Break-Up Sensor & Re-Entry SatCom Unit

RUAG Space Switzerland

Opto-Electronics & Instruments

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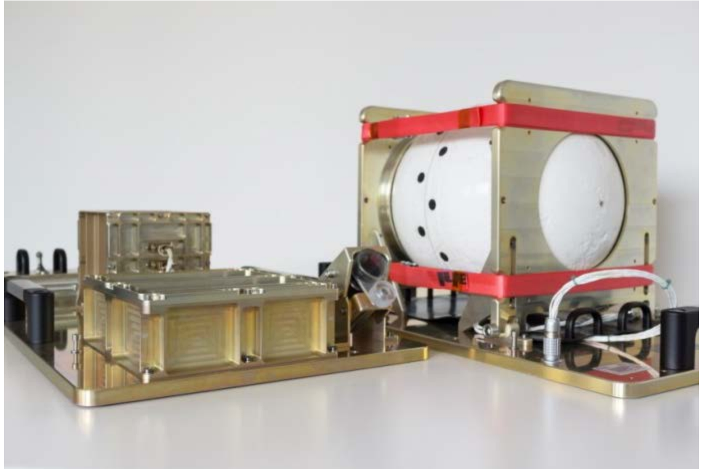

ESA Clean Space Industry Days

25th May 2016 – ESTEC

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Introduction – Background & Objectives

- ESA's Aerothermodynamic domain proposed to fly an **infra-red camera on board the ATV-5 to collect re-entry data** as part of the re-entry observation campaign

- Other foreseen contributions to the campaign
  - NASA's REBR — Removed after decision for nominal re-entry
  - JAXA's I-Ball — Lost in Cygnus launch failure
  - Observation from ISS
  - Observation by Aeroplane

- Data is important for improvement and fine-tuning of the models that describe the break-up process at atmosphere re-entry
  - for better prediction of debris fields
  - in preparation of the de-orbiting of the ISS
  - to support ESA's Clean Space and design-for-demise

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Introduction – Challenges

- Starting point
  - Infra-red camera from EXPERT
  - Data handling unit from IXV
- Challenges
  - Autonomous triggering of data acquisition prior to S/C break-up
  - Intermediate data storage (usually no TM in this mission phase)
  - Robustness against environmental loads during break-up
    - Shock, quasi static, thermal loads, etc.
  - Data transfer to ground
  - Very tight schedule to develop and deliver H/W

