

Claim Space, the Libre Way

GNU Radio Conference 2018

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Libre Space Foundation



Introduction

- A non profit organization based in Athens, Greece
- Focus on space applications
- Commitment to open technologies
- Educational activities

- Established in 2014 after winning the Hackaday prize
- The winning project was the core of the **SatNOGS**

SatNOGS

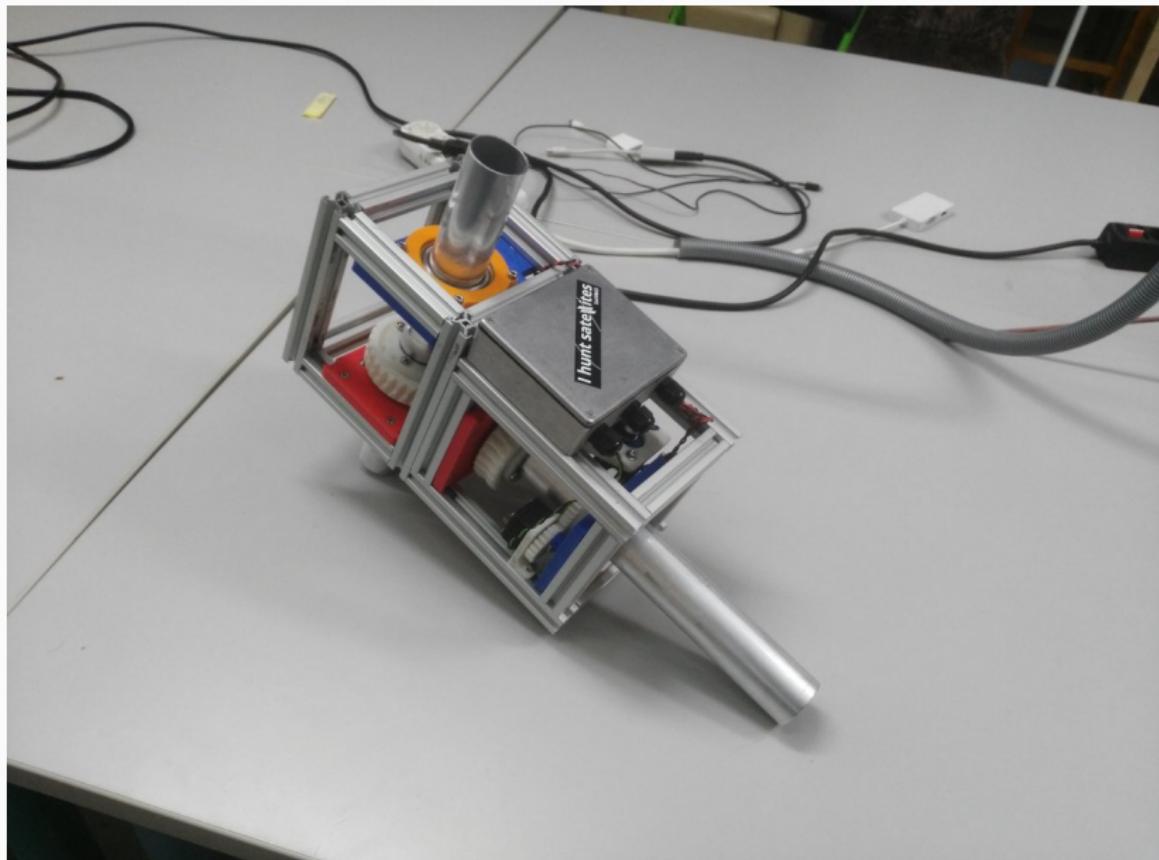
SatNOGS in a nutshell



SatNOGS in a nutshell

- Global network of ground stations
- Focus on receiving LEO satellite signals
- Open Software **and** Open Hardware
- Typical station costs about 400 USD
- SDR enabled RF front-end for maximum flexibility

SatNOGS Rotator

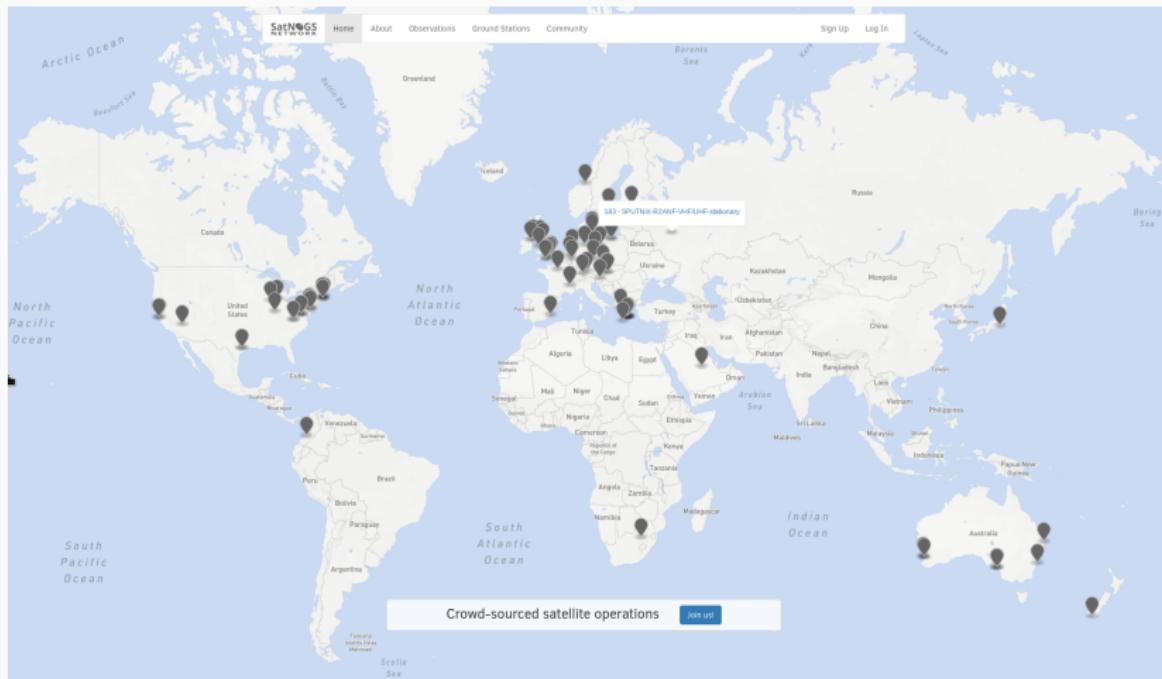


SatNOGS Rotator



SatNOGS Network

- 60 stations online
- 40 under testing



SatNOGS Network

- Over 1000 observations per day

SatNOGS NETWORK Home About Observations Ground Stations Community Sign Up Log In

Observations

« 1 2 3 4 ... 9470 »

