LEOCONN 2022

IoT in Space: Now and Future

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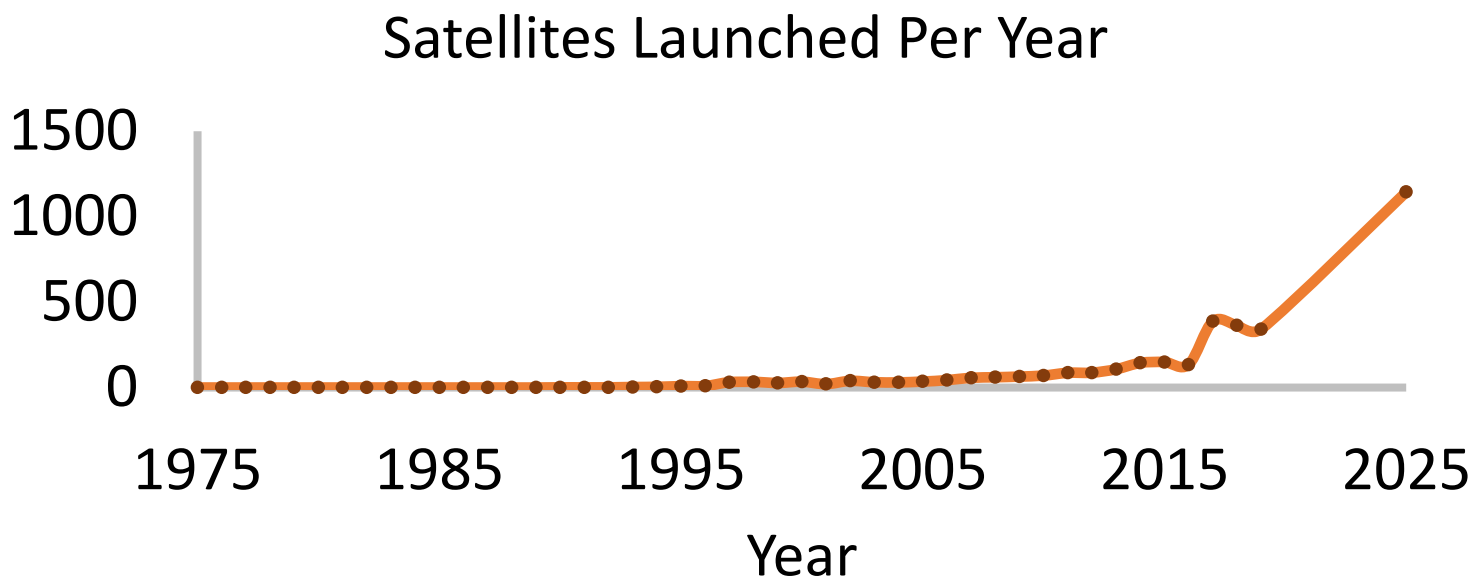
Microsoft Research

