Orekit for small satellite missions at TU Berlin

Clément Jonglez | Orekit Day 2019 | Darmstadt

- 16 satellites launched since 1991
- 1 to 56 kg
- 8 satellites currently operated
- 4 ground stations in use
- 6 missions in preparation

The TUBiX20 platform

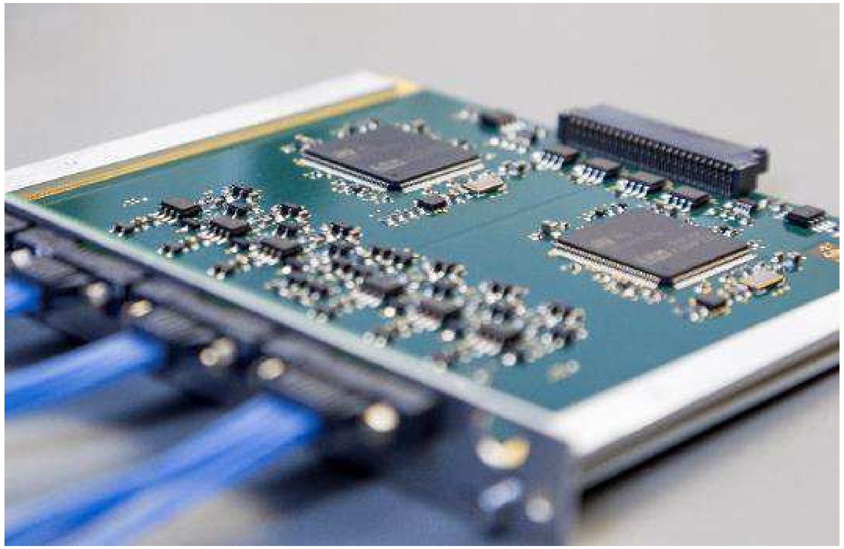
Satellite platform for missions above 20 kg

Hardware:

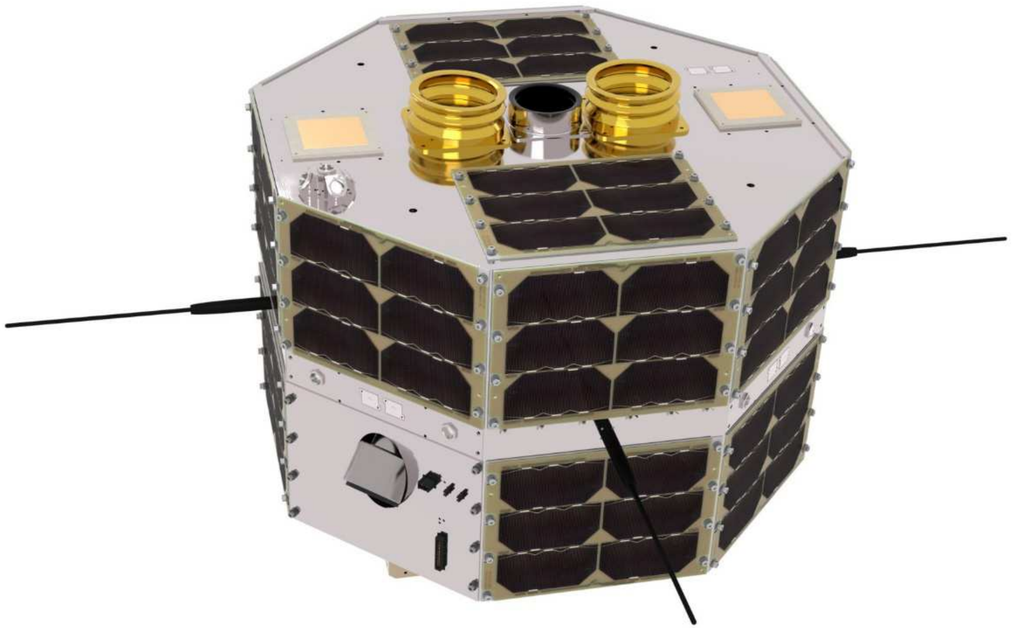
- Network of redundant computational nodes
- Standardised hardware interface

Software:

- Network of building blocks
- Publisher/subscriber protocol



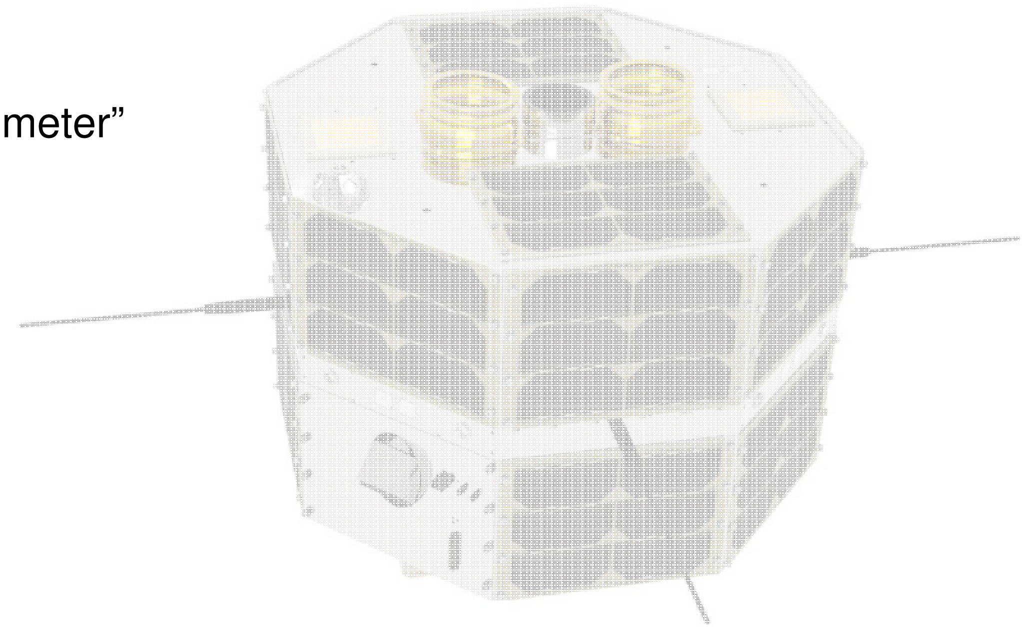
The TUBIN mission



The TUBIN mission

“To demonstrate wildfire detection
with a thermal infrared microbolometer”

