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A TERABIT OPTICAL FEEDER LINK

HOW TO ACHIEVE 1 TBPS THROUGHPUT OVER AN 36000 KM FREE-SPACE OPTICAL LINK

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A TERABIT OPTICAL FEEDER LINK
OVERVIEW

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03. WHAT DOES THE TBPS TOMCAT SYSTEM LOOK LIKE
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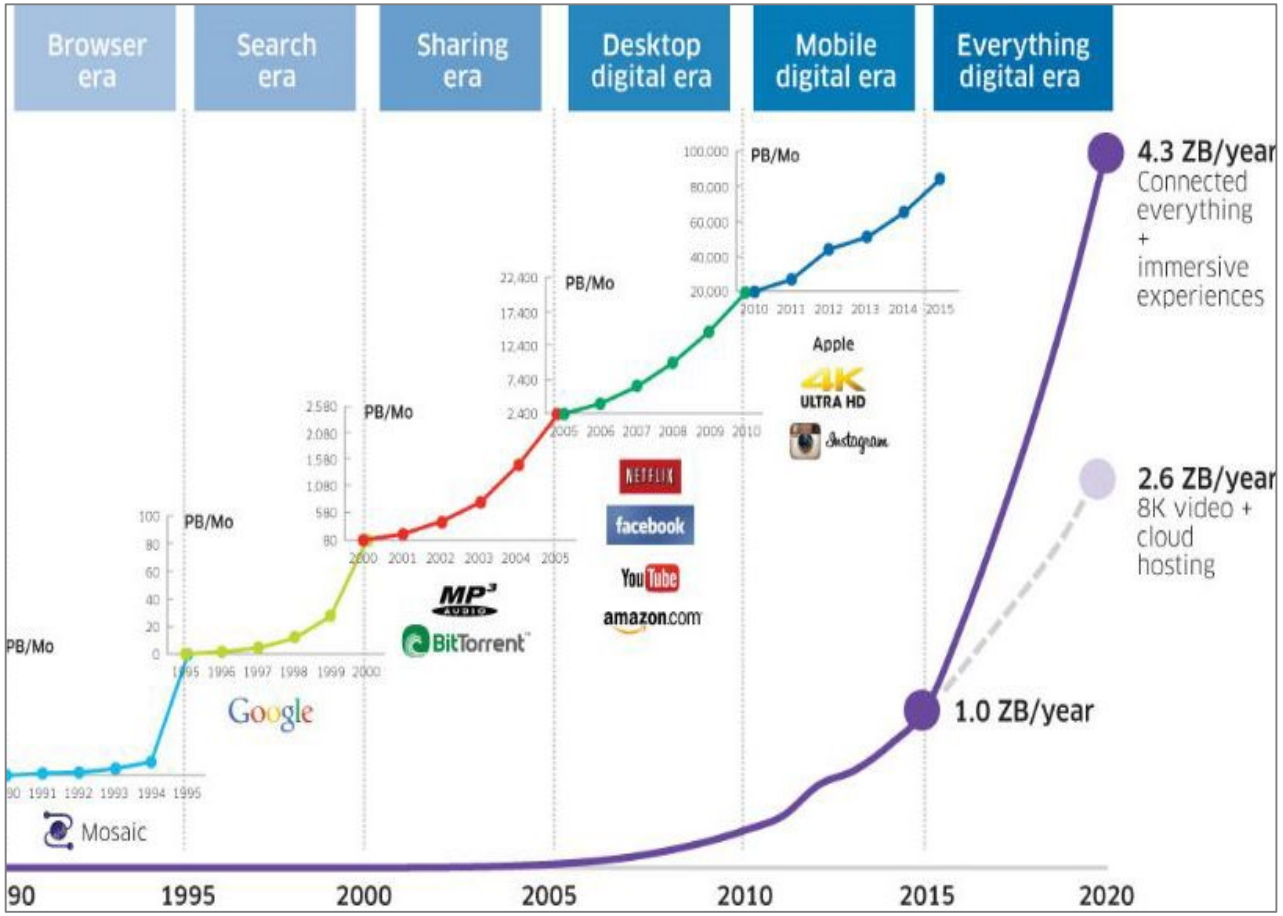
USE AND NEED OF A OPTICAL FEEDER LINK

THE FEEDER LINK APPLICATION

- Geostationary ultra High Throughput Satellites (uHTS), which are used for Telecommunication purposes
- These uHTS are servicing/offering to following Users:
  - Consumer Connectivity/Broadband, for:
    Remote, rural, unserved and underserved areas
  - Industry Connectivity, for :
    Offshore, Maritime, Oil & Gas, M2M applications, to rural and remote areas
  - Mobility industry, with :
    Connectivity in airplanes, M2M of airplanes, Trains, Cruise ships
  - Defence/Security Agencies, for global secure connectivity/broadband



USE AND NEED OF A OPTICAL FEEDER LINK
WHY OPTICAL INSTEAD OF RADIO-FREQUENCY TECHNOLOGY

- **Orders of magnitude higher throughput**
  - Higher throughput i.e. 1 Tbps per OGT instead of in the order of 20Gbps per RF ground stations
- **Significant higher value for money ratio (lower cost per bit)**
  - As the ground segment will need multiple less ground stations (e.g. around 15 instead of 40 to 100) for a Terabit-Class uHTS
- **Higher Security**
  - Optical communication links have highly narrow beams compared to the significantly broader RF beams. This makes that Optical Links are extreme hard to interrogate and intrinsically secure.
- **More resilient to jamming and interference.**
  - KA- and Q/V- band based feeders are not resilient to jamming and interference.
- **No need for licensing**
  - The Radio-Frequency band is subject to licensing, whereas the optical band is not.

