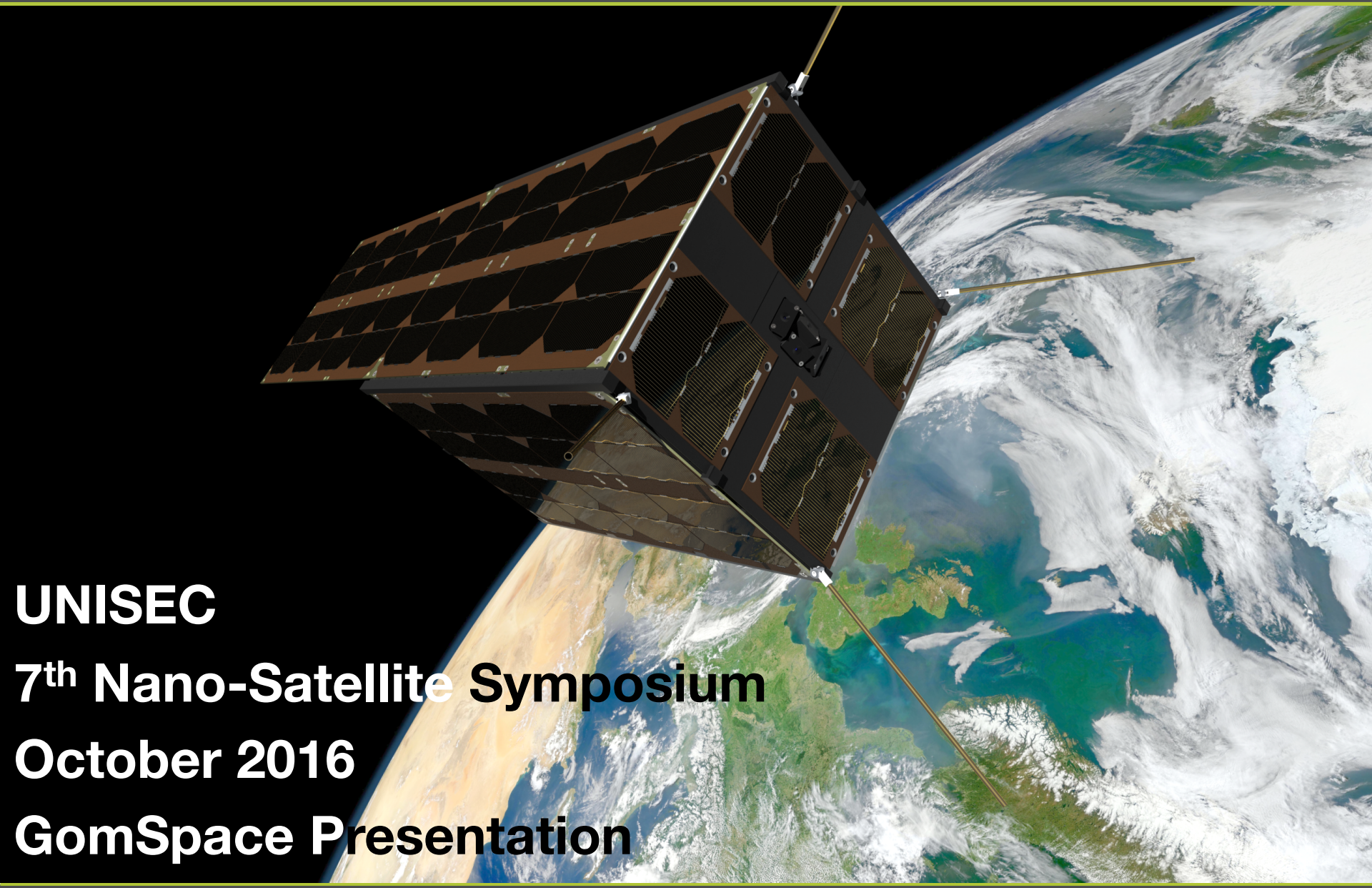
GOMSPACE



UNISEC

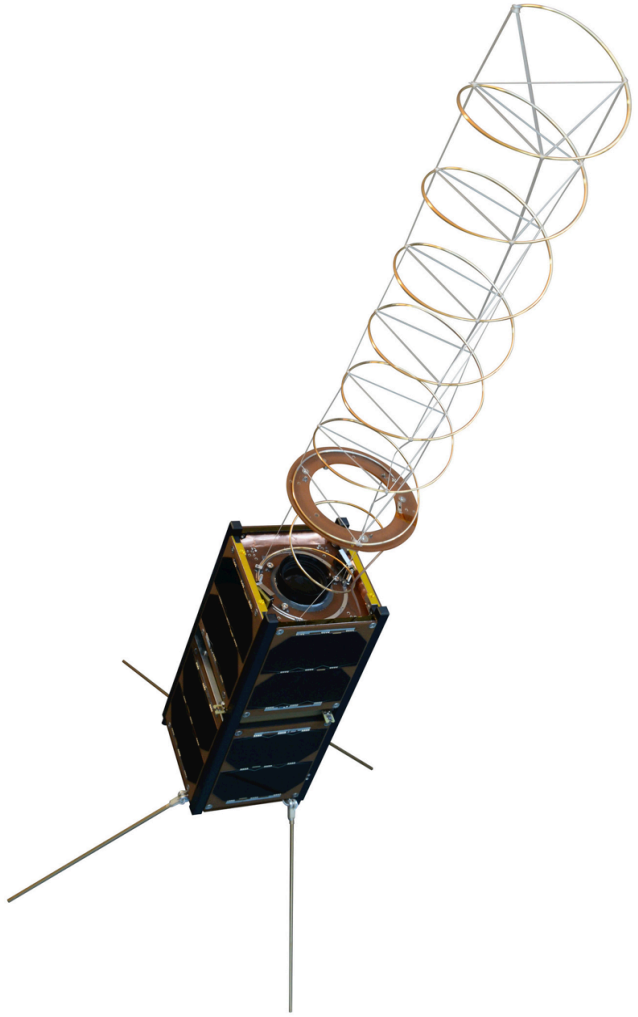
7th Nano-Satellite Symposium

October 2016

GomSpace Presentation

Presentation Agenda

- GomSpace at a glance
- Platform Overview
- New products & Roadmap
- GOMX-3 in-orbit results

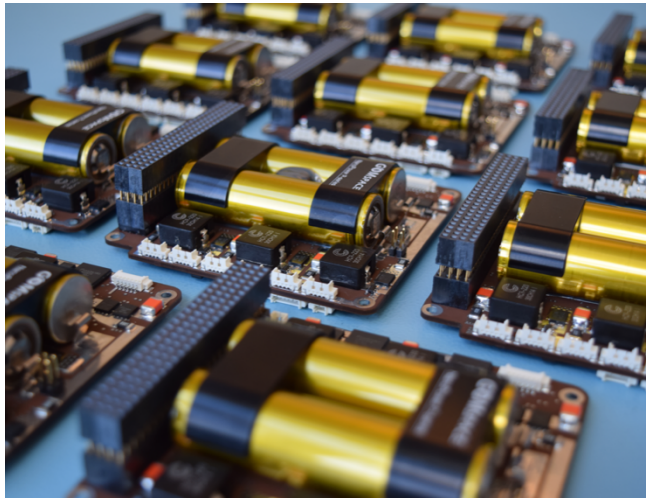


GomSpace at a Glance

- A nanosatellite company, situated in Denmark, founded in 2007 and listed in Stockholm June 2016 (GOMX)
- Experienced management team with background in defense, cyber and space
- 70+ highly qualified international staff
- Focus on professional satellite subsystems, radio payloads and turn-key solutions
- Has exported space hardware to customers in more than 50 countries

Why Choose Products from GomSpace?

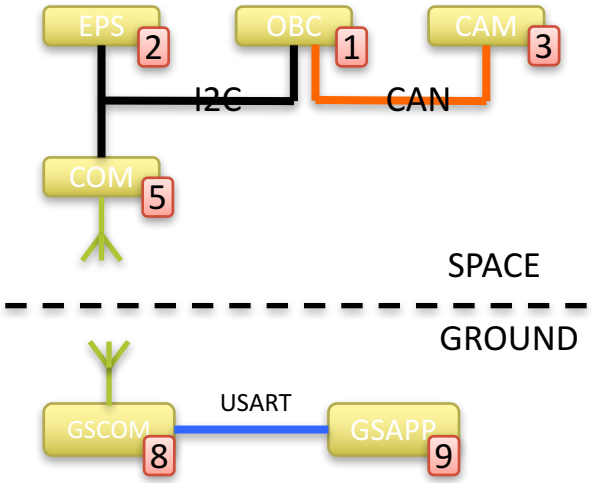
- We ship >1000 subsystems yearly to customers in 50 countries
- Our products are developed, qualified and in-orbit validated through our GOMX flight test program
- Performance of our products as demonstrated in space is second to none
- Batch production ensure high quality, low lead time and attractive cost



"A fantastic company not only in technical aspects also in customer care and help. Definitively, a team in which you can rely and trust for your space mission."
– Alex Beccera, CEO of Aurora Space, Chile

Common Features of our Products

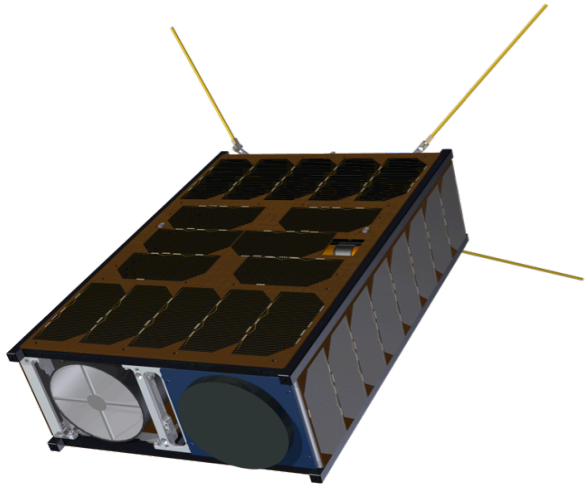
- Cubesat Space Protocol (CSP): open source network stack for smartly connecting systems in a network
- GomSpace Shell (GOSH): Easy check-out & configuration of any subsystem using a PC
- All boards manufactured in space grade print circuit board material and lay-out
- FRAM on many systems allows persistence of settings across reboots




```
nanocom-ax # param mem 4
Using param mem 4
nanocom-ax # param list
  0x0000 temp_brd        I16 260
  0x0002 temp_pa         I16 262
  0x0004 last_rssi       I16 -87
  0x0006 last_rferr      I16 -185
  0x0008 tx_count        U32 0
  0x000C rx_count        U32 0
  0x0010 tx_bytes        U32 0
  0x0014 rx_bytes        U32 0
  0x0020 boot_count      U16 1354
  0x0024 boot_cause      X32 0x00000001
  0x0028 last_contact    U32 948844800
  0x0030 tot_tx_count    U32 16969488
  0x0034 tot_rx_count    U32 111618
  0x0038 tot_tx_bytes    U32 4099682
  0x003C tot_rx_bytes    U32 21821612
nanocom-ax #
CTRL-A Z for help | 500000 8N1 | NOR | Min
```

