Spacecraft Beacons: radiocommunication approaches towards interoperable autonomous self-identification and tracking

09. October 2024, Clean Space Days, ESTEC

Sebastian Lange
Chair of Space Technology
Technische Universität Berlin (TU Berlin)

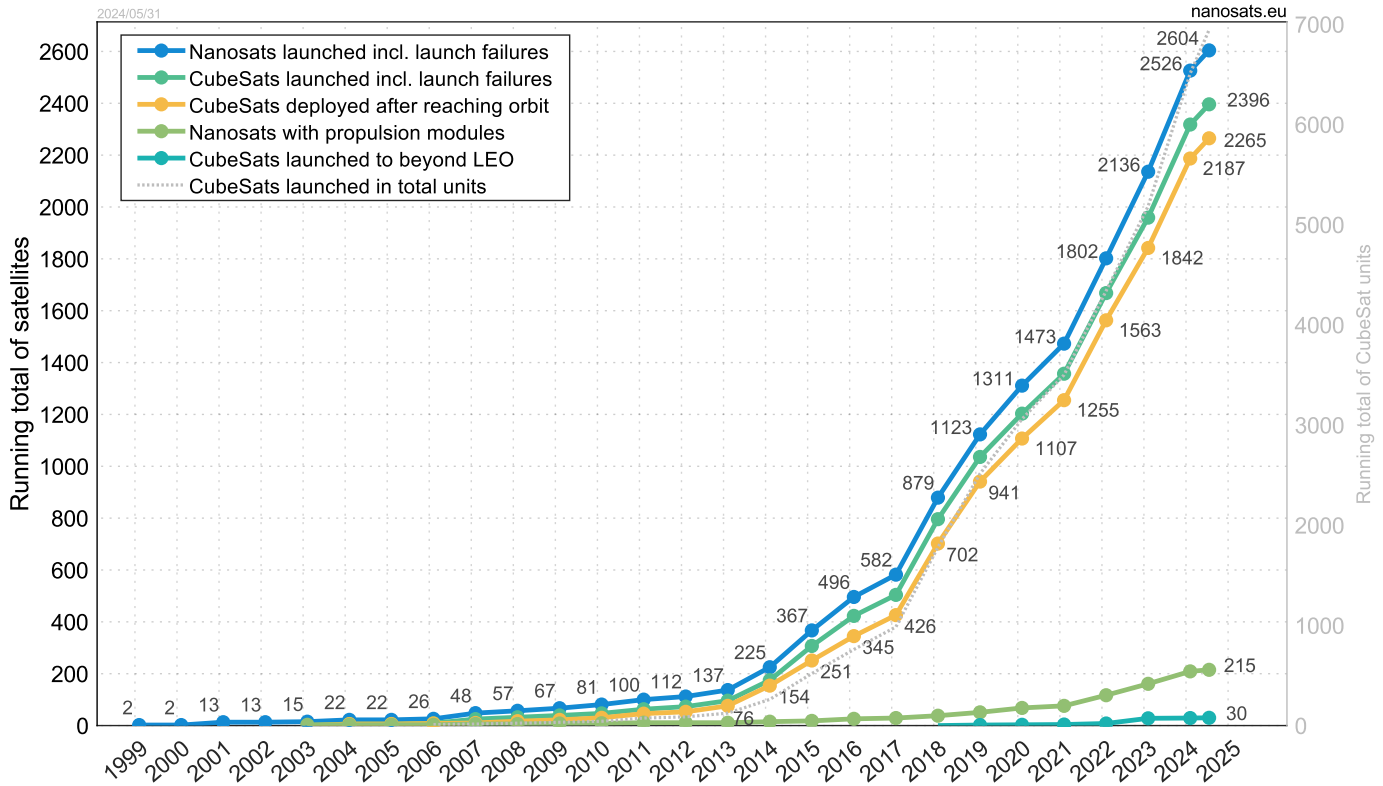
Chair of Space Technology

- **Satellite missions**
  - In orbit: 19 missions with 30 satellites
  - 2 constellations, 2 swarms
  - 375 g – 22.5 kg … 50 kg (upcoming)
  - Planned: 4 missions with 4 satellites
- **Exploration technologies**
  - Planned: 1 experiment on lunar surface
- **Multiple platforms, e.g.**
  - TUBiX5
  - TUBiX20

