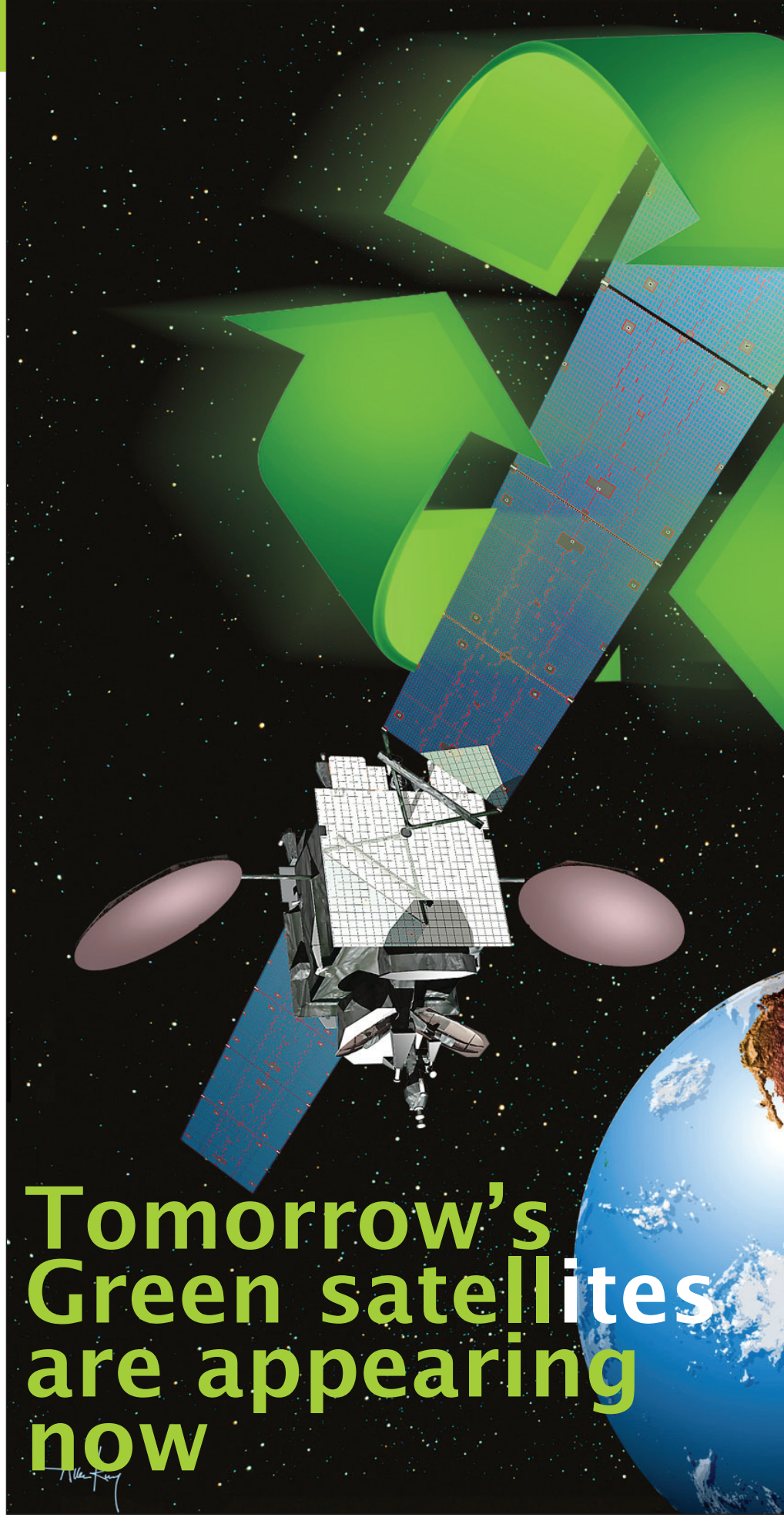
Tomorrow's Green satellites are appearing now

Satellites are having to adapt to meet future launch and broadcasting requirements. Chris Forrester explains.



Satellites are already phenomenally 'green' devices. They are classified as 'High Tech/Low Carbon' machines by the European Information and Communications Technology Industry Association (EICTA) because they are one of the most efficient networking and broadcasting solutions in terms of carbon emissions.

Satellites are already low-energy, but many of them are about to get even lower – and much more efficient – users of energy. Typically today a satellite's rocket is launched amid a cloud of smoke – itself mostly harmless water vapour. 'But what of the harmful rocket fuel,' you might ask. Well, the truth is that a conventional rocket launch is dramatic, and noisy, and thrilling to watch but actually generates less CO_2 than a trans-Atlantic 'jumbo' jet, and the satellite makes just one launch journey in about every 17 years or so.

