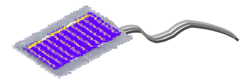
SURREY SATELLITE TECHNOLOGY LTD

Towards Spacecraft-on-a-Chip



Alex da Silva Curiel,
Phil Davies, Adam Baker
SSTL

Dr Craig Underwood, Dr Tanya Vladimirova
Surrey Space Centre

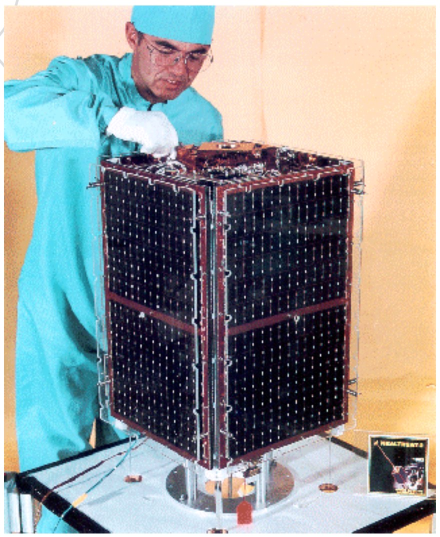
Introduction

- Surrey miniaturised spacecraft programme
  - Role of Micro and Nano technologies in this work
  - Role of ultra-small spacecraft in micro-nano-technology development

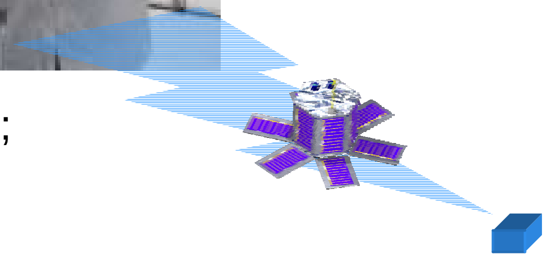
- SNAP-1 mission (2000)
- PalmSat development work
- ChipSat development work

Satellite Evolution

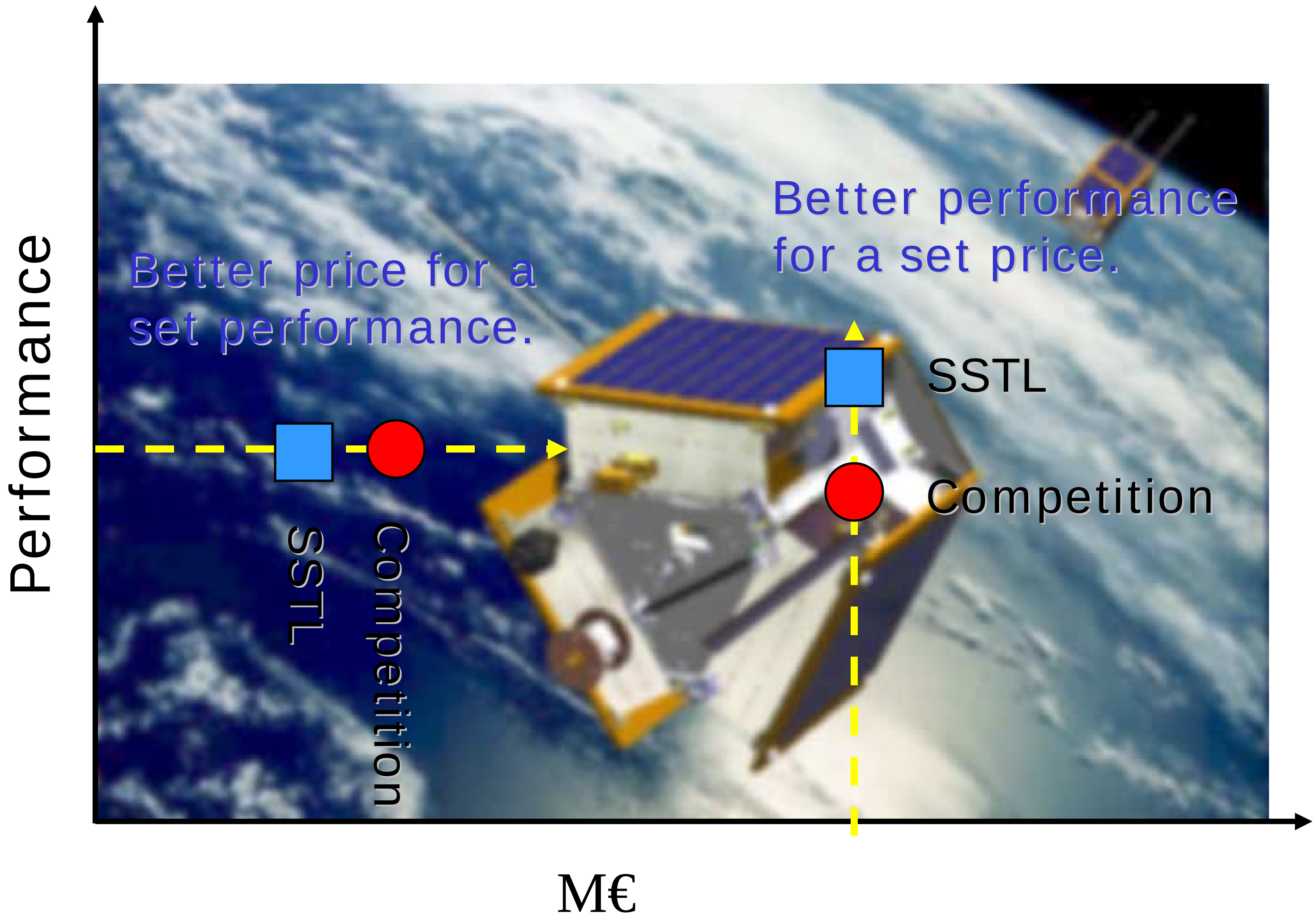
- Standard and small satellites:
  - Standard - 500 kilograms or more;
  - Mini-satellites - 100 to 1,000 kilogram;
  - Micro-satellites - 10 to 100 kilograms;



