Seizing Opportunity: Spire's CubeSat Constellation of GNSS, AIS, and ADS-B Sensors

Dallas Masters, Director of GNSS, Spire Global, Inc.

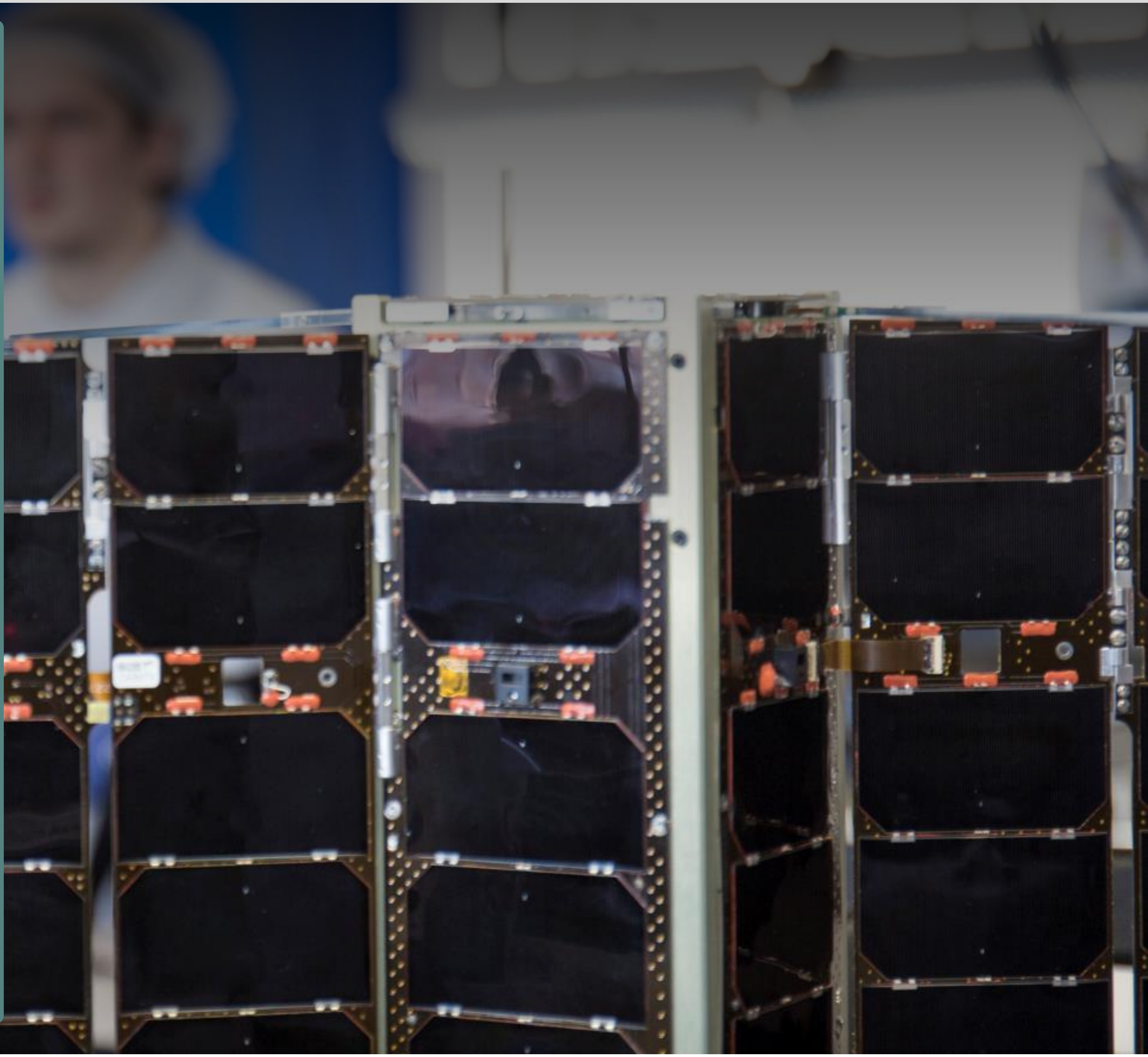
spire

WHO & WHAT IS SPIRE?

