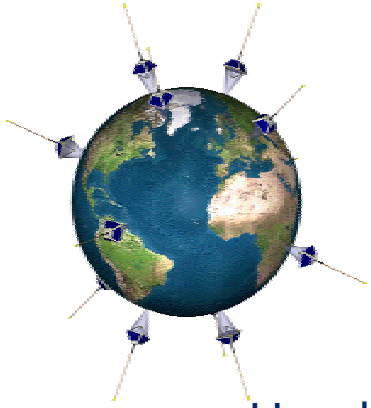
SURREY

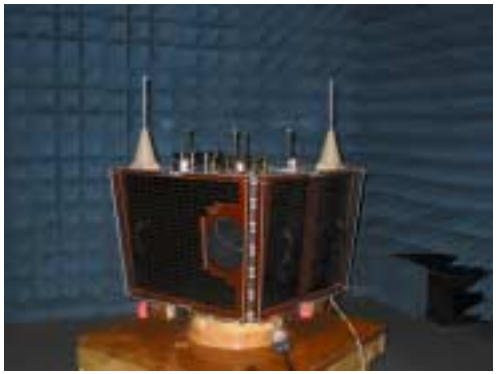
SATELLITE TECHNOLOGY LTD

Small Satellites in Constellation

Constraints



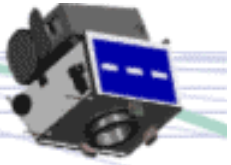
GAMBLE WORKSHOP



Alex da Silva Curiel

Head of Research and Development

Introduction



- Small Satellites
- Statement of constraints
- State of the art
- Outlook
- Conclusion

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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?

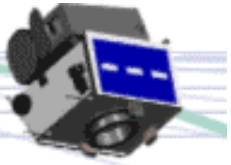
- Industry desire for:
  - Very cost-effective missions
  - Quick response missions
  - Very flexible/versatile missions
- Possible if there is an opportunity to
  - Change ways of working, or
  - Challenge the requirements, or
  - Accept higher risk

"80% performance for 20% cost"

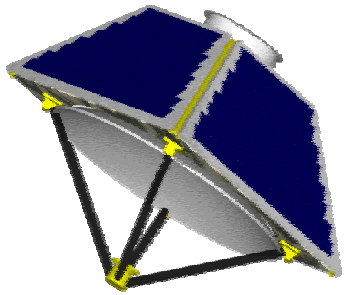
"Smaller, Faster, Better, Cheaper"

"Smarter"…..

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

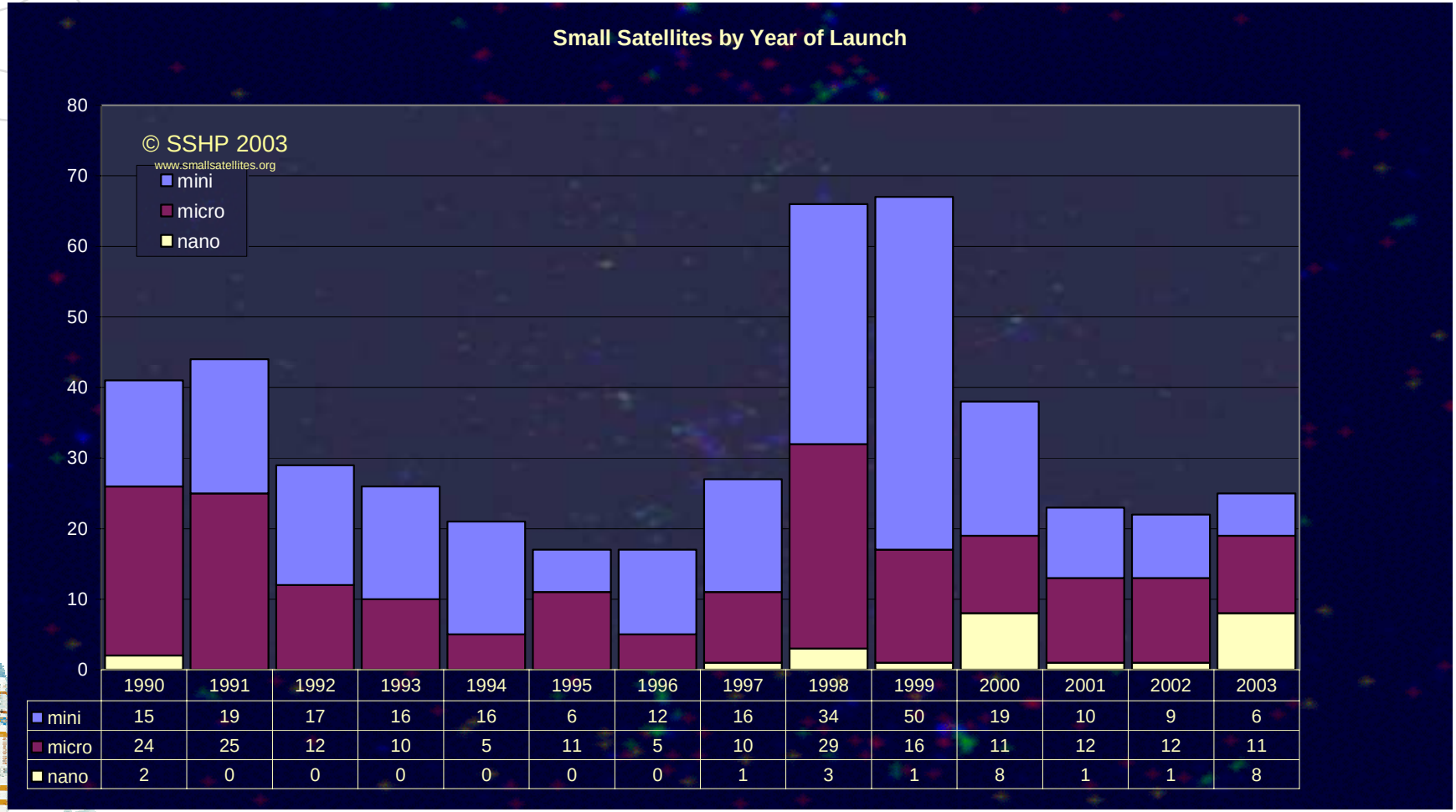


- Exploitation
  - Lowest cost of entry missions
  - In constellations

- For altimetry
  - Spatio-temporal resolution
    - Multiple deployments from small launcher
  - Low surface area
    - Low radiation pressure disturbances