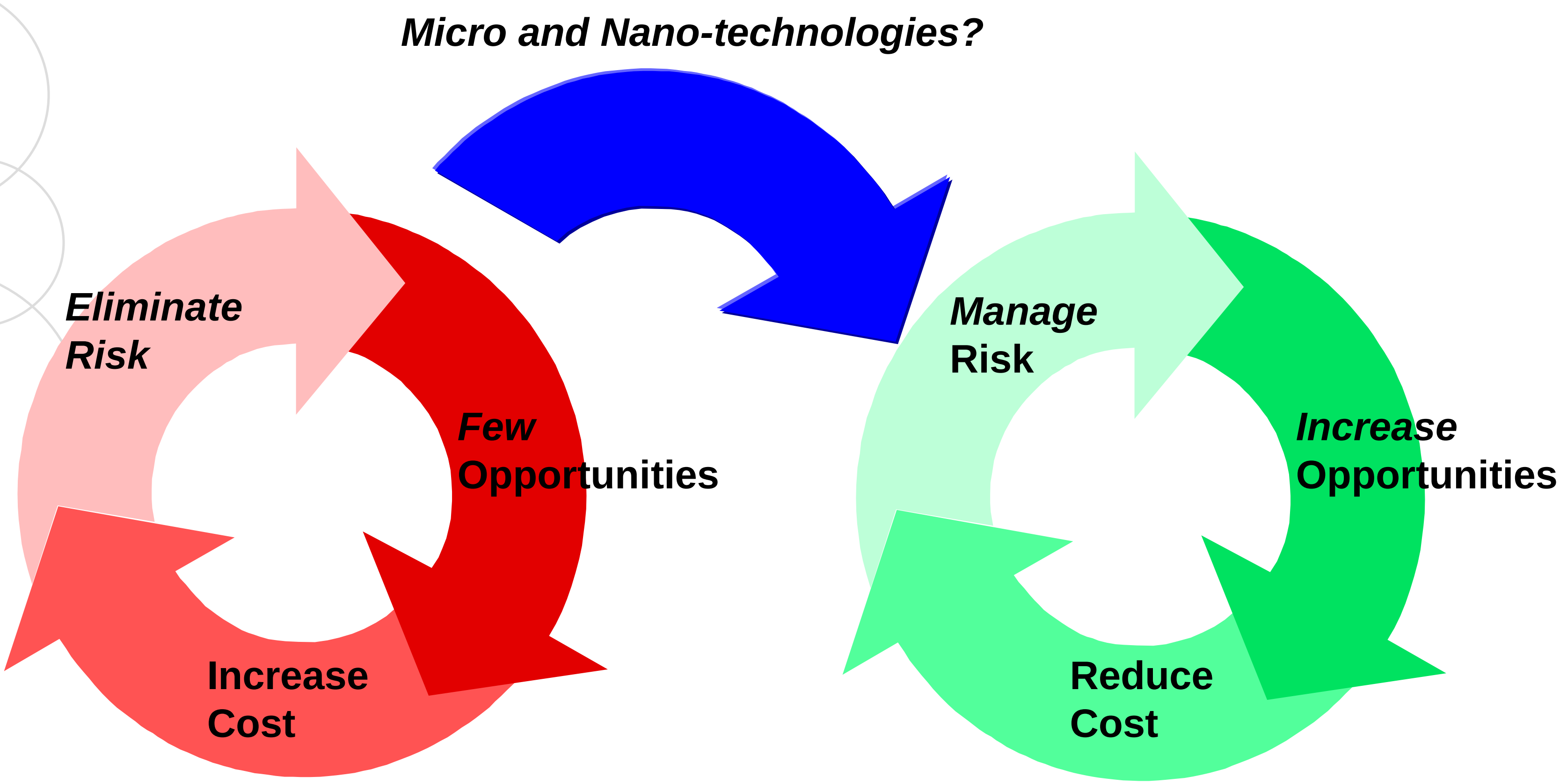
- Ultra small satellites:
  - Nano-satellites - 1 to 10 kilograms;
  - Pico-satellites - <1 kilogram;
  - Femto-satellites - <0.1 kilogram.



What SSTL aims to offer



SSTL Recreates Space



Vicious circle?

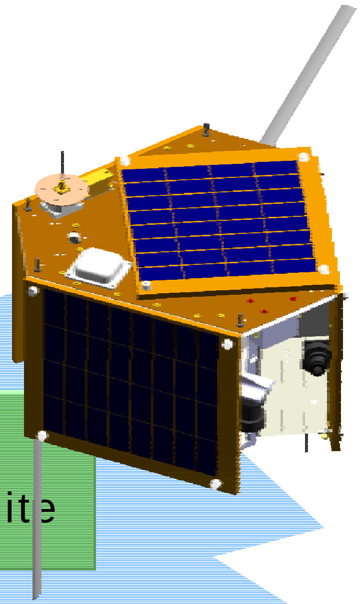
Virtuous Circle!

SSTL's preferred model !

SSTL miniature spacecraft roadmap

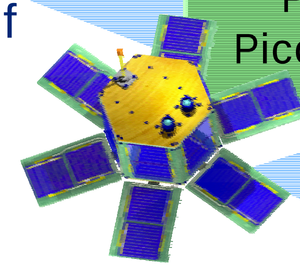
Micro-System Technology products have a number of distinguishing attributes:

- suitability for low cost, high volume production
- reduced size, mass and power consumption
- high functionality
- improved reliability and robustness



