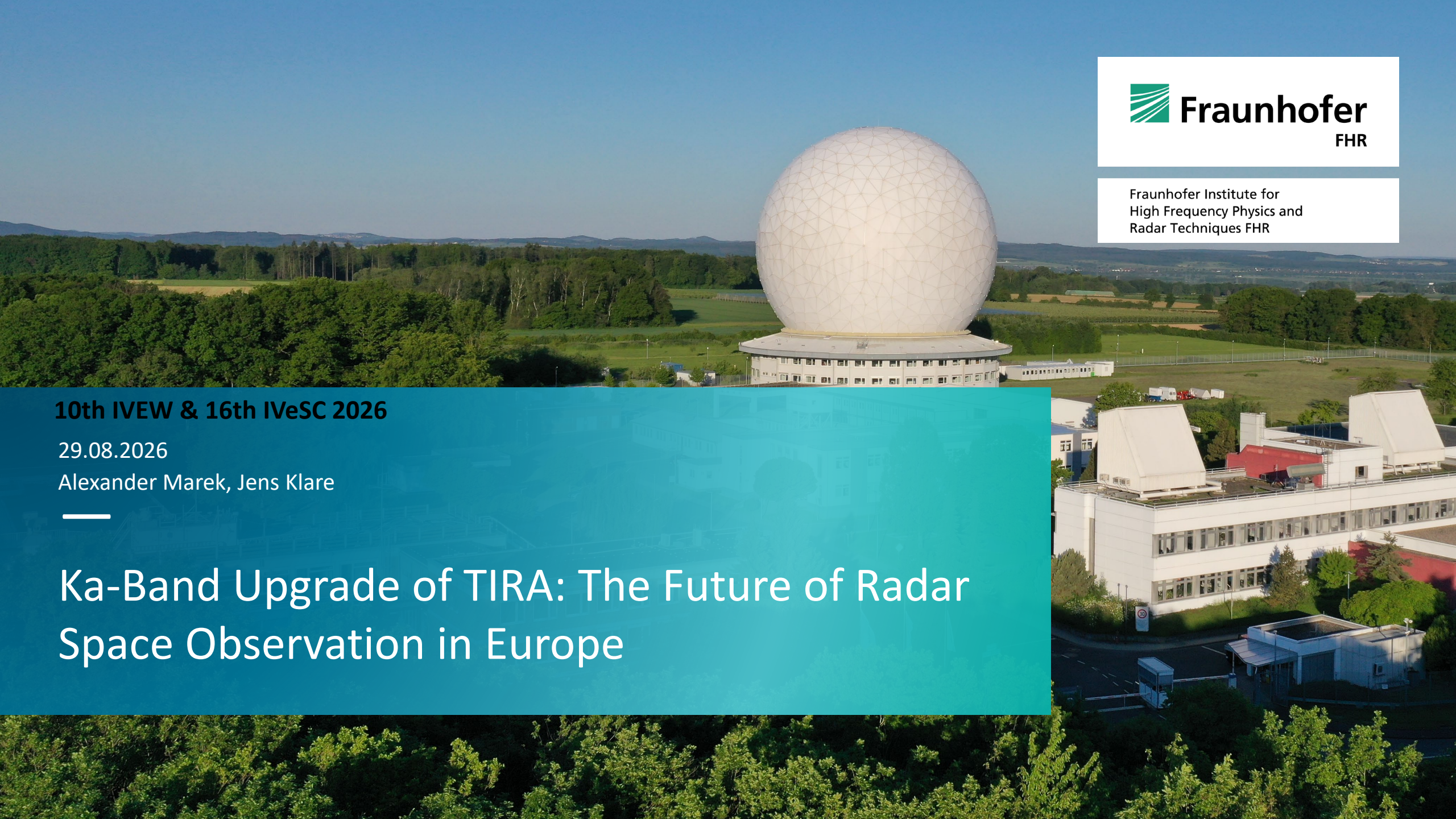


Fraunhofer FHR

Fraunhofer Institute for
High Frequency Physics and
Radar Techniques FHR

10th IVEW & 16th IVeSC 2026

29.08.2026

Alexander Marek, Jens Klare

Ka-Band Upgrade of TIRA: The Future of Radar Space Observation in Europe

Fraunhofer FHR at a Glance

Tailored solutions for radar systems and electromagnetic sensors – since 1957

- System designs and demonstrators for new radar applications
- Signal processing and imaging methods
- Technology consulting
- Capabilities for measurement, HPC, etc.
- Staff: ≈ 400

Locations

- Main location: Wachtberg
- Other locations, Networking with Universities

RWTH AACHEN UNIVERSITY RUHR UNIVERSITÄT BOCHUM RUB KIT Karlsruher Institut für Technologie UNIVERSITÄT SIEGEN

Tracking and Imaging Radar (TIRA)
Overview

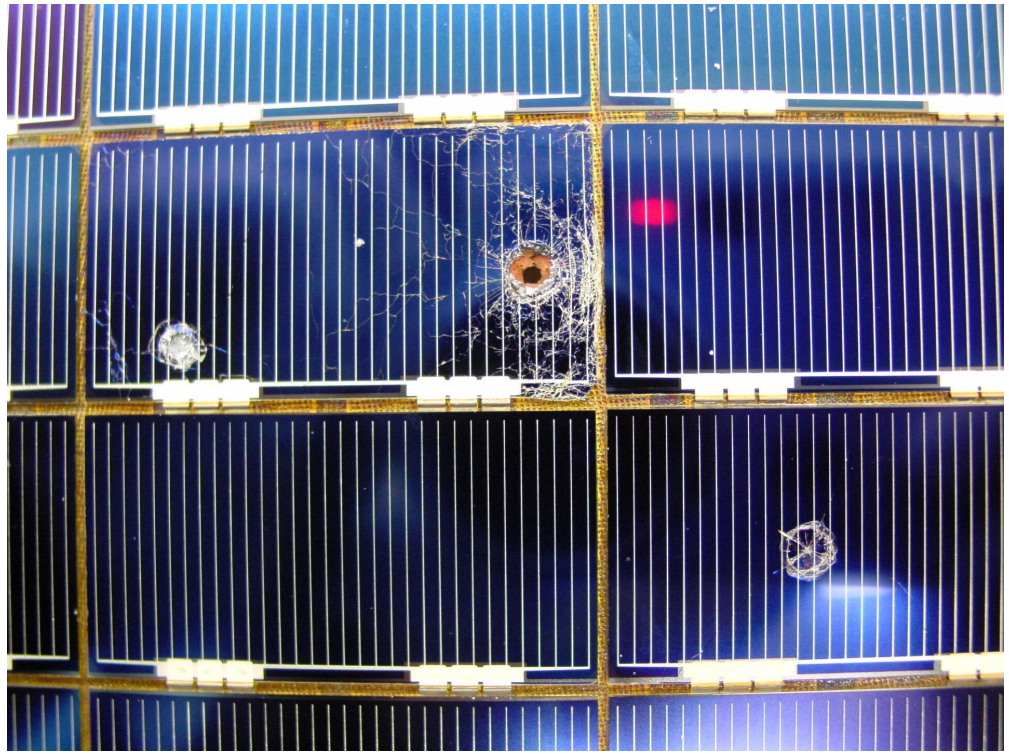
- Space observation radar
- Parabolic antenna
  - Diameter / Weight: 34 m / 240 t
  - System covered by 47.5 m radome
  - Rotational speed: 24° / s (360° in 15 s)
  - Pointing accuracy: 5 cm at a distance of 1000 m
- L-Band Tracking Radar
  - Frequency: 1.33 GHz
  - Detection sensitivity: 2 cm in 1000 km
- Ku-Band Imaging Radar
  - Frequency: 16.7 GHz
  - Image resolution: < 20 cm

