HydRON: Internet backbone beyond the clouds

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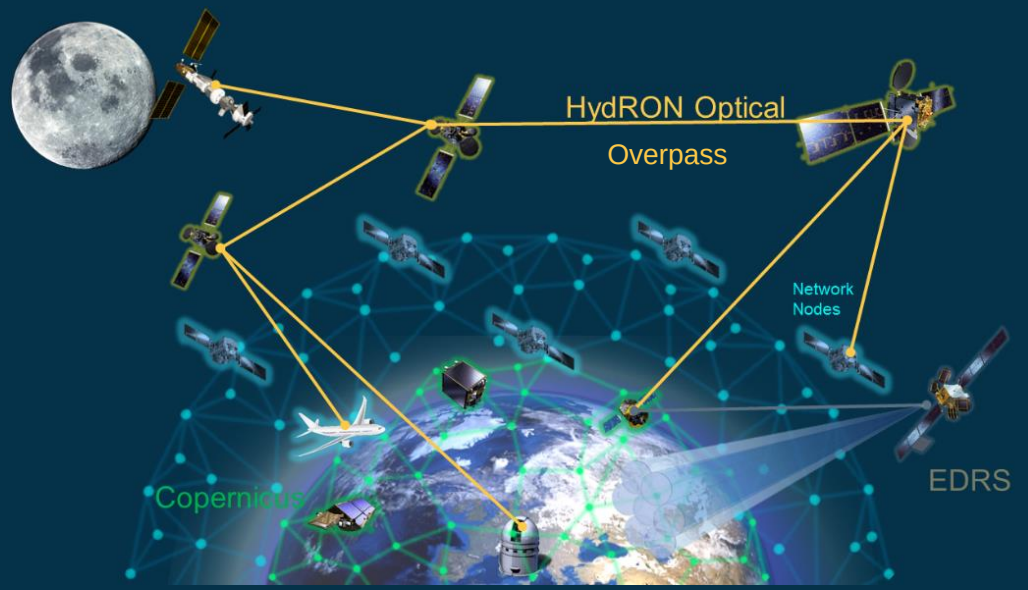
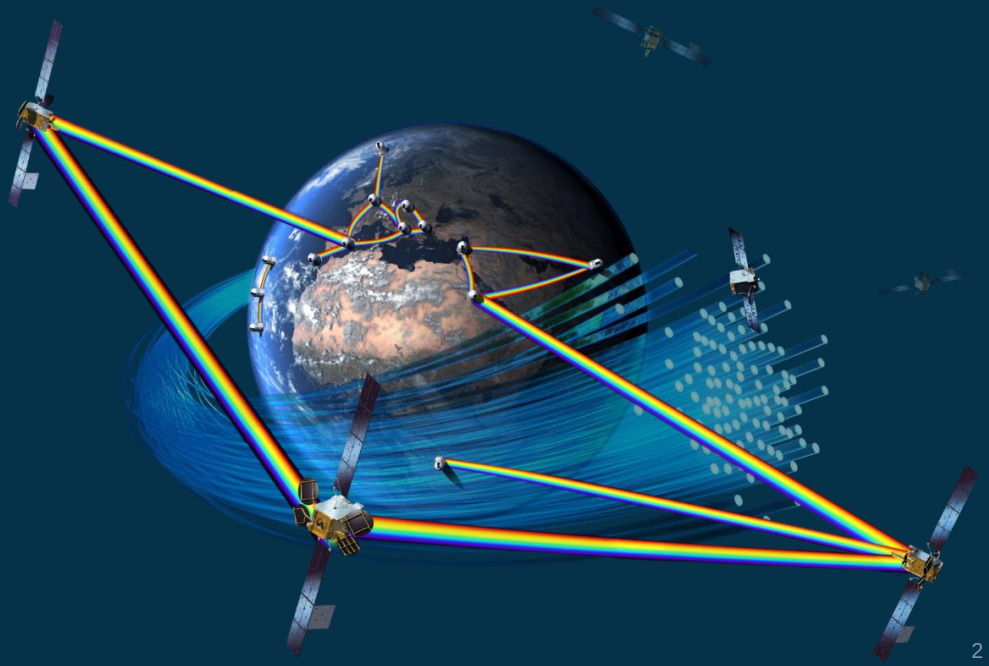
Background