GomSpace Platforms

- Our products are developed, qualified and in-orbit validated through our GOMX flight test program
- Based on our flexible in-house product port-folio *we configure a specific platform design to match your requirements* – because no two missions are identical



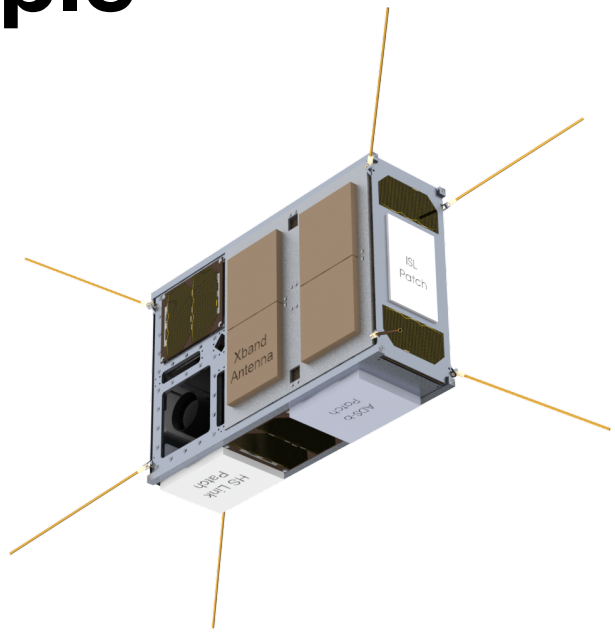
Platform Configuration Overview

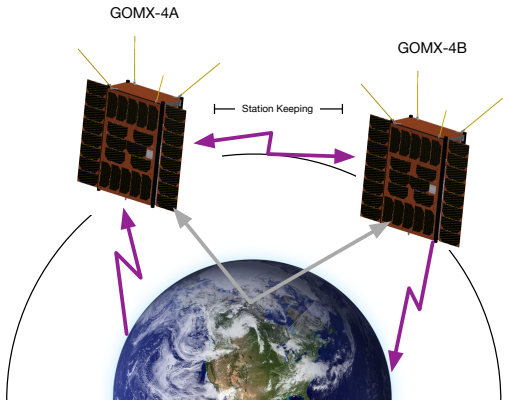
Platform Size	Basic Platform Options					Advanced Platform Options				# of payloads possible	Standard Payloads Options			
	Core Platform	GPS	Fine ADS	Fine ACS	S-Band	Star-tracker	Inter-satellite-link	Deployable panels	Propulsion		RGB Camera	AIS Receiver	ADS-B Receiver	SDR sensing platform
1U	X									1	(X)	X		X
2U	X	X	X	X						2	X	X	X	X
3U	X	X	X	X	X	X	X	X	X	2-3	X	X	X	X
6U	X	X	X	X	X	X	X	X	X	3-4	X	X	X	X
Minimum recommended platform options to support payload											Fine ADS + ACS		Fine ADS + ACS	Fine ADS + ACS

- Table above provides an overview of recommended configurations. Other alternatives are possible, ask!
- Request access to our technical whitepapers to learn more about the technology applied in our platforms

6U Platform Example

- Advanced capabilities incl.
  - Propulsion
  - Inter-satellite linking
  - Fine pointing with star-tracker
  - Redundant systems
- Can accommodate multiple small or a single more demanding payload
- In 2017 we will launch two 6Us to demonstrate formation flying and inter-satellite linking – the building blocks of formations





1U, 2U & 3U Platforms

- Core platform
  - Structure
  - Battery, power supply solar panels
  - UHF radio and antenna
  - On-board computer
- Add-on options include
  - GPS & fine attitude control options
  - High-speed communication & ISL
  - Propulsion
  - Deployable panels
- Off-the-shelf payloads
  - Color camera
  - AIS receiver for ship tacking
  - ADS-B receiver for aircraft tracking
  - Software defined radio platform

Platforms

Flexibile, flight proven nanosatellite platforms to support your mission profile requirements

- High capacity power storage coupled with advanced solar cells and EPS for maximum power
- Robust communication systems featuring advanced forward error correction and dynamic in-flight configurability
- Advanced GomSpace daughterboard architecture maximizes volume available to payloads
- Cubesat Space Protocol networking and the included GomSpace Integrated Platform software makes integration easy with adaptible subsytems capable of integrating your mission payloads

Platform Technical Features

	1U	2U	3U
Minimum Platform Volume	90 x 92 x 38 (mm)	90 x 92 x 46 (mm)	90 x 92 x 46 (mm)
Recommended Battery Capacity	19.25Wh	38.5Wh	38.5Wh
Average Payload Power	1.3W	2.5W	3.7W
ADCS Capabilities	Detumble	Detumble Fine Attitude Knowledge (Fine Attitude Control)	Detumble Fine Attitude Knowledge Fine Attitude Control
Software Included	GomSpace Flight Software + Powerful SDKs Available	GomSpace Flight Software + Powerful SDKs Available	GomSpace Flight Software + Powerful SDKs Available
Other Options	Payloads	GPS Payloads	GPS High Speed Radio Payloads

The 2U provides improved attitude control capabilities and can host a wide range of payloads including an AIS receiver, ADS-B receiver, NanoCam camera systems, and a powerful Software Defined Radio payload as offered by GomSpace. Ask us how one of our 2U's survived a launch vehicle explosion without a scratch.

The 3U configuration can support multiple payloads and/or redundant systems, and can be delivered with a highly agile ADCS system. Ask us for a full presentation of GOMX-3 in-orbit results including SDR and ADS-B payload performance.

Even the small 1U configuration provides ample space and ressources for payload integration. It is possible to fit the GomSpace NanoCam camera payload with Schneider Kreuznach 35mm optics. GomSpace can secure the platform, launch, and deployment from the ISS with a typical purchase-to-orbit time of less than 12 months.

Product Categories

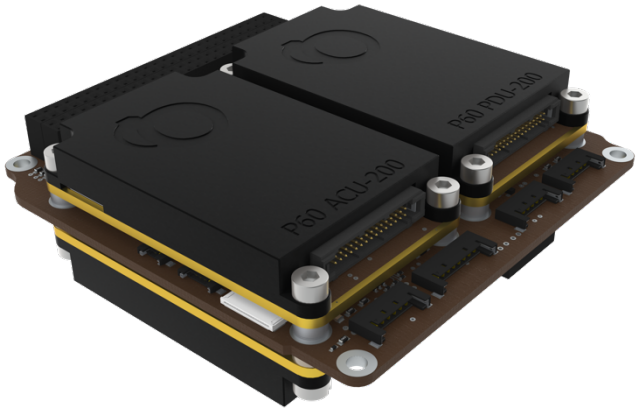
Category Name	Content
NanoPower	Power supplies & distribution, batteries, solar panels
NanoMind	On-board computers, payload processing & FPGA
NanoCom	Transceivers, antennas, RF front ends
NanoSense	ADCS sensors
NanoTorque	ADCS actuators
NanoDock	Docking modules for miniaturized functional modules
NanoUtil	Misc. systems to put it all together
Software	SW modules for mission management and ADCS
Payloads	Payload Modules

Naming is not always consistent

NanoPower Power Supplies

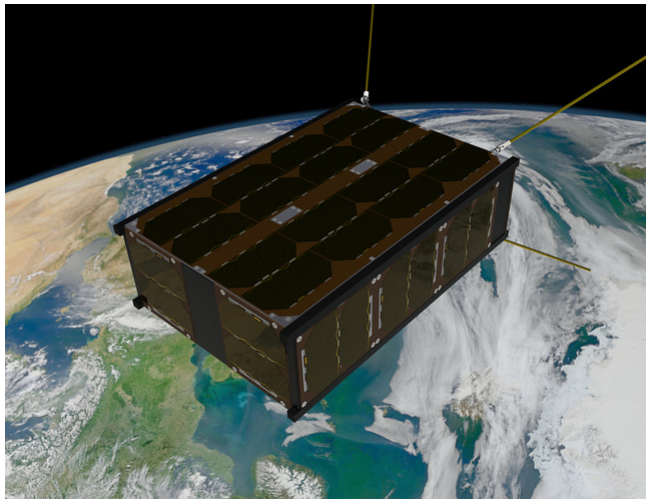
- NanoPower P31U & P31US:
  - Maximum power point tracking, battery charge management, battery pack, regulation & distribution - all in one
  - Perfect for 1U, 2U and 3U designs
  - 6 input channels, 6 output channels + raw battery, regulated 3.3V & 5V, up to 30W
  - ISS approved

- NanoPower P60:
  - Modular and scalable for 6U and larger
  - Up to 12 input channels and 27 outputs
  - 3.3V, 5V, 8V, 12V, 18V, 24V output voltages
  - Up to 100W power handling

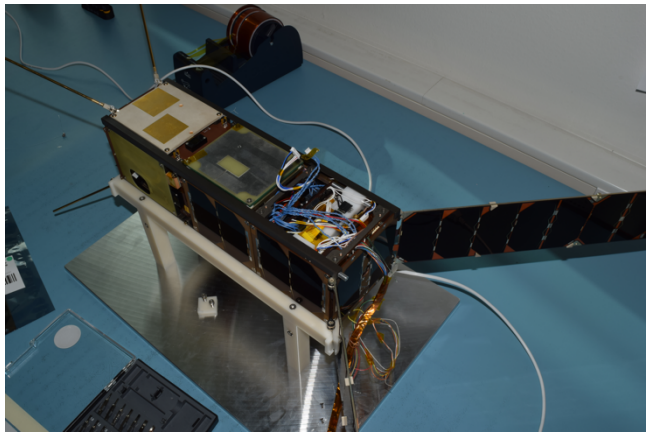


NanoPower Upcoming Products

- Solar panels for 6U satellite currently under development for GOMX mission and will become standard product in 2017