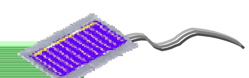
SNAP
Nano-satellite

COTS allows a steady pace of miniaturisation towards pico-satellites



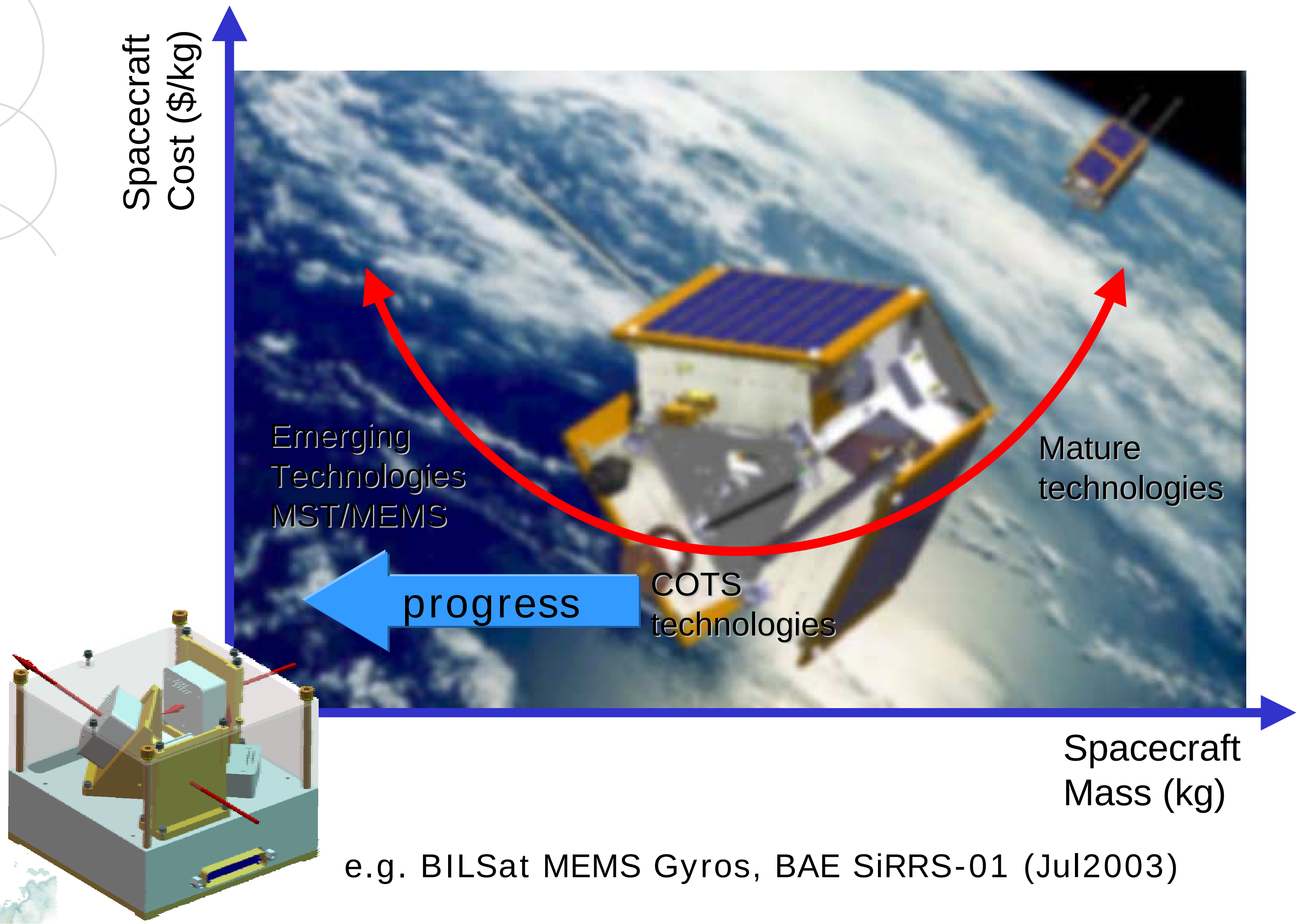
PalmSat
Pico-satellite

Leading towards integrated satellites “Spacecraft-on-a-chip”



ChipSat
Femto-satellite

Cost benefit of minisaturisation



e.g. BILSat MEMS Gyros, BAE SiRRS-01 (Jul2003)

Applications of miniature spacecraft

- At present - to serve as a platform for testing miniature technologies and techniques.
  - E.g. Micro Systems Technology validation and space qualification
- Educational applications – as cost effective tools to develop an experienced workforce
- Scientific applications - agricultural, mineral, and water resources could be mapped and monitored continuously. Space weather applications.
- Military applications - swarms of such satellites, launched together on single, inexpensive rockets, could communicate with sensors on a battlefield and convey important surveillance and tactical information.
- Disposable spacecraft
- Remote inspection

Nano/Pico-Satellites

- SNAP-1 is the UK's first nano-satellite.
  - Designed and constructed by SSC staff and students and SSTL engineers. Funded by SSTL as an R&D Project.
  - SNAP-1 design begun in earnest in October 1999.
  - Spacecraft delivered in May 2000.
  - Launched June 28th 2000 – 9 months design-to-orbit.

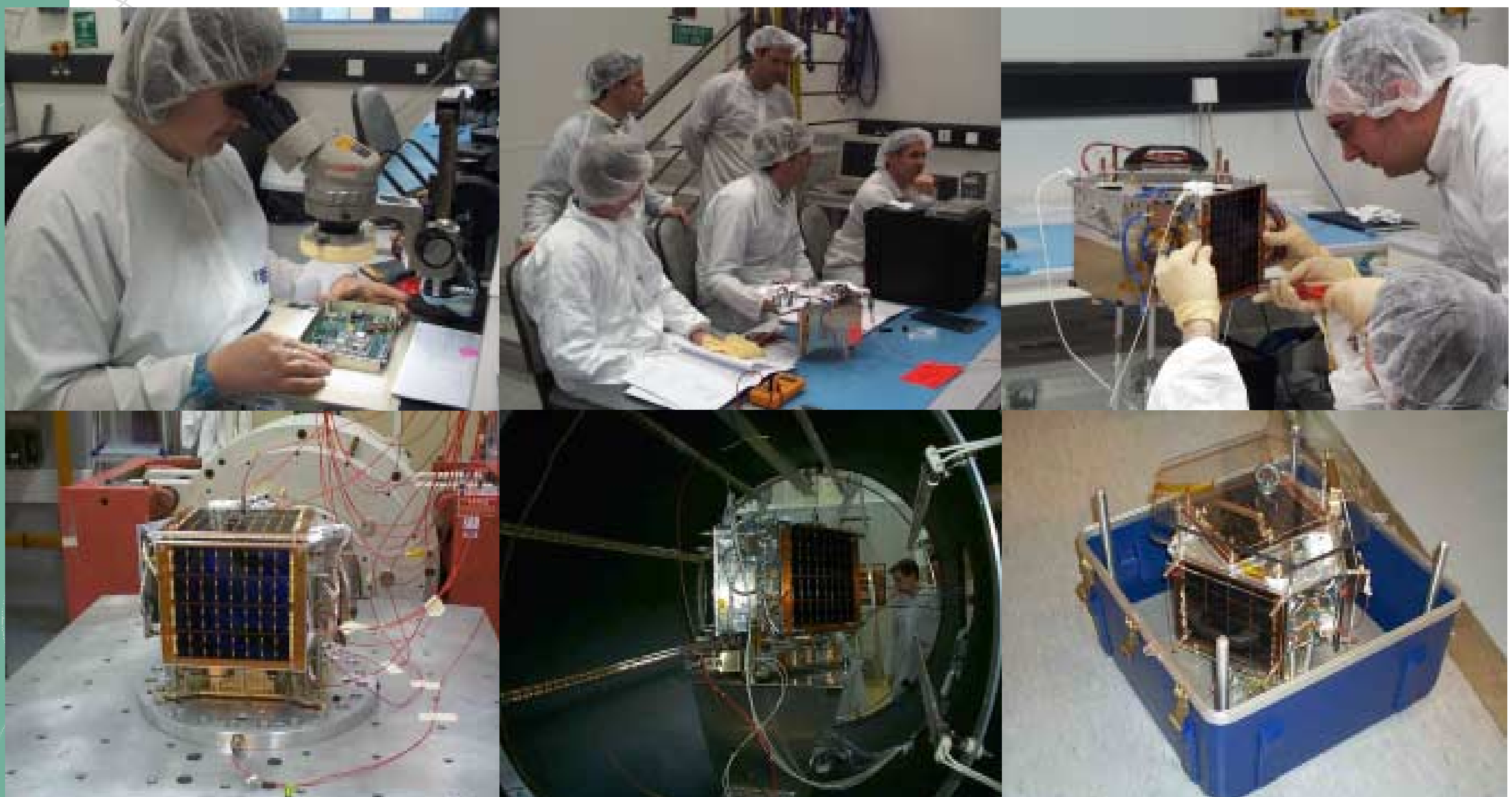
Jerome Salvignol, Project Manager
Ed Stevens, AIT Manager

