Inside Story of OPS-SAT Space Lab: Part 2

David Evans, OPS-SAT Space Lab Manager, ESA

ESTEC Lunchtime Lecture

23/11/2023

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What is OPS-SAT Space Lab?

OPS-SAT Space Lab is a service enabling in-orbit experimentation open to European/Canadian industry, research institutes, academia and international space agencies.

Principle	How?
No charge	No contracts, simple processes, best effort service
Safe	Special design of space and ground assets, ESA expertise available in the design and testing phases
Independence	ESA can as laboratory provider can assure confidentiality and exclude breaching of industry IPRs
Fast	ESA handles the risk and execution, allows experimenters to concentrate on rapid value creation, fail fast to succeed quickly approach
Open	Experiments are not predefined, the ground and space assets carry powerful reconfigurable hardware and software, an unprecedented level of access is granted to the experimenters

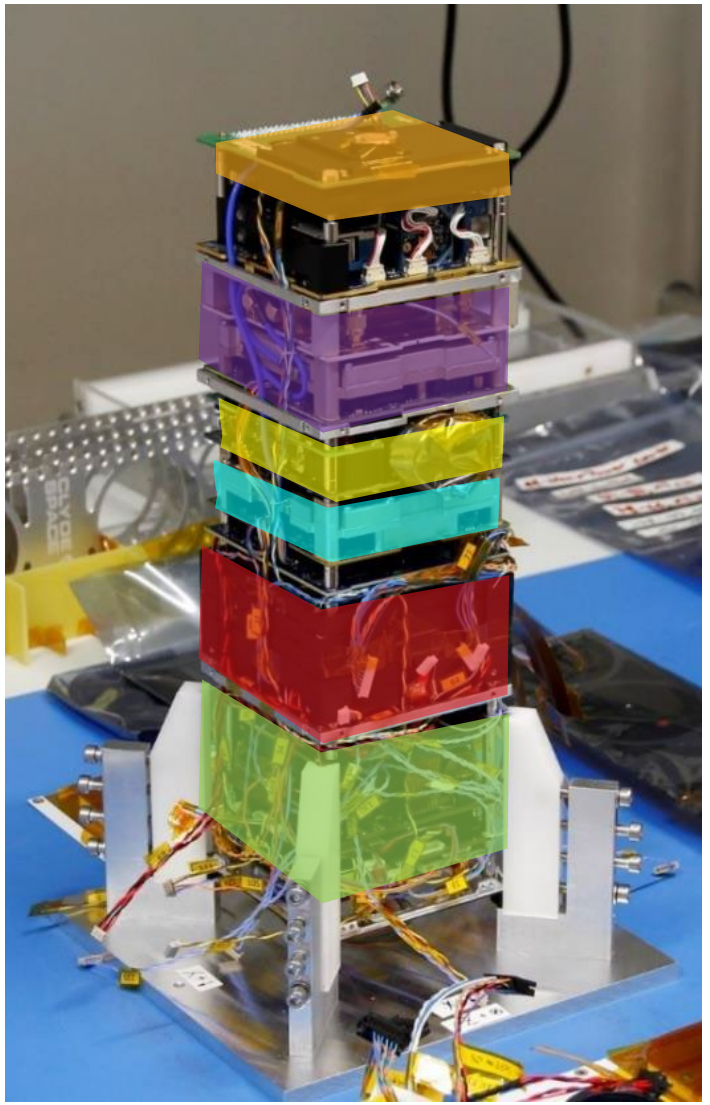
OPS-SAT-1

Satellite bus:

- Gomspace UHF AX100 radio + EPS/ACU
- Nanomind A3200 OBC (On-board computer, AVR32)
- S-band (2.2 GHz) TRX TMTC encoder/decoder (256kbps↑ 1Mbps↓)
- GNSS receiver

Satellite payloads available to experimenters:

- Software Defined Radio (LMS6002D)
- HD-camera (Nadir-facing)
- Optical receiver (data uplink via laser)
- Advanced iADCS (Attitude Determination & Control Sys.)
- X-band transmitter (3-50MBit/s)
- 2x Cyclone V SoC (800MHz Dual Core ARM Cortex-A9 + FPGA fabric) (called the SEPP)



OPS-SAT-1 Mission Status

- 100+ companies from 20 countries registered 268 experiments
- JPL, JAXA, CNES, DLR, EU commission now on-board
- Many start-ups, research institutes and New Space
- ESA Academy, Fly your satellite, University courses (LUX, Zurich…)

GPS jamming experiments with Austrian Air Traffic Control, Army

1st ever Search and Rescue messages decoded in space for the first time

1st ever successful in-flight reprogramming of a Neural Network

D3TN ring road (interplanetary internet) successfully tested for 1st time

1st ever successful stock market trade in space with FlatexDEGIRO and Tradegate

On-board AI in daily use to classify camera pictures (SMART CAM)

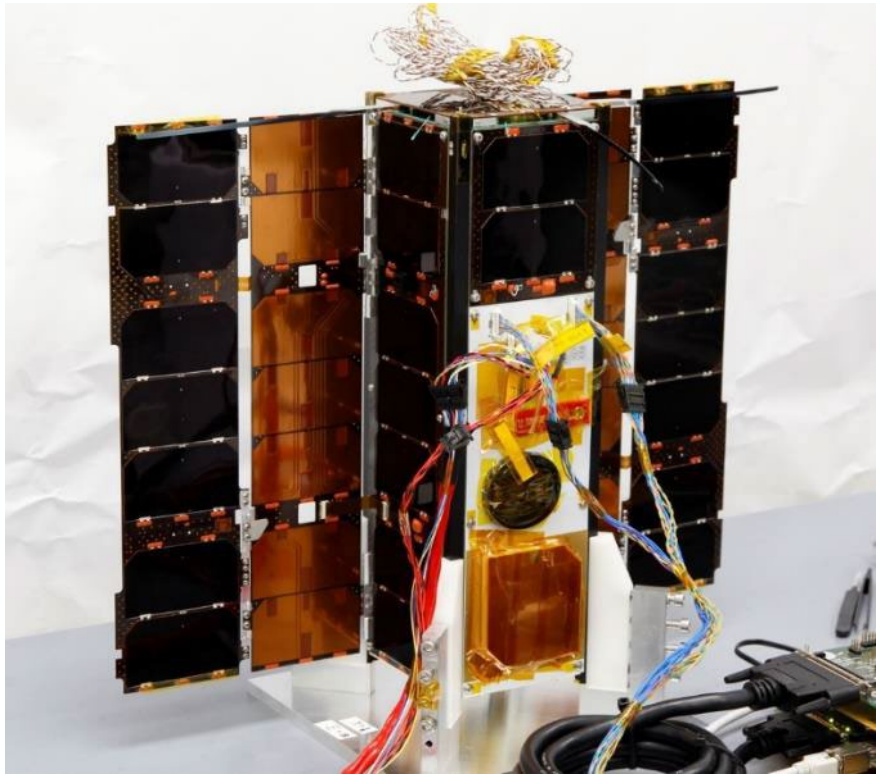
Direct commanding of satellite over the internet by experimenters now routine

TCP/IP direct connection to satellite, allowing standard IT tool use e.g. SSH, Rsync..

