Laser Communication Systems for Aerial Platforms - from Perspective of a Startup in Mobile-FSO

Dirk Giggenbach

ViaLight Communications GmbH (VLC)

www.vialight.de

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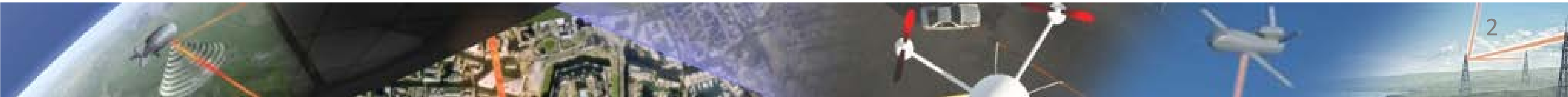
- **Atmospheric Boundary Conditions**
- **Aircraft Downlinks**
- **Inter-Platform Links**
- **Components**



ViaLight Communications - Who we are

- Founded as DLR-Institute Spinoff in May 2009
- …by three (former) Members of the “Optical Communications Group” of German Aerospace Center, Institute of Communications and Navigation
- Won first incubation-money from ESA-BIC program in April 2010
- 2010: Rooms in AZO-Oberpfaffenhofen (close to German A.S. Cntr - DLR)
- Won in-kind support by “Helmholtz-Fonds”
- June 2012 Offices in “ASTO”-Business-Park at Airport Oberpfaffenofen
- Currently 12 staff members (2014)

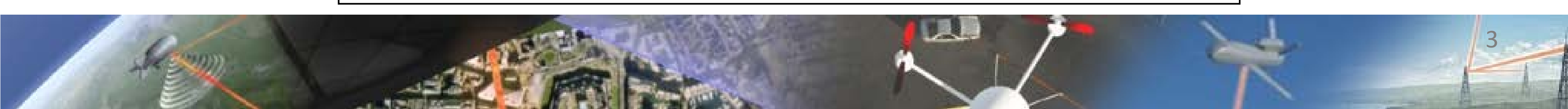
- Coop. Agreement with DLR-Institute of Communications and Navigation
- Licensing Agreement with same

Branch Offices ESA BIC Bavaria

At ESA BIC Bavaria start-ups can choose from three different branches: the headquarters at Oberpfaffenhofen, Nürnberg or Berchtesgadener Land.

Oberpfaffenhofen

At the head office at the prominent aerospace location Oberpfaffenhofen, close to Munich, start-ups benefit from the exceptional proximity to the German Aerospace Center (DLR), offering expertise and access to testing facilities as well as from additional high-tech companies and a productive economic environment.



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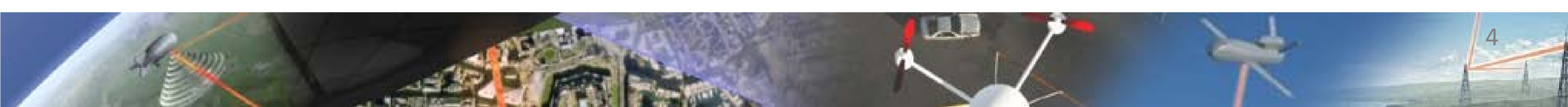
ViaLight Communications – Where we come from

- **German Aerospace Center (DLR)**
  Institute of Communications
  and Navigation (**IKN**)
  → Optical Communications Group
  (inside Satellite-Networks Department)

- More than 25 Years working in
  Optical Inter Sat, Sat-Ground, and Aeronautic Laser Links…

DLR Project Heritage in mobile FSO:
- SiLEx (Optical Inter-Satellite Link Terminal, 1990s)
- DLR-LCT – Ground-Tests and IOV
- KIODO (LEO-Downlinks)
- CAPANINA (Stratospheric Downlinks)
- VABENE (Aeronautic Downlinks), QuaKey (Quantum-Key Distr.)



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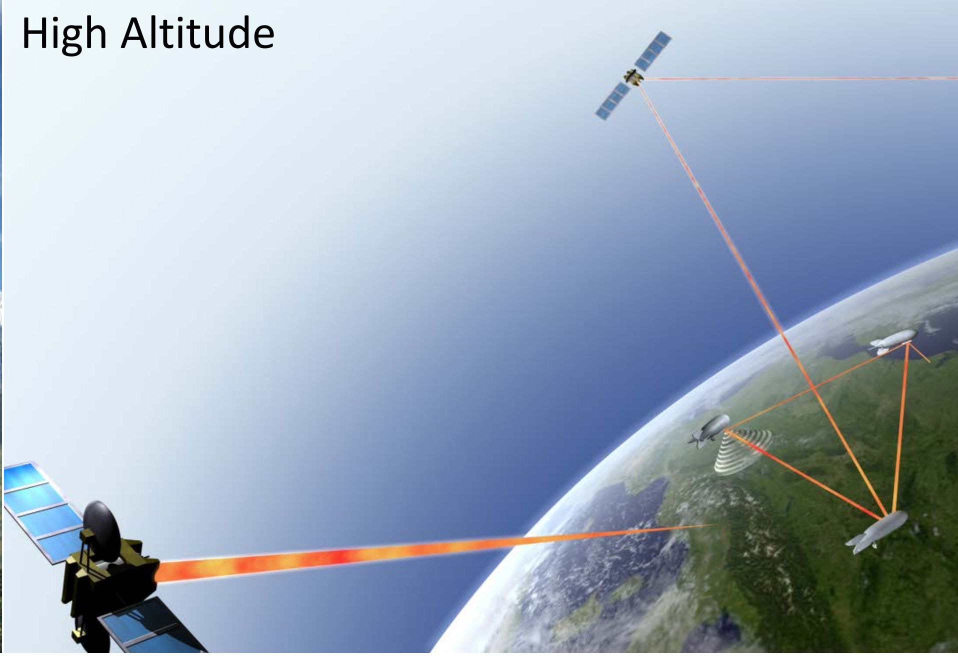
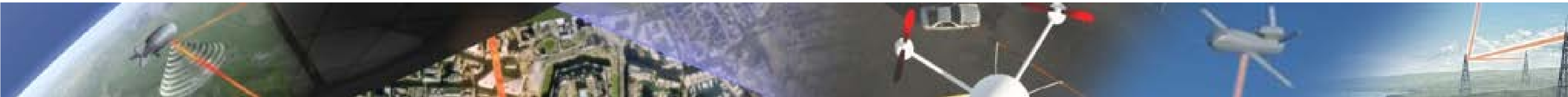
The Communication Bottleneck in mobile Point2Point Links

