# CALIBRATION CONCEPT FOR THE UPCOMING ESA ROSE-L MISSION

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DLR SAR Calibration Center

ROSE-L is a Programme of the European Union co-funded with esa.

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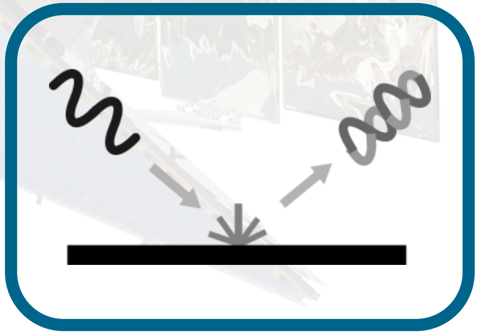
# Outline

Calibration Requirements

Coverage Analysis

Geometric Calibration



Polarimetric Calibration

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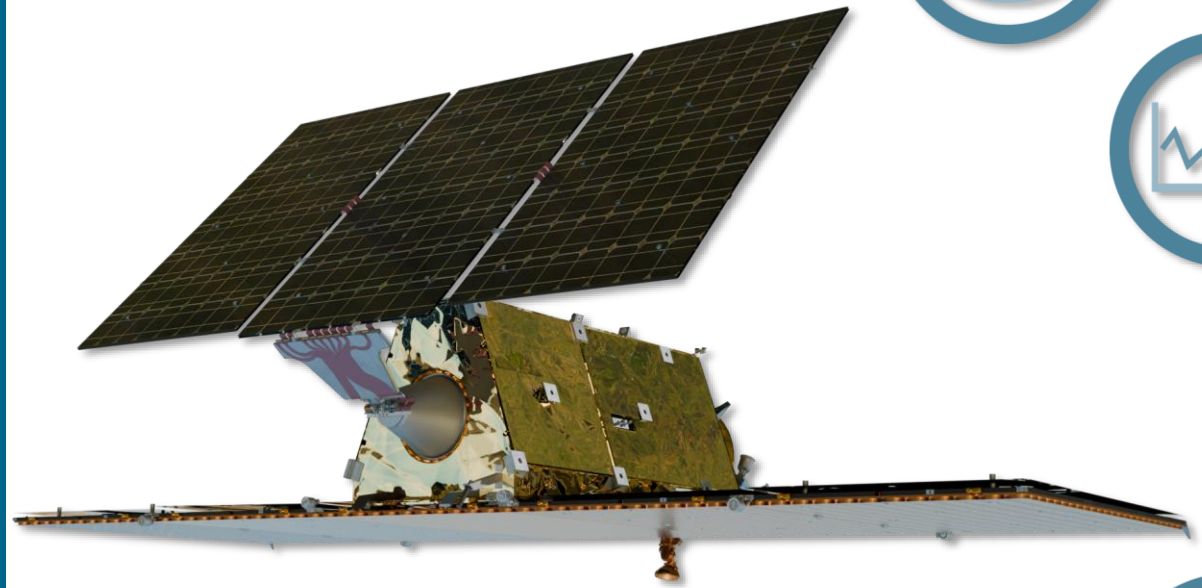
# SSRD Calibration Requirements (3σ)



Pixel Localization Accuracy with Atmosphere 5 m

Pixel Localization Accuracy w/o Atmosphere 1.2 m

Radiometric Stability 0.5 dB

Relative Radiometric Accuracy 0.3 dB

Absolute Radiometric Accuracy 1.5 dB

*Instrument*

Polarimetric Gain Imbalance 0.38 dB

Polarimetric Phase Imbalance 5 deg

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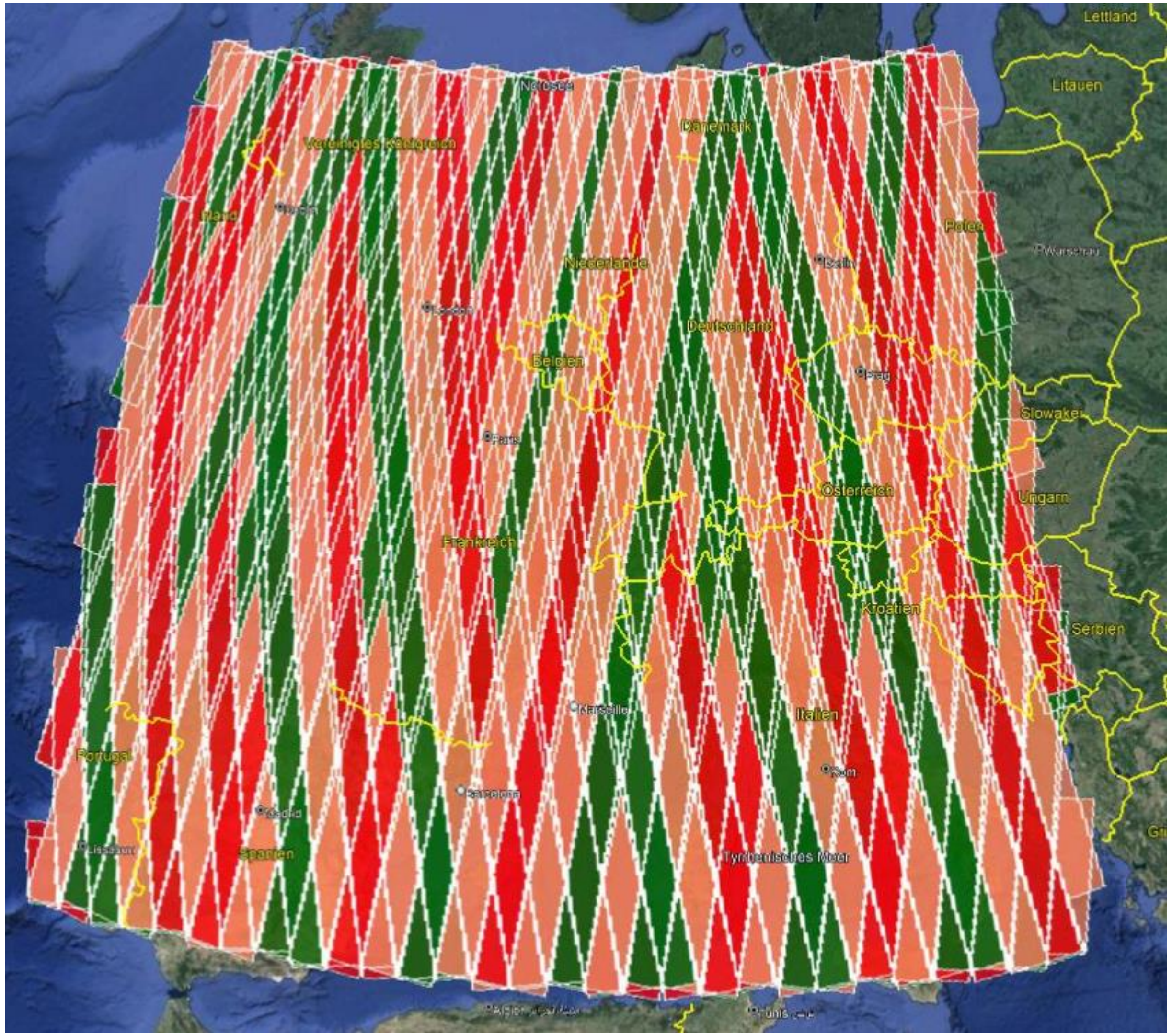
# Coverage