Why do we need Space Observation Radars like TIRA

Space Debris

“Ever since the start of the space age there has been more space debris in orbit than operational satellites”

(First sentence in the ESA’S ANNUAL SPACE ENVIRONMENT REPORT 2024)

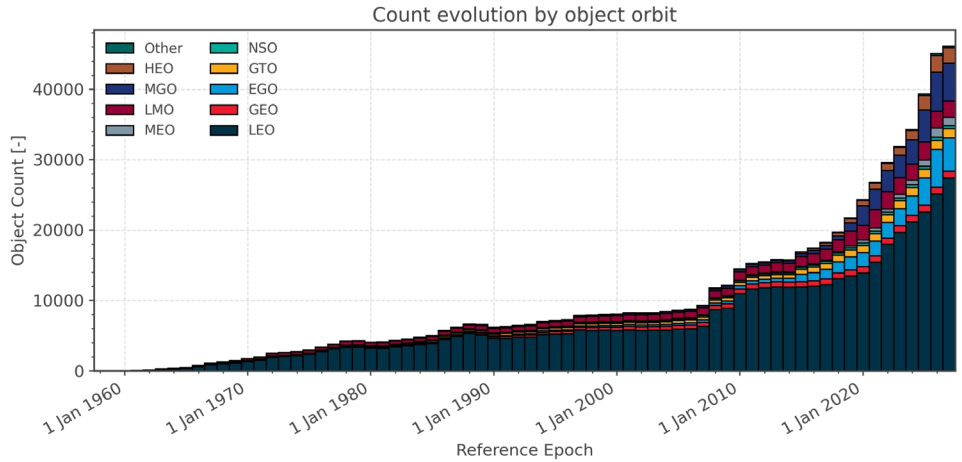


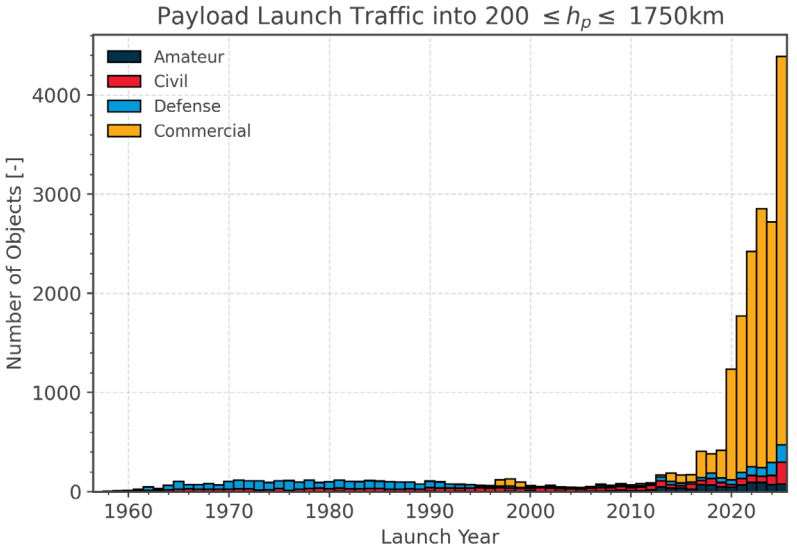
Impact holes in the solar panel of the HUBBLE telescope ©ESA

Alexander Marek, Jens Klare

Space Debris

- ~ 60% of the catalogued objects are in the LEO region (altitude 200 – 2.000 km)
- ~ 2.5% of the catalogued objects are in the GEO region (altitude 36.000 km)
- 700.000 non-trackable objects > 1 cm
  Detectable only with powerful sensors, e.g. TIRA





