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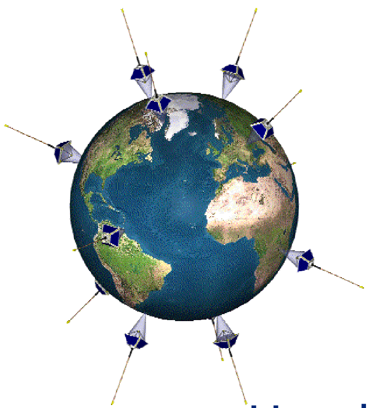
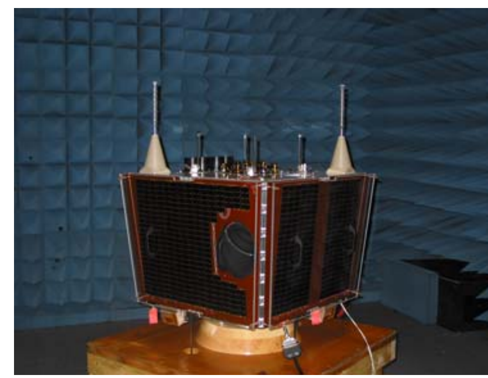
Small Satellites in Constellation
Constraints

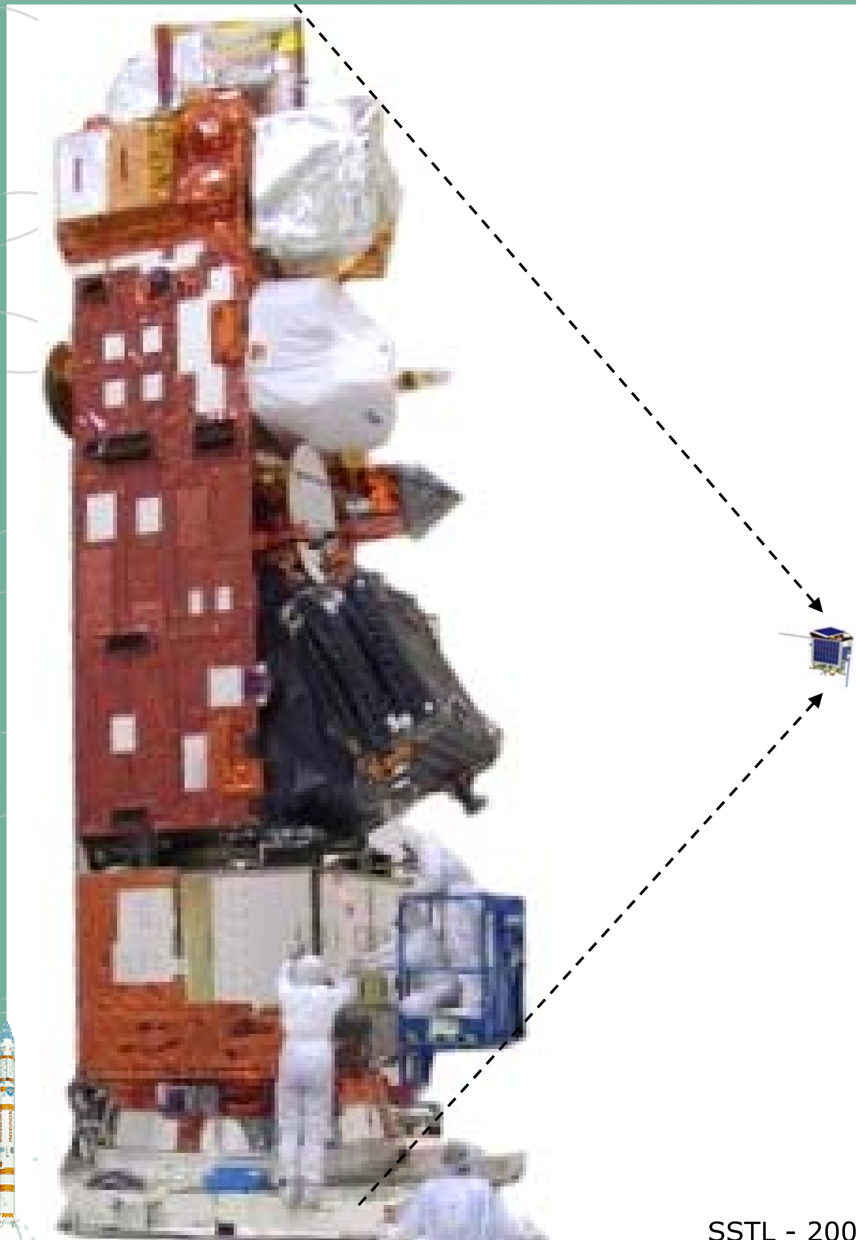


GAMBLE WORKSHOP



Alex da Silva Curiel
Head of Research and Development

What are 'Small Satellites'?

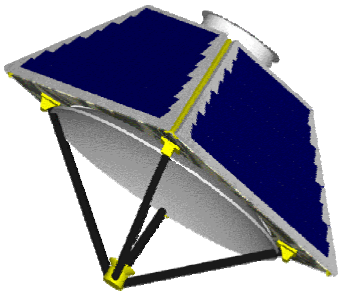


	Mass	*Cost*	*Time*
Large	1000kg+	$200M+	5-15yrs
Small	500kg	$40-80M	2-3yrs
Mini	250kg	$20M	2yrs
Micro	**100kg**	**$10M**	**1.5yrs**
Nano	10kg	$1M	~1 yr
Pico	<1kg	>$100k	<1yr

Why small satellites?

