



# **Description of MEMS 3D-System-in-Package Spacecraft Subsystems and Packaging Technology**

**Ångström Aerospace Corporation**

**R. Thorslund, P. Nilsson, M. Antelius, J. Davidsson, M.  
Hagström, E. Källén, E. Lamoureux, R. Lindegren, K.  
Lindqvist, V. Lindskog, A. Ljunggren, L. Stenmark, F.  
Bruhn**



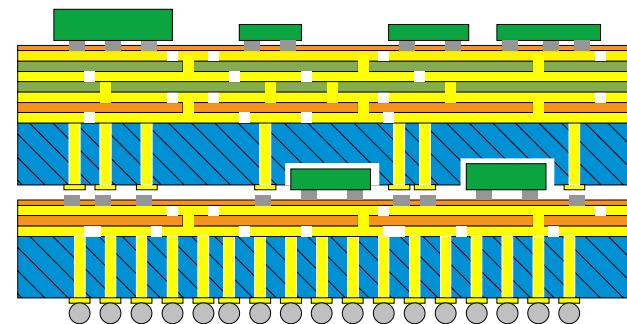
# Outline

- 3D-System-in-Package (3D-SiP) module
- QA Procedures
- Manufacturing Examples
- 3D-SiP Remote Terminal Unit
- 3D-SiP Magnetic Attitude Controller
- 3D-SiP Solid State Mass Memory
- Flight Scheduled July 2008
- Acknowledgement



# 3D-SiP Module

- Extreme Size and Weight Reduction
- Heat Transfer
  - FR4 with 2metal layers  $k_{pe} \sim 21\text{W/mK}$ ,  
 $k_{ne} \sim 0.3\text{W/mK}$
  - Silicon  $k=170\text{W/mK}$
- Thermal Expansion Match
- Short Signal Paths
- Fine Pitch Capabilities

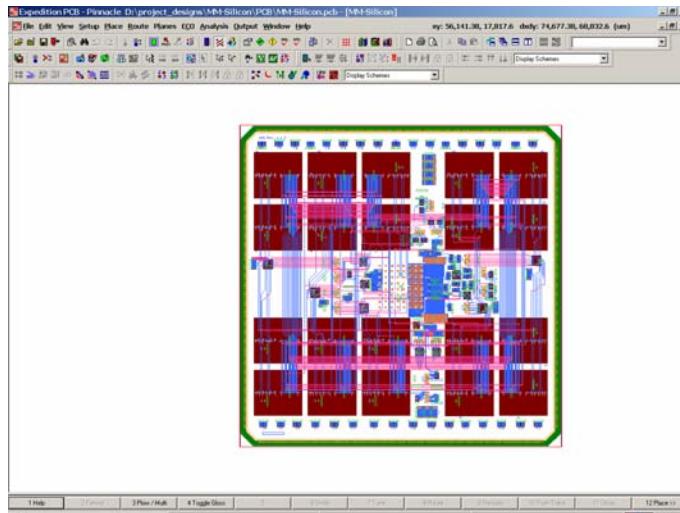


# Standardized QA Procedures

- Component and Layout Database
  - Verified die map library
  - Standard layout library
- Standardized Test Procedures
- Process and Test Protocols
  - All process data recorded
  - QA test pattern
- Recipe Database
  - MEMS "cookbook"

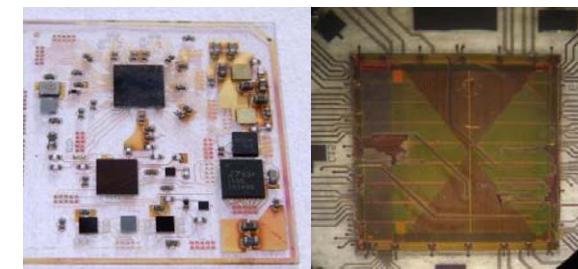
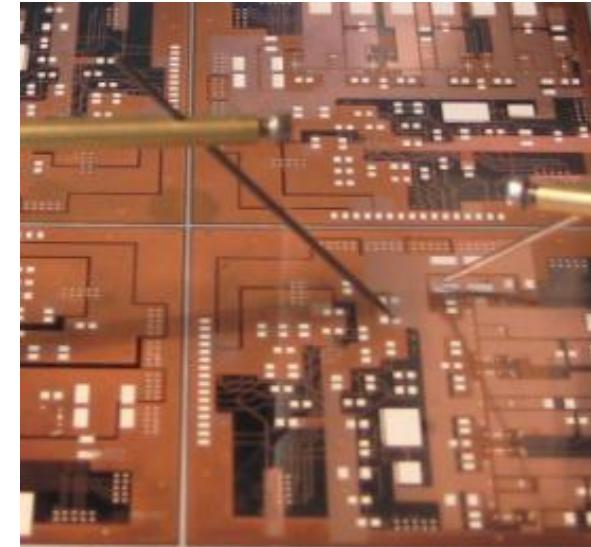
The screenshot shows a Microsoft Internet Explorer window displaying the Ångström Aerospace Admin Center. The URL is [http://aodor.aerospace.com/a\\_admin/admin\\_main.php?act=1](http://aodor.aerospace.com/a_admin/admin_main.php?act=1). The page title is "A-Admin Center". On the left, there's a sidebar with links like "Logout", "Help", "Search reseller", "Public chip", "Public vendor", and a "Classifiers" section with categories such as Discrete, IC, ADC, DAC, FMSA, Hall, MCU (1), Memory, Oscillators (1), Registers, Sensors, Transceiver, Voltage reference, and Other. The main content area is titled "Detailed information for chip, < A189LS1103 >". It shows the following details:

- Manufacturer: ATMEL
- Chip type: MCU
- Temperature range: 55 to 85
- Industry status: Obsolete
- Time to end [months]: 0
- Minimum order QTY: 100
- AACinhouse QTY: 40
- Function: Main controller AVR1, CAN, ADC, USART, 64kB Flash
- Manufacturer reference: AT83C5131A/5618
- Reseller reference: Value
- Package Type: Plastic do
- Package code: AT83C5131A/5618
- Price: 0.60 MHz
- Size [mm] (H,W,L): 0.33, 4.82, 4.965
- Surface area [mm<sup>2</sup>]: 23.153905
- Volume [mm<sup>3</sup>]: 7.429858
- Comment: space compatible

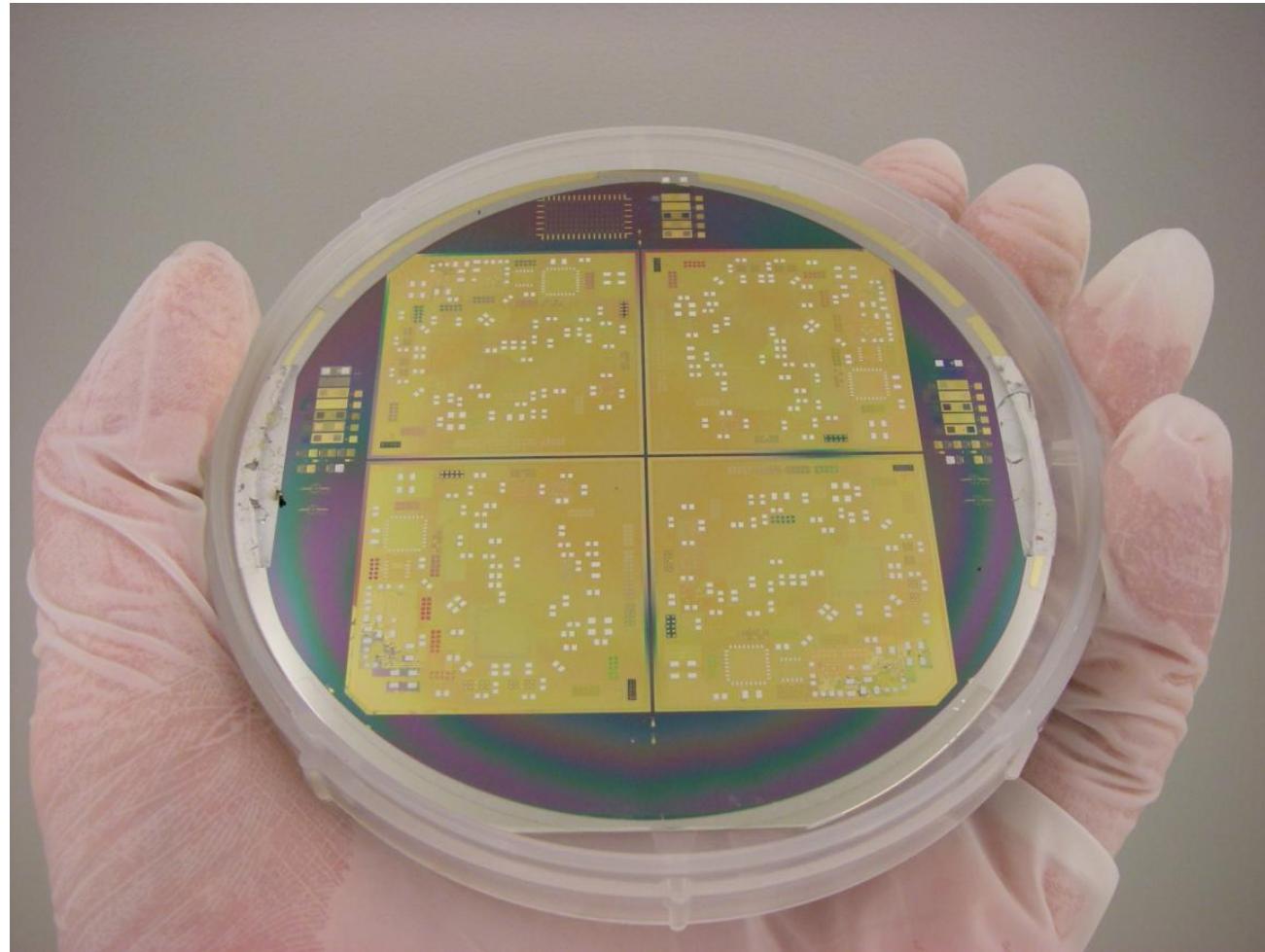


# Standardized QA Procedures

- Continuous Probing During Manufacturing
  - Standardized testprotocoll
- Temperature Cycling
- IR Inspection
- X-ray Inspection
- Glas/Pyrex Wafers
  - Soldering verification
  - Pad layout verification

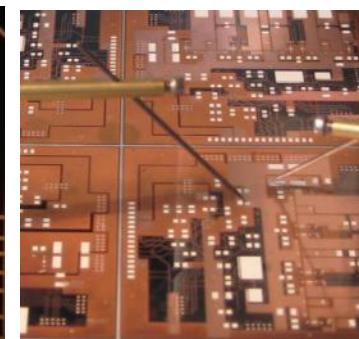
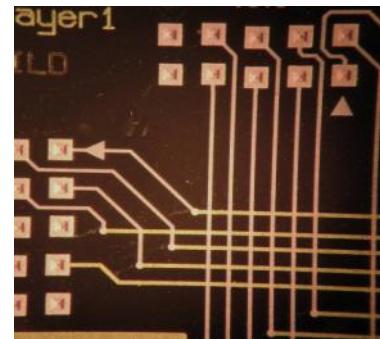
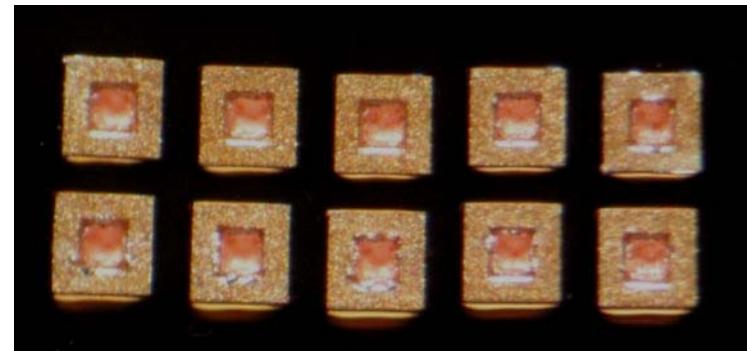
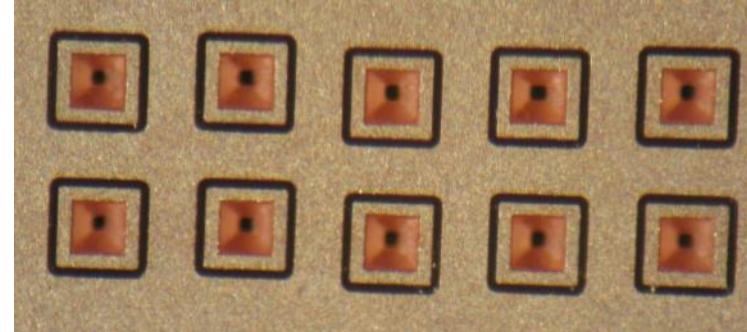