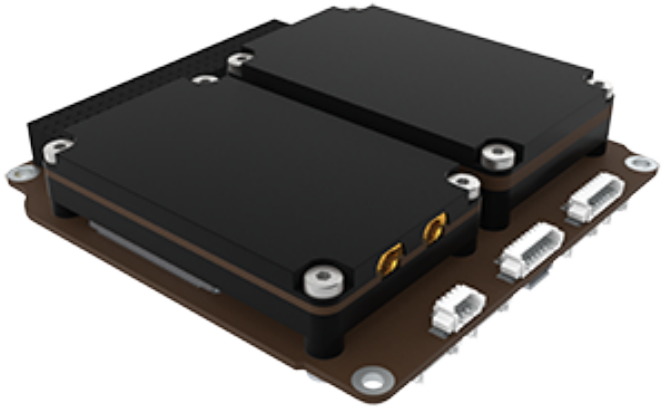
- Deployable solar panel for 3U SEAM mission to fly in 2017 and lead to standard products for 3U/6U deployable panels



NanoCom Transceivers

- General Features
  - Forward error correction and Viterbi coding for robust link
  - Local buffering for high throughput
  - Automatic file transmission with CSP protocol incl. compression and encryption

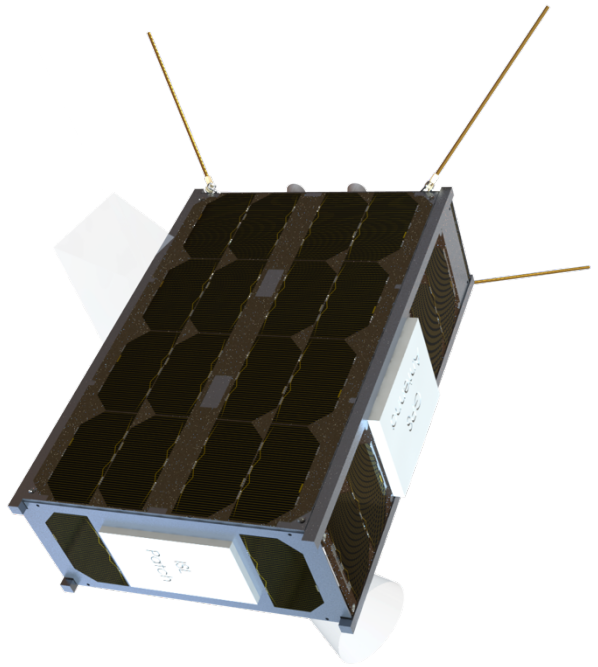
- NanoCom AX100
  - UHF and VHF versions available
  - Full-duplex operation up to 115kbps



- NanoCom S100
  - S-band (RX: 2025-2110, TX 2200-2290)
  - Full-duplex operation up to 25Mbps
  - SDR based

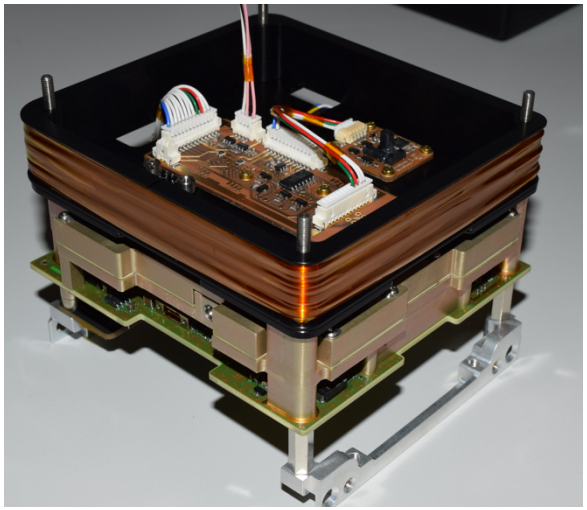
NanoCom Roadmap

- Many new NanoCom products will result from GOMX-4 project and become available in 2017
- Antennas
  - 6U version of UHF antenna
  - S-band patch antenna for NanoCom S100 transceiver
- Radios
  - Inter-Satellite Link (ISL) version of S100 transceiver
- Ground Equipment
  - S-band option for ground station

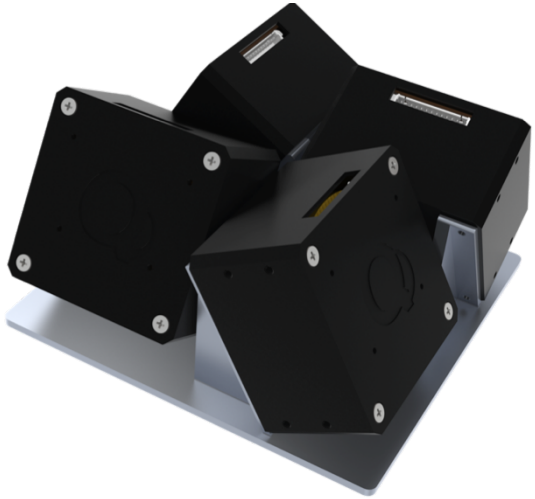


NanoTorque Attitude Actuators

- For ≤3U satellites magnetorquers are integrated in NanoPower P110 panels
- NanoTorque TorqZ is a Z-torquer for internal mounting to complement panel based torquers



- NanoTorque GSW600
  - High-performance reaction wheels recommended for 6U and larger satellites
  - Set of 4 wheels mount in 0.5U space
  - Momentum storage per wheel: 24mNms

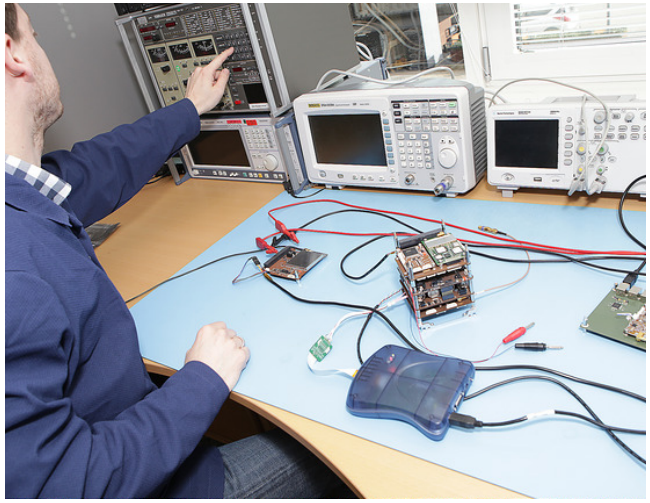


ADCS Upcoming Products

- Internal 3-axis magnetorquer for 6U and larger satellites
- Fit in 0.25U
- Available in Q1 2017

Supporting Elements and Services

- In addition to the satellite hardware platforms we provide extensive project support options
  - Flexible flight proven software modules
  - Ground station set-ups
  - Tailoring to specific mission requirements
  - Integration and test services
  - Training
- Request our “platform offerings whitepaper” for full details

