PHOTONICS TO AND IN SPACE

SWISSPHOTONICS / 20231204

RETO MUFF @THALESALENIASPACE.COM

Date: 4.12.23
Ref: SwissPhotonics
Template: 83230347-DOC-TAS-EN-011

JOINT VENTURE

ThalesAlenia Space
a Thales / Leonardo company

THALES (67%)
LEONARDO (33%)

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ABOUT THIS PRESENTATION

///Space …

///Different use-case examples for **Photonics in Space**

///Focus: Optical «Free»Space Communication links

- Link scenarii
- Optical Link
- Optical Terminal architecture and related photonic building blocks and needs

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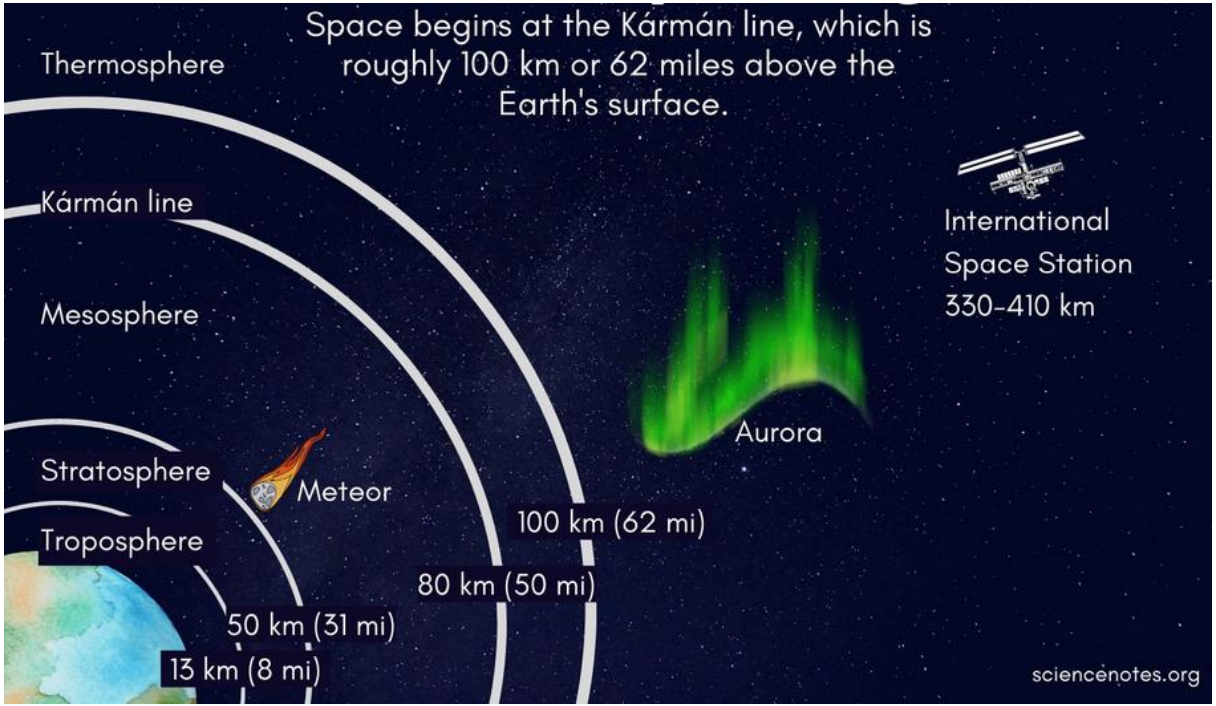
Space – where does it begin?

«SPACE»

/// **Formal Definition**: Karman Line @ 100km altitude

/// **Practical**: Orbit and beyond
→ Challenges

- Launch / Pyro
  - Mass, cost/kg
  - Mechanical robustness
- Specific environmental loads
  - Temperature
  - Radiation
  - Micro-vibration
- Bad accessibility
  - No repair → reliability
  - No H/W upgrade



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CHALLENGES

/// On-ground (storage)

- Cleanlyness
- Salty air

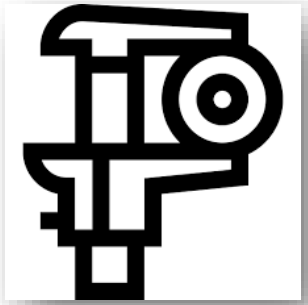
/// Launch loads

- Vibration
- Shock
- Depressurization

… in view of precision …

/// On-Orbit

- Vacuum
- Radiation environment
- Temperature ranges and cycling
- Mechanical loads
- Bright objects (sun)
- No (difficult) access for repair and upgrade
- Limited resources