# Manufacturing – 4" silicon wafers with Through Silicon Vias



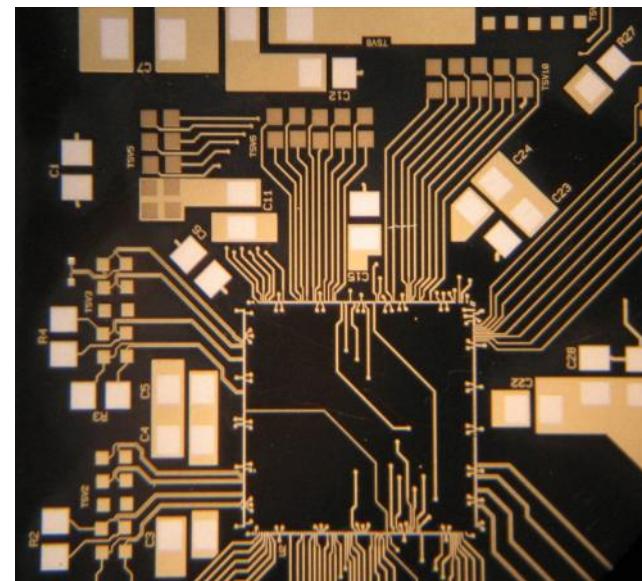
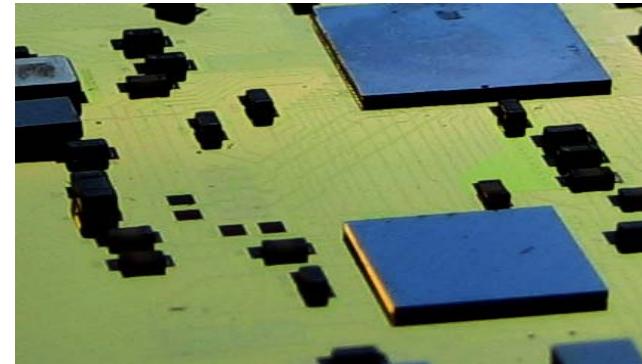
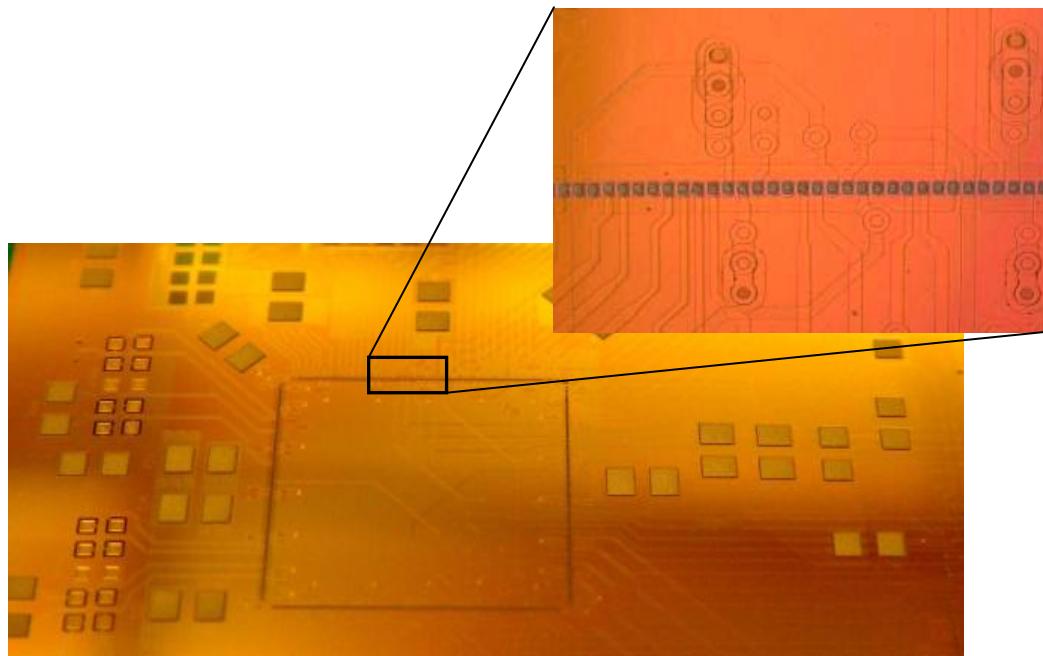
# Manufacturing - Examples

- *Patent Pending* Through Silicon Vias (TSV)
  - High yield process
  - Variable Pitch
  - $\leq 20\text{m}\Omega$
- Metal Multilayers
  - Various metals
  - Choice of thickness
