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

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

• Bias characterisation process gives full performance over operating temperature range (-20degC to +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
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
Thank You