- Mass: 23 kg
- Launch: 2020
- Orbit: 600 km, SSO (tbc)
- Project phase: phase D

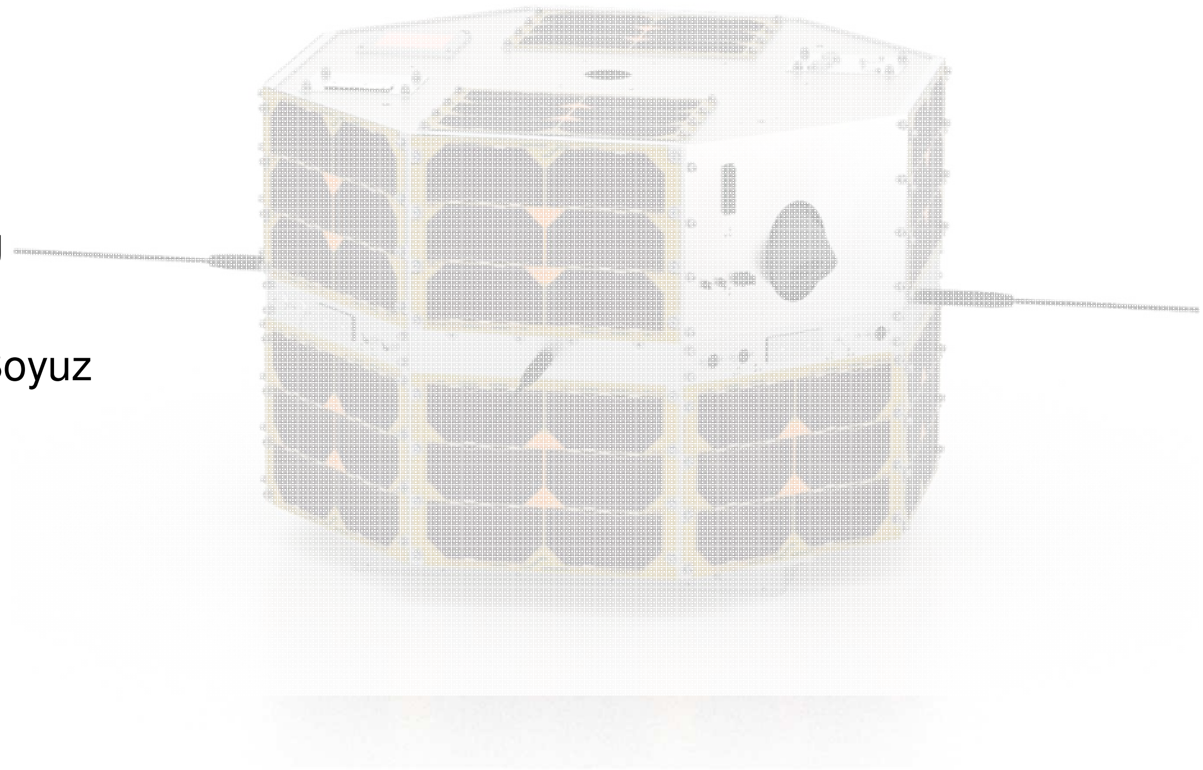


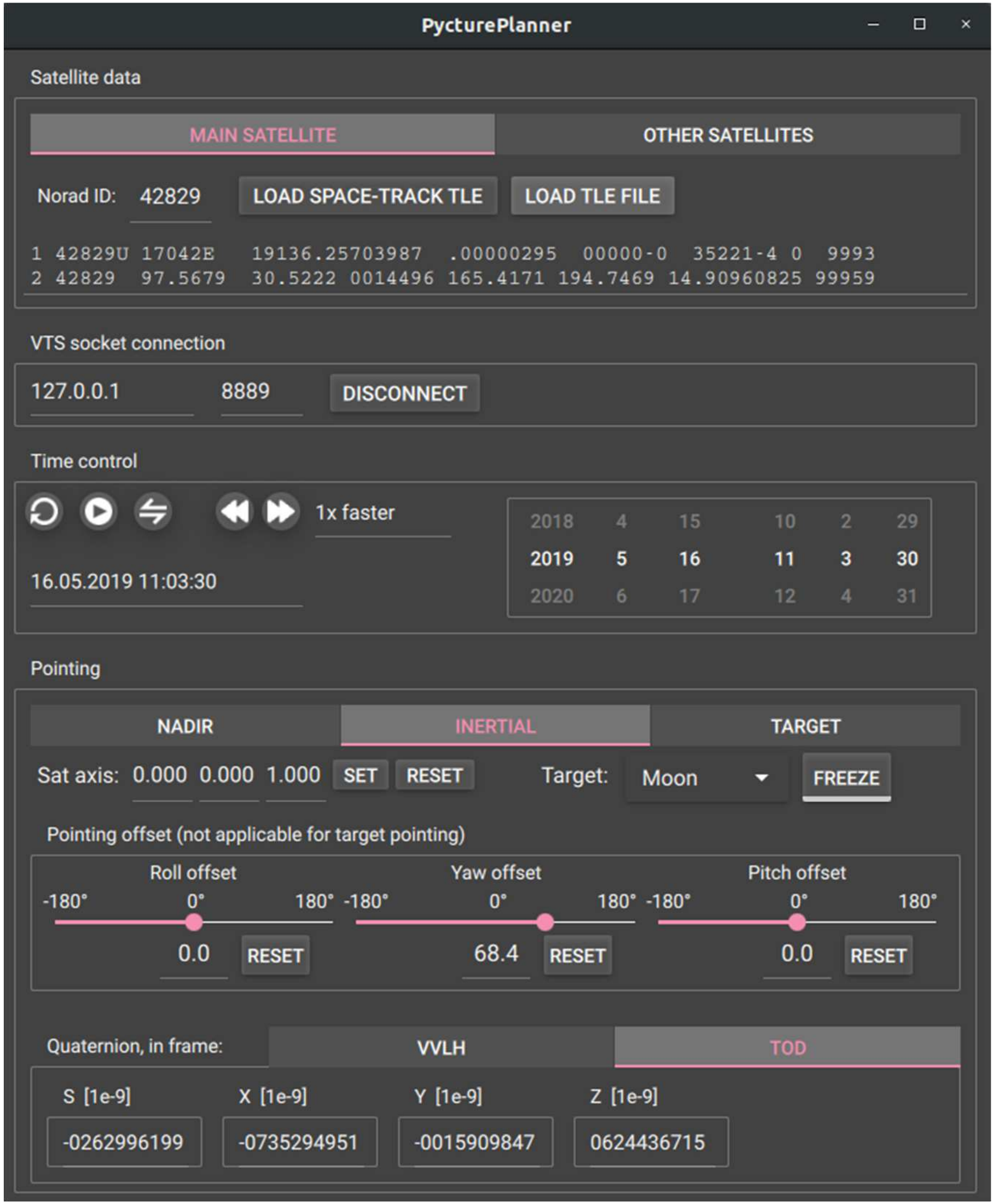
The TechnoSat mission

The TechnoSat mission

“Demonstrating novel small
satellite technology on orbit”

