In-orbit results of TOTEM, an advance multi-application SDR payload, in Lume-1 mission

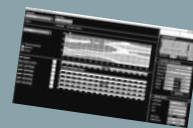Professor Fernando Aguado Agelet
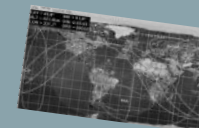
Aarón Nercellas Ventas
Electronics Engineer
5th IAA Conference, Rome, 28-31 January 2020

Background

Services

Client Business Inputs · Platform & Mission Design · Subsystems Acceptance and Verification · Nanosatellite Integration · Environmental Test Campaigns · Launch Support · Constellation Operation · Data/Service delivery
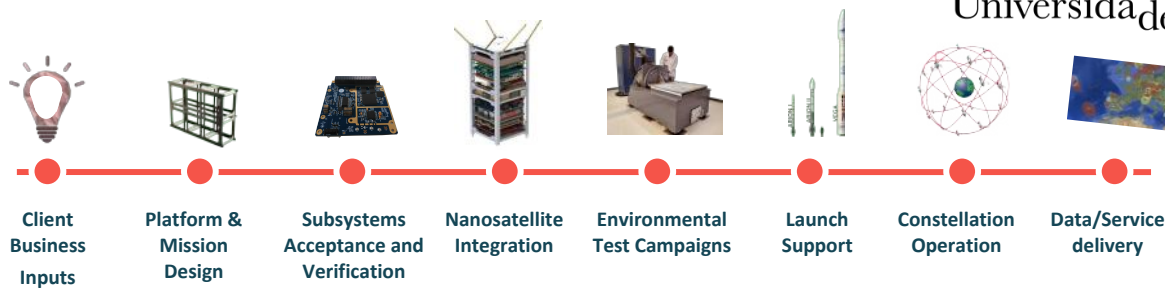
Products

TOTEM SDR · On-Board Software · Mission Control Software

Heritage

Xatcobeo 1 x 1U (2012) · HUMSAT-D 1 x 1U (2014) · SERPENS 1 x 3U (2015) · DustCube 1 x 3U (2015/2016) · LUME-1 1 x 2U (2018) · 1 x 2U (Commercial Client-2018)
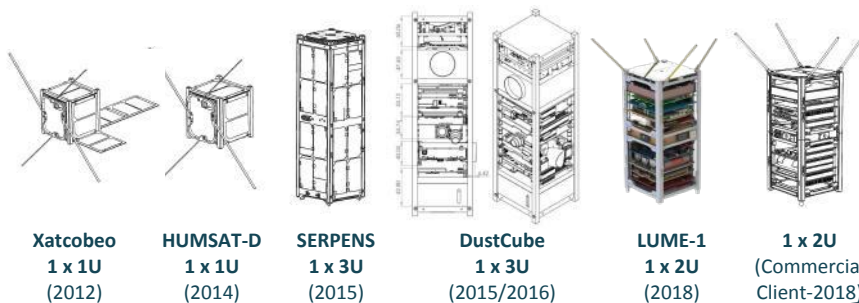
LUME-1 Mission

Wildfire detection and characterization
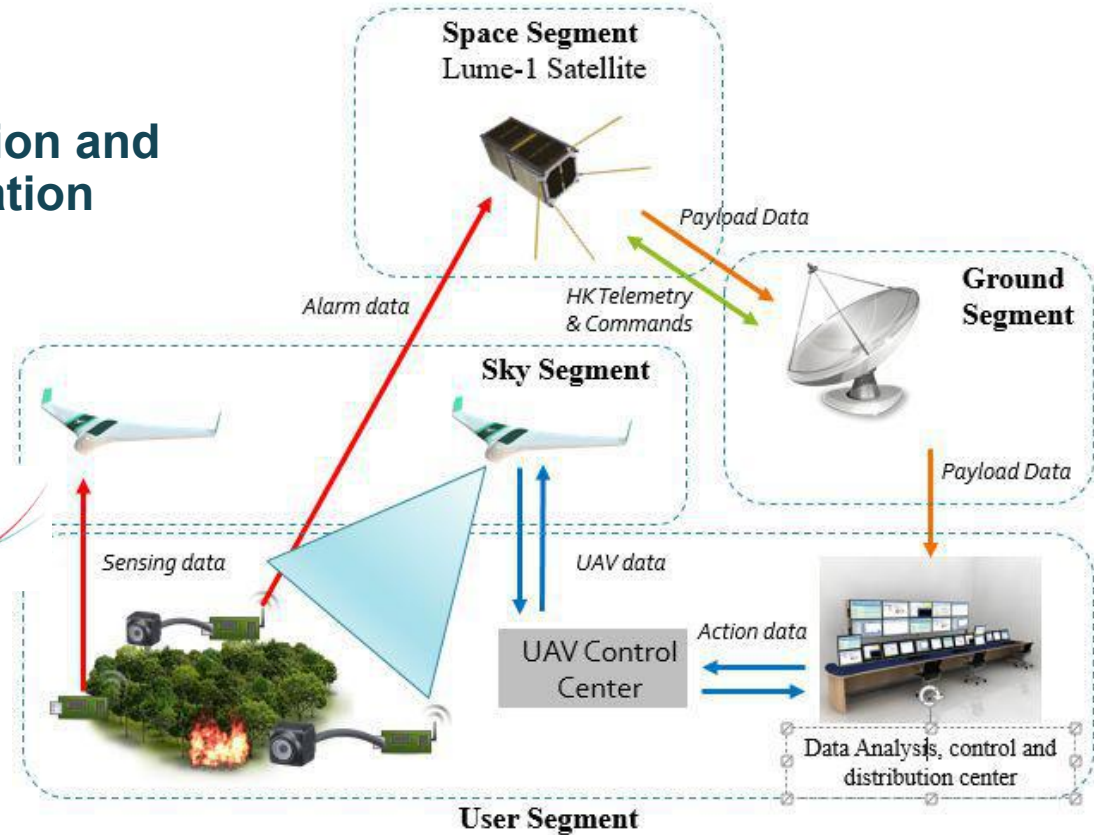
TOTEM SDR