Status: ✓ ! ✗ ? ▲

Results: List Map Timeline

Satellite: All

Observer: All

Station: All

Start Time: Calendar

End Time: Calendar

Update filters

ID	Satellite	Frequency	Encoding	Timeframe	Results	Observer	Station
251749	ELFIN-B	437.475 MHz	GFSK19k2	2018-09-16 16:45:50 2018-09-16 16:55:32	sp2zie	254 - SP2ZIE - 70cm	
251490	CP 7 (DAVE)	437.150 MHz	FSK9k6	2018-09-16 16:45:21 2018-09-16 16:55:59	Patrick Dohmen	49 - OZ7SAT	
251578	SurfSat	437.275 MHz	FSK9k6	2018-09-16 16:45:06 2018-09-16 16:56:27	Dimitrios Papadeas	31 - GI7UGV - UHF	
251705	CP 7 (DAVE)	437.150 MHz	FSK9k6	2018-09-16 16:44:34 2018-09-16 16:55:43	Cees Bassa	40 - CGBSAT-UHF	
251476	CP 7 (DAVE)	437.150 MHz	FSK9k6	2018-09-16 16:43:46 2018-09-16 16:54:55	Patrick Dohmen	37 - DL4PD	
251005	XW-2A	145.660 MHz	CW	2018-09-16 16:43:14 2018-09-16 16:54:11	Dimitrios Papadeas	183 - SPUTNIX-R2ANF-VHF/UHF-stationary	
251529	CP 7 (DAVE)	437.150 MHz	FSK9k6	2018-09-16 16:43:09 2018-09-16 16:53:59	Alex DD1ALX	47 - DBORV	
251674	S-NET C	2263.000 MHz	FM	2018-09-16 16:42:41	Dimitrios Papadeas	2 - KB9JHU	

8

SatNOGS Observation

Observation #251820

⌚ Timeframes are in UTC

 Discuss

Satellite

43017 - FOX-1B

Station

223 - W2MMD GCARC

Observer

Clubhouse

Status

Jon Pearce

Good

Transmitter

TLM

Frequency

145.960 MHz

Encoding

DUV

Timeframe

2018-09-16 16:08:59

2018-09-16 16:19:53

Rise

124.0°

Max

15.0°

Set

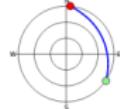
5.0°

Client Version

0.7

▶ { 4 items }

Polar Plot

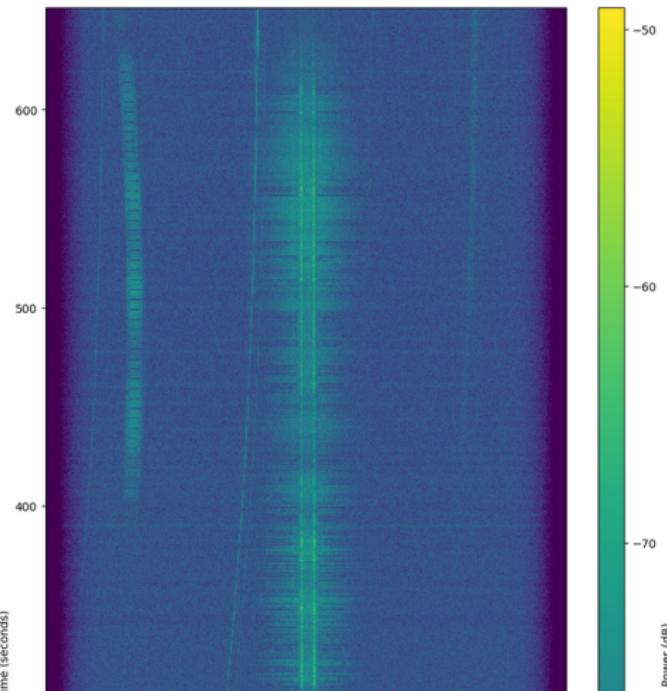


Downloads

 Audio

 Waterfall

Waterfall Audio Data 23



Time (seconds)

SatNOGS Observation

SatNOGS NETWORK Home About Observations Ground Stations Community

Sign Up Log In

Observation #251820

⌚ Timeframes are in UTC

[Discuss](#)

[Satellite](#) 43017 - FOX-1B

[Station](#) 223 - W2MMD GCARC Clubhouse Jon Pearce

[Observer](#) Good

[Status](#) TLM

[Transmitter](#) 145.960 MHz

[Frequency](#) DUV

[Encoding](#)

[Timeframe](#) 2018-09-16 16:08:59
2018-09-16 16:19:53

[Rise](#) 124.0°

[Max](#) 15.0°

[Set](#) 5.0°

[Client Version](#) 0.7

[Metadata](#) { 4 items }

[Polar Plot](#)

[Downloads](#)

Waterfall Audio Data 23

[Audio](#) [Waterfall](#)

SatNOGS Observation

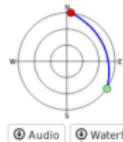
Observation #251820

⌚ Timeframes are in UTC

[Discuss](#)

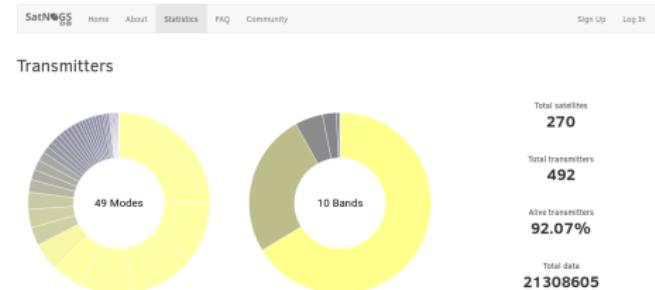
Satellite	43017 - FOX-1B
Station	223 - W2MMD GCARC
Observer	Clubhouse
Status	Jon Pearce
Transmitter	Good
Frequency	TLM
Encoding	145.960 MHz
Timeframe	DUV
Rise	2018-09-16 16:08:59
Max	2018-09-16 16:19:53
Set	● 124.0°
Client Version	15.0°
Metadata	● 5.0°
Polar Plot	0.7
Downloads	▶ { 4 items }

① Audio
② Waterfall



Satnogs DB

- 270 satellites
- 492 different transmitters
- Over 21M frames decoded



Data per satellite

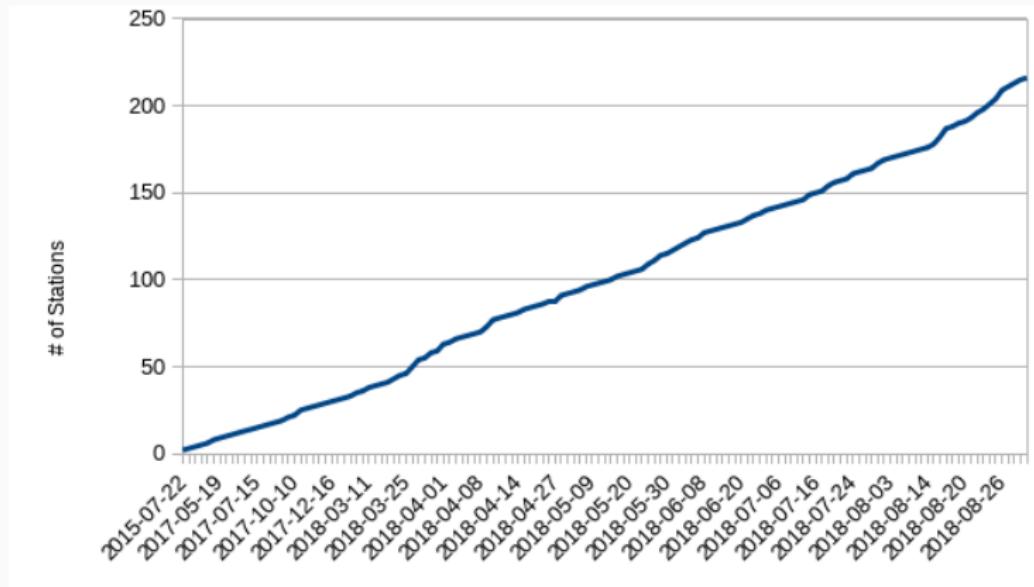
Norad ID	Name	Data	Latest
42761	CAS-4A	7308090	2018-09-16 16:31:08
42759	CAS-4B	5502229	2018-09-16 09:38:35
39090	STRAND-1	1640253	2018-09-16 16:31:40
40014	BUGSAT-1	1192961	2018-09-16 12:52:41
40012	UNESAT-6	916440	2018-09-16 09:41:42
40043	TIGERSAT	748117	2018-09-16 08:11:07
30776	FALCONSAT 3	910874	2018-09-16 16:35:09
40379	GRIFEX	434028	2018-09-16 12:40:45
40948	GOME-3	260034	2016-10-16 11:40:56
40907	KW-2D	2460342	2018-09-12 04:38:30
40911	KW-2B	238127	2018-09-15 08:41:52
42768	LITUANICASAT-2	238085	2018-09-16 09:03:15
41789	ALSAT 1N	213999	2018-09-16 11:41:10
43466	1KUHS-PF	148034	2018-09-15 20:08:36

