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NANO- & MICRO-SATELLITES: FOR SPACE TRAINING

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ABSTRACT

Modern microsatellites have revolutionised space in the same way that the personal computer or 'PC' has revolutionised computing, enabling any nation, or indeed individual universities and government departments, to access space directly in an affordable and low risk manner. Since 1979, the Surrey Space Centre at the University of Surrey (UK) has pioneered cost-effective satellite engineering techniques for small satellites, and has developed a series of highly sophisticated, yet inexpensive, mini-, +micro- and nano-satellites. Nineteen such microsatellites have been launched by Surrey into low Earth orbit carrying a wide range of satellite communications, space science, remote sensing and in-orbit technology demonstration payloads - both civil and military - built for around US$3-5M each. Surrey has developed a comprehensive and in-depth microsatellite technology know-how transfer and training programme within a unique environment thus combining both academic research and postgraduate teaching with commercial development & manufacturing of satellites through its spin-off company, Surrey Satellite Technology Ltd (SSTL). Nine highly successful satellite 'know-how' transfer and training programmes have been delivered between Surrey and emerging space nations such as Korea, Portugal, Pakistan, South Africa, Chile, Singapore, Malaysia and Thailand and P.R. China - leading to the launch of their first national satellites providing rapid response, low risk and affordable access to space. New programmes have commenced in 2000/2001 with Algeria, Turkey and Nigeria.

INTRODUCTION

In the same way that the personal computer or 'PC' has revolutionised computing, bringing powerful and affordable computing onto individual desktops world-wide, the microsatellite has similarly revolutionised space.

Low-cost, rapid-response yet powerful microsatellites now enable any emerging space nation, or indeed individual universities and government departments, to access space directly in an affordable and low risk manner.

The breaking-down of the 'mystery of space' means that developing countries need no longer be excluded from the direct benefits of possessing space assets - whether it be for communications, Earth observation or science. Furthermore, a national small satellite programme stimulates academia, industry and, above all, young scientists and engineers - helping prevent the drift of expensively-trained personnel to better jobs overseas.

Whether a satellite is 'large' or 'small' depends on your stand-point and so the following classification has become widely accepted:

Class	Mass (kg)	Cost (£M)
Large satellite	> 1000	>100
Small satellite	500 -1000	30 - 100
Mini-satellite	100 - 500	7 - 20
Micro-satellite	10 - 100	2 - 4
Nano-satellite	1 - 10	0.2 - 1
Pico-satellite	<1	<0.2

Nano-, micro- and mini-satellites have been used for the following applications:

- Specialised Communications Services & Research
- Earth Observation & Remote Sensing
- Small-Scale Space Science
- Technology Demonstration/Verification
- Education & Training

This paper describes summarises the Surrey microsatellite know-how technology transfer and training programme that has been used successfully to introduce nine new nations to space.

SURREY MICROSATELLITES

Surreys' first experimental microsatellites (UoSAT-1 & 2) were launched with NASA on DELTA rockets in 1981 & 1984 respectively. Since then, a total of 17 low cost yet sophisticated microsatellites have been placed in low Earth orbit using Ariane, Tsyklon, Zenit, Cosmos & Dnepr launchers for a variety of international customers and carrying a wide range of payloads. In 1999, Surrey successfully launched the 315kg UoSAT-12 minisatellite from the Baikonur Cosmodrome carrying EO and technology payloads from Surrey and a collaborative communications payload developed with Nanyang Technological University in Singapore. Then in 2000 SSTL launched Tsinghua-1, TiungSat-1 and the nanosatellite SNAP-1, which has produced so much interest in Russia, China and the USA.