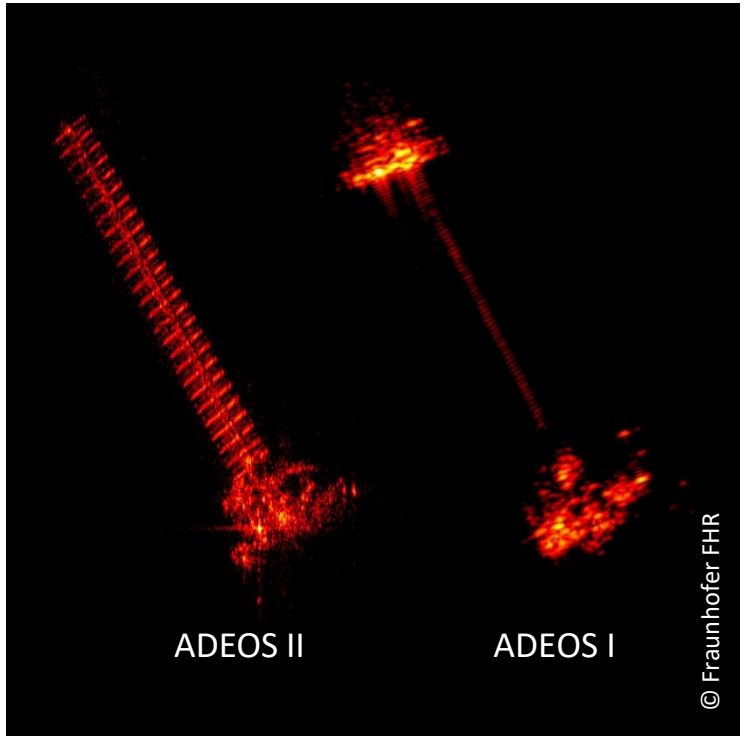
TIRA & space debris

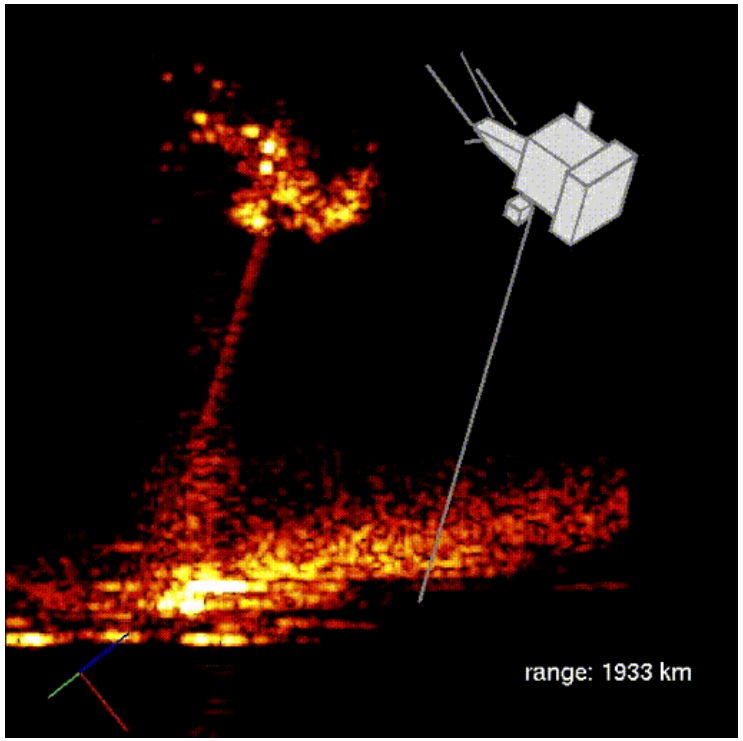
- Searching and tracking of space objects (orbit determination)
- Characterization
- Validation of space-debris models
- Tracking re-entering (risk) objects
- Supporting de-orbiting operations
- Radar measurements of meteoroid streams

[ESA'S ANNUAL SPACE ENVIRONMENT REPORT 2026]

Tracking and Imaging Radar (TIRA)

Damage analysis: ADEOS I + ADEOS II





- Damage analysis:
  The solar panel of ADEOS I is torn down. (1997)

L-Band Tracking Radar
Overview

Radar characteristics

- Frequency: 1.33 GHz
- Power: up to 1.5 MW
- Antenna gain: 50 dB
- Beam width 0.49° (8.6 km at R = 1000 km)

Tracking

- 4-horn monopulse system for tracking
- Single-pulse sensitivity 2 cm at range R = 1000 km

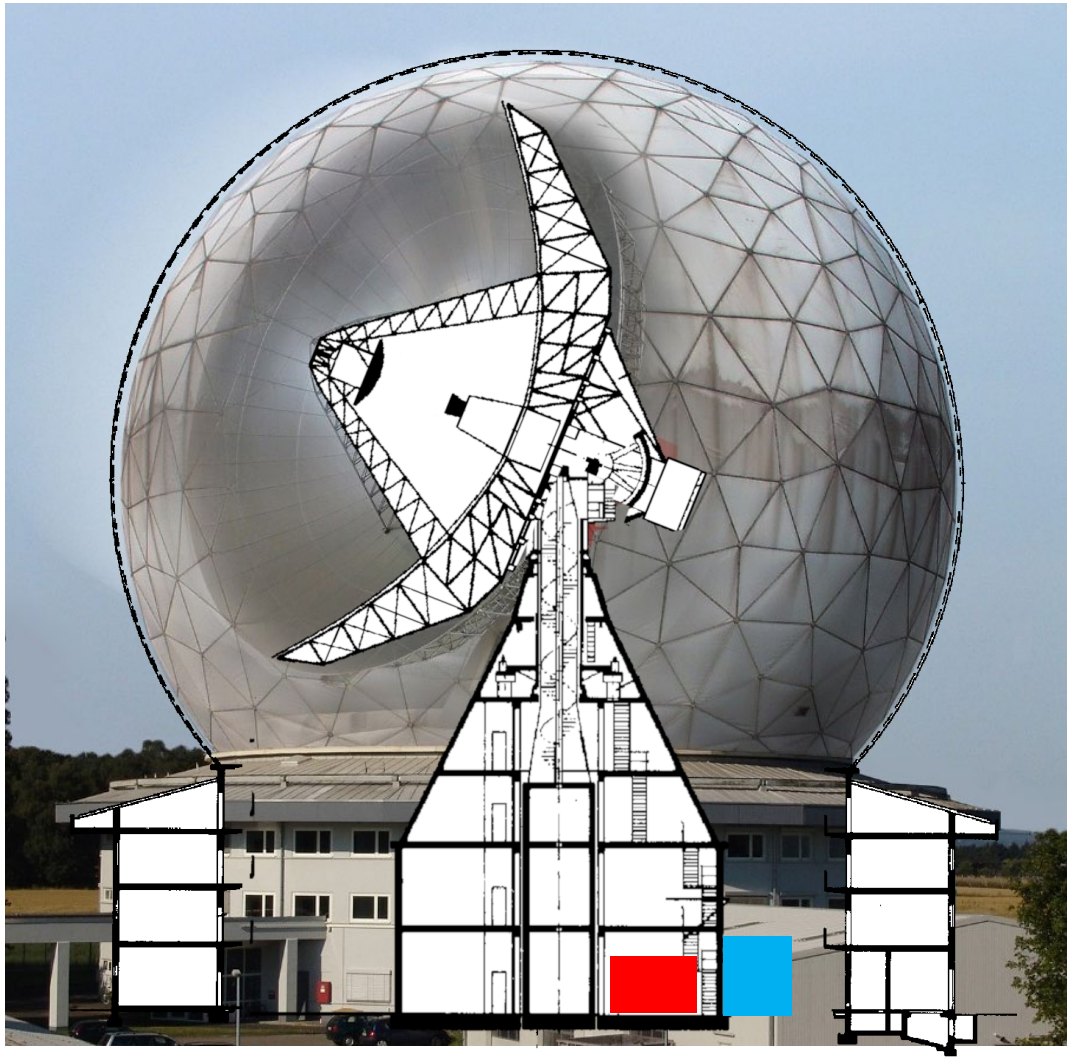
L-Band Tracking Radar
Power Amplifier & Modulator