Current State: Smallsat (R)evolution

- **Exponentially increasing number of objects**
  - Projections for coming decade: tens of thousands to millions
- **Mainly stochastic *traffic management* via orbital lifetime**
- **No interoperable passive tracking system**
  - Left to operators themselves

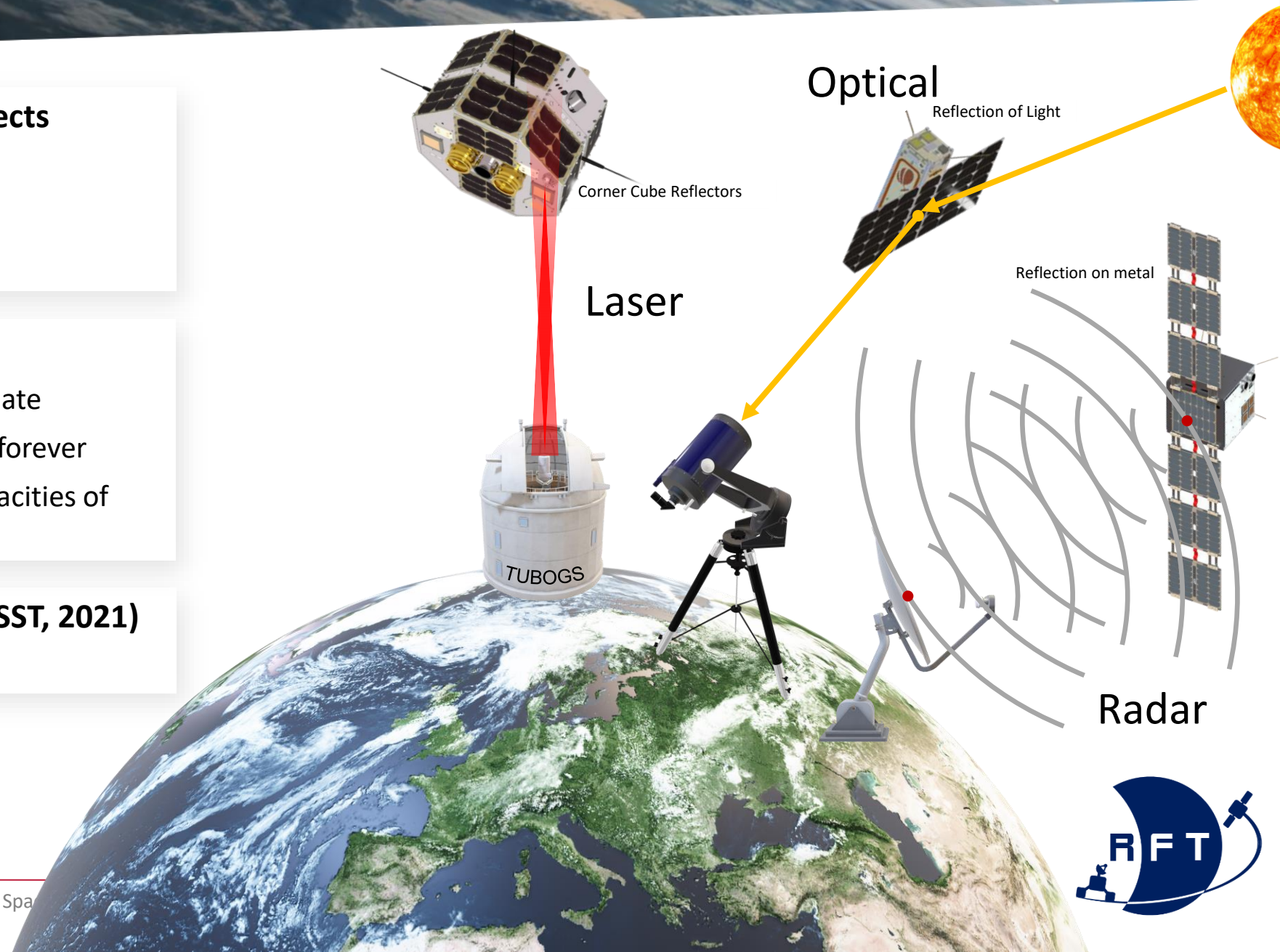
Total nanosatellites and CubeSats launched