“New Space” revolution

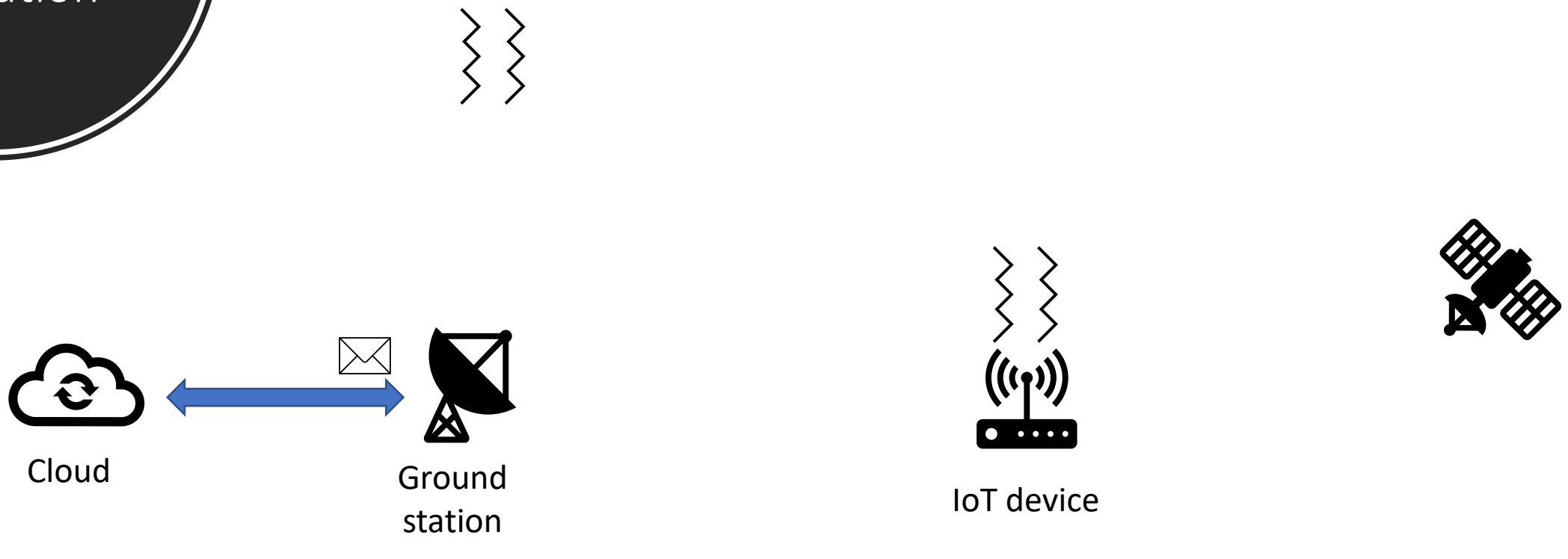


- Low-cost LEO Cubesat
- $10M for a constellation

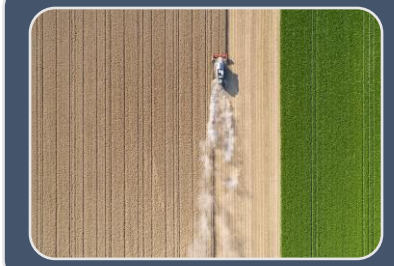
Direct to Satellite (DtS) IoT

- IoT devices directly communicate with LEO satellite
- Satellite works as a global gateway in space
- No backhaul, no tower setup for gateway