- Spacecraft mass: 20 kg
- Orbit: 600 km, SSO
- Launch: July 2017 on Soyuz



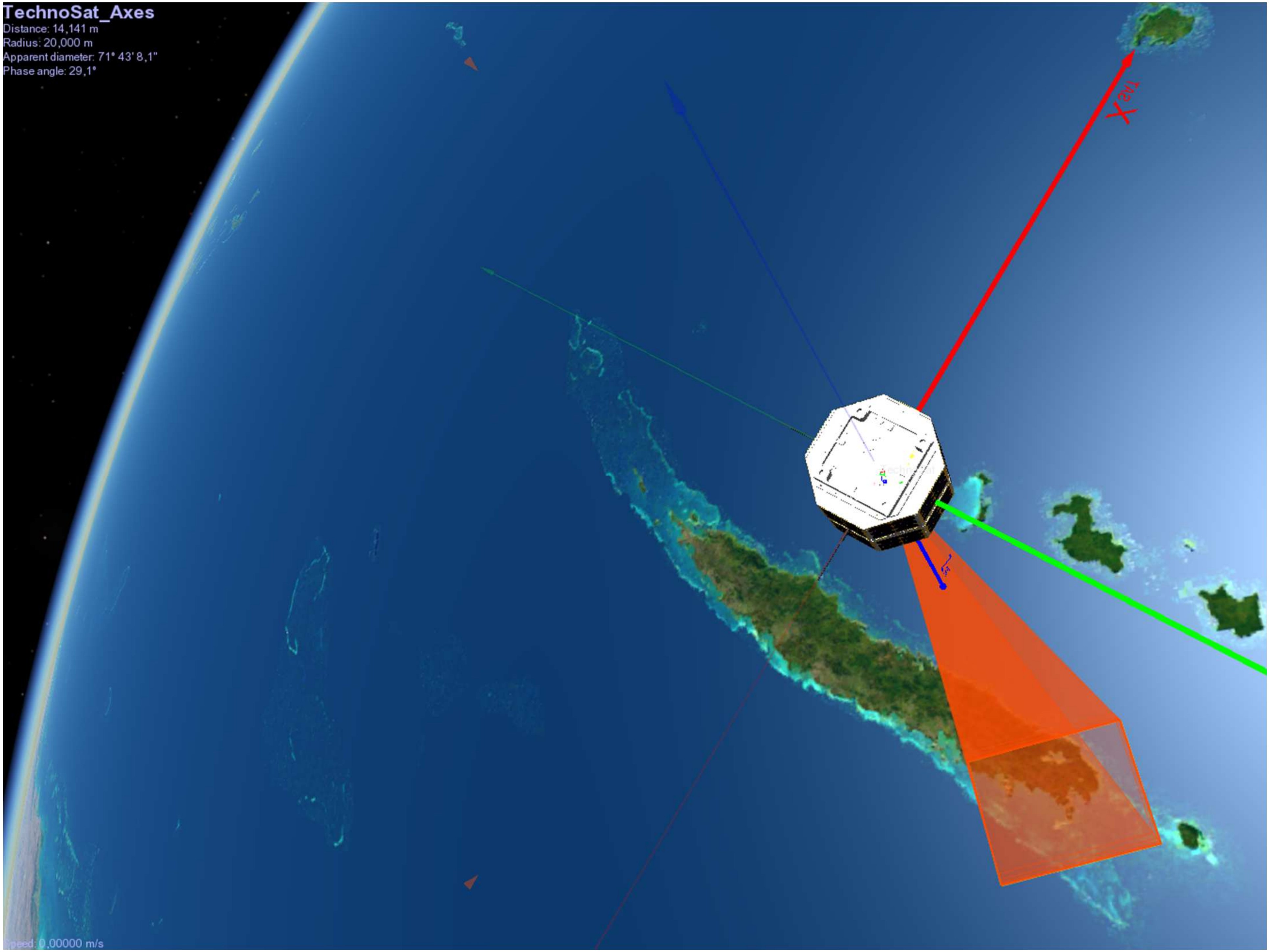


Technische Universität Berlin

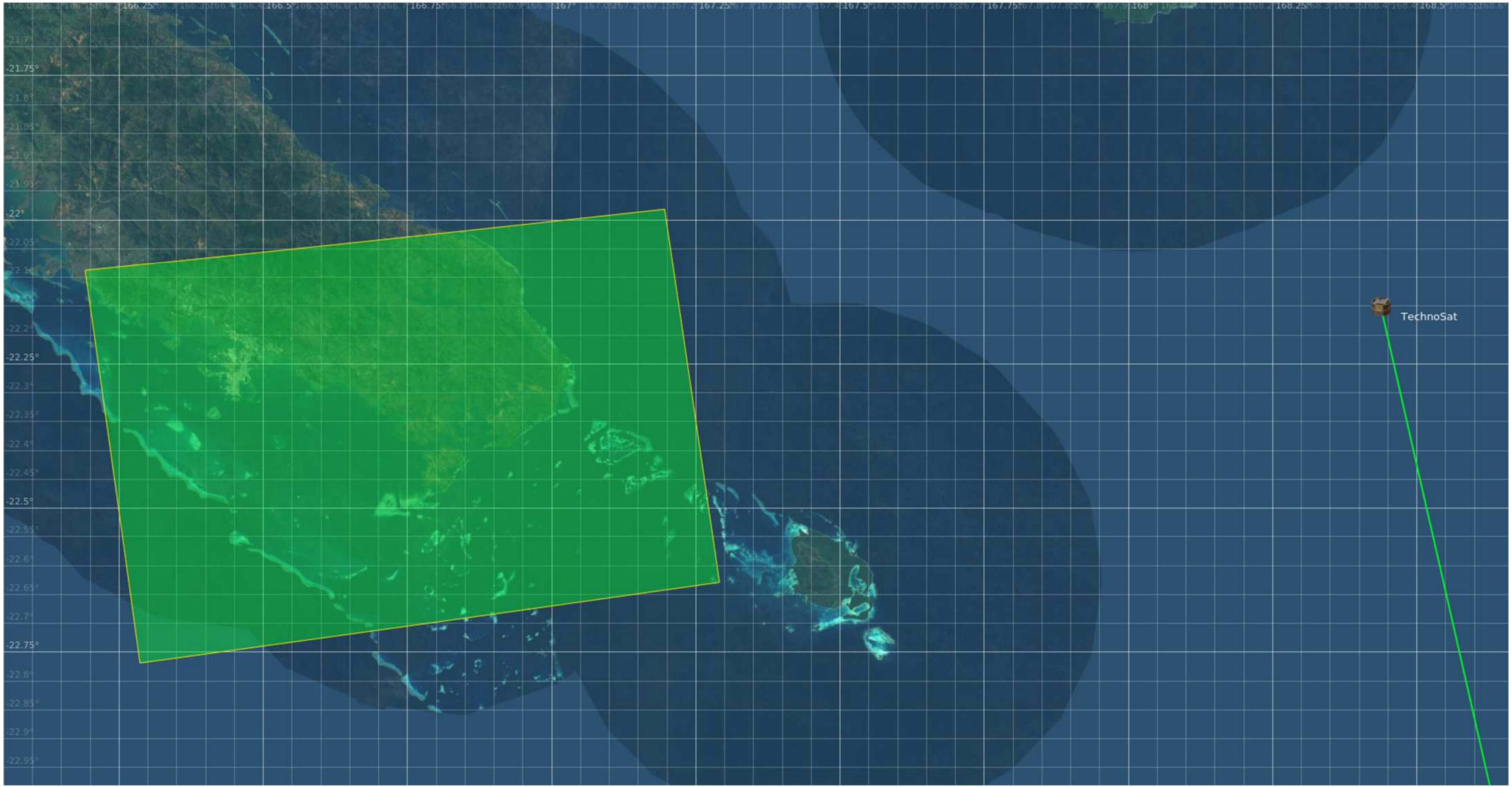
Picture planning

PyctuePlanner: GUI in Python + PySide2 + Orekit

- VTS visualization (Spacebel/CNES)
- One main satellite with configurable attitude + secondary target satellites
- Attitude modes:
  - Nadir
  - Inertial
  - Celestial body
  - Satellite target
  - Ground target


