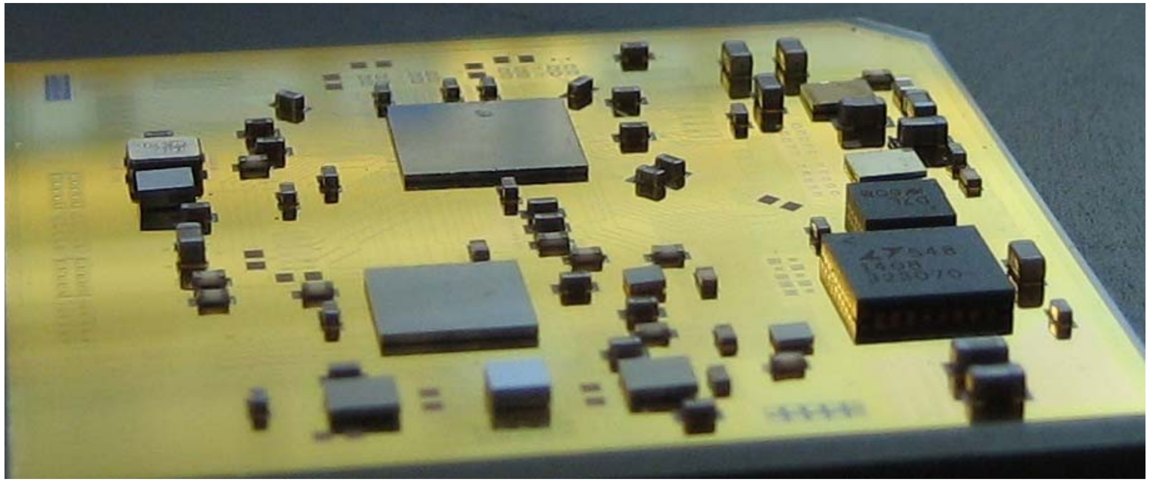
MEMS is here - Technology Overview, Future Outlook, and Two Technology Demonstration Spaceflights in 2008



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*** Ångström Aerospace Corporation**
† Swedish Institute of Space Physics

Short information on Ångström Aerospace Corporation (ÅAC)

- ✓ Private Company
  - 3rd year of operations
  - Customer financed
  - 70% of operations in space
- ✓ Business Area
  - Multifunctional MEMS
  - Design, Development and Production
- ✓ Products/Services
  - RTU / Distributed Sensor Networks
  - MACS
  - Mass Memory
  - Micro fuel-cells
  - Unique processing capabilites
- ✓ Processing
  - In-house cleanroom
  - MSL Uppsala Univ.
  - MC2 Chalmers Tech. Univ.
  - In-house processing engineers
  - Collaboration with MEMS foundries

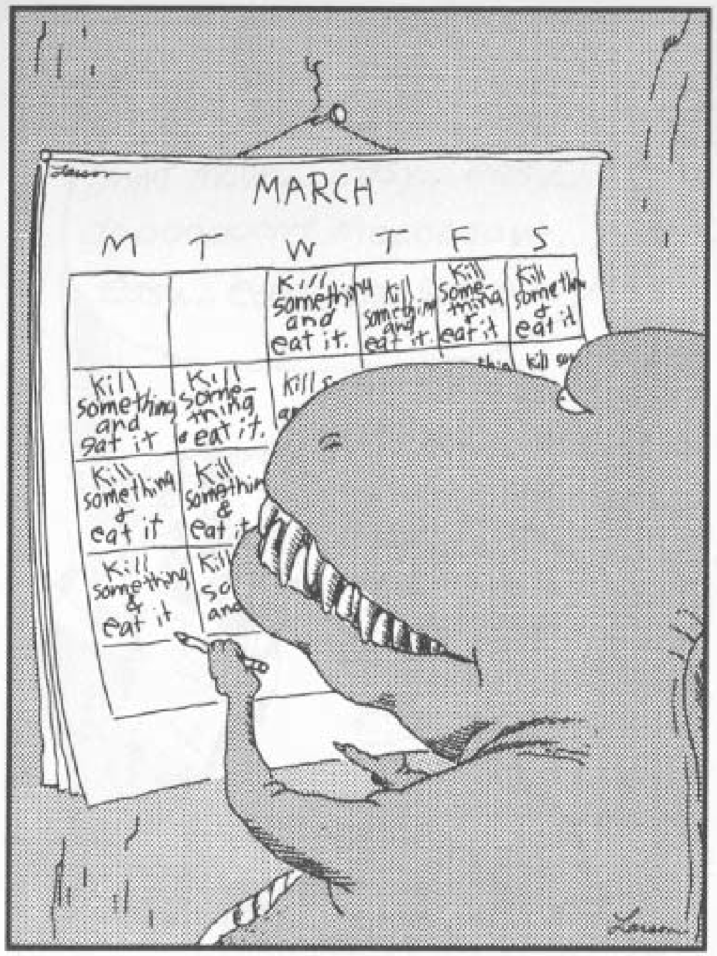
- ✓ Main Owners
  - Fredrik Bruhn
  - Lars Stenmark
  - Kalogi (fm employees of ÅSTC, Uppsala University)
  - Uppsala University
  - Key personel