IoT in "New Space" revolution



IoT in space: Applications



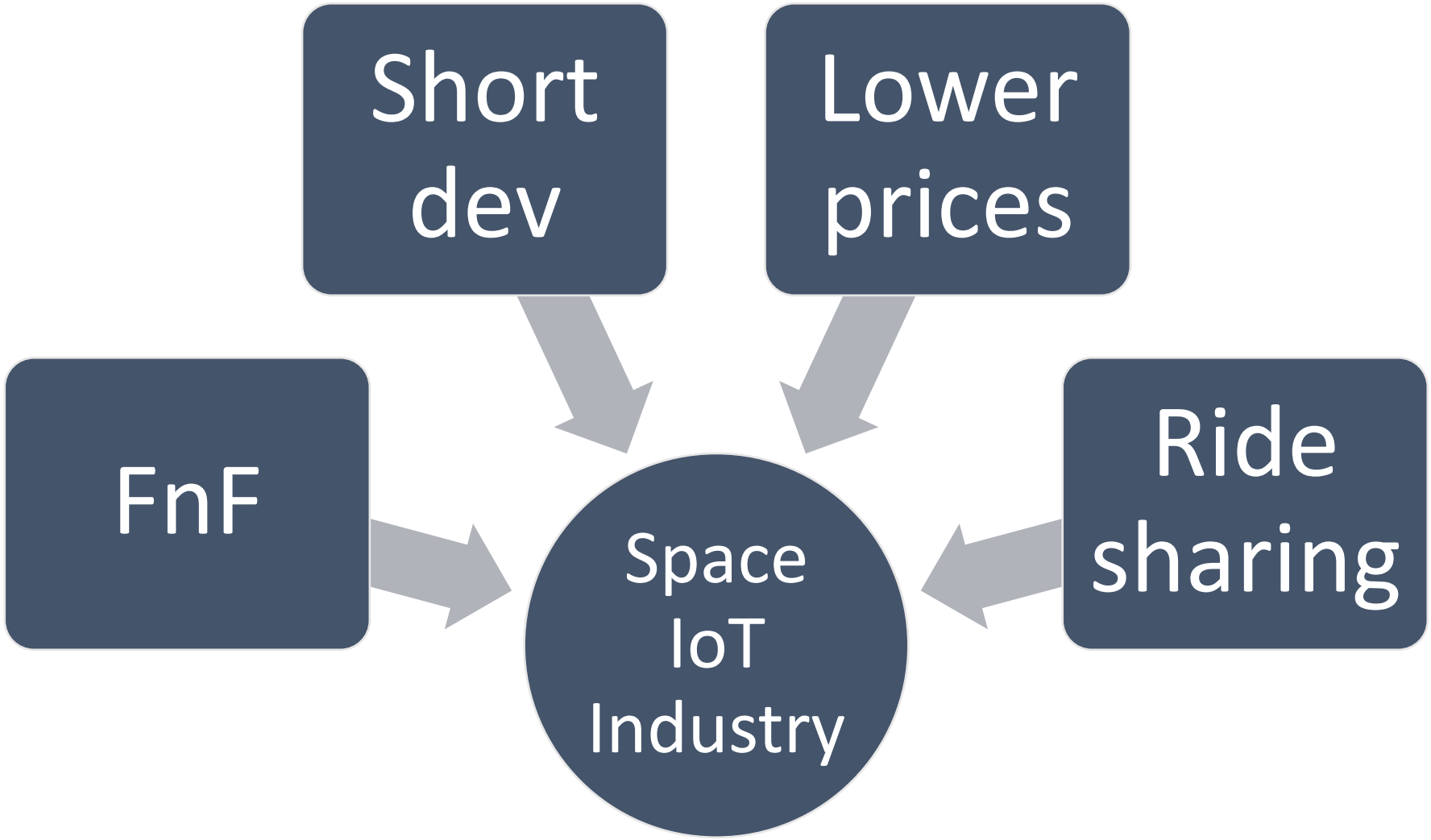
Agri & food

Supply chain

Environment

Maritime

IoT in Space: Industry



IoT in Space: Industry

SWARM

Myriota

Hiber

FOSSA

Lacuna

Iridium

Astrocast

Kineis

ORBCOMM

Tech Deep Dive

IoT Satellite Constellation

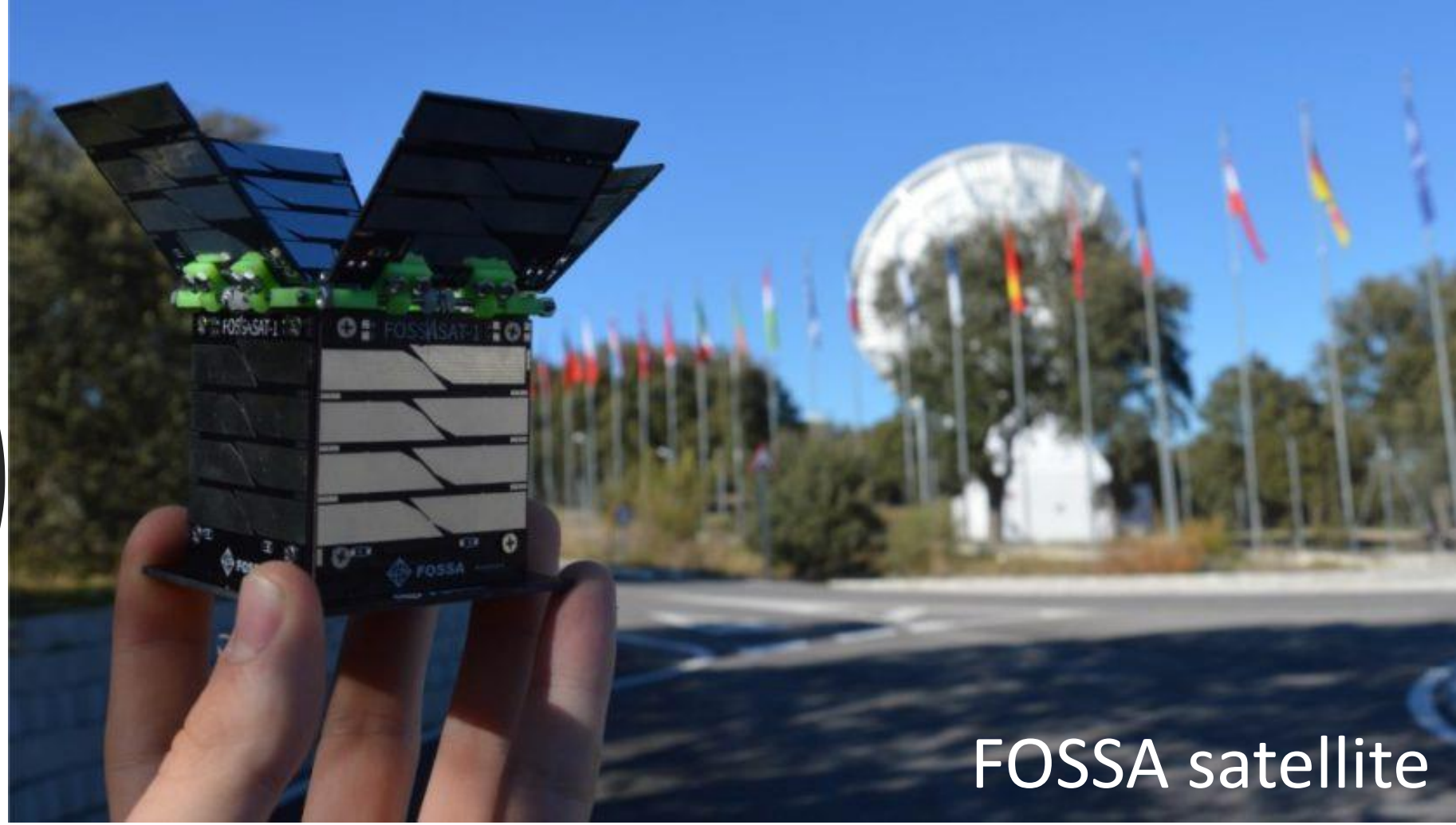
LEO ORBIT (450 – 550 KM)

UP TO 150+ SATELLITES

3 TO 4 PASSES A DAY

*Background image credit: SWARM Technologies

IoT Satellite



Carry the satellite in your pocket

- Size < 1U
  - Up to 6U
- Mass < 0.5 kg
  - Up to 8 kg

IoT Satellite

Solar panel

Battery pack

Onboard computing unit (OBC)

