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SATELLITE-BASED LASER COMMUNICATIONS

EPIC Online Technology Meeting on Quarterly Briefing on New Space Communications and Monitoring

31 MARCH 2021

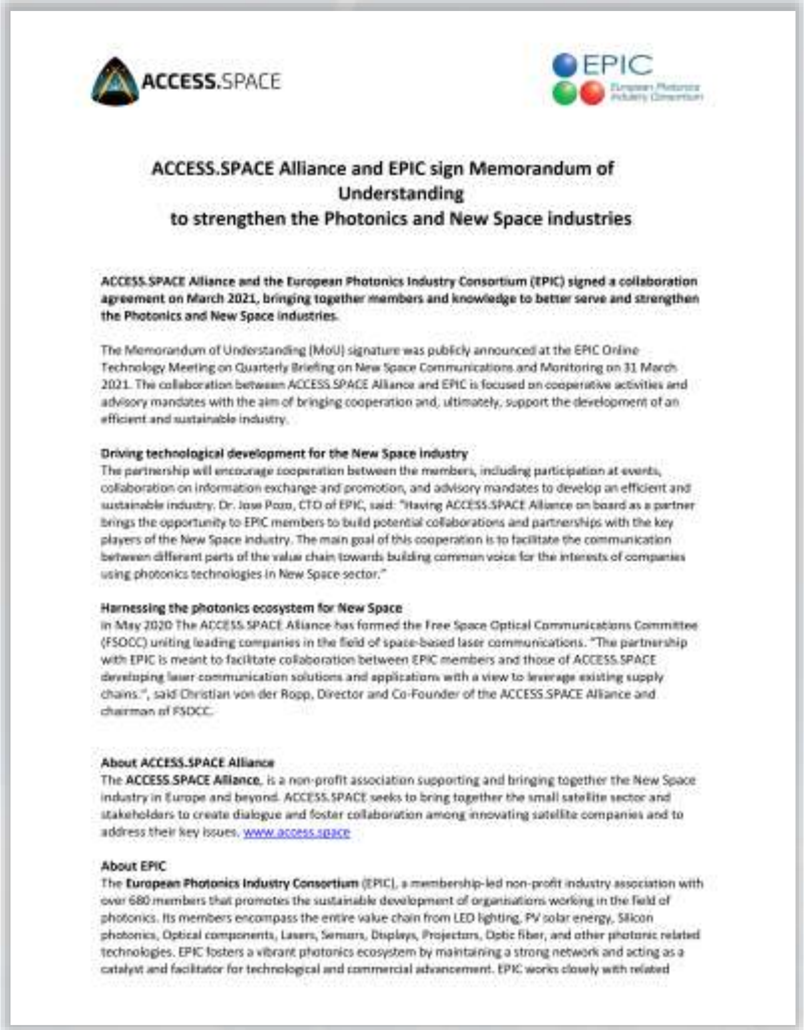
CHRISTIAN FRHR. VON DER ROPP

ABOUT

Christian von der Ropp
Stuttgart, Germany
Director & Co-Founder

ACCESS.SPACE is an industry body for the small satellite sector uniting 49 companies and organizations globally

COLLABORATION WITH EPIC



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EPIC
European Photonics Industry Consortium

**ACCESS.SPACE Alliance and EPIC sign Memorandum of Understanding
to strengthen the Photonics and New Space industries**

ACCESS.SPACE Alliance and the European Photonics Industry Consortium (EPIC) signed a collaboration agreement on March 2021, bringing together members and knowledge to better serve and strengthen the Photonics and New Space industries.

The Memorandum of Understanding (MoU) signature was publicly announced at the EPIC Online Technology Meeting on Quarterly Briefing on New Space Communications and Monitoring on 31 March 2021. The collaboration between ACCESS.SPACE Alliance and EPIC is focused on cooperative activities and advisory mandates with the aim of bringing cooperation and, ultimately, support the development of an efficient and sustainable industry.

Driving technological development for the New Space industry
The partnership will encourage cooperation between the members, including participation at events, collaboration on information exchange and promotion, and advisory mandates to develop an efficient and sustainable industry. Dr. Jose Pozo, CTO of EPIC, said: "Having ACCESS.SPACE Alliance on board as a partner brings the opportunity to EPIC members to build potential collaborations and partnerships with the key players of the New Space industry. The main goal of this cooperation is to facilitate the communication between different parts of the value chain towards building common voice for the interests of companies using photonics technologies in New Space sector."

Harnessing the photonics ecosystem for New Space
In May 2020 The ACCESS.SPACE Alliance has formed the Free Space Optical Communications Committee (FSOCC) uniting leading companies in the field of space-based laser communications. "The partnership with EPIC is meant to facilitate collaboration between EPIC members and those of ACCESS.SPACE developing laser communication solutions and applications with a view to leverage existing supply chains.", said Christian von der Ropp, Director and Co-Founder of the ACCESS.SPACE Alliance and chairman of FSOCC.

About ACCESS.SPACE Alliance
The **ACCESS.SPACE Alliance**, is a non-profit association supporting and bringing together the New Space industry in Europe and beyond. ACCESS.SPACE seeks to bring together the small satellite sector and stakeholders to create dialogue and foster collaboration among innovating satellite companies and to address their key issues. www.access.space

About EPIC
The **European Photonics Industry Consortium** (EPIC), a membership-led non-profit industry association with over 680 members that promotes the sustainable development of organisations working in the field of photonics. Its members encompass the entire value chain from LED lighting, PV solar energy, Silicon photonics, Optical components, Lasers, Sensors, Displays, Projectors, Optic fiber, and other photonic related technologies. EPIC fosters a vibrant photonics ecosystem by maintaining a strong network and acting as a catalyst and facilitator for technological and commercial advancement. EPIC works closely with related

- EPIC and ACCESS.SPACE today announce an MoU to collaborate and facilitate partnerships between both organizations‘ memberships.
- Harnessing ecosystems and unlocking new opportunities for all members
- Focussed on but not limited to laser communications

TERMINOLOGY

Synonyms:

- Free Space Optical Communications
- Optical Satellite Communications
- Laser Communications
- Lasercomms
- „Space Lasers“

ACCESS.SPACE LASER-RELATED ACTIVITITES

Formed in 2020 the Free Space Optical Communications Committee or FSOCC as a working group of ACCESS.SPACE is bringing together the supply chain and vendors of laser communication terminals with existing and future operators of the same with a view to promote collaboration and standardization.