We're a new, innovative satellite & data services company that you might not have heard of…

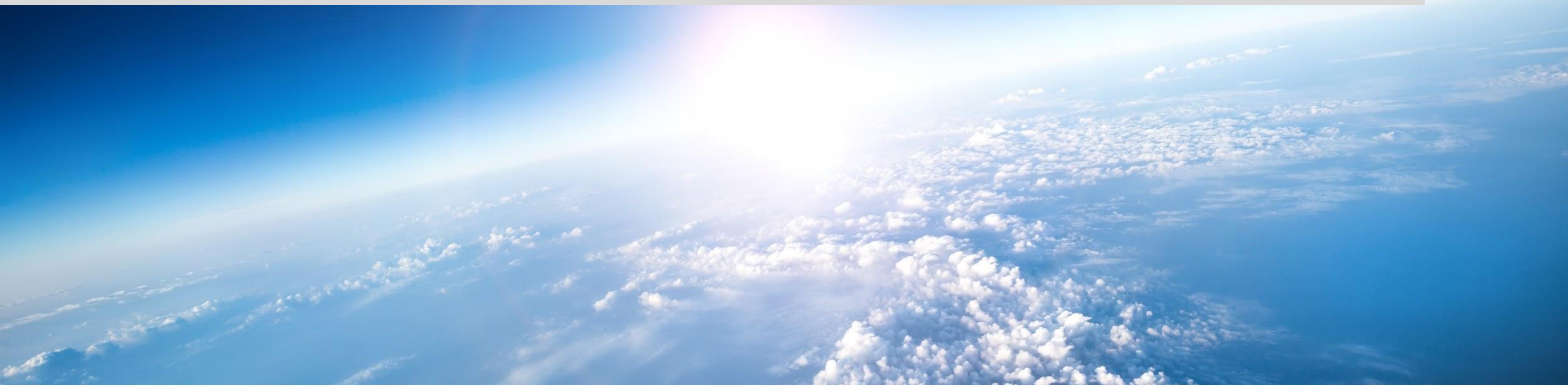
We're what you get when you mix agile development with nanosatellites…

We're the transformation of a single , crowd-sourced nanosatellite into one of the largest constellations of satellites in the world…



spire

OUTLINE



1. Overview of Spire
2. Spire satellites and PNT payloads & products
    a. AIS ship tracking
    b. GNSS-based remote sensing measurements: radio occultation (RO), ionosphere electron density, bistatic radar (reflections)
    c. ADS-B aircraft tracking (early results)
3. Spire’s lofty long-term goals

AN OVERVIEW OF SPIRE

SPIRE TODAY

Two of Spire's first LEMUR (Low-Earth Multi-Use Receiver) CubeSats just after launch

- 150 people across five offices (a distributed start-up)
  - San Francisco, Boulder, Glasgow, Luxembourg, and Singapore
- 60+ LEO 3U CubeSats (10x10x30 cm) in orbit with passive sensing payloads, 30+ global ground stations
  - 16 launch campaigns completed with seven different launch providers
  - Ground station network owned and operated in-house for highest level of security and resilience
- Observing each point on Earth 100 times per day, everyday
  - Complete global coverage, including the polar regions
- Deploying new applications within 6-12 month timeframes
- World's largest ship tracking constellation
- World's largest weather data constellation
- World's only commercial global weather forecasting engine
- $130M+ raised with top institutional investors, including
  - Bessemer Venture Partners, RRE Ventures
  - Qualcomm Ventures, Airbus
  - Luxembourg Future Fund, Seraphim Capital

WHAT MAKES SPIRE UNIQUE?

