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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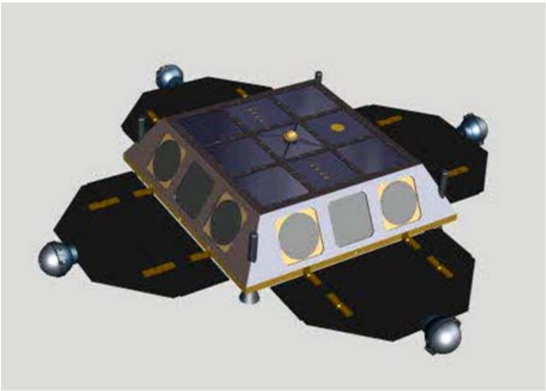
Outline

- 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?

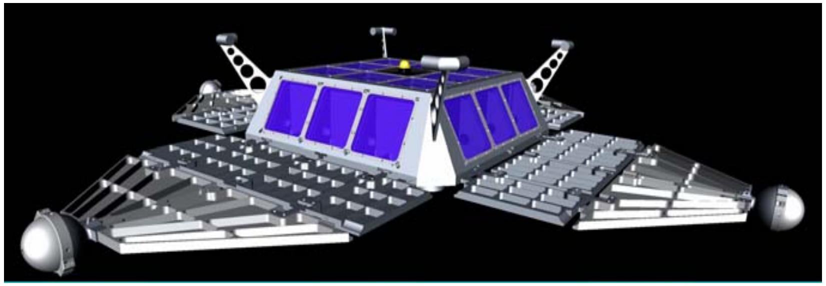
Summary

- 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.

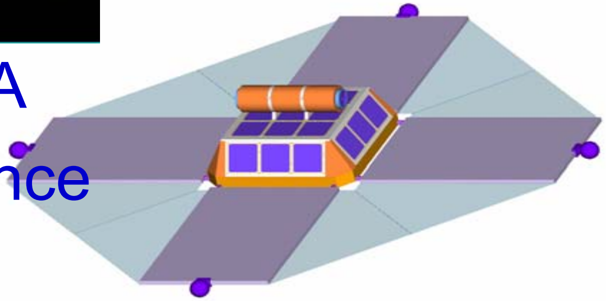
NanoSpace – The MMS road from airbrush to flight



- 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



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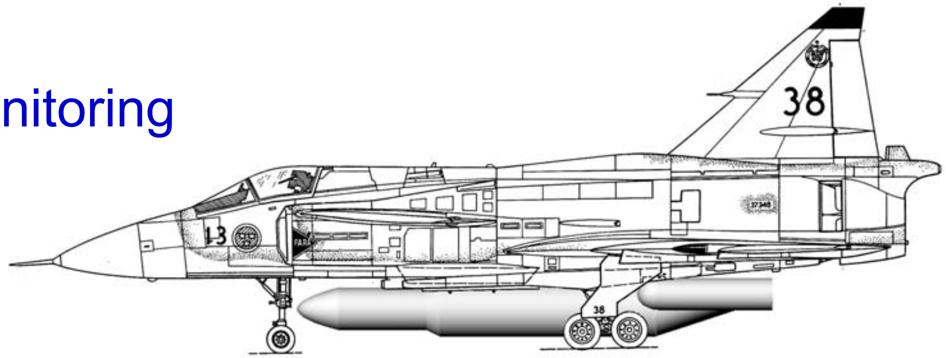
Earth Intelligence Surveillance (E.I.S.)