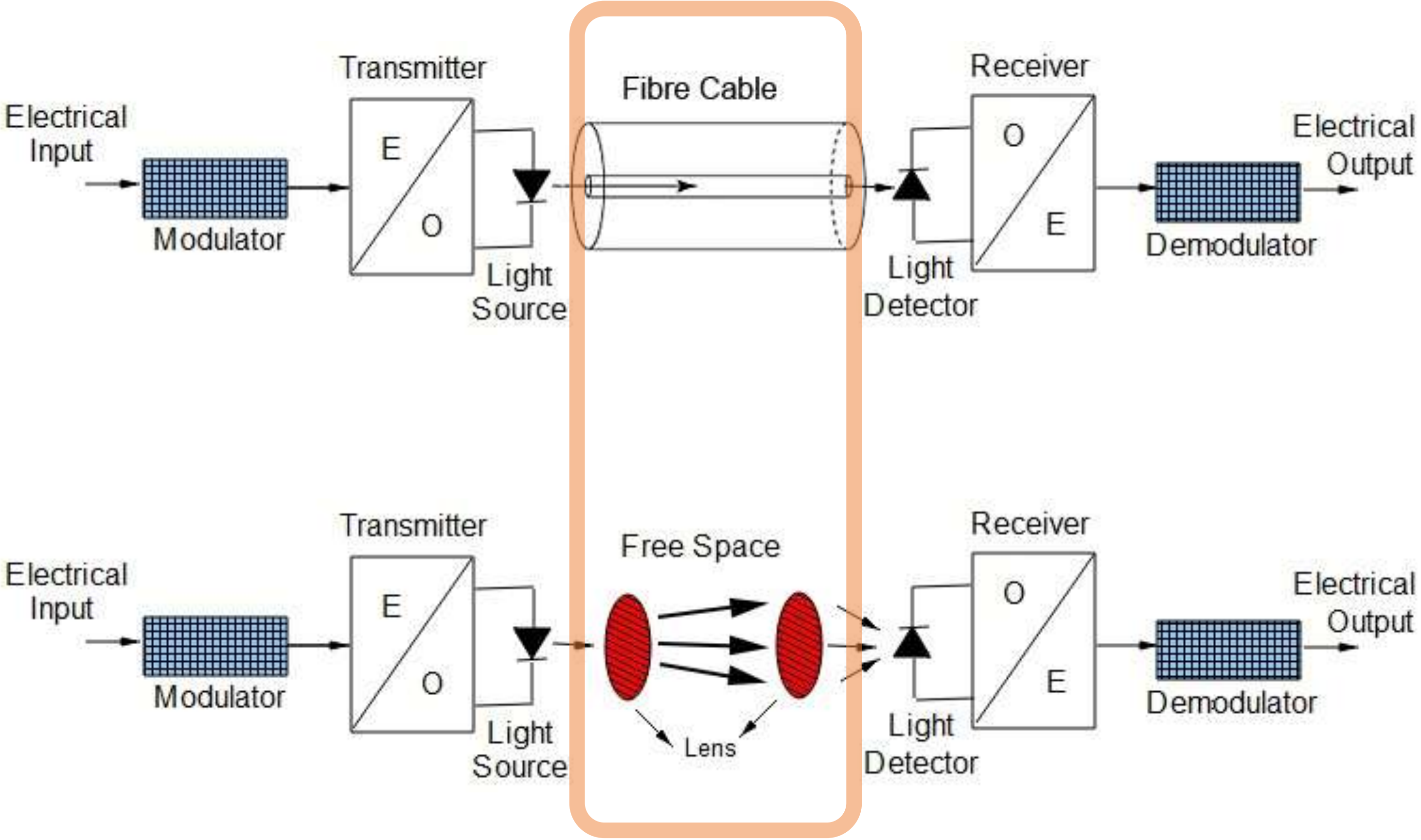
FSOCC Board of Chairs

Christian Frhr. von der Ropp
Company Director at ACCESS.SPACE Alliance

Robert Brumley
CEO at CommStar & Laser Light Communications

Sven Meyer-Brunswick
C3PO at Mynaric

FIBRE OPTICS VS. FREE SPACE OPTICS



BELL'S "PHOTOPHONE" AND INVENTION OF LASER

fig. 1 Theodore Harold Maiman with his laser in July 1960

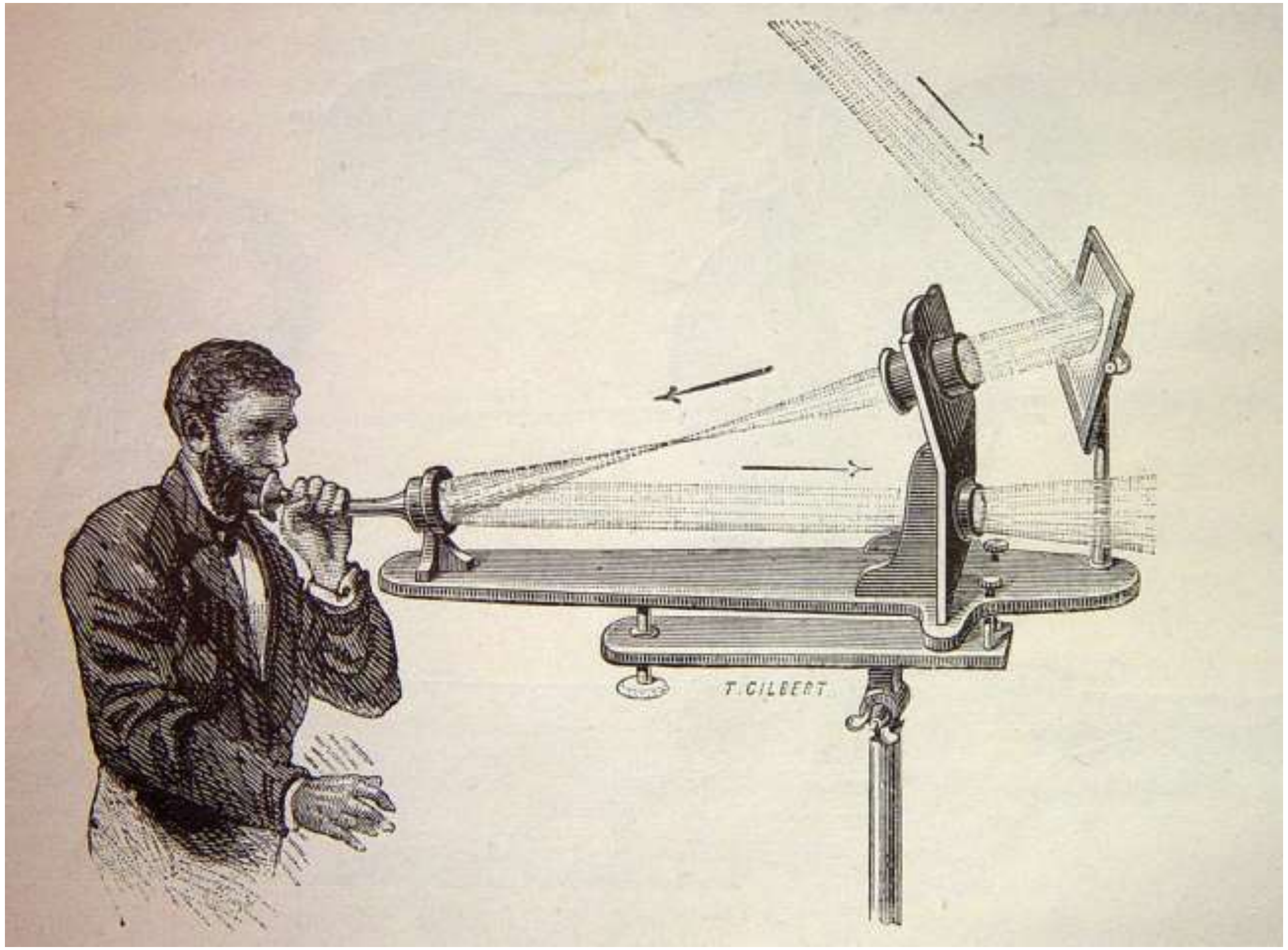


fig. 2 Alexander Graham Bell's „photophone" patented in 1880

FIBRE OPTIC CABLES DISTRACTED INTEREST

- Laser communications via the air suffer from a number of limitations:
  - Clear line-of-sight required
  - Bad weather outages
  - Precise alignment of terminals
- When fibre optics were discovered in 1965 attention shifted quickly to fibre cables that avoid above issues