Full-Stack Satellites

It's a Spire product from start to finish *(except for the rocket)*

Passive RF Sensing

Focused on receiving RF "signals of opportunity" for asset tracking and Earth observation: AIS, GNSS, ADS-B

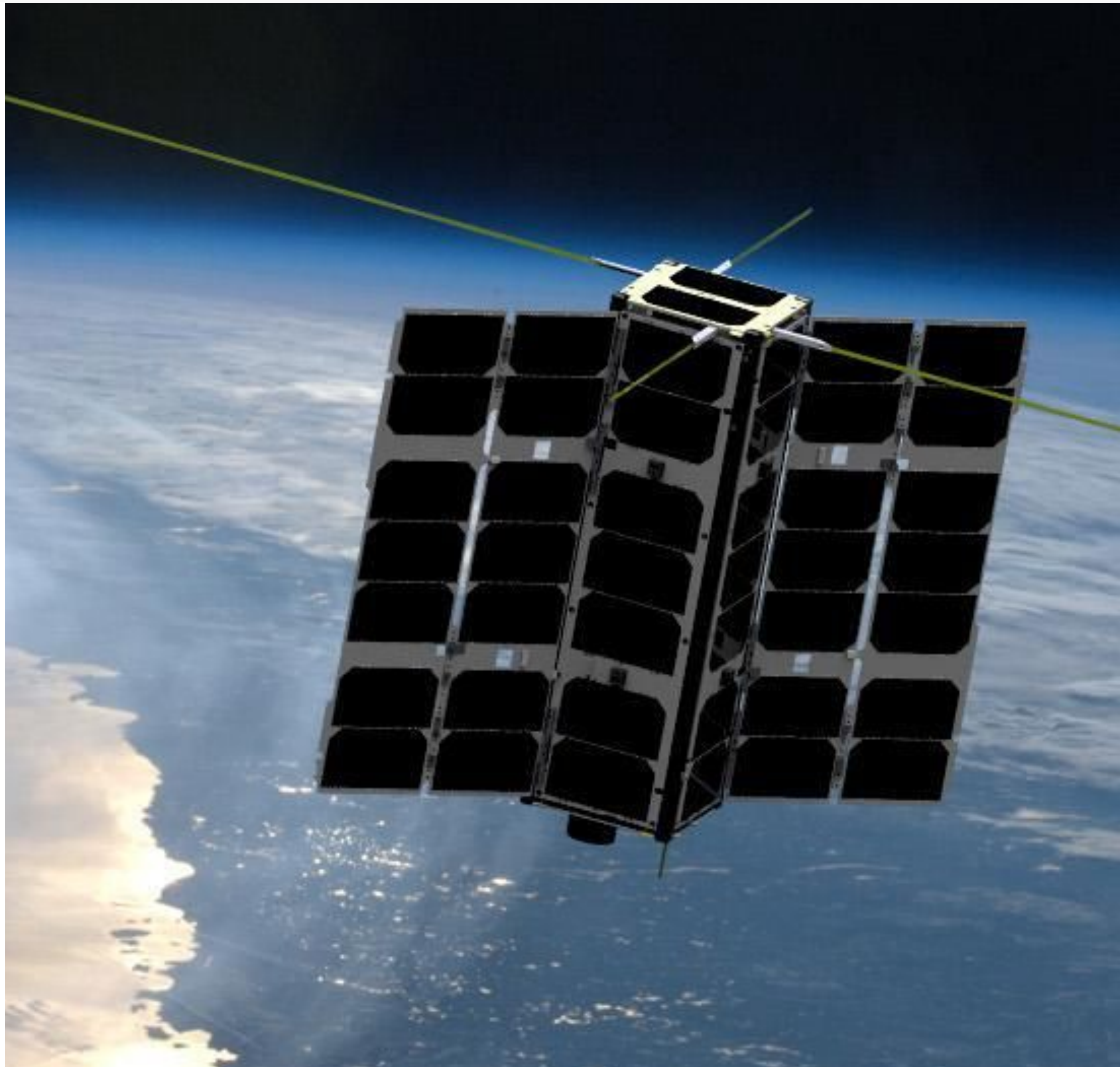
Fastest Hardware Upgrades In the Industry

