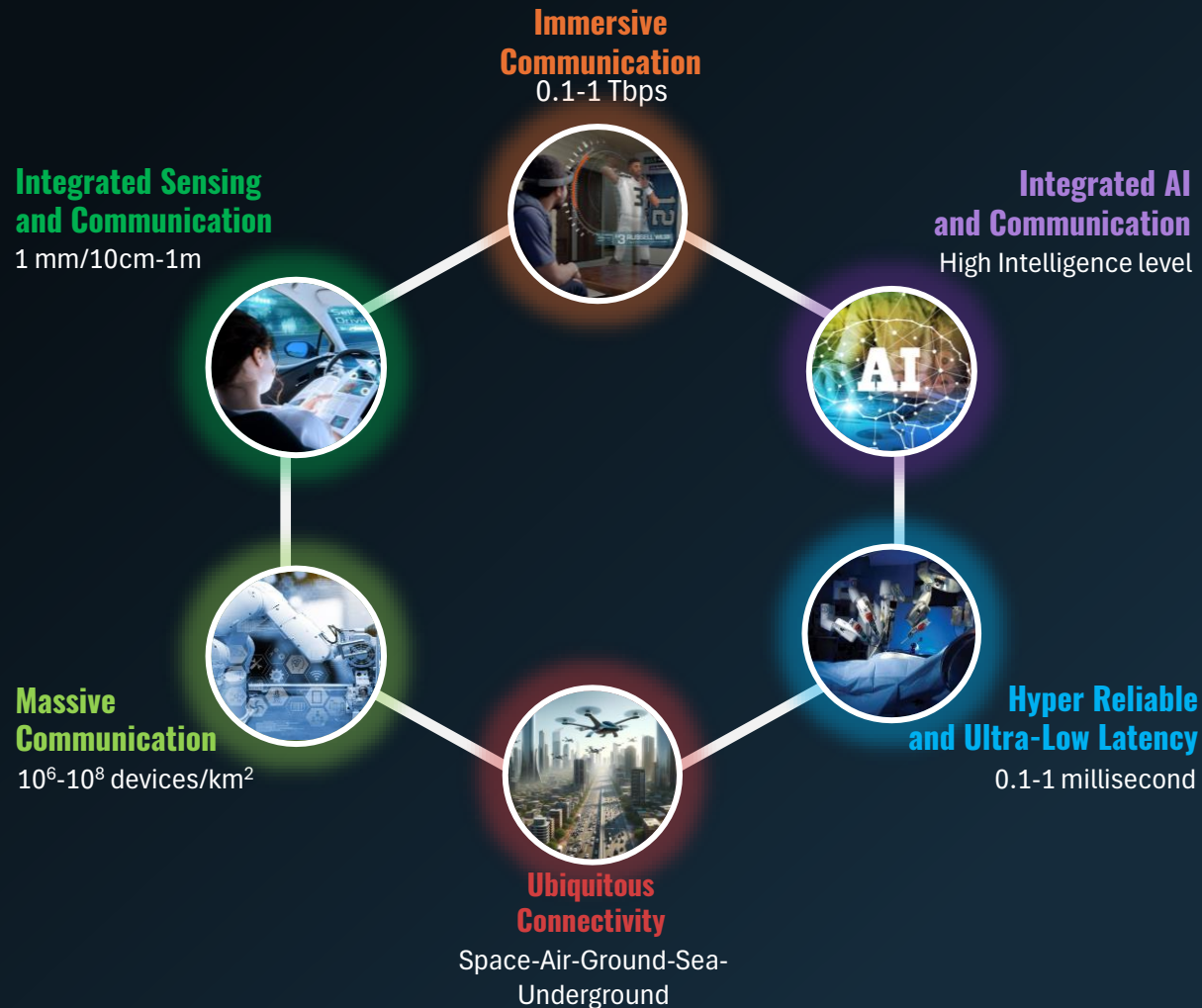


Site Diversity Planning for Free-Space Optical Ground Stations



Mohamed-Slim Alouini
KAUST

6G Sixth generation of cellular networks



People

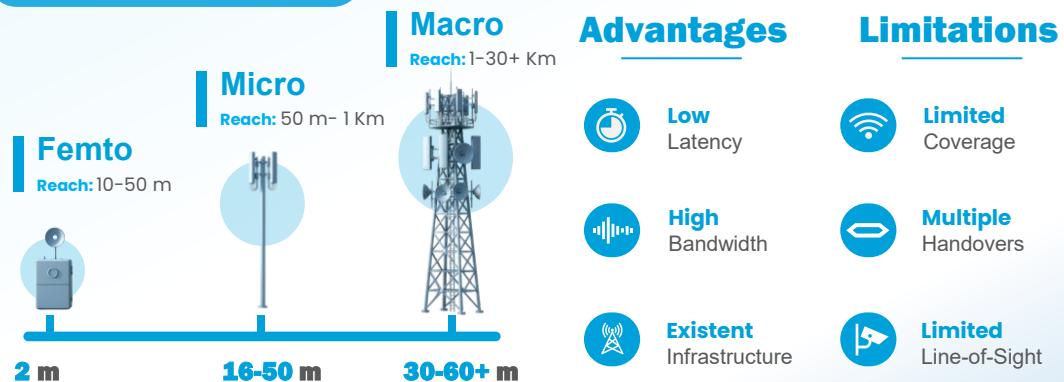
Bridge the connectivity and digital divide by connecting remote and underserved communities