ATV BUC – Mission Scenario

Activation &
De-Docking

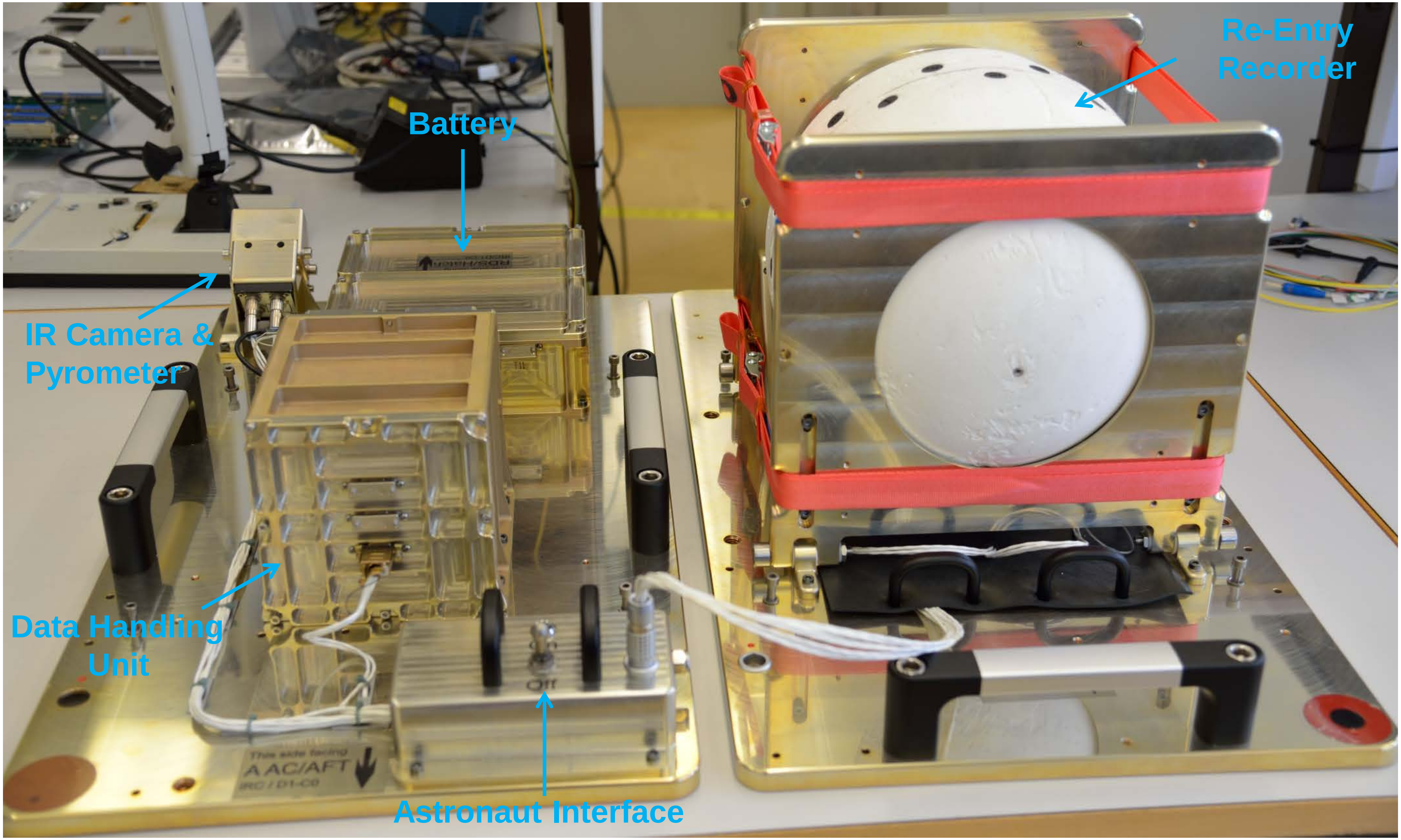
Hibernation &
Waiting for Final Boost

ATV BUC – Requirements

- **Mission Requirements for ATV Break-Up Camera**
  - Upload with ATV-5 in Cargo Transportation Bags
  - Installation & activation by ISS Crew before ATV de-docking
  - Autonomous operation after activation
  - Support of nominal and shallow re-entry scenarios
    - Different de-orbiting time lines
  - Support re-entry mission timeline of up to 15 days

- **Functional Requirements**
  - Trigger to detect unambiguously the ATV re-entry
  - Capture IR video of ATV forward cone of the last minutes before break-up
  - Store data during break-up and re-entry
  - Use Iridium network for downlink of data
  - Downlink as much data as possible (priority on video data)
  - Comply with ATV & ISS safety requirements

ATV BUC – Concept/Hardware

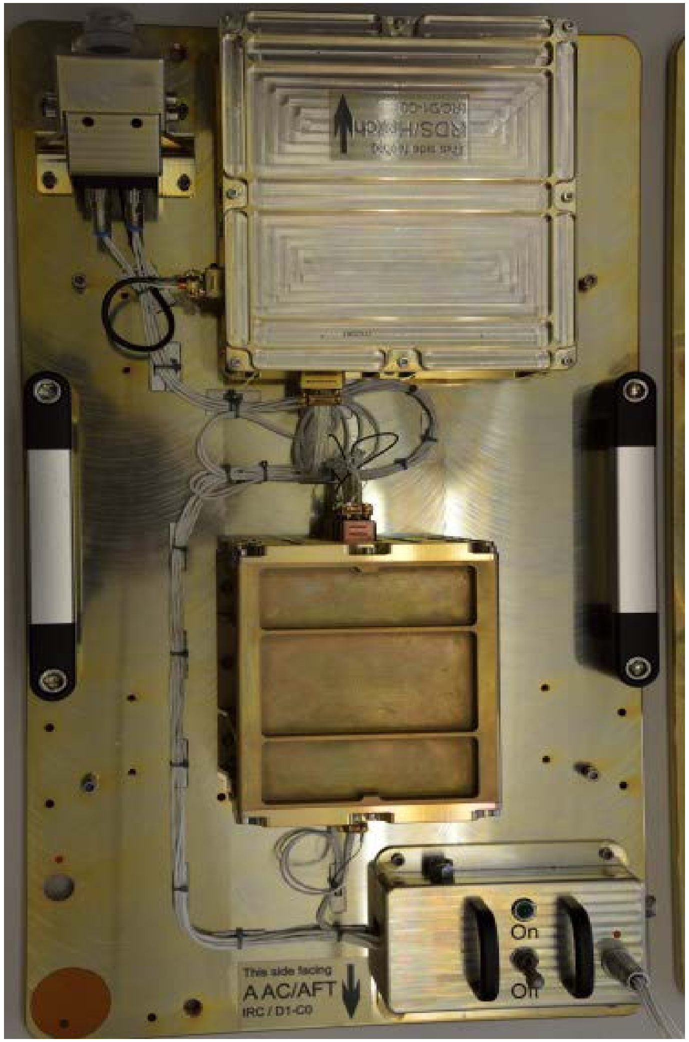


IRC Front-End

SatCom Unit

ATV BUC – IRC Front-End

- Tasks
  - Hibernation & Triggered power-up
  - Capture Images from IR camera
- Design
  - Based on ruggedized COTS products
  - DHU re-built from IXV
  - Camera re-used from EXPERT
  - Batteries from our partner GOMSPACE had to be qualified