New hardware: 6 months from development to launch

Currently launching on average **every six weeks**

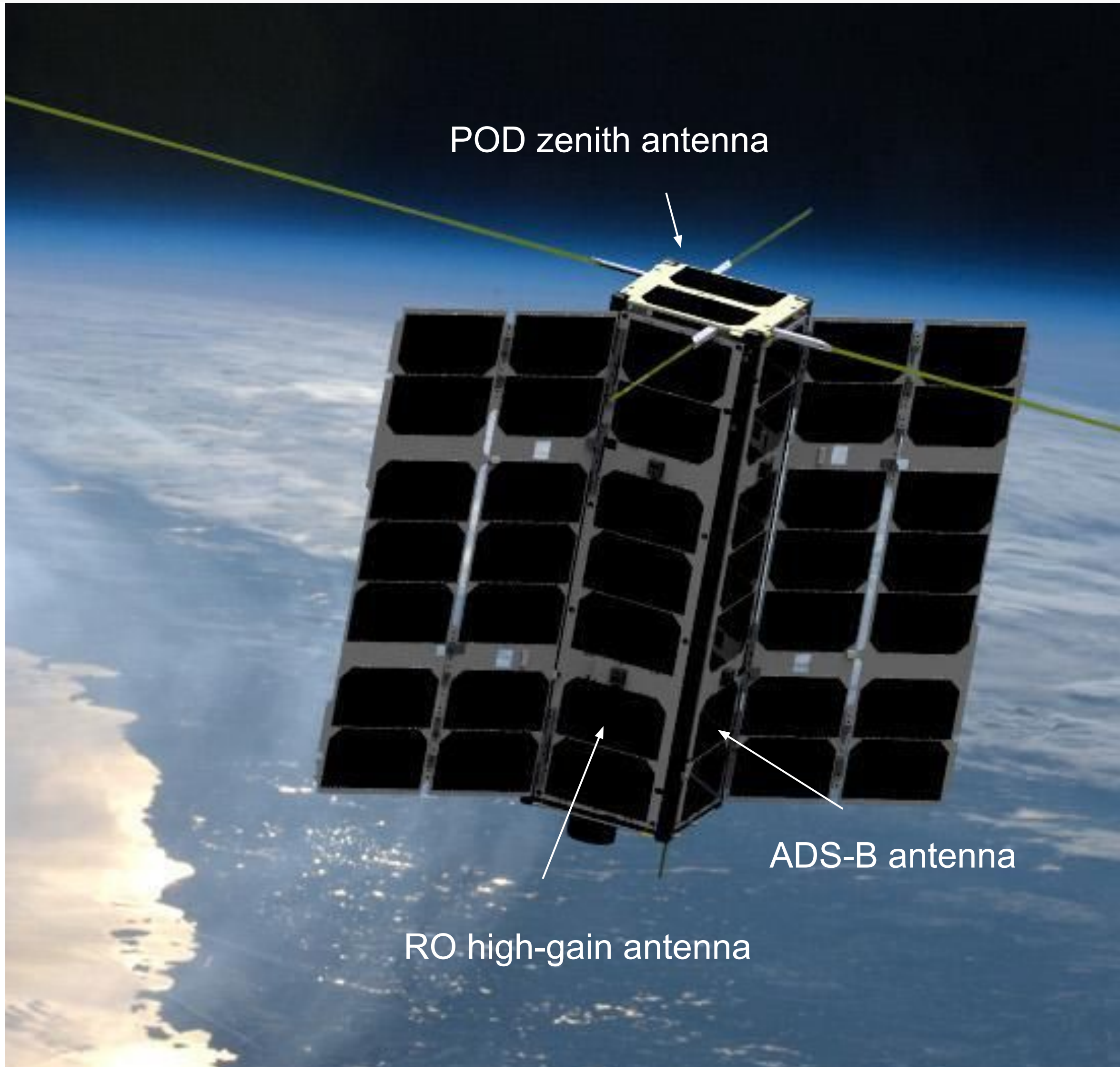
Consistent On-Orbit Performance Upgrades