Memory

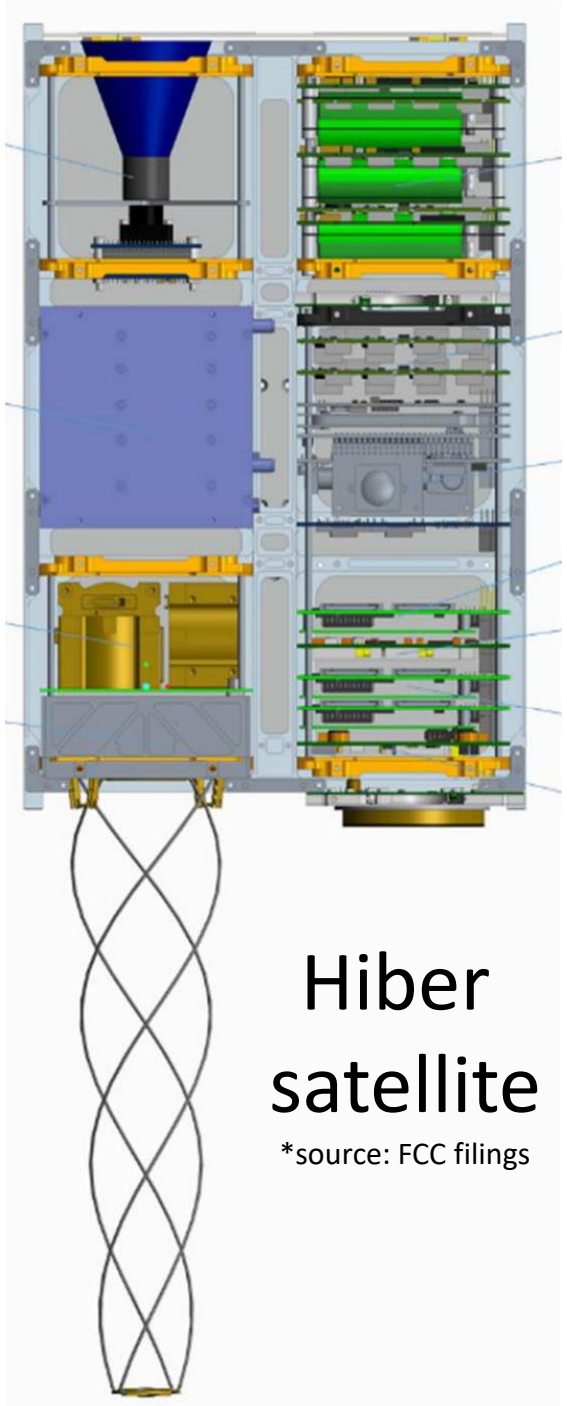
Sensors (gyro, accelerometer, etc.)

GPS

Actuators (magnetorquers, reaction wheels, etc.)

Radio(s)

Antenna



Hiber satellite

*source: FCC filings

Communication: Channel plan

Mostly operate in VHF, UHF, and sub-GHz bands

- Suitable for IoT operation

A few are in higher frequency bands

- L, S, Ku

Separate TT&C link

- Typically, in the same band as data com

Company	Operation frequency band (in MHz)
SWARM	Uplink: 148-150 Downlink: 137-138
Kineis	401
Hiber	Uplink: 399.9 - 400.05 Downlink: 400.15 - 401.00
FOSSA	401

Communication: Channel plan

Very narrow bandwidth

- Not for than 250 kHz

Data downlink is narrowband as well

- Exceptions are there with high-end satellite

Assigned bandwidth should consider doppler effect

- Larger bandwidth is assigned than the operation bandwidth

SWARM channel bandwidth	
Necessary b/w (in kHz)	**Assigned b/w (in kHz)**
7.8	16
10.4	20
15.6	24
20.8	30
31.3	40

*source: FCC filings

Communication: Link (Sat to ground)