5-cavity klystron from Thales

- RF pulse output power: ≤ 2 MW
- Gain: 42.4 dB
- Efficiency: 39 %
- Beam Voltage: ≤ 96 kV
- Beam Current: ≤ 58 A
- Weight: 240 kg

Modulator from Research Instruments

- Modulator type: Hard-tube, capacitor-/transformer-coupled
- Switching device: 4x IGCT in series
- HV power supply: 300 kW, DC
- Capacitor bank: 6400 µF



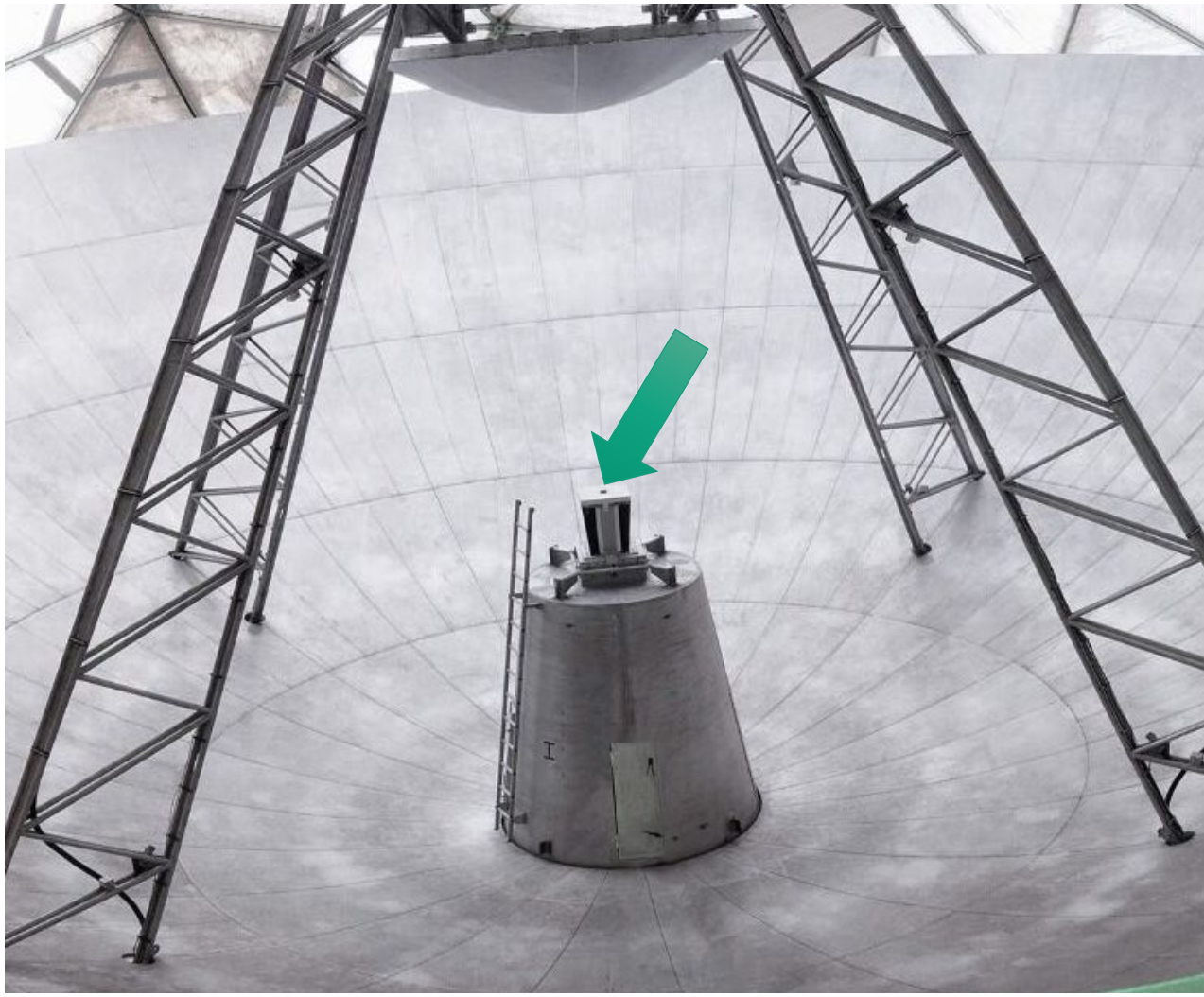
Ku-Band Imaging Radar
Overview

Radar characteristics

- Frequency: 16.7 GHz
- TWT from Hughes Electronics with up to 10 kW
- Antenna gain: 73 dB
- Beam width 0.031° (540 m at R = 1000 km)

Imaging

- Guided by the tracking radar
- Coherent, wide-band, LFM-chirp pulse radar
- ISAR
- Image resolution: < 20 cm



Ka-Band Upgrade
Overview

Klemens Letsch at the
3rd ITG International Vacuum Electronics Workshop 2012:
“*Also for the Ku-band transmitter a mid-term upgrade may be necessary resp. a new imaging radar with a higher transmit frequency (e.g. Ka-band) utilizing a larger bandwidth*”

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Overview

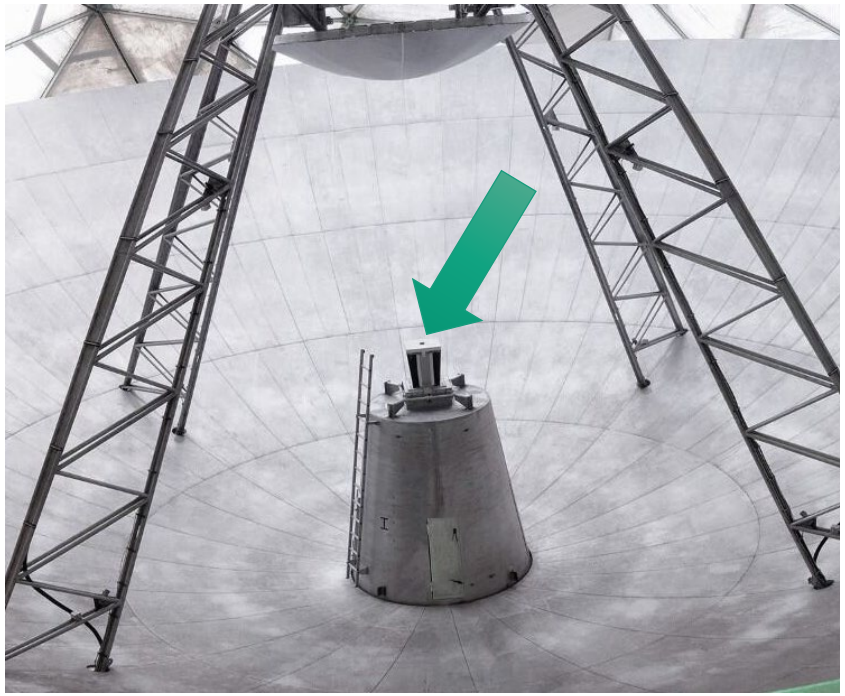
Klemens Letsch at the
3rd ITG International Vacuum Electronics Workshop 2012:
"Also for the Ku-band transmitter a mid-term upgrade may be necessary resp. a new imaging radar with a higher transmit frequency (e.g. Ka-band) utilizing a larger bandwidth"