Demonstrated increase in data performance, downlink performance, and tasking



SPIRE CUBESAT SPECS

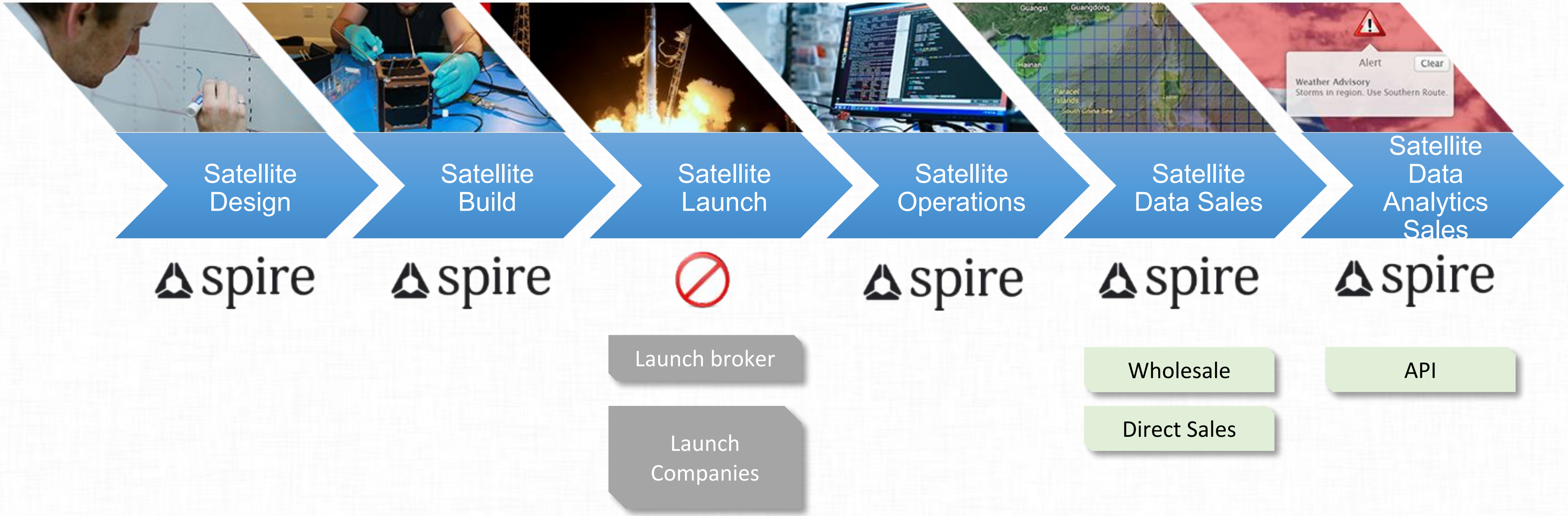
- 3U form factor (10x10x30 cm)
- Main payloads:
  - Automatic Identification System (AIS) receiver (terrestrial vessel tracking)
  - STRATOS GNSS radio occultation (RO) & precise orbit determination (POD) receiver
    - POD antenna: zenith, L1/L2 RHCP
    - High-gain RO antennas: fore/aft, L1/L2 RHCP
  - Automatic Dependent Surveillance-Broadcast (ADS-B) (aircraft tracking)
- 3-axis attitude control/knowledge via Spire ADCS
- Comms: UHF, S-band



spire

SPIRE ADVANTAGE: VERTICAL INTEGRATION

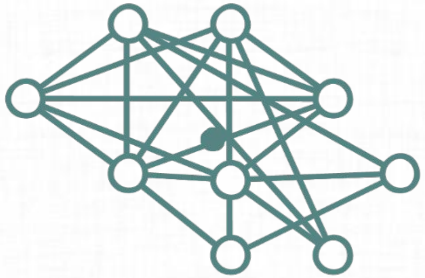
Spire's ownership of design through delivery, coupled with **select external partnerships** for satellite launches enables speed, reliability and control.



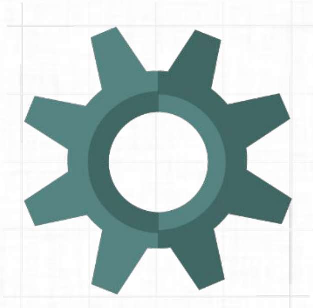
Full Control over Quality – Superior Scale Advantages – Fastest Innovation Cycle

SPIRE'S THREE STRATEGIC PILLARS

Spire collects data when/where no one else can. This means we focus on data which can only be collected from space.