Data per station

#	Name	Data	Latest
1	W7KKH-CM72sa	3431769	2018-09-16 16:34:50
2	DN4HF-JC214b	1458321	2018-03-03 17:09:09
3	PEDSAT-JD21fh	1455034	2017-07-15 21:40:20
4	SV0CD-KH17gh	1444697	2018-09-16 16:07:54
5	Rainer-JD71b	1418768	2017-12-23 05:16:04
6	W2RTV-FN018q	1158454	2018-09-16 16:12:22
7	N2ACQ-FM074g	1066460	2018-09-16 16:33:09
8	EU1XX-KD33ru	929876	2018-09-09 15:40:06
9	ZR1ADC-LI34s	881940	2018-09-16 16:31:40
10	DUBMCO-JN68fb	835238	2018-09-16 09:05:16
11	EAEWBQ-JM19rh	748520	2018-09-16 13:05:51
12	AQ7NP-CMB7rp	647284	2018-08-03 21:17:17
13	DK3WN-JM49fr	601150	2018-09-13 20:43:56
14	JAGGDE-PH953ws	543458	2018-09-16 09:51:21

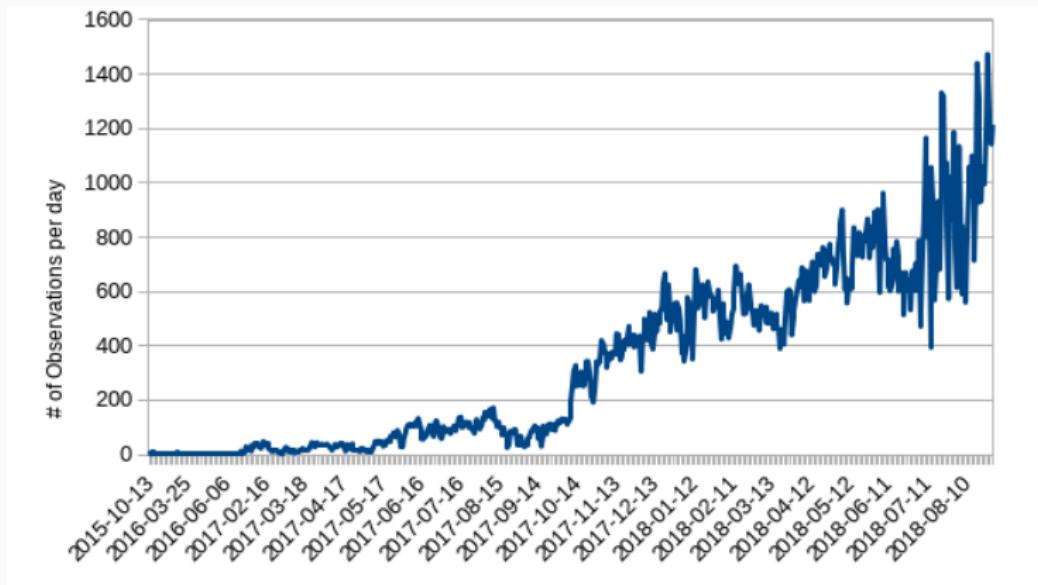
SatNOGS Stats

Registered Stations



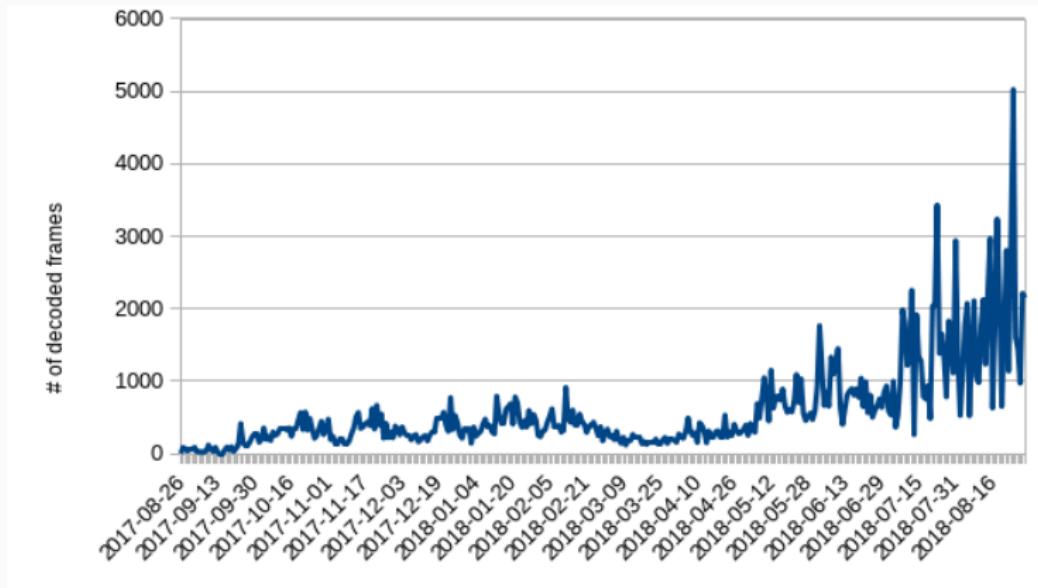
SatNOGS Stats

Observations per day



SatNOGS Stats

Decoded frames per day



SatNOGS SDR Receiver

- *gr-satnogs* is the GNU Radio OOT module of SatNOGS
- Supports most of the SDR devices
- Compensates the Doppler shift
- Support for custom RF parameters (gain, device arguments, sampling rate)
- Flowgraphs for automatic decoding

