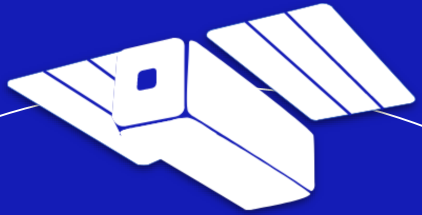

Welcome Small Data Network
VTC 2019

Wen Cheng Chong
CTO, Kepler
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A mission to provide connectivity for space

Building assets for ground communications and growing long term to in-space connectivity

Kepler Today

12 Months
Napkin to Orbit

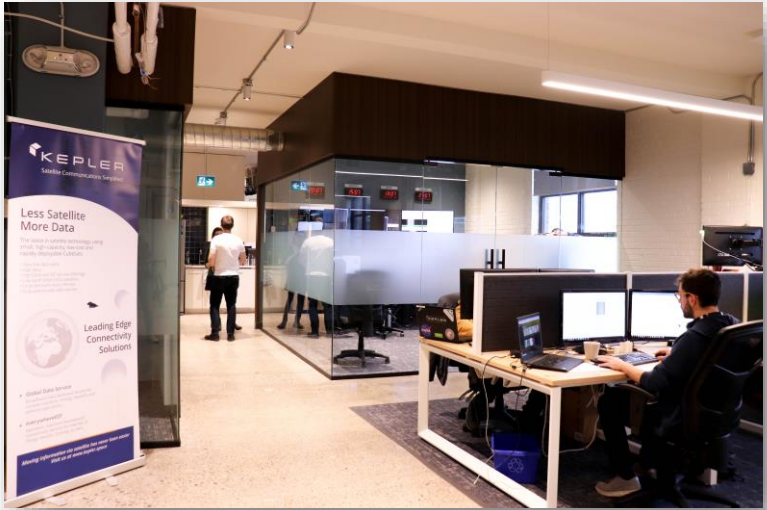
38 Person
Team

Proprietary
Satellite

Acquired
Spectrum

Government
Contracts

Where We Operate



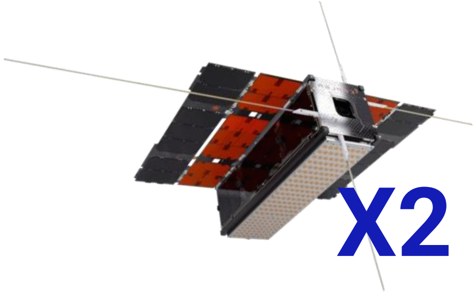
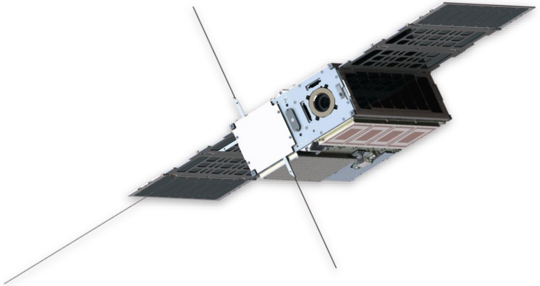
MAIN OFFICES

Headquarters and R&D located in Toronto, Canada

GROUND INFRASTRUCTRE

Locations in Inuvik (Canada), Svalbard (Norway), and New Zealand

Kepler’s Satellites

Current	Next Year
	
Ku-Band	Ku-Band S-Band
Global Data Service	everywhereIOT

Wideband and Narrowband Services

Global Data Service™

A hybrid wideband satellite service, routing data over multiple satellite networks to optimize bandwidth and reduce costs