Space Wire successfully implemented in-orbit increasing data downloads by 10

1st ever in-flight control of a satellite using EGS-CC

1st ever offensive Cyber Security demo on a live operational spacecraft (Thales)



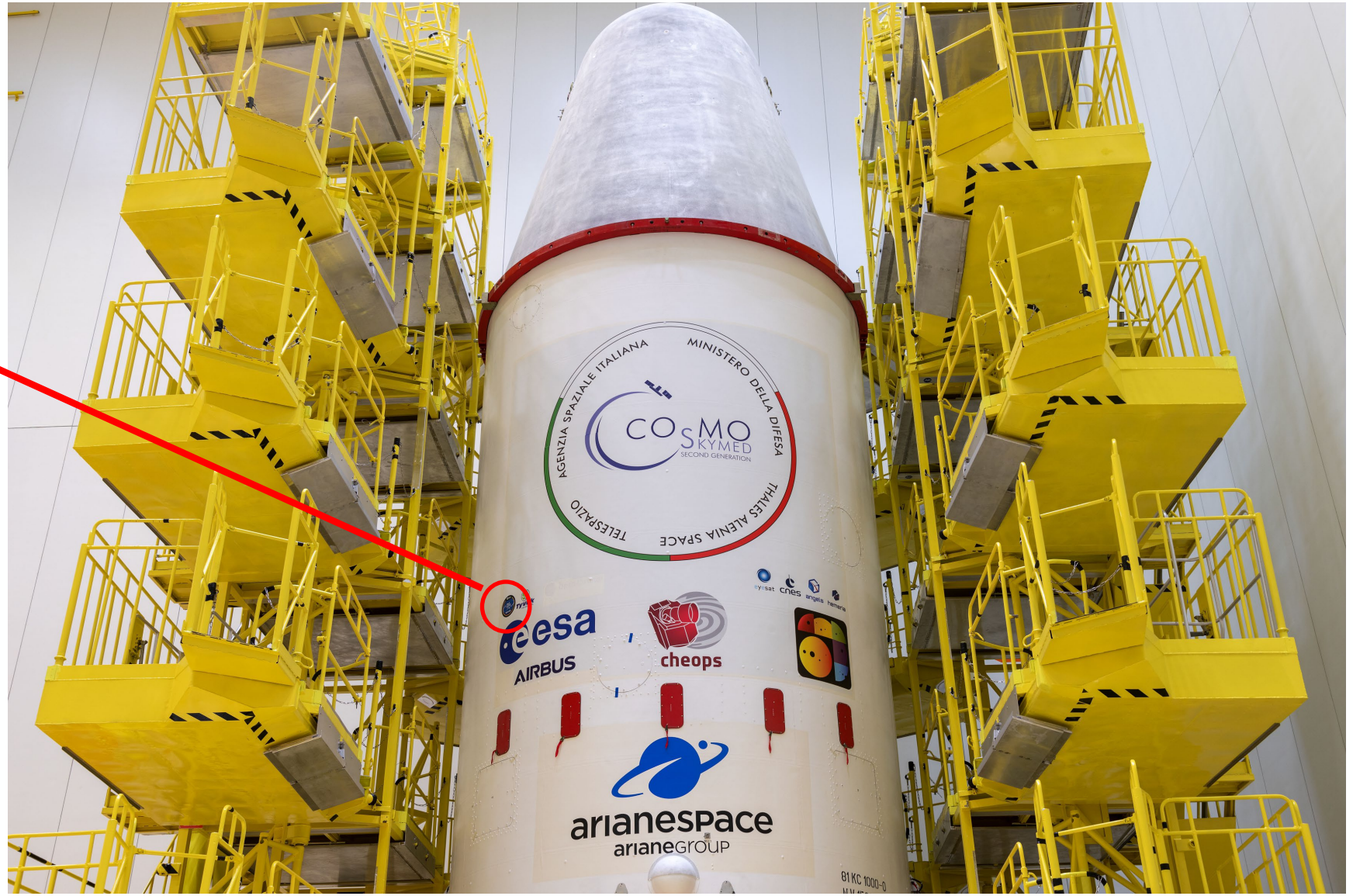
Fastest submission to results time was 72 hours

The inside story….. problems leading up to launch

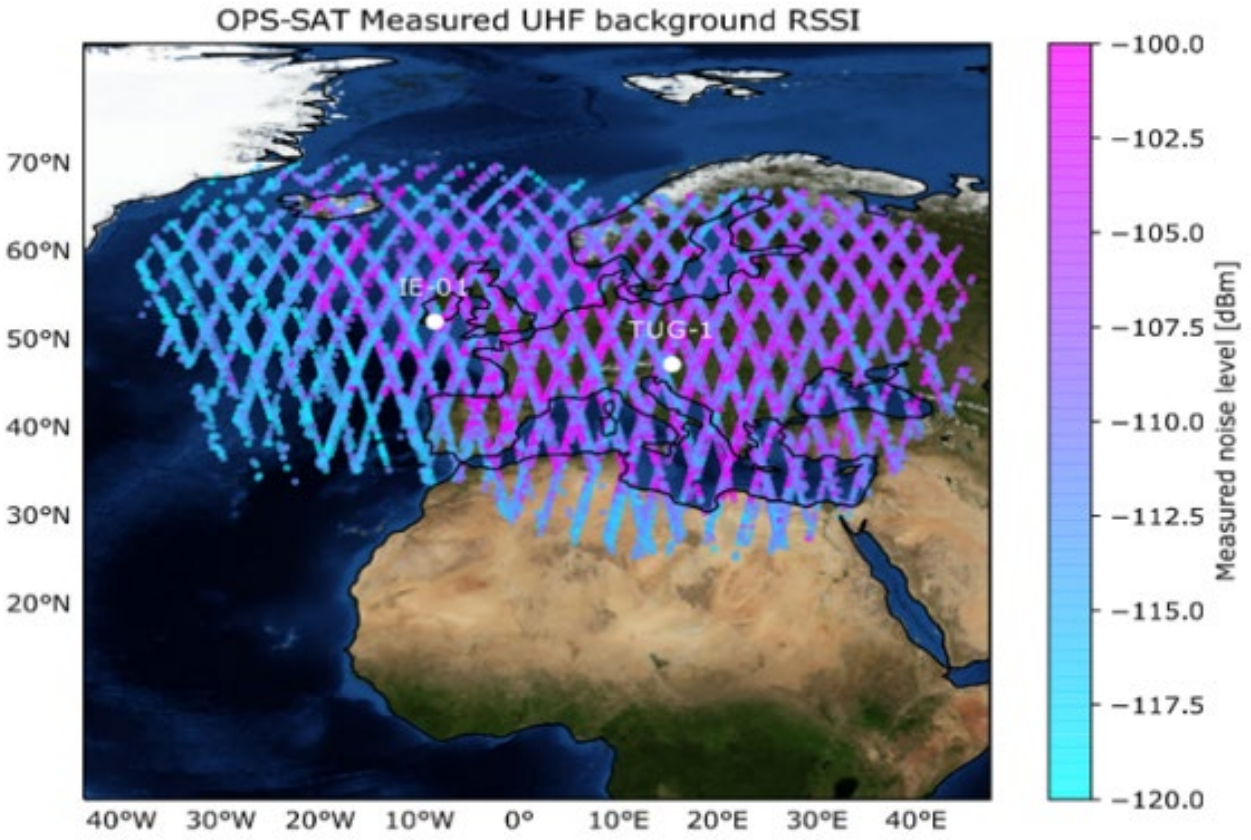
- GPS open field test fails
- SEPP-1 fails intermittently after TVAC
- Ops budget cut by 33%
- Does not fit in the deployer

The launch

OPS-SAT Logo!