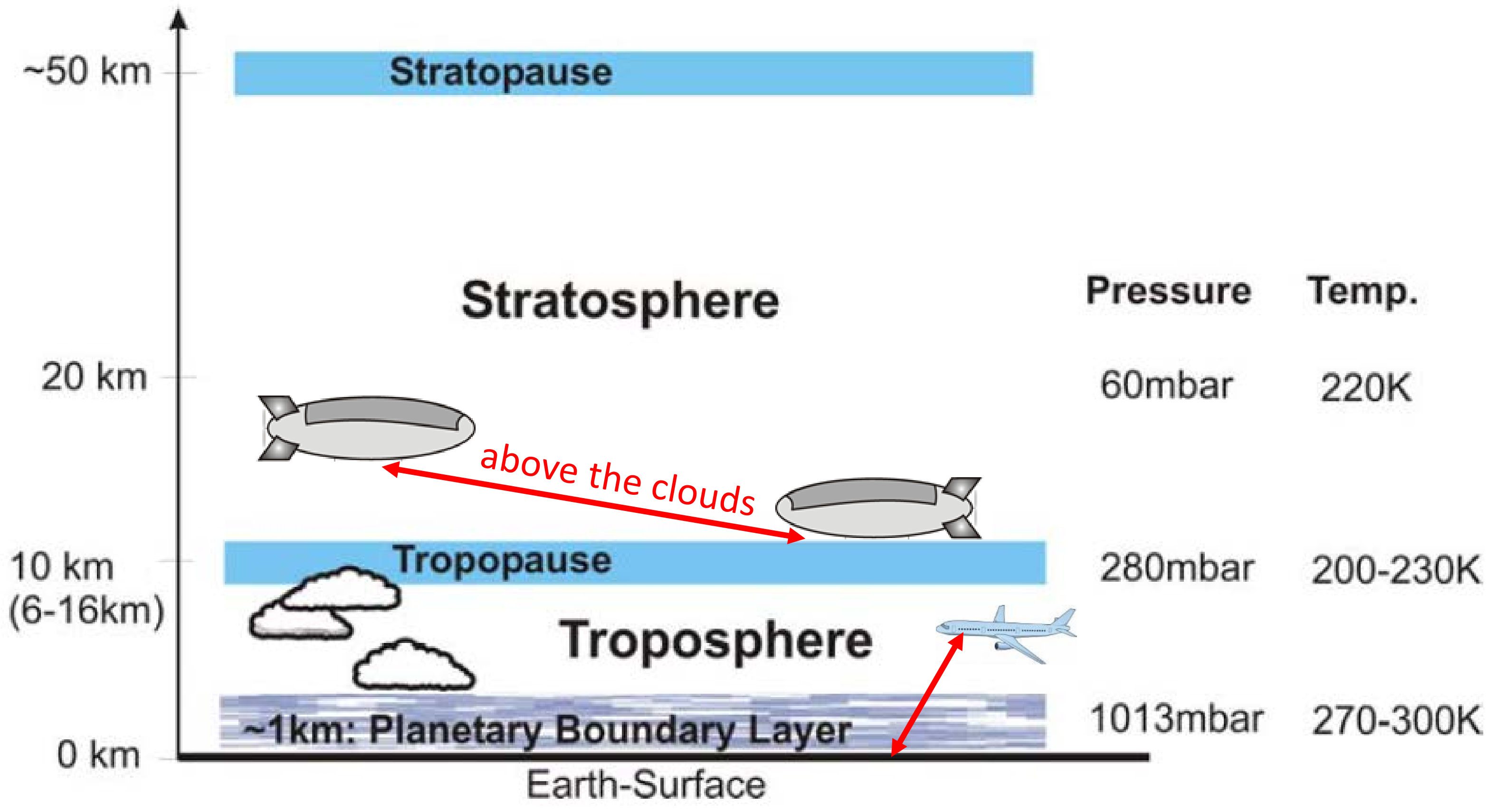
- Direct radio communication links are at the limit of available bandwidth (esp. for long-range free-space and mobile)
- **Datarate, Distance, Antenna-Size & Mass, Spectrum-Regulation, Stealthiness**
- Data-sources: High resolution sensors, Communications.

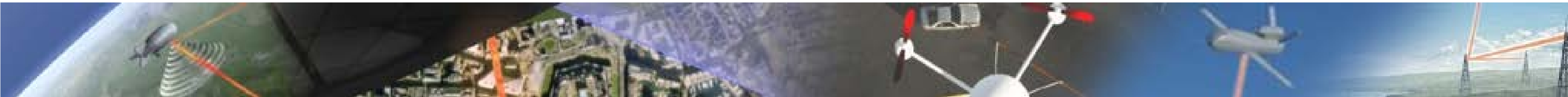




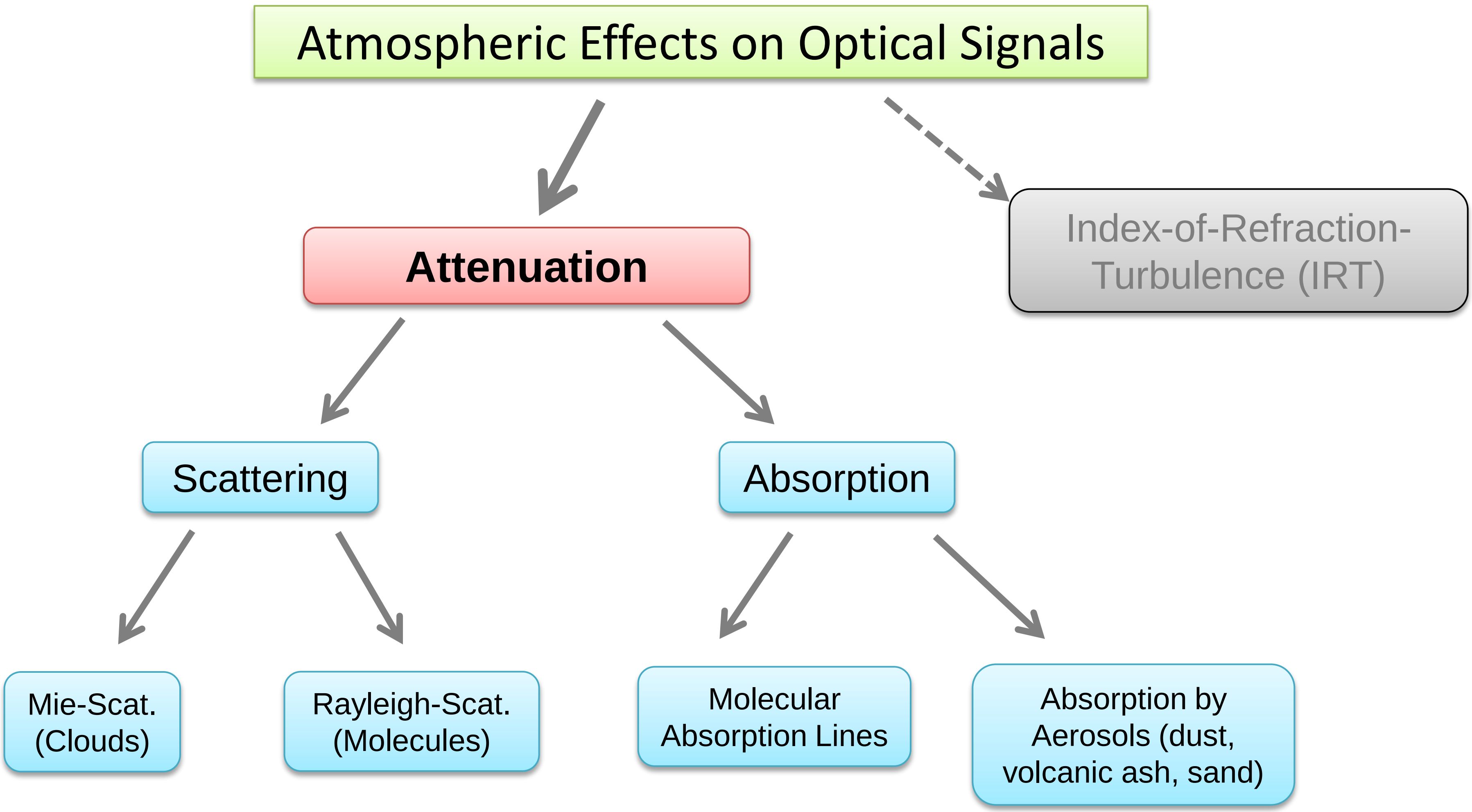
Atmospheric Transmission Channel

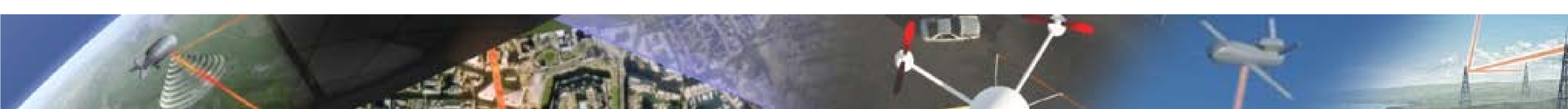
Structure of Earth' Atmosphere relevant to Aeronautic FSO