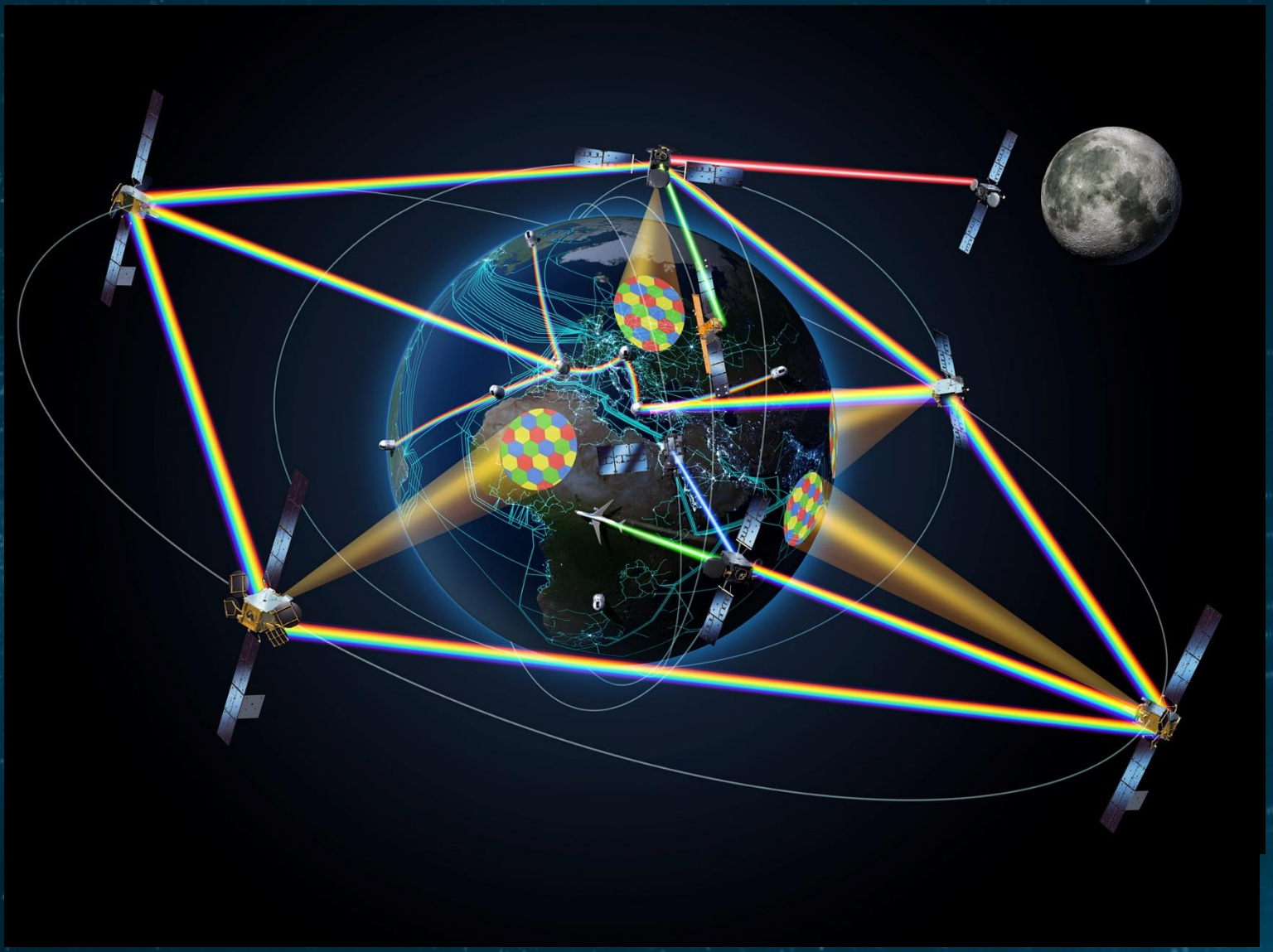
- High thRoughput Optical Network (HydRON) vision of the European Space Agency (ESA) is to seamlessly extend terrestrial high-capacity networks into space.
  - “Internet backbone beyond the cloud(s)”.
- <u>Outline of this talk:</u>
  - a brief overview of the overall HydRON System concept
  - summary of the design options and trade-offs





HydRON is the extension of the terrestrial fiber network into space

- A space-based optical network extension to terrestrial optical networks. Complementing terrestrial networks
  - services to remote areas,
  - dynamic offload of excess traffic,
  - for selected applications/customers, by-passing compromised or clogged parts of terrestrial networks,
- HydRON payloads are embarked either on dedicated satellites in LEO, MEO and GEO (or are hosted payloads)
- Terabit/s links to other satellites, airborne vehicles and ground stations.



Objectives of the HydRON Project

Define the architecture of HydRON that meets the user requirements

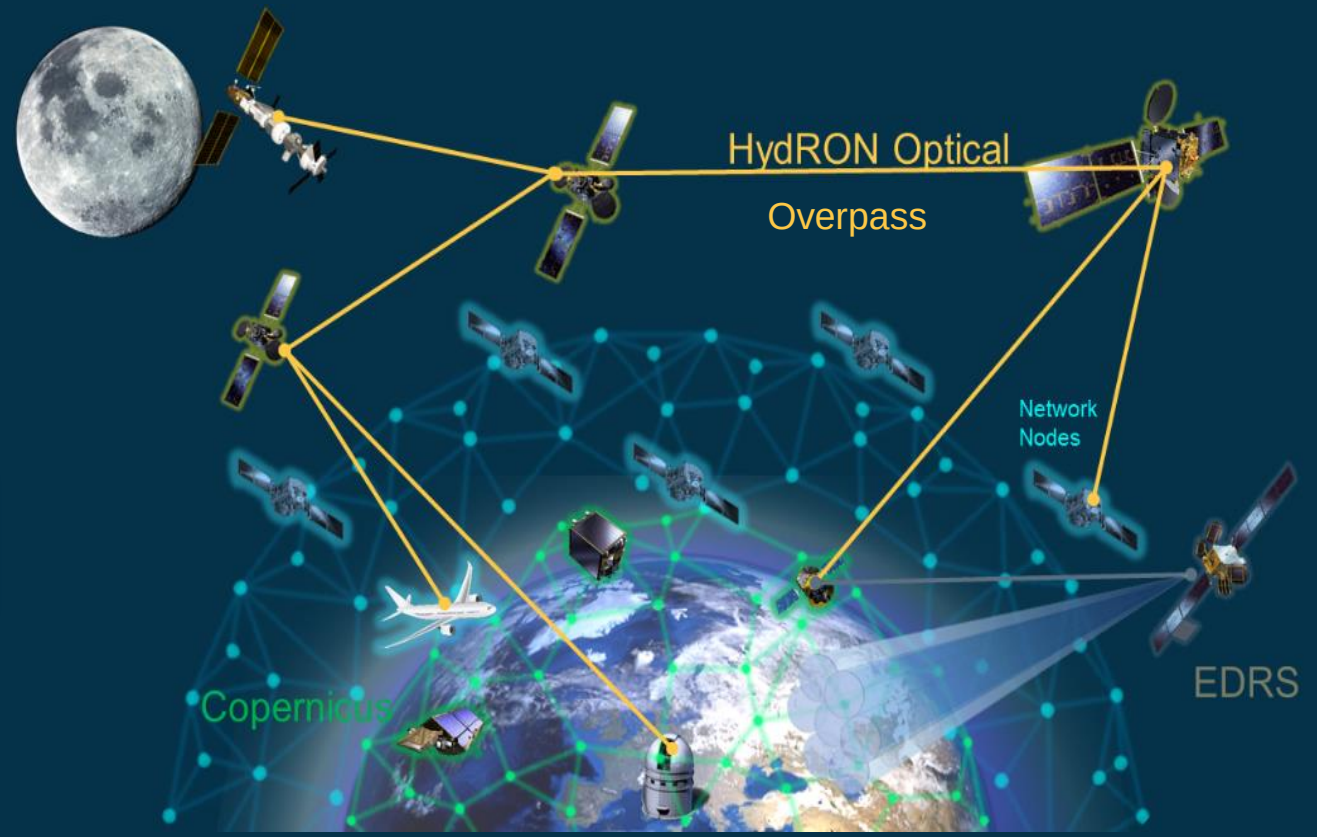
Implement and validate key technologies in an end-to-end HydRON Demonstration System