Hardware highlights

- Zynq-7000 SoC + Wideband transceiver

- 4Gb ECC RAM

- 8Gb NAND Flash

- **Tuning range**: 70 MHz to 6 GHz

- **Bandwidth**: 200 kHz to 56 MHz

- Data interfaces: CAN, I2C, Ethernet, UART

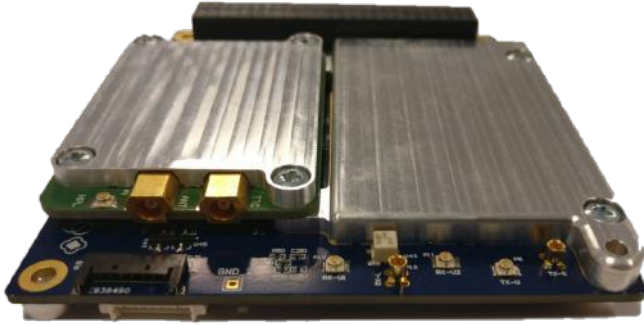- Optional RF Frontends as piggyback boards

TOTEM SDR

Software highlights

- Embedded Linux

- CCSDS Packet Utilization Standard support layer

- Safe in-orbit updates

- Radio applications / waveforms development:

  - SoapySDR driver provided

  - GNURadio support

  - Custom IP cores integration in FPGA fabric

TOTEM in Lume-1

UHF Frontend (TX/RX)
Omnidirectional antenna, shared with TTC
430-440 MHz

ADS-B Active Patch Antenna (RX Only)
L band, 1090 MHz

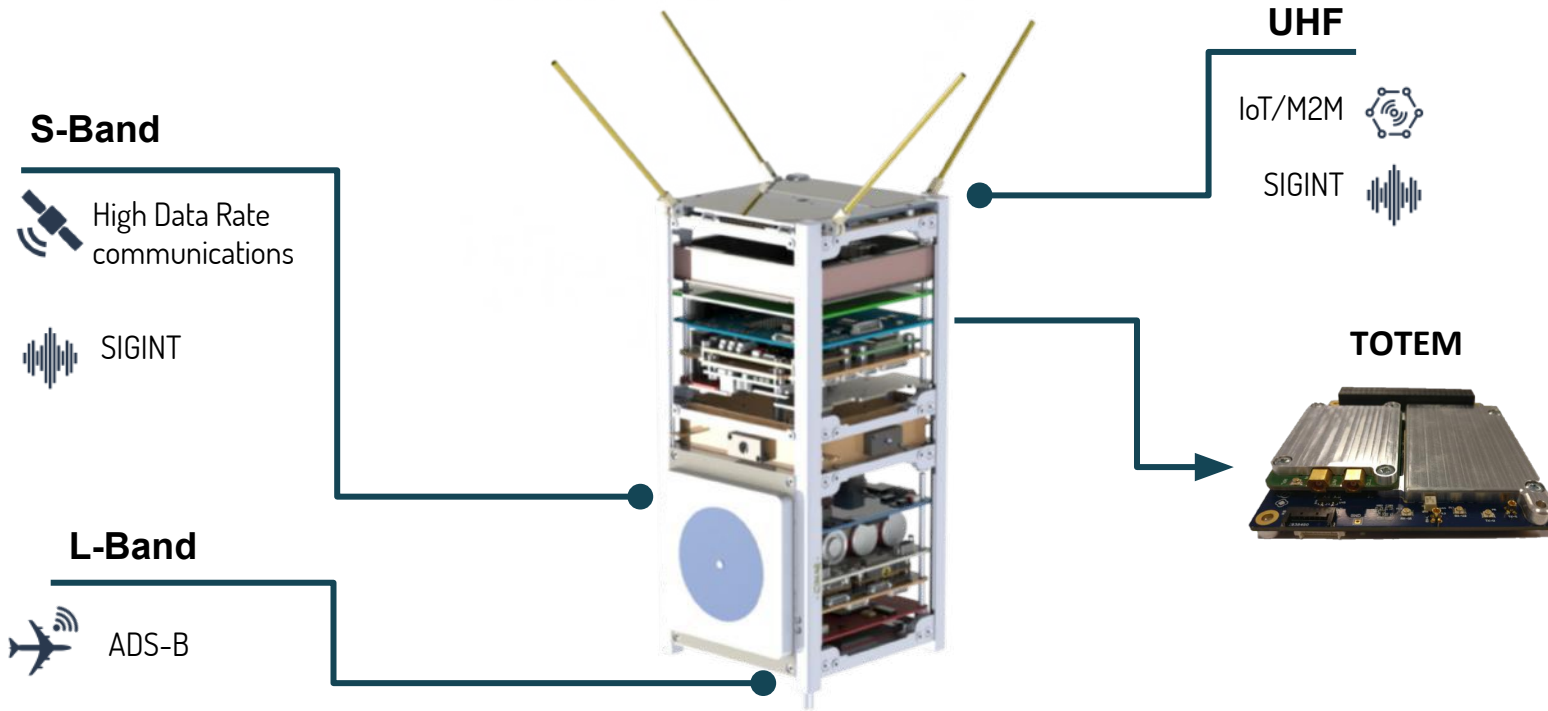**S-Band Active Patch Antenna (TX/RX)**
RX 2025-2110 MHz, TX 2200-2290 MHz

TOTEM in Lume-1

S-Band
High Data Rate communications
SIGINT

L-Band
ADS-B

UHF
IoT/M2M
SIGINT

TOTEM

Main Dashboard

OBC

P OBC BOOT CAUSE — OCDRST
P OBC BOOT COUNT — 3
P OBC CURFLASH — 0
P OBC FS MOUNTED — 1
P OBC RAM IMAGE — 0
P OBC TEMP A — 19
P OBC TEMP B — 19.5

P OBC OBC MEMFREE — 11419493
P OBC OBC BUFFERFREE — 2042
P OBC OBC UPTIME — 1941018