SatNOGS SDR Receiver

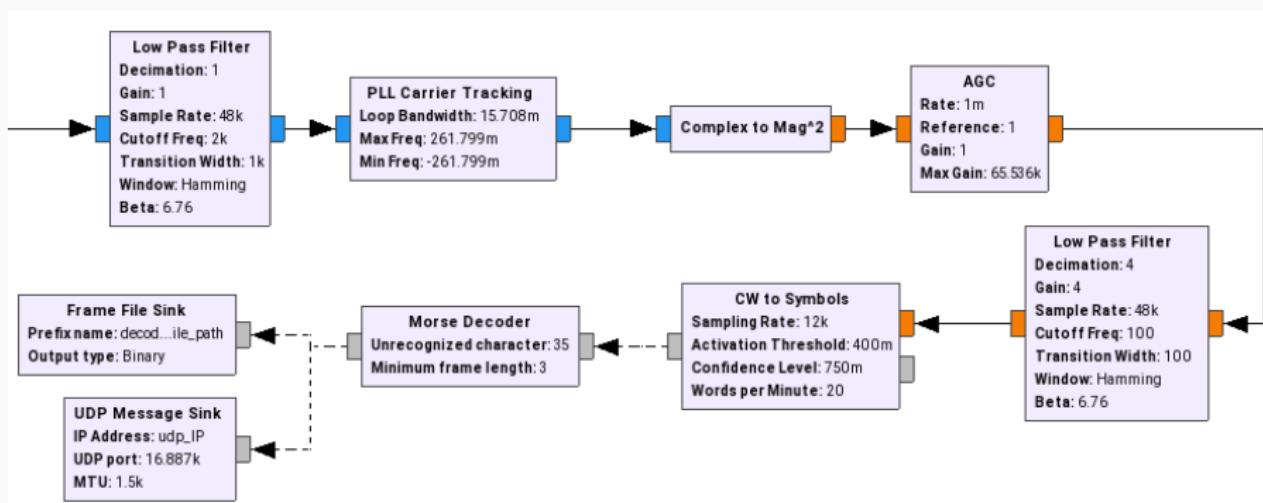
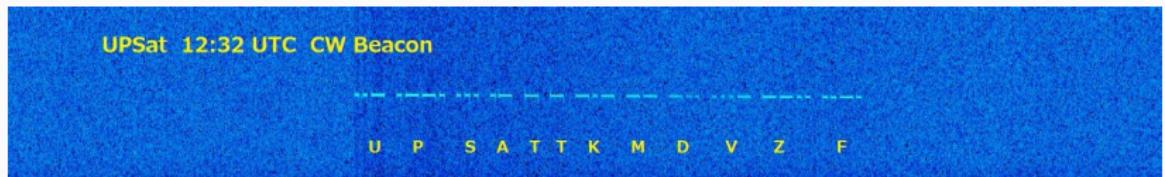
gr-satnogs currently supports decoders for:

- CW
- APRS1200 and APRS9600
- AX.25 FSK(1200-19200)
- AX.25 MSK(1200-19200)
- AX.25 AFSK(1200-9600)
- APT
- DUV
- BPSK1200

Flowgraphs of the decoders can be retrieved from the [apps](#) directory of the [gr-satnogs](#) OOT GNU Radio module

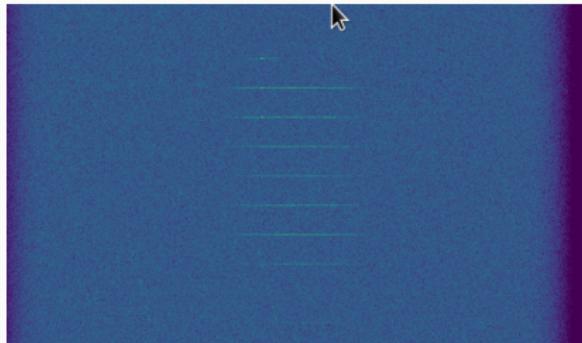
CW (Continuous wave, Morse Code)

- Extremely popular in Cubesat missions
- We developed an PLL-assisted amplitude based decoder



AX.25 FSK

- Very popular in hamradio and Cubesats
- G3RUH self synchronizing scrambler for baudrates > 1200
- CRC32 for integrity check



Waterfall Audio Data

data.obs/251027/data_251027_2018-09-16T17-35-19

```
86 A2 40 40 40 40 60 98 AA 6E 82 82 00 E1 03 F0 FF FF F0 00 01 00 00 16 71 5B 9E 94 57
80 06 AC 84 08 28 CD 98 01 01 00 00 6A 48 02 01 00 00 08 08 27 03 01 00 00 2F 79 83 8D
80 18 83 45 01 B7 03 69 00 99 04 01 0A 80 00 87 05 01 00 00 08 08 00 22 0A FB CB C9 F8 80
3C 00 9F 04 13 80 00 00 4D FF CD FF B3 00 00 7A 00 00 21 09 00 00 92 D4 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
```

data.obs/251027/data_251027_2018-09-16T17-36-19

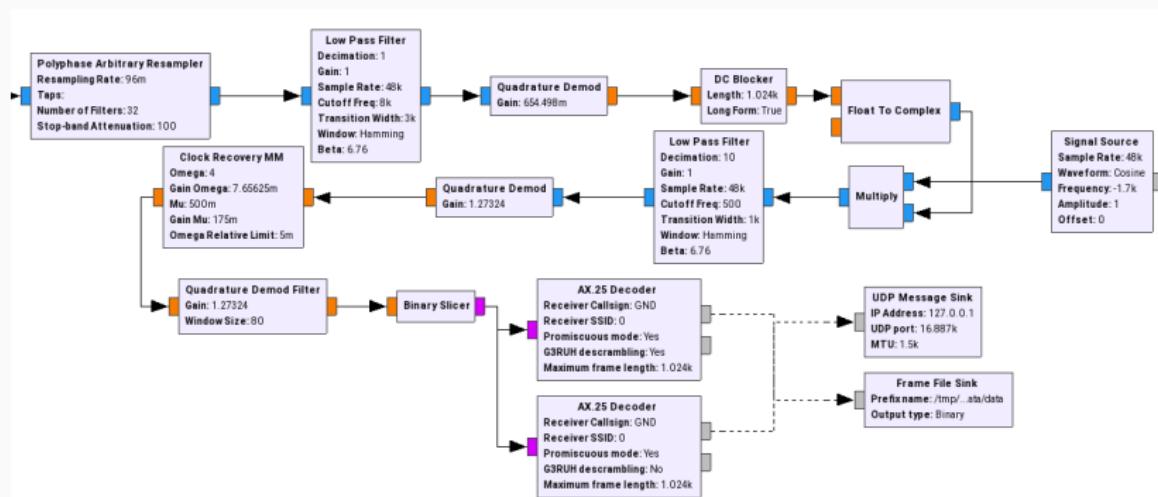
```
86 A2 40 40 40 40 60 98 AA 6E 82 82 00 E1 03 F0 FF FF F0 00 01 00 00 16 AD 5B 9E 94 92
80 06 AC 84 08 28 CD 98 01 01 00 00 6A 48 02 01 00 00 08 08 08 27 03 01 00 00 00 2F 79 83 7B
80 18 83 45 01 D1 03 09 00 98 04 01 0A 8C 00 89 05 01 00 00 00 08 3B 2E F6 62 16 62 FB
DA 00 A2 01 80 00 08 00 46 FF C0 FF B4 00 00 A5 00 00 21 0C 00 00 02 5B 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
```

data.obs/251027/data_251027_2018-09-16T17-36-04

```
86 A2 40 40 40 40 60 98 AA 6E 82 82 00 E1 03 F0 FF FF F0 00 01 00 00 16 9E 5B 9E 94 83
80 06 AC 84 08 28 CD 98 01 01 00 00 6A 48 02 01 00 00 08 08 27 03 01 00 00 00 2F BB 83 85
80 17 83 46 01 CE 63 69 00 97 04 01 0A 8A 00 8B 05 01 00 00 08 08 08 3F 17 F8 78 07 A3 FC
97 00 9C 02 BA FF F9 00 43 FF C8 FF B3 00 00 A5 00 00 21 0A 00 00 02 15 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
```

