify the underlying costs of such a two-tier distribution approach.

Healthy 4 P’s in a non-saturated market

The IP-Prime fall does not appear to be the result of intensifying competition nor marketing mix issues. Despite **EchoStar** recently increasing competition by joining SES and Avail Media as providers, the pool of U.S. telcos wishing to add IPTV is far from saturated, leaving room for growth. SES has had a feature-rich offering, distributed via good partners, to a dispersed, fragmented and satellite-receptive Tier 2/3 telco sector and with a good value proposition.

That was then, this is now...

In 2004, the conditions for satellite-delivered IPTV in North America looked promising and unique. C-band capacity was abundant in time for a MPEG-4/DVB-S2 technology leap. Early successes of telcoTV in Europe set IPTV expectations worldwide; telephone companies were facing an eroding telephony business and needed ARPU/churn enhancing service diversification. A forward-looking assessment in 2004 suggested that U.S. telcos would embrace IPTV.

With a unique base of over 1,500 small telcos, conditions looked good for turnkey super-headend solutions that would lower entry barriers to television for small telcos via a CAPEX-for-OPEX value proposition. In anticipation of such an opportunity, the **Intelsat Technical Labs** started exploring the satellite play for IPTV

in 2003 and, after a few false steps, both **SES** and **Intelsat** launched their respective wholesale IPTV offerings. As a result of the fusion of **Broadstream** and **Telesat**-hosted ***Auroras TV***, **Avail Media** later became Intelsat's IPTV key partner and developed its own network of distributors and integrators including **Falcon**, **Nortel** and **Motorola**.

Fast forwarding to today's environment, the situation is quite different. While now IPTV is a fast growing business, especially in urban areas with high broadband penetration, it remains small in the overall pay TV picture and has fallen short of expectations on a worldwide basis. Even in France, where ***Orange*** leads the European IPTV market and is the world's second largest player (after China), less than 30 percent of Orange's DSL users are eligible to receive TV via DSL.

Part of the satellite-IPTV problem is that while the satellite distribution is easy to do, end-to-end system integration became more difficult than anticipated. The drivers for telcos to enter IPTV have not changed, but the long run of DSL lines in rural America limits the number of DSL lines with the quality and speed necessary to support bandwidth-hungry TV, particularly for HD as DTH competition intensifies.

Technology, Service Expectations and Capacity Opportunity Costs Diverge

The U.S. HDTV boom might also have contributed to SES's decision, raising the opportunity cost on satellite space segment. Although there is no capacity shortage in North America, the divergence between IPTV service expectations and opportunities to pursue less-risky and less operational-intensive services might have weighted in the decision.

Additionally, one cannot ignore the ever-growing dis-intermediation threat of the Internet. Between 2004 and 2009 "over the top" (OTT) Internet offerings have proliferated. Just like **Vonage** and **Skype** challenged the telephony business, broadcasters are increasingly putting their content online, and the emergence of OTT-TV offerings like **Hulu** and **Netflix** contribute to more challenging conditions for telco IPTV. Although possibly a differentiating opportunity for telcos, Internet TV poses real threats fostered by higher broadband speeds, advancements in video compression, PC progressive downloads, empowered consumers and the net neutrality / non-discriminatory principles of the Internet.

Finally, technology continues to evolve at Moore's Law speed, and the CAPEX differential between core headend equipment and edge processors tends to erode, slowly diminishing the advantages of an outsourced super-headend. Due to this, HITS players attempt to reach the largest possible audience regardless of last-mile technology, blurring the boundaries between cable-HITS, telco-HITS and DTH (especially in Ku-band).

Even some of the latest IP-Prime announcements such as the **Comcast** HITS offering illustrate this confusing scenario. Last-mile transport characteristics of DSL, coaxial cable and DTH are distinct, but HITS players will tend to focus uplink signal packaging toward the largest target segment and extending reach via edge processing to handle last mile transrating, transcoding and transport adaptation issues. Band neutrality discussions for HITS/DTH in India, **Telefonica**'s (apparent) intentions to leverage its DTH platform in Latin America for white-label B2C/B2C video distribution and IPTV Americas' shift to cablecos are other examples of this HITS "hedging" trend.

Viability In Jeopardy

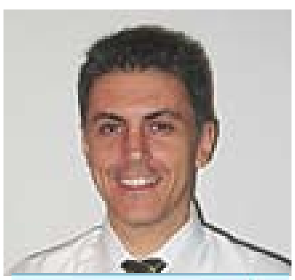
The IP-Prime case makes one wonder "what's next" for IP-Prime competitors. NSR believes that, while at first glance, this means less competition to Avail Media and EchoStar, it also brings an overall negative effect on the sector, raising questions about the long-term viability of satellite-delivered IPTV for linear (live) content.

Avail Media and EchoStar will likely pursue further differentiation by focusing on a distinct converged distribution approach. After acquiring ***ViewNow***, Avail has the advantage of VOD, having recently reached one million subs. With IPTV results negligible for a multi-billion dollar revenue generating company like EchoStar, it might find value by seeking a broader cross-platform play, possibly with **Sling** place-shifting, DVR and set top box (STB) manufacturing in the spotlight.

Satellite-IPTV naturally brings a higher risk-reward element than capacity leasing for operators. NSR noted in the past that North America was a testing ground for satellite-delivered IPTV and that players would first validate such offerings before devoting resources elsewhere. With more ways to access media and service providers adopting pragmatic moves across traditionally competitive platforms, TV distribution is becoming less platform-bounded, and any distribution enhancing platform will need to consider these trends as well as the dis-intermediation forces of the Internet.

Video demands high bandwidth, and satellite broadcast remains an excellent medium for video transport provided such distribution passes "the audience test" with an aggregate number of consumers justifying the hybrid food chain expenses. IP-Prime is a prime example that bottlenecks in rural America's DSL access, among other factors, have made satellite IPTV fail to pass this test.

About the author



NSR

Carlos Placido has more than 12 years of progressive experience in the areas of consulting, program management, research and engineering in telecommunications and entertainment. He has carried out independent business development, technology assessment and management activities, including market research studies for NSR, assessment of regional business potential for vendors and project management at Telefonica. Until 2004, he led a development team at Intelsat in Washington, D.C. where he was responsible for identifying and validating emerging video and data technologies for their potential applicability to new and existing services. Mr. Placido's development efforts at Intelsat included advanced video networks, IP television, satellite multicasting and broadband, spearheading satellite IPTV, and improving Internet via high-speed satellite LAN-to-LAN.gineer at Impsat Fiber Networks.

Speaking Of Small Satellite Support...

*by Dr. Milind Pimprikar, Chairman, **CANEUS***

Participants at the CANEUS 2004 and 2006 Conferences, held in Monterey, California and Toulouse, France, agreed that in order to open up the market for small satellites and facilitate dialogue between the many stakeholders in the industry, it was necessary to create an international consortium to coordinate, standardize, and offer launch opportunities for the small satellite industry.

The ***CANEUS Small Satellite Sector Consortium*** took an approach similar to that of the semiconductor industry, namely, the **SEMATECH** industry group. The consortium focuses on providing opportunities for industry representatives to participate in cutting-edge technical discussions while establishing the future direction of the small satellite industry. The consortium oversees five projects and initiatives dedicated to:

- *Developing standards so as to ensure international interoperability*
- *Identifying launch opportunities and services*
- *Providing stakeholder liaison and strategic development*
- *addressing Intellectual Property and ITAR issues in accordance with CANEUS International's broader mission*
- *Organizing launch certification services*

This article describes Small Satellite developments within the international cooperation framework of the **CANEUS** network.

Background

The current state of the international small satellite industry, although fragmented, has seen significant momentum and a niche share from the traditional satellite market. Numerous governments and private agencies run sub-critical small satellite programs, however, with very little communication between these groups. Furthermore, many component and sub-system developers are not familiar with small satellite end-user needs and customer requirements.

There is also concern that there exists a lack of transparency between developers and end-users. Participants at the CANEUS 2006 Conference in Toulouse, France agreed that in order to open up the market for small satellites and facilitate dialogue between the many stakeholders in the industry, it was necessary to create an international consortium for the coordination, standardization, as well to offer secondary payload launch opportunities for the small satellite industry.

Small Satellites (***1 to 100 kg range***) have captured the imagination worldwide of civilian and defense satellite end-users due to its exciting technological and economic possibilities. Unfortunately, what may be lost in this euphoria is the practical, hard reality that very few of these emerging micro-nano-pico-satellite concepts will be able to successfully bridge the "Valley of Death" in the path of development to usable systems or products. This is particularly true, as there are additional stringent requirements for performance and reliability of these small satellites. The CANEUS organization, which is an international body of engineering, management, and investment professionals, has been set up to address this precise need.

The Small Satellite Sector Consortium Mission

There are three elements that comprise the mission of the CANEUS Small Satellite Sector Consortium:

- *To provide advocacy for its members and foster the advancement and increased use of MEMS and Nano Technology toward the expansion of the small satellite market*
- *To be the world's catalyst for the small (Micro/Nano/Pico) satellite industry to bring breakthrough ("disruptive") technologies to the space sector by ensuring space qualification, reliability, lower cost and added-value*
- *By setting a global direction, to create opportunities for the flexible collaboration and conduct of strategic research and development (R&D) so as to yield a significant return on investment (ROI) to the Small Satellite industry partners*

Objectives

The core objectives include...

- *Advancing the maturity of emerging MNT concepts via the development of end-to-end system development strategies*
- *Encouraging an attractive investment environment focused on the rapid, cost-effective development of MNT and related technologies that will lead to an expansion of the Small Satellite market*

- *Fostering increased access to space by enabling the periodic and routine availability of primary and secondary space lift opportunities for Small Satellites*
- *Leading in the development of functional and performance standards for Small, Micro and Nano-Satellites*
- *Working with members to be a rapid and cost-effective mechanism that drives the pervasive use of next-generation Micro/Nano/Pico space satellite systems*
- *Addressing critical challenges in advanced Micro/Nano/Pico satellite technologies, and finding ways to speed development, reduce costs, share risks, and increase utilization*
- *Mitigating risks and costs collectively for the Small Satellite stakeholders by*
- *Providing space flight arrangements to validate MNT and related technologies*
- *Arranging NPS satellite constellations*
- *Expediting launch on demand*

Implementation Plan

The arrangements for implementing the activities of the CANEUS Small Satellite Sector Consortium envisages, within the spirit of international cooperation, the sharing of tasks and funding among members in, initially, Canada, Europe, and the U.S.A.

Standards Development

This initiative aims to define form factors for nano and micro platforms, develop a collection of existing and emerging standards relevant to the sector, establish onboard data interface requirements, and ensure interoperability for international operations. Tactical goals include identifying task-groups around technology/platform areas, such as electrical interfaces, physical form factors, plug-and-play formats, data formats, and systems engineering; defining technical requirements for each technology/platform area; surveying the existing standards landscape within other subgroups, and performing gap analysis.

Launch Services

The Launch Services initiative hopes to advocate to the primary launchers (PP) to fly secondary payloads (SP) by appealing to the funding sources of those primary launchers and acquiring agency-level mandates (directives) to fly secondary payloads. This initiative aims to assist SPs in getting rides on primary missions. To this end, it must...

- *Establish an executive committee to rank and recommend SPs for rides*
- *Act as a broker between the PP and SP communities to manage the SP roster*
- *Certify an evaluation agency to score SPs for competencies*
- *Help fund SP standards for development and verification*
- *Acquire funds to assist in the integration costs for SPs*
- *Fund CANEUS-sponsored SP missions in the future*

Stakeholder Liaison and Strategic Development

Objectives of this initiative include bringing together all the stakeholders, individuals, and organizations that could benefit from a sustainable Small Satellite industry sector; identifying and prioritizing the key technology elements required for the Small Satellite sector, and developing and maintaining the supply chain infrastructure.

The goals are oriented to benefiting governmental laboratories and university research groups. This initiative shall ensure greater mission assurance through...

- *Improving reliability*
- *Providing an alternate means to rapidly qualify new technologies*
- *Lower the cost of demonstrating new technologies in space*
- *Expanding launch opportunities*
- *Supporting plug-and-play developmental efforts*
- *Advancing concepts in modular design methods*
- *Accelerating technology maturity up the TRL curve*

- *Enabling university TRL 3 projects to get flight experience and facilitate moving to TRL 6 and beyond*
- *Helping to shorten the acquisition timelines*
- *Improving the alignment with the emerging technology development cycle*
- *Enhance the space industrial base*
- *Supporting educational outreach and human capital for future jobs in the space industry*

Project In The Works

Two new projects/initiatives are being formed. The framework of the total of five initiatives will provide a comprehensive support infrastructure from satellite developer through launch certification.

Intellectual Property and Export Control

The objective of this initiative is to leverage the consortia community and develop a streamlined support mechanism for addressing the intellectual property issues. One focus will be related to patent related technology development, while the other effort will address the formal process on handling ***International Traffic in Arms Regulations*** (**ITAR**) and ***Export Administration Regulations***.

Launch Certification

This initiative aims at addressing launch certification services. Many launch organizations and government customers will require a certification sign off process and this initiative will compile a list of certification organizations and help facilitate the introduction and interactions.

Getting Down To Business

An important goal of the CANEUS Small Satellite Sector Consortium is to ***mitigate risk by pooling the financial resources and developments from several countries to rapidly gain acceptance for small satellites as a viable space mission platform***. It will apply the CANEUS principles of coordinated development to promote the growth of the Small Satellite industry sector by bringing together all of the stakeholders, individuals, and organizations that can benefit from a sustainable Small Satellite industry sector.

The Small Satellite Sector Consortium will consider and prioritize the key technological elements required for the Small Satellite sector. These elements will be defined in the context of compelling business models for creating and sustaining the sector.

Workshops in France, Canada, and the United States gave rise to a formalized consortium structure, mission, and objectives, and implementation plans for the resulting projects and initiatives. These include standards development, launch opportunities and services, stakeholder liaison and strategic development, Intellectual Property and ITAR issues, and launch certification services. Furthermore, the array of consortia coordinated by CANEUS International allows for cross-sector collaboration and the funding and development of cost- and risk-mitigating projects responding to a variety of needs by developers and end-users in technology and applications.

By making use of recent breakthroughs in nanotechnologies and micro-electrical mechanical systems, the small satellites developed through the coordination efforts of the CANEUS Small Satellite Sector Consortium would be considered a 'disruptive technology' on par with the information technology revolution that has propelled new industries, services and capabilities for society.

For additional information, please contact Dr. *Milind Pimprikar*, Chairman of CANEUS International & CANEUS NPS at ***milind.pimprikar@caneus.org***

About the author

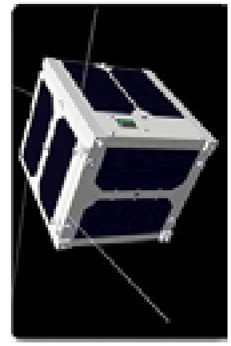
Dr. Milind Pimprikar is listed in the "World's Who's Who" and the "Oxford Dictionary of International Biography." He was nominated as an individual of "National Interest" by the Government of Canada. Dr. Pimprikar is founder and chairman of CANEUS, a network of countries developing micro and nanotechnologies for aerospace applications as well CANEUS NPS, an entity to produce nano and pico satellites for mass commercialization. He is also chairman of the Centre for Large Space Structures and Systems in Montreal, Canada.

From Cubes To Nanos To Picos... To Business!

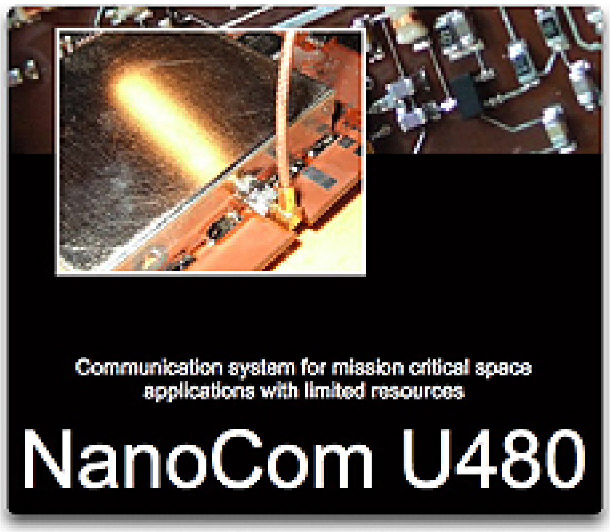
by Lars Alminde, Managing Director, ***GomSpace***

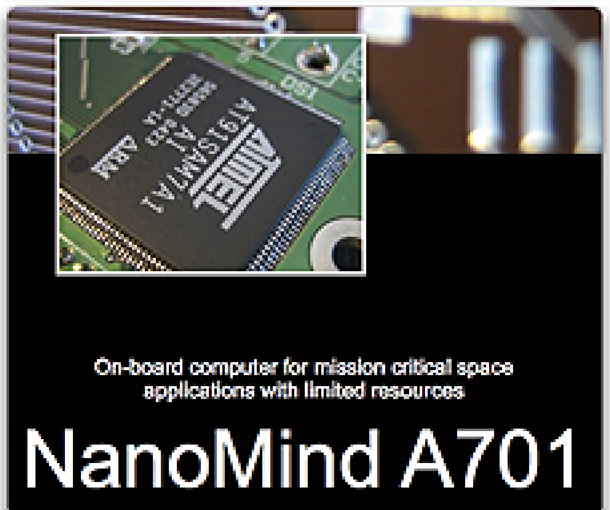
Over the last few years, driven by the cubesat idea, the industry has seen increasing global interest in pico- and nano-satellite research at universities. So far, the motivation for these activities has been mainly educational and often an exemplar of the ''me too attitude'' where the university initiates a project due to the interest from students — and let's not forget the media attention such projects can attract!