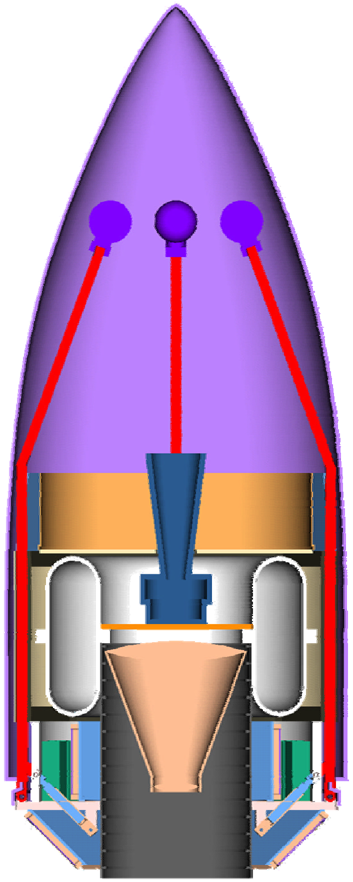
FMV

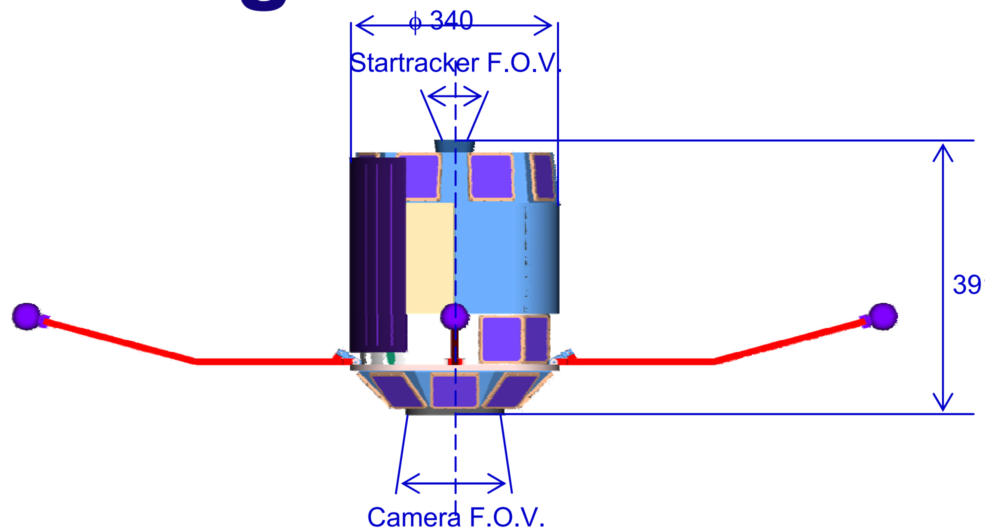
- Sponsored by the Swedish Defense
- First satellite based on MMS for customer demand
- Applications are both Military and Civilian,
  - Visual monitoring (3m-ground resolution)
    - Natural disasters
    - Criminal activities
    - International conflict monitoring
    - Military intelligence
  - Radio/Signal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



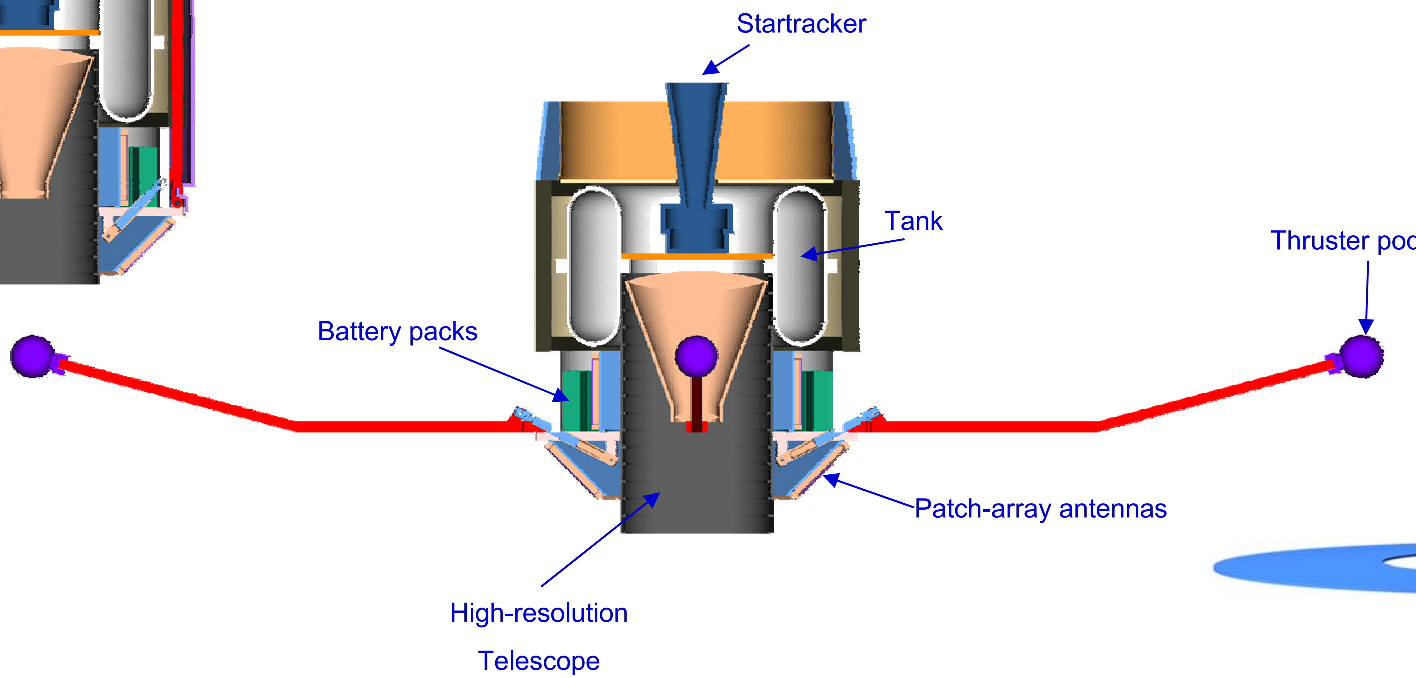
- Top requirement: The E.I.S. system shall be deployable with a fighter jet

EIS - Design





ϕ 340
Startracker F.O.V.
391
Camera F.O.V.



