Changing the Economics of Space

Surrey Satellite Technology US LLC

Surrey Satellite Technology US & Hosted Payload Programs
June 2015

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602-284-7997
ABOUT SURREY SATELLITE TECHNOLOGY
Changing the economics of space

Through the provision of high-quality, rapid, cost-effective small satellite solutions, applications, and services
Surrey—A History of Success

- 43 satellites launched—over 250 satellite years of on-orbit operational experience
- 21 satellites in manufacture
- 24 payloads in progress (5 optical, 22 navigation)
Surrey—A History of Success

- **RESULTS**
  - All projects **fixed price**, delivered **on time and on budget**

- **SUCCESS**
  - Very high mission success—**100% in last 15 years**—proven equipment and full redundancy

- **MISSIONS**
  - Spanning science, Earth observation, navigation, and communications

- **CUSTOMERS**
  - Ranging from experienced operators through commercial space entrepreneurs
Accepted Heritage and Industrial Approach

- **Selected by NASA RSDO**
  - Inclusion in NASA Rapid III Catalog
    - SSTL 150, 300, and 600 platforms
  - Participating in new on-ramp

- **Key requirements**
  - Payload accommodation
    - >100 kg / 100 W
  - Proven heritage
    - >2 missions as prime contractor
  - Proven industrial approach

“We’re very pleased to have SST-US in the catalog as you have three very capable platforms at great prices.”
Structure and Ownership

- An autonomous entity within the Airbus group

- Satellites and supporting infrastructure
  - U.K. office

- Satellites and supporting infrastructure
  - U.S. office

- Launch services

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Surrey Satellite Technology US LLC

- U.S. Delaware-registered company; headquartered in Englewood, Colorado
- U.S.-focused satellite, satellite subsystems manufacturing, and mission operations provider
- Technology and know-how access
  - Fully licensed to use intellectual property, designs, methods, and systems developed by SSTL
  - Create new jobs and mission enabling price points
- Efficient operations
  - Simple U.S. company-to-company interactions with clients
    - TAAs in place with SSTL
    - ITAR and export compliant
Surrey US—Why Denver?

- Colorado: second in aerospace industry behind California
- Costs and regulations in DC and California restrictive
- Large pool of knowledge and experience base
- Complementary space company base
  - Lockheed Martin
  - GeoEye
  - DigitalGlobe
  - SNC
  - SWRI
  - Ball
- Complementary higher education and space organizations
  - CU
  - LASP
  - NOAA
  - UCAR
  - USAFA
  - Space Command
- Excess space facilities
  - Environmental test
  - AIT
New Facilities

- Inverness Park, Englewood, Colorado (March 2013)
- High bay, missions operation center, and offices

345 Inverness Drive South, Suite 100
Englewood, Colorado 80112
Major US programs

» OTB (Orbital Test Bed)
  • First U.S. prime mission
  • First commercial dedicated satellite
  • Dedicated payload hosting ESPA platform similar to CFESat
  • Launch 2016, Falcon Heavy with Formosat-7

» CYGNSS
  • Earth Venture-2 mission
    o Surrey providing GPS reflectometry instruments and expertise
    o Builds off previous Surrey mission that flew ocean reflectometry
    o With SWRI and University of Michigan
    o Eight nanosats doing ocean reflectometry
    o First major NASA program for Surrey US
# Surrey US Platform Capability

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SSTL-100</th>
<th>SSTL-150</th>
<th>SSTL-300</th>
<th>SSTL-600</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payload Mass</td>
<td>15 kg</td>
<td>23 kg</td>
<td>50 kg</td>
<td>Not quantified</td>
</tr>
<tr>
<td>Payload Power (OAP/Peak)</td>
<td>24/48 W</td>
<td>33/67 W</td>
<td>50/100 W</td>
<td>Increased with larger deployables</td>
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<tr>
<td>Pointing Control</td>
<td>2880 arcsec</td>
<td>360 arcsec</td>
<td>360 arcsec</td>
<td>Not quantified</td>
</tr>
<tr>
<td>Stability</td>
<td>15 arcsec/sec</td>
<td>1.5 arcsec/sec</td>
<td>1.5 arcsec/sec</td>
<td>Not quantified</td>
</tr>
<tr>
<td>Data Downlink</td>
<td>80 Mbps (X)</td>
<td>400 Mbps (X)</td>
<td>80 Mbps (X)</td>
<td>400 Mbps (X)</td>
</tr>
<tr>
<td>Data Storage</td>
<td>16 GB</td>
<td>128 GB</td>
<td>16 GB</td>
<td>256 GB</td>
</tr>
<tr>
<td>Delta-V</td>
<td>20 m/s</td>
<td>56 m/s</td>
<td>36 m/s</td>
<td>125 m/s</td>
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<tr>
<td>Design Life</td>
<td>5 years</td>
<td>7 years</td>
<td>Heritage in Progress</td>
<td>4 years</td>
</tr>
<tr>
<td>Price from</td>
<td>$10M</td>
<td>$16.5M</td>
<td>$23.5M</td>
<td>$36M</td>
</tr>
<tr>
<td>Number launched</td>
<td>8</td>
<td>10</td>
<td>1</td>
<td>1 (MEO)</td>
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</table>