Multi-Orbit GEO/LEO/MEO/HAPS 3-D interconnection

Switching & routing in space

Ultra-High Speed Terabit/second

Extendability for global reach



Optical Network overpass in Space

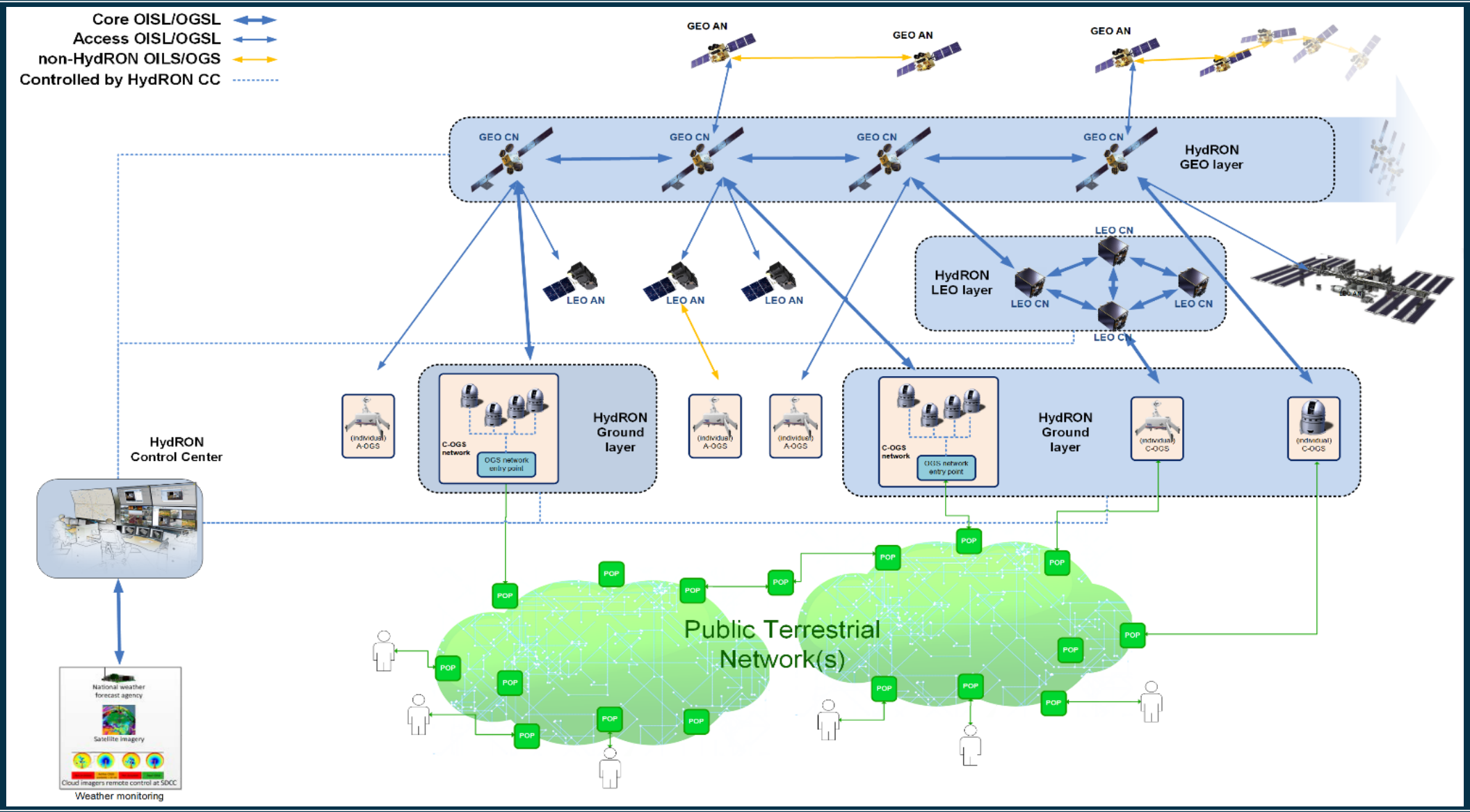
Space & Terrestrial Networks seamlessly integrated