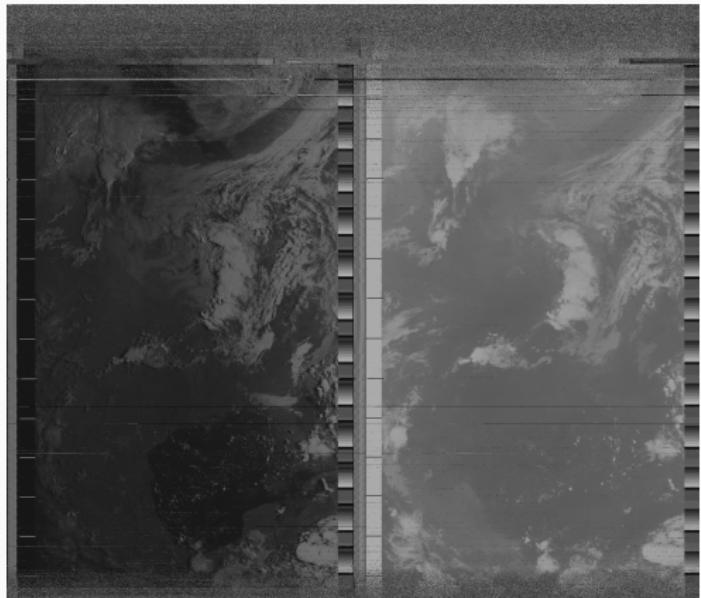
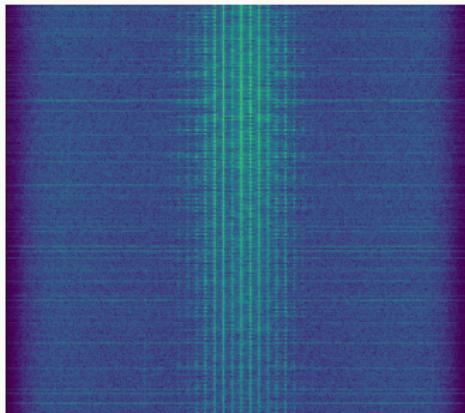
AX.25 AFSK 1200

- Audible FSK over an FM carrier
- Very popular in LEO missions
- Two quadrature demodulators for the decoding



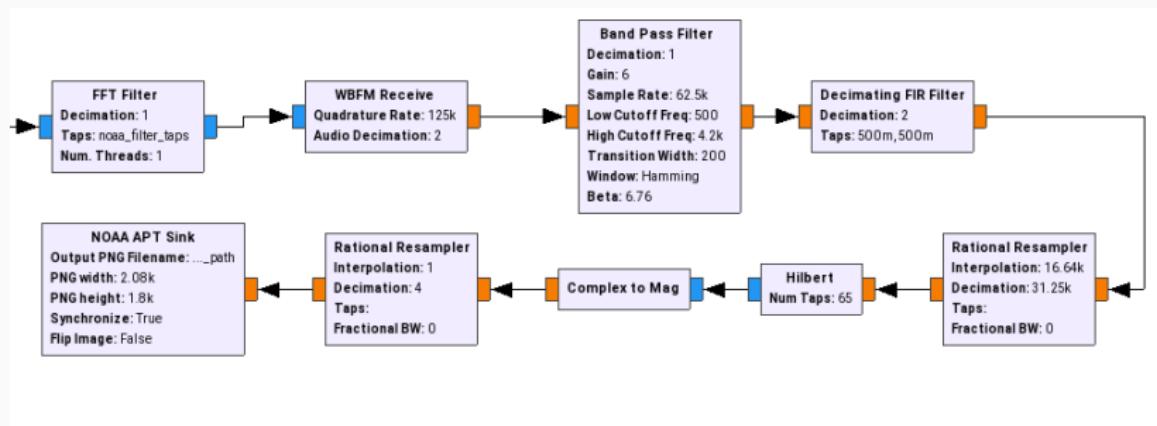
APT (Automatic Picture Transmission)

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



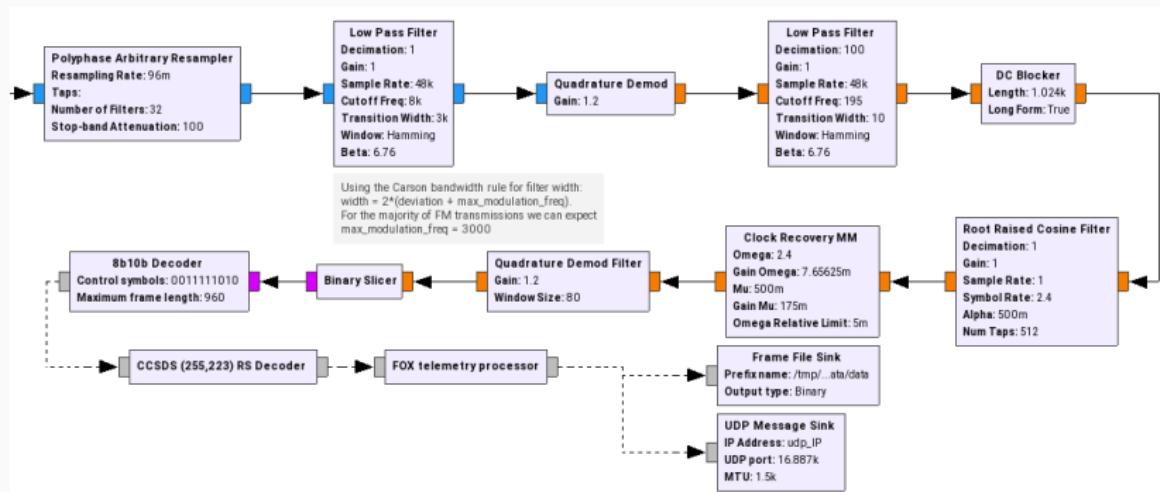
APT (Automatic Picture Transmission)

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



DUV (Data Under Voice)

