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Wildlife research and conservation with AI and satellite-based mioty® technology

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Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

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Fraunhofer-Institut für Integrierte Schaltungen IIS

Leibniz-Institut für Zoo- und Wildtierforschung
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DLR Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

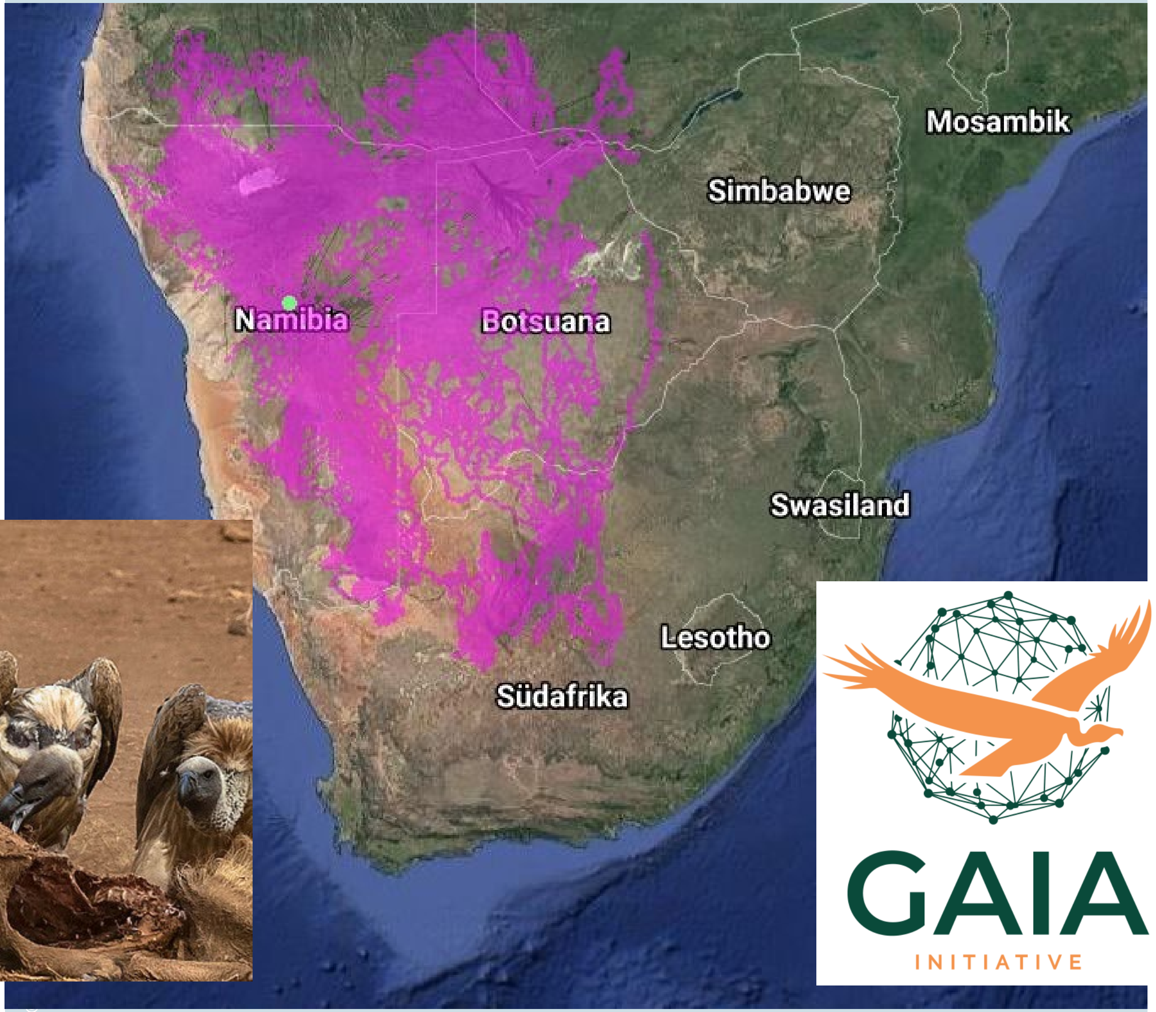
Wildlife Research and Nature Conservation with AI and Satellite IoT Technology

Research of and with vultures

Why vultures?

- Little researched
- Movement profile covers a large area
- The vultures' swarm intelligence (discovering carcasses) can deliver important information on mass animal deaths due to diseases