Microsatellite	Launch	Orbit	Customer	Payloads
UoSAT-1	1984-D	560 km	UoS	Research
UoSAT-2	1984-D	700 km	UoS	S&F, EO, rad
UoSAT-3	1990-A	900 km	UoS	S&F
UoSAT-4	1990-A	900 km	UoS/ESA	Technology
UoSAT-5	1991-A	900 km	SatelLife	S&F,EO, rad
S80/T	1992-A	1330 km	CNES	LEO comms
KitSat-1	1992-A	1330 km	Korea	S&F,EO, rad
KitSat-2*	1993-A	900 km	Korea	S&F,EO, rad
PoSAT-1	1993-A	900 km	Portugal	S&F,EO, rad
HealthSat-2	1993-A	900 km	SatelLife	S&F
Cerise	1995-A	735 km	CNES	Military
FASat-Alfa	1995-T	873 km	Chile	S&F,EO
FASat-Bravo	1998-Z	835 km	Chile	S&F,EO
Thai-Phutt	1998-Z	835 km	Thailand	S&F,EO
UoSAT-12	1999-S	650 km	SSTL & Singapore	EO, Comms
Clementine	1999-A	735 km	CNES	Military
TiungSAT-1	2000-Z	1020 km	Malaysia	EO, Comms
SNAP-1	2000-C	650 km	SSTL	Technology
Tsinghua-1	2000-C	750 km	PR China	EO, Comms
PicoSAT	*2001-Ath*	*650 km*	*USAF*	*Military*
Tubitak	*2002-S*	*650 km*	*Turkey*	*EO*
DMC (5)	*2002-S*	*650 km*	*5 Nations*	*EO*

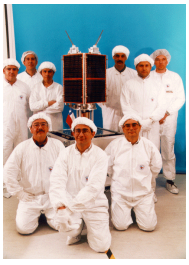
University of Surrey Microsatellite Missions
** built in Korea using SSTL platform & KAIST payload*
A=Ariane; C=Cosmos; D=Delta; S=SS18/Dnepr; T=Tsyklon; Z=Zenit; Ath=Athena

MICROSATELLITE KNOW-HOW TRANSFER PROGRAMMES

Although microsatellites are physically very small, they are nevertheless complex and exhibit virtually all the characteristics of a large satellite - but in a microcosm. This makes them particularly suitable as a focus for the education and training of scientists and engineers by providing a means for direct, hands-on experience of all stages and aspects (both technical and managerial) of a real satellite mission - from design, construction, test and launch through to orbital operation.

The very low cost, rapid timescale and manageable proportions makes this approach very attractive to emerging space nations who wish to develop and establish a national expertise in space technology through an affordable small satellite programme.

The Surrey Space Centre & SSTL specialise in well-structured and comprehensive small satellite know-how transfer and training (KHTT) programmes - each carefully structured according to the specific requirements or circumstances of the country or organisation concerned. The unique combination of both academic and commercial activities housed within the Surrey Space Centre enables SSTL to offer complete, detailed satellite knowledge and experience to collaborating international partners - founded on deep academic knowledge of the engineering and scientific principles - typically comprising:



- Academic Education (MSc, PhD degrees)
- Hands-On Training (seconded to SSTL)
- Groundstation (installed in country)
- Microsatellites (1st at SSTL, 2nd in country)
- Know-How Transfer (satellite design licence)

Thus the Surrey KHTT programme provides comprehensive, in-depth training for a team of engineers and scientists through direct and complete involvement throughout the concept, design, construction, test, launch and orbital operation of national microsatellite in orbit. The programme provides a licence and comprehensive information to design, manufacture, test and launch future microsatellites independently for domestic, non-commercial, and research purposes.

Unlike other space organisations, Surrey is completely comfortable, willing, and able to transfer complete satellite know-how to its collaborating partners - as has been demonstrated through 8 international technology transfer programmes. Indeed, because of the academic roots of the Surrey Space Centre enhanced by an efficient commercial interface through SSTL, we look for a long-term collaborative partnership with growing mutual benefit rather than just short-term projects.

Specifically to foster such long-term relationships, the Surrey Space Centre has formed the Surrey Space Club to provide a regular forum for our international technology transfer partners to exchange ideas, stimulate collaborative research and jointly propose new small satellite missions and services.

Joint SSTL and Korean team with KITSAT-1; Korea's first microsatellite

SSTL is the only organisation in the world to have successfully transferred comprehensive small satellite know-how to international customers as a complete turn-key programme. Nine highly successful international know-how transfer programmes have been completed by SSTL and new programmes to build elements of the Disaster Monitoring Constellation are just starting with three new countries.