P OBC FLASH TOTAL — 65011712
P OBC FLASH USED — 16506880
P OBC FLASH FREE — 48504832

P OM STATE — NOMINAL

Transfer layer and stores

TMTC Transfer layer
P OP TR CONN — 0
P OP TR CONN ACTIVE — 0

131 4 spacecraftId
131 4 vChannelId
131 4 packetErrors
131 4 frameErrors

TM stores
15 13 filled 0
15 13 filled 1
15 13 filled 2
15 13 filled 3
15 13 filled 4
15 13 filled 5
15 13 filled 6

EPS

	+Z	+/- Y	+/- X
P EPS CURIN 0	26	P EPS CURIN 1 — 0	P EPS CURIN 2 — 0
P EPS VBOOST V 0	319	P EPS VBOOST V 1 — 329	P EPS VBOOST V 2 — 330
P EPS TEMP 0	14	P EPS TEMP 1 — 15	P EPS TEMP 2 — 14

P EPS TEMP 3 — 15   P EPS CURSUN — 0
P EPS PPTMODE — 1

P EPS TEMP 4 — 12   P EPS VBATT — 8234
P EPS TEMP 5 — 12   P EPS BATTMODE — 3

P EPS CURSYS — 323

OBC   P EPS OUTPUT 0 — 1   P EPS CUROUT 0 — 61   P EPS LATCHUP 0 — 0
AOCS   P EPS OUTPUT 1 — 1   P EPS CUROUT 1 — 63   P EPS LATCHUP 1 — 0
        P EPS OUTPUT 2 — 0   P EPS CUROUT 2 — 0   P EPS LATCHUP 2 — 0
TTC   P EPS OUTPUT 3 — 0   P EPS CUROUT 3 — 6   P EPS LATCHUP 3 — 0
HUMPL   P EPS OUTPUT 4 — 0   P EPS CUROUT 4 — 1   P EPS LATCHUP 4 — 0
TOTEM   P EPS OUTPUT 5 — 1   P EPS CUROUT 5 — 407 P EPS LATCHUP 5 — 0
Heater P EPS OUTPUT 6 — 0