- Small satellite features
  - Often driven by cost and timescale, not always performance
    - Shorter programme duration
    - Reduced programme costs/risks
    - Often adapt PA/QA to programme needs
    - Can provide similar functions to those offered by larger platforms

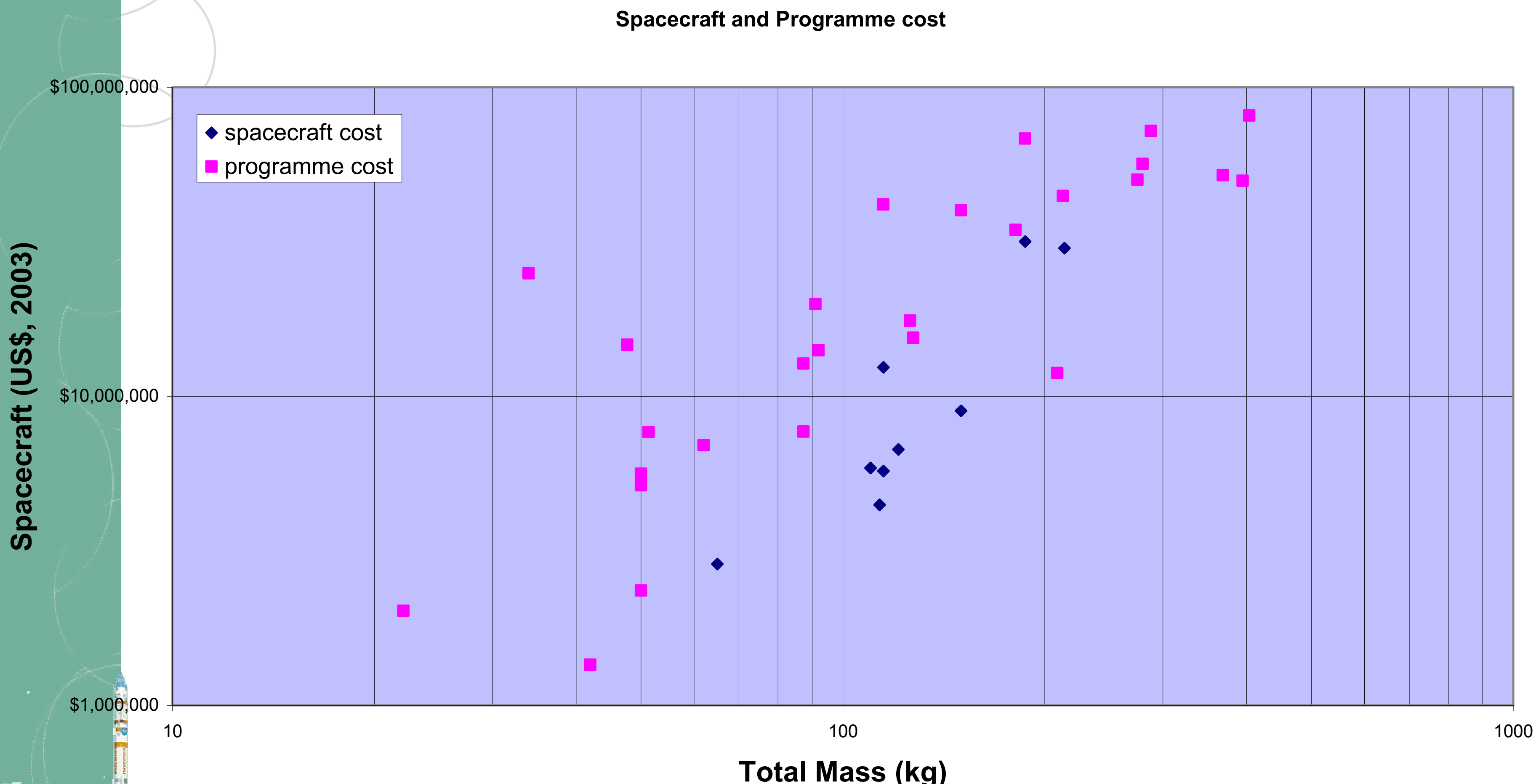
"80% performance for 20% cost"



- Exploitation
  - Lowest cost of entry missions
  - In constellations
- For altimetry
  - Spatial-temporal resolution
    - Multiple deployments from small launcher
  - Rapid response in-orbit capability maintenance

Is there a size and cost relationship?