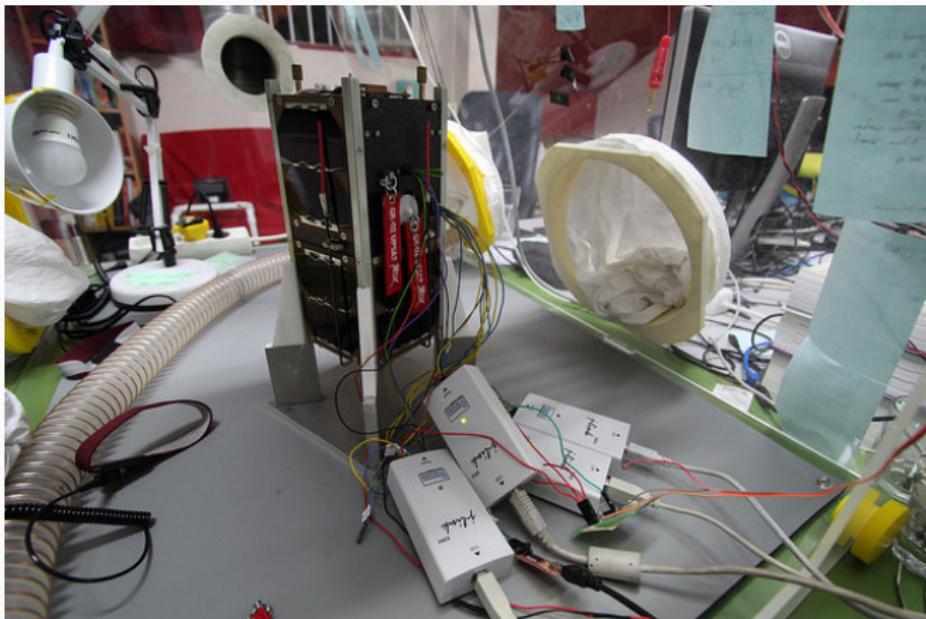
- Used in AMSAT FOX satellites
- Low speed telemetry under FM voice transmissions
- 8b10b encoding and RS