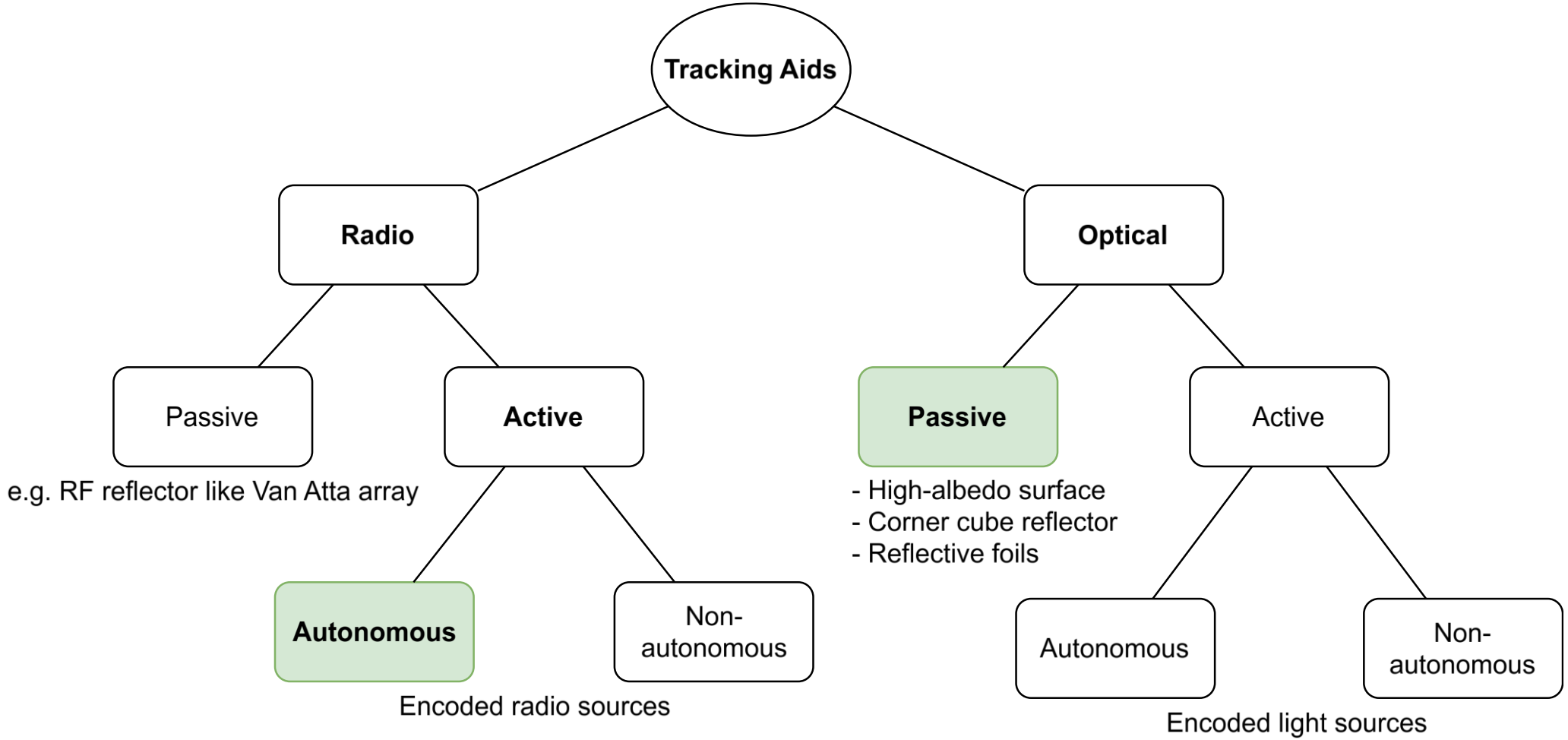
Source: https://www.nanosats.eu/img/fig/Nanosats_total_2024-05-31.svg

Current State: Detection and Identification

- **Limited identification of space objects**
  - Characteristics of reflection(s)
  - Radio transmissions
  - Separation parameters
- **Challenges**
  - Manual processes, difficult to automate
  - Identification takes days, months or forever
  - Limited tracking capabilities and capacities of radar systems
- **EU Space Surveillance & Tracking (SST, 2021)**
  - Merging European sensor data



Tracking Aids: Overview



Motivation

- **Closing gaps to radar systems**
  - Trackability
  - Information: identification, status etc.
  - Scalability
- **Features**
  - Facilitate first contact till re-entry with information
  - Simplify emergency intervention (optional)
  - Trigger End of Life (EOL) disposal (optional)
- **Sustainability**
  - Economic: protection of space assets
  - Ecological: avoidance of space debris
    - Sustainability and security goals (national, ESA, EU, UN)

