# gr-satellites

## A collection of GNU Radio decoders for Amateur satellites

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19 October 2019
2nd Technology Forum on Student Micro/nano-satellites, Harbin

# About the speaker

- From Madrid, Spain
- PhD in Mathematics
- Amateur radio operator: EA4GPZ (Spanish licence), M0HXM (UK licence)
- Day job: designing and building GNSS receivers and simulators at GMV in Madrid
- Involved in many personal projects and experiments regarding radio
- Blog `http://destevez.net`
- Twitter @ea4gpz

# What is gr-satellites?

- A GNU Radio out-of-tree module with a collection of telemetry decoders for Amateur satellites
- Input: IQ RF samples (from SDR, conventional radio or recording)
- Output: packets in hex or parsed telemetry values
- Currently supports nearly 80 different satellites
- Project goal: providing an open-source solution for decoding every satellite that transmits on Amateur bands
- Essentially a one man's project, but I'm eager to collaborate with other people

# Some history about gr-satellites

- In November 2015 I started studying and modifying gr-lilacsat, the LilacSat2 decoder by Wei Mingchuan (Harbin Institute of Technology). I wanted to learn how these decoders worked.
- After this, I started writing decoders for some other satellites, just for learning and fun.
- At some point, this took shape as a project with the goal of maintaining a collection of decoders for all Amateur satellites.
- Reason: ITU Radio Regulations state that Amateur transmissions "shall not be encoded for the purpose of obscuring their meaning".
- Consequence: specifications and decoders should be publicly available for all satellites using the Amateur bands.

# Usual development workflow

- A new satellite gets launched
- Amateurs do some recordings of the signal
- I work with the recordings and documentation available online to see what protocols/specifications are used
- Usually the documentation is incomplete or inexistent: do reverse-engineering or try to get in touch with the satellite team to ask questions
- If all goes well, eventually we figure out all the specifications
- Write a decoder, put up a blog post

- If you're designing an Amateur satellite and need help to write a decoder, please contact me
- I will help you with your decoder
- I might even write it for you, as I was probably going to write a decoder anyway

# A few words about documentation

- Currently there is an ongoing discussion in the Amateur community about the importance of publishing documentation and specifications about the signals used by Amateur satellites
- We are trying to get things more strict: complete specifications must be publicly available at some point before launch
- If you are designing a satellite that will use Amateur radio spectrum, please do:
  - Get in contact with the Amateur community. We are here to help
  - Write and publish good and complete specifications for your protocols