Link margin varies with elevation angle, altitude, weather, among others

- Lower elevation angle, lower the link margin

According to ITU, PFD on earth surface < -125 dBW/m^2/4kHz

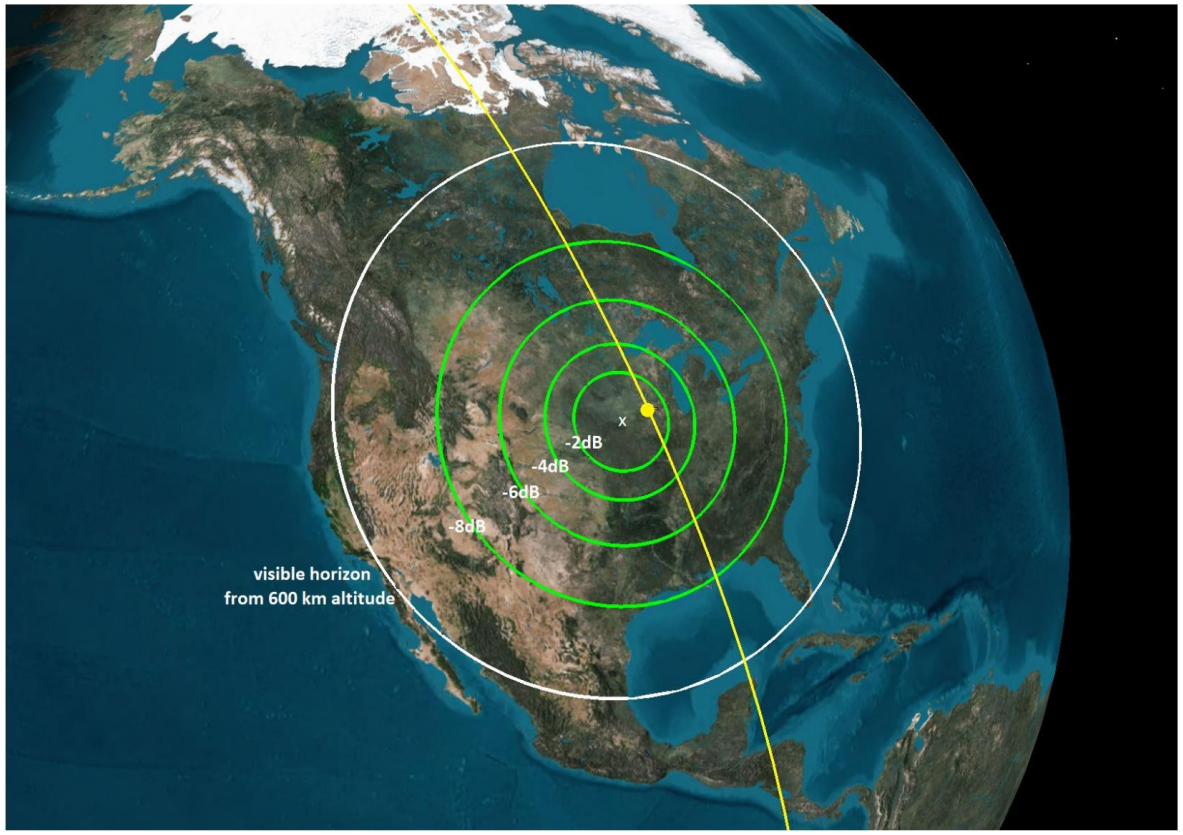
- Coordination is not required

Antenna radiation pattern is omni, NO beamforming

- Can cover 1/3 of the U.S. within the footprint

Antenna gain contour of Myriota satellite

*source: FCC filings

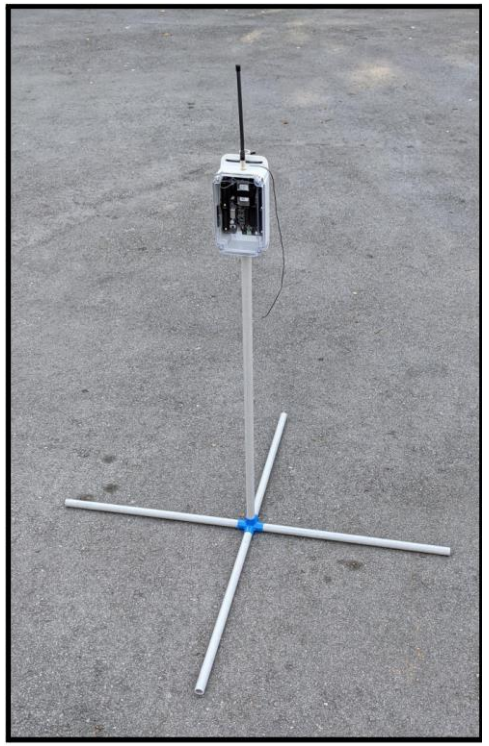


IoT Device

- Mostly similar design as a terrestrial IoT device
- Battery powered
- Incorporates GPS

Myriota IoT device

Hiber IoT modem



SWARM installation

IoT Device: Comm

Very high transmission power

- SWARM: 1A, Hiber: 1.25A, Iridium: 1.3A

Small packet size

- Swarm: 192B, Hiber: 144B, Myriota: 20B, Astrocast: 160B

Omnidirectional antenna, No rotator

- Swarm: ½ or ¼ wave antenna

IoT Device: Comm

IoT device transmits when satellite is overhead

- Listens to satellite beacons
- Mostly async communication without an ACK

Custom power-efficient modulation

- LoRa is very popular choice here as well
- Low data rate

Very simple network stack

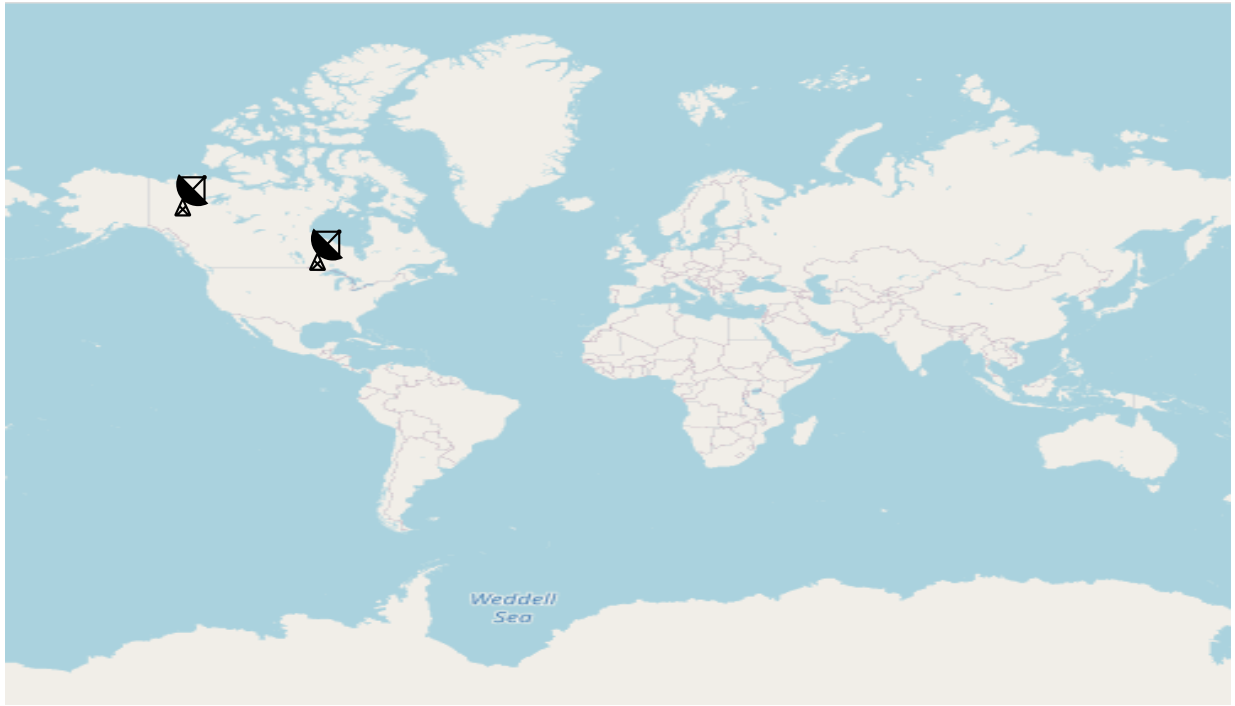
- Store and forward mechanism
- Not beyond layer 2