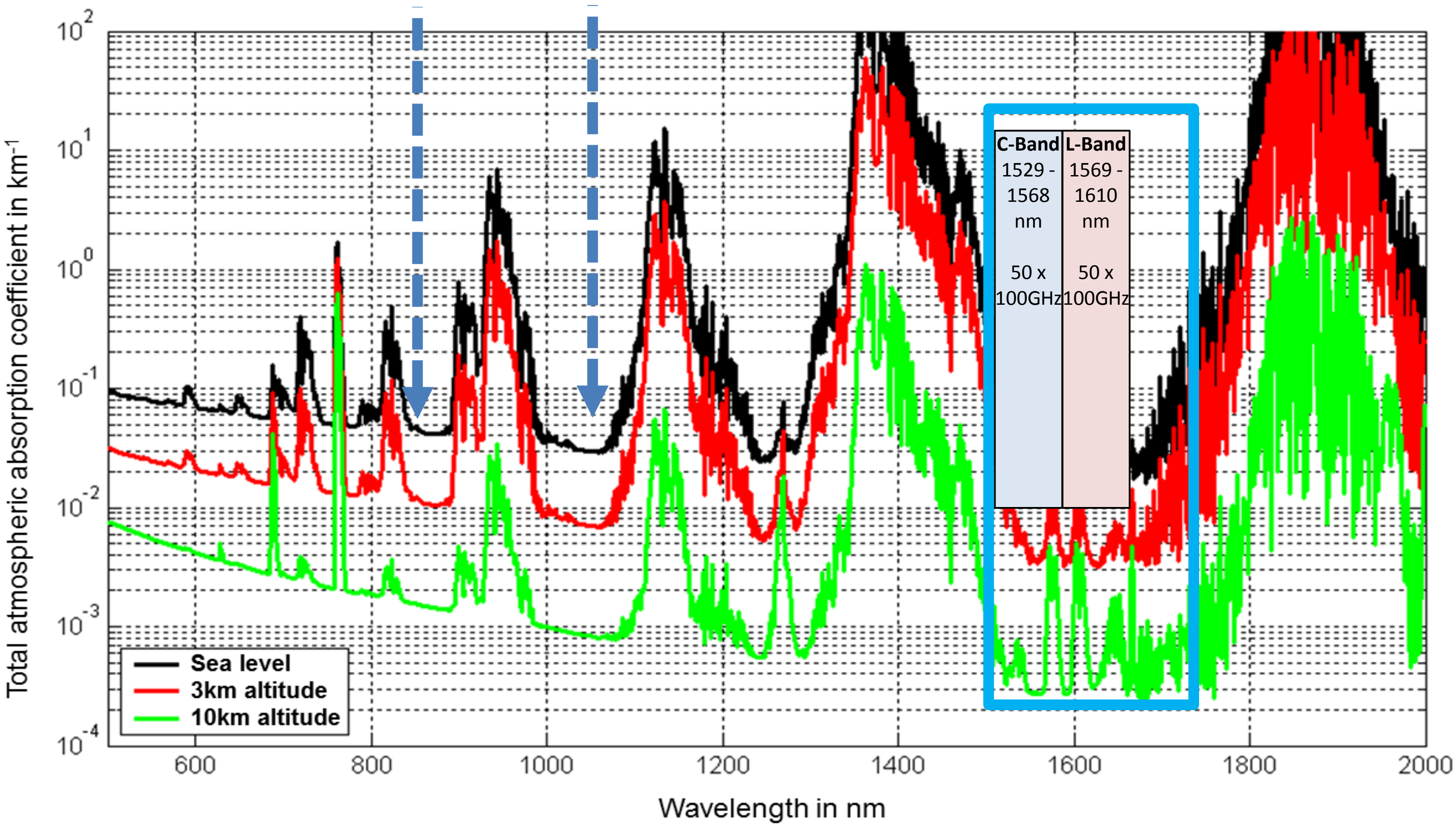
Atmospheric Attenuation Effects

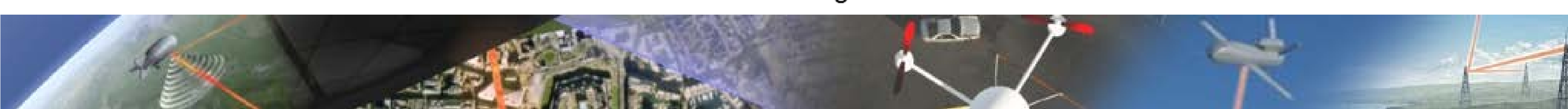




Chosing the Transmission Wavelength

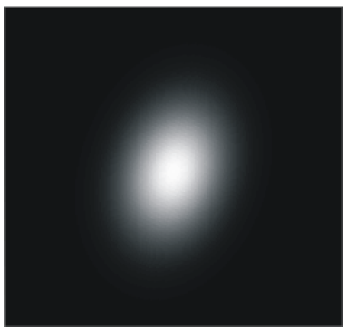
Selection based on Atmospheric Transmission Window and maturized Components from terrestrial fiber communications





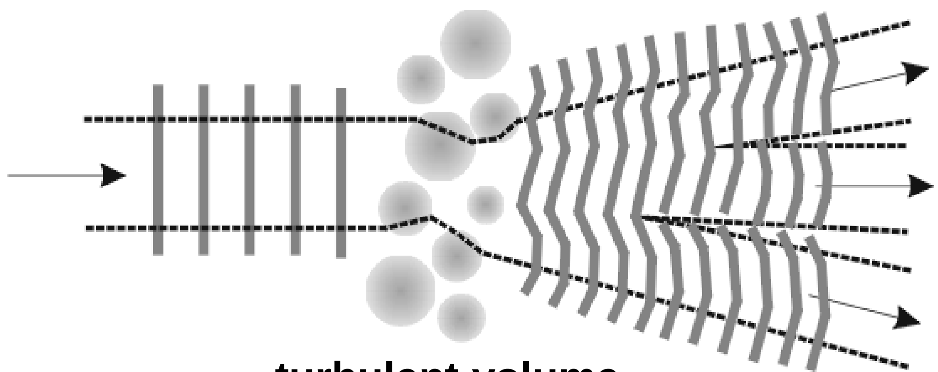
Index-of-Refraction Turbulence (IRT)

What happens when an optical beam passes through turbulent air?

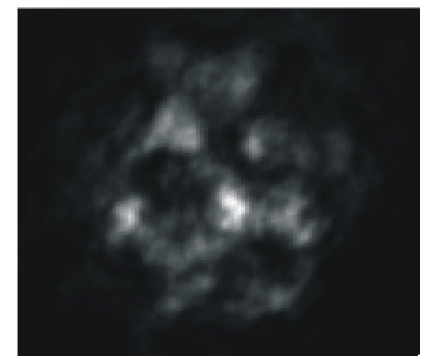


collimated laser beam at Tx

Wavefront distortion **→ Interference**



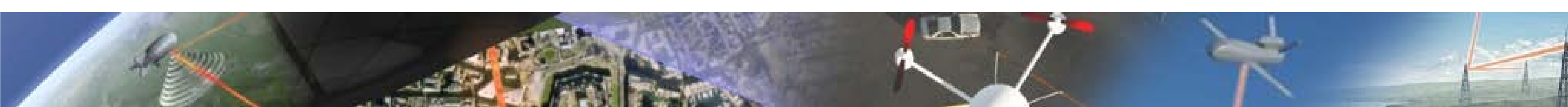
turbulent volume with IRT-strength „C_n^2“