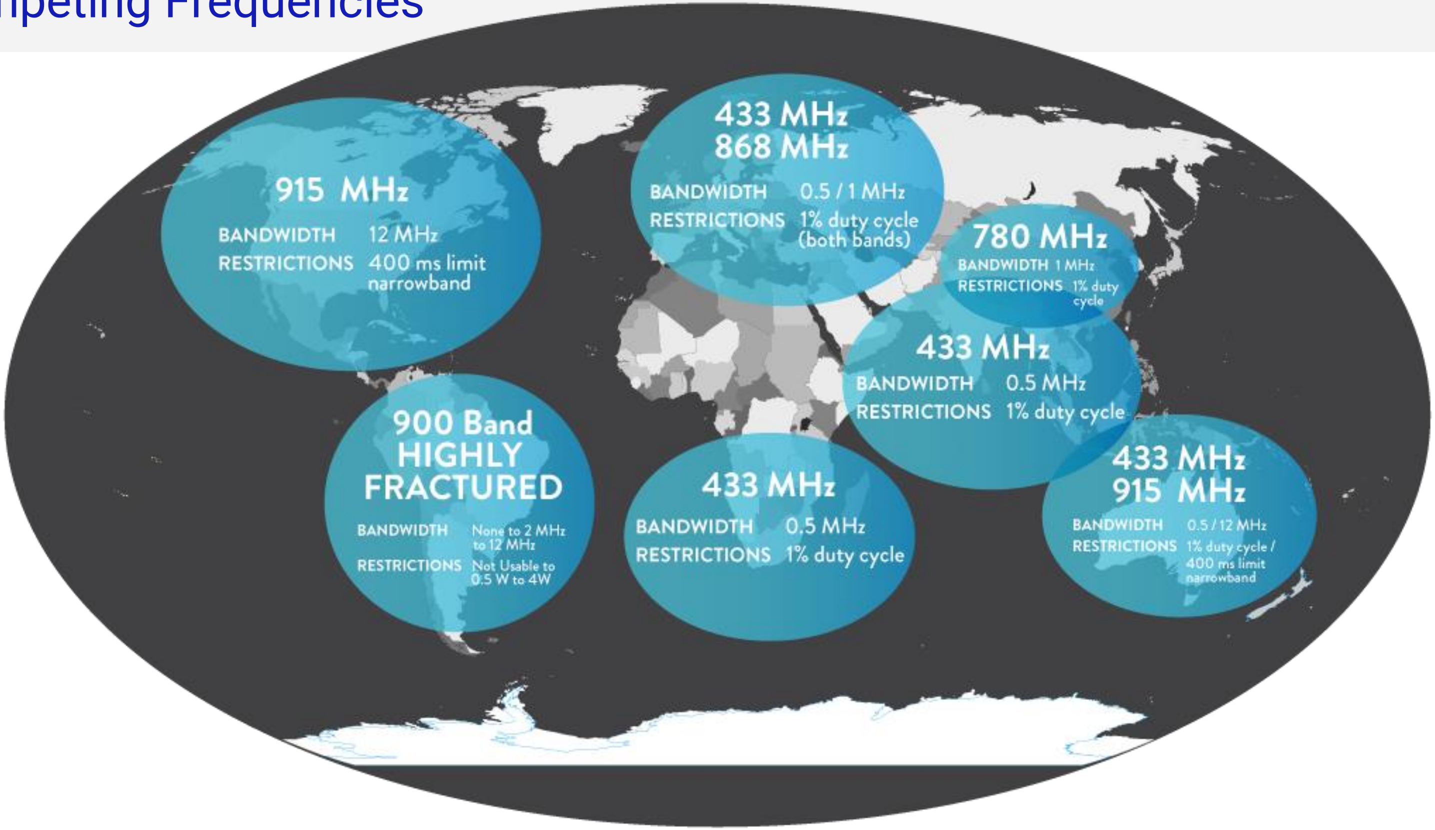
everywhereIOT™

A cellular-like and globally-available connection for Internet of Things devices

Why Satellite IoT?