However, a satellite also carries about two tonnes or so of fuel to fire the tiny on-board rocket thrusters which are vital for keeping the satellite correctly aligned towards the Earth, and to compensate for minor drift in the satellite's position away from its designated orbital slot. This gentle drift is caused by external influences such as solar wind. Too much drift and its signals would not be received by the millions of small dishes pointing toward it. Every 20 days or so, ground-based technicians bring the drifting craft back to an ideal position and the process starts all over again.

"We can provide a totally new viewing experience with the U-HDTV."
DR KEIICHI KUBOTA, HEAD OF R&D AT NHK
IMAGE: COURTESY, NHK

PAYLOAD. For some years, satellite builders have incorporated XIPS (Xenon-Ion

Propulsion Systems) onto a satellite's payload. The general plan – to date - has always been to use the XIPS technology to augment the craft's on-board thruster fuel. XIPS would potentially add life to a craft that had almost exhausted its fuel, either because the 'end of life' for planned fuel consumption had been reached, or more advantageously the XIPS technology could be used where there had been some sort of on-board glitch that had consumed more thruster fuel than had been anticipated.

> Christoph Dosch, Chairman of the Broadcasting Service Study Group, writing in *ITU News* said: "U-HDTV promises to bring about one of the greatest changes to audio-visual communications and broadcasting in recent decades. Technology is truly at the cusp of transforming how people experience audio-visual communications."
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> (ITU) Secretary-General Dr Hamadoun Touré, looking ahead to the day when UHDTV will become a reality, said, "U-HDTV will create an immersive experience for viewers and will generate a host of new business and marketing opportunities."

XIPS technology has been added to satellites for some time. The world's leading space agencies have long used XIPS (or other electric propulsion variants) for deep space missions. Boeing (when its satellite division was called Hughes Space and Communications) built craft for many Direct-to-Home (DTH) customers with XIPS technology on board (including PanAmSat/Intelsat and SES Astra) and it is fair to say there have been some past problems with XIPS technology. But importantly nobody depended wholly on the system.

That's now changing. In March 2012 Boeing announced it had received orders for four all-XIPS satellites (from Asia Broadcast Satellite and SatMex) and with options for four more. The first two satellites, ABS-3A and Satmex 7, are scheduled to be delivered together in late 2014 or early 2015. Details about the other two satellites and their launch plans will be announced at a later date, said Boeing.

THRUSTERS. Importantly, these satellites will carry no conventional chemical propulsion thrusters, and thus no fuel to fire conventional thrusters. The satellites will depend entirely on XIPS technology, and this will save about two to 2.5 tonnes of on-board fuel and weight. The first two satellites under this contract will be readied in 32 to 34 months, but subsequent craft should take only about 24 months to build and to be ready for launch. Ideally, says Boeing, they are looking for 'pairs' of orders in order to maximise the weight-saving and to translate that into dramatically lower launch cost benefits.

Boeing Satellite Services' president Stephen O'Neill said 18 satellites were currently flying with XIPS systems on board, although none were wholly dependent on electrical propulsion. Luxembourg-based satellite operator SES is also planning at least one, and possibly more, all-electric propulsion satellites. Martin Halliwell, CTO at SES, says such a satellite would save around 2.5 tonnes from its launch weight (from a typical 6.5 tonnes for a conventionally fuelled satellite) with commensurate savings in launch costs.

SES president Romain Bausch confirmed the SES scheme, saying SES would likely issue its Requests For Proposals (RFPs) to satellite builders shortly. Bausch explained that going 'all electric' offered other benefits, not least using the saved weight to add more payload options. "We could increase the number of transponders," he said, and thus add to a satellite's versatility.

ELECTRIC. However, even though plenty of satellites have carried a Xenon-Ion electric propulsion (XIPS) option as an addition to conventional fuel, it is believed that no other satellite operator has gone with only electric propulsion.

It is also acknowledged that XIPS-equipped satellites take much longer to manoeuvre into position following launch, and Bausch said the ideal situation would be to launch such a craft as a replacement vehicle for an established satellite, where the existing satellite still had plenty of life left in it. The XIPS craft could then slowly move onto its designated position, and potentially then free up the original satellite to be located elsewhere. The difference in speed is quite dramatic. A conventionally-launched satellite – with chemical propulsion – is usually in position, ready to go to work, around 30 days following launch. A XIPS-only craft might take six months to achieve the same location.