Spire collects data where the number—rather than size—of sensors matters.



Spire collects data with sensors that are programmable and reprogrammable in orbit (software-defined radios and FPGAs), applying Moore's law to space.

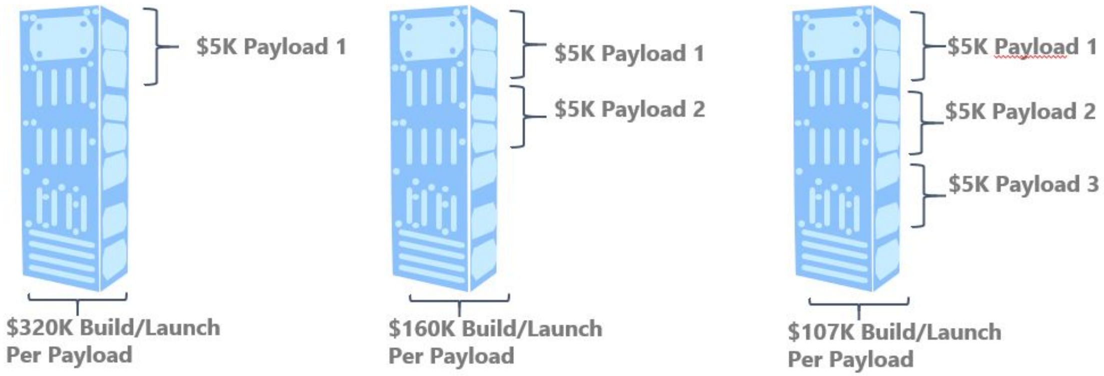
All Spire Applications Have to Satisfy All Three Requirements