Objects

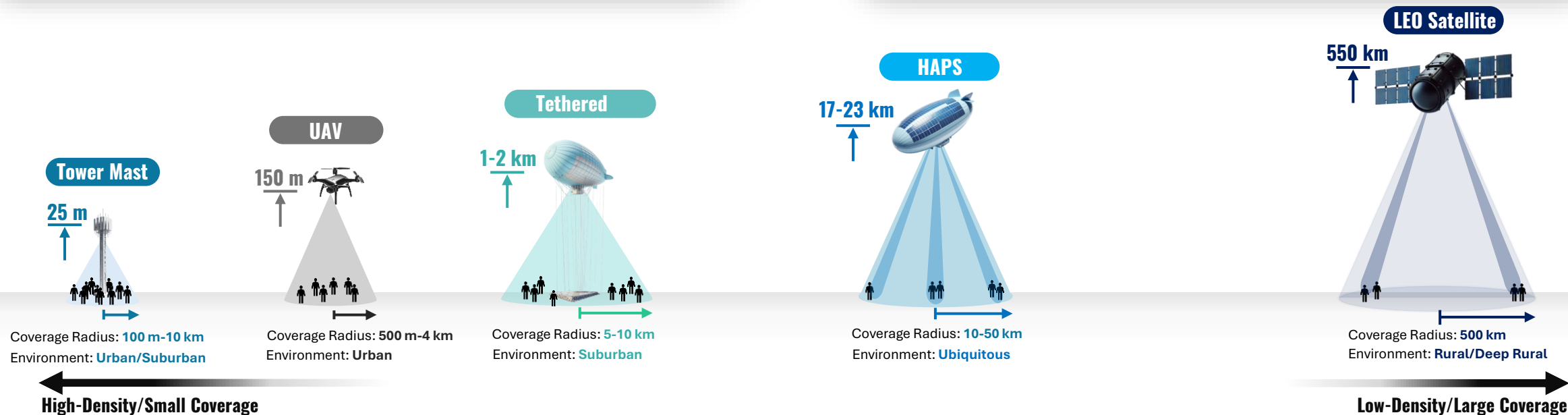
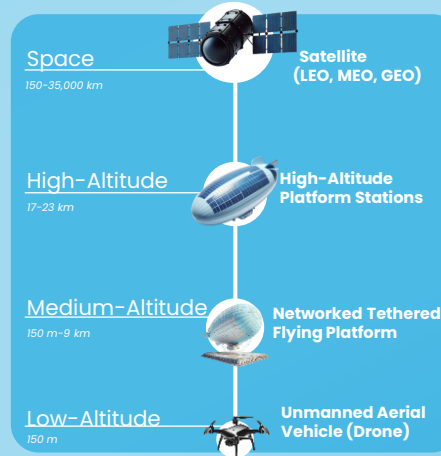
Connecting billions of smart devices and sensors to enable a global Internet of Things network

Terrestrial Tower



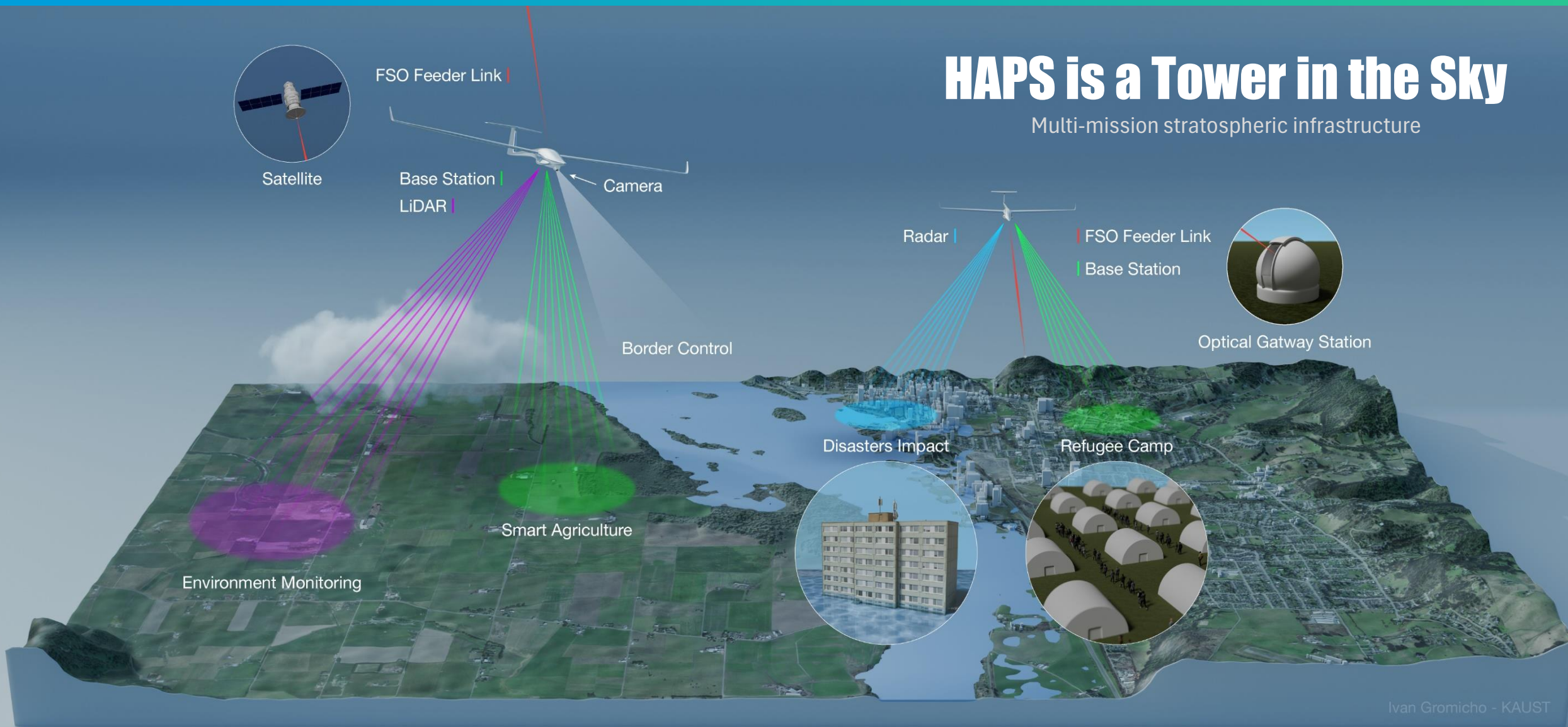
NTN Tower

- ✓ Technology Agnostic
- ✓ Easy and A quick Deployment
- ✓ Cost-Efficient
- ✓ Large Coverage
- ✓ Few Handovers
- ✓ Clear and Non-Obstructed LOS