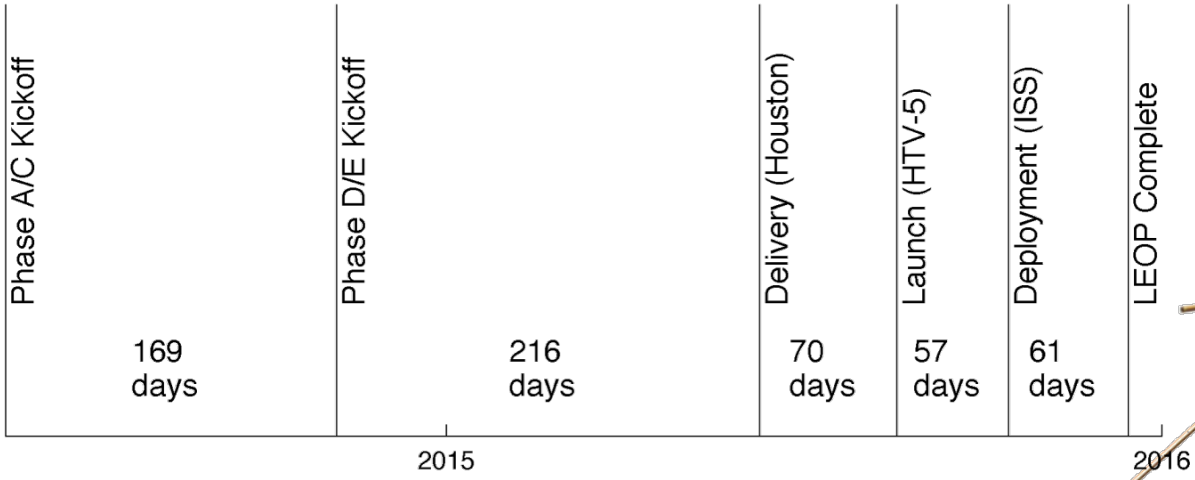


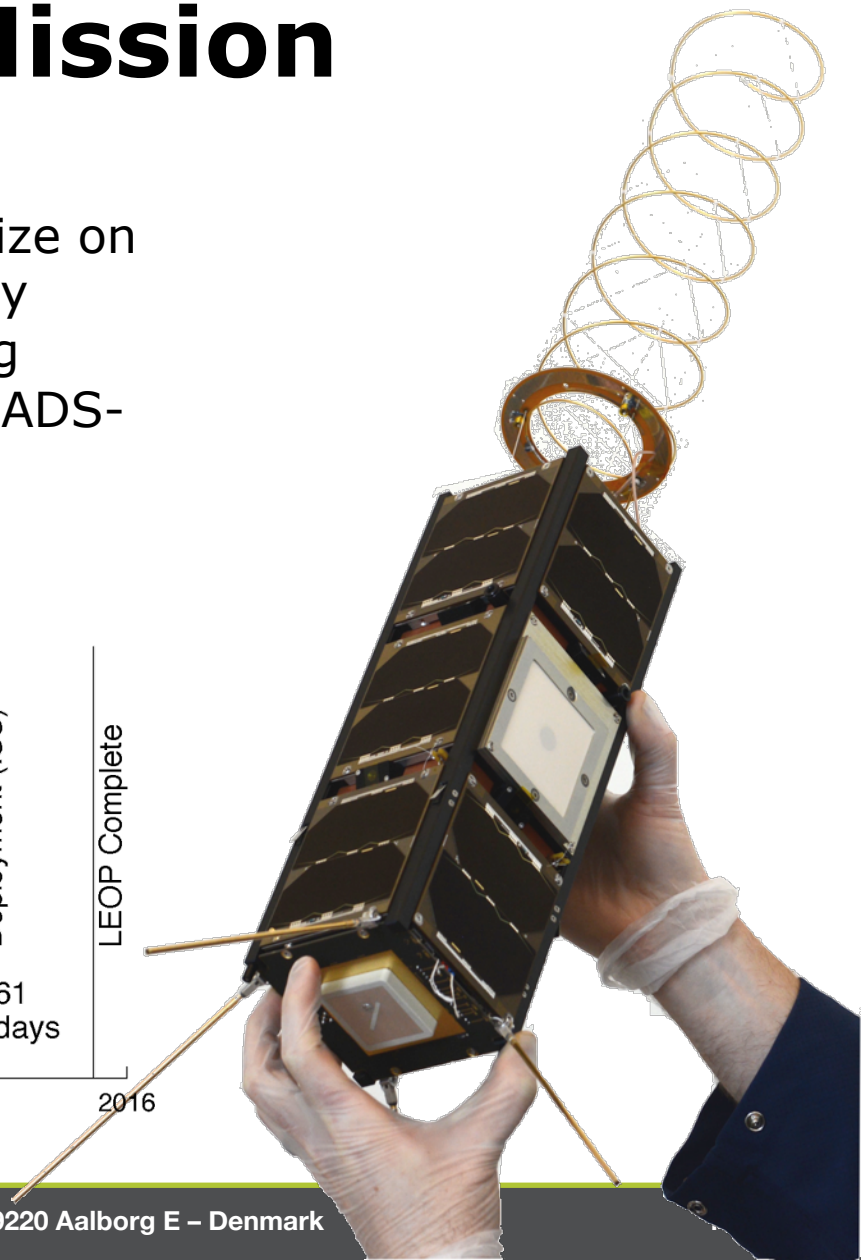
GOMX-3 Mission

Mission Statement:

- The GOMX-3 satellite will capitalize on a 2015 ISS launch opportunity by demonstrating advanced pointing while receiving both L-band and ADS-B signals.

Timeline





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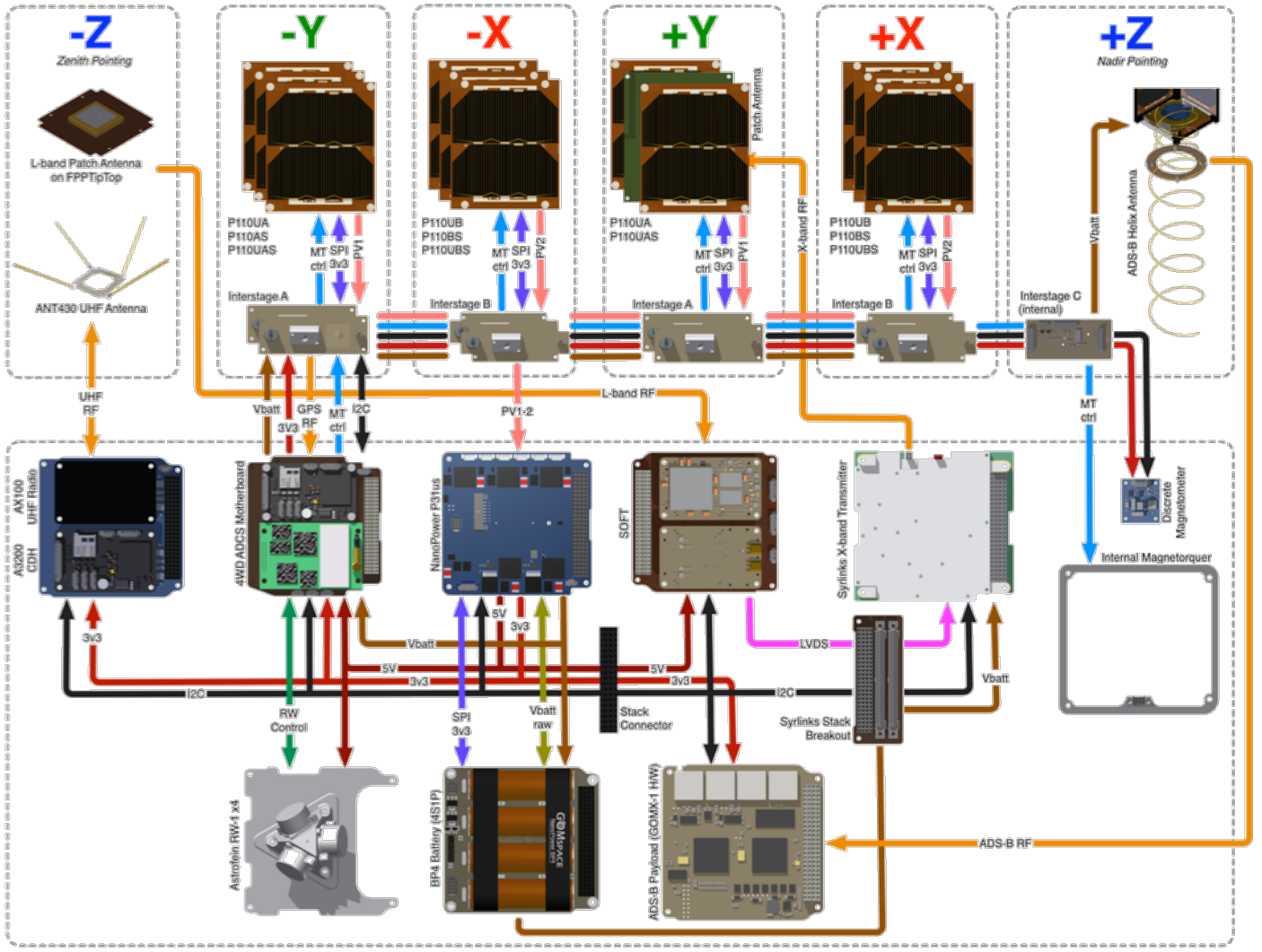
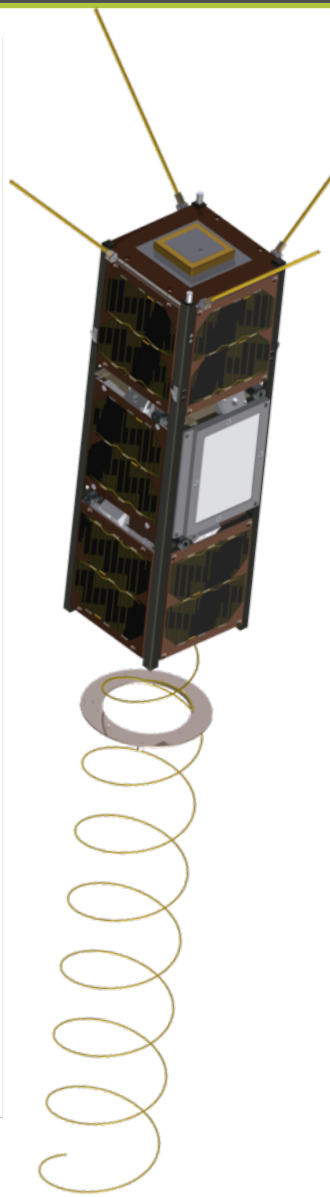
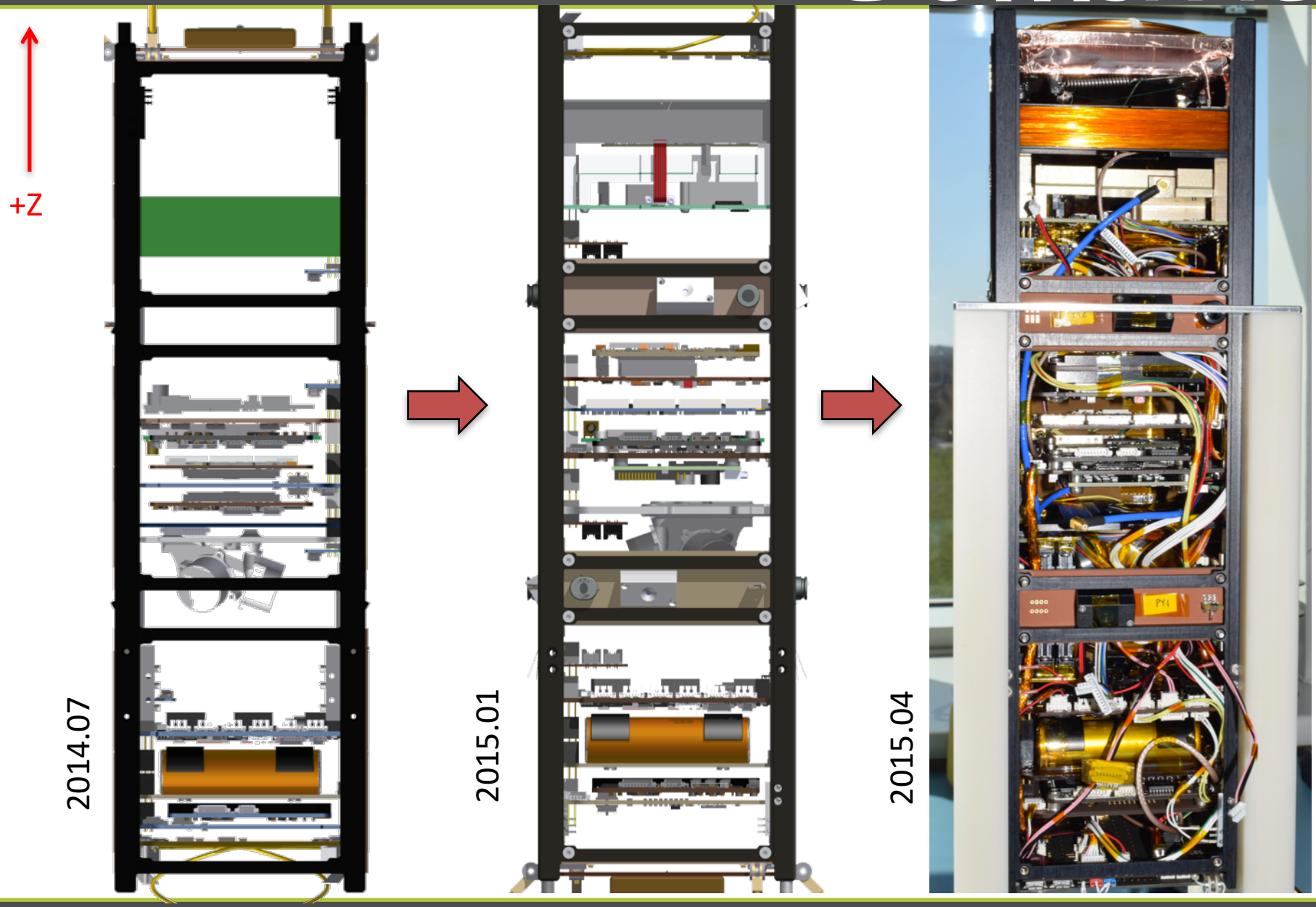
GOMX-3