Country	Dates	Satellites
Pakistan	1985-89	BADR-1
South Africa	1989-91	UoSAT-3/4/5
S.Korea	1990-94	KITSat-1/2
Portugal	1993-94	PoSAT-1
Chile	1995-97	FASat-Alfa/Bravo
Thailand	1995-98	TMSAT-1
Singapore	1995-99	Merlion payload
Malaysia	1996-98	TiungSAT-1
China	1998-99	Tsinghua-1
Algeria	*2000-2002*	*AlSat -1*
Turkey	*2001-2002*	*Tubitak*
Nigeria	*2001-2002*	*NigeriaSat-1*

SSTL know-how transfer & training programmes

A total of 96 engineers have been trained through these in-depth KHTT programmes at Surrey — a further 620 MSc and PhD students from countries world-wide have graduated in Satellite Communications Engineering unrelated to these KHTT programmes.

Once developing space nations have mastered microsatellite technology, the minisatellite provides a logical next step in the development of an increasingly capable national space infrastructure.

KNOW-HOW TRANSFER PROGRAMMES

An important feature at Surrey is that real technology transfer is made possible by total in-house technology and end-to-end capability covering: satellite platforms, payloads and ground systems. This capability encompasses: research; concept and mission analysis; detailed spacecraft platform & payload design; manufacturing and test; launch services and orbital commissioning; through to in-orbit operation and data retrieval. SSTC are thus directly involved 'hands-on' in all elements and stages throughout the life-cycle of the microsatellite - from initial concept to eventual orbital operation.

The innovative technical and management techniques pioneered by Surrey enable highly sophisticated small satellite missions to be realised rapidly and at extremely low cost. When combined with sound academic training alongside real, in-depth, hands-on experience and skills, KHTT personnel will be very well-placed to build a comprehensive satellite facility in their own country.

Surrey has fifteen years extensive experience with highly successful international technology transfer and training programmes. SSTL has successfully completed nine technology transfer and training programmes with international partners world-wide – in each case working with their engineers and scientists to realise their first national satellites in orbit.

STRUCTURE OF KNOW-HOW TRANSFER PROGRAMMES

As SSTL possesses a complete in-house capability covering spacecraft and payload research, design, manufacture, test, launch services and orbital operations, SSTL is able to provide a comprehensive know-how transfer for the satellite, the payload and the ground segment. SSTL in this respect is unique in its ability to provide the complete range of services necessary for SSTC under one roof, a so called "one-stop-shop".

Typically, a carefully structured team of 8-10 engineers are seconded to SSTL for a period of up to 18 months for a programme comprising:

- Team selection
- Orientation
- Introductory short course
- Technical lectures
- Mission study and definition
- Technology training
- Microsatellite design, manufacture, test
- Ground Segment training, installation & commissioning
- Launch
- In-orbit commissioning and spacecraft operations
- Mission exploitation
- Technology transfer package & licence
- Academic research & education

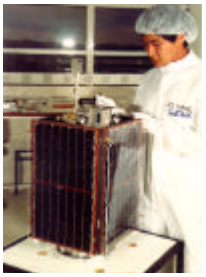
KHTT Team Selection: The selection of appropriate candidates for the Know-How Transfer Team is critical to the success of the Programme. Candidates are selected from the following areas of expertise, typically:

- mission analysis, simulation
- digital electronics engineering
- analogue systems, sensors
- radio-frequency engineering
- software engineering
- Earth observation
- mechanical engineering

Orientation: Recognising that KHTT team will be arriving in a foreign country with many different customs and a unfamiliar environment, SSTL provides a 'welcome package' and support through a dedicated Customer Care Officer (CCO). The CCO provides an explanation of the operation of the Surrey Space Centre & SSTL, and assists with arrangements such as accommodation, banking, healthcare etc., for the team and any accompanying family members, and familiarisation with UK culture and the local environment in Guildford and London

Introductory Short Course: A Spacecraft Engineering Introductory Short Course is given in the beginning of the programme.

