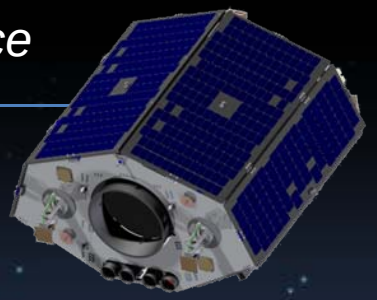
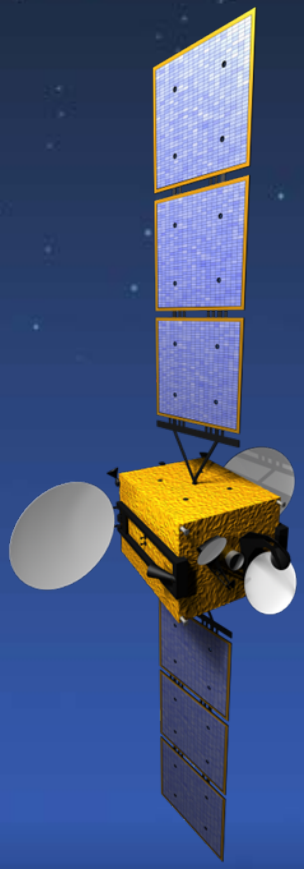
SURREY SATELLITE TECHNOLOGY LTD

Changing the economics of space



MEMS in Space – A New Technology Advancing from Flight Experiment to Proven COTS Product



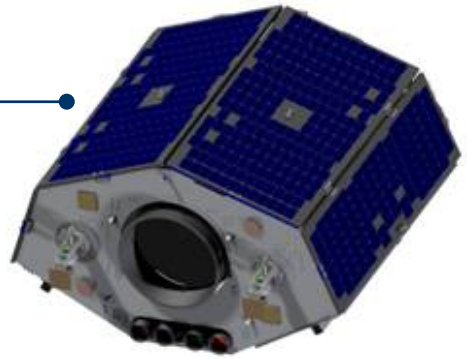
Andrew Carrel (Surrey Satellite Technology)

Paul Alderton (Atlantic Inertial Systems)

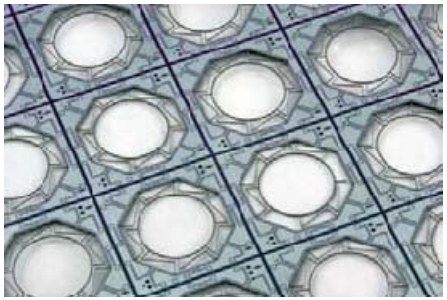
Presented by: Alex da Silva Curiel
(Surrey Satellite Technology)

MEMS Technology & Small Satellites

- Small satellite missions
  - Compact, low mass
  - Smaller power budgets
  - Low cost

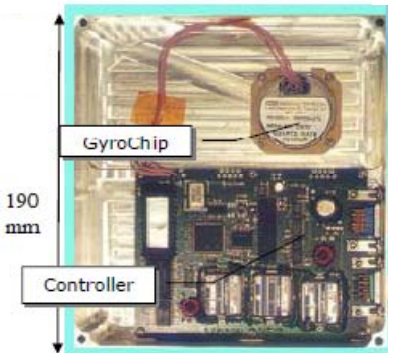


- MEMS sensor technology
  - Wafer-thin, micro-machined sensors
  - Low power consumption
  - Cost-savings of mass production techniques



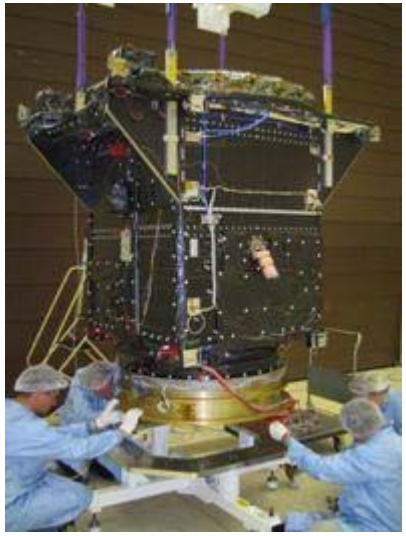
Past Success with MEMS Rate Sensors

- MEMS rate sensor (QRS11) flight experiment on UoSat-12 mission (1999)



UoSat-12 MEMS Rate Sensor

- This MEMS unit is used in the Giove-A inertial sensor
- Operating well in MEO since December 2005