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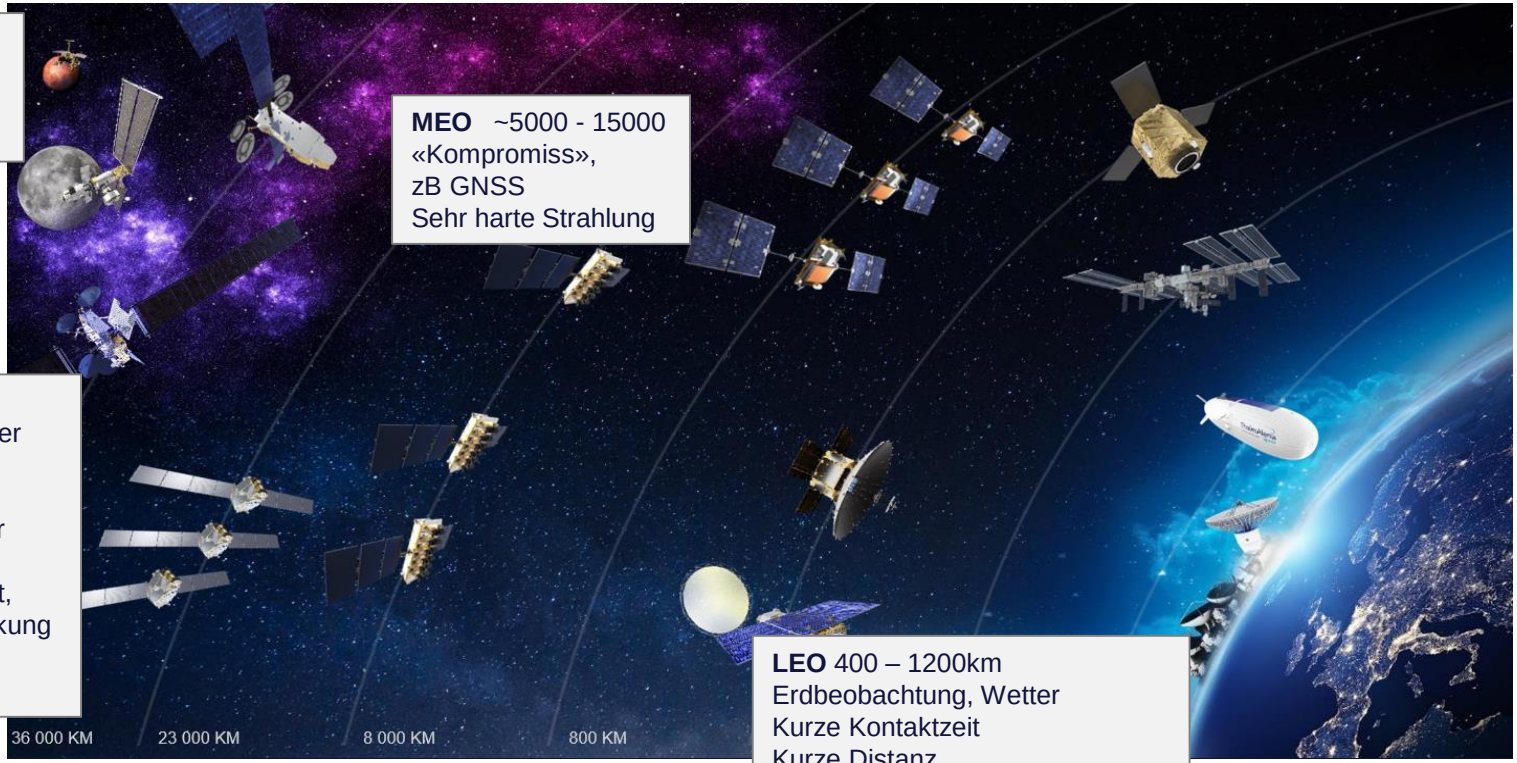
ORBITS (LOW-, MEDIUM-, GEOSTATIONARY EARTH ORBIT, → LEO, MEO, GEO)

DeepSpace
«Aufwändig»
Noch science-dominiert



MEO ~5000 - 15000
«Kompromiss»,
zB GNSS
Sehr harte Strahlung

GEO 36000km
Geostationär, über Äquator
Lange Distanz
Relay/TV, Wetter
Erdbeobachtung
lange Kontaktzeit, definierte Abdeckung
Harte Strahlung
Langer Launch

LEO 400 – 1200km
Erdbeobachtung, Wetter
Kurze Kontaktzeit
Kurze Distanz
SpaceDebrit / Restatmosphäre
Strahlung unterschiedlich
Kurzer Launch

Sources: TAS

PHOTONICS USE-CASES FOR «SPACE»

/// Observation

- Imaging
- Spectroscopy
- LiDAR

/// Frequency Generation / Reference Oscillators

- RF up/down convertion / mixing
- Optical oscillators (optical quartz → optical clocks)