USE AND NEED OF A OPTICAL FEEDER LINK

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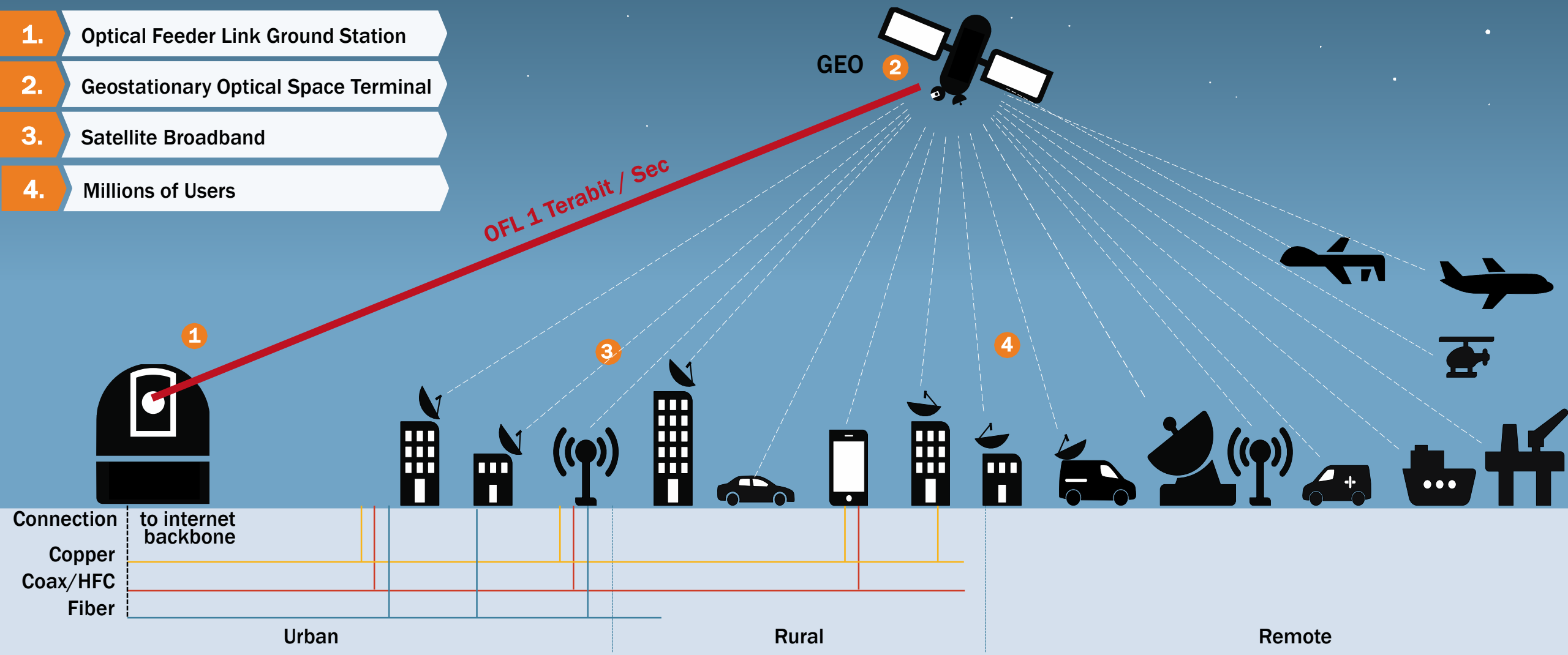
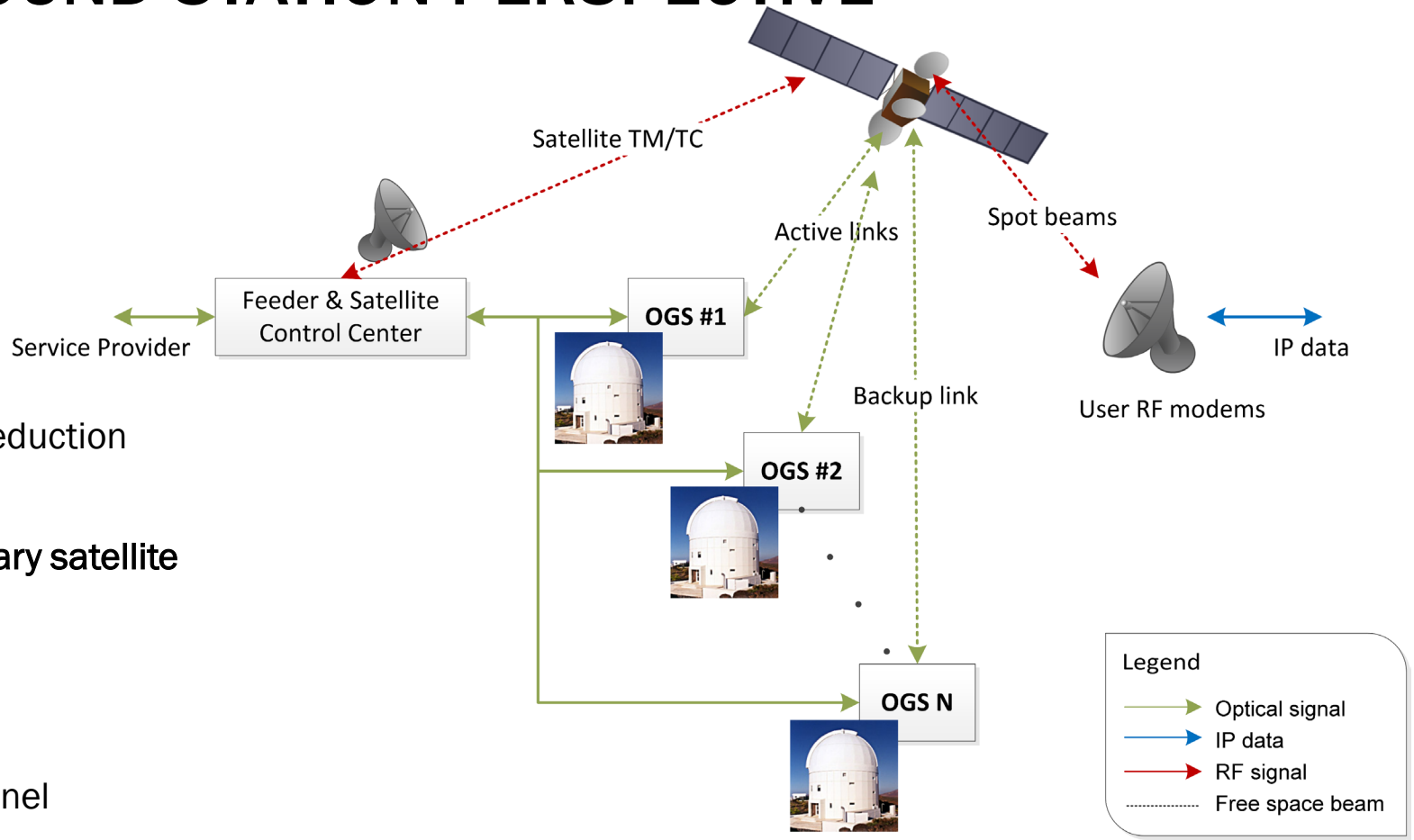
Optical Feeder Links (OFL) enable uHTS : a sustainable solution concerning the RF spectrum problem, allows growth in throughput, and enables significantly lower Cost/Mbps

