SURREY
SATELLITE TECHNOLOGY LTD

Commissioning of a small satellite constellation:
methods and lessons learned

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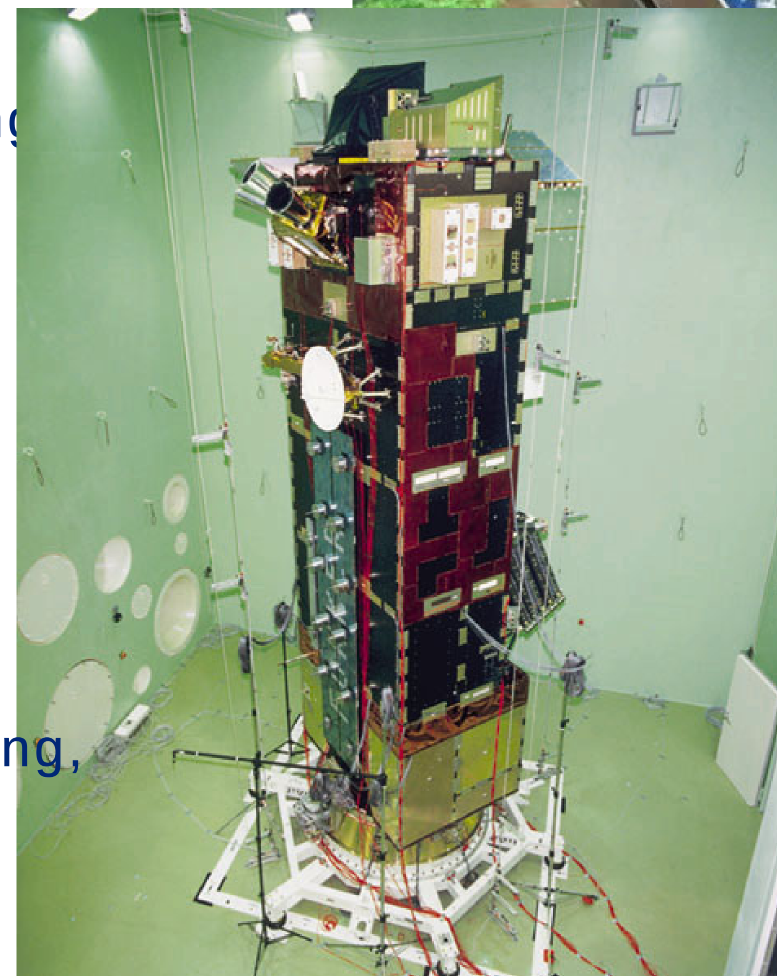
Disaster Monitoring Constellation

- 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

<u>Space Segment</u>

- ALSAT-1 (2002)
- NigeriaSat-1 (2003)
- BILSat-1 (2003)
- UK-DMC (2003)
- DMC+4 (2005)

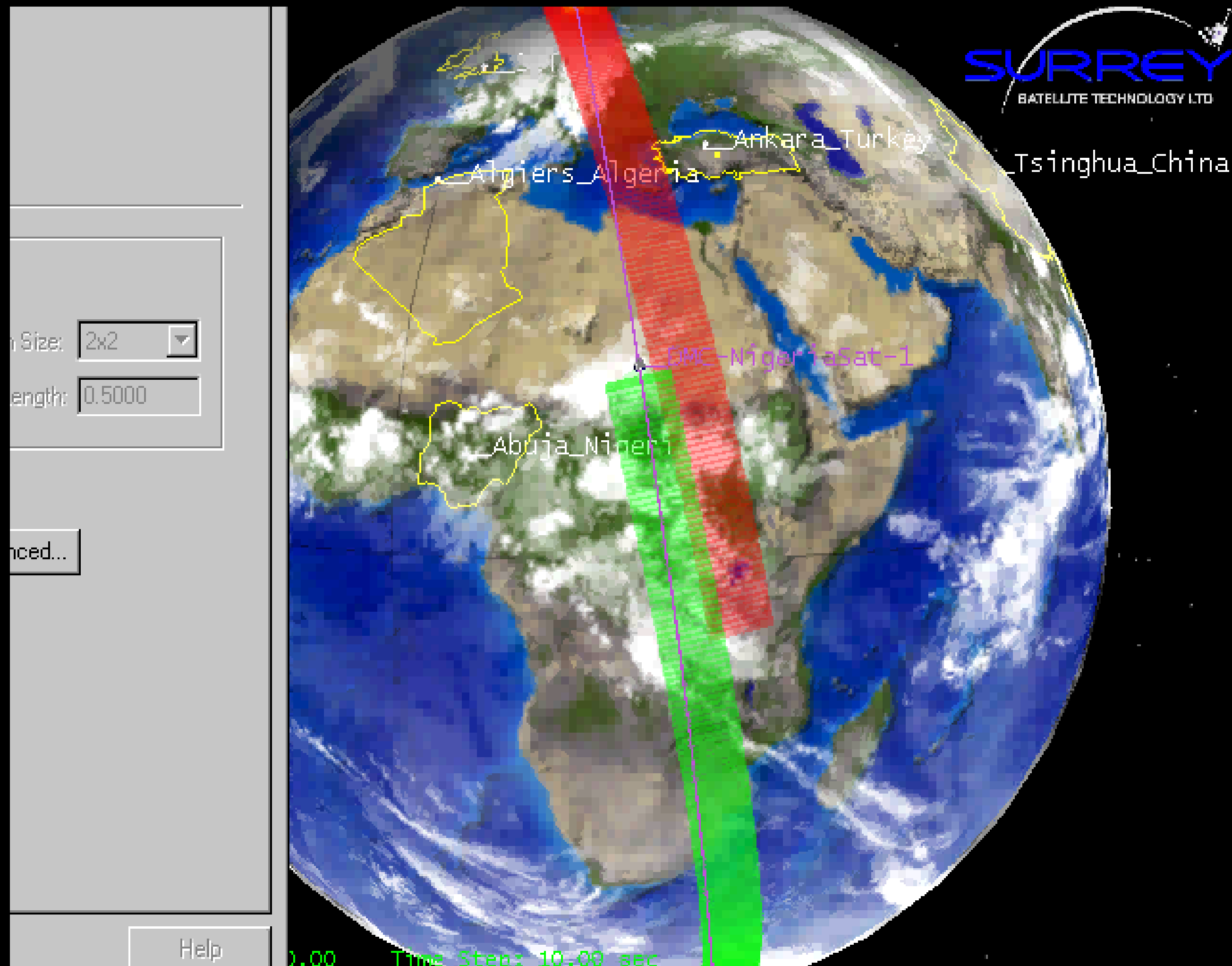
- 686km SSO
- >600km swath

<u>Ground Segment</u>

- 4 stations operational
- 1 station due ’05

<u>Operations</u>

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



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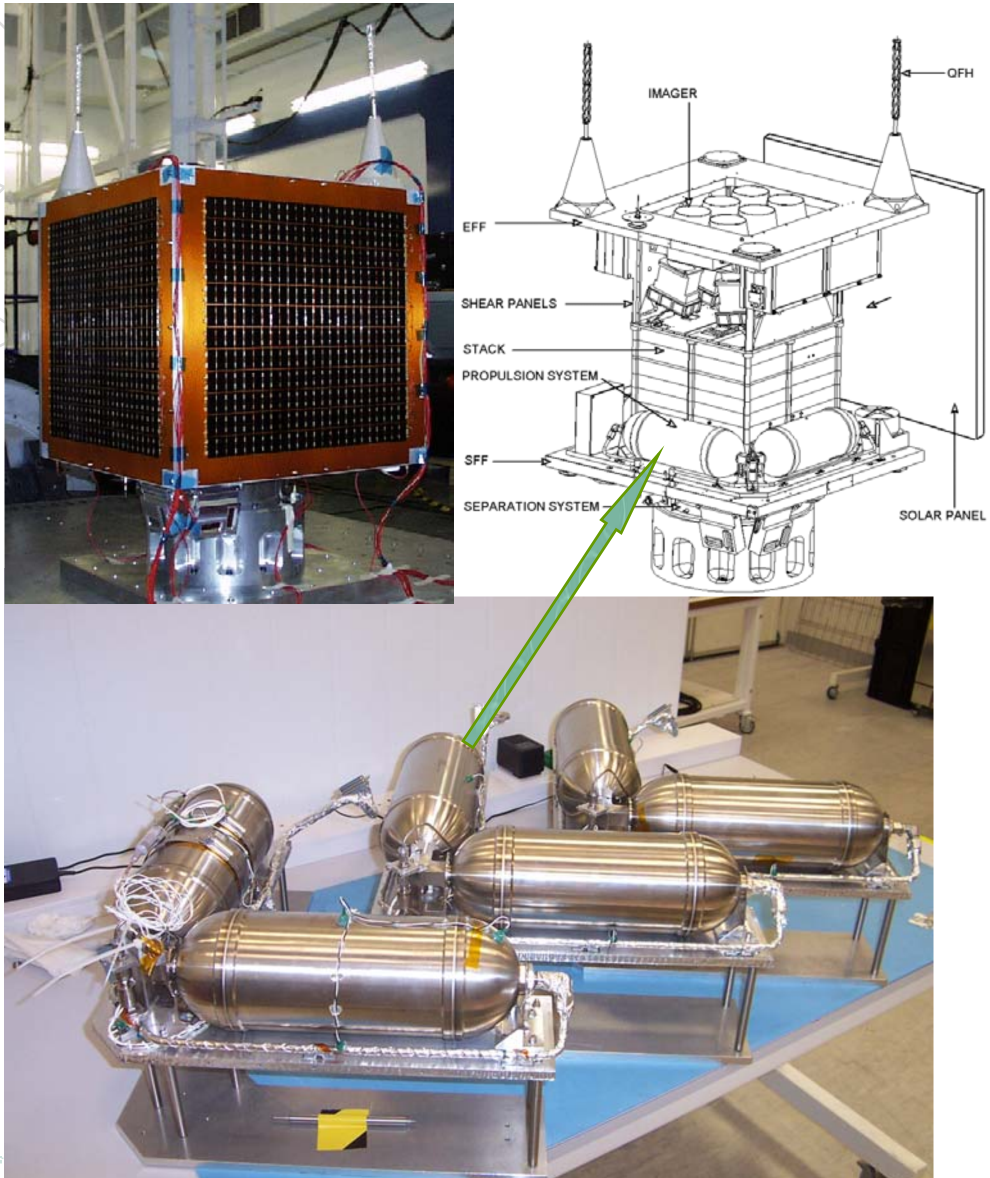
DMC spacecraft