Movement Profile of tagged vultures in Africa



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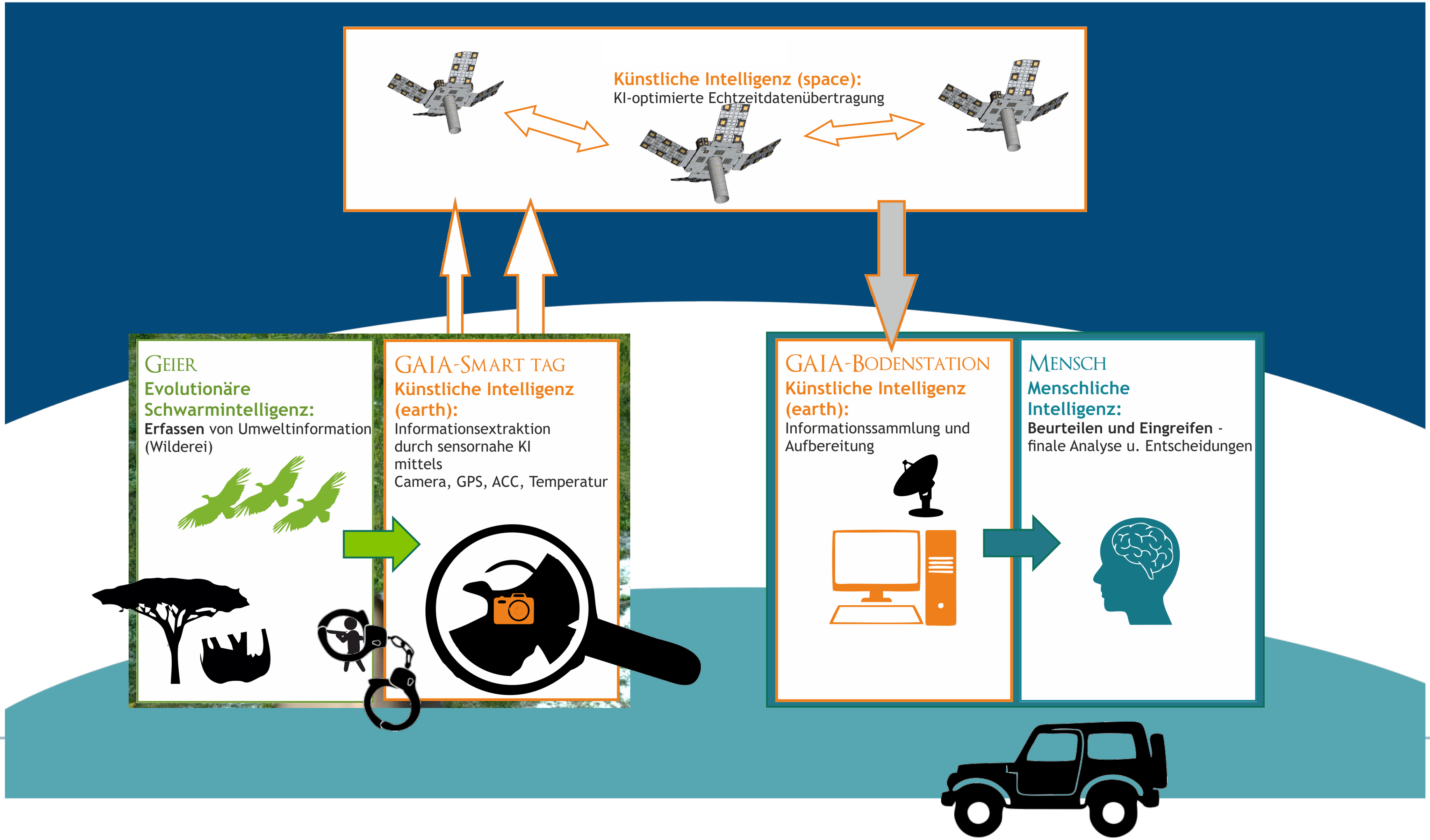
Basic Idea for Poaching Prevention – Making use of the 3 intelligences



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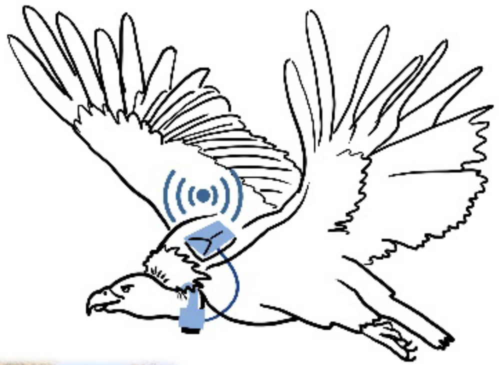
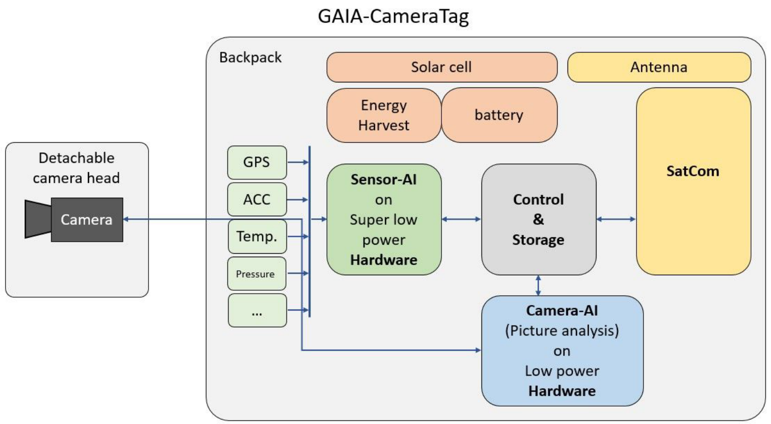




Vulture approaches dead animal and eats

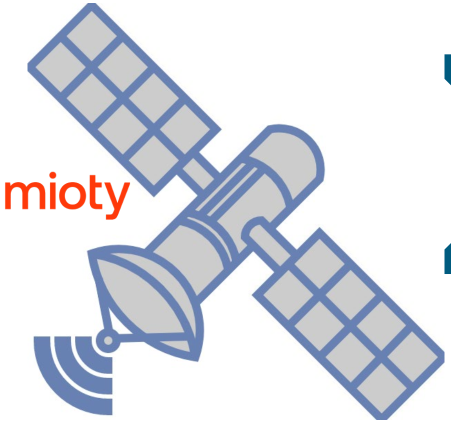
AI evaluation of the acceleration data triggers camera

Camera captures image

Onboard AI classifies alarm status

mioty®-SatCom module transmits alarm

Swarm Intelligence → Extreme Edge Networks



LEO satellite receives data

Data is forwarded to ground station

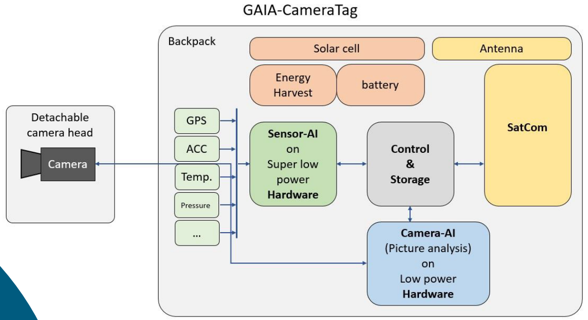
Automatic data processing

User (biologist) analyzes data

GAIA-Inititiative – Key Aspects of Research Areas

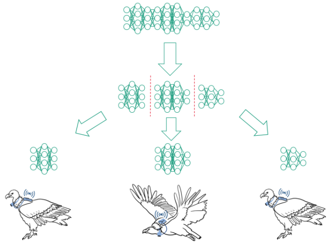

Wildlife Observation and Field Work (Leibniz IZW)

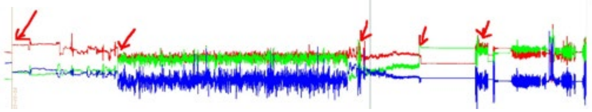




Camera Tag Design & Implementation

Embedded AI for Sensor and Image Processing





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mioty® SatCom Transmission

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mioty

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Department RF & SatCom Systems