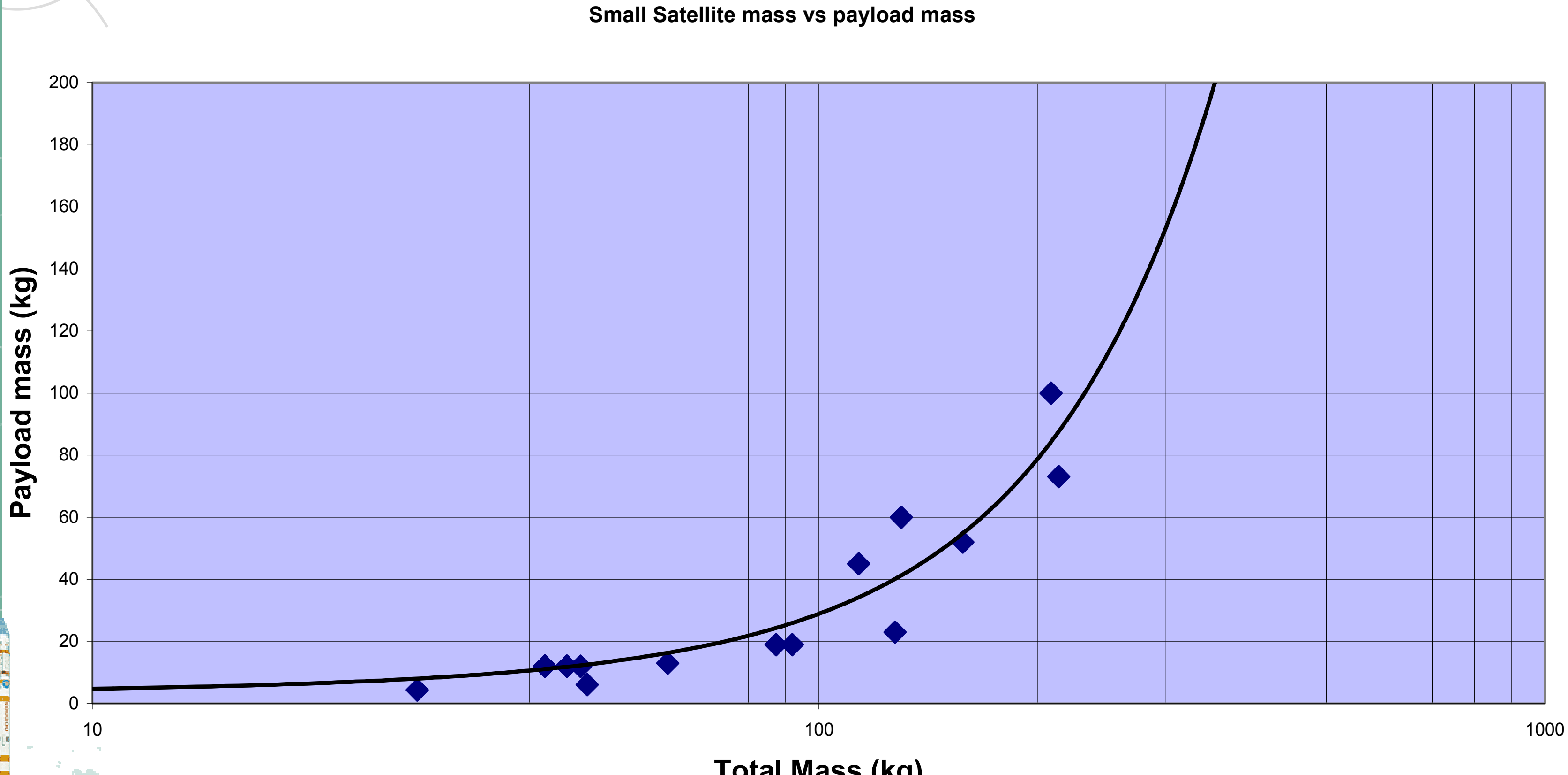
- Providing conventional technology is used….



SSTL - 2003

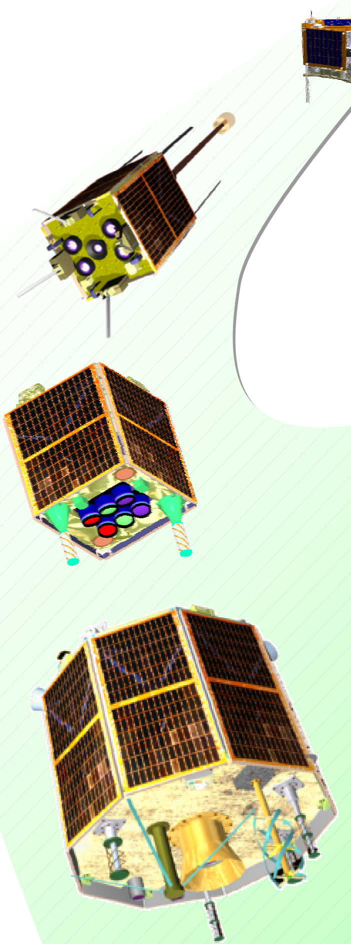
Constraints: Mass

- Mass is constraint
  - Direct relationship to launch cost (€/kg)
  - Payload mass fraction reduces with smaller spacecraft
    - 20%-30% for 100kg spacecraft typical



Constraints: Power

- As size reduces, so does available panel area
  - Body mounted panels most common
  - Deployed panels rare on smaller spacecraft
    - Mass constraint
    - Complexity (cost constraint)
    - Attitude disturbance