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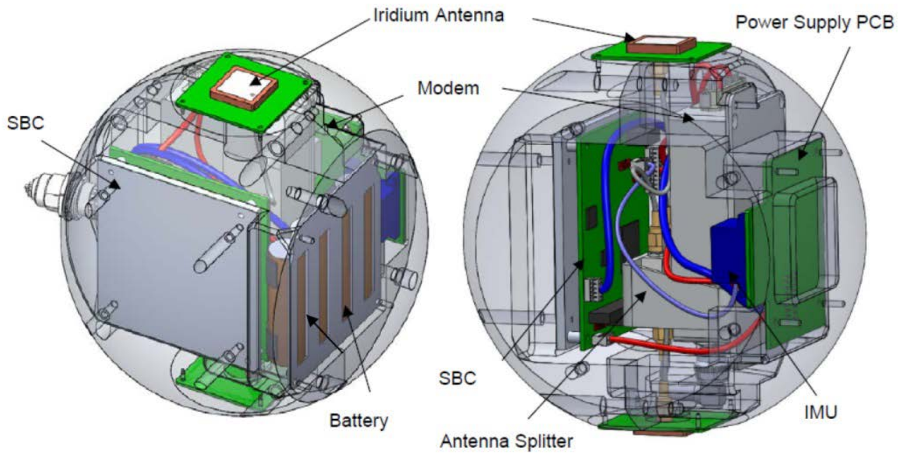
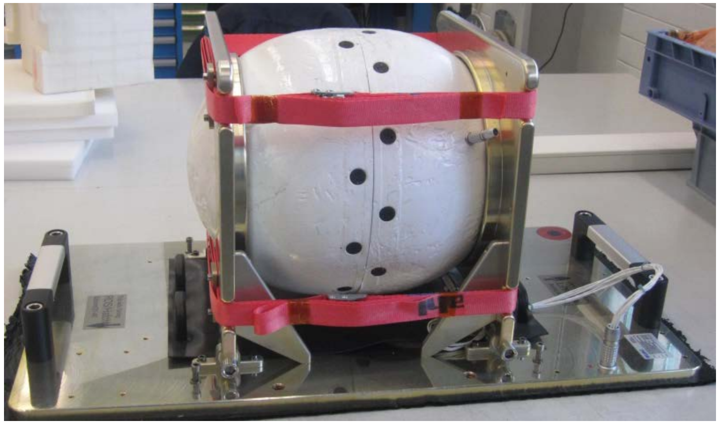
ATV BUC – SatCom Unit

- Tasks
  - Acquire Housekeeping Data
  - Video Processing and Storage
  - Downlink Management
  - Power Up Management
- Design
  - Electronics based on ruggedized COTS products
  - Thermal Protection System based on WHIPOX (provided by DLR)
  - Antenna System based on Iridium (provided by ViaSat)





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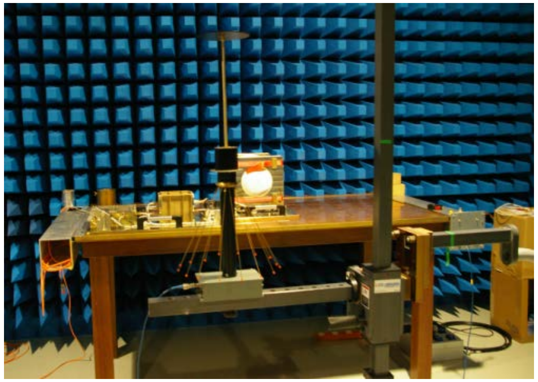
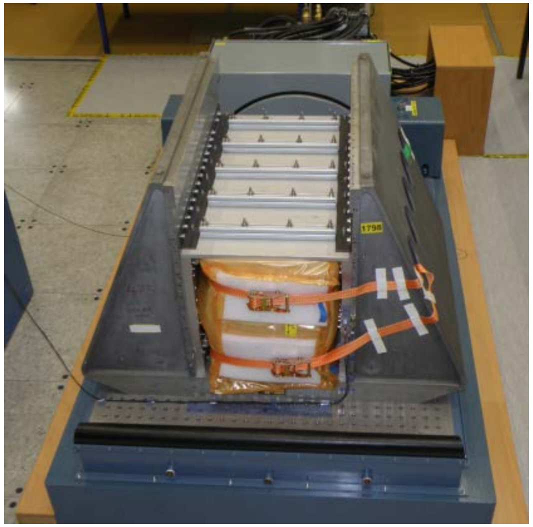
ATV-BUC – Testing