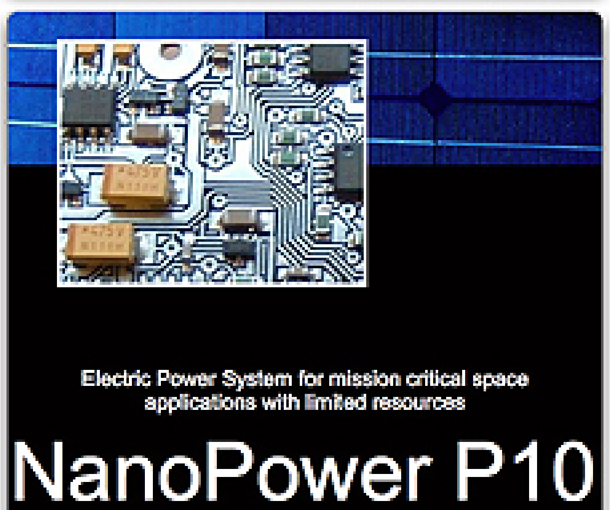
In the future, these endeavors will become focused on more concrete mission objectives relating directly to science, technology demonstrations, and the evaluation of commercial applications. This focus will emerge out of necessity due to the requirements for the acquisition of project funding. The idea of building a cubesat with student participation is no longer a new concept. Funding will no longer be attracted unless the university presents concrete mission objectives in addition to the educational realizations of such projects. Recently, the **ESA** (***European Space Agency***) and the **National Science Foundation** in the U.S. have announced access to university cubesat launches, which combine educational objectives with sound mission ideas.



Guarantees of service must be provided to ensure funding for long duration missions. Pico-satellite (picosat) technology has not yet developed to the stage where such satellites are a viable selection for such commercial activities. Over the coming years, this will occur, and there will be some extremely interesting missions based on pico-satellite technology.







The winners will be those who launch truly innovative and reliable picosat missions. The unique qualities found within the commercial and educational sectors will be leveraged through ongoing networking, learning from one another. Incremental progress will be achieved through such collaboration to develop viable strategic roadmaps.

Universities have started to realize this fact. Not long ago, when our company approached universities about cooperation and inclusion of systems supplied by GomSpace in their missions, the attitude encountered was they wanted to do everything all by themselves.

This attitude seems to be changing. Universities recognize the value of building their satellite missions around proven technology. This allows the educational sector to maximize their efforts by truly adding value as well as unique aspects to their missions. If, for example, a university is building a new, miniature science instrument, why have the mission fail because a readily available power system from the commercial sector wasn't obtained, and an internal, patched-together system designed in the last minute was used instead.

In the future, pico- and nano-satellites will provide a new business model for space missions. Today, larger satellites are the focus due to capacity issues (e.g. for imaging or communication needs) and are all that is offered to the marketplace as the solution. With picosat and nano-satellites (nanosats), the cost and lead time is low enough wherein a service could be tailored to a specific customer to meet a unique set of requirements, currently not being served by existing satellite-based communication and/or imaging solutions.

In 2009, **GomSpace** expects an increasing level of activity to support missions in development at universities. The company expects to announce commitments to a number of strategic development projects that will result in new products addressing some of the unique challenges faced by small spacecraft.

About the author

Lars Alminde is the Managing Director of GomSpace and he graduated from Aalborg University in 2004 with a specialty in intelligent autonomous systems. He subsequently studied for a Ph. D. at the same university within advanced model based methods for control and estimation. He is a systems engineer and an expert in model based control and estimation of complex electro-mechanical systems, with emphasis on attitude and orbit control systems for spacecraft.

The Ground System Contribution to Responsive Space

by Scott Herrick, **Newpoint Technologies**

Small satellites (TacSats, microsatellites, nano-satellites, pico-satellites — whatever the nomenclature) potentially offer many positive benefits when compared to traditional satellite programs. Lower costs, shorter development and acquisition timelines, increased operational responsiveness, and an ability to augment on-orbit capabilities highlight a few examples of positive benefits. To fully realize their potential, these assets will require responsive ground systems that are flexible, expandable, capable of supporting multiple platforms, and responsive to technological advances.

In a 2007 report to Congress, the “***Plan for Operationally Responsive Space (ORS)***,” the ***Department of Defense*** (**DoD**) outlined an implementation concept that stated “*...the Commander, United States Strategic Command (CDRUSSTRATCOM) has expressed three desires: first, to rapidly exploit and infuse space technological or operational innovations; second, to rapidly adapt or augment existing space capabilities when needed to expand operational capability; and third, to rapidly reconstitute or replenish critical space capabilities to preserve operational capability. These desires have led to a multi-dimensional concept to implement ORS to improve the responsiveness of existing space capabilities (e.g. space segment, launch segment, ground segment) and to develop complementary, more affordable, small satellite/launch vehicle combinations and associated ground systems that can be deployed in operationally relevant timeframes*.”

For those of us in the satellite ground system and network management business, this is a significant statement because it documents and elevates the importance of the ground segment to the same level as the space and launch segments in achieving operational responsiveness.

In short, the report challenged the classical ground segment approach on two fronts. First, can we still afford to acquire satellite programs requiring their own mission-unique “stovepipe” control system characterized by limited focus and functionality in terms of flex-

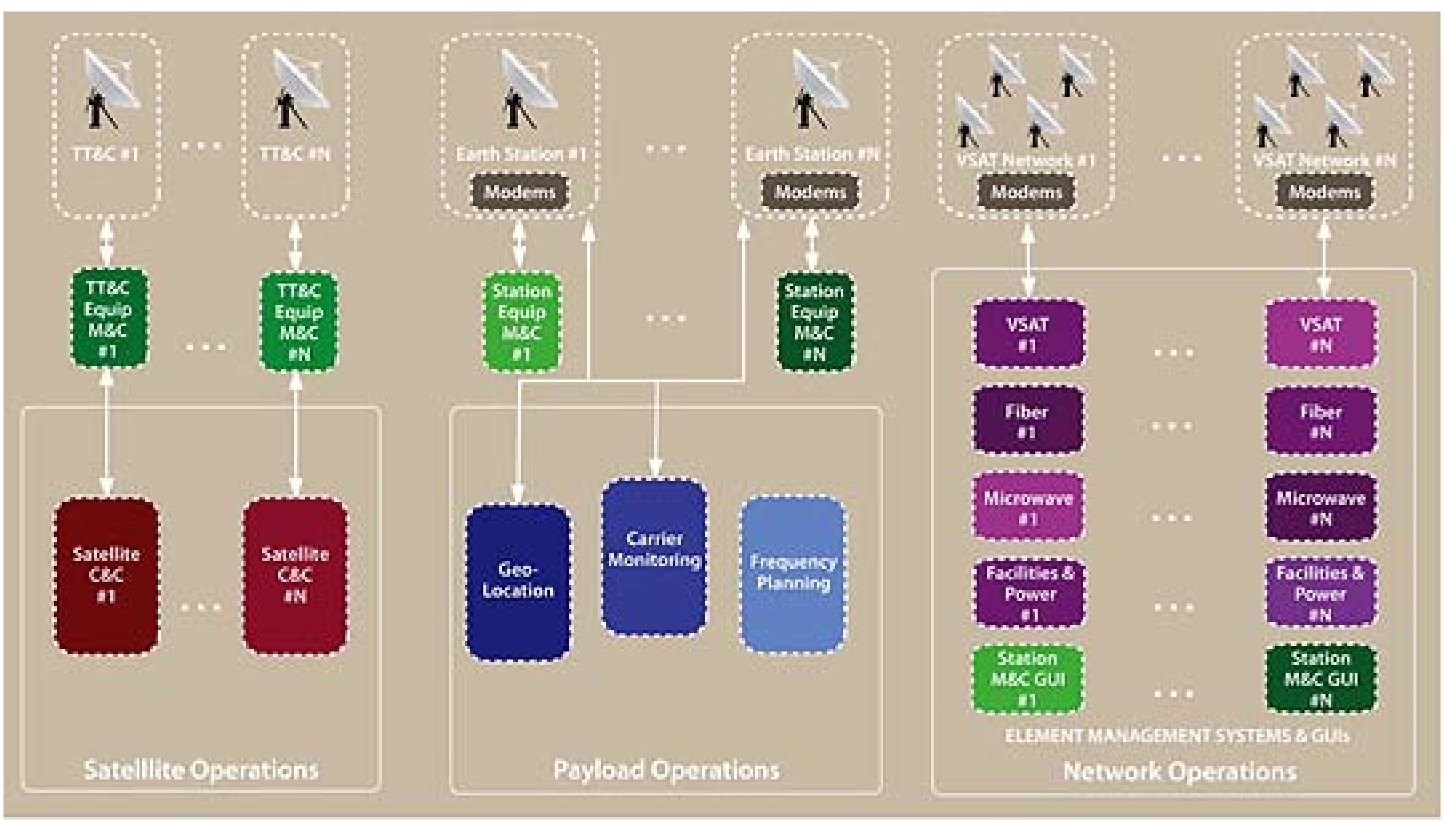


Figure 1. Traditional Stovepipe Satellite Ground System
Duplication functionality and limited interfaces for data sharing

ibility and expandability (i.e., improve the responsiveness of existing space capabilities). ***Figure 1*** on the previous page depicts a typical ground system providing functionality for ***Telemetry, Tracking, and Command*** (**TT&C**), Earth station ***Monitoring and Control*** (**M&C**), and network operations. This system is a collection of multiple stovepipe systems duplicating functionality — there are multiple ***Command and Control*** (**C&C**) systems (one for each satellite) and multiple Earth station M&C systems. In addition, the stovepipe systems do not interface with each other. For example, the C&C systems do not interface with each other (preventing fleet-based operations) or with other systems, thereby preventing a common control interface.

The second challenge — find a better way to identify and acquire capabilities that are designed from the outset to be flexible, scalable, and open systems that can readily, and cost effectively, grow or adapt to changing requirements. Fundamentally, this means we should develop complementary, more affordable, small satellite/launch vehicle combinations and associated ground systems that can be deployed in operationally relevant timeframes.

Integral Systems, Inc. (**ISI**) of Lanham, Maryland, has long understood the value in developing capabilities that are extensible and adaptable enough to accommodate advances in technology and dynamic requirements. Integral Systems and its subsidiaries, **Newpoint Technologies, Inc.**, and **SAT Corporation**, are market leaders in the areas of satellite command and control systems, network and equipment management, spectrum monitoring, and interference detection and characterization. We are well postured to meet these challenges and help define the future of satellite command and control.

ISI's ***EPOCH T&C Server*** provides complete off-the-shelf satellite telemetry and command processing for operations and test environments. EPOCH delivers front-end data processing, distribution, and command formatting as part of an end-to-end command and control solution. ***EPOCH IPS*** (***Integrated Product Suite***) can manage a single satellite, multiple satellites from different manufacturers, or an entire constellation of satellites. Every operator using the EPOCH IPS has exactly the same core software, no matter what satellite types their fleet includes. Using

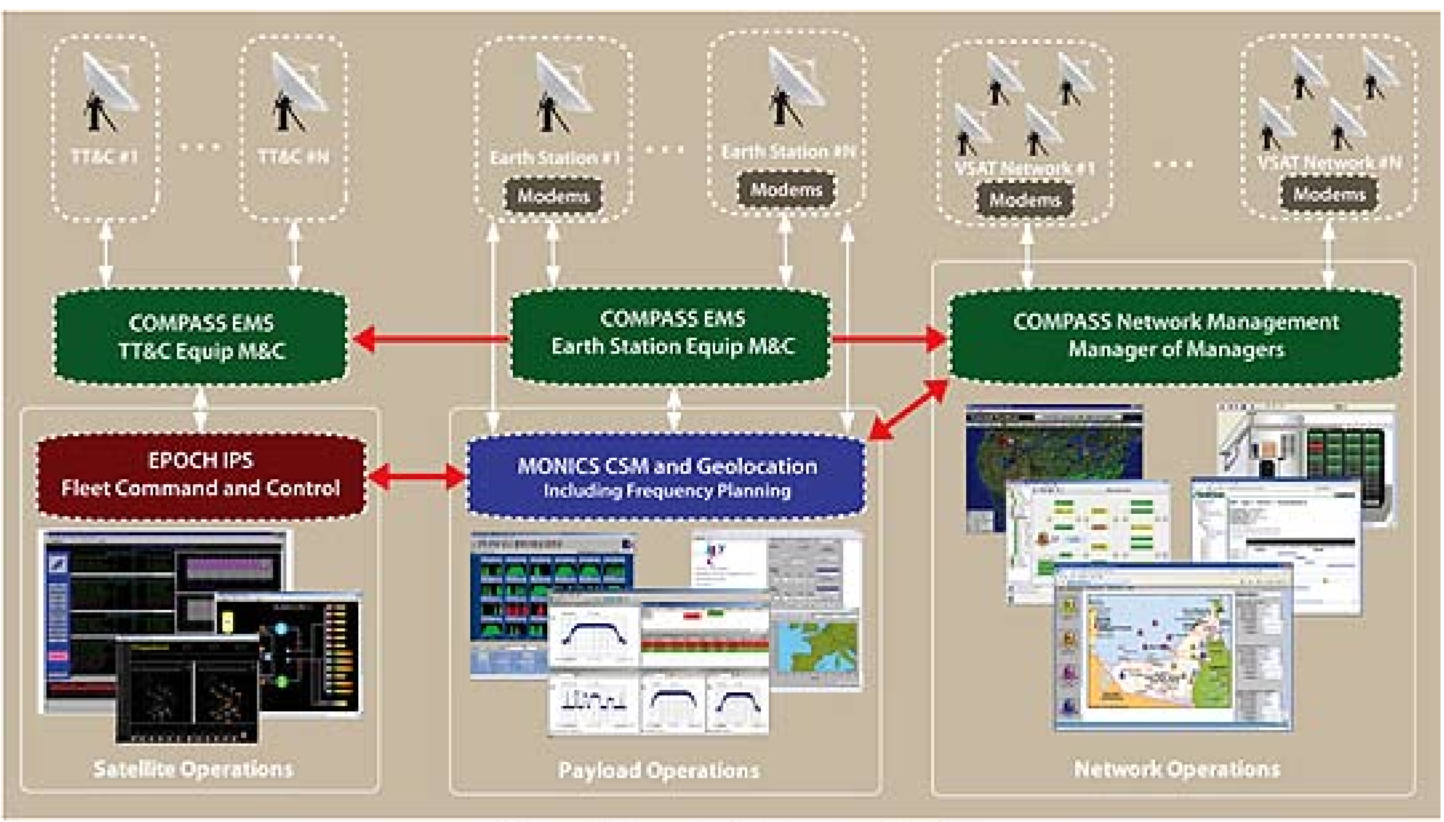


Figure 2. Integrated Satellite Ground System
Integrating at the product level eliminates multiple, duplicated stovepipe solutions

extensible COTS as a system's core frees developers to concentrate on mission-unique components and not worry about developing basic command and control elements. In addition, EPOCH is based on an open architecture, so increasing the command and control system's capabilities without a major redevelopment of the entire platform allows operators to rapidly integrate and realize new capabilities. The ground system depicted in ***Figure 2*** on the previous page depicts an integrated COTS system assembled with ISI's products. Contrast this with the stovepipe systems shown in Figure 1, and note the absence of multiple, duplicated systems and the addition of data sharing between satellite, payload, and network operations.

Newpoint Technologies expands on this approach to provide spacecraft operators with an integrated, end-to-end ground system M&C capability. Through our approach, a single user interface can manage a wide variety of legacy and new hardware and software subsystems. Historically, divergent interfaces made this extremely difficult, if not impossible. The development of network standards such as ***Simple Network Management Protocol*** (**SNMP**), attempted to overcome this problem, but even then, not all devices supported such standards and upgrading already fielded components introduced additional cost and risk to the operation.

Today, the application of a multi-tiered ***Manager of Mangers*** (**MoM**) architecture using components that can interface to a wide variety of standard and non-standard hardware, as well as existing equipment monitor and control systems enables operators to achieve a single solution for managing ground systems with divergent hardware and interfaces.

Newpoint's ***Compass*** MoM solution (***Figure 3 below***) provides satellite, terrestrial, and transmitter network operators a single solution for managing all the equipment comprising the transmission network. Compass accomplishes this by directly interfacing to the network equipment, or by interfacing with existing third-party M&C systems already in place, thereby providing operators with a single system for managing their entire network.

The implications of this technology are far reaching. Using the MoM approach, users can have complete situational awareness across the entire ground segment for any mission that needs to be brought online quickly by using the existing ground infrastructure already in place. Existing government and commercial M&C infrastructure can be kept in place and Compass software can interface into these existing systems quickly to provide overall situational awareness across these disparate systems. System maintenance and administration costs are greatly reduced through this consolidation. Training costs for operators are also reduced when training only needs to be provided for one operating platform.

Labor savings can be realized by automating and integrating systems and responses previously requiring operator intervention. Human error is minimized, as automated scripts perform appropriate actions faster and in the correct order each time, all the while testing to ensure the network is in the correct state before progressing to the next test. All information is now displayed on a single console. "***Situational Awareness Dashboarding***" of multiple systems' status is possible using the onboard report generation tools that eliminate the need to "pull" information from individual systems. Trouble ticketing is now centralized and can be automated as well. System faults may automatically generate a priority message to a technician or operator. Specific mission impacts can be forwarded to appropriate personnel, thereby encouraging proactive action.