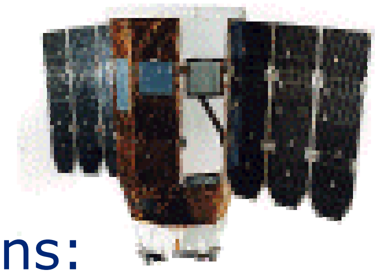
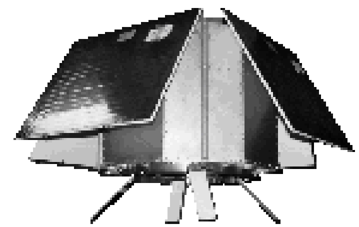
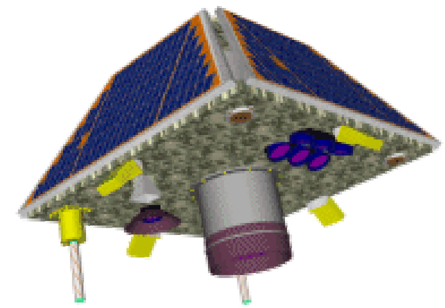



Fixed Deployed


Tracking

Constraints: Power

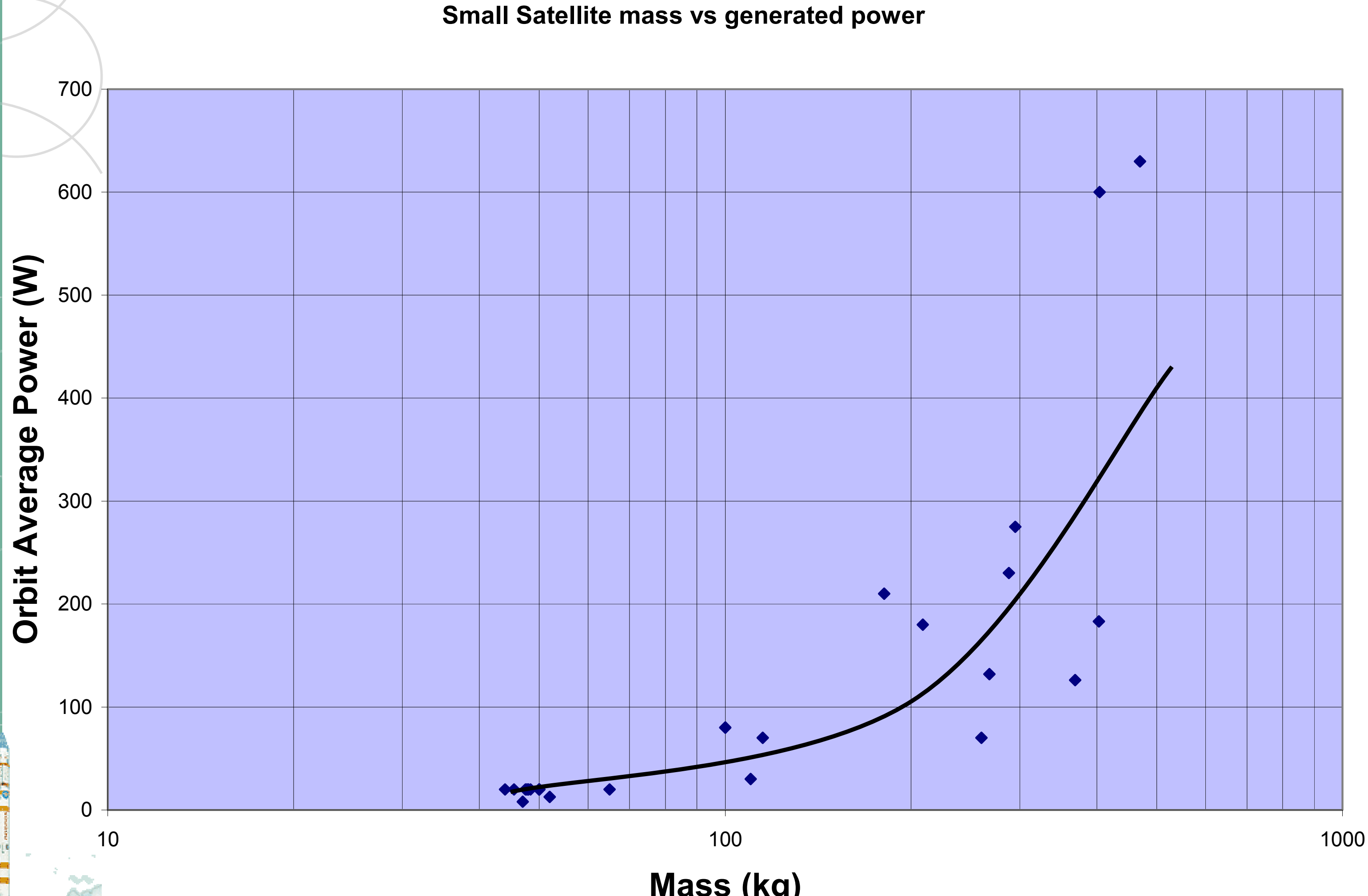
- Power demand does not naturally reduce with spacecraft size

- Common solutions:
  - Panel orientation can be optimised
  - Power cycling of sub-systems and payloads. Some missions duty cycle payload operations
  - Sun-basking mode sometimes adopted
    - As payload operations allow
  - Reduced data return, or more costly ground-segment