LEOP



x 10 increase in S band RX noise when TX ON

x 4 loss of loss of uplink power SSPA failure

x 40 loss in signal to noise ratio for commanding

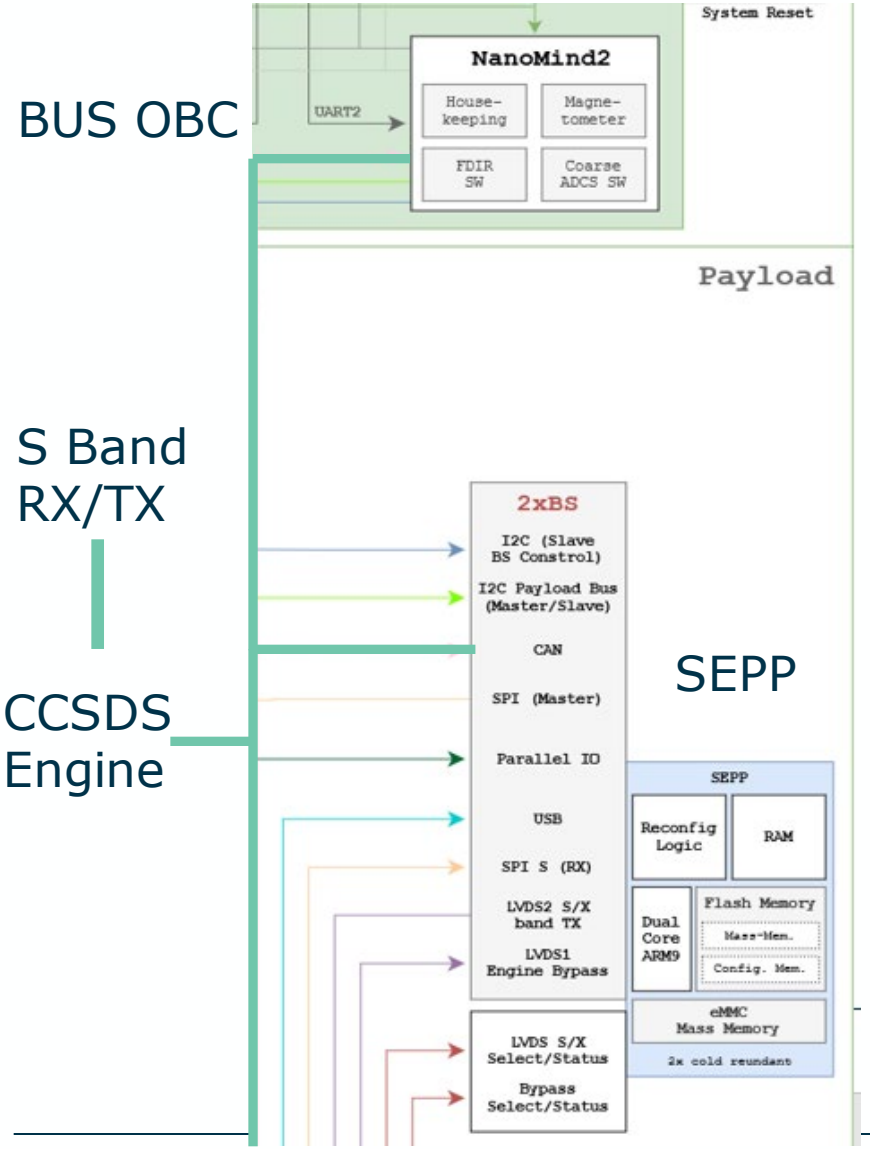
COVID arrived and the world stopped. Our ground station was not repaired for nine months

Other problems:

UHF communication noise floor unexpectedly high

Not a single ADCS mode working correctly

Spoofing the OBC



Updating the OBSW required 5000 commands each of which has to arrive otherwise you have to start again,

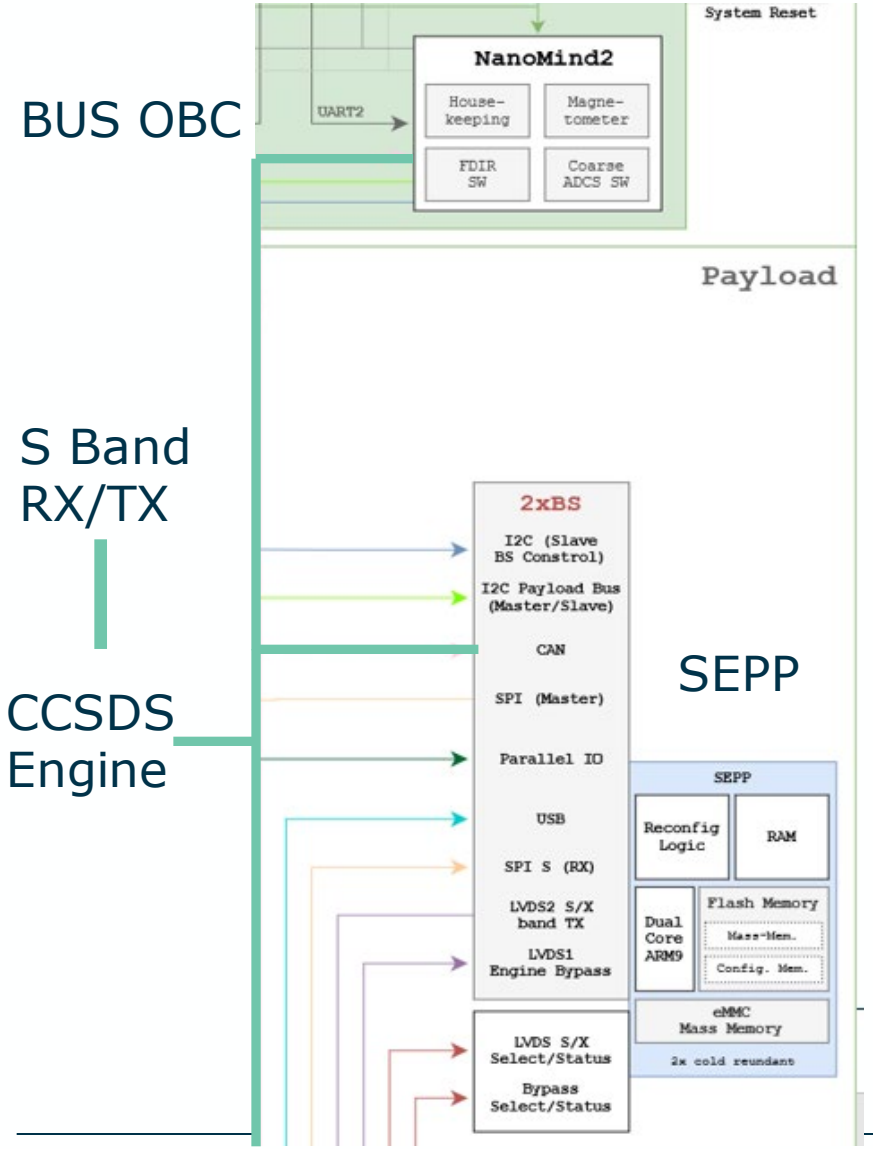
How could we do this with two minutes of commanding per day and it was completely unpredictable when it might occur?

SOLUTION:

- When commanding is available load a compressed file to the SEPP that contains all the space packets needed for the OBSW load
- Spoof the Bus OBC into thinking the SEPP is the ground and send them slowly out of ground coverage
- Apply an ACK/NAK protocol on-board so the SEPP is sure every command has arrived before it sends the next one