Enabling Access to Space

A spectrum of procurement approaches

<table>
<thead>
<tr>
<th>Infrastructure or equipment provision</th>
<th>Commercial procurement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Surrey US terms and conditions</td>
</tr>
<tr>
<td></td>
<td>- Customer terms and conditions</td>
</tr>
<tr>
<td></td>
<td>- Government terms and conditions</td>
</tr>
<tr>
<td></td>
<td>Catalog procurement</td>
</tr>
<tr>
<td></td>
<td>- RSDO Catalog</td>
</tr>
<tr>
<td></td>
<td>- GSA Schedule</td>
</tr>
<tr>
<td></td>
<td>eCommerce</td>
</tr>
<tr>
<td></td>
<td>- <a href="http://www.surreysatellite.com/shop">www.surreysatellite.com/shop</a></td>
</tr>
</tbody>
</table>

| Service provision                     | Pure service provision |

| Payload hosting                       | OTB satellites |
|                                       | HoPS LEO & GEO IDIQ holder |

Procurement or contractual approach can be tailored to fit the customers requirements or constraints

Closing first GEO satellite contract this summer!
SURREY US HOSTING PROGRAMS
Who Can Benefit from Payload Hosting?

- Budget-crunched entities that need a more cost-effective way to orbit
- Operations/services that need easier and lower cost contracting to get the data they need and not the mission they don't
- Investigators with a payload but no budget for a full mission
- Subsystem developers that need on-orbit heritage, testing, and TRL benefits
Benefits of Payload Hosting

- Significantly lower cost than a dedicated mission
- Reliability and mission assurance of high-heritage standard buses
- Contracting ease of just hosting and operations
  - Flight Services Agreement (FSA)
  - Hosted Payload Operations Agreement (HPOA)
  - Currently done by JPL on OTB
- Launch provided
  - Ride share
- Continuity of OTB line: if not ready in time for one launch, then go for the next!
  - Two-year centers for opportunities
  - Possible hosting available on our other missions
- Contract operation for as long or as short as needed
  - One to seven years, renewable
- Possible lowering of hosting cost by “bringing value” to the spacecraft
TechDemoSat-1

- First of Surrey’s dedicated hosting missions
- A U.K.-funded initiative, offering “in-orbit test facility” to space-qualify and gain heritage for innovative U.K. payloads and software
- Developers that need on-orbit heritage, testing, and TRL benefits
  - Payloads and subsystems
- Heritage 150 bus (150 kg)
- Launched July 8, 2014
# TechDemoSat-1 External Payloads

<table>
<thead>
<tr>
<th>Payload</th>
<th>Supplier</th>
<th>Description</th>
<th>Illustration</th>
</tr>
</thead>
<tbody>
<tr>
<td>MuREM</td>
<td>University of Surrey (Surrey Space Centre)</td>
<td>The Micro (μ) Radiation Environment Monitor (MuREM) is a miniature radiation environment and effects monitoring payload</td>
<td><img src="image1.png" alt="Image" /></td>
</tr>
<tr>
<td>ChaPS</td>
<td>Mullard Space Science Laboratory (MSSL)</td>
<td>The Charged Particle Spectrometer (ChaPS) is designed to measure electron and ion populations in the orbit of the host spacecraft</td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>LUCID</td>
<td>Langton Star Centre</td>
<td>The Langton Ultimate Cosmic ray Intensity Detector (LUCID) allows characterization of the energy, type, intensity, and directionality of high energy particles</td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td>CMS</td>
<td>University of Oxford/RAL</td>
<td>The Compact Modular Sounder (CMS) is a set of compatible optical, detector, cooling and electronic subsystems, which can be used to implement miniature infrared remote sensing spectrometers and radiometers</td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td>HMRM</td>
<td>Rutherford Appleton Laboratory</td>
<td>The Highly Miniaturised Radiation Monitor (HMRM) is an ultra-compact, low-power radiation monitor developed for reuse on future ESA missions</td>
<td><img src="image5.png" alt="Image" /></td>
</tr>
<tr>
<td>CubeSAT ACS</td>
<td>Satellite Services Ltd</td>
<td>The CubeSAT ACS payload is a compete three-axes attitude determination and control subsystem for cubesats</td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
<tr>
<td>DOS</td>
<td>Cranfield University</td>
<td>The De-Orbit Sail (DOS) is intended to demonstrate a novel means for de-orbiting a satellite at the end of its mission lifetime through deploying a sail to increase aerodynamic drag</td>
<td><img src="image7.png" alt="Image" /></td>
</tr>
<tr>
<td>Sea State Payload</td>
<td>Surrey Satellite Technology Limited (SSTL)</td>
<td>The Sea State Payload passively monitors ocean roughness via detecting reflected GPS signals and provides orbit determination via dual-band GPS (SGR-ReSi)</td>
<td><img src="image8.png" alt="Image" /></td>
</tr>
</tbody>
</table>
TechDemoSat-1 Status and Schedule