Agile and dynamic service provision

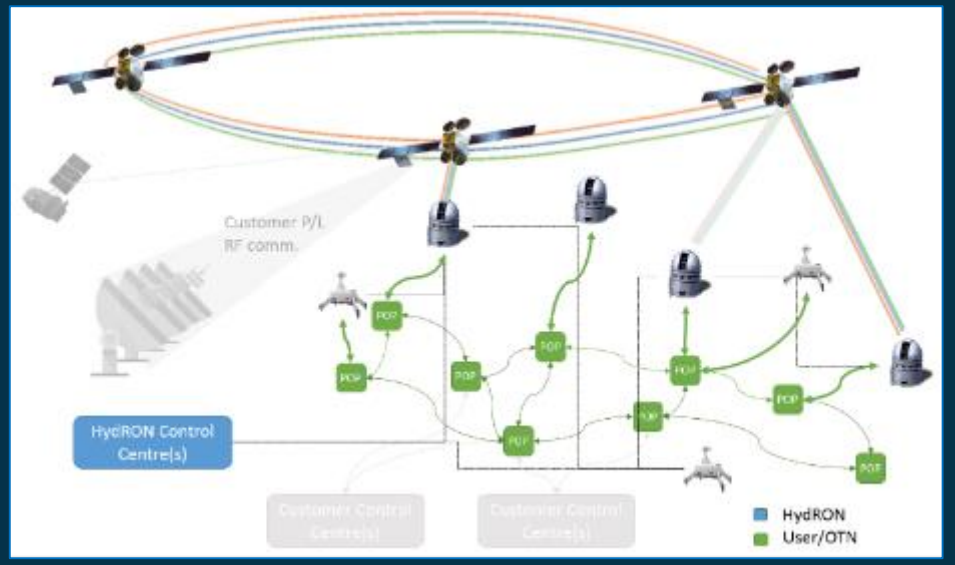
AI/ML-powered network optimisation

Efficient and dynamic bandwidth allocation

HydRON system concept

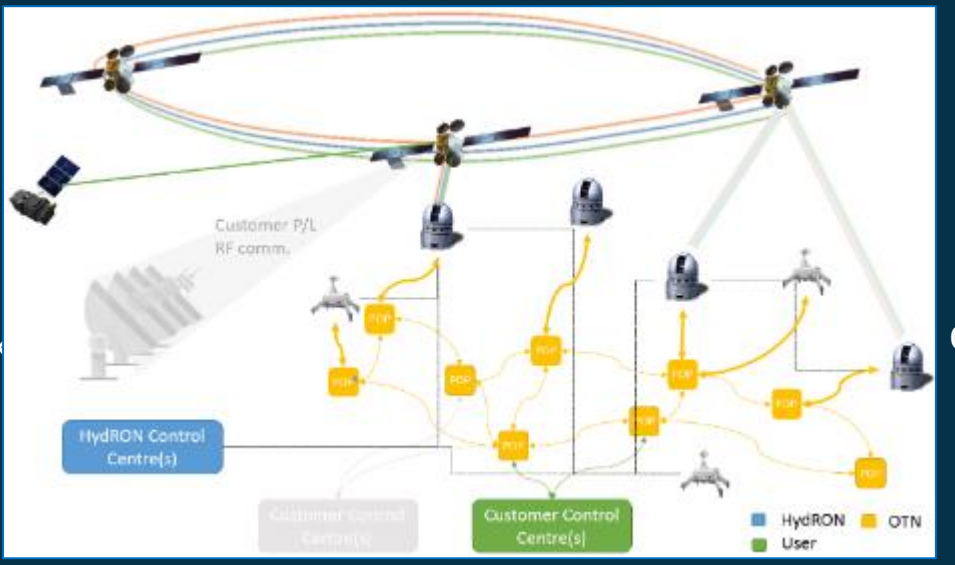


HydRON User Categories



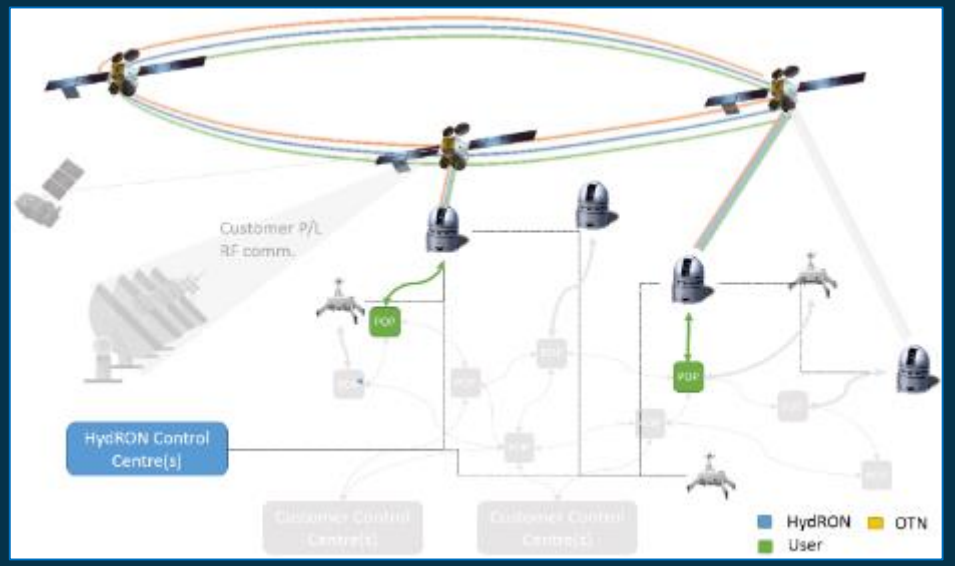
Terrestrial Network Operators

expanding their terrestrial network to route traffic
(ground to ground)