TechnoSat_Axes
Distance: 14,141 m
Radius: 20,000 m
Apparent diameter: 71° 43' 8,1"
Phase angle: 29,1°
Speed: 0,00000 m/s

Picture planning

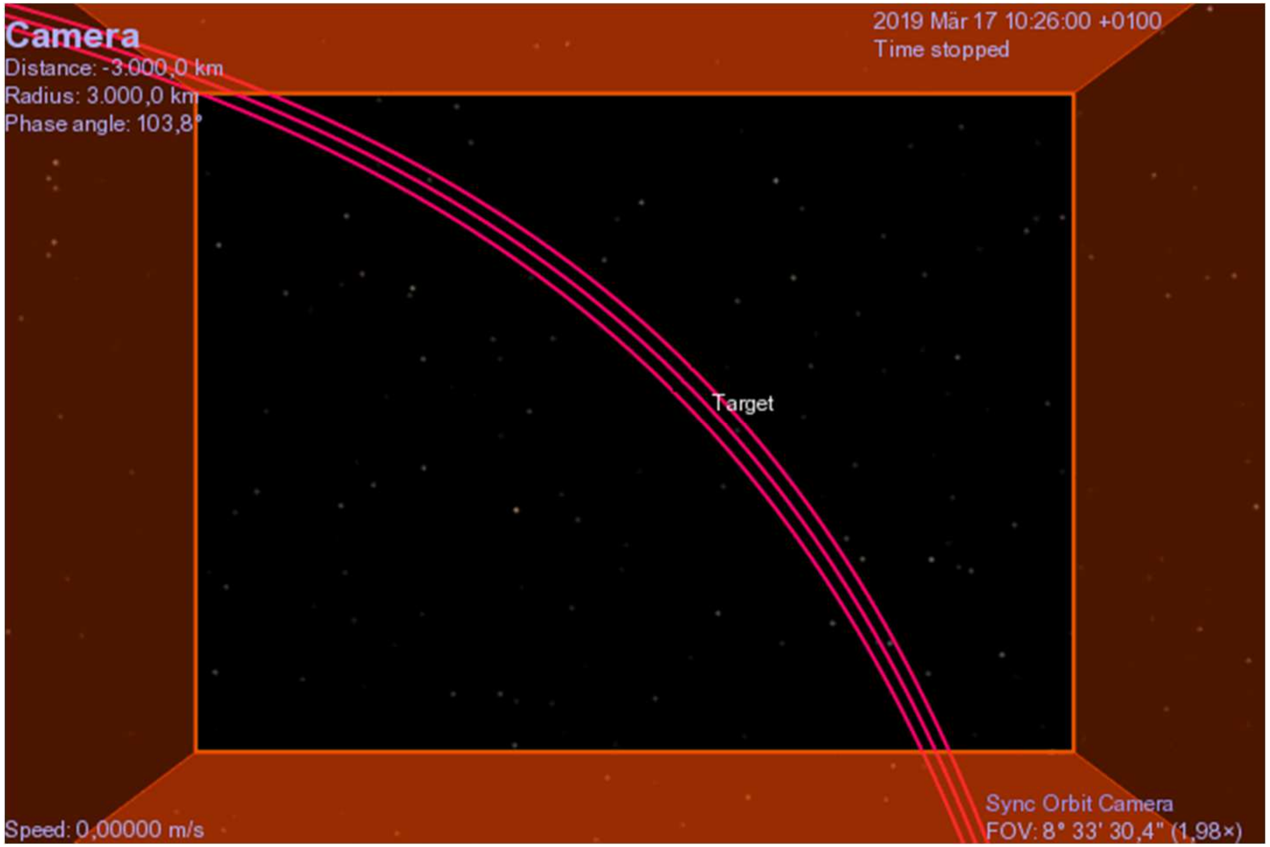


Picture planning

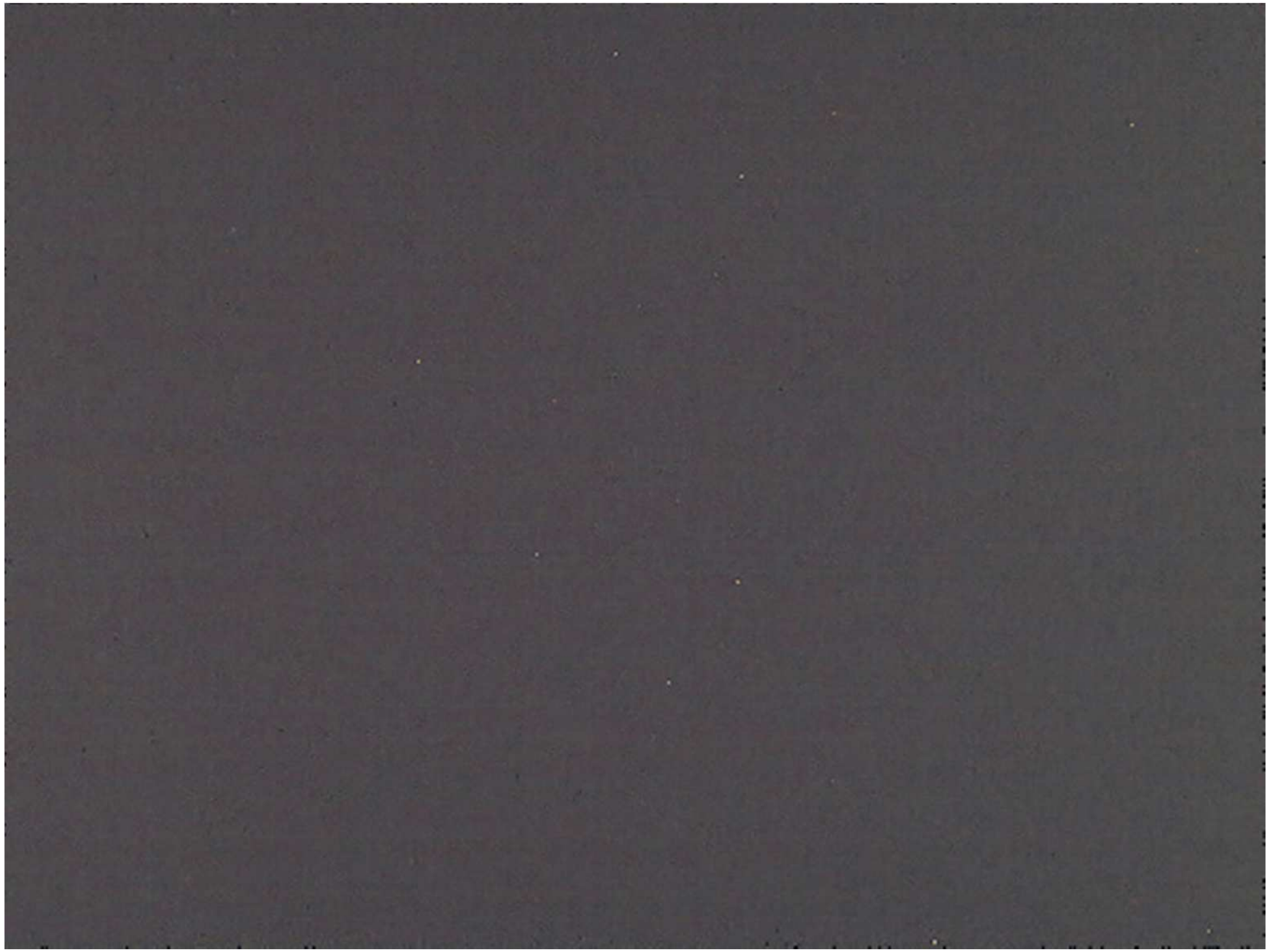
Result: close enough!