Terrestrial ISM Spectrum

Competing Frequencies



2G/3G Network Sunset

Ongoing shutdown
Legacy hardware

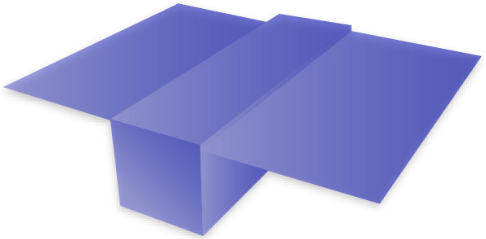
Transition starting

Inconsistent rollout
of CAT NB/M1

Terrestrial vs. Satellite IoT

Frequency Standards

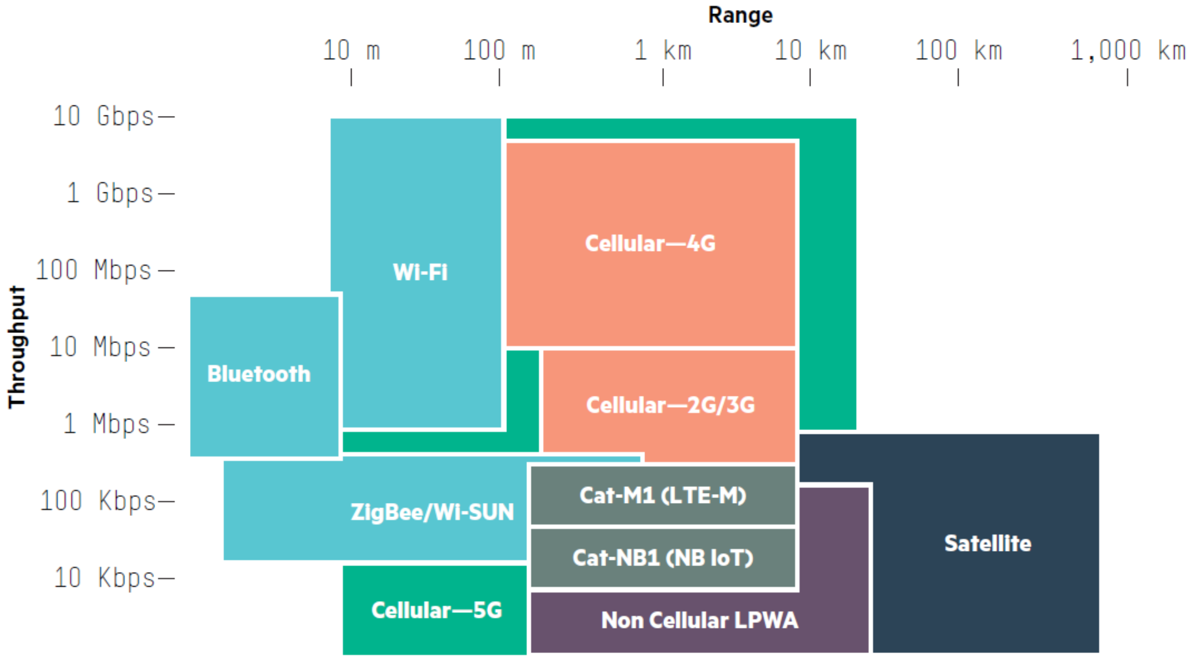
Different frequencies needed for different geographical areas



One frequency works worldwide

Terrestrial vs. Satellite IoT

Coverage and Throughput



Source: Hewlett Packard Enterprise (2016). Low Power Wide Area (LPRA) networks play an important role in connecting a range of devices, Business white paper. Available at: https://h20195.www2.hpe.com/V2/getpdf.aspx/4AA6-5354ENW.pdf?ver=3.2

Terrestrial vs. Satellite IoT

Coverage

~36,000 Ground Stations

Continental U.S.

1 LEO Satellite

Global

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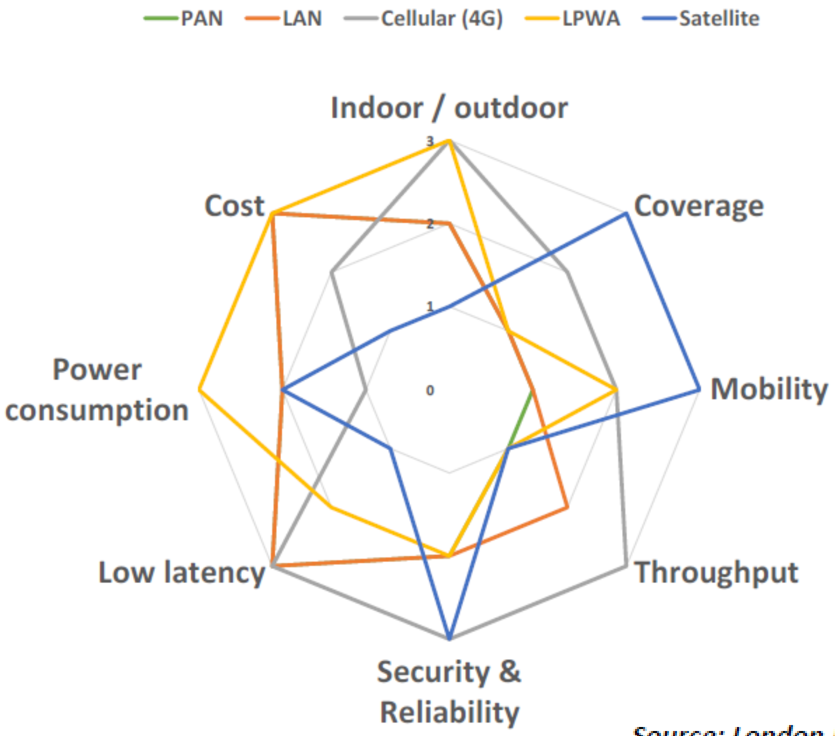
Terrestrial vs. Satellite IoT