Startracker
Tank
Thruster pod
Battery packs
Patch-array antennas
High-resolution
Telescope

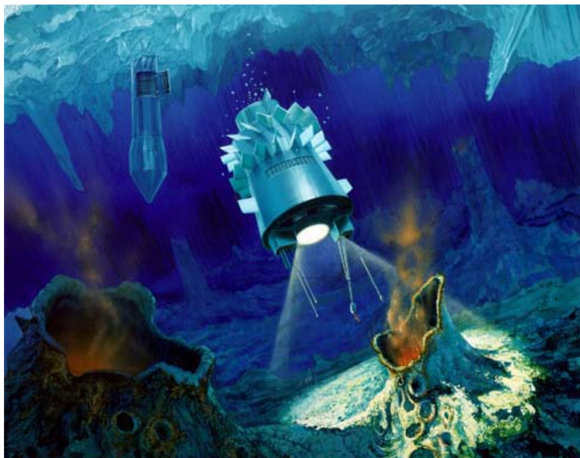
MMS enabling interplanetary endeavors

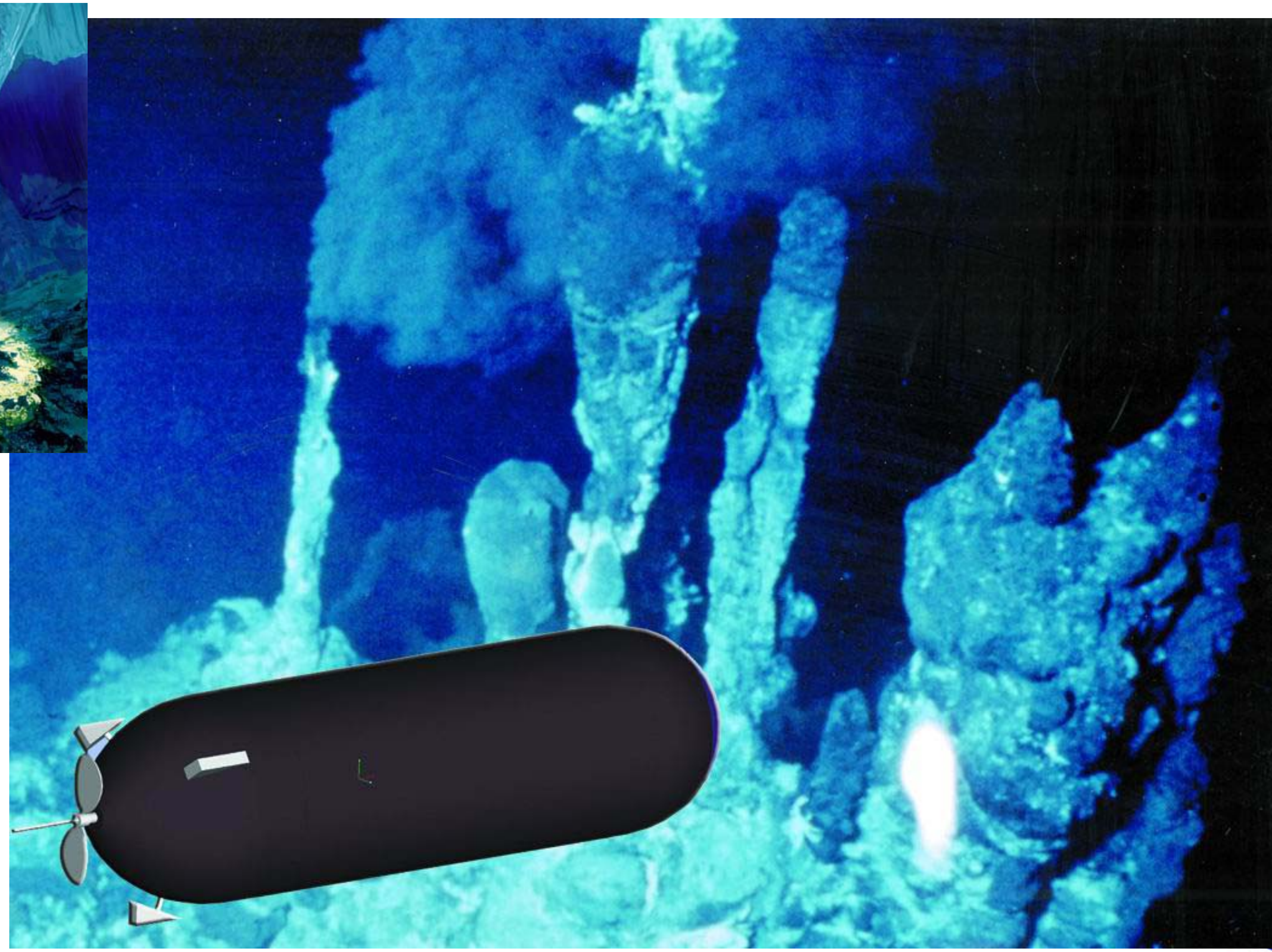
- Reduction of size and mass of electronics
  - Increased performance / weight, such as