1. Optical Feeder Link Ground Station
2. Geostationary Optical Space Terminal
3. Satellite Broadband
4. Millions of Users



CHALLENGES FSO COMMUNICATION GROUND-TO-SPACE
FROM AN OPTICAL GROUND STATION PERSPECTIVE

- **Clouds obscure the signal**
  - No signal, availability
- **Atmosphere distorts the optical signal**
  - Scintillation, fades and optical power reduction
- **The shear distance towards a geostationary satellite**
  - Pointing accuracy and optical power
- **Obtaining The terabit throughput**
  - Optical power and throughput per channel

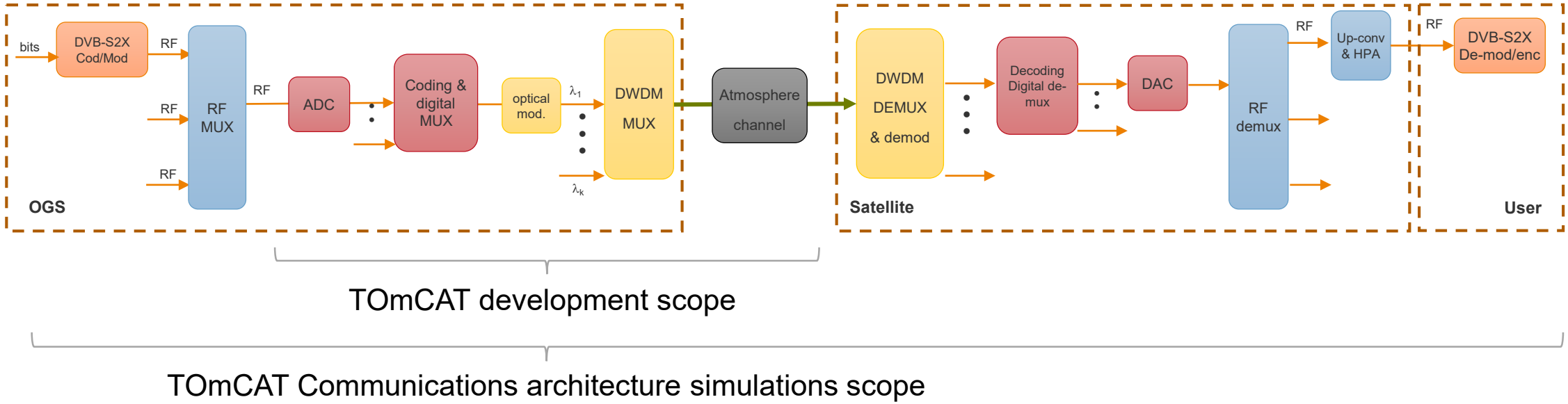


CHALLENGES FSO COMMUNICATION GROUND-TO-SPACE
TECHNOLOGICAL SOLUTIONS

- **Clouds obscure the signal**
  - Location diversity, in the order of 14 ground stations in Southern Europe to guarantee availability
- **Atmosphere distorts the optical signal**
  - Adaptive Optics Pre-correction in combination with interleaving and error correction
- **The shear distance towards a geostationary satellite**
  - Highly directive beams using accurate sensing and pointing actuators in combination with shear optical power (500 – 1000 Watt)
- **Obtaining The terabit throughput**
  - Coherent transceivers in combination with Dense Wavelength Multiplexing using a bulk multiplexer

WHAT DOES THE TBPS TOMCAT SYSTEM LOOK LIKE FROM AN OPTICAL GROUND STATION PERSPECTIVE

- Digital Transparent communication architecture



- 3 OGT links provide a bi-directional effective RF user data throughput capacity of **1 Terabit/s**
- 1 OGT link provides a bi-directional gross optical data throughput capacity of **2 Terabit/s**