Dr Craig Underwood,
SNAP-1's Chief Architect and Co-Project Manager

Dr Guy Richardson, SNAP-1's Chief Mechanical Engineer

SNAP-1

SNAP-1 AIT & EVT – Spring 2000



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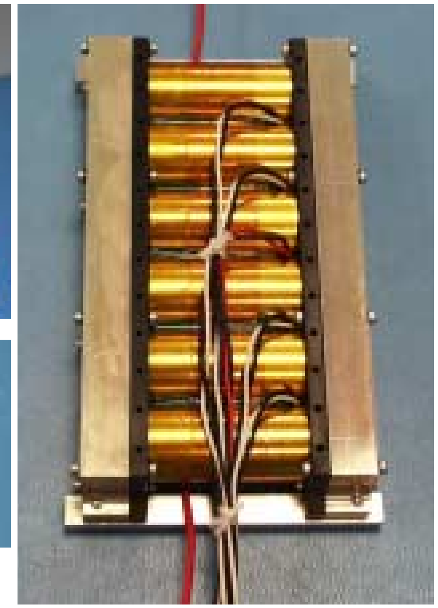
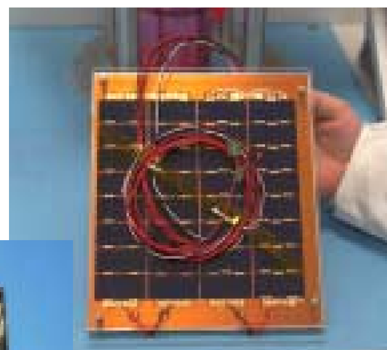
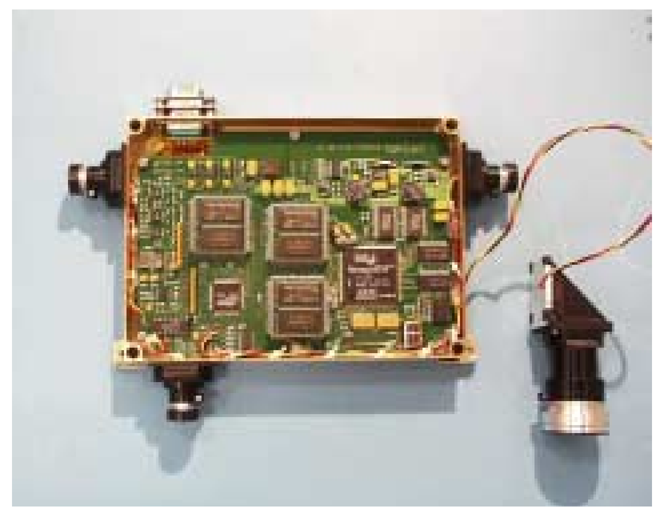
SNAP-1