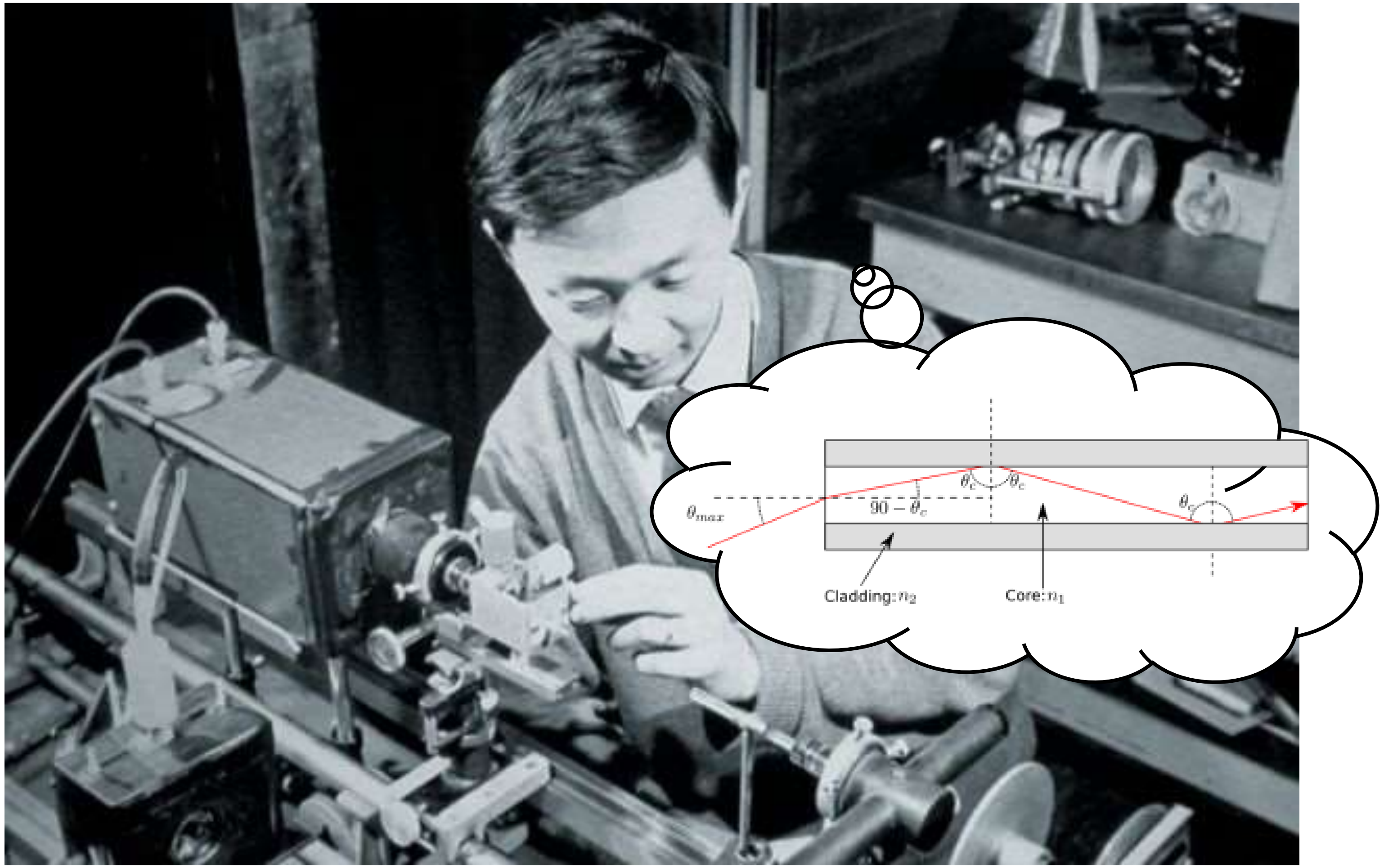


fig. Charles Kao doing an early experiment on optical fibres in 1965

REVIVED INTEREST IN LASER COMMUNICATIONS

In recent years interest in laser communications revived due to

- Increased bandwidth requirements (earth observation/remote sensing satellites and LEO constellations of 100s to 1000s of satellites handling massive amounts of data)
- Scarcity of radio frequency spectrum
- Cost and time to secure spectrum rights
- Growing interference issues (many satellites share the same spectrum with the earlier filed having priority)
- Lower probability of detection
- Lower probability of intercept
- Jamming-resistance

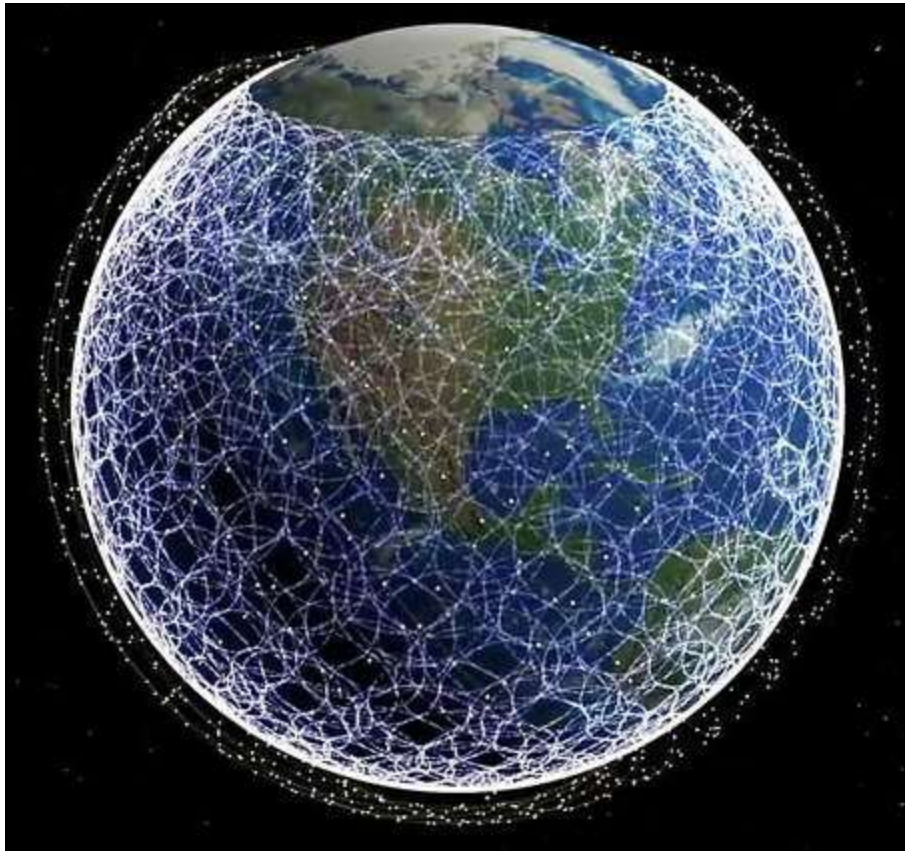
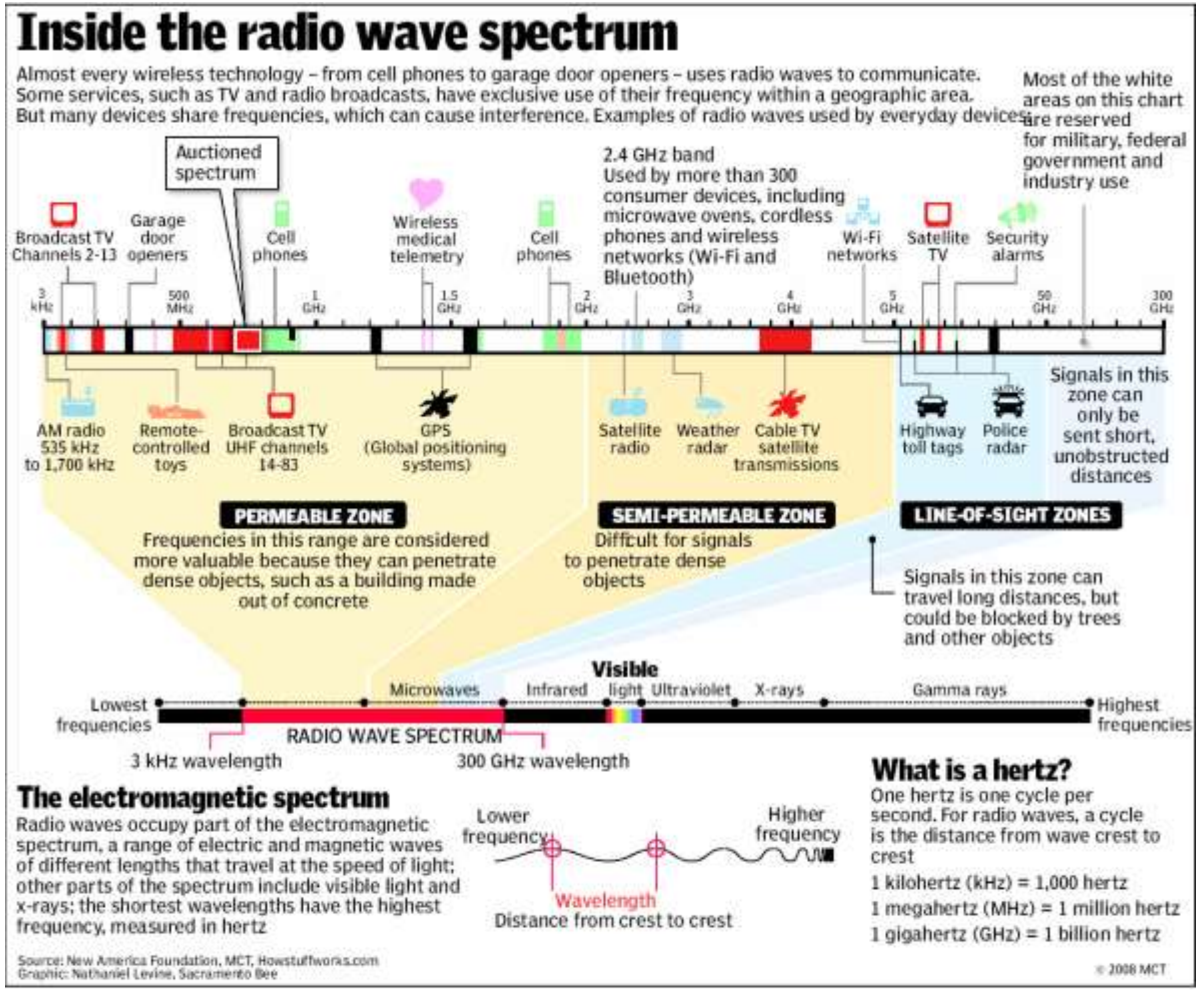


fig. Visualization of a LEO constellation satellite, Image: Prof. Mark Handley/University College London