Small Satellites launched

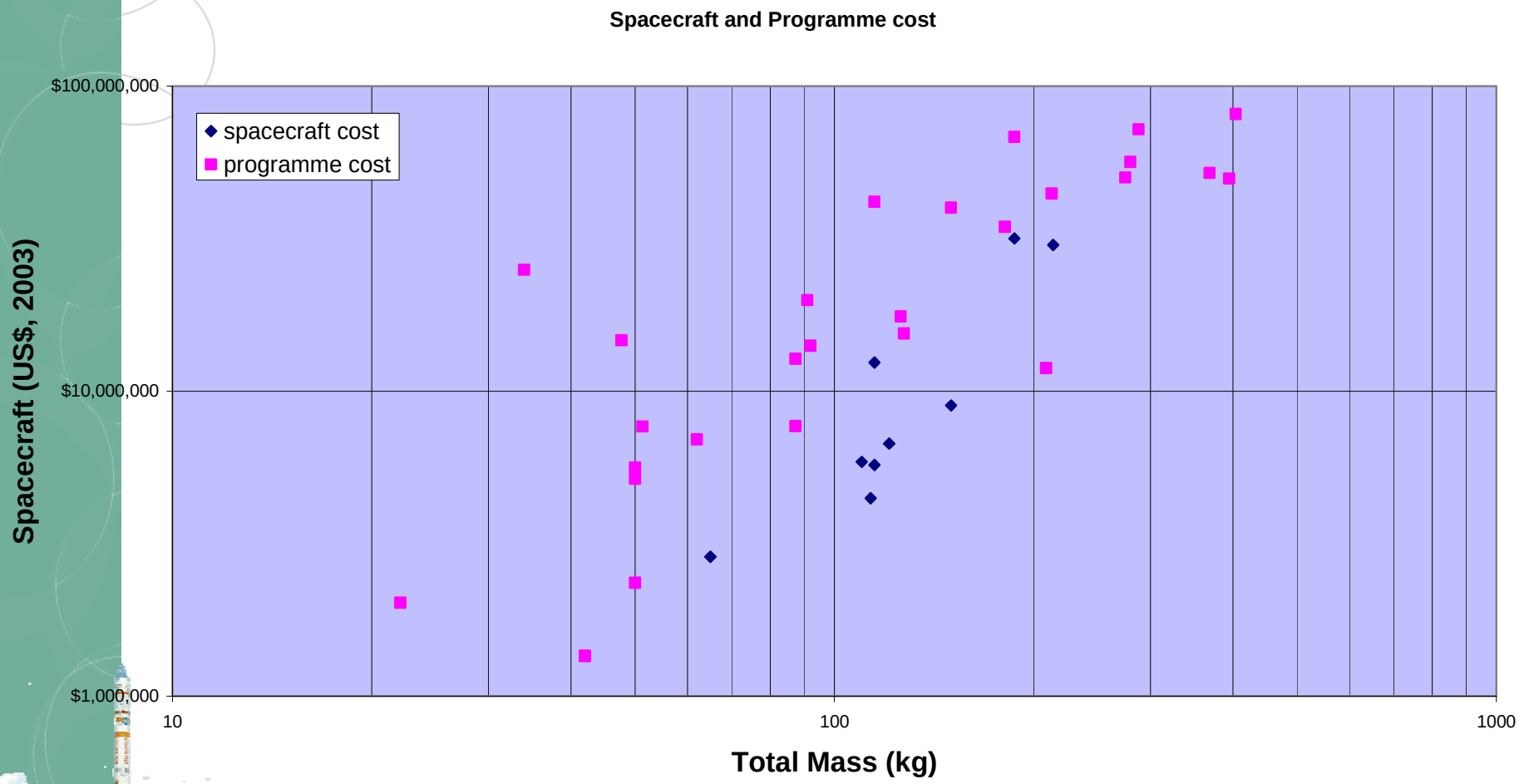
- Approx. 20-30/year



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
mini	15	19	17	16	16	6	12	16	34	50	19	10	9	6
micro	24	25	12	10	5	11	5	10	29	16	11	12	12	11
nano	2	0	0	0	0	0	0	1	3	1	8	1	1	8

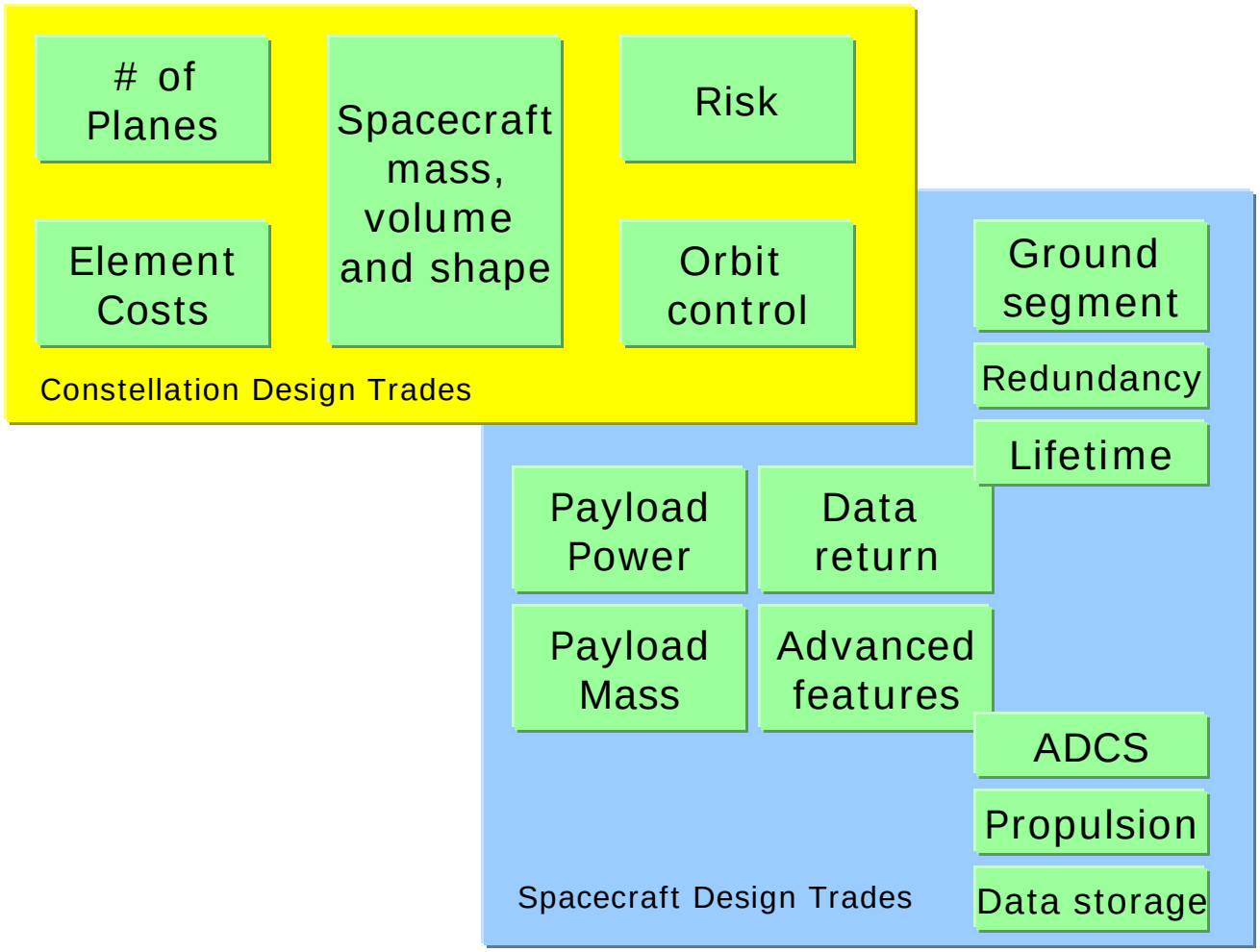
Is there a size and cost relationship?

- Providing conventional technology is used….