MEMS Projects as of October 2007

	Type of project
US Air Force (USAF) / Air Force Research Laboratories (AFRL)	Development for USAF Rapid Response Satellites
SAAB Group	❑ Future fighter jet architectures ❑ UAV architectures
European Space Agency (ESA)	Micro/Nano Satellite Technologies
The Swedish Space Agency / Rymdstyrelsen (SNSB)	Development projects 3D-SiP modules
Swedish Defense Materiel Administration / Försvarets Materielverk	Development projects
Taiwan Space Agency (NSPO)	Technical assistance
Vinnova in partnership with SAAB Microwave Systems and FOI	Development projects
BAE Systems Bofors	Development projects

The Space Community is a conservative crowd!

Laurand Marchand's challenge from the 5th Round Table. Get things flying!
Will anyone make it before the next round table. Answer seem to be no.
NASA has tested some MEMS on and Modular panels on the ST-5 satellites.

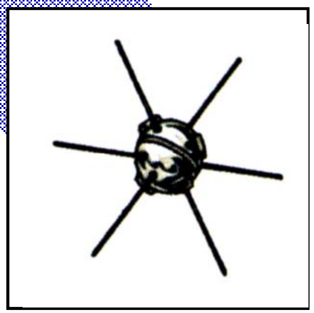


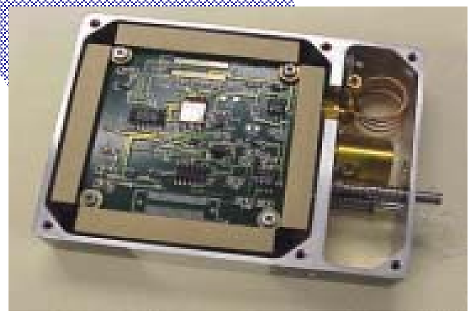
Jurassic calendars

Motivation: Leveraging Moore's Law

The Evolution of Manufacturing (from Aerospace Corp):

Custom assembly of non-standard parts → **Custom assembly of standardized parts** → **Assembly-line manufacturing (serial)** → **Batch-processing (parallel)**

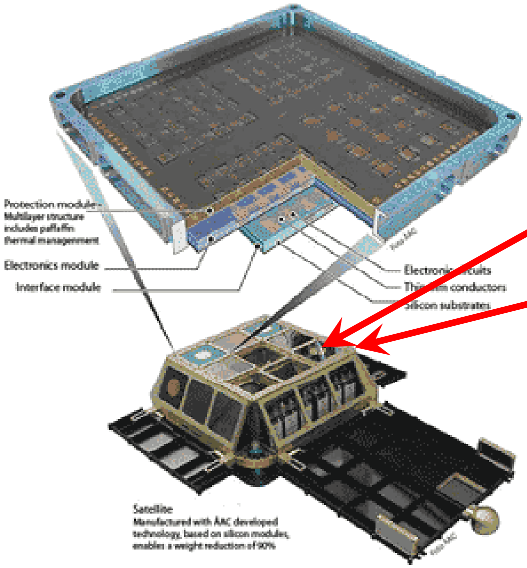




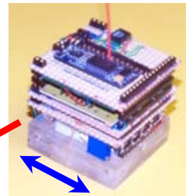
Small Spacecraft:	Vanguard 1	DARPA PICOSAT	"Integrated" Satellites
Launch Year:	1958	1999	~2005
Functional Elements: **(Incl. Transistors)**	~100	~100,000	~100,000,000