Technical Lectures: A series of in-depth presentations by SSTL Team Leaders, Senior Engineers and Work Package Managers describing each of the subsystems and payloads for the SSTL microsatellites is given.

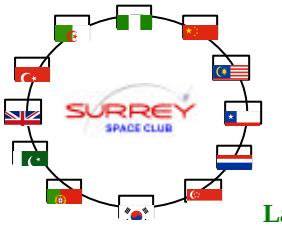


Mission Study & Definition: The first stage of the programme is to undertake a detailed review of requirements for the KHTT mission in parallel with mission analysis to arrive at candidate microsatellite configurations, summarised in a mission study.

Know-How Training: The know-how training programme provides the KHTT engineers and scientists with direct, first-hand practical experience and skills acquired through working on an actual satellite project thus taking an intimate role in the whole satellite life-cycle process.

Microsatellite Design, Manufacture & Test: The KHTT team participates fully in the design, manufacture, integration and testing of the sub-systems and payloads.

Ground Station Training, Installation and Commissioning: KHTT team engineers participate in the SSTL ground station and operations training programme performing operations and monitoring duties of existing SSTL micro and minisatellites in orbit..



Launch: The KHTT team members participate in the preparations for the launch campaign which culminates in the mating of their microsatellite to the launch vehicle at the launch site followed by the launch observed by the SSTL/ KHTT team and guests.

In-Orbit Commissioning & Spacecraft Operations: is achieved by the KHTT operations team using their own Space Mission Control Centre groundstation - supported, as necessary, by the SSTL Space Mission Control Centre groundstation at the Surrey Space Centre in the UK.

Mission Exploitation: SSTL work with the KHTT team to maximise the return value from their mission not only by efficient and effective spacecraft orbital operations but also by sophisticated on-board and ground based data processing which turns the raw data into useful information.

Technology Documentation & Licence: As an integral component of this programme, SSTL provides complete designs and design documentation to the KHTT team and grants a non-commercial licence to use the know-how acquired.

Academic Training: Formal academic training and qualifications through postgraduate MSc taught and research courses in Satellite Engineering and PhD courses in Satellite Engineering provided by the Surrey Space Centre at the University of Surrey can be incorporated in the Know-How Transfer Programme for suitably qualified candidates.

Academic Research: By collaborating with the Surrey Space Centre and SSTL, the KHTT team has opportunities to observe and participate in numerous advanced research projects underway in the Centre.

SURREY SPACE CLUB

Over the last decade, Surrey has enjoyed working collaboratively and very successfully with nine international partners on the transfer and development of microsatellite and minisatellite technologies.

The "Surrey Space Club" was formed in 1998 to:

- Exchange new ideas
- Collaborate on small satellite constellations - build and launch the Disaster Network of five EO Microsatellites
- Participate in planetary exploration - through international co-operation in a Lunar Mission
- Co-ordinate low cost launch opportunities for members' national & collaborative missions
- Help new members maintain the momentum of a long term national space programme
- Share satellite resources - from the microsatellites currently in orbit by Club members
- Gain greater access time to spacecraft in orbit - when needed through the network of Club members' ground systems around the world linked via Internet

The Surrey Space Club holds an annual meeting and small satellite workshop, hosted by each member organisation in turn, during which members can present their latest activities and future plans.

The first such meeting and workshop was hosted by the Surrey Space Centre in December 1998 and was inaugurated by HM Queen & HRH Prince Philip. The second was held at NTU, Singapore in 1999 and the next is planned for 2001.

Following the formation of the Surrey Space Club, strong interest in joining this forum has been expressed by ESA, NASA and over 40 other countries.

CONCLUSIONS - Surrey's comprehensive microsatellite technology know-how transfer and training programme combines both academic research and postgraduate teaching with commercial development and manufacturing of satellites. Nine highly successful 'know-how' transfer and training programmes have been delivered between Surrey and emerging space nations leading to the launch of their first national satellites. Many more nations are embarking on the programme demonstrating the real value of affordable access to space. The author recognises and thanks all international partners for their support.