- ILD Multilayers
  - Various ILD's
  - Choice of thickness
- Open or Sealed TSV's
  - Open: fluidic/gas and electric
  - Closed: electric/environmental protection



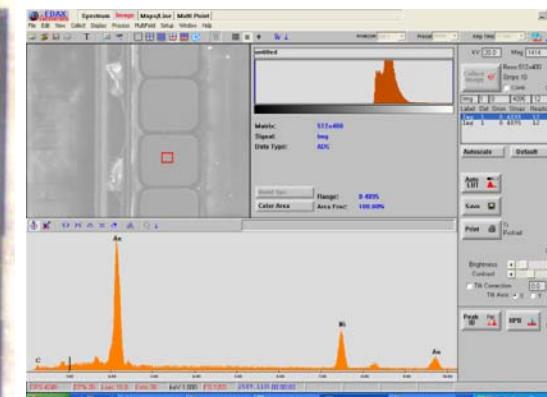
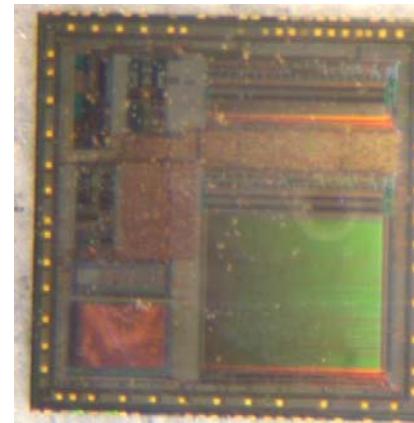
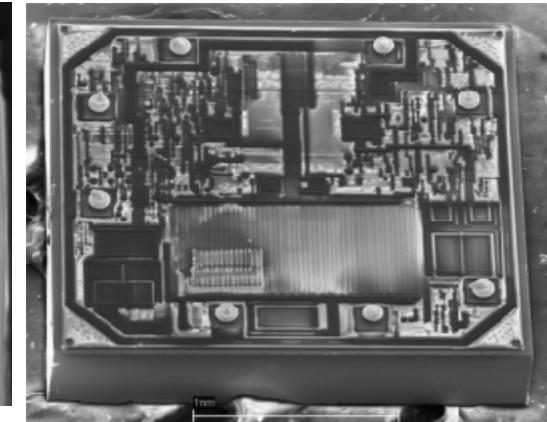
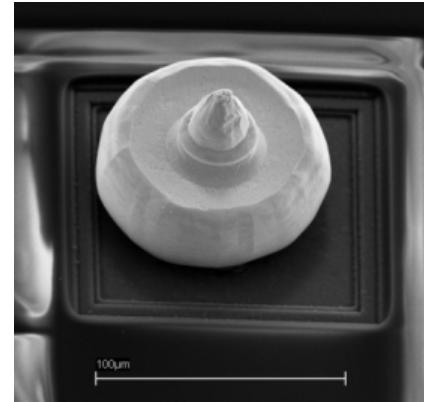
# Manufacturing - Fine Pitch Chip Mounting