## Coverage Illustration for RIWS Mode




### RIWS Mode

| | Swath 1 | Swath 2 | Swath 3 | Sum |
|---|---|---|---|---|
| D26 Oberpfaffenhofen | 4.71 | 9.71 | | 2 |
| D38 Berg | 9.71 | | 2.72 | 2 |
| D42 Oberrammingen | 6.23 | 1.23 | | 2 |
| D43 Penzing | | 1.23 | | 1 |
| Sums | 9 | 8 | 8 | 25 |

### Target Hits (CR+TR)

| Orbit time | RIWS | QWS | NWS | RWM1 | RWM2 | Az Notch |
|---|---|---|---|---|---|---|
| 1.23 | 3+4 | 2+2 | 2+2 | 0+0 | 0+0 | 0+1 |
| 2.72 | 2+3 | 0+0 | 0+0 | 0+0 | 0+1 | 1+2 |
| 4.71 | 0+1 | 2+2 | 2+3 | 1+1 | 0+0 | 1+1 |
| 6.23 | 2+3 | 3+4 | 3+4 | 0+1 | 0+0 | 2+0 |
| 9.71 | 3+4 | 3+4 | 3+4 | 0+0 | 0+0 | 1+2 |

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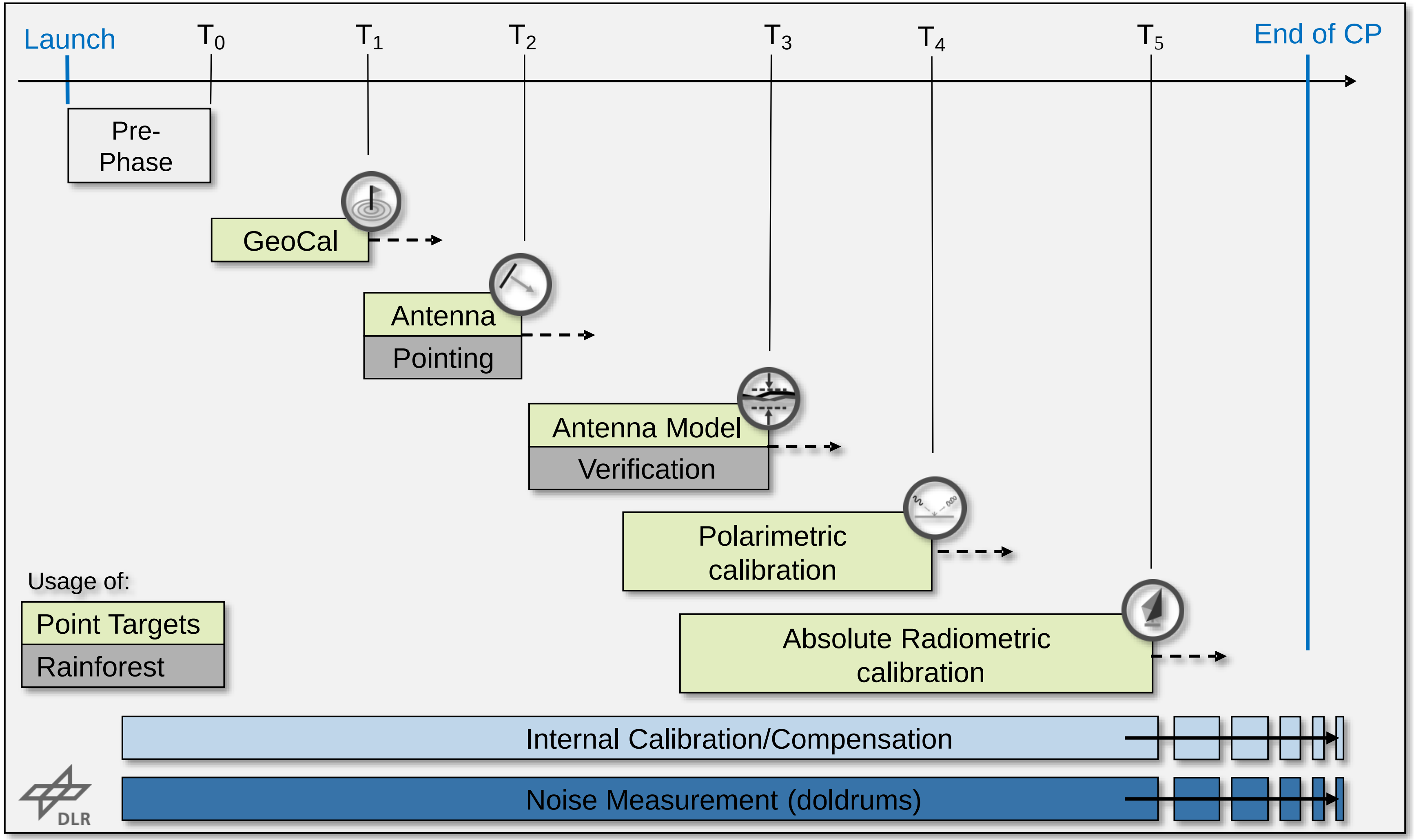
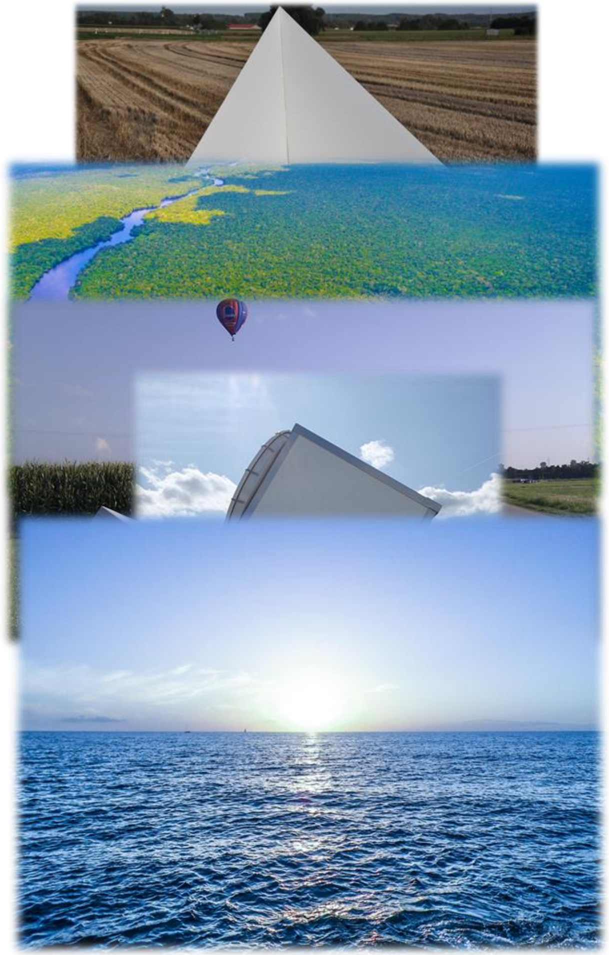
# In-Orbit Calibration Plan