CONGESTION OF RADIO FREQUENCY SPECTRUM



Radio frequency spectrum is…

- congested
- particularly low frequencies with favourable propagation properties
- subject to licensing
- often very expensive to license
- prone to interferences (whether unintentional or deliberate jamming)
- rededication to terrestrial applications (C-band) or band sharing increases competition between satellite and terrestrial applications

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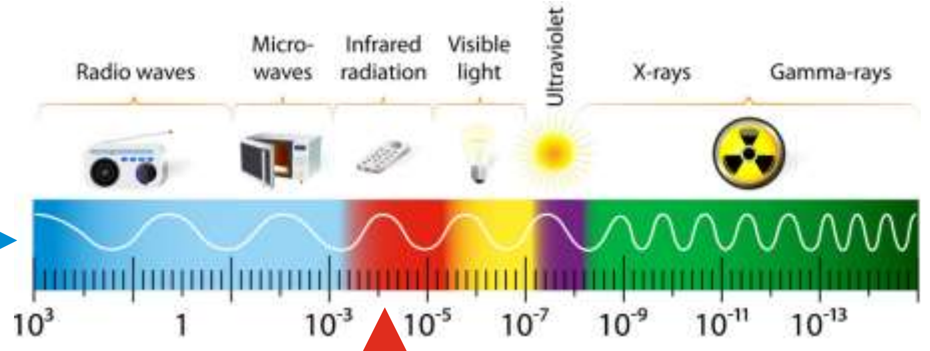
COMPARISON OF AVAILABLE SPECTRUM

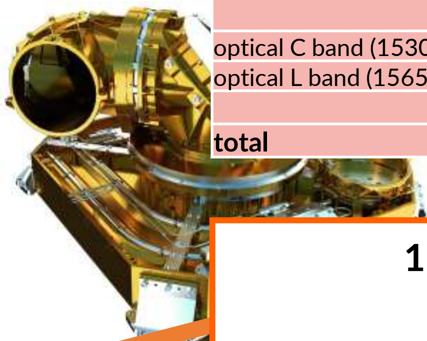
RF spectrum available for satellite communications

	lower end in MHz	*upper end in MHz*	*bandwidth in MHz*
VHF band	136	138	2
	144	146	2
	148	150	2
	149,95	150,05	0,1
	240	270	30
UHF band	399,9	403	3,1
	432	438	6
	460	470	10
L band	1200	1800	600
	1670	1710	40
S band	2025	2300	275
	2500	2670	170
C band	3400	4200	800
	5900	6400	500
X band	8000	9000	1000
Ku band	10700	11700	1000
	11700	12200	500
	14500	14800	300
	17300	18100	800
Ka band	23000	27000	4000
V band	37500	39500	2000
	39500	42500	3000
	47200	50200	3000
	50400	51400	1000
total			**19,040.2**



optical spectrum available for satellite communications

	lower end in MHz	*upper end in MHz*	*bandwidth in MHz*
optical C band (1530-1565nm)	191,560,676	195,942,783	4,382,106.97
optical L band (1565-1625nm)	184,487,666	191,560,676	7,073,009.58
total			**11,455,116.5**

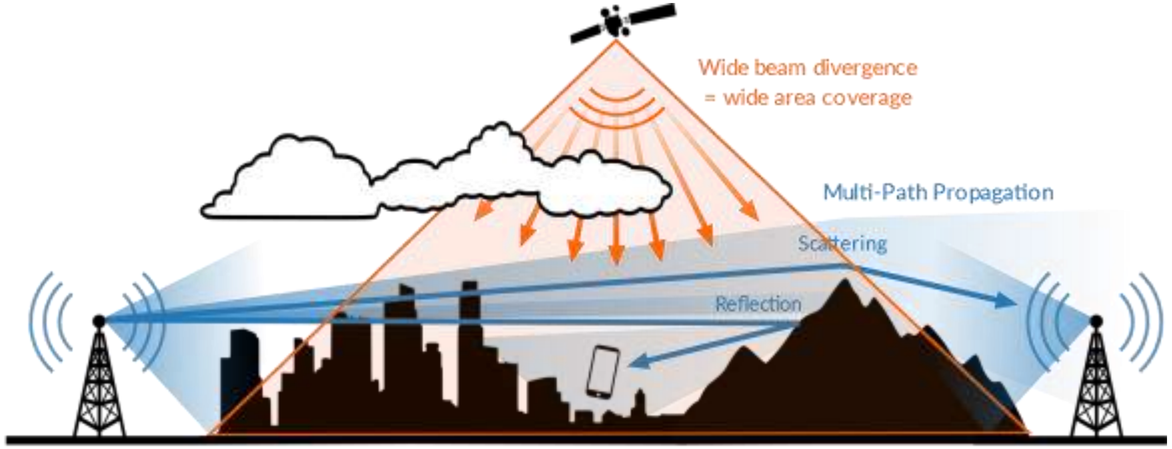


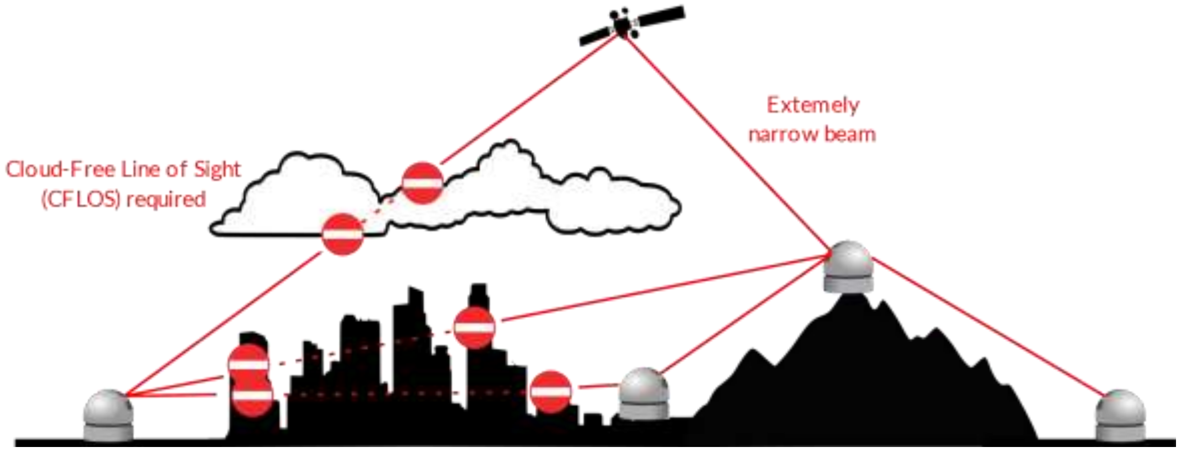
19 vs 11,455 GHz bandwidth:

601 times

more spectrum available for optical communications than for RF communications

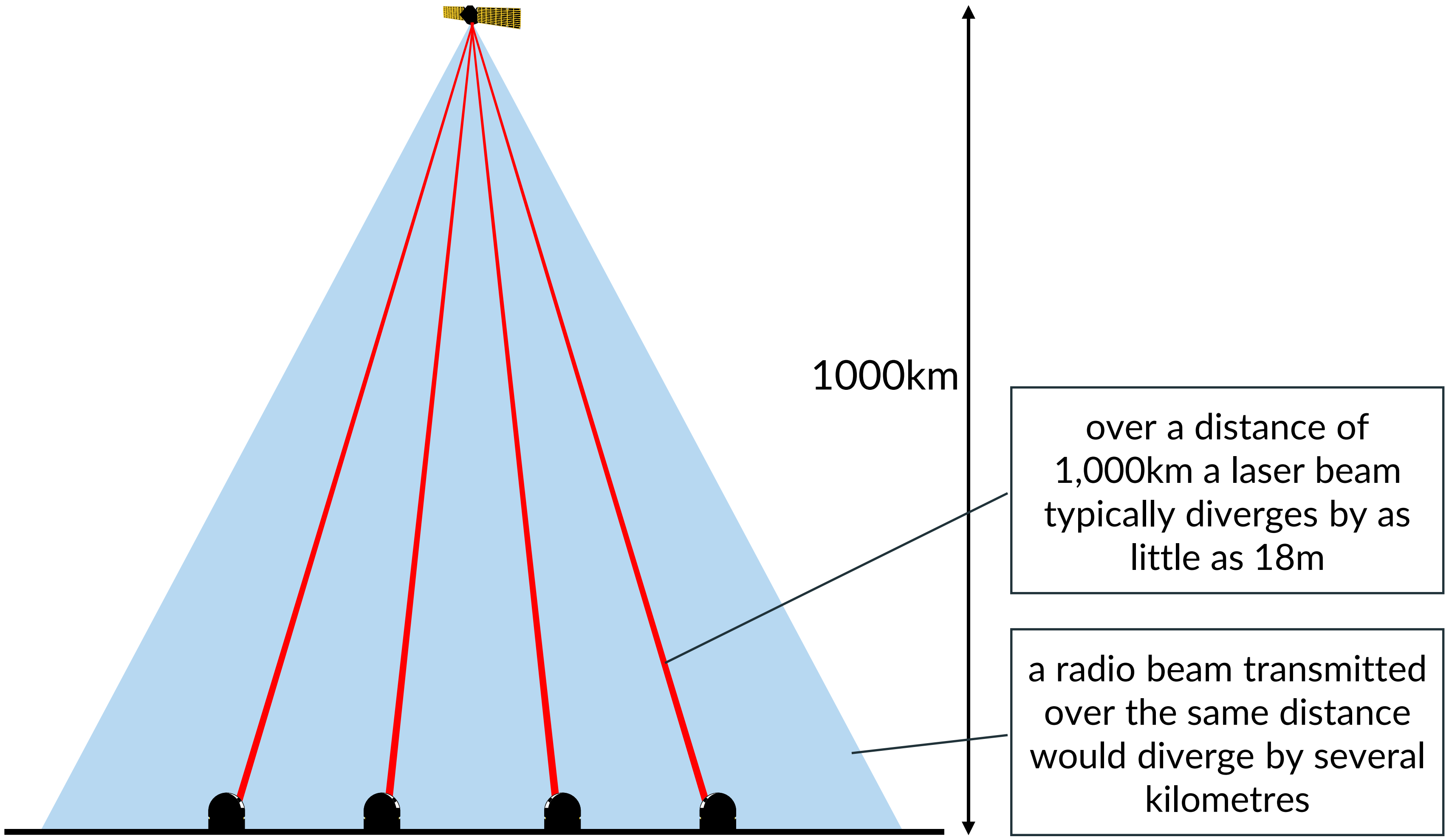
RADIO FREQUENCY VS. LASER COMMUNICATION





- favourable propagation of RF signals as radio waves benefit from various dispersion effects (reflection and scattering)
- RF signals can penetrate clouds and precipitation
- Hence RF links (depending on frequency) do not always require free line-of-sight
- **Laser however requires a <u>cloud-free line of sight</u> (CFLOS)**

DIFFERENCES IN BEAM DIVERGENCE

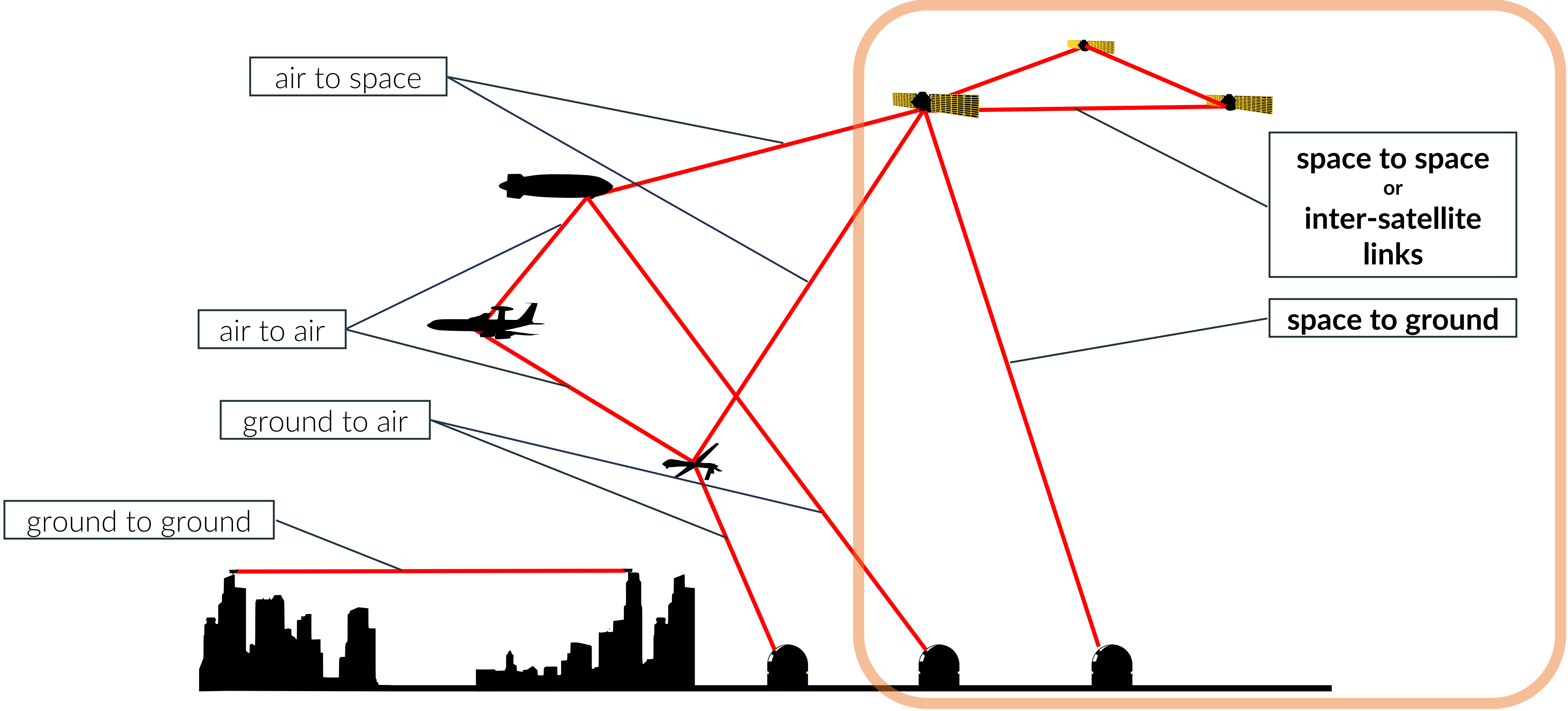


However because laser beams must be extremely focussed while radio waves spread out widely laser has two great advantages:

- Interferences are virtually impossible
- Spectrum can be reused in a much denser scheme than RF = spatial diversity
- Spectrum reuse allows for multiplication of bandwidth
- Laser beams are almost impossible to detect and intercept

But laser requires highly accurate pointing, acquisition and tracking (PAT)

APPLICATIONS FOR FREE SPACE OPTICS



LASER COMMUNICATION TERMINALS (LCTs)