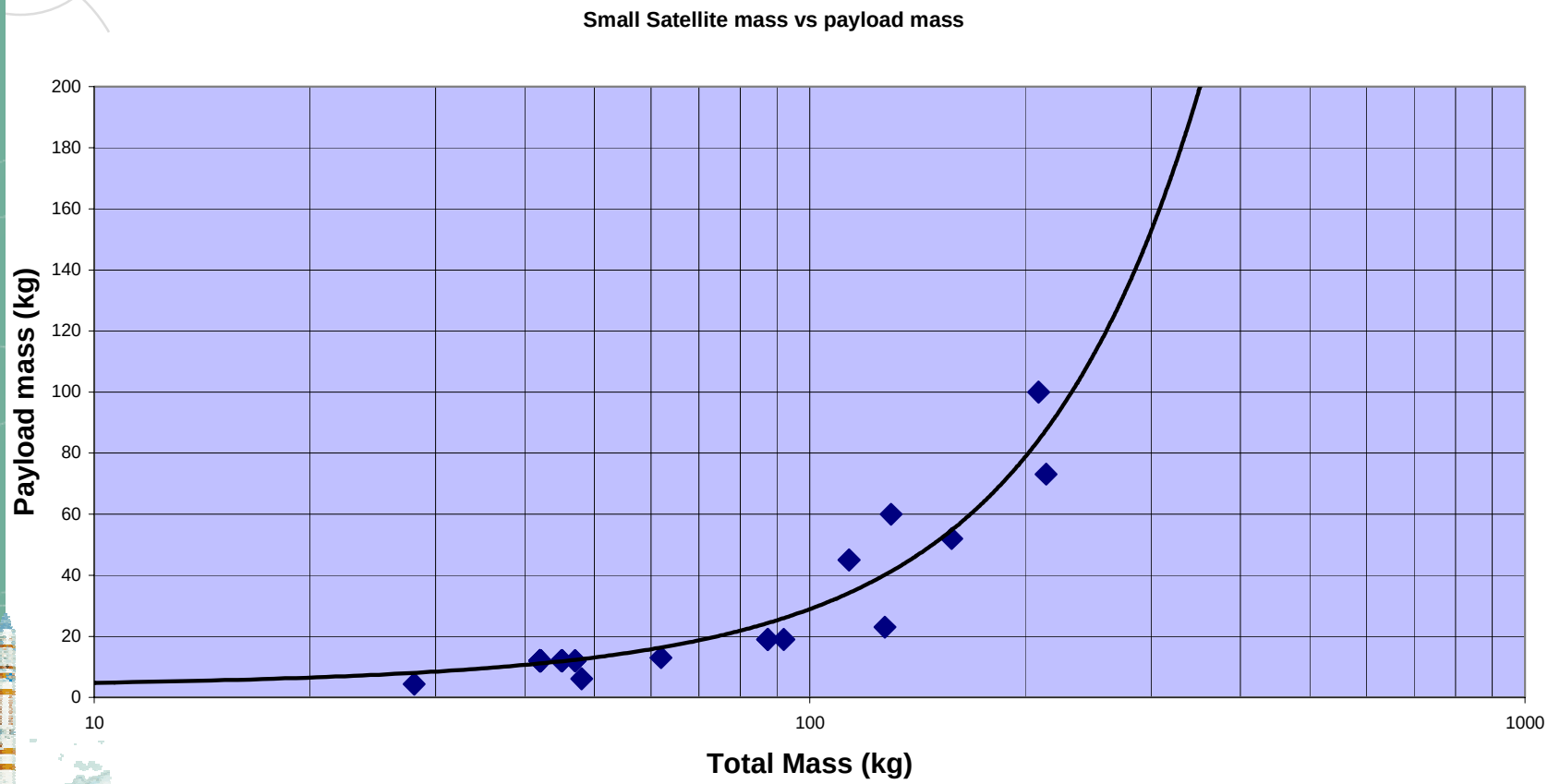
Small satellite constellations

- Small satellite philosophy is largely the careful investigation of trades that lead to cost / time-scale reductions:



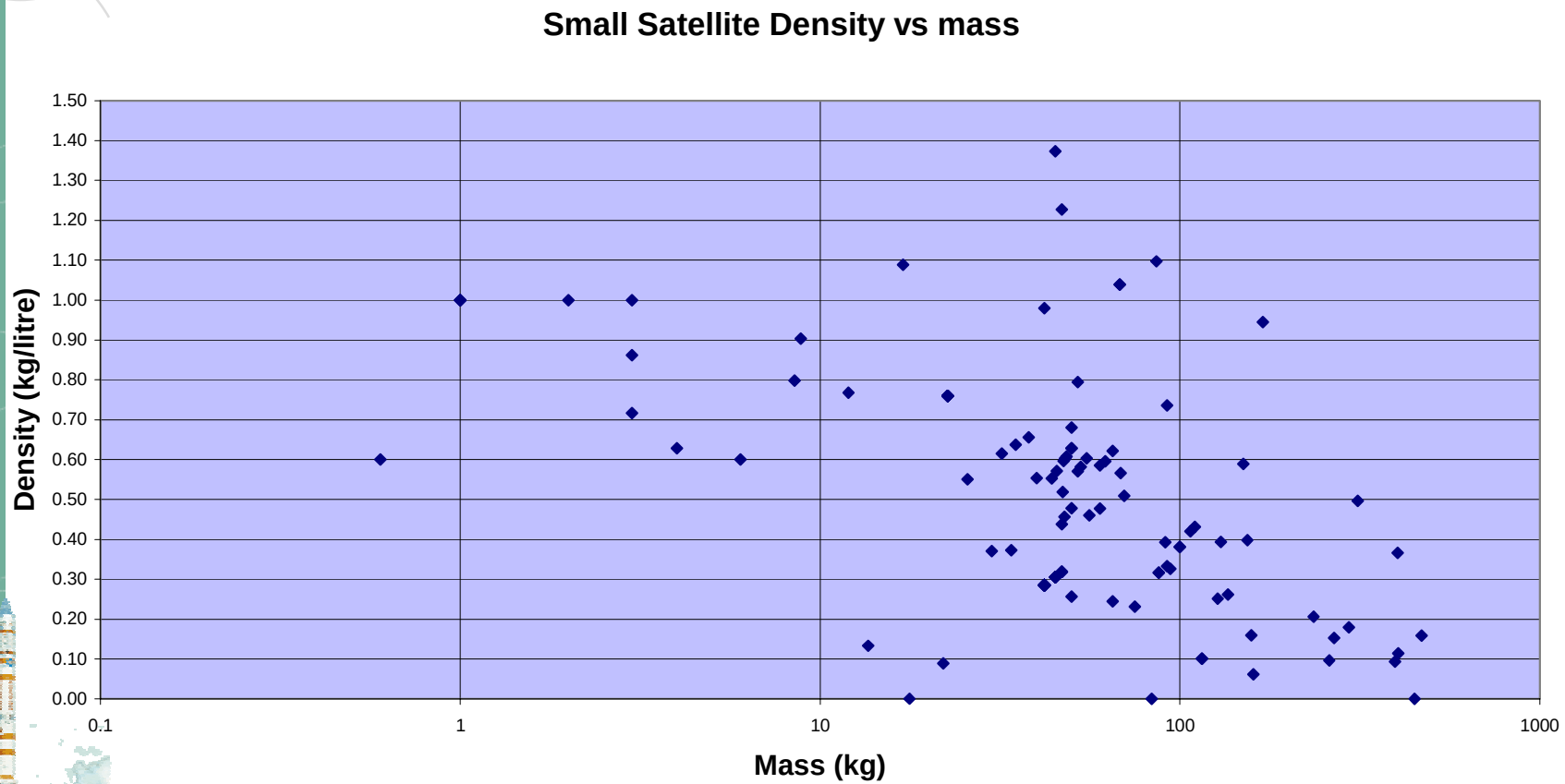
Constraints: Mass

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



Constraints: Density

- Small spacecraft are also likely to be more dense
  - Issues
    - EMC/EMI
    - Thermal