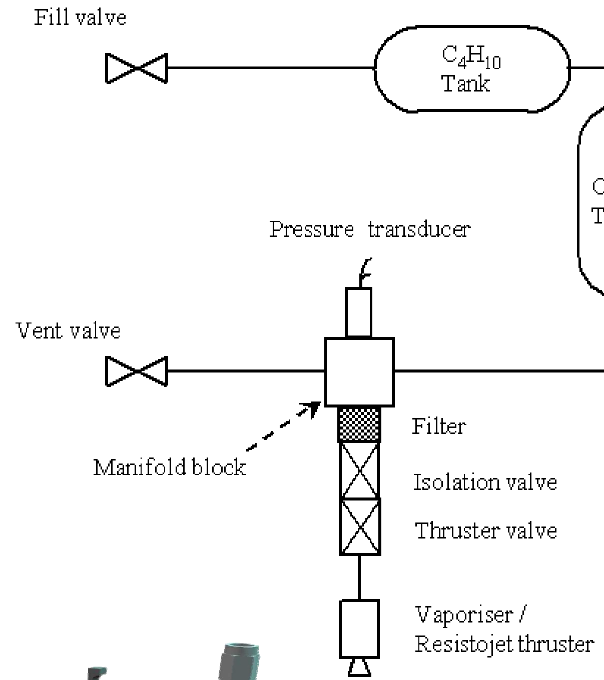


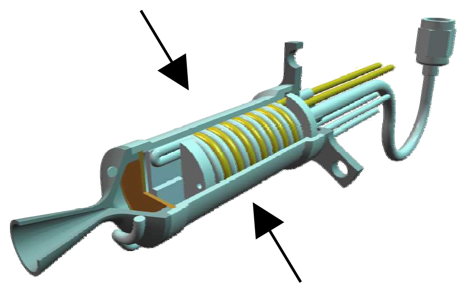
Constellation support

- 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

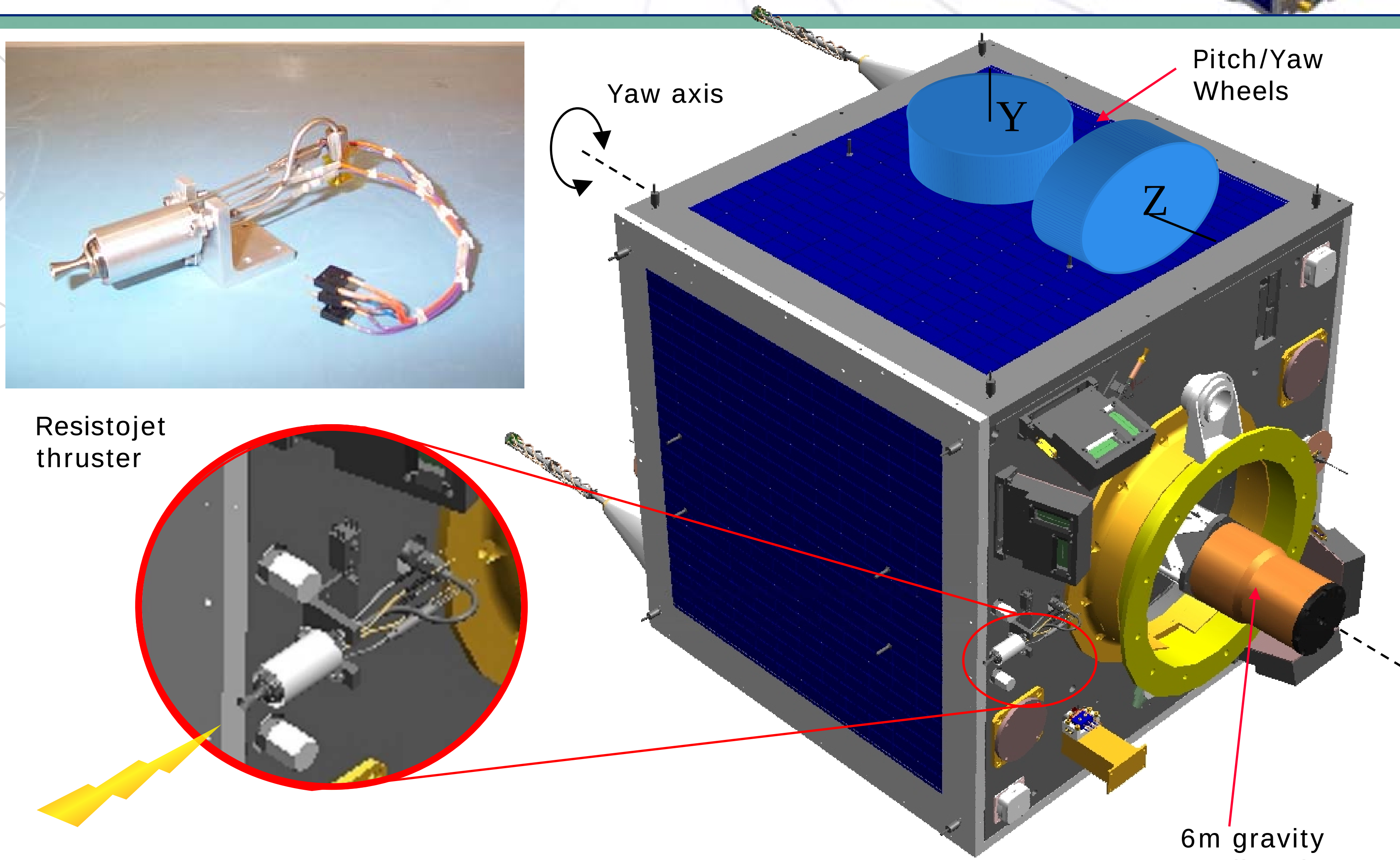
Propulsion system

- 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



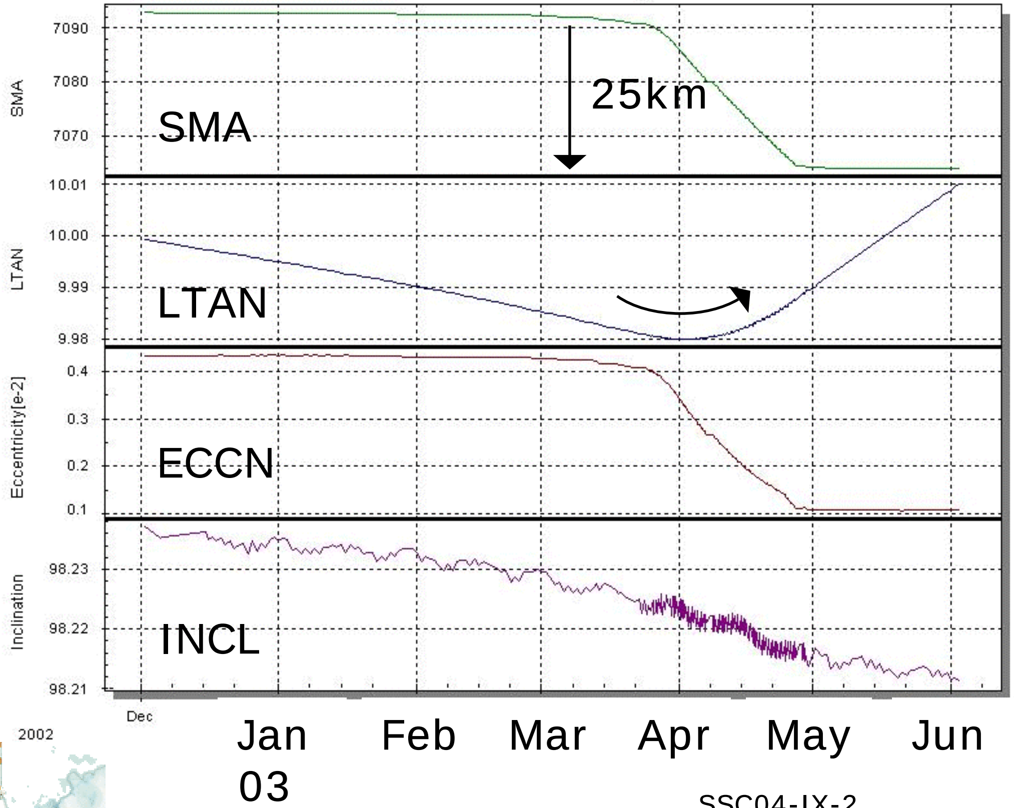
- Z wheel controls direction: Ram / anti-ram
- Disturbances compensated for by operation of wheels and torque rods

Commissioning

first launch

- AlSAT-1 launcher injection correction
  - Semi-major axis and LTAN correction
  - 168 firings of 3 minutes each over 1 month period
  - Isp of 100s Calculated