Research Opportunities

High Latency of multiple hours

Scalability

- Paucity of GS
- Max 3 to 4 passes a day over a GS
- Contact time of 6 to 7 min on avg
- Narrowband downlink



Complex legal proceedings

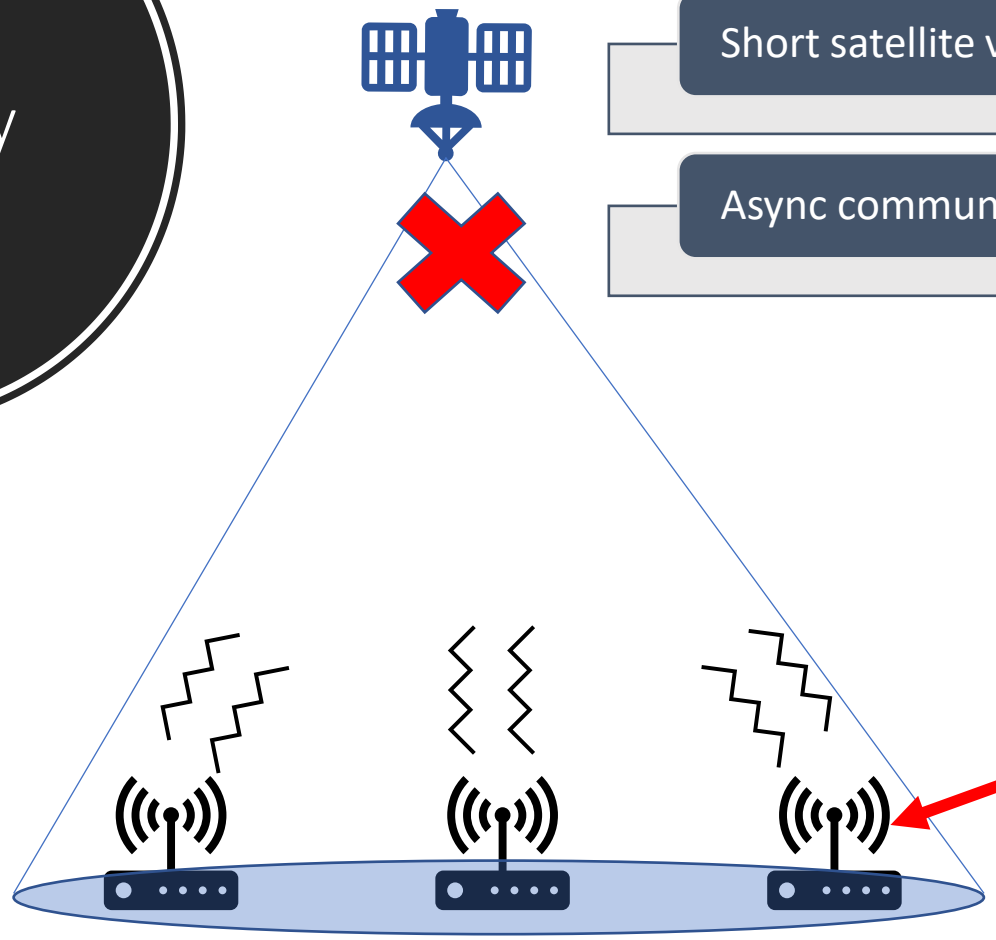
High setup cost

IoT data is time critical

Low Uplink Throughput

Scalability

- Very large satellite footprint, NO beamforming
- Thousands of IoT devices in the footprint
- Short satellite view time of 6-7 min
- Async communication protocol