- Fine Pitch Capabilities
- Example
  - FPGA 350 MHz ACTEL 1MGate ProAsic3+
  - Pitch 57µm, pad-pad 27 µm



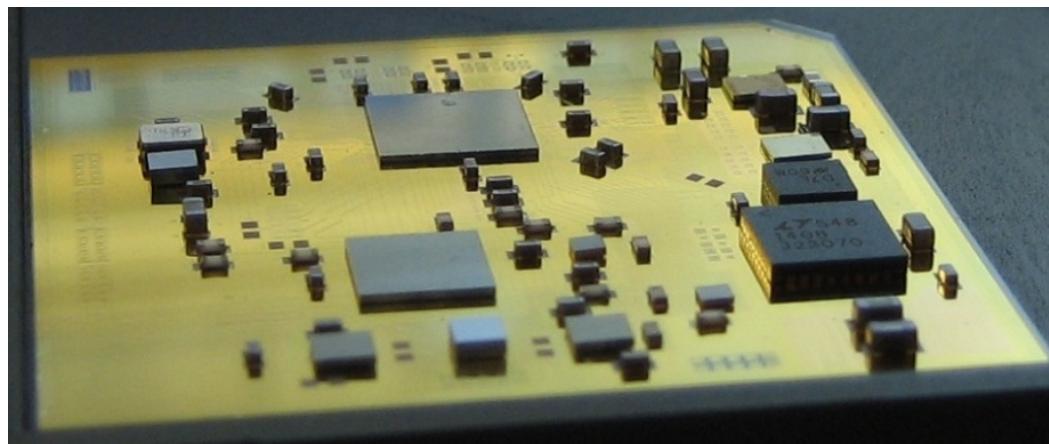
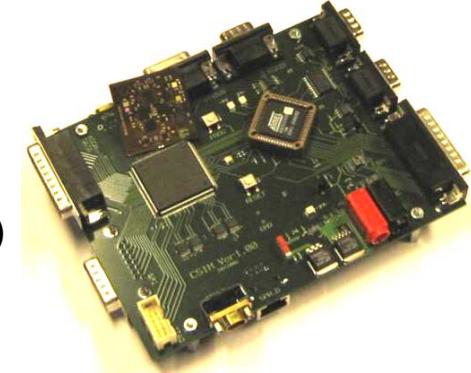
# Manufacturing - Under-Bump-Metallization

- Flip Chip Technology
- Stud Bumping
- Remetallization at Chiplevel
  - Fine pitch
- Extensive Testing
  - SEM
  - EDS
  - ESCA
  - Roughness
  - Height