HAPS is a Tower in the Sky

Multi-mission stratospheric infrastructure



Ivan Gromicho - KAUST



BACKHAUL

Feeder Link for HAPS

Backhaul link or feeder link serves as the high-capacity data bridge connecting the stratospheric platform to a terrestrial gateway or satellite network



Optical Laser Crosslinks

FSO-RF Coexistence

FSO Backhaul Performance

Ultra-High Throughput FSO

Hybrid FSO-RF Integration

Channel Modeling FSO

HAPS-Satellite FSO Backhaul

Coexistence with Terrestrial Network

Adaptive Optical Beamforming

LEO-to-HAPS Optical Relay

Point-to-Multipoint Optical Links

Adaptive Optical Beamforming

FSO for HAPS



Narrow Beam

Focus energy into highly directional, secure, and interference-free data paths



Optical wireless transceiver

use laser beams to transmit and receive high-speed data through free space



Connecting transceiver

Narrow beam connects two optical wireless transceivers

Benefits

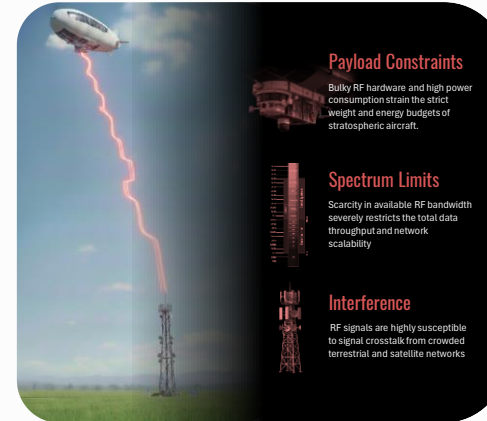
- Unlicensed spectrum
- Cost-effective
- Energy efficient
- Narrow beam-widths
- Immune to interference
- Secure
- Behind windows
- Fast turn-around time
- Suitable for brown-field

Challenges

- Unlicensed spectrum
- Cost-effective
- Energy efficient

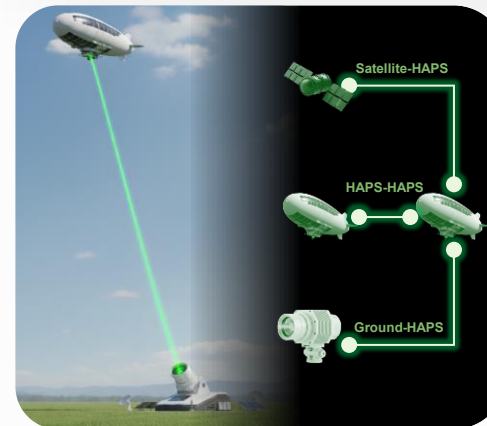
Applications

- Initially used for secure military
- Last mile solution
- Optical fiber back-up
- High data rate temporary links
- Wireless Backhaul in cellular network