WHAT DOES THE TBPS TOMCAT SYSTEM LOOK LIKE

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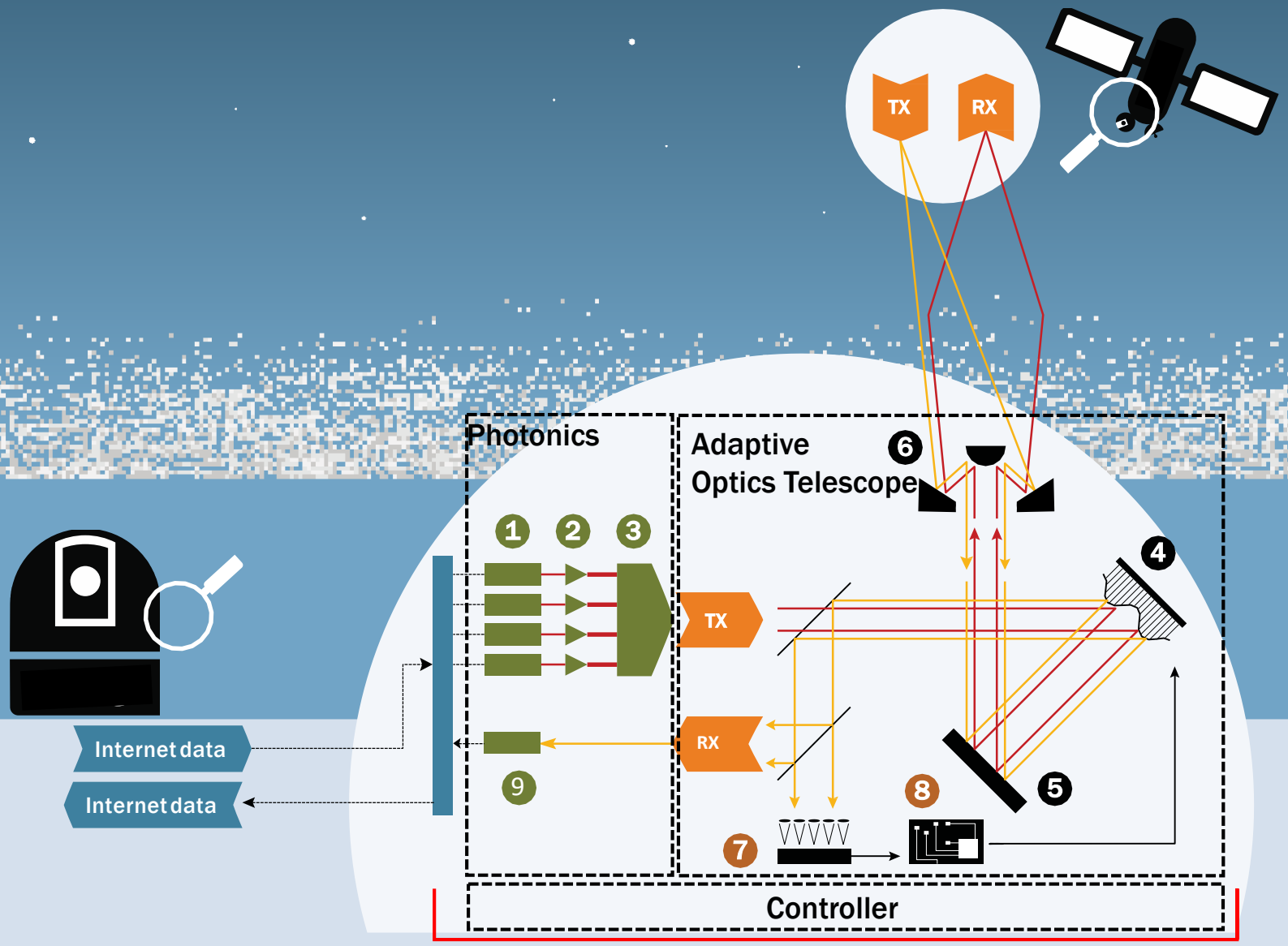
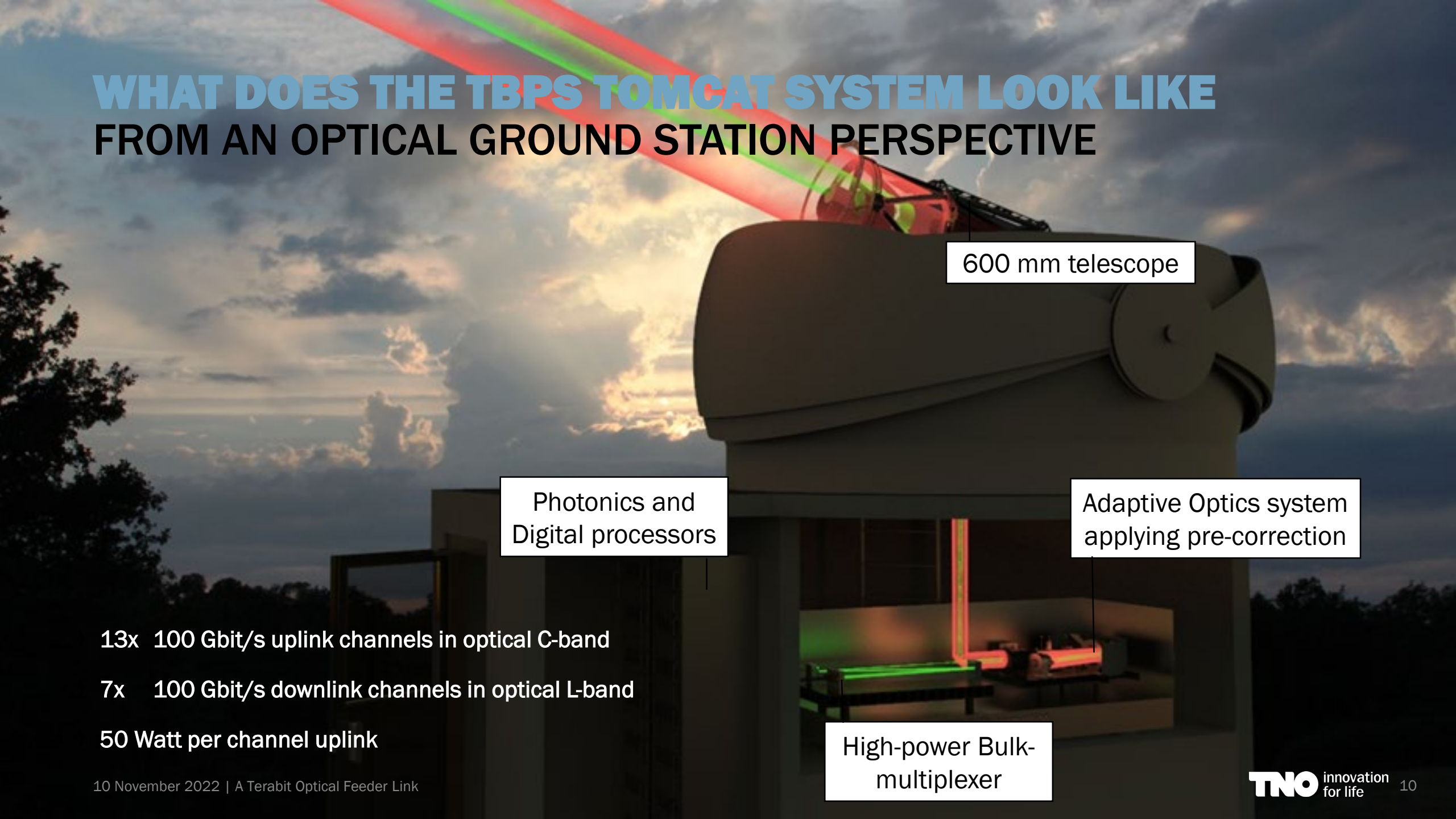


1. Optical modulator
2. Amplifier
3. High power multiplexer
TX Transmitter
4. Corrective element
5. Tilt corrector
6. Telescope
RX Receiver
7. Wavefront sensor
8. Control system
9. Optical demodulator

