



Group of Astrodynamics for the Use of Space Systems

INTERNATIONAL WORKSHOP ON LEAN SATELLITE

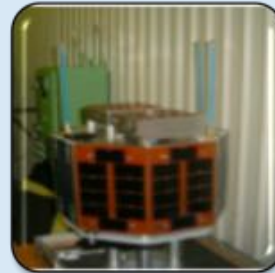
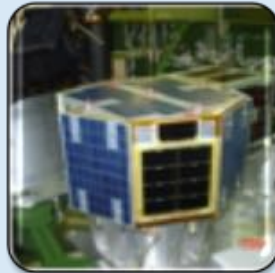
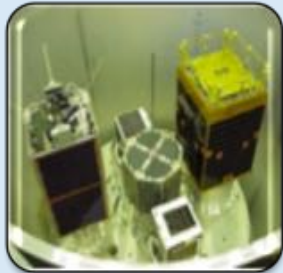
KITAKYUSHU, JAN 22-24 2018

GAUSS APPROACH TO THE LEAN-SATELLITE METHODOLOGY

2018

Riccardo Di Roberto - GAUSS Srl

- ❑ **Early 1990: G.A.U.S.S.** (*Gruppo di Astrodinamica dell'Università degli studi La Sapienza*) was established as a Laboratory of the *School of Aerospace Engineering* in La Sapienza Rome University. The purpose was to **involve directly the students in the design and the manufacturing of University Microsatellites**.
- ❑ **Up to 2012: Six microsatellites have been developed and launched into orbit** with Dnepr and Vega launch vehicles.
- ❑ **2012:** Starting from the experience and the enthusiasm grown at the School of Aerospace Engineering, some professors, researchers and students decided to continue the tradition of the school in the private sector. **The Italian limited liability company G.A.U.S.S. Srl (*Group of Astrodynamics for the Use of Space Systems*) was founded.**
- ❑ **2013-2014: GAUSS Srl** realized the innovated idea of **an autonomous micro-platform able to launch nanosatellites as CubeSats**. Since then, **two micro-platforms**, UniSat-5 and UniSat-6, **have carried into space 12 nanosatellites**.
- ❑ **2016 onwards: UniSat-7 micro-platform**, with several CubeSats onboard, **is under development**.



Unisat

26 Sep
2000

Unisat-2

20 Dec
2002

Unisat-3

29 Jun
2004

Unisat-4

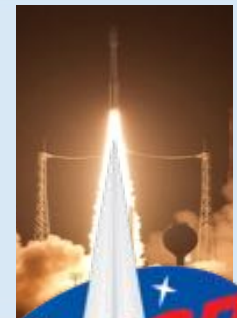
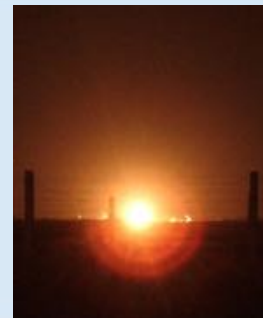
26 Jul
2006

EduSat

17 Aug
2011

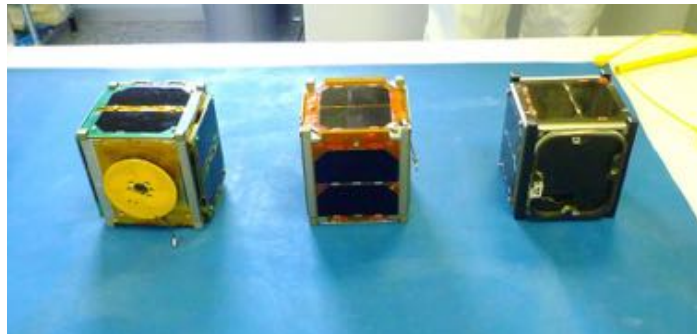
UniC-GG

13 Feb
2012

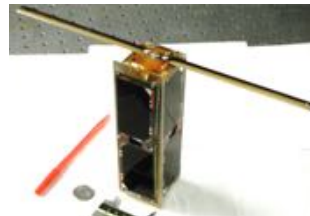


CubeSats and PocketQubes carried into Space by UniSat Missions

- In less than two years UniSat-5 (2013) and UniSat-6 (2014) have carried into space 12 small satellites



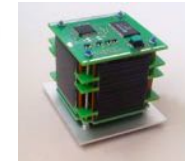
PUCP-Sat (1U) iCube (1U) HumSat-D (1U)



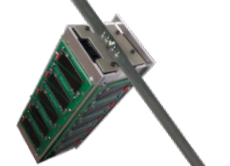
QBSat (2,5P)



Eagle-2 (1,5P)



Wren (1P)



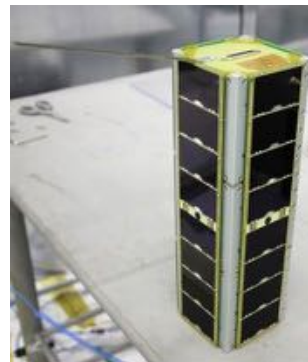
Eagle-1 (2,5P)



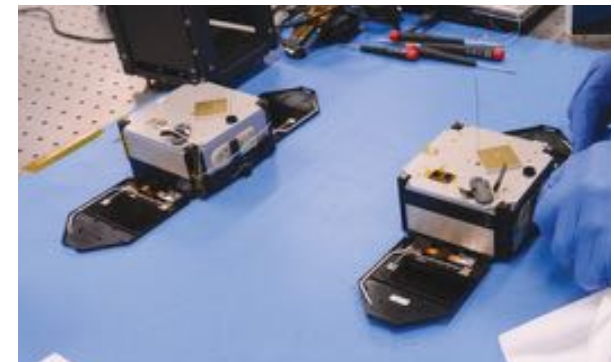
AntelSat (2U)



Lemur-1 (3U)



TigriSat (3U)

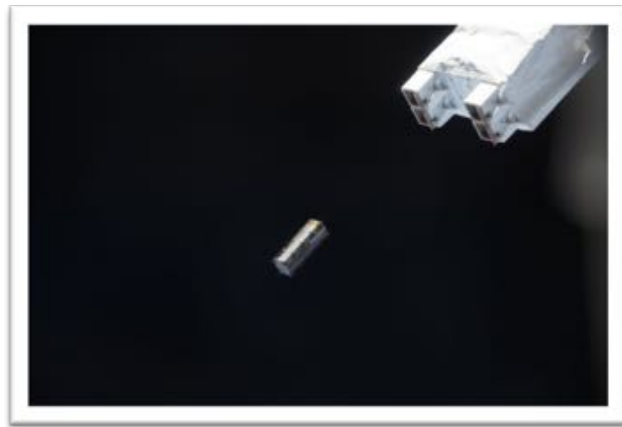
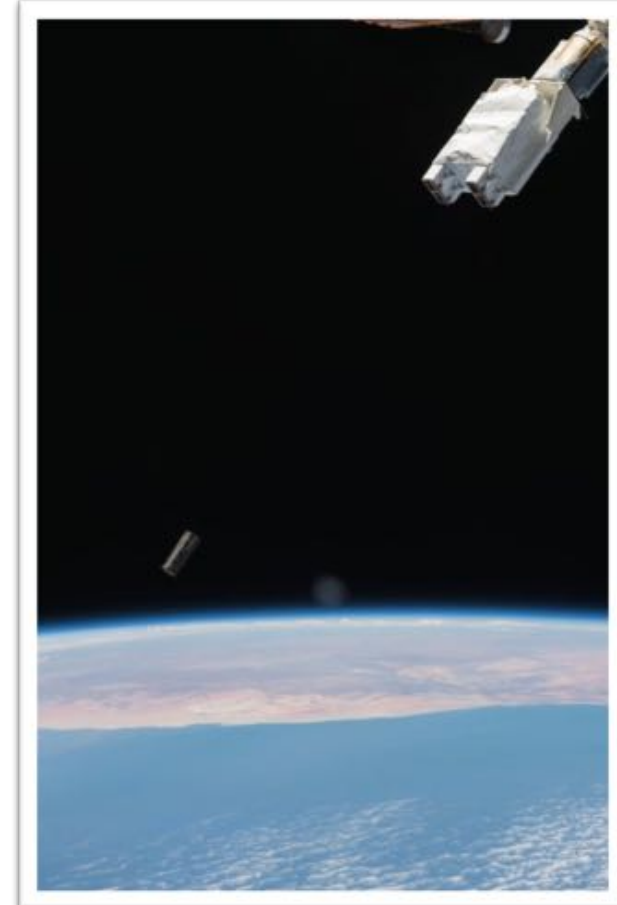


AeroCube-6 (two 1/2U)

GAUSS developed one of the first TubeSats ever launched



TuPOD Deployment from ISS on January 16, 2017, at 10:50GMT



Activities and Products

Launch Services

- Launchers
- ISS

Design and Manufacturing

- Structure
- Solar Panels
- EPS
- OBDH
- RF systems
- Remote controlled Groundstations