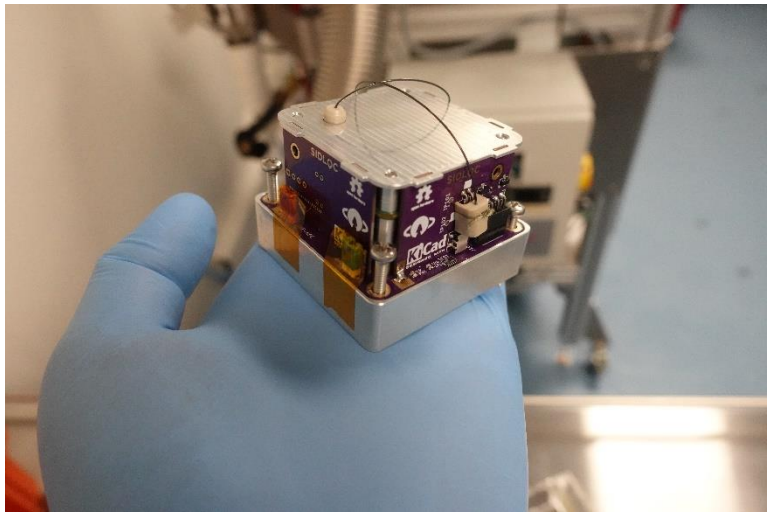
Approaches to date

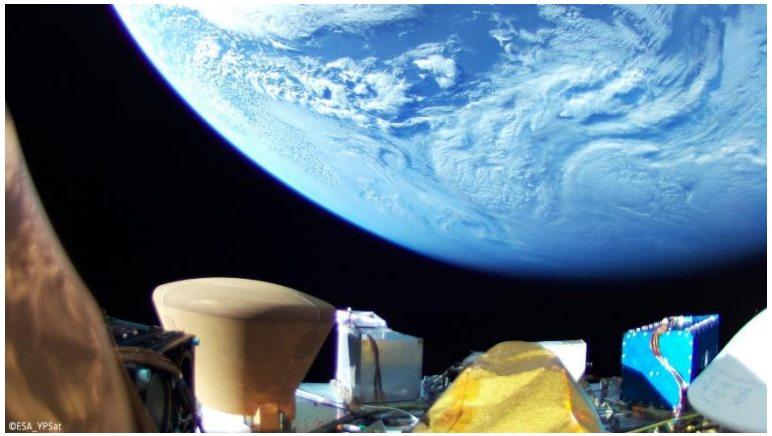
System	Developer	Origin	Shape	Modulation	Freq. Band	Lifetime	License
Black Box	NSL	USA	Three versions	(W)CDMA *Globalstar*	1600 MHz	autonomous	proprietary
Blinker	Aerospace	USA	Side Panel Box	FSK?	915 MHz (ISM R2)	autonomous	proprietary
CUBIT	SRI	USA	Elec.+Ant. Unit	FSK?	915 MHz (ISM R2)	30 days	proprietary
OWL	C3S	ESA/HNG	Tuna Can	FSK?	137 MHz	18 hours	proprietary
RILDOS	Kratos et al.	USA	*Specs only*	DSSS BPSK	*TM Inband*	none	open
SIDLOC	LSF	ESA/GRC	PocketQube	DSSS BPSK	401 MHz	autonomous	open

SIDLOC (Satellite IDentification and LOCalization)

- **Libre Space Foundation (LSF)**
  - Manifesto: 5 principles, 4 pillars incl. open knowledge
  - Multiple ESA and FOSS community projects
    - Satellite Networked Open Ground Station (SatNOGS)

- **SIDLOC scope**
  - Identification and tracking via Doppler shift measurements
  - Proposed coexistence with other space operations
  - Project state:
    - Successful on-orbit verification of principle with Ariane 6
    - See FOSDEM presentation[1]