SNAP-1 Advanced Miniaturised Technologies

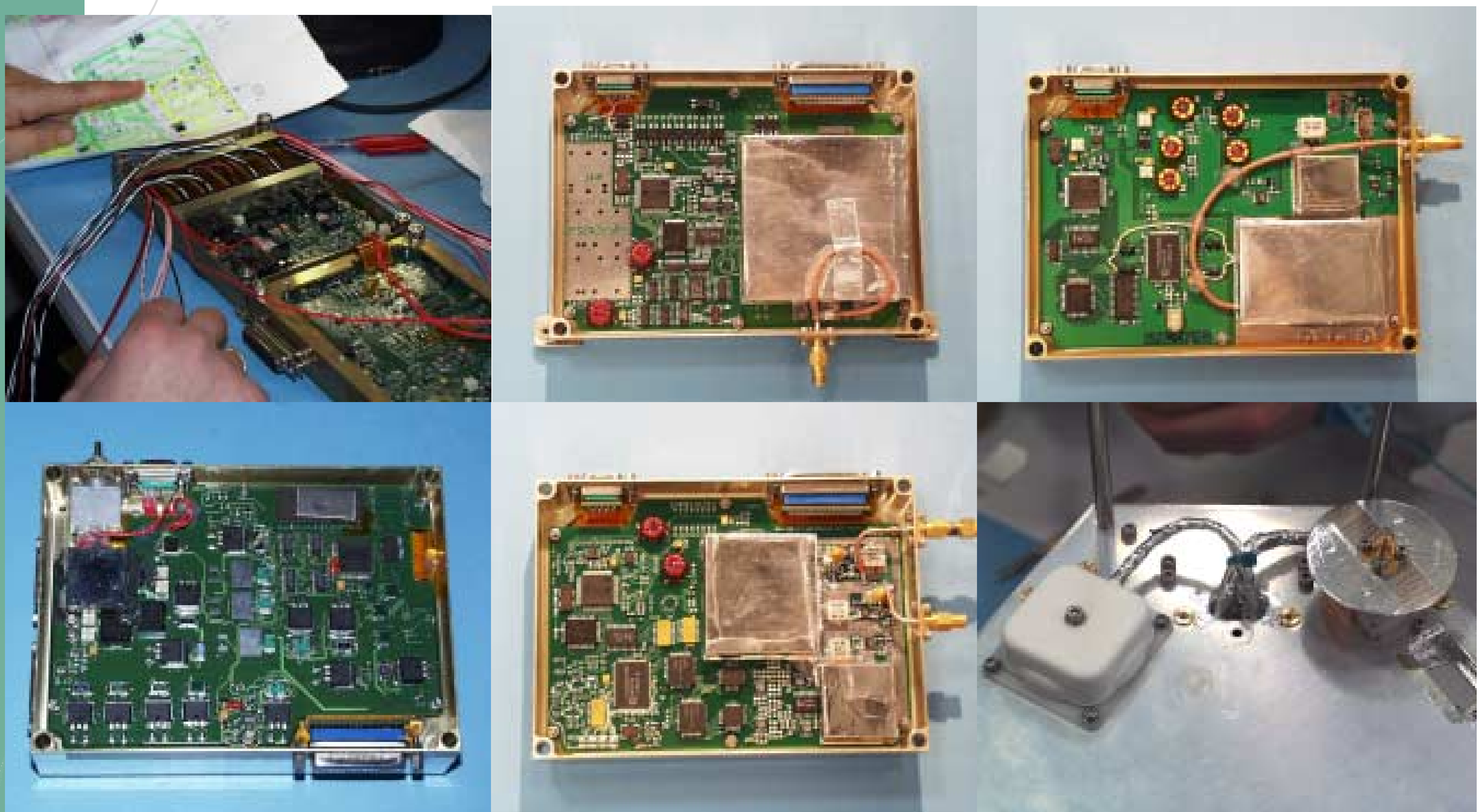






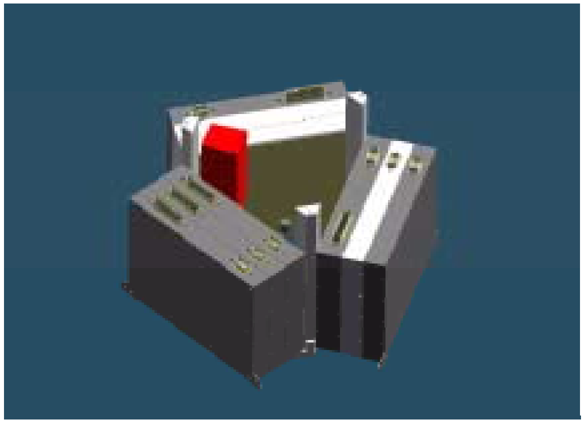
SNAP-1

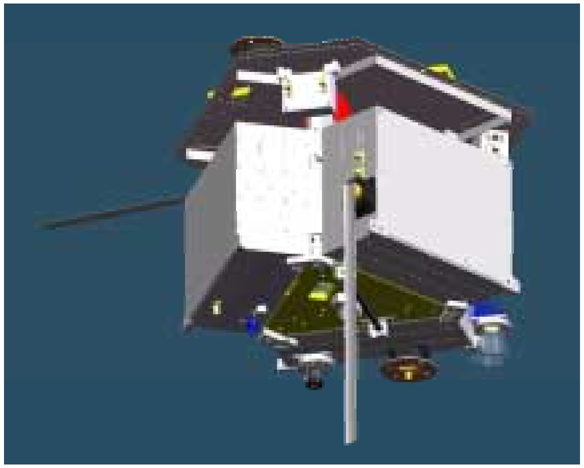
SNAP-1 Power System; VHF U/L Rx.; Spread-Spectrum Comms. Payload; S-Band D/L Tx.; GPS Antenna



SNAP-1 key features

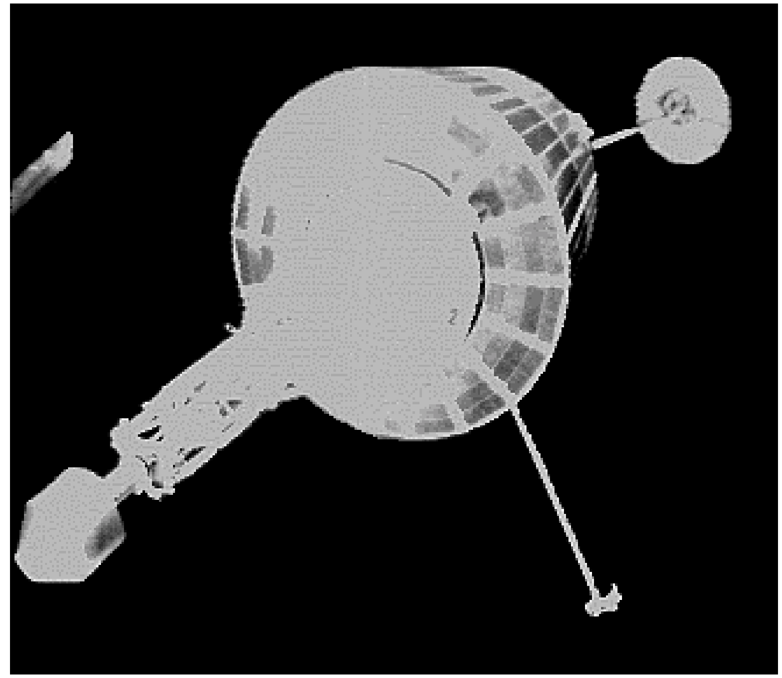
- **Structure**
  - 6.5 kg mass – modular, COTS-based design.
- **Power**
  - 4 GaAs solar panels; advanced NiCd battery.
- **Data Handling**
  - 3.3V/1.5V 220 MHz SA-1100 32 bit RISC; 4 Mbyte DEDDEC EDAC RAM; FPGA implemented sub-systems.
- **RF / TTC**
  - VHF U/L at 9600 bps FSK; S-Band D/L at 38.4 kbps BPSK or 76.8 kbps QPSK; internal CAN bus.
- **ADCS / GNC**
  - 3-axis stabilisation with orbit control via a modified 12 channel "ORION" GPS receiver, a compact 3-axis flux-gate magnetometer, 3 miniature magnetorquer rods and a single miniature pitch-axis momentum wheel.
  - Butane Cold-Gas Thruster (50 mN; ~3.5 m/s DV)
  - UHF Inter-Satellite Link Receiver Payload
  - VHF Spread Spectrum Communication Payload
- Payloads
  - Machine Vision System Payload - four "5th Generation" CMOS video cameras for remote inspection and Earth imaging.