Radar characteristics

- Frequency: 35 GHz
- Antenna gain: 80 dB
- Beam width 0.016° (280 m at R = 1000 km)

Imaging & Tracking

- Integrated multi-mode tracking
- Full polarimetric imaging

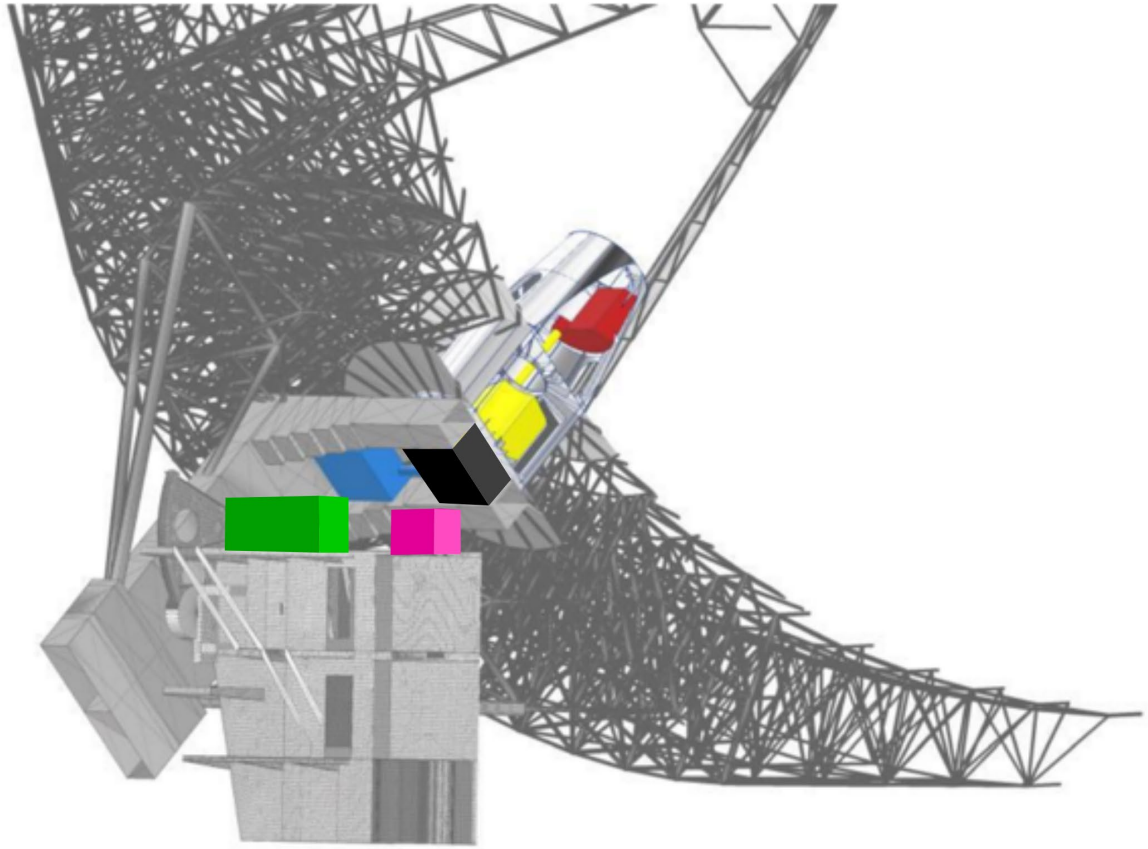


Replacing the Ku-band system

Ka-Band Imaging Radar
Highly Integrated System

Highly Integrated into the Antenna

- High power TWT (red) – coupled with a quasi-optical antenna frontend to the antenna
- Distributed high-power modulator (yellow, blue, green)
- Cooling system (pink)
- Signal evaluation (black)



All Components are Custom and Optimized

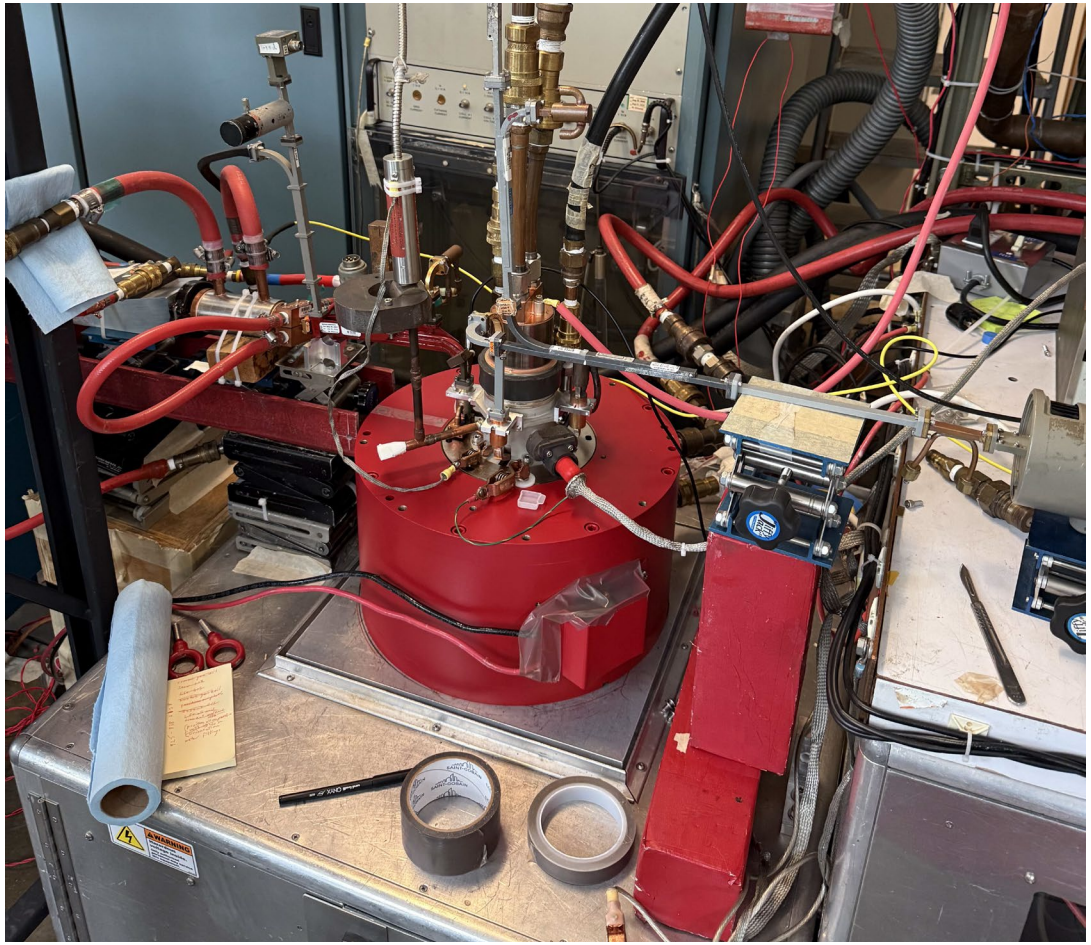
- Low weight & volume
- Support position change during the movement of the antenna
- Support high ambient temperature