In addition, the MoM solution delivers centralized management for equipment- and service-related faults and performance data. Alarm centralization and intelligent correlation gives operators the ability to quickly view the overall health of missions and rapidly respond to problems isolated to a device or widespread across

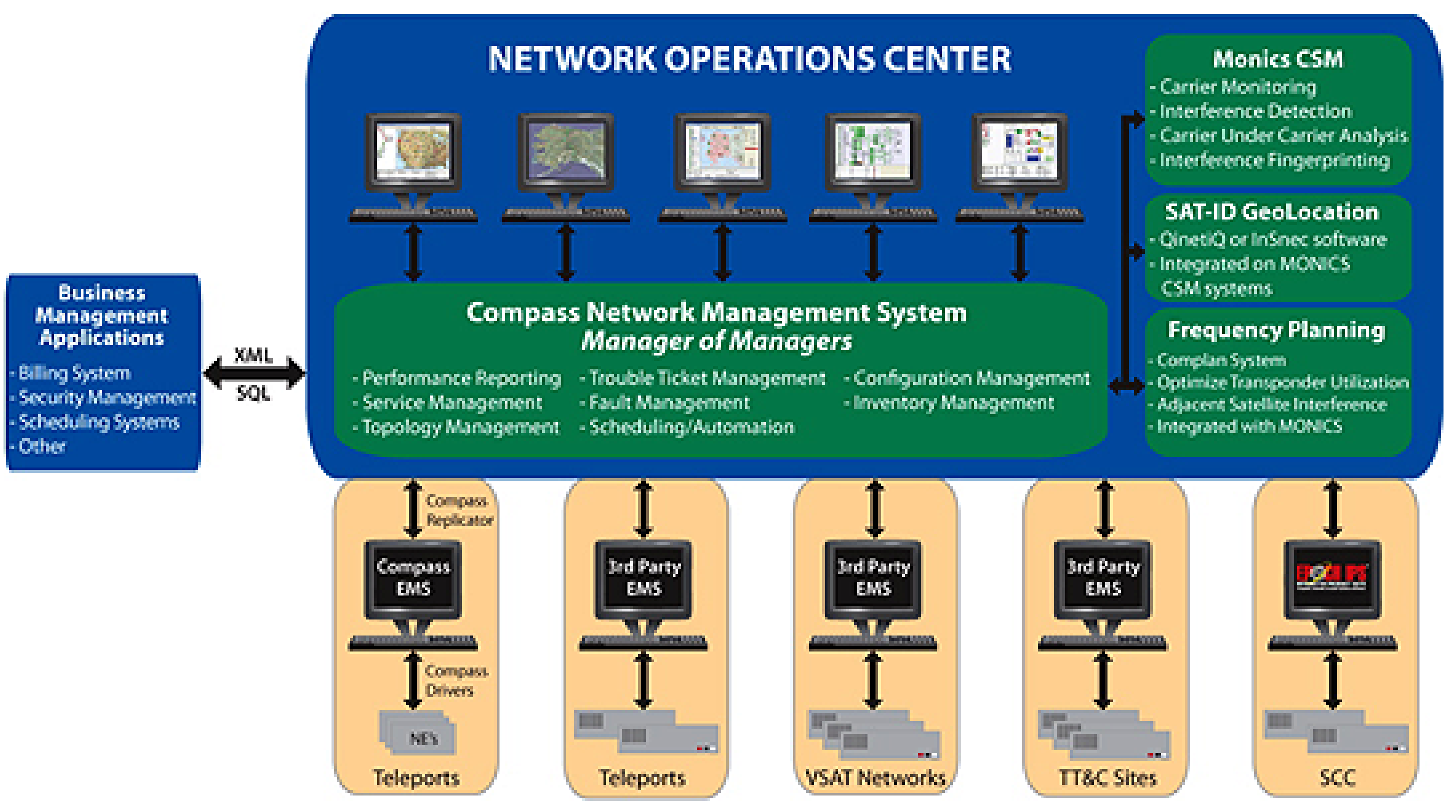


Figure 3. Newpoint Compass - Manager of Manager

Compass forms the hub to support multiple access points for receiving and distributing information all network operations. Network operators can quickly respond to problems by having necessary information immediately available through a web-based Graphical User Interface such as that provided by Newpoint's TrueNorth product (***Figure 4 below***). This gives operators both the ability to prevent problems before they occur and troubleshoot in real-time before system performance degrades.

The previous examples highlight the MoM solution's ground segment network management functions and its ability to provide system-wide situational awareness. The final element making this approach unique is an ability to integrate, monitor, and manage third-party applications required by a specific platform being controlled, or in response to changing requirements or technological advances. You can add functionality without having to redesign your ground system.

For example, RF interference problems continue to worsen, especially in the current global climate. Satellite operators and data users will continue to contend with this interference and must be able to mitigate its impact. Tools such as **SAT Corporation**'s ***Monics Carrier Monitoring System*** are used to identify and characterize interference, will remain in high demand. ISI's integrated system approach now provides operators with alarms and notifications from the same console used to control the satellite and monitor the ground system. This eliminates the need to correlate degradation with data from a standalone system, and enables a quick diagnosis and response to problems.

To quote a popular advertising phrase, "***it's all about the network***" seems especially relevant in terms of providing responsive satellite command and control capabilities. The role of small satellites in the DoD or commercial arenas is yet to be determined; however, companies such as Integral Systems that provide fully-networked, integrated, end-to-end command and control solutions clearly have a role to play with evolving space capabilities.

About the author

Scott Herrick is the Director of Government Business Development for Newpoint Technologies. Prior to joining Newpoint, he was a career US Air Force officer and served in numerous space operations and command and control assignments.

Figure 4. Newpoint's Compass /TrueNorth product can provide management of existing network management systems to create a single, fully integrated view and control of the entire ground network

Executive Spotlight On...

Prior to our interview with Dr. Steve Mackin, the Chief Scientist at DMCii Ltd. (Disaster Monitoring Constellation International Imaging), some background information is in order. The DMC was initially designed as a proof of concept constellation, capable of multispectral imaging of any part of the world every day. Each satellite is independently owned and controlled by a separate nation, but all satellites have been equally spaced around a sun-synchronous orbit (SSO) to provide daily imaging capability.

The satellites are all designed and built at **Surrey Satellite Technology Ltd.** (**SSTL**) in the U.K. Through the support of the **British National Space Centre**, SSTL owns and operates the U.K. satellite in this constellation. Although its headline objective is to support the logistics of disaster relief, DMCii's main function is to provide independent, daily imaging capability to the partner nations, those being Algeria, Nigeria, Turkey, U.K. and China.

DMC satellites provide unique Earth Observation resources that enable daily revisits anywhere in the world. This is possible with only a few satellites as each one is designed to image a large area of up to 600 x 600 km. This greatly improves the value of the data as it often avoids the need for mosaics of images from different seasons.

All DMC Members agree to provide 5 percent of capacity free for daily imaging of disaster areas. This data is channelled to aid agencies through ***Reuters AlertNet*** in the beginning. The DMC Consortium has agreed to consider participation in the ***International Charter for Space in Major Disasters***, contributing daily imaging capability to fill the existing 3 to 5 day response gap. **UK-DMC** also provides data through an **ESA** project called ***RESPOND***. In addition, the DMC Members are interested in encouraging the use of DMC data for scientific and commercial applications.

The builder of the small satellites, Surrey Satellite Technology Limited, is a privately owned company, with ownership shared between...

Country	Designation	Type	Imager	Launch
Algeria	Alsat-1	DMC	32m MS	2002
China	Beijing-1	DMC+4	32m MS / 4m Pan	2005
Nigeria	Nigeriasat-1	DMC	32m MS	2003
Turkey	Bilsat-1		Mission Completed 2006	
UK	UK-DMC	DMC	32m MS	2003
Spain	Deimos-1	DMC	22m MS	2008
UK	UK-DMC2	DMC	22m MS	2008

- *The University of Surrey (85 percent) — SSTL originally started as a department of the University devoted to space and satellite research. The University saw the potential of a commercial enterprise to further develop its new satellite technology and incorporated Surrey Satellite Technology Limited (SSTL) in 1985.*
- *SpaceX (10 percent) — SpaceX is a launch provider in the U.S., founded by PayPal co-founder Elon Musk in 2002. With a very similar approach to space exploration (combining low-cost, high-speed, reliable space technology), SpaceX is a natural partner for SSTL.*
- *SSTL staff (5 percent) — Professor Sir Martin Sweeting and SSTL employees hold 5 percent of SSTL shares.*

Believed to be one of the largest monetary rewards in history for any British University, was the April announcement that **EADS Astrium** had decided to purchase the **University of Surrey** shares of SSTL. This is now a fait accompli as the final blessing for this acquisition has been given by the **European Commission**. The final step for this union was the assurance of the antitrust regulators of the **European Union** to the blending of the former University of Surrey property with Astrium for an 80 percent stake. The actual financial considerations have not been revealed as of this writing.

Dr. *Steve Mackin* pioneered a new approach for deriving quality control indicators from **Disaster Monitoring Constellation** data. The new framework, which is being implemented by DMCii, holds great potential for quality control and consistency in multi-source imaging projects, such as the ***European Global Monitoring for Environment and Security*** (**GMES**), now known as ***Kopernikus***. The **European Space Agency** (**ESA**) has expressed interest in the techniques that Dr. Mackin presented in his role as one of the U.K.'s representatives in the ***Working Group for Constellation Calibration on the Committee on Earth Observation Satellites*** (**CEOS**). The first dedicated GMES satellites, ***Sentinel-2*** and ***Sentinel-3***, will demonstrate (at least in part) the new framework as a quality control measure for GMES.

Dr. Mackin commented, "This has never been done before and its application holds great potential for projects where imaging is sourced from multiple providers and satellites. As a GMES contributor, DMCii has begun implementing this new quality control framework within the Disaster Monitoring Constellation to validate it for wider use."

UK-DMC satellite

The new framework provides a clearer quality statement with defined error budgets at each stage and hence identifies low quality data before it can be issued. The traceability of data is also improved, enabling the rapid identification of the processing area at fault.

Dr. Mackin states the proposed methodology holds many benefits for imaging users: "It makes sense for any customer to request standardized quality control information from imaging suppliers. Only then can you be sure of the quality of your end product and its fitness for purpose. It also allows users to compare data across image providers in a fast and simple manner and determine who meets the user's requirements at the lowest cost — hence saving time and money for the end-user".

Executive Spotlight On...

SatMagazine

Thanks for taking the time to talk with us, Dr. Mackin. We appreciate your insight. Please tell us what this new constellation calibration achieves.

Dr. Mackin

It makes sense for any customer to request standardized quality control information from imaging suppliers. Only then can you be sure of the quality of your end product and its fitness for purpose.

The system should allow for the first time, true traceability through the entire processing chain from data acquisition to higher level product generation with uncertainties described for each step of the process, by each step down to fundamental operations, with corresponding QC of the outputs from each of these fundamental operations. The amount of work to set this up in a modular form is huge, with even small processing chains such as those used by **DMCii Ltd.** having potentially hundreds of modules.

However, once created, it is simple to create quite complex ***QA/QC*** (*Quality Assurance / Quality Control*) chains for new sensors by re-use of the modules, much like objects in C++ programming. Currently, traceability is either limited to small parts of the processing chain, or not at all. For the first time we should be in a position to say that I have a determined uncertainty on any product and prove it without extensive validation exercises and hence directly cross-compare data sets and derived products with simple quality indices.

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What was the driving force behind this decision?

Dr. Mackin

The ideas have been developing slowly within **CEOS WGCV** (***Commission on Earth Observation Satellites Working Group for Calibration and Validation***) for many years and have been partially addressed within the level processors of the major space agencies. There is a growing statement from the agencies that there is a need for some form of traceability and quality statement for every EO data set. This is partially

UK-DMC-2 satellite

driven by the rapid growth of applications expected under the ***European Kopernikus*** (formerly ***GMES***) initiative and in part by the requirement from the climate change scientific community for statements of uncertainty in their input parameters to improve model prediction performance.

Hence, there is a push from **ESA** in their statement for increased information on ***Third Party Missions*** (data quality, calibration, and so on) plus the requirement from ***Kopernikus*** for a quality statement for each data product. CEOS WGCV has taken up these concerns as it is driven by the agencies to a large degree. This led to the ***QA4EO*** (***Quality Assurance Framework for Earth Observation data***) initiative developed by a small group including *Nigel Fox* (**NPL**) and *Pascal Lecomte* (**ESA**) which has as its basis guidelines which form the basis for traceability in EO data. This has been adopted by the CEOS WGCV and is discussed in some depth in the **CEOS WGCV Cal/Val Portal** at ***http://calvalportal.ceos.org/CalValPortal/qa4eoInfo.do***

DMC has worked closely with **ESA** and **NPL** in supporting the activity. The biggest problem now (which was raised at the *Avignon* meeting of the CEOS WGCV at the beginning of October last year) was how to implement the high level QA4EO guidelines. At the same meeting, DMC presented information on how it has begun to take the first steps in implementation.

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Why has DMCii adopted this technique?

Dr. Mackin

DMCii was really one of the first companies to offer constellation data. As we operate a constellation of satellites, we are able to revisit locations on a daily basis to provide change monitoring and achieve cloud-free imaging over very large areas within a given time-frame which is impossible with a single satellite. As the company has matured and become involved in many high profile and demanding projects, we have developed our own measures and methods of calibration and quality control.

Through our work with ESA as part of the Kopernikus project, we identified the customer's need for universal measures and procedures to assist with purchasing and operational decisions. Kopernikus is an ambitious European project that seeks to combine remote sensing information from many different suppliers to provide global monitoring information for environment and security services. DMCii has adopted this method for many reasons...

- *Satisfies ESA TPM and Kopernikus requirements on quality information*
- *Provides the means for an automated QA/QC system including automatic intervention if system parameters are exceeded*
- *Provides a means of simulation of new sensors and new methodologies, which can be included rapidly in the proposed modular system.*
- *Guarantees traceability through the entire system*

- *Helps identify those processes that add uncertainty to the final data product that can be targeted for replacement in future modifications to the processing chain.*
- *Provides a rapid means of developing future QA/QC systems for new satellites.*
- *Is needed as the constellation expands to provide an automatic means of managing data over very large constellations, which may have mixed system characteristics.*

SatMagazine
How will the framework be applied to ESA's own ***Sentinel*** *satellites?*

Dr. Mackin
ESA is proposing to incorporate the ideas for use in both ***Sentinel-2*** and ***Sentinel-3***. The difficulty in this case is that the contracts for the level processors have already been assigned. Hence, the QA/QC system will have to sit outside the level processor and interface it. This is not the ideal way of developing the system. However, by interfacing the level processor correctly it should be possible to have a parallel chain that can provide the QA/QC information without impacting too much on the current developments.

The big difference with the Sentinel Missions is the much larger number of modules required, which means a slow implementation covering several years. However, the development is in its early stages, so we need to wait to see the benefits for the Sentinel Missions. In future, it would be expected to have a much tighter integration of the QA/QC system and the level processor.

Note, however, that the level processor is a temporal sequence, while the QA/QC structure is not. The QA/QC shows the uncertainty flow for the whole temporal sequence, but, for example, a QA/QC sequence can be "Get Dark Current Data" followed by "Get White Diffuser Measurement," while in reality these two measurements can be separated by a long time interval of minutes to days. For QA/QC purposes they form part of a single sequence.

SatMagazine
How does it work?

BEIJING-1 satellite

Dr. Mackin
The system is entirely modular. Every process in a processing chain is identified and a module created for every "independent" measurement. By independent, we mean the whole measurement can be encapsulated in a single module. Modules can be aggregated into larger management modules to make the system more manageable. For each single module, there is a description, a protocol, a reference standard (if required), and an uncertainty budget. This is essentially the QA element of the process. The protocol needs to be accepted to some degree (certified for want of a better word). Outside of the module sits a corresponding QC element that tests that the output from the module meets the QA within the module in terms of uncertainty.

The QC element, in theory, can contain feedback actions in cases where the limit set in the QA is exceeded, even to the point of modifying the process. An example might be dark current measurement for calibration. Dark current tends to increase with time. In theory, if an upper limit was set in terms of QA for the noise component, then this could be exceeded with time. However, again in theory, with an automated system the QC could detect an out of bounds condition and modify the process to increase the number of dark image lines taken. This reduces the dark current noise component back into the defined limits for calibration.

This is a simple example of how the system could automatically control the operation.

Additionally, by using parameter files and test data, it would be possible to simulate an instrument QA/QC flow and predict the output data uncertainties, even prior to the instrument being physically created. As the instrument is developed, changes to parameters or processes can be substituted with no other impacts to the system as it is entirely modular.

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What makes this different to current quality control measures?

Dr. Mackin
Current QA/QC measures do not provide traceability throughout the whole system. Normally, they consist of QA/QC applied to particular steps in the processing, often with little or no quantification of the uncertainty at each stage of the processing.

The QA/QC can be patchy with limited justification for the choice of protocol in certain stages. For example

why are 512 white lines used for calibration of ***MERIS***, but 1024 dark lines used for dark current estimation. There is no real justification for the choice of numbers and no quantification of the residual error in the choice.

The overall aim would be to apply guidelines at a high generic level (based on those developed for QA4EO) and from these develop a set of generic (high level) modules which apply to a particular sensor type. At this level, these generic processes can be "certified" and form the basis for the development for physical modules that address the behaviour of the actual system and the processing of the data from that system. These physical modules could, in theory, be very different from operator to operator, but they will both follow the generic guidelines and hence be equivalent. For the physical modules, there will be a well defined uncertainty budget and corresponding QC which turns the "certified" generic into reality.

SatMagazine

*Does the QA/QC method only relate to constellations, or can it be applied to satellites such as **Landsat?***

Dr. Mackin

The point in this whole process is diversity of solutions but within a well-defined generic set of guidelines. We do not wish to prevent innovation. Each protocol implementation may be very different with different uncertainties. For example, DMC may have uncertainty at the 4 percent level in a radiance product, while Landsat may achieve 2 percent. However, the implementation from DMC may be simpler and meet the requirements of its customers while that from Landsat may be far more complex to produce a lower uncertainty in line with a proportion of its customers.