- Development Testing
  - Video Compression Strategies
  - Iridium Link Services (SBD, RUDICS)
- Qualification Programme
  - Functional
    - Switch-On IRC
    - Image acquisition
    - Switch-On SatCom
    - Synchronisation
    - Video Compression
    - Downlink
  - Offgassing (ECSS-Q-ST-70-29-C) @ ESTEC
  - EMC (Radiated Emission & Susceptibility) @ ESTEC
  - Vibration (in Cargo Transportation Bag)
  - Functional Test (as above)





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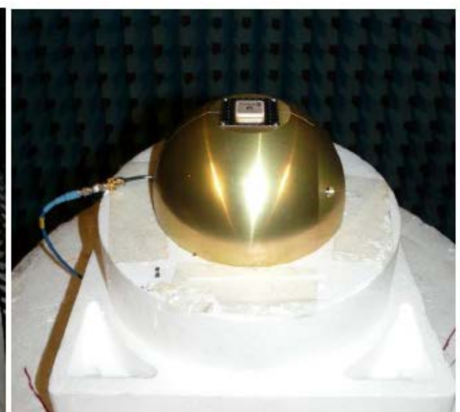
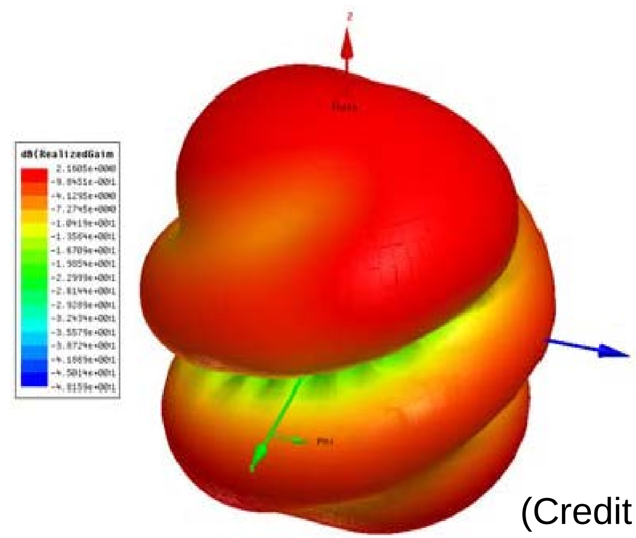
ATV-BUC – SatCom Antenna System Test

- Measurement of as built SatCom radiation pattern in anechoic chamber performed by our partner ViaSat
- Nearly omnidirectional radiation pattern achieved with gain minimum in equatorial plane

(Credit ViaSat)



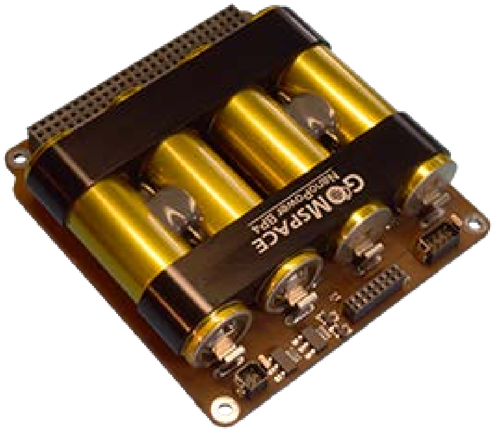
(Credit ViaSat)



(Credit ViaSat)