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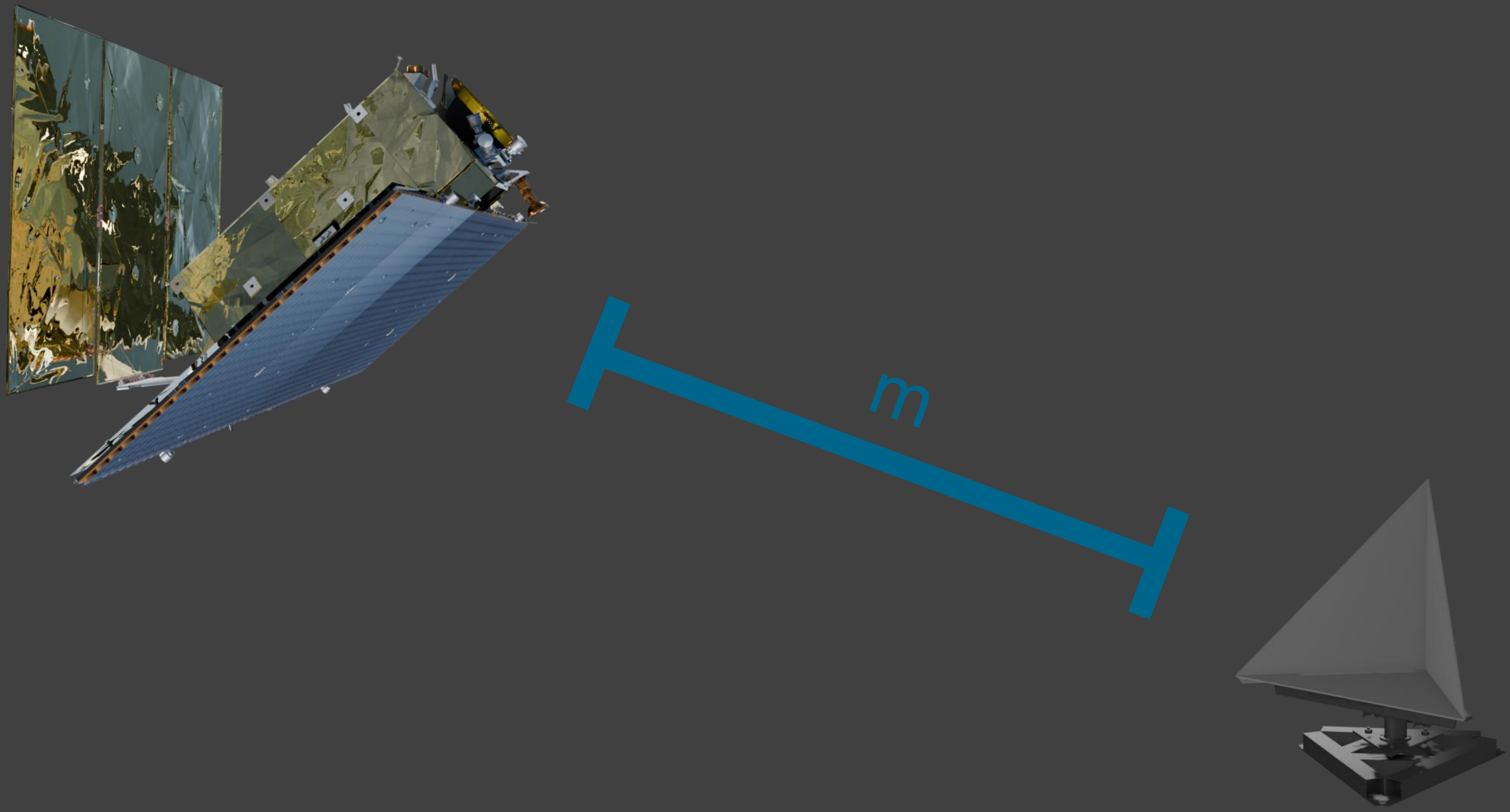