It has been agreed generally that multiple solutions to the same measurement problem exist and all we are saying is that we require the uncertainty on those solutions to give to the end-user, so they can weigh up perhaps the lower costs and higher uncertainties on one product against the higher costs with low uncertainty of a similar product for a specific application. Applications tend not to be uniform in their needs, so a higher uncertainty may be acceptable in many circumstances.

NIGERIASAT-1 satellite

The user can make the final selection. It's really about standardising the quality measurement of data both within a constellation and between imaging sources. That having been said, projects using Landsat data in combination with other imaging data would benefit from such a QA/QC framework. This would enable buyers to compare data with that from other providers.

If you consider that within **GEOSS** the aim is to have virtual constellations with satellites from different countries with different characteristics, working together, as well as physical constellations such as ***DMC*** or ***Rapideye,*** then the method is equally applicable. The aim is that for each satellite in the virtual constellation we can know the uncertainty in measurement rather than estimate it using large validation campaigns. We can then compare the output from each sensor and choose those most useful for a specific application.

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You mentioned traceability — why is this important?

Dr. Mackin

Currently there is no true traceability in EO data and there are many assumptions on the uncertainties within the system. Many areas of uncertainty are poorly explored. The whole process is validated by using post-launch validation procedures against other ground collected data to determine the uncertainty on the final data product. This has limitations in that this is a combined uncertainty, and the causes of the level of uncertainty are not known in many cases and hence can not be reduced. With traceability, we know the uncertainty at each level of processing of the data and can therefore not only define the uncertainty for the final data product and compare this against any validation effort, but also know the contributors to our overall uncertainty budget.

In Metrology institutes for any measurement there is a requirement to trace it back to some form of international standard. In many cases, we should be able to trace the uncertainty back to an original calibrated diffuser, or lamp, standard on the satellite in question for those with on-board calibration, or to a field site which has been extensively characterised where the instruments characterising the surface can be traced back to international standards. This provides a direct means to say that, for example, the ***TOA*** (***Top Of Atmosphere***) radiance has a specific value with a specific uncertainty associated with this value. This is a key element in global climate change, where the uncertainty on the parameters for the models must be known for accurate prediction (radiance of surfaces, water, land, cloud etc.).

SatMagazine

How would these quality control measures typically be used by your customers?

Dr. Mackin

Currently satellite operators do not give quality statements on their low level products. Value-adders do not give quality statements on their higher level products (except perhaps in the case of atmospheric sciences which seems a little more advanced than the other areas). It is impossible for an end-user or application developer in Kopernikus to say which data is most suitable for a specific application, or even the induced errors in any product produced from this data. It is difficult at this time to say there is a single quality measure. We are proposing that the quality information from each module can be aggregated in higher level modules and suitable indices designed to provide to users with different needs. The lower level information should be there, either as single or a limited number of values in the metadata or as quality "products" which may contain pixel by pixel quality information (if this is required).

It will require some experimentation with the end-user to determine exactly what they require. Perhaps a simple labelling such as energy-efficiency of devices for example. Or some quantitative statement of the uncertainty in any final product, such as ppm of an atmospheric gas, uncertainty of water leaving radiance, uncertainty in a DEM. This in many ways has still to be decided and until that point the user will have the possibility to drill down through the metadata and indexed quality products to examine exactly how each product satisfies the user needs.

SatMagazine

Thank you, Dr. Mackin, for your expalanation of the new calibration process. For further reader information regarding DCMii, please select the graphic at the bottom of Page 37.

Cubesats - How Small Can Satellites Get?

by Michael Thomsen

You've definitely heard of the, those small, 1 kg satellites called Cubesats, so named due to their physical dimensions being that of a 10 cm cube. They are extremely popular as an educational tool at universities, but is it truly feasible to create a functioning satellite within so small a package? Additionally, do Cubesats have any practical use, or are they merely just a toy?

Until the 1990s, satellites grew ever larger, typically having as mass of several tons. As a means to counter the ever increasing size and cost of space projects, the NASA administrator at that time, *Daniel Goldin*, pioneered the "faster, better, cheaper" approach that would allow NASA to continue to operate a wide variety of programs without exponentially increasing the costs. **Minisatellites** (200-500 kg) became the new point of focus. Even **micro-satellites** (below 200 kg) started to gain interest, one such example is the Danish 61 kg ***Ørsted*** satellite, which was launched in February of 1999 to perform measurements of the magnetic field of the Earth. Several universities have designed and built even smaller satellites called **nano-satellites**, which have a mass of less than 10 kg.

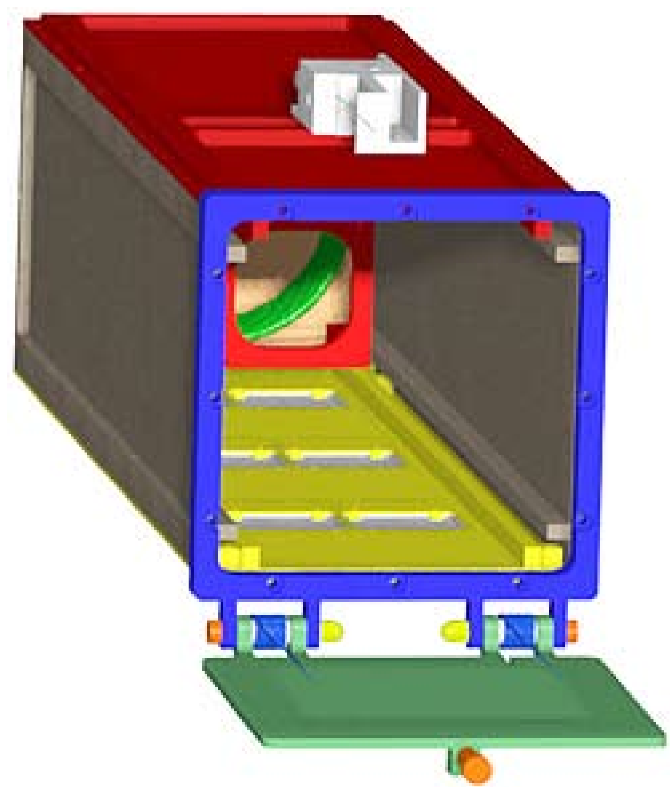
However, two issues in particular prevented most of these satellites from being launched. One was the cost of the launch. To reduce this heady cost, small satellites were always launched as a secondary payload. This lead to another major hurdle, namely the rigorous requirements to ensure the nanosatellite did not interfere with, or even destroy, the primary payload during launch. Imagine what could happen if a small university satellite deployed, by mistake, its solar panels or antennas before separation.

As is the case for other universities, **Stanford University** and **California Polytechnic State University** (**Cal-Poly**) had been attempting to find a solution to these problems to allow students to launch and communicate with their own satellite as an integral component of their higher education.

A team lead by professor *Bob Twigs* at Stanford University developed the ***Poly Picosat Orbital Deployer***, or **P-POD**. This small container holds a payload of **10 x 10 x 30 cm3**. The P-POD payload is used for small satellites, either with the full 10 x 10 x 30 cm3 size, or even smaller 10 x 10 x 10 cm3 cubes.

The P-POD protects the launch vehicle and other satellites from the Cubesats as well as providing a standard interface between the launch vehicle and the Cubesats. Only the P-POD needs to interface to the launch vehicle. As deployment is accomplished through the use of a spring that slides the Cubesats out along four rails inside the P-POD, the interface between the P-POD and the Cubesats is relatively uncomplicated.

The predecessor of the P-POD was the 23 kg **Stanford OPAL** (***Orbiting Picosat Automatic Launcher***) satellite, which deployed six picosatellites in January of 2000. The concept worked, and shortly afterwards, several universities around the world initiated student Cubesat projects.



Single P-Pod Design for a triple Cubesat payload

The small volume and mass of Cubesat satellites was thought to result in a low launch cost of US$30,000 (nowadays, launch costs have increased to about

US$50,000). Such was affordable to universities and there was an expected fast turn-around time of between one and two years from project initiation to launch of the satellite. As university students are rarely involved in a project for more than a few years, and as the motivation among the students is significantly increased when you have a chance of communicating with your own satellite in space at the end of the project, it is important to ensure the project time remains fairly short.

A problem many, particularly small and new, aerospace companies encounter, is the requirement to prove their technology works in space before they can sell their product. In particular, flight heritage is an important factor. This was meant as another big selling point for the Cubesat platform — you could test new hardware in space at a very low cost.

The first Cubesats were launched on a Eurockot on June 30, 2003. These Cubesats represented a wide variety of projects, both professional and university led, some of which had been started just two years earlier. Since then, a total of 38 Cubesats have been launched, although with varied success (***see Table 1 on Page 42***.) Fourteen Cubesats were lost during a launch failure in July 2006, four have never been contacted, and only limited contact has been possible with another five Cubesats.

However, a further 15 satellites have fulfilled all of their mission goals. They cover a wide variety of missions from bus verification (most including a camera), through component testing, to complete science missions (including astrobiology, and ionospheric research).

Some of the obvious challenges of designing a Cubesat are the small volume, and small mass — due to

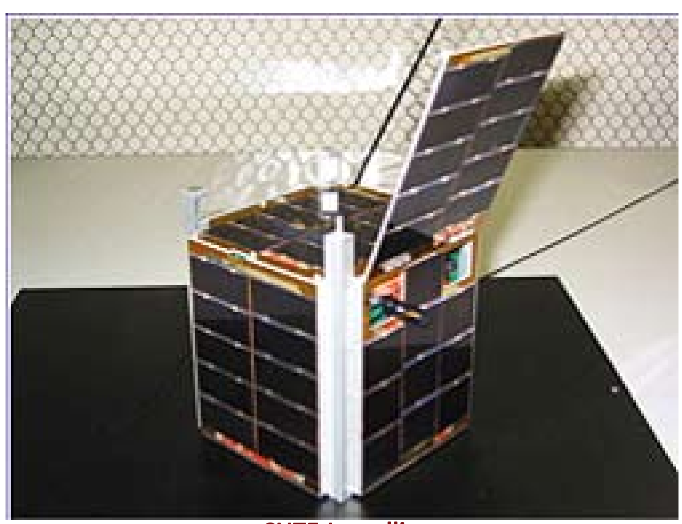
Batch #	LV Failure	No contact	Some contact	Full contact	Total
1 (Jun. 2003)	0	2	1	2 + 1 triple	5 + 1 triple
2 (Oct. 2005)	0	1	0	2	3
Solo (Feb. 2006)	0	0	0	1 double	1 double
3 (Jul. 2006)	13 + 1 double	0	0	0	13 + 1 double
Solo (Dec. 2006)	0	0	0	1 triple	1 triple
4 (Apr. 2007)	0	1	3 + 1 triple	2	6 + 1 triple
5 (Apr. 2008)	0	0	0	3 + 1 double + 2 triple	3 + 1 double + 2 triple
TOTAL	13 + 1 double	4	4 + 1 triple	9 + 2 double + 4 triple	30 + 3 double + 5 triple

Table 1 — Cubesat Success Rate

the size issue, redundancy is rarely considered. In addition, a result of the reduced volume is the small area available for solar cells. This area is often reduced further as deployable antennas necessitate adequate room, and often sensors and payload require additional surface area.

Another major challenge, specifically for universities, is how to manage the project. Sometimes the projects are student led, and at other times a more 'professional' management style is used. Another key issue is the decision regarding how long a project should run and when to commit to a launch opportunity. If a project is scheduled early, there is a known deadline to work against, which can be a good motivator. However, on the other hand, delays in the project can easily result in cutting the final and critical test and verification phases to a bare minimum. If you wait until the design has been proven, you may have to wait a year or two before the satellite can be launched.

Many of the first Cubesats were designed as a test platform to verify the basic spacecraft bus, consisting of the mechanical structure, power system, onboard computer, communication, attitude control, and so on, worked properly. Some of the early ones were the Japanese ***CUTE-I*** (**Tokyo Institute of Technology**) and ***XI-IV*** (**University of Tokyo**), and the Danish ***AAU Cubesat*** (**Aalborg University**). All of these satellites were small 1 kg Cubesats. The two Japanese Cubesats worked flawlessly — several pictures were downlinked from XI-IV (the camera on CUTE-I was used as a sun



CUTE-I satellite

sensor, and the raw images could not be downlinked by design), and they still, more than five-years later, continue to transmit their beacon signal.

The AAU Cubesat, on the other hand, never properly worked entirely. In the beginning, the beacon signal was heard, but it was weak. The assumption was made the tracking of the ground station antenna was not correct, but that turned out not to be the case. Instead, the team managed to borrow an 8 m dish, which was available approximately one month after launch. This allowed the team to receive and decode the beacon signals. Unfortunately, the housekeeping data transmitted in the beacon indicated the battery capacity was severely reduced. A full communication link was never accomplished.

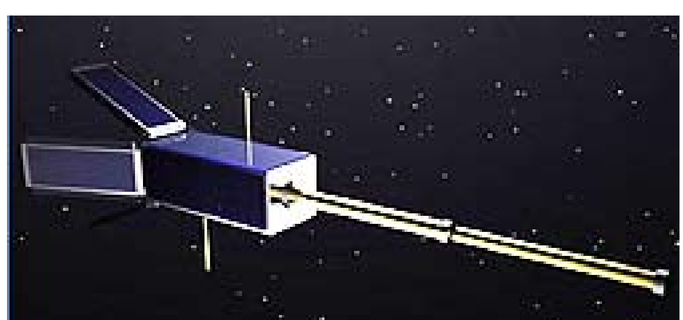
The conclusion as to the reason for the low signal strength was that two of the deployable antenna whips had not completely unfolded and were short-circuited during deployment. The reason for the loss of the battery capacity was the batteries were packed in a foil. When operated in a vacuum, the batteries could swell and would severely reduce capacity. This problem was actually known before the launch and was 'solved' by mounting the batteries between two aluminum plates to ensure the batteries could not expand [1].

Later launches included several missions dedicated to test a Cubesat bus, including ***Boing*** (***CSTB-1***) and ***Aero Astro*** (***AeroCube-2***). The latter contained a camera designed at **Harvey Mudd College**, which automatically started taking pictures shortly after the satellite was ejected from the P-POD. Those photos include the picture of another Cubesat, ***CP4*** from California Polytechnic Institute (***see top photo, Page 44***).

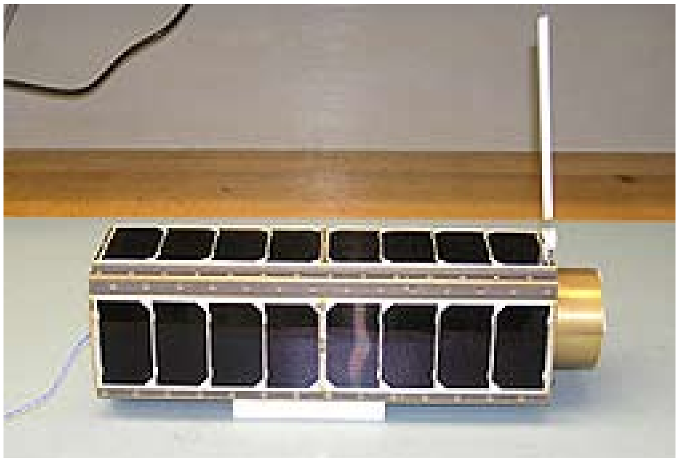
Apart from missions designed to educate and generally gain experience with very small satellites, or to test components or sensors in space, a few Cubesat missions have focused on a scientific mission objective. Two are ***QuakeSat*** and ***GeneSat***.

QuakeSat was a triple Cubesat developed at Stanford University whose mission was to study earthquake precursor phenomena from space. This is accomplished by measuring extremely low frequency magnetic signals in low Earth orbit, downloading the data to a ground station, and post processing the data on the ground. QuakeSat was launched in July of 2003 and was designed to be a single year mission. A 0.7 m deployable boom contained the magnetometer in order to minimize the magnetic disturbance from the satellite on the sensor. Like most other Cubesats, communication was facilitated through the use of a HAM frequency band at 9600 baud using the AX.25 protocol. The satellite also had deployable solar cells. Downloads of about 500 MB of data were managed during the mission, and a new, larger, 150 kg class satellite is now being developed as a result of the knowledge gained from the original Cubesat mission.

Another example of a scientific Cubesat based mission is GeneSat. This project was a collaboration between **NASA Ames**, industry partners, and universities. The satellite consisted of a satellite bus, which had the



QuakeSat-1 (AKA QuakeFinder)



GeneSat (NASA)

same dimensions as a single Cubesat, while the payload took up an additional 10 x 10 x 20 cm3. The objective was to develop a miniature life support system that could fit into a triple Cubesat and could deliver nutrient and perform assays for genetic changes in E. Coli. The satellite payload consisted of a pressurized sealed vessel, an integrated analytical fluidics card assembly, which included a media pump, valves, microchannels, filters, membranes, and wells to maintain the biological viability of the microorganisms. Optical sensors were used to detect genetic changes. During the experimental phase, which lasted for 96 hours, the payload temperature had to be regulated within 0.5 °C. The satellite monitored the external and internal Cubesat temperatures, as well as the radiation environment.

The biological experiment was initiated on December 18, 2006. Approximately two days after launch, and after 96 hours of project implementation, the biological experiment was complete and all of the baseline data had been downloaded. After the completion of one month of on-orbit operations, all primary mission objectives had been met. Control of the satellite was turned over to students at Santa Clara University, which used the satellite for educational purposes as well as to monitor the health of the satellite to determine how well the components worked as a reference for future missions.