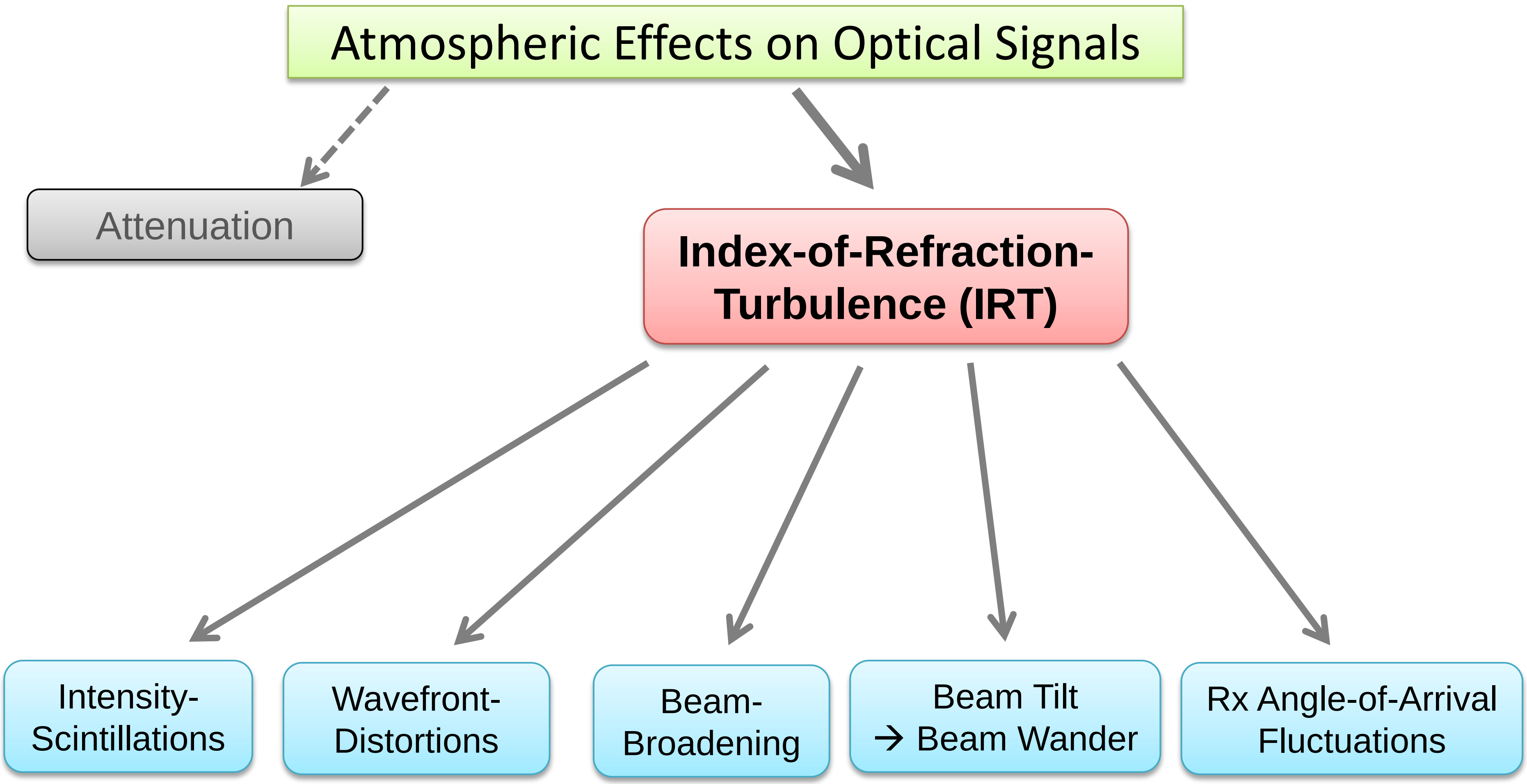
Far-field intensity-speckles

Intensity-Speckles: glittering stars at night

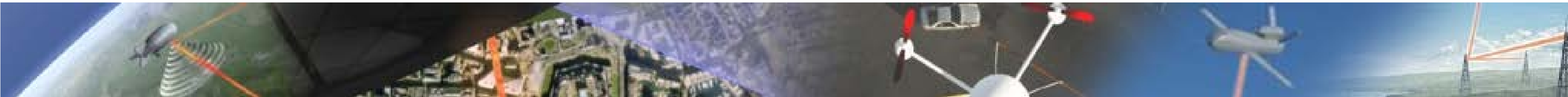
Wavefront-Distortions: warped view over hot street



IRT-Effects

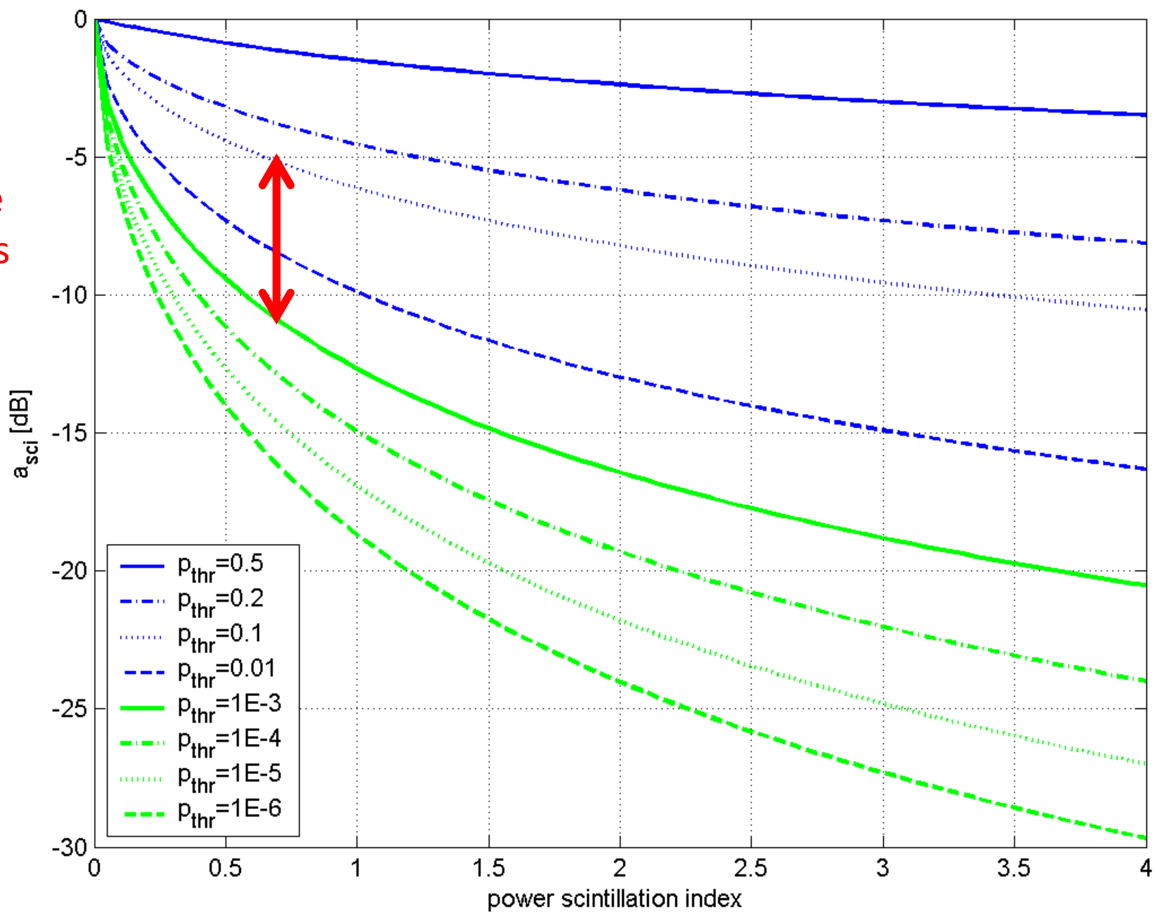


Strengths of effects is scenario-dependent
(beam-divergence, wavelength, distance, C_n^2-profile)



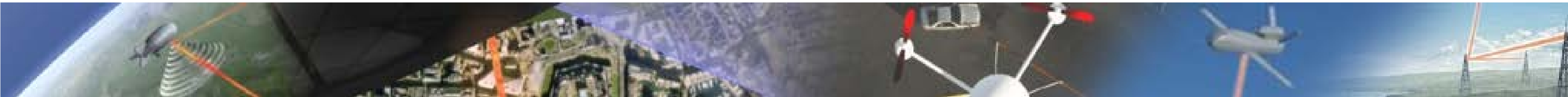
Scintillation Loss depending on σ_P^2 *(after aperture averaging)* for different loss-probabilities p_{thr}

Typical range of fading-loss



Allowed loss is given by system's Error Control Coding abilities

D. Giggenbach, H. Henniger, "Fading-loss assessment in atmospheric free-space optical communication links with on-off keying", SPIE - Journal of Optical Engineering, Vol. 47, No. 4, April 2008



Aircraft Data Downlinks

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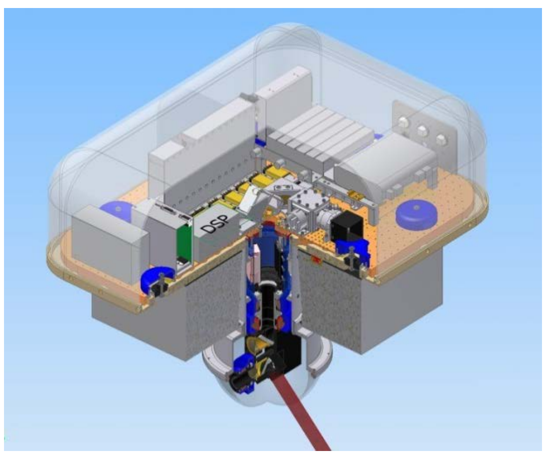
Market Segment: Low Altitude Data-Downlink

Application Scenarios: Traffic control, Aerial photo/surveillance service providers, border control, police, rescue, disaster relieve, film industry, TV, terrestrial networks, surveillance of large premises, defense reconnaissance.