P EPS COUNTER WDT CSP 1 — 0   P EPS WDT CSP PINGS LEFT — 5
P EPS COUNTER WDT GND — 0   P EPS WDT GND TIME LEFT — 218978
P EPS COUNTER WDT I2C — 0   P EPS WDT I2C TIME LEFT — 0

GSSB

	+X	+Y
P GSSB PX CURRENT STATE	0	P GSSB PY CURRENT STATE — 0
P GSSB PX ANTENNA STATE	1	P GSSB PY ANTENNA STATE — 1

	-X	-Y
P GSSB NX CURRENT STATE	0	P GSSB NY CURRENT STATE — 0
P GSSB NX ANTENNA STATE	1	P GSSB NY ANTENNA STATE — 1

AOCS

P AOCS BOOT CAUSE — POR
P AOCS BOOT COUNT — 251
P AOCS FS MOUNTED — 1
P AOCS RAM IMAGE — 0

P AOCS CURFLASH — 0
P AOCS CURGSSB1 — 0
P AOCS CURGSSB2 — 0
P AOCS CURPWM — 0
P AOCS CURGPS — 7
P AOCS CURWDE — 0

P AOCS GYRO TEMP 32 — 14.2035293579101562
P AOCS EXTMAG TEMP 32 — 8.375
P AOCS SUNS TEMP
P AOCS FSS TEMP — 111.0.7.437

P AOCS TDIFF UNIX
P AOCS TORQUER DUTY

TTC

P TTC BOOT CAUSE — POR
P TTC BOOT COUNT — 790
P TTC RX BYTES — 15557
P TTC RX COUNT — 181
P TTC TX BYTES — 1399392
P TTC TX COUNT — 8007
P TTC LAST RFERR — -1694
P TTC TX DUTY — 5
P TTC ACTIVE CONF
P TTC LAST CONTACT — 3120

UTC

UTC 2019/02/28 12:13:33

LUME-1 TOTEM
PERFORMANCE

UHF: M2M/IoT CONOPS

Space Segment

Storage &
Forward
Data relay

Bidirectional channel
Short message exchange
Multiuser

Ground Segment

Internet
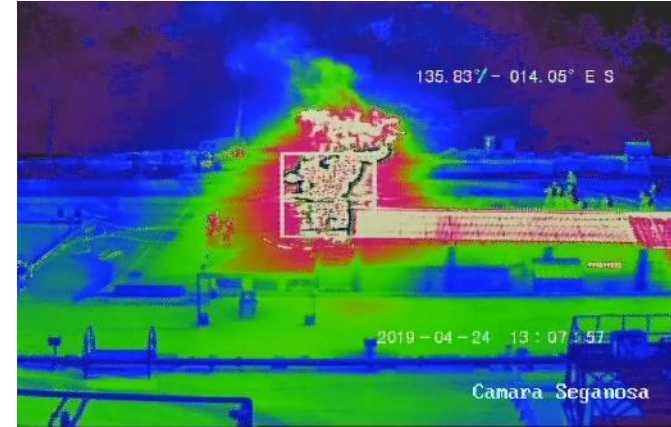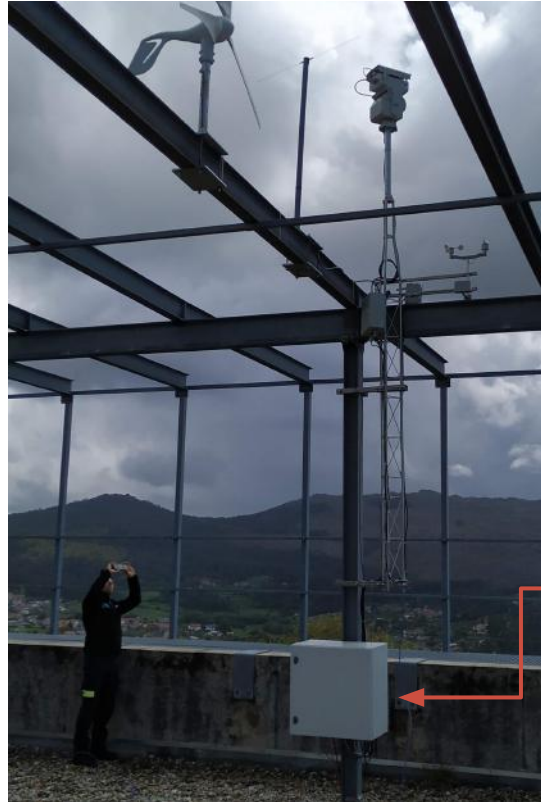
User Segment