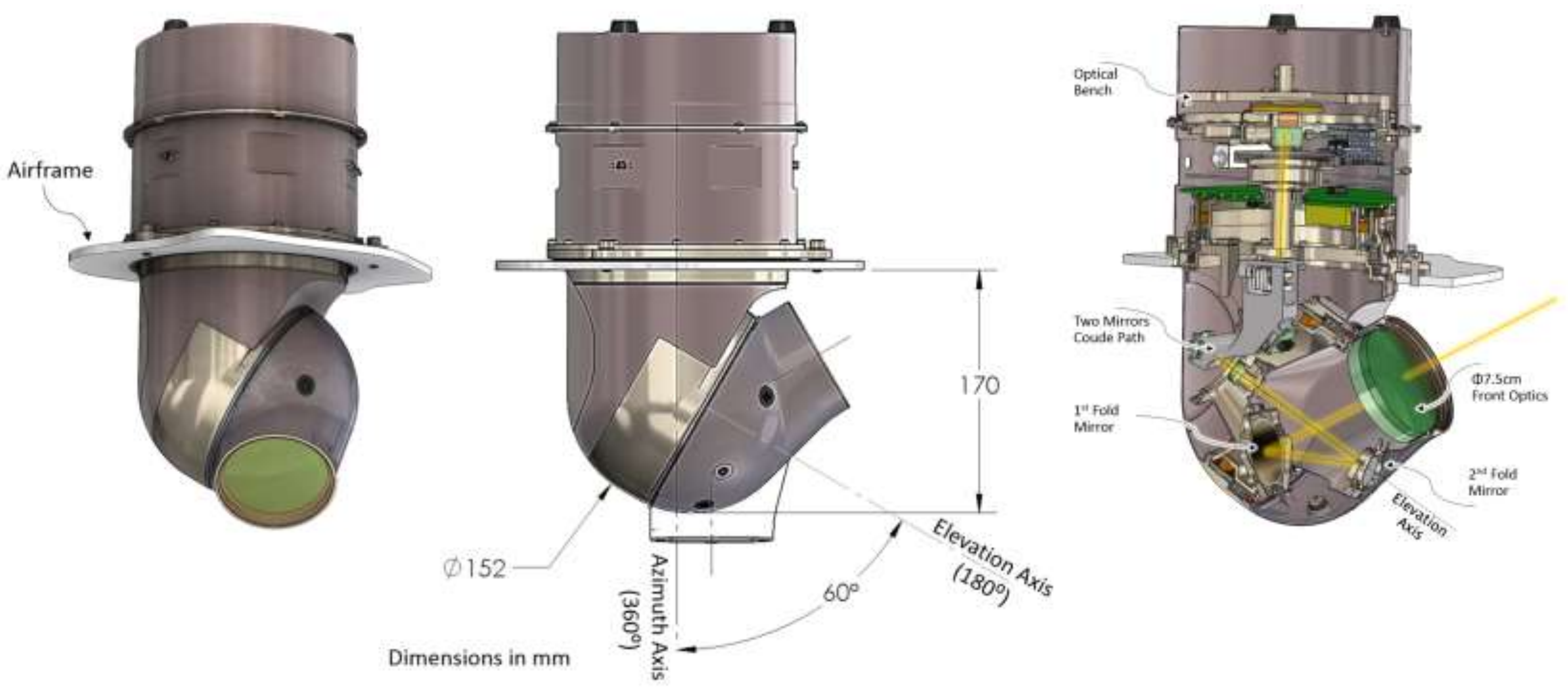


fig. Facebook concept for a laser communications terminal design based on two-axis gimbal, image: Facebook

fig. Cubesat-sized laser terminal, image: DLR (CC-BY 3.0)

OPTICAL GROUND STATIONS

fig. Optical ground station, image: Laser Light Communications

fig. Optical ground station, image: DLR

NASA‘S LLCD EXPERIMENT

- In 2013 NASA achieved a data rate of 622 Mbps over a link stretching 380,000km between an optical ground station on Earth and the LADEE probe orbiting moon

fig. Optical ground station, image: NASA

EDRS – „SPACE DATA HIGHWAY“

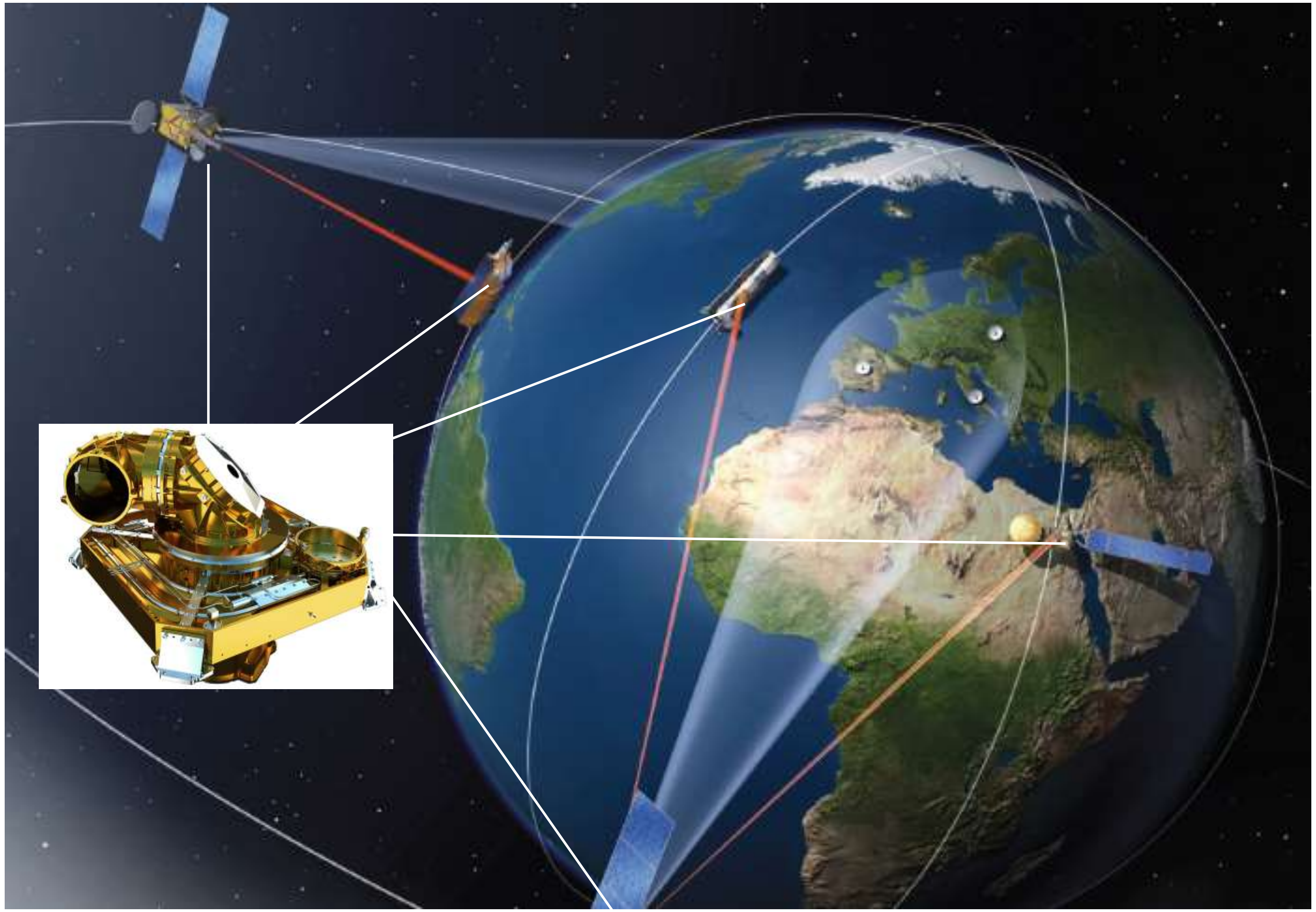


fig. Airbus and ESA‘s EDRS system and Tesat Spacecom‘s LCT, image: Airbus and Tesat Spacecom

- EDRS = European Data Relay Satellites operated by ESA and Airbus
- 4 earth observation satellites in LEO (Sentinel 1A, 1B, 2A and 2B) equipped with LCTs each connect up to **15 times per day** to…
- 2 geostationary satellites (Eutelsat 9B hosting EDRS-A at 9°E and EDRS-C at 31°E) with **1.8Gbps** over a distance of up to **45,000km** which relay the data through traditional RF links in the Ka band to the ground
- more than 20,000 data links established since 2016 and more than 1 PB transferred
- service availability >99.5%

THRUST (TERABIT THROUGHPUT SATELLITE SYSTEM TECHNOLOGY) PROJECT

fig. THRUST trial setup, image: DLR

- German Aerospace Centre (DLR) trialed purely terrestrial laser links between two ground sites over a distance of 10.45km
- The atmospheric turbulence over this distance so close to the ground corresponds to that of a laser link from the ground to a GEO satellite at an altitude of 35,786km
- In May 2018 a bandwidth of **13.16Tbps** was reached over this setup setting a world record for free space optics and proving similar results are possible to satellites