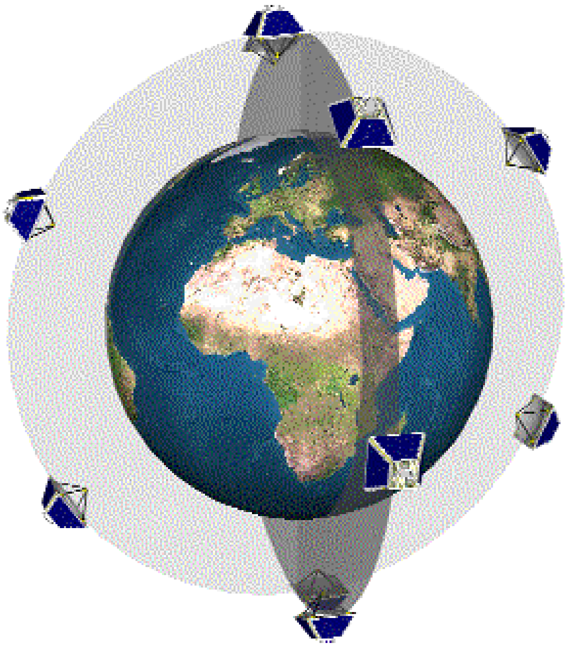
Constraints: Power

- 50-70W Orbit Average Power for 100kg spacecraft
- Approx 30-50W for payload



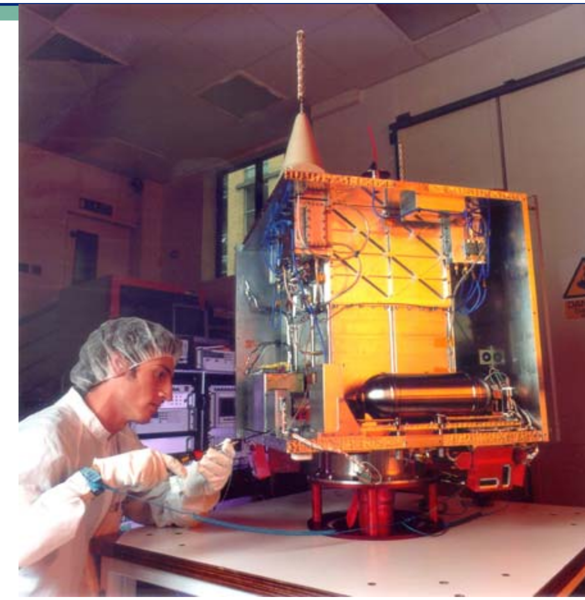
Constellation constraints

- Orbit control
- Navigation
- Launch



Constellation - constraints

- Orbit control system must be included
  - Modest delta-vee for
    - Launcher injection corrections
    - Constellation phasing
    - Constellation station keeping
    - De-commissioning
  - Multiple launches drives requirements
  - State-of-the-art solutions
    - Low thrust Cold gas, Hot gas
    - Resources:
      - 3kg for 10-50m/s
      - Volume!



Constellation - constraints

- NORAD navigation typically used
  - <100km error
- State-of-the-art is to use GPS (or equivalent) receiver
- E.g. SSTL SGR-20 for time and orbit determination
  - Total mean error 2.8 metres (1.5 m 1-sigma)
  - 3cm/s velocity (1-sigma)
- Resources
  - 1kg, 5W

Constellation constraints

- Design for launch
  - Several approaches
    - Dedicated vs shared
    - Segmentation vs Stacking
    - Single source, or multiple options

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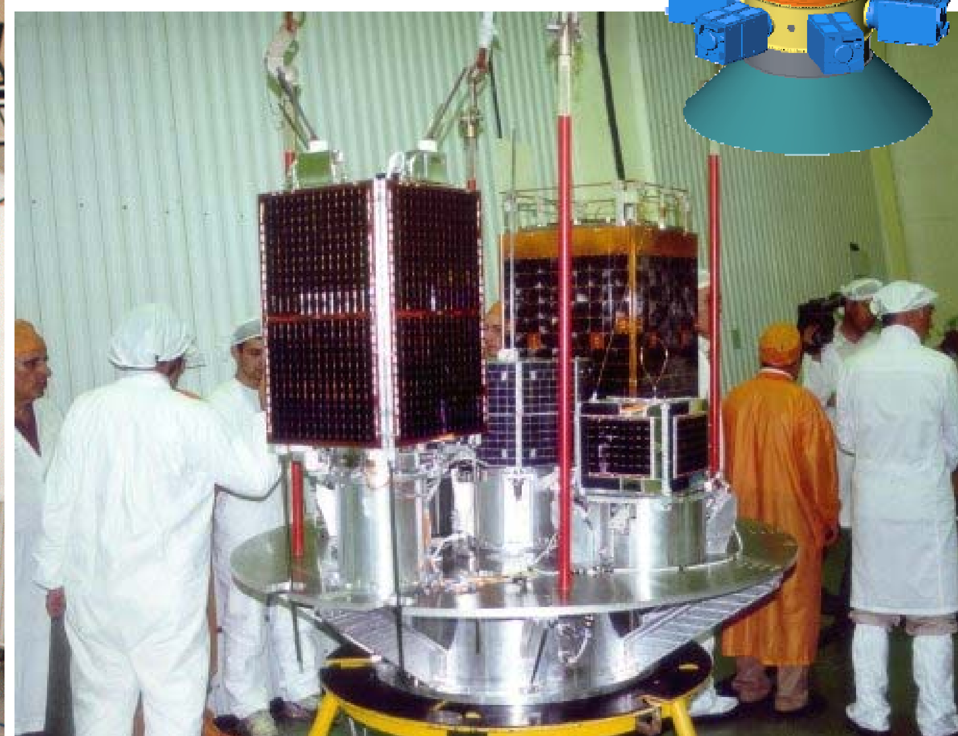
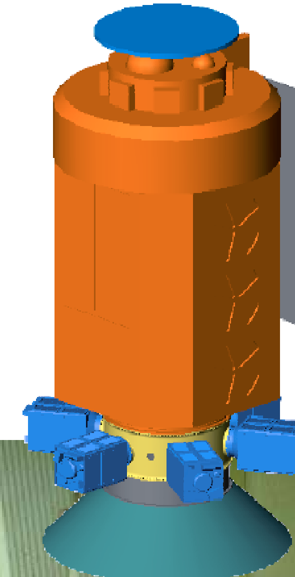
Constellation - design for launch

