Claim Space, the Libre Way, using SDRs

FOSDEM 2018

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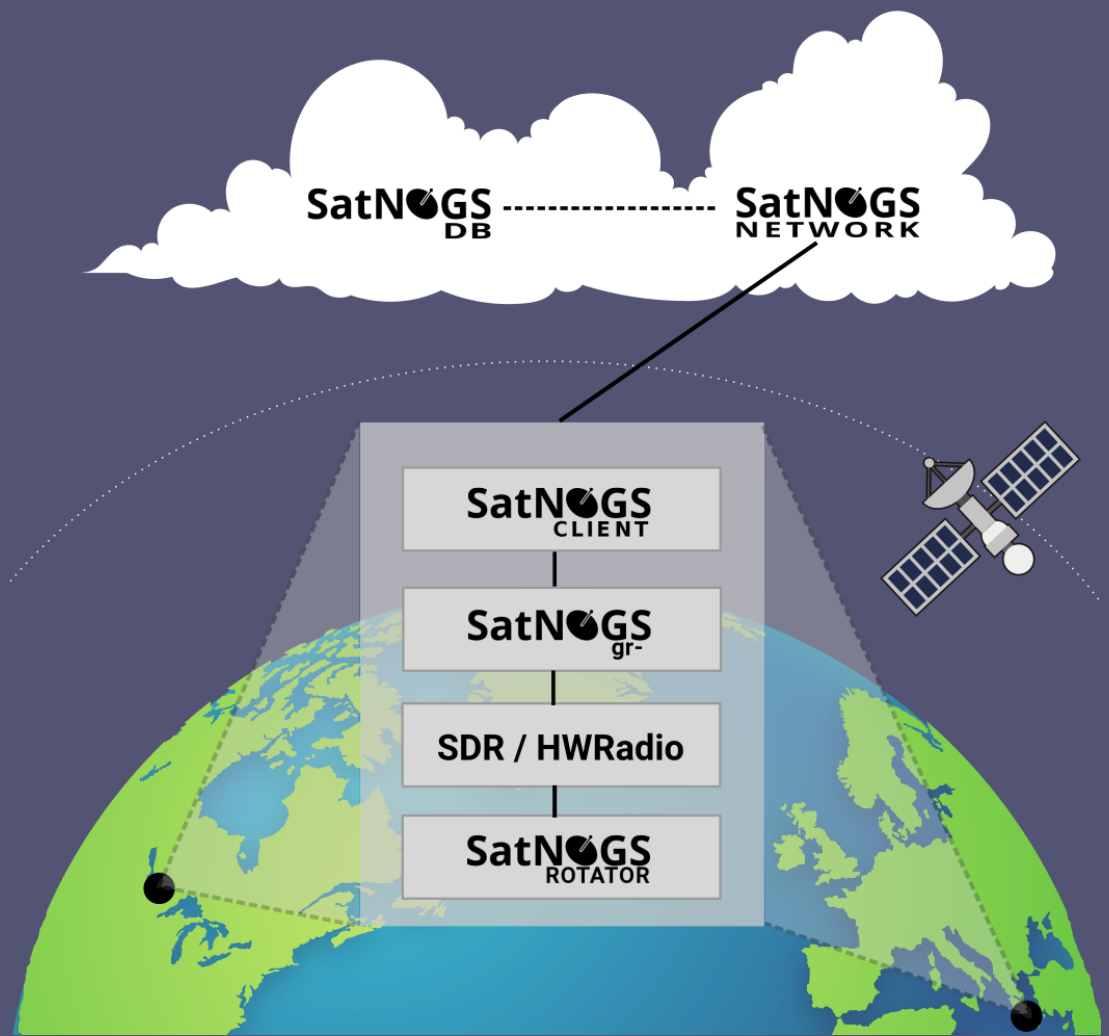
SatNOGS

Introduction

SatNOGS in a nutshell



SatNOGS in a nutshell

- Global network of ground stations
- Focus on receiving LEO satellite signals
- Open software **and** hardware
- Costs about 300 to 500 USD
- SDR enabled RF front-end for maximum flexibility

SatNOGS in a nutshell

SatNOGS in a nutshell

Existing Solutions

- Amateur radio operators use a set for different tools to decode a single satellite
- Most of them are closed sourced, with zero parameterization capabilities
- Time consuming process
- Observations can be performed only at the site of the operator

SatNOGS in a nutshell

SatNOGS SDR ground station

- Different RF SDR frontends (RTL-SDR, Airspy, HackRF, USRP)
- Operates without problems on RPi3 or equivalent host
- Crowd-sourced
- Web services for storing observation data and visualization

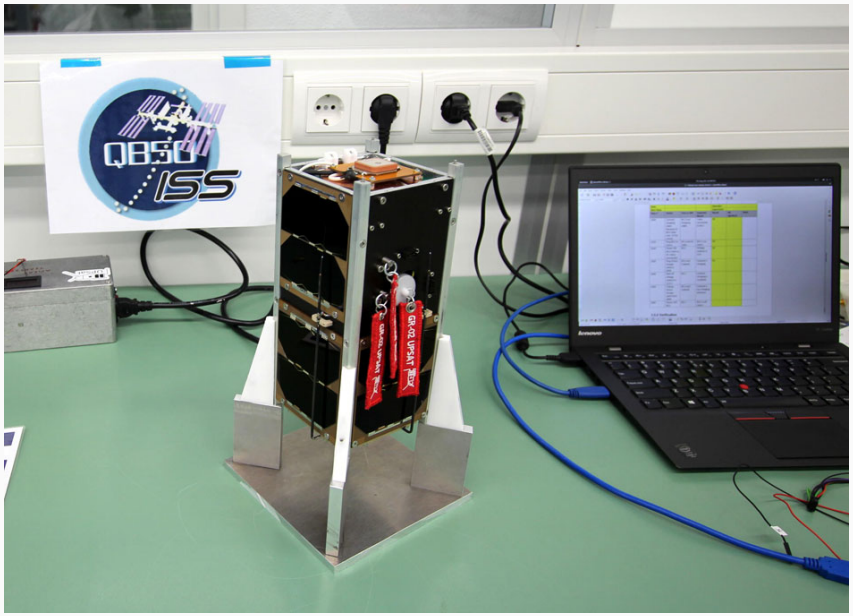
A very busy year!

- SatNOGS v3
  - Hardware and Software upgrades
  - New GNU-Radio decoders
  - Software optimizations for ARM-based boards (RPi3, Tinker etc)
- UPSat deployment from ISS
- Scale up of the network and web services infrastructure
- High power Rocketry!
- Open Source Cubesat Workshop 17

UPSat

UPSat

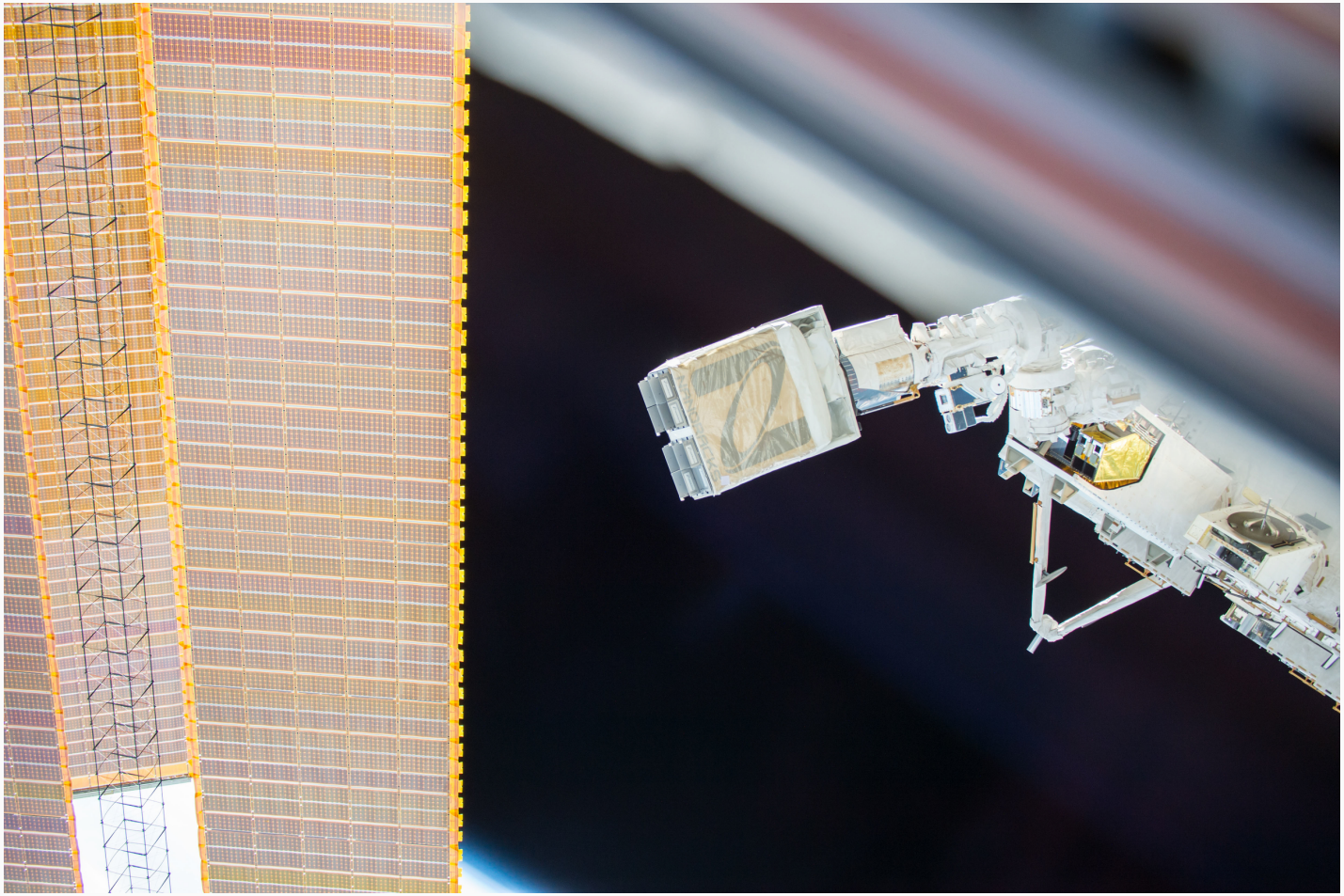
- First open-source hardware/software cubesat
- Part of the QB50 project
- Developed by the LibreSpace Foundation and the University of Patras