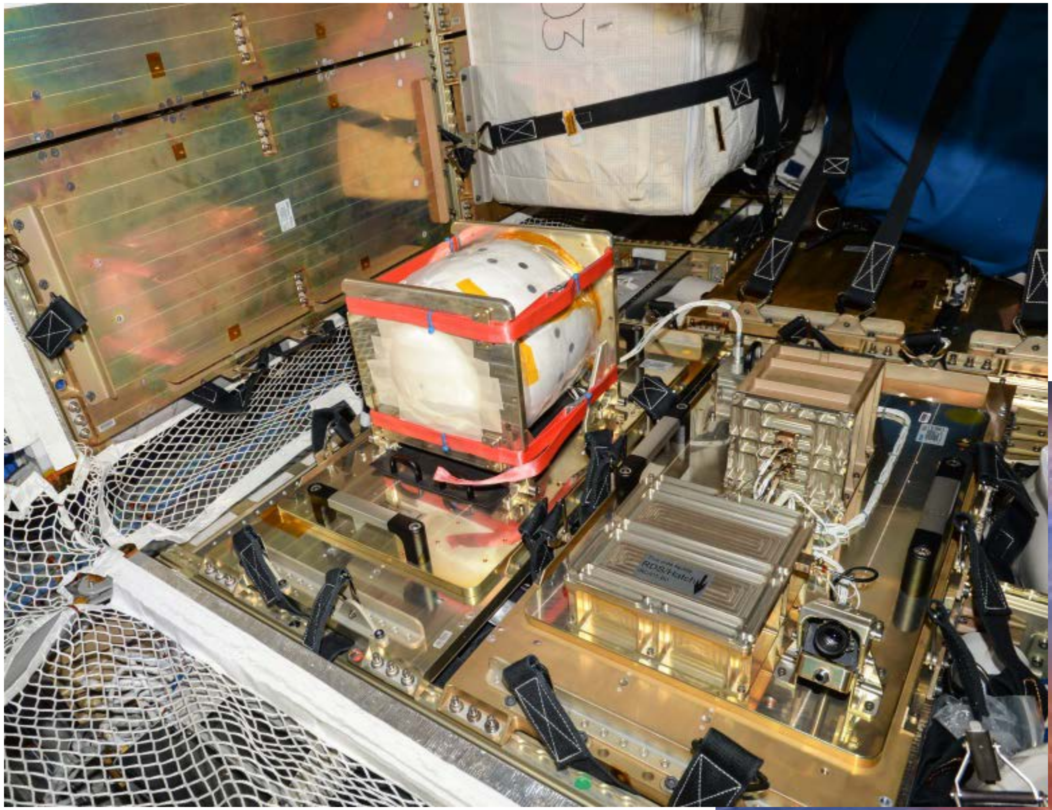
ATV-BUC – Battery Qualification

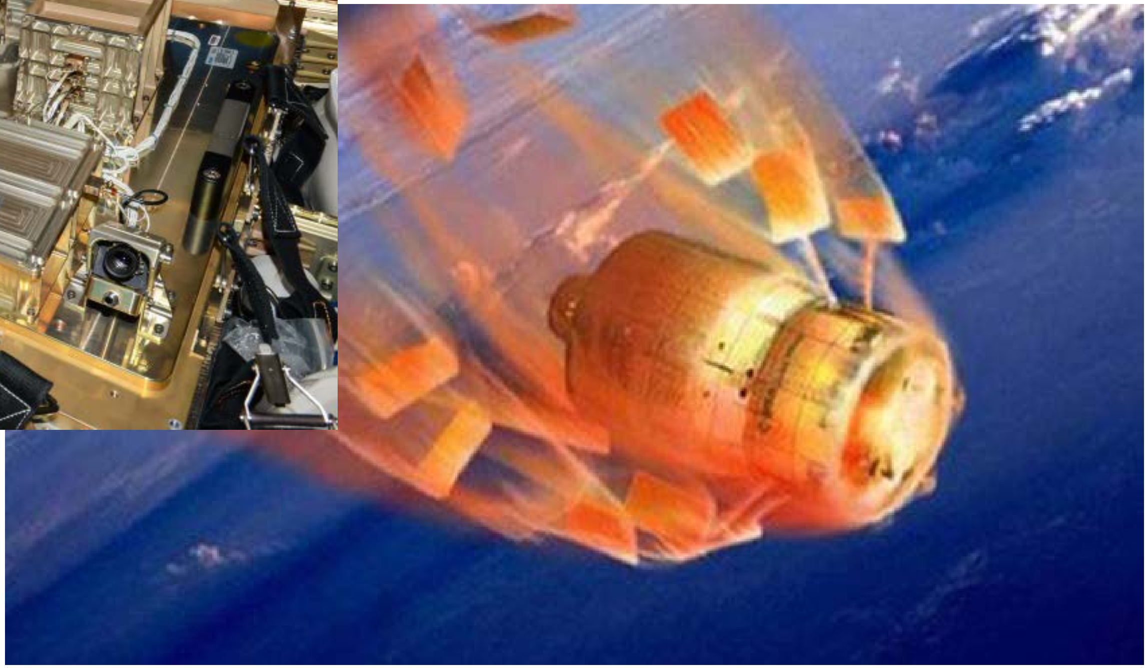
- Battery Qualification performed
  - Test Items:
    - BP4 (SatCom)
    - BPX (IRC)
  - Qualification-Steps:
    - Visual Inspection
    - Dimension
    - Weight
    - Open Cell Voltage (OPV)
    - Closed Cell Voltage (CCV)
    - Charge/Discharge Cycle
    - Vaccum/Leak Test
    - Vibration Test
    - Over-Discharge/External short cut
  - Flight Battery Acceptance Testing



(Credit GomSpace)