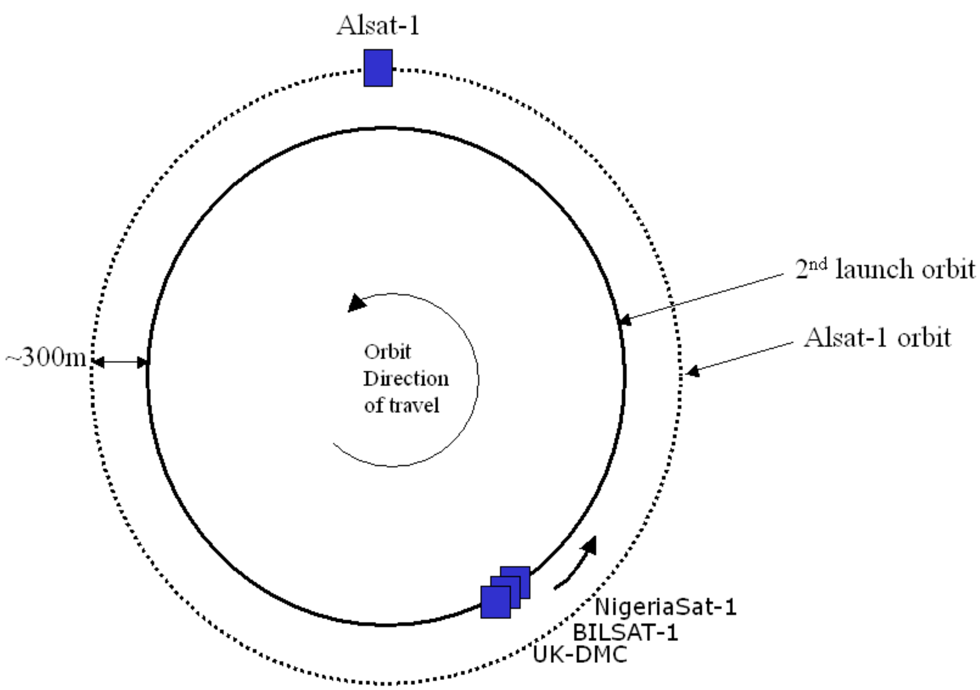
AlSat-1 Orbit Trend Analyses



Commissioning

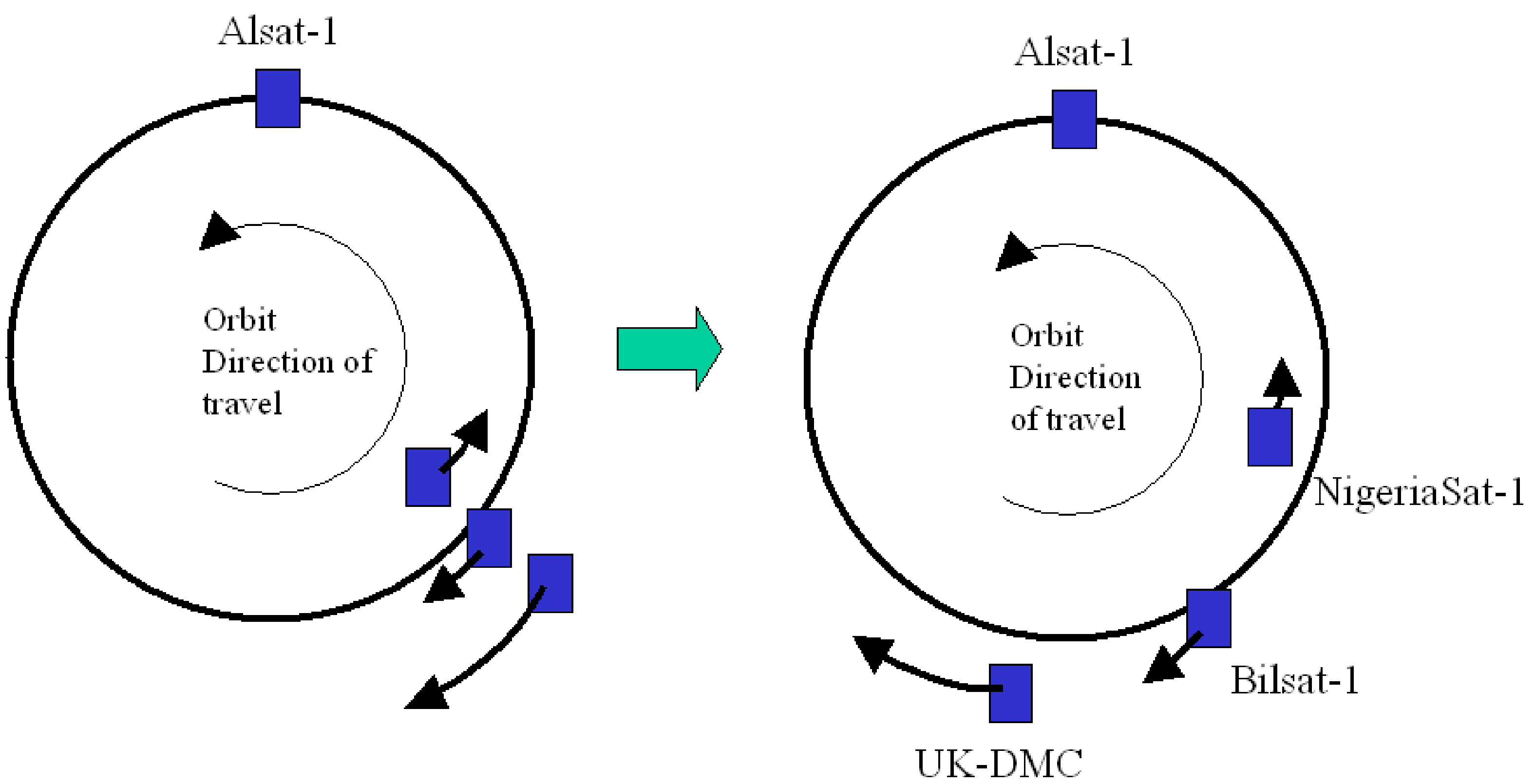
second launch

- 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



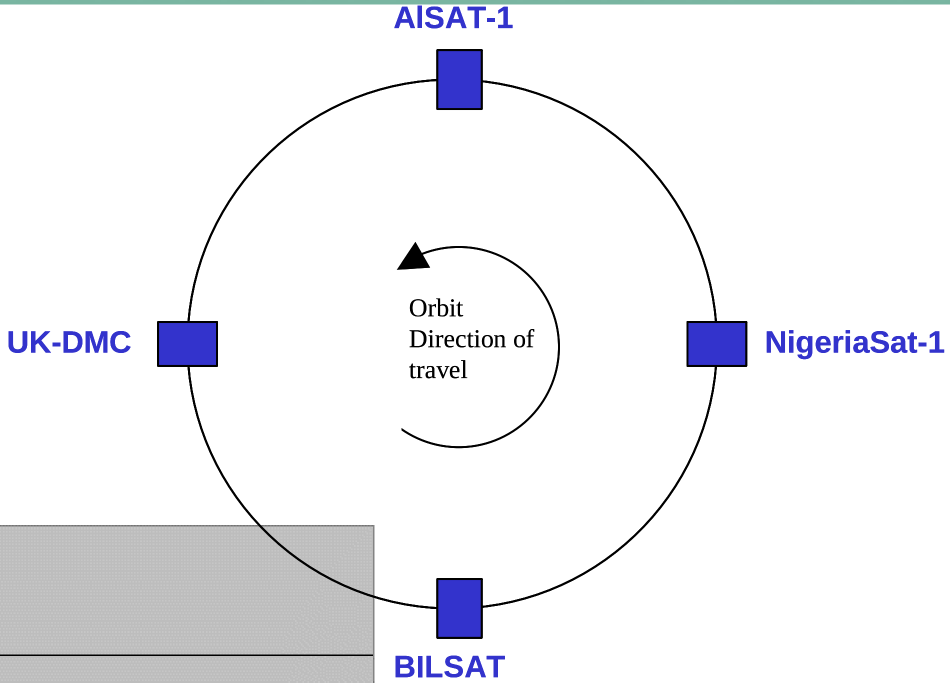
Station acquisition 1/2

