rate sensors using MEMS technology

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System Engineering & Assessment Ltd
- SME founded in 1988
- space/marine/defence/transport
- >400 man years of space experience
- 200 staff (up to 50 staff working on space projects)
  - located in Filton (Bristol) & Bath

background

- MEMS rate sensing widely applied in terrestrial applications.
- Volume markets (eg automotive) driving technology innovation, production processes and costs.
- Low to moderate performance sensors complement star sensor improvements

current study

- Team of SEA and BAE Systems studying
  - Requirements
  - Market
  - Technical Feasibility
  - Production Cost
- SEA addressing market and space electronics/qualification. BAE technology and design support.

technology advantages

- Mass
- Power
- Volume
- Robustness

Si Gyro Sensor Head

configuration
**how does it work?**

Carrier mode  
Response mode

**Vibration Cycle**

- ** Carrier mode**
- **Response mode**

**forces driving market**
- Star sensor miniaturisation, performance and accommodation.
- Commercial EO requires better revisit/ higher resolution.
- Launch technology relatively mature.
- Operations costs become significant.

=> multiple, smaller spacecraft with high performance and robust operations.

=> routine integration with star sensors for attitude measurement on all platforms.

**future performance**

Draper Labs (US) prediction in 1998

**current performance**
- Analogue electronic drive/compensation.
- <10 deg/h bias instability (fixed conditions).
- 0.1 deg/s bias repeatability.
- < 50 g.
- <250 mW.

**how do we get to the future?**

Potential improvements include:-

- Digital drive schemes
  - Better repeatability/ minimal ageing.
  - More sophisticated compensation schemes.
  - Removal of flicker.
- Electrostatic balancing.
  - Reduce frequency split
  - Rate integration mode.
- Larger resonator head
  - Process and frequency improvement
- ‘Deep’ compensations.
  - Multi-parameter calibration.

**needs**

- EO
- Science
- Communications
- Navigation
- Launchers
- FDIR

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Courtesy of Draper Labs
Digital drive scheme allows the measurement/estimation of many control and compensation parameters. Applied to current sensors this approach has demonstrated 2 orders of magnitude improvement over ‘inherent bias’.

Limitation on digital technologies, however space applications do not (usually) require:
- Large bandwidth (50 Hz plus)
- Large Dynamic Range
- Operations at 1000g

These factors (and others) can be used to trade mass, power, performance and electronics selection.
industrial context

- ‘market pull’ and ‘technology push’ are not provided by the space industry.
- BAE are the world leader in this technology
- SEA are undertaking the adaptation required to meet the needs of space - radiation, electronics packaging and tuning
- BAE have provided a ‘low dynamic range/high performance’ design for SEA, but sensor technology is scalable for applications, digital drive is core function and key.
- SEA are working closely with BAE to offer this technology to the space industry.

technology route map

1. ESA funded study for market and technical feasibility.
2. Agree licence/IPR issues ESA/BAE/SEA
3. Port and adapt BAE digital drive and IMU algorithms to space component processor.
4. Integrate and test with current ‘production’ resonator heads.
5. Develop Gyro/IMU Packaging scheme.
6. Integration/test of packaged Gyro IMU BAE/Sowerby Development
7. Integration and testing with modified resonator head.
8. Software mods/Integration and testing with capacitive sensing technology Output: Improved Performance Science IMU/Gyros
9. Port from general purpose processor/software to ASIC/FPGA core for lowest power applications. Output: Very low power/IMU Gyro Product
10. PROBA 2 Demonstration Flight Output: Product with flight history for de-risking.

Output: Space quality breadboard electronics elegant breadboard demo.
 Output: Flight prototype gyro/IMU package.

target specifications

Per 3 axis set:
- mass < 0.5 kg
- power < 3 W (ASIC version)
- radiation: compatible with GEO
- Performances:
  - Family of devices with bias from 10 deg/h to 0.1 deg/h
- Availability: within 2 years as space qualified packages.

industrialisation

- SEA: lead plus electronics design
- BAE ISD: technology
- BAE SSD: packaging design/test and manufacturing

thanks

- To BAE for their excellent support on the current effort.
- To BNSC for supporting the precursor work.
- To ESA for supporting the current work.