9
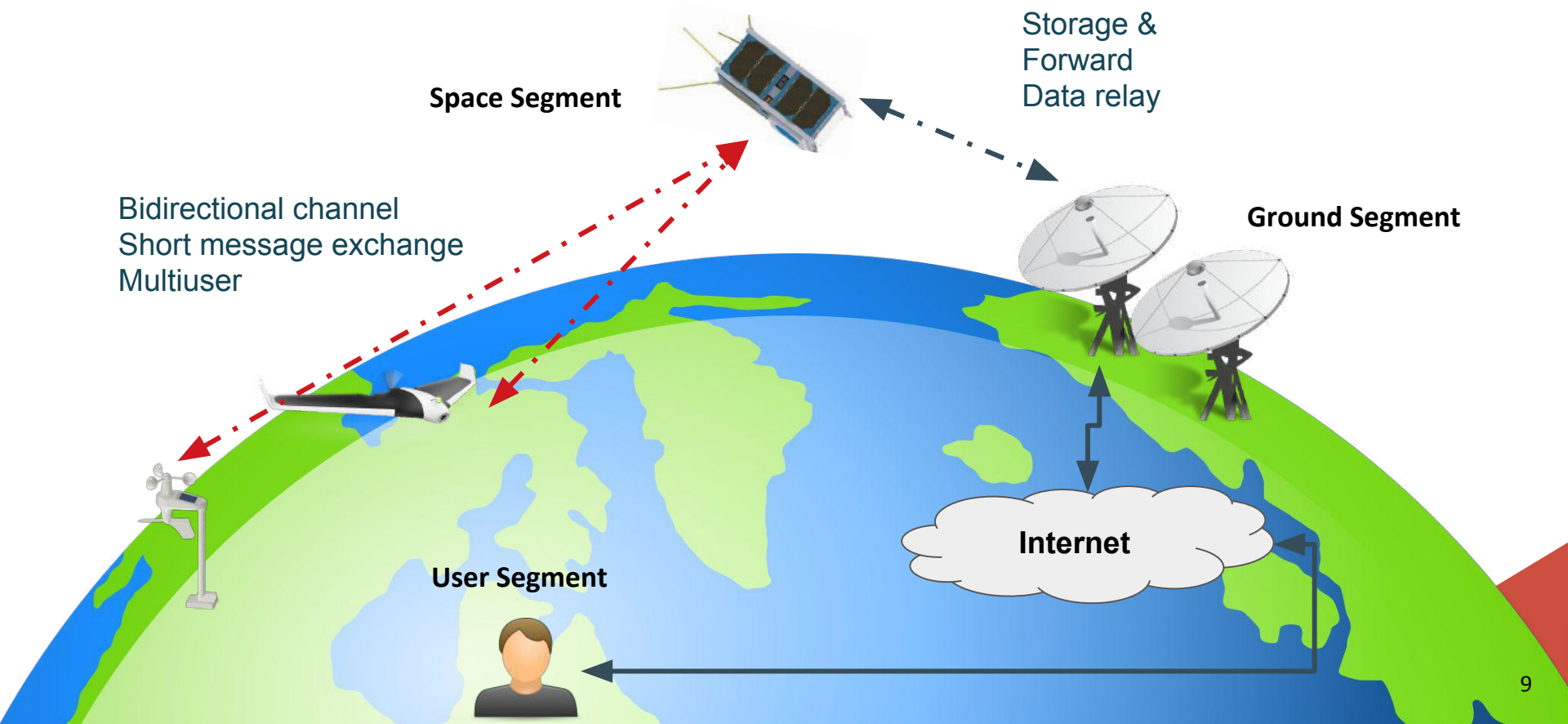
UHF: M2M/IoT Demo

Main objective of the satellite

Strong interference in the UHF amateur band

- Channel characterization (spectrum monitoring)
- Adjustment of radio parameters for real scenario
- Uploaded modifications to TOTEM (in-orbit update)