UPSat

- Launched on 18^{th} April 2017 on an Atlas V rocket

UPSat



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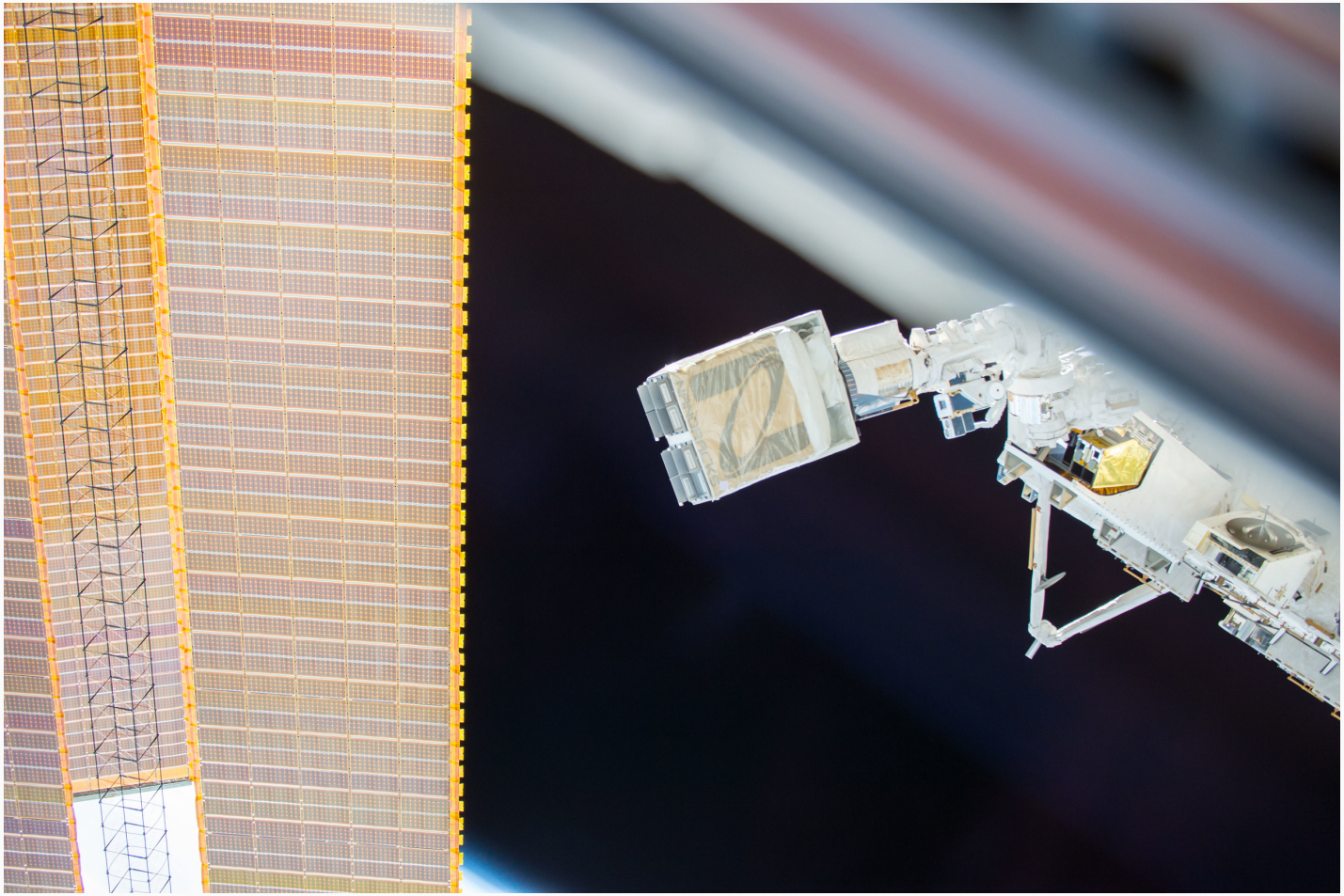

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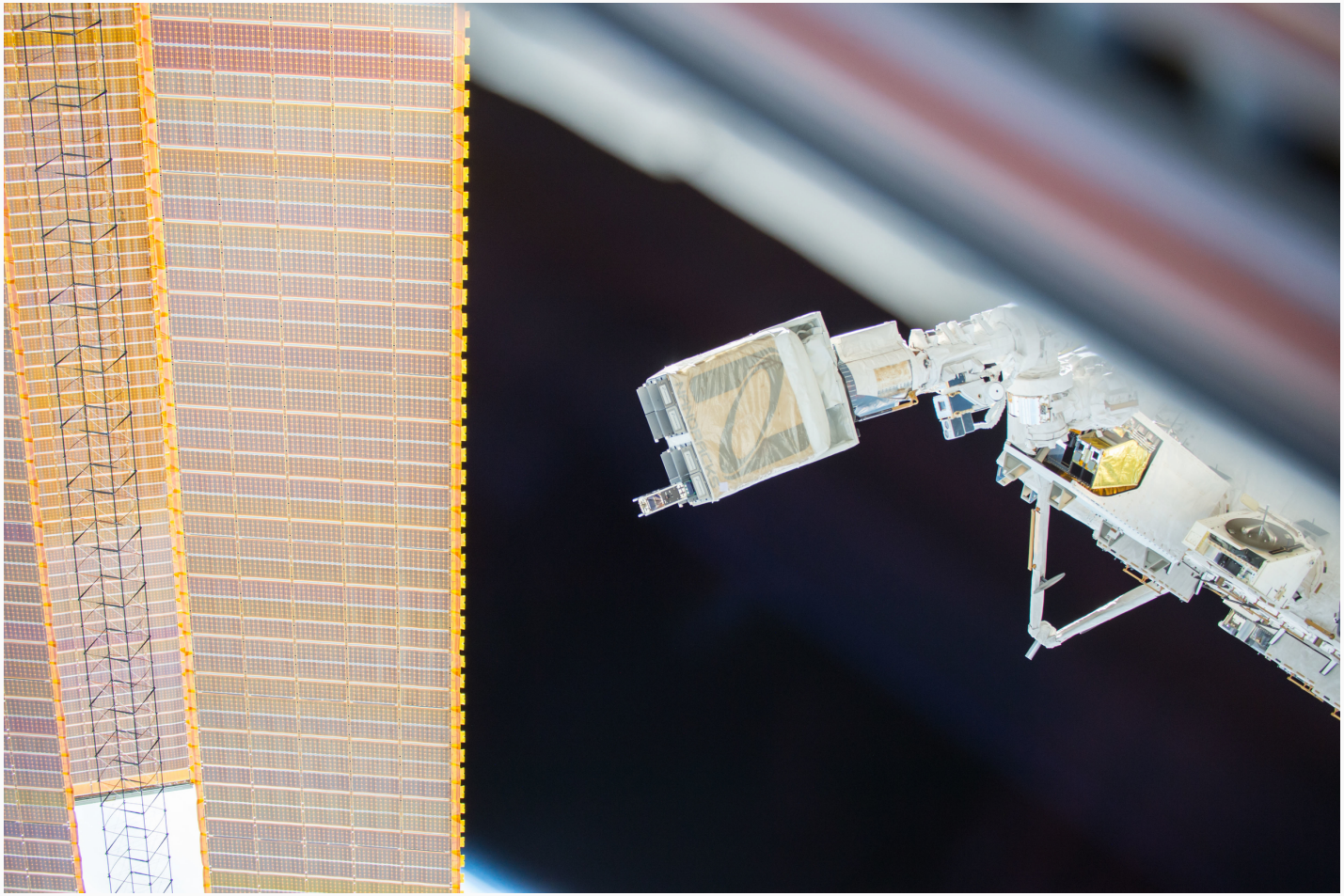

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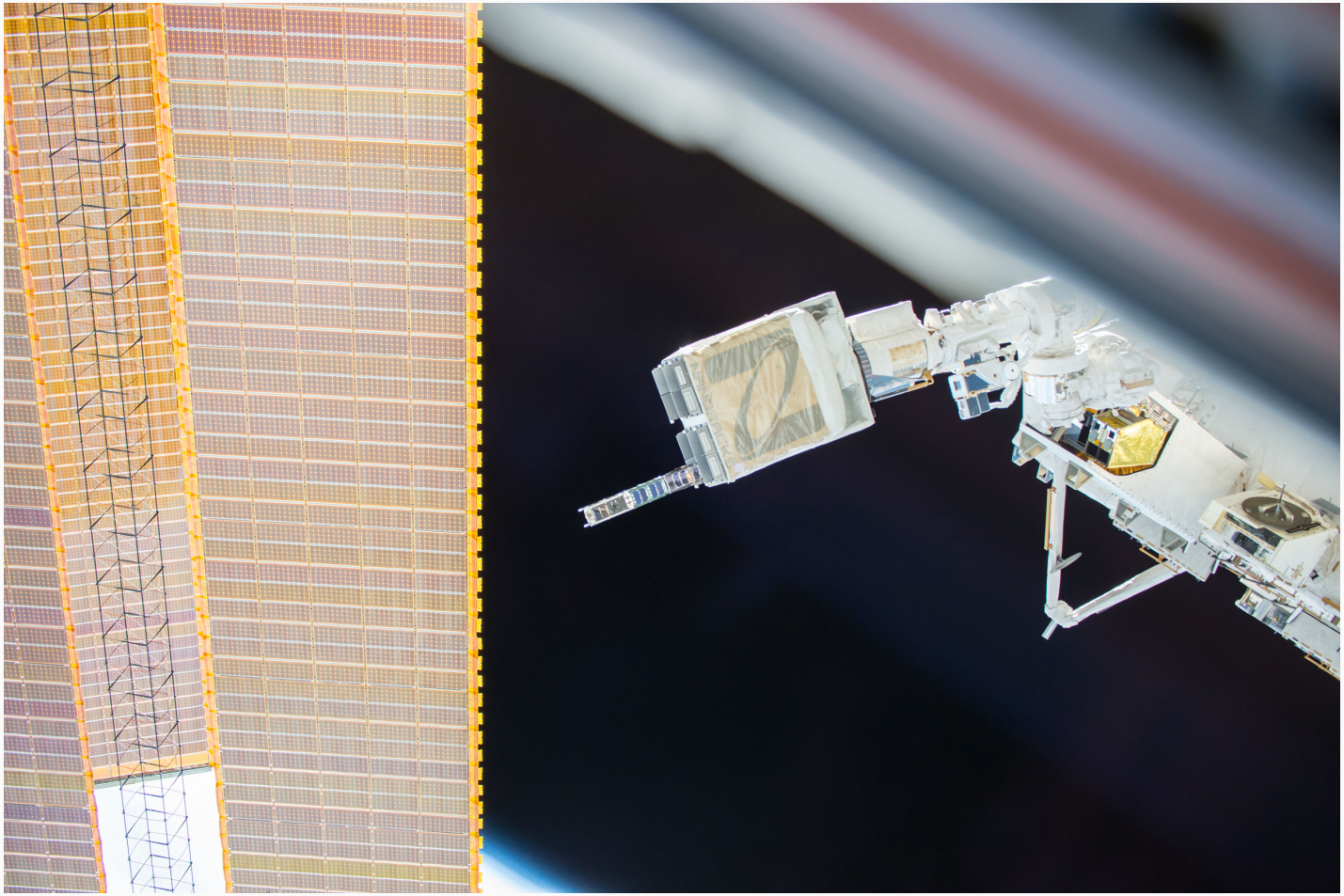