    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





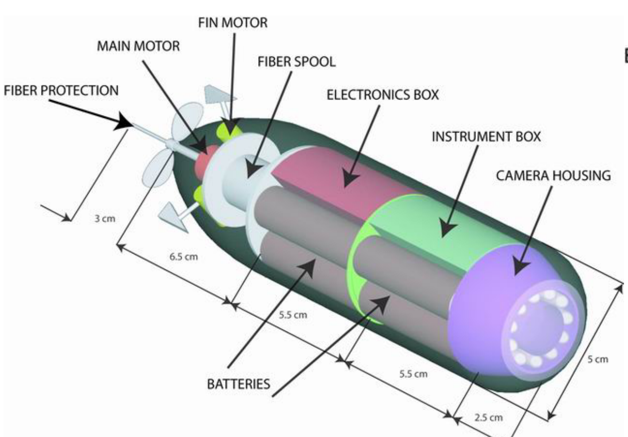
Micro AUV – Requirements

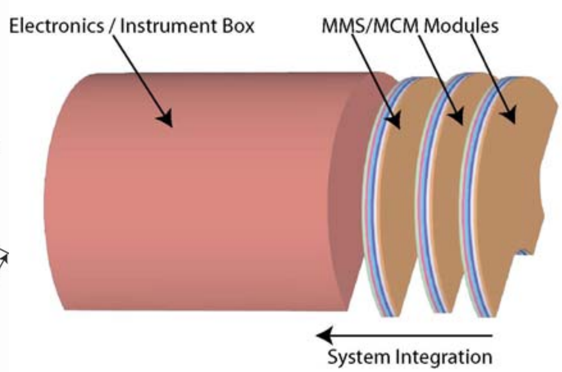
- Have maximum size of;

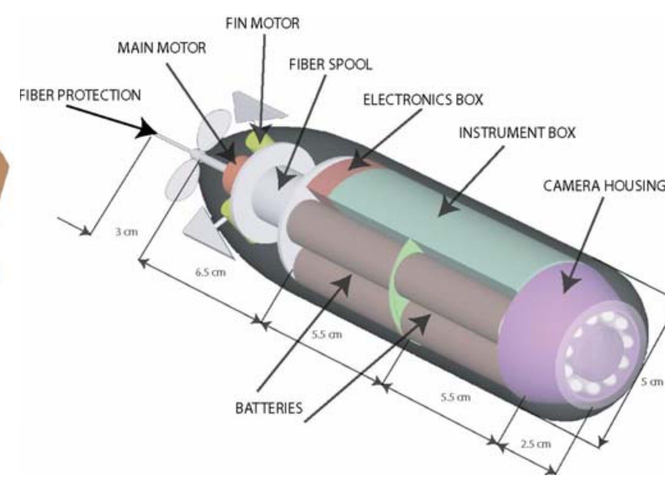
  Diameter: 8cm, Length 30cm
- The AUV shall measure Conductivity, Temperature, and Depth (CTD) and at least accommodate two other instruments
- The AUV shall have a high-resolution camera
- The AUV shall be deployable from other dimensionally constrained host vehicles for operation in naturally occurring 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 I^2C bus







SMIPS – Autonomous Inflatable Micro Rover/Robot for Planetary Exploration

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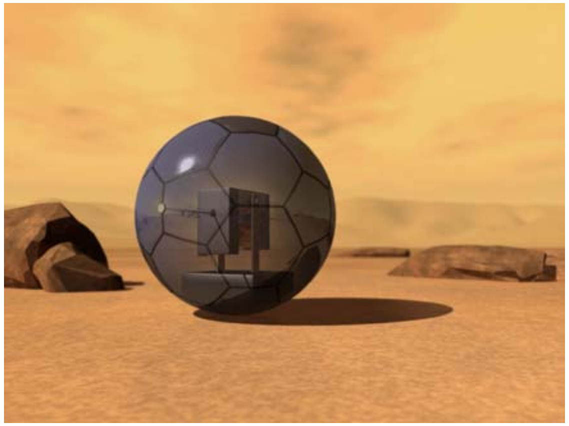
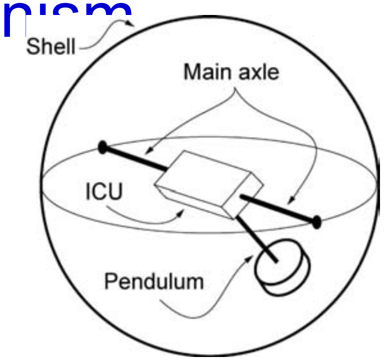
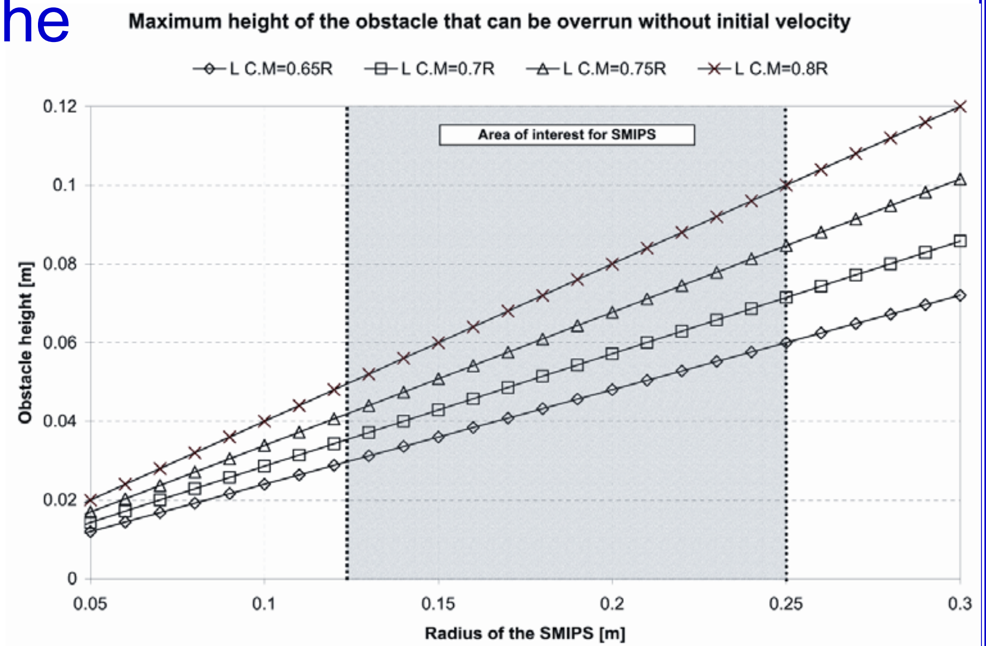
SMIPS – Design Goals