RF-HAPS Backhaul

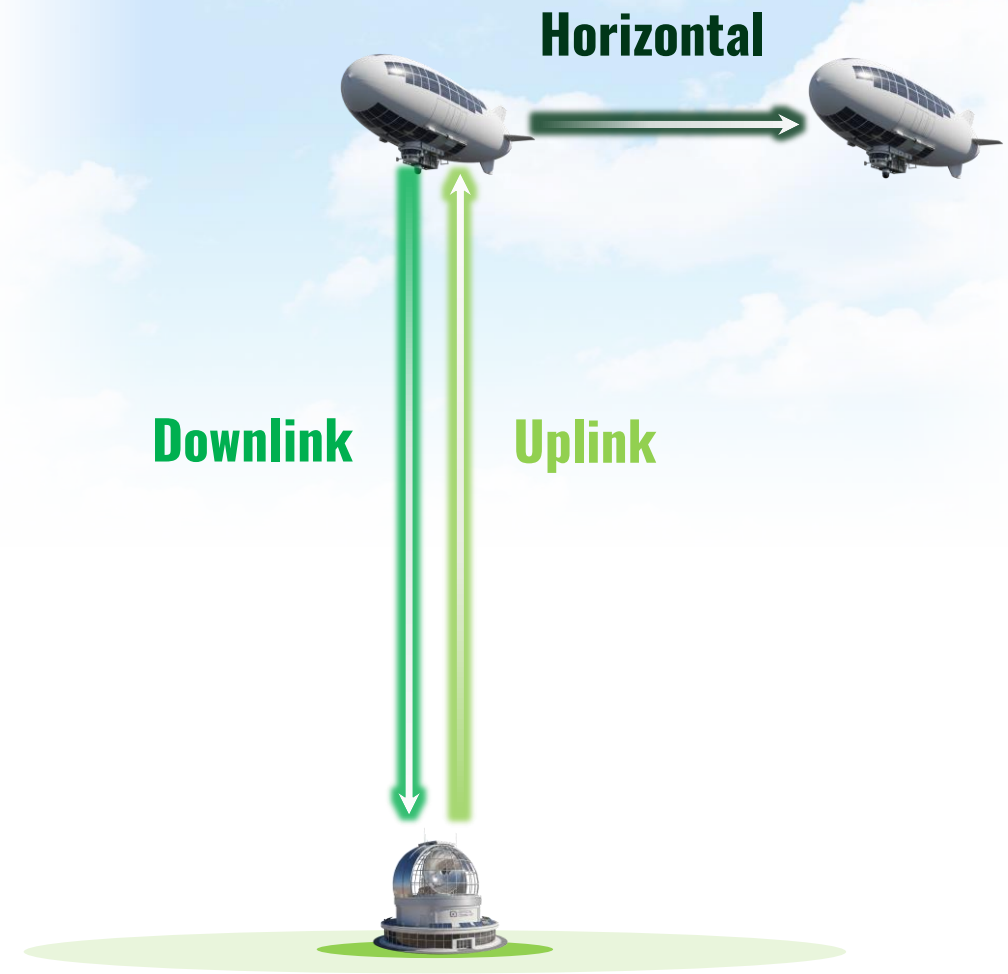
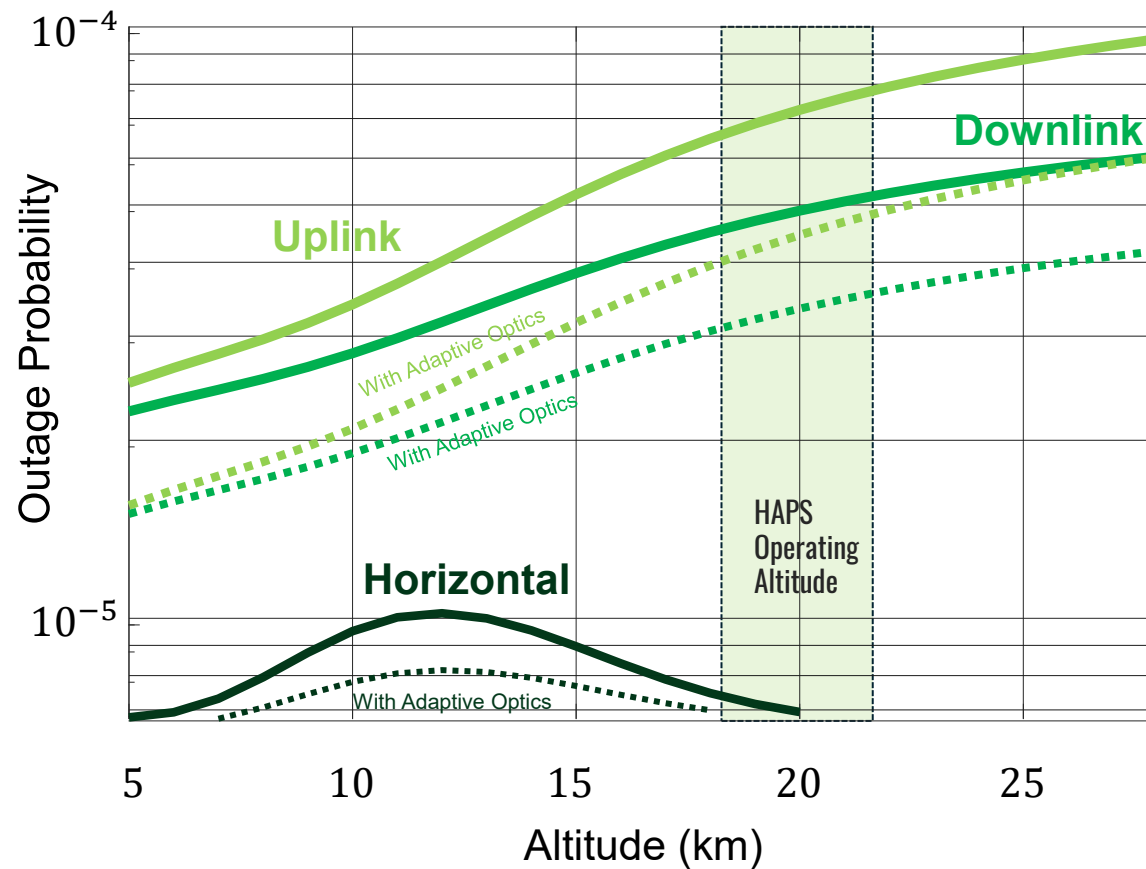
- ✗ SWaP constraints of airborne and spatial platforms
- ✗ Bandwidth limitation of conventional RF solutions
- ✗ Interference with terrestrial RF networks