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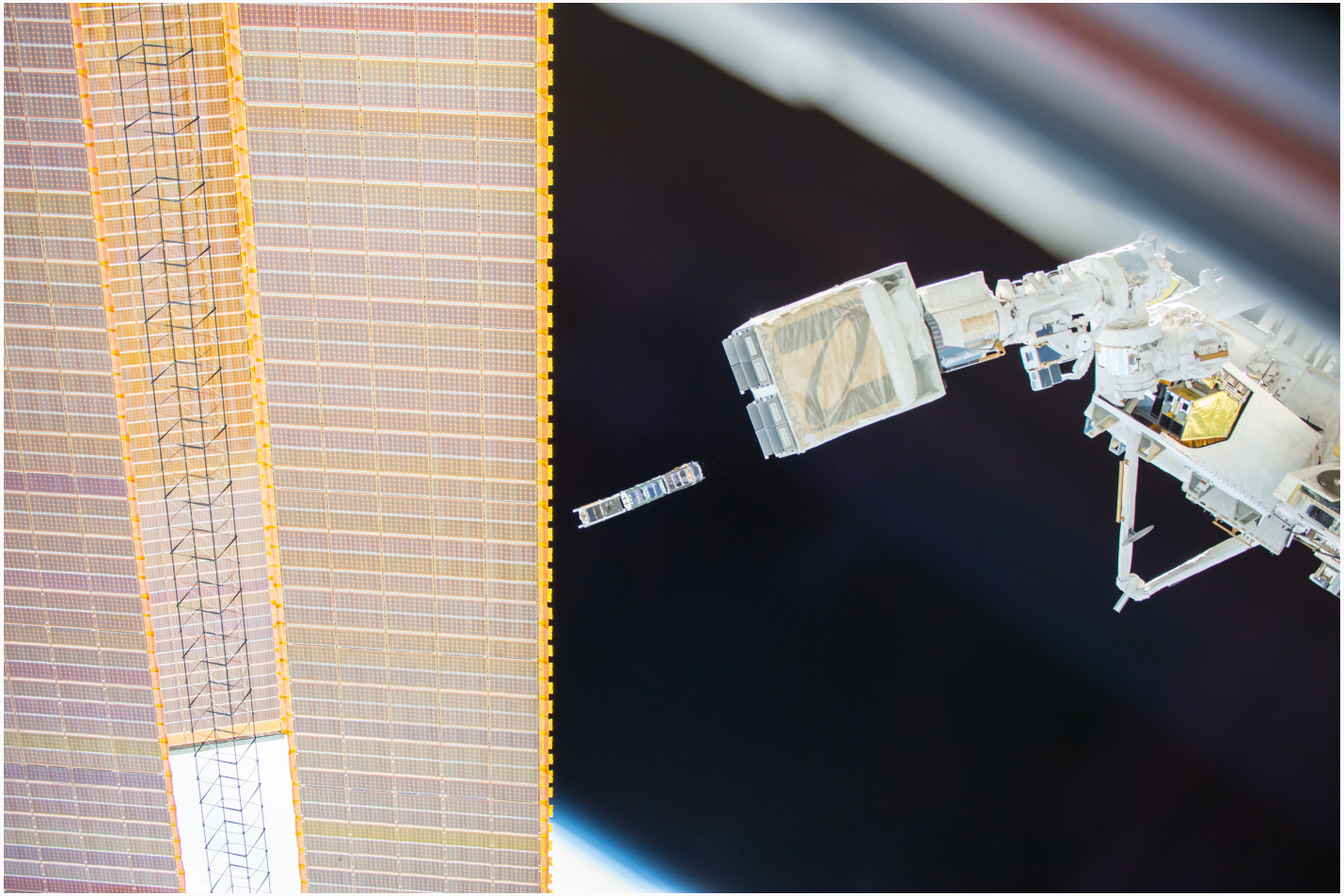

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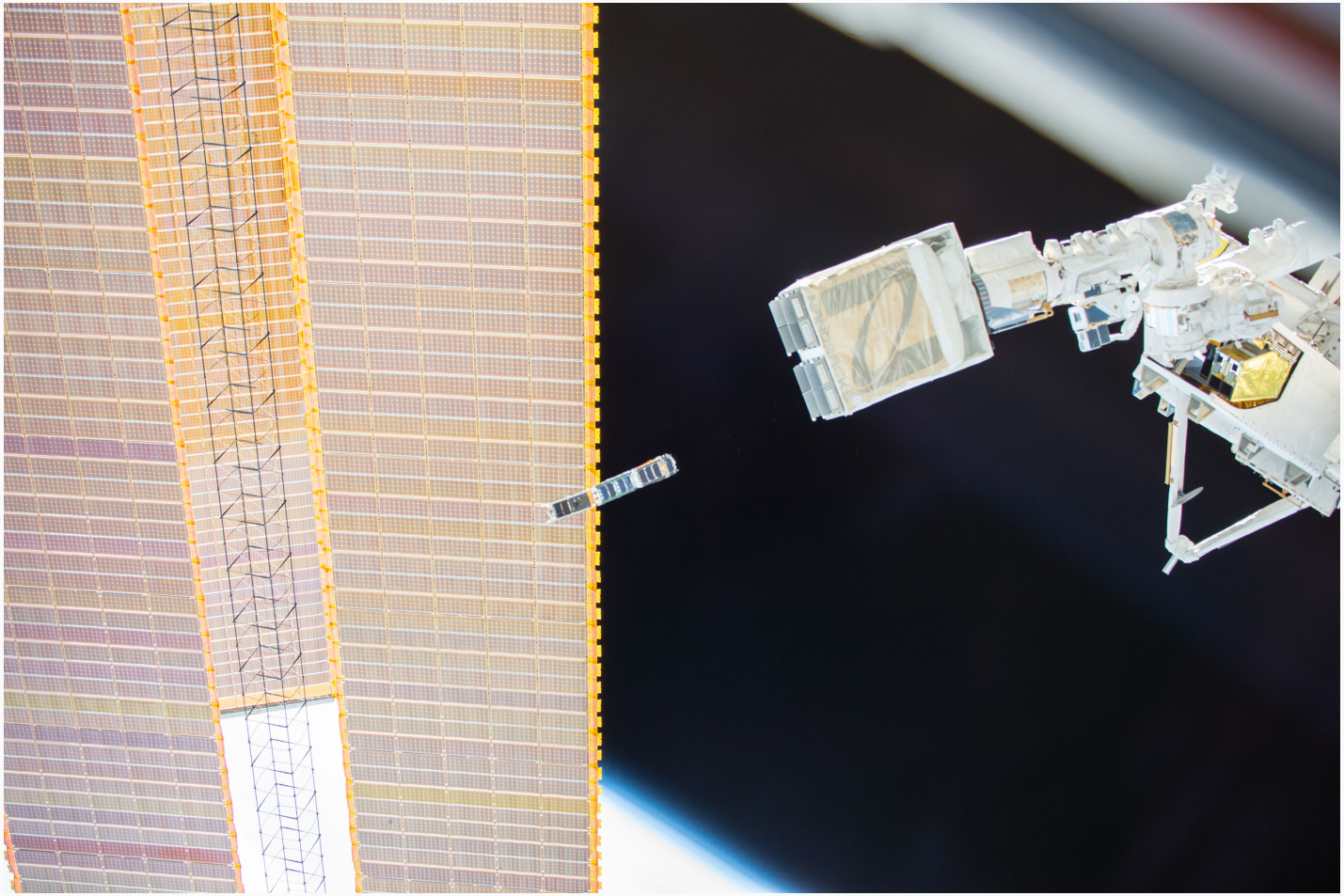

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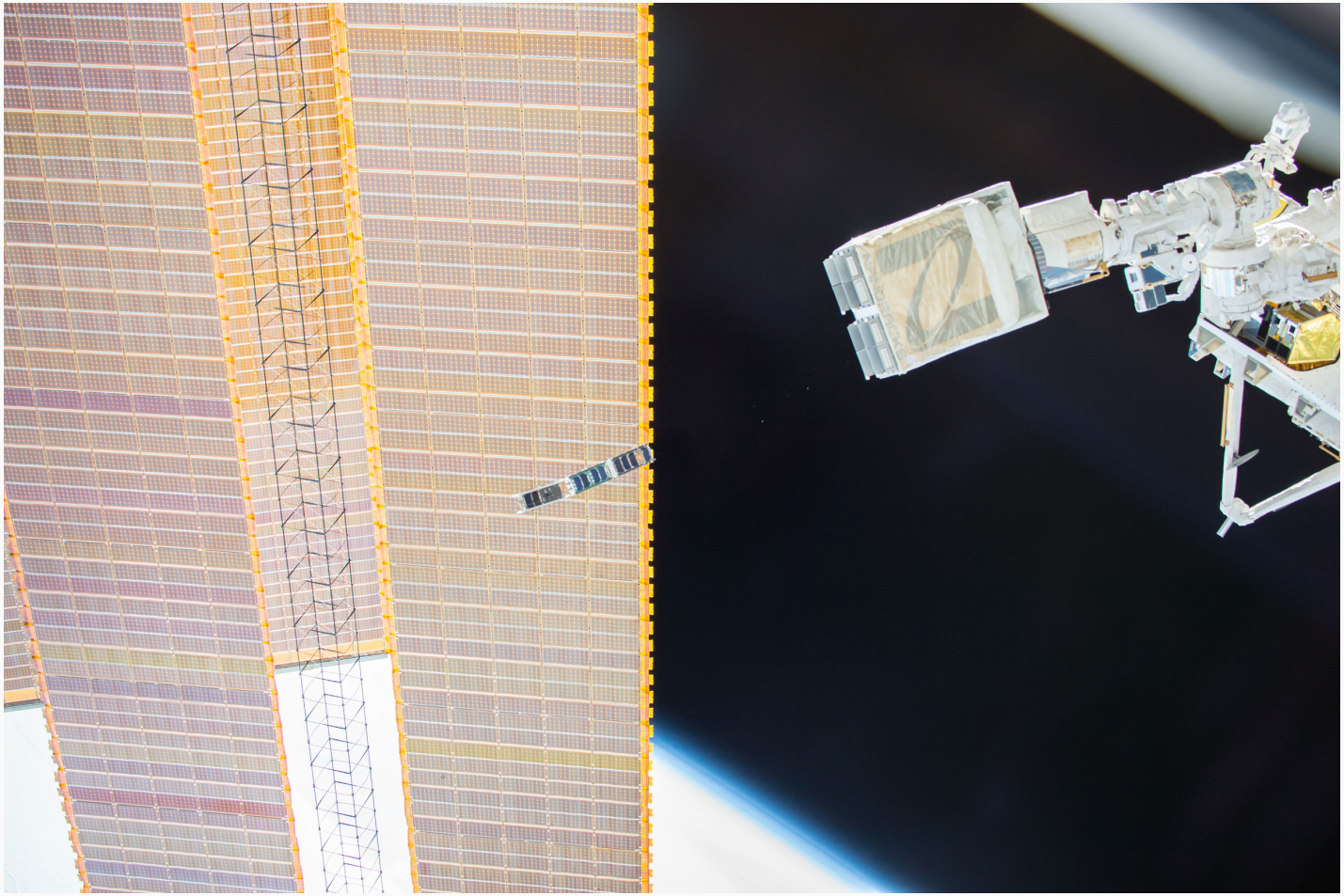