UPSat

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

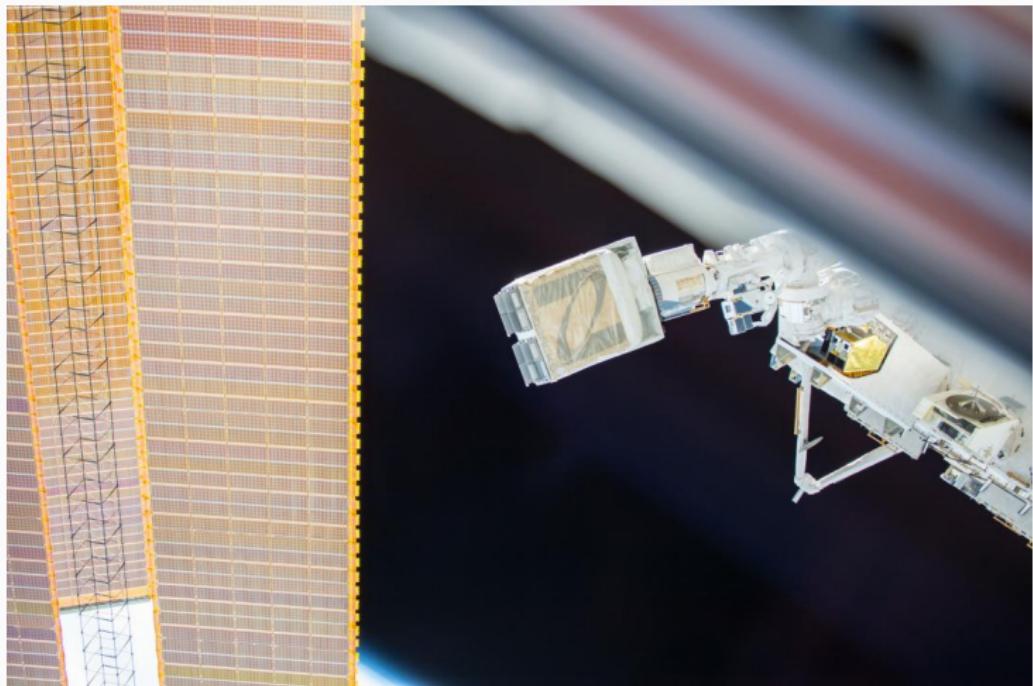


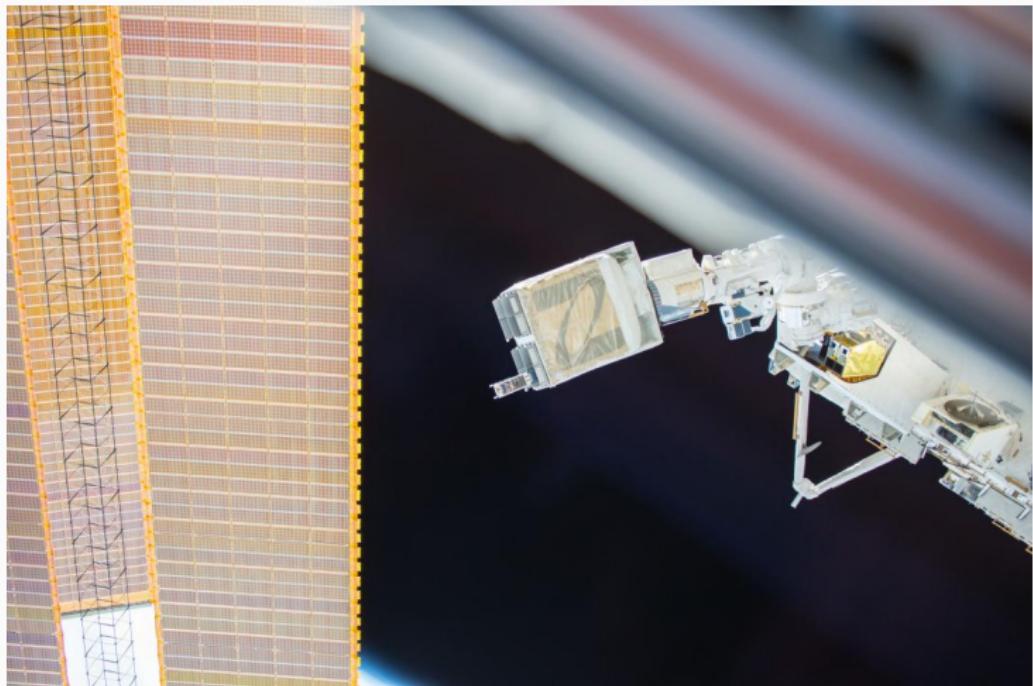


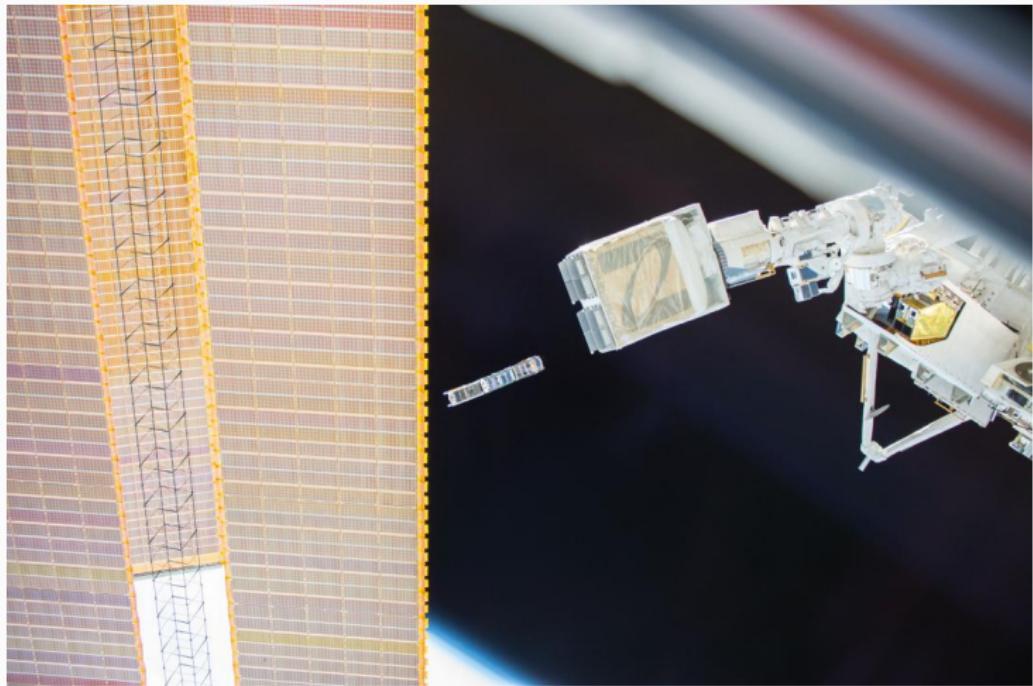


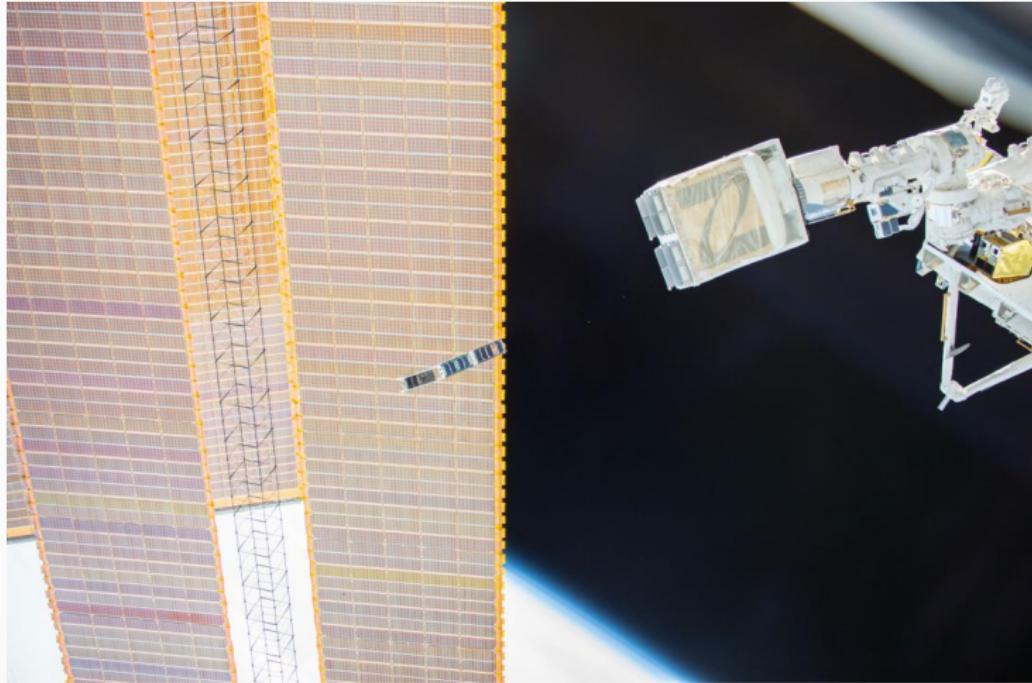


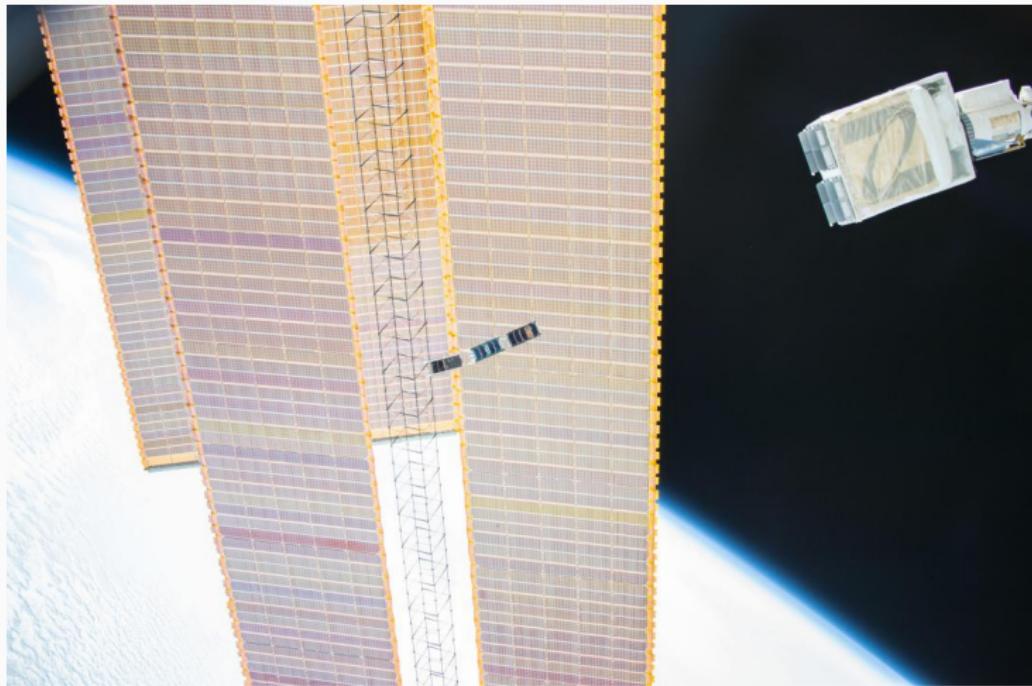
- Launched on 18th April 2017 on an Atlas V rocket