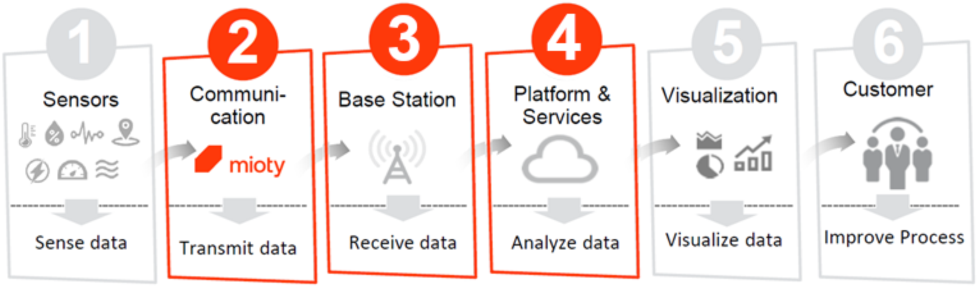
Satellite based mioty®

Florian Leschka: florian.leschka@iis.fraunhofer.de

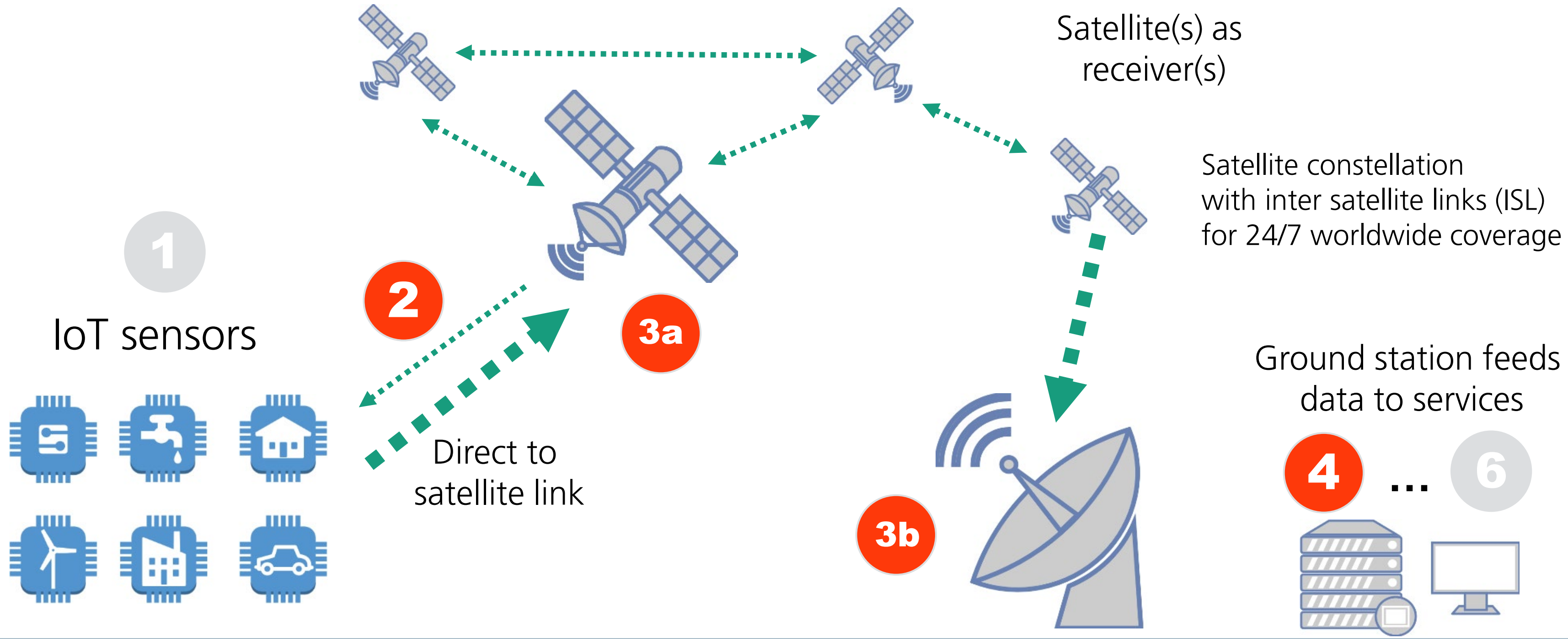
From terrestrial to satellite

IoT via satellite example concept

Typical terrestrial case



Satellite equivalent (concept)



Battery operation for many years, use cases: e.g., agriculture, shipment tracking, maritime

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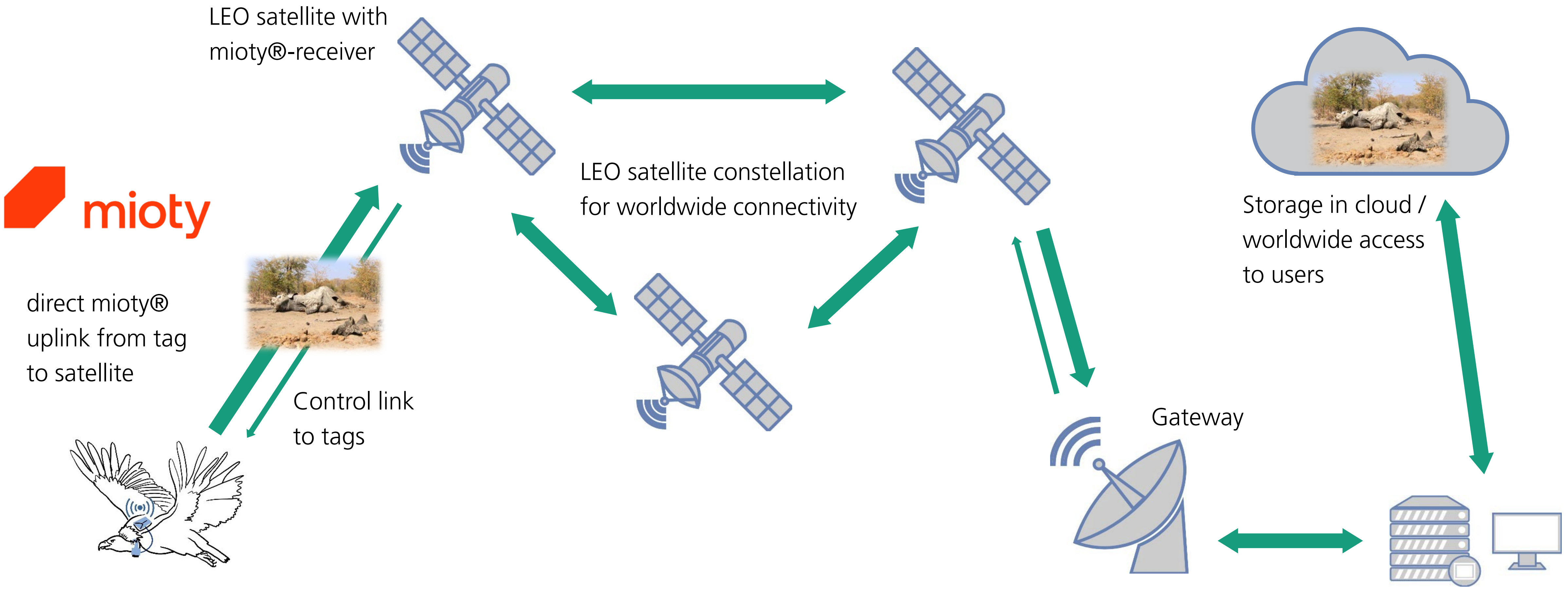
GAIA-Sat-IoT System