WHAT DOES THE TBPS TOMCAT SYSTEM LOOK LIKE FROM AN OPTICAL GROUND STATION PERSPECTIVE

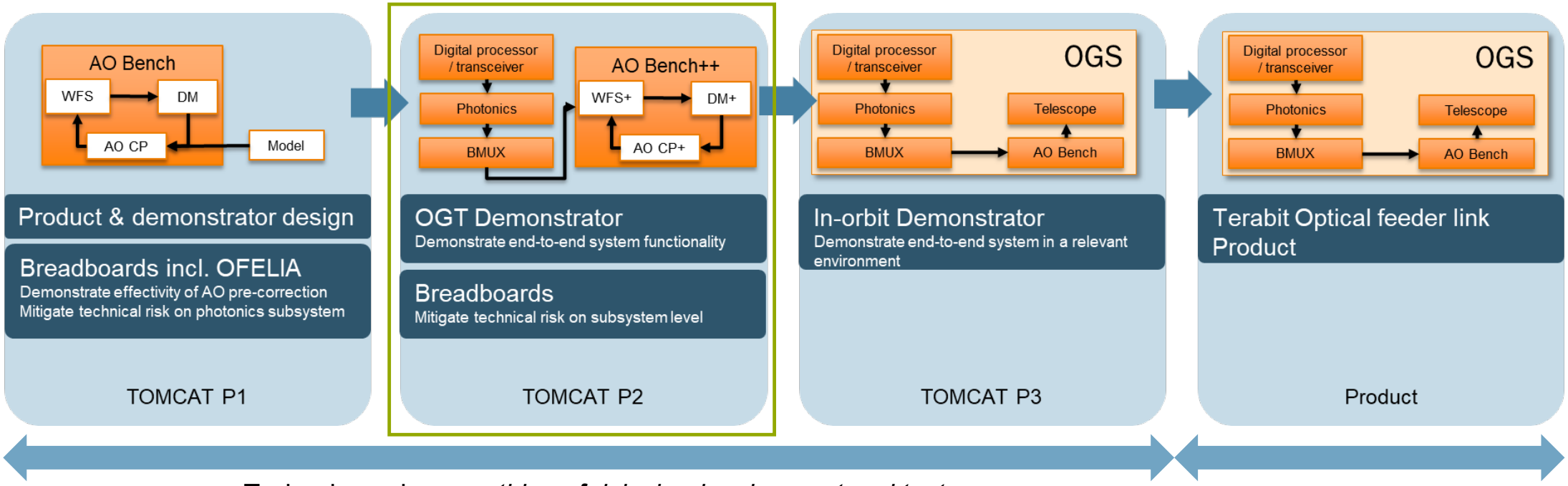


13x 100 Gbit/s uplink channels in optical C-band

7x 100 Gbit/s downlink channels in optical L-band

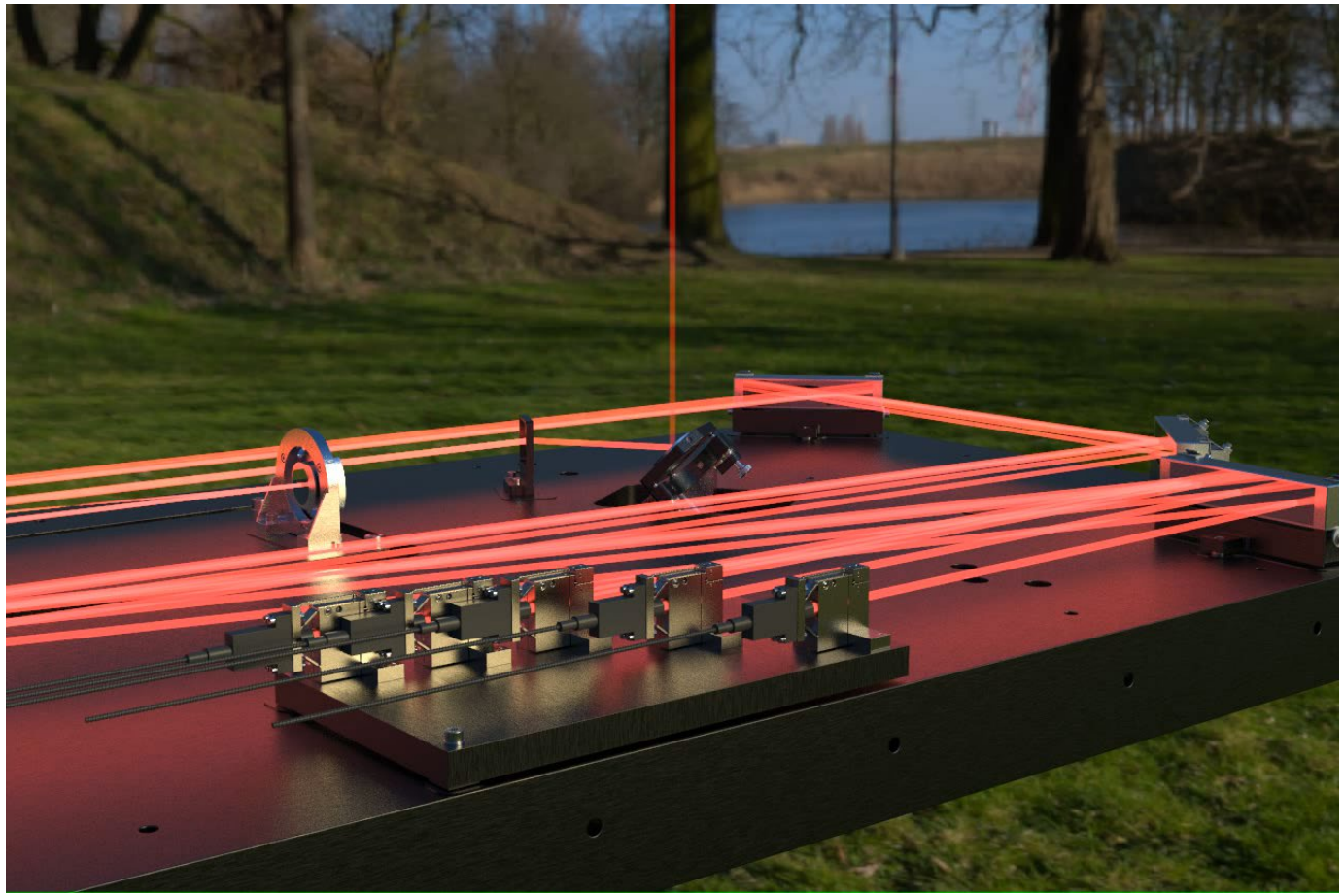
50 Watt per channel uplink

TOMCAT FIELD TESTS
DEVELOPMENT PATH TOWARDS A PRODUCT



TOMCAT FIELD TESTS
THE DEMONSTRATOR SETUP