- 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

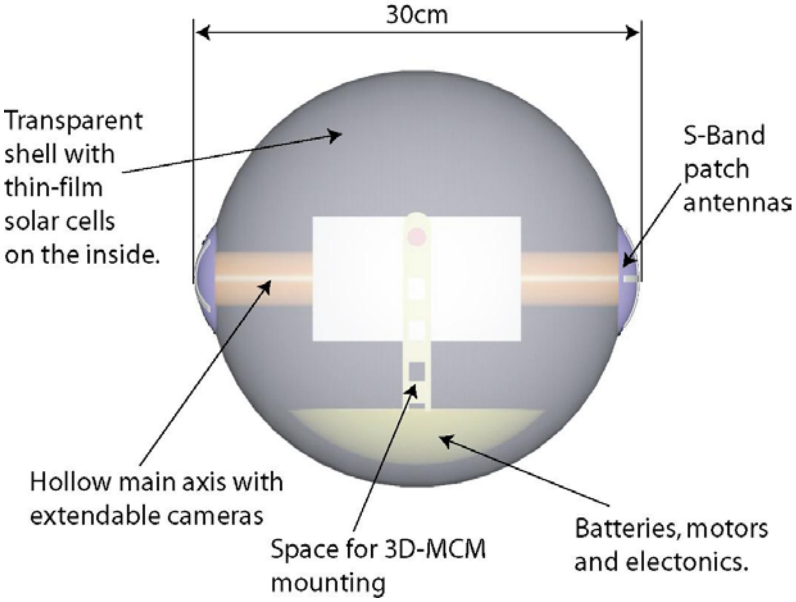


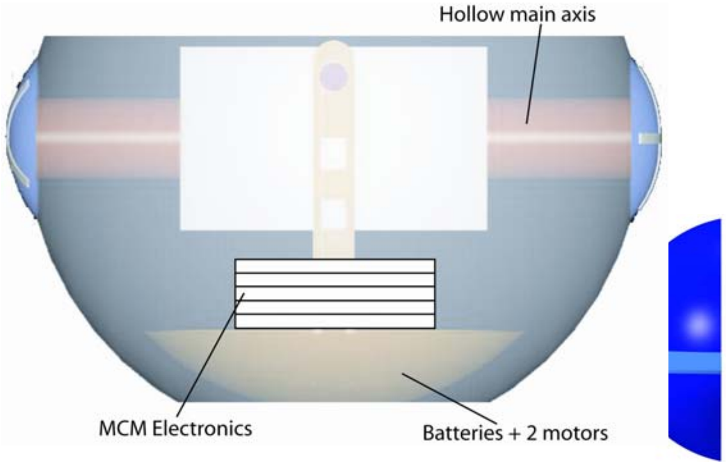




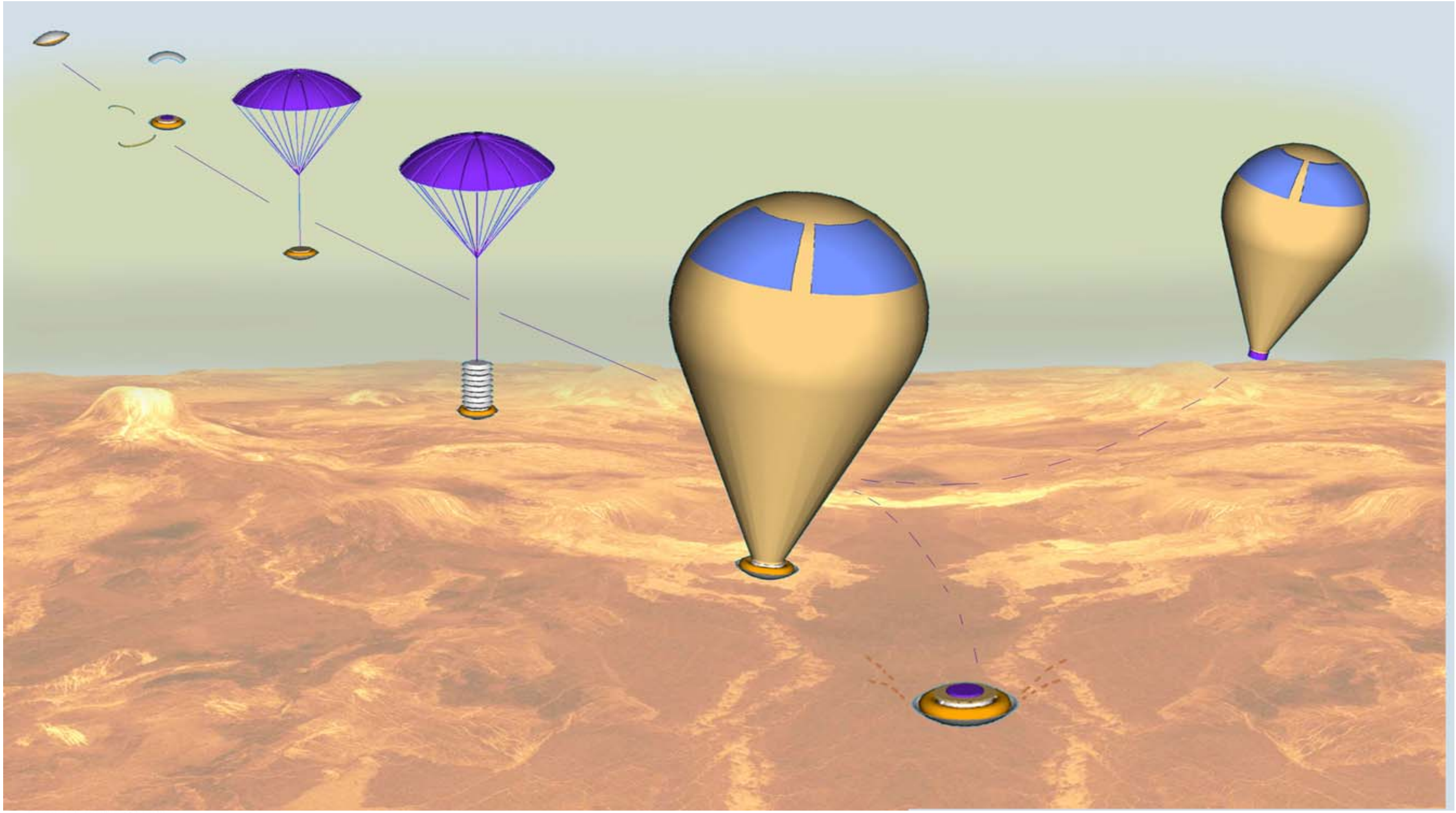
SMIPS – MMS design benefits

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





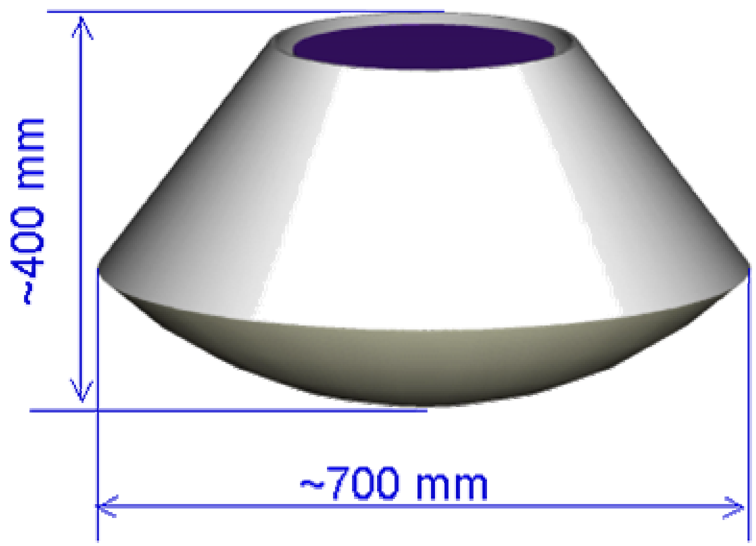
Venus Exploration – LOVECraft