/// Communication

- Fibered, on-board
- Nearfield, LiFi, VLC
- Freespace links, long distance

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OBSERVATION

/// Detectors

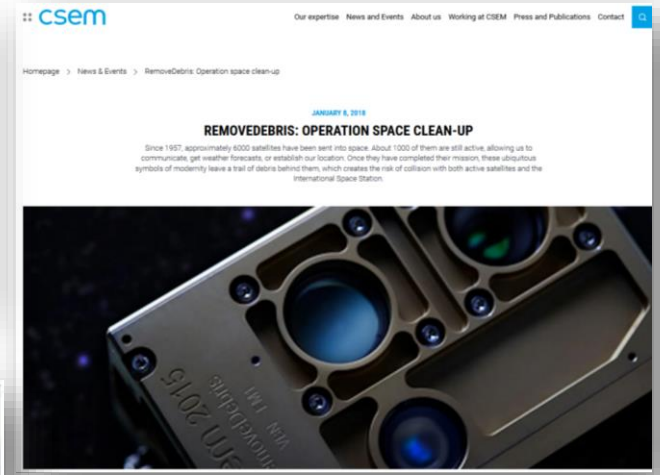
- UV → LW IR → γ → p+ → HI, …
- Spacial resolution
- Sensitivity
- Responsitivity / Speed
-

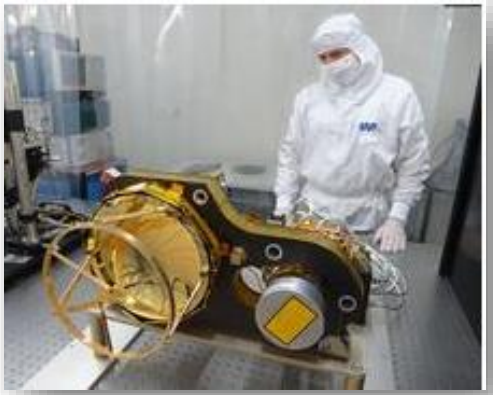
/// Illuminators,
referent light sources

/// Spectral filters / Gratings

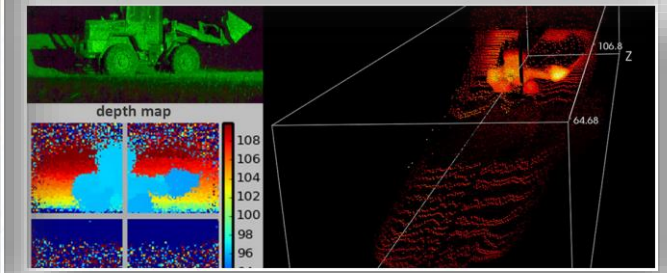
/// Opto-mechanical function /
routing of beam

Exomars CloseUp Imager





Bepi Colombo Laser Altimeter



RemoveDebris Flash Lidar

Ref: Uni Bern, CSEM, TAS-CH

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FREQUENCY GENERATION AND REFERENCES

Another example for the application of fiber-optic timing distribution links are radio telescope arrays, where many antennas have to be synchronized for accurate telescope pointing, synchronization of processing instrumentation and online manipulation of observation data [2].

In general, optical clock distribution and synchronization will become more important in future. Technologies and applications such as ultraprecise navigation, gravitational sensing, coherent arrays or relativity experiments will require time comparison and synchronization over terrestrial fiber-optic links or satellite free-space links.

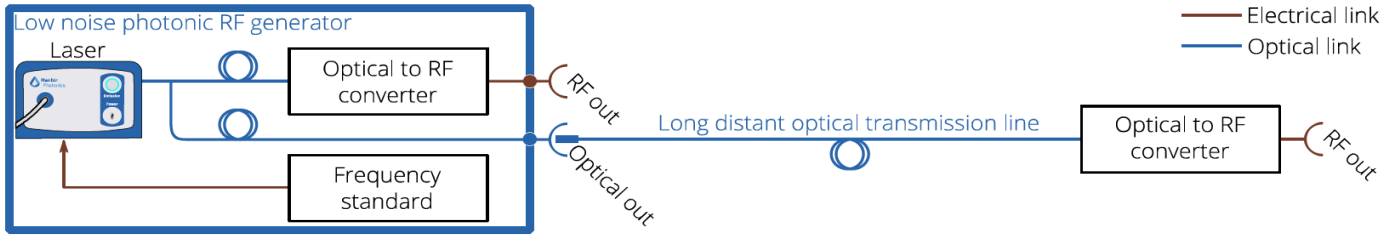

Figure 1 — Schematic of the photonic low-noise RF generator (blue box) using the MENHIR-1550 laser as photonic source. The output RF frequencies are defined by two factors: the oscillator (laser) fundamental frequency and the optical to RF converter bandwidth. The optical output can serve to disseminate the RF signal to a distant location from the local oscillator. The transmission of a RF signal via optical fiber provides significantly higher performance than traditional bulky and stiff RF waveguides.