# GEOMETRIC CALIBRATION

# Geometric Calibration – Uncertainty Budget

| **Satellite Contributors** | |
|---|---|
| Satellite Position Knowledge | … m |
| … | … m |
| **Propagation Path** | … m |
| **Calibration Targ** | |
| Target Locatio | |
| IRF Accuracy | |

world

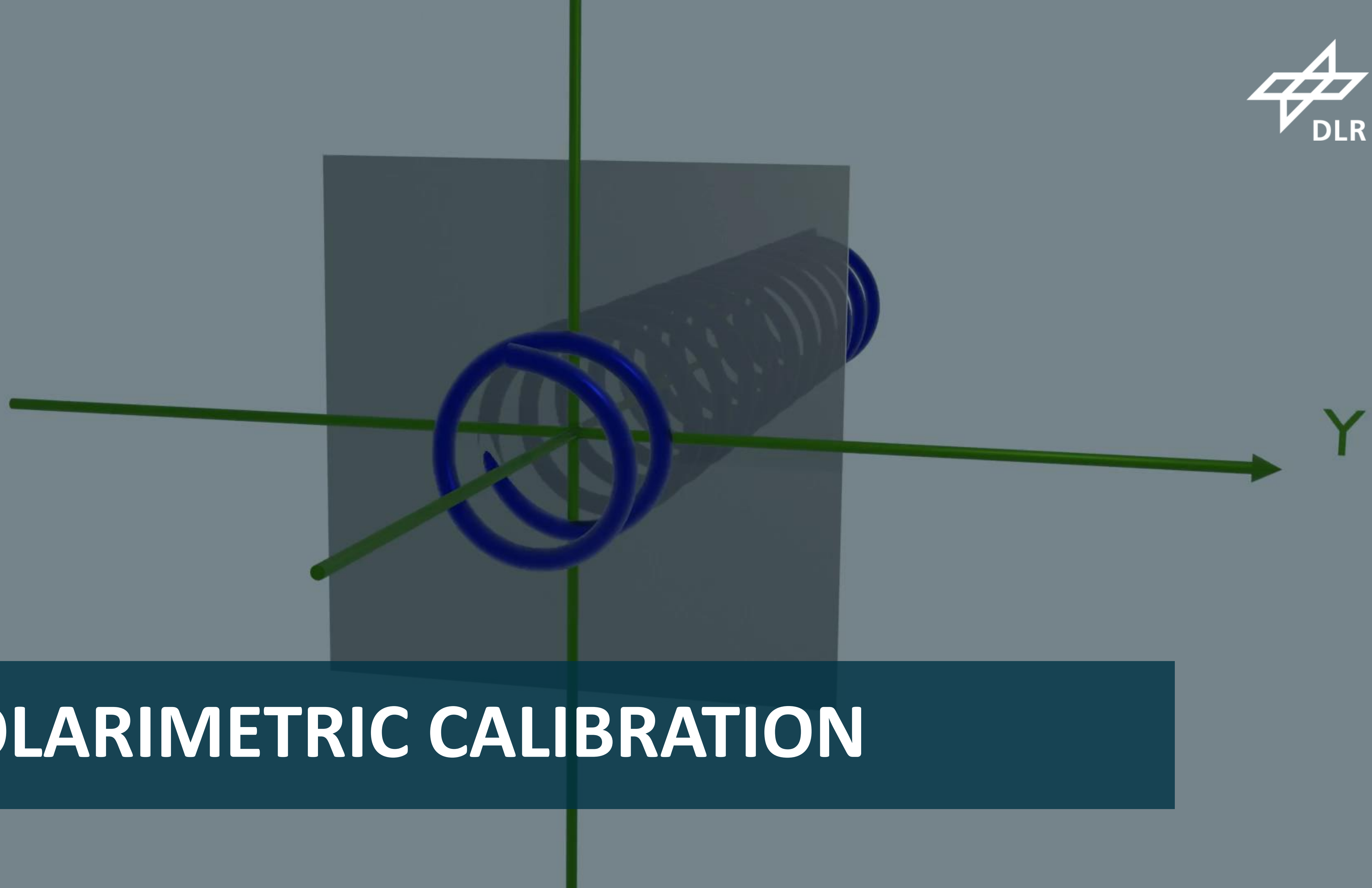
SAR image

**Conventional truths need to be reconsidered every time!**

| | | |
|---|---|---|
| **Target Location Knowledge** | | |
| Phase Center Knowledge | 2…3 cm | 7…10 cm |

$$\sigma_{SCR} = \frac{1}{\pi}\sqrt{3/2}\frac{\rho}{\sqrt{SCR}} \quad (1)$$

(1) Balss et al. „Measurements on the Absolute 2-D and 3-D Localization Accuracy of TerraSAR-X“, MDPI Remote Sensing, 2018




# POLARIMETRIC CALIBRATION

# Polarimetric Calibration

Measured Signal | Antenna Distortions Receive | Faraday Rotation On Receive Path | Target Scattering Matrix | Faraday Rotation On Transmit Path | Antenna Distortions Transmit | Transmit Signal

$$\begin{bmatrix} M_H \\ M_V \end{bmatrix} = \begin{bmatrix} 1 & \delta_{rx,2} \\ \delta_{rx,1} & f_{rx} \end{bmatrix} \begin{bmatrix} \cos\Omega & \sin\Omega \\ -\sin\Omega & \cos\Omega \end{bmatrix} \begin{bmatrix} S_{HH} & S_{HV} \\ S_{VH} & S_{VV} \end{bmatrix} \begin{bmatrix} \cos\Omega & \sin\Omega \\ -\sin\Omega & \cos\Omega \end{bmatrix} \begin{bmatrix} 1 & \delta_{tx,2} \\ \delta_{tx,1} & f_{tx} \end{bmatrix} \begin{bmatrix} E_H \\ E_V \end{bmatrix}$$

- Non-linear equation with some non-independent parameters
  - Faraday rotation matrix (Ω) and antenna distortion matrix (δ, f) are correlated

  → One can construct an antenna distortion matrix that looks similar to a Faraday rotation matrix

  **Mathematically ill-conditioned problem**
- Additional constrains required for a unique solution, e.g.
  - X- or C-Band: $\Omega = 0$
  - Calibrated System: antenna distortion matrices are known
  - ROSE-L: δ is known from On-Ground Characterization (OGC)