Network Diagram



Source: London Economics analysis

Technical Challenges in Satellite IoT

All About Orbits

Low Earth Orbit (LEO)

- More bandwidth and lower power ground equipment
- Steerable ground antenna needed for broadband
- Many (>50) satellites needed for real-time coverage
- **Kepler satellites**

Medium Earth Orbit (MEO)

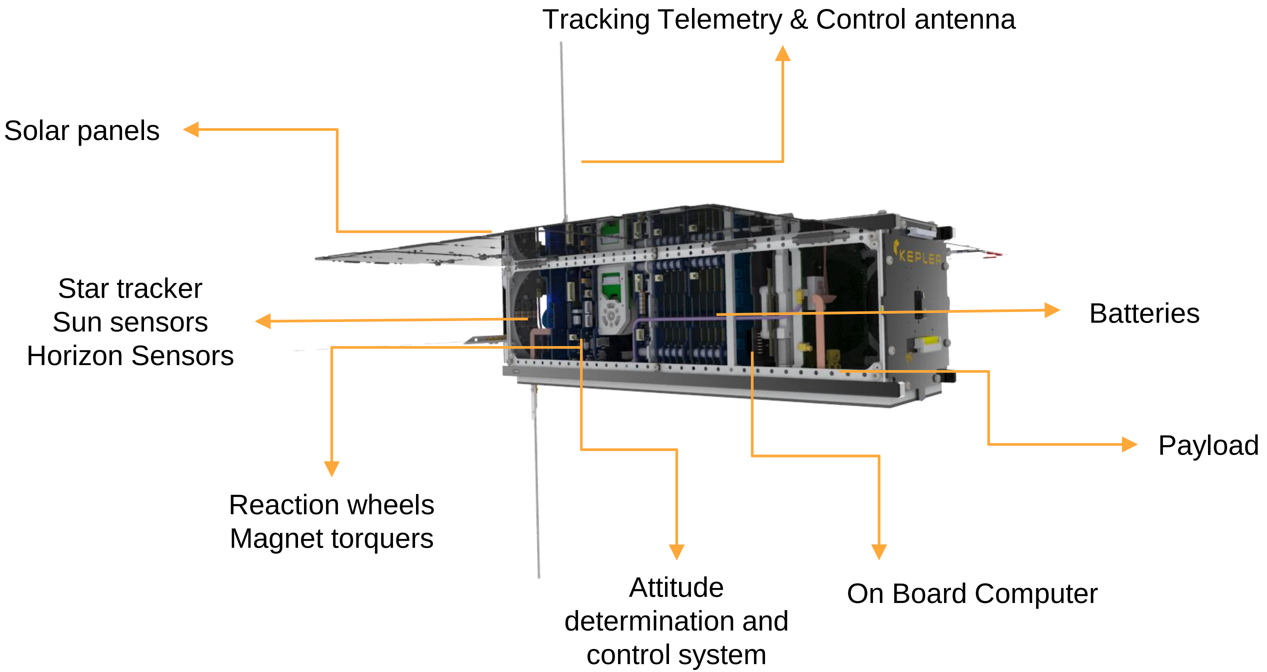
- Medium bandwidth, medium power ground equipment
- Steerable ground antenna needed for broadband
- Modest (>5) satellites needed for real-time coverage
- **GPS satellites**

Geostationary Earth Orbit (GEO)

- Low bandwidth and high power ground equipment
- Simple fixed antenna needed for broadband
- Single satellite needed for regional real-time coverage
- **Traditional telecom satellites**