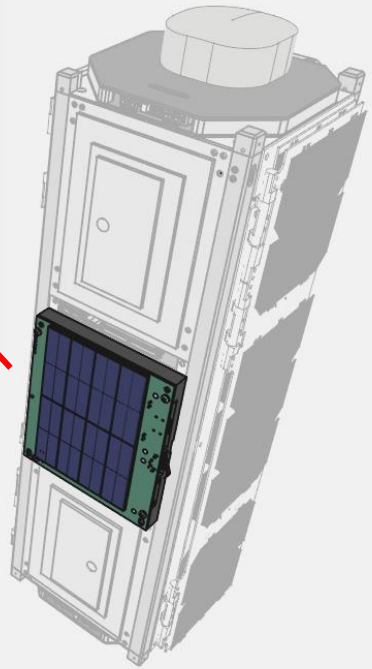


[1]: https://archive.fosdem.org/2024/schedule/event/fosdem-2024-2114-sidloc-spacecraft-identification-and-localization-system/

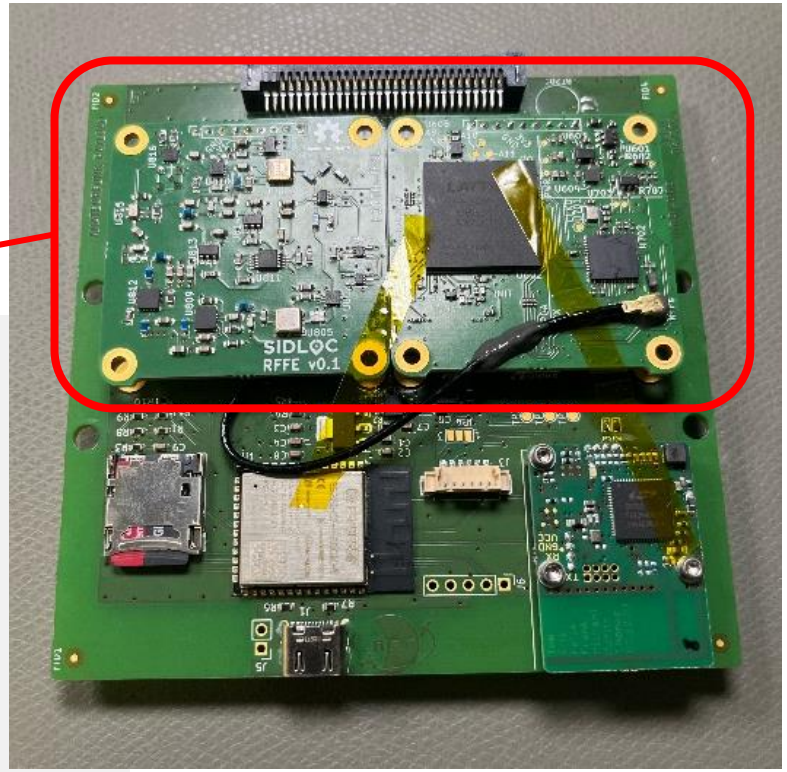
SIDLOC-BEECON: Mission Overview

- **Mission schedule 2024-2026**

Mission	Ops	Launch	Spacecraft
Ariane 6	LSF	2024-07-09	2nd Stage
InnoCube	TUB	01/2025	3U CubeSat
Erminaz	LSF	06/2025	PocketQube
UARX	LSF	06/2025	PocketQube
PHASMA	LSF	06/2025	3U CubeSat
QUEEN	TUB	Q4/2026	64U “Cube”



PHASMA Beacon Design
(approx. 97x83x9 mm³)



InnoCube Beacon Hardware
(approx. 90x45x10 mm³)

BEECON (Berlin Experimental and Educational Beacon)

- **Objective**
  - European cooperation → International solution
- **Challenges**
  - Regulatory frameworks: National, CEPT, ITU
  - Technical development: miniaturisation, energy efficiency, low cost, fail-safe, simple integration
  - Harmonisation/standardisation: which bodies?
  - Adoption
- **Vision**
  - Simple plug&play attachment
  - No expensive and time-consuming coordination

SIDLOC

esa

DLR

Bundesministerium für Wirtschaft und Klimaschutz

BEECON

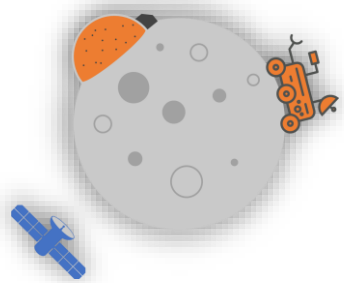
Summary & Outlook

- **Where are we?**
  - First approaches and flight experiments
  - Distinct companies and communities
  - No interoperable autonomous self-identification and tracking
  - **We’re at the very beginning!**