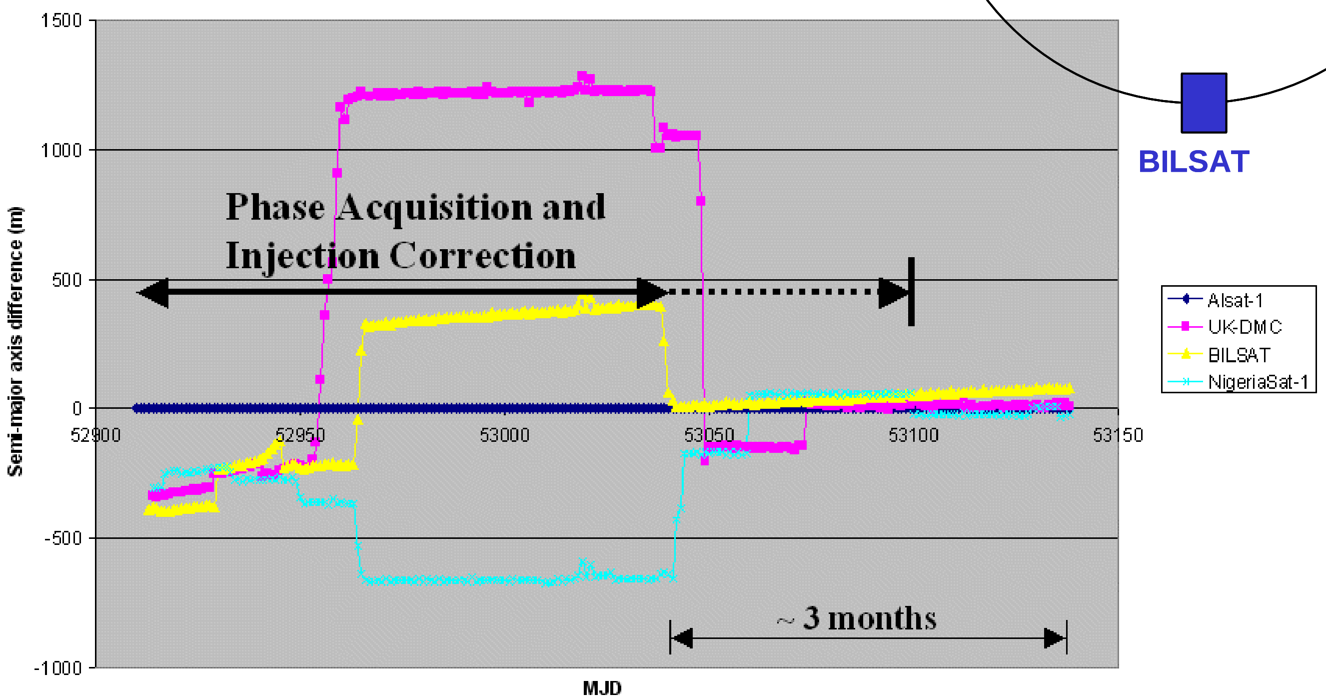
- AlSAT used as reference spacecraft
- Other spacecraft manoeuvred into place over 90 day period



Station acquisition 2/2

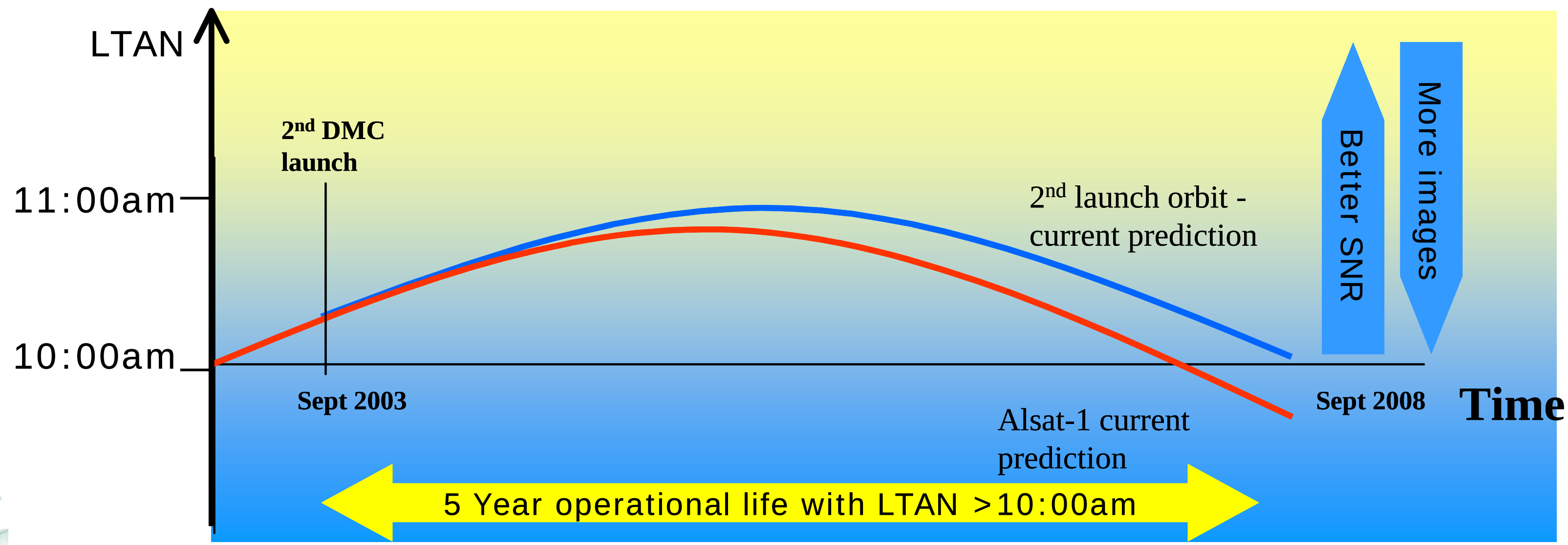
- Between December 2003 and March 2004
- UK-DMC overshoot due to station scheduling