VABENE Project (by DLR): Aeronautic Laser Downlink for realtimeTraffic and Mass-Events Observation

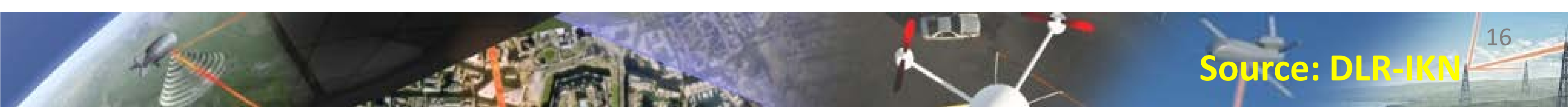


- Coarse Pointing Assembly (CPA) outside the test A/C „Do-228“
- Flexible Optical Bench, Fine-Pointing-Assembly (FPA) and Electronics inside the aircraft
- 60 kg / 70 W
- Up to **1,25 Gbit/s**
- System demonstrated at up to **150 km** distance
- C-Band (1,45µm and 1,60µm) beacon- and communication-laser

  → separation of Tx and Rx (through one optics) by wavelength

Source: DLR-IKN

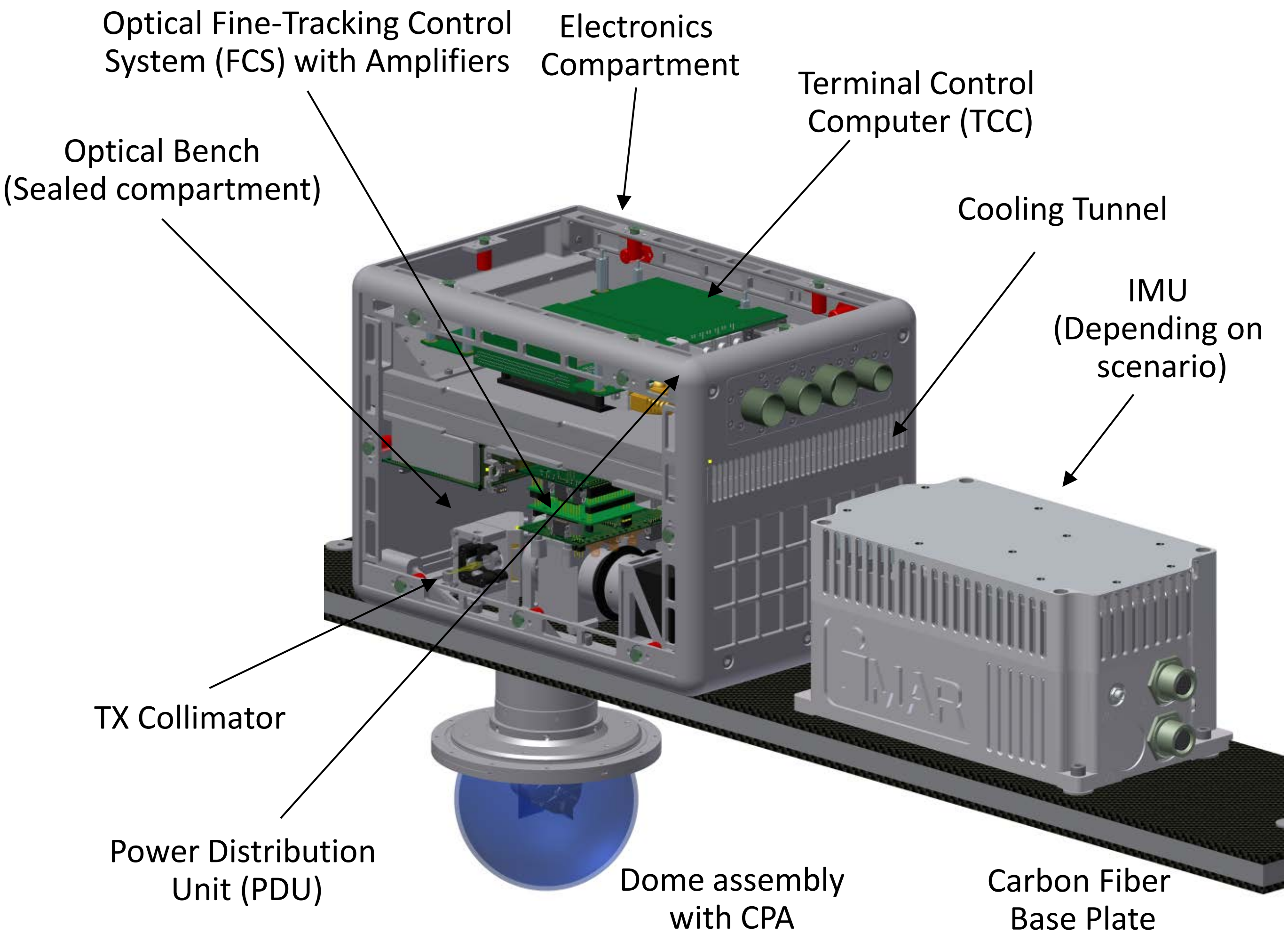
VABENE: Coudé-CPA attached to Do-228 aircraft



Source: DLR-IKN

MLT-20
Aeronautic Downlink Terminal

Miniaturized Terminal MLT-20



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DODfast: Cassidian/Airbus, DLR, ViaLight

Motivation:

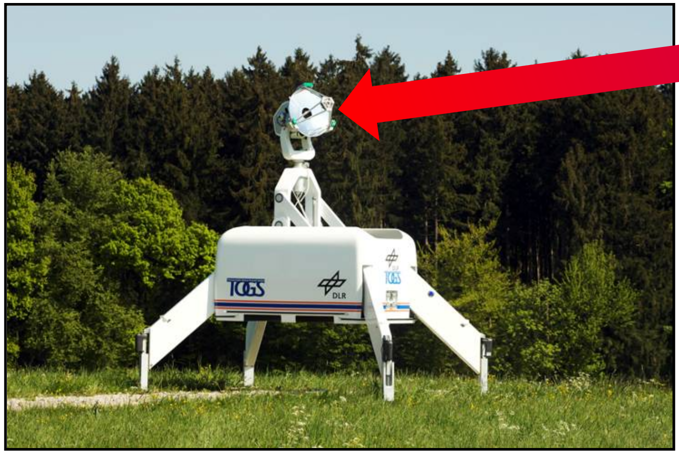
Data dump during flyby

- Aim of project DODfast: experimental demonstration of a high data-rate optical downlink from a fast flying platform

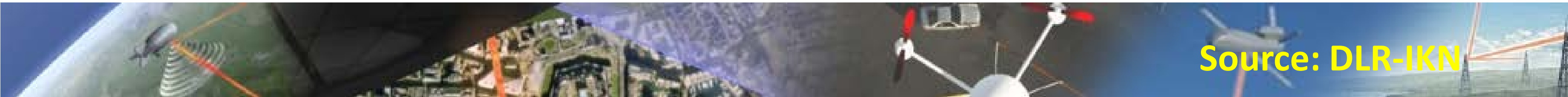
Tornado with attached ADT-Pod

© Dr. Andreas Zeitler

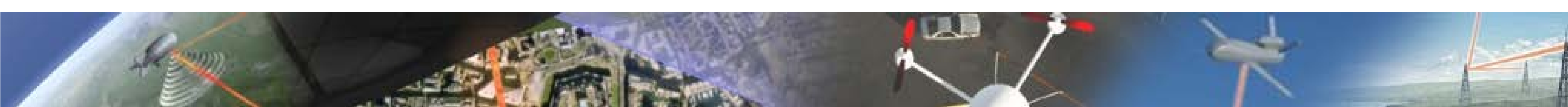
Transportable Optical Ground Station



- Technologgy demonstration with single DWDM channel (Downlink wavelength: 1545 nm)
- Data rate: 1.25 Gbit/s
- Up to 60km, flying at Mach 0.7