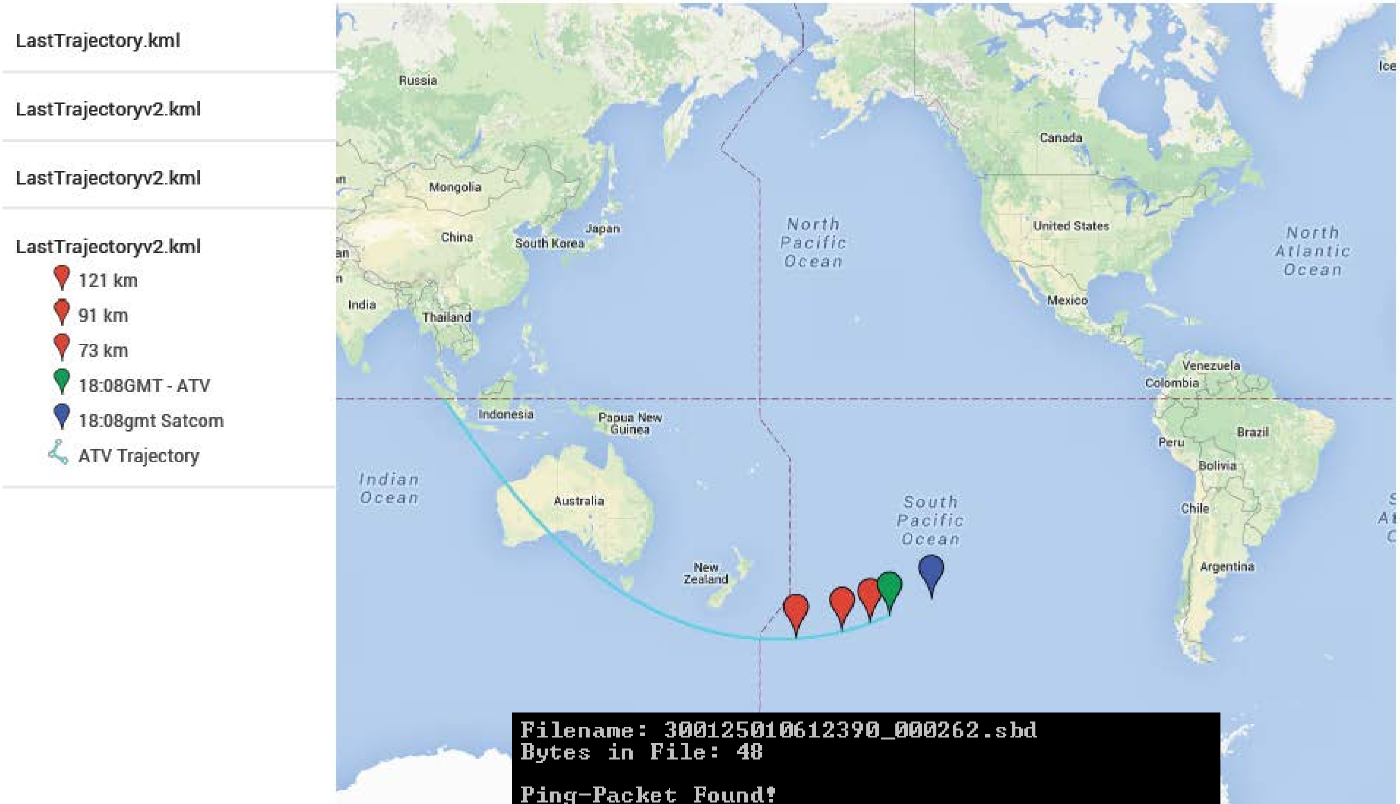
Results from ATV-5





(Credit ESA/NASA)

Results from ATV-5




```
Filename: 300125010612390_000262.sbd
Bytes in File: 48

Ping-Packet Found!
Ping-No: 4
Time [sec]: 1282
IMU Starttime [sec]: 1228
CPU Temp [Deg. C]: 32
Transfered Images: 5967
Number of Magnetic Field Samples: 54
Gyro X: -10.028515
Gyro Y: -4.909513
Gyro Z: 7.034924
Acc X: -5.125000
Acc Y: 2.660156
Acc Z: -4.554688
Magnetic Field X: -24.545456
Magnetic Field Y: 126.545456
Magnetic Field Z: -6.530612
```

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Results from ATV-5

- Timeline Summary:
  - Power On 17:46:06
    - Trigger Source:
      - Accelerometer => yes, Final Boost
      - Pyrometer => no, Temperature in Cargo Bay at 21.5° C
  - Video Start: 17:47:06
  - **<u>Video Stop</u>**: 18:06:59
    - Lost connection to IRC
      - Break Up?
      - SatCom separation?
  - Last ATV TM: 18:04:13
  - Transmission Start: 18:07:14
  - Ping Message: 18:08.08
  - Splash Down: 18:12:00 (Prediction)