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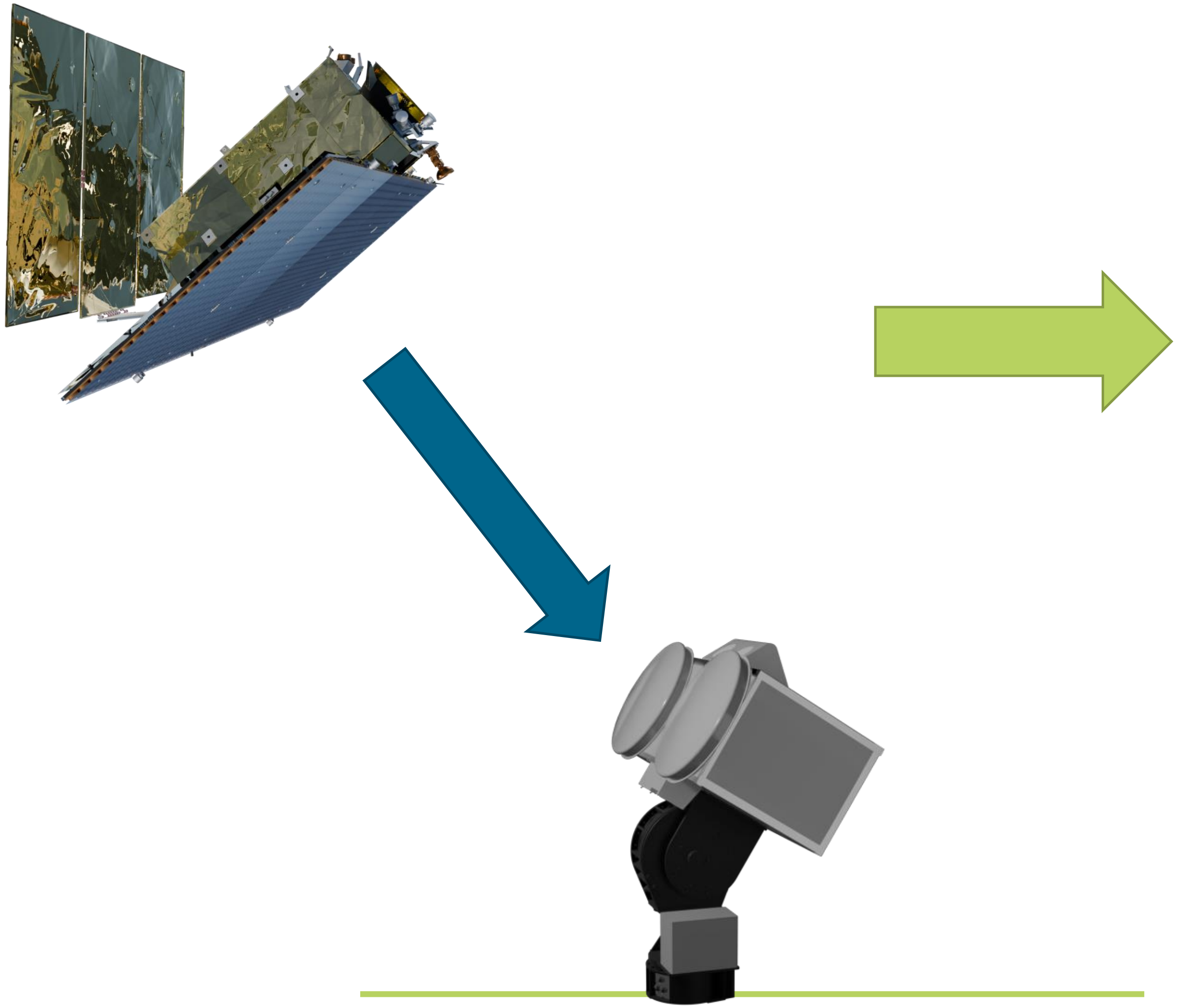
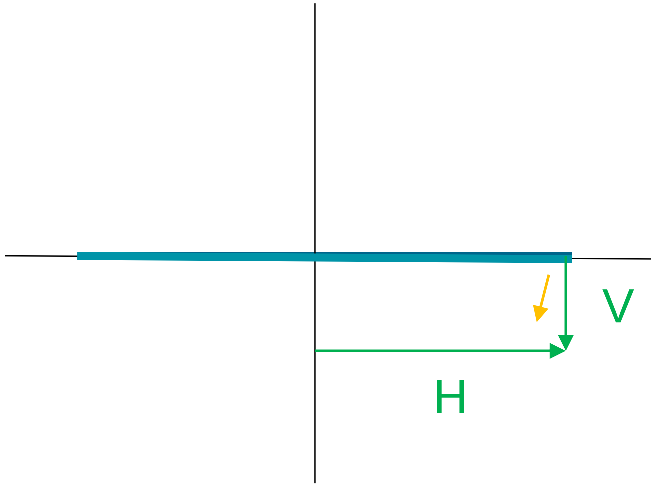
# Faraday Rotation Measurement

## Ground Receiver Operation



## Dual-Pol Receiver




$$\mathrm{H/V{-}ratio} = \rho = \frac{H}{V}$$

$$FR = 0.5 \cdot \mathrm{atan}\left(\frac{2 \cdot Re\{\rho\}}{1 - \rho \cdot \rho^{*}}\right)$$

(Orientation angle)

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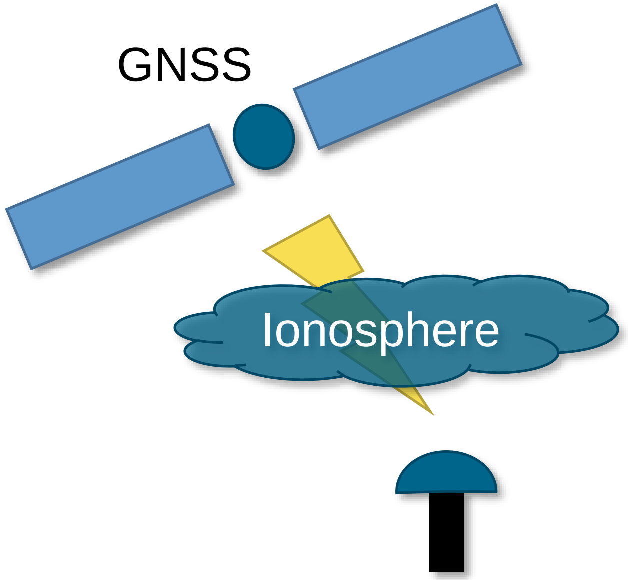
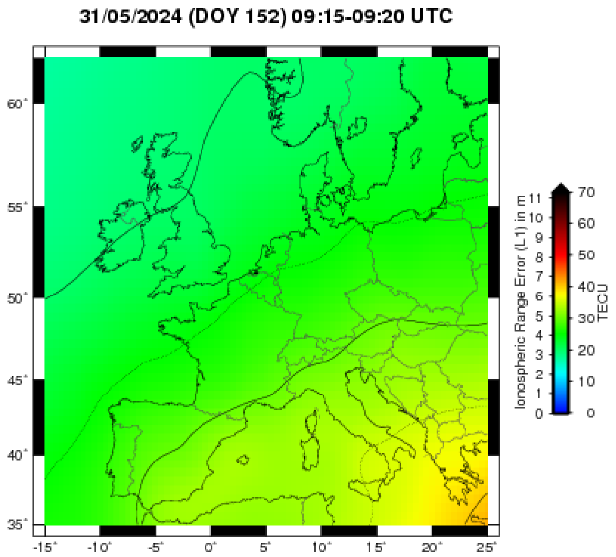
# Faraday Rotation Estimation