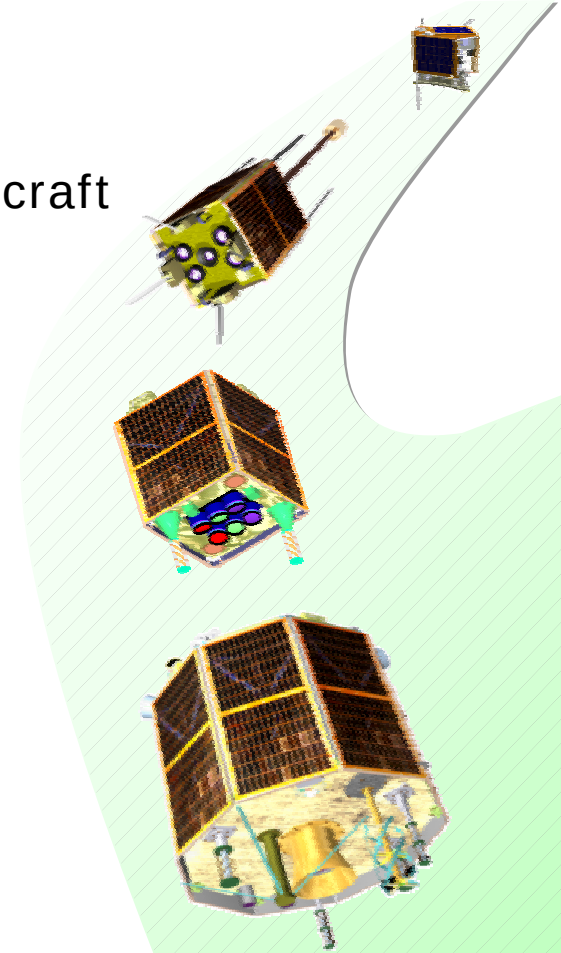


Constraints: Power

- 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

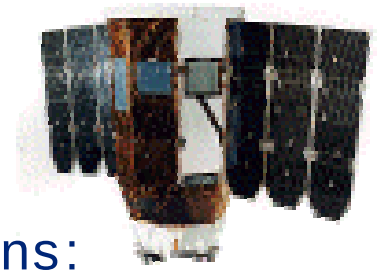
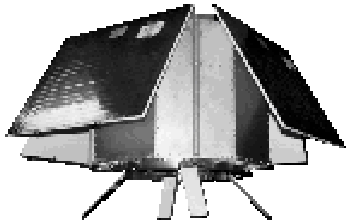
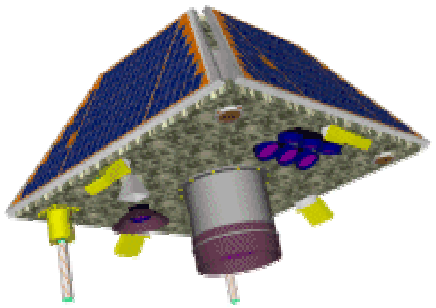
Fixed Deployed

Tracking



Constraints: Power

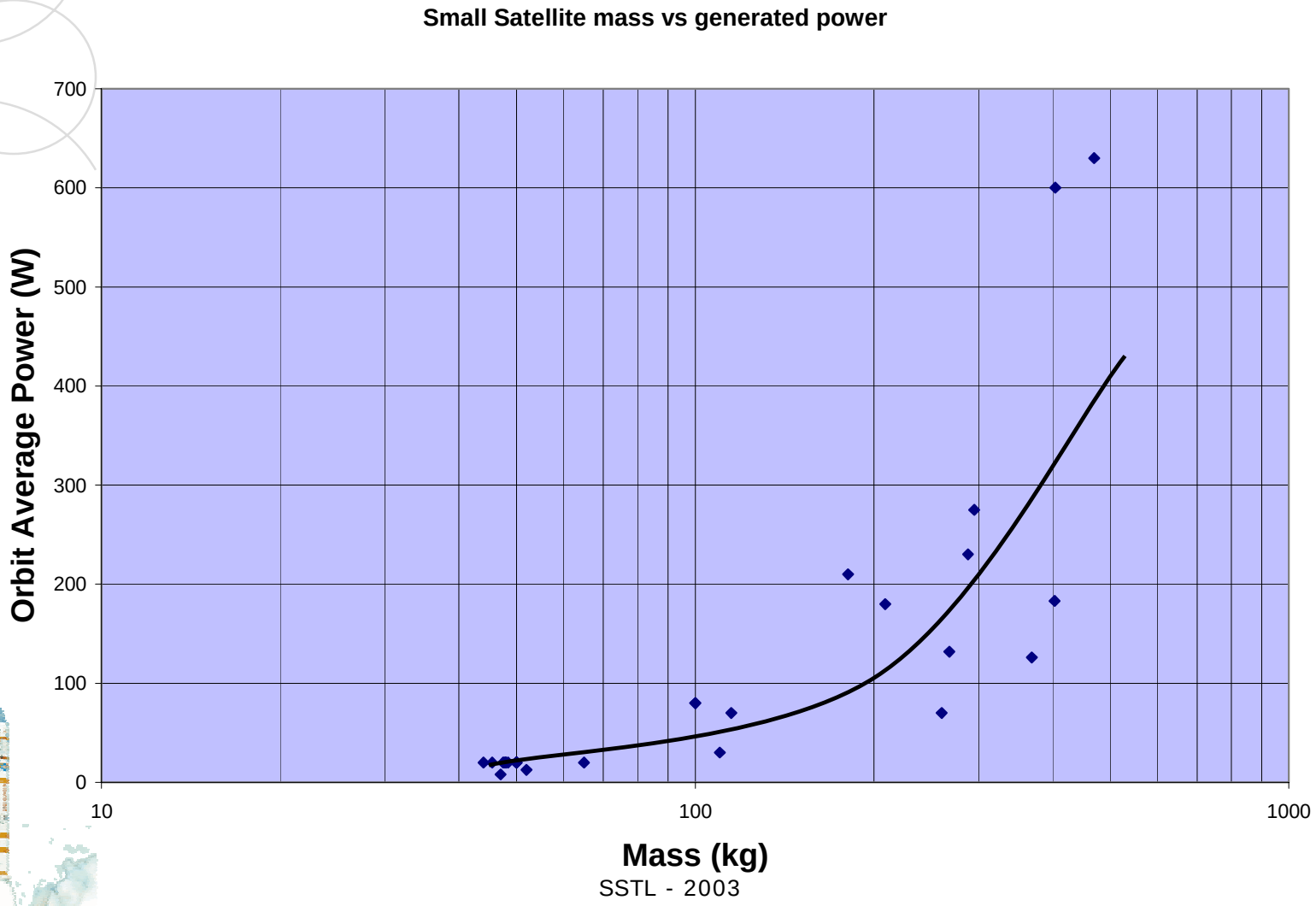
- Power demand does not naturally reduce with spacecraft size