As a final example, I have proposed a mission of a 2.5 kg 10 x 10 x 30 cm3 Cubesat, which is to measure the magnetic field of the Earth. This would be a successor to the Danish ***Ørsted*** satellite, and the European ***Swarm*** mission. The scientific justification focuses on the necessity to monitor the magnetic field of the Earth on a continuous basis in order to generate accurate navigational models that are used, for example, in deep well drilling in the petrochemical industry. The required resolution for such work is difficult to obtain from ground stations. It is also necessary to obtain magnetic field measurements from space in order to study the interaction between the solar wind and the magnetic field of the Earth, an area that is still not completely understood. The satellites will consist of a miniature 3 axis fluxgate magnetometer, which is a miniaturized version of the Ørsted magnetometer, a GPS receiver (e.g., SGR-05 from **SSTL**, and a small boom to ensure magnetic contamination is minimized at the sensor [2].

There are very few resources available to a payload if limited to the 1 kg Cubesat. However, many tasks can be implemented if expanding to a double or triple Cubesat. Even though the launch cost of a double or triple Cubesat is somewhat higher (although far from double or triple, as the cost for launch support from the ground personnel is a major portion of the cost), it may still offer far better results, as mass, volume, and power are less restricted.

You may well be asking yourselves, okay, how much does a Cubesat program cost? As most of the Cubesat projects are university based, it is hard to calculate their cost, as the main workload is completed by students, and professors rarely charge their expenses directly against the project budget. As an example the 1 kg ***DTUsat*** required a budget of US $200,000, excluding salaries.

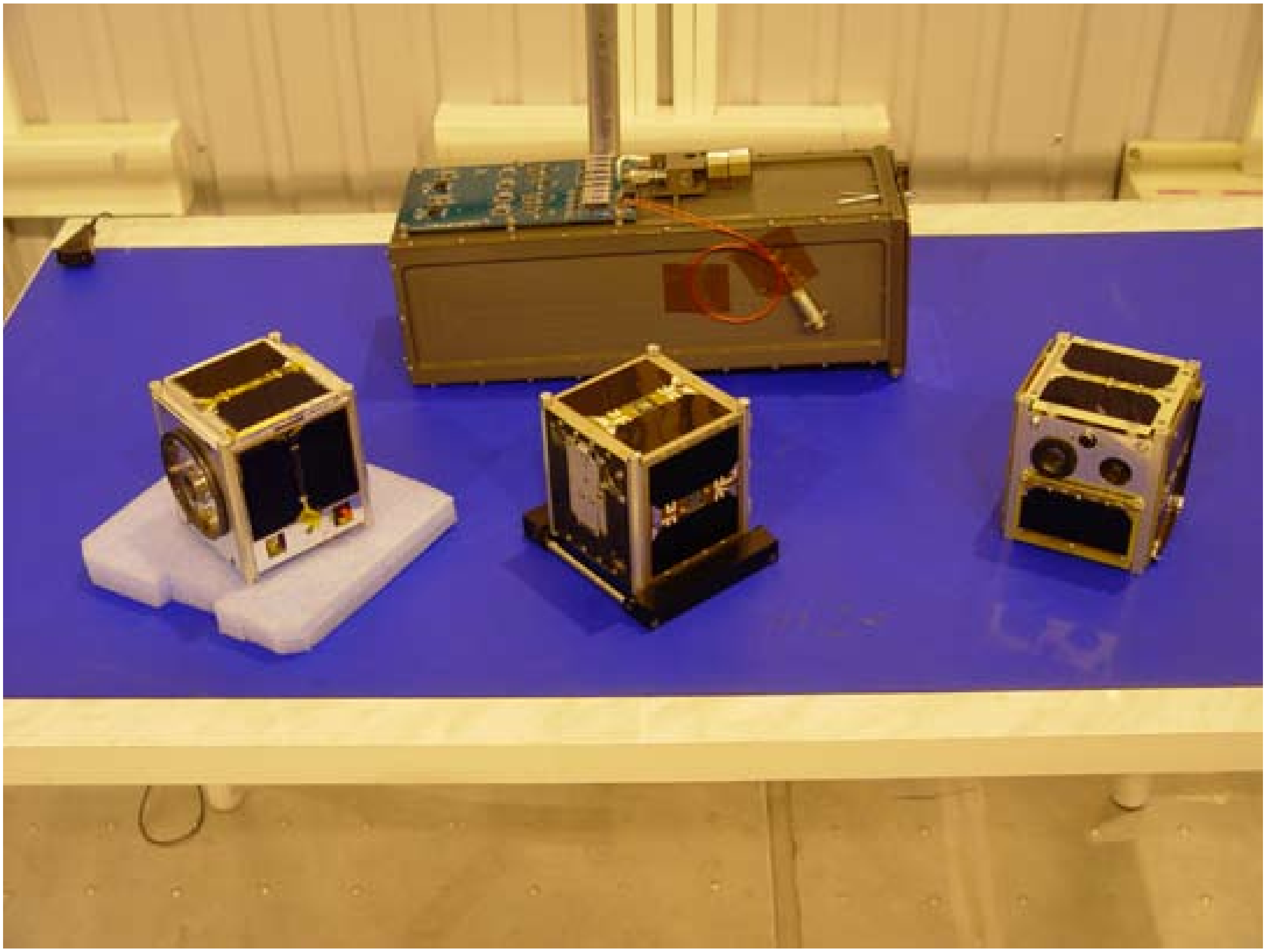
MAST—deployed (l.) and launch configuration (r.)

A couple of the commercial projects have released their budgets. QuakeSat had a total budget of US$1 million, including launch, but not including all salary and an additional operational cost of US$170,000 per month. The ***MAST*** mission by **Tethers Unlimited (see image, previous page)**, consisted of three tethered picosatellites and had a price tag of about US$1 million for the entire program.

As so many projects are underway, it is hard to keep track of them all. I began compiling a list of Cubesat projects a couple of years ago, which can be viewed on the Internet [3]. When going through the list of Cubesat projects being developed, it turns out many still focus on the spacecraft bus, often including a camera and/or a radiation detector. Obviously, it is a wise decision to start with a simple project. Many already launched Cubesats with more advanced mission objectives have failed. What is surprising to me is that so many universities are working on the same type of problem instead of working together and truly coordinating their projects. Imagine what could be accomplished if they operated in an open-source manner. Knowledge others had gained could be reused and potential design problems would be more easily identified.

Certainly, engineering students would find it extremely interesting to design and build a satellite bus, launch it, and listen for it in space. In my opinion, it would be more valuable if the effort was concentrated into other areas. For instance, designing a new payload, or designing a new attitude sensor, rather than continually 'reinventing the wheel.'

Focus will, more than likely, switch in this direction over the next few years, as so many universities soon



AAUsat, DTUsat and CanX-1 in front of their P-POD (photo courtesy of the DTUsat project)

will have a proprietary spacecraft bus they can reuse, or update, for future projects. Until Cubesats become open source, and even if a university does not already have a Cubesat bus, getting started is relatively easy. Several companies, including **Pumpkin Inc**., are selling Cubesat kits, which can be used as a foundation for a project. Three Cubesats have already been built and launched based on parts from such a kit.

Currently, 15 new Cubesats are on manifests to be launched in the near future. Three will be launched together with TacSat-III on a Minotaur-1, another three have been selected for a NASA flight currently scheduled for June 2009, and another nine (plus two backups) have been selected for the ESA Vega maiden flight, currently scheduled for a November 2009 launch.

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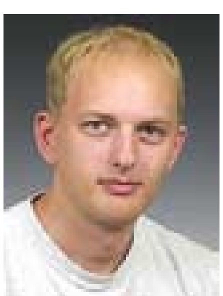
[1] L. Alminde, M. Bisgaard, D. Vinther, T. Viscor, K.Z. Østergaard: "The AAU-Cubesat Student Satellite Project: Architectural Overview and Lessons Learned", 16th IFAC Symposium on Automatic Control in Aerospace, St. Petersburg, 2004

[2] M. Thomsen, J.M.G. Merayo, P. Brauer, S. Vennerstrøm, N. Olsen, L. Tøffner-Clausen: "Feasibility of a Constellation of Miniature Satellites for Performing Measurements of the Magnetic Field of the Earth", 6th IAA Symposium on Small Satellites for Earth Observation, Berlin, 2007

*[3] M. Thomsen: "Michael's List of Cubesat Satellite Missions", <**http://mtech.dk/thomsen/space/Cubesat.php**>*

About the author

Michael Thomsen holds an electronic engineering Master and Ph.D. degree from the Technical University of Denmark and a Master of Space Studies degree from the International Space University. Michael was working on the DTUsat Cubesat, which was launched on June 30th, 2003. He has since followed the Cubesat community closel, and regularly updates "Michael's List of Cubesat Satellite Missions". Currently Michael works at the Danish National Space Center, in the section developing the fluxgate magnetometers and star trackers for the ESA Swarm mission.



Pumpkin, Inc.'s, CubeSat Kit

The kit conforms fully to the CubeSat specification, and is an affordable, off-the-shelf, hardware and software development and deployment solution that includes:

- *Complete, finished and ready-for-launch CubeSat structure with high strength, low mass, and exceptionally large internal volume*
- *TI MSP430-based ultra-low-power electronics with bus-based expansion, with Flash emulation tool (FET) for programming and debugging*
- *Both a Development Board for in-lab development and testing, and a separate FM430 Flight Module for the actual Flight Model*
- *Plug-in modem / transceiver support and built-in USB*
- *Pumpkin's multitasking Salvo Pro RTOS software*
- *HCC-Embedded's EFFS-THIN FAT file system for use with the CubeSat Kit's SD card socket*
- *Example projects, code and software libraries*
- *Power supplies and tools*

All you need is a PC and an MSP430 C compiler certified for use with the CubeSat Kit to start work.

Anatomy of the Space eCommerce Revolution

by Craig Clark, CEO + CTO, ***Clyde Space***

In the 1990s, the space community witnessed the revolution that is now the Small Satellite market. Small satellites were initially written off as not being large enough to have any real practical function; however, since the early 2000s, space companies large and small have been falling over themselves to get involved in Small Satellites. This class of spacecraft has proven to be much more useful than the sceptics proffered. With the Small Satellite market experiencing brisk business, many of us within the Small Satellite community are now wondering where the next revolution will come from. Most think that the smart money is on Picosatellites and Nanosatellites, but this class of spacecraft has yet to prove its technical capability, ye it is clear that it is fast becoming the most economically viable method of accessing space.

This article examines the commercial world of **picosatellites**. In particular, we will look at how the approach to standardisation on platforms such as Cubesats has resulted in the evolution of Internet sales of satellite subsystems. As a direct result of standardisation, it has become viable for space companies to produce relatively large numbers of the same subsystem and, as a result, drive down the cost of those systems. This is forcing companies involved in the picosatellite market to look to alternative methods of doing business in order to help reduce these costs even further. E-commerce is turning out to be the ideal tool for selling microspacecraft subsystems, and it has a huge number of benefits that help the customer make their product selection and also to provide after-sales support. Once picosatellites have proven their technical viability as a useful platform, the next revolution in spacecraft could well already be underway and it looks likely to be a web-based space market.

Introduction

Following a rapid growth in the number of picosatellite and nanosatellite missions over the last 12 to 18 months, the number of off-the-shelf subsystems and services available for microspacecraft missions has also grown dramatically. This growth in demand for **microspacecraft** related hardware is leading to changes in the way that spacecraft hardware is being bought and sold. In 2007, **Clyde Space** completed the development of their first Cubesat subsystem. It was an ***Electrical Power System*** (**EPS**) that was physically and electrically compatible with the standard Cubesat format, and also compatible with the ***Cubesat Kit*** from **Pumpkin, Inc.**

This standardisation of size and electrical connections has meant that it was possible for Clyde Space to produce the EPS in relatively large numbers; for example, our current production run is for 50 units. Due to the ability to mass produce a satellite subsystem such as this, the cost of the system is now low enough to be purchased outright with a credit card. In fact, the author would love to say that the idea of credit card sales for Cubesat systems was his, but the reality is that most of our Cubesat customers want to pay with credit card and regularly request to do so. Therefore, it is the market that is driving the change in the way that these systems are sold, but with this change will come opportunity to make significant steps forward in microspacecraft cost, schedule and engineering design.

Within the next two years, we predict that it will be possible to perform the spacecraft systems design on our website, add the required subsystems to the online shopping basket, and then proceed to the check-out to buy with a credit card.

Independent International Standardisation

There has been much effort over the last few years to standardise electrical and mechanical interfaces on subsystems. The objective is to reduce the design and integration time currently required when putting a mission together, and also to directly (materials cost) and indirectly (in-house labour cost) reduce the cost of the mission. In particular, there has been substantial effort in the development of 'plug-and-play' standards for the ***Responsive Space*** programme. The standardisation of larger spacecraft buses is perhaps more complex than on smaller spacecraft. But even when taking this into account, it is still impressive to witness how a small number of independent organisations have managed to come together to agree a microspacecraft standard that has now become an international blueprint for picosatellite and nanosatellite missions.
The 10x10x10cm, 1kg (1U) Cubesat standard has

evolved to become the basis for the most widely accepted family of picosatellite and nanosatellite designs. As a result of this standardisation, there now exists regularly scheduled launch opportunities for Cubesats — tens of Cubesats being launched every few months, and the number is increasing.

The Calpoly '***P-POD***' is the industry standard 'Cubesat' launch interface and the P-POD is finding its way to being a permanent passenger on most launch vehicles. With the growing number of launch opportunities, there are also a growing number of Cubesat missions (both activities are fuelling each other).

Many of the missions are university projects where the spacecraft is used as a teaching tool, but there are also an increasing number of commercial and scientific missions. Cubesats are being viewed as an ideal platform to demonstrate the viabilities of new technologies in space. There is also an appetite with many involved in Cubesats to see just how far this size of platform can be pushed in terms of technological capability; it is very probable that there are still significant performance gains to be made with this platform, and this will be demonstrated over the coming years.

The Cubesat picosatellite concept was originated by Professor *Bob Twiggs* who pioneered the concept of using very small spacecraft as an educational tool for universities, schools and other organizations. Our colleagues at Pumpkin, Inc. in San Francisco were quick to realise that there was opportunity to have a commercial interest in Cubesats and in 2003 sold its first Cubesat Kit. ***The latest revision of the Cubesat Kit 1U structure is shown on Page 47***.

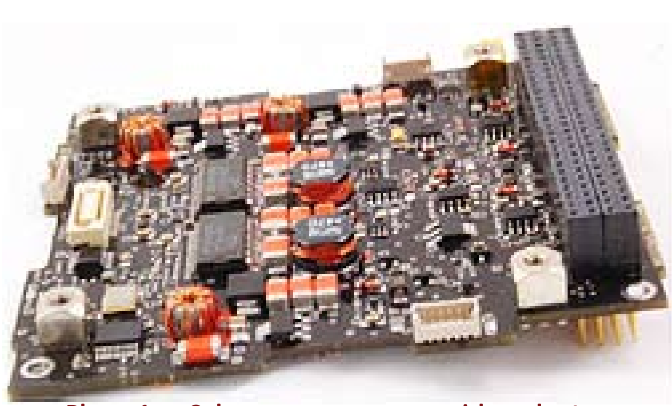


Photo 1 — Cubesat power system without battery

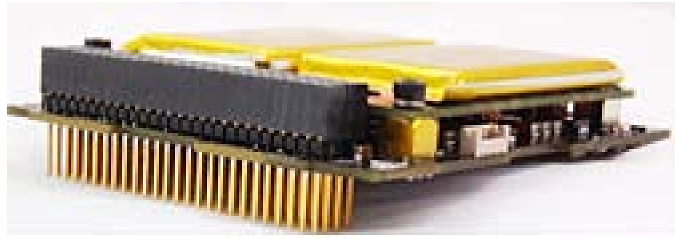


Photo 2 — Cubesat system with battery

The Cubesat standard has evolved since Prof Twiggs' original concept, and it is likely that it will continue to evolve, but there is now a community of parties with a vested interest in the specification of future direction of the Cubesat standard. The most interesting thing about this, however, is that this community seems keen to work together to take the Cubesat concept forward and progress is rarely hindered. This is perhaps a key factor in the success of this standard. As a result, there are an increasing number of commercial organisations producing Cubesat subsystems. Clyde Space is one of those organisations to see the attraction of this approach to spacecraft standardisation and the contrasting business model compared to the traditional space industry.

There are currently more than 20 1U EPS boards with customers and a further 50 in production. Some key features of the ***Cubesat EPS*** include ***Peak Power Tracking*** of the solar arrays with integrated charge management, regulated 5V and 3.3V, over current protected voltage buses, and I2C for telemetry and telecommand. The system is designed for increased reliability, through careful design and selection of commercial components (to mitigate problems relating to radiation tolerance, and so on.).

Photo 3 — Battery Daughter Boards; 1.25Ah at 8.2V

At the same time as developing the EPS, we also developed a battery that could be integrated with the EPS. ***Photo 2 on Page 49*** show the 1U EPS with a 10Whr battery daughter board. Another daughter board (***Photo 3***) can be stacked on top to provide an additional 10Whrs.

In addition, Clyde Space also supplies the solar arrays for Cubesats, making it a one-stop-shop for Cubesat power components and have also manufacutred 1U solar panels and solar panels with integrated magnetorquer coils.