Sources: MENHIR - Photonics

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EARLY FIBERED / SMOS – MOHA (MIRAS OPTICAL HARNES)

Fig. 7. A MIRAS arm segment with 6 LICEF, 1 CMN, and a fibre-optic 1x8 splitter

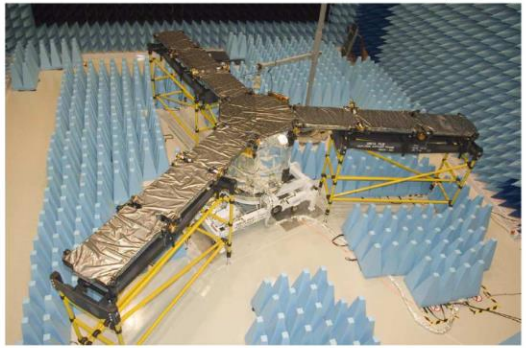


Fig. 8. The deployed MIRAS payload at ESTEC's Maxwell EMC chamber

Proc. of SPIE Vol. 10565 105650Z-7

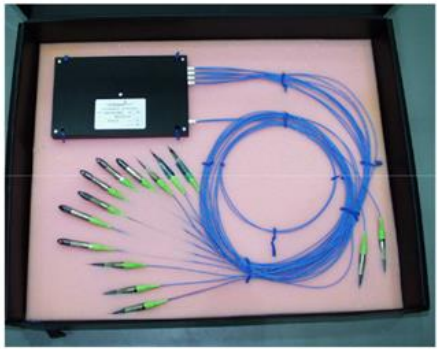
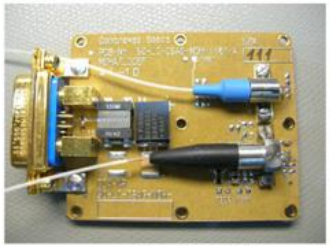


Fig. 4. MOHA fibre-optic 2x12 splitter, flight model



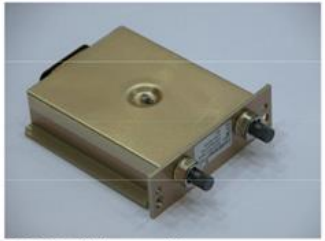
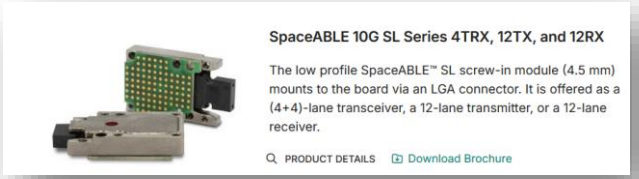


Fig. 5. MOHA module in LICEF, flight model

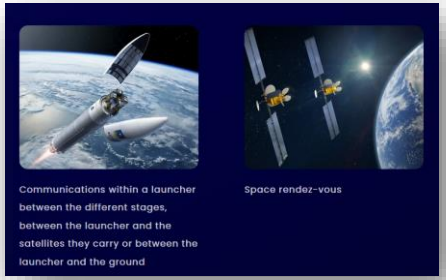
SHORT RANGE OPTICAL COMMUNICATION (FEW EXAMPLES)

/// Fibered Links, using photonic transceivers, 10, 25, … Gbps



https://www.smithsinterconnect.com

/// NearField applications, LiFi, VLC, xGbps



https://www.oledcomm.net

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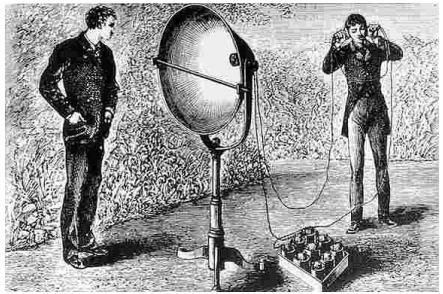
FREESPACE OPTICAL COMMS

/// Optical Comms is old ….

- Lighthouses, signal fires
- PhotoPhone
- Flashlight, Morse
- Candle light dinner