- 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

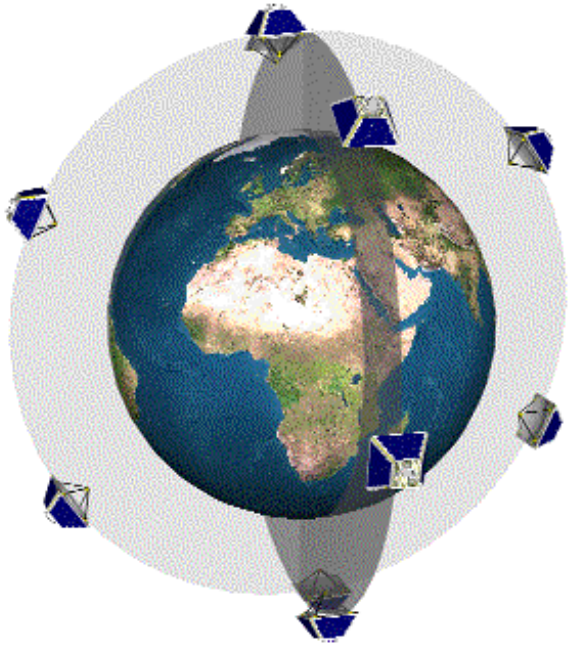
Constraints: Power

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



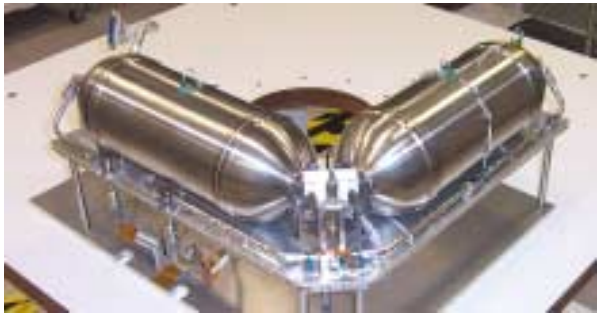
Constellation constraints

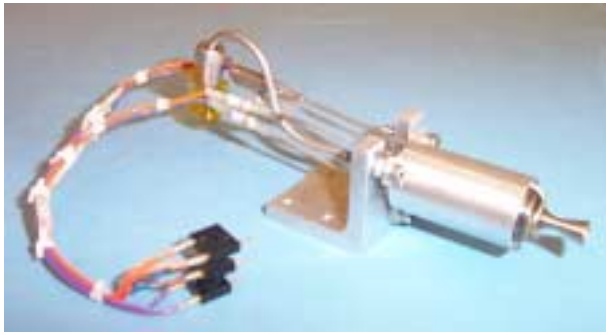
- Orbit control
- Navigation
- Launch



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
  - Prop system drives ADCS system requirements
  - State-of-the-art solutions
    - Low thrust Cold gas, Hot gas
    - Resources:
      - 3kg for 10-50m/s
      - Volume!

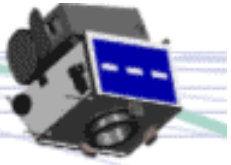




Constellation - constraints

- 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)
- PPS available
  - PPS edge within 1µs from GPS second (internal to GPS unit)
  - Spacecraft timing within 100 µs from UTC
  - RS422 signal to spacecraft
- Resources
  - 1kg, 5W

Constellation constraints



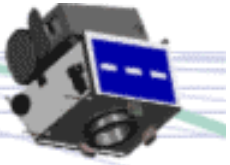
- Design for launch
  - Several approaches
    - Dedicated vs shared
    - Segmentation vs Stacking
    - Single source, or multiple options

Launcher driven requirements

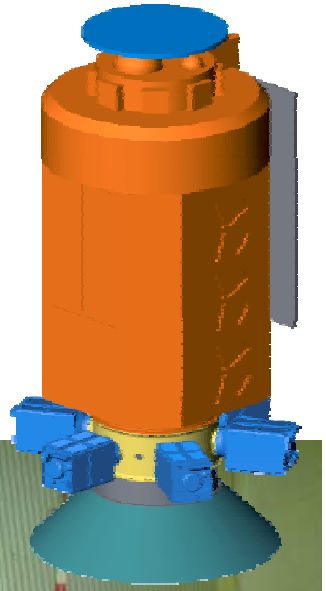
Volume and size constraints set by launch