Technical Challenges - Satellite Platforms

(Low Cost) Satellite Anatomy



Technical Challenges - Satellite IoT

User Terminal

Bi-Directional

Low Power

Low Cost

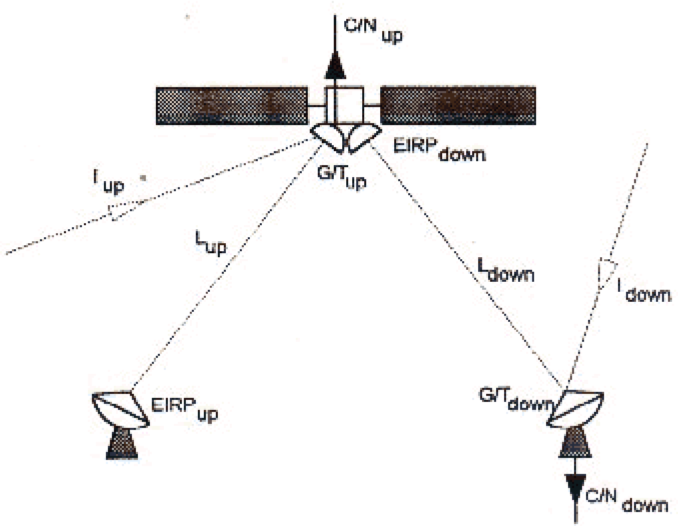
Technical Challenges - Satellite IoT

Link Budget

Low Power Transmitter

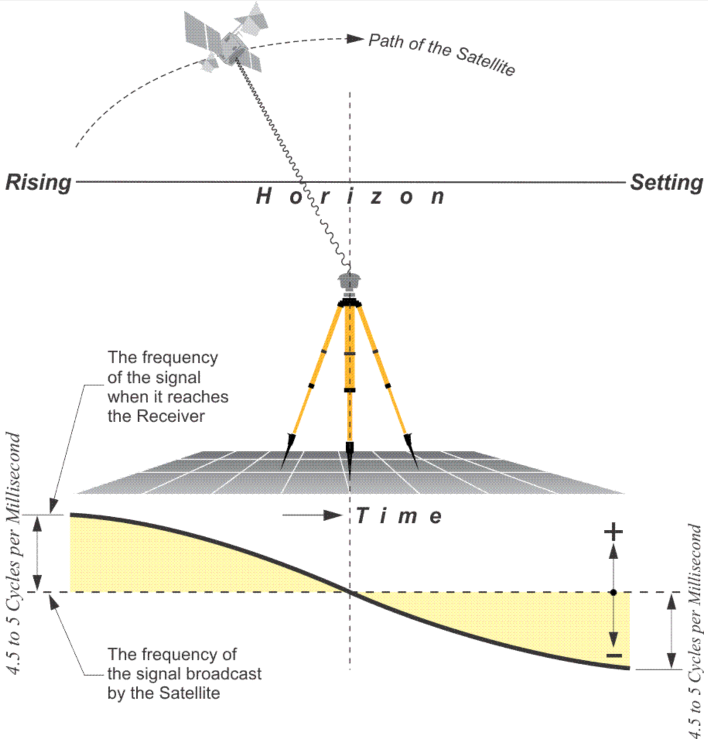
Large Distances

Small Satellite



Technical Challenges - Satellite IoT

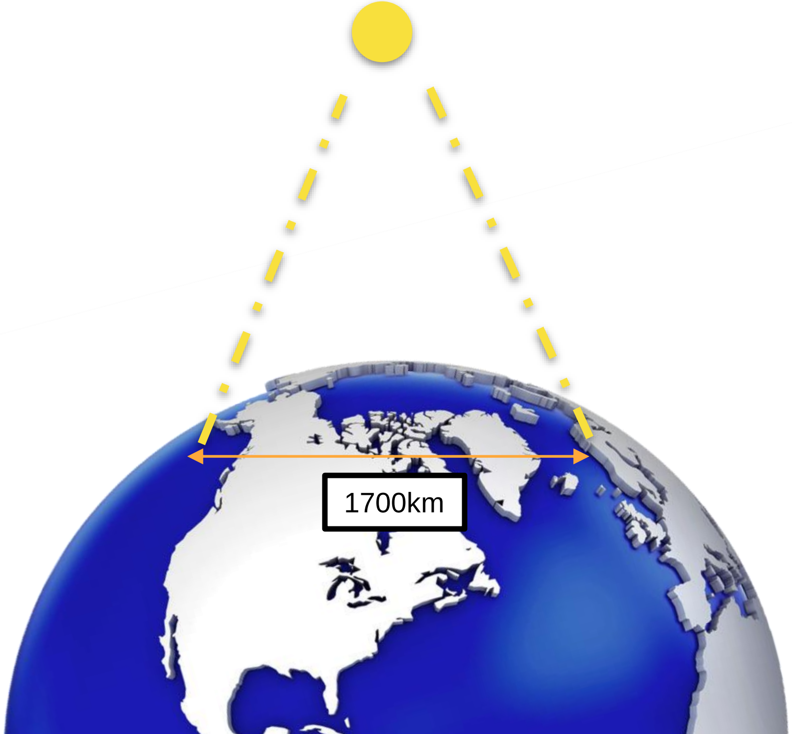
Doppler Shift



Max Doppler of approx.
±40kHz @ 2GHz

Technical Challenges - IoT

Multi-Access Schemes



Each satellite has a large footprint which translates to supporting **>20,000 terminals** simultaneously