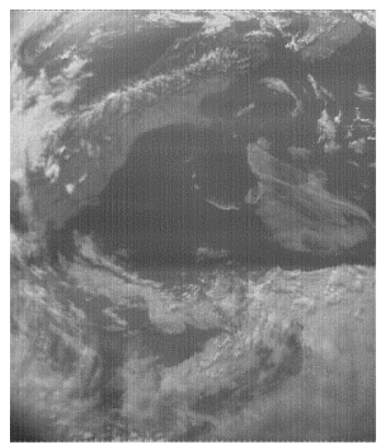




SNAP-1 achievements

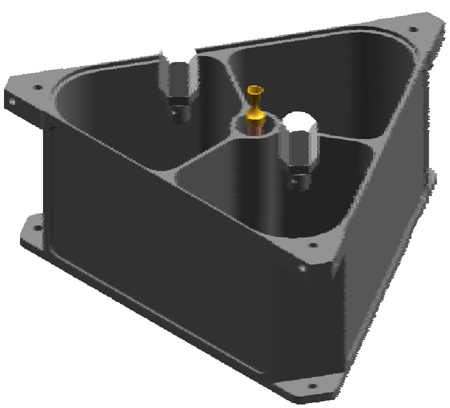
- Rapid mission: 9 months from design to orbit;
- Low mission cost: < €1.6m.
- First nanosatellite to image other space vehicles – remote inspection capability confirmed.
- First nanosatellite to demonstrate three-axis attitude control;
- First nanosatellite with on-board propulsion to demonstrate orbital control and manoeuvring;
- SNAP's suitability for agile nanosatellite missions is confirmed.



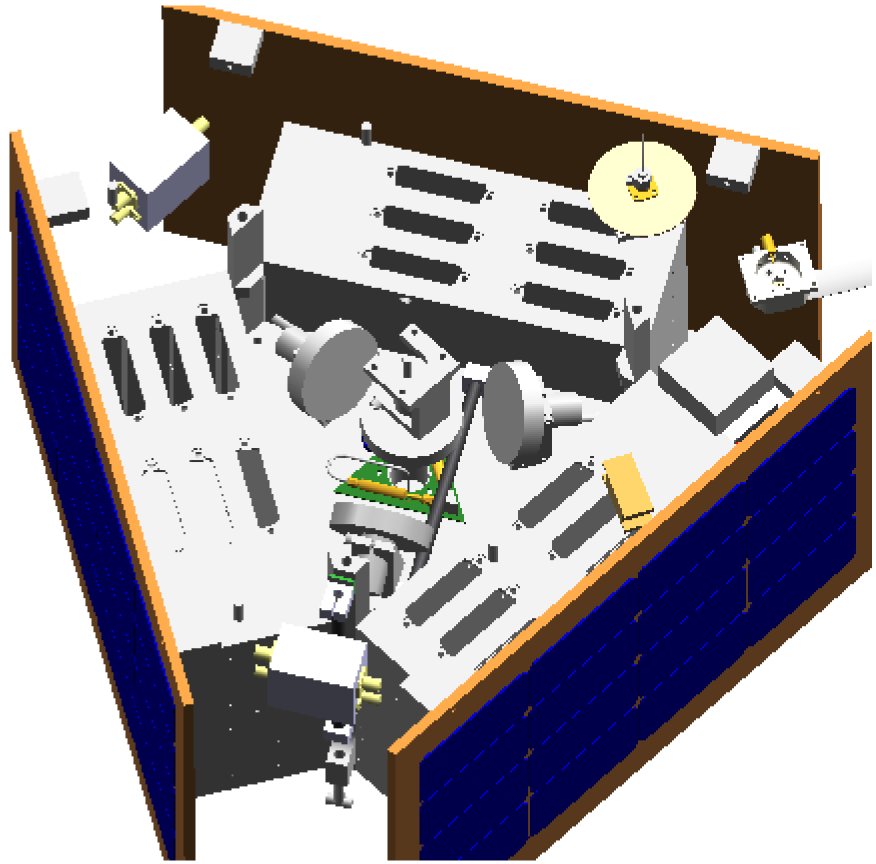


Recent work

- Platform and technologies
  - ADCS
  - Inter-satellite link work
  - Fuel tank upgrade

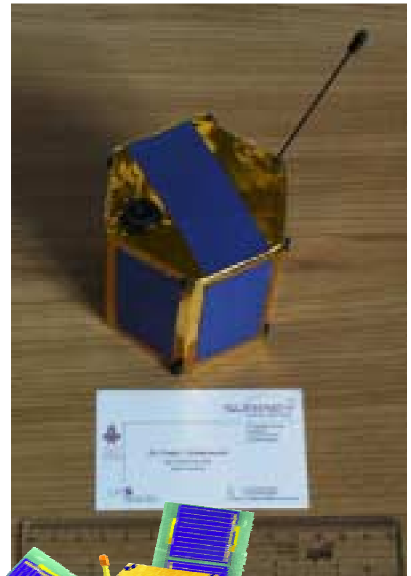


Fuel tank

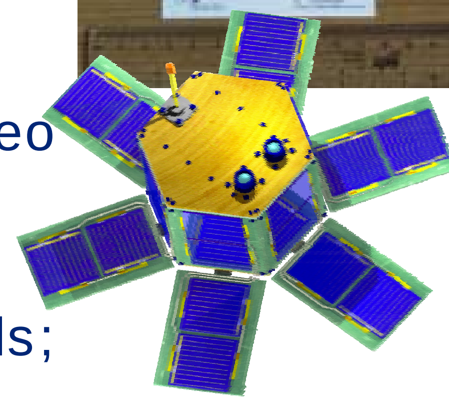


SNAP upgrade

PalmSat (preliminary specs)