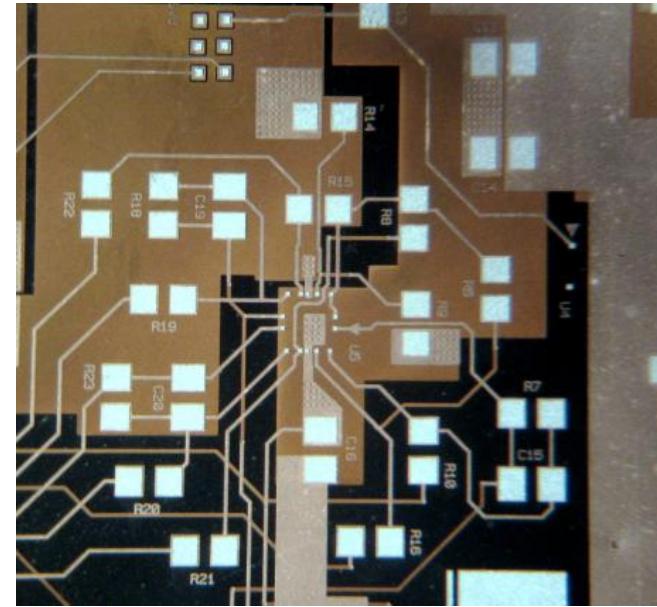
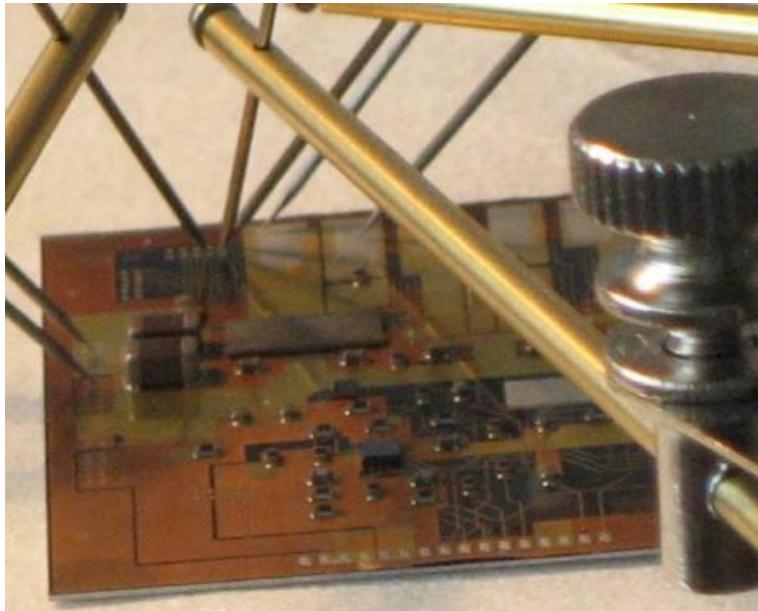
## 3D-SiP Examples -RTU

- 350 MHz ACTEL 1MGate ProAsic3+
- 60 MHz ATMEL T89C51CC03 Microcontroller
- Redundant Controller Area Network (CAN 2.0b compliant)
- Redundant high-speed LVDS drivers (SpaceWire or 1553)
- 6 x 14 bit Analog to Digital conversion user inputs (ADC)
- 4 x 12 bit Digital to Analog conversion user outputs (DAC)
- 48 bit CAN synchronizable System Elapsed time (32 bit seconds, 16 bit fractions)
- General 8-bit user I/O port (6 bit addressing and interupts)
- Dimensions: 33 x 33 x 1 (mm)
- Mass: 3 grams