But the upside gains are considerable. Saving two tonnes or more of launch payload will also bring the cost of launching the satellite down significantly. If the technology proves itself, and Boeing's argument is that it is now well-proven, then insurance rates should also be somewhat lower on the basis that there's less to go wrong with an all-XIPS craft. Boeing also say that they will build in full redundancy for the lightweight XIPS services thereby doing their level-best to ensure in-orbit longevity for these 'next generation' beasts. The satellites, which were initially designed by Boeing's Phantom Works

unit and will be built in Boeing's El Segundo factory, are designed to operate in a DTH/geostationary orbit. The 702SP is compatible with all major launch vehicles, including Falcon 9, Ariane 5, Sea Launch, Proton, Soyuz, Atlas 5 and Delta IV.

Ka-. The Ka-band is, in the words of all satellite technicians, "just another set of frequencies". The statement is true, but Ka-band represents another 'great leap forward' for the satellite industry. The next major developments for the industry is the expansion into Ka-band, in particular for upcoming 'Ultra HDTV' signals which will transmit in either 4,000 or 8,000 lines, and deliver spectacular images.

Take comments from Philip Goswitz, DirecTV's SVP/space and communications/R&D who says DirecTV is already transmitting very successfully in the Ka-band to its North American 'local into local' customers. Goswitz described his Ka-band satellites as "spectacular". Indeed, DirecTV could successfully argue that its Spaceway Ka-band satellites are the most profitable satellites being used anywhere (whether in Ku, Ka or any other band) as they are helping generate some $20billion a year in revenues for DirecTV because of their spot-beam and 'local into local' HDTV services over North America.

Goswitz admits that few viewers to DirecTV even know that Ka-band is being used, such is its seamless integration into DirecTV's overall portfolio of satellite assets. "I am not even sure our own executives know! They don't know the difference between Ka and Ku-band, and why should they?"

QoS. Goswitz, describing Ultra-HDTV, says "4,000 and 8,000-line services are great for the satellite industry, and will ensure that satellite broadcasting continues to distinguish itself for image quality of service. We see this as a key strategic advantage for us. At DirecTV, we see a couple of things happening. First, our subscribers are migrating away from Ku-band, and upgrading themselves to Ka-band and its HDTV services. In four or five years, our Ku-band [transmissions] could end. We are also developing the so-called Reverse Band for DBS services, and these are on our Road Map for future international services. 4,000-line is exciting to us because of its image quality, and the potential for glasses-free 3D."

"U-HDTV will create an immersive experience for viewers and will generate a host of new business and marketing opportunities."
DR HAMADOUN TOURÉ, ITU

Incidentally, Goswitz's reference to 'Reverse Band' transmissions cover the 17-24 GHz bands, and these – at least as far as North America is concerned – have always included video services.

Currently, DirecTV as a whole operates 12 geo-satellites, eleven owned and one leased. The fleet currently operates seven Ku-craft (three at 101 degrees West, one at 110 degrees W, one at 119 degrees W, one – leased – at 95 degrees W and a spare that has been moved from 72.5 degrees W to 110 degrees W). DirecTV also has two Ka-band craft at 99 degrees W and three at 103 degrees West. Its future plans include contracts for two new Ka-band craft D-14 (Q1-2014 launch being built by Loral) and D-15 (Q4-2014, Astrium) to "provide additional HD, replacement and back-up capacity" says a recent SEC filing, and expected to be used for its Latin American services.

HI-RES. What Goswitz did not elaborate on was when the 4,000-line services would start, and it is fair to say that there's still a great deal to be done on compression and other enabling technologies in order to bring these very high-resolution images into viewers' homes, It is nevertheless clear that DirecTV wants to see its lead maintained over terrestrial TV, and in particular cable and DSL-type delivery services, and Goswitz sees satellite as maintaining that technological edge.

Japan's planned introduction of Ultra-HDTV is scheduled for 2020, and will use Ka-band, a largely unused set of frequencies around the globe. In February, the ITU's World Radiocommunications Conference in Geneva also agreed that Ka-band would be used as the future carrier of U-HDTV signals.

As mentioned, putting a 'start date' on U-HDTV is tough. However, the 2012 Olympic Games will – in part – be covered in U-HDTV, and the next few years will see further developments in camera and, in particular, transmission technology. Indeed, February 2012 was a busy month for those looking at 'next

How Green is a Satellite?

"With access to sunshine reserves one billion times greater than those that reach the earth, space-related technologies are truly disruptive technologies that offer dramatic potential for replacing traditional terrestrial processes with low energy alternatives," EICTA says, adding that, "there is scope for achieving orders of magnitude energy savings by switching to satellite technology to perform terrestrial network infrastructure tasks, particularly in the communications field."