- End-to-end, RF-to-optical-to-RF, High Throughput Optical Feeder Link demonstration
  - Through turbulent atmosphere: 10 km
  - Optical transceivers: 25 Gbit/s per channel
  - Bulk multiplexing technology: 3 - 5 channels
  - Combined with adaptive optics pre-correction
  - Scalable to Terabit/s data rates



TOMCAT FIELD TESTS
IN THE FIELD

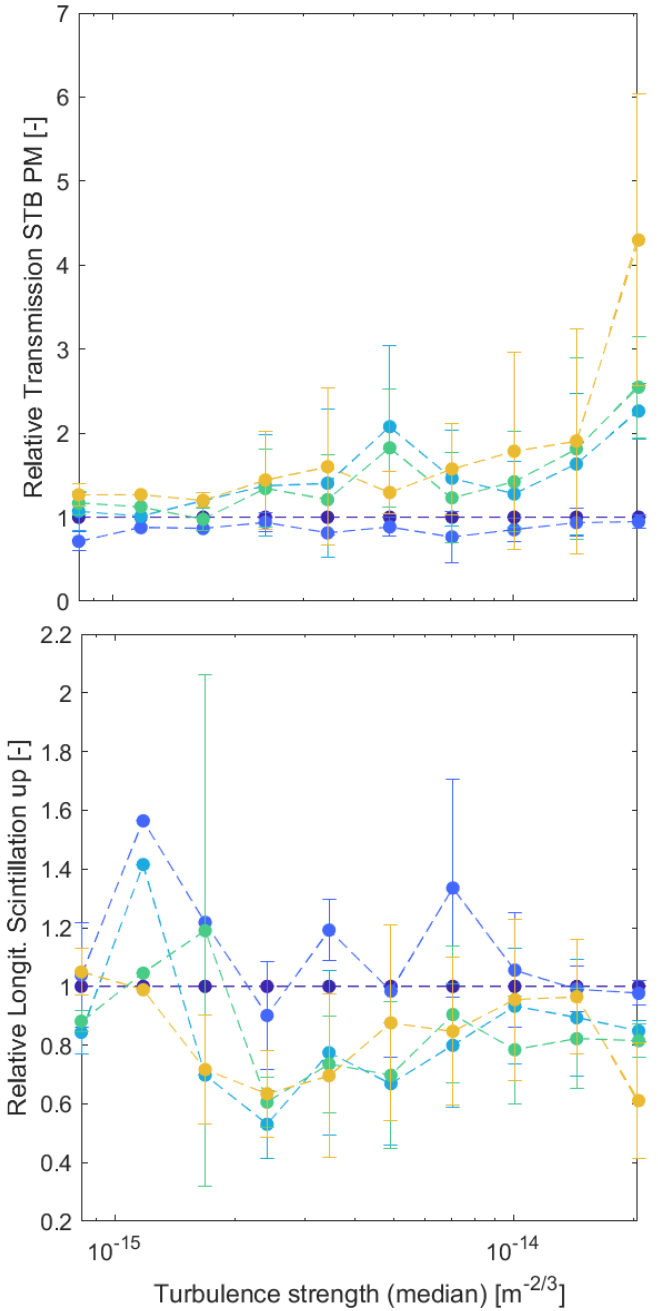
~10 km path at 1.3° inclination, environmental monitors to measure conditions

