**TECHNOLOGY OBJECTIVE**

The JPL MEMS gyroscope is an enabling technology for a variety of commercial, space and military applications. Gyroscopes are needed for inertial navigation and precision instrument pointing. The IP for JPL’s disc resonating gyroscopes (DRGs) has been licensed; the DRG is the highest performance MEMS gyroscope in the world. The present development at JPL (for Creare Inc., under Army SBIR funding) is focused upon further increase in precision and on improvement of the shock tolerance (>20,000 g’s) of the device. All military needs for gyroscopes map one-to-one to NASA applications: gyros are needed for both munitions and precision pointing of spacecraft antennae and cameras, inertial navigation is required as a back up navigation system to GPS and for star trackers, and the analogue for a GPS denied environment (where inertial navigation becomes the primary means of navigation) is the entry, descent and landing phase of a mission.

**BENEFITS TO NASA**

- MEMS technology enables dramatic reductions in size, weight and power (SWaP)
- Performance of the MEMS disc resonator gyro (DRG) is now comparable to macro systems flown on previous flight missions
- Combination of high performance and low SWaP will increase mass and power margins on existing types of missions, and will enable new types of applications (e.g. personal navigators for astronauts) and new missions (e.g. formation flying of miniature spacecraft)
- Small size and monolithic material construction / wafer-scale vacuum packaging increase shock tolerance. In addition, this technology does not suffer from radiation issues (e.g. laser life and optical fiber darkening) that plague optical gyros.
- Component concepts and development leveraged for other technologies:
  - Discrete LCC vacuum packaging technique utilized for JPL CNT harsh environment electronic devices
  - Wafer-scale vacuum packaging methodology and electronics design leveraged on JPL seismometer design

**TECHNOLOGY STATUS**

- Current TRL level: 4-5 (IP has been licensed by Sensors in Motion (SIM), and is under commercial development)
- Candidate for integration into various DoD smart munitions systems (independent testing performed by Army at AMRDEC test facility)
- Roadmap for technology development and maturation at JPL:
  - Development of wafer-scale vacuum packaging process
  - Improved resonator geometric design
  - Development of resonator mechanical trimming process
  - Tech demonstration on low cost flight opportunity for TRL advancement
  - Development of analog ASIC for front end electronics
  - Resonator performance can be further improved through fabrication out of low thermo-elastic damping material (e.g. fused silica, ULE glass) as demonstrated by JPL in the DARPA NGIM program, and is currently being pursued in the MRIG and TIMU programs

**JPL MEMS Gyroscope**

(K. Yee, J. Gill)

- **Optical gyro**
  - GG1320 (RLG) (Honeywell)
  - FOG 1000 (Limon)
  - IRG (Limon)
  - SI DRG (SIM)
- **Vibratory gyro**
  - Bias stability (°/hr) 0.004 0.01 ~0.01 0.01
  - ARW (°/rt-hr) 0.004 0.004 0.0006 0.000

<table>
<thead>
<tr>
<th>Mass (kg)</th>
<th>Optical gyro</th>
<th>Vibratory gyro</th>
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<tr>
<td>0.01 kg</td>
<td>0.1 kg</td>
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<tr>
<td>0.1 kg</td>
<td>1 kg</td>
<td>10 kg</td>
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<td>1 kg</td>
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**JPL MEMS Seismometer**

(K. Yee, B. Banerdt, K. Hurst, B. Blaes, J. Gill, V. White, V. Scott)

- Current TRL level: 2-3. Estimated readiness date for tech infusion: 2017
- Designed for lower mechanical noise floor (higher MTQ product) and lower electronic noise floor than InSight MEMS seismometer
- High shock survivability (> 100g) for compatibility with rough lander / penetrator missions (e.g. DS-2), enabling low cost deployment of network of seismometers
- Two sense axes
- Wafer-scale vacuum packaged
- Results in surface mountable chip
- Enables tighter integration with front end electronics

**Flown on previous NASA missions**

- **MMS Inertial Sensors fabricated from intrinsically high Q materials**
- **JPL MEMS Seismometer** (Karl Yee, B. Banerdt, K. Hurst, B. Blaes, J. Gill, V. White, V. Scott)

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- **Designed for lower mechanical noise floor (higher MTQ product) and lower electronic noise floor than InSight MEMS seismometer**
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- **Two sense axes**
- **Wafer-scale vacuum packaged**
  - Results in surface mountable chip
  - Enables tighter integration with front end electronics