"Broadcasting is a good example of this: all the current terrestrial TV broadcast systems across Europe together consume between 600 and 900 mW and release between three and 4.5 million tons of CO_2 per annum," the EICTA report pointed out. "Three satellites could provide all of Europe's TV in HD format and release nearly zero CO_2 into the atmosphere in the use phase. They are powered purely by sunlight. Even the uplink requirement is miniscule in comparison – far less than 1% of terrestrial demand."

Source: EICTA

Further growth for satellites

According to Euroconsult's *Satellite Communications & Broadcasting Markets Survey*, the satellite bandwidth used for traditional DTH and related services will be worth almost $15 billion in 2020. "While we have seen slowing growth rates in leased capacity, FSS operators' revenue growth has continued to outperform the global economy, and operating margins remain high for most operators.

In the near term, the difficult economic environment could weigh on the market," said Pacôme Revillon, CEO at Euroconsult. "Still, connectivity needs and the growth of digital TV in emerging regions, combined with the launch of new generation high throughput satellite systems should continue to drive growth."

Euroconsult's study estimates that 1,145 satellites will be built for launch from 2011 to 2020, 51% more satellites than the previous decade. Revenues from the manufacture and launch of these 1,145 satellites will be worth $196 billion worldwide, of which 70% can be attributed to government demand.

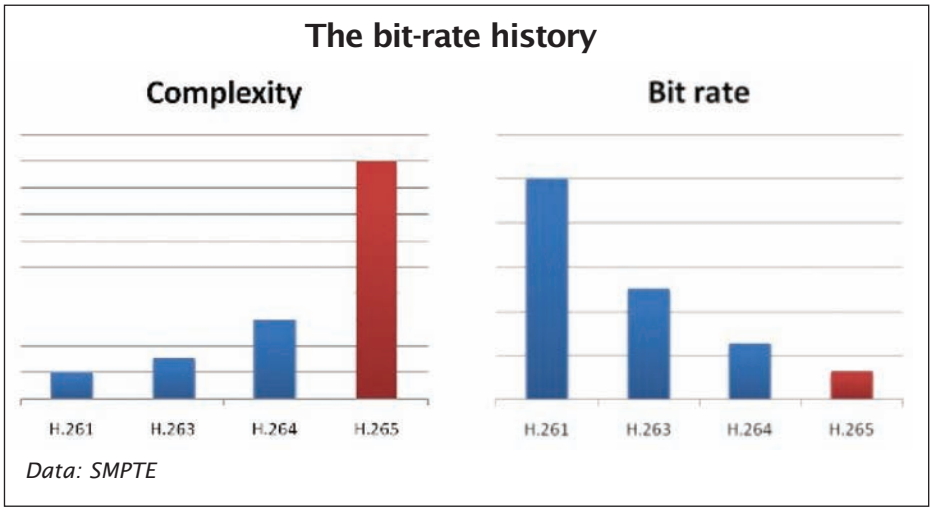
XIPS propulsion is not new for SES Astra. Its 2C satellite had a XIPS payload

Image Courtesy: SES

generation' television. In the heart of Silicon Valley, in San Jose, California, the Joint Collaborative Team on Video Coding (itself a combination of the ITU-T's committee and the MPEG team) sat down and finalised a Committee Draft of the so-called H.265 MPEG codec. Their work, while not quite establishing an industry 'standard', makes a major move towards fixing the High Efficiency Video Coding (HVEC), an essential next step on the road to higher-definition broadcasting.

COMPRESSION. The team's efforts, along with those from SMPTE, have one goal in mind, which is to fix an industry wide standard for further signal compression and thus enabling 4K and even 8K image capture and transmission to take place. The San Jose meeting suggested that H.265 could provide improvements to streaming efficiencies by 35% to 40%, although one adventurous panelist talked about a 67% saving in bandwidth.

Attendees at San Jose had mixed opinions about whether or not the standard was now stable enough to start design work. Some companies suggest they are already starting design work on their IC chips for HEVC, others say they will wait about six months for



the standard to progress to the next and more stable milestone.

That 'next step' is scheduled for this July, when the draft international standard should emerge. Then further examination and testing will take place and the final standard should be ratified by January 2013. The goal is that HEVC should provide 2x better video compression performance than H.264 @ High Profile (that is, around half the bit rate for about the same visual quality). However, as with all things, nothing is for free. This performance takes some serious processing power. Sources say that the decoder will be up to two times the complexity while the encoder will be significantly more than that. The good news is that by the time HEVC is available in products, those products will likely be running chipsets that are powerful enough to efficiently support the processing requirements.