Fly-bys

- Regular fly-bys with other satellites



Fly-bys



ADCS verification: Moon & Jupiter conjunctions

- Planning: PycturePlanner + VTS
- Analysis: JupyterLab + Python + OpenCV + Orekit
  - Computation in Orekit of the satellite position and the vectors to celestial bodies
  - Attitude determination using Numpy's SVD
  - Comparison with onboard attitude determination

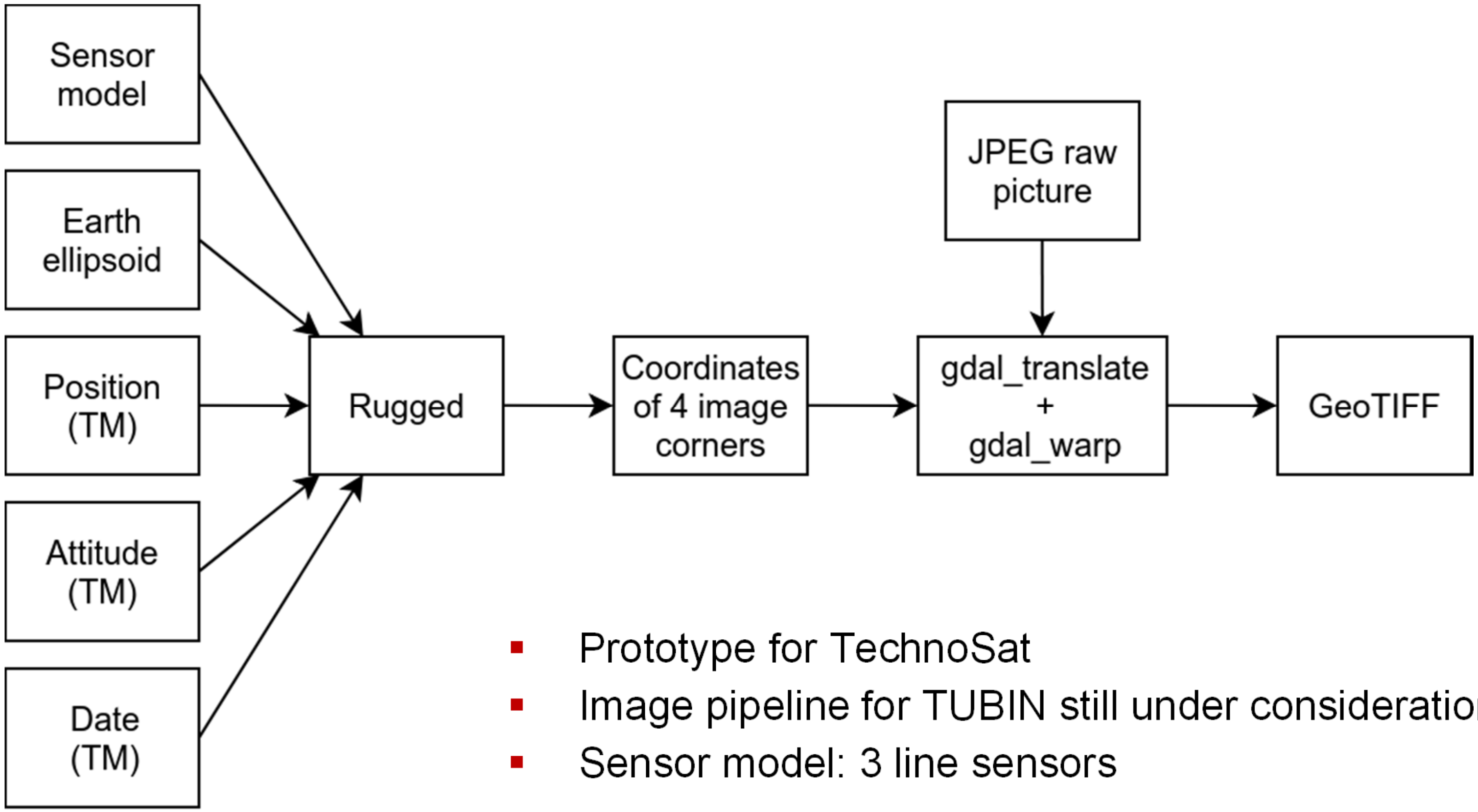
Software verification

Generation of reference data using Orekit from Matlab for:

- Onboard Kepler propagator for short-term GPS interpolation (similar to *shiftedBy* method)
- Coordinate systems and transformations
- Environmental models, e.g. IGRF