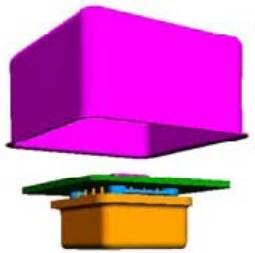


Giove-A

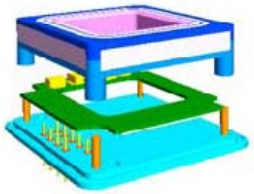
Giove-A Inertial Sensor & ADCS Interface

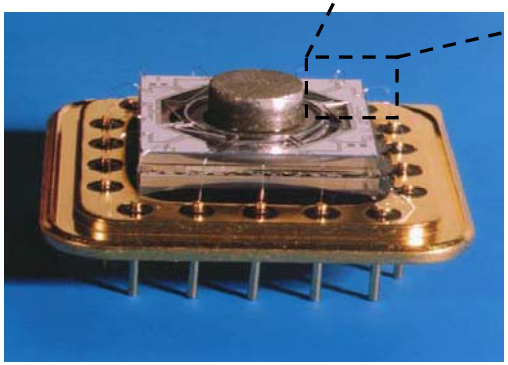
Silicon Ring MEMS Rate Sensor

- RRS01 unit from Atlantic Inertial Systems



- Resonating silicon ring
  - Coriolis force moves node of oscillation
  - Motion of node is controlled to null position
  - Control drive current is then proportional to angular rate

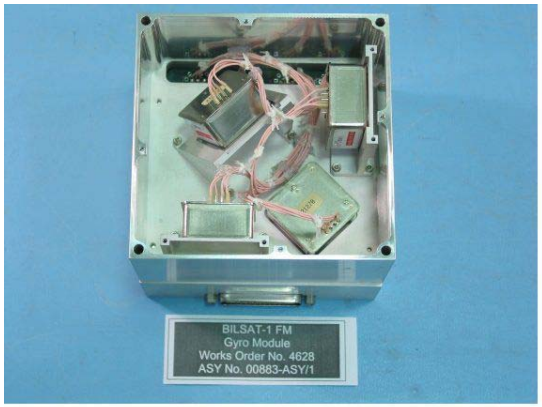




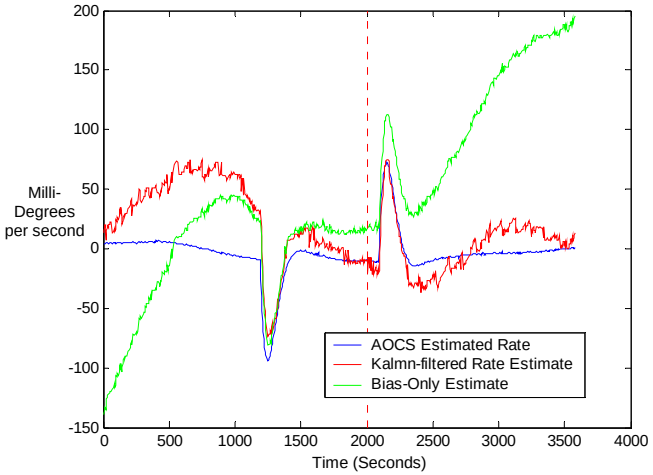
Silicon Resonator

First Flight on BilSat-1

- Launched September 2003
- Inertial Sensor module with 4 RRS01 rate sensors
- Rate sensor performance assessed on-orbit
- Useful flight experience
- Improved understanding of bias characteristics