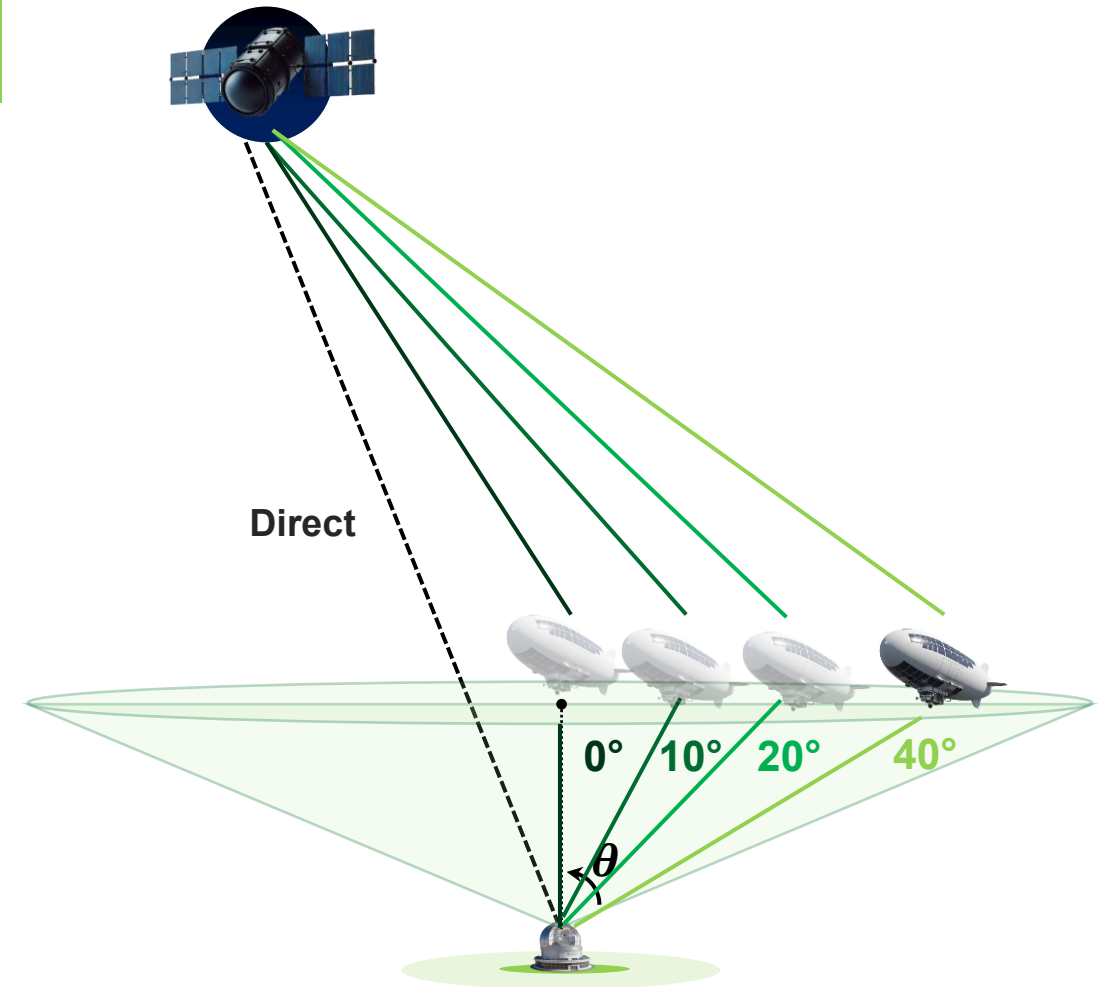
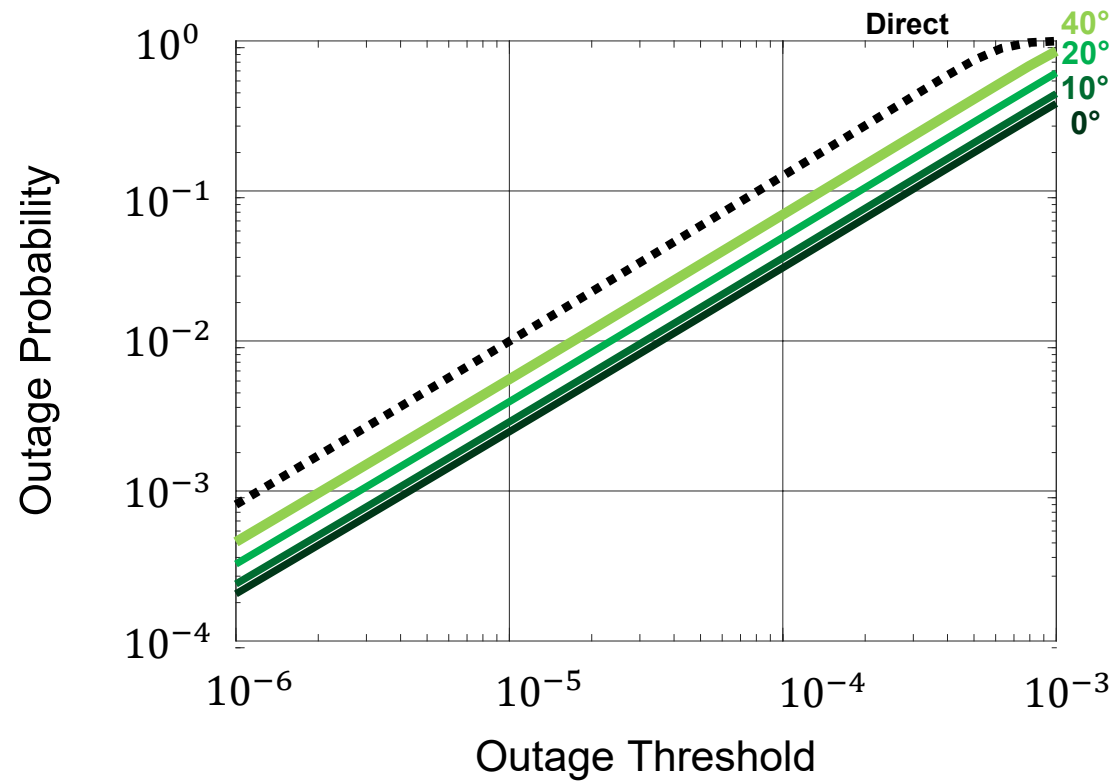
FSO-HAPS Backhaul

- ✓ Zero interference through narrow-beam lasers
- ✓ Massive bandwidth via unregulated optical spectrum
- ✓ Optimal SWaP with lightweight, compact hardware.

HAPS vs. Terrestrial Base Station



HAPS-Relayed Communication





UNESCO

Chair on Education
Connect the Unconnected



جامعة الملك عبد الله
للعلوم والتقنية
King Abdullah University of
Science and Technology