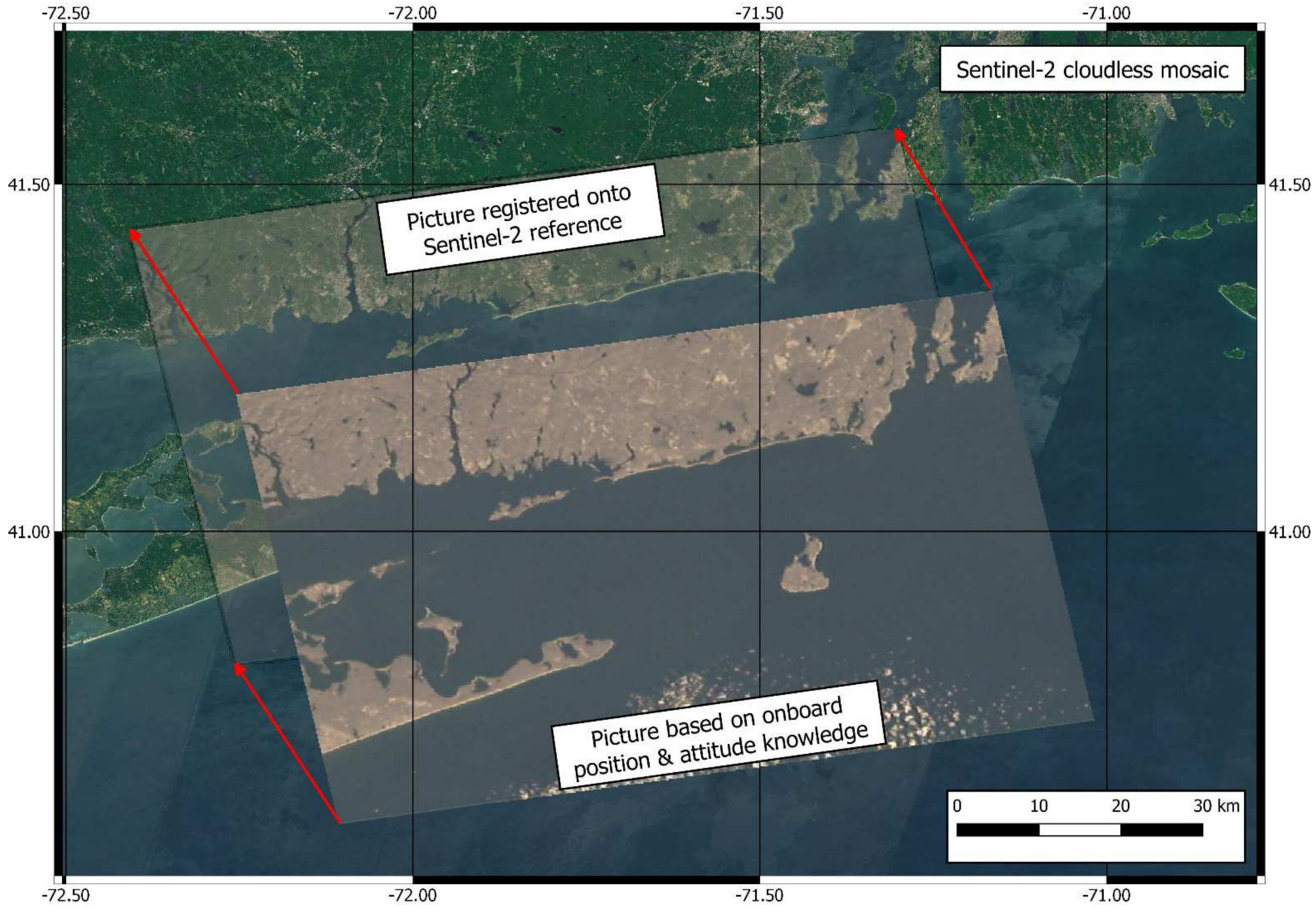
- Generation of C++ data file using Orekit from Matlab
- Integration in catch2 unit tests (https://github.com/catchorg/Catch2)
- Same input data for Orekit and for the onboard software, checking that the output is similar

Image direct location and georeferencing



- Prototype for TechnoSat
- Image pipeline for TUBIN still under consideration
- Sensor model: 3 line sensors

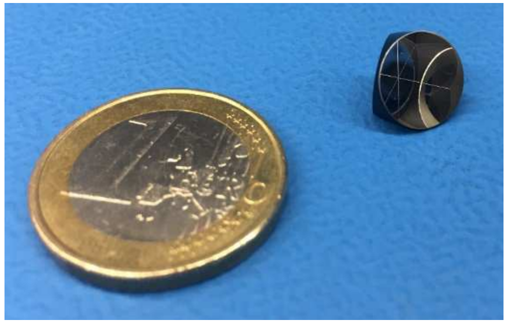
Image direct location and georeferencing



SLR orbit determination

First demonstration of 10mm COTS laser retro-reflectors on TechnoSat

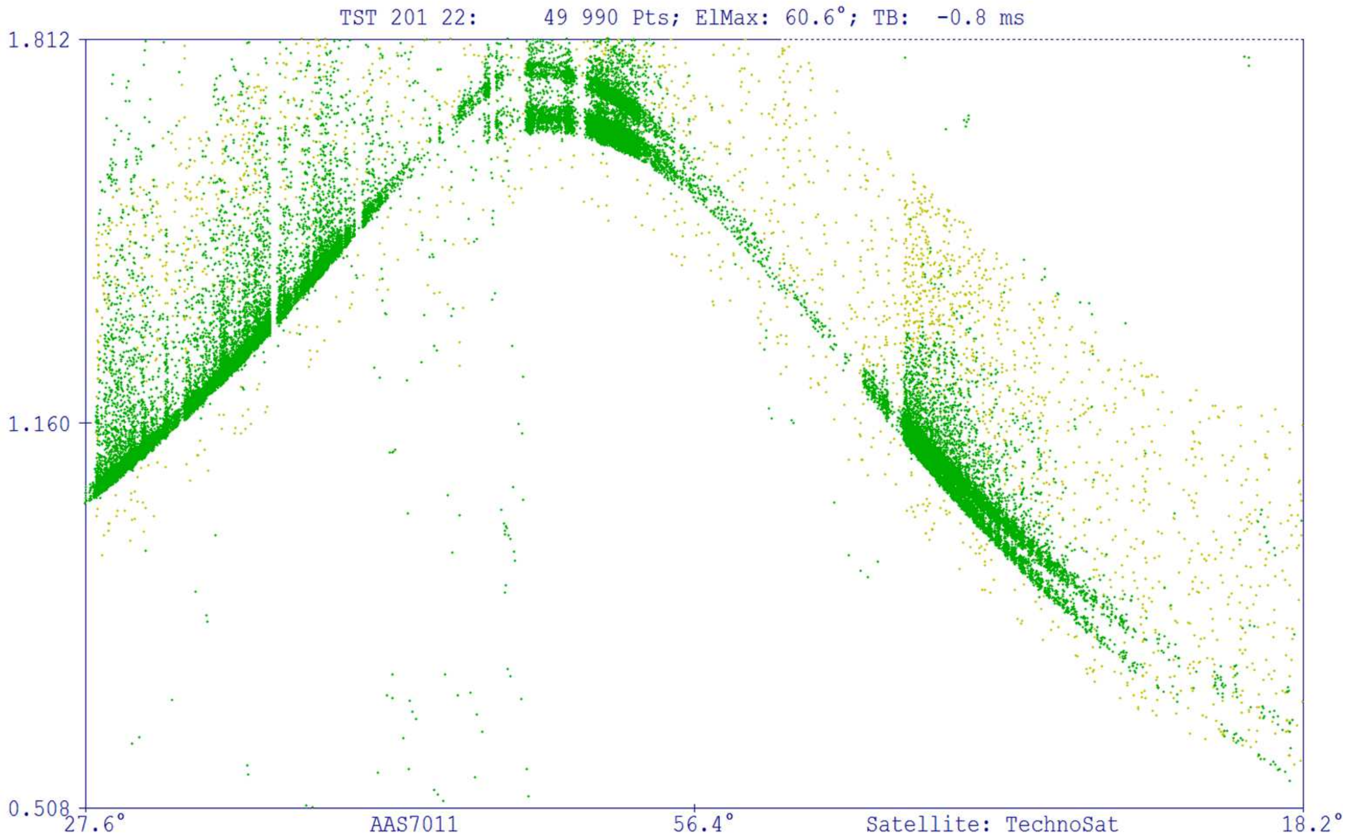
Now flying on S-NET too, and on future TU Berlin satellites