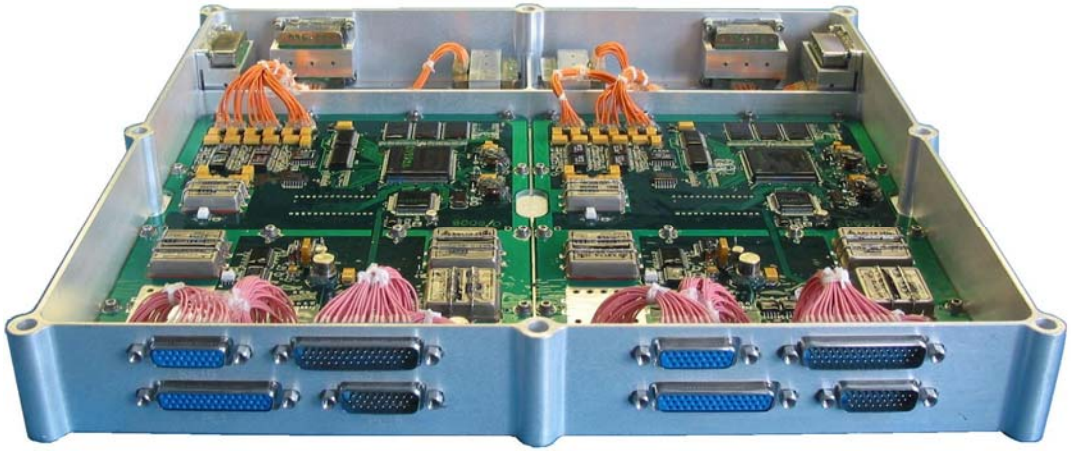


BilSat-1 IS Module



MIRAS-01 Development

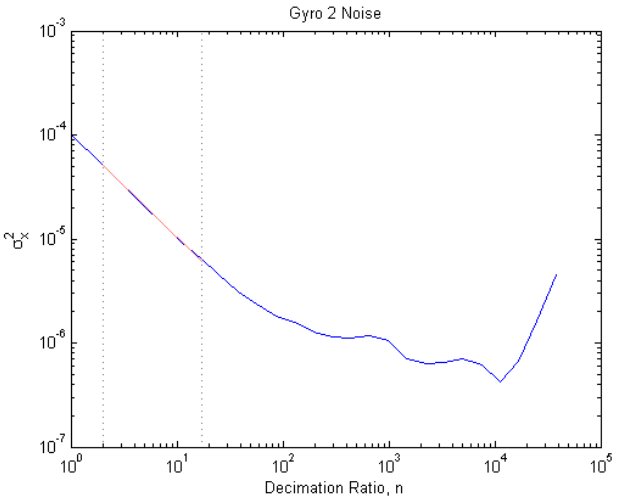
- RRS01 rate sensor incorporated into SSTL MIRAS-01 Inertial Sensor
- Bandwidth is limited to 10Hz to minimise noise
- PPS input to synchronize clock
- Processing electronics use SSTL heritage parts



Cold-Redundant Pair of MIRAS-01 Inertial Sensors

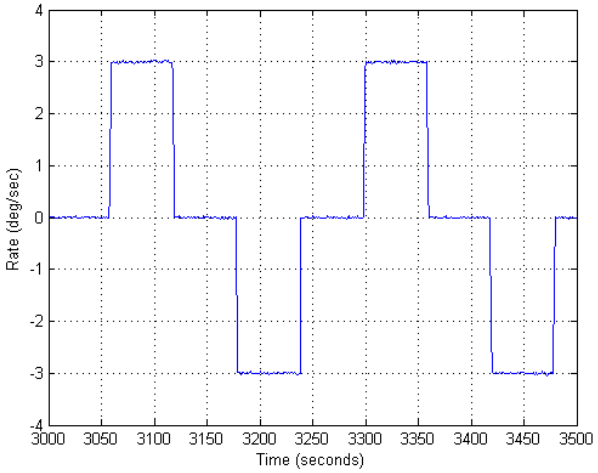
Performance

- Allan Variance testing used to characterise noise & bias stability of each unit
  - Noise is 0.01 deg/sec/rt-Hz
  - Bias stability is 10 deg/hr over 1hr



Allan Variance Plot

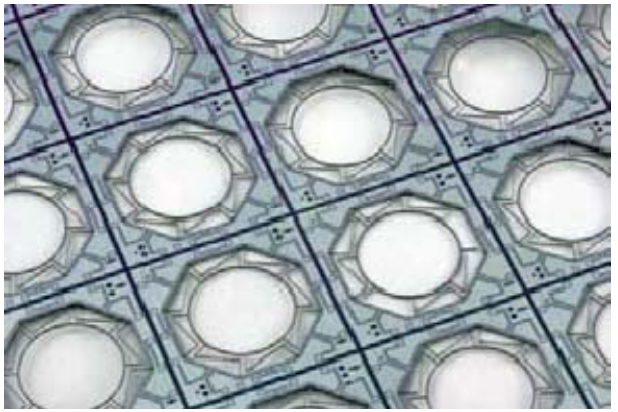
- Bias characterisation process gives full performance over operating temperature range (-20degC to +50degC)



Rotation Test at +50degC

Reliability of Performance

- Resonating ring sensors are made using silicon-wafer mass-production techniques