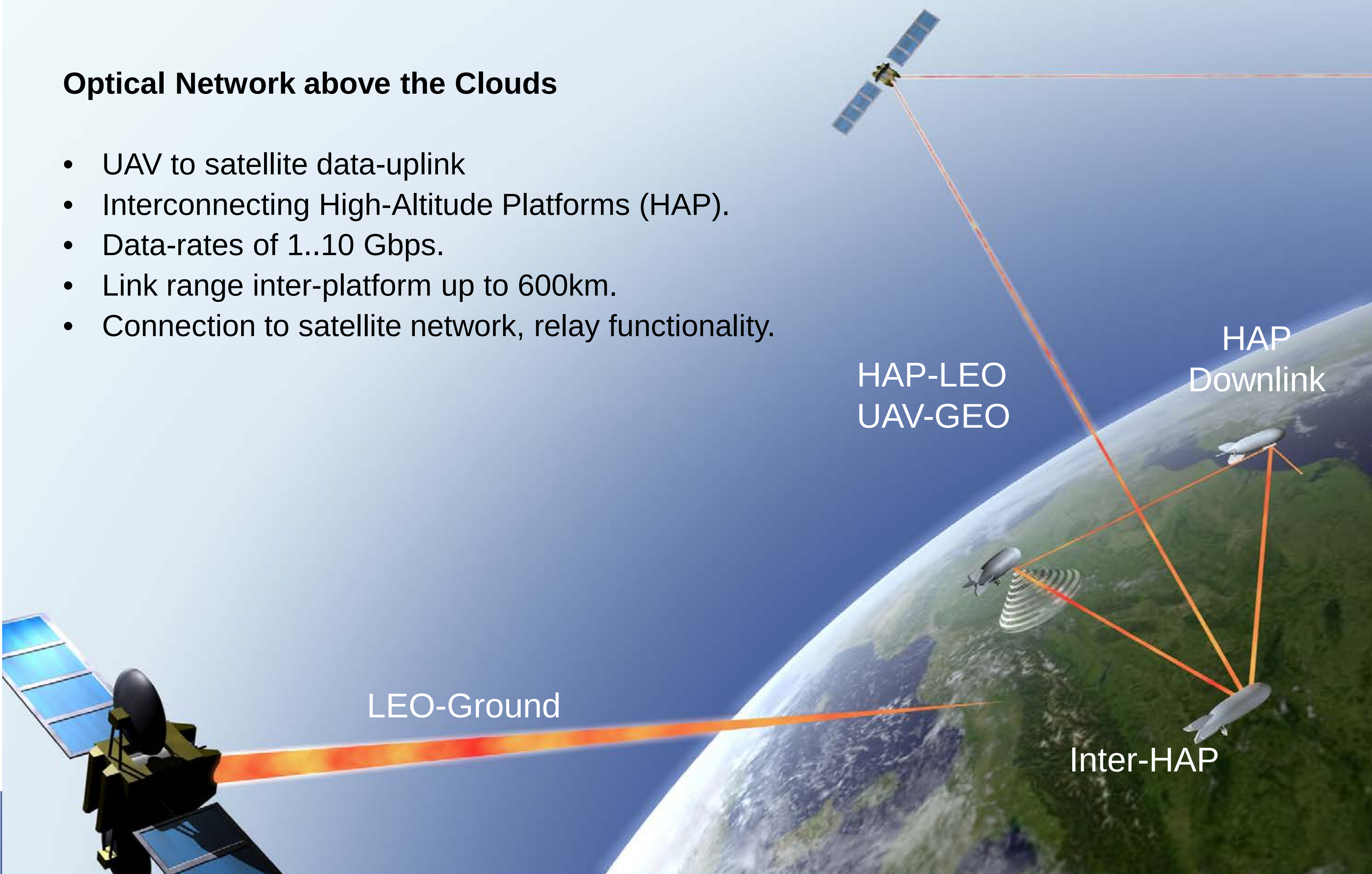
Optical Inter-Platform Links (OIPL)



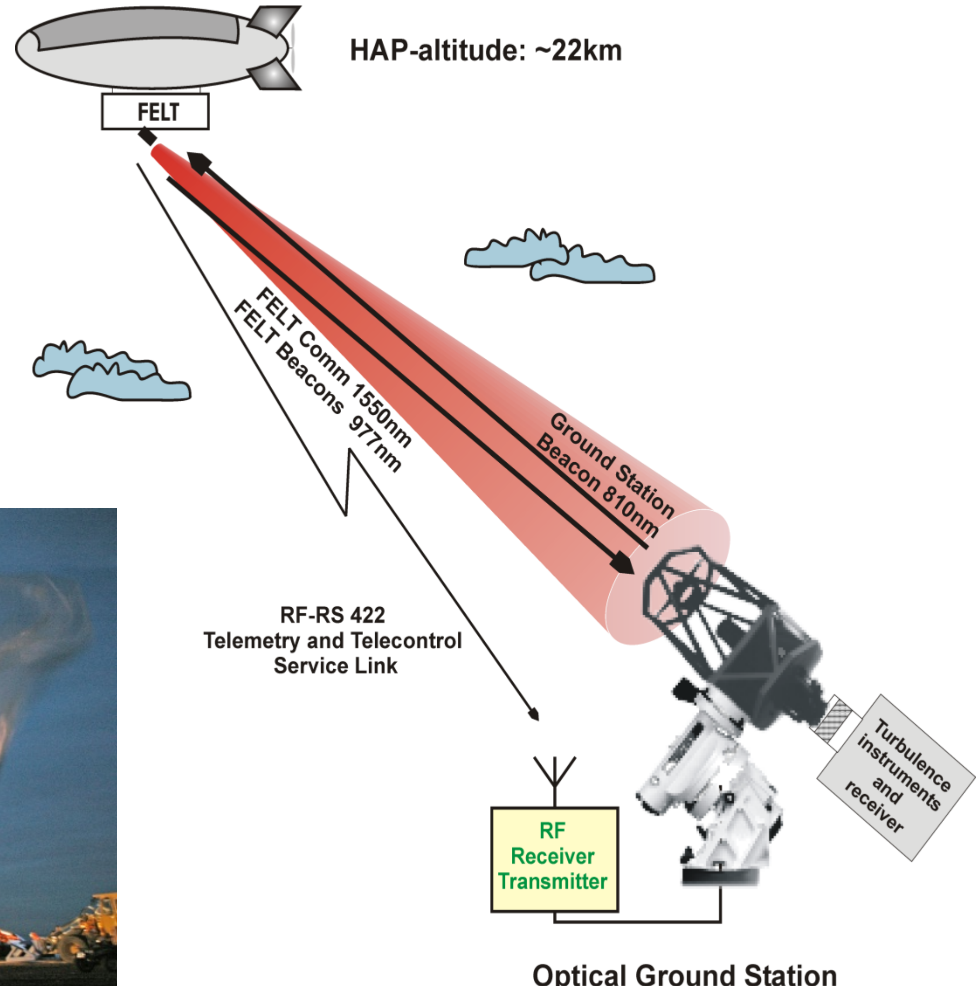
Market Segment: Stratospheric Communications Platforms

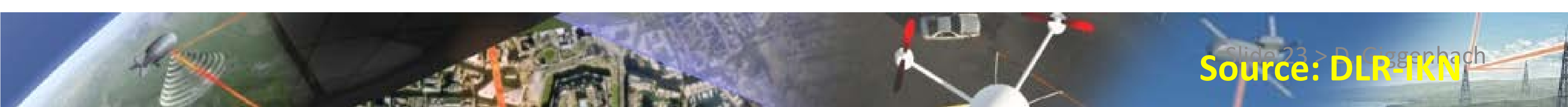
Optical Network above the Clouds

- UAV to satellite data-uplink
- Interconnecting High-Altitude Platforms (HAP).
- Data-rates of 1..10 Gbps.
- Link range inter-platform up to 600km.
- Connection to satellite network, relay functionality.