DELTA ARIANE TSYKLON ZENIT SS18/Dnepr COSMOS ATHENA

Constellation - design for launch

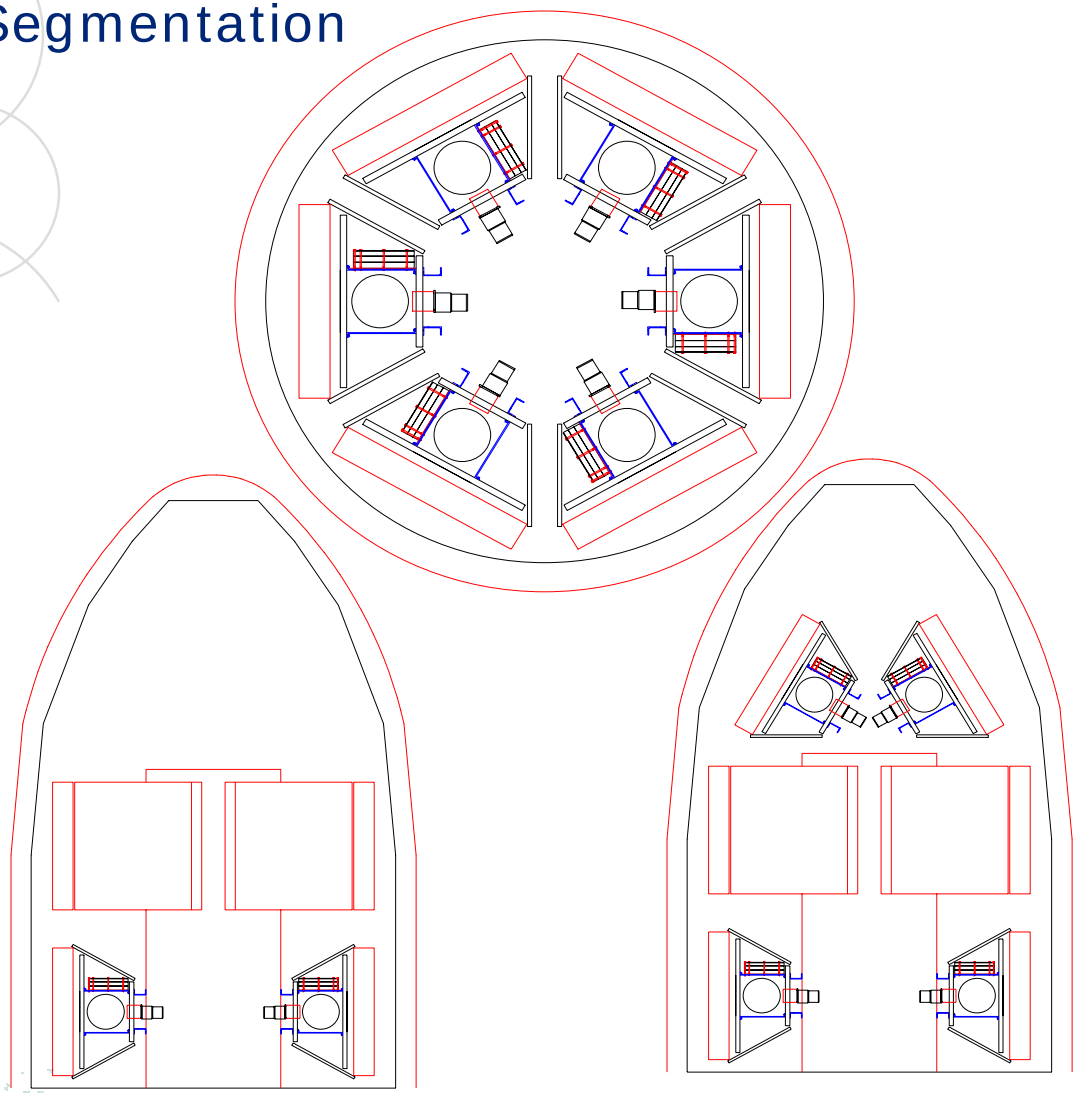


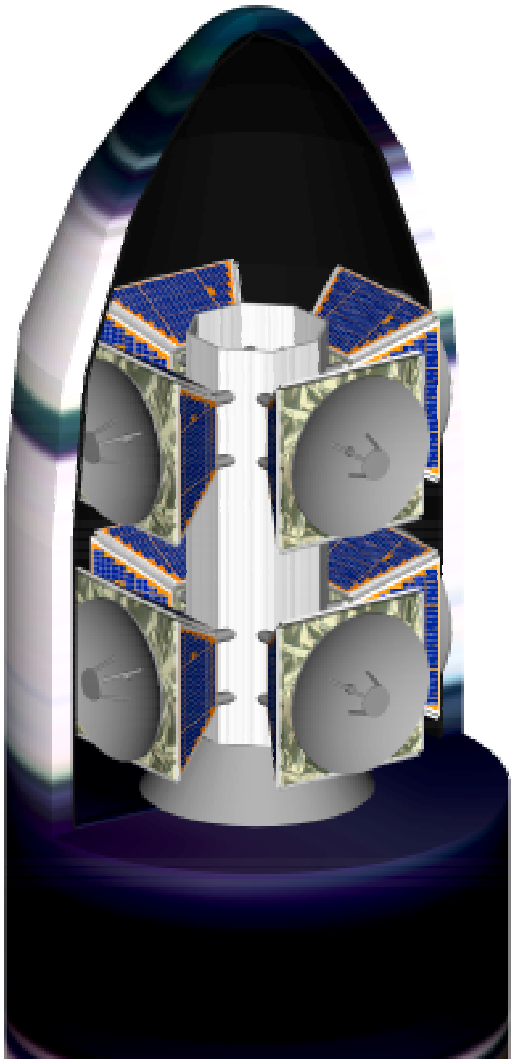
- Shared vs dedicated
  - Control over orbit and services



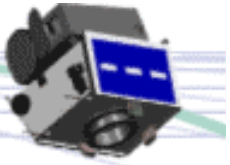
Constellation - design for launch

- Segmentation

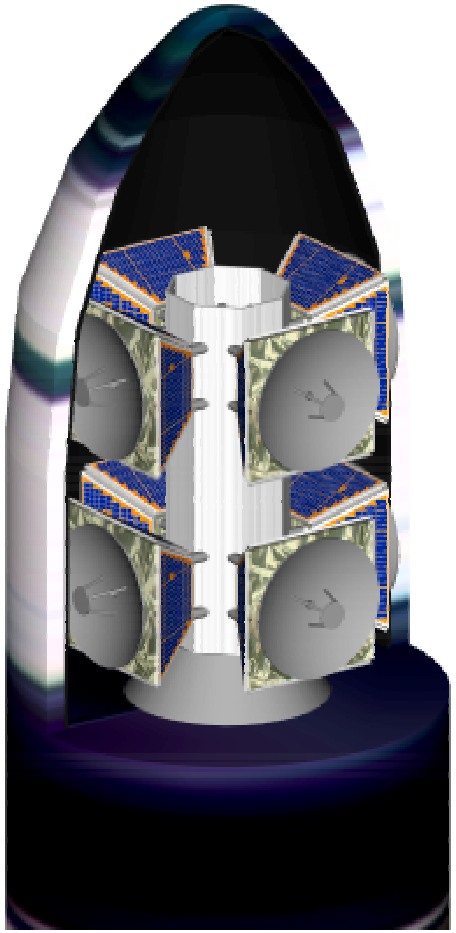




Constellation - design for launch



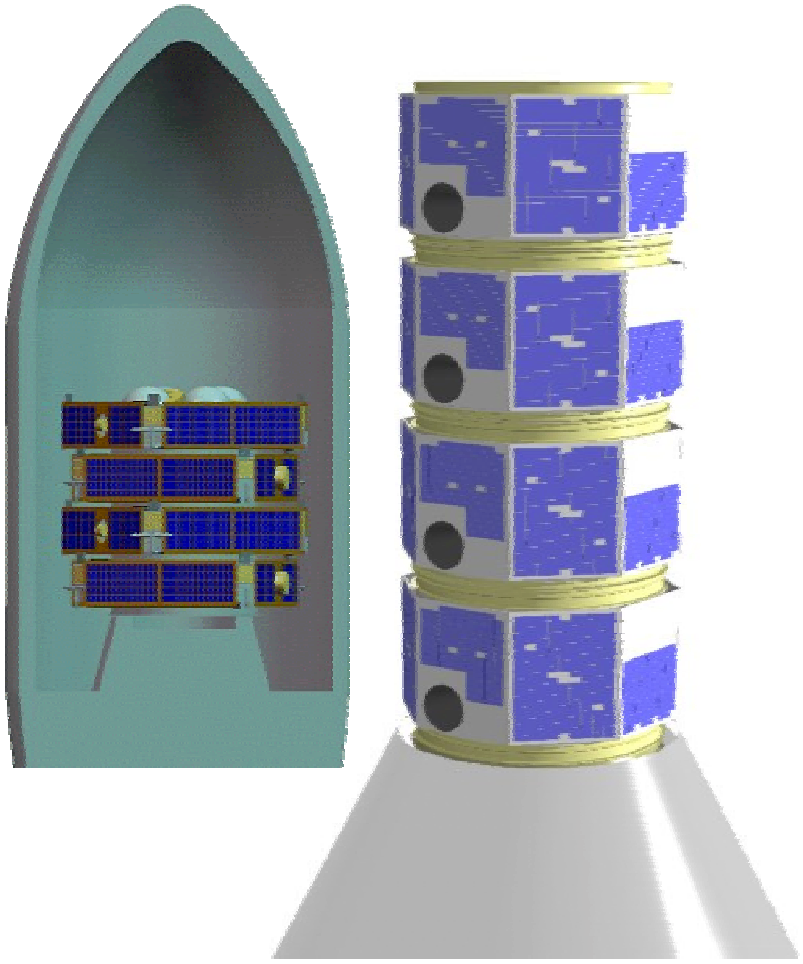
- Needs mission specific support structure
- Allows for spacecraft appendages