Photo 4 — Solar panel for a 3U CubeSat

Recent introductions to the range include a 3U EPS; this system has higher power ratings on the Peak Power Trackers to cope with the larger solar panels on a 2U and 3U Cubesat. (***See Photo 5, below***)

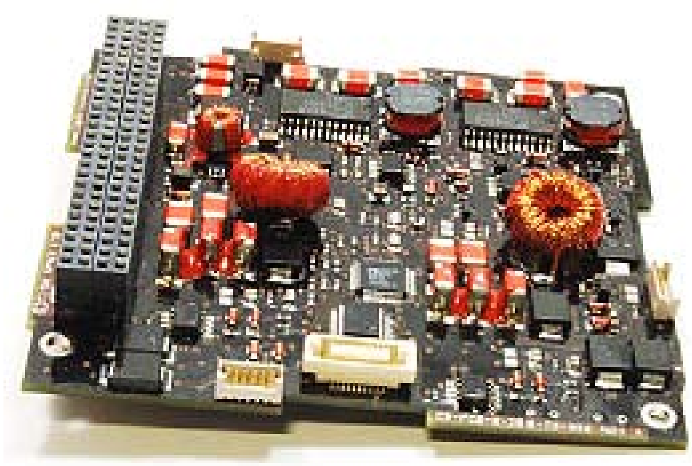


Photo 5 — 3U/2U CubeSat Power System

Due to the larger components on the 3U EPS, it wasn't possible to fit a battery daughter board on this system. Therefore, a separate battery that was compatible with the Cubesat Kit needed to be developed. This battery is capable of being sized up to 30Whrs per unit, which is more than sufficient for most 3U Cubesat missions. The 3U Battery is shown in ***Photo 6, below***.

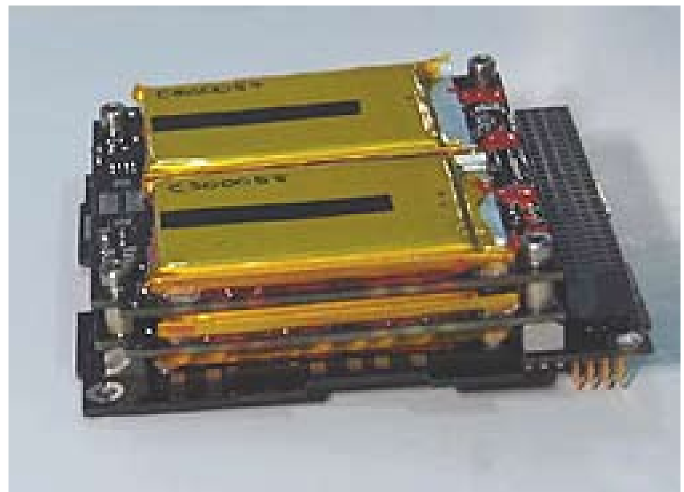


Photo 6 — 3U/2U 30Whr Battery

Immediate Benefits of eCommerce

Given the nature of the products described in the previous section, it becomes clear that this is, indeed, a very different approach to spacecraft, not just from a technical perspective, but also from a commercial perspective. As mentioned previously, there is a pressure from industry to introduce the ability to buy components using a credit card. We investigated the options available to us in terms of credit card sales:

- *The standard option was to have a credit card terminal at Clyde Space and process payments over the phone, but this method is actually only cost effective if you are making multiple transactions per day; Cubesats aren't quite at those kind of volumes yet.*
- *The second option was to use Internet sales. This can also be expensive, especially when considering the percentage of the sale that 'Paypal' and 'WorldPay' will take for each transaction. When a customer is making a payment of over $1,000, these percentages become significant. There is also the issue of the customer being directed off the main website onto a payment website, which is not ideal.*

In the end, we found a method of having an e-commerce element integrated with our website, and not having to pay a premium to the banks for each transaction (although it is still more than we would like).

Now that we had decided on the route we would take to enable credit card sales, it was apparent that the ability to have our products sold online on our website, combined with the technology available for online sales, could open up a whole new approach to the specification and selection of spacecraft systems.

With online sales, it is possible to list related products on a webpage when a main product of interest is selected. This is not only important as a sales tool, but it is also important for the customer, as they will have more information at their finger tips to help them select the systems, accessories and test equipment that they require to make their mission run as smoothly as possible.

For instance, with the 1U Cubesat EPS, most customers will buy one or more flight battery, but some also buy a workhorse battery to ensure that the flight battery is in optimum condition for the mission. Customers also require other items such as the solar panel to EPS harness, solar panels, solar panel clips, magnetorquers integrated with solar panels...the list goes on. It is possible to communicate these additional items in text on a datasheet or proposal, but it is much easier to add the additional items to an online shopping basket and buy all of the required items in one transaction. Figure 9 Example of how 'related products' helps to guide customers to other required items.

We have reasonably detailed product datasheets, but due to the nature of the Cuebsat products, it is not practical to have a datasheet for each variation of Cubesat item. It is also not practical to have

Some of Pumpkin' Cubesat products, distributed in Europe by Clyde Space

datasheets for small items such as harnesses, clips, extra connectors, etc. The nature of ecommerce, however, forces the vendor to detail each item so that the customer knows exactly what they are placing in their basket. This means that there is more information available at the customer's finger tips to enable an informed buy decision to be made.

This level of detail in the online product description enables the customer to place an order at any time of the day from any place in the world with Internet access. Given the international nature of the space industry, this is a very powerful capability as it means that at a minimum, a day can be saved in the order placement, this could be critical for projects with tight schedules.

Frequently Asked Questions

No matter how fast the response time from a company to a customer enquiry, there is nothing quite like having the information at your finger tips. We are often asked questions about our designs that we have not yet considered as something that would be on the minds of our customers. We try to ensure that as much information as possible is included in our User Manual, but it is sometimes not practical to include everything. In addition, many of our customers are undergraduate students, and they perhaps don't have the engineering experience that a professional engineer takes for granted. Another useful resource for us and our customers is the *Frequently Asked Questions* (**FAQ**) page. This enables us to list the commonly asked questions about the system (and anticipate a few others) and have them listed on the website for immediate access for the customer. The FAQs can even direct the customer to other sites that have software or interfacing components that can be used to address whatever issue has been encountered. Again, this is a very powerful tool to have, and is ideal for the Cubesat community.

User Forums

Another very useful tool we have included in our website is a user forum. This is different from FAQs in that the forum needs to be moderated to ensure that the content is appropriate. However, as with most consumer products, users/customers can be extremely useful in ironing out bugs (we all get them) and suggesting future upgrades to the system.

Shipping

As with most online stores, it is also possible to have information on the shipping costs immediately when making the purchase.

Stock Indicators

At the time of writing this paper, a stock indicator on the Clyde Space website is not up and running yet, but this again is a very useful tool for customers. If there is an immediate need for a Cubesat system, the customer can see what we have in stock at any time. Stock availability has a huge influence on the lead-time of the component, and it could mean the difference between taking delivery in a few days from order, or 4-6 weeks from order. Stock indicators will also affect the timing of when the order is placed by a customer (i.e. they may buy earlier or later than planned when knowing the stock levels).

Export Control

Given the nature of Cubesats, it is highly unlikely that a Cubesat or Cubesat component will be used for anything other than military benign applications. However, because it is 'space', there are still some items that fall under export control; for some areas of the world at least. Thankfully, however, most of our Cubesat components do not fall into risk categories and can be shipped to most countries without the need for export license. The main exception to this is the solar panels. Due to the need to have the most efficient solar cells on the small available solar cell area of a Cubesat, we do need to be careful of where these items are sold. However, when selling within Europe, Japan and the USA this is not an issue (depending on launch vehicle selection).

Future Benefits of eCommerce

Clyde Space is continuing to grow its microspacecraft and Cubesat product line through the development of new in-house systems and also through the licensing of existing subsystems from other organisations. The ultimate goal of Clyde Space in this respect is to have a full mission suite of subsystems available to buy on-line off-the-shelf. There are two main objectives:

- *To encourage Cubesat projects to use the Clyde Space website to buy the subsystems they require and also as a resource for their mission planning and design.*

- *To make it possible for a complete Spacecraft to be created and then purchased online using a credit card.*

Objective number '**2**' is key as it will involve the use of web-integrated mission design tools that will down select the appropriate subsystems for the mission. An analogy for this capability is like buying a Dell computer online, where it is possible to customise the system to individual requirements. We see this capability being available on the Clyde Space website in the following two steps.

Power Budget Analysis and Power System Sizing

As mentioned previously, the core capability of Clyde Space is in power systems. Our expertise in power systems is not just in the design and manufacture of the components, but also in the sizing and specification of the system for a given mission profile. Therefore, we are planning to introduce an online mission design tool that will enable users to select the solar arrays, battery and power system for their mission. The tool will provide the ability to view *Beginning of Life* (**BOL**) and *End of Life* (**EOL**) performance data. All users will be able to register on the website and save their mission design information online. The mission design software will have a function where the hardware selected for the mission can automatically be added to the online basket ready for purchase. Again, the basket can be saved for purchase at a later date.

Mission Analysis and Design

The next step, however, is more ambitious and will involve an online mission design tool. This element of the online design tool will be developed to coincide with the availability of complete subsystem suites and support systems from the online shop. This tool will include the power budget analysis feature already described, but will include other parameters such as pointing accuracy, on-board data rates, data storage, processing capability, uplink and downlink speeds, groundstation locations, and so on.

From the information entered by the user, it will then be possible to build up a picture of the mission requirements and how they relate to the available subsystems. It is likely that this will be an iterative process and refinements will need to be made by the user throughout the process to, for example, optimise the link budget, etc. Ultimately, there will be the ability to build up the necessary subsystems, add them to the online basket and buy the complete system when ready. Another benefit of this would be the fact that all of the systems would be already tried and tested, compatible with each other. This will reduce the amount of time spent by the customer in spacecraft testing and interface development, further reducing the time to launch of the mission.

It is clear that there is a growing market for low-cost subsystems for microspacecraft, especially Cubesats. There has been a steady growth in the number of microspacecraft under development and, consequently, the demand for low-cost, off-the-shelf subsystems for these missions. The standardisation of mechanical and electrical interfaces for microspacecraft platforms such as Cubesats has meant that many vendors are able to produce subsystems in large quantities to help keep the unit costs as low as possible.

The next natural step has been to provide an online sales capability to meet this demand, enable the use of credit card sales and to continue to help keep costs low. This paper has also shown how this can lead to a number of other useful online tools and services to help microspacecraft primes as users of these subsystems. In particular, plans to provide online mission design tools will assist customers with selection of subsystems to meet their mission requirements. The development of online sales and design tools is a revolutionary step for space business, and it is the author's opinion that the satellite community will see its first Internet procured satellite by the end of 2010. It is also expected that it will be possible to procure a spacecraft 'kit' off-the-shelf and have it delivered within a few days — this will be the commercial space industry's own low-cost, responsive space platform. It will be interesting to see if, in a few years' time, we will see micro and mini satellites being procured in the same way.

About the author + company

Clyde Space is a relatively young company, started in 2005 when founder, Craig Clark, became the first Surrey Satellite Technology Ltd (SSTL) employee to leave that firm and start a spacecraft hardware business. Craig was Head of Power Systems at SSTL for many years, and Clyde Space was set up to provide Power Systems, batteries, and solar panels for the small satellite community. At the time of starting Clyde Space, there was a real problem with Cubesat failures related to the electrical power system; it was clear to Craig that Cubesats should be the first in-house developed power system for Clyde Space.

by Alan Gottlieb

Inmarsat, traditionally the dominant player in shipboard communications, is rapidly loosing ground to VSAT alternatives as the demand for fixed-price broadband goes to sea. The rapidly evolving desire for high transmission rates at 512 Kbps and above in the large merchant shipping fleets, along with requirements for gigabytes of data transmission per/month, means Inmarsat's data hungry, high-end users will move to take advantage of soon to be complete Global Ku-band coverage.

Traditionally, 80 percent of most company's revenues come from 20 percent of their customers. If that rule holds true for Inmarsat, then 20 percent of **Inmarsat**'s customers — and 80 percent of its revenue — could move to Ku-band. Just at **Motorola**'s ***Iridium*** service was rendered largely obsolete by global GSM coverage, Inmarsat's i4 satellites now face a similar fate.

C-band has been largely confined to oil industry and cruise ship markets. This is due to the size and cost of a 2.4-meter antenna. However, recent changes in Ku coverage, along with innovative technology advances in IP switching and automatic antenna re-pointing technology, combine to offer mainstream shipping markets the advantage of a smaller, and much less expensive, 1-meter VSAT antenna along with fixed-price broadband. The availability of Ku over major ocean shipping routes, and the technologies to exploit it, are recent developments that extend the availability of unlimited voice and data access right into the heart of Inmarsat's richest market, a development largely unforeseen by architects of the i4 network.

When ***FleetBroadband*** was conceived, Ku coverage was largely confined to the continents. Only C-band and global beams and Inmarsat were available over deep ocean routes. With the launch of the now abandoned Boeing Connexion service, Ku availability over Pacific and Atlantic Ocean became a reality. Since then, major VSAT operators have been quick to recognize maritime VSAT market potential. They have added, or are adding, additional Ku coverage to complete a worldwide network of overlapping Ku Beam footprints.

Telstar-11n

In December of this year, **Telesat**'s new ***Telstar-11n*** satellite will extend Ku coverage across Europe as well as U.S. routes to South America. **Eutelsat** has just announced planned coverage of the Southern Indian Ocean. These satellites will complete a network of nearly 20 satellite beams that will make it possible to circumnavigate the globe under Ku coverage. Despite this coverage, however, Ku service providers cannot assure coverage of all locations — Ku does, of course, suffer from susceptibility to interruption due to rain fade. To overcome these obstacles, a clever Ku/L-band and hybrid system is rapidly being deployed. It is this system that represents the greatest threat to Inmarsat.

The Ku/L Band Hybrid

The Hybrid involves the deployment of Ku service and the use of ***Inmarsat-i4*** or ***Iridium OpenPort*** as a backup system. Integrating the two services is facilitated through an IP switching device manufactured by several firms. Perhaps the best known and frequently deployed is the ***Commbox***, manufactured by **Virtek** in Norway. Designed specifically for maritime use, the Commbox essentially offers ***least-cost routing*** (**LCR**) intelligence. When Ku is available, all transmissions are routed over the Ku. In addition, the Commbox can store large file transmissions, which are not urgent, until Ku is available. Hence, the L-band system is relegated to limited use as a backup system only. With Ku coverage increasing, it easy to see that backup L-band will be required less and less, further reducing revenues to the L-band providers. Of course, the final question is how will ships' crews re-point the Ku antenna as the ship traverses from one Ku beam to another?

The final component of the hybrid is the automatic beam re-pointing technology recently developed by **iDirect** and **Vipersat**, a division of **Comtech EF Data**. Activated through a software upgrade at the hub and the placement of a special server aboard the vessel, Seatel antennas can now be automatically re-pointed without crew intervention. A ship can circumnavigate the globe seamlessly passing from one Ku coverage area to the next.

Of course, the implications to the L-band providers are obvious. As the demand for transmission of large amounts of data increases and higher speeds are in demand, pricing by data volume becomes uneconomical and the Hybrid system becomes the only logical choice. Yet, the question remains, what will drive the demand for high volume, fixed-cost transmission?

What's Driving Broadband Adoption at Sea?

In a recently completed study of the maritime communications markets, **Gottlieb International Group** surveyed containership, tanker, and bulk shippers in Greece and Germany. Essentially, we found that most operators were "throttling" their use of pay-by-the-byte Inmarsat services to around $1,000 per/month per/ship due to the high variable cost of usage. However, there was a strong desire to add numerous high data volume applications that, if implemented, would cause the cost of Inmarsat services to soar to an impractical, and unaffordable, level.

While many ship owners were containing the usage to less than 100 Megs per/month, the applications they really wanted to perform would have caused usage to soar to gigabytes per/month. Ship owners are now realizing that the cost of installation of a Hybrid system is justified by the vast array of efficiency enhancing shipboard applications and benefits to crew. With fixed-price broadband, they could:

- *Centralize routine ship management on shore, thereby reducing personnel required at sea*
- *Implement fuel optimization programs automatically downloading wind and current data*
- *Perform remote PC Management including downloading patches and software updates to entire fleets simultaneously, thereby reducing the need to send IT personnel to the ships to effect software upgrades and diagnose and correct PC related problems*
- *Transmit data from ships' board sensors that report engine performance and fuel consumption*
- *Receive pages from technical manuals to facilitate repair of shipboard systems or hardware at sea*
- *Transmit data on cargo and crew to customers and immigration prior to docking, thereby saving time in port*
- *Video Conference*
- *Provide Telemedicine services*
- *Have low cost VoIP telephony capability at a huge discount compared to Inmarsat phone rates*
- *Provide cellular services at sea*
- *Track cargo*
- *Allow the crew to surf the Internet on unlimited basis — a practice that is now cost prohibitive*
- *Stream late news and entertainment*

The Speed of Change – Tough Choices for Inmarsat

With so many advantages, the trend toward ***Ku-at-Sea*** is already underway. The only restraining factor at this point is the sudden and precipitous fall of shipping rates in the global recession with the resultant restrains to capital outlays. The fact that hardware and installation costs of a system are in the $60,000 range, and that many customers have dozens of ships that must be equipped, has slowed the transition to the Hybrid Ku/L Band alternative.

However, as the recession passes — and they always do — the unstoppable trend toward achieving enhanced efficiency aboard ship through the adoption of high-speed fixed broadband will continue, forcing Inmarsat to make some tough choices.

Burdened by the obligation to recoup the high capital and ongoing operating costs of the i4 system, and threatened by a myriad of tough new VSAT competitors, Inmarsat will be forced to defend its turf. As L-band technology does not allow for unlimited, fixed price access at reasonable cost, we see Inmarsat's adoption of its own Fleet Broadband/VSAT offering as a necessary strategy to meet the rapidly evolving demands of its core market.

As most strategists will agree, adoption of new, and more cost efficient, technologies is an essential element of business survival.