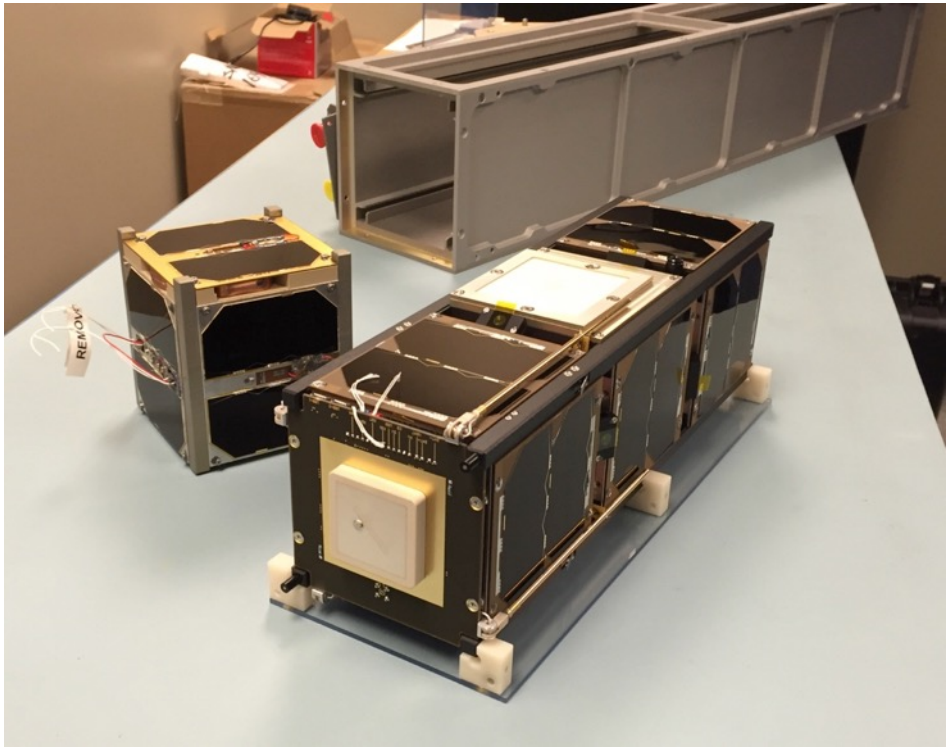





+Z
2014.07
2015.01
2015.04

GOMX-3 Integration

- Successfully completed 10 June 2015
- Integrated with AAUSAT5



GOMX-3 Launch

- 19 Aug 2015
  - Successful launch
- 24 Aug 2015
  - Successful Berth to ISS
- 18 Oct 2016
  - Deorbit

blogs.nasa.gov

nasa.gov

LEOP

Pass 1

Step	Description
0	Ground Station Setup
1	Downlink – Beacon Received
2	Sat OK (few beacons)
3	Uplink – Data Dump
4	Sat OK (more beacons)
5	Reset Watchdog Timers
6	Timesync

LEOP

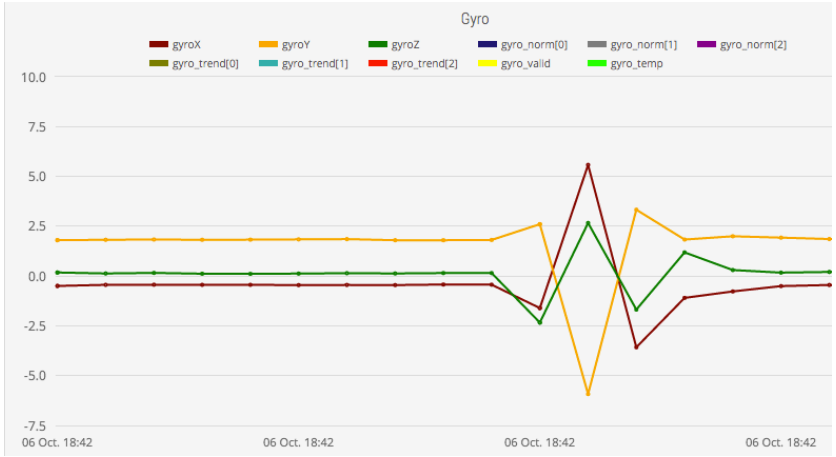
Day 1

Step	Description	Day Completed	Pass Completed
7	UHF antenna disarm	1	2
8	Upload TLE	1	2
9	Enable SGP4 ephemeris mode	1	2
10	Enable UKF determination	1	3
11	SOFT checkout (short)	1	3
12	Increase COM link to 9600 baud	1	3
13	Increase COM link to 19200 baud (downlink)	1	4
14	Enter free-floating ADCS mode	1	4

LEOP

Day 2

Step	Description	Day Completed	Pass Completed
15	Deploy ADS-B antenna	2	7
16	Downlink ADS-B data	2	7

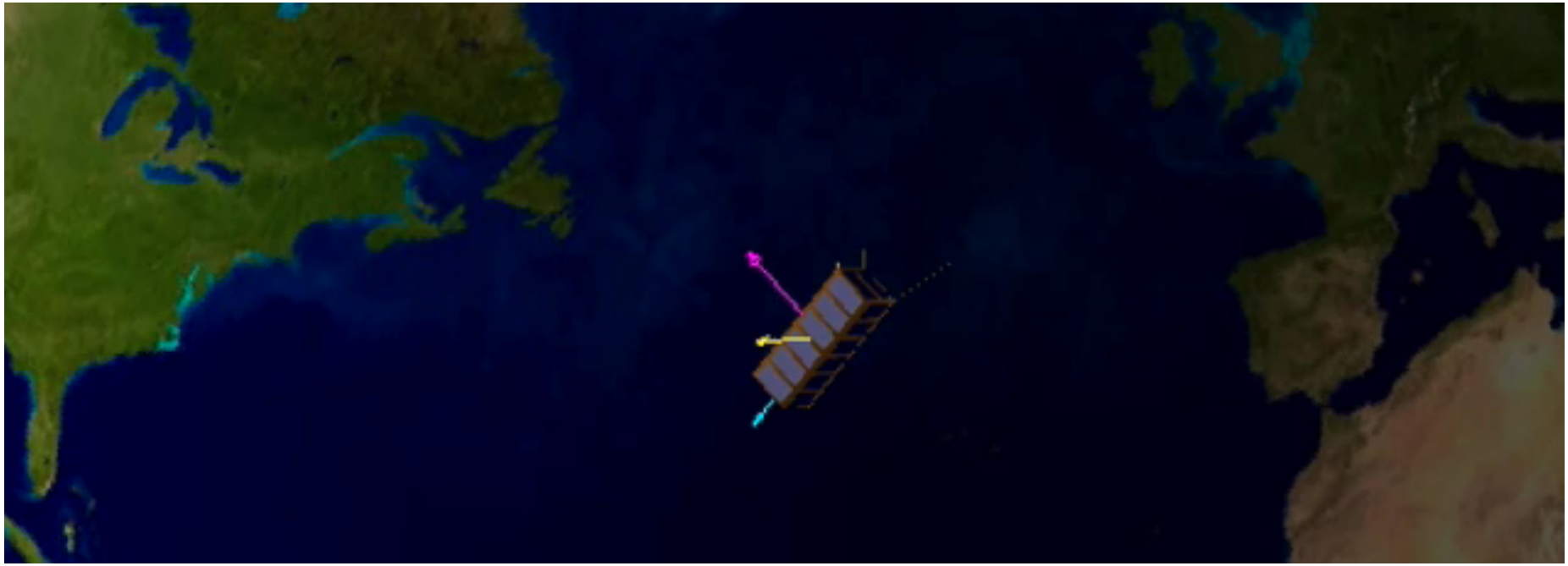


Antenna deployment captured by rate gyro (1 Hz data)