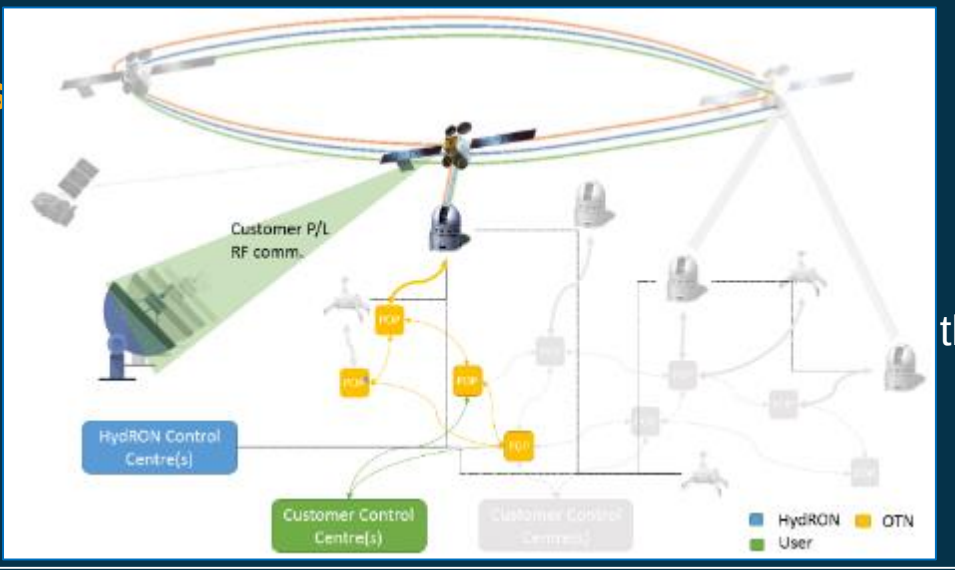
Satellite / Airborne Users

connecting own satellites / UAV / aircraft to the network
(space to/from ground)



Private Network Users

securing connections avoiding terrestrial infrastructures
(ground to ground)



Telecom Satellite Operators

connecting their fleet to the Network
(space to/from ground)

HydRON payload architecture(s)

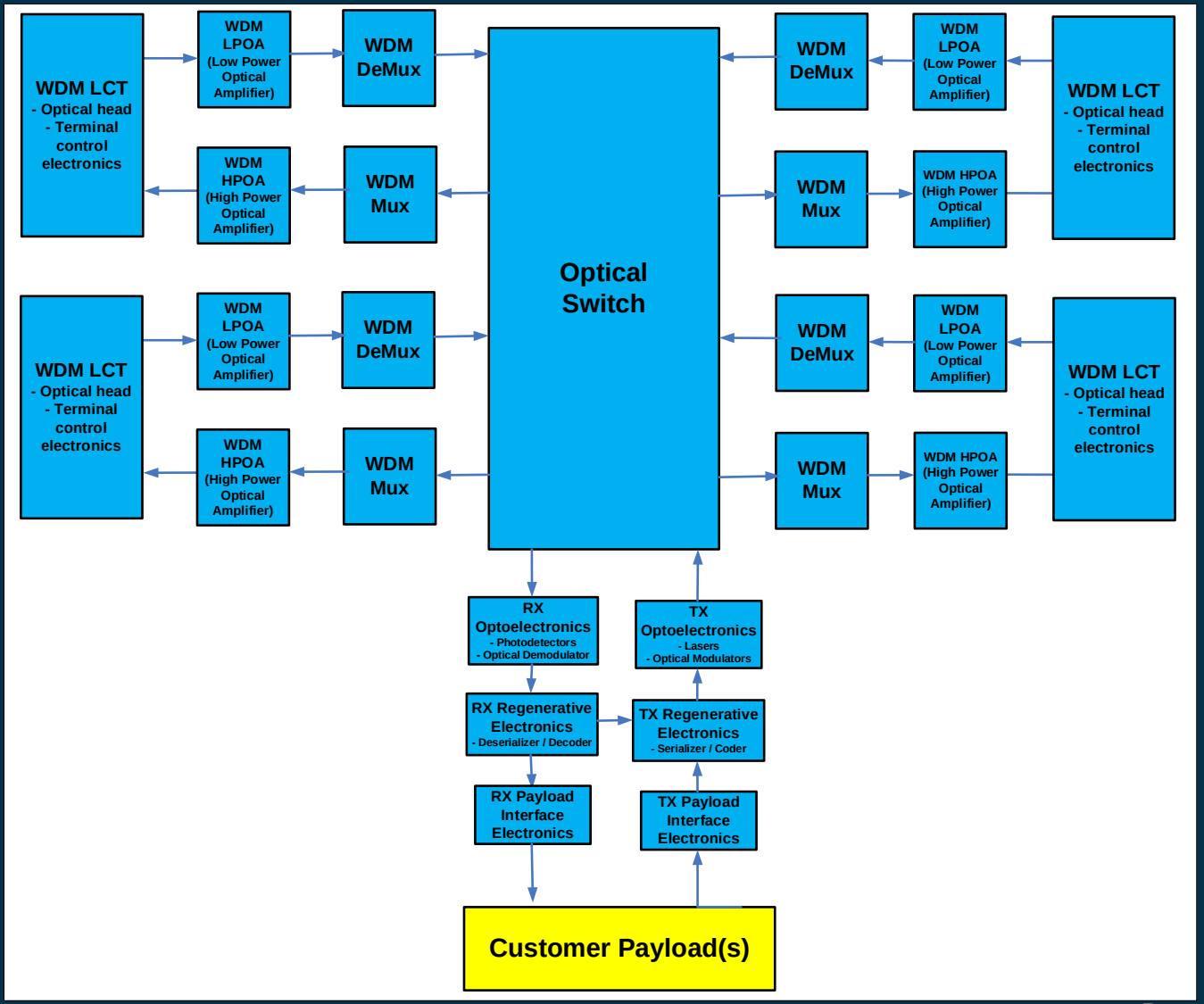
Depending on

(i) the signal type processing (transparent or regenerative) and

(ii) the implementation of the switch (optical or electrical),

three different HydRON payload architectures can be outlined:

- Optical (digital or analogue) transparent with optical (circuit) switch, as shown in figure.
- Electrical regenerative with optical (circuit) switch.
- Electrical regenerative with electrical circuit switch.
- Electrical regenerative with electrical packet switch.



