Follow that groundstation!
Increasing the data return from small satellites

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SSTL’s Earth Observation missions

- SSTL has long history of Earth Observation missions
- Recently:
  - Disaster Monitoring Constellation: 32m
  - UK-DMC2 & Deimos-1: 22m (launch this year)
  - RapidEye: 6.5m
  - Beijing-1: 4m
  - TopSat: 2.8m
  - NigeriaSat-2: 2.5m (launches next year)
- Resolution steadily increasing
- Still using small satellites
SSTL EO mission capability

• A steady progression in GSD$^1$
  – 1990, >1km
  – 1992, 200m
  – 1998, 100m
  – 2000, 30m
  – 2003, 12m
  – 2005, 4m & 2.5m
  – 2009, 1.2-2.5m
  – 2010, <1m

• From to

Balancing EO mission value for money

- Maximise commercial, military or scientific value through:
  - Low cost infrastructure and fast implementation
  - High capacity and long lifetime

<table>
<thead>
<tr>
<th></th>
<th>Setup Time</th>
<th>System Costs</th>
<th>Data return</th>
<th>Lifetime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce!</td>
<td></td>
<td></td>
<td>Increase!</td>
<td></td>
</tr>
</tbody>
</table>
SSTL-300i platform: NigeriaSat-2

- 2 Day Revisit to Anywhere on Earth
- 2 Instruments
  - Panchromatic 2.5 metre x 20 kilometre
  - 4 Band Multi-Spectral 5 metre x 20 kilometre
  - 4 Band Multi-Spectral 32 metre x 300 kilometre
- 7.5 Year Design Life
- High accuracy pointing
- 5 Operational Modes
  - Scene, Strip, Fast-response, Area, Stereo
  - Fast slewing in roll and pitch
  - **Real time downlink: Image and downlink simultaneously**

Real time downlinking becomes a mission driver
Key requirements

- Maximise data volume
  - Without affecting price unduly
  - Without increasing satellite size or power

- Spacecraft is agile

- Real Time image downlinking

- (7.5 year on-orbit lifetime)
  - Approx 20,000 passes
Increasing data throughput

\[ P_R = P_T \times G_T \times G_R \times G_M / \left[ FSL \times L_A \right] \] (simplification)

- Increase dish size
- Improve LNA
- Better Modulation/Coding scheme

For order of magnitude improvements, increasing antenna gain is only viable option
### Increasing antenna gain

<table>
<thead>
<tr>
<th>Solution</th>
<th>+ positive points</th>
<th>- negative points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iso-flux antenna</td>
<td>+ Relatively simple implementation</td>
<td>- Difficult to implement for an agile mission</td>
</tr>
<tr>
<td></td>
<td>+ Constant Power flux density</td>
<td>- Careful beamshaping required</td>
</tr>
<tr>
<td>Omni directional antennas</td>
<td>+ Simple implementation</td>
<td>- Very poor antenna gain</td>
</tr>
<tr>
<td></td>
<td>+ Broad Coverage</td>
<td>- Inefficient for supporting simultaneous imaging and real-time</td>
</tr>
<tr>
<td>High gain antenna</td>
<td>+ High gain</td>
<td>- Would need to slew spacecraft to track groundstation</td>
</tr>
<tr>
<td></td>
<td>- Can not support simultaneous imaging and real-time</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Key</th>
<th>Non-compliant</th>
<th>Compliant</th>
<th>Selected</th>
</tr>
</thead>
</table>

~12dB link variation

650km → 3000km
Increasing antenna gain

<table>
<thead>
<tr>
<th>Solution</th>
<th>+ positive points - negative points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switched antennas</td>
<td>+ Next simplest implementation</td>
</tr>
<tr>
<td></td>
<td>+ High gain</td>
</tr>
<tr>
<td></td>
<td>- Fixed number of positions possible</td>
</tr>
<tr>
<td></td>
<td>- Need many switched antenna elements before benefit is gained</td>
</tr>
<tr>
<td></td>
<td>- Switch matrix can become complex</td>
</tr>
<tr>
<td>Electrically tracked antenna</td>
<td>+ Can have high gain</td>
</tr>
<tr>
<td></td>
<td>- Highly complex / costly development</td>
</tr>
<tr>
<td></td>
<td>- Limited cone of pointing</td>
</tr>
<tr>
<td></td>
<td>- Poor Axial ratio</td>
</tr>
<tr>
<td>Mechanically tracked antenna</td>
<td>+ Can have high gain</td>
</tr>
<tr>
<td></td>
<td>- Potential mechanical disturbance and wear-out issues</td>
</tr>
<tr>
<td>Steered mirror on instrument</td>
<td>+ Can have high gain</td>
</tr>
<tr>
<td></td>
<td>- Potential mechanical disturbance and wear-out issues</td>
</tr>
<tr>
<td>Key</td>
<td>Non-compliant</td>
</tr>
</tbody>
</table>