mioty® data transfer via LEO satellites for future constellation deployment



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GAIA-Sat-IoT / SyNaKI (part of GAIA-Initiative)

Developments of mioty® technology for SatCom Scenario

Gefördert durch:

Bundesministerium für Wirtschaft und Energie

aufgrund eines Beschlusses des Deutschen Bundestages

DLR Deutsches Zentrum für Luft- und Raumfahrt

Raumfahrtmanagement

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Development of single components for LEO satellite IoT systems

Our key aspect of both projects:

- Higher data rate for mioty®
- Bigger message size for mioty®
- Tag development for S- and L-Band
- BiDi-Support via Satellite
- Enhanced Doppler compensation (*)
- Receiver architecture for distributed LEO constellation

- **prepare mioty® technology for LEO satellite mission**

mioty

(*) based on patented ideas

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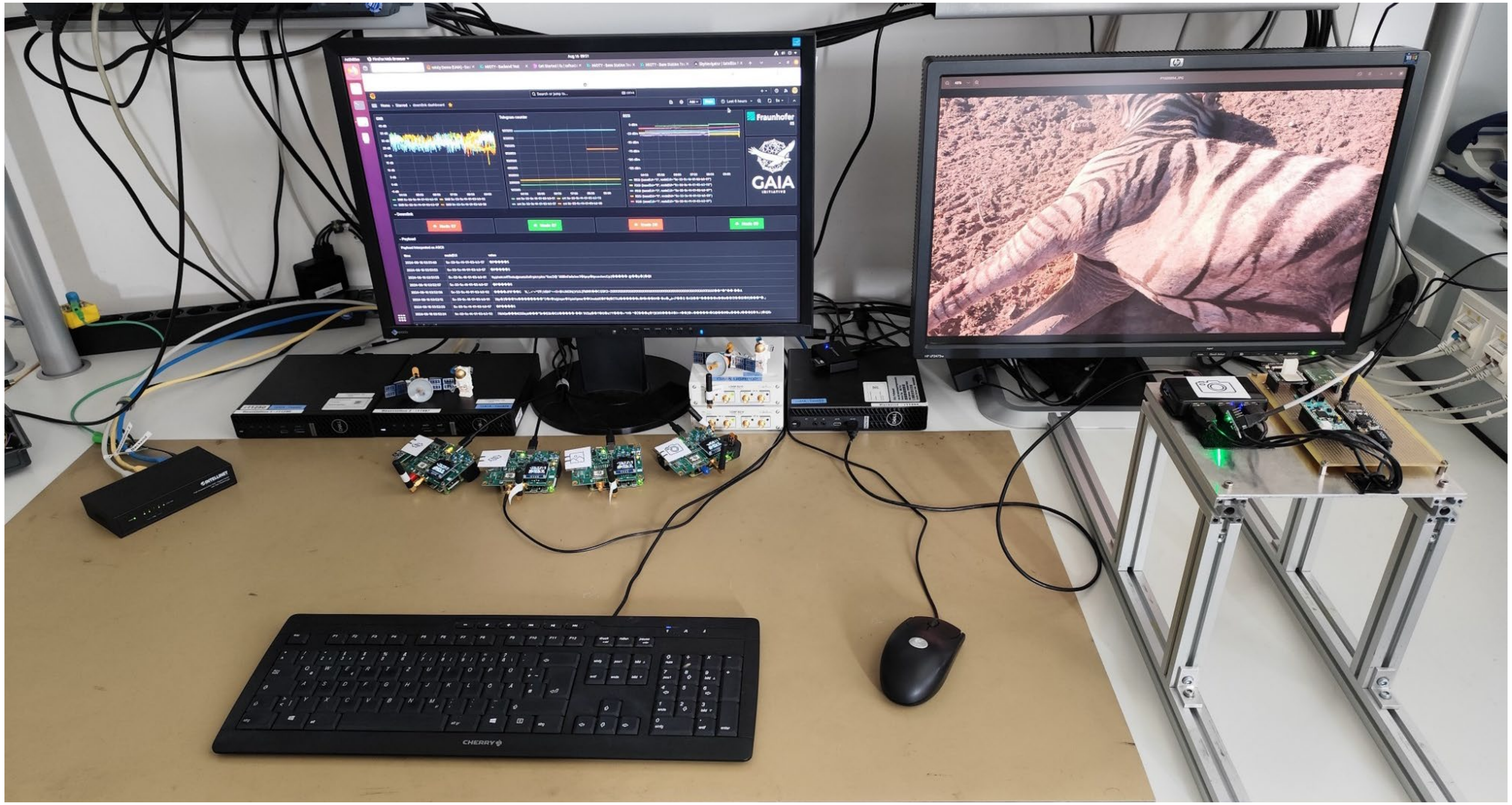
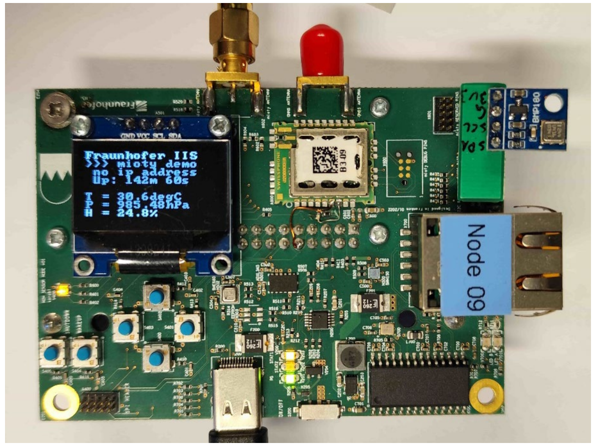
GAIA - Lab Demonstrator