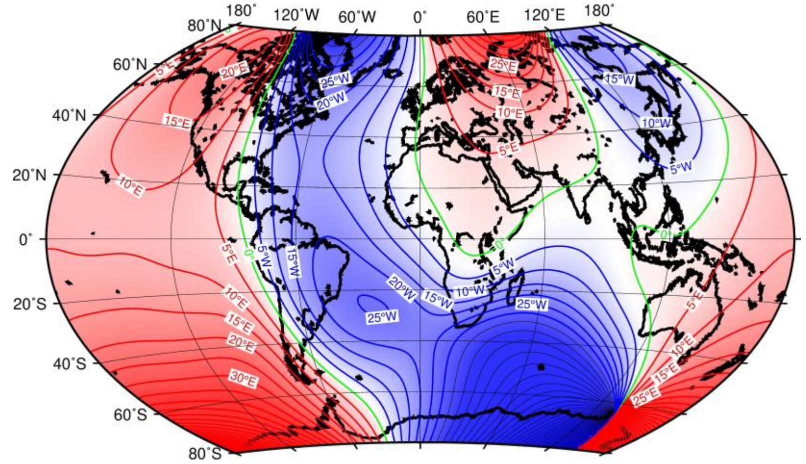



## Overpass Time, Position, and Alignment

Assumption: Ionosphere as thin layer

## IGS Model for Earth Magnetic Field



## Prediction of Faraday Rotation

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# Faraday Rotation Estimation (2024)

$$Ratio = \frac{derived\ FR}{predicted\ FR}$$

| | | Measurements | | |
|---|---|---|---|---|
| Date | Satellite | H/V-Ratio | Derived FR | Prediction |
| 13.01. | SAOCOM | 19.65 dB | 5.94° | 4.19° |
| 14.02. | SAOCOM | 19.23 dB | 6.24° | 7.16° |
| 17.03. | SAOCOM | 17.24 dB | 7.82° | 9.08° |
| 18.04. | SAOCOM | 14.01 dB | 11.27° | 14.58° |
| 19.04. | ALOS-2 | 18.65 dB | 6.66° | 8.41° |
| 08.05. | ALOS-2 | 20.42 dB | 5.44° | 6.00° |
| 20.05. | SAOCOM | 14.99 dB | 10.09° | 11.54° |
| 25.05. | ALOS-2 | 15.90 dB | 9.11° | 11.71° |
| 31.05. | ALOS-2 | 22.80 dB | 4.14° | 6.15° |
| … | ... | … | … | … |

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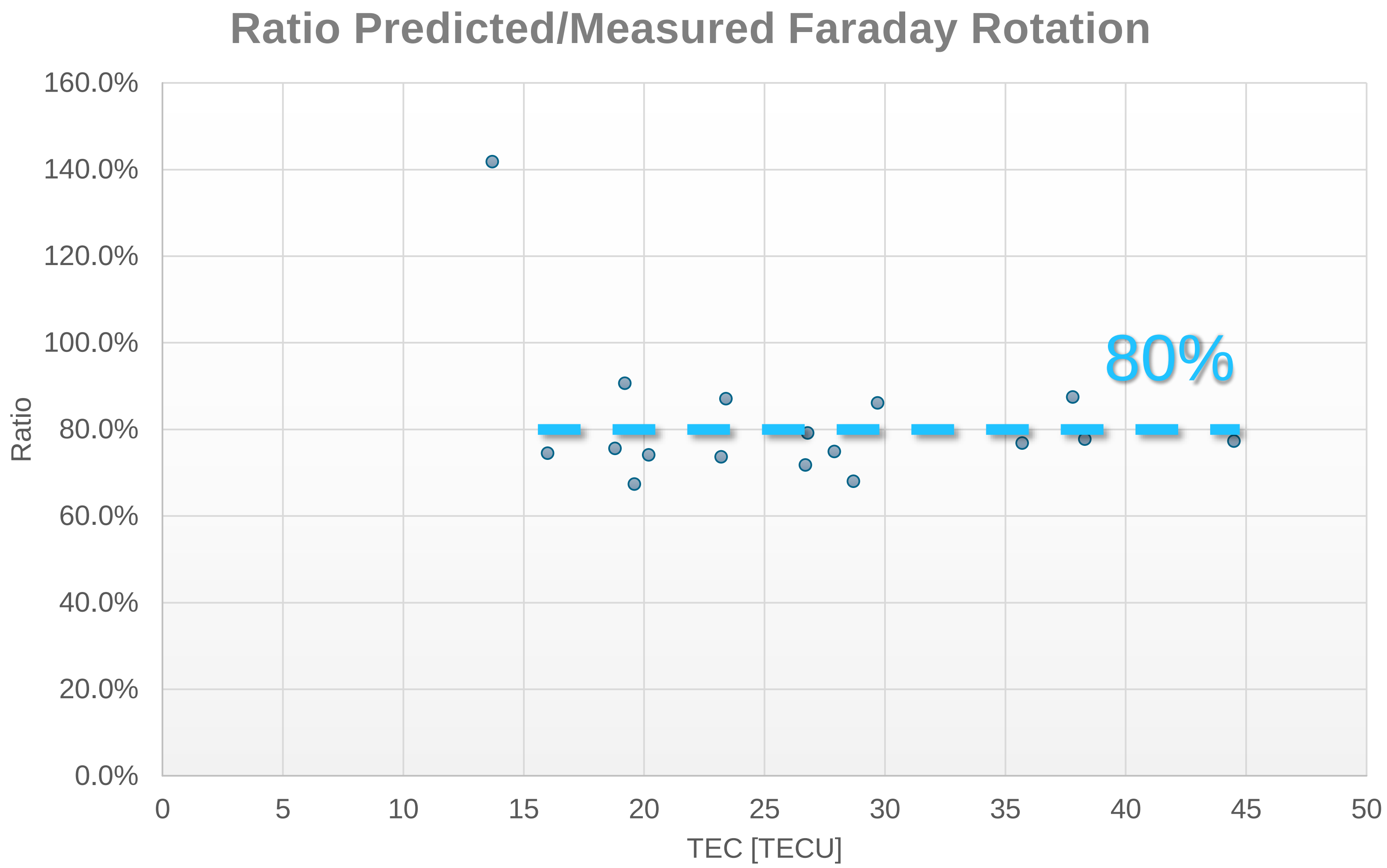