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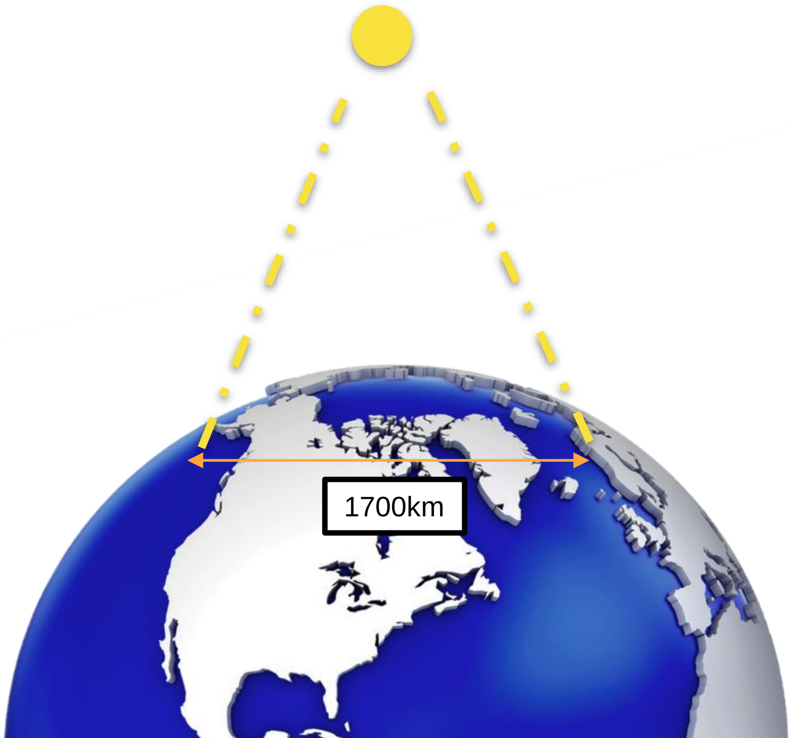
All operate with potentially **different Doppler shifts** and **power levels**

Technical Challenges - IoT

Multi-Access Schemes



Challenging channel conditions for synchronization (both time and frequency)

Uncoordinated/Random access

Potentially mutually interfering signals

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Technical Challenges – Satellite IoT

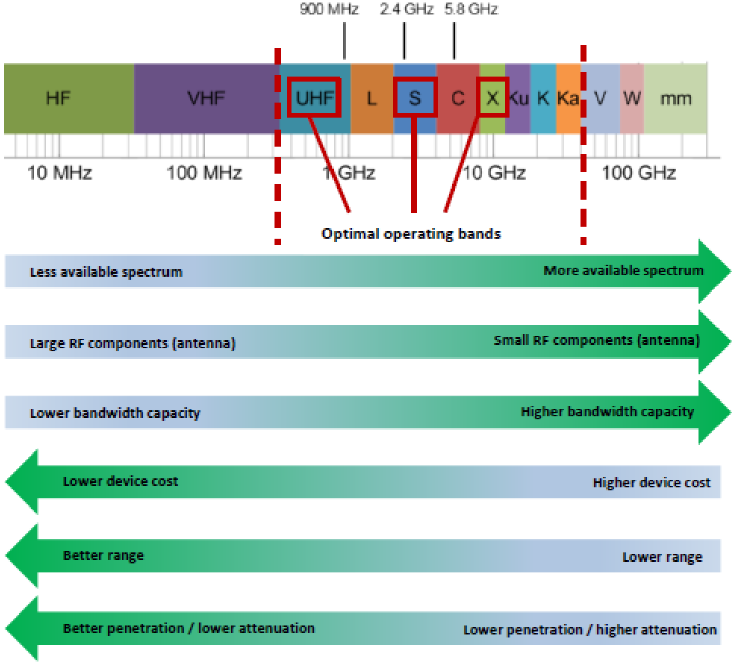
Regulatory and Spectrum

Licensed vs

Bandwidth

Choice of fr

range, pene



Note: Example of common ISM bands within the IEEE frequency band chart.