SLR orbit determination

- Motivations:
  - Making our own high-accuracy orbit predictions
  - Assess error of SGP4 model & TLEs
  - Generate better TLEs
  - For TUBIN (launch in 2020), compare SLR OD with onboard GPS
  - Estimate drag and reflection coefficients
  - Better geolocation accuracy for TechnoSat's pictures (no GPS onboard)
  - It would be a pity not to use SLR data, in open access via an API: https://edc.dgfi.tum.de/en/api/doc/

SLR orbit determination: raw range data



20.07.18 UTC 22:42:28 - 22:47:30
Austrian Academy of Sciences [1]

Raw (full-rate) data:

- Multiple tracks: different satellite sides
- Many data points (thousands per pass)

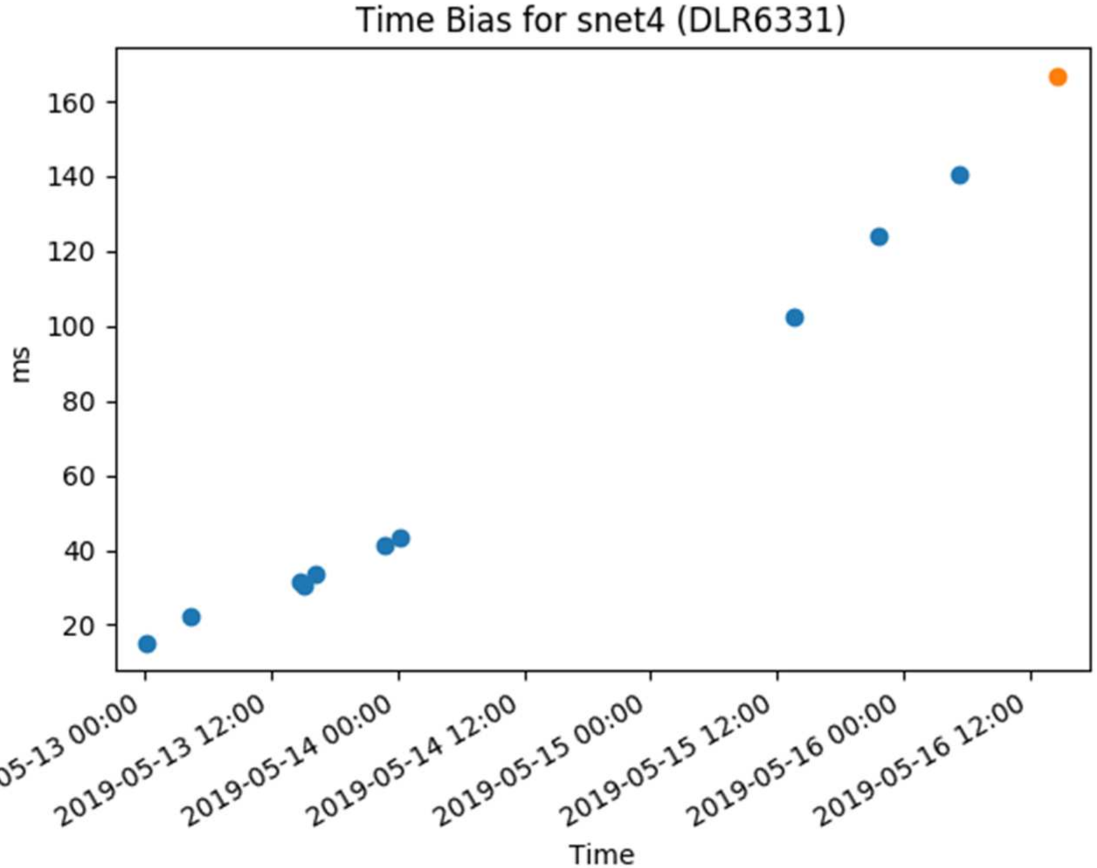
Normal point data:

- Multiple tracks are filtered
- 30 second sample time: much lighter

SLR orbit determination: time bias of existing predictions

- Time error between predicted and measured ground station pass
- Along-track error increases by several hundreds of meters per day

(Credit: GFZ Potsdam / DiGOS)