Changing to Modular and Small

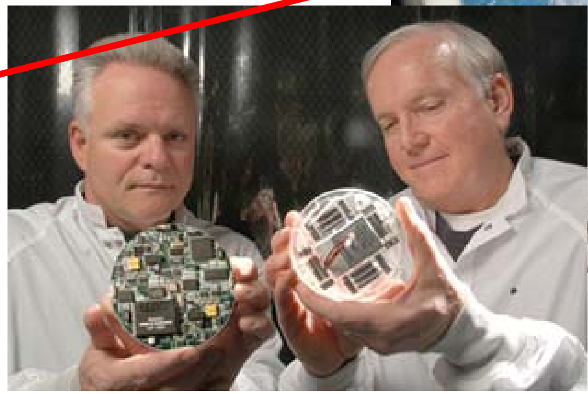
NanoSat Platform



Glass/Ceramic Sat



PicoSats



THE AEROSPACE CORPORATION

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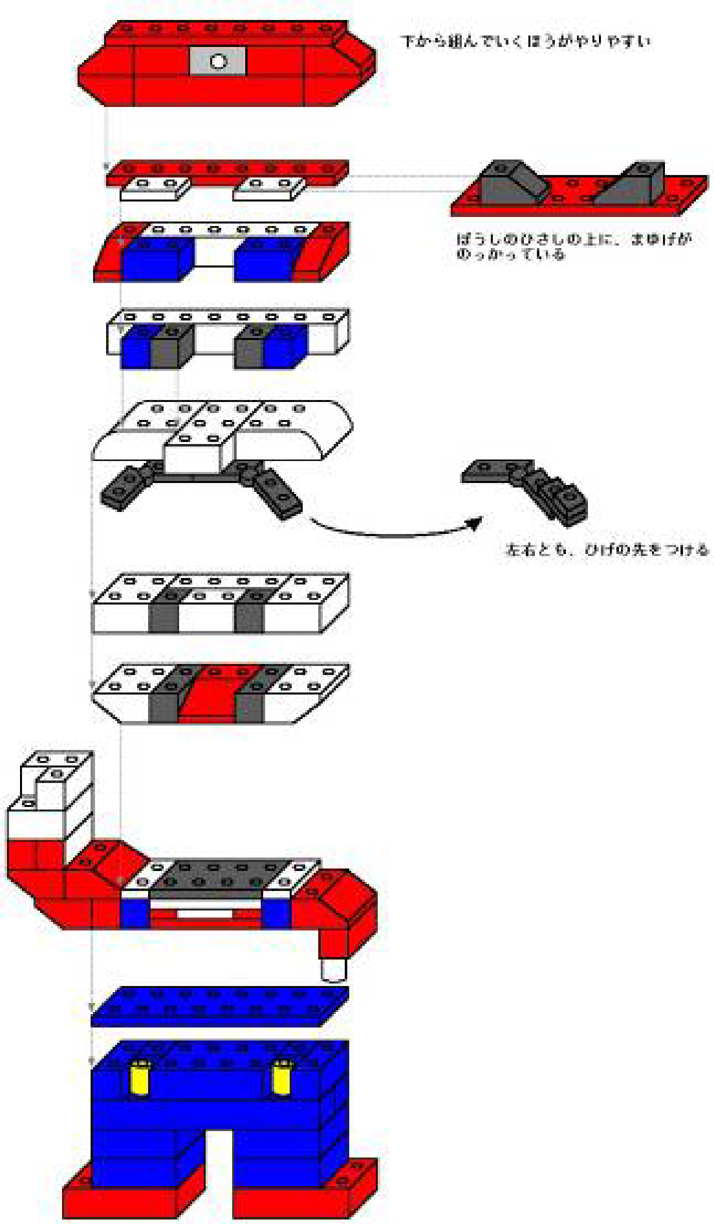
Based on the heritage
from ÅSTC/Uppsala University.
Illustration includes ÅSTC/NanoSpace-1
satellite model.