Source: LE analysis and annotation based on stakeholder interviews and Dixon, J., Politis, C., Wijting, C., (2008). Considerations in the Choice of Suitable Spectrum for Mobile Communications. Available at: http://www.wwrf.ch/files/wwrf/content/files/publications/outlook/Outlook2.pdf

Frequency diagram sourced from Southwest Antennas, Inc. (2016). Modern Co-Site RF Interference Issues and Mitigation Techniques. Based on "Frequency Band Comparison" by Treinkvist. Please see: https://southwestantennas.com/sites/default/files/white-paper/Whitepaper_Modern-Co-Site-Interference-Mitigation-Techniques_Southwest-Antennas.pdf

Technical Challenges – Satellite IoT

Other

Requirement for Mobile Satellite Services – Listen before transmit

Data landing rights – deploy ground station on demand

Data integrity and security - encryption

Market Opportunities

Key Verticals

Asset Tracking	Smart Agriculture	Maritime
		
Largest Segment	Fastest growing	

Key Verticals

Key Verticals

Key Verticals

Key Verticals

Kepler’s IoT Solution

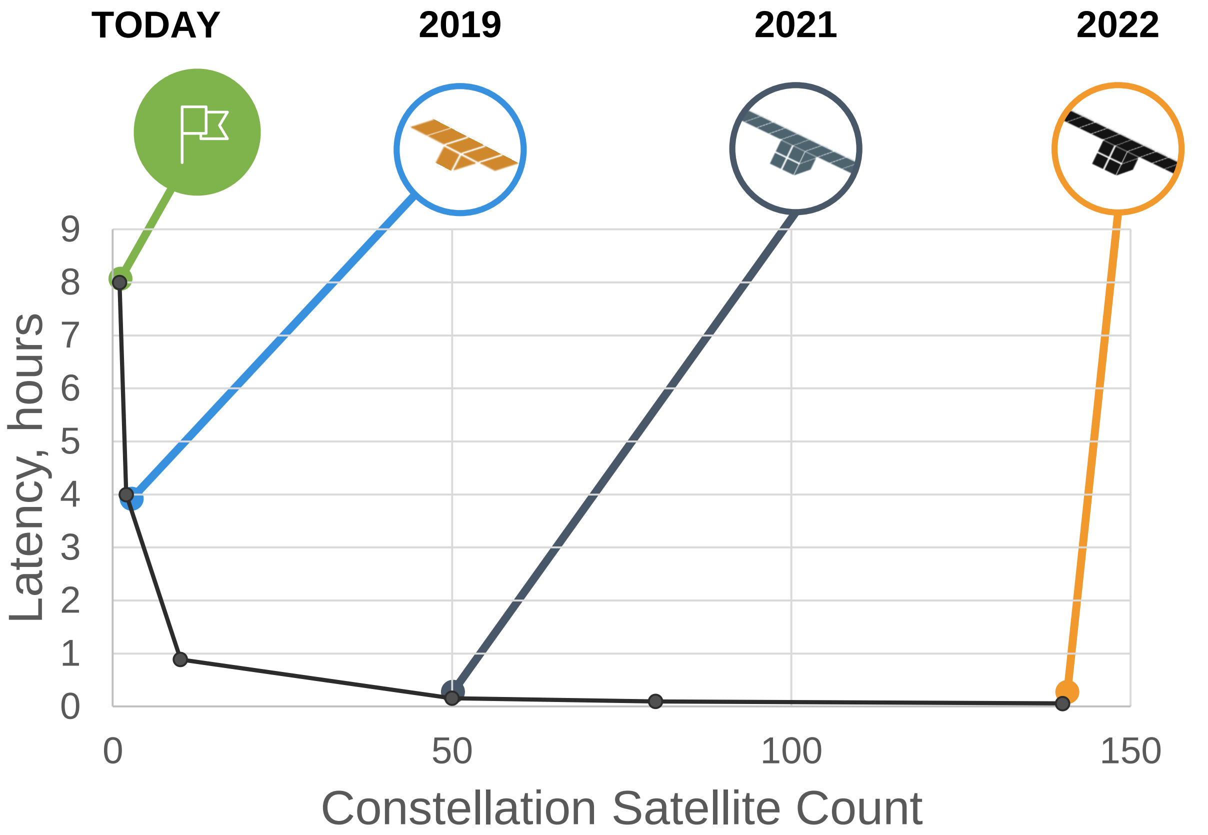
Kepler's Solutions

How does Kepler deal with the challenges of IoT?