Eager for Ultra-HDTV Image: Courtesy of NHK, Japan

UHDTV. Many industry players, including the all-important ITU, predict a day when Ultra-HDTV will be a reality, and that potential reality is not so very far off. Take the words of Japan public broadcaster NHK's head of R&D, Dr Keiichi Kubota, speaking in February: "We are developing the U-HDTV, or Super Hi-Vision, as a next generation television beyond the current digital HDTV. We call it 'the last and final 2D television', because system parameters for the UHDTV are selected to create a highly immersive feeling for viewers. This is the flagship research project of our laboratory."

He adds: "An U-HDTV image has 33 million pixels in one frame, 16 times that of HDTV, and the frame rate is 120 Hz. It has the capability to produce a wider colour gamut. The sound system for production is 22.2 multi-channels. It is designed for viewing from a distance of 0.75 times picture height. This viewing distance produces the visual angle of 100 degrees, and the wide visual angle provides viewers with an immersive feeling. This is the original design concept of U-HDTV. At the same time, the audience can enjoy the stunning images of U-HDTV at any viewing distance. I believe that we can provide a totally new viewing experience with the U-HDTV."

"As a broadcaster," Kubota added, "our target is to provide U-HDTV broadcast service to homes from 2020 through satellite using the 21 GHz band. This is a challenging target because we have to develop a new transmission scheme that overcomes high rain attenuation in the 21 GHz band. The terrestrial broadcasting of UHDTV will follow the satellite service as it demands a much higher compression rate and a new transmission technology."

ROAD MAP. Dr Kubota reminds us that NHK's initial HDTV toe in the water took 30 years to come to fruition, while satellite R&D took 20 years. Japan's DTT system took 15 years to evolve into reality. "U-HDTV will become an essential element of future broadcasting beyond the current digital services. HDTV has a wide range of applications other than broadcasting and thus U-HDTV will similarly have multiple functions."

Interestingly, NHK is already pushing its R&D envelope that bit further, looking 20 years down the line towards a 3D-TV holographic/spatial system that does not need glasses and without any visual fatigue effects.

There are, of course, many 'final links' in the chain. Broadcasters, almost certainly from the pay-TV side of the industry, will be the first adopters of U-HDTV. Within their portfolios of hundreds of broadcast channels the first to be 'converted' to U-HDTV will be sports. There's little doubt that these broadcasters, whether in Japan, or DirecTV in the USA or BSkyB in the UK, will push for U-HDTV in order to differentiate their services from those of cable and DSL. However, this also means that Outside Broadcast crews will need to re-equip – yet again – their expensive trucks, and that major satellite service companies like SIS, Globecast, Arqiva and others will need to make huge investments in equipment and technology. The likes of Sony, Panasonic and the other leading equipment suppliers can't wait to get started!

In other words, the broadcasting 'road map' might be reasonably clear, but the investment needed over the next ten years will be considerable. Saving a few tens of millions on each 'green' satellite will help operating margins, but is but a small fraction of the total bill. And, as ever, it is the subscriber who will end up footing these costs.

How XIPS works

The on-board XIPS system is used primarily for spacecraft stationkeeping. Small thrusts are required to correct for the tug of solar or lunar gravity and to reposition the satellite in its proper orbit and altitude. A satellite's lifetime as well as its launch weight is thus determined by the amount of fuel aboard for its thruster system.

While most current satellites use a chemical bipropellant propulsion system, a XIPS-equipped satellite instead uses the impulse generated by a thruster ejecting electrically charged particles at high velocities. XIPS requires only one propellant, xenon, and does its station-keeping job using a fraction of that required by a chemical propellant system.

The heart of the XIPS is the Ion thruster, measuring less than 10 inches across. Two other key units include a small tank containing Xenon gas and a power processor.

Thrust is created by accelerating the positive ions through a series of gridded electrodes at one end of the thrust chamber. The electrodes, known as an ion extraction assembly, create more than 3,000 tiny beams of thrust. The beams are prevented from being electrically attracted back to the thruster by an external electron-emitting device called a neutralizer.

Ions ejected by the Hughes-designed XIPS travel in an invisible stream at a speed of 30 kilometers per second (62,900 miles per hour), nearly 10 times that of its chemical counterpart. And, because Ion thrusters operate at lower force levels, attitude disturbances during thruster operation are reduced, further simplifying the craft's station-keeping task.