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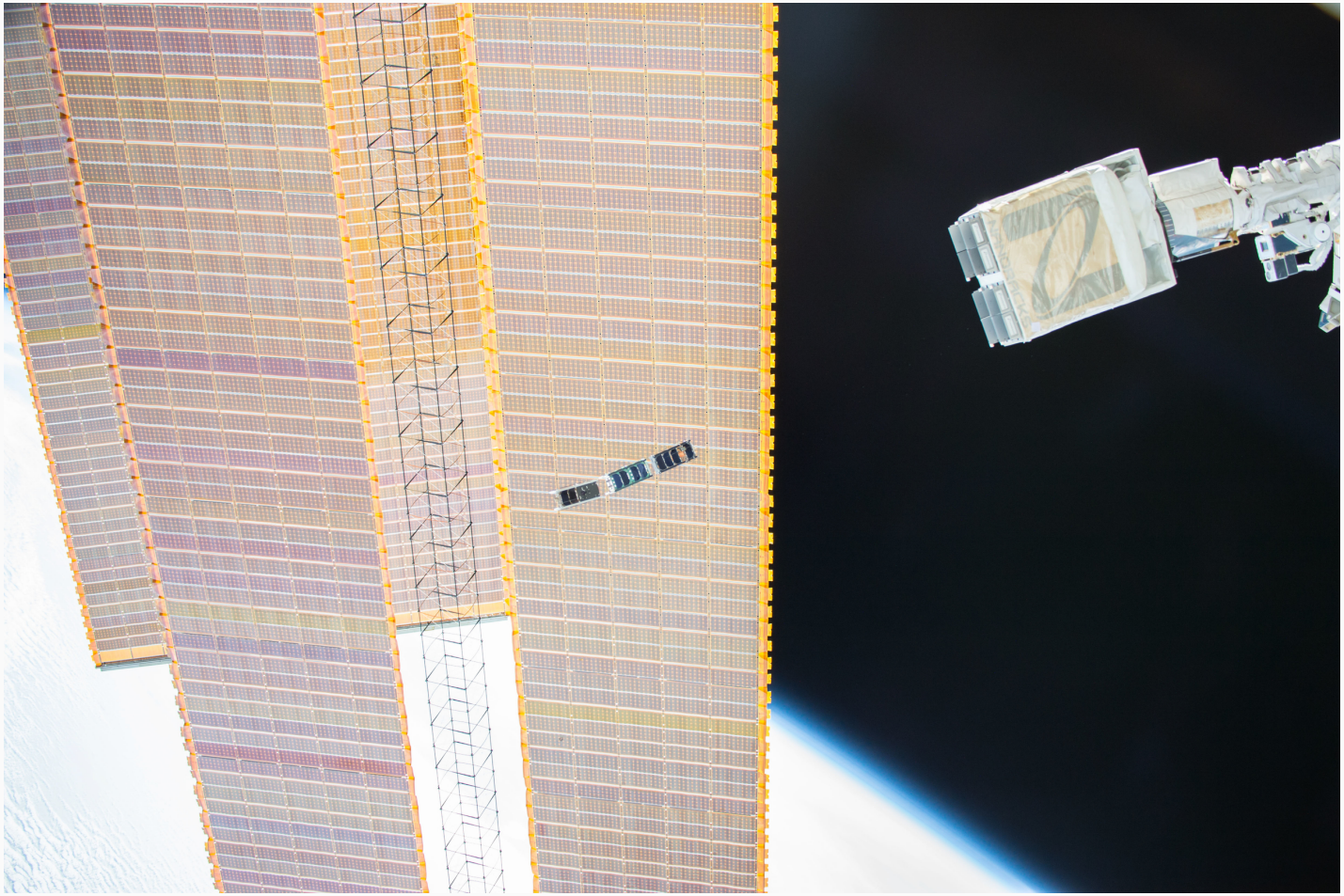

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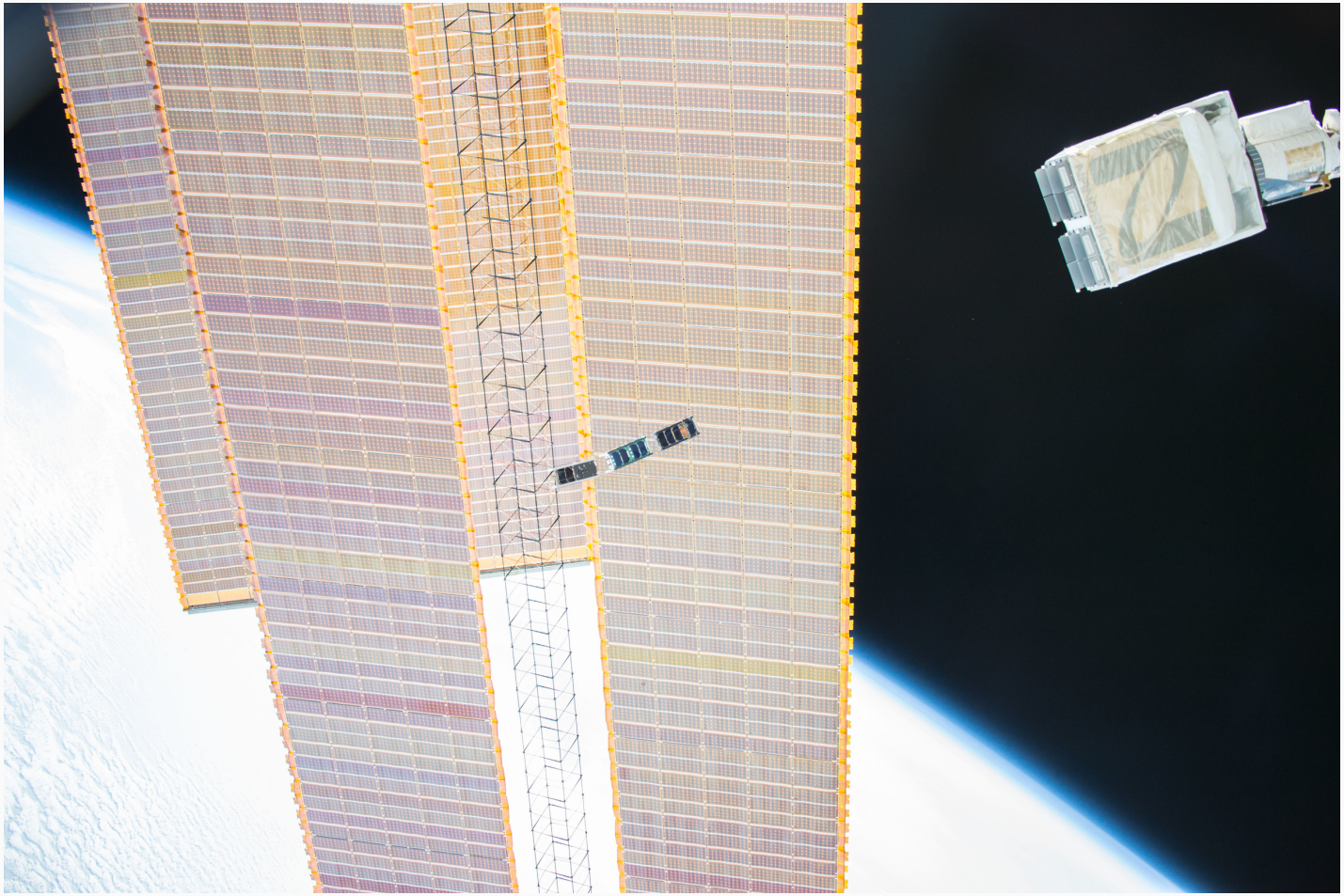

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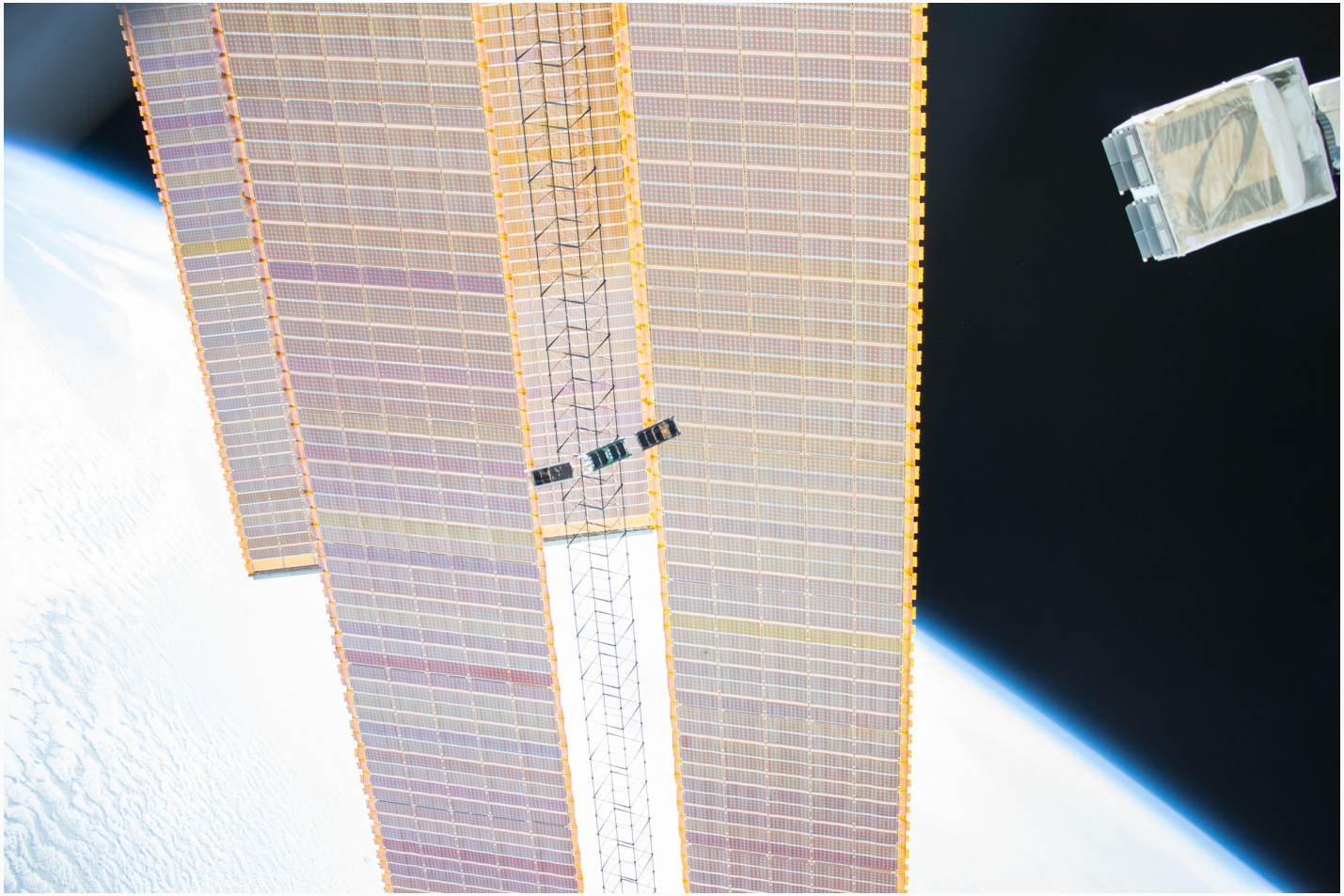