→ But all is NOT Photonics

Source: www.yachtcharter.de



Source: en.wikipedia.org/wiki/Photophone

Source: https://www.navytimes.com

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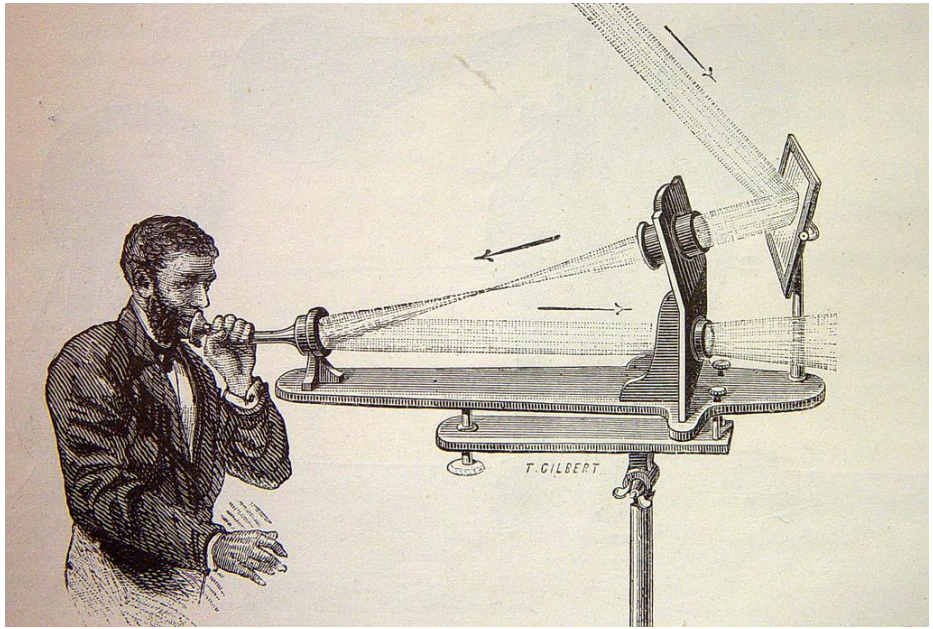
1881 – PHOTOPHONE (ALEXANDER GRAHAM BELL AND SUMNER TAINTER)



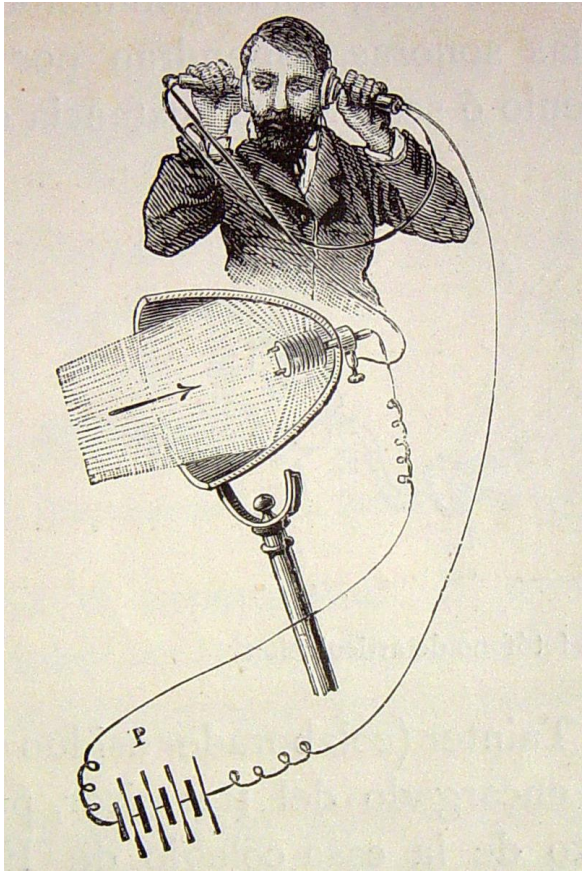


Illustration of the photophone's transmitter, originally from: El mundo físico : gravedad, gravitación, luz, calor, electricidad, magnetismo, etc. / A. Guillemin by: Guillemin, Amédée, published by: Barcelona Montaner y Simón, 1882

Illustration of the photophone's receiver, originally from: El mundo físico : gravedad, gravitación, luz, calor, electricidad, magnetismo, etc. / A. Guillemin by: Guillemin, Amédée, published by: Barcelona Montaner y Simón, 1882

COMMUNICATION «USE CASES» IN / FOR SPACE

/// Mission Control / TCTM

- Command
- Control and Monitor

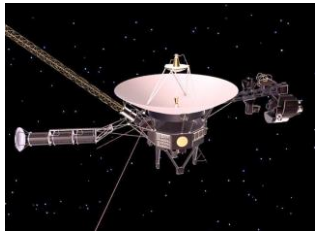
YouTube [Failure is not an option / Mission Control]

/// Sensor Data repatriation

- Earth Observatio
- Science (near Earth to deep space)

/// Telecom

- Complementary to terrestrial infrastructure
- Internet
- TV Broadcast, grossflächige Verteilung



Sources: NASA/JPL-Caltech, ESA-ESTRAC, BostonGlobe, WanderSite.ch, TAS, KKL

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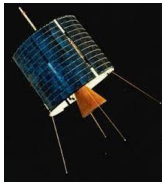
EVOLUTION (EUROPE FOCUSED VIEW, NOT COMPLETE)