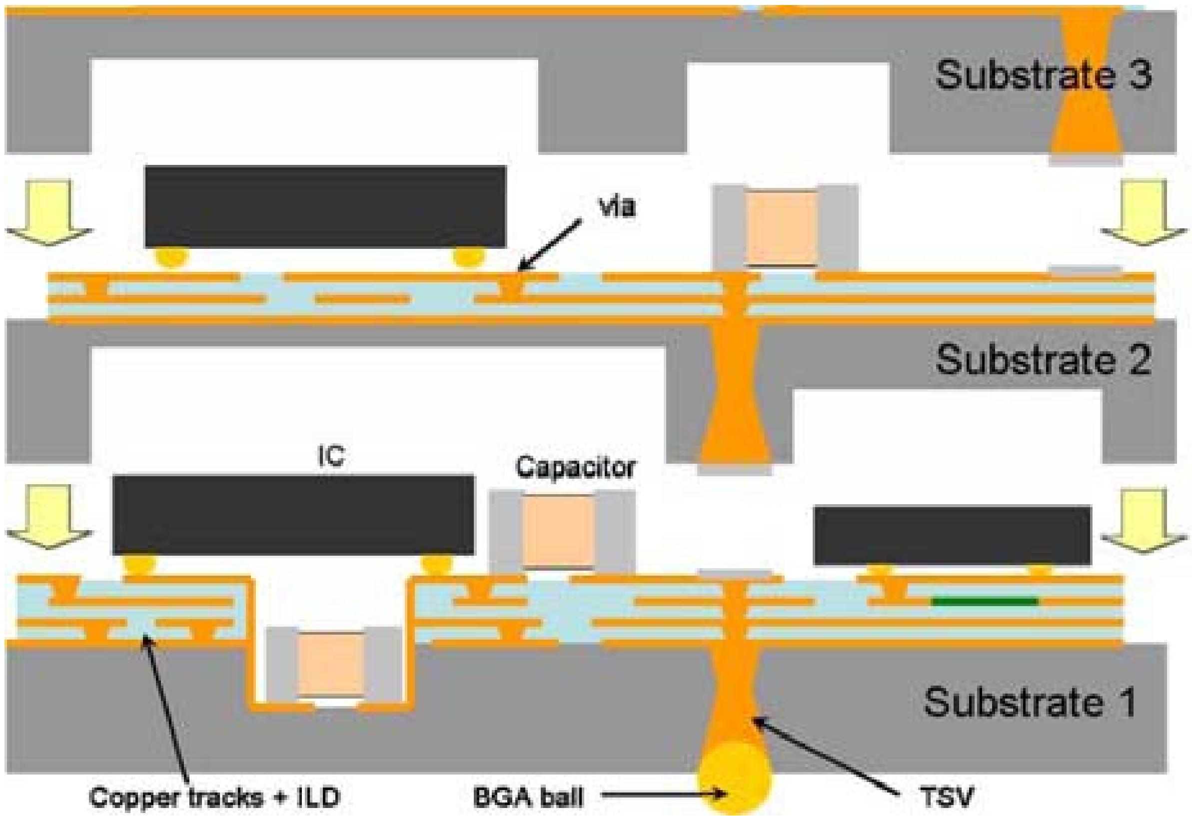
Multifunctional Microsystems (MMS)