- **How to proceed?**
  - More technical development, experiments and public results
  - Technical harmonisation and standardisation important
  - Frequency band(s) not subject to coordination mandatory
  - Usage of open standards most promising path
  - **Collaborate and contribute on European and global level!**

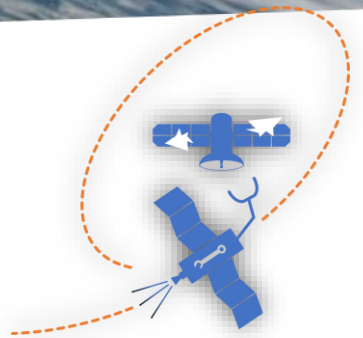
Further information … ☺

Chair of Space Technology

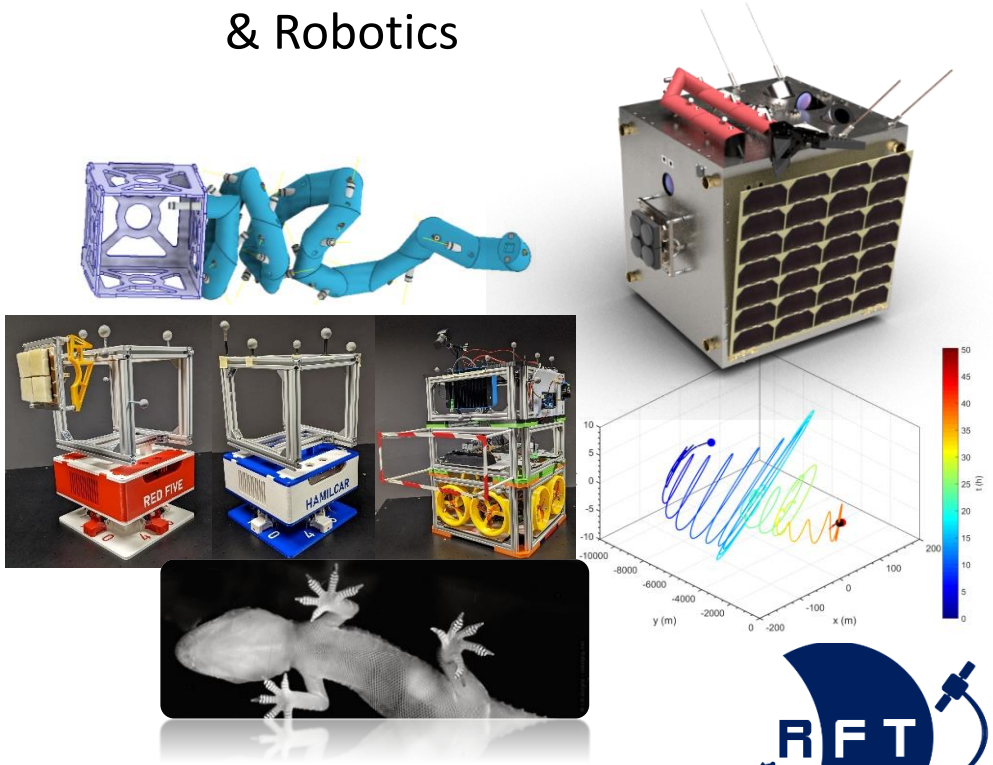


Exploration & Propulsion

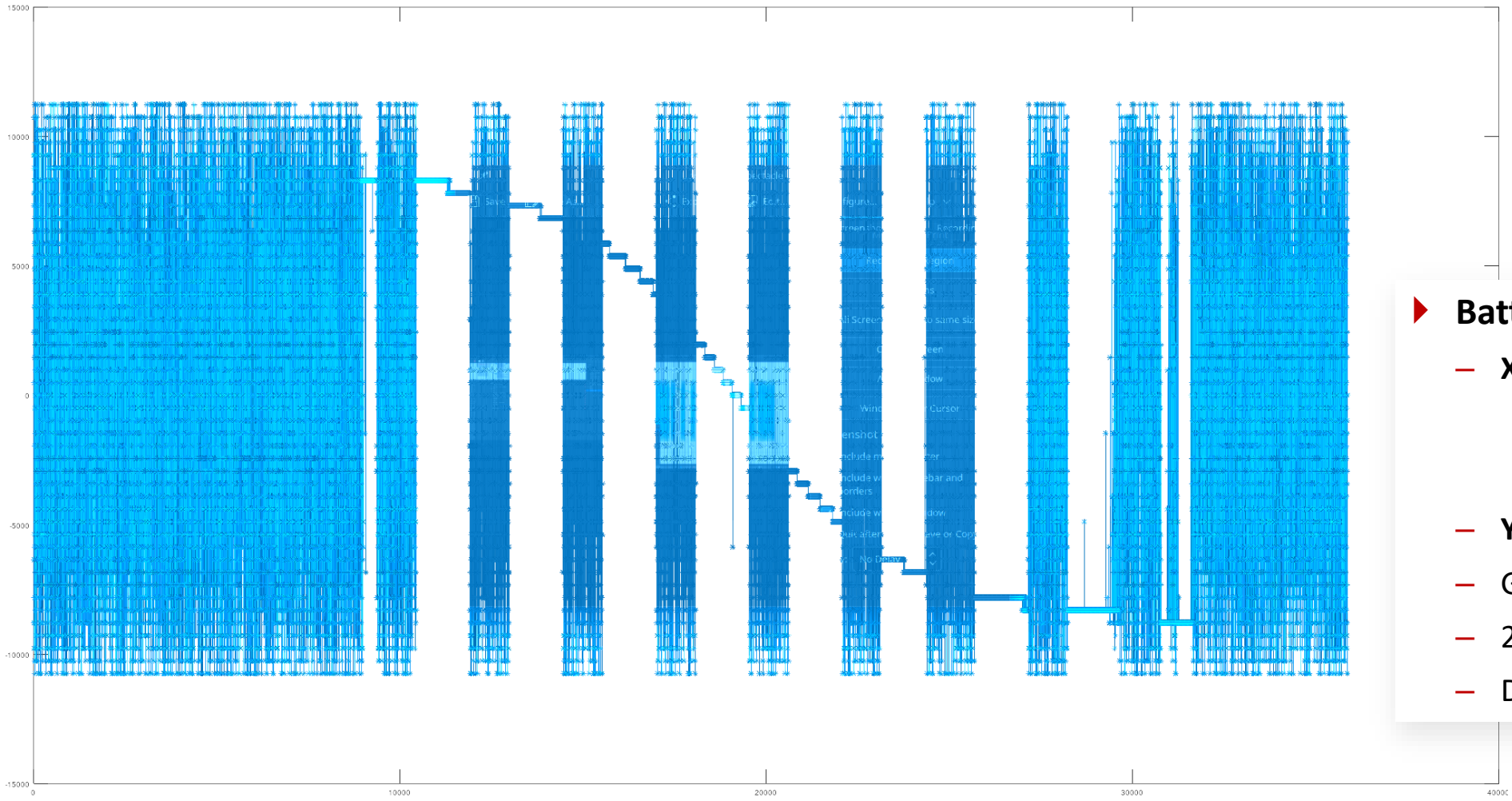
Distributed Space Systems

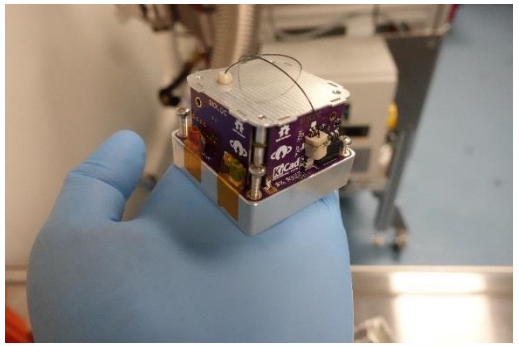


SmallSat Rendezvous & Robotics



SIDLOC-AR6 Experiment

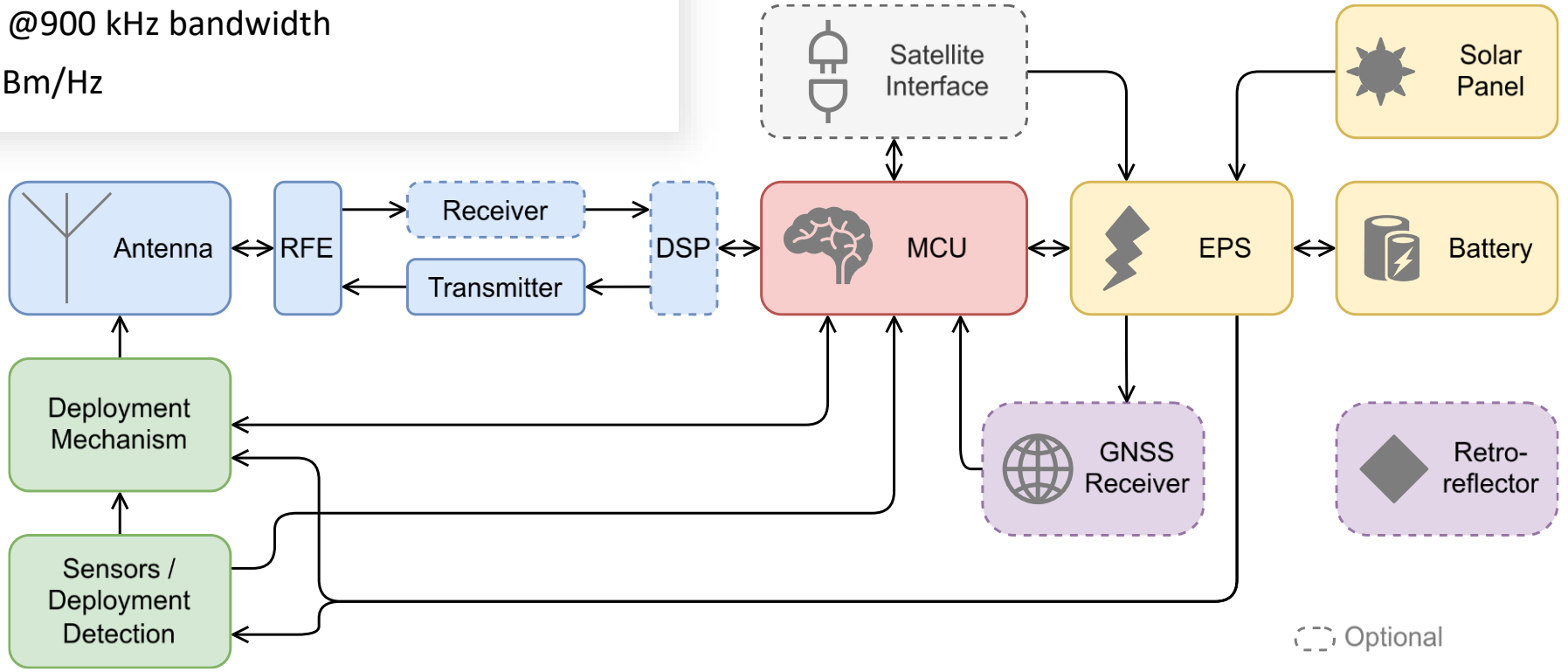




- **Battery-powered PoC**
  - **X-axis**: decimated samples
    - 30 s TX
    - 20 s pause