First ADS-B data directly after antenna deployment

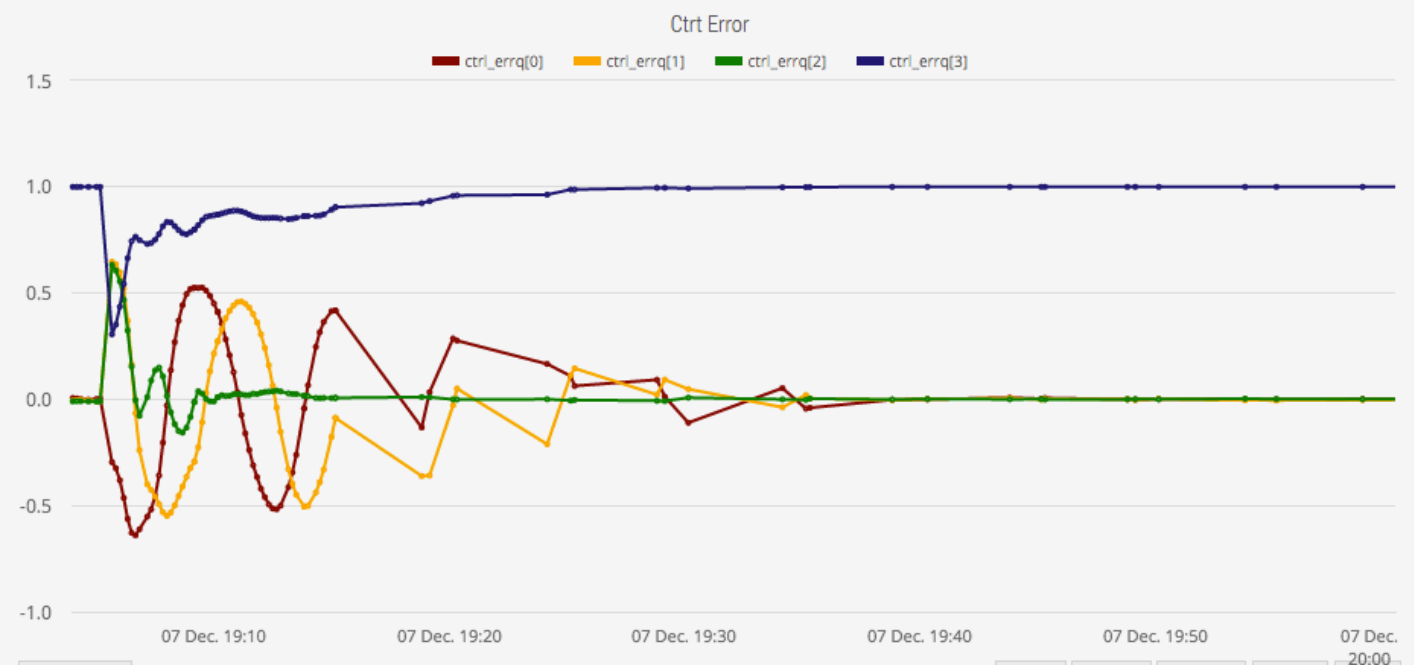
LEOP

Step	Description	Day Completed	Pass Completed
17	Reaction Wheel Checkout	2	8
18	Enable MPPT tracking mode	3	12
19	Enable nadir pointing	4	19



LEOP

Step	Description	Completed
20	GPS checkout	2015.10.28
21	Generate ADCS calibration params	2015.11.04
22	Upload ADCS calibration params	2015.11.04



Satellite Status: Comm

As of 2015.12.03 (deploy + 59 days)

Via UHF link:

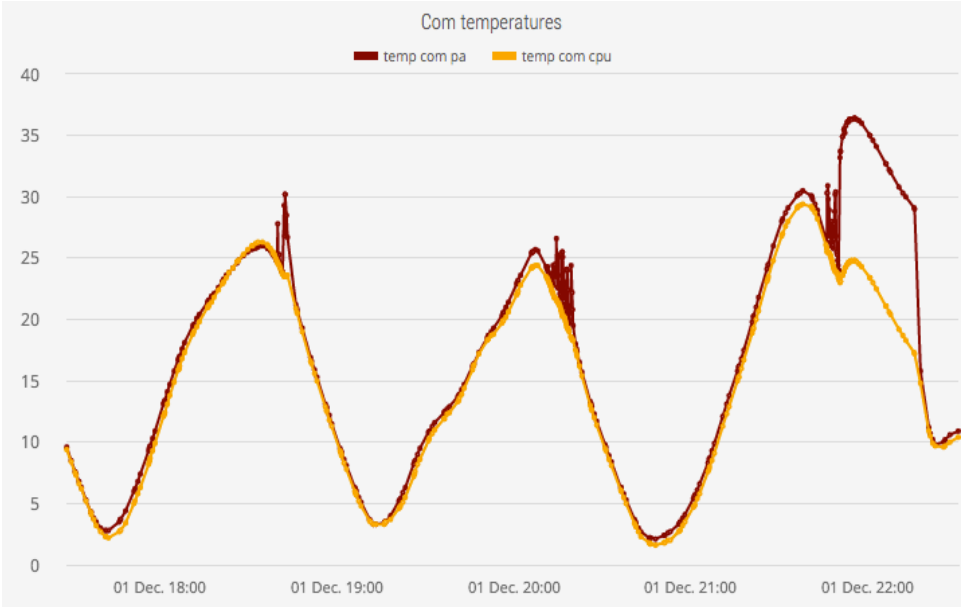
- Total Sat Tx: 765 MB
- Total Sat Rx: 14.4 MB
- Ground Rx: 221 MB

Temperatures within operational bounds

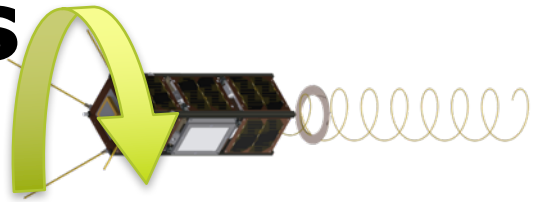
- Even during long Tx periods

Uplink Freq Shift:

- Noticed prob. with FTP
- Traced to local noise
- Worked with IARU to shift freq to avoid noise