Constellation - design for launch

- Stacked
  - Efficient packing
  - Limited scope for appendages

ORBITAL stack



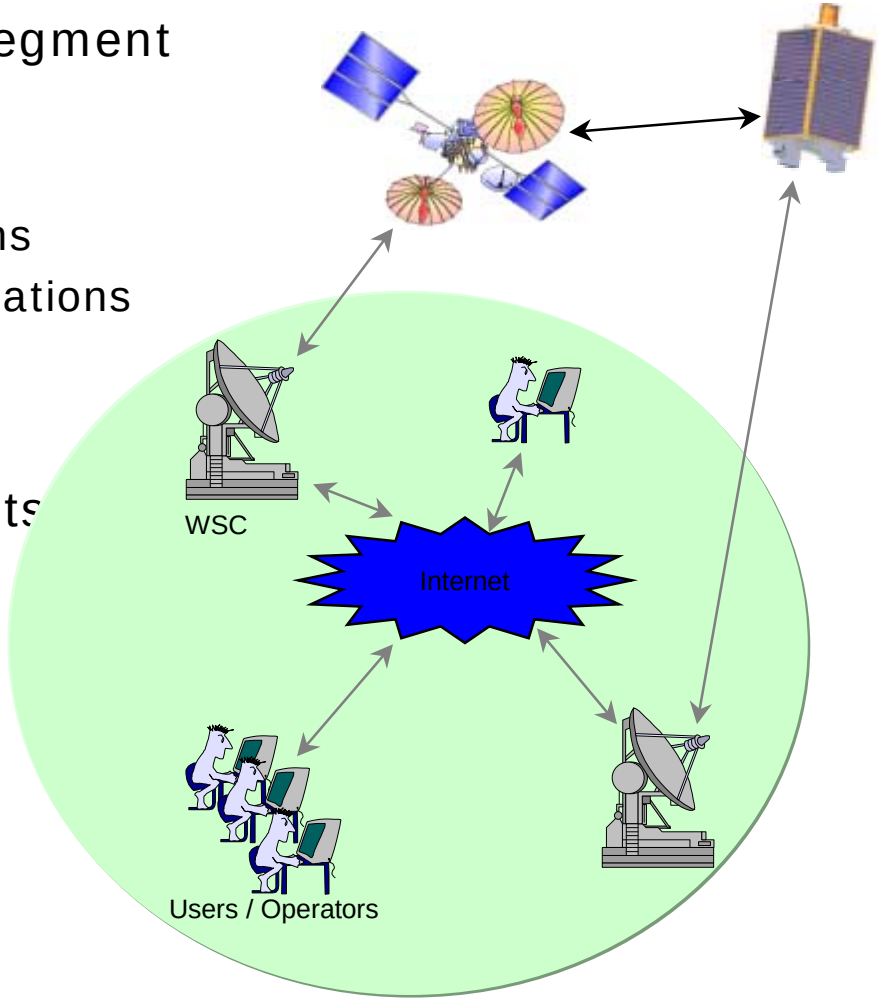
Attitude Control

- Momentum bias becoming common
- 3-axis control capability still rare
- Accurate sensors still large and exper
- Stability often very good
- Disturbance torques important
  - E.g. high power payloads
- E.g. for 0.1 degree absolute pointing
  - Earth sensors
  - Star cameras