Ground Operations

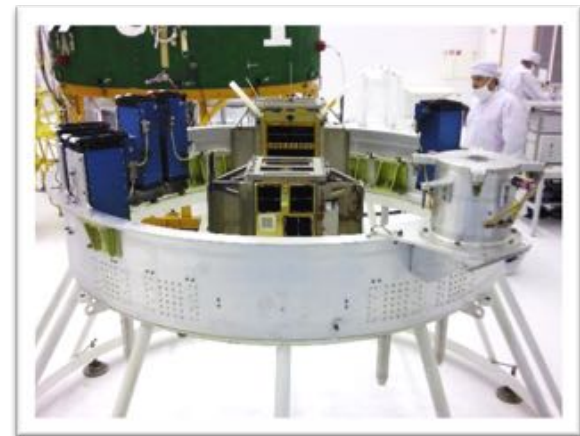
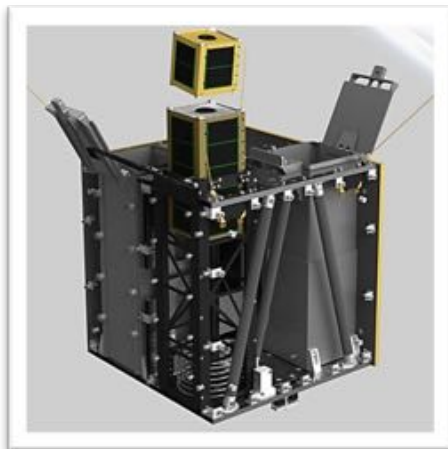
- UHF/VHF TT&C
- C and S Band
- Monitoring

Space Debris and Astronomy

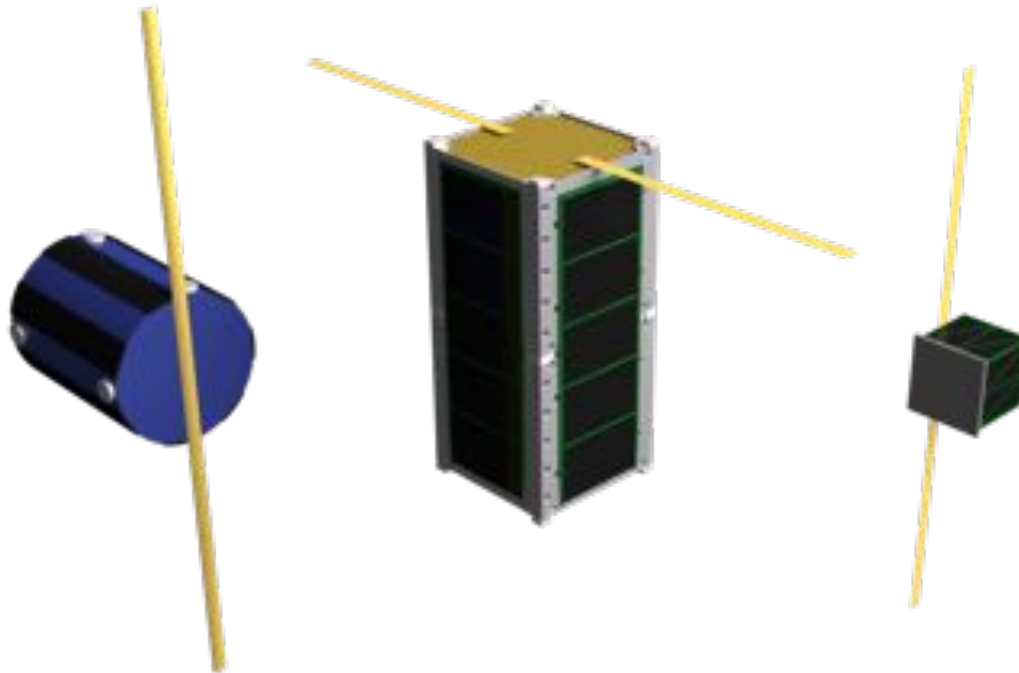
- Observation
- Removal

Mission Analysis

- Several universities and research centers around the world have launched their satellites through the company's UniSat launching platforms, thus letting **GAUSS** being a small satellites **launch provider**.
- GAUSS as a **launch broker** can help you launch any kind of satellite, up to 40kg, using its releasing platform (UniSat) or deployers fixed to a launcher
- **GAUSS products business** is mainly related to the **design and realization** of **micro-satellites**, which are also intended as CubeSat, PocketQube and UniSat releasing platforms, and their **subsystems**.



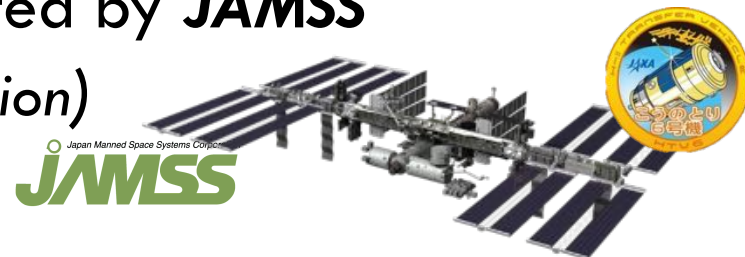
We are the **only launch company** in the space industry that can provide services in the LEO orbits for **ANY** kind of **micro-, pico-satellites** and **nano-satellites** standards.



- ☐ **LeanSats**
- ☐ **CubeSats**
- ☐ **PocketQubes**
- ☐ **TubeSats**

GAUSS can launch your satellite using:

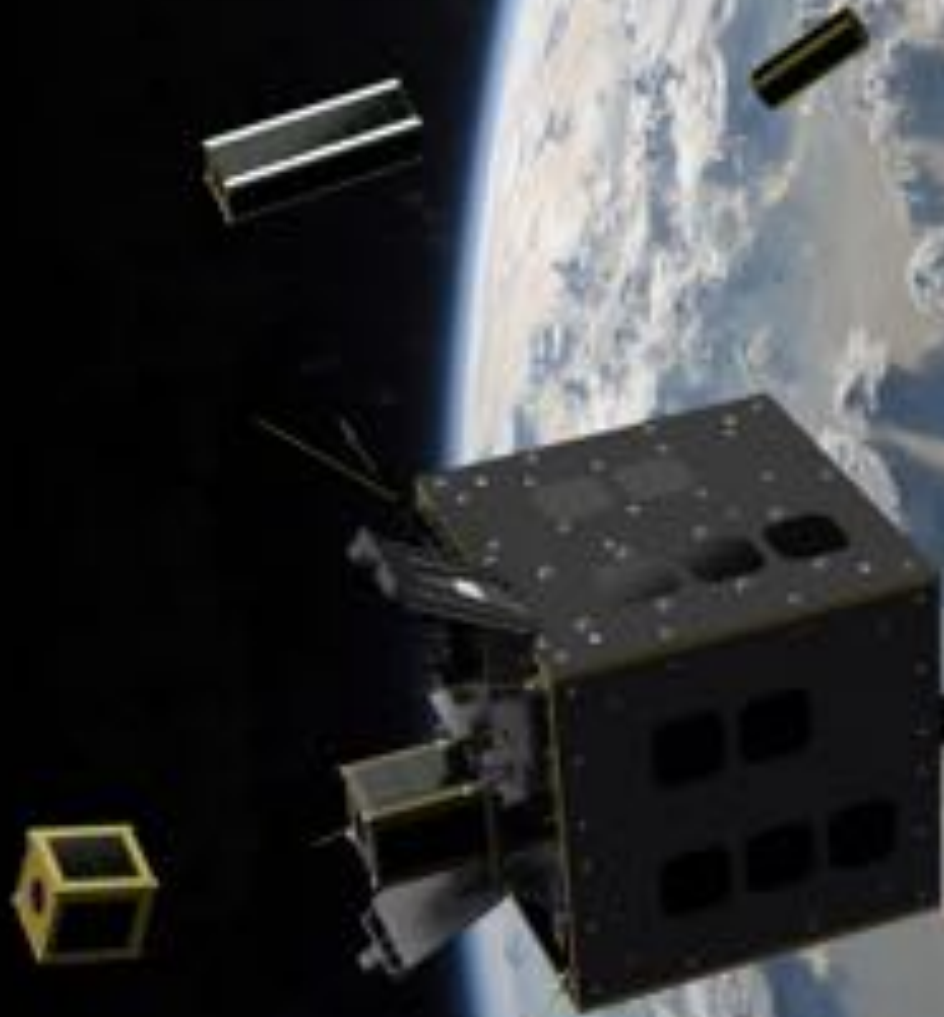
- The **ISS**, via the KIBO module operated by **JAMSS**
(*Japan Manned Space Systems Corporation*)



- Several launch vehicles reaching LEO orbits with two available configuration:
 - into **GPOD** Deployers fixed to the launcher
 - into **UniSat** Release Platform



What's new?