30 dBm in both ends

- No directive antennas
- Turnstile in the satellite
- Dipole on ground

135.83° / - 014.05° E S

2019 - 04 - 24 13 : 07 : 57

Camara Seganosa

M2M Terminal

UHF: M2M/IoT TOTEM TM

UHF: M2M + TTC

During operation of M2M application, we can also operate the satellite
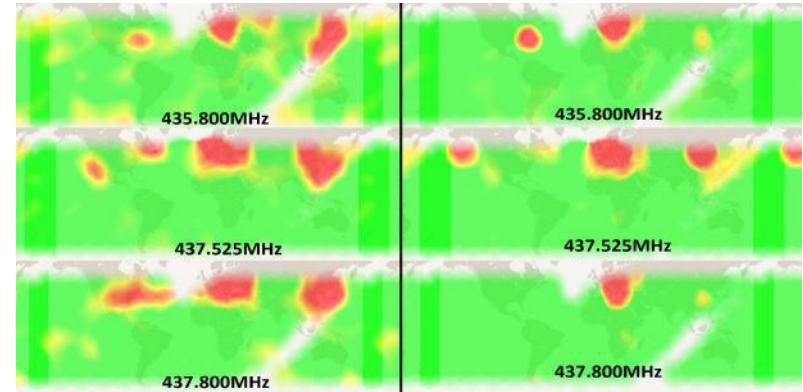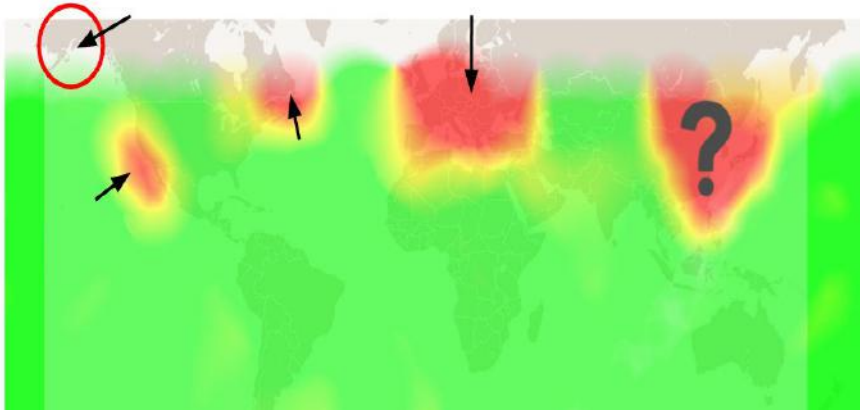
- Software TTC

Fully compatible with main radio

Frequency and bandwidth tuned to capture both UHF channels

Each channel is then downconverted and processed independently
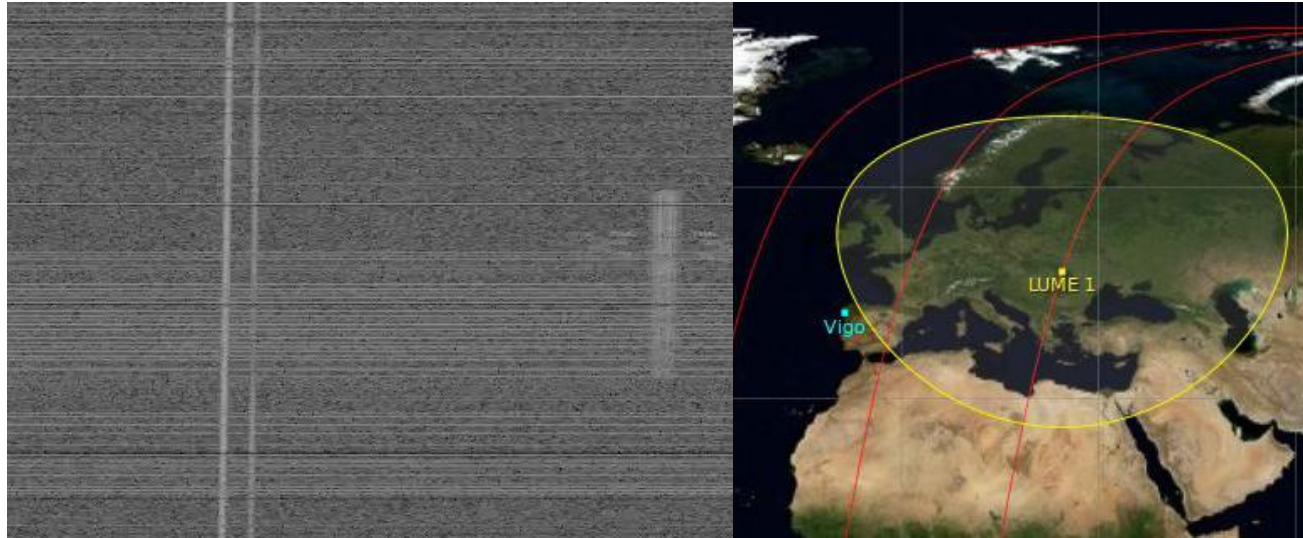
UHF & S-Band: Spectrum Monitoring