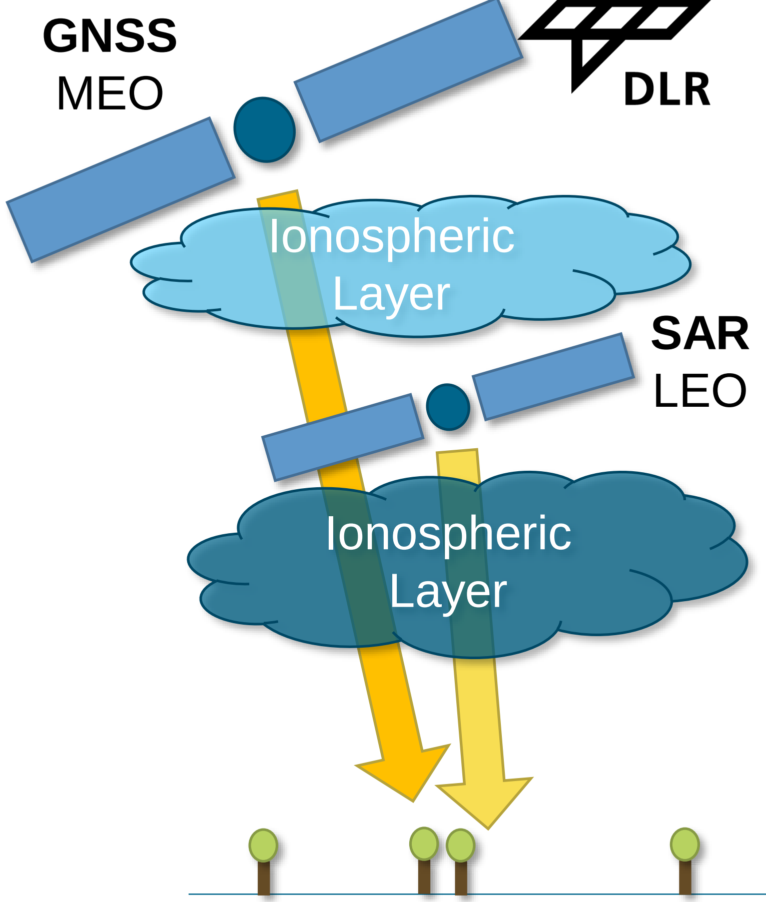


Higher predicted TEC values are expected because GNSS satellites see “more“ ionosphere (higher orbit)

# Faraday Rotation Estimation

| | | Measurements | | | |
|---|---|---|---|---|---|
| Date | Satellite | H/V-Ratio | Derived FR | Prediction | Ratio |
| 13.01. | SAOCOM | 19.65 dB | 5.94° | 4.19° | 141.76% |
| 14.02. | SAOCOM | 19.23 dB | 6.24° | 7.16° | 87.1% |
| 17.03. | SAOCOM | 17.24 dB | 7.82° | 9.08° | 86.2% |
| 18.04. | SAOCOM | 14.01 dB | 11.27° | 14.58° | 77.3% |
| 19.04. | ALOS-2 | 18.65 dB | 6.66° | 8.41° | 79.2% |
| 08.05. | ALOS-2 | 20.42 dB | 5.44° | 6.00° | 90.7% |
| 20.05. | SAOCOM | 14.99 dB | 10.09° | 11.54° | 87.5% |
| 25.05. | ALOS-2 | 15.90 dB | 9.11° | 11.71° | 77.8% |
| 31.05. | ALOS-2 | 22.80 dB | 4.14° | 6.15° | 67.4% |
| … | ... | … | … | … | … |

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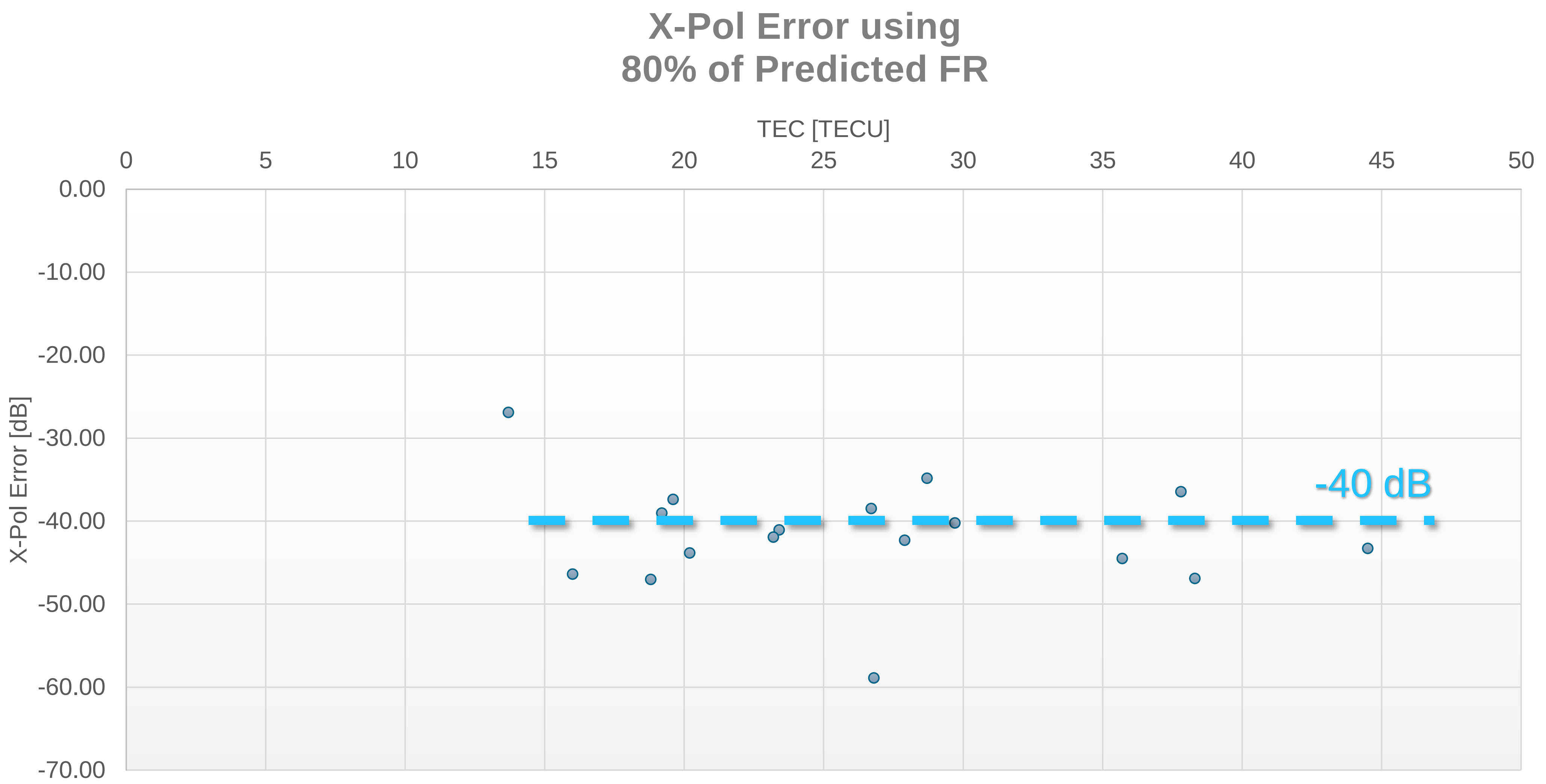