Space terminal; 226 m altitude at Gebrandy Tower

Ground Terminal; 0 m located at KNMI

TOMCAT FIELD TESTS
THE DEMONSTRATOR SETUP

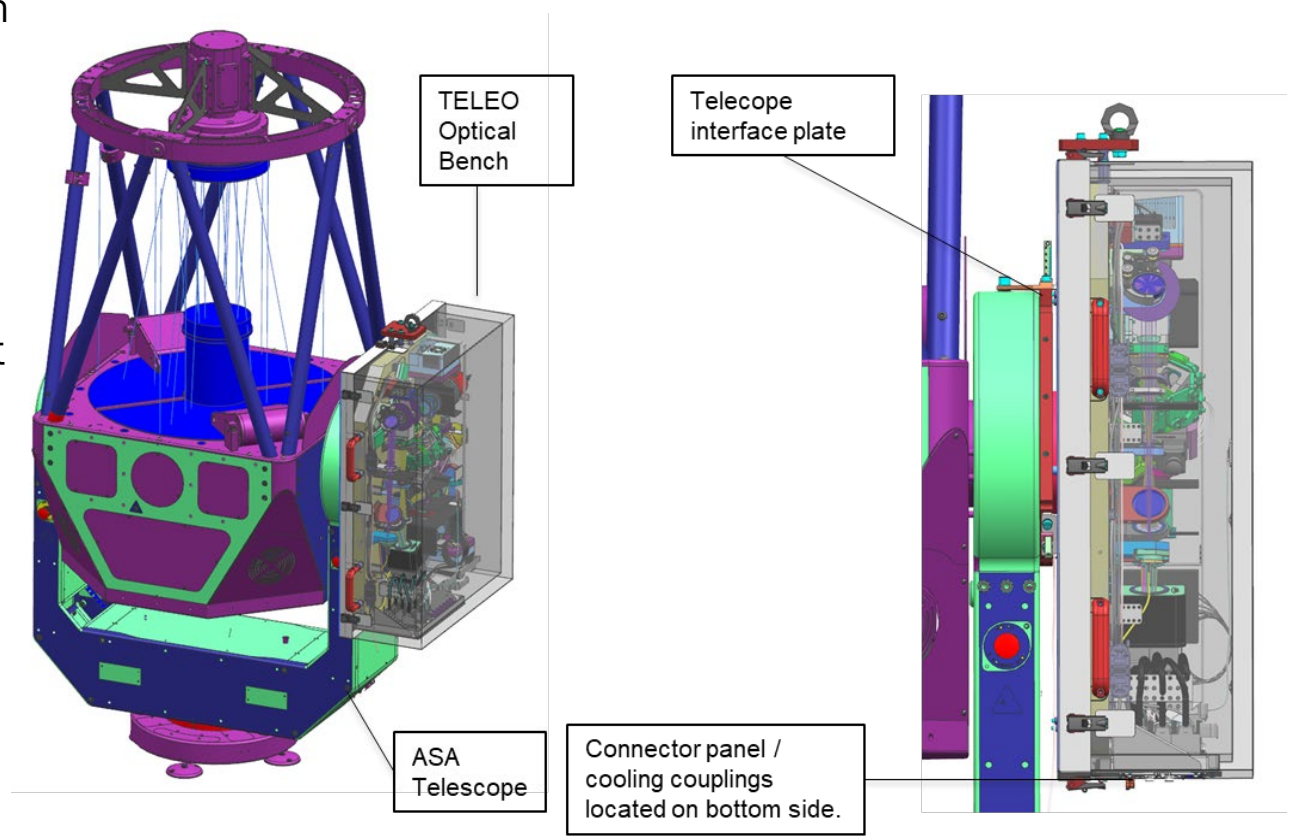
- Adaptive Optics Demonstrator to show impact of pre-correction technology
  - At strong turbulence conditions an average gain of 4 (6 dB) for 28 AO modes with respect to the tip-tilt reference case could be obtained
- OGT Demonstrator to show end-to-end communication over an Optical Feeder Link
  - Results still being analysed
  - Virtual error free communication shown for multiple minutes



FUTURE DEVELOPMENTS, IOD'S
TELEO - CREOLA IN ORBIT DEMONSTRATOR

- TELEO is an piggyback Payload on BADR-8 satellite mission developed by Airbus Toulouse
- Airbus Defence & Space Netherlands to develop Optical Ground station
- TNO to develop Tx Adaptive Optics Bench to show pre-correction, single channel Gigabit uplink communication at 2x10 Watt transmit power

- Future developments should be aimed on component developments to work towards a product; Reliable 50 Watt EDFA's, High Power deformable mirror, High power Bulk multiplexer and Optical Bench.....

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