Overview





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Robustness against Time Variant Doppler Shift

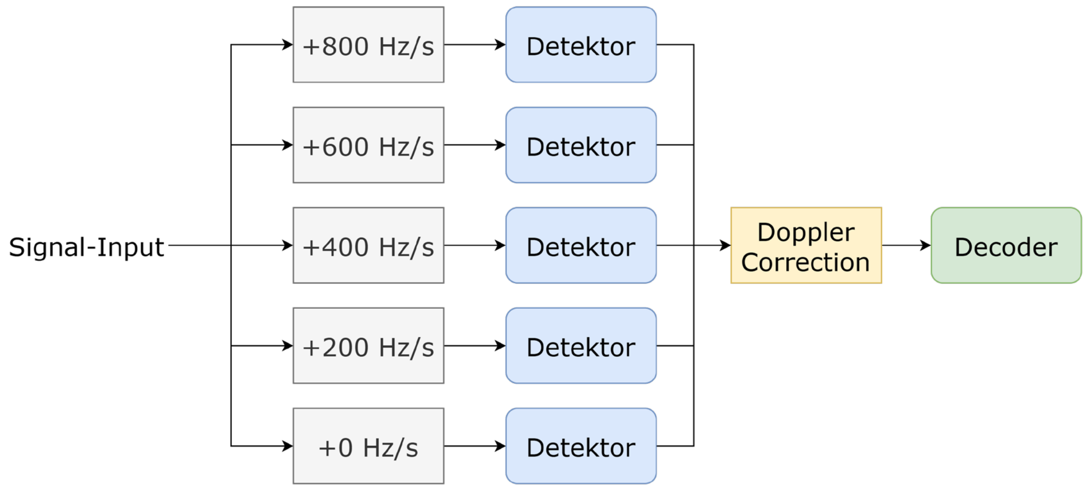
Assumptions and Design Goals

Goals

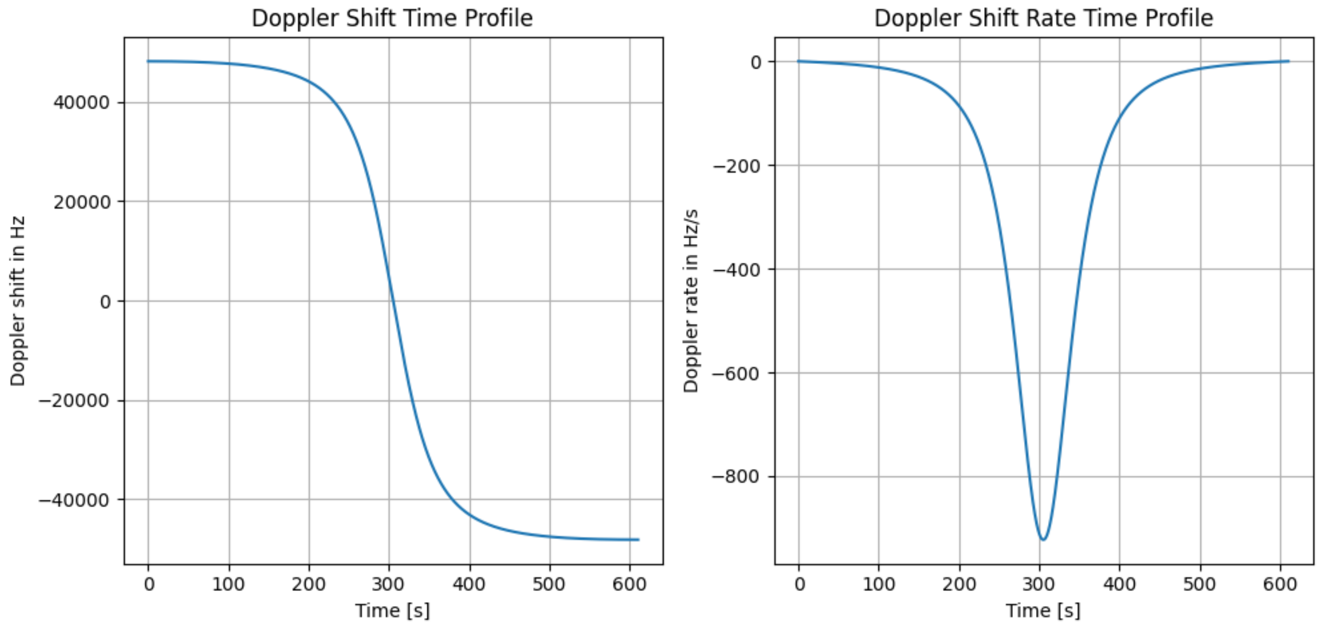
- No changes to Nodes (Transmitters)
- Less than 2dB Performance Loss compared to Terrestrial at 1% PER

Assumptions

- Doppler Profile: Max Values see figure on the right
- Terrestrial Receiver is already robust to a Doppler rate of ~100 Hz/s



Schematic overview of Doppler robust receiver



Doppler Profile for LEO sat at 400 km, Radio Frequency 2000 MHz

See: S. Roy, U. L. Dang, J. Kneissl, G. Kilian, R. Meyer and F. Obernosterer, "Time Variant Doppler Compensation for TS-UNB," 2023 IEEE International Conference on Acoustics, Speech, and Signal Processing Workshops (ICASSPW), Rhodes Island, Greece, 2023, pp. 1-5, doi: 10.1109/ICASSPW59220.2023.10192999.