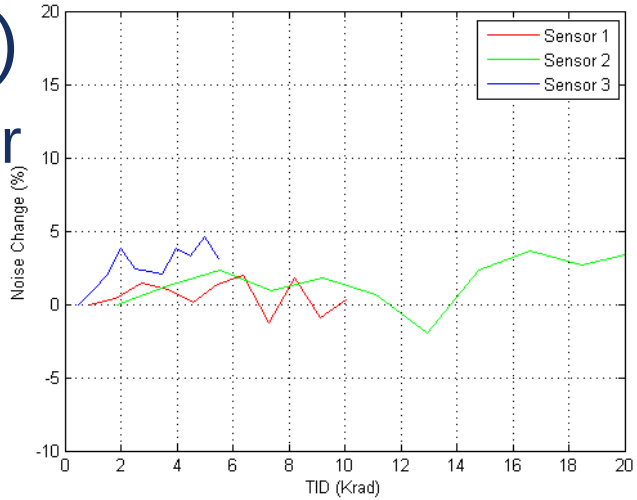


- These are produced by the million for the commercial market
- RRS01 sensors are the selected upper percentile, ensuring consistency of performance
- High volumes give excellent understanding of small variations in characteristics

Qualification

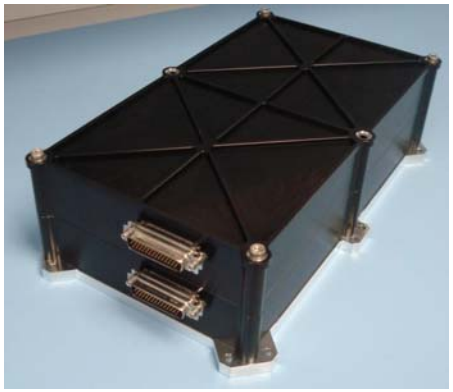
- Robust RRS01 rate sensors, built for military applications
  - MIRAS-01 random vibration tolerance is 25 g-rms
  - Silicon ring is very strong, giving module high shock tolerance

- Sensors tested to 20kRad (Si)
  - Little affect on performance over this range
  - Dose rate inside box can be shielded down for harsher environments



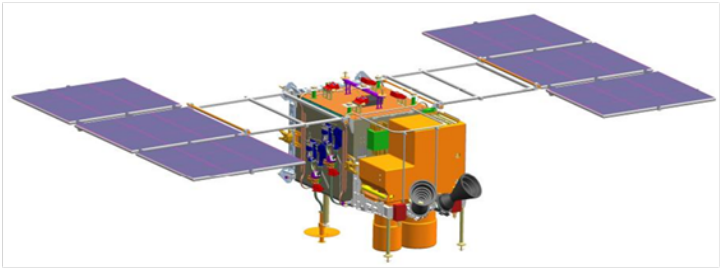
Applications

- 6 modules delivered to space missions
- 4 more built and another 4 in manufacture
- Different uses on missions:
  - Agile spacecraft
  - Autonomous de-tumble & Sun acquisition
  - Star camera blinding mitigation
  - Anomaly detection



MIRAS-01

NigeriaSat-2



Kanopus

Evolving Technology

- Improved resonator ring design now available
  - Addition of second conductor track
  - Doubled sensor SNR
  - Can be incorporated directly into MIRAS-01

- MIRAS-02
  - Will be based closely on MIRAS-01 heritage
  - More compact, lower mass
  - Performance enhancements

Conclusions

- MEMS technology well-suited to Small Satellite missions
- SSTL have taken MEMS Inertial Sensors from space flight experiments to a production product
- In-flight experience has shown MEMS sensors to be effective for space missions

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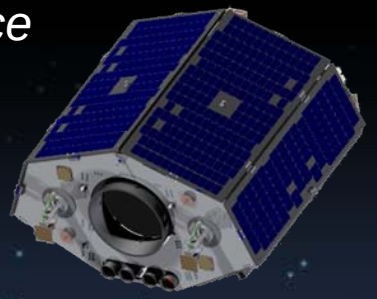

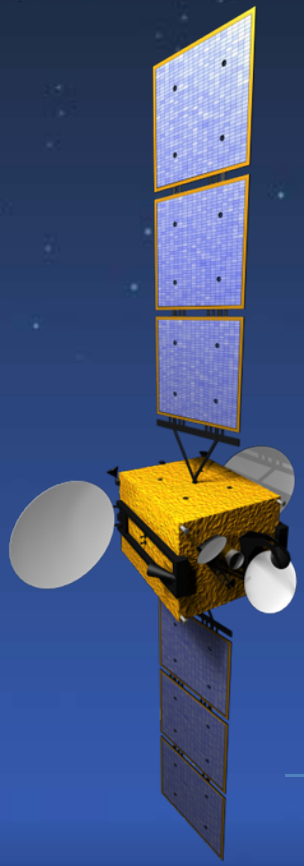

Thank You

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