LASER LIGHT COMMUNICATIONS – „SPACE CABLE“

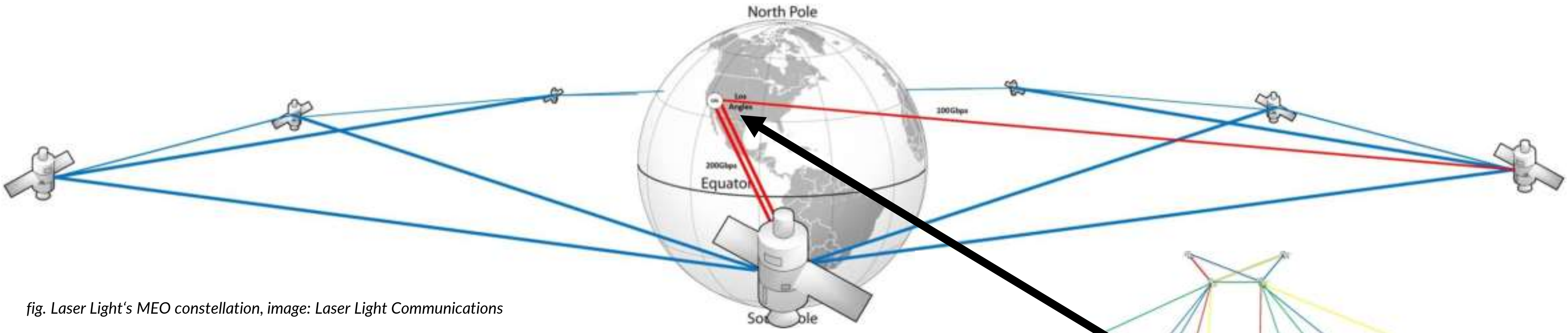
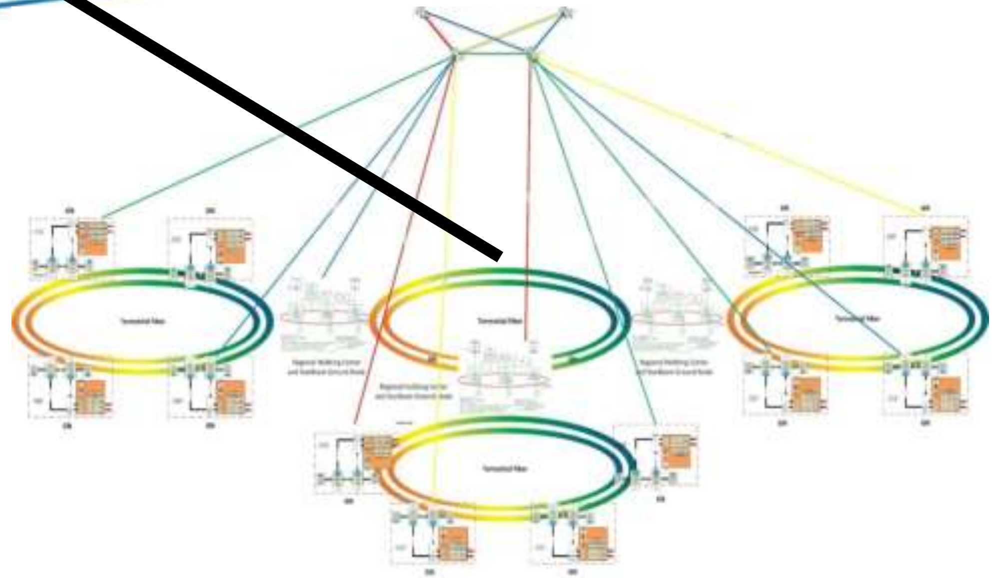


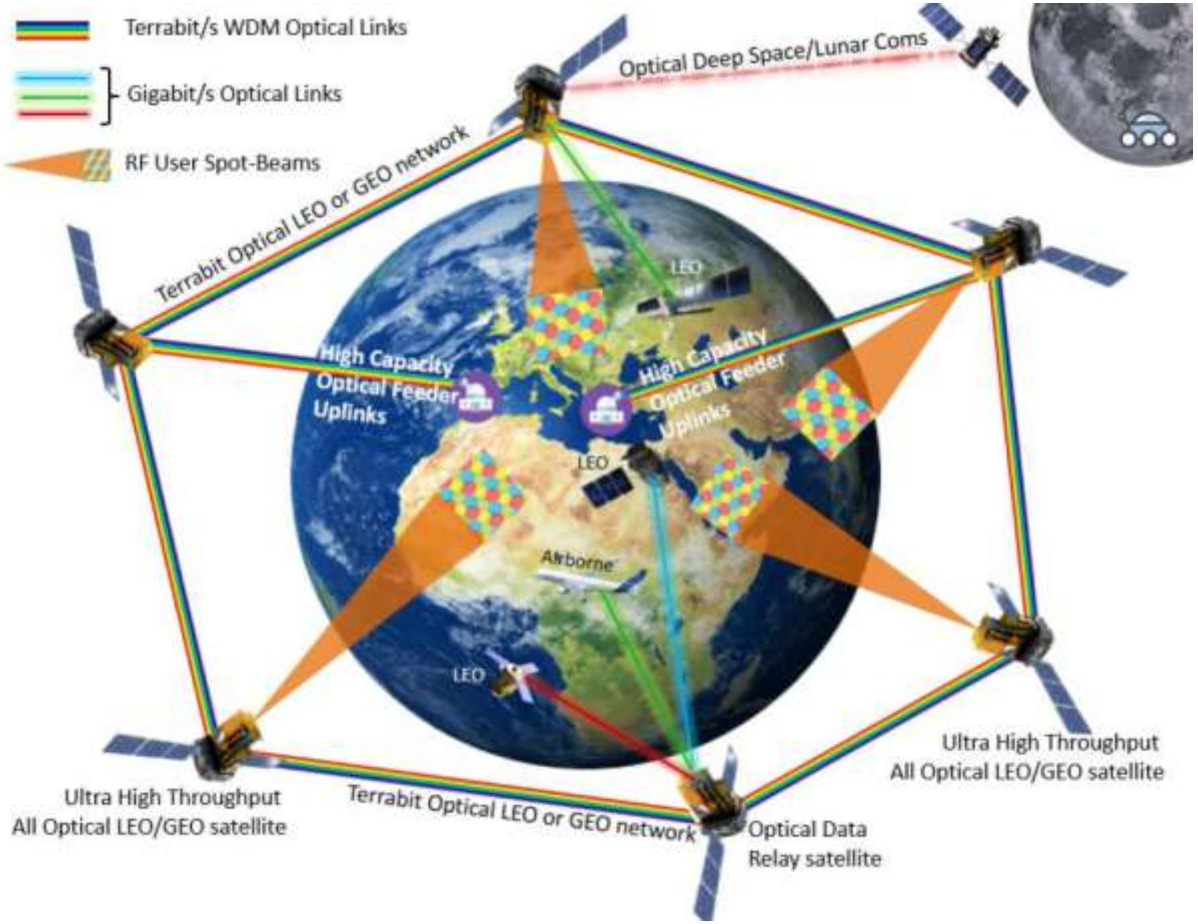
fig. Laser Light‘s MEO constellation, image: Laser Light Communications



A constellation of 8 satellites in MEO with multiple LCTs would feature…

- 200Gbps laser links among each other
- n×100Gbps laser links to clusters of multiple ground nodes across the continents for spatial diversity (bad weather)
- low latency connectivty on demand at lower cost per bit per mile than fibre optic cables

ESA'S HYDRON PROJECT – „FIBRE IN SPACE"