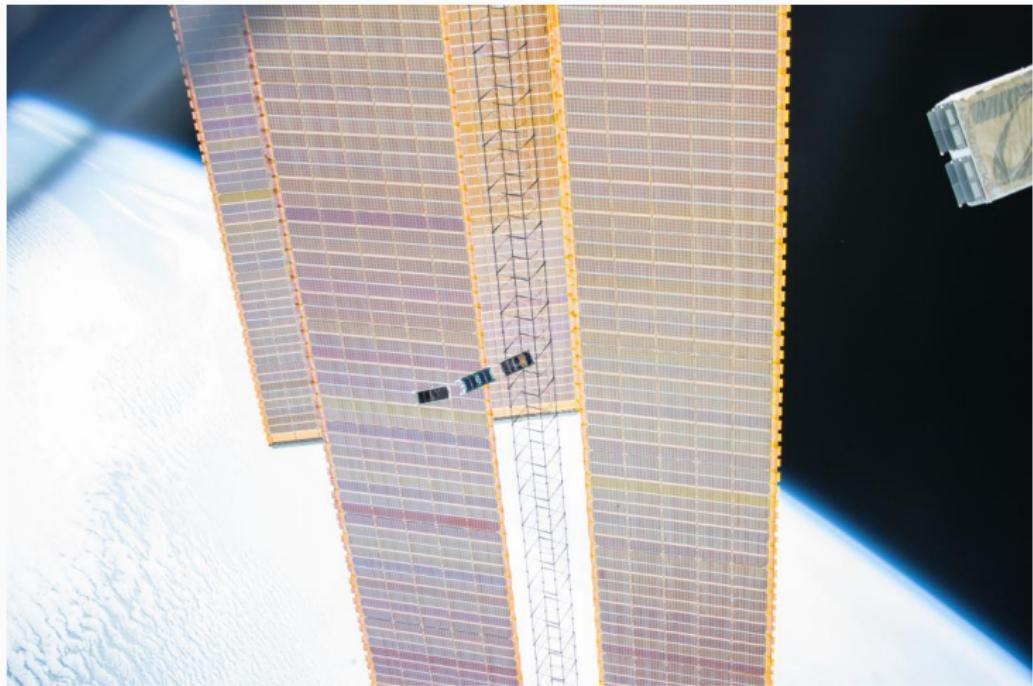


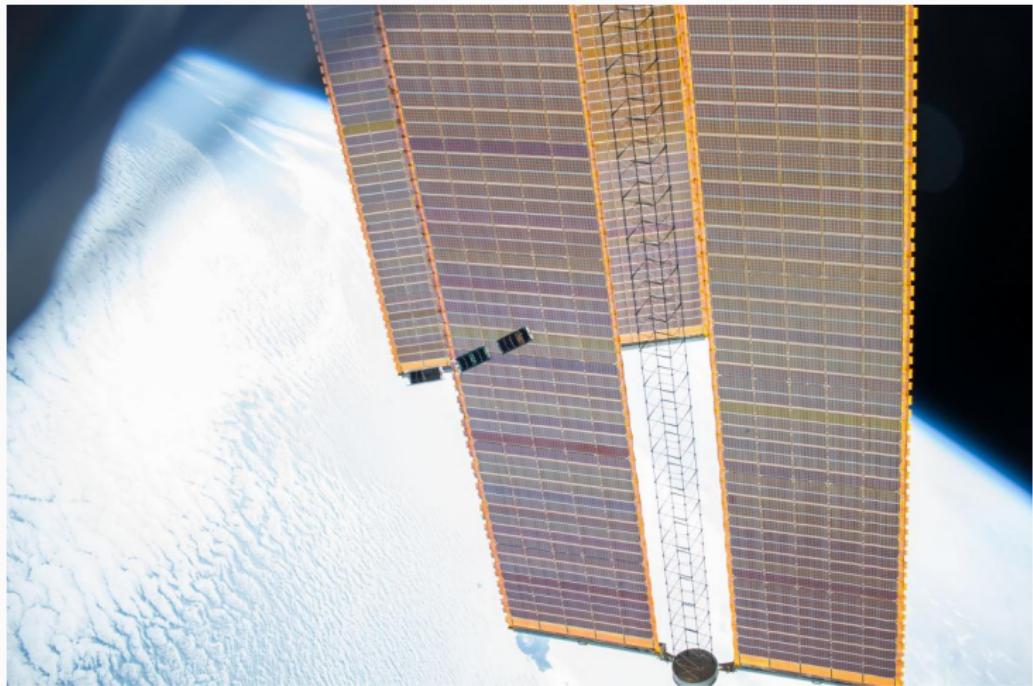


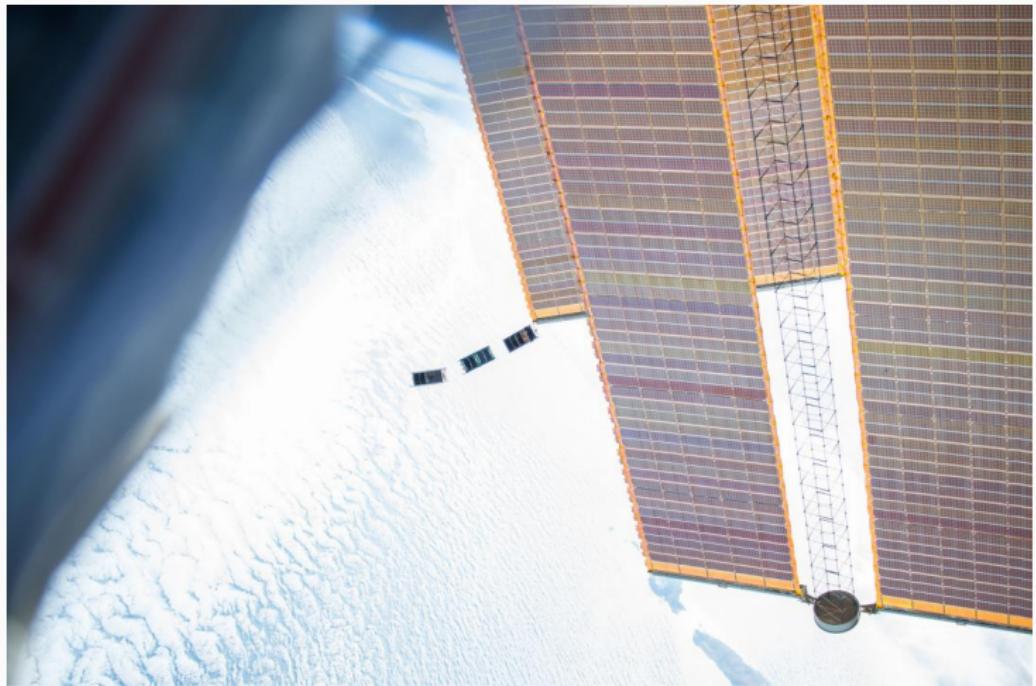






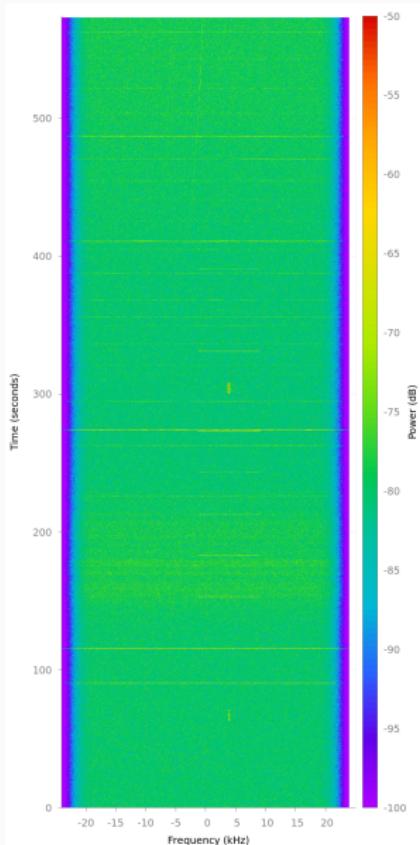








- First transmissions received just 30 minutes after deployment by a SatNOGS ground station in the USA
- CW and FSK9600 frames decoded using gr-satnogs decoders



ESA SDR Makerspace

- An ESA - LSF collaboration
- 14-month program with a budget of 500k euros
- Investigate the use of SDR technology in space applications
- Umbrella activity for 15+ subactivities around SDR and space communication
- Several subactivities include contributions to GNU Radio
- All results released as open source software and hardware



- Use Soapy API to interface with SDR hardware
- Extract device capabilities dynamically
- Deprecates the gr-osmosdr
- <https://gitlab.com/librespacefoundation/gr-soapy.git>



- A model emulating the LEO channel
- Path loss based on distance and/or atmospheric absorption
- Doppler effect
- Great tool for prototyping and experimentation
- <https://gitlab.com/librespacefoundation/gr-leo.git>

More to come

- SDR hardware radiation testing
- Contributions to DVB-S2
- CCSDS Decoders
- New SDR software platforms
- Framework for SDR testing CI/CD
- More info at <https://sdrmaker.space>





Thank you!