A Satellite as Launch Platform!!!

Advantages of Using UniSats as Launch Platform

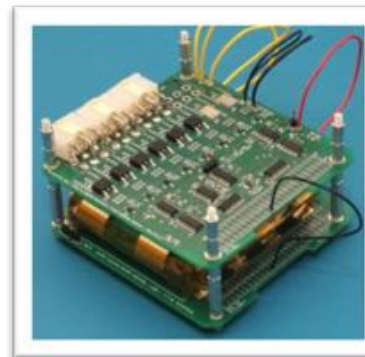
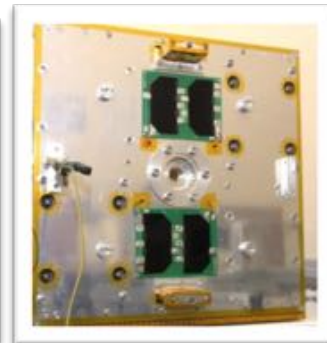
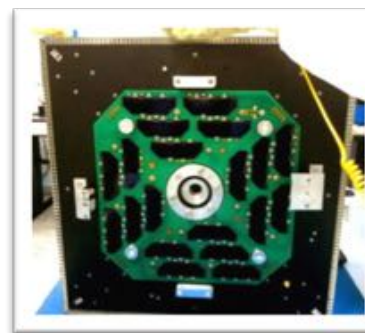


- ❑ Payloads (satellites) are no longer tied to the **scheduled mission of the launch vehicle**
- ❑ It is possible to be far from **the clouds of satellites** at the separation time
- ❑ It is possible to release the Payloads far from each other
- ❑ It is easier to recognize a CubeSat following the TLEs of UniSat
- ❑ More satellites of a **constellation** can be launched on the same cluster launch, but released **at different times**
- ❑ **Future goals for GAUSS:** to provide next UniSats with **propulsion** and **AOCS**

You may fly your own experiment onboard the **UniSat** Platform!

UniSat Platform as IOD/IOV

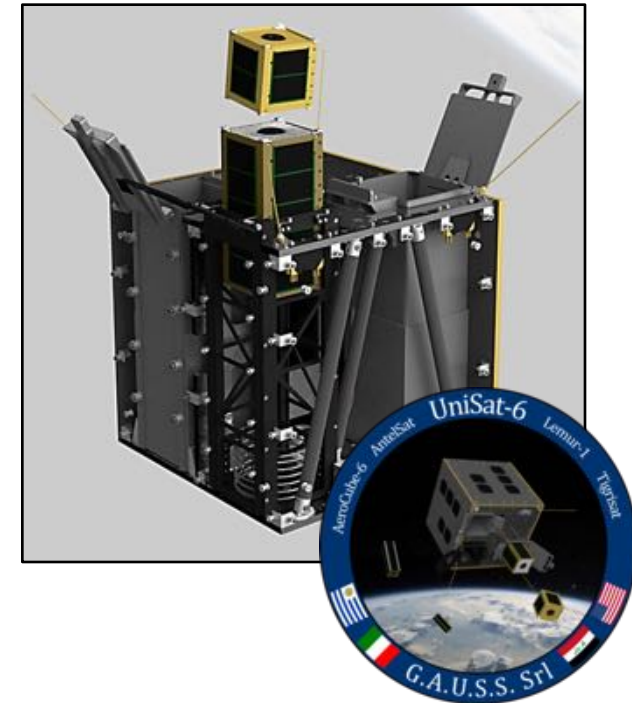
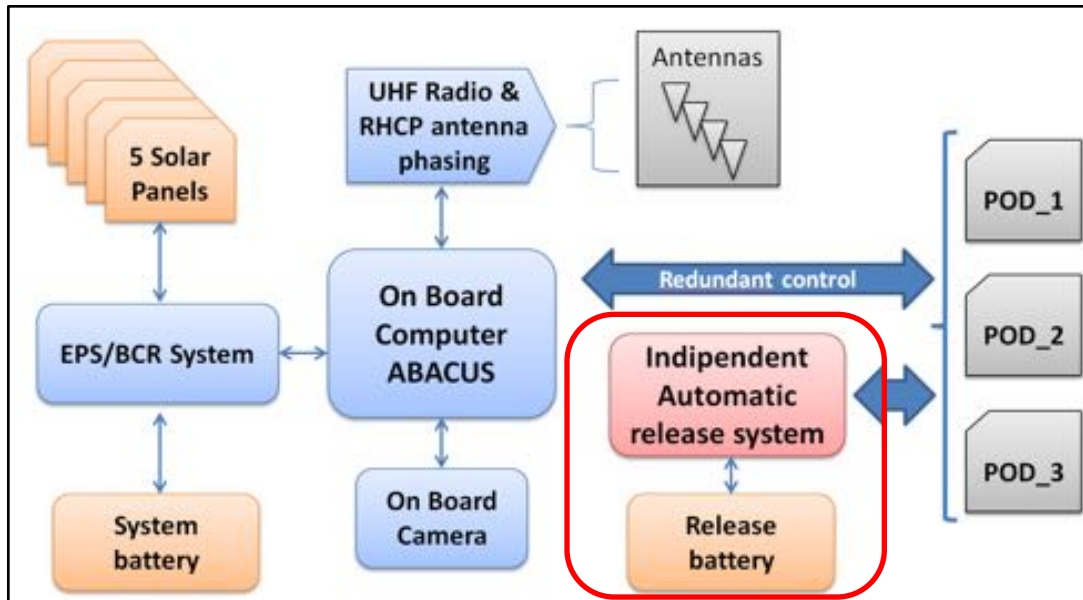
- ❑ Deorbiting devices
- ❑ Solar panels
- ❑ COTS cameras
- ❑ GAUSS' products



- To **Release 4 CubeSats** in Orbit
- To **test electronic hardware** developed for microsatellites
- To **test UniSat space bus**
- **Earth Observation operations** with a COTS camera
- To **test ground segment equipment** and software
- To **test ground segment procedures**

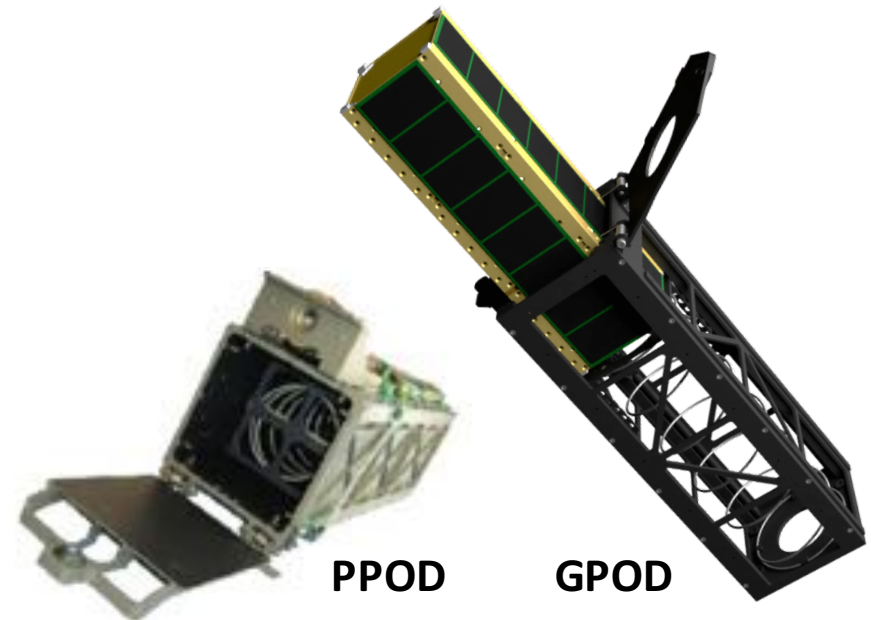


- Cubic shape of 40cm side by side with a weight of 26 Kg including all payloads
- Structure: aluminium/carbon fiber panels and reinforcing bars