About the author

Mr. Gottlieb is CEO of Gottlieb International Group. His firm, Gottlieb International Group Inc., specializes in market research, business development, and sales of satellite and wireless communication technologies to Oil and Gas, Maritime, International Construction and Mining markets. His career encompasses an unusual diversity of background in many segments of the wireless industry including VSAT, Cellular, and Mobile Commerce. He has served as Vice President of Sales for Audiovox Communications; Director of Sales for Southeast Asia for COMSAT and Aether Systems; and Corporate Market Research Manager for a Division of Baker International (now Baker-Hughes). Mr. Gottlieb has been responsible for initiating and managing successful market entries into Southeast Asia and the South Pacific Markets, and assisting satellite related companies with diversification into new market niches and geographies. Contact Mr. Gottlieb at ***algottlieb@gottliebinternationalgroup.com****. To visit the company website,* ***select this direct link****.*

by Dauna Coulter

A solar sail is a spacecraft without a rocket engine that is pushed directly by light particles from the Sun, with the sunlight reflecting off its giant sails. Composed of a gossamer material, when unfurled in the vacuum of space, the sail feels the pressure of sunlight and is propelled by that pressure to carry spacecraft among the stars.

Long ago, someone stood alone on a sandy shore and gazed longingly out at the seemingly endless expanse of ocean, musing, "I wonder, what's out there?" Then, they fashioned a boat, rigged it with a large cloth to catch the wind, and set sail to exciting new adventures and lands unknown.

Not as long ago, someone also stood alone on a sandy shore and gazed longingly up at the seemingly endless expanse of space, suffused softly with sparkling stars, musing, "I wonder, what's out there?" They then fashioned a spacecraft, rigged it with a large cloth to catch the sun, and set sail.

The first paragraph: Already happened. The second: ***Any day now…***.

Two very special missions, one in the past and one in the future, were designed to deploy a solar sail to harness the power of sunlight. **NASA**'s ***NanoSail-D*** was a small solar sail that fell victim to a failed launch on August 2nd, 2008. The **Planetary Society**'s ***Cosmos-2*** does not yet have a specific launch target date and its goal is to make "a controlled flight under sunlight pressure." [1] To fully appreciate these two missions, let's travel back in time for a brief history of solar sailing.

Sailing Into History

Almost 400 years ago, German astronomer, *Johannes Kepler*, observed comet tails being blown by what he thought to be a solar "breeze."[2] This observation inspired him to suggest that "ships and sails proper for heavenly air should be fashioned" to glide through space. Little did Kepler know, the best way to propel a solar sail is not by means of solar wind, but rather by the force of sunlight itself. In 1873, *James Clerk Maxwell* first demonstrated that sunlight exerts a small amount of pressure as photons bounce off a reflective surface. This kind of pressure is the basis of all modern solar sail designs.

The Milky Way beckons to a sky watcher in the south of France.
Photo credit: Laurent Laveder, July 28, 2008.

Echo-1

In 1960, ***Echo-1*** felt these solar pressure effects loudly and clearly. "Photon pressure played orbital soccer with the Echo-1 thin-film balloon in orbit.... The shards were flung far and wide by sunlight."[3]

NASA had a more positive experience with solar sailing in 1974 when the ***Mariner-10*** spacecraft ran low on attitude control gas. As Mariner-10 was on a mission to Mercury, there was plenty of sunlight around and this gave mission controllers an idea: They angled Mariner's solar arrays into the sun and used solar radiation pressure for attitude control. It worked.

Though Mariner 10 was not a solar sail mission, and though the radiation pressure it used was incredibly small, this ingenious use of Mariner's solar arrays did demonstrate the principle of solar sailing. Also in the 1970s, Dr. *Louis Friedman*, then at NASA's **Jet Propulsion Laboratory**, led a project to try the first solar sail flight. ***Halley's Comet*** was to make its closest approach

Mariner-10 spacecraft, circa 1974. Image: NASA to Earth in 1986, and NASA conceived the exciting idea of propelling a probe via solar sail to rendezvous with the comet. Eventually, the project was scrapped. Still "the year-long work on preliminary design demonstrated that, indeed, solar sailing was a feasible spacecraft-propulsion technique."[4]

In 1993, the **Russian Space Agency** launched a 20-meter diameter, spinning mirror called ***Znamya-2***, hoping to beam solar power back to the ground. "Some call Znamya-2 a sail because it was made of a large, lightweight reflector and unfurled like a solar sail might be unfurled," says *Les Johnson* of the NASA **Marshall Space Flight Center**, co-author of the book ***Solar Sails: A Novel Approach to Interplanetary Travel***. "In fact, if I were asked to demonstrate solar sail technology and was constrained to deploy it from a large spacecraft, I might design a 'sail' like Znamya." The foil reflector unfurled and, when illuminated, produced a spot of light, which crossed Europe from France to Russia. Unable to control its own flight, however, the mirror burned up in the atmosphere over Canada. Russia's proto-sail program was abandoned in 1999 after a larger, follow-up mission (***Znamya-2.5***) failed to deploy properly.

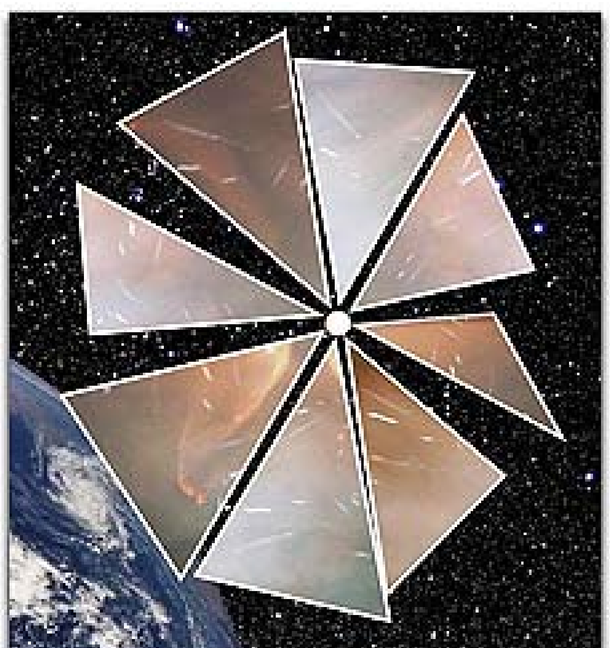
Solar sails were an accessory on India's ***INSAT-2A*** and ***-3A*** communications satellites, circa 1992 and 2003. The satellites were powered by a 4-panel solar array on one side. A solar sail was mounted on the north side of each satellite to offset the torque resulting from solar pressure on the array.

In 2004, Japan deployed a big, think film for solar sail in space. The ***S-310*** rocket carried aloft two kinds of deploying schemes of films with 7.5 micrometers thickness. A clover type deployment (***see image, next column, top***) started at 100 seconds after liftoff at 122 km altitude. A fan type deployment was started at 169 km altitude at 230 seconds after liftoff, following the jettison of the clover type system. Both deployments and subsequent experiments were successful, and the rocket splashed down into the sea approximately 400 seconds after liftoft.

Although this flight was not a demonstration of a free-flying solar sail that could be used for deep-space exploration, the deployment was nevertheless "a valuable

milestone" remarks Friedman, who appreciates the challenges of deploying gossamer sheets from fast-moving spacecraft.

To date, no solar sail has been successfully deployed in space as a primary means of propulsion. The Planetary Society hoped to demonstrate the technology with its ***Cosmos-1*** (***see image, below***) mission in 2005. "Cosmos 1 was a fully developed solar sail spacecraft intended to fly only under the influence of solar pressure for control of the spacecraft's orbit," says Friedman, now the director of the Planetary Society.



Cosmos sail

NanoSail-D poses after a successful laboratory deployment test. Edward E. Montgomery's team from the Marshall Space Flight Center worked in cooperation with Elwood Agasid's Ames team on deploying the NanoSail-D solar sail.

"If all had gone as planned, the U.S.-based Planetary Society, working with Russia, would have been the first to fly a fully functional, though performance-limited, solar sail in space," says Johnson. "It would have been the first spin-stabilized, free-flying solar sail to fly in space."[5] Cosmos-1, however, was lost when the launch vehicle failed.

Meanwhile, NASA has also continued to dabble in solar sailing. Between 2001 and 2005, the Agency developed two different 20-meter solar sails (fabricated by **ATK Space Systems** and **L'Garde, Inc.**, respectively) and tested them on the ground in vacuum conditions.

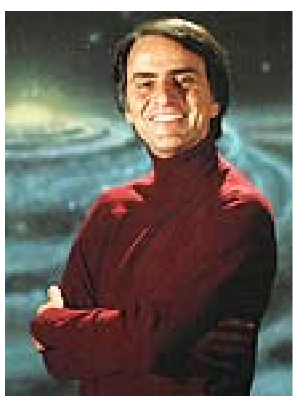
"These sail designs are robust enough for deployment in a one atmosphere, one gravity environment and are scalable to much larger solar sails — perhaps as much as 150 meters on one side." "A NASA flight test is possible by the year 2010."[6]

"Our primary objective is to demonstrate successful deployment of a lightweight solar sail structure in low Earth orbit," says *Montgomery*. The NanoSail-D would have felt two kinds of pressure: (1) aerodynamic drag from the wispy top of Earth's atmosphere and (2) the pressure of sunlight. Unfortunately, Montgomery's team's hope of measuring both types of pressure as the sail circles Earth did not come to fruition.

Next stop, the stars? An artist's rendering of an interstellar solar sail.

What of Cosmos-2? The mission is a privately funded project, a partnership of The Planetary Society and **Cosmos Studios**. Work has begun at the **Russian Space Research Institute** on some Cosmos-2 spacecraft hardware. They are also studying possible launch configurations on a reliable launch vehicle.[7]

"Solar sailing is the only means known to achieve practical interstellar flight," says Friedman. "It is our hope that the first solar sail flight will spur the development of solar sail technology so that this dream can be made real."



Each effort is a stepping stone, as stated by the great visionary *Carl Sagan*'s, along "the shore of the cosmic ocean," [8] leading us closer to sailing among the stars." Future attempts will surely take us the rest of the way.

"'Twas all so pretty a sail it seemed
As if it could not be,
And some folks thought 'twas a dream they'd dreamed
Of sailing that beautiful sea."[9]

Footnotes

[1,7] New developments on the road to Cosmos 2 by Dr. L. Friedman

[2] Measuring Up to a Solar Sail—- NASA feature story

[3] Solar-sail mission reflects past and future —- MSNBC

[4] The History of Solar Sailing by Dr. L. Friedman

[5,6] From Solar Sails: A Novel Approach to Interplanetary Travel, by Giovanni Vulpetti, Les Johnson (Author), Gregory L. Matloff.

[8] From Cosmos, by Carl Sagan, page 5.

[9] Excerpt from Winken, Blinken, and Nod, by Eugene Field, 19th century poet.

About the author

Dauna Coulter is an avid runner and writer with Schafer Corporation and supports NASA's Marshall Space Flight Center's Office of Strategic Analysis and Communications.

More information regarding NASA's Solar Sail projects is available at this website... select the graphic for additional details...

Article *courtesy of ICT Results*

Satellites are achieving unparalleled efficiency with a new protocol, DVB-S2. The performance of DVB-S2 satellite systems is very close to the theoretical maximum, defined by the Shannon Limit. That efficiency could be pushed even further by network optimization tools and equipment recently developed by European researchers.

The newly developed **DVB-S2**, which stands for digital video broadcast satellite second generation, improves on DVB-S by a purported 30 percent.

"Using satellite resource management tools, based on cross-layer techniques, the European Union (EU)-funded IMOSAN project is trying to push that technology even further, in order to make it more attractive not

European researchers have created network optimization hardware and software tools that are able to manage satellite resources more efficiently. The developed tools are able to push the state of the art in satellite transmission technology even further. The increased efficiencies lead to cheap broadband, TV, and voice access from anywhere.

The satellite option is a compelling solution to the broadband problem for rural areas, known as the digital divide. Currently, the vast majority of broadband access is confined to Europe's cities and towns, where people live close to telephone exchanges and can access cheap and efficient ADSL. However, vast numbers of Europeans also live in rural, or even isolated regions — providing broadband access for them is more complicated.

Perhaps not for much longer — recent progress in satellite technology has led to vastly improved bandwidth efficiencies.

only from the technical aspects, but from the business point of view as well," explains *Anastasios Kourtis*, co-ordinator of the EU-funded project. Cross-layer techniques work across the application, service and physical layers of a communication medium to maximize efficient usage of bandwidth.

Approaching The Shannon Limit

The Shannon Limit establishes the maximum capacity of any channel. A channel is subject to bandwidth and noise restrictions, but its capacity can be improved with clever modulation and multiplexing techniques. The theoretical ultimate limit of a channel for specific bandwidth and signal-to-noise ratio is called the Shannon Limit. Like the speed of light, that limit cannot be overcome and, again like the speed of light, it is very difficult even to approach it. The inherent feature of DVB-S2, called ***Adaptive Coding and Modulation*** (**ACM**), allows a satellite system to adapt, in real time, to various transmission conditions and service demands. In this respect, satellite channels are very close to their theoretical limit.

"The IMOSAN consortium developed innovative software and hardware modules and protocols, called the ***Satellite Resource Management System*** (**SRMS**) that apply ACM to voice, data and TV in a clever way, allowing the provision of cost-effective 'triple-play' satellite services to users in rural or isolated areas," Kourtis explains.

Key Advance

SRMS was a key advance, but only one of a series of innovations and improvements the team performed on the DVB-S2 system. They also developed hardware and software that supports **MPEG-2 HDTV**. They developed software that can use both the older ***Multiprotocol Encapsulation*** (**MPE**) scheme and the newer ***Ultra Light Encapsulation*** (**ULE**) one. Both have also been optimized for **IPv4** or **IPv6**.

IPv4 is the current ***Internet Protocol*** (**IP**) that we mainly use for all data communications. However, the unique IP addresses are running out rapidly, and the protocol is creaking under the strain of modern network demands. IPv6 will address this shortage and offer other new features to improve the Internet.

IPv6 offers so many unique addresses that it would be possible to give an address to every individual grain of sand on earth and still have enough numbers remaining to give a unique one to every individual on the planet, any pets they have, and all the devices they own. IPv6 also provides better security and error correction, and it is the IP standard of the future. Including it in their system means that **IMOSAN** has future-proofed its work.

Significant Impact On Satellite Communications

"The innovative tools and techniques that were developed in the frame of IMOSAN, gave [us] a great opportunity [for] efficient collaboration among private-sector companies and public academic organizations, with a common goal: to provide cost-effective broadband satellite services to rural and isolated areas," Kourtis concludes. This should help tackle the digital divide problem.

Now that the technical problems are solved, the research team is working hard on the business case. Service providers could start offering satellite TV, broadband, and voice services for less than 50 euros. **Eurostat** estimates that 10 percent of the European population, or 30 million people, are too isolated to be covered by landline broadband services and, so far, no viable solution has presented itself.

Experts hoped that ***WiMAX*** — a long-range version of the ***Wi-Fi*** wireless technology — would fill the gap, but large WiMAX networks are expensive to deploy and the technology is just beginning to mature. Satellite services could fill the gap, but in this case, the bandwidth costs are very high. A basic Internet service via satellite can cost 150 to 200 euros, way out of reach for the vast majority of users.

Those costs could drop dramatically as European researchers from the IMOSAN project continue their work on integrated multi-layer optimization in broadband DVB-S2 satellite networks. IMOSAN has taken advantage of new standards to squeeze more bandwidth from satellite transmissions.

The team also developed components that could offer 'triple-play' services — TV, Internet, and telephony.

Finally, they developed optimization software that could help ensure the best possible service quality in bad weather, or during high-demand periods.

Impressive Technical Hurdles

The EU-funded IMOSAN solved many of the technical hurdles facing widespread satellite adoption for triple-play services. An equally important element of their task was to prove the business case to make these services viable.

“We had to study the market and examine all possible business models to try and establish a competitive offering for satellite triple-play services,” explains Natassa Anastasiadou, a researcher at IMOSAN responsible for market studies and director of the department of funded programs at OTEplus.

“The technical advances made by the IMOSAN project mean that satellite bandwidth is 30 percent more efficient, but we had to see how that translated into real-world costs for real-world business scenarios,” she relates.

Anastasiadou and colleagues whittled the possible offerings to three scenarios for rural and remote regions. They first covered residential users in isolated areas, served by a purely two-way satellite solution, enjoying high-end services, including high-definition TV channels. IMOSAN calls this the ‘gold scenario’. The ‘business scenario’, meanwhile, looked towards isolated areas served by a hybrid satellite-Wi-Fi solution, where the emphasis is put on fast Internet access. Finally, for the ‘basic scenario,’ the team looked at delivery to scattered residential users, served by a hybrid satellite-WiMAX solution, where a standard triple-play package is provided — similar to common packages provided in urban areas by ADSL technology

“Obviously, the lowest price the IMOSAN provider could charge the end-user for the triple-play service package provided depends strongly on the maximum number of users it can serve with a given investment,” notes Anastasiadou.

Going For Gold

The gold service package was designed to fulfill the requirements of residential users in isolated areas and included fast Internet access of 1 Mbps download, VoIP services, and 13 TV channels (10 standard and 3 high definition). The analysis showed that this package should be priced monthly at 147.60 euros (at least) for the investment to be depreciated over ten years. At that rate, the terminal had to be provided to end-users for free, whereas if the end-user paid for it, the monthly rate came down to 87.50 euros. However, an IMOSAN terminal would cost 1,500 euros against 350 euros for standard satellite terminals.

The business scenario fared better. The service package envisaged fast Internet access of 2 Mbps download, VoIP services, and five standard-definition TV channels. It required a monthly rate to be charged to the user/business of 181.30 euros, again over 10 years. It included the terminal, and would be competitive with existing services, especially given the very high quality and service standards, as well as the triple-play offer.