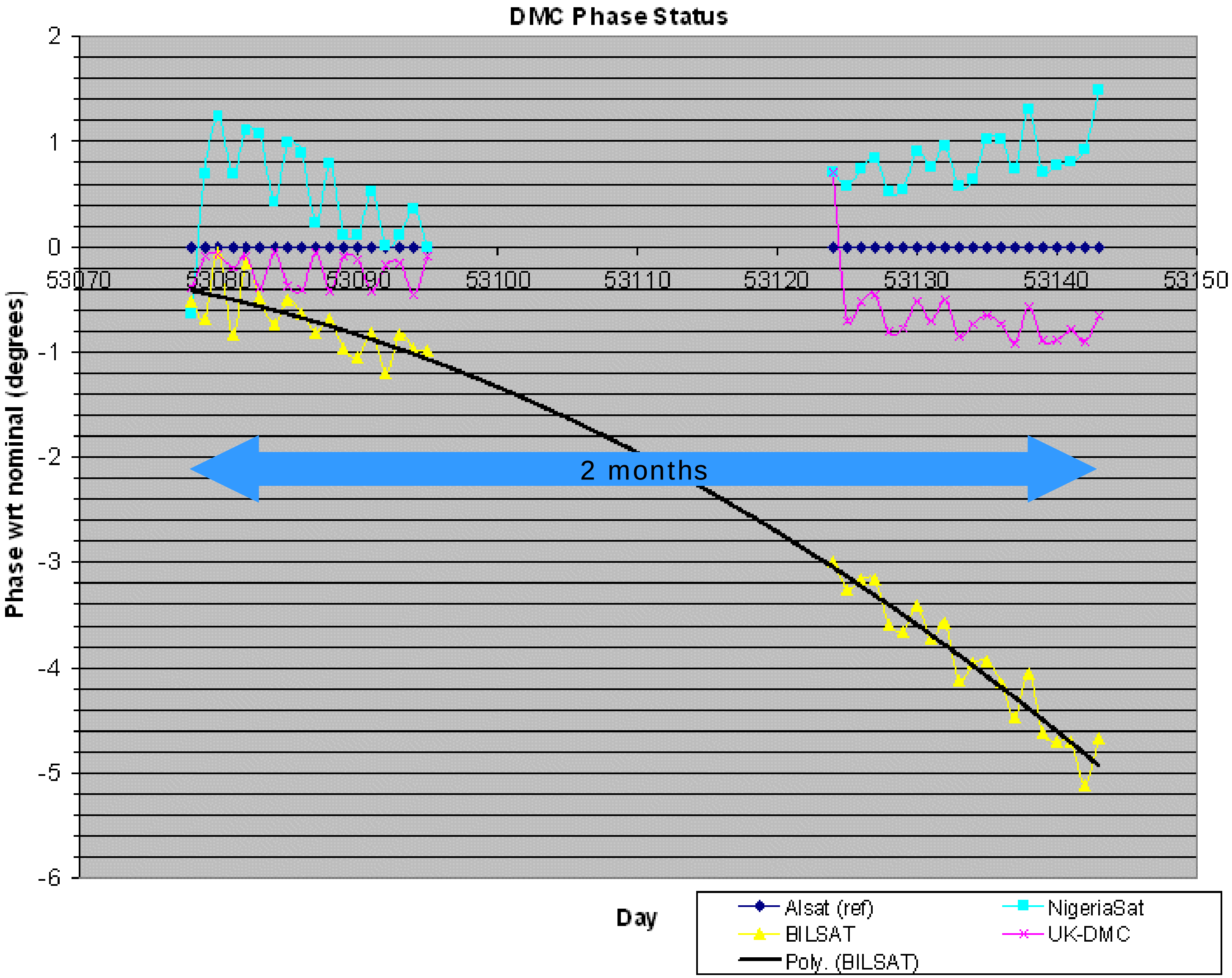


Propellant budget

	Estimated Remaining DeltaV (ms^{-1})		Estimated Required DeltaV (ms^{-1})			Estimated Spare DeltaV (ms^{-1})
	Excluding margins	Including margins	Inclination adjustment	Phase Acquisition	Phase Maintenance	Excluding Margins
Alsat-1	5	9	0.6	-	-	4.4
BILSAT-1	13	16	-	0.45	< 3	> 9.5
NigeriaSat-1	19	24	-	0.77	<< 3	> 15.2
UK-DMC	19	24	-	1.35	<< 3	> 14.6



Station keeping



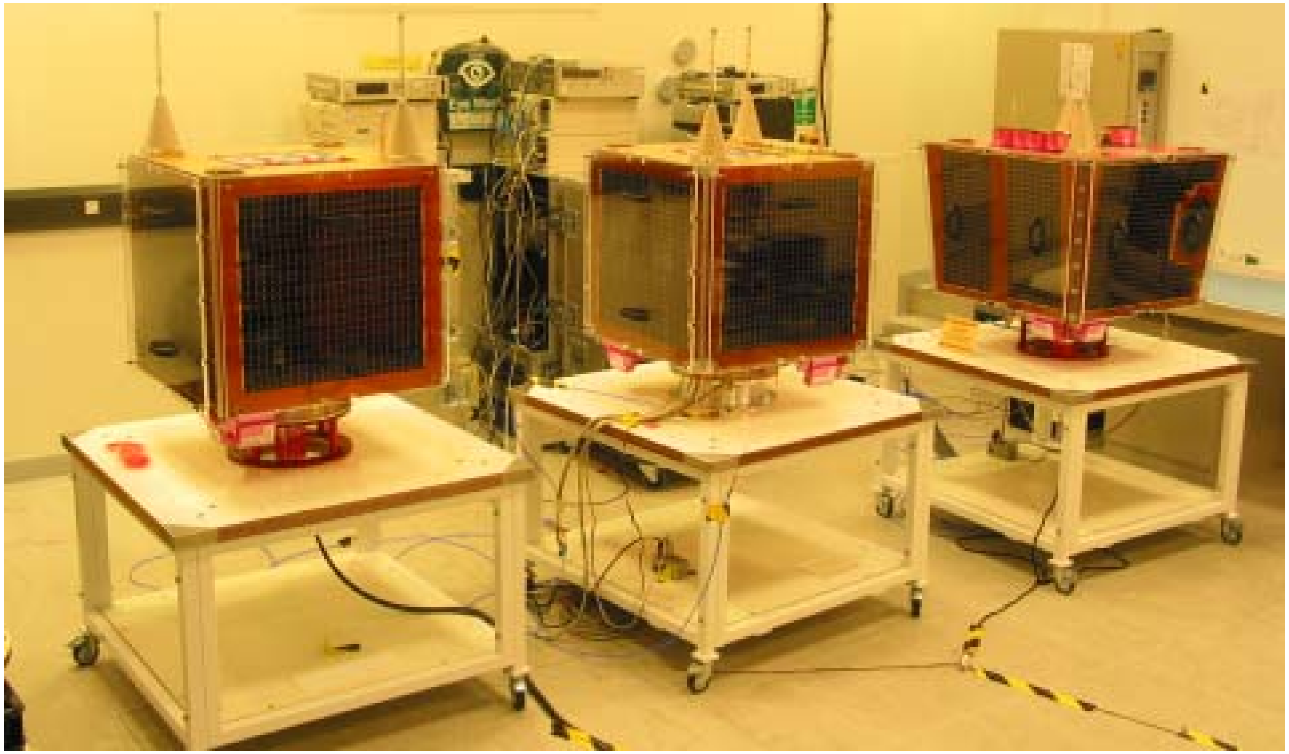
Station Keeping

- 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

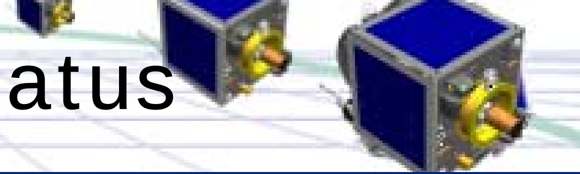
NigeriaSat-1
88kg

UK-DMC
88k

BILSAT-1
130kg



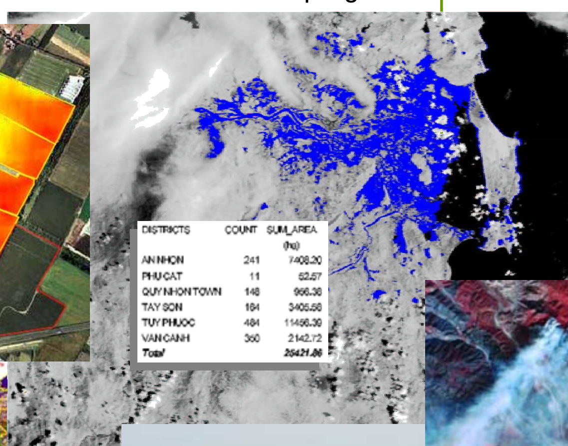
DMC user support status



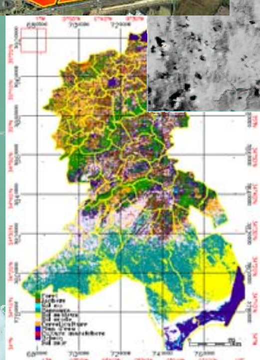
- **National**
  - Significant use
  - 2 user conferences
  - Applications evaluation
    - Flooding
    - Burn scar measurement
    - Precision farming
  - Applications support
    - Calibration campaigns

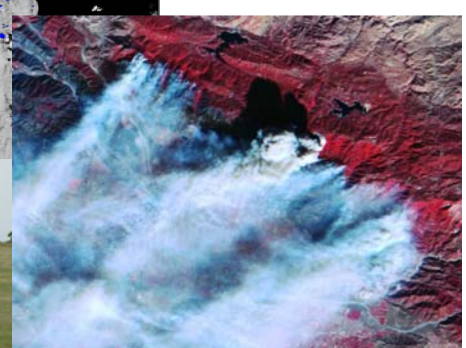
- **International**
  - Regular DMC consortium meetings
  - Demonstrated Disaster monitoring and support
    - Haiti
    - Vietnam flooding
    - Montserrat volcano
    - Bangladesh flooding
    - Iraq pipeline sabotage
    - California forest fires (Oct03)
  - Apply to join international Charter for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