HydRON Trade-Offs: Wavelength Selection / Reliability through the atmosphere

Wavelength selection

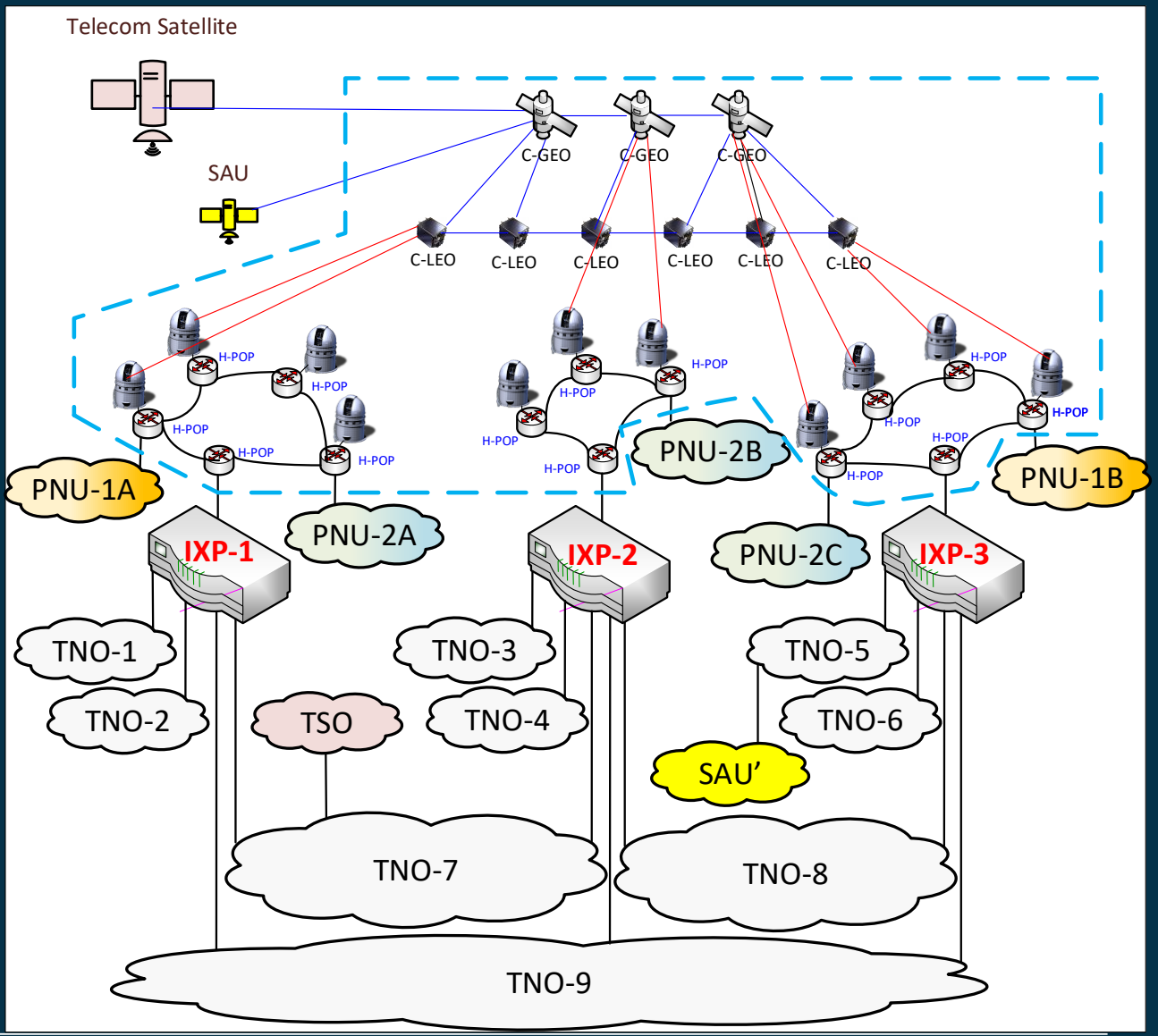
- Two candidates for HydRON : 1064nm &1550nm waveband (C-band).
- The wavelength selection depends on;
  - the availability of space qualified HPOA
  - the wall plug efficiency of the booster amplifier
  - the availability of space qualified passive photonic components, e.g. (high power) WDM.

Reliable Optical Feeder Links through the atmosphere

- ESA's ONUBLA study: OGS network with 10 OGSs is necessary for an annual network availability of 99.9%.
- For an American OFL and an Asian OFL, the number of OGS are ~8 and ~15, respectively, for 99.9%.
- Assuming CFLOS conditions, additional layers of link protection against atmospheric turbulence :
  - Adaptive Optics and pre-distortion techniques
  - FEC coding / interleaving, end-to-end coding / interleaving at the digital domain.