It suffers due to
a low elevation angle

Spectrum sharing

Spectrum

Radio spectrum is a finite resource

Rapid growth of space network

Coexistence of Sat & terrestrial for the best interests

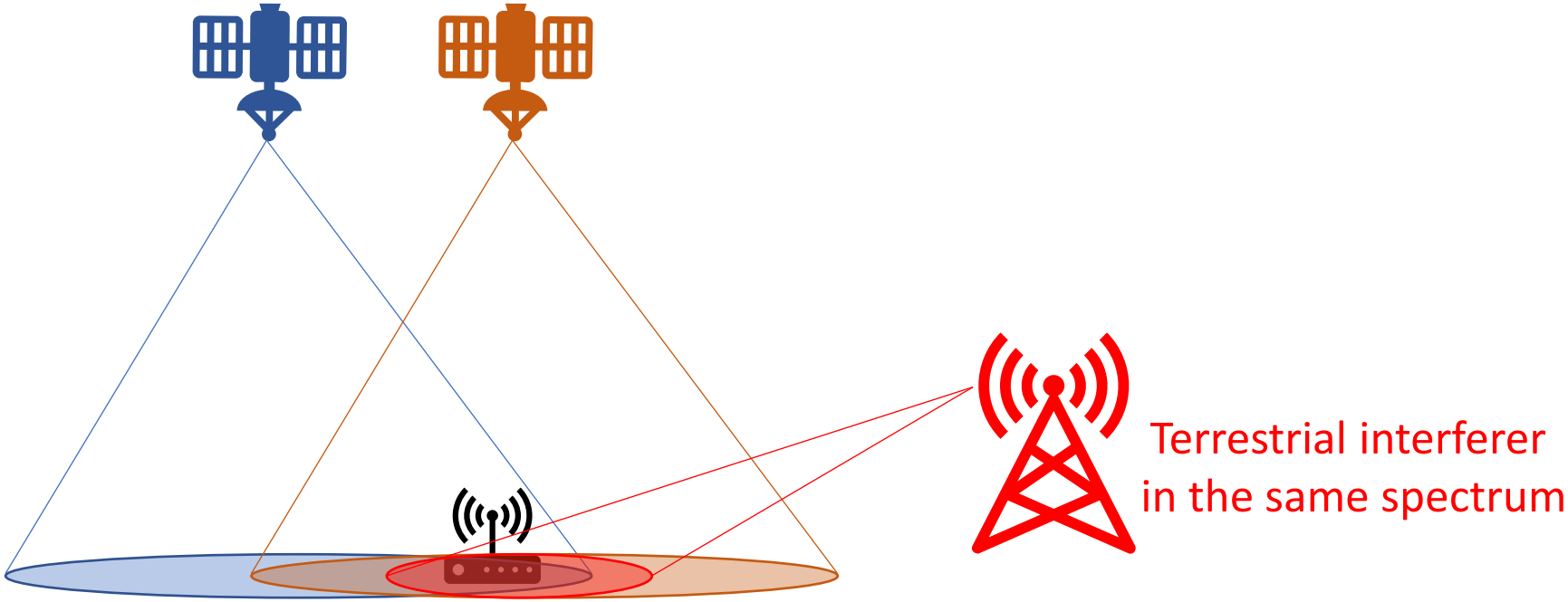
Spectrum sharing

Spectrum

Very large footprint without beamforming

Depointing due to satellite tumbling

Low-end ground station

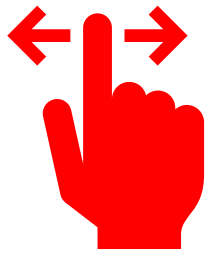


Computation on satellite

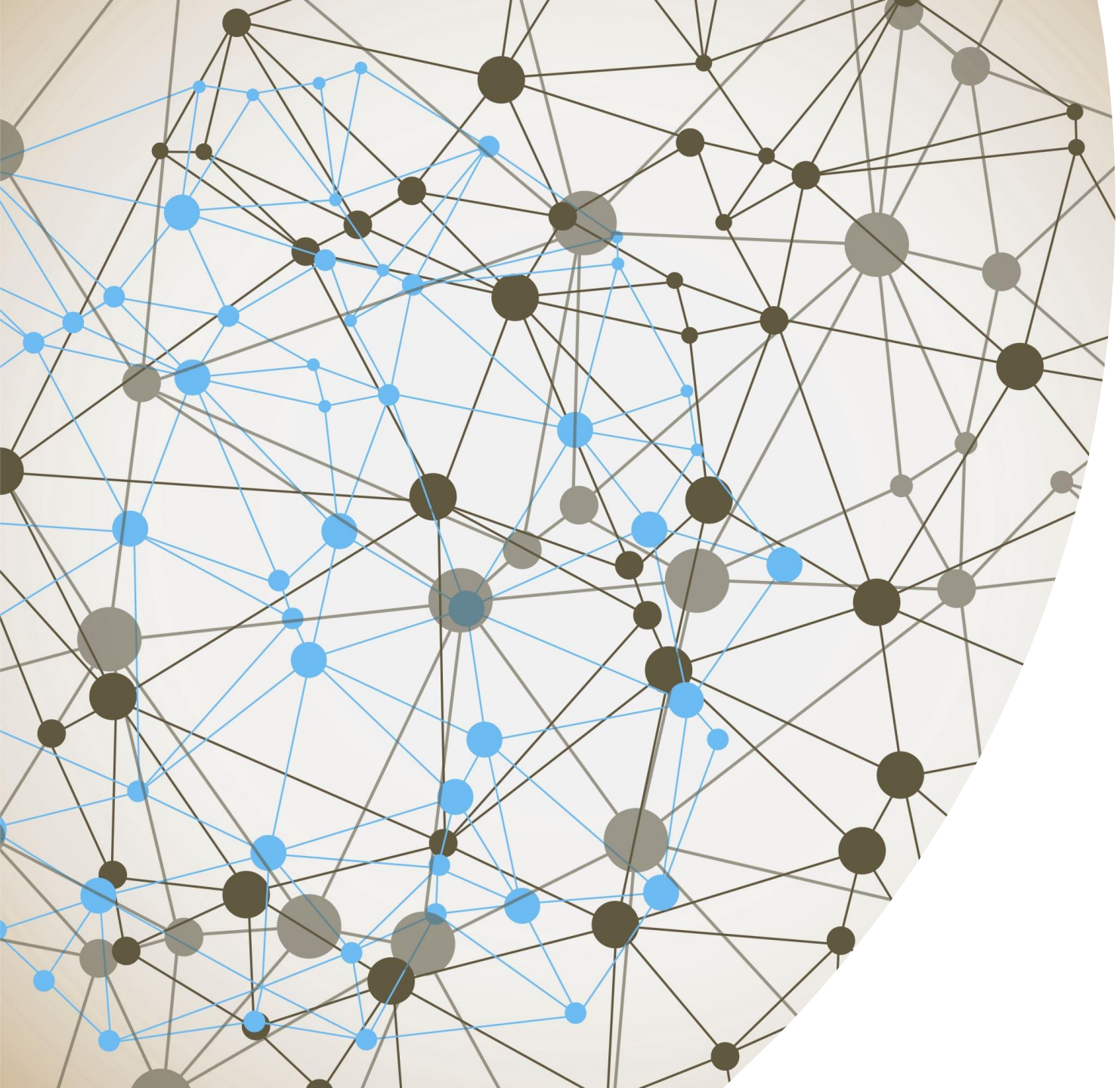
Process IoT data on satellite for insight and compression