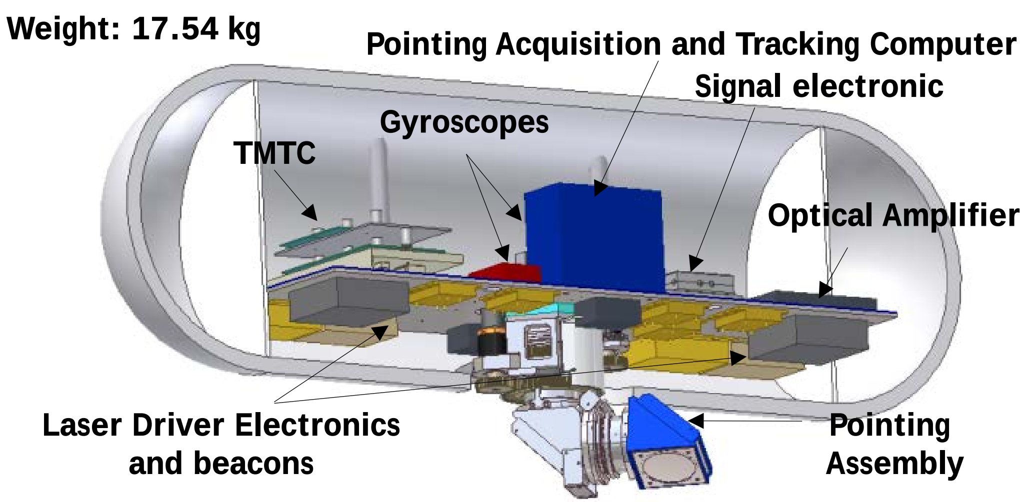
DLR-Heritage: CAPANINA-Project (EU-FP6)
Aim: Stratospheric Optical Inter-Platform Links

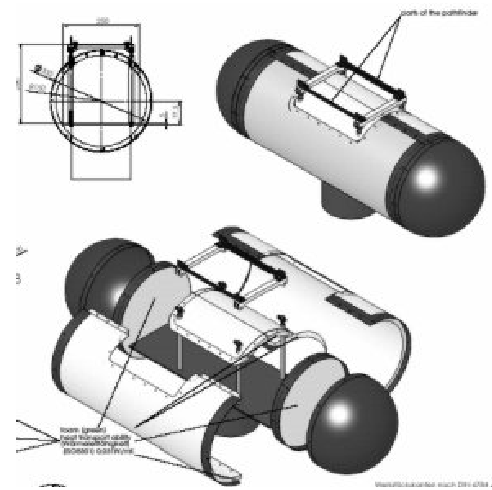


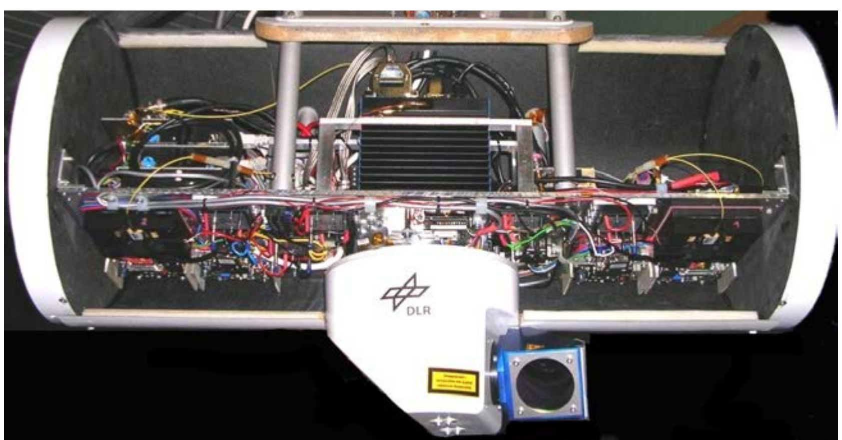


Source: DLR-IKN

Stratospheric Optical Inter-Platform Link Terminal (DLR)



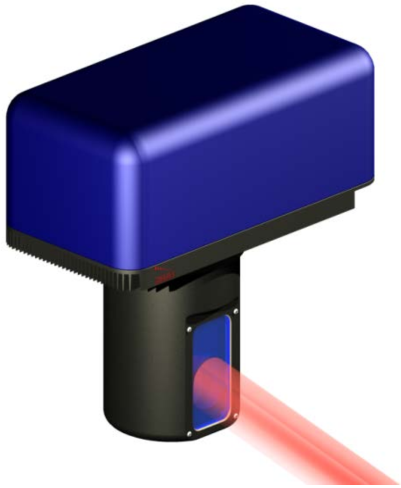


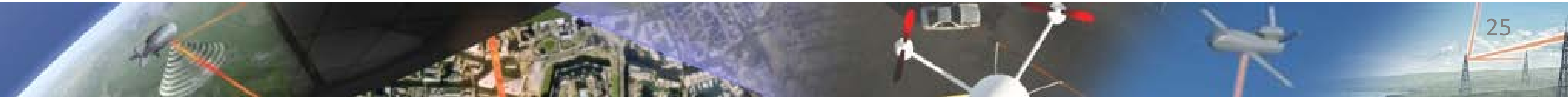


Source: DLR-IKN

Inter-Platform Link Terminal 70mm/100mm Version (ViaLight)

Parameter	Value
Aperture Diameter D	70mm/100mm
Transmit beam	1545-1560 nm at 1W, < 50µrad divergence Arbitrary connectivity configuration available
Communication System	Asymmetric or bidirectional with variable data rates: 10, 100, 1000Mbps
Weight (excl. IMU)	3kg (70mm, Stratospheric Vehicle) 15kg (100mm, Airship)
Mean power consumption	80W, 28V (configurable)
Stabilization	Coarse Pointing (Az. 360° cont., El. -19°...90°) Fine Tracking System (±1.9°, 2-axes)
Data communication interface	Giga-Bit Ethernet
TMTC link	Serial interface at 9.6kbps





Ground Stations

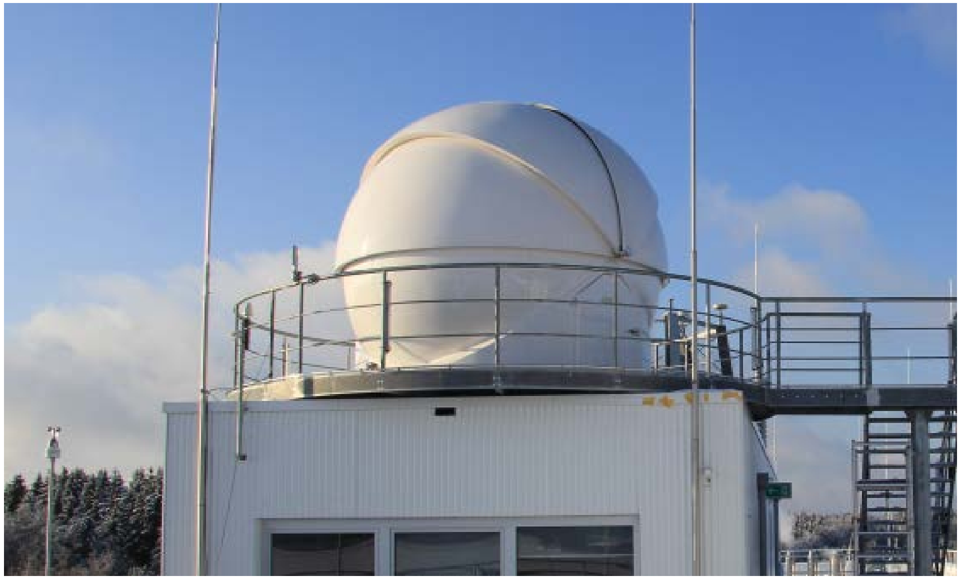
Stationary Optical Ground Station

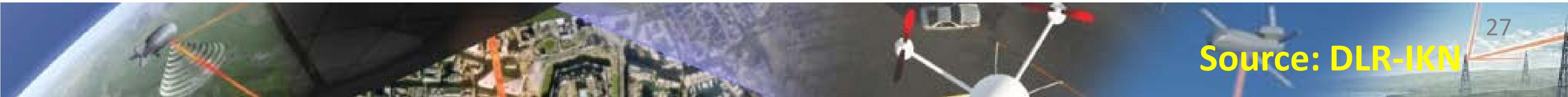
The OGS for Satellite-to-Ground Links:

- 40cm telescope with high precision mount
- Optical ground station for satellite-to-ground and aircraft-to-ground links
- Separate operations room container available; low-temperature options

Operations

- Laser Communication Core (LCC) Software Package for aircraft/UAV and satellite laser communication





Transportable Optical Ground Station (TOGS)