OBSW update went from one week to 90 minutes

Misusing the CAN bus



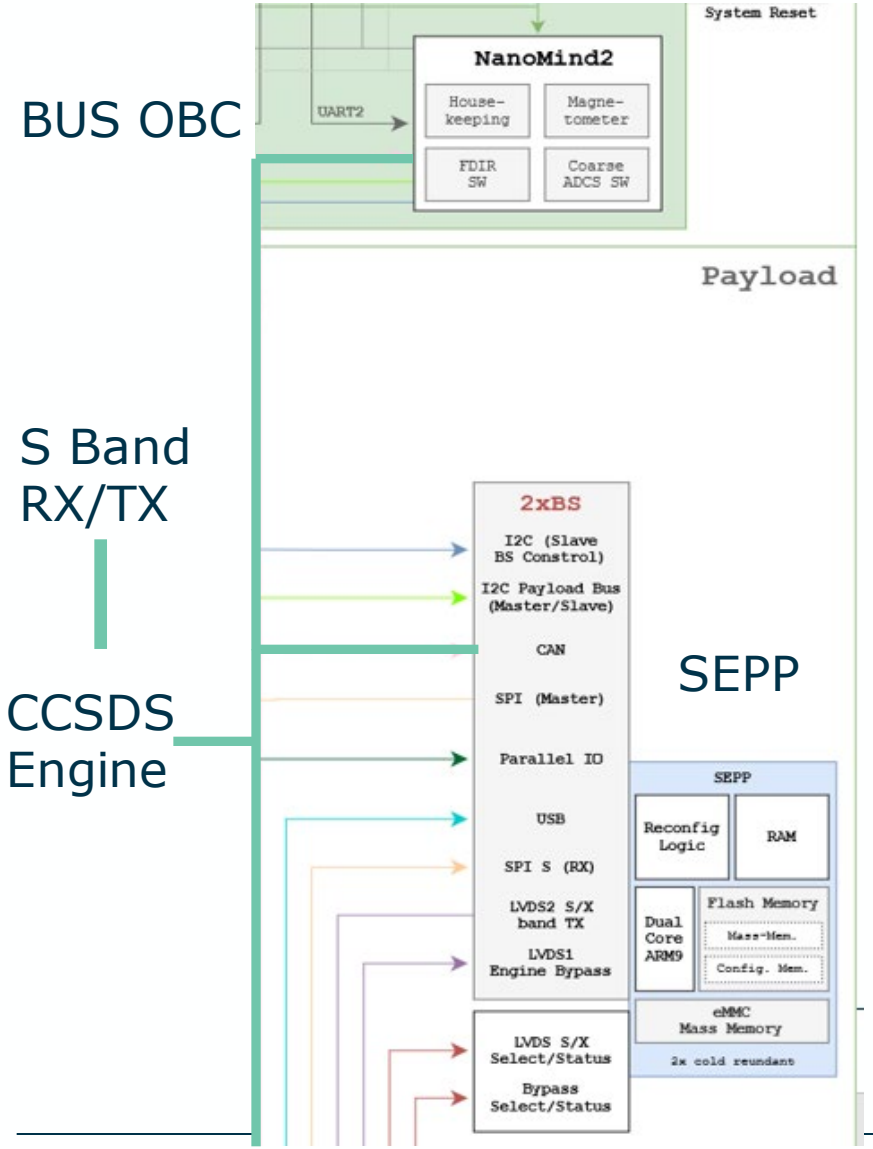
What getting high quality housekeeping in such conditions?

SOLUTION:

- Send TM to the CCSDS engine even when the TX is off
- Load a SEPP application to sniff the CAN bus and collect the traffic
- Filter for the HKTM packets, collect in a file and compress
- Whenever commanding becomes available downlink the small files using CFDP

10x increase in TM volume compared to ideal nominal case

Performing an offline commissioning



What running all the payload commissioning procedures?

SOLUTION:

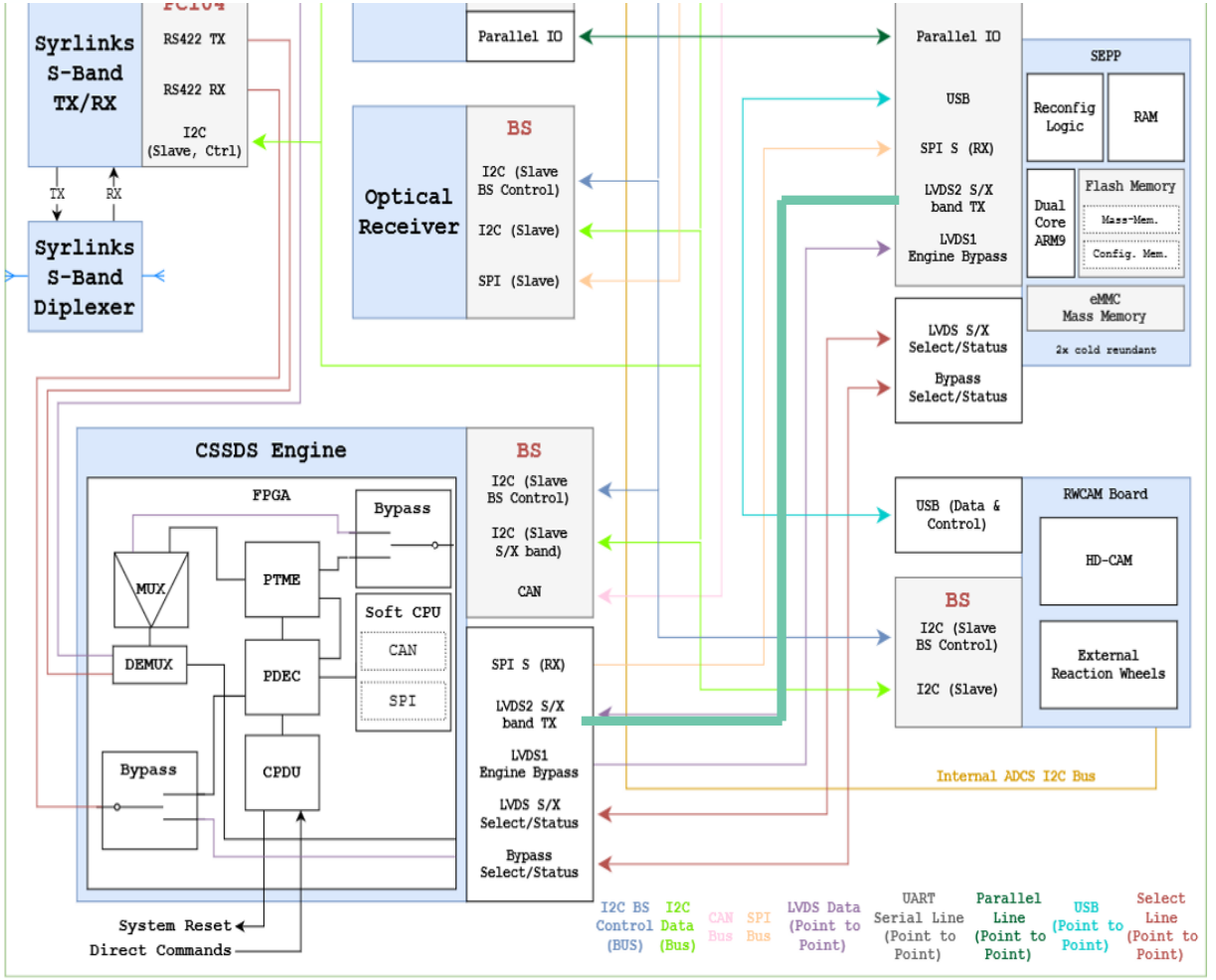
- All the commissioning procedures were converted to scripts with associated logs
- These scripts could be triggered by the TTQ
- The logs would be compressed and downloaded by CFDP, analysed and the scripts adjusted if necessary

90% of the commissioning procedures were completed before we got the ground station repaired

4 weeks later the OPS-SAT Space Lab service was open for business

Implementing a new data bus… in orbit

CAN was OK for normal control but far too slow for the massive amount of data the camera could produce taking pictures and videos. We needed a faster on-board bus.



Spacewire Lite implemented on the LVDS interface on the CCSDS engine side only. Then fused..

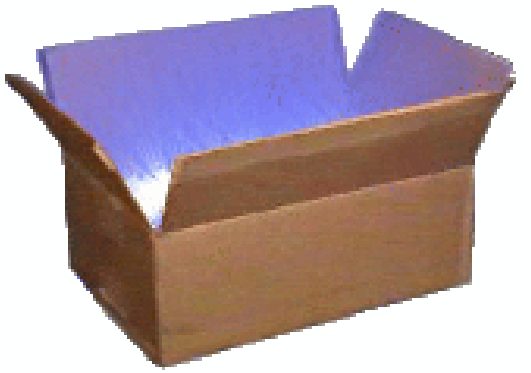
Loop back tested with the SEPP i.e. works up to the handshake level but not data

In orbit Spacewire Lite was loaded to the SEPP FPGA but it did not work initially. Analysis showed the CCSDS engine was not sending the last byte of the forwarded space packets.