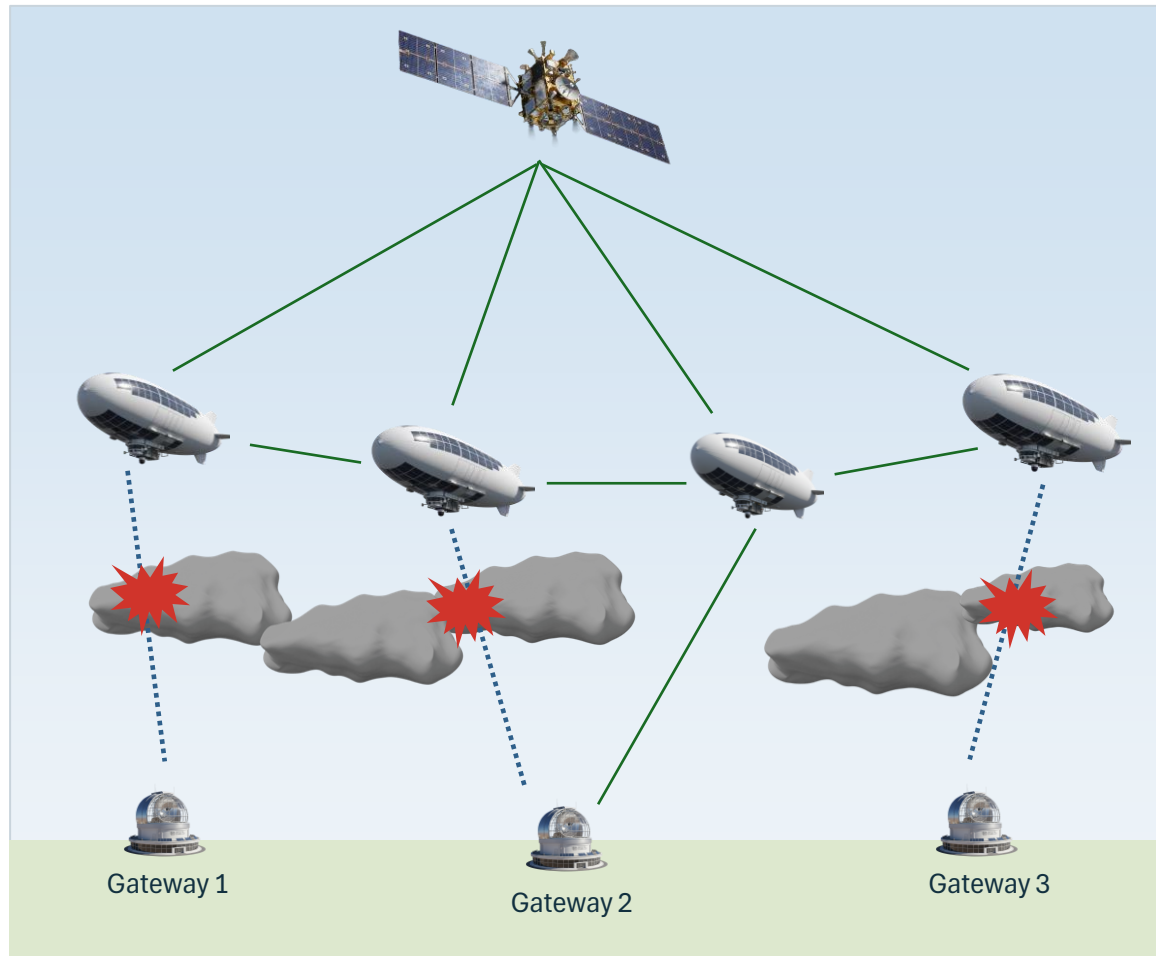
PLANNER

Ground Feeder Stations

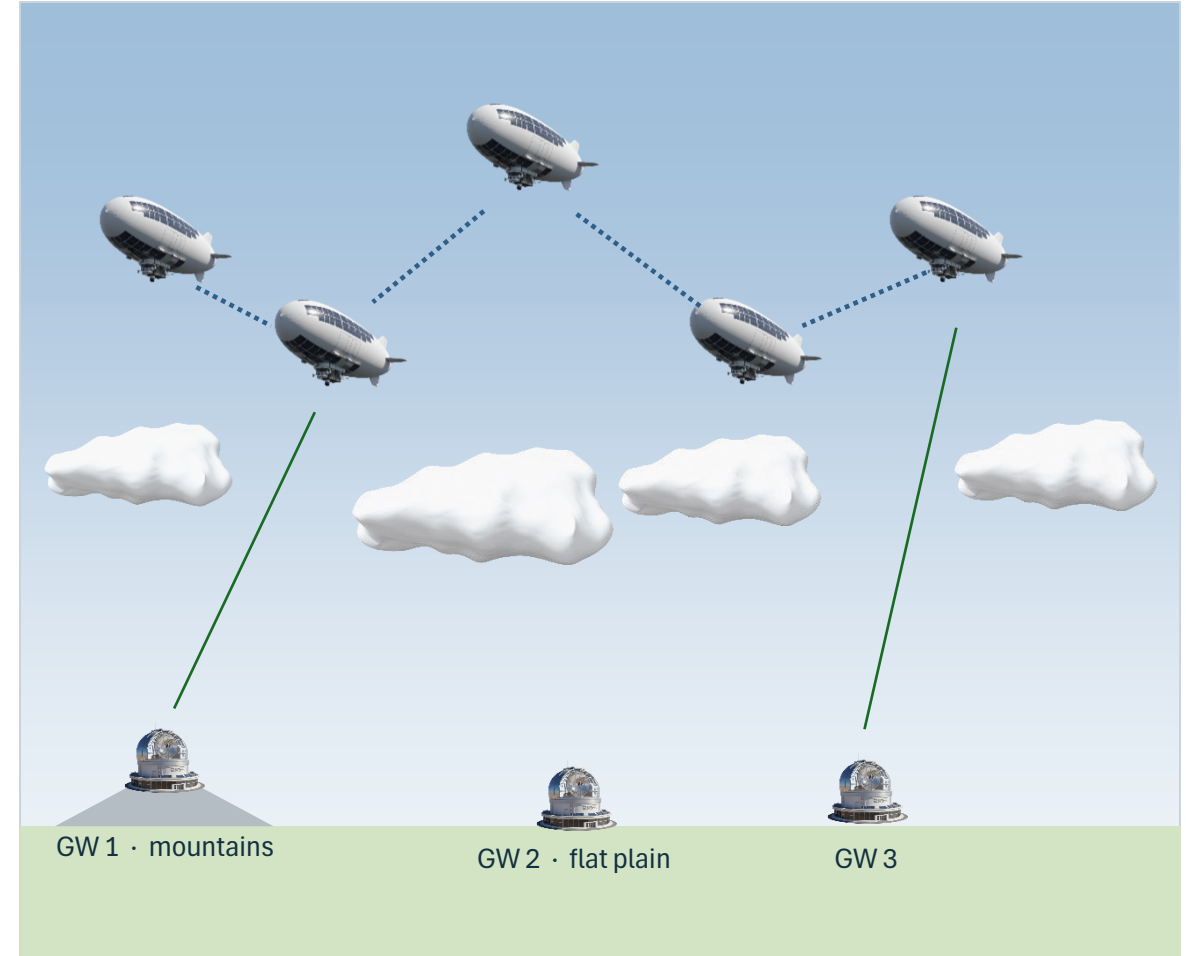
The laser link from the stratosphere is like fiber, but a cloud can break it. The planner chooses where to build the ground stations so that, at any moment, at least one of them sees clear sky.