Popov/Marconi
Morse Radio

1880

Sputnik 83.6kg,
Beep auf 20MHz
und 40MHz

~1890+ 1957



EarlyBird,
I1 34kg,
2xC-Band
1 TV

1965

STS program
Easy Access

1980

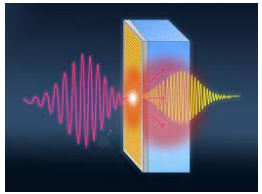
EDRS A
66xKu

2016

TV bradcast → Internet

SES-17
6400kg, 15kW

2021



TerraHetz
Technology
(Symbolic Pic)

Bell
PhotoCam

1960

Th. Mailan
First Laser

1970

FiberCom

1990s

ARTEMIS
Laser
Demo Sat

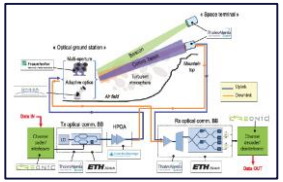
2019

EDRS C
Ka, 1064nm,
1.8Gbps

2020

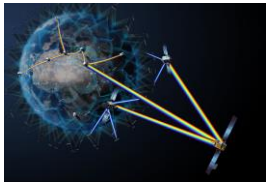
Constellations
n x 10Gbps+

2022



VERTIGO /
H2020
Tbps Feeder
Tech Demo
(non-space)

2023+



FiberIn The Sky,
HyDRON,…

Sources: NASA, ESA, ETH, nature, www.letilaser.fr,TAS, fasttrackcomm.net

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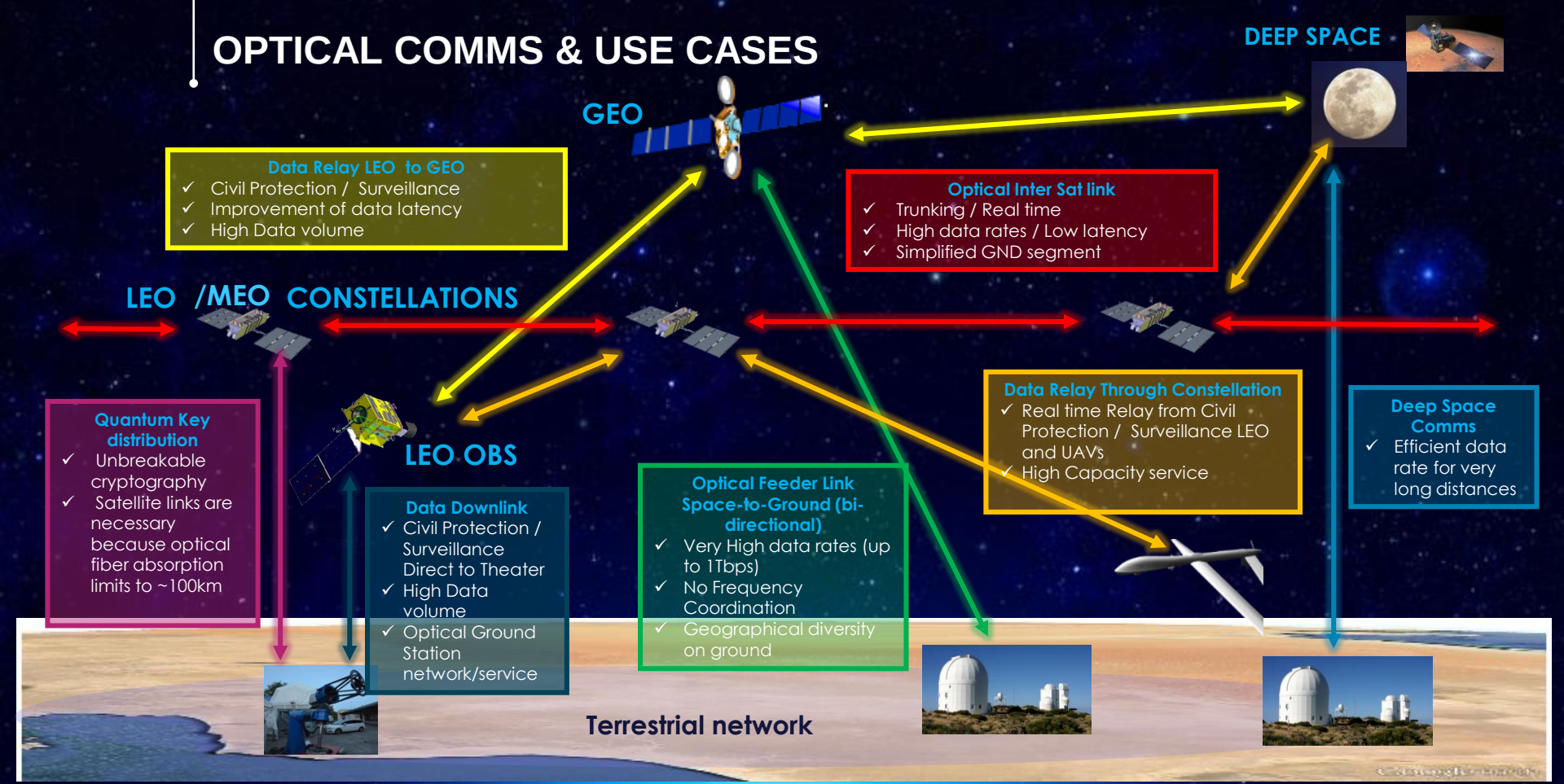
OPTICAL COMMS & USE CASES