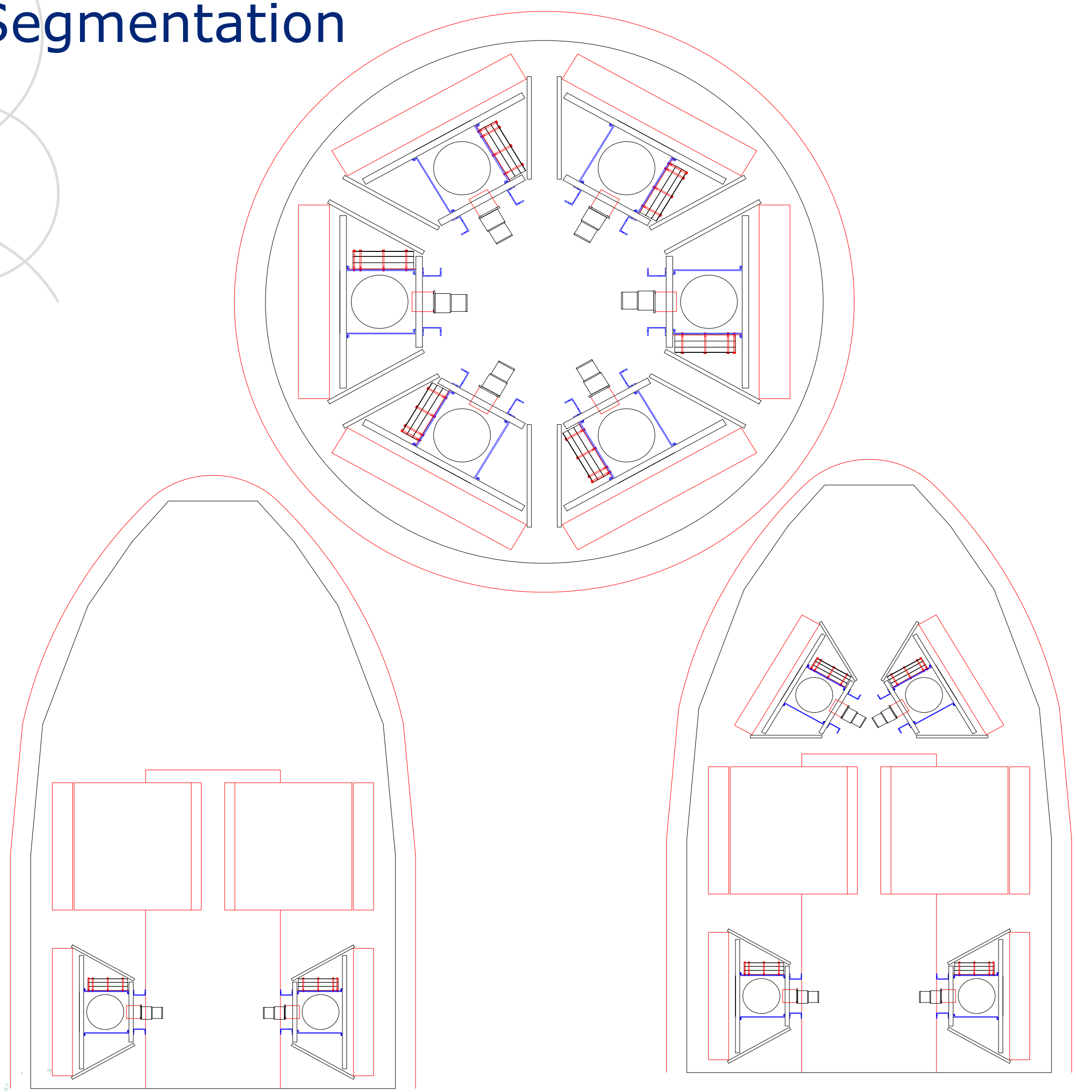
- Shared vs dedicated
  - Control over orbit and services