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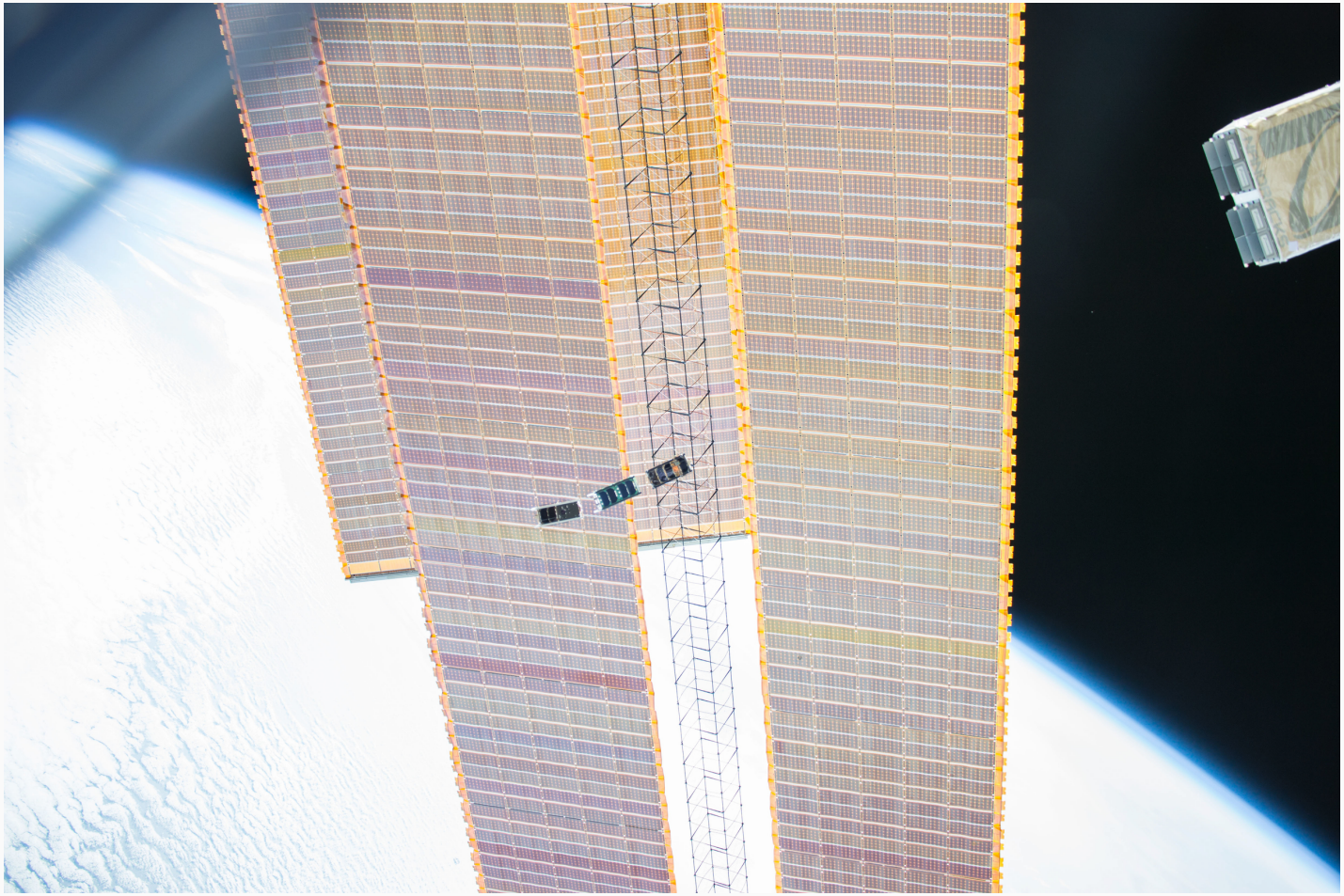

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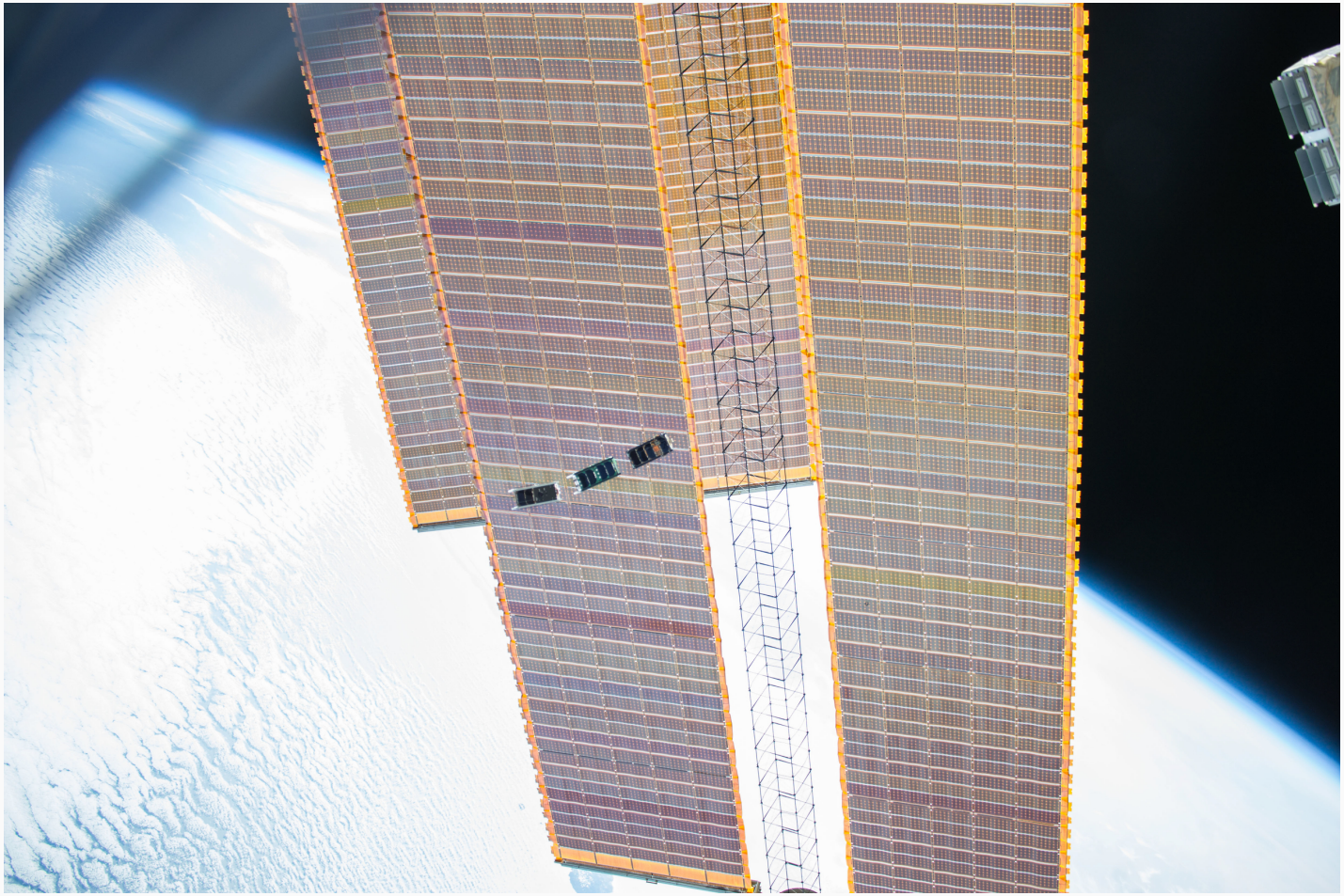

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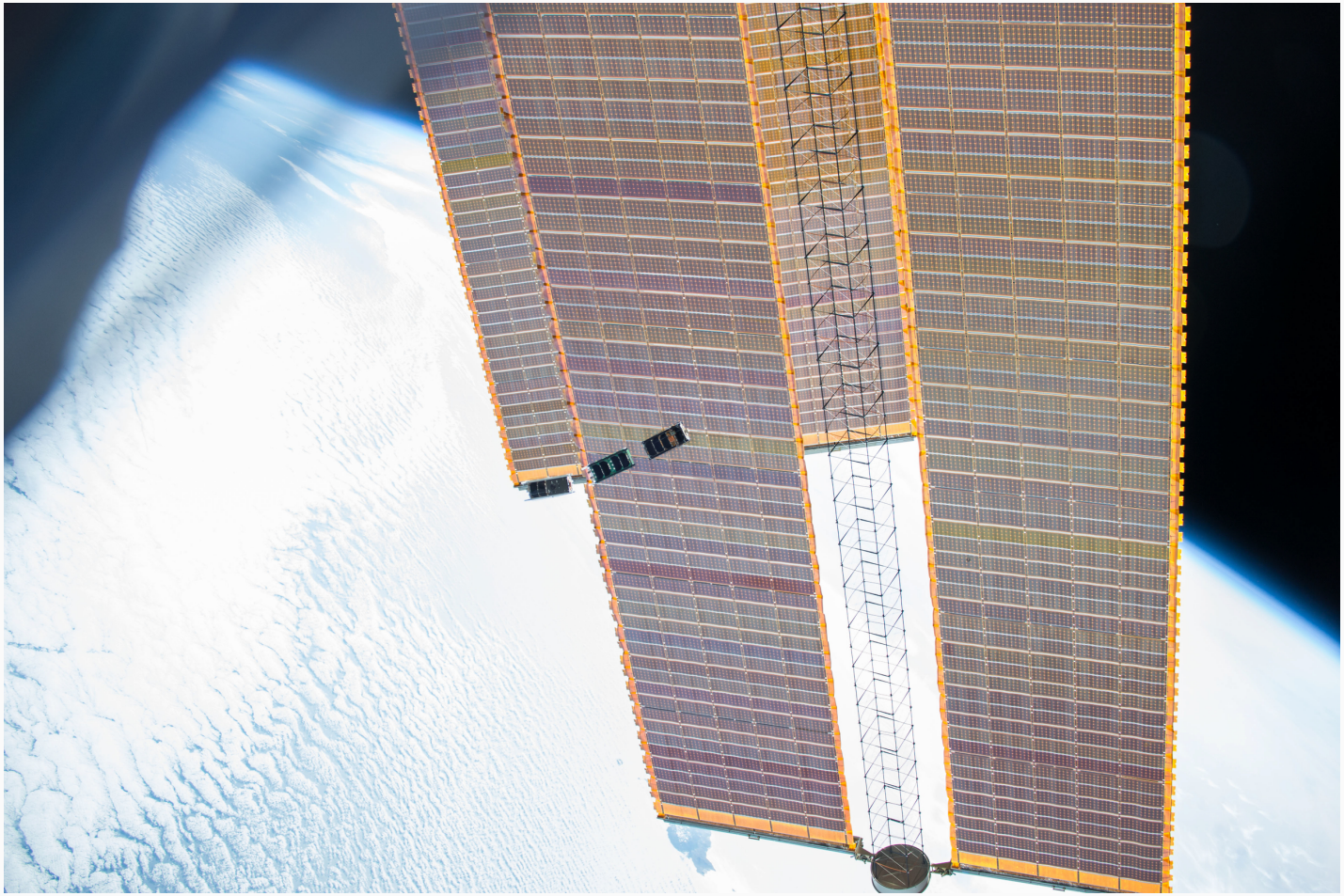