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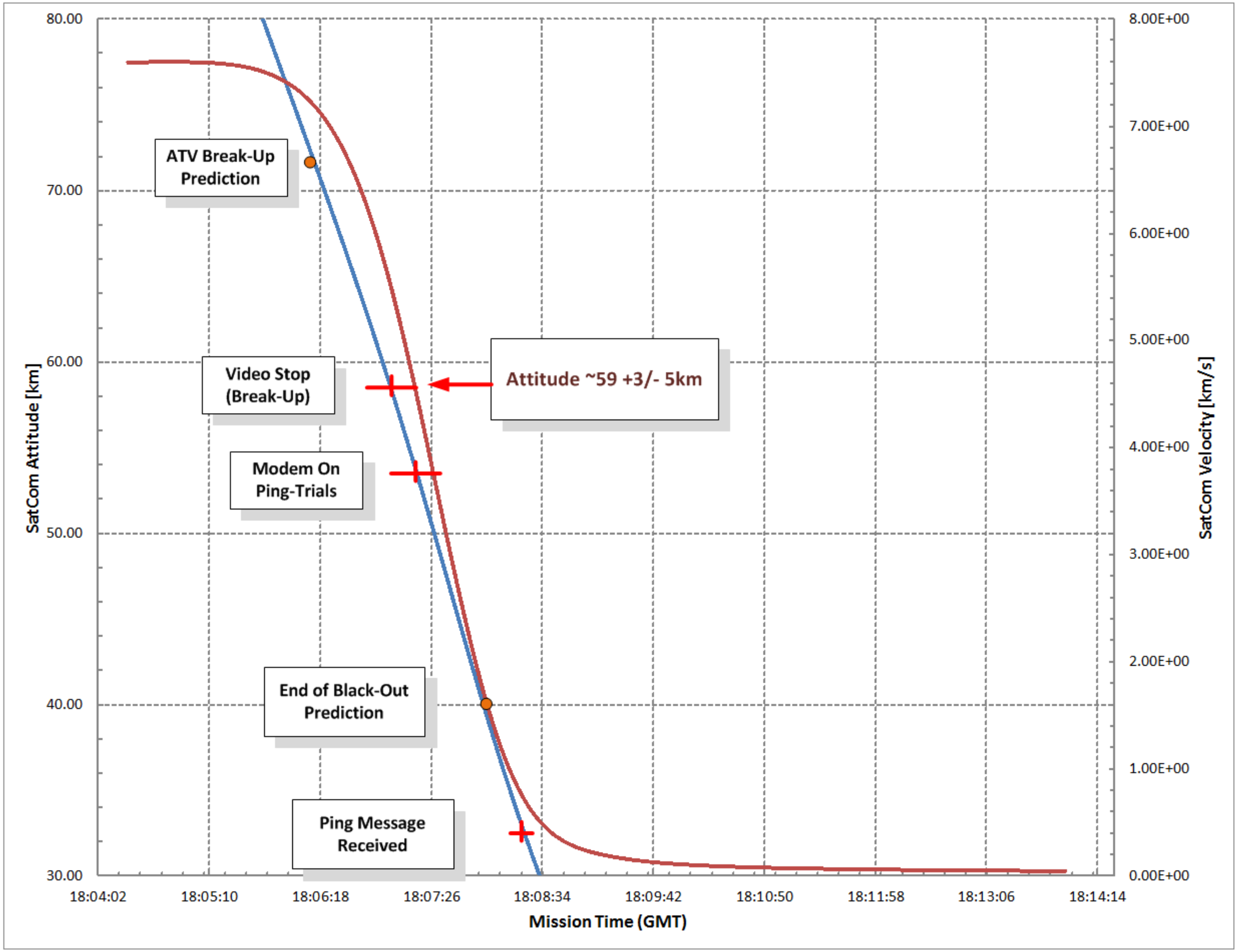
Results from ATV-5



Results from ATV-5

IRC

Trigger	☑	Final boost detected
Video Capture	☑	~10 minutes recorded
Video Transfer	☑	5967 images stored in SatCom
Power Management	☑	

SatCom

Safety Inhibits	☑	Modem powered
TPS	☑	SatCom internal temperature low
Data acquisition	☑	Housekeeping data available
Downlink	☑	Ping message received
Video compression	☑	Worked (tested on ground)
Download	☐	Connection lost
Power Management	☑	

Generic Re-Entry SatCom Design

Idea: Re-entry recorder working as **«Spacecraft Black Box»**

Properties:

- Stand-alone operation
- Robust against break-up and re-entry loads
- Data transmission during free-fall phase
- Sensor suite tailored to mission/scientific goals

➢ What needs to be done to have such a black box?

Generic Re-Entry SatCom Design

- ATV-BUC SatCom Technical Data
  - Mass: 24.9 kg
  - Power Consumption (Peak): 19.1 W
  - Standby Time: 15 days

- Lessons Learnt from ATV-BUC
  - Downlink capability very limited → transmission only during free-fall time
  - Back-up downlink is recommended
  - Power consumption needs to be optimized to support long standby times
  - Implementation of generic interface design

Generic Re-Entry SatCom Design

- Potential Improvements and Next Steps
  - Miniaturization → What is the physical limit?
  - Alternative downlink possibility (e.g. S-band, Inmarsat, etc.) can solve coverage issues
  - Buoy design to use floating period in the water for enhanced downlink capability
  - Standardized interface for external sensor front end via Ethernet, USB or Wireless
    - Remotely accommodated sensors (strain gauges, temp, camera etc.)
    - Free floating sensors for initial debris dispersion investigations (delta v, break-up timeline)
    - Front-end equipment like IRC
  - Re-charge capability for battery in case long term storage in orbit is necessary