HAPS + Satellite Relay



HAPS Constellation



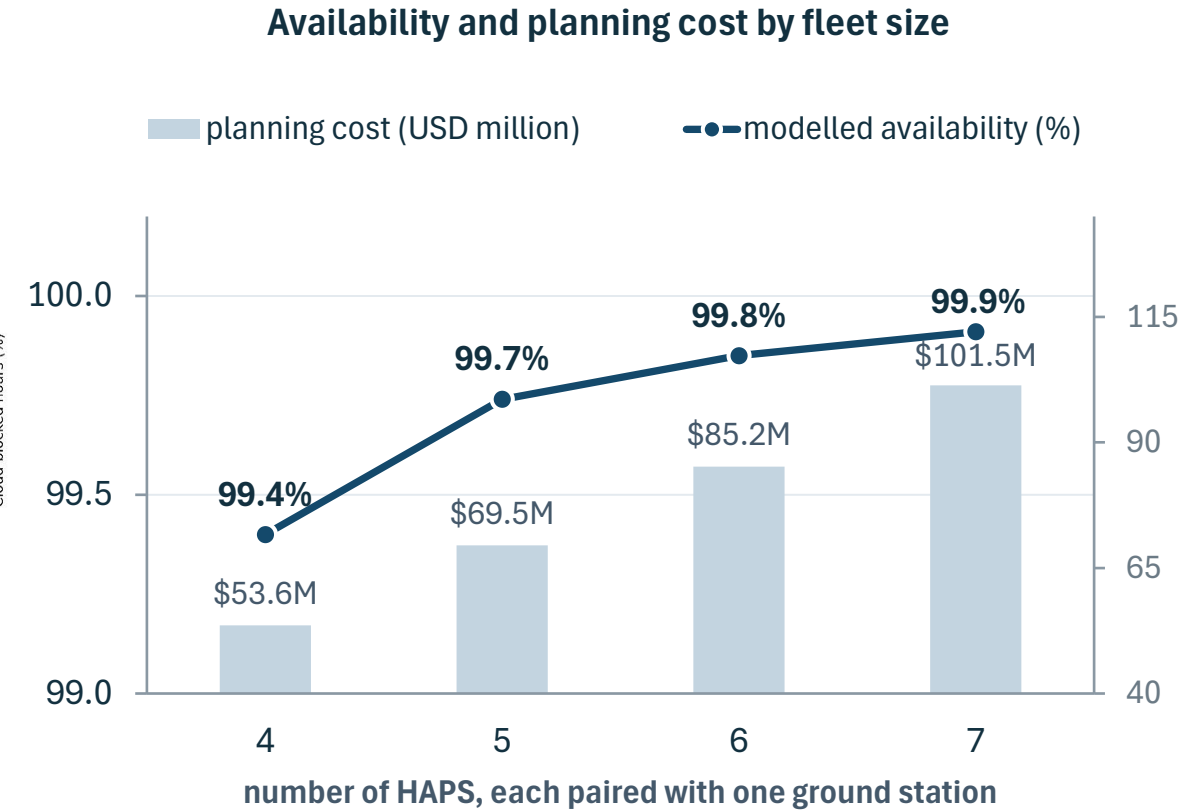
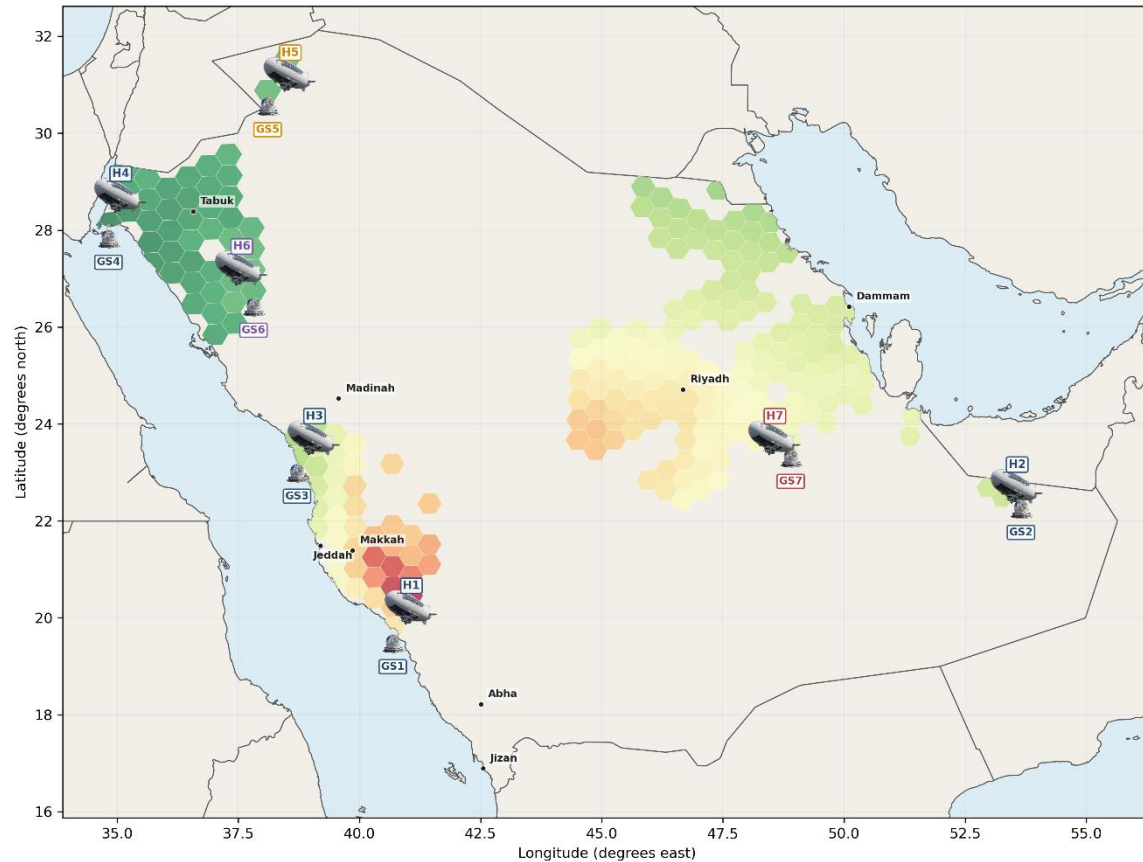
We evaluate two HAPS deployment scenarios:

- HAPS as relays between gateway stations and satellites
- An interconnected HAPS fleet forming an aerial mesh network

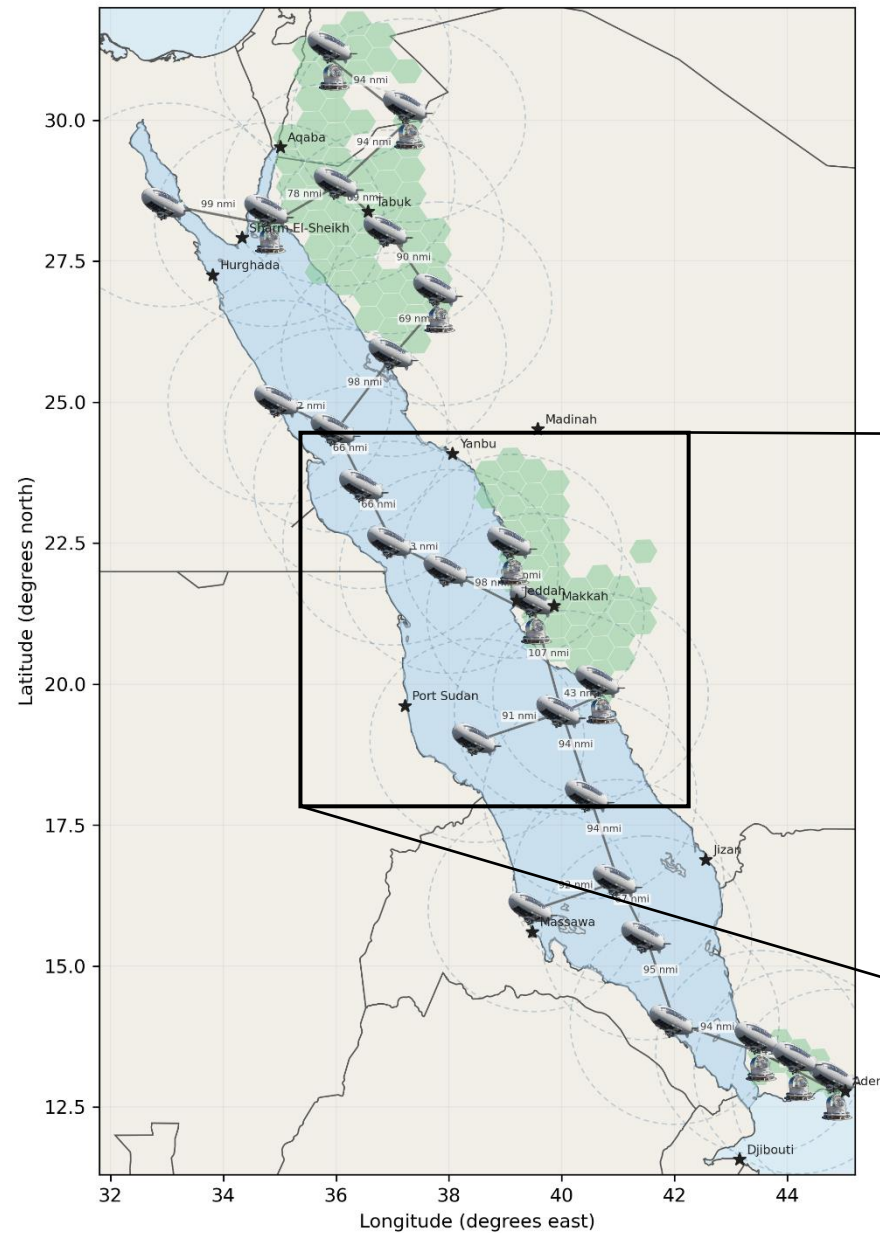


HAPS + SATELLITE Scenario: SELECTED SITES · 7 HAPS, 7 GROUND STATIONS

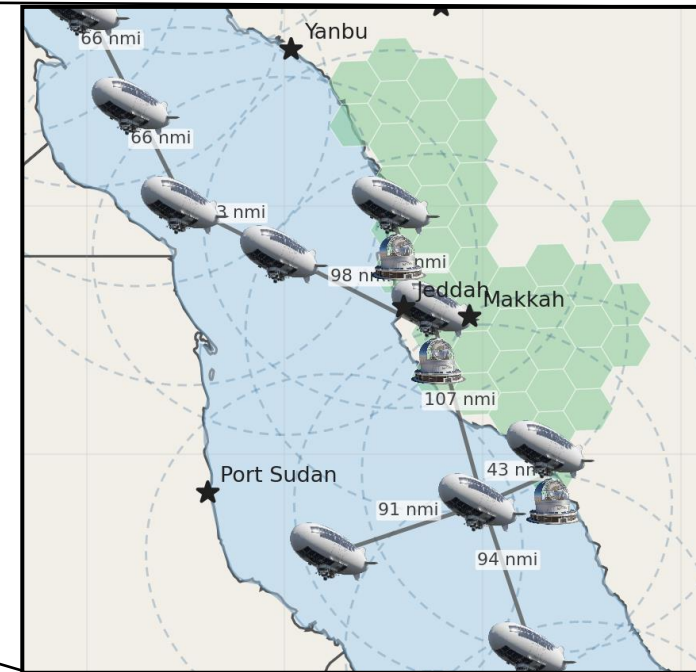
AVAILABILITY VERSUS PLANNING COST



The fifth HAPS delivers the largest availability gain: 99.40% to 99.74% for a further \$15.89M. The sixth and seventh add 0.17 percentage points between them, with the seventh finally exceeding the 99.9% target at a total cost of \$101.47M.



The optimization found a optimum deployment of 26 HAPS and 10 ground stations, achieving 99.90357% availability. The HAPS form a connected backbone with every selected inter-HAPS link below 200 km (108 nmi); the longest link is 197.6 km (106.7 nmi).



Thank You !







KAUST-CTL Media
YouTube Channel






UNESCO
Chair on Education
Connect the Unconnected