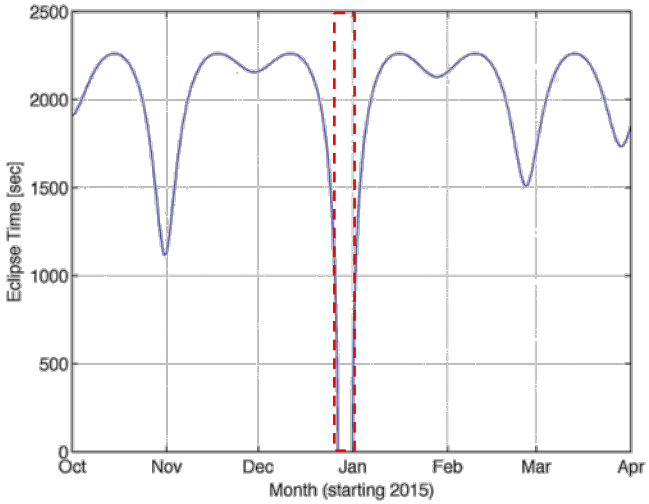


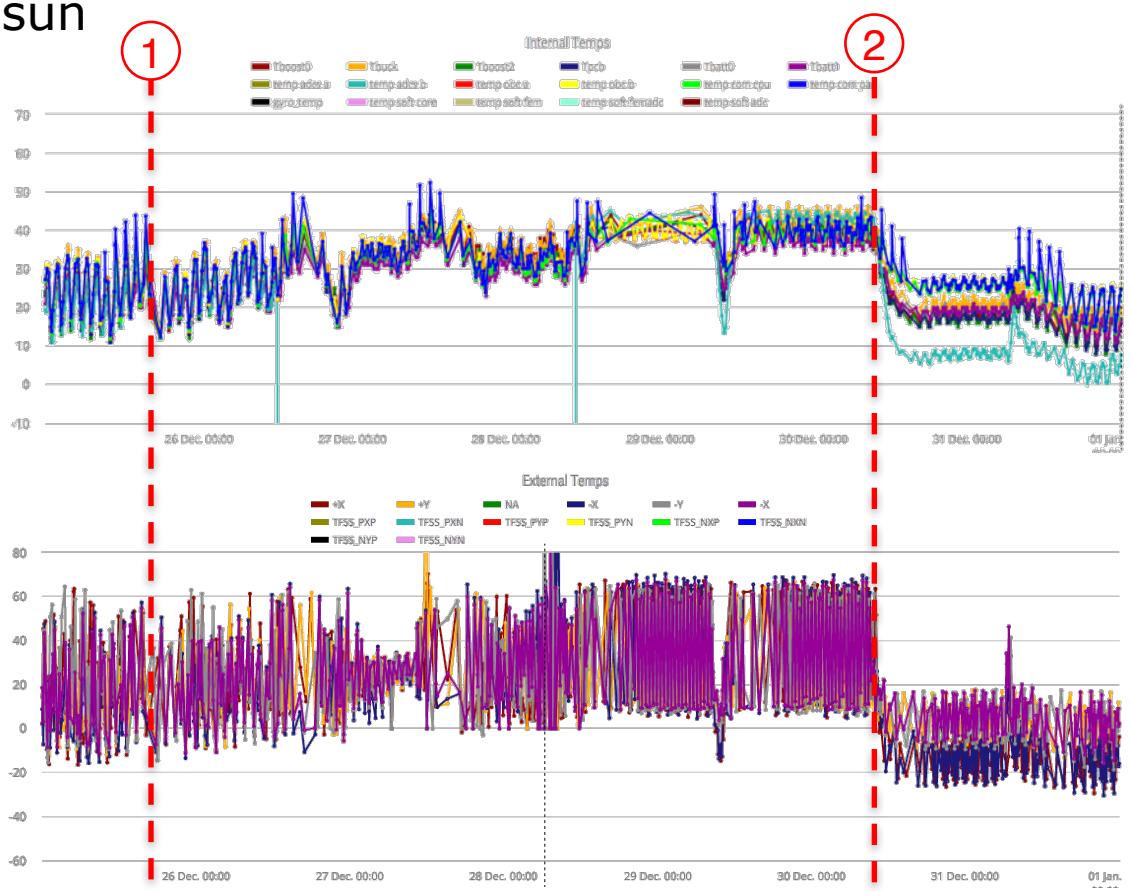
Temperatures



Stress test over holiday period

1. Used "BBQ roll" control mode
2. Pointed 1U face to sun



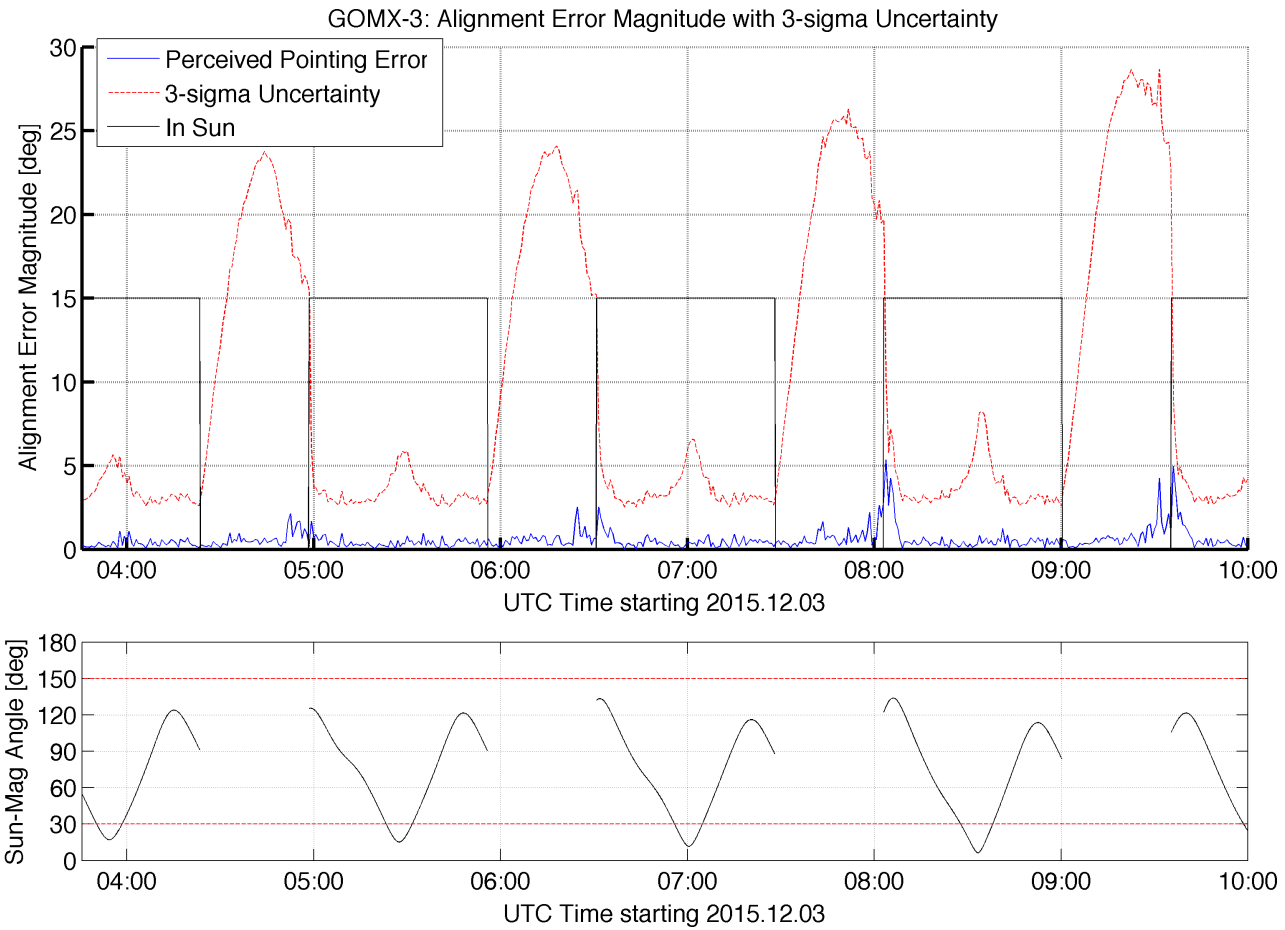


ADCS - Pointing Accuracy

Conditions

- Nadir pointing
- UKF uncertainty estimates

Attitude Determination limits ADCS pointing

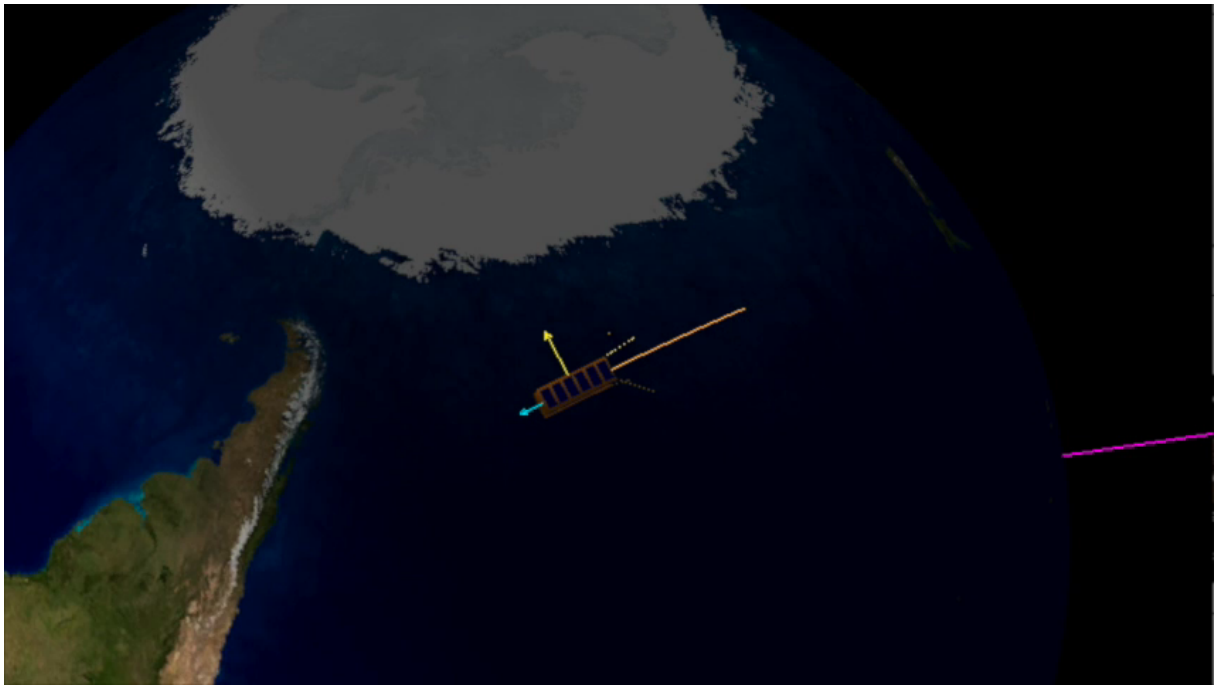


Star tracker required to achieve < 3° pointing

ADCS Conclusion

Demonstrated Capability

- Detumbling
- 3-axis pointing
- On-orbit calibration
- On-orbit software upload
- Momentum dumping
- Nadir Pointing
- Ram Pointing
- ECEF Tracking
  - Earth Fixed Point (Aalborg, Kourou)
  - Geostationary Satellite (Inmarsat 3F2)

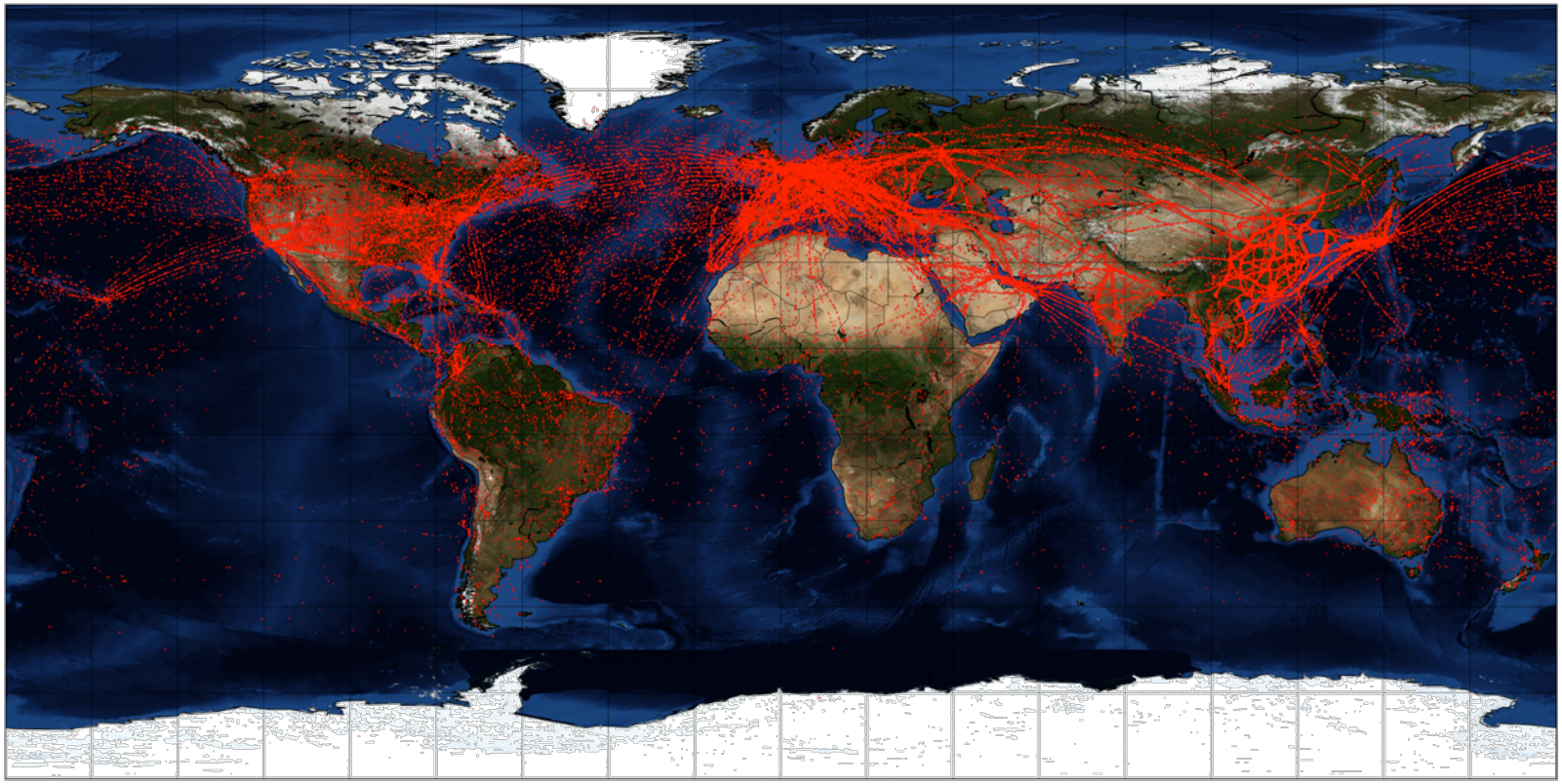


190x speed
1 sec ≈ 3 min

Payloads: ADS-B

- Downlinked 25,523 unique aircraft
- Downlinked 172,432 total ADS-B positions (2,870 / day)