TOGS as stand-alone system; the flight container can be transported by air-cargo to any place in the world

Operations room

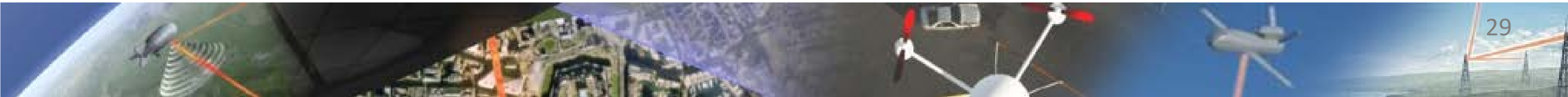
Deployment directly in the van with the operations room

Source: DLR-IKN

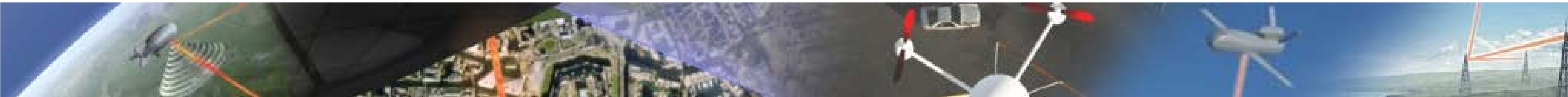
GS-200 Data Sheet (ViaLight)

Parameter	Value
Aperture Diameter D	200mm RX, 50mm TX
Transmit beam	1545-1560 nm, 2x 1-5W (max. optical TX power)
Communication System	Asymmetric or bidirectional with variable data rates: 10, 100, 1000Mbps
Weight (excl. IMU)	<40kg
Mean power consumption	150W, 28V (configurable)
Stabilization	Coarse Tracking System (Az. 360°, El. -10°...85°)
Data communication interface	Giga-Bit Ethernet
TMTC link	Serial interface at 9.6kbps
Standards	Mil-Std-810G, IP66 protection

In development



Components

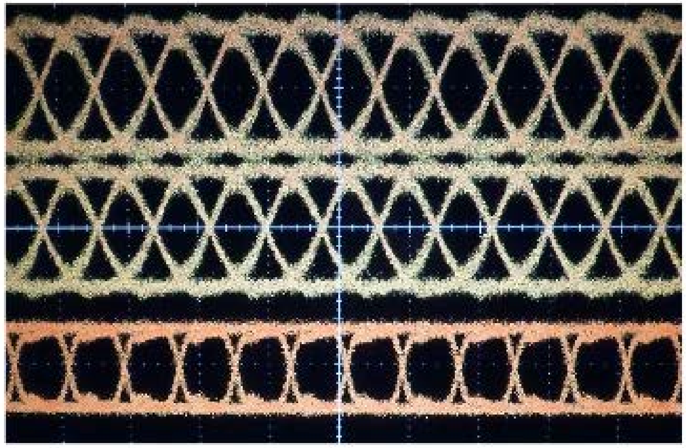


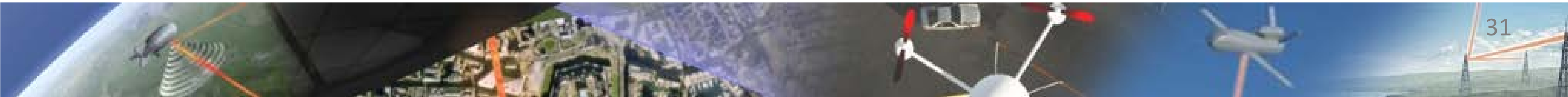
High-Sensitivity InGaAs-APD Receiver Frontends

Sensitivity @ 1550nm:

1.25Gbps: 460Ppb@1E-4
780@1E-6

3.2Gbps: 620Ppb@1E-4
940Ppb@1E-6





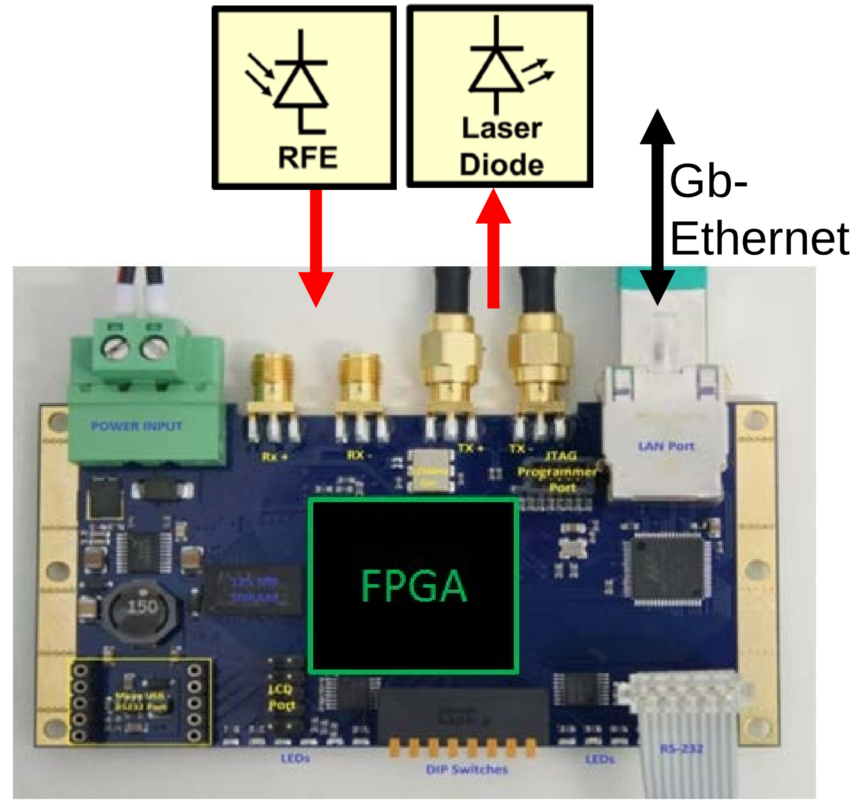
Error-Control-Coding Stack for FSO-Channel (→ DLR)

"Laser-Ethernet-Transceiver" (LET)

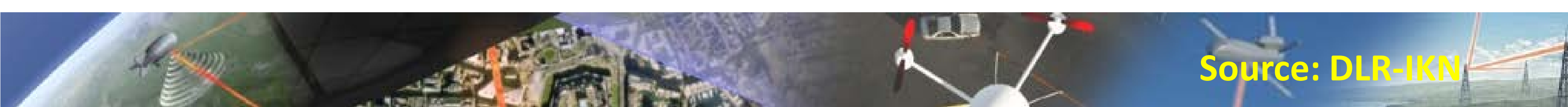
Low-overhead ARQ for lossy return channel

Interleaved Packet-Layer FEC (Burst Errors from IRT-Fading)

Robust Data-Recovery and Bit-Level FEC



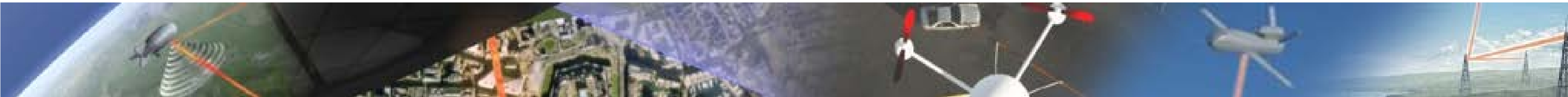
FPGA-Implementation



Summary

- From Experimental Scenario Investigations (DLR-IKN) to Product Developments (ViaLight)
- Topic requires strong connection to ongoing Scientific Research
- Aeronautic mobile FSO Terminal market currently a niche, however some promising applications are developing

Contact:
Dr. Dirk Giggenbach
ViaLight Communications GmbH
Friedrichshafener Str. 1
82205 Gilching, Germany
giggenbach@vialight.de



Links and References *(will be emailed on request)*

- **ViaLight-Brochure** under**:**
  http://www.vialight.de/

- **Mobile FSO at DLR**:
  http://www.dlr.de/kn/en/desktopdefault.aspx/tabid-4142/8378_read-14314/

- Schmidt, Horwath, Shrestha, Moll, Brechtelsbauer, Fuchs, "High-speed, high-volume optical communication for aircraft." SPIE Newsroom. SPIE 2013

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