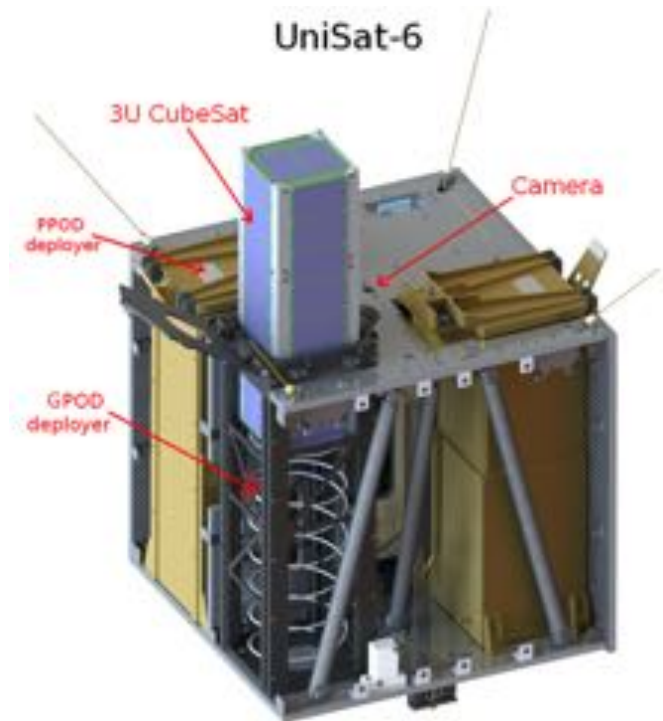


- Several redundant electronic devices to guarantee the release of the CubeSats

- A total of 9U CubeSats were released in orbit 25 hours and 38 minutes after launch
- Used deployers: 2 PPODs from Tyvak and 1 GPOD from GAUSS
- Confirmation of the deployment 15 minutes after the release receiving the telemetry of UniSat-6 over Italy
- CubeSats were received around the world confirming their good health



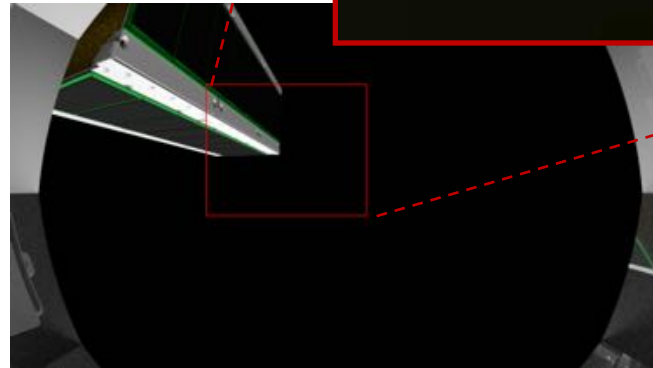
- The release event was also captured by the on-board camera of UniSat-6



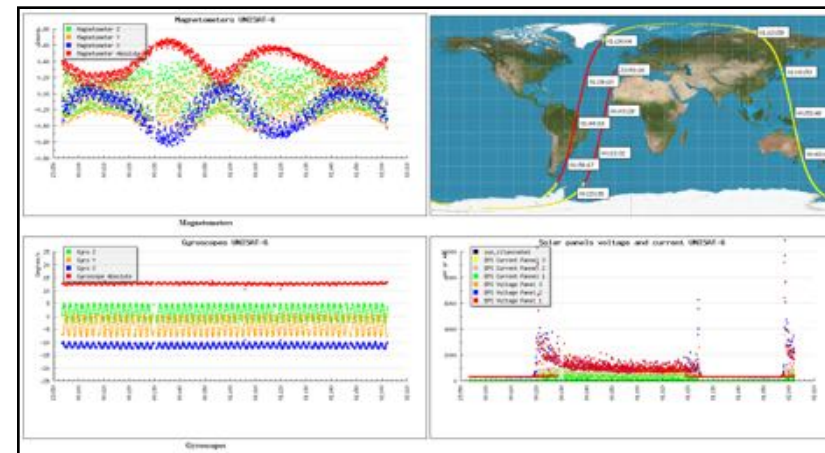
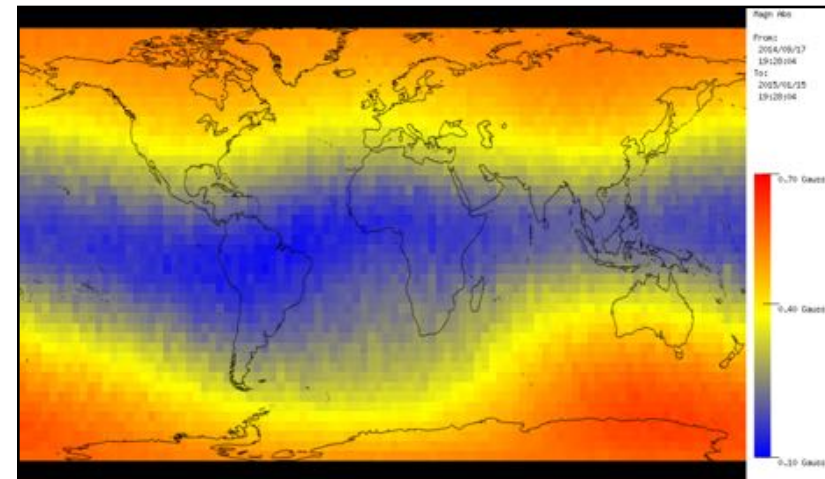
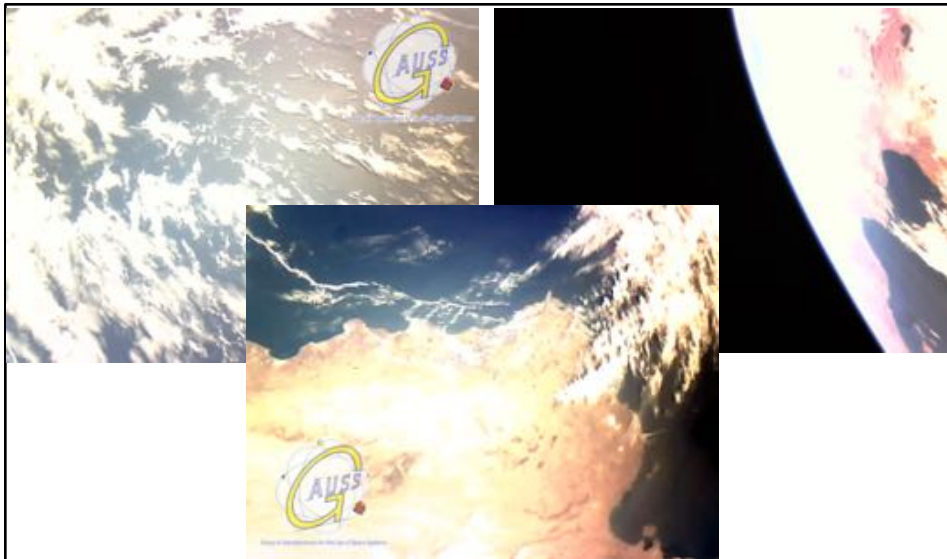
Real picture