Robustness against Time Variant Doppler Shift

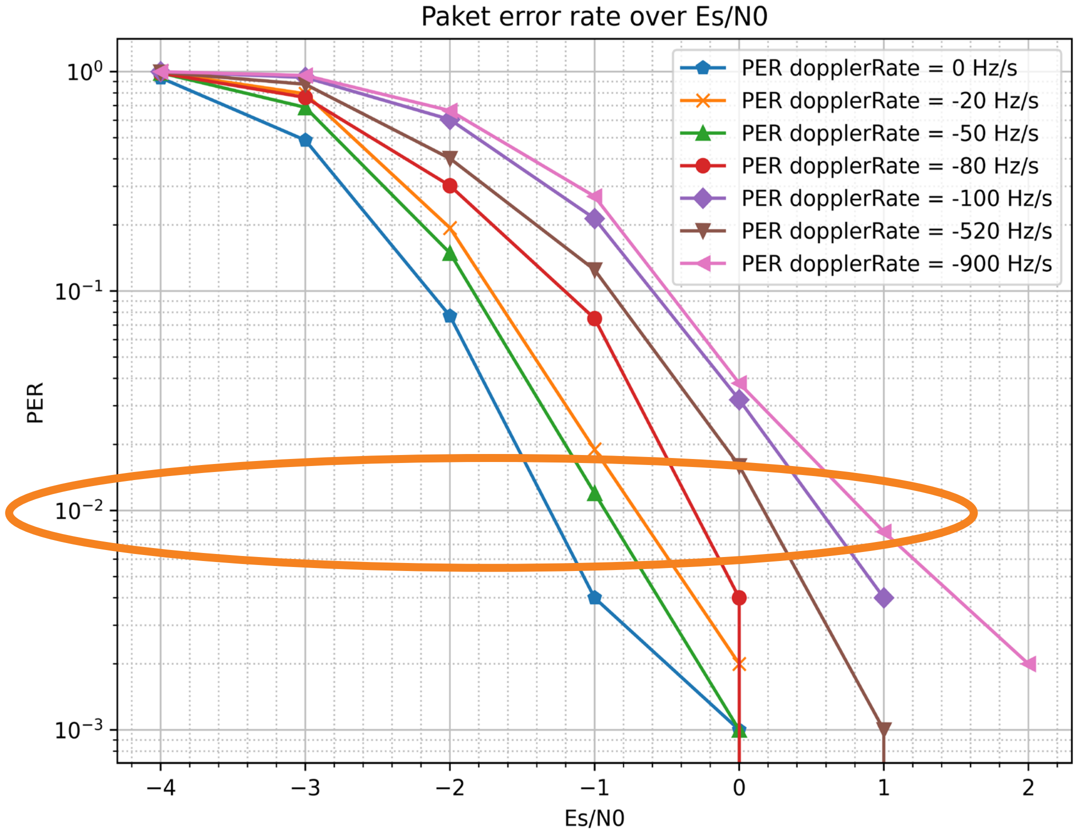
Results and comparison to LoRa

Doppler Robustness

- **mioty®**
  - **Receiver with Doppler compensation developed and tested**
  - **Waveform can stay untouched** (Rx compensation)
  - Performance depends on the receiver and link budget
  - **Only slight degradation** (≤ 2dB @ PER = 1%)

Note: Classical LoRa is 4.5 dB worse than mioty® at 200 Hz/s

Mioty® vs LoRa study report https://mioty-alliance.com/mioty-vs-lora-study-report/



PER at different values for the Doppler-Rate using a Doppler-compensating mioty® receiver

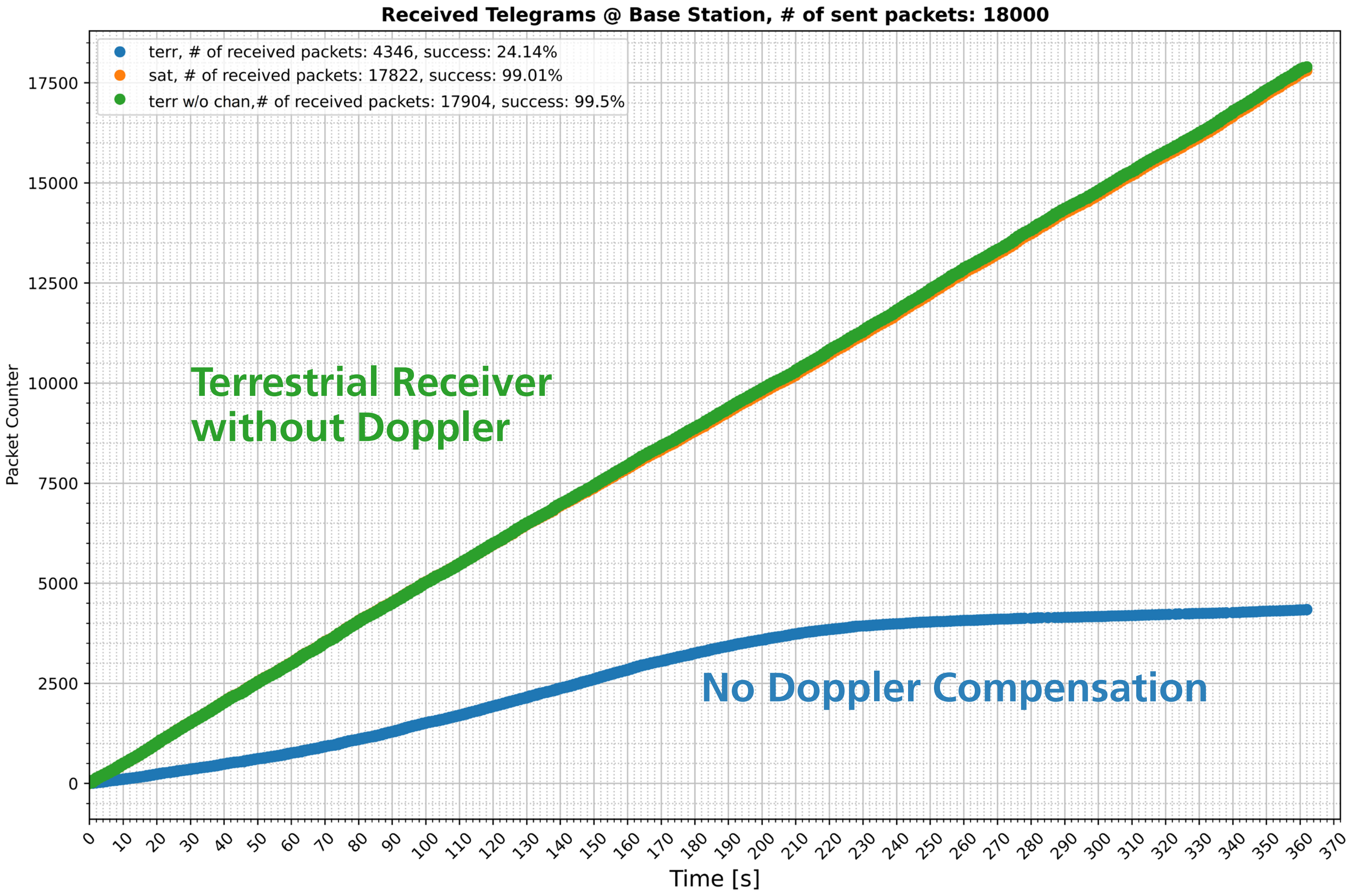
See: "mioty comparative Study Report" by TU Ilmenau, https://mioty-alliance.com/mioty-vs-lora-study-report/