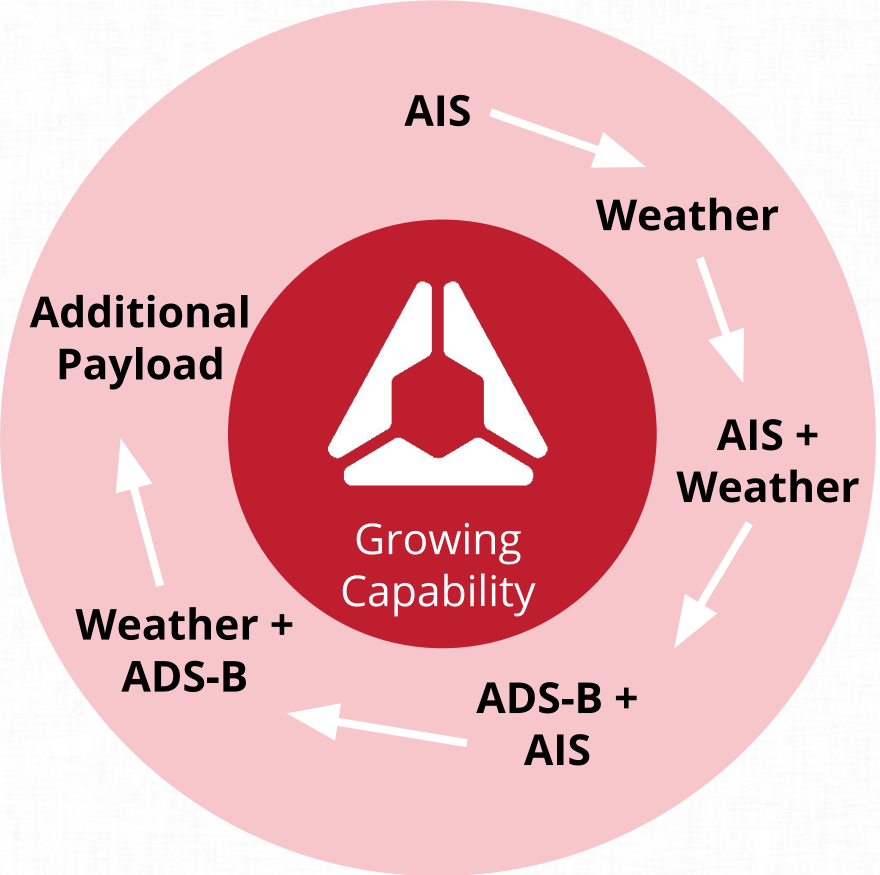
THE SPIRE FLYWHEEL

Every application reinforces all other applications

- The business behind each payload and innovation carries forward to building the next payload
    - AIS led the way for weather payload
    - Weather combined with AIS produces additional unique innovation
    - ADS-B makes use of AIS by sharing radio
- Satellite bus supports multiple payloads at the same time
- Additional payloads (GNSS-RO, GNSS-R, High Performance Computing, etc.) all supported by the flywheel effect