After a while we found a workaround and increased the effective end to end data rate by factor of six

Moving to IP

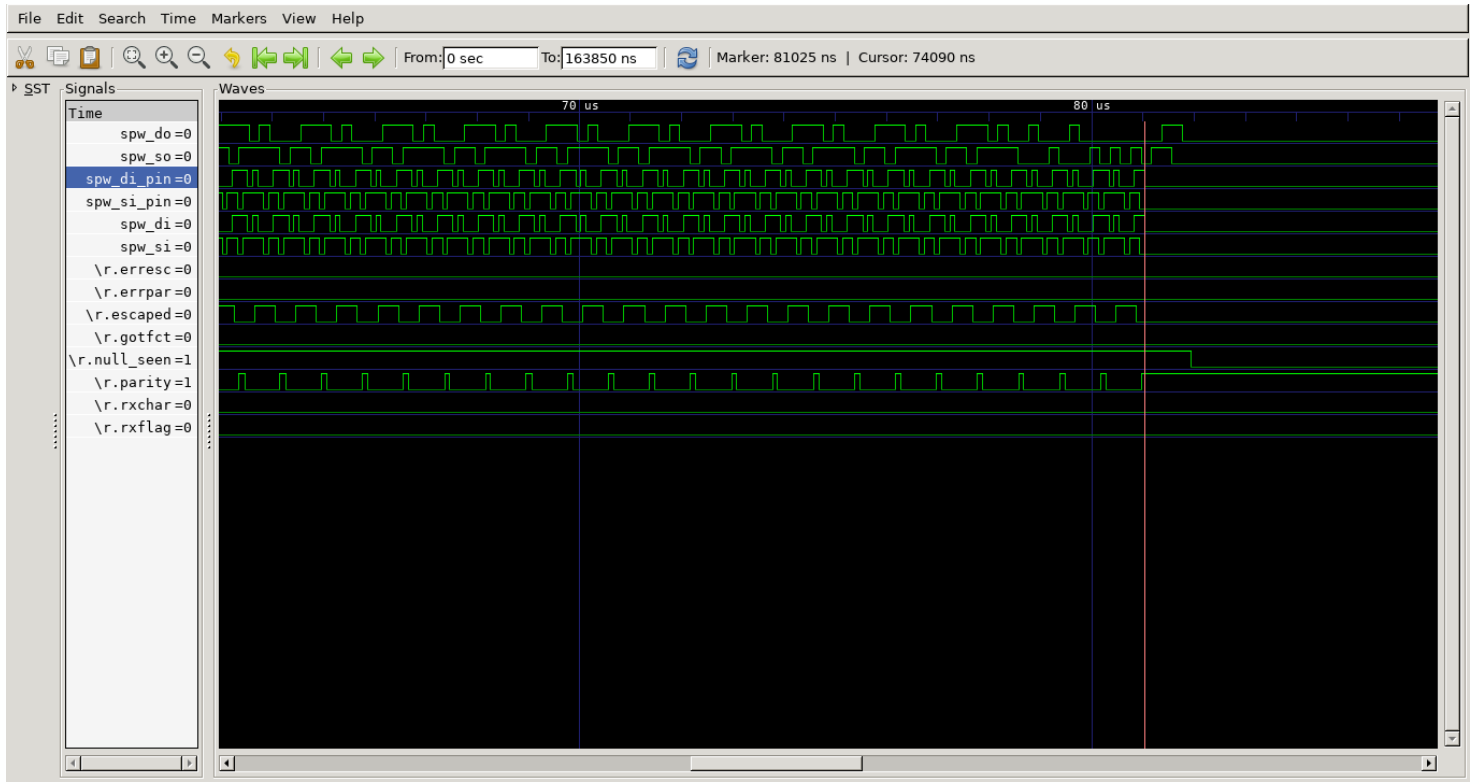
- With SpW implemented it allowed MTUs that were large enough to allow IP over CCSDS space packets to be sent
- So we added a thin IP layer when selecting the SpW interface and everything changed



We love Busybox

- As the SEPP is running Linux and suddenly many of the native Linux services became available out of the box e.g. Rsync, SSH, remote kernel messages, demons, http and everything in Busybox!
- This allowed the mission control team to increase the productivity of the mission by an order of magnitude with very little effort. Functions that previously would have to written by us, tested and then loaded to the spacecraft became “one-liners”
- The experimenters also benefited from this – allowing many new types of concepts to be easily tried out in space

Exploiting the FPGA for failure analysis



Sometimes the SpW interface failed and we had to fall back to CAN and no TCP/IP

However the power of having a reconfigurable FPGA again came to the rescue

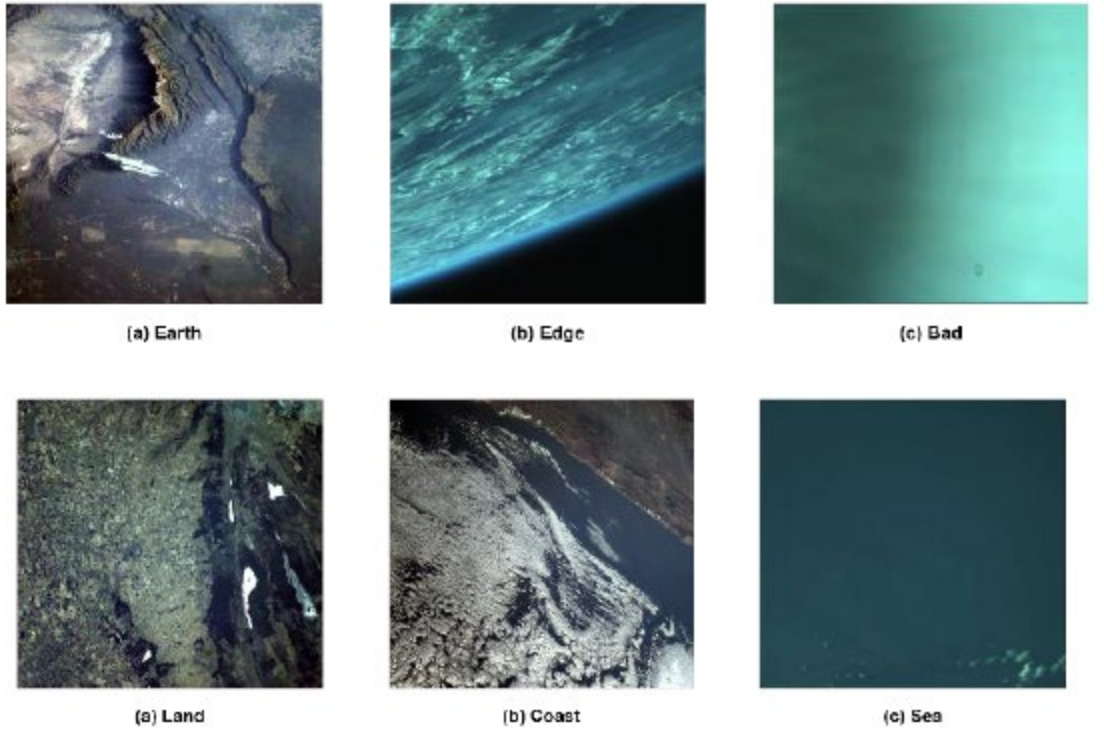
We loaded a logic analyser to the FPGA fabric and were able to carry out low level tests as if the spacecraft was in the lab

We have been able to perform tests on the link in-orbit that are unthinkable on a traditional space mission

- The logic analyser recorded the voltage levels on the SEPP pins
- Delaying the strobe and/or the data lines and sweeping +/- 300 nanoseconds to see what happens
- Inverting the lines
- Monitoring the statistics on the link up/down transitions, CRC errors, packets sent and received etc