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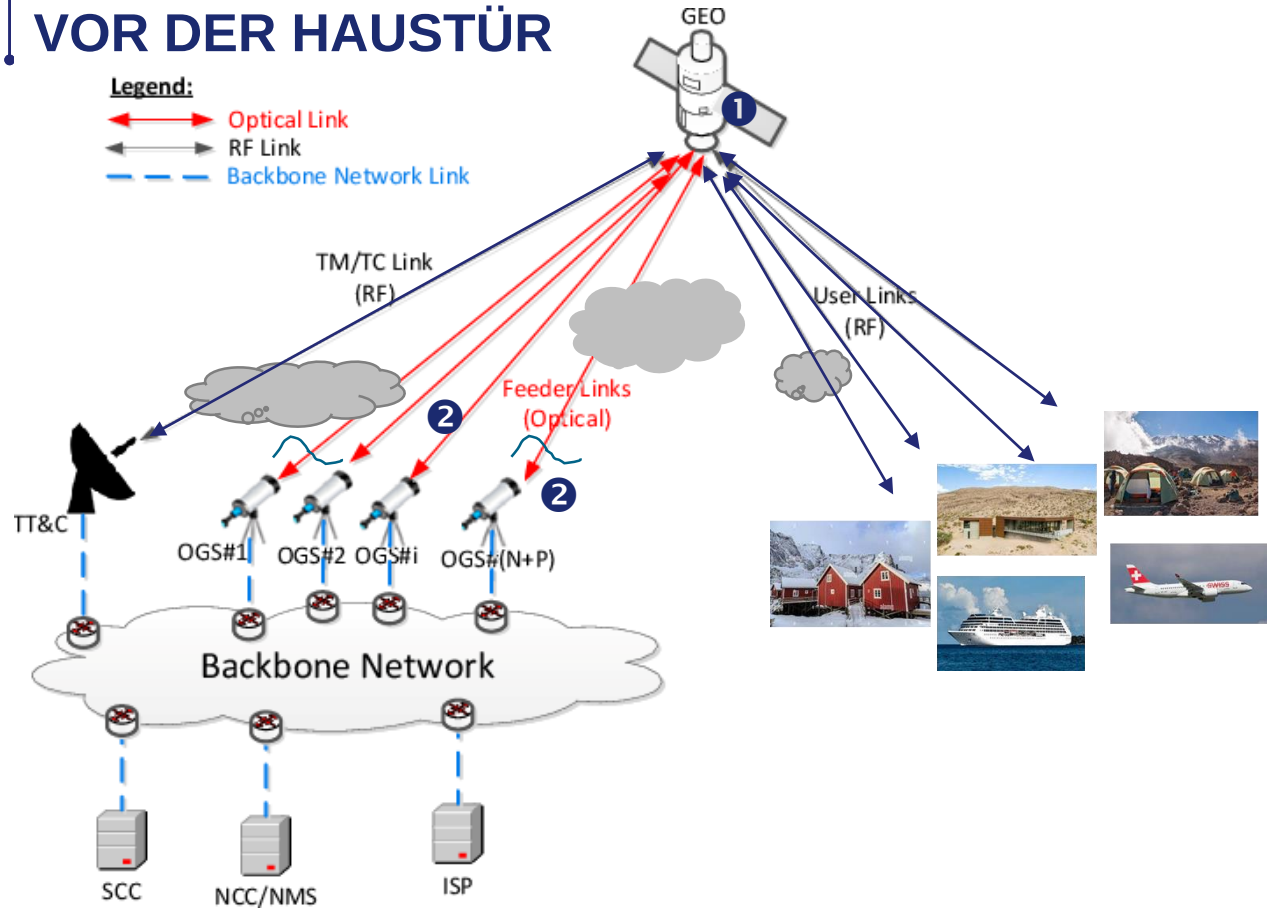
VOR DER HAUSTÜR