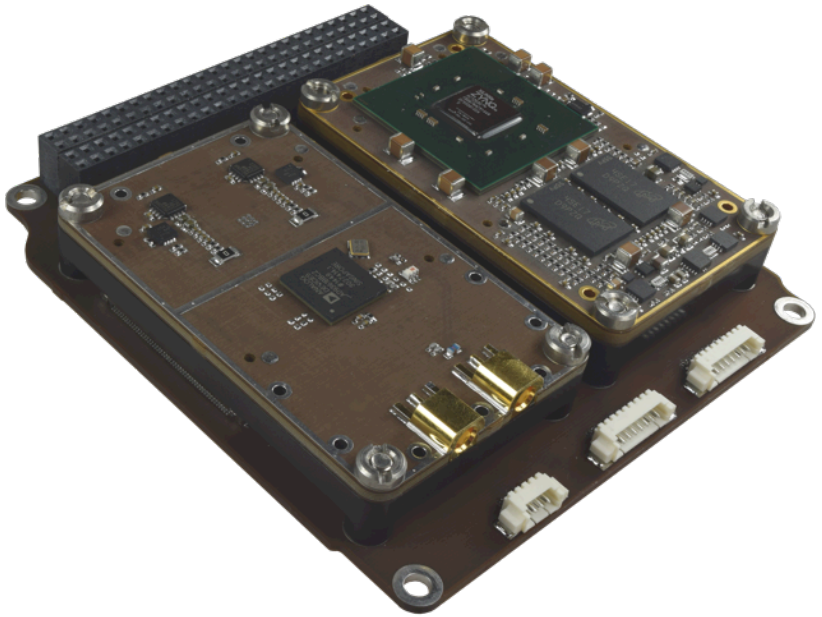
(As of 2015.12.04)



Payloads: SOFT

SDR Platform:

- Consists of FPGA module + RF front ends tailored to mission
- Flight Heritage with GOMX-3



FPGA module:

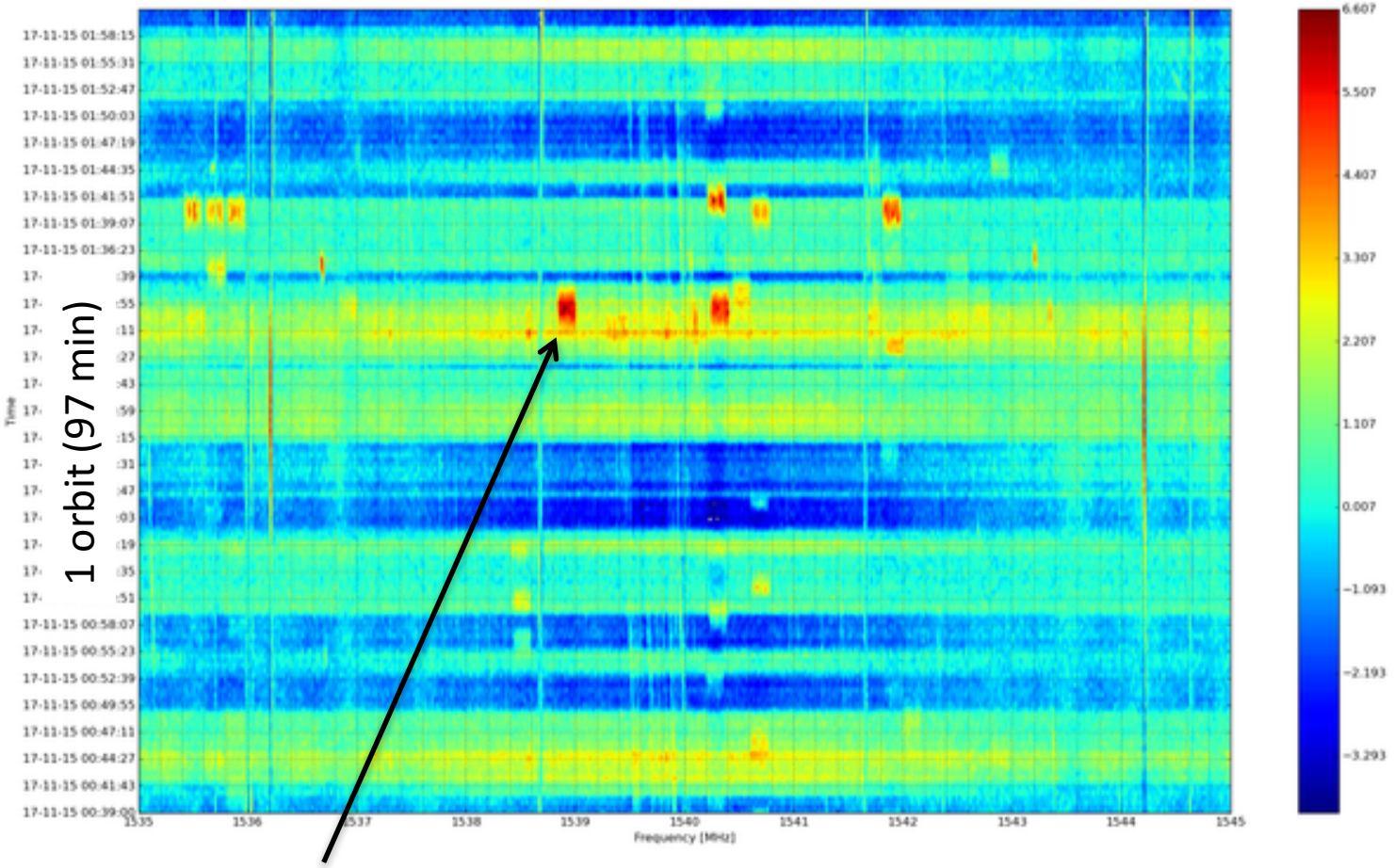
- Xilinx Zynq 7030 Programmable SoC
- Dual ARM Cortex A9 MPCore up to 1GHz
- 1GB DDR3 RAM
- 4GB NAND flash + 64MB NOR flash
- Powerful FPGA module – 125K logic cells
- Linux operating system

Transceiver module:

- Tunable in range: 70 MHz to 6 GHz
- Up to 56 MHz bandwidth

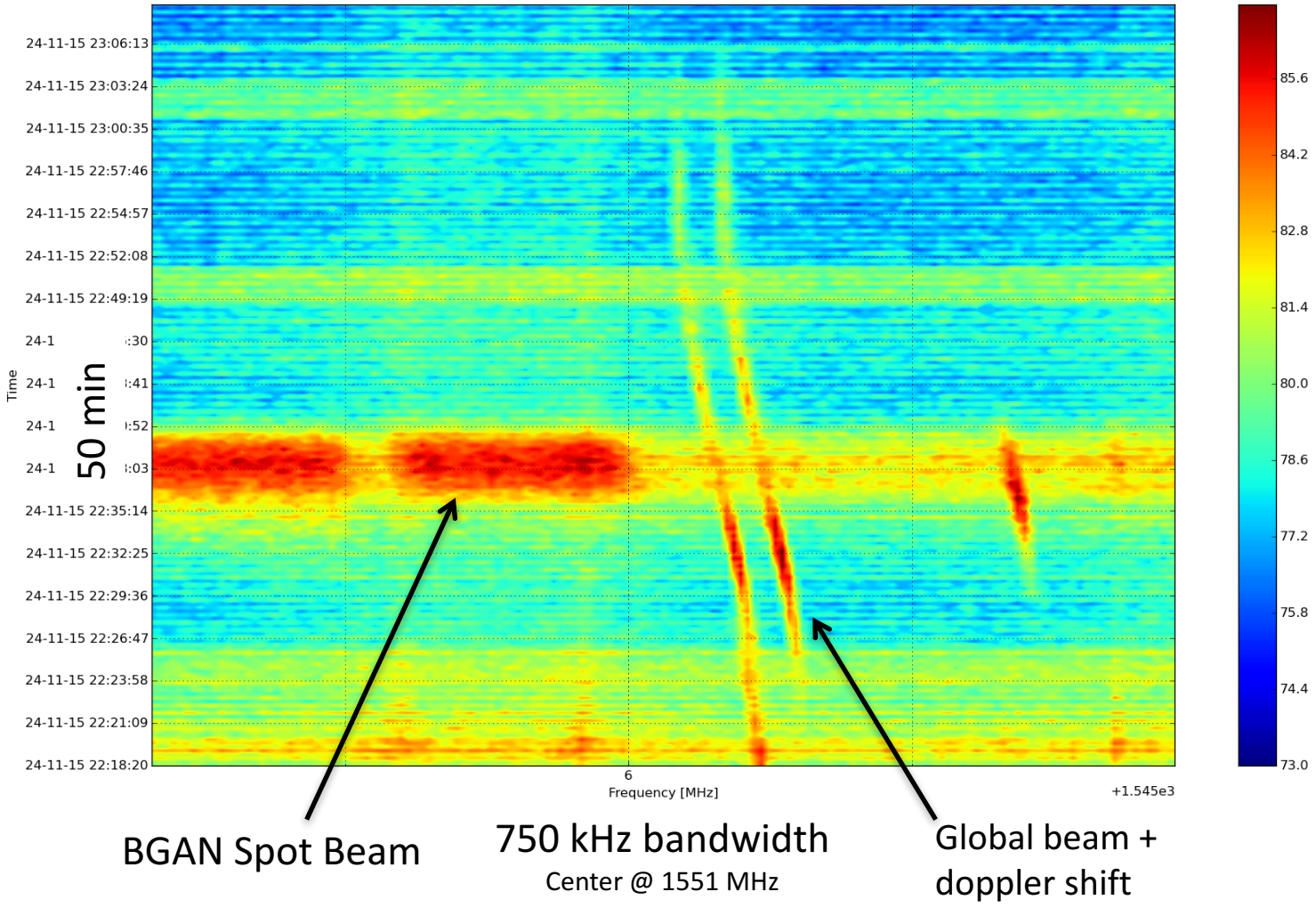
Payloads: SOFT

- Record spectrum while tracking Inmarsat 3F2
- L-band is quite active



Payloads: SOFT

- L-band is quite active



Payloads: Xband

GomSpace support for Syrlinks Xband transmitter:

- Testing
- Troubleshooting & Coordination

GS has supported 9x Kourou passes:

- Week 47-48
  - Achieved PLL lock
  - ASM could not be found
  - Found & corrected endian flip error
- Week 51
  - Successful downlink of 3 MB frames decoded

Main Achievements

General:
- GomSpace excels at robustness + adaption to solve problems at low cost
- Flight heritage!

ADCS:
- 3 axis control
- In-orbit calibration

ADS-B:
- Successful operation

SOFT:
- Demonstrated frequency monitoring
- ESA **very** impressed

High-Speed Downlink:
- Demonstrated operational capability
- Successfully integration of 3rd party payloads in-orbit

Contact for more information

Dennis Elgaard
Head of Sales APAC
del@gomspace.com
Phone: +45 9635 6111