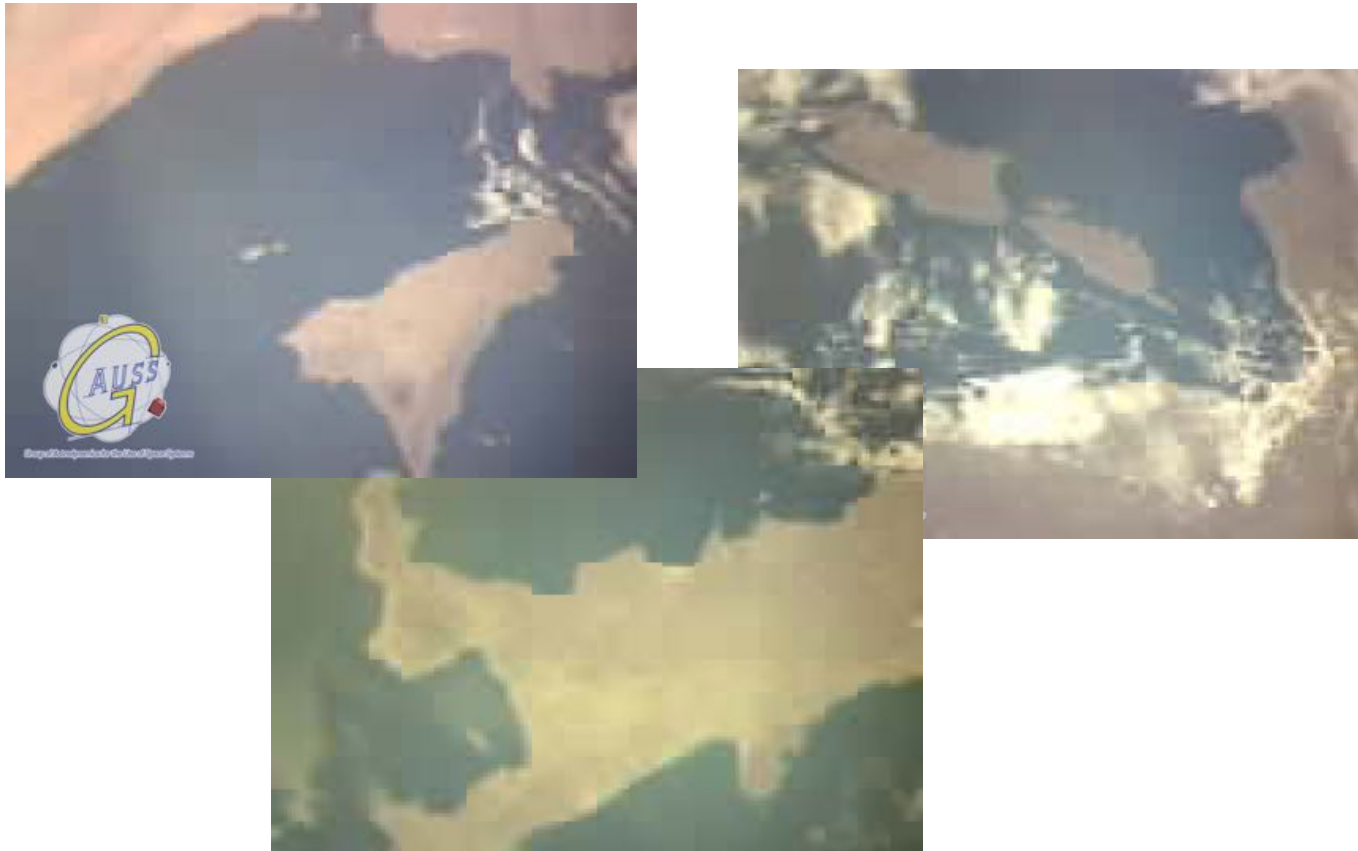
Render



- UniSat-6 continues its mission testing payloads, collecting data, taking pictures and providing flight heritage for GAUSS's products

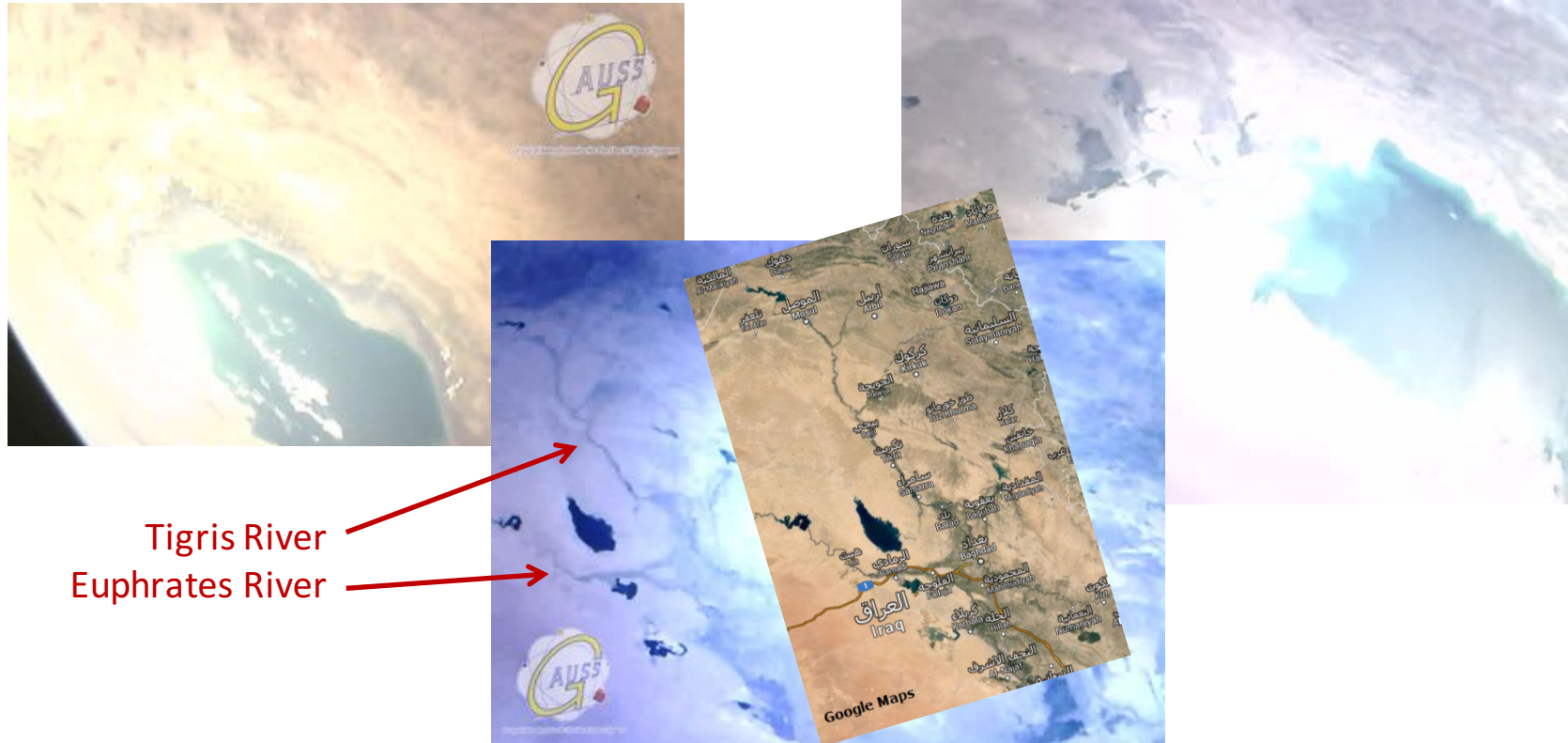


UniSat-6: Mission Results



Some pictures in low resolution (for video) in a pass over Italy

UniSat-6: Mission Results



Mid resolution pictures: Caspian Sea, Iraq and Persian Gulf

UniSat-6: EM manufacturing time-lapse



UniSat-7: Satellite overview

It will be equipped with:

Deployer Systems (to be activated after 25 hours from the launch)

- **4 MRFODs** (for PocketQubes release)
- **4 GPODs** (total mass: 1 2U CubeSats, compatible with 3U+)

Optical Payloads

- Wide angle camera
- Narrow angle camera (50m Res.)

Telecommunications

- S-Band 2.4GHz
- GAUSS newly-developed UHF Radios



UniSat-7: Satellite overview

Prices for **CubeSats**:

- 1U: **80K€**
- 2U: **130K€**
- 3U(+): **190K€**

Only a few slots left!

Orbit:

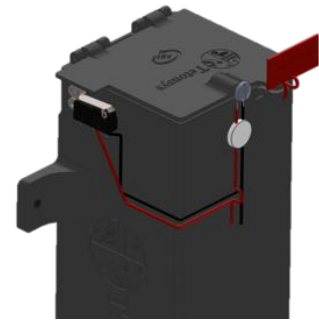
- SSO
- 500-600 km altitude ($i=97^\circ$)
- LTAN 11 AM

launch@gaussteam.com

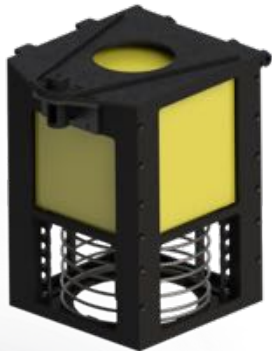


□ Deployers for nano-satellites:

- ▣ The **GPOD**, for **CubeSats** release (customizable on request)
- ▣ The **TuPOD**, for **TubeSats** Release
- ▣ The **MRFOD**, for **PocketQubes** Release



The **MRFOD** Deployer



1U version **GPOD**

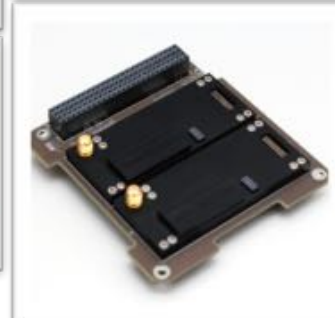
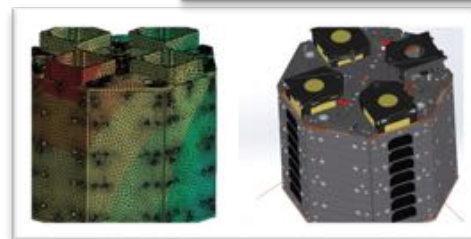