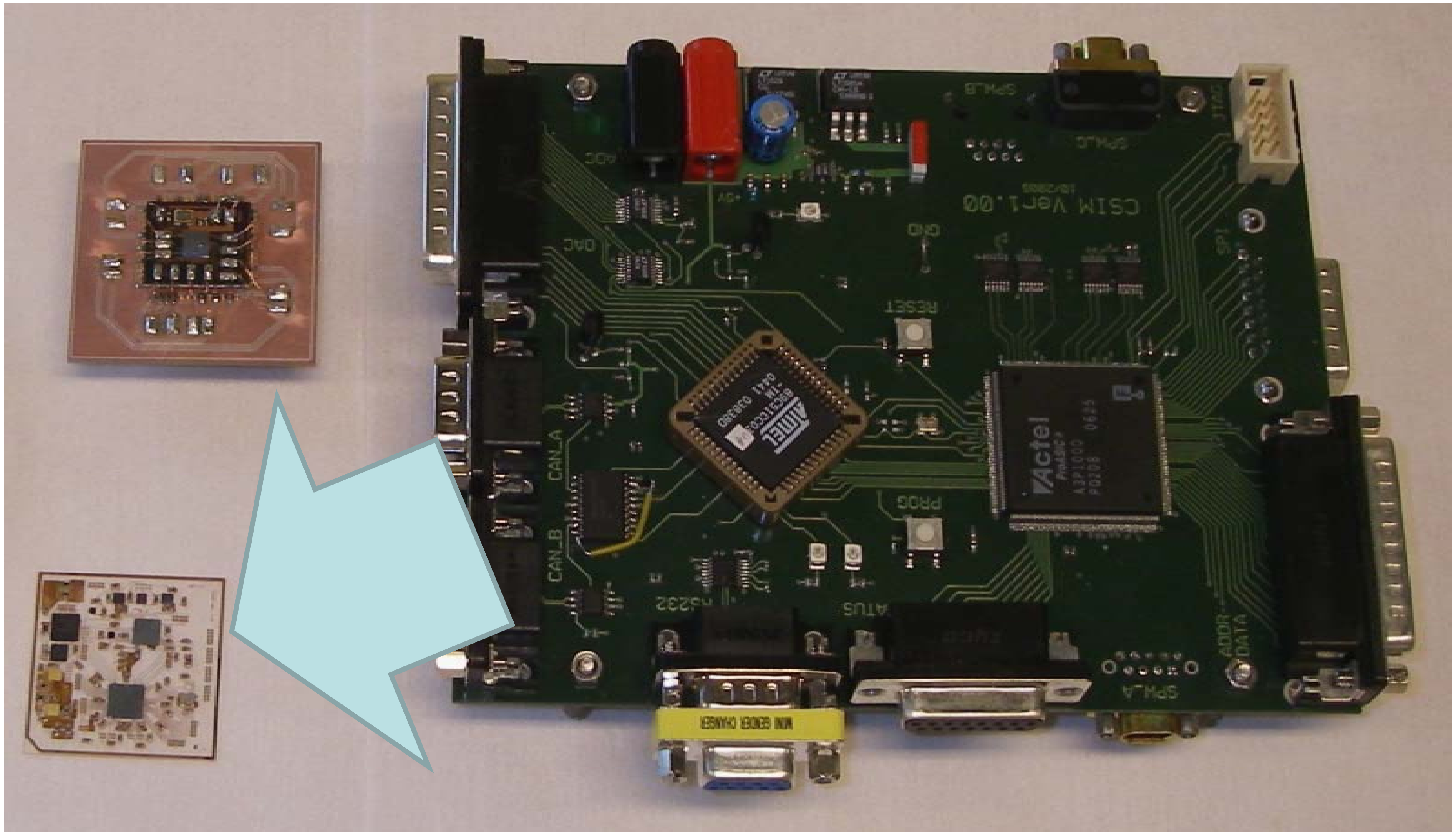
- Standardizing
- Modularization / scalabilitity
- Miniaturization
- Integration

Ångström Aerospace 3D-SiP technology

- Silicon substrate
- Silicon/SiC chips
- CTE ~ 0 => Huge Temperature ranges
- Structural element, heat conductor (module pipe?), electrical function