Generic Re-Entry SatCom Design

- Possible applications
  - Re-entry in-situ observation
    - Controlled deorbiting of space debris (e.Deorbit, RemoveDebris, …)
    - Uncontrolled re-entry of dead satellites
    - Re-entry of launcher upper stages
    - Collection of more scientific data → Re-entry models, D4D verification, …
  - Applications for launch vehicles
    - Thruster/plume monitoring
    - Trouble shooting during launch
  - Flight recorder

Summary

- European re-entry recorder, SatCom, developed within only 9 month from scratch
- IRC-Front-End and SatCom (ATV-BUC) flown on ATV-5 mission
- Suitability of system concept verified
- Message sent in ~35km altitude indicating ATV break-up in ~60km altitude

- Generic design would lead to a standardized «Spacecraft Black Box» that could also support other aspects of the Clean Space initiative

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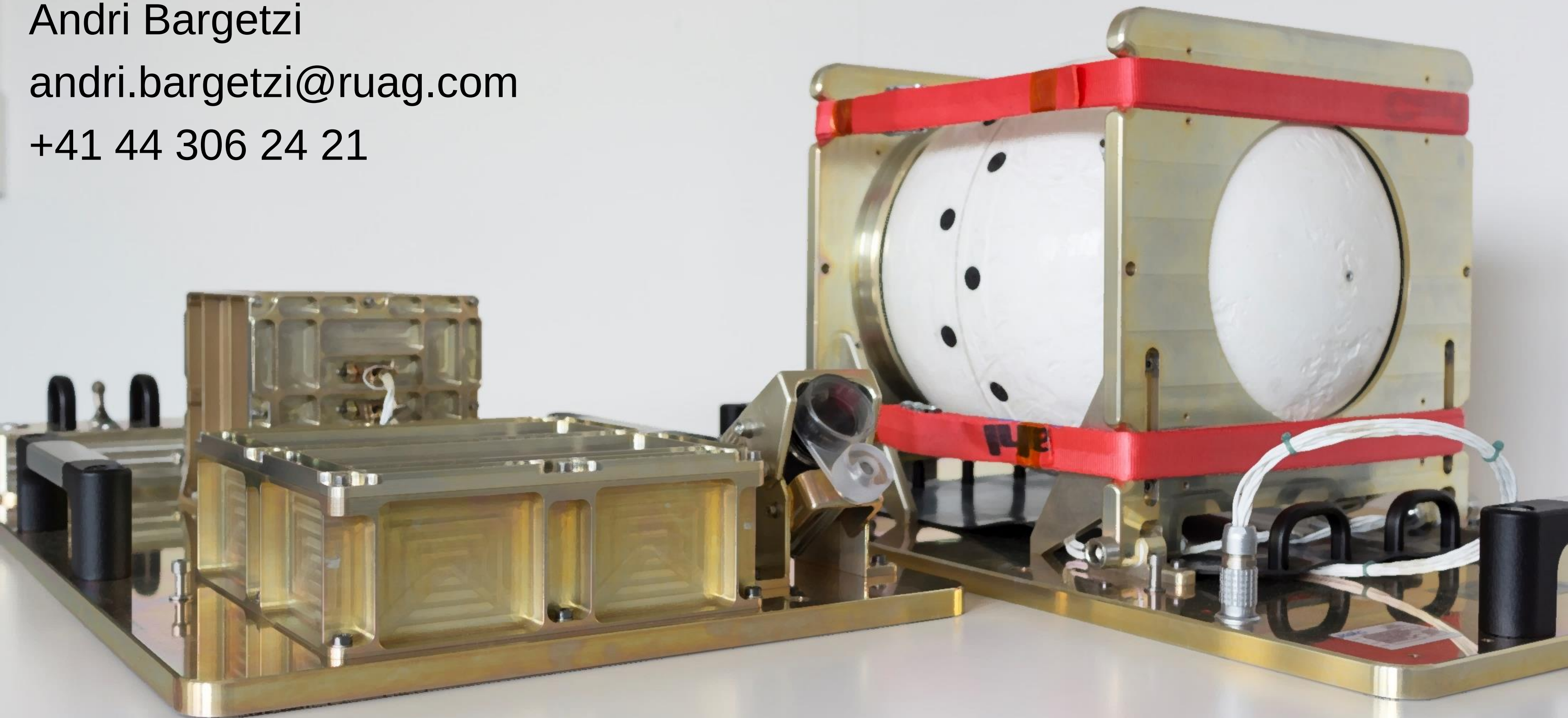

Thank you for your attention!

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