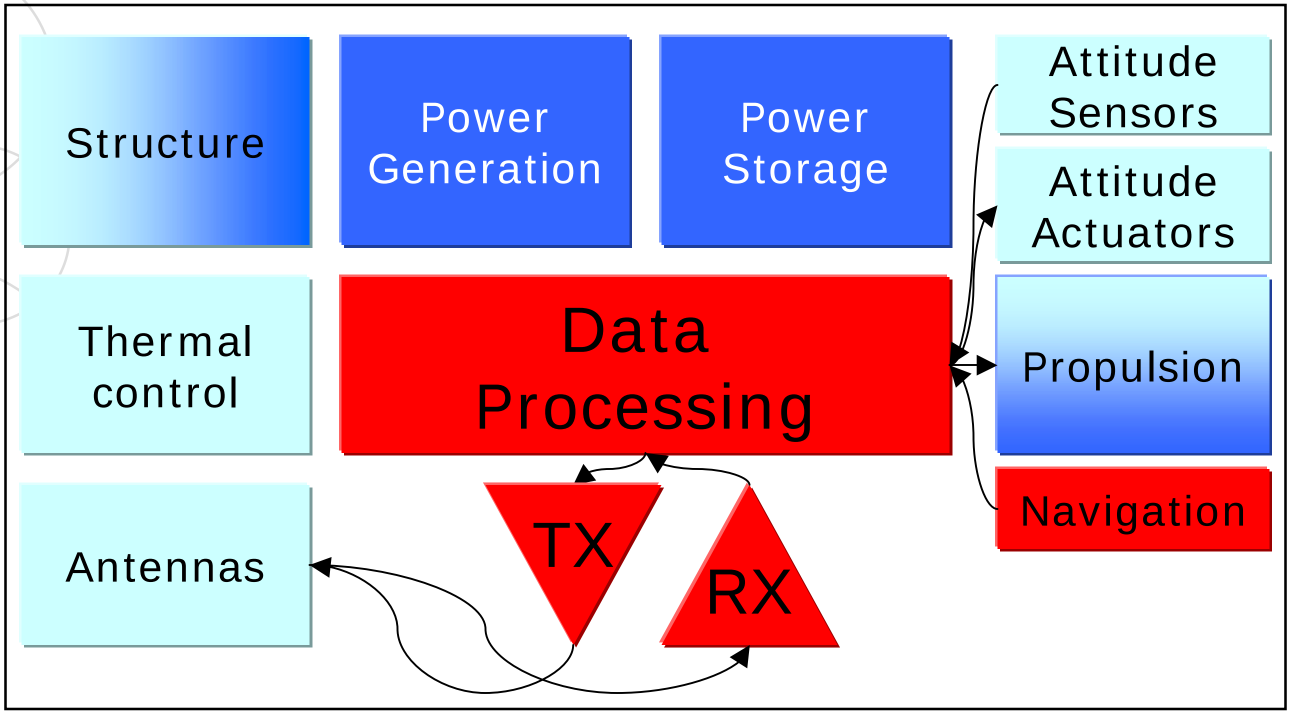
- <1 kg mass – integrated, COTS-based design.
- Power – 18 GaAs/Ge dual-junction solar cells; advanced 4 cell NiCd battery; ~2W power;
- OBC/Bus Controller – 3.3V 20 MHz PIC Micro-Controller; EEPROM memory.
- RF/TTC/ISL – Low power 2.4 GHz SS ISL; Amateur Band(s) U/L & D/L;
- ADCS/GNC – Passive magnetic.
- CMOS Camera Payload – One VGA CMOS video camera for remote inspection and Earth imaging.
- Options – Advanced Triple Junction Solar Cells; GPS Positioning; Active Magnetic ACS; MEMS gyro INU; Optical Attitude Determination; MEMS Micro-Thruster.

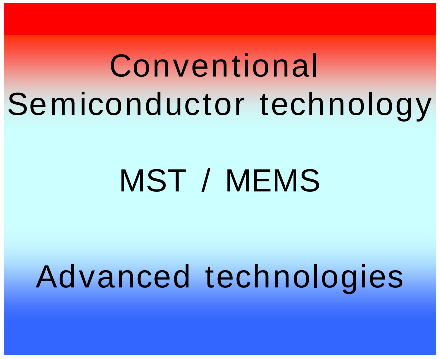


Satellite-on-a-Chip

- Most satellites are constructed from physically separate sub-systems, each of which is composed of some combination of circuit boards and components.
- Through the use of semiconductor fabrication techniques, all the components required for a state-of-the-art satellite can be implemented on silicon chips.
- Space engineers can use MST / MEMS to make femto-satellites in the form of:
  - layered silicon wafers containing sensors, computing power, communications systems, mechanical devices and even micro rocket thrusters.
- Unique properties enable silicon to become most of the mass of a satellite - it can simultaneously function as structure, heat transfer system, radiation shield, optic, and semiconductor substrate
- A long-term prospect is an entirely integrated satellite that contains all the subsystems of a fully functional satellite condensed into one module.