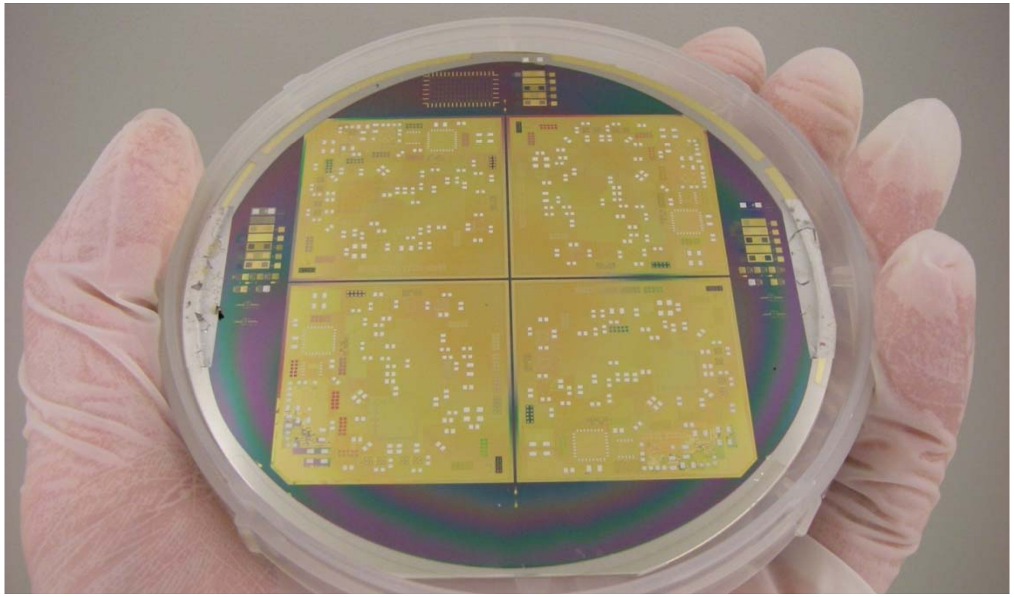


Remote Terminal Unit PCB vs 3D-SiP



Manufacturing and cost – 4″ silicon wafers with Through Silicon Vias

- ✓ By moving from 4″ university environment to a commercial 8″ fab, the cost per substrate will directly be reduced 4 times.
- ✓ ÅAC through silicon vias (TSV) are metallic low cost vias compliant with available MEMS foundries
- ✓ Transfer of university scale development to MEMS fab is around months to one year.

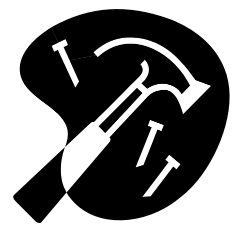


Simple System Analysis for a Powerful Nano/Pico Satellite Bus

Assume a small spacecraft design consisting of the following ÅAC parts

- 3 RTU
- 1 OBC (software tweaked RTU)
- 1 Mass memory

- ✓ This would give a total of 4 * 40 MIPS = 160 MIPS in the system
- ✓ It would have redundant CAN busses (with Plug n Play features)
- ✓ It would have a SpaceWire network (with SpaceWire routers)
- ✓ Up to 32 LVDS channels (for SpaceWire, 1553, Fast LVDS AD converters etc.)
- ✓ Up to 32 Gbit of fault tolerant memory
- ✓ Up to 24 Analog/Digtal (AD) 14 bit input channels
- ✓ Up to 16 Digital/Analog (DA) 12 bit output channels
- ✓ Up to 400 general IO connected to FPGAs
- ✓ I2C, UART, SPI, etc. Interfaces.
- ✓ Temperature, voltage (1.5, 2.5, 3.3, 5V), current (1.5, 2.5, 3.3, 5V) house keeping.