Robustness against Time Variant Doppler Shift

Measurements

Number of received mioty messages during an emulated LEO pass

- Emulation frequency: 2 GHz
- Satellite alltitude: 1500 km
- 50 Messages per second
- **75%** packet loss without compensation
- **1%** packet loss with Compensation
- Practical identical performance of terrestrial receiver



Robustness against Time Variant Doppler Shift

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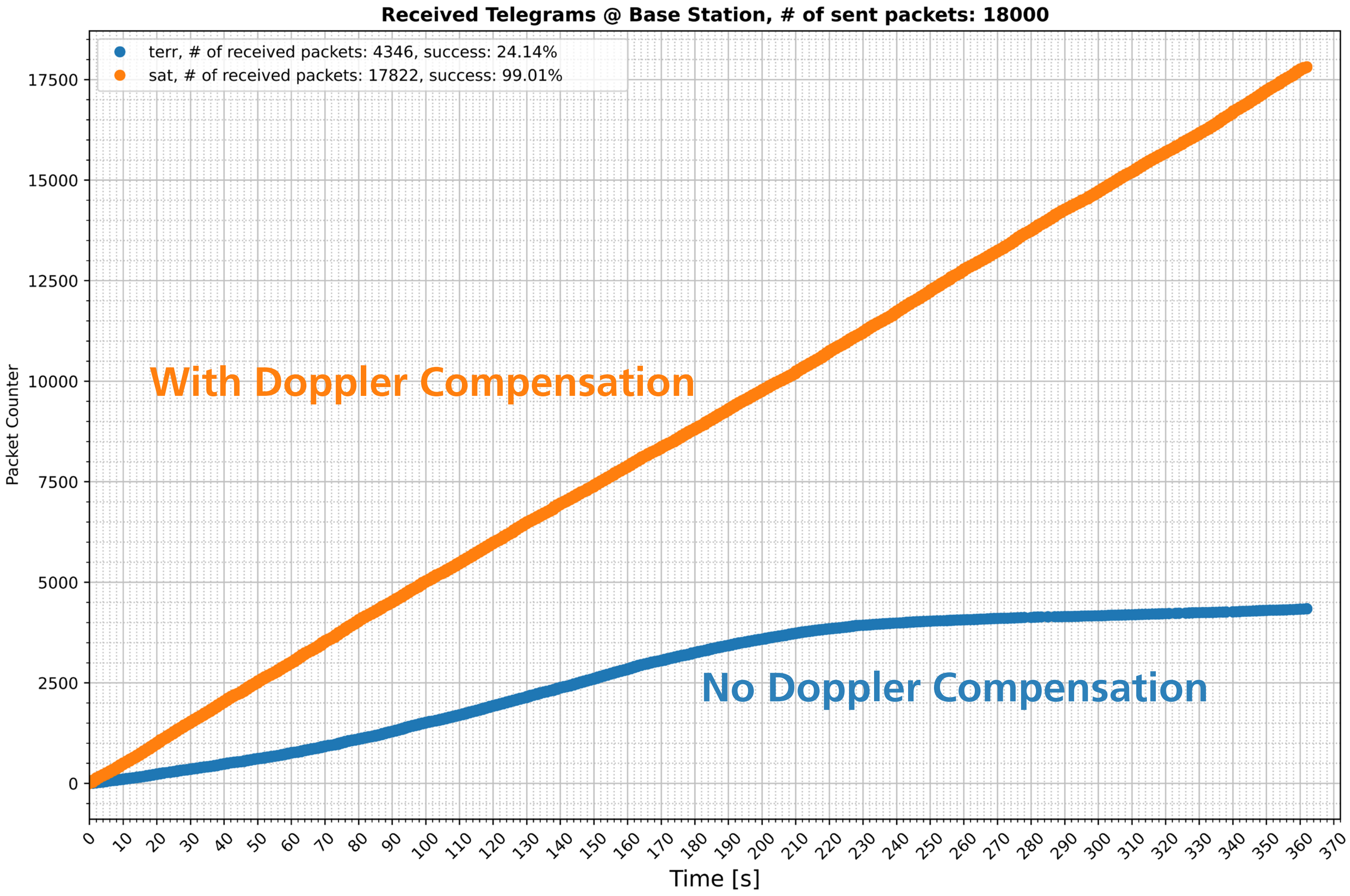

IoT via Satellite

System Capacity Considerations

mioty's capacity is better by at least a factor of 8 compared to LoRa FHSS!

Study by TU Ilmenau: https://mioty-alliance.com/mioty-vs-lora-study-report/

System Capacity

- Number of successful packet transmissions
- Measured within a specific time-frame
- Considered within a given channel bandwidth

Capacity importance in NTN

- Large cell → crucial for handling more users
- High capacity: Essential for high user density without service degradation
- From economic perspective:
  - Supporting a wide range of commercial applications necessary
- Not feasible to densify existing deployments (done in LoRa TN networks)

System Capacity is THE key feature for successful SatCom IoT business cases

See: J. Mrazek, S. Kisseleff, C. Rohde, J. Robert, J. Kneissl and F. Leschka, "mioty superiority over both LoRa-versions in satellite-IoT applications," *41st International Communications Satellite Systems Conference (ICSSC 2024)*, Seattle, USA, 2024, pp. 63-70, doi: 10.1049/icp.2024.4613.

Capacity Analysis

- Capacity simulations need to model realistic node distribution, i.e. more nodes with lower reception power.
- Dynamic range for terrestrial: 69 dB
- Dynamic range for satellite: 10 dB
- Higher Capacity for satellite system:
  - due to smaller dynamic range weaker messages don't get overshadowed by stronger ones.

Doubled capacity for mioty® over satellite!