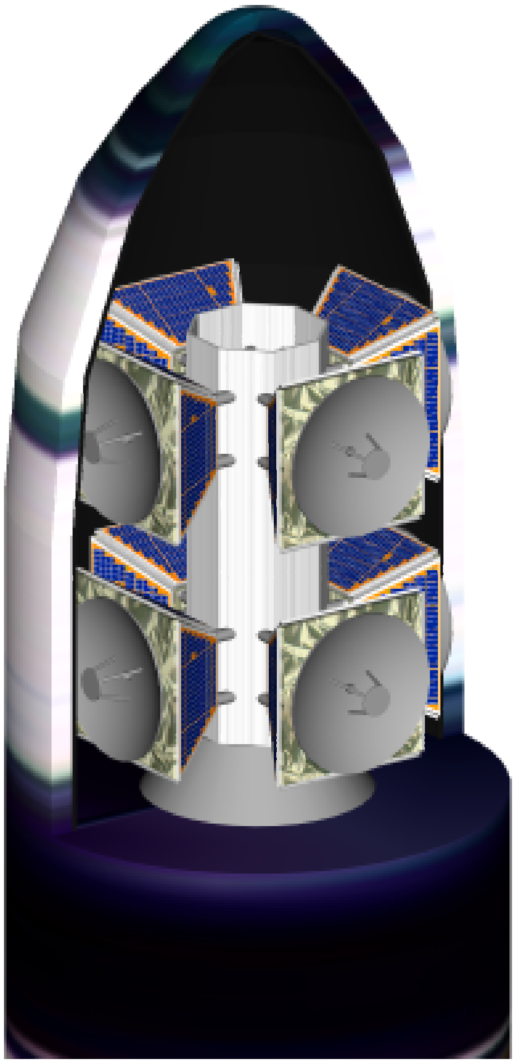




Constellation - design for launch

- Segmentation



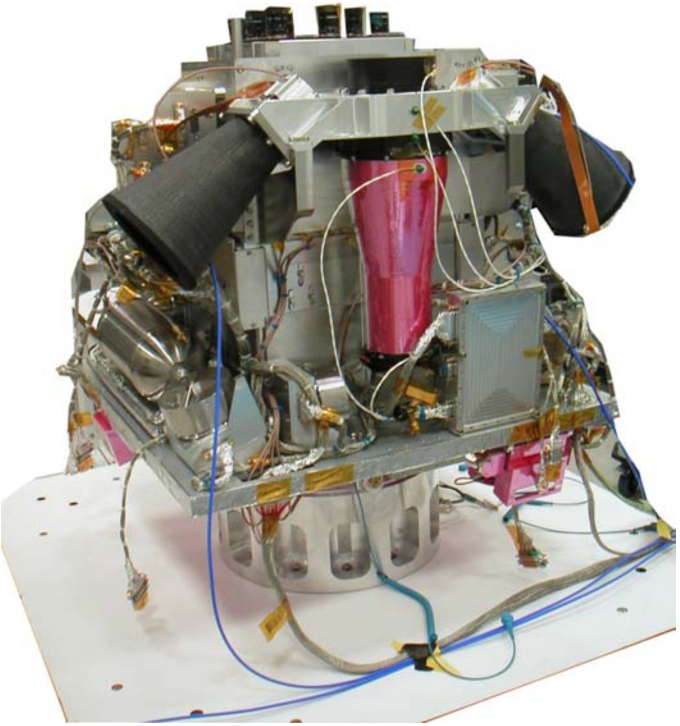


Attitude Control

- Momentum bias becoming common
- 3-axis control capability still rare
- Accurate sensors still large and expensive

- Stability often very good

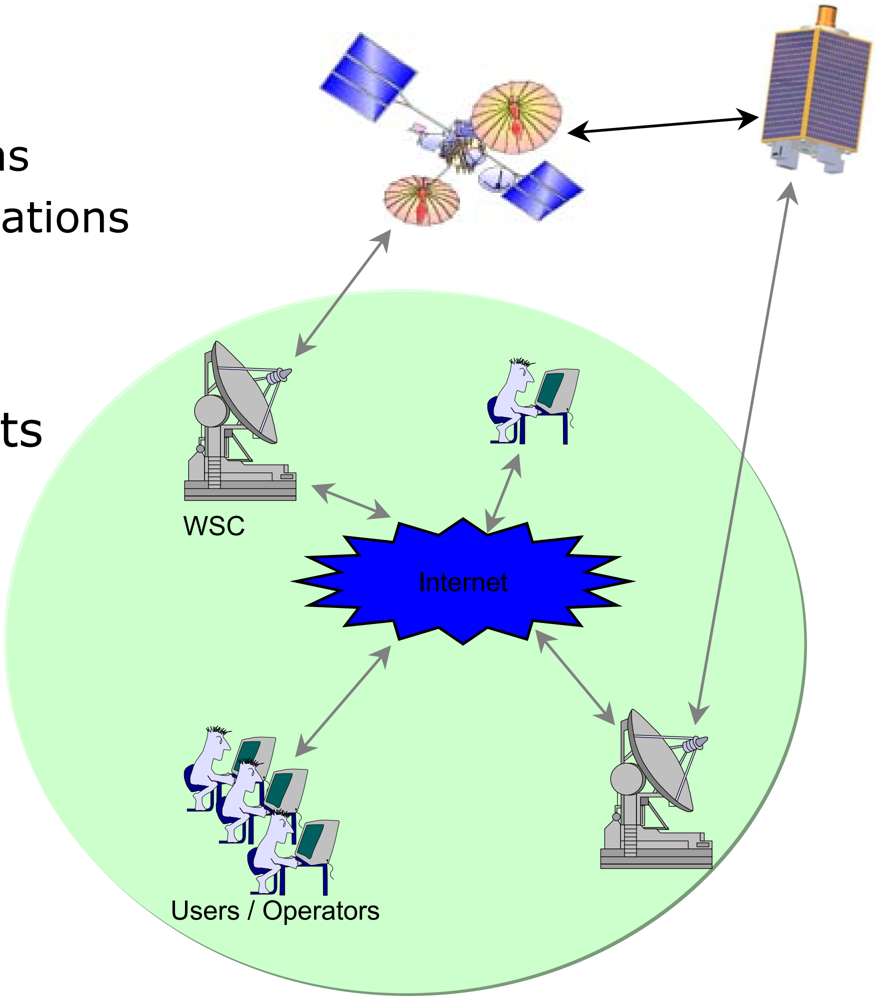
- E.g. for 0.1 degree absolute pointing
  - Earth sensors
  - Star cameras