  - **Y-axis**: freq. offset estimation
  - Gold sequence: 2047 bits
  - 20 repetitions / spread symbol
  - Doppler estimation ±11 kHz

SIDLOC-BEECON: Technical Overview

- **Design goals 2026**
  - Transmit unique satellite ID (optional: location, satellite status)
  - Self-contained system within 50x50x6 mm³
  - Avg. power budget: 40 mW
  - RF peak power: 400 mW @900 kHz bandwidth
  - RF power density < -33 dBm/Hz



Radiocommunication: Regulatory

- **Past**
  - **1959**: First Space services in RR
  - **1968**: Art. 5, 30.005-30.010 MHz SPACE (Satellite identification)

- **Present**
  - **2019**: “ITU-R’s contribution in implementing the outcomes of the World Summit on the Information Society and the 2030 Agenda for Sustainable Development” (Res. 61-2, Radio Assembly RA-19)
  - **2022**: “ITU's role in the implementation of the "Space2030" Agenda” (Res. 218 and 219, Plenipotentiary Conference PP-22)

  …

Radiocommunication: Regulatory (cont.)

- **2023 (RA-23)**
  - Proposed Study Question (SQ) not adopted: “Studies related to possible radiocommunication solutions for the identification and tracking of spacecraft [and debris]”
  - Res. ITU-R 74: “Activities related to the sustainable use of radio-frequency spectrum and associated satellite-orbit resources used by space services”
- **2024 (RA-27)**
  - Study Group (SG) 4, Working Party (WP) 4A tasked with ITU-R 74:
    1. Technical activities in all SGs
    2. Handbook on best practices
  - Reply Liaison Statement from SG 7, WP 7B:
    - noting it covers space radiocommunications applications,
    - encouraging members to provide contributions