Using AI operationally

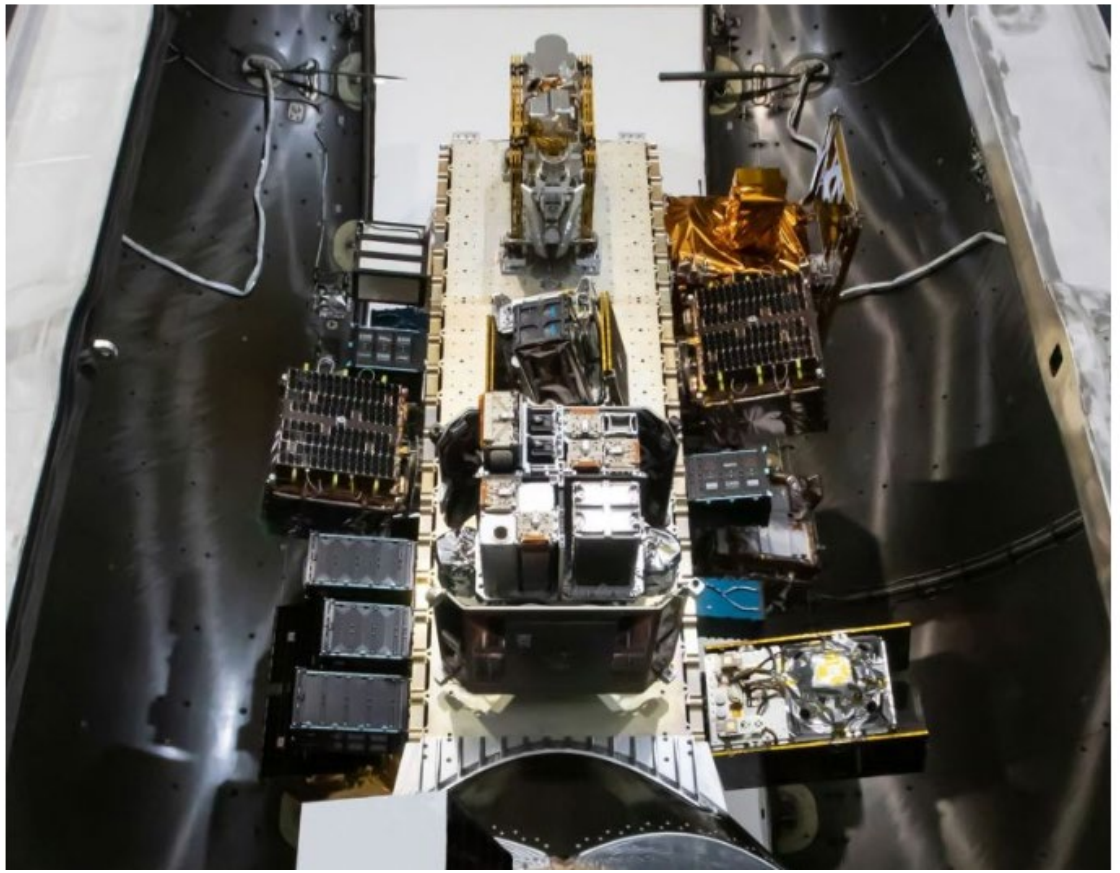
Georges Lebreche and SMART CAM



An example of industrial impact – the S band system

Ronan Foubert • 1st
Nanosat/Cubesat Product Owner chez SYRLINKS
1w • Edited •

Next Space-X Transporter-9 mission is scheduled for Saturday and there are more than 20 SYRLINKS Nano/CubeSat radios integrated in the several CubeSats, MicroSats, and orbital transfer vehicles 🔥



Most relevant

David Evans • You
Advanced Operations and OPS-SAT Space Lab Manager at Europeans Spa...
3d

Wonderful to see that first development for #OPSSAT eight years ago bearing so much fruit Ronan. Congratulations to you all!

Like · 2 | Reply · 1 Reply

Ronan Foubert Author
Nanosat/Cubesat Product Owner chez SYRLINKS
3d

Thank you David ! OPSSAT means so much for us. It's so rewarding to see what this project has achieved so far, and it's just the beginning !

A 50K Software Defined Radio steals the show

Feature Article:

DOI. No. 10.1109/MAES.2022.3143875

Implementation of a GNU Radio-Based Search and Rescue Receiver on ESA's OPS-SAT Space Lab

Tom Mladenov, David Evans, **European Space Operations Centre (ESOC), 64293 Darmstadt, Germany**
Vladimir Zelenevskiy, **Telespazio Germany GmbH, 64293 Darmstadt, Germany**

INTRODUCTION

Software-defined radio (SDR) is already widely adopted in ground applications and currently present in many consumer devices such as mobile transceivers and car radios. Currently, also in aerospace applications, SDR is slowly

proposals for experiments on OPS-SAT, and get selected after which the development process begins [2]. The purpose of OPS-SAT is to break the "has not flown will not fly" boundary present in space operations. The spacecraft is illustrated in Figure 1.

The spacecraft bus, payloads, and structure are designed

Then an experimenter found it worked at GPS L1….
Then another reconfigured the interface in the FPGA to produce a streaming interface…

Cyber Security

The Bank

ENABLING & SUPPORT

A successful first stock trade in space, celebrated by ESA's Rolf Densing and CEO of flatexDEGIRO, Frank Niehage