The basic package was tied into WiMAX technology. WiMax is a long-range, high-speed wireless networking standard that is just beginning to experience large-scale deployment in the U.S. and the EU. The satellite transmits directly to the WiMAX transmitter, which then delivers service to individual customers.

“It is much more cost-effective to offer the service this way,” reveals Anastasiadou. “Every single end-user does not have to get a satellite receiver, which costs over 1,000 euros, but shares the cost of a WiMAX station instead which, although currently costing about 10,000 euros, can serve about 300 end-users effectively.”

As they continue deployment, WiMax receiver prices will probably drop dramatically, making the basic scenario even more cost competitive over time.

Europe’s Broadband Losers

The IMOSAN basic scenario consisted of seven standard TV channels, 1 Mbs Internet, and VoIP targeted at the largest group still without ADSL access: scattered residential users in rural areas. It was the most successful scenario studied by IMOSAN, costing 57.20 euros with a contention ratio of 30:1. The contention ratio indicates how many users can access a single channel at one time. At a ratio of 50:1, which is reasonable for residential services, monthly costs would drop to 37 euros per month, which is very competitive with alternatives such as standard satellite to individuals. The work has generated considerable excitement among service providers and satellite operators, with one company currently considering a basic service deployment in Greece, and many others interested.

Through its technical advances, IMOSAN will have an impact on satellite services generally, but its greatest impact could be ensuring that all Europe’s citizens have economic access to the Internet — one of the most essential services of the information age.

ICT Results

by Guy Adams, CTO, **Parallel**

Very Small Aperture Terminal (VSAT) is overwhelmingly the most prevalent mechanism for satellite communications. While most elements of this document cover all forms of satellite communications, for convenience, the term VSAT will be used throughout.

The advantages of VSAT communications are now widely accepted and understood. At a high level the main reasons for this have not changed for many years. However customer management requirements have been increasing rapidly propelled by developments in terrestrial network management.

Additionally the requirements for higher bandwidths combined with increased space segment scarcity have driven manufacturers to develop and implement more and more sophisticated systems to squeeze every bit per hertz, but these have created some of the most complicated management issues in any networking technology.

This is compounded by the generally poor acceptance by most (with certain exceptions, such as **iDirect**) VSAT vendors have the need to provide adequate management and upstream management interfaces.

VSAT Technology Background

Very Small Aperture Terminal (VSAT) has been in use for over 10 years for a wide variety of applications such as corporate networks, rural telecoms, distance learning, disaster recovery, ship-board communications — the list goes on. VSAT technology has enjoyed steady growth, making it one of the most enduring networking technologies. Industry figures show that this growth is set to continue and accelerate.

This popularity is primarily due to:

- *Last mile solution*
- *Suitability for disaster recovery*
- *Speed and cost of deployment*
- *True global coverage (i.e. no dependence on the quality of local infrastructure)*

However, if one has, or is thinking of, deploying VSAT, there are a number of unique characteristics that need to be considered, particularly with reference to Network Management.

Network Management

Virtually every enterprise or organization in the world depends on a computer network: from a simple small business sharing documents and gaining access to the Internet, or global banking ventures transferring billions of dollars a day. Any organization that relies on its network to do business should have some type of Network Management in place. Organizations that rely in some way on VSAT networks generally need a much higher level of Network Management than most.

Network Management is the process of monitoring and controlling a network to increase efficiency and productivity. It is done 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.

With networks being essential to the day-to-day operations of all staff, customers and business partners, 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 business. The cost of having no, or ineffective, network management can spell disaster for an organisation. Prolonged or frequent network downtime can result in loss of reputation, productivity, revenue or even a decrease in financial performance.

Traditional Network Management

Considerations for VSAT Technology

Nothing that has been discussed so far is particularly revolutionary or ground breaking for terrestrial networks. However is it still something that is typically very badly done by many organizations. This is usually because Network Management is not given enough profile or importance within a company. Most organizations have a dedicated (or a team of) Database Administrators (DBAs). How many organizations have an equivalent number of dedicated Network Administrators to manage and look after the network? Very few, but what use is a beautifully maintained database if no-one can get to it? Having spent several years performing both these roles in the past, I would certainly rate looking after a set of database clusters as easier than managing a typical (multi-technology, multi-provider, multi-equipment, rapidly changing) large network.

The simple fact that there are literally hundreds of Network Management Systems designed for terrestrial networks compared to only a handful of database administration tools provides some idea of the size of the problem. 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.*
- *In band or out of band management. 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 is true as far as it goes. If all we are looking for is simple red/green icons and a couple of pre-generated graphs then these tools may be enough.

Network Management + VSAT Technology

VSAT Network Management is caught in the middle between opposing forces:

- *Rapidly increasing customer demand for on-line, real time and historical reporting with huge levels of detail, SLA Reporting, QoS Monitoring and many other complex requirements*
- *Greater and greater sophistication and complexity within the VSAT technologies that make even simple monitoring difficult*

VSAT technologies which are still primarily designed to be standalone and managed only using vendor proprietary tools (although this is changing with some manufactures like **iDirect** now actively supporting upstream integration and access by other management systems)

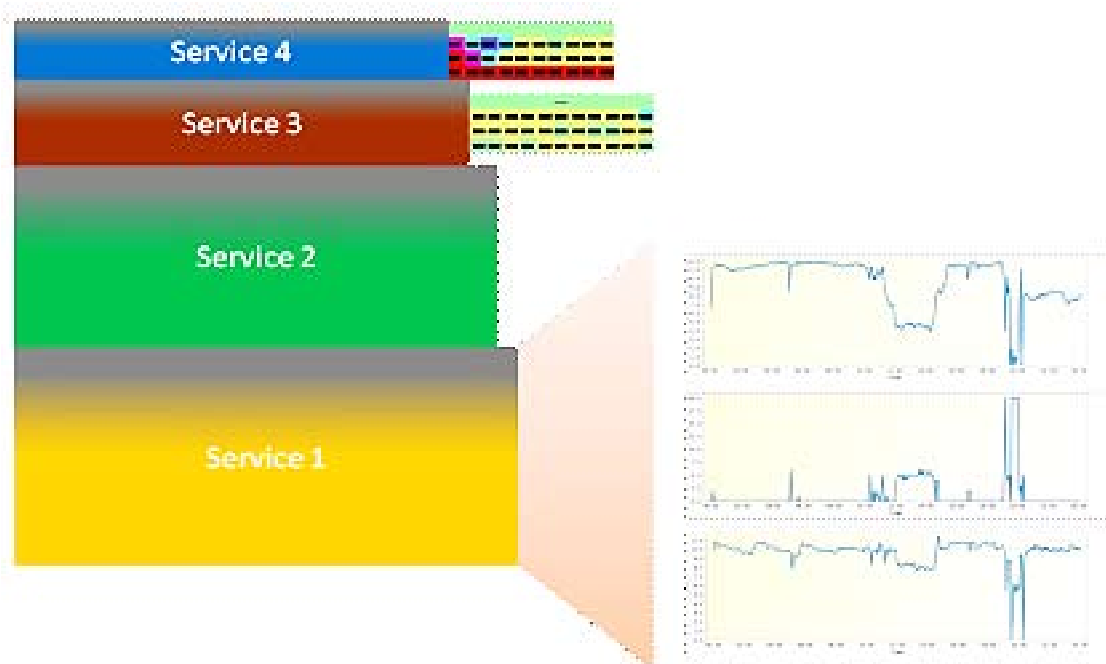
This presents a 'perfect storm' scenario, customers are demanding more, the technology advancement is making it harder just to stand still and manufacturer support, in many cases, is limited or worse.

We will deal with each of these areas of complexity in turn.

Increasing Customer Requirements

Ten years ago most clients were happy to be told whether their circuit was up or down. Five years ago they would have liked to know total traffic volumes, latency and maybe EbNo/SNR. Two years ago the range of metrics they wanted to report on had expanded greatly, now incorporating packet loss, jitter and starting to breakdown traffic into more detailed component parts. They were no longer satisfied with one set of reports for the VSAT part and another set for their terrestrial parts, they wanted full end-to-end monitoring. However, in quite a few cases, when reporting was presented in an effective way an interesting thing started to happen.

Bucking the trend for wanting more and wanting it cheaper, many organisations started to realise how important this data was to them, and were prepared to pay additional fees to get to it. Clearly this was not (and still is not) universal, but the trend had started. Today the trend is for clients to want the level of reporting they had on a per circuit basis, but to have this replicated down to Virtual Circuits or Service Classes. For example, where they used to have single metrics per circuit for Jitter, Latency, Packet Loss, they now want these separately for their VoIP traffic class, their Sensor and Telemetry traffic class, their ***Citrix*** traffic class and so on.



It goes without saying that they want all this information and functionality web-based, in real time (plus the ability to go back months or years for historical reporting) and from anywhere in the world. Oh, and they would like to be notified proactively to their smart phone about anything affecting service, not just outages, but congestion, VoIP chop, overheating equipment and much more!

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 no small amount of complexity. But it is the drive for higher performance, lower latency and greater and greater bandwidth efficiency to match industry growth with increasingly scarce space segment that has driven most of the technical developments and complexity. Automatic power control, advanced acceleration and compression, dynamic QoS and CIR changes and Adaptive Coding and Modulation are well known examples of these developments, and every one brings with it great 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, so 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 themselves constantly changing, is a nearly unique challenge to satellite communications, and one totally beyond any terrestrial management system.

There is another dimension to the technology sophistication, and this is the rate of change. To determine what is required today, how to achieve it and then implement it is one thing, but by the time this has been achieved the newly presented technological advances also need managing.

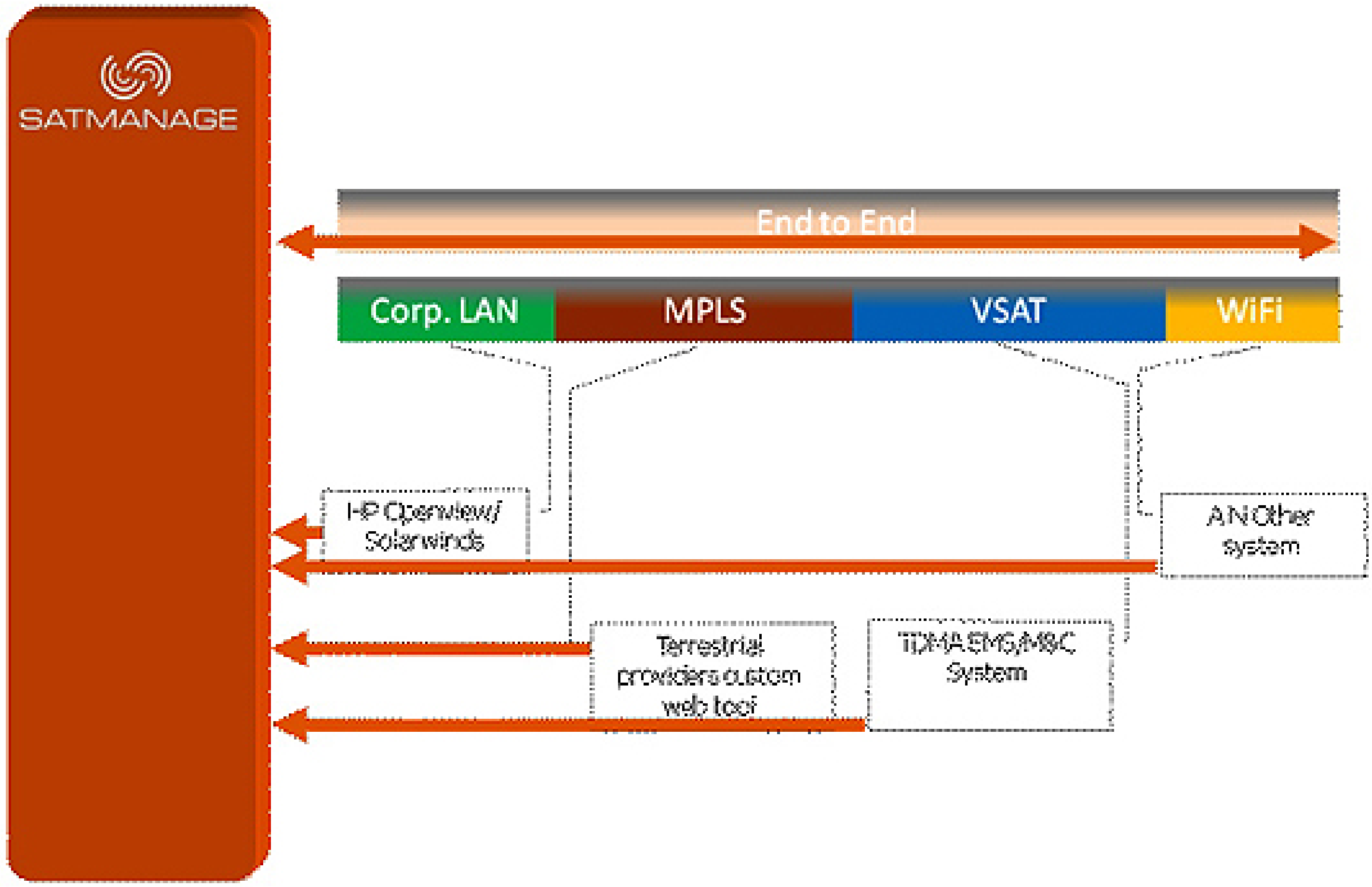
This can easily become a never ending catch up process, and is one of the biggest reasons organizations elect not to try to build (or start to build and then abandon) all this management for themselves. The cost and resource required to get up to date and keep up to date with advancing technology driven at ever increasing rates by bandwidth scarcity is a huge undertaking and impossible to do cost effectively for individual organizations.

The final great challenge with VSAT technologies is the lack of both a friendly and efficient management interface and a lack of management standards. Many organizations believe that by adding a standard management stack e.g. SNMP (Simple Network Management Protocol) their management responsibilities have been met (and some of these are implemented very badly). The real question should be 'is this the right management interface?'

For example, a very common requirement is to get data that can only be obtained from the remote device (e.g. transmit and receive traffic, temperate, buffer fill levels, etc). In a typical management scenario there could be 15 of these metrics we want 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 addition 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).

It is widely accepted that since SNMP has been a defacto standard for management of terrestrial networks and components, it is a perfect solution for all networks. However, with the very high cost of satellite bandwidth this is rarely the case for satellite networks. The second problematic situation is where a useable system exists but is not standards-based in terms of Network Management.

This usually means that an efficient and comprehensive integration is possible, but requires very complex and customized integration into a Management System. In practice these systems are usually possible to integrate into 'standard' network management



systems since they generally only support standards based integration.

The final situation it that neither option is available i.e. neither a useable or standards-based management interface. Fortunately on modern VSAT systems this is rare, although it still exists, but there are still many legacy systems in use and it will be many years before these are retired completely.

These issues are VSAT specific, however there are very few pure VSAT networks. Most 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. The Management System for such a network must be able to handle all of these properly and accurately, in addition to all the special considerations made for the VSAT element.

As has been discussed previously, end-to-end management is becoming a critical requirement for most customers, and the ability to both 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. But such can also provide great opportunities for time saving, automation, customer satisfaction and generating additional revenues.

About the author

In 2004, Guy Adams was named the U.K.'s Network Professional of the Year – in recognition for his work for SatManage and its clients. He has overseen the development of a satellite network management system now used in many of the world's largest and most prestigious organisations. His groundbreaking data correlation, visual displays and trouble ticketing automation form the basis of SatManage, a comprehensive satellite network management suite. Guy is the Chief Technical Officer for Parallel's SatManage product.

2009 Editorial Calendar
SatMagazine + MilsatMagazine

SatMagazine + MilsatMagazine are offered as online viewable magazines and also as downloadable ".pdf" versions — there is no charge for access. Some issues are also printed for distribution at various conferences, exhibitions, and trade shows, and they are so indicated in the list below. SM = *SatMagazine*, MSM=*MilsatMagazine* — SatNews ***deadlines are 5:00 p.m. daily, California time.***

- ***JANUARY SM — Deadline: December 10 — Theme: The Microsatellite Market (Nanos, Picos, Minis, Micro)***
- ***JANUARY MSM — Deadline: December 10 — Theme: Intelligence/Surveillance (also UAV connection)***
- ***FEBRUARY SM — Deadline: January 10 — Theme: The U.S. Satellite Market***
- ***MARCH SM (PRINTED) — Deadline: February 10 — Theme: All Things Broadcast Related (300 dpi graphics minimum)***
- ***MARCH MSM (PRINTED) — Deadline: February 12 — Theme: Advanced Military Communications (300 dpi graphics minimum)***
- ***APRIL SM — Deadline: March 10 — Theme: New Applications***
- ***MAY SM — Deadline: April 5 — Theme: Imagery & Earth Observation***
- ***MAY MSM — Deadline: April 10 — Theme: New Technologies***
- ***JUNE SM (PRINTED) — Deadline: May 11 — Theme: Asia + pan-Pacific Market***
- ***JULY/AUGUST SM — Deadline: June 5 — Theme: MSS + Ground Stations | Teleports***
- ***JULY/AUGUST MSM — Deadline: June 10 — Theme: The Warfighter***
- ***SEPTEMBER SM — Deadline: August 5 — Theme: European Markets***
- ***SEPTEMBER MSM — Deadline: August 10 — Theme: Military Satellites***
- ***OCTOBER SM (PRINTED) — Deadline: September 12 — Theme: Satellite Launch Sector markets (300 dpi graphics minimum)***
- ***NOVEMBER SM — Deadline: October 5 — Theme: MENA + Latin American markets***
- ***NOVEMBER MSM (PRINTED) — Deadline: October 10 — Theme: COTS + Mobility (300 dpi graphics minimum)***
- ***DECEMBER SM — Deadline: November 10 — Theme: Year In Review***

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Pattie Lesser, Editor

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