3U version **GPOD**



The **TuPOD**

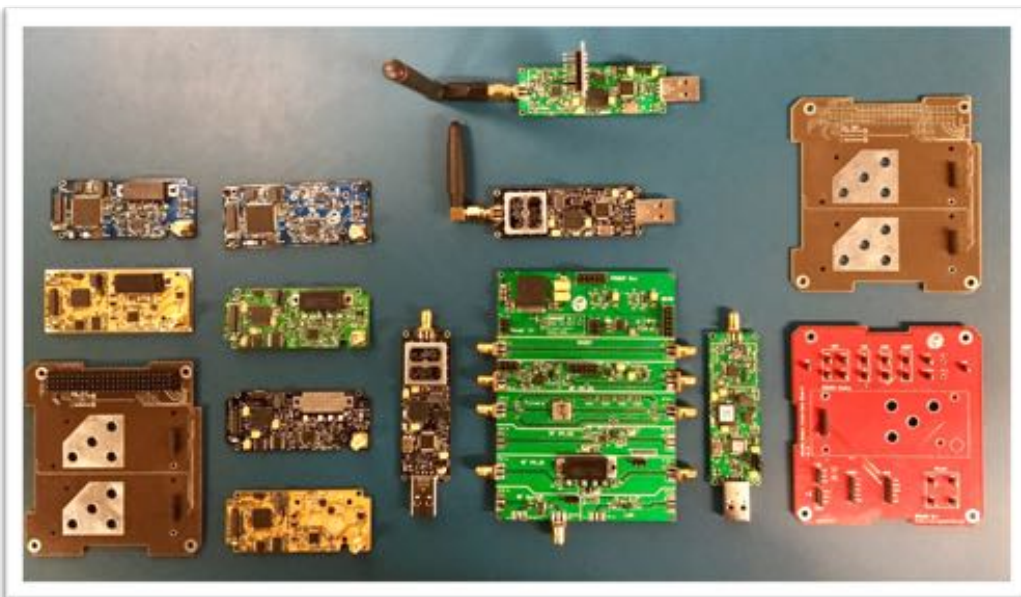
- On Board Computer (OBC) : **ABACUS** and **HERCULES**
- Electrical Power Subsystem (EPS): **VOLTA**
- UHF Radios: **GAUSS Radio UHF 2W** and **5W, Dual Radio configuration**
- UHF Radio for EGSE: Mini Ground Dongle UHF
- **Complete structures for nano-satellites**
- **Automated Groundstations**

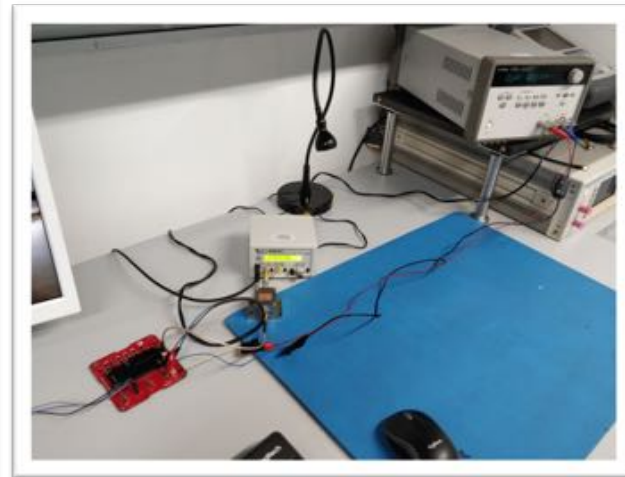
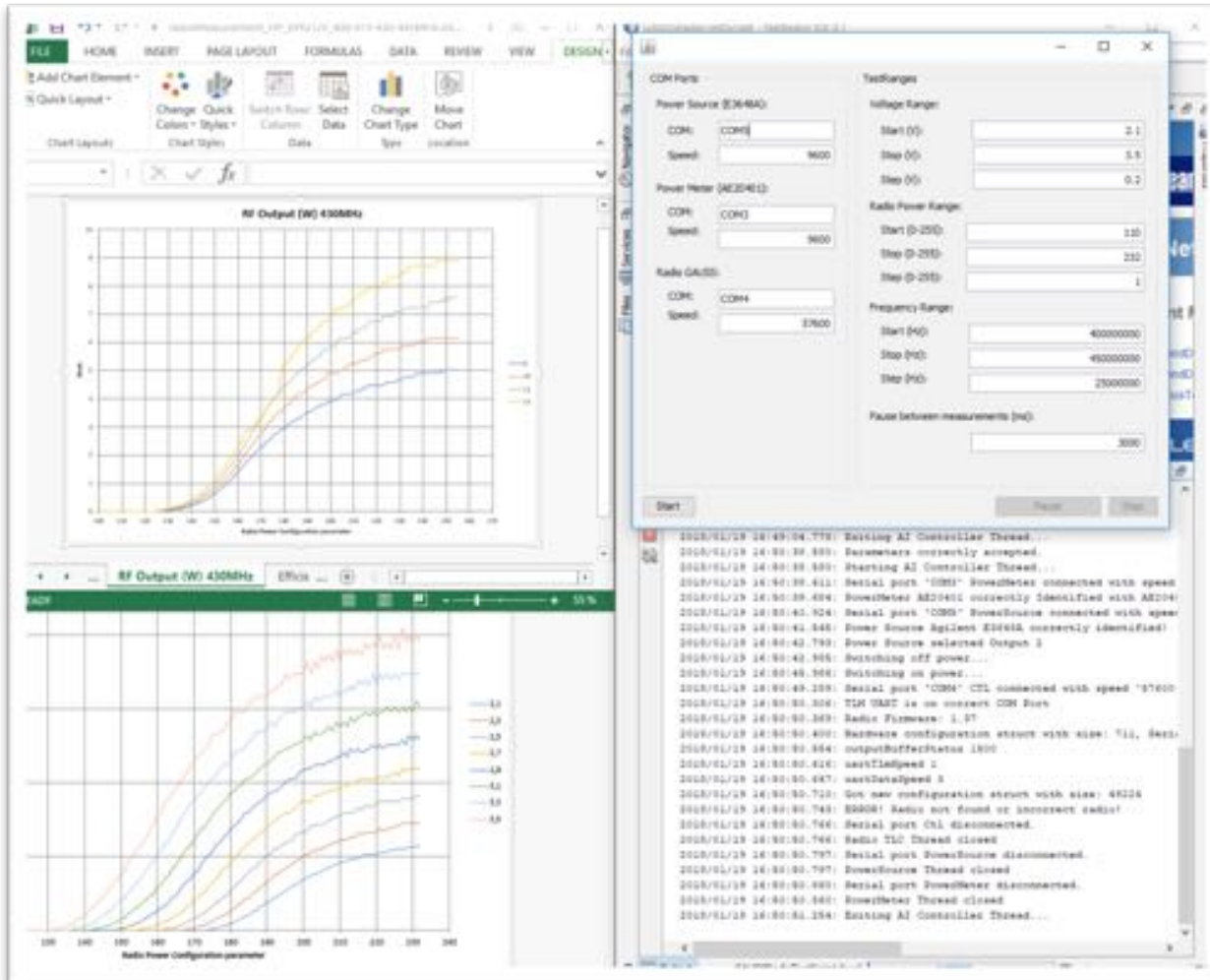


- ❑ Fast design, based on previous versions and experience
- ❑ Fast prototyping to quickly begin tests
- ❑ Electronic components choice based on supplier availability (*assuming same features*)
- ❑ Max of 3 revisions before final product
- ❑ Quality and characterization tests conducted with help from AI

GAUSS Engineers must be:

- ❑ **Multi-purpose**
- ❑ **Multi-tasking**

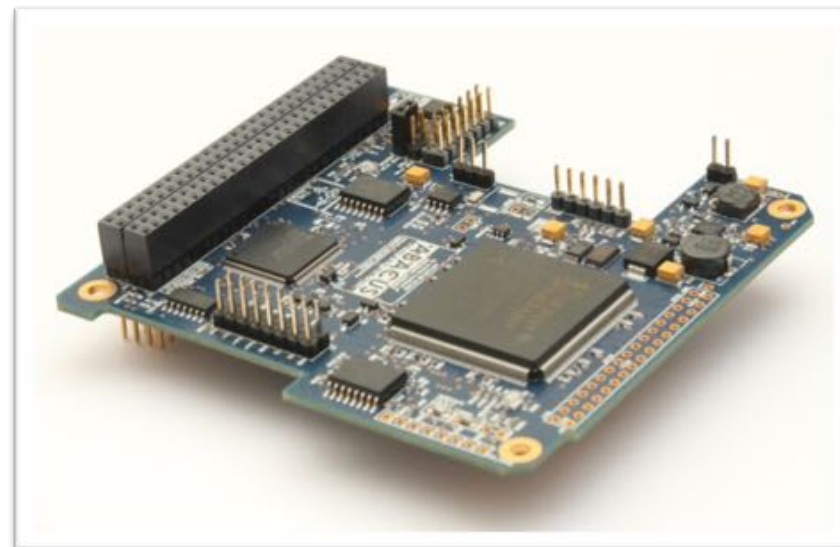
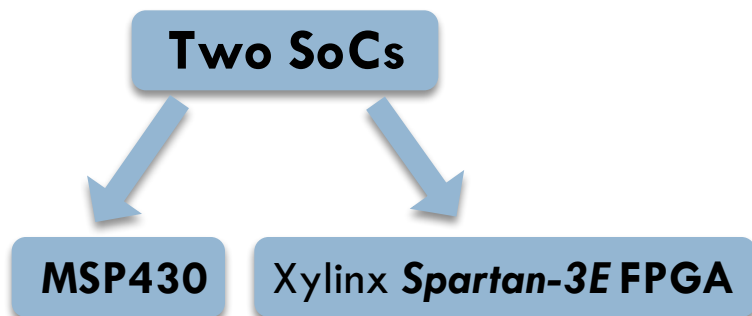