- **The more payloads that are added, the more the satellite bus is amortized**





spire

SOYUZ
FALCON-9 (SPACEX)
H-IIA
DNEPR
ATLAS-V
PSLV
ANTARES
ELECTRON
SPARK
LAUNCHERONE

ON AVERAGE, SPIRE BUILDS ONE SATELLITE PER WEEK & LAUNCHES 4-8 SATS EVERY SIX WEEKS, WITH A GOAL OF 100s SATS IN ORBIT

- ***Quantity of measurements to reduce error***



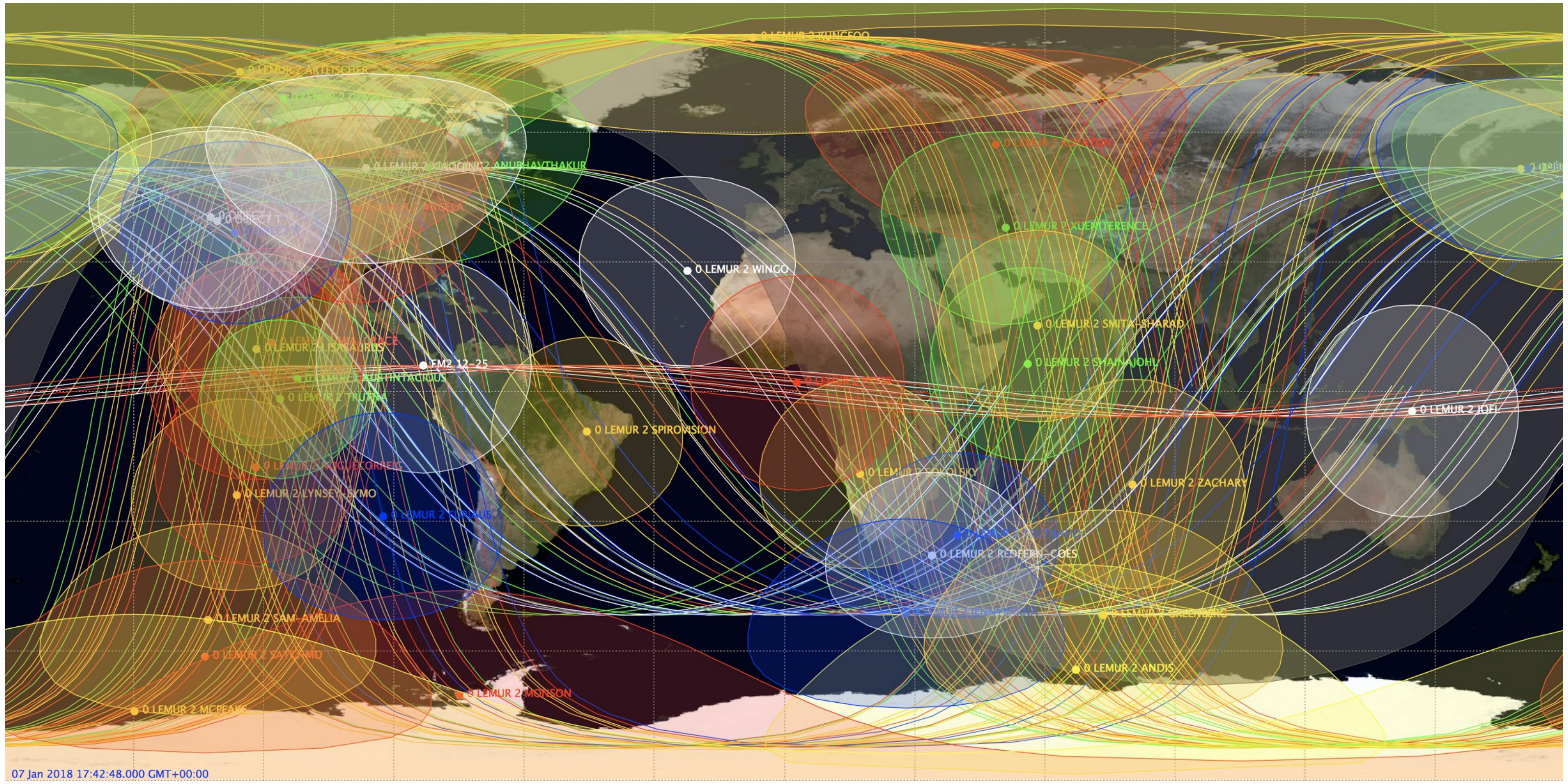




SECURE, RELIABLE GROUND STATION CAPABILITY

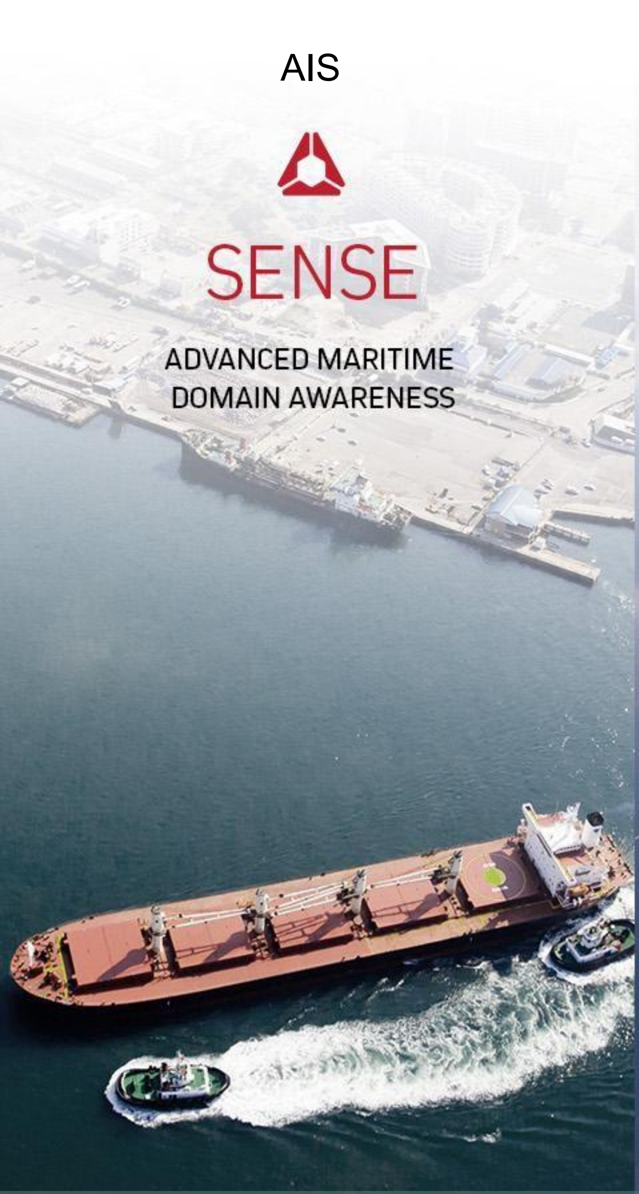
- World-wide Bent Pipe Ground Stations with S-Band Downlink
- 30+ Ground Stations Installed Today
- Global Coverage Supports Multiple Orbits