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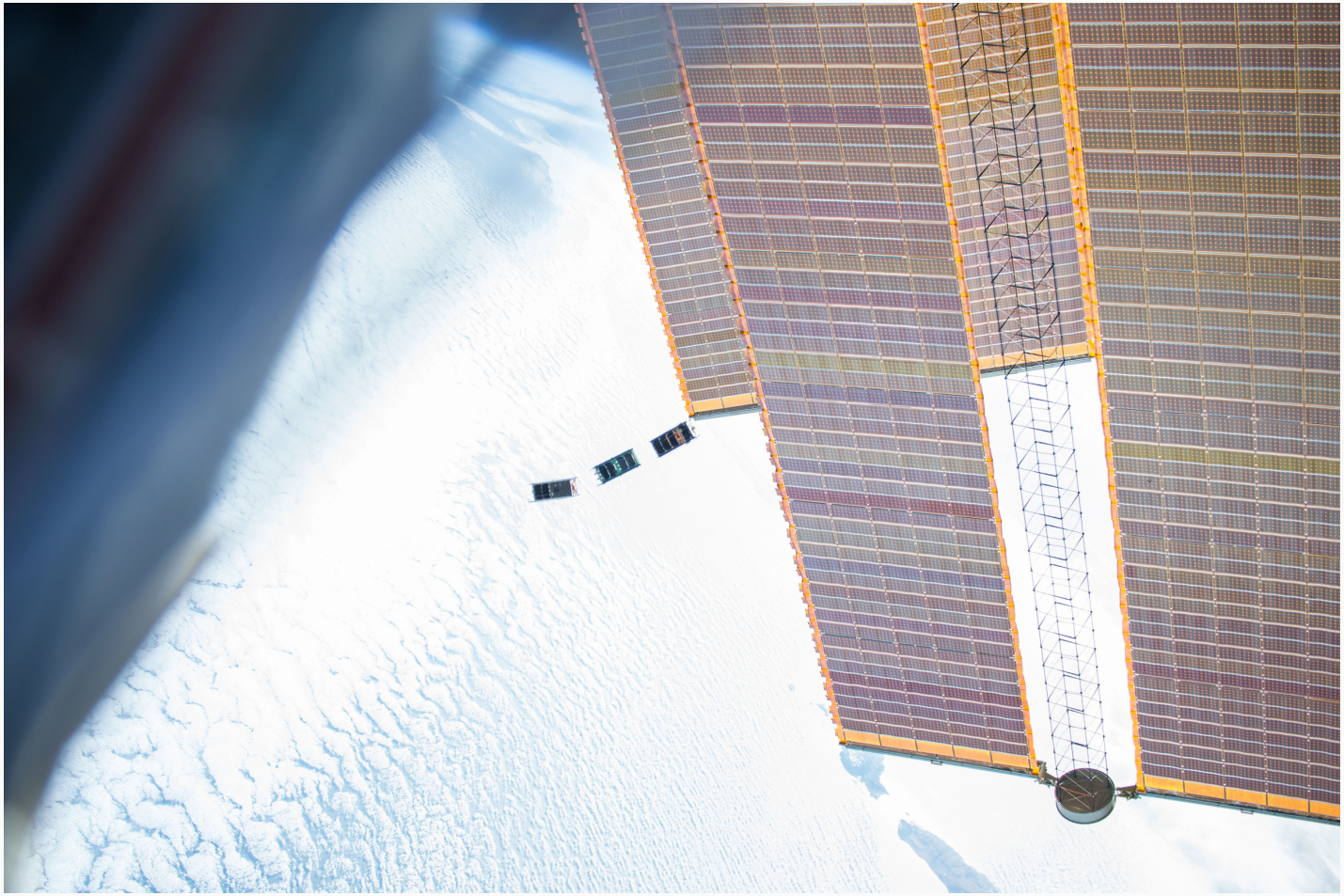

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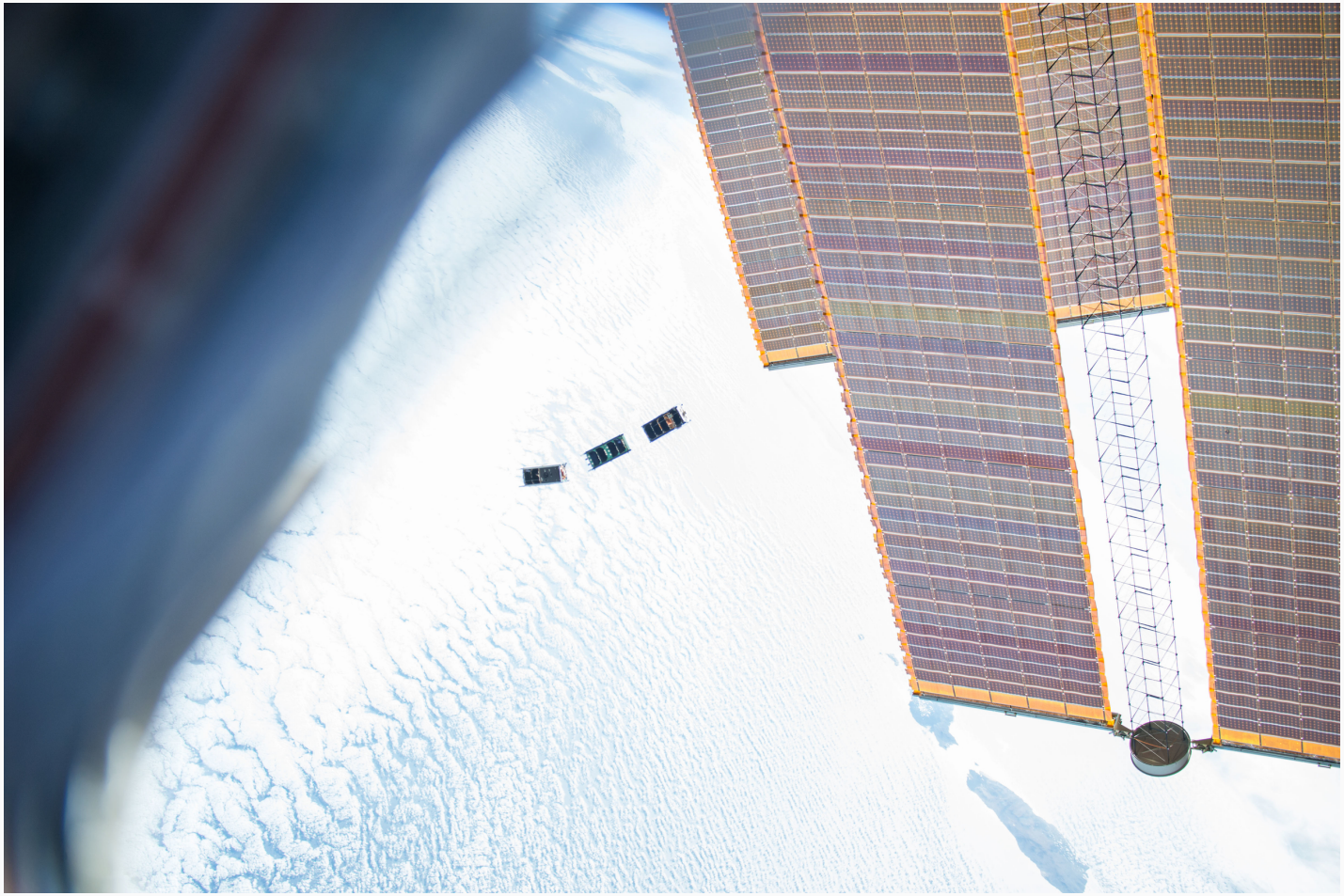