- **Switched antennas**
- **Tracked antenna**
  - Electrically tracked
  - Mechanically tracked

Example of Electrically steered antenna (Roke Manor Research)

Example of steered instrument

Mechanically steered antenna selected
Concept development

Azimuth-Elevation scheme Engineering Model.
Swashplate scheme Engineering Model.
AE-90 Antenna Pointing Mechanism Qualification Model.
Design Qualification and test

- Life test
  - 30,000 Az-El cycles (10 years in LEO)
- Vibration
- Thermal Vacuum
- RF tests
Development status

- Design, EM and QM completed
- Two units to be flown on N2 mission (2010)
  - Project passed TRR
Antenna Pointing Mechanism - Movie
## Design Specifications

<table>
<thead>
<tr>
<th>Description</th>
<th>QM Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. axes</td>
<td>2</td>
</tr>
<tr>
<td>Pointing accuracy</td>
<td>0.72° TBC</td>
</tr>
<tr>
<td>Step size</td>
<td>≤0.024°</td>
</tr>
<tr>
<td>Slew range</td>
<td>EI ±110°, ±Az 270°</td>
</tr>
<tr>
<td>Slew rate</td>
<td>Up to 19.1°/s</td>
</tr>
<tr>
<td>Micro-vibration</td>
<td>Qualified for typical 1m GSD mission</td>
</tr>
<tr>
<td></td>
<td><strong>Attitude disturbance model characterised</strong></td>
</tr>
<tr>
<td>Reaction torque</td>
<td>&lt;1mNm</td>
</tr>
<tr>
<td>APM external volume</td>
<td>241.6x196.2x185 mm³</td>
</tr>
<tr>
<td>Total APM mass</td>
<td>2.7kg</td>
</tr>
<tr>
<td>Power (inc.electronics)</td>
<td>3.2W</td>
</tr>
<tr>
<td>Life (qual cycles)</td>
<td>Mech Life-test 10.3 years (35827 cycles)</td>
</tr>
<tr>
<td>On-station stability</td>
<td>Stable when un-powered</td>
</tr>
<tr>
<td></td>
<td><strong>Does not need launch locking mechanism</strong></td>
</tr>
</tbody>
</table>
Antenna - Test Results

- Horn Antenna Tests
  - Co-polar gain patterns and axial ratio measurements of EM antenna taken using near-field antenna test facility
  - Main purpose: To confirm the horn gain pattern and axial ratio antenna performance is as required for N2

15dBiC gain
25deg BW
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![Graph showing axial ratio vs. angle for SSTL X Band Horn Antenna at 8.2 GHz Overhead Axial Ratios](image)
Benefits 1/3

Dish diameter reduced by factor of 4.5

9-11m dish  →  2-3m dish
Benefits 2/3

Data return increased by factor of 20
Benefits 3/3

- Spacecraft Power reduction by factor of 20
## Payload downlink solution

### Typical use

- **GPS**
- **Data Recorder**
- **Payload**
- **XTX**

### Data Storage
- 8/16 Gbytes per unit

### Downlink Data Rate
- Up to 300Mbps

### Data inputs
- 150Mbps each

### 2-axis tracking antenna
- El ±110deg, Az ±270deg
- 0.024deg steps
- Up to 19deg/s
- Pointing within 1deg

### X-band downlink
- 7dBW RF power
- 15dBi antenna (boresight)

### Payload Data Processor
- PowerPC based

### Mass
- 7kg

### Volume
- XTX: 200x191x129mm
- HSDR: 330x160x30mm
- APM: 240x196x185mm

### Power
- 5W (Standby)
- 65W (Downlinking)
Conclusion

- Increasingly sophisticated high resolution small satellite missions are becoming feasible, but data volume drives their size and mass.

- An Antenna Pointing Mechanism can increase the data throughput for small satellites by more than an order of magnitude
  - Supports simultaneous imaging and downlinking
  - Supports system trades

- Complete payload downlink solution
  - LEO missions
  - Space Science and Earth Observation
Thank you