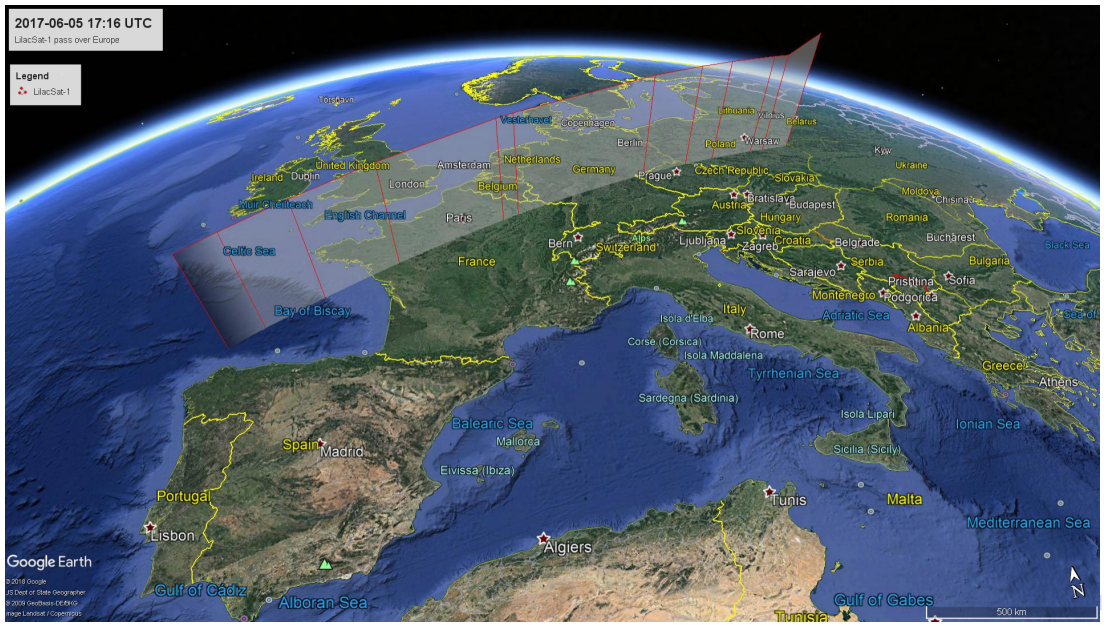
# Protocols and modems supported

- AX.25, with custom framer/deframer and KISS encoder/decoder. Several decoders for BPSK AX.25, with optional G3RUH descrambling.
- GOMspace radios
  - NanoCom U482C. Support for Viterbi decoding, descrambling and Reed-Solomon decoding.
  - NanoCom AX100. Modes supported: ASM + Reed-Solomon (with G3RUH asynchronous scrambler) and ASM + Golay-encoded header (with CCSDS synchronous scrambler).
- CSP protocol: header parser and CRC checker block.
- CCSDS stack: Viterbi decoding, descrambling and Reed-Solomon decoding
- AO-40 FEC protocol, used in the FUNcube family of satellites. Uses a distributed syncword, interleaving, convolutional coding, CCSDS scrambling and Reed-Solomon.

- TT-64 protocol, used in QB50 AT03 PEGASUS. Uses a (64,48) Reed-Solomon code and CRC16-ARC checksum.
- Mobitex-NX, used by the TU Berlin satellites. Uses a (12,8,3) linear code FEC. Mobitex, used by D-STAR One satellites.
- Custom protocol for S-NET satellites. Uses BCH FEC and interleaving.
- Custom protocol for ÑuSat. Uses a (64,48) Reed-Solomon code and CRC8.
- Intelsat IESS-308/V.35 descrambler.
- Texas Instruments CC11xx decoder. Used by Reaktor Hello World and 3CAT-1.
- Non-standard AX.25 used by ESEO.
- FX.25 (AX.25 with Reed-Solomon FEC). Used by Astrocast 0.1.
- AO-40 uncoded protocol, used in the Es'hail 2 QO-100 Amateur radio GEO transponder.
- Pacific Crest XDL Micro 4FSK protocol, used by EQUiSat.

# Other features

- Real-time image decoding for BY70-1, D-SAT, K2SAT, LilacSat-1, 1KUNS-PF
- K2SAT uses a 2Mbaud QPSK S-band image transmitter. The decoder has been made in collaboration with the K2SAT team at KAIST, South Korea.
- LilacSat-1 and Taurus-1 Codec2 digital voice decoder
- GPS to KML telemetry conversion for LilacSat-1
- ADS-B airplane position data to KML conversion for GOMX-3

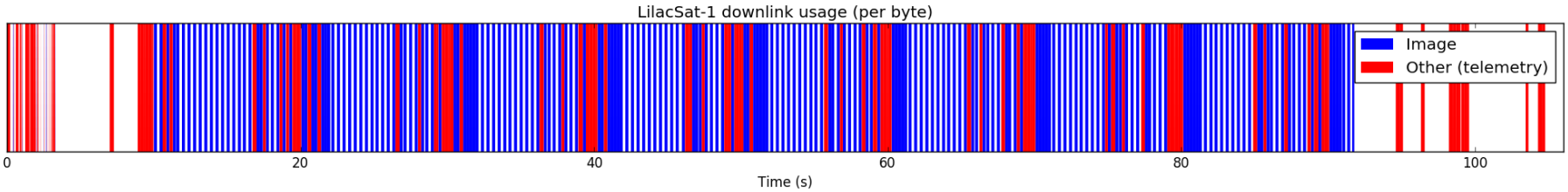


# Telemetry submission

- Support for sending telemetry to the following servers:
  - SatNOGS, and other servers supporting SiDS protocol
  - FUNcube warehouse
  - PW-Sat2 server
  - EQUiSat server
- If you are building your own telemetry server, I suggest you use SiDS or contribute your own telemetry submitter block
- The Amateur radio community is an inexpensive and very useful global groundstation network

# Some experiments done with gr-satellites and LilacSat-1

- Downlink usage




- Digital voice repeater: FM up, Codec2 down. QSOs made by several Amateurs

- Receiving images (below, image received by DK3WN and EA4GPZ)

## Demo of LilacSat-1 real-time image decoder

# gr-satellites versions and development

- GNU Radio 3.7: Versions 1.x.y. Branch `maint-3.7`. Last version 1.8.1. Perhaps last version for GNU Radio 3.7.
- GNU Radio 3.8: Versions 2.x.y. Branch `maint-3.8`. Last version 2.0.0. New versions will be released on this branch.
- Refactor: Many important changes coming in the future. Branch `next`. Work in progress. Alphas released showing new functionality. Will eventually be released as 3.0.0.

# Why is gr-satellites useful?

- Building blocks for people interested in developing their own communication systems
- Material for the study of how different satellite modems are implemented
- Readily available groundstation solution for many existing satellites

Thank you!