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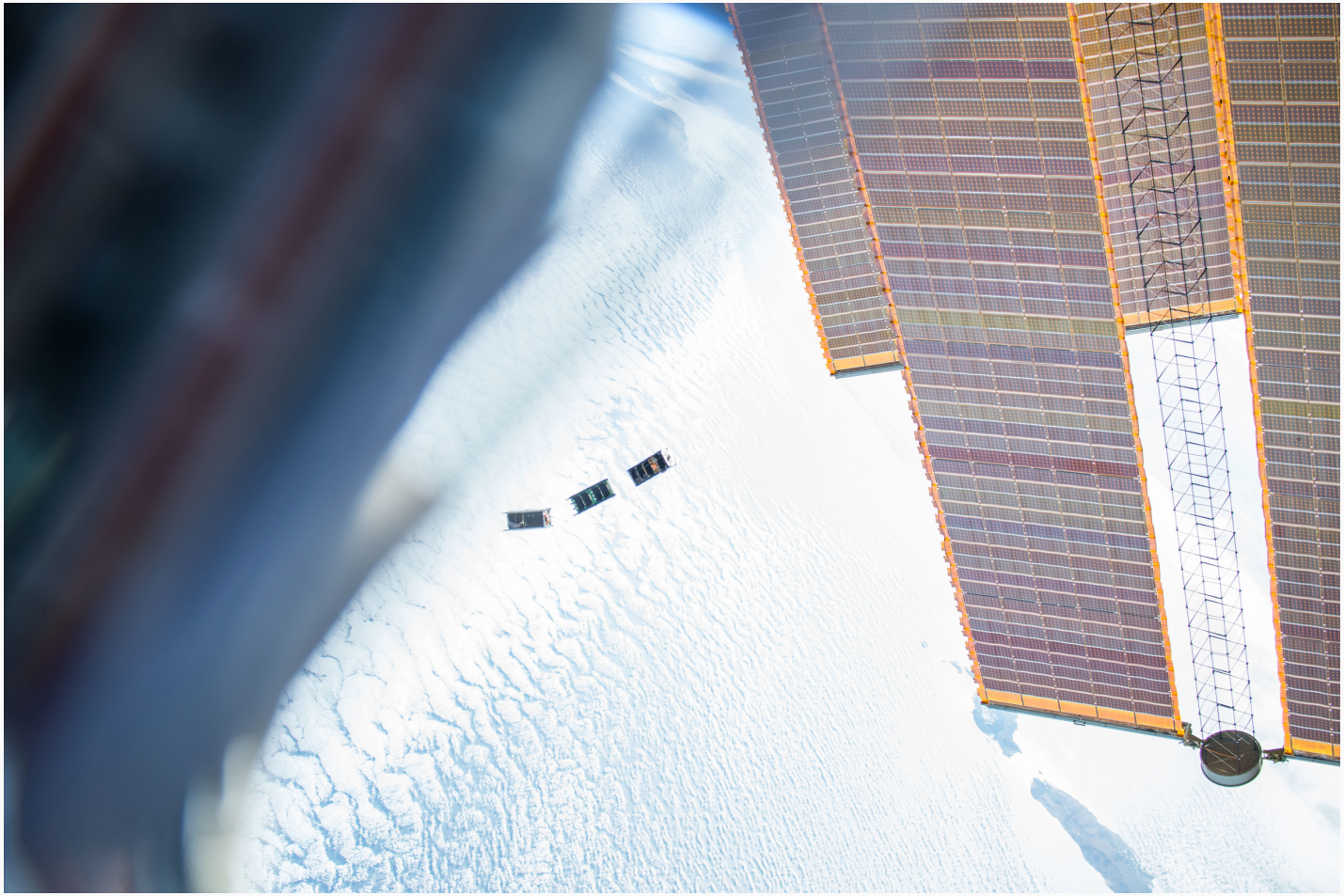
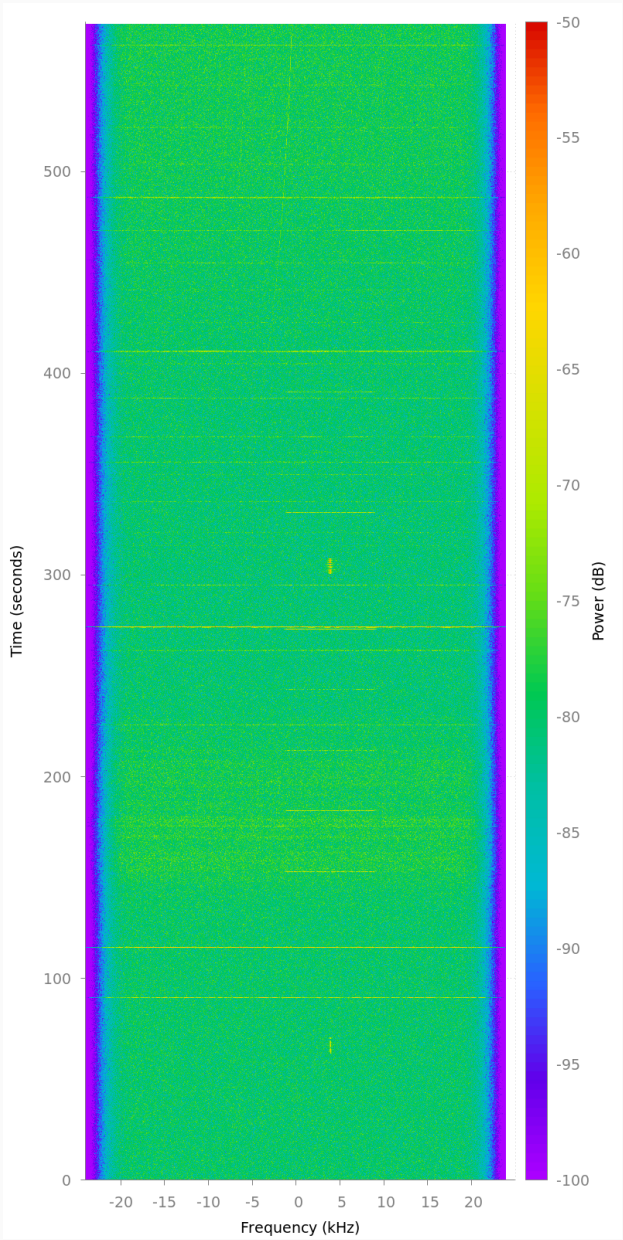


UPSat

- First transmissions received just 30 minutes after deployment (!!!) by a SatNOGS ground station in the USA
- CW and FSK9600 frames decoded using gr-satnogs decoders



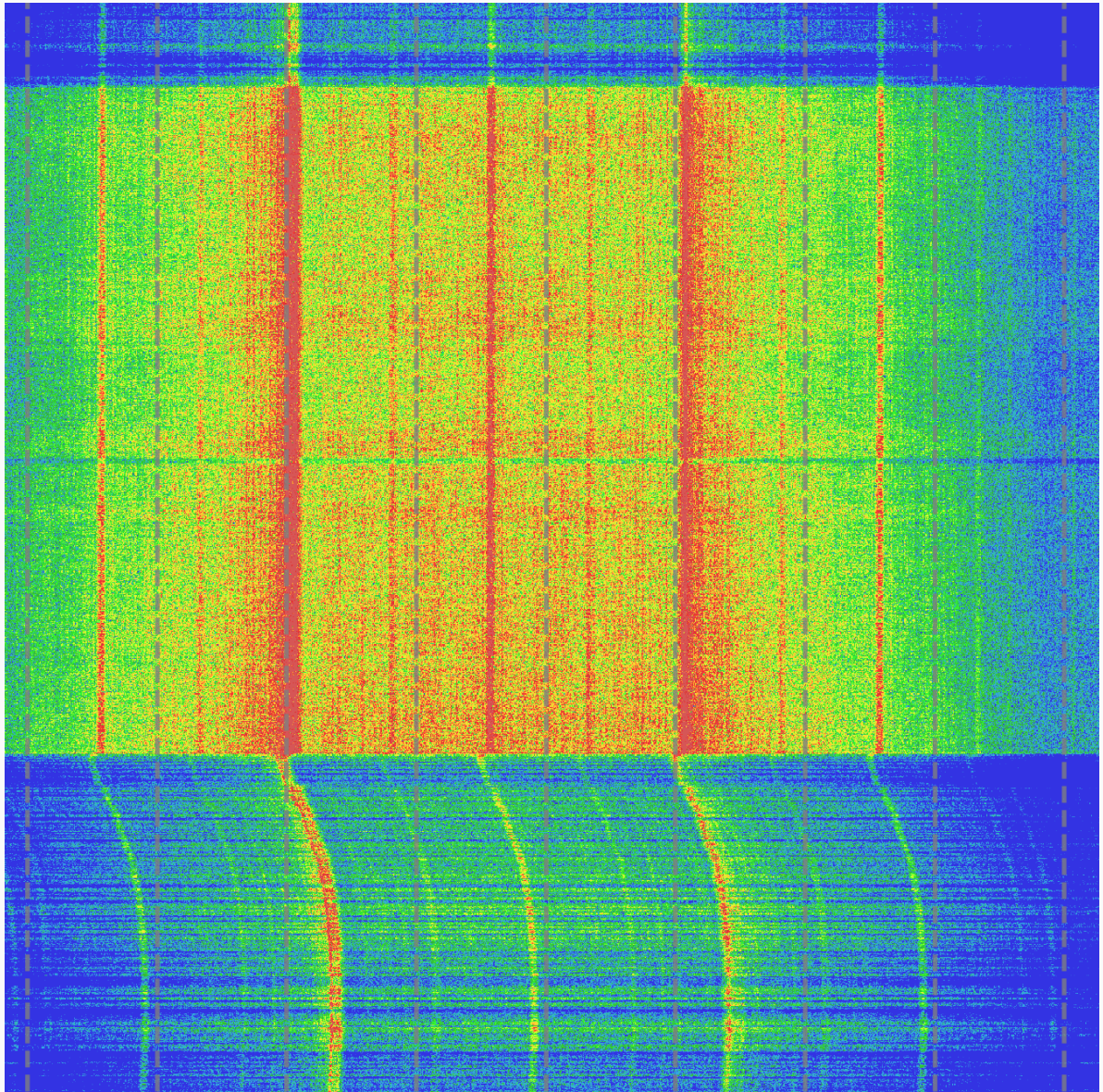
High Power Rocketry

High Power Rocketry

- Open hardware and software telemetry board
- https://gitlab.com/librespacefoundation/rocketry

High Power Rocketry

- SDR based telemetry decoder using GNU Radio



High Power Rocketry

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High Power Rocketry

SatNOGS New Features

SatNOGS v3

- Flowgraphs supporting the majority of SDR hardware
  - Different RF parameters for each SDR hardware
  - Can be altered on demand by the command line arguments
- Spectrum waterfall for each satellite observation
- New real-time decoders for popular transmission schemes
- Decoded data are uploaded to network for further visualization

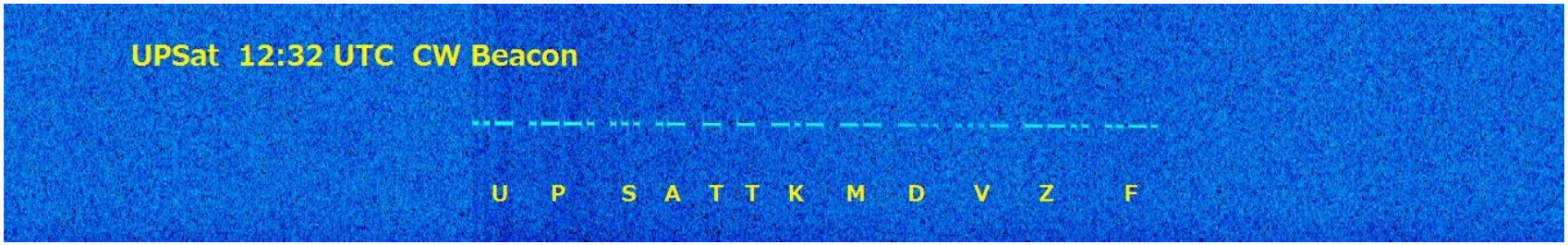
Automatic Signal Decoders

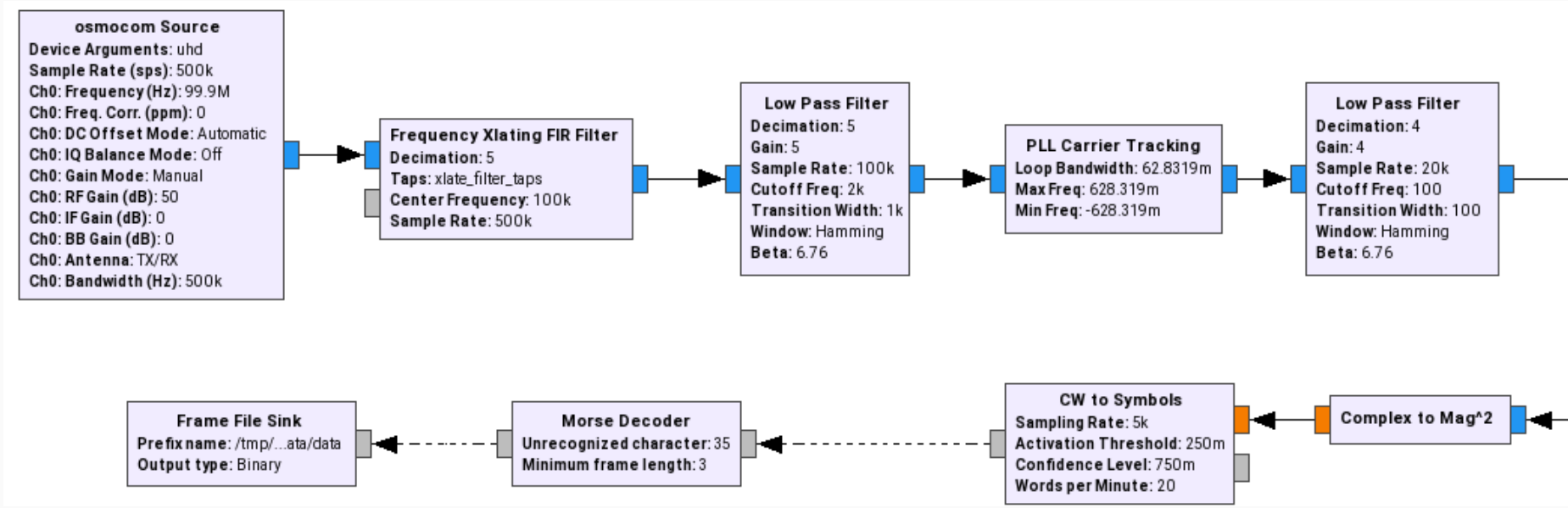
- CW
- AFSK1200 - APRS 1200
- APT
- FSK9600 - APRS 9600
- DUV
- LRPT (under dev!)
- PSK31, BPSK1200 (under dev!)