Ka-Band TWT
High Power & Bandwidth

Traveling Wave Tube (TWT) from MPP

- Best commercial available broadband high-power amplifier
- Coupled cavity TWT
- Beam Voltage: ≈ 45 kV
- Beam Current: ≈ 8 A
- Weight: > 150 kg (with magnet)

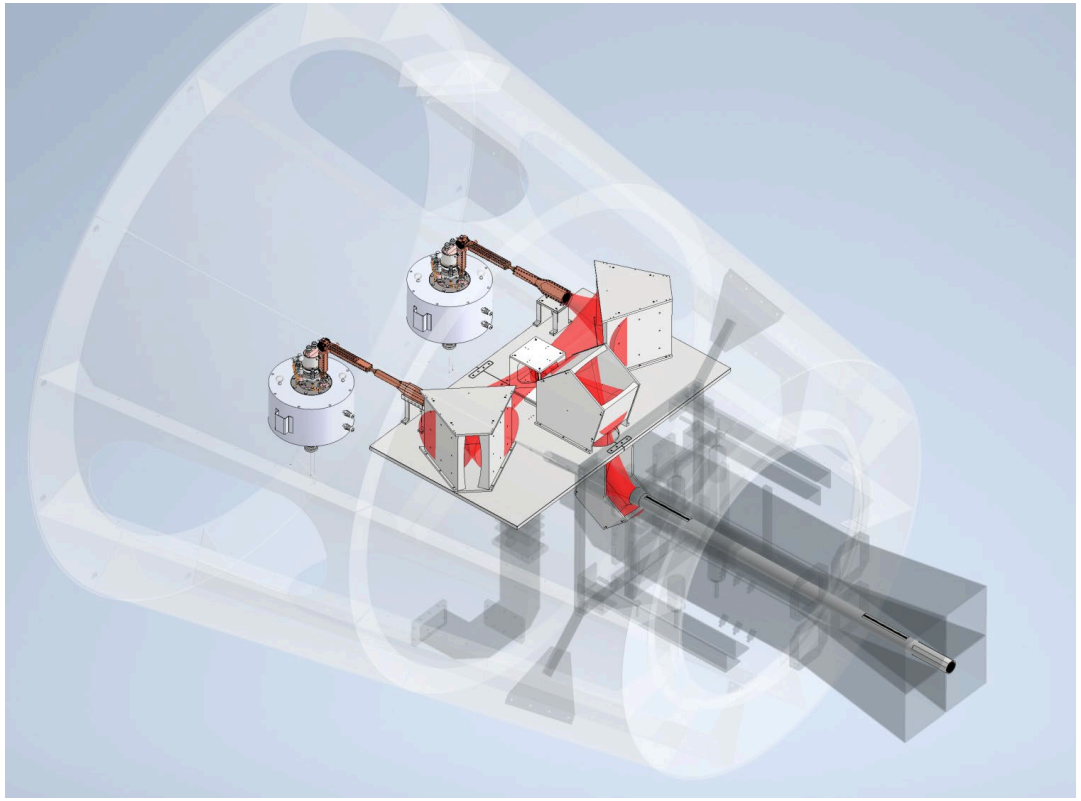
Delivery end of 2026



Power Combining
Quasi-Optical Antenna Frontend

For highest TX power: Power combining of 2 TWTs

- Q.O. power combining
  - Minimal losses
  - Highest power capabilities
  - Broad bandwidth
- Supports propagation of higher-order TEM modes (multimode tracking)
- Freely selectable Tx polarization