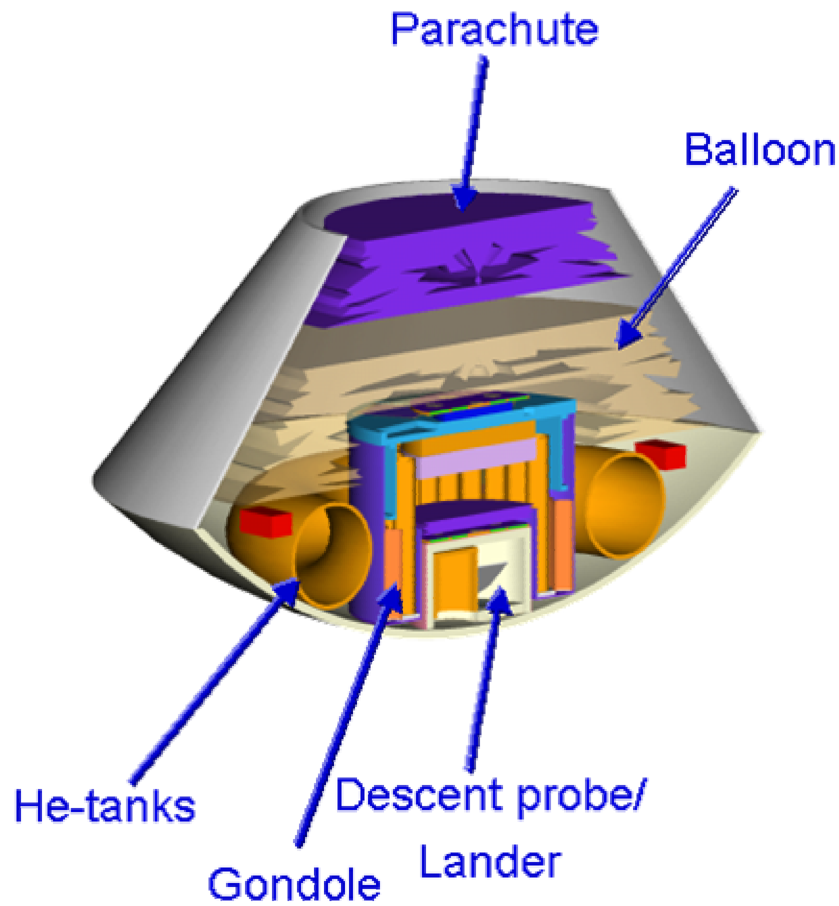


LOVECraft – MMS Implementation

- 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

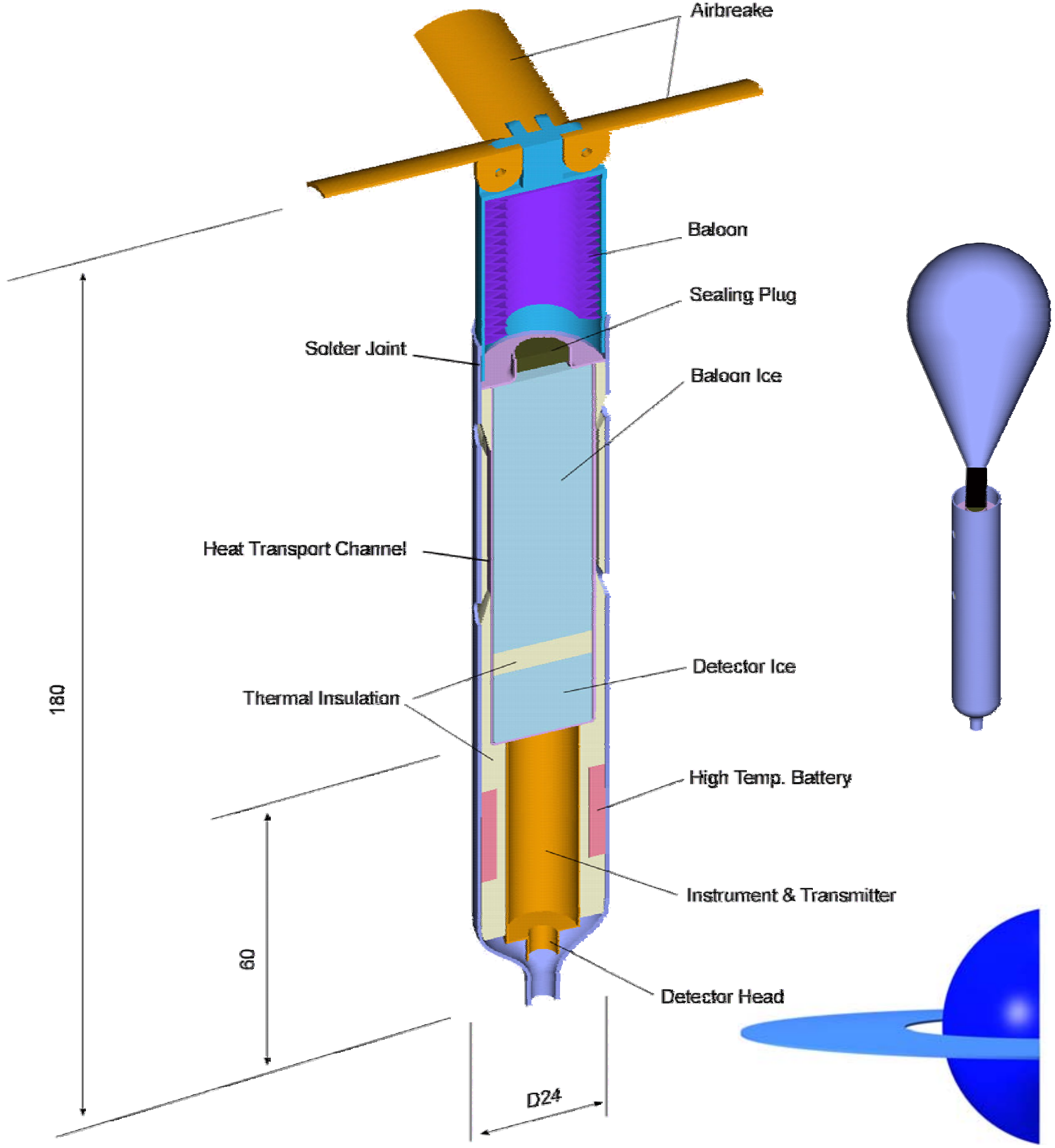
LOVECraft - Design





LOVECraft – Ballast probes

- Length: 180mm
- Diameter: 24mm
- Weight: 100g



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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**