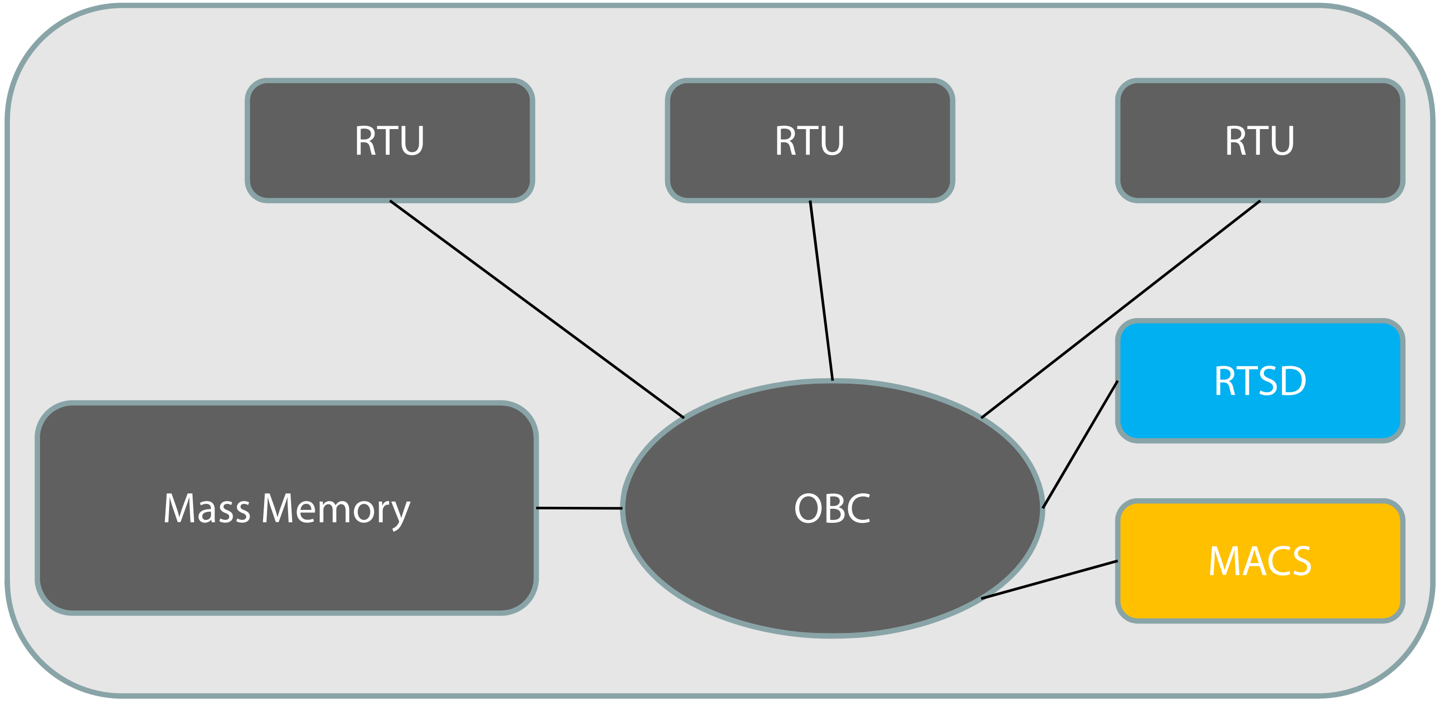


Mass:

4 * 6 grams, 24 grams (each RTU is ~ 3 gram + 100% for packaging and connector) +

1 * 200 grams (for Mass memory incl. packaging and connector). **Total: 224 grams.**

Future outlook: Simple Analysis Schematic

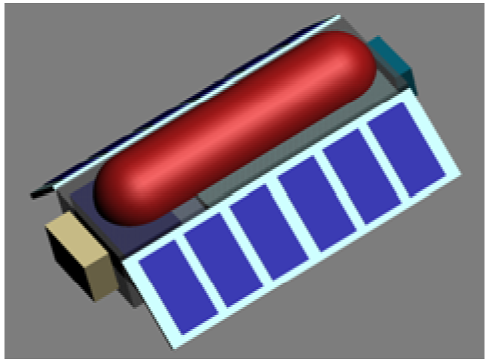


- 224 gram (OBC, 3xRTU, MM)
- Add 3 grams for a Magnetic Attitude Control module, 227 gram (OBC, 3xRTU, MM, MACS)
- Add another 10 grams for a 3-Motor Control module, 237 gram (OBC, 3xRTU, MM, MACS, RTSD)

Flight qualification, NanoRubin-1 (OHB System)