➔ **Even a simple ionospheric model and reasonable assumptions allow for a good prediction of Faraday rotation**

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# Take-Away Messages

- DLR SAR Calibration Center has developed on Calibration Concept for ROSE-L
- Best Solutions might not always be obvious
  - Transponder might be better than Corner Reflectors for Geometric Calibration
- We can Test our Calibration Algorithms with real SAR Data even Today
  - Working Reference Targets (Transponder and Corner Reflectors)
  - Test Data from ALOS-2, SAOCOM (and hopefully NiSAR in the future)
- Similar Calibration Performance as Sentinel-1 is expected for ROSE-L
  - Include lessons learned from Sentinel-1

ROSE-L is a Programme of the European Commission European Union Copernicus Europe's eyes on Earth co-funded with esa.

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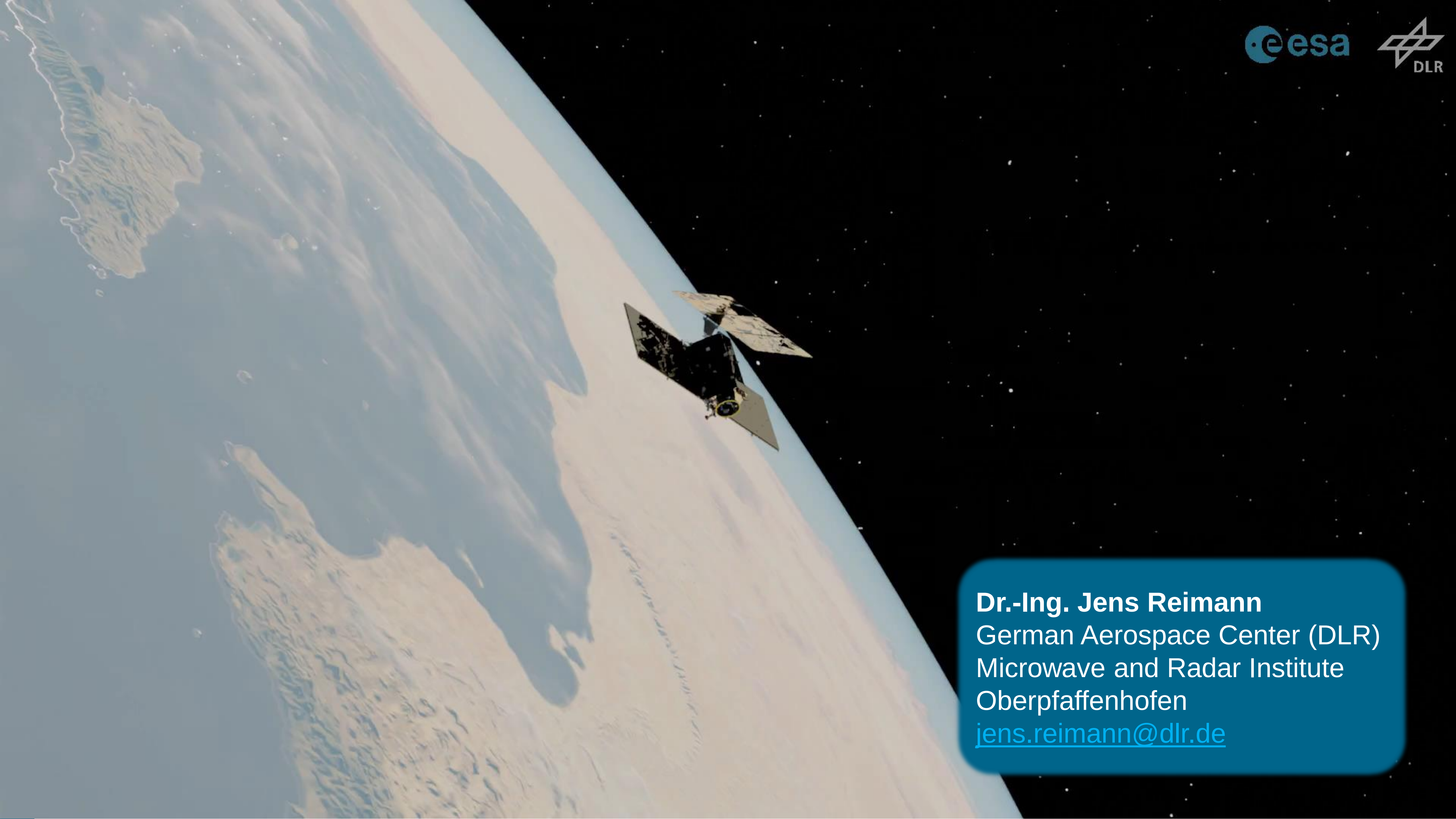


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