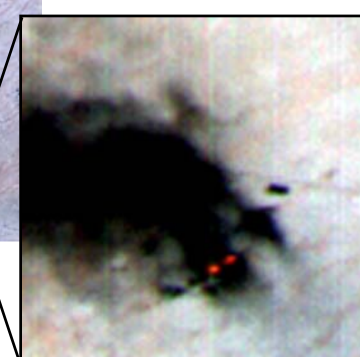
- **Commercial**
  - Several commercial customers
  - Independent quality assessments
  - Developing data processing and billing systems
  - Exploitation company set up "*DMC Imaging Ltd.*"



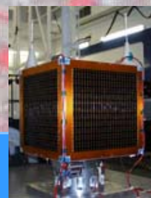
DISTRICTS	COUNT	SUM_AREA (ha)
AN NHON	241	7408.20
PHU CAT	11	52.57
QUY NHON TOWN	148	956.38
TAY SON	164	3405.58
TUY PHUOC	484	11456.39
VAN CANH	360	2142.72
Total		*25421.86*





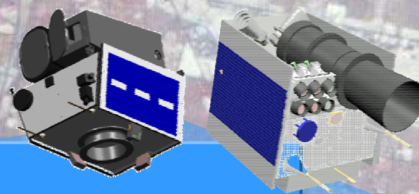


DMC Roadmap



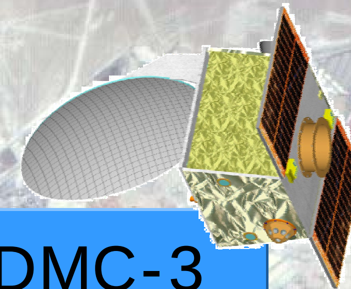
DMC-1
Optical, medium resolution multispectral

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

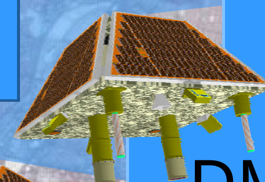
SAR "imaging"
- Night time
- All weather
- Flooding

Daily coverage

DMC-3
Infrared

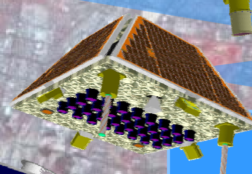
IR night time imaging
- hotspot detection

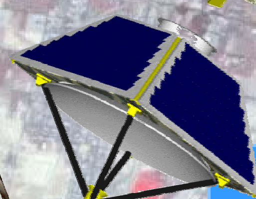
12 hourly coverage



DMC-3
Hyperspectral

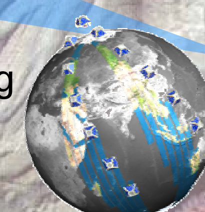
Hyperspectral imaging
Identification and detection
Daily coverage





DMC-3
Ocean Colour

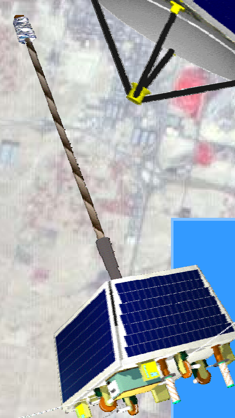
Ocean colour imaging
Pollution and fisheries
Daily coverage



DMC-3
Sea State

Sea State monitoring
Disaster mitigation
3-6 hourly coverage

VISTA
Near Real-Time imaging constellation



DMC-3
Earthquake

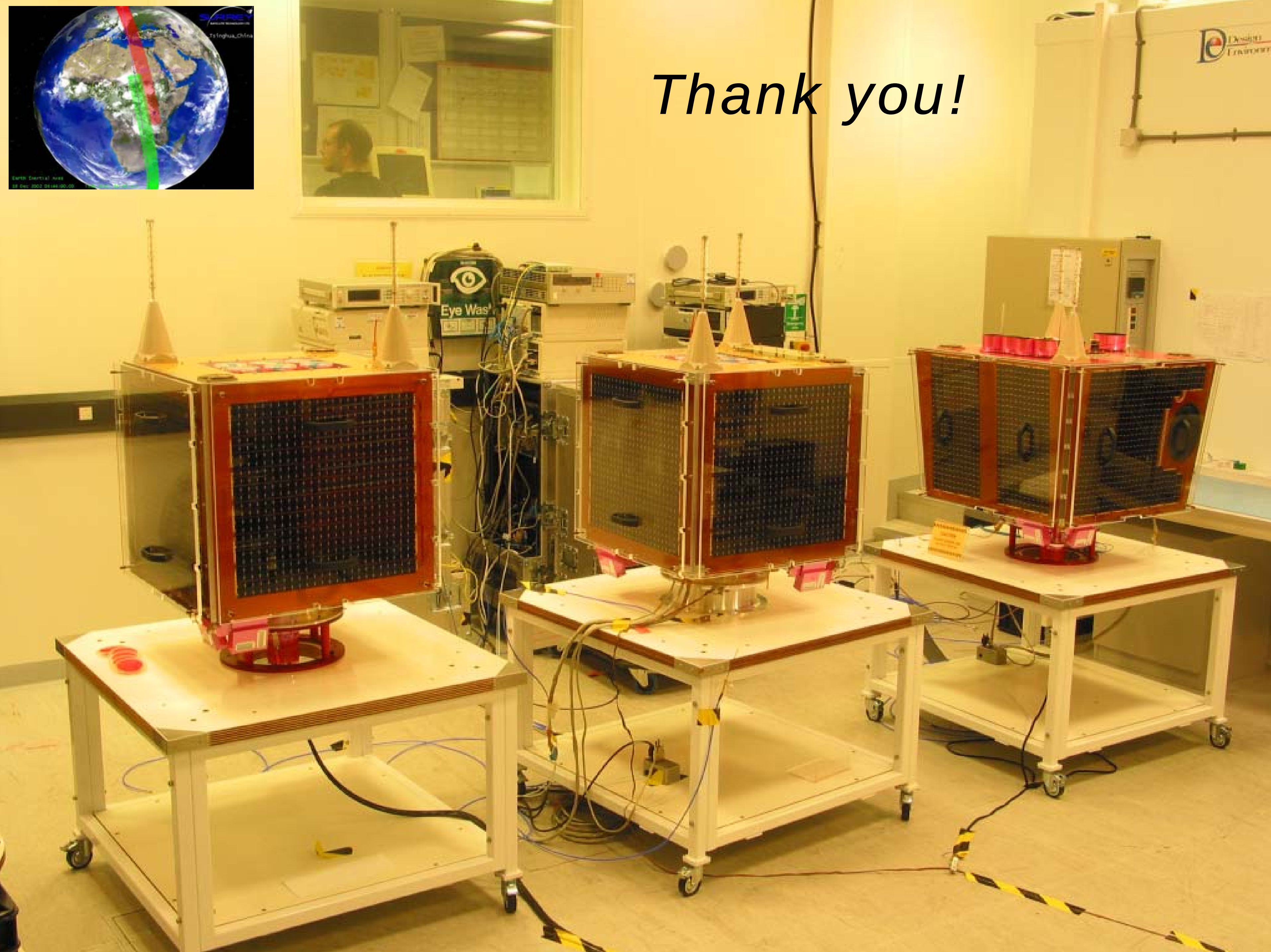
Earthquake science
Disaster science

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!