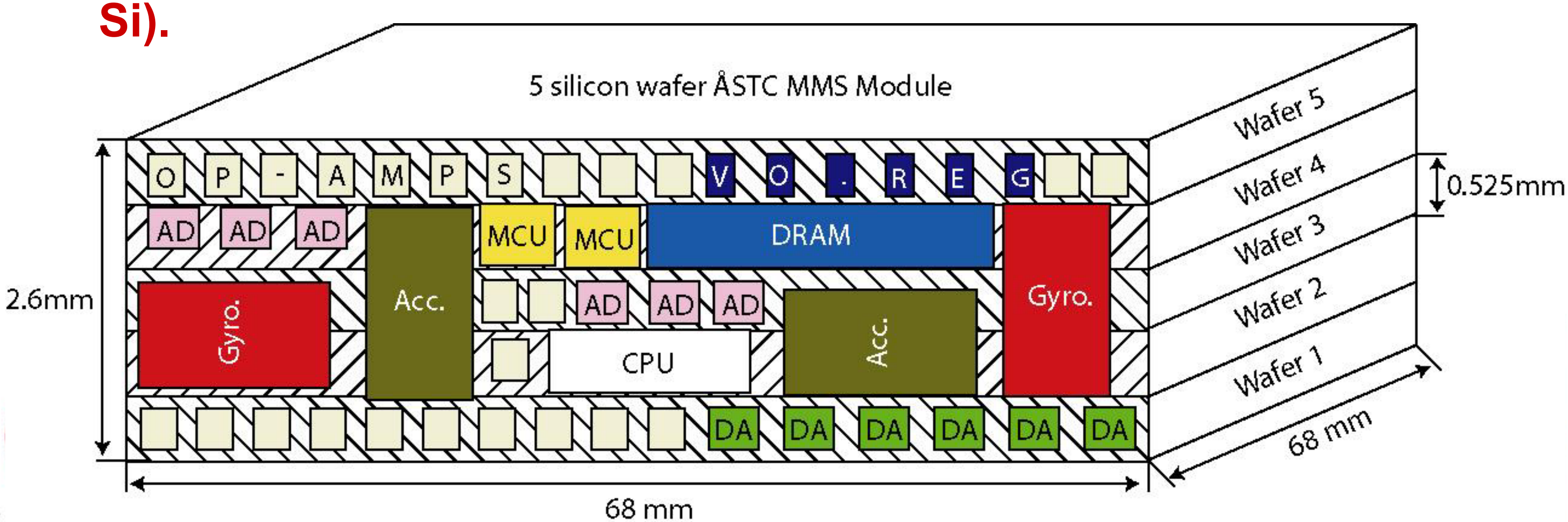
- **Let us look at a imaginary module consisting of;**

  12 ADC, 12 DAC, 50 OP AMPs, 8 Gbit DRAM, 2 CPU, 4 MCUs, 4 Gyros, 4 Accel., 6 Volt. reg., 40 diodes.

Component	Die dimension
ADC (12-bit)	2 x 3.3 mm
DAC (12-bit)	2.9 x 2.8 mm
OP AMP	1.9 x 2.4 mm
DRAM (4Gbit)	23 x 23 mm
Volt. Switch reg.	1.8 x 1.8 mm
MEMS Gyro	7 x 7 mm (avg.)
MEMS Accel.	7 x 7 mm (avg.)
CPU (AMD, PPC,…)	13 x 13 mm (avg.)
uC, MCU	3 x 3 mm (avg.)
Diode	0.4 x 0.4 mm

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 mm^3
- Volume of all selected components:1510 mm^3
- 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.