- GEO Satellit ❶
  - Stationär
  - Einfaches Tracking
  - Rel. Lange Distanz
  - «grosse» Resourcen
- Feeders von/zu Gateways ❷
  - Stationär auf Erde,
  - wenige, aber leistungsfähig
  - Site-Diversity (Wetter)
- SpotBeams zu End-User ❸
  - mehrere Benutzer/Beam
  - mobil
  - remote
  - kleine Resourcen

Sources: TAS, VERTIGO, ETH

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GENERIC ARCHITECTURE OF A LASER TERMINALS

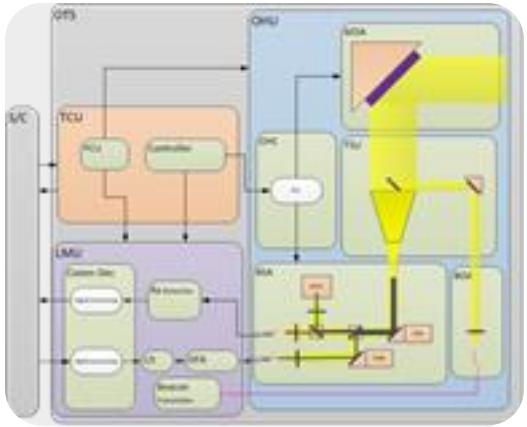
OPTEL-C / TAS
Constellation Terminal
- 130 mm telescope
- 2 W opt. power
- 10Gbps duplex
- 6000 km
- 1550nm band, no WDM

/// Optical Head

- Coarse- and finesteering (micro-radians!!)
- Expansion (tx) of the beam (telescope)
- Beam management (combine, split, filter stabililize)
- Point, aqcuire, track

/// Laser Modem (not shown)

- Datainterface to Platform / Router
- Coding, error correction, framing, …
- (De-)modulation of laser light
- Amplification of the modulated light
- Time and ranging function



Generic Architecture of an Optical Terminal

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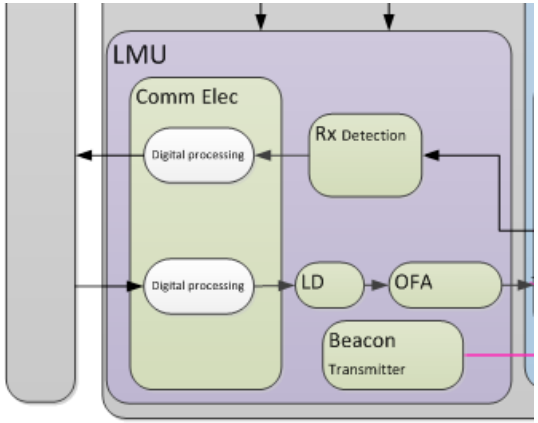
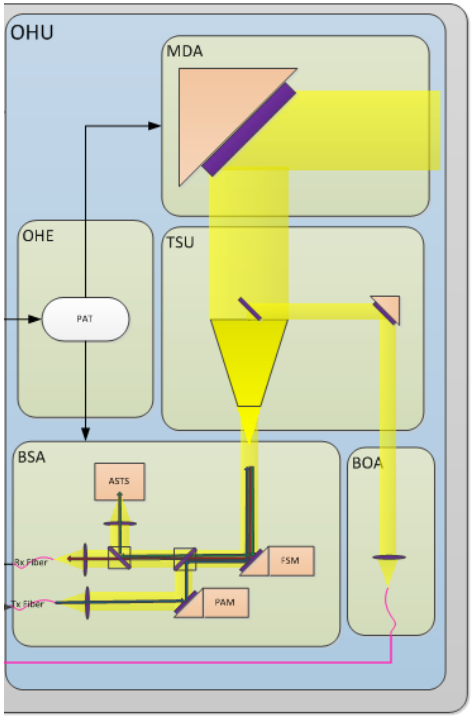
OPTICAL TERINAL ARCHITECTURE (EXAMPLE)

10 Gbps duplex



~ - 40 dBm

~ + 32 dBm



8 um

8 mm

130 mm

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FROM NOW TO NEXT

Building Block	«State of art»	What could be		Remarks
Coarse Pointing	Mechanical, mirrors, actuators	Non-mechanical, phased beam		Different FoR req, up to
Quantum	Early stage	Many opportunities assumed		Not part of this presentation

Full slide will be provided upon request

Reto.muff@thalesaleniaspace.com

CONCLUSION

Space offers many

- ❑ Opportunities

but / and

- ❑ Challenges

…. for photonics as enabler for novel approaches for (classical) problems

Reach out to the community

Example for TAS

Space Business Catalyst, TAS industrial accelerator in Toulouse and Torino for StartUps
https://www.thalesaleniaspace.com/en/space-business-catalyst

Offering technical, commercial and financial support through two levels of coaching, the accelerator hosts startups from all over the world, drawing on Thales Alenia Space's geographic footprint in Europe and the United States.

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