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Extra slides

Image pre-processing Tool Chain

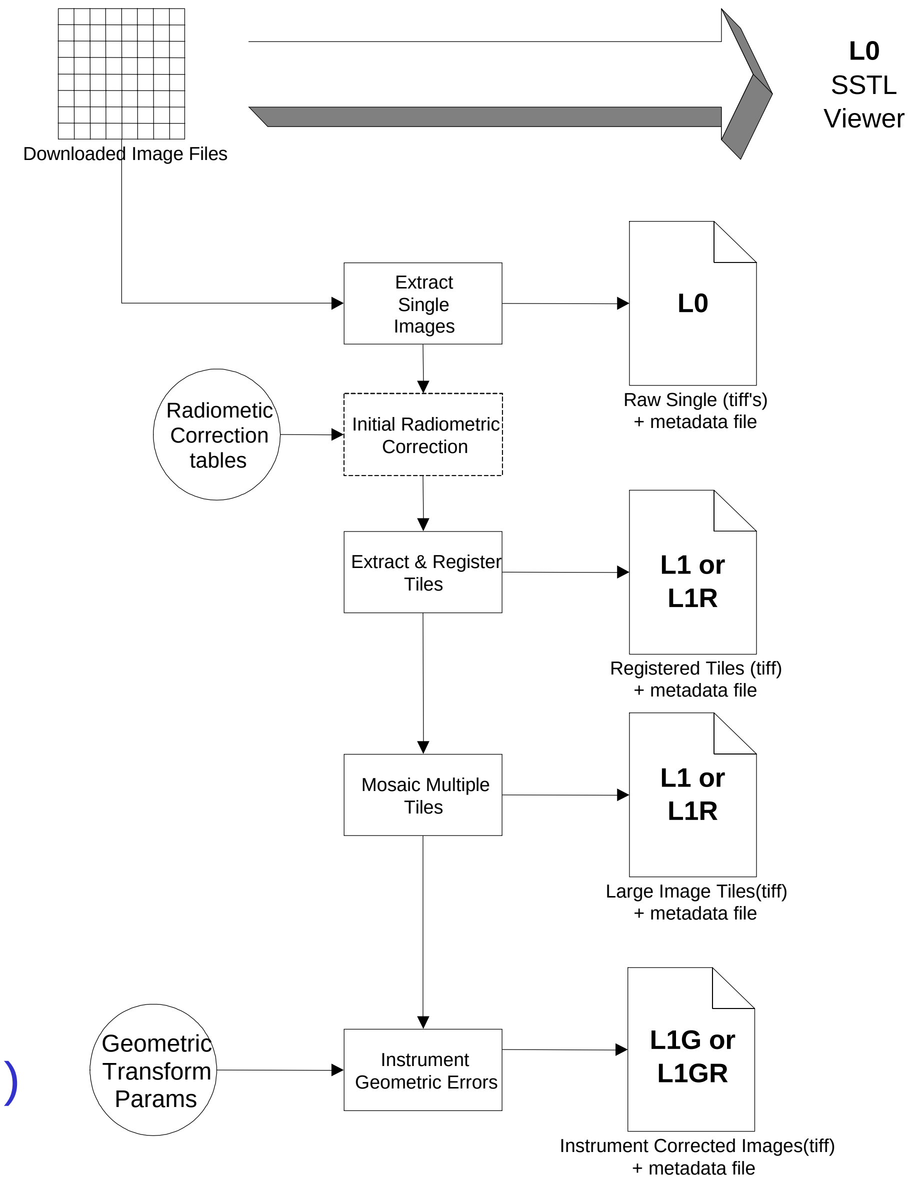
Band Splitter

Initial Radiometric Correction

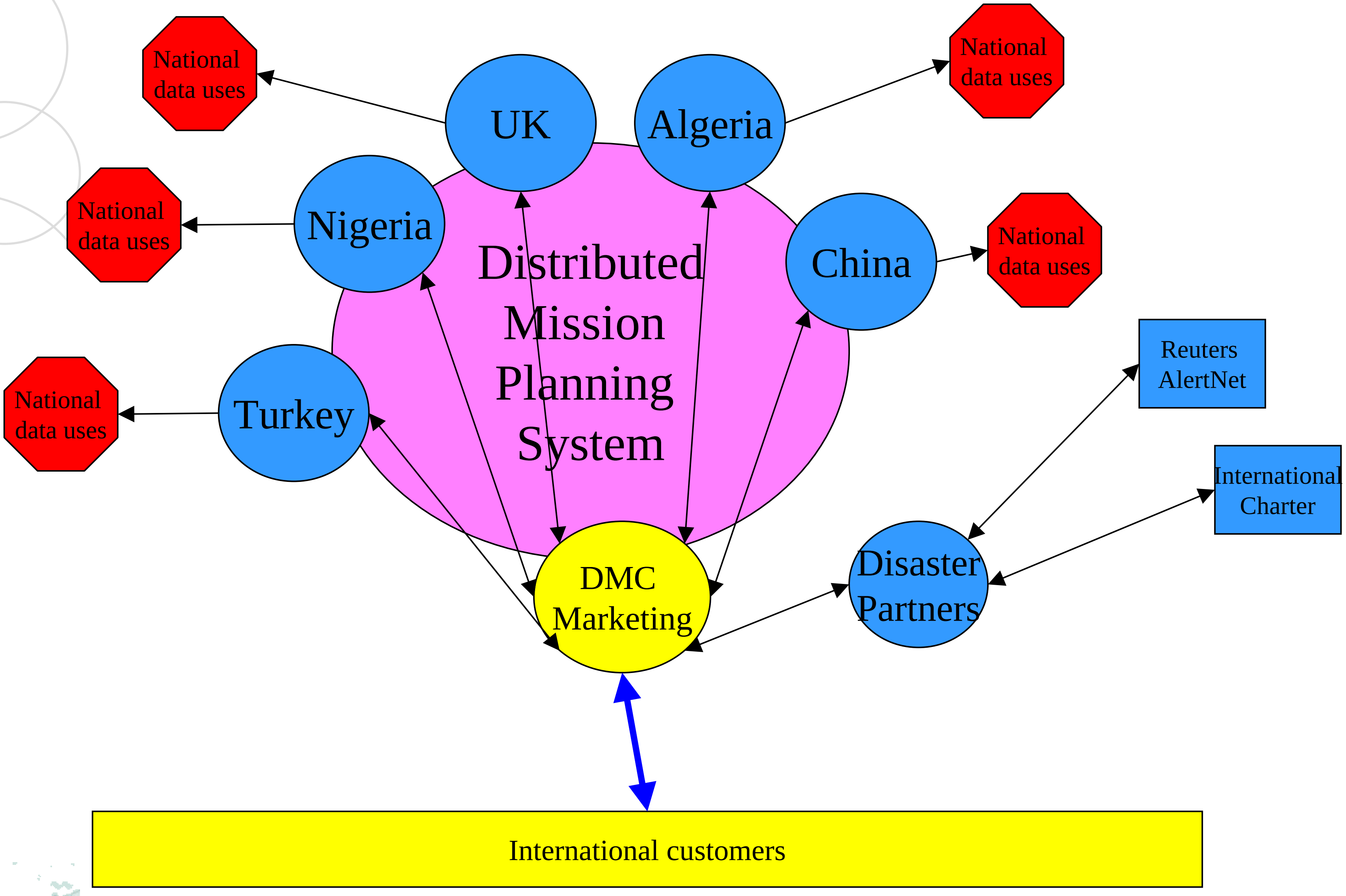
Tile extraction
Band-to-band Co-registration

Tile Mosaic

Elementary Geometric Transformation (North Pointing)



Centralised commercial system



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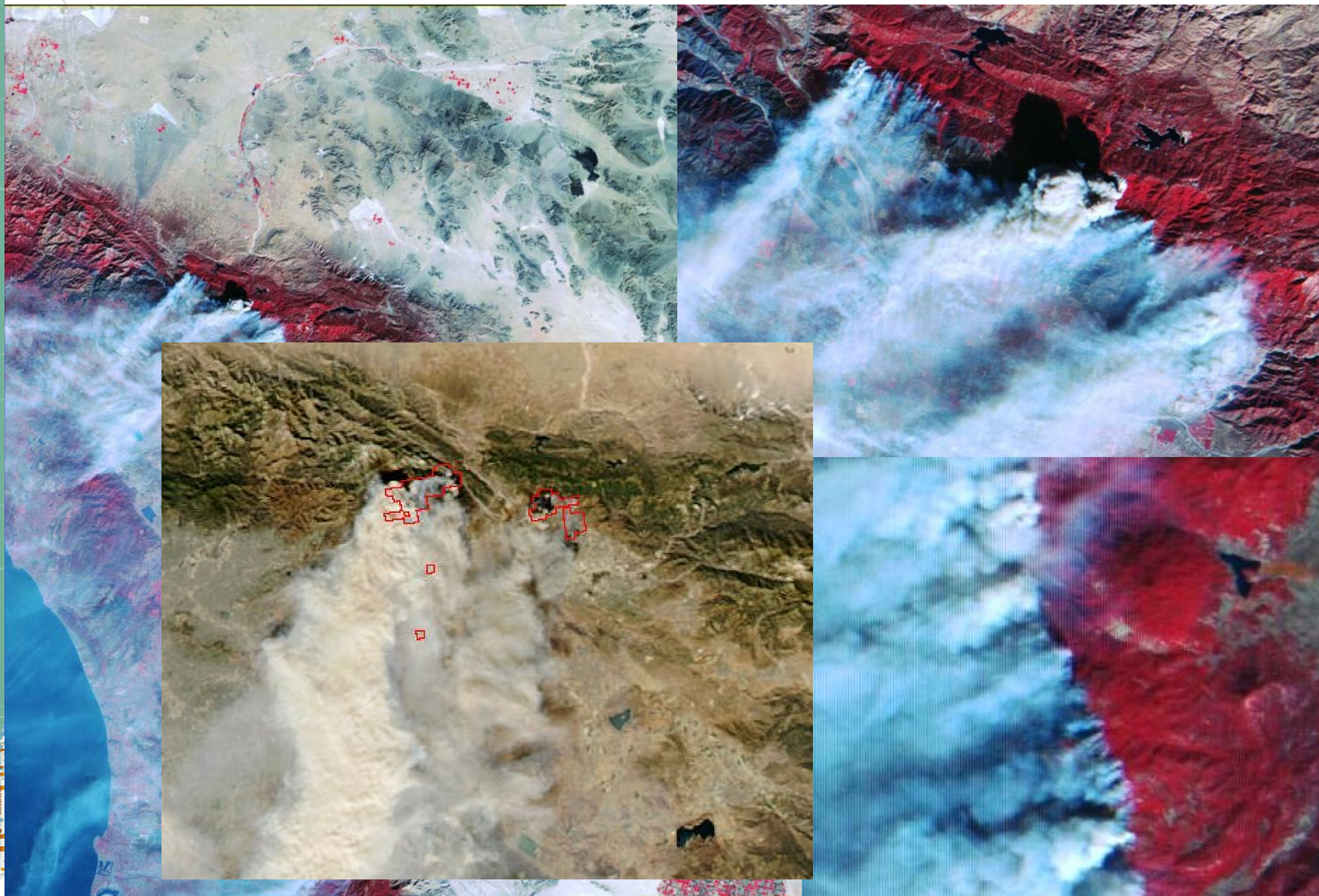
Earth Observation