FLIGHT DATA

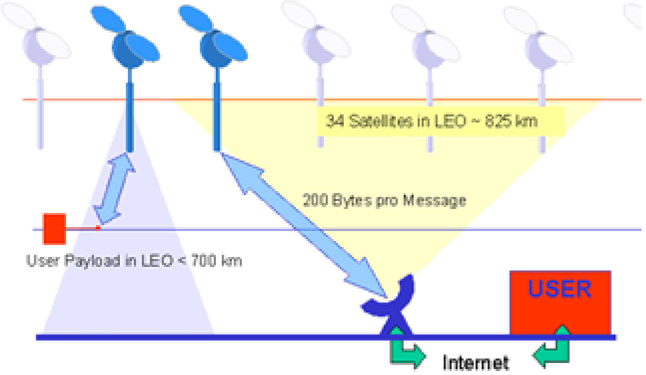
- NanoRubin-1
- Customer: Swedish Space Agency
- Integrator: OHB System AG (Bremen)
- Launch vehicle: Russian COSMOS-3M rocket
- Launch: July 2008
- Satellite mission: Dedicated Technology Demonstrator Satellite
- Operation: Operation from ÅACs facilities in Uppsala for 1 year.



NanoRubin MNT internal (I1) and external (E1 & E2) payload accommodation

ÅAC Contributions

- Prototypes of MACS
- Prototype of Mass memory with SAAB Space
- Prototypes of RTU
- Flight software validation



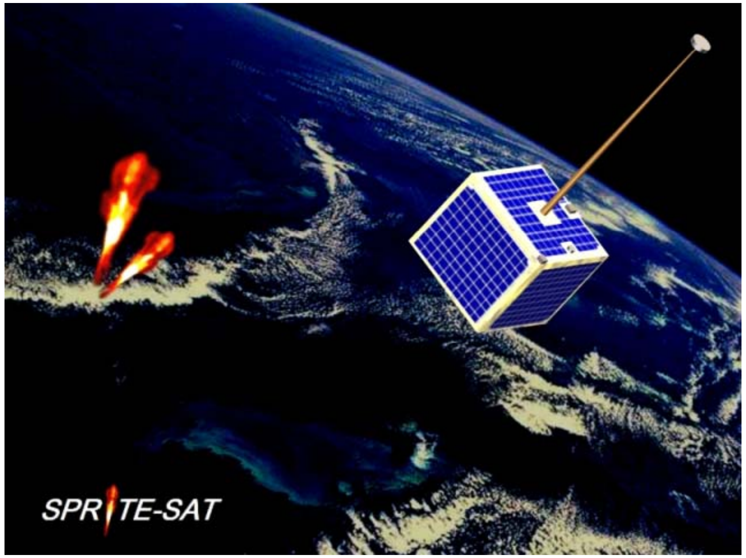
Communication with NanoRubin is performed via the ORBCOM network

Public Reference: B.Ziegler, Prof. I. Kalnins, Dr. F. Bruhn and Prof. L. Stenmark. Rubin – A Frequent Flyer Testbed for Micro- and Nano Technologies, 57th International Astronautical Congress 2006, Valencia, Paper no: IAC-06-B5.6.14

Flight qualification 2, Sprite-Sat (Tohoku Univ. /JAXA)

FLIGHT DATA

- SPRITE SAT
- Customer: Japan Aerospace eXploration Agency (JAXA)
- Integrator: Tohoku University (Sendai)
- Launch vehicle: Japanese H2A rocket
- Launch: August 2008
- Satellite mission: To study the upper atmosphere lightning (sprites) effects and interaction with Ozone (O_3)



ÅAC Contributions

- Technology validation Prototypes of 3D-SiP modules
- Flight software validation

Conclusions

- With two spaceflights in 2008, expect technology evaluation and feedback during the 7th Round Table.
- The modular approach, with the substrates being multifunctional enables very powerful micro/nano satellites.
- The economy of scale works just like any MEMS device
- Silicon substrates works with good results
- Plug and play is necessary to keep costs down and allow for rapid-response.

THANK YOU FOR YOUR ATTENTION

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