Preview example – Serpens & Humsat Satellites 2015

UHF & S-Band: Spectrum Monitoring

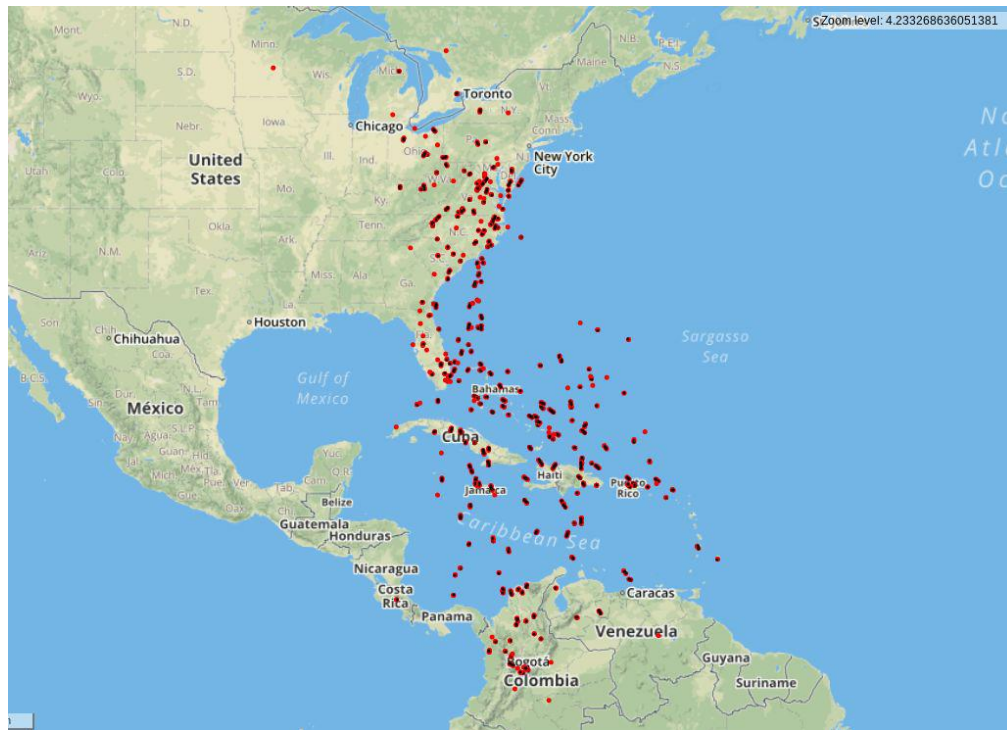LUME-1 spectrogram, 437.160 MHz, 25 kHz BW, 5 secs. (2019/03/01)

On-board postprocessing for band selection:

- Downconversion
- Filtering
- Downsampling

L-Band: Air traffic

First ADS-B capture using TOTEM

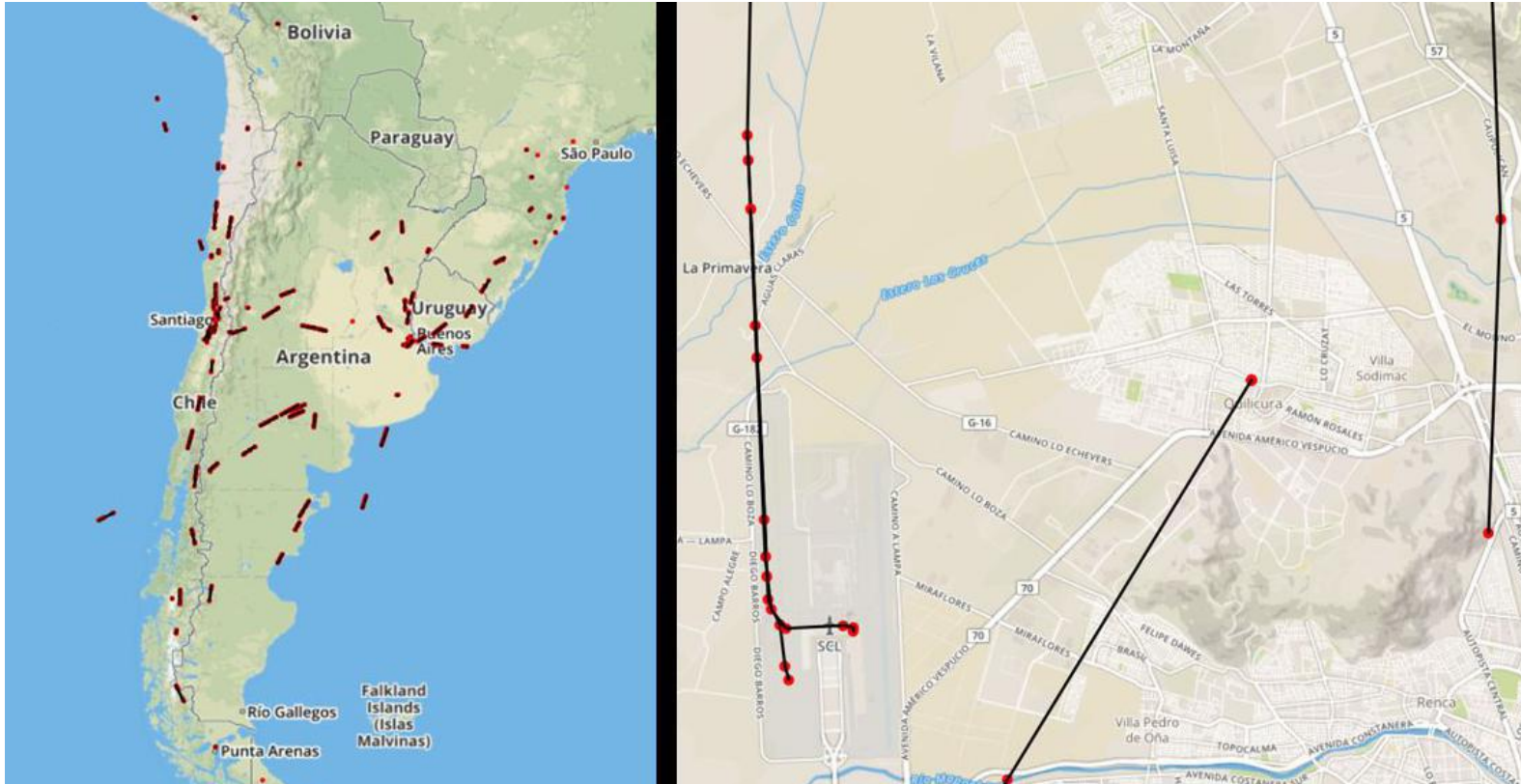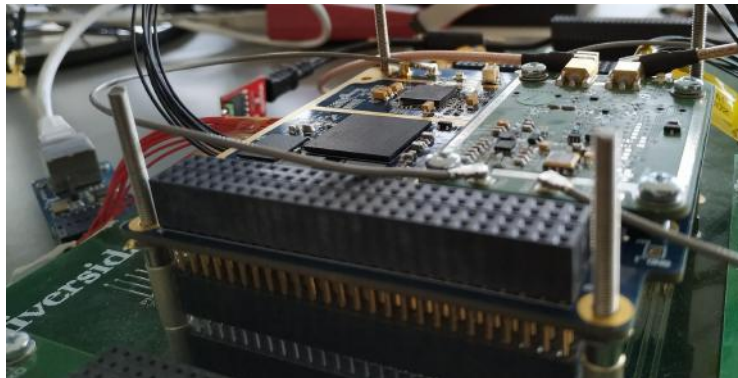|	
Location	New York, JFK
Duration	10 minutes
On-board data processing	Filtering (30 secs between positions) Compression
Statistics (after filtering)	3359 messages 1344 ICAOs 850 complete positions 305 ICAOs with complete positions