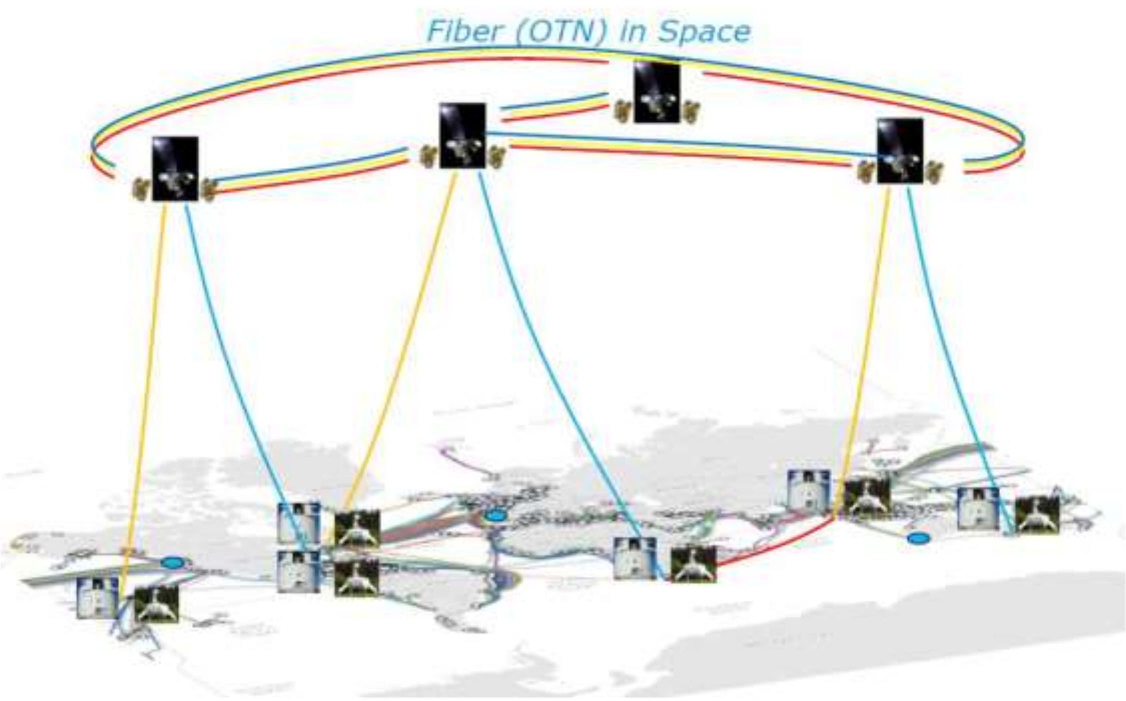
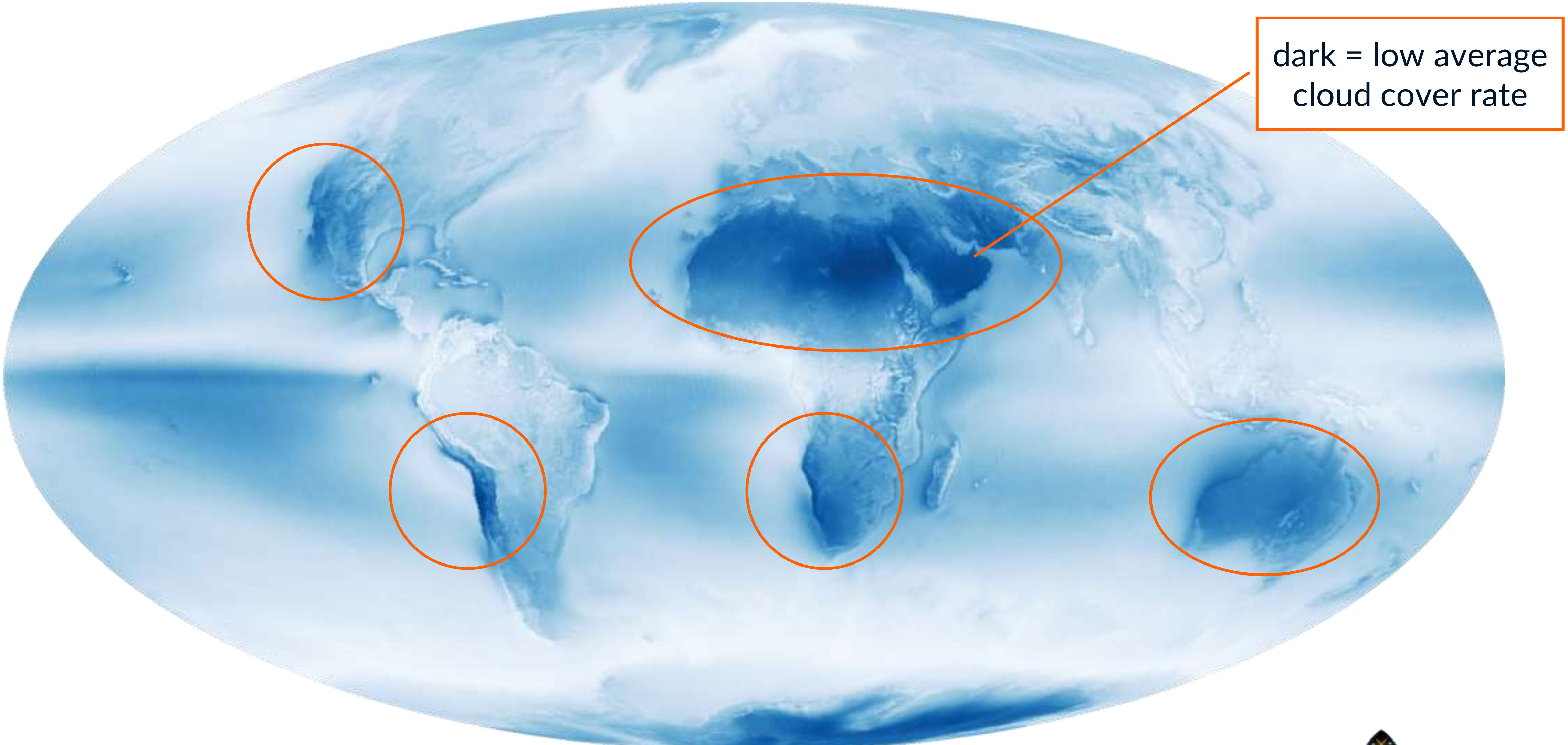


fig. Topology of ESA's Hydron Project

MAP OF AVERAGE CLOUD COVER RATE



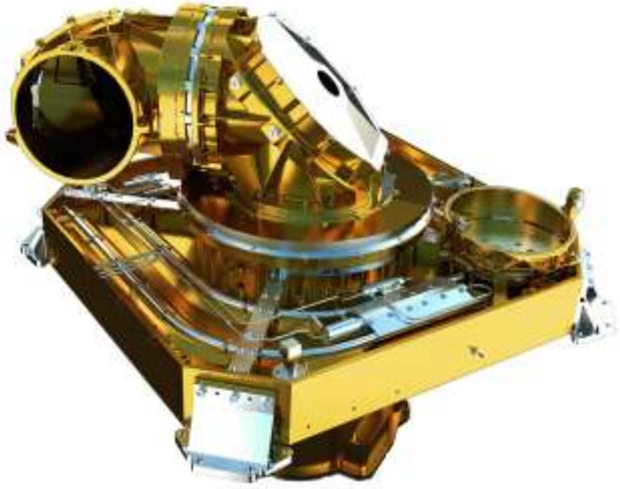
SWAP OF LASER COMMUNICATION TERMINALS (LCTs)

Property	RF	Optical	Net gain of optical vs. RF
Carrier frequency	25 GHz (12 mm)	282 THz (1064 nm)	+81 dB (127 Mio)
Transmitter power	50 W	5 W	-10 dB
TX antenna diameter	2.5 m	0.25 m	-20 dB
RX antenna diameter	10 m	1 m	-20 dB
RX noise temperature	100 K	13500 K	-21 dB
Total			+10 dB

CHALLENGES OF LASER COMMS

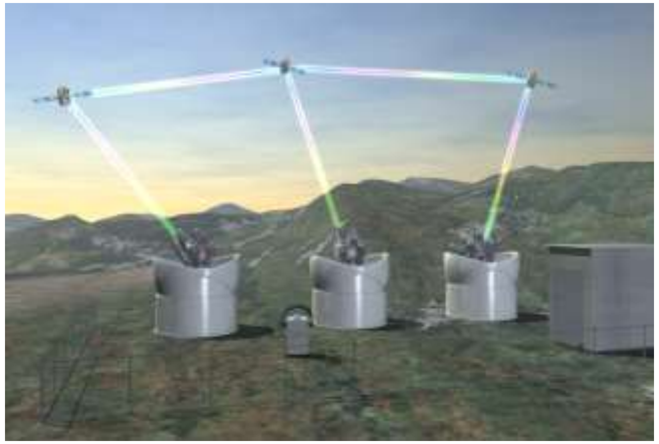
Technical:

- Highly precise pointing, acquisition and tracking (PAT) while keeping SWaP low
- DWDM equipment for bandwidths >100Gbps is still bulky and not space-worthy yet, miniaturization and stronger integration required
- Mitigation/avoidance of atmospheric turbulences (CFLOS) requires highly dynamic routing which has become possible thanks to SDN technology



Commercial:

- Laser Communication Terminals are still expensive (>$0.25 million per unit)
- Large orders allow scale production of Laser Communication Terminals bringing down unit costs
- Building a global network in orbit and on the ground requires high Capex investments



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THANK YOU

FOR YOUR ATTENTION

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31 MARCH 2021

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