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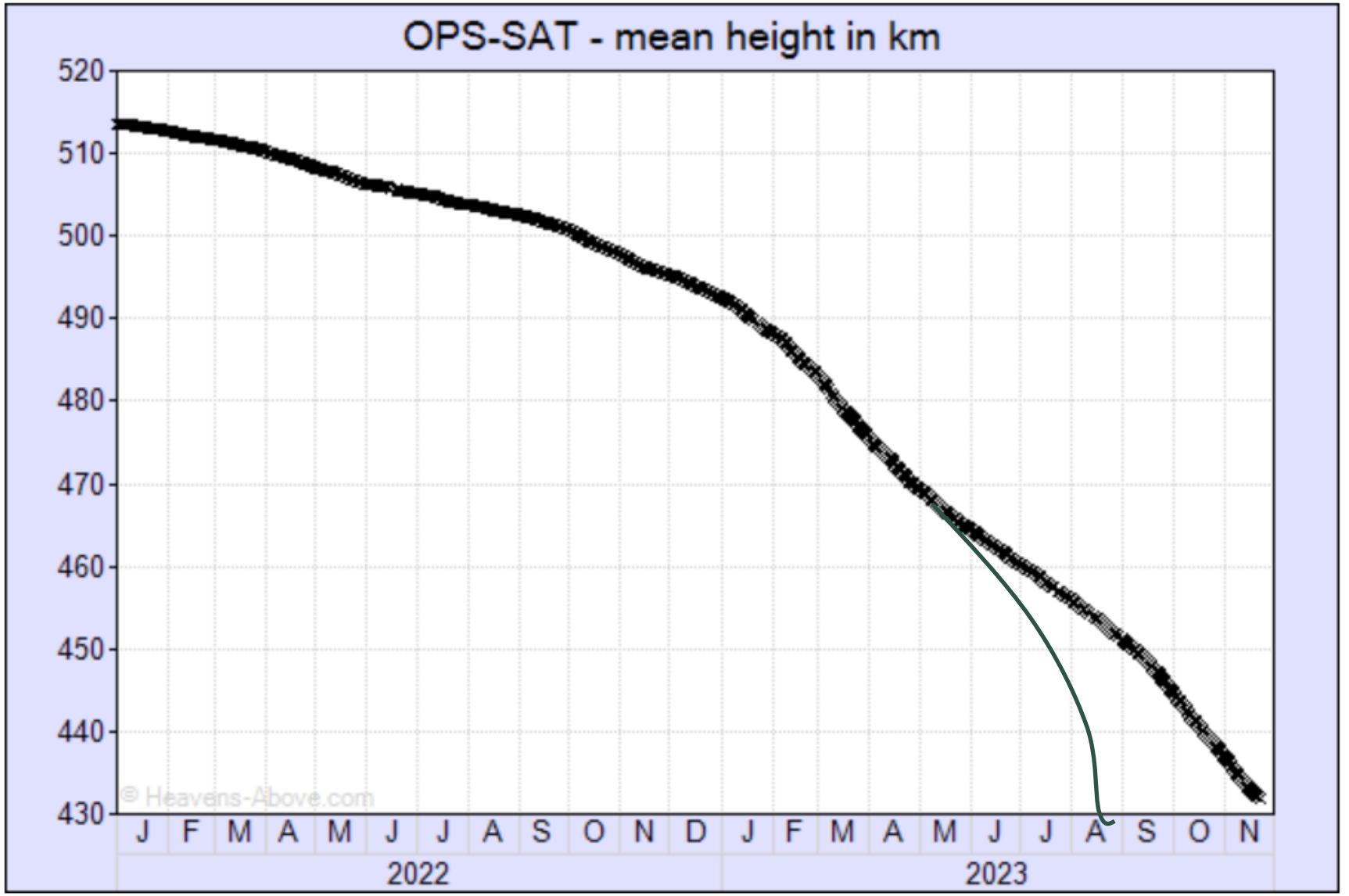
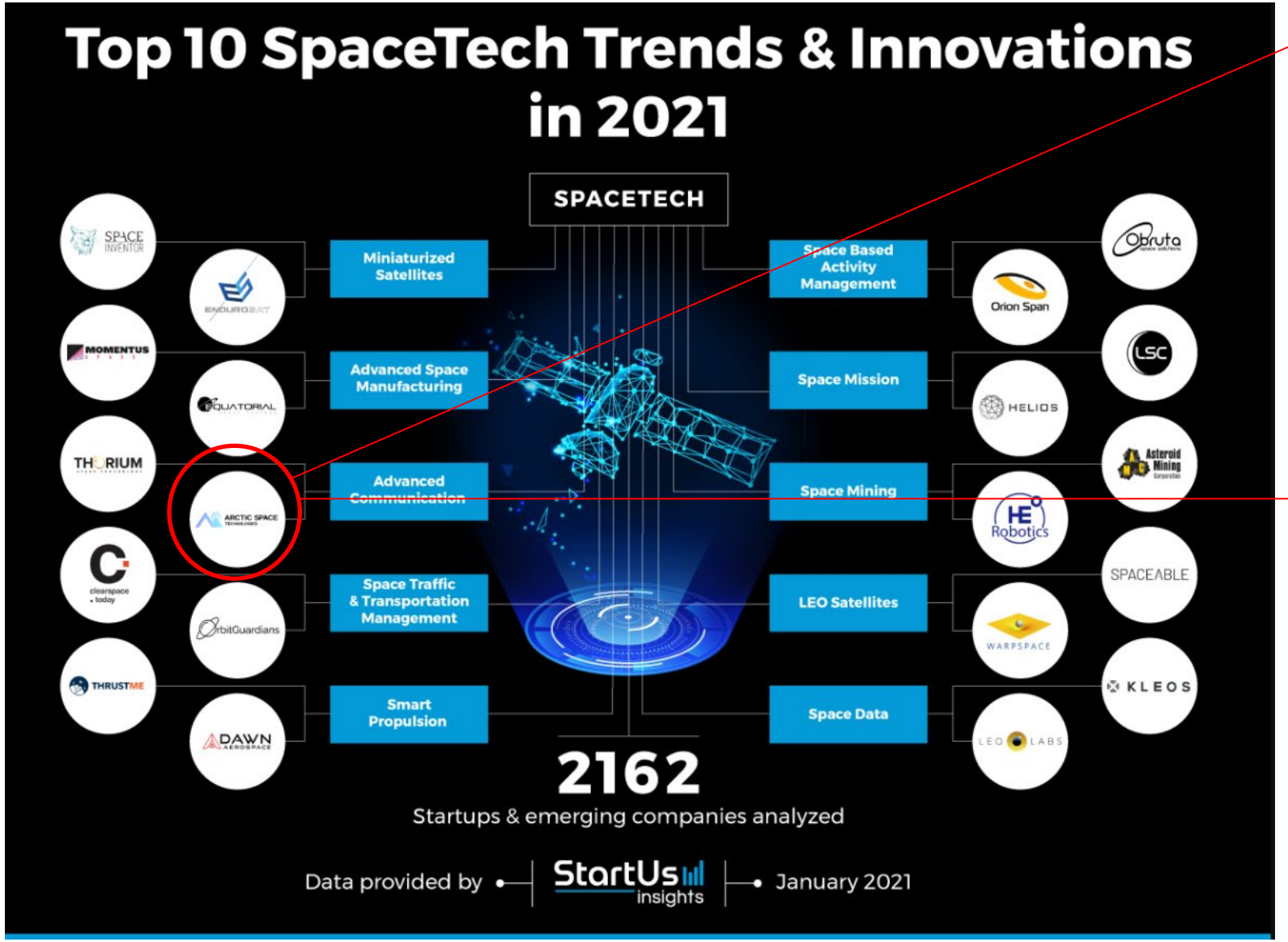
SpaceOps 2023

Keeping the mission alive





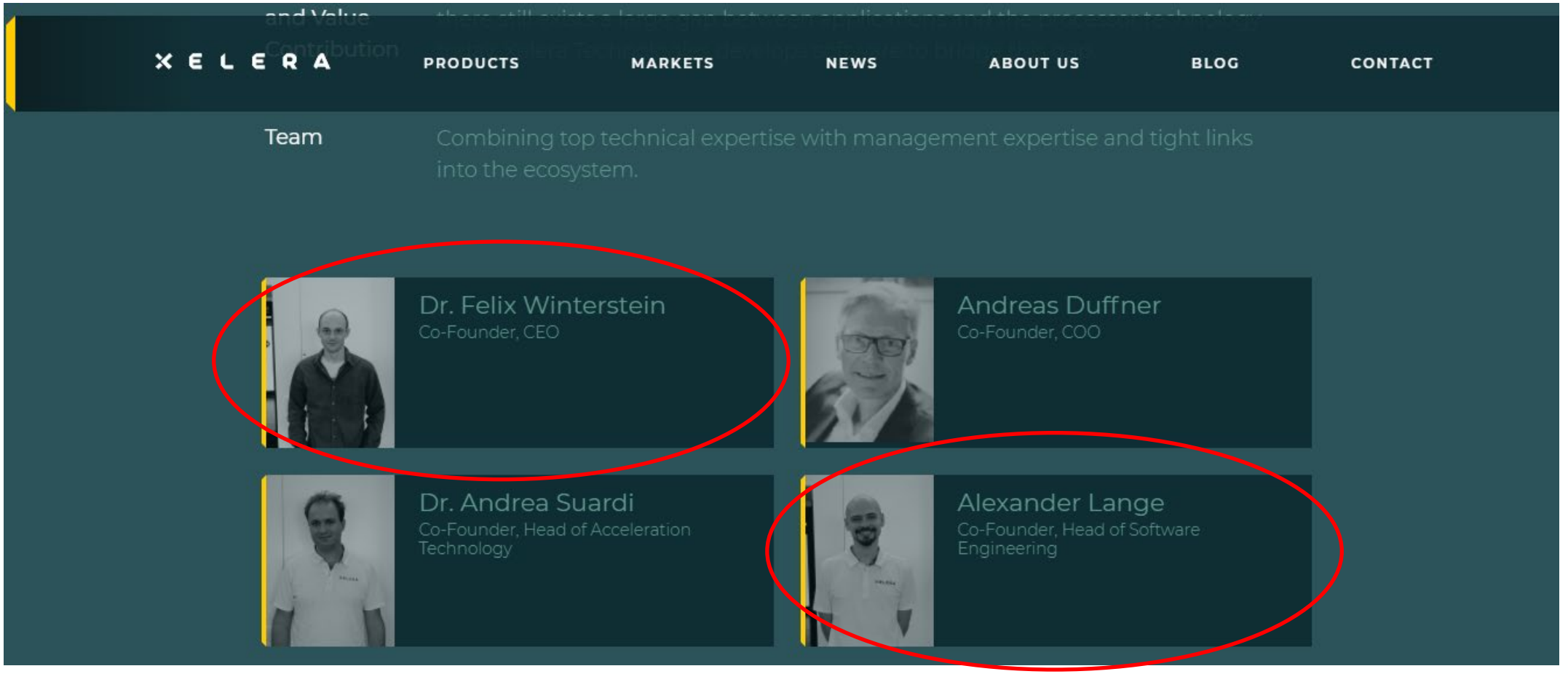
Benjamin Fischer OPS-SAT YGT
Sept 18 – Aug 18