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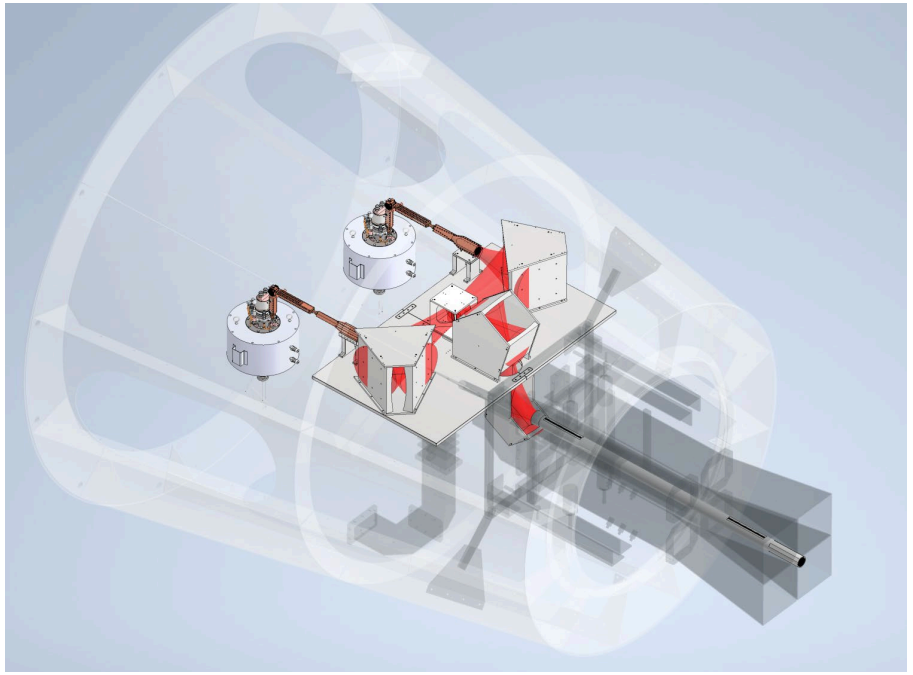
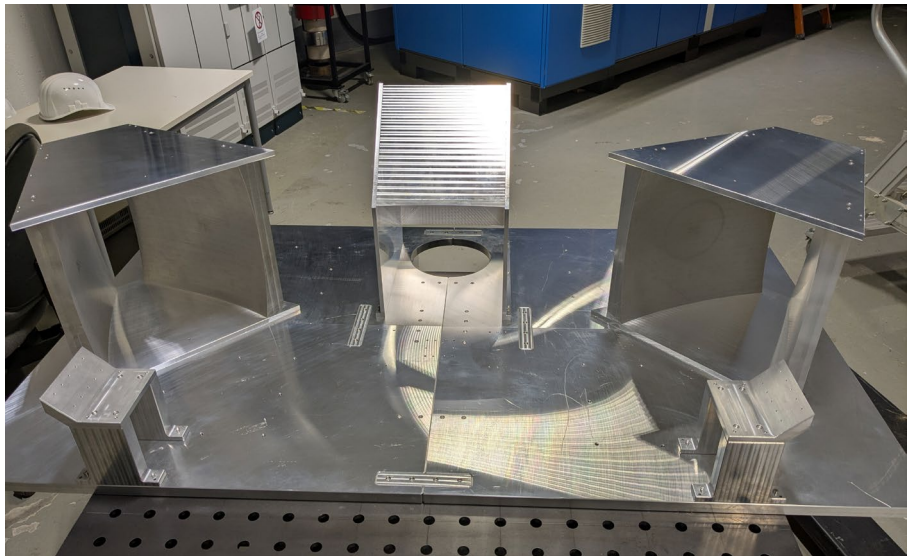


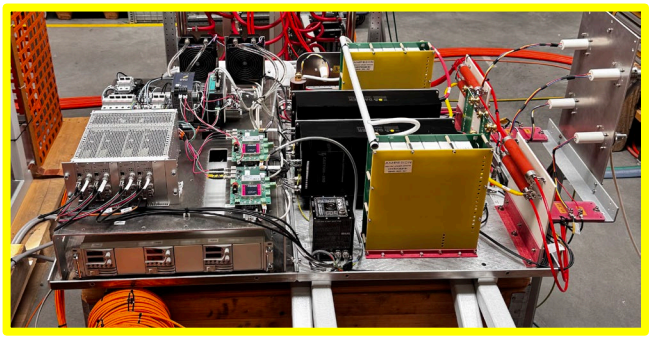


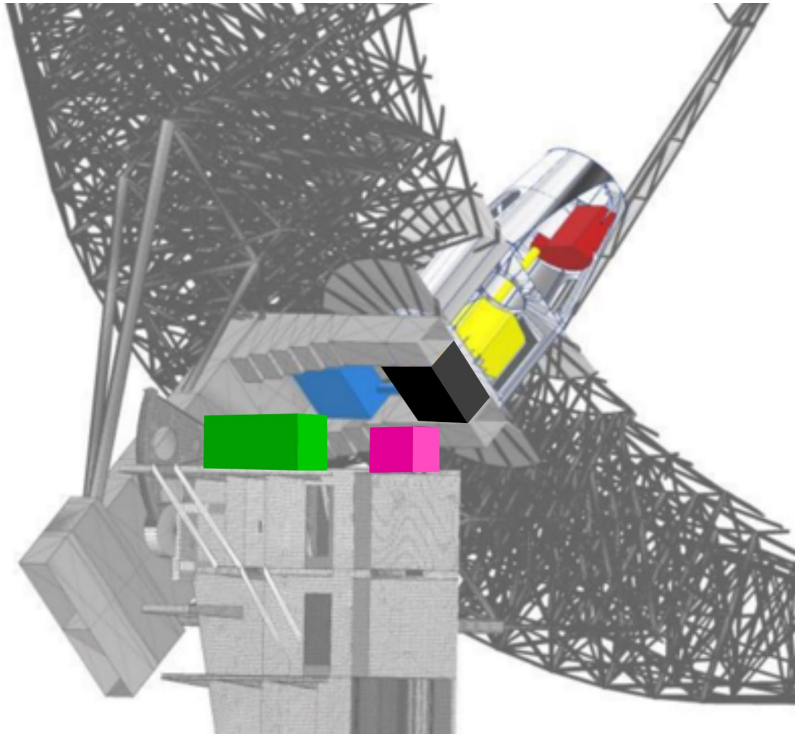
Integrated Power Supply

Pulse-Modulator from AMPEGON

- Distributed system
- Optimized for low weight
- Supports position change during the movement of the antenna