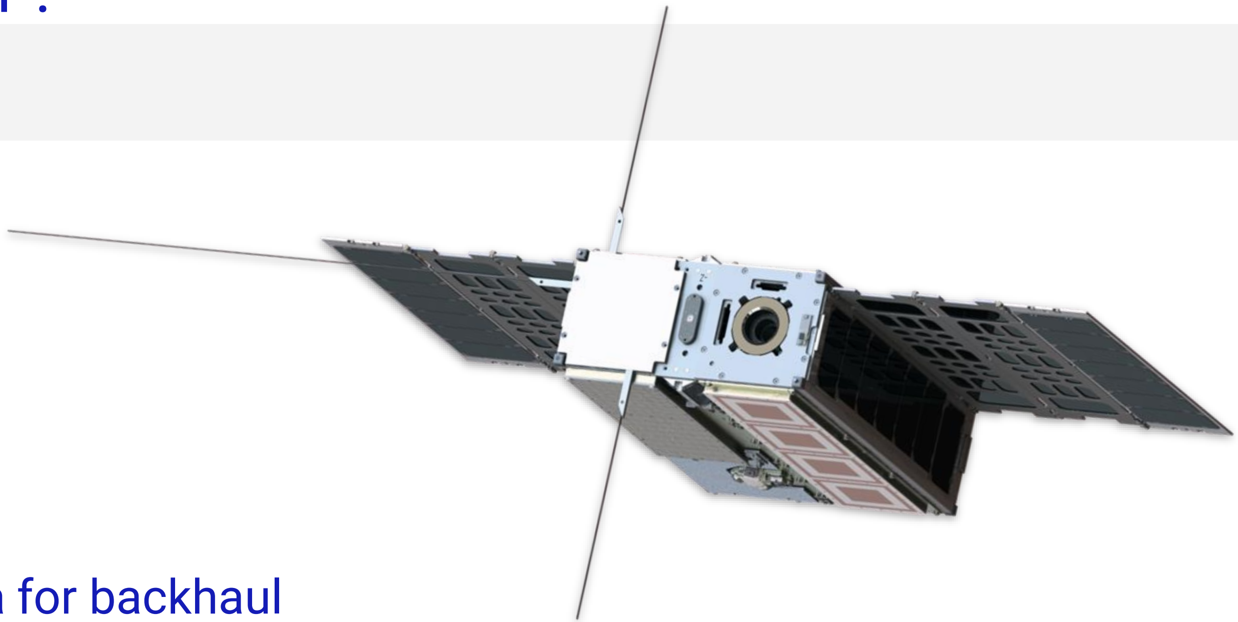
50 Satellite Constellation

5 Ground Stations

Space Segment Average Latency



The Next Frontier :
TARS



- Reconfigurable SDR
- High gain Ku antenna for backhaul
- High gain S-band phased array antenna
- Launching end of 2019/Q1 2020

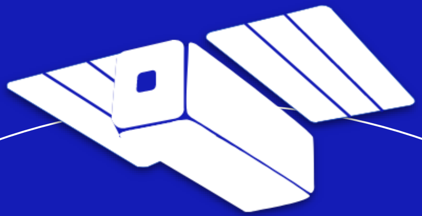
1st Generation User Terminal

- 3” x 4” footprint
- 2 KB per day uplink capacity
- Bi-directional communication
- Low-profile antenna (<1”)

Protocol Selection

- Store raw IQ samples on-orbit and forward to ground station for processing
- Experimented with various spread spectrum technologies in the lab environment (LoRA, RPMA, E-SSA)
- Both user terminal and satellite are fully reconfigurable
- TARS is an on-orbit laboratory to experiment with various protocols in 2020 (perhaps SIC)

KEPLER



Thank You

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