HydRON Trade-Offs: Integration into terrestrial OTN

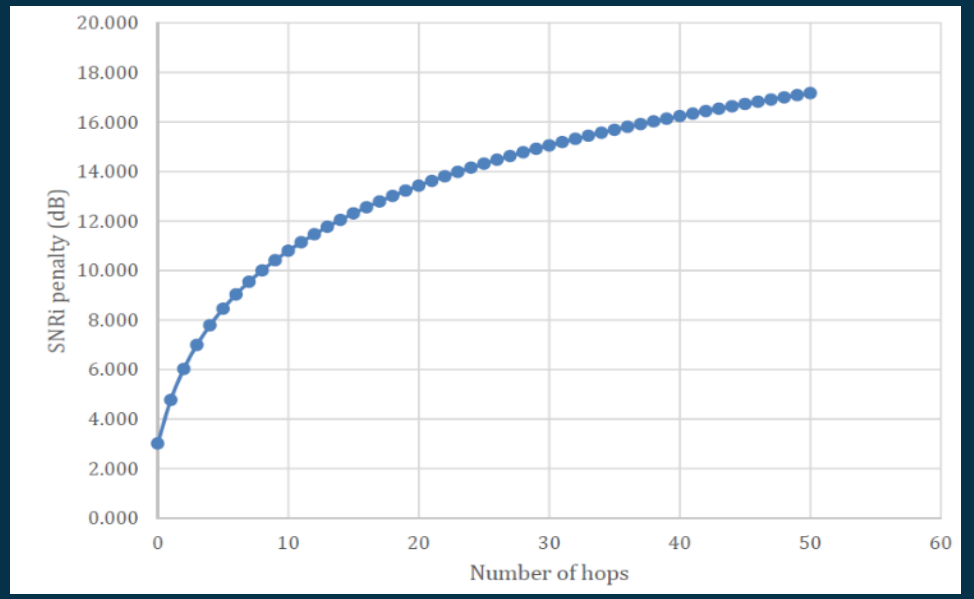
- Essential to demonstrate inter-operability of HydRON with terrestrial OTNs.
- HydRON may provide various services to other networks: e.g., G.709 connections, dynamic BGP peering, remote peering, EVPN, VPLS, E-Line, IP VPN, etc.
- Network protocols internal to HydRON are transparent to external networks. Routing/forwarding, link protection and restoration, QoS support, congestion management internal to the HydRON.
- Agile and dynamic service provision. HydRON Control Centre interfaces with external networks for service provision and re-configuration. Control plane API, Service Level Agreements.



HydRON Trade-Offs: Switching / Forwarding / Routing

On board switching

- Balance between “all optical transparency” and “electrical regeneration”.
- SNR penalty factor due to analogue transparency, as a function of the number of ISL hops (incl. up-/down-link)



Forwarding / Routing options

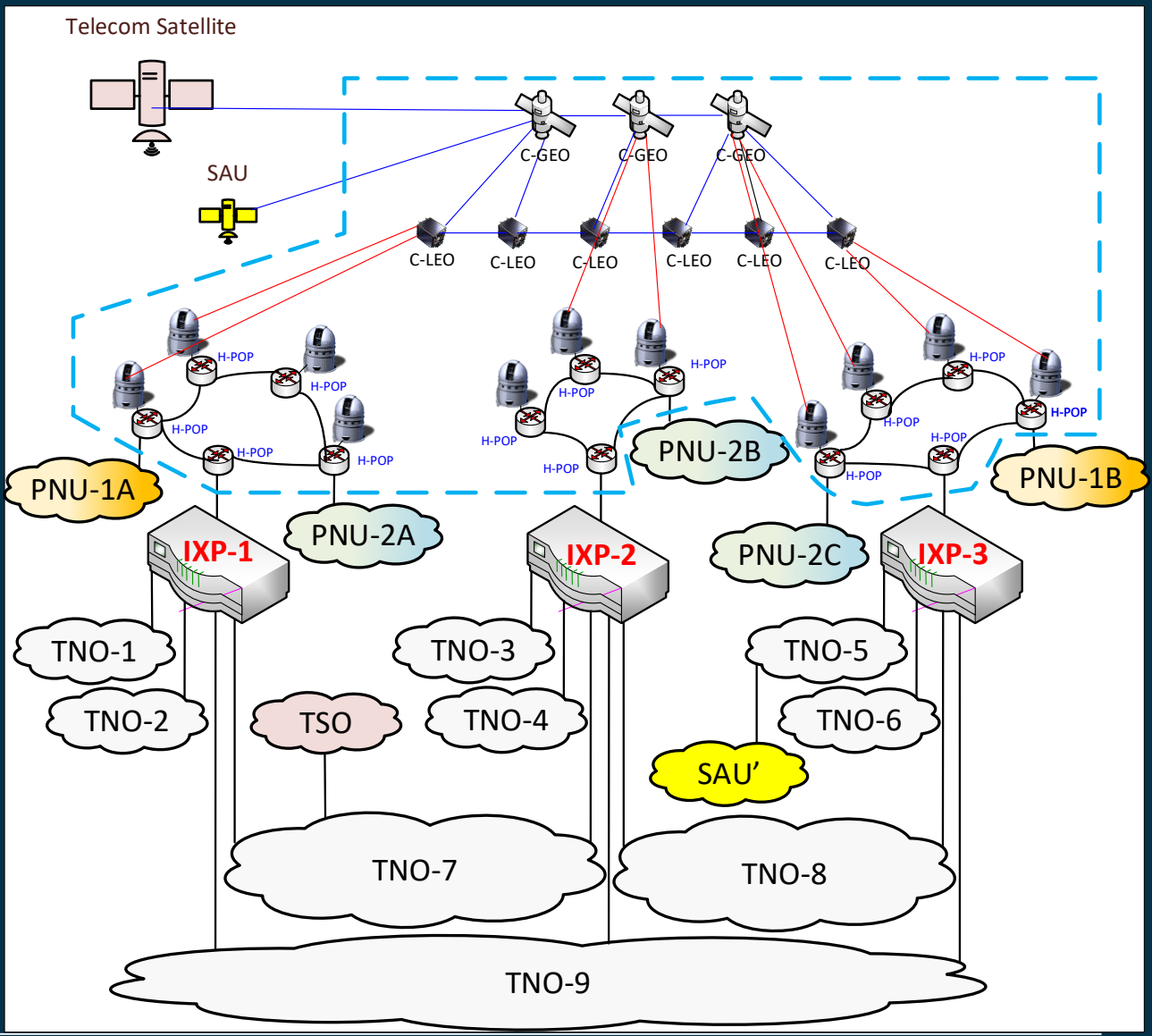
I. Circuit switching: E2E paths computed on ground, simplified on-board control-plane processing, no support for statistical multiplexing. Examples, G.709, SONET/SDH, custom-design.