Current detailed analysis show that direct to satellite mioty® system can deliver **6.25 Mio Messages/day/200kHz** instead of 3.6 Mio

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From Terrestrial to Satellite IoT

Why mioty® for (satellite) IoT networks?

KPI System Capacity:
6.25M Messages/day/200kHz/beam

Multi-source transceiver hardware

Energy efficiency
Long battery lifetime of nodes

Low-cost nodes

High market readiness, entire value chain available → mioty® alliance

Easily adaptable & scalable to specific satellite scenarios

LPWAN protocol with highest system capacity
→ mioty® for large roll-outs
See mioty® comparison study:
https://mioty-alliance.com/mioty-vs-lora-study-report/

Robust against Doppler and interference
Developed in ESA and DLR projects

Open ETSI standard
TS-UNB, vendor independent

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Key Takeaways & Outlook

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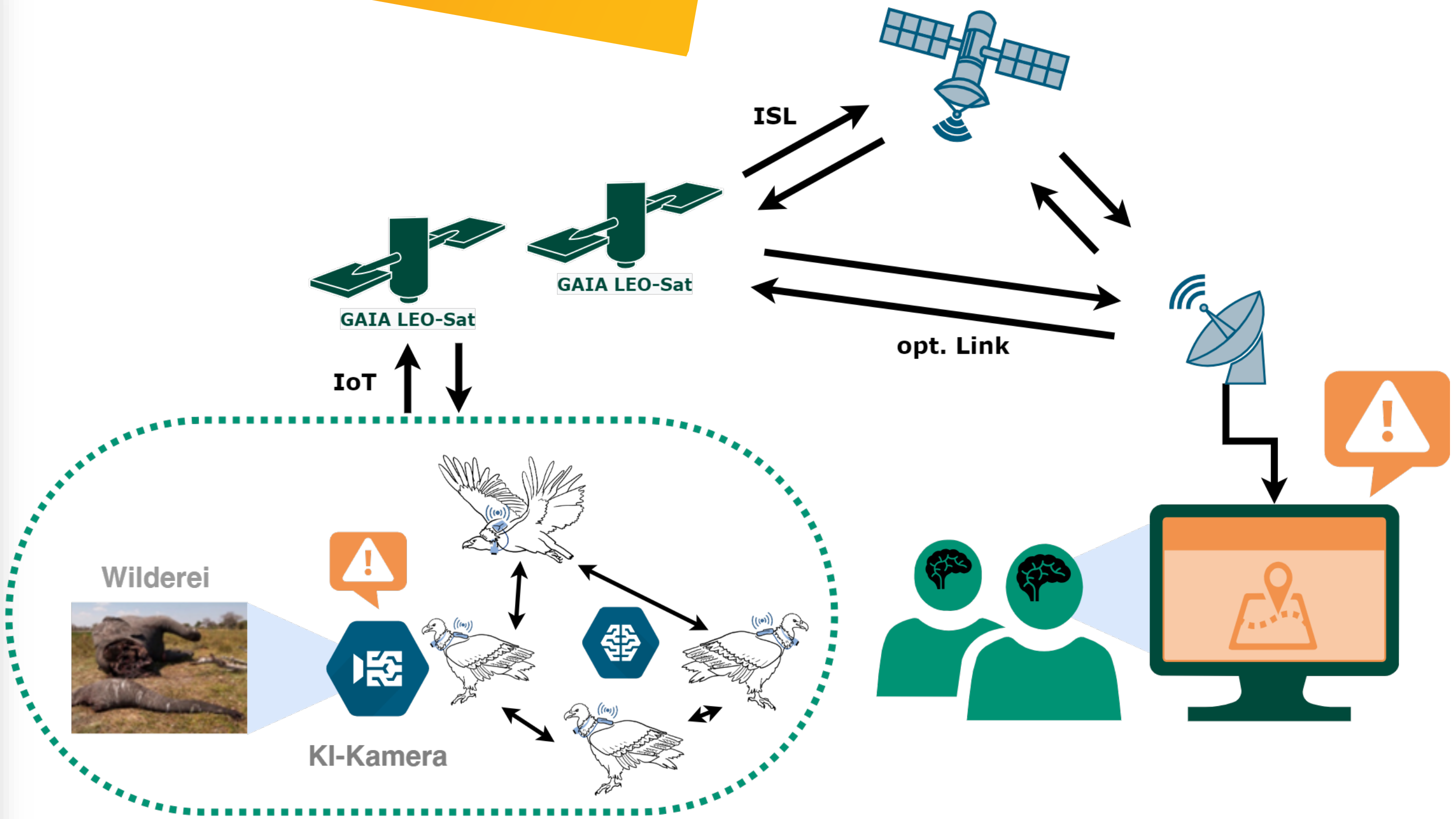
Next Step: GAIA-MISSION … 2025

Delayed due to budget restrictions at caused by elections in Germany this year



TESAT · TU berlin · RAPID CUBES · Leibniz-Institut für Zoo- und Wildtierforschung · Fraunhofer IIS

Key Takeaways and Outlook

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Our Offer:

Fraunhofer IIS supports national and international SatCom players in:

- **Consulting**
- **R&D in SatCom**
- **System Design**
- **System Simulations**
- **Constellation Design**
- **Test & Verification**

1. **GAIA-Initiative**: **developing a new generation of animal tags** equipped with on-board artificial intelligence (AI) & camera and **satellite-based IoT communication** technology (mioty®)
2. Envisioned **GAIA-MISSION** for **demonstrating entire system** in the field for wildlife observation and nature conservation
3. **Scalable Satellite IoT network**: more applications from other verticals will be show-cased in the future
4. **Looking for partners** and satcom/IoT operators **for** future **demonstration and testing**

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Key Takeaways and Outlook

mioty

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1. **mioty®** can easily be adopted to specific SatCom IoT scenarios
2. **System Capacity is key feature** for successful SatCom **business cases**
3. **TS-UNB/mioty® outperforms IoT/LPWAN protocol competitors**
4. **Trends in IoT: AI, Distributed Computing & (Satellite) Swarms**

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Wanna Meet our Vulture Rudi?

Our Vulture Rudi
GAIA Business Developer

From Paris Air Show 2025 to

… Wacken 2025
Heavy Metall Festival

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12. Paper ICSSS 2024: mioty® Superiority over Both LoRa®-Versions in Satellite-IoT Applications https://ieeexplore.ieee.org/document/10915777

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