Delivery September 2026





Ka-Band Teststand

The only substitute for testing is more testing

Requirement: Minimal down-time of TIRA

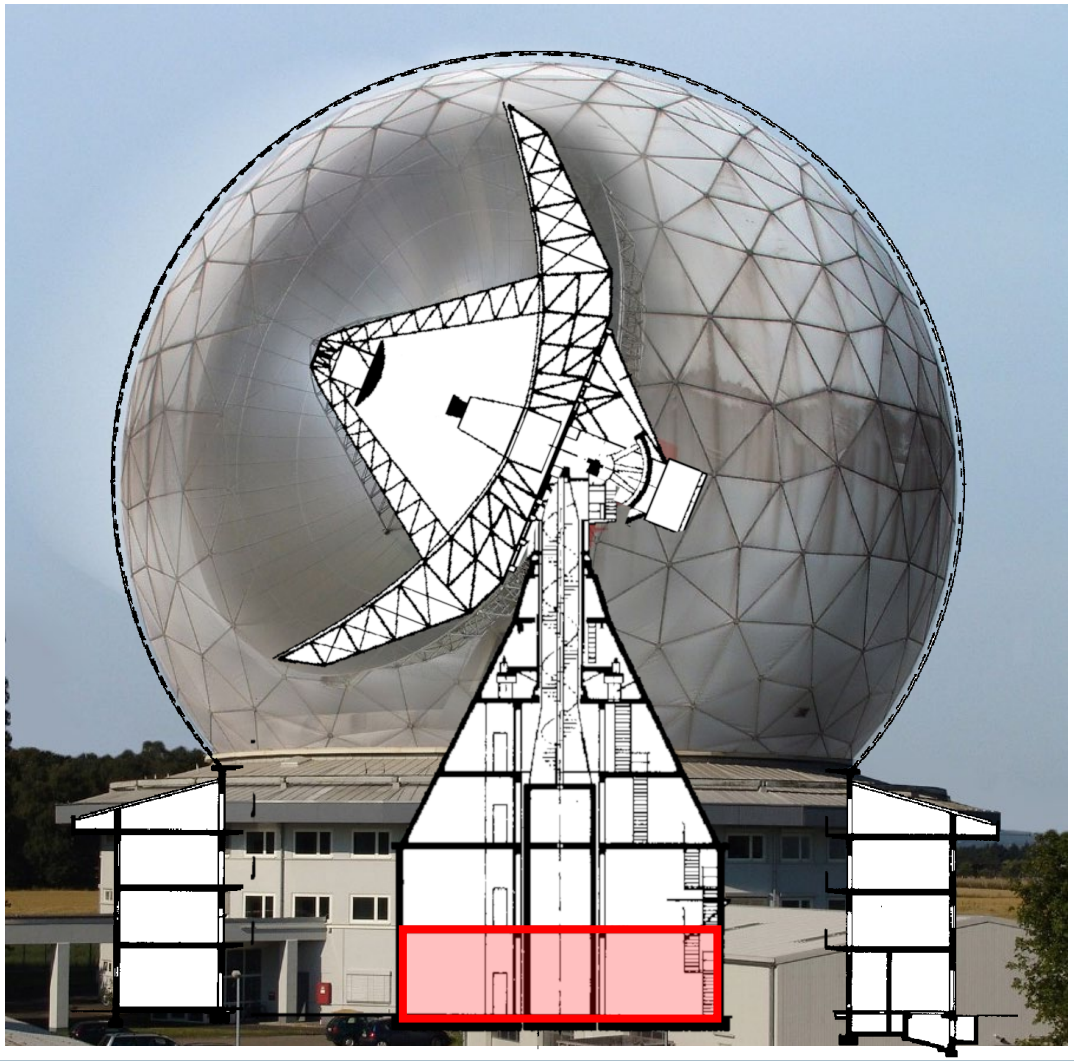
→ Test of the complete Ka-band system before the integration into the antenna

New Ka-Band Teststand

- On the ground floor of the antenna building
- Allows the test of all components at full-power

High-Power Dummy Loads

- Electrical dummy load for modulator tests under full load
- Waveguide RF dummy load for tests of TWTs
- Quasi-optical RF dummy load for test of q.o. antenna frontend



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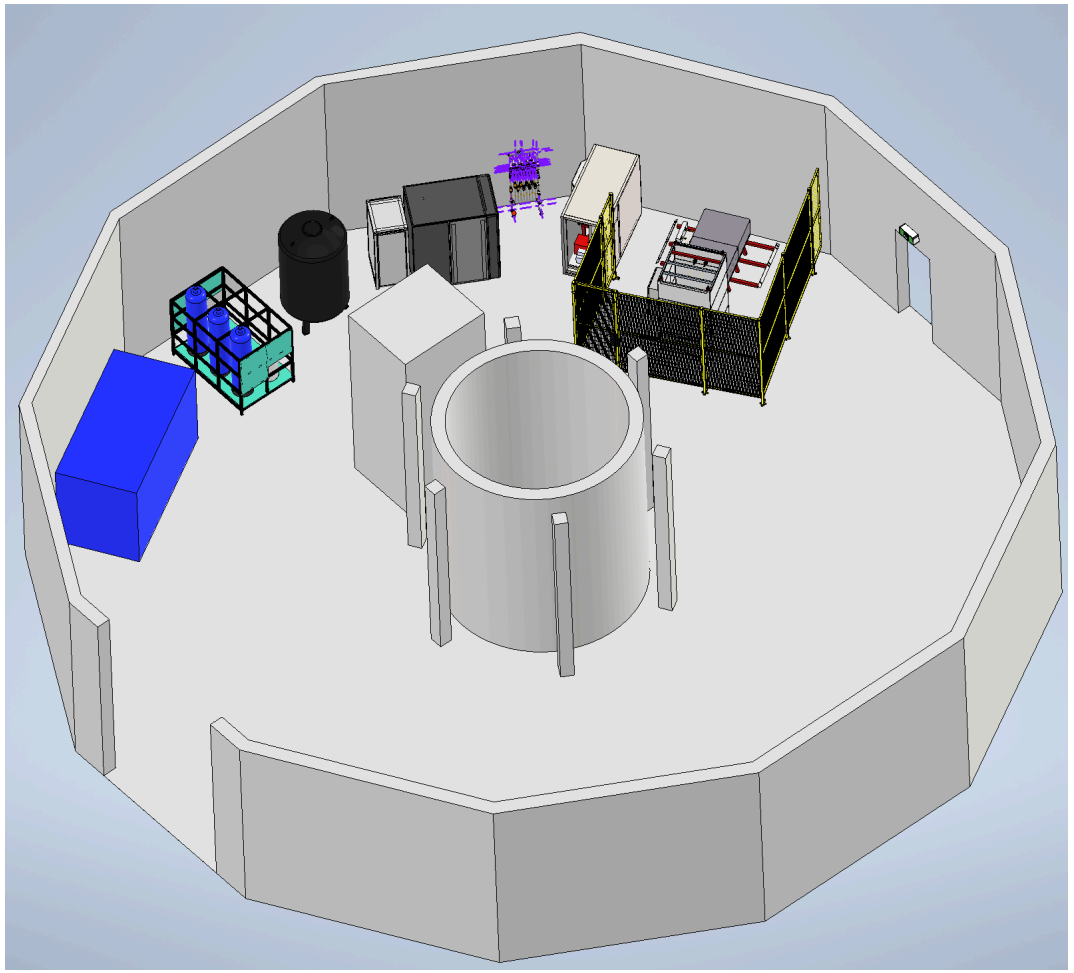

Conclusion & Outlook

- Vacuum tube amplifiers are the back-bone of ground based space-observation radars
- With the Ka-band upgrade, TIRA will remain one of the world's most capable space observation systems
  - Frequency upgrade: High spatial resolution
  - Polarimetry upgrade: Structural and material analyses
- Future upgrades, e.g. to higher transmit power, are under discussion

TIRA will keep up with the rapid developments in space

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Thank you for your attention!
Questions?