SLR orbit determination: model

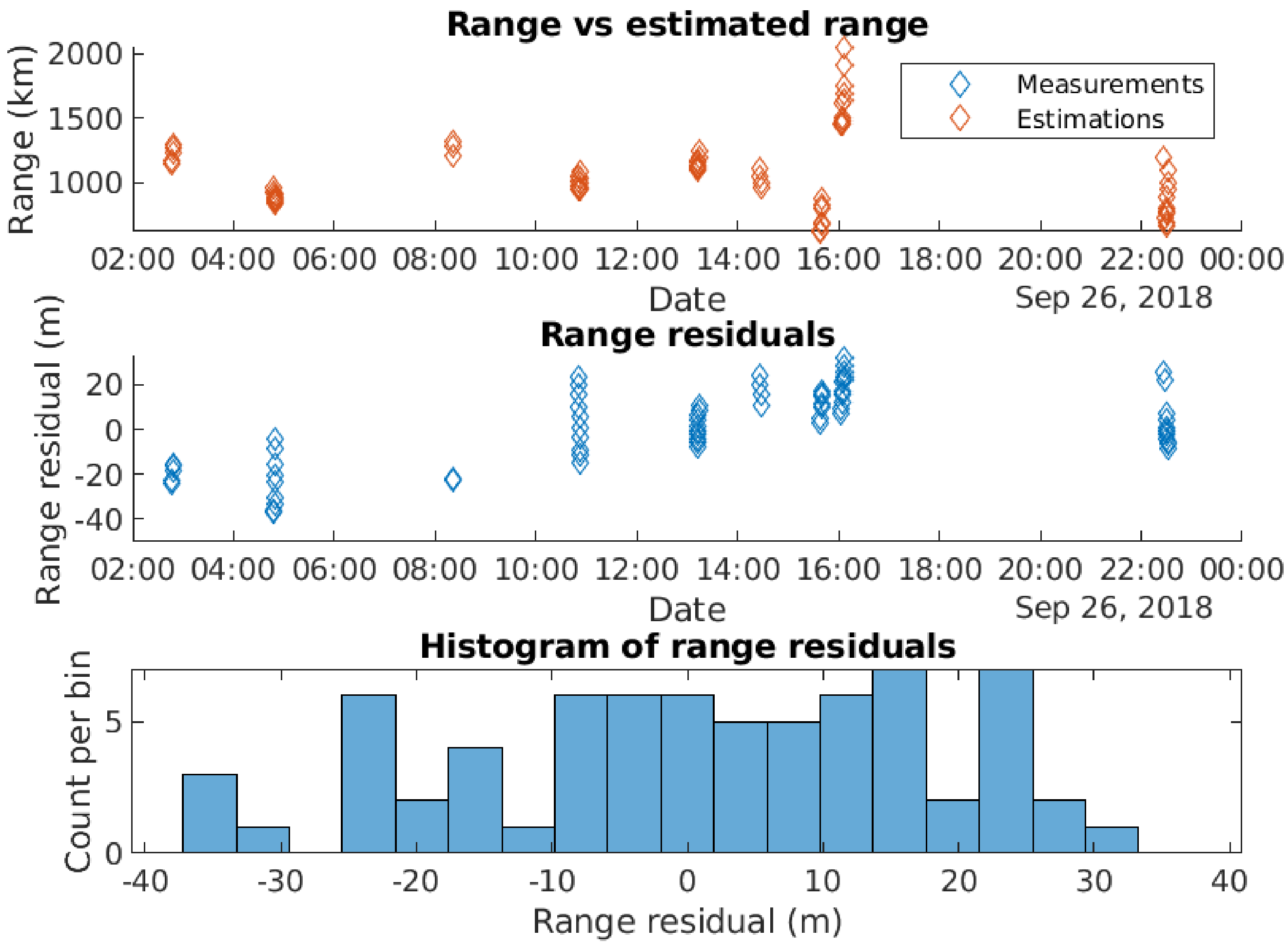
Orbit propagator:

- DormandPrince853Integrator
- Gravity: order 64, degree 64
- Third-body attractors: Moon, Sun
- Isotropic solar radiation pressure
- NRLMSISE00 atmospheric model fed by monthly F10.7 bulletins
- Isotropic atmospheric drag

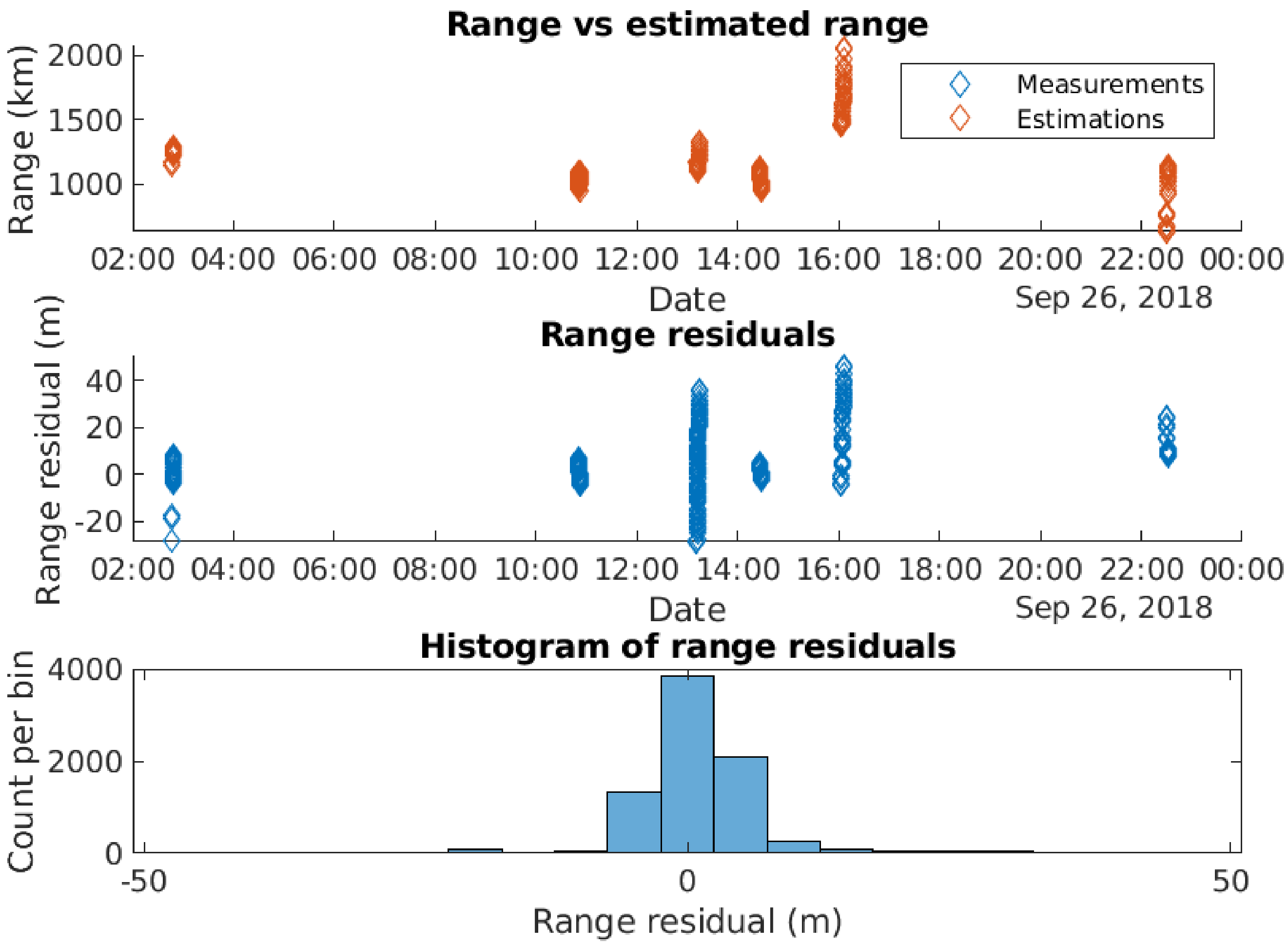
Estimator:

- Batch Least-Squares estimator
- QR Decomposer
- Gauss Newton optimizer

SLR orbit determination: NPT range residuals



SLR orbit determination: FRD range residuals



Future Orekit uses at TU Berlin

- More integrated in ground segment
- More automation
- Operational image georeferencing pipeline for TUBIN
- Future satellite missions with need for more advanced flight dynamics

Acknowledgements

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Orekit for nanosatellite missions at TU Berlin

Clément Jonglez | Institute of Aeronautics and Astronautics | Chair of Space Technology

Technische Universität Berlin

References

[1] Wang, P., Almer, H., Kirchner, G., Koidl, F., Steindorfer, M., Barschke, M., & Werner, P. kHz SLR application on the attitude analysis of TechnoSat.