Commissioning of a small satellite constellation: methods and lessons learned
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Dr Phil Palmer – Surrey Space Centre
• Natural disasters regularly cause huge loss of life, and enormous cost to economies.
  - ($1 billion p.a.)
• Many organisations considering remote sensing solutions
  - Focus on existing resources
• Imaging Requirements
  - High resolution pan
  - Medium resolution multispectral
  - Thermal IR
  - SAR
  - Regular coverage
• Basic needs for disaster warning, monitoring and mitigation
  - Global reach
  - Daily imaging capability
• Use of constellation
DMC system

Daily imaging, Anywhere on the globe

Space Segment
- ALSAT-1 (2002)
- UK-DMC (2003)
- DMC+4 (2005)
- 686km SSO
- >600km swath

Ground Segment
- 4 stations operational
- 1 station due ‘05

Operations
- Distributed mission planning system
- Internet connectivity
- Commercial, National and Humanitarian users
DMC spacecraft

Constellation support

- Propulsion system contains 2.35kg of butane and a 15W resistojet, giving a delta V of up to 25m.sec\(^{-1}\)
- GPS positioning to 15m
- 0.5deg. attitude control
  - GG boom
  - Wheels
  - Torque rods
- Ground Support
  - Mission Planning software
Propulsion system

- Miniaturised resistojet thruster
  - UoSAT-12 heritage
  - 2x15W heaters

- Butane propellant
  - SNAP Heritage
  - Self pressurised to 2 Bar
  - 5 minute pre-heat to >500K
  - Double storage density of Nitrogen at 200 Bar
In-orbit operation

- **Z wheel controls direction:** Ram / anti-ram
- **Disturbances compensated for by operation of wheels and torque rods**

SSC04-IX-2
• AISAT-1 launcher injection correction
  – Semi-major axis and LTAN correction
  – 168 firings of 3 minutes each over 1 month period
  – Isp of 100s Calculated
Commissioning
second launch

- **Second launch – highly accurate!**
  - 300m difference in semi-major axis
  - 0.005deg difference in inclination
  - Phased by 165 degrees

- **Spacecraft commissioned from their respective control stations**

- **Constellation controlled from Surrey**
Station acquisition 1/2

- AISAT used as reference spacecraft
- Other spacecraft manoeuvred into place over 90 day period
• Between December 2003 and March 2004
• UK-DMC overshoot due to station scheduling
Propellant budget

<table>
<thead>
<tr>
<th>Estimated Remaining DeltaV (ms⁻¹)</th>
<th>Estimated Required DeltaV (ms⁻¹)</th>
<th>Estimated Spare DeltaV (ms⁻¹)</th>
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<tbody>
<tr>
<td>Excluding margins</td>
<td>Including margins</td>
<td>Inclination adjustment</td>
</tr>
<tr>
<td>Alsat-1</td>
<td>5</td>
<td>9</td>
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<tr>
<td>BILSAT-1</td>
<td>13</td>
<td>16</td>
</tr>
<tr>
<td>NigeriaSat-1</td>
<td>19</td>
<td>24</td>
</tr>
<tr>
<td>UK-DMC</td>
<td>19</td>
<td>24</td>
</tr>
</tbody>
</table>

More images
Better SNR

5 Year operational life with LTAN >10:00am

2nd DMC launch
2nd launch orbit - current prediction

Sept 2003
Sept 2008

SSC04-IX-2
Station keeping

DMC Phase Status

Phase wrt nominal (degrees)

Day

-6
-5
-4
-3
-2
-1
0
1
2

53070 53080 53090 53100 53110 53120 53130 53140 53150

2 months

Alsat (ref)  NigeriaSat  BILSAT  UK-DMC  Poly. (BILSAT)
Station Keeping

- No tight station keeping constraints due to margins
  - Timing, Attitude control, Position determination

- Difference in ballistic ratio
  - “Standard” DMC drop rate 1.56m/day
  - BILSAT drop rate 0.91m/day
  - BILSAT phase needs to be corrected every two months

<table>
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<tr>
<th>Satellite</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>NigeriaSat-1</td>
<td>88kg</td>
</tr>
<tr>
<td>UK-DMC</td>
<td>88k</td>
</tr>
<tr>
<td>BILSAT-1</td>
<td>130kg</td>
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</tbody>
</table>
DMC user support status

- **National**
  - Significant use
  - 2 user conferences
  - Applications evaluation
    - Flooding
    - Burn scar measurement
    - Precision farming
  - Applications support
    - Calibration campaigns

- **International**
  - Regular DMC consortium meetings
  - Demonstrated Disaster monitoring and support
    - Haiti
    - Vietnam flooding
    - Montserrat volcano
    - Bangladesh flooding
    - Iraq pipeline sabotage
    - California forest fires (Oct03)
  - Apply to join international Charter for Space and Major Disasters

- **Commercial**
  - Several commercial customers
  - Independent quality assessments
  - Developing data processing and billing systems
  - Exploitation company set up "DMC Imaging Ltd."

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DMC Roadmap

DMC-1
Optical, medium resolution multispectral
- 2002/2003
- 32m GSD
- 3 spectral bands
- Daily coverage

DMC-2
Optical, high resolution
- 2.5 & 4m GSD
- Daily coverage

DMC-3
- Synthetic Aperture Radar
  - SAR “imaging”
  - Night time
  - All weather
  - Flooding
  - Daily coverage
- Infrared
  - IR night time imaging
  - Hotspot detection
  - 12 hourly coverage
- Hyperspectral
  - Identification and detection
  - Daily coverage
- Ocean Colour
  - Ocean colour imaging
  - Pollution and fisheries
  - Daily coverage
- Sea State
  - Sea State monitoring
  - Disaster mitigation
  - 3-6 hourly coverage
- Earthquake
  - Earthquake science
  - Disaster science

VISTA
Near Real-Time imaging constellation
Conclusions

- Lessons learned
  - Coordinating multiple customers
  - Internet connectivity

- Small satellites are complementary
  - Constellations of small, low cost satellites, provide new opportunities
    - Affordable temporal resolution

- Small satellites are disruptive?
  - DMC is starting to serve some of the Landsat and SPOT users...
Thank you!
Extra slides
Image pre-processing Tool Chain

- Band Splitter
- Initial Radiometric Correction
- Tile extraction
- Band-to-band Co-registration
- Tile Mosaic
- Elementary Geometric Transformation (North Pointing)
Centralised commercial system

Distributed Mission Planning System

UK

Algeria

Nigeria

Turkey

China

DMC Marketing

Disaster Partners

International customers

National data uses

Reuter AlertNet

International Charter
Earth Observation
UK-DMC: California Forest Fires (October 2003)

• 240km swath before boom deployment and calibration
Earth Observation
UK-DMC: Dubai (December 2003)

ESA Images 28/1/04 : Before and After from ERS-2/Envisat
Earth Observation
IRAQ: Basra Oil Fires (12 April 2004)
England and Wales