GAUSS – On Board Computer for the *lean-satellites*



GAUSS' version of the OBC is **ABACUS**



- **Independent**
- **Cooperative**
- **Hardware Redundancy**
- **Common Mode Fault Tolerance**

- Powered from the **5V bus** (or 3.3V)
- PC104 standard, 59g
- Several **Low-Power Consumption modes**
- **Master/Slave/Multi-master**
- RTL Coding and TMR for the FPGA
- **MCU and FPGA Firmware reflash in flight**

GAUSS – On Board Computer *for the lean-satellites*



GAUSS' version of the OBC is **ABACUS**

- Dual core (MCU MSP430 and FPGA Spartan-3E) direct interconnected with a 24 line bus
- Texas Instruments MSP430 core 16 bit RISC MCU running at up to 25MHz (1 to 8MHz by default)
- Several 3,3V Analog Input and Digital GPIO channels
- 16x Voltage level shiftable GPIOs with interrupt features
- 4x **COM** ports (one of them also in RS422/485 standard levels)
- 2x **I²C** and 1x **SPI** bus interfaces
- Xilinx Spartan-3E FPGA RAM based core with 500K gates for intensive operations like ADCS, Image processing, or Turbo codes
- 34x GPIO and 8x GPI channels from FPGA
- FPGA running from 13,5MHz to 54MHz (default)
- Embedded 1Mb SRAM memory dedicated to the FPGA
- Embedded IMU with 3 axis **magnetometer**, **accelerometer** and **gyroscope**
- Embedded sensors: 3x **temperature** sensors, 1x drawn **current monitor**
- Embedded **RTC**
- Embedded 2x 16MB flash NOR memories

GAUSS – On Board Computer *for the lean-satellites*



GAUSS' version of the OBC is **ABACUS**

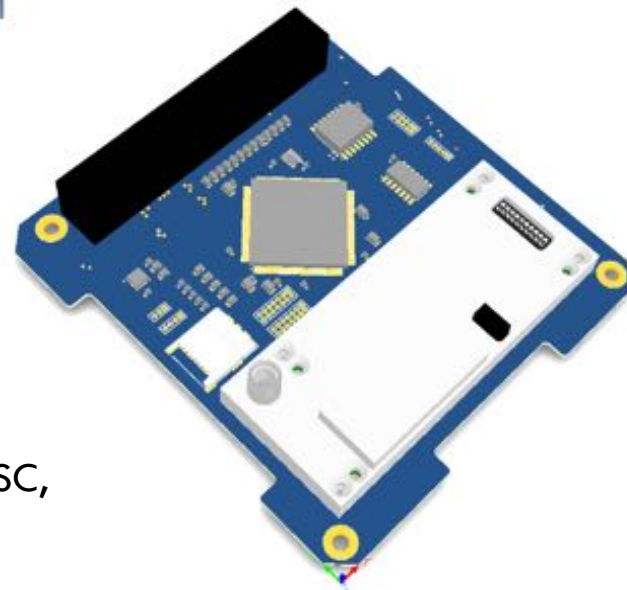
Software included to quickly start developing your satellite:

- **User friendly software libraries** for the IMU, temperature sensors, RTC, flash memory, I2C, COM, SPI bus control and GPIO
- Libraries for using with the **GAUSS Radio** and EPS, the **AstroDev** radios and **GomSpace EPS**
- **Example code** for using the libraries.

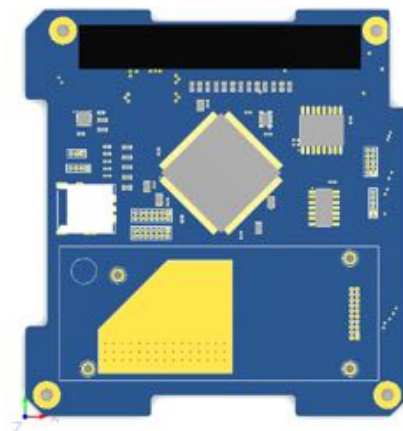
GAUSS – Advanced OBC *for the lean-satellites*



GAUSS' new advanced OBC is **HERCULES**



- ❑ **ARM Cortex R4F**, 220MHz, **dual-core lockstep** 32bit RISC,
- ❑ CPU designed for **Safety Critical Applications**
- ❑ **Cores oriented differently** to avoid Common Mode Faults
- ❑ PC104 standard, **65g**
- ❑ 16 Analog INs and more than 20 GPIOs
- ❑ **2xCAN, I²C, SPI, 2xUART** (RS422 & RS485)
- ❑ Connector for up to **3 Motors** and **3 coils**, 6 PWMs, 7 ADCs and 12 GPIOs
- ❑ 2x N2HET with up to 32ch
- ❑ Dual embedded IMU with 3-axis Magnetometer, accelerometer and Gyro
- ❑ 4Mbit **FRAM**, 1Gbit **NOR Flash**, **SD Card** socket



GAUSS – UHF Radios for the *lean-satellites*



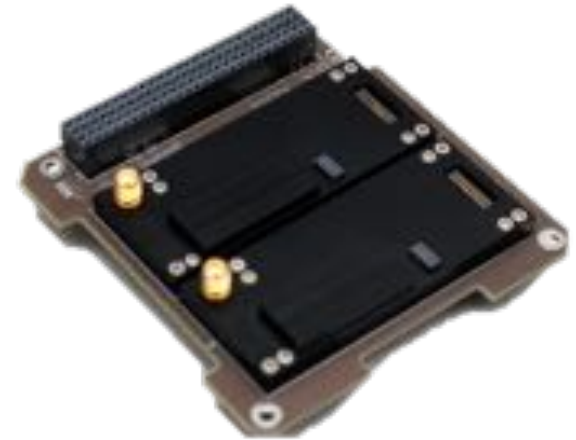
GAUSS' version of the UHF Radio is “**AITOR**”

“Aerospace Innovative Tool for Onboard Radio”

- Built from scratch using the experience gained with UniSat satellites and GAUSS Groundstations
- Knowing the limits of our competitors' products
- Firmware can be customized on user request

2 Versions available:

- **2W** (33dBm), 50% η
- **5W**, (37dBm), 45% η



- **36 dBm** TPO, 50% η
- **I2C, UART and CAN-bus** interface support
- **FSK/MSK/GFSK/GMSK** modulations
- **AX.25 / FEC** Protocols
- **Sensitivity:** -122dBm @1.2kbps, -119dBm @9.6kbps, -109dBm @50kbps
- Data rates from 1200bps to 250kbps
- Operating temperature range -40°C to +85°C
- Hardware **cold redundancy** with **two radios on one PC104**
- Libraries to connect it to **ABACUS OBC**
- **Full reconfiguration / Reflashing in flight**

VHF & S-Band versions coming soon!

GAUSS – UHF Radio Ground Dongle *for the lean-satellites*



A **workbench** for your **Satellite RF** and **TT&C** tests

- A portable groundstation at your fingertips
- Developed to be easy to use
- Integrated UHF transceiver and TNC
- Powered via the USB bus
- Can be configured via a multi/OS application
- Same RF section of the “**AITOR**” UHF radio
- Test you sat until the very last minute before integration



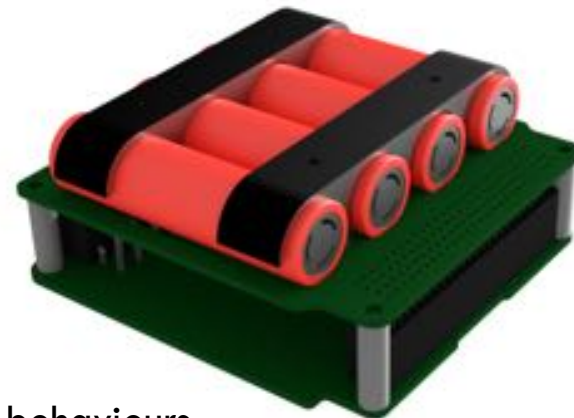
S-Band version coming soon!