Low power generation on satellite (NOT more than 2W)

Data from thousands of IoT devices in the footprint



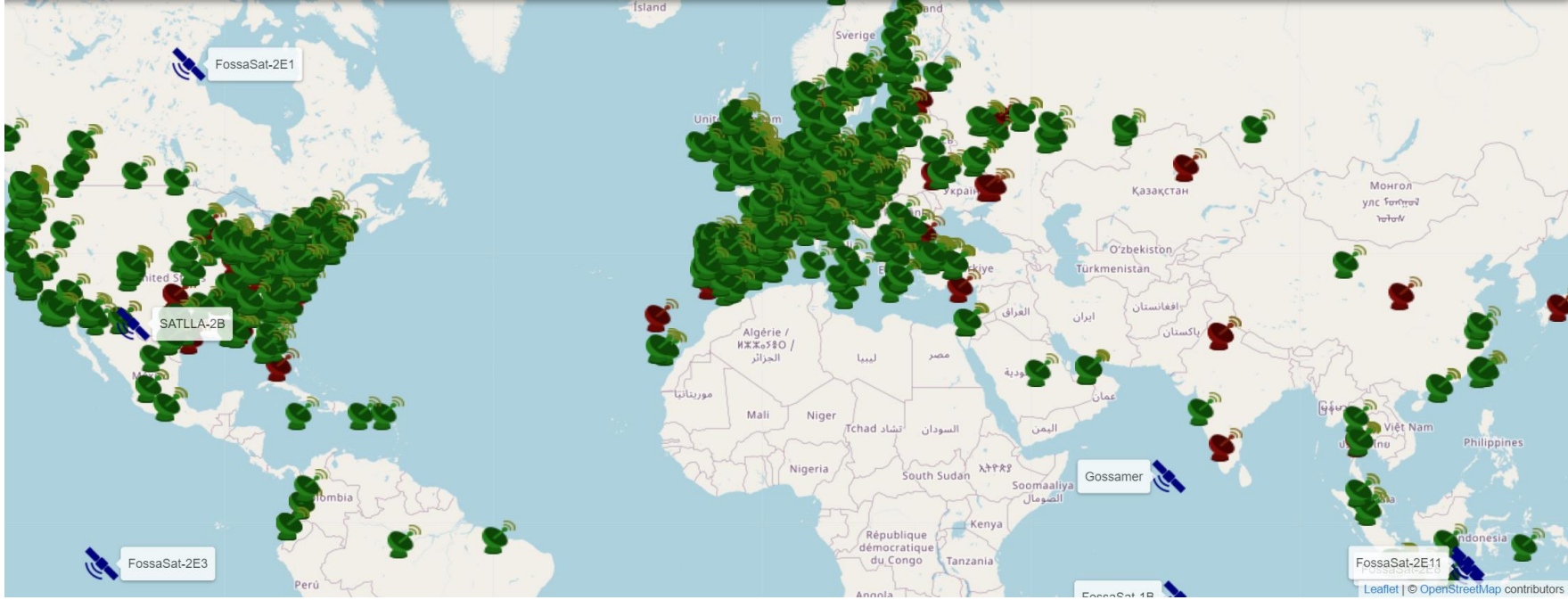
NO ISL available



Get Started

TinyGS.com

Make your own GS



Open network of GS

LoRa radio chip based

< $100

Very small form-factor

DIY backyard installation

Interesting dataset

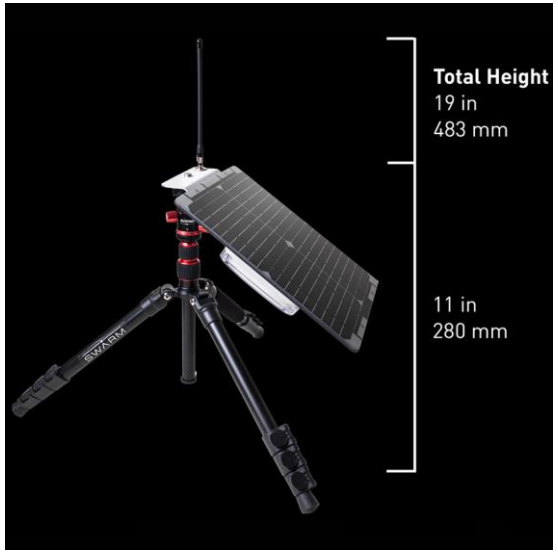
Get your data on Satellite

Myriota dev kit

*source: https://myriota.com/developers/

Astronode DevKit

*source: https://www.astrocast.com/products/astronode-devkit/



SWARM eval kit

*source: https://swarm.space/product/swarm-eval-kit/

Iridium Edge demo kit

*source: https://www.iridium.com/products/iridium-edge-demo-kit/

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