- Launched July 8, 2014
  - Launcher: Soyuz-2-1b Fregat-M
  - Main satellite: Russian Meteor M-2 (825 km)
    - Fregat upper stage maneuvered down to 635 km
  - One of eight piggyback satellites

- Operational phase now
First Reflectometry Operation in Orbit

- DDMs and raw data gathered September 1, 2014
  - 09:01-09:04 only DDMs and raw—lost GPS position data
  - 10:33-11:27 UTC
  - 20:08-21:05 UTC

- Red indicates raw data, yellow indicates DDM tracks
First Wind Measurements

- From raw data collection in Gulf of Alaska
- Inversion using NOC model
- Compared with ASCAT data from NOAA website
- Further validation and refinement planned
FeatherCraft

- 100 kg ISS-deployed Spacecraft
- Payload hosting for up to 5 years
- Contract to launch in 19 months or less
- Aerojet Rocketdyne Electronic Propulsion system
- Provides notable performance and capability at a fraction of the cost of conventional payload hosting missions
  - $6M–12M

Mission Lifetime: (up to) 5 years
Available Orbits: (up to) 550 km
Payload Mass: (up to) 45 kg
Payload OAP: 50 W (200 W peak)
FeatherCraft

| MONTHS | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|--------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Payload Development | | | | | | | | | | | | | | | | | | | | | | | | | |
| Payload Kickoff | X | | | | | | | | | | | | | | | | | | | | | | | |
| Payload Design prep for Safety Review | | | | | | | | | | | | | | | | | | | | | | | | |
| NASA Safety Review Phase 1 | | | | | | | | | | | | | | | | | | | | | | X | |
| Payload Development | | | | | | | | | | | | | | | | | | | | | | | | |
| NASA Safety Review Phase 2 | | | | | | | | | | | | | | | | | | | | | | X | |
| Assembly, Integration, and Testing | | | | | | | | | | | | | | | | | | | | | | | | |
| Payload Readiness Review | | | | | | | | | | | | | | | | | | | | | | X | |
| NASA Safety Review Phase 3 | | | | | | | | | | | | | | | | | | | | | | X | |
| Payload Integration & Testing | | | | | | | | | | | | | | | | | | | | | | | | |
| Environmental Testing | | | | | | | | | | | | | | | | | | | | | | | | |
| Launch and Mission | | | | | | | | | | | | | | | | | | | | | | | | |
| Launch | | | | | | | | | | | | | | | | | | | | | | | | |
| Launch Operations | | | | | | | | | | | | | | | | | | | | | | | | |

Payload: 4.25 ft³
Power: 50 W
OTB (Orbital Test Bed)

- The first true commercial all hosting satellite
- Owned and operated by Surrey US from Denver MOC
- Started as RSDO 150 bus with multispectral cameras
- Grew to accommodate five primary payloads, ride share launch (ESPA) and more power
- Heritage CFESat design
- See AAS paper 14-075

OTB-1 in integration in Englewood facility
OTB Payloads

Hosted payloads

• U.S. Air Force Academy iMESA-R: sampling of electrostatic field, electron density, plasma irregularities
• AFRL/Vanguard MSA: modular solar panels
• NASA JPL Deep Space Atomic Clock
  o USO, TRIG GPS, Antenna/choke and Payload interface unit
• TUI terminator tape deorbit device

Surrey primary payload suite: evaluation, demonstration, heritage

• Electronic Test Bed: New electronic components, processors, and memory devices
• FlexRX receiver: programmable receiver
• RadMon sensor: radiation effects monitor
  o Surrey typically flies these sensors as an integral part of their parts program allowing us to make maximal use of commercial parts
• CUSP instrument: University of Colorado collaboration, off-the-shelf components
• High-efficiency solar cell experiment: performance characterization
OTB architecture based on 150 platform—nine currently flying with demonstrated life of five to eight years
OTB Spacecraft
(Including JPL DSAC Payload)
OTB Operations

Based in:

- Surrey Mission Operations Center, Englewood, Colo., USA
- Optionally Surrey Mission Operations Center, Guildford, England