BILSAT-1, with two star cameras

Small satellite CONOPS

- Ground networks
  - Typically low cost ground segment
    - Single station
  - Increasingly internet based
    - Networking of small stations
    - Compatibility with larger stations



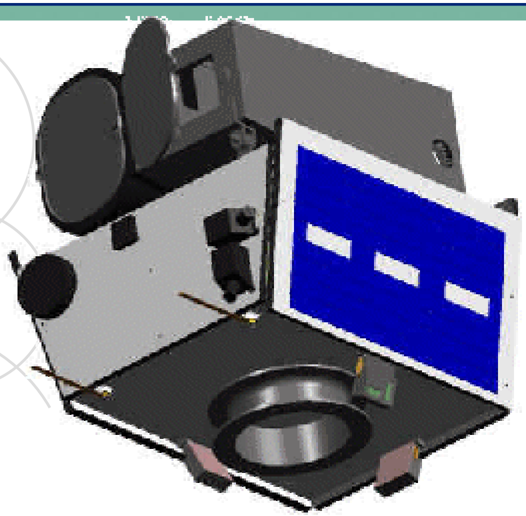
- Operations
  - Low cost operations concepts
  - High degree of autonomy

Con Ops

- Autonomous operation

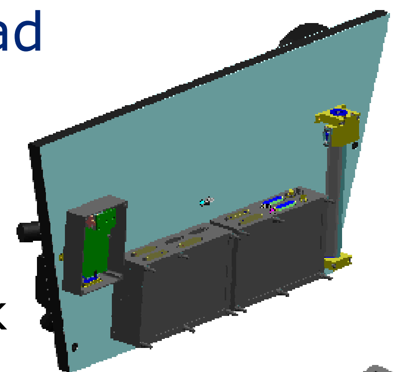
Surrey Mission Control Centre

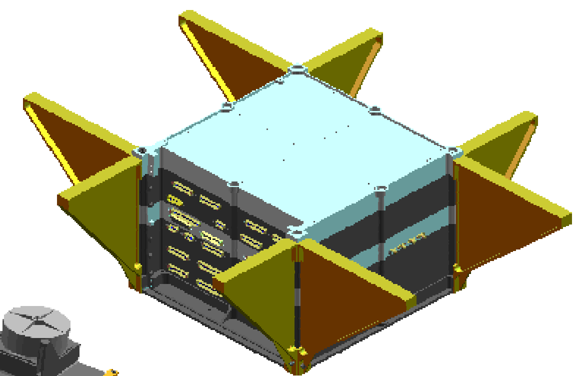
Example: TOPSat platform



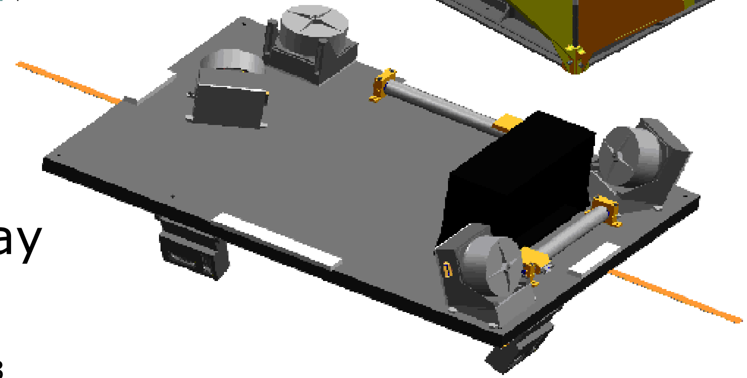
- SSTL TOPSat platform
  - 120 kg class polar orbit platform
  - Redundancy
  - Agile 3-axis control
  - SSTL Microsatellite heritage

- Externally provided payload
  - 41kg, 260litre
  - 2.5 m gsd camera
  - Data handling unit
  - 10 Mbps X-band downlink





- Trades have been made
  - TOPSat has intermittent operation
  - Target spec for only 1 scene/day
  - 1 year design lifetime



Outlook

- Mature small satellite technology ready for exploitation in constellations
  - Science missions
  - Commercial missions
- As technology progresses, small satellites will become the norm
- Improved payload services will rapidly evolve
  - Avionics miniaturisation
  - Advanced Attitude Control
  - Precision Orbit control

Conclusions

- Small satellite constraints in mass, power, volume and performances – cost saving remains major benefit

- Small satellites are improving in capability at a phenomenal rate due to advances in technology and ability to qualify new hardware rapidly

- The low cost engineering approach to small satellites makes many applications affordable and available at short notice – lower entry-cost and/or more missions for a fixed budget

- Small satellites are competing with big satellite for certain applications – but will not replace big satellites completely

- Constellations – 'killer app' of small satellites

- *"80% capability at 20% price"*


Thank you