Spacecraft elements

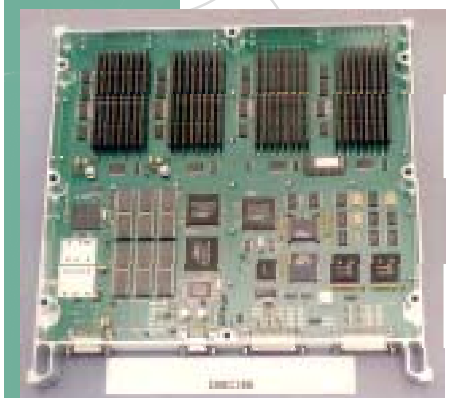




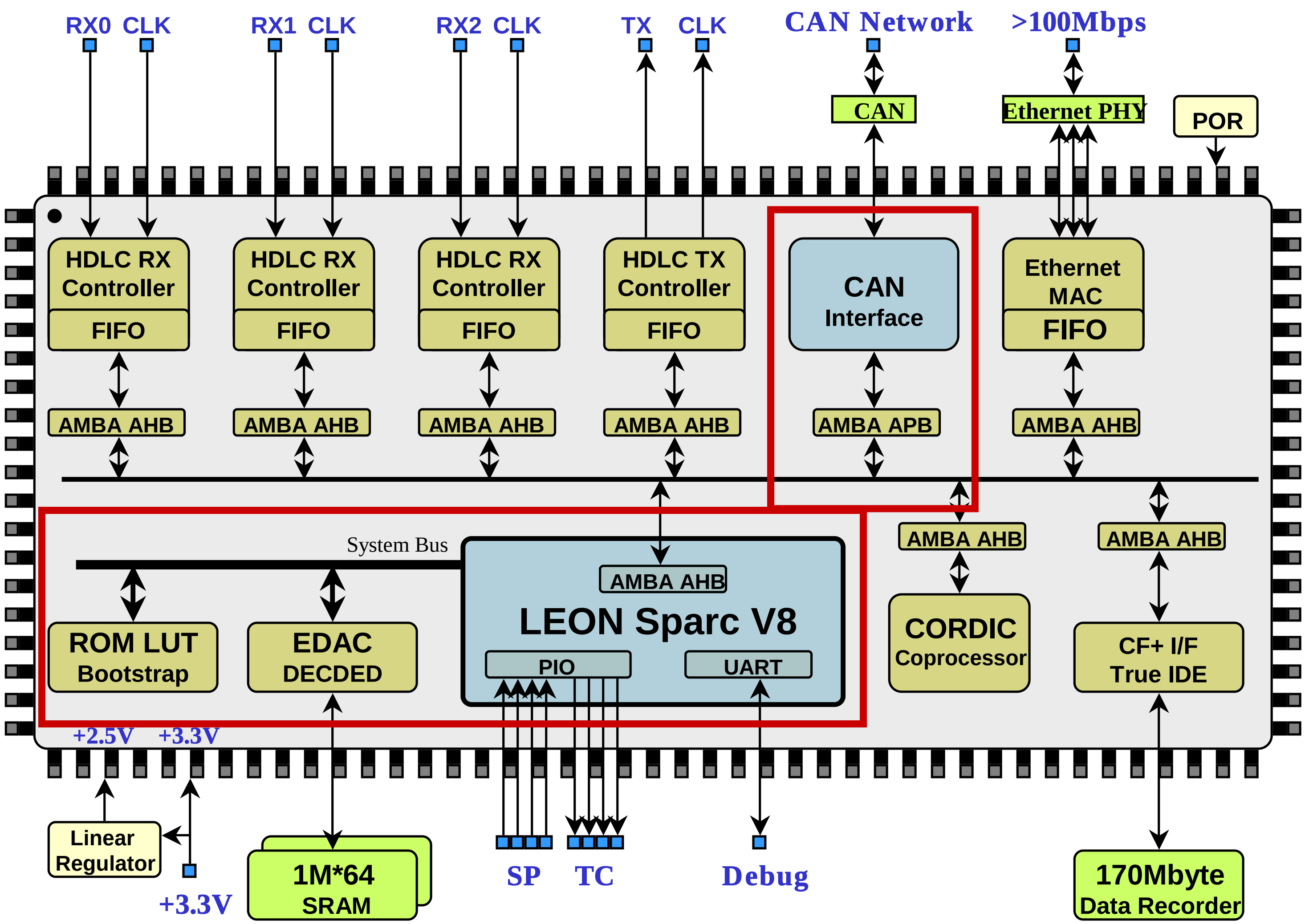
Enabling Technologies

- Technologies
  - Microelectronics – System-on-a-Chip + low energy consumption, evolvable hardware
  - MEMS – extremely small sensors, optical communication components, power supplies
  - Accurate Position Sensing and Actuation
  - Advanced Imaging Sensors
  - Formation Flying Techniques
  - Advanced Computers, Reconfigurable Computing, Remote Programmability
  - Distributed System Design Methodologies
  - Cluster Management Algorithms
  - Artificial Intelligence
- Challenges
  - Independent tracking
  - End-of-Life Disposal
  - Drag!

Satellite-on-a-chip research



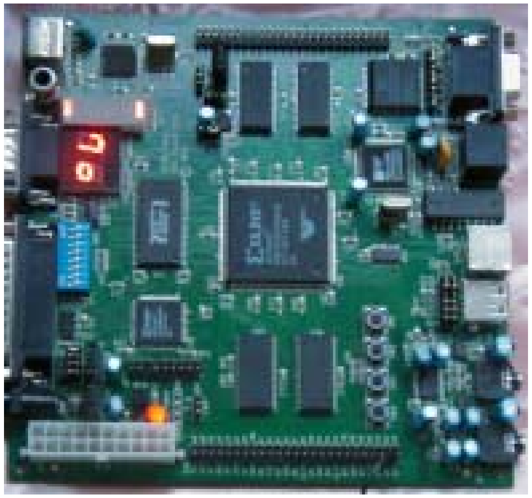
Surrey Satellite Technology (SSTL) On-Board Computer (OBC)



XILINX Virtex XCV800 FPGA

Experimental set-up

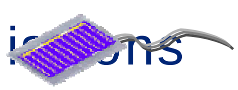
- Processor - LEON 2-1.0.2a VHDL IP core (SPARC V8) (ESA)
  - Working Frequency – 25 MHz
  - UART Baud Rate – 38,400 bps
  - Internal S-Record Boot Loader
- On-Board Network (Node 1) - HurriCANe VHDL IP core (ESA)
  - Baud Rate: 312,500 bps
- EDAC – EDAC VHDL IP core (SSTL)
  - Double-bit correcting Quasi-Cyclic (16,8) shortened EDAC code
- Prototyping Board - XESS XSV800 (Xilinx Virtex XCV800 FPGA)
  - Up to 100 MHz programmable oscillator
  - 16M Bits SRAM (two banks - 512K x 16)
  - 16M Bits flash RAM
- On-Board Application Program – S-Record
  - 160K Bytes (CCSDS_SC Software Package)



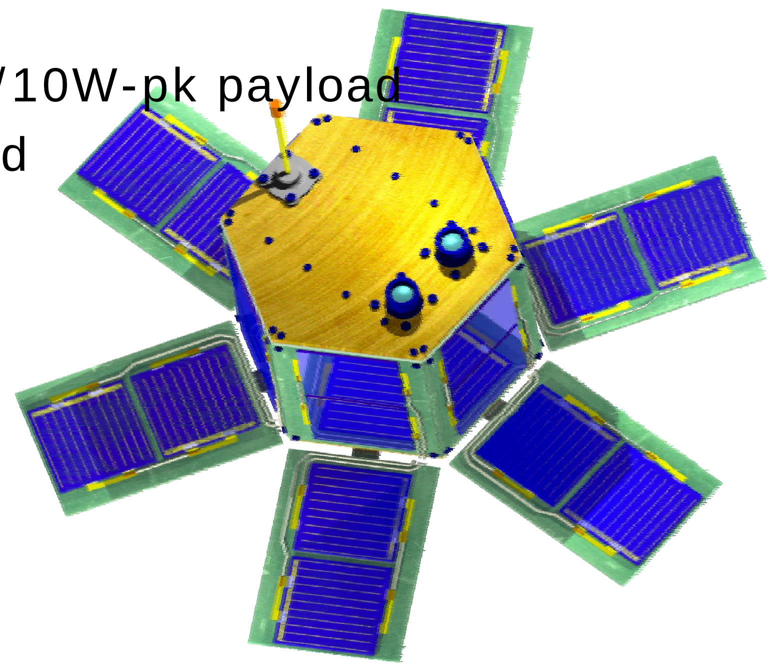
Conclusions

- Emerging micro and nano-technologies will revolutionise some space missions
  - Through technology infusion into existing systems
  - Through spacecraft miniaturisation

- Small, inexpensive satellites, can play a key role in validating complex micro and nano-technologies rapidly for use in space.
  - E.g. SNAP spacecraft can carry 1kg/10W-pk payload
  - E.g. PalmSat can carry 100g payload



- Spacecraft-on-a-chip missions are on the horizon.




Thank-You!