Ground stations in U.S., U.K., and around the world as needed

- Johnson will also be used for OTB due to low inclination

High-capacity S telemetry and X downlink

Payload downlink data provided to the customer via secure FTP site

Operations available in one-year increments up to design life of satellite, five to seven years
OTB-1/DSAC Mission Architecture Example

- Controls are handled with uploaded schedule files that can be sent on every station pass
- Payload schedules are received from customer and compiled into these as needed

International GNSS Service (IGS): ~400 GPS tracking stations globally
IGS timescale (ensemble clock with ~5.e-16 stability)
Hosting Opportunities Now Available on OTB-2

- OTB-2 planning for a sun-sync launch in the 2017-2018 timeframe
  - Launch and altitude variability
  - Five to seven years of operation
- OTB-Xs are subsequent missions on two-year centers for future opportunities
- Small remote sensing payload
- Typical RSDO 150 starting point
- Typical nadir pointing bus
- Con-ops flexible

<table>
<thead>
<tr>
<th>Standard</th>
<th>Enhanced</th>
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<tbody>
<tr>
<td>50 kg</td>
<td>73 kg</td>
</tr>
<tr>
<td>50/100 W</td>
<td>80/130</td>
</tr>
<tr>
<td>360 arcsec</td>
<td>36 arcsec *</td>
</tr>
<tr>
<td>1.5 arcsec/sec</td>
<td>1 arcsec/sec</td>
</tr>
<tr>
<td>80 Mbps (X)</td>
<td>800 Mbps (X)</td>
</tr>
<tr>
<td>16 GB</td>
<td>256 GB*</td>
</tr>
<tr>
<td>36 m/s</td>
<td>136 m/s</td>
</tr>
</tbody>
</table>
Getting Started

Getting a fast hosting quote:

- Go to Surrey’s OTB-2 webpage www.surreysatellite.com/rideshareopps
  - Click on the Candidate Payloads Requirements Form link
  - Fill out the form and/or e-mail to Brent Abbott at babbott@surreysatellite.com

- Pricing dependent on:
  - Satellite capacity used
    - Mass, power, downlink...
  - Integration costs
  - Value added
  - Priority/Con Ops
  - Operations
    - Years needed
    - Con ops
Hosting Electrical Interfacing

Hardware hosting interfacing mechanisms:

- Redundant SBCs
  - Spacewire and MIL-STD-1553B links
  - LVDS I/Q: 3x 10-bit parallel channels, up to 10 serial channels
  - Dual-redundant CAN TM/TC interface
  - More information on the SBCs on website
- Payload interface units
  - Custom as needed
  - 422, 485 etc.

### BASELINE PERFORMANCE PROPERTIES

<table>
<thead>
<tr>
<th>Processor</th>
<th>IBM PPC750FL</th>
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<tr>
<td></td>
<td>1333 Dhrystone 2 MIPS; 296 Whetstone MWIPS</td>
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<table>
<thead>
<tr>
<th>Operating System</th>
<th>VxWorks, RTEMS</th>
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<tbody>
<tr>
<td></td>
<td>Others available on request</td>
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</table>

<table>
<thead>
<tr>
<th>Memory</th>
<th>256 MB (EDAC 16,8)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16 MB MRAM</td>
</tr>
<tr>
<td></td>
<td>16 MB Flash (EDAC 16,8)</td>
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<table>
<thead>
<tr>
<th>Interfaces</th>
<th>MIL-STD-1553B</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>2x dual CAN bus</td>
</tr>
<tr>
<td></td>
<td>8x LVDS inputs, 8x LVDS outputs</td>
</tr>
<tr>
<td></td>
<td>4x opto isolated inputs</td>
</tr>
<tr>
<td></td>
<td>4x opto driver outputs</td>
</tr>
<tr>
<td></td>
<td>8x RS485/MLVDS transceivers</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Protocols</th>
<th>MIL-STD-1553 (option)</th>
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<tr>
<td></td>
<td>Spacewire (option)</td>
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<tr>
<td></td>
<td>CAN-SU</td>
</tr>
<tr>
<td></td>
<td>UART</td>
</tr>
<tr>
<td></td>
<td>HDLC</td>
</tr>
<tr>
<td></td>
<td>Pulse-per-second synchronization</td>
</tr>
<tr>
<td></td>
<td>Others available on request</td>
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</table>
Hosting Interfacing and Contracting

- Payload top level specifications
  - Power, mass, thermal, susceptibility, con ops, downlink...
  - If still in development these will have to be “not to exceeds”
  - Dummy mass/payload for integration and testing

- Flight services agreement
  - For the integration into the bus

- Hosted payload operations agreement
  - Contracted by the year for as long as customer needs operations
  - Delivery of data from Denver MOC

- Sit back, watch the data come in, and leave the driving to us
Thank You

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