II. Label switching E2E paths computed on ground or at head-end nodes. More dynamic and complex on-board control-plane functions. Statistical multiplexing supported. Examples MPLS and Segment Routing. May use IGPs.

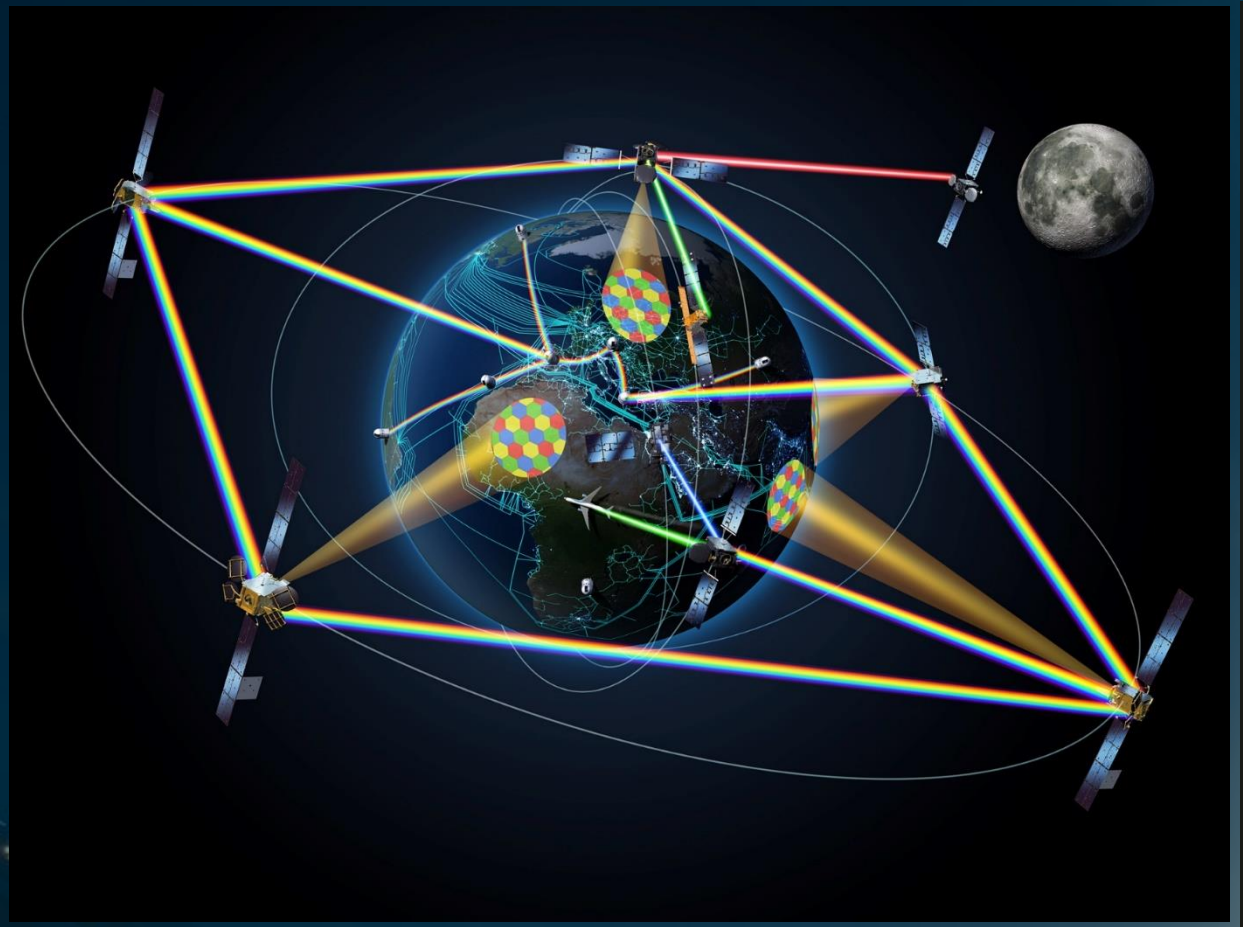
III. Datagram switching: E2E paths are not computed in advance, supports statistical multiplexing. Intermediate nodes independently select an output port to forward each packet. Need for IGPs.

HydRON Trade-Offs: OGS Switchover due to cloud obstruction

- Weather monitoring -> quasi-predictable cloud obstruction events -> Optical Ground System (OGS) switchover
- OGS H-POPs interconnected via terrestrial optical networks: leased lines vs spectrum service; meshed topology vs ring topology; 1+1 vs 1:1 redundancy etc.
- Next-OGS selection when current feeder link is blocked
- OGS switchover particularly problematic with LEO constellations with optical inter-satellite links (ISL)
  - Traffic re-routing in terrestrial network to alternative OGS, and in ISL network to alternative LEO satellite;
- Essential to demonstrate OGS switchover with real terrestrial networks interconnecting OGS H-POPs.



Thank you for your attention!



<u>For us, key questions are:</u>

- HydRON aims to complement and extend terrestrial coverage.
  - What can HydRON do for terrestrial network operators?
- HydRON needs terrestrial networks to switchover traffic among OGSes.
  - How can HydRON use terrestrial networks?
- We need to demonstrate HydRON on ground prior to launches.
  - How can we collaborate with terrestrial network operators in such demonstrations?