Micro/Nano Probes Enabling Next Generation Space Exploration

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4th Round Table on Micro/Nano Technologies for Space

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Outline

- Summary
- NanoSpace – The MMS road from airbrush to flight
  - Earth Intelligence Surveillance (E.I.S.) satellite concept
  - EIS Design
- MMS enabling interplanetary endeavors
  - Micro Autonomous Underwater Vehicle AUV
  - Inflatable Spherical Micro Rover/Robot
  - Inflatable Venusian Balloon (LOVECraft)
- How much electronics and mechanical functions can a MMS hold?
Summary

- Light-weight high-performing Micro/Nano Probes/Spacecraft are really feasible

- Enabling parallel exploration of the planetary system to a moderate cost

- Enables cluster exploration of a planetary body surface

- Much higher percentages of payload possible, i.e. more multifunctional components that are not just dead weight.
NanoSpace – The MMS road from airbrush to flight

- Currently part of SNSB Phase-A study (TechoSat)
- MMS designed platform
- General modules => Direct spin-offs to new applications

- Well defined processes and QA/PA
- Valuable lessons learned, experience on system level integration of complex MEMS modules
Earth Intelligence Surveillance (E.I.S.)

- Sponsored by the Swedish Defense
- First satellite based on MMS for customer demand
- Applications are both Military and Civilian,
  - Visual monitoring (3m-ground resolution)
    - Natural disasters
    - Criminal activities
    - International conflict monitoring
    - Military intelligence
  - Radio/Signal monitoring

- Top requirement: The E.I.S. system shall be deployable with a fighter jet
The Ångström Space Technology Centre

Fredrik Bruhn, 4th Round Table on MNT for Space, May 20, 2003, ESTEC
MMS enabling interplanetary endeavors

- Reduction of size and mass of electronics
  - Increased performance / weight, such as autonomy, distributed systems, artificial intelligence, neural networks, scientific computing, re-configurable electronics

- Reduction of interconnections, wiring between mechanical functions, inertial navigation components

- High performing modules can be used in different missions with software updates

- Less overall weight, thus reducing costs and Δv-requirements
Micro Autonomous Underwater Vehicle AUV for Europa

In collaboration with NASA/Jet Propulsion Laboratory
Micro AUV – Requirements

- Have maximum size of:
  Diameter: 8cm, Length 30cm
- The AUV shall measure Conductivity, Temperature, and Depth (CTD) and at least accommodate two other instruments
- The AUV shall have a high-resolution camera
- The AUV shall be deployable from other dimensionally constrained host vehicles for operation in naturally occurring sites characterized by small size and acidic or alkaline water.
Micro AUV – MMS design benefits

- Optical Fiber Transceiver, 100s of meters to km of onboard spooled optical fiber
- Electronic compacted in size and mass by 10-15 times
- Allowing high power densities
- System Electronics and navigation packed in three modules; Weight: ~ 100g
- Internally distributed intelligence over I²C bus
SMIPS – Autonomous Inflatable Micro Rover/Robot for Planetary Exploration
SMIPS – Design Goals

- Total weight of 3.5-4kg for deployment on Mars
- Minimize the weight of electronics and instrumentation
- Batteries and DC-motors shall have a large % of the total mass and be positioned as far down on the pendulum as possible => higher $L_{cm}$
- Jump Mechanism
SMIPS – MMS design benefits

- High $L_{cm}$ ratio, $0.75R$ is expected
- Thin film solar cells
- S-band patch antennas
- MCM-packed electronics
- Sun sensors, cameras, accelerometers, gyros
Venus Exploration – LOVECraft
LOVECraft – MMS Implementation

- Total weight: < 30kg
- Multifunctional ballast probes
  - Count: 20 probes
  - Weight: 100g/each
  - Each ballast probe includes scientific instrumentation, a small breaking balloon, radio transmitter
- CIGS Thin-film solar cells
- 3D-MCM Modules
- Phased Array antenna
- Micro Cold Gas Thrusters, de-spinning
LOVECraft – Ballast probes

- Length: 180mm
- Diameter: 24mm
- Weight: 100g
How much electronics and mechanical functions can a MMS hold?

- Typical naked-die dimensions on some typical circuits;
- The thickness of typical dies are normally, 330um, 525um or less
- Let us look at a imaginary module consisting of; 12 ADC, 12 DAC, 50 OP AMPs, 8 Gbit DRAM, 2 CPU, 4 MCUs, 4 Gyros, 4 Accel., 6 Volt. reg., 40 diodes.

<table>
<thead>
<tr>
<th>Component</th>
<th>Die dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADC (12-bit)</td>
<td>2 x 3.3 mm</td>
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<tr>
<td>DAC (12-bit)</td>
<td>2.9 x 2.8 mm</td>
</tr>
<tr>
<td>OP AMP</td>
<td>1.9 x 2.4 mm</td>
</tr>
<tr>
<td>DRAM (4Gbit)</td>
<td>23 x 23 mm</td>
</tr>
<tr>
<td>Volt. Switch reg.</td>
<td>1.8 x 1.8 mm</td>
</tr>
<tr>
<td>MEMS Gyro</td>
<td>7 x 7 mm (avg.)</td>
</tr>
<tr>
<td>MEMS Accel.</td>
<td>7 x 7 mm (avg.)</td>
</tr>
<tr>
<td>CPU (AMD, PPC,...)</td>
<td>13 x 13 mm (avg.)</td>
</tr>
<tr>
<td>uC, MCU</td>
<td>3 x 3 mm (avg.)</td>
</tr>
<tr>
<td>Diode</td>
<td>0.4 x 0.4 mm</td>
</tr>
</tbody>
</table>
How much electronics and mechanical functions can a MMS module hold? (2)

- A typical ÅSTC MMS module consists of four to six 525um silicon wafers and have the dimension of 68 x 68 x 2.6 mm, example below is average with 5 wafers.
- Total volume of silicon that can be removed: 12020 mm³
- Volume of all selected components: 1510 mm³
- 13% of the volume is utilized for chips, weight: 25g (everything Si).
How much electronics and mechanical functions can a MMS module hold? (3)

- Not included in previous 13% utilization of the module is
  - Supporting circuits such as resistors, capacitors, inductors, diodes
  - Internal conductors
  - Interconnection interface to another MMS module, or to macroscopic world.
  - Local radiation shields, typically of ~ 400um thickness or more

- All this together will typically fit into 45-55% of the total volume.