GAUSS – Electrical Power System for the *lean-satellites*



GAUSS' version of the EPS is “**VOLTA**”

- **3x Separate and autonomous MPPT input stages**
- Up to 43W per input stage ($V_{IN\ max} : 37.8V\ (VOC) *$; $I_{IN\ max} : 2.08A\ (ISC) *$)
- Multi-chemistry for the charging stage (**Li-Ion/Li-Po/LiFePo4**)
- **Battery pack heater**
- High configurability and reliability
- **Several safety systems** to ensure system recovery from unexpected behaviours
- **6x current and voltage monitors** available by serial bus communication
- **Expandable input and output stages with daughter boards**
 - 3 DC/DC regulated buses at **3.3V, 5V** (max 3A) and **1x adjustable output** (max 18W)
 - Li-Ion 16.8V, **50Wh battery pack** (default configuration), **up to 26V** (6 Li-Ion / 7 LiFePo4)
 - **Single battery cell monitoring and balancer**, available by command or with security thresholds
 - Switchable and latch-up protected outputs
 - **Watchdog Timer**
 - **Unregulated battery bus** (up to 28V)



GAUSS - Groundstation Kit for the *lean-satellites*

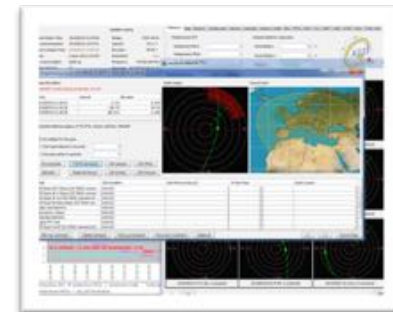
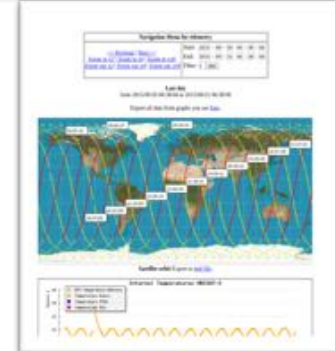


- **VHF / UHF** and **S-Band** for higher datarates
- **Hybrid approach:** Radio-amateur equipment developed and/or modified by **GAUSS**
- Fully automated with software developed at **GAUSS**



Groundstation Kit Includes:

- **High gain Yagi-Uda VHF and UHF Antennas** (>16 dBi for UHF)
- Low-noise amplifiers and band-pass filters for VHF and UHF bands
- **Low-loss RF coaxial cables**
- **1.5m parabolic dish** for higher frequencies downlink (up to 6GHz, default feed is for S-band)
- **VHF:** Uplink and Downlink up to **100W** using radio and TNC, SDR optional
- **UHF:** Uplink and Downlink up to **70W**, using radio and TNC, SDR optional
- TX using **ICOM-9100** hardware, RX recording and decoding via SDR
- Several **RF and electrical fuses** for lightning protection
- **S-Band:** Downlink using SDR for recording and post-processing of I/Q RF data
- **Az/El rotor** for high-torque maneuvering
- **Hardware components power switch on/off** to minimize power consumption
- **Full HD Camera** for instant antenna monitoring and picture logging



GAUSS Ground Station Automation for the *lean-satellites*



GAUSS has developed AI Routines for a smooth satellite housekeeping

□ RF Communication protocol developed for **advanced future automation**

- Use **counters** and **indexes** on all packets so it is easy to track packets and implement an Artificial Intelligence (AI) on your GS
- More byte-efficient than traditional radioamateur **AX.25**
- Several **FEC algorithms** for increased ACKs on more passes



□ **Fully automated groundstation:**

Useful when only 1 GS present

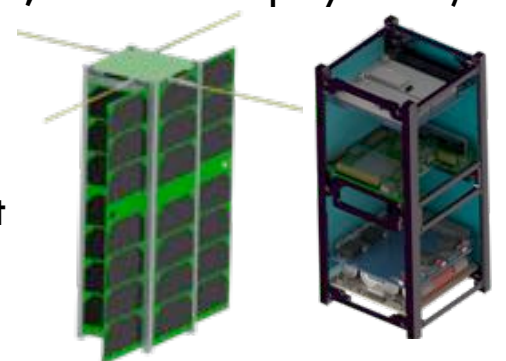
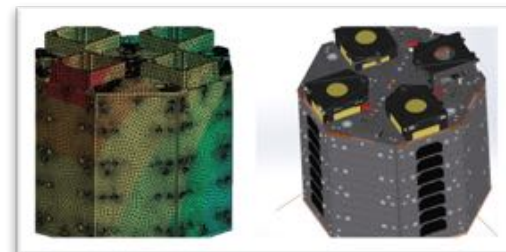
- **Automatic activation** of the ground station HW on needs
- **One-button** programming, **multiple satellites control** & **integrated data handling**
- **Smart weather status check** to avoid using GS on dangerous conditions
- **AI SGP4 propagator** for the orbits of the satellites, **commands TX** and **data RX** from the satellite in a **completely autonomous way**
- **Compatibility** with several **Radios**, **TNCs** and **Rotor Controllers**
- All data is logged and stored in an easy-to-use **web database** for quick retrieval
- Operators are immediately alerted on satellite/hardware anomalies
- TCP/IP connections compatible, for remote GS and TCP operations



GAUSS has more than ten years in the design of small satellite structures

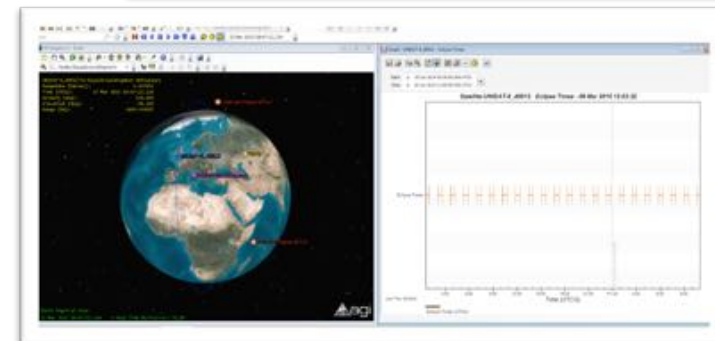
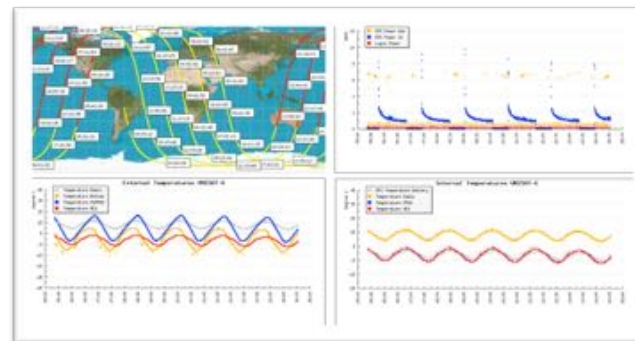
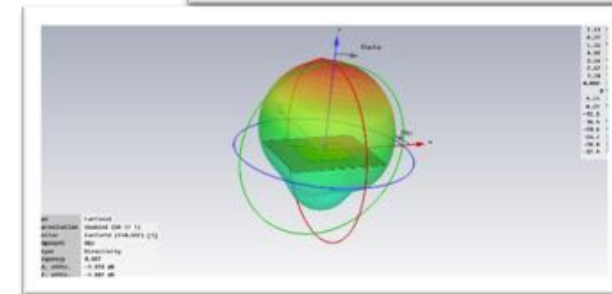
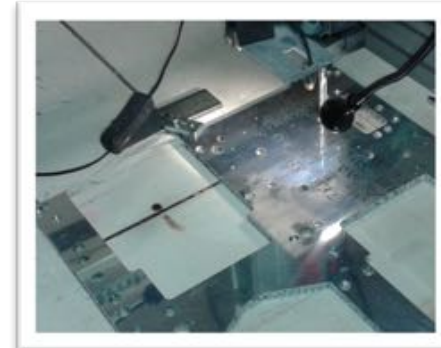
Solutions are given for a wide range of cases:

- ❑ **1U, 2U, 3U CubeSats** main structure, custom structure design
- ❑ **Solar panels**
- ❑ Deployable systems 
- ❑ **Custom cases** for electronics, antennas, batteries, etc.
- ❑ Interfaces and adapters for structural tests
- ❑ Solutions for scientific and technological experiments (optical devices, biomedical payloads)
- ❑ CubeSat **solar panels deploying systems**
- ❑ CubeSat and microsatellites boom deployment systems
- ❑ AIT operations of Clients systems in a ISO-7 Cleanroom environment



Our Services are:

- ❑ **Space Mission Analysis**
- ❑ **AIT Ops in ISO-7 Certified CleanRoom**
- ❑ **Complete Satellite Design**
- ❑ **Structural FEM analysis**
- ❑ **Groundstation Data Services**
- ❑ **RF Tests and Antennas consulting**
- ❑ **Firmware development for embedded devices**



- **GAUSS** has gained an **extensive knowledge** on nano-satellites, their subsystems and their launches.
- The **UniSat** platform has been a **success** offering new ways and opportunities to **access Space** for **CubeSats** and **PocketQubes**.
- **GAUSS** Products are **valid** and **cost-effective** solutions for your Satellite

Do you want to orbit with us?

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Group of Astrodynamics for the Use of Space Systems