Flowgraphs of the decoders can be retrieved from the apps directory of the gr-satnogs OOT GNU Radio module

CW (Continuous wave, Morse Code)

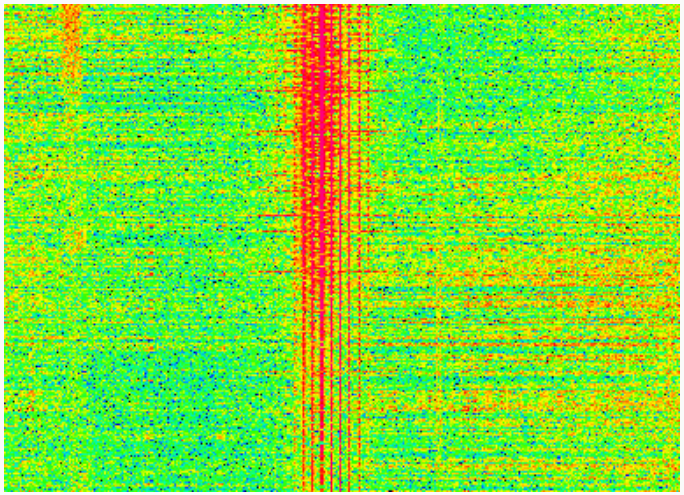
- Surprisingly, there was no SDR-based Morse Decoder
- Extremely popular in Cubesat missions
- Using a PLL and steep filtering does the job
- Reduce sampling rate so the filtering is not an issue on RPi3

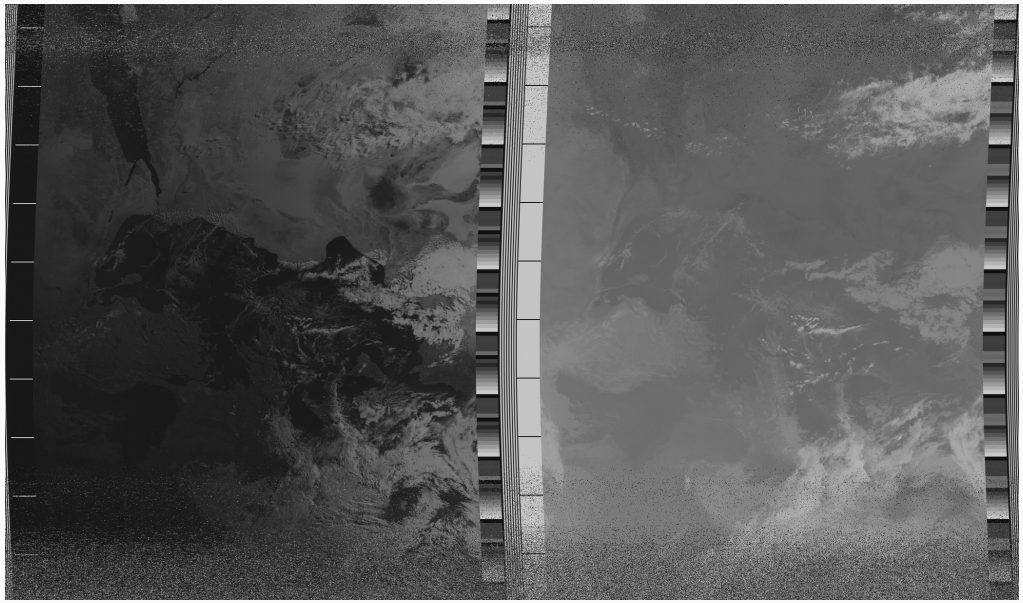




APT (Automatic Picture Transmission)

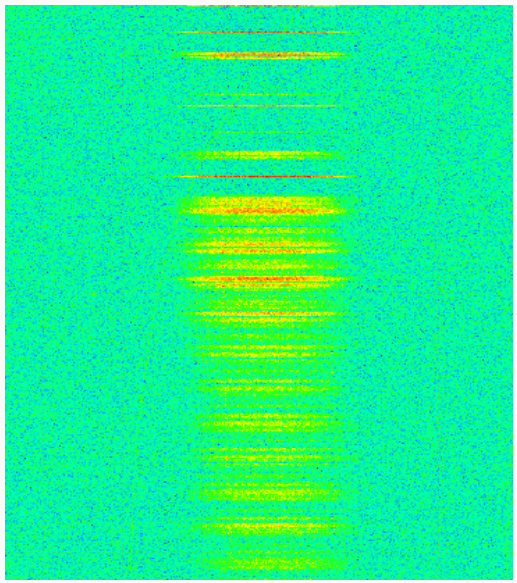
- Analog image transmission
- Used by NOAA weather satellites
- AM over FM @ 34 kHz bandwidth
- 5 Watts on 137 MHz





AX.25 FSK9600

- Very popular in hamradio and Cubesats
- Physical and data link of APRS 9600
- Used mainly in UHF
- G3RUH self synchronizing scrambler
- CRC32 for integrity check



Satellite	40012 - UNISAT-6
Station	31 - GI7UGV - UHF
Observer	Dimitrios Papadeas
Status	Verified
Transmitter	9k6 FSK TLM
Frequency	437.421 MHz
Encoding	FSK9k6
Timeframe	2017-12-08 08:52:50 2017-12-08 09:06:07
Rise	157.0°
Max	73.0°
Set	347.0°
Downloads	Audio Waterfall

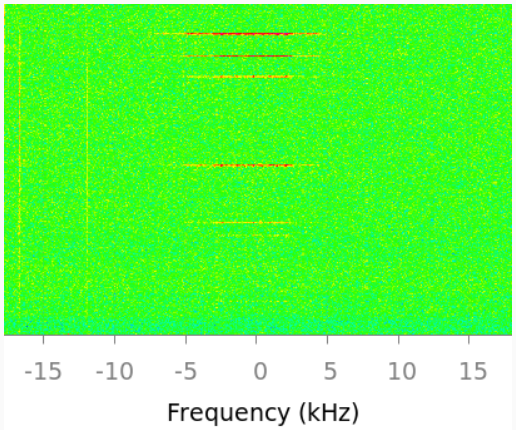
Waterfall Audio Data 6

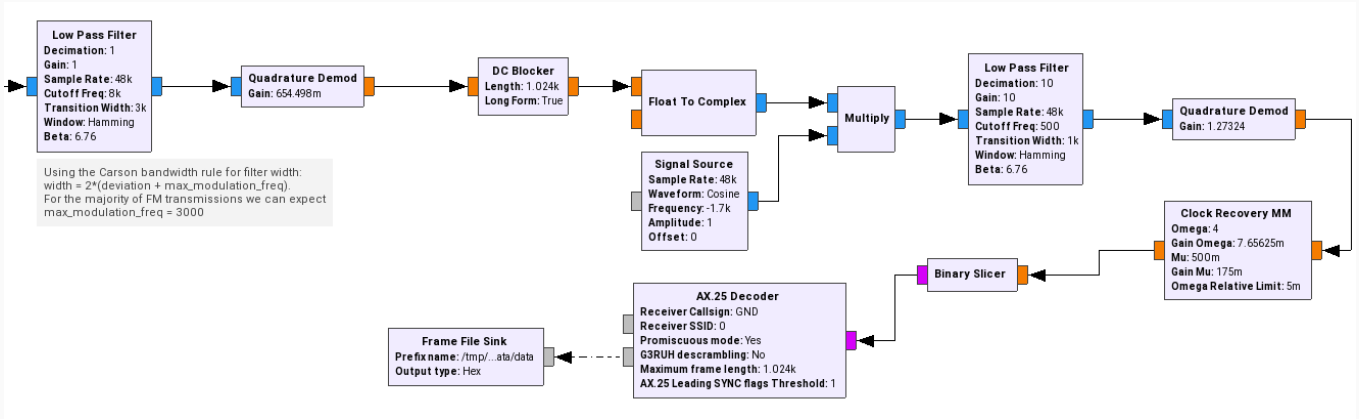
data_payloads/data_42212_2017-12-08T08-58-23.hex

0x86 0xa2 0x40 0x40 0x40 0x40 0x60 0x92 0x92 0x60 0xaa 0xa6 0x40 0xe1 0x3 0xf0 0x55 0x53 0x36 0 xa1 0x45 0x18 0x47 0x3 0x9b 0x1 0xde 0x2d 0x35 0 0xff 0xff 0xff

AX.25 AFSK 1200

- Audible FSK over an FM carrier
- Very popular in LEO missions
- No scrambling
- Many false positive frames due to poor SYNC word





Quadrature Demodulated Signal Filtering

The problem:

- Too many false alarms due to poor sync words
- Cannot rely on energy detection
  - Different SDRs across the SatNOGS network
  - Different RF setups (LNA, antenna, etc)

The solution:

- Signal free quadrature demodulated signal is quite noisy
- Compute the mean and the variance to extract samples when signal is present

Challenges

- Realtime decoding in RPi3 is challenging
  - Poor SIMD instruction set
  - Interface between SDR and the board may be the bottleneck
  - Filtering
- Low SNR
  - Hard frame detection
  - Most amateur transmission schemes have no FEC
- Lack of framing information
- No IQ database for development and debug

Next Steps

Next Steps

- Extract only interesting time instances of the spectrum (hard!)
  - Prune observations with no data automatically
  - Reduce size of stored files
- IQ dumps data base
- SigMF integration
  - Wanna contribute?! ;)
- AX.25 packet forwarding using *ax25* Linux kernel module

- SDR **can** be used for the telecommunications of small satellites
- We invite small satellite operators to take advantage of our existing network of ground stations
- Contribute with the decoder of the mission (if not already implemented)

Conclusions

Conclusions

- SatNOGS project has expanded significantly in the last year
- New decoders are systematically added on gr-satnogs
- UPSat has proved that SatNOGS network can be efficiently used for monitoring any mission's transmissions
- SatNOGS network is an appropriate platform for developing and testing amateur satellite communications