L-Band: Air traffic

UHF: APRS Digipeater

APRS digipeater for the amateur radio community

APRS digipeater

- AX.25 data link layer
- AFSK1200 modulation

70-cm Radio Amateur Band

30 dBm transmission power

Developed with satellite already in orbit

- Ground testing with EM of TOTEM and TNC + Radio
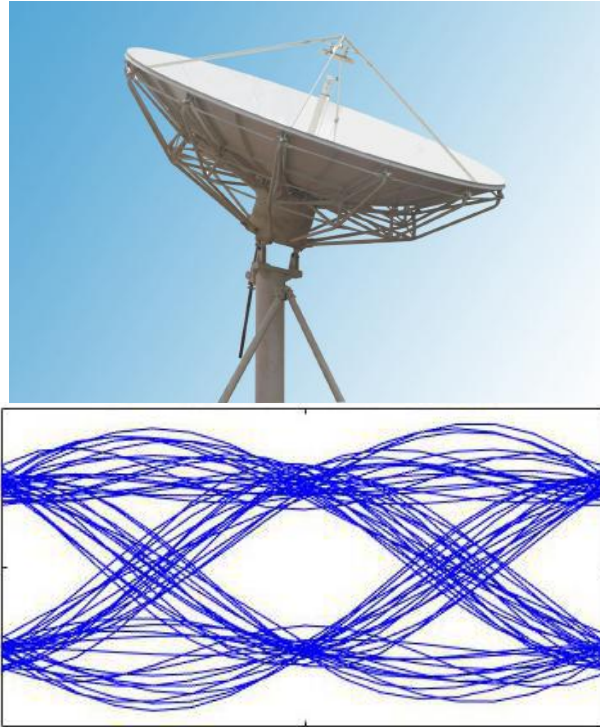
Frequency coordinated by IARU (27 May)

Tests on ground successfully completed

In-orbit test performed

- Not so good...UHF interference, no FEC...

S-band: High Data Rate communications

High data rate communications

- DVB-S2 transmitter
- First software for preliminary channel testing already on board
- **BUT** right now, antenna can only used for RX (spectrum monitoring)
- Need permission for use as TX:
  - *Frequency coordination in progress*

Remarks

TOTEM apps successfully tested in-orbit:

- M2M communications
- TTC
- Spectrum monitoring
- ADS-B air traffic reception
- APRS digipeater

Soon:

- DVB-S2 transmitter

Some of these applications uploaded after launch through remote updates

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