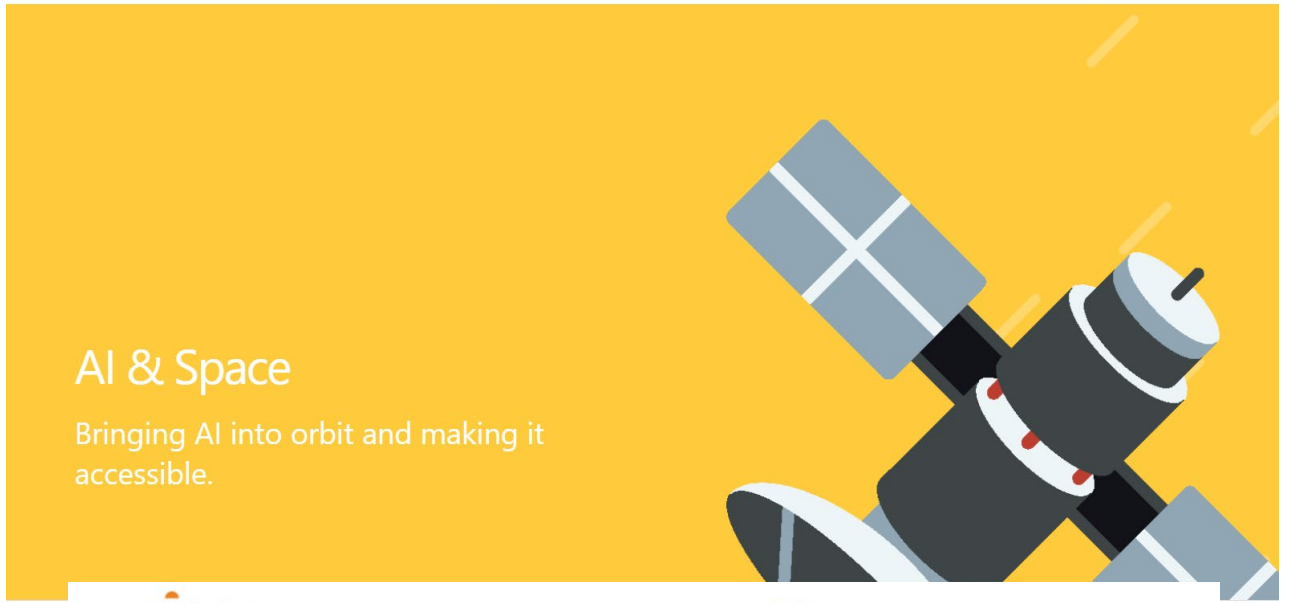
CEO and Co-Founder at Arctic Space Technologies, Sweden
Advanced communications, data compression, teleport services

Felix Hessinger OPS-SAT Intern
Jan 19 - Aug 19

Co-Founder & CTO at Arctic Space Technologies, Sweden
Advanced communications, data compression, teleport services

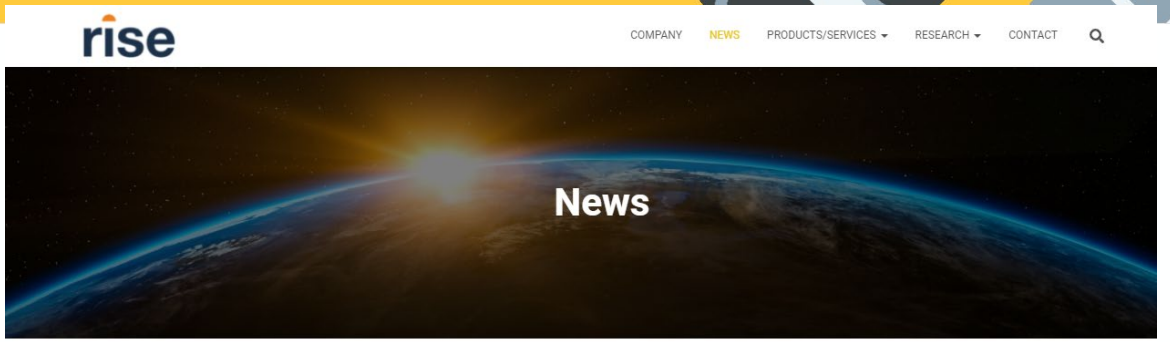
Co-Founder and Head of Software Engineering
Xelera Technologies, Germany
Data Processing Acceleration using FPGAs (Alex was first exposed to FPGAs on OPS-SAT)

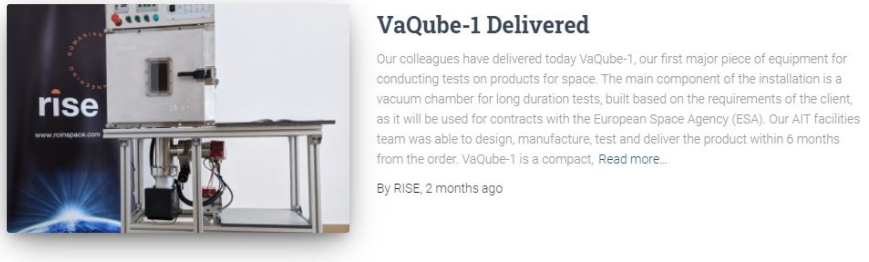




Georges LaBreche OPS-SAT Intern Sept 20 – Jan 21

CEO and Founder at Tanagra Space, Estonia
AI & Space specialists
Georges was instrumental in loading and experimenting with the AI infrastructure on-board OPS-SAT-1





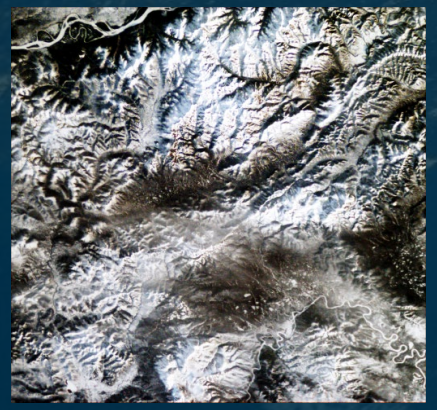
Claudiu Cherciu OPS-SAT YGT Sep 16 – Aug 18

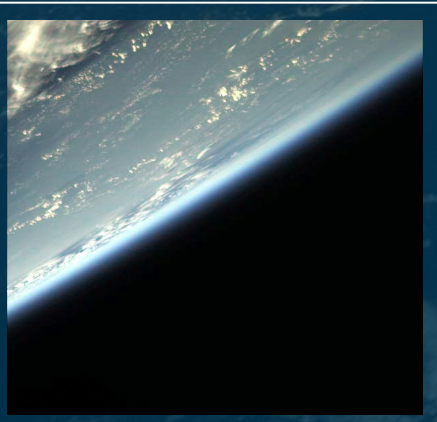
After YGT joined 1 year old start up (as first employee after founders)
Romanian InSpace Engineering (RISE), Romania

OPS-SAT the next generation…

More OPS-SAT spacecraft in the pipeline…..

Thank you!





David.Evans@esa.int