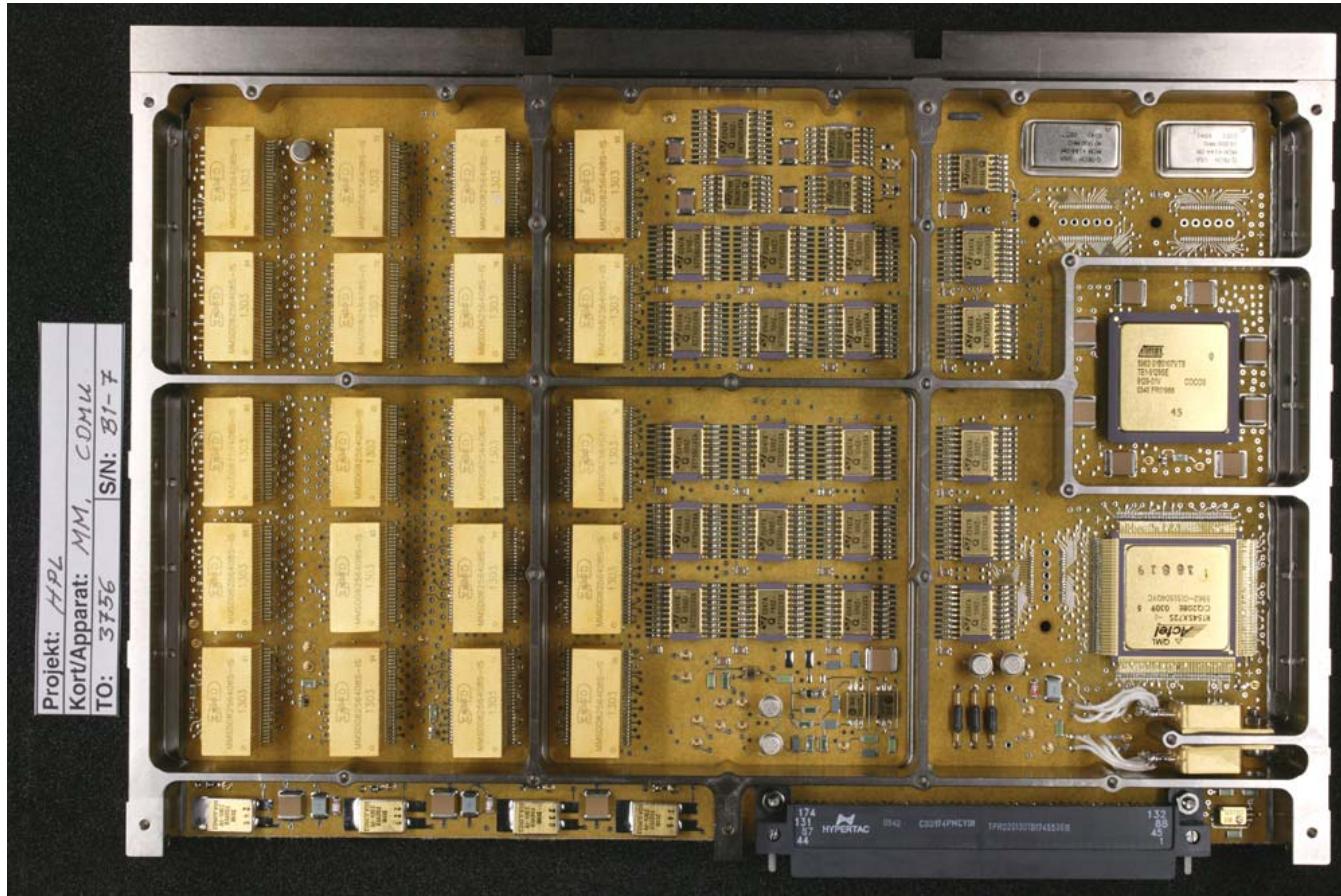
## 3D-SiP Examples -MACS

- 3 independent H-bridges 3A@12V, Max. 55V
- Filtering
- Pulse-width modulation (PWM) control
- Solderable to PCB and other substrates (optional)
- Analogue and serial magnetometer interfaces
- Dimensions: 33 x 33 x 1 (mm)
- Mass: 3 grams



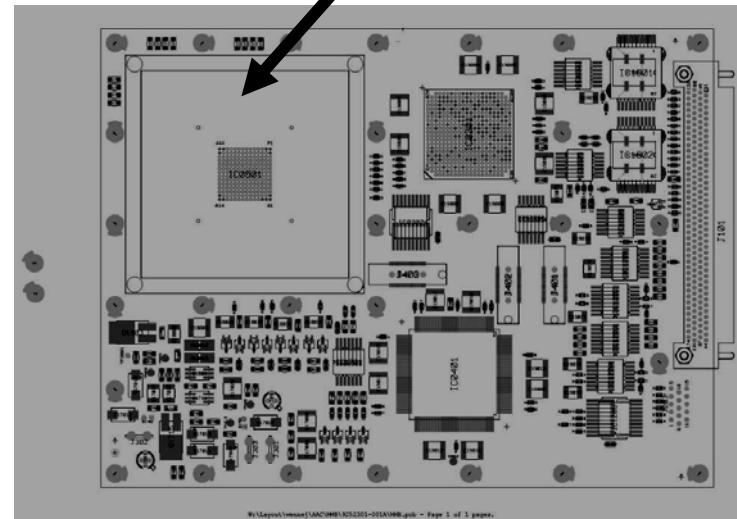
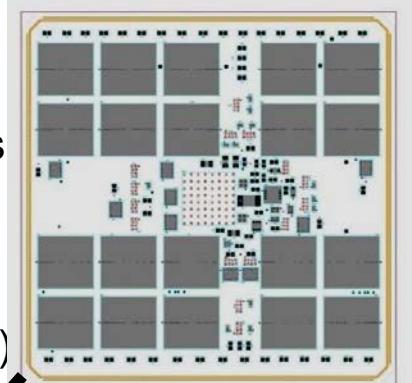
## 3D-SiP Examples - AAC / SAAB Space SSMM

- Solid State Mass Memory (SAAB Space, ESA Herschel Plank)