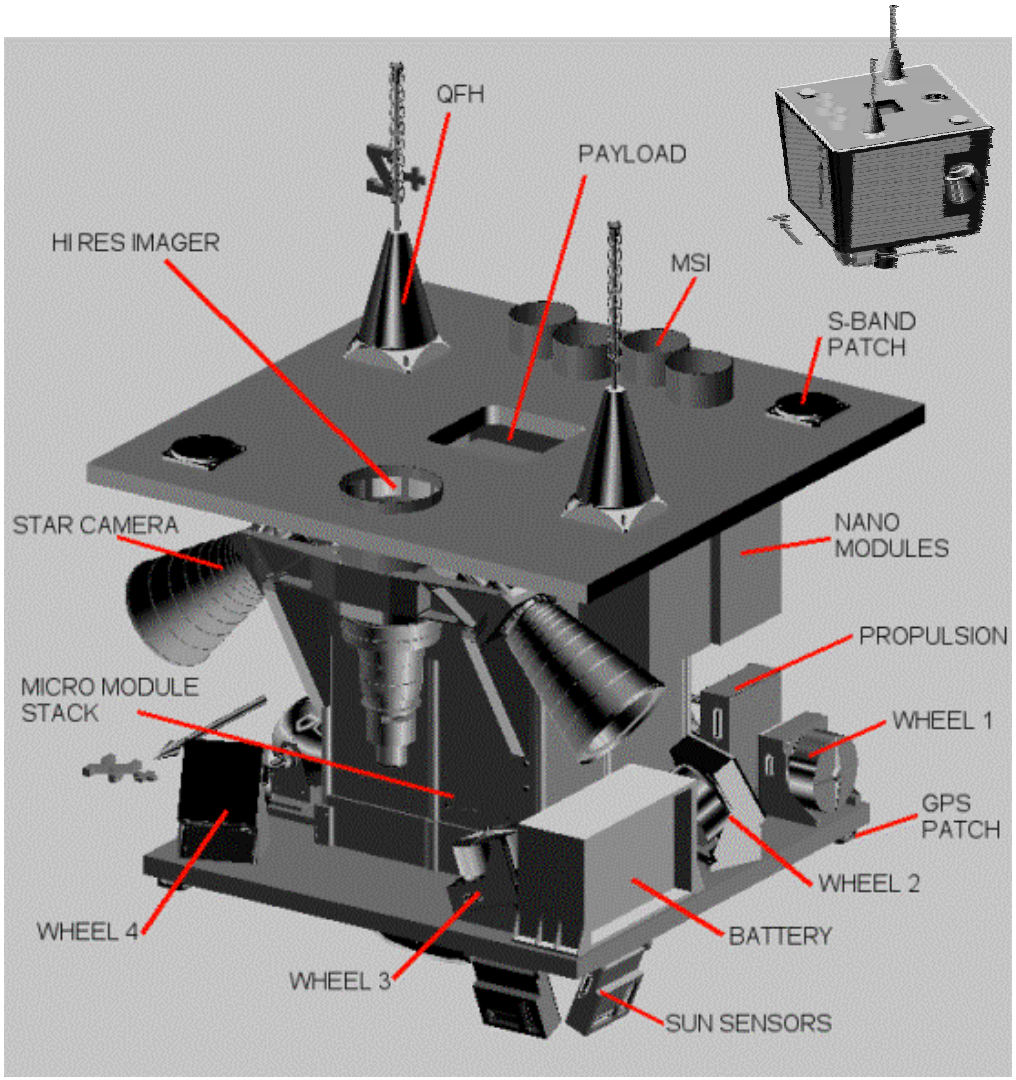
BILSAT-1, with two star cameras

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



Example: BILSAT



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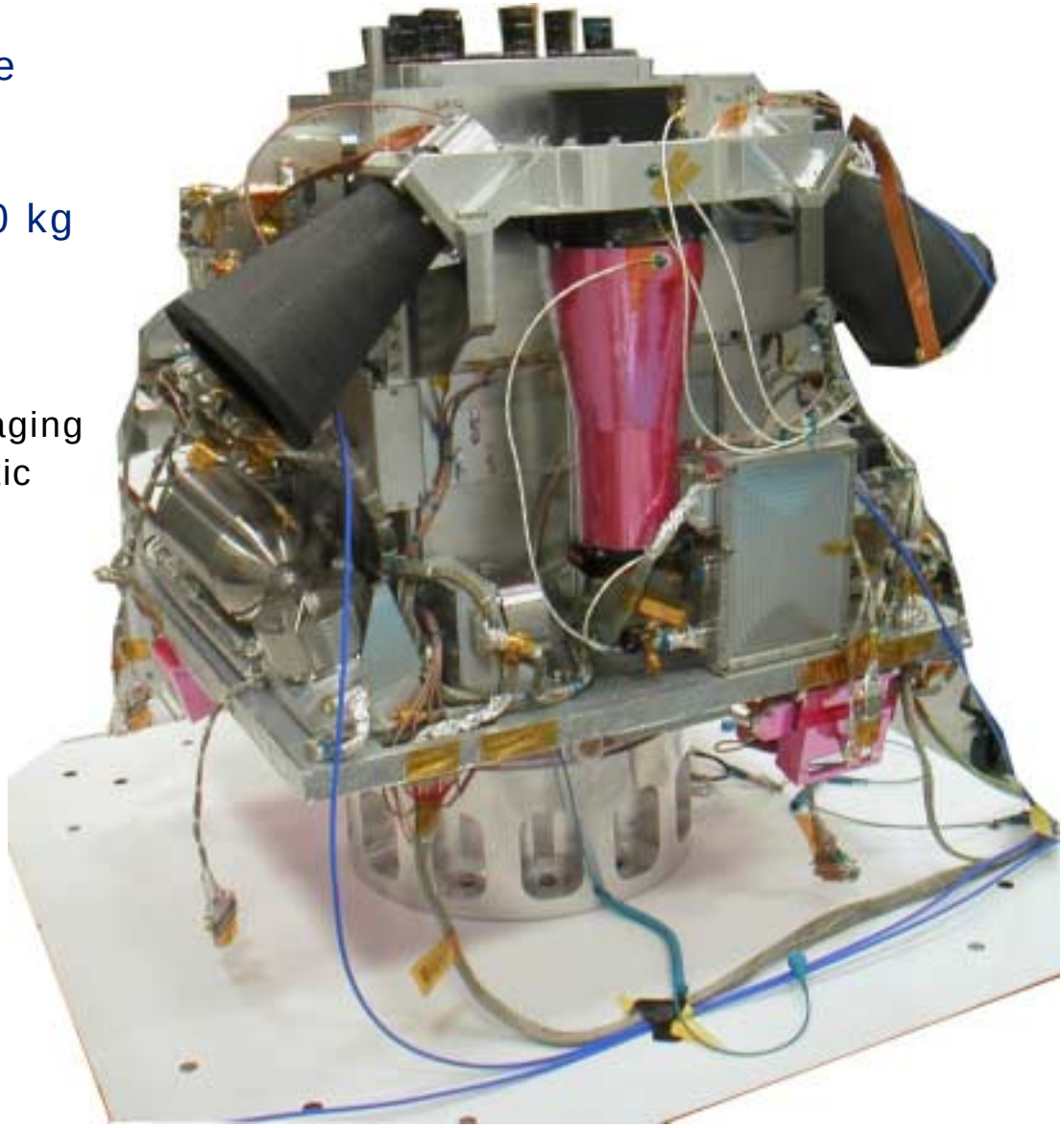
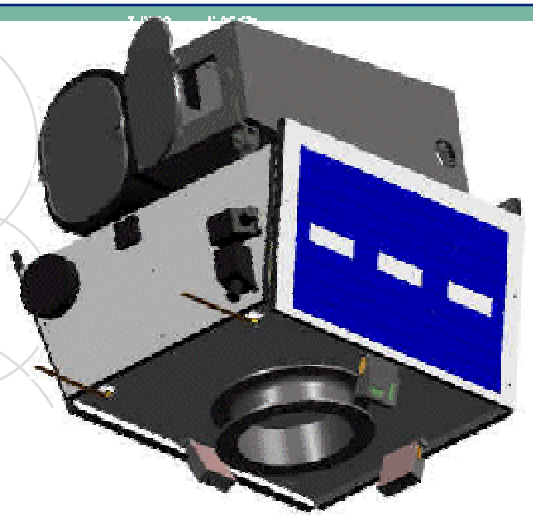
Example: BILSAT-1 (DMC)

- For Turkish research institute (BILTEN)
- Enhanced microsatellite: 120 kg
  - 23kg payload, 70W OAP
- Payloads
  - 26 m resolution, 4-band imaging
  - 12 m resolution panchromatic imaging
- 5-year design life
  - With orbit station keeping
- 3-axis ADCS with agility
  - Dual star sensors
  - 4 x reaction wheels
  - CMG cluster
- Launched Sep 2003
  - Cosmos LV from Plesetsk

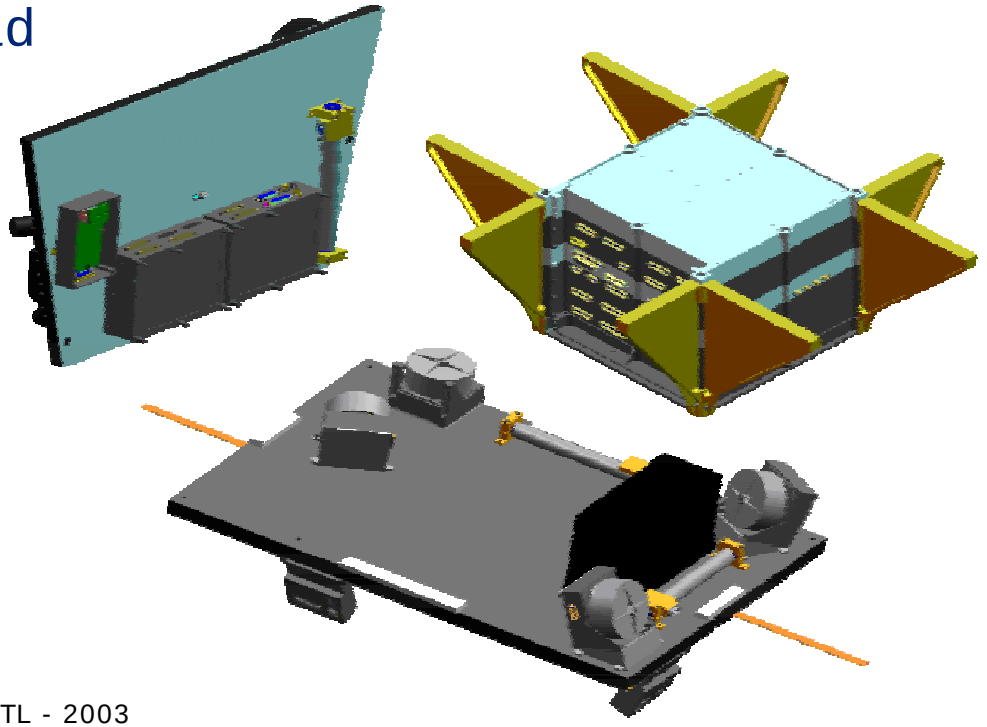


Example: TOPSat platform



- 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 only 1 scene/day
  - 1 year design lifetime

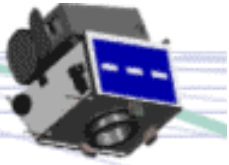


Con Ops

- Autonomous operation

Surrey Mission Control Centre

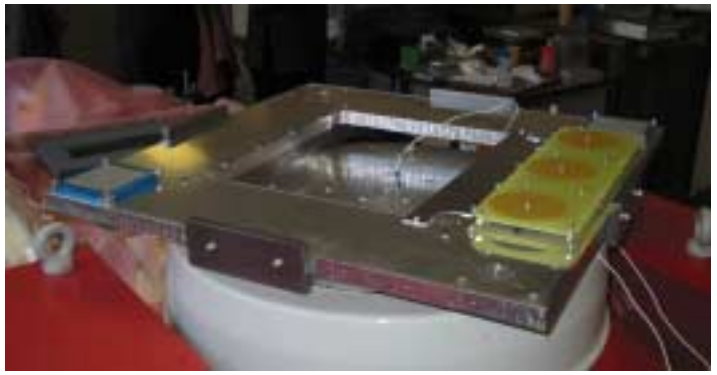
Outlook



- 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

Research - Advanced methods

- Research
  - GPS reflectometry experiment on UK-DMC
  - Demonstrate the possibility of using GPS **reflectometry** to measure wave heights
  - High gain GPS antenna, nadir pointing
  - Funded by SSTL
  - Launched 27Sep2003
  - PI: Scott Gleason S.Gleason@sstl.co.uk



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