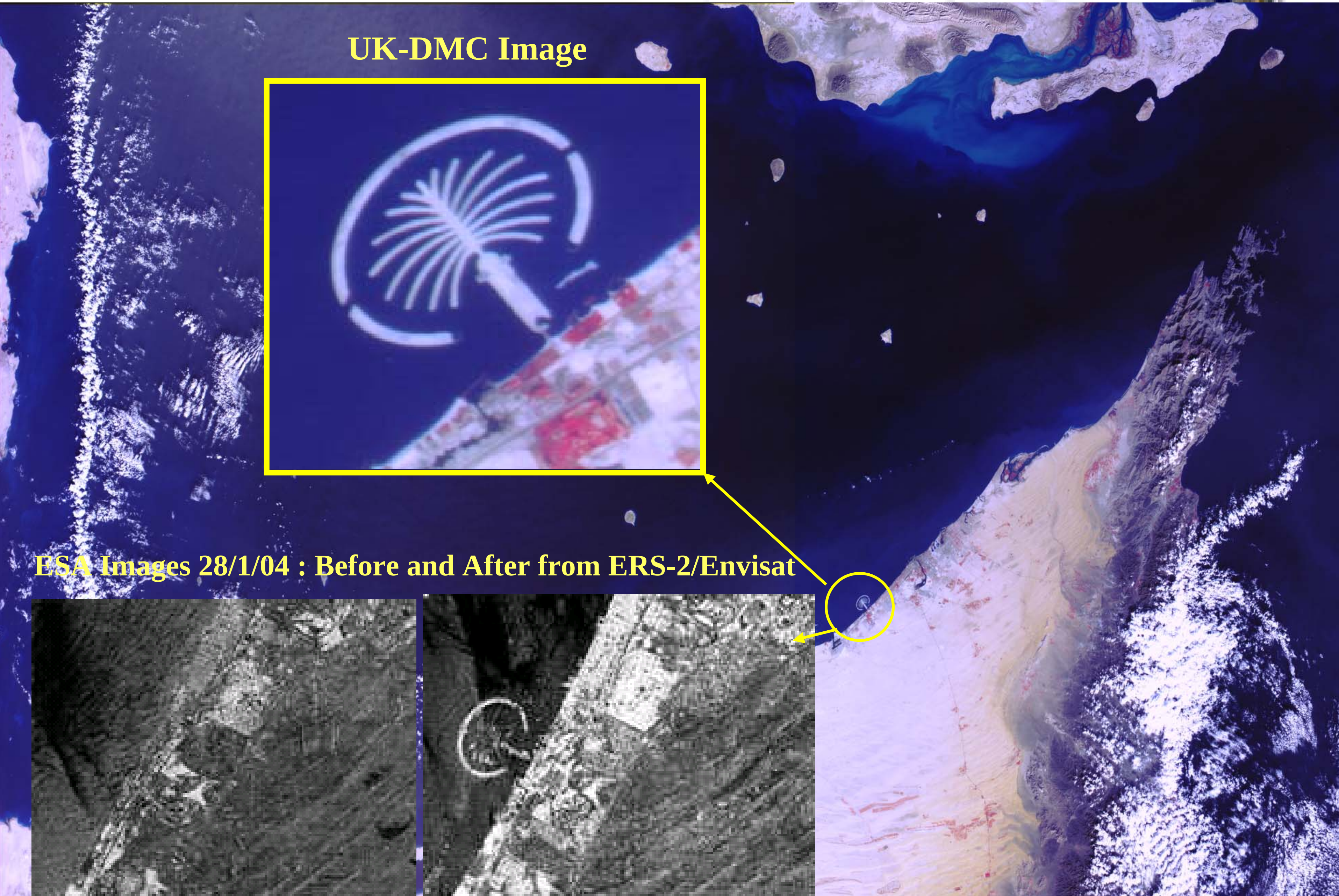
UK-DMC: California Forest Fires (October 2003)

- 240km swath before boom deployment and calibration



Earth Observation

UK-DMC: Dubai (December 2003)



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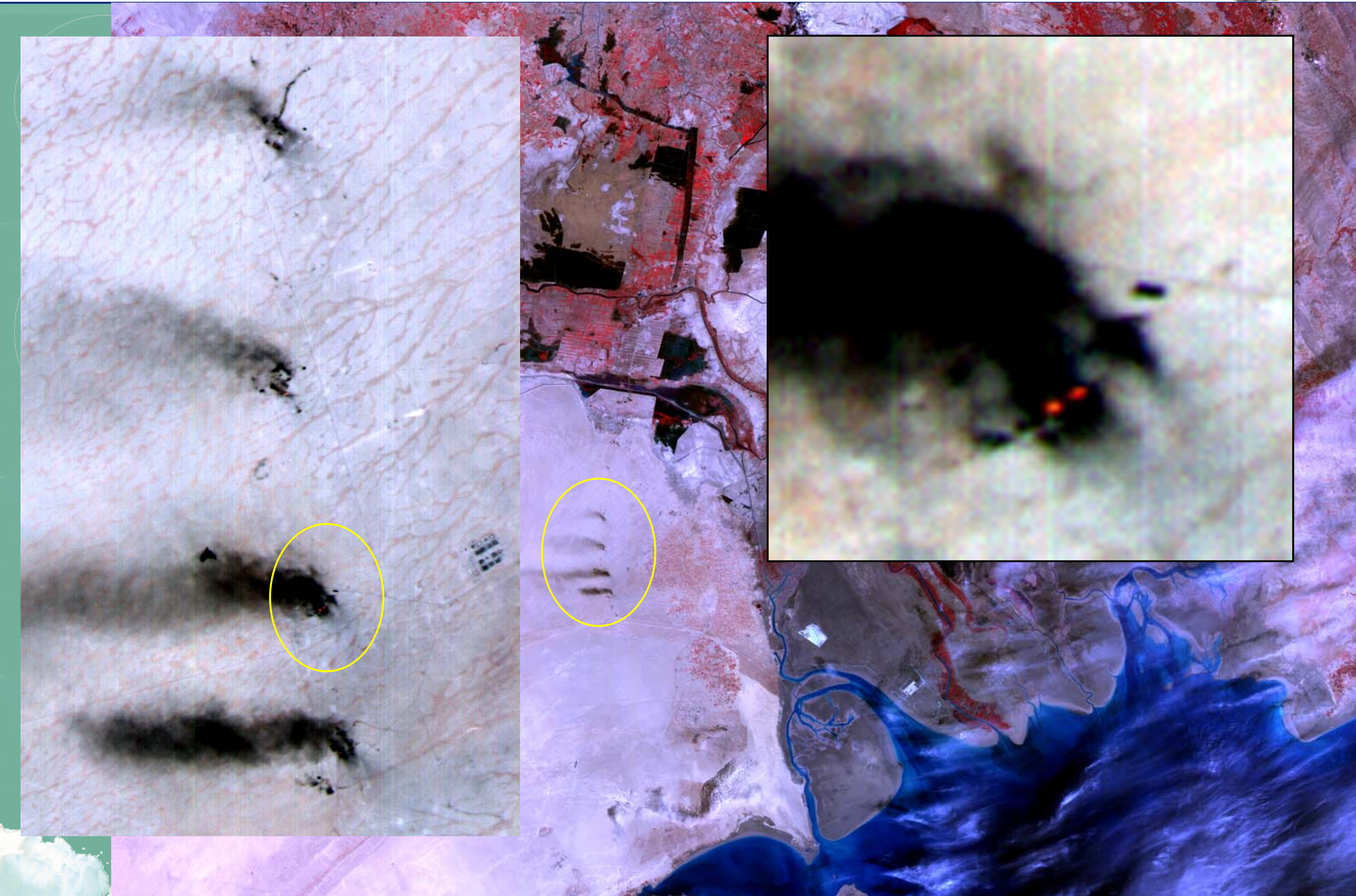
Earth Observation

IRAQ: Basra Oil Fires (12 April 2004)



England and Wales