## 3D-SiP Examples - ÅAC / SAAB Space SSMM

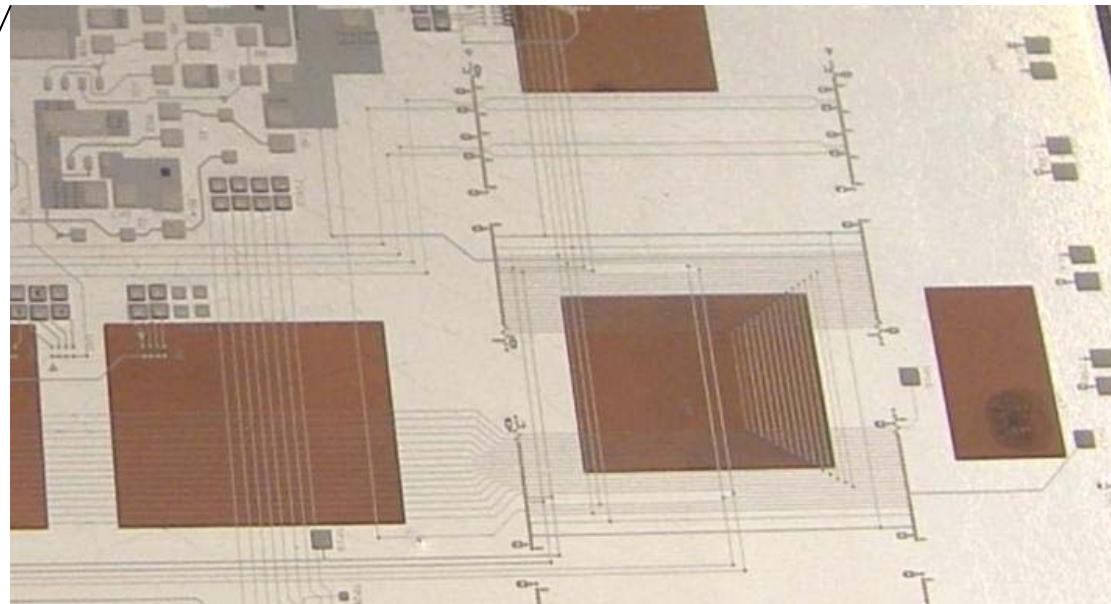
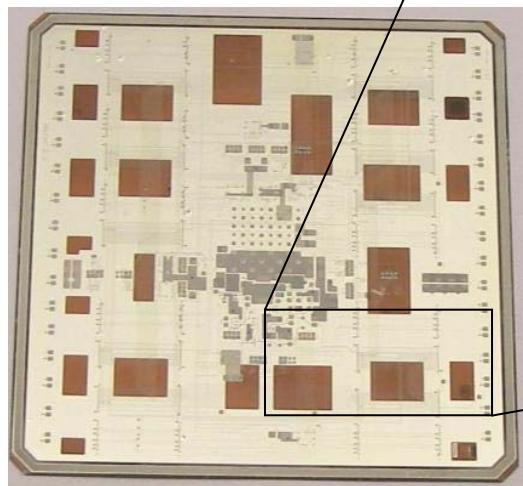
- 32 Gbit (40 Gbit incl. EDAC) SDRAM Solid state MASS MEMORY
- 10 Gbit (incl. EDAC) / silicon wafer. Up to 4 stacked wafers
- Through Silicon Via (TSV) Technology
- Built in SEL protection in the silicon, response time ~ 100 ns
- All buffers built in the silicon
- Dimensions: 68 x 68 x 1(mm) , 8Gbit
- Only external part is memory controller (SAAB COCOS/NUT)



**SAAB**



## 3D-SiP Examples - ÅAC / SAAB Space SSMM



**SAAB**



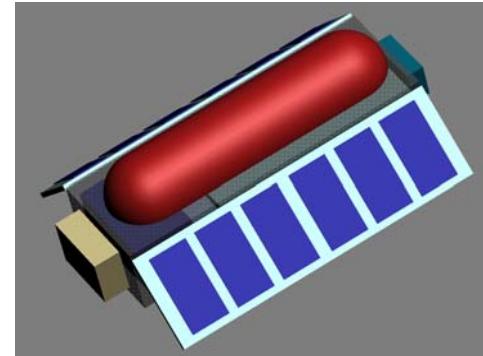
# NanoRubin (Prime OHB System)

## FLIGHT DATA

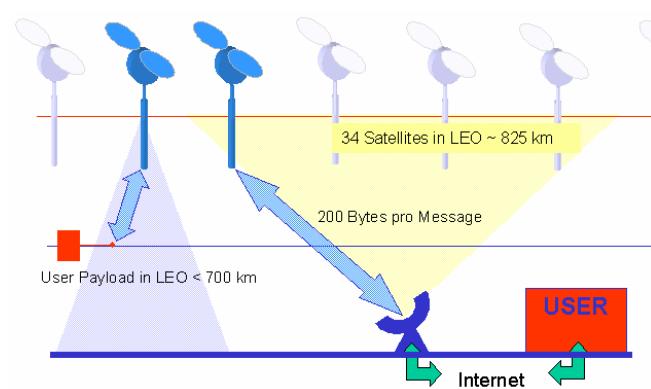
- NanoRubin-1
- Customer: SNSB
- Integrator: OHB System AG (Bremen)
- Launch vehicle: Russian COSMOS-3M rocket
- Launch: July 2008
- Satellite mission: Dedicated Technology Demonstrator Satellite
- Operation: Operation from AACs facilities in Uppsala for 1 year

## ÅAC Contributions

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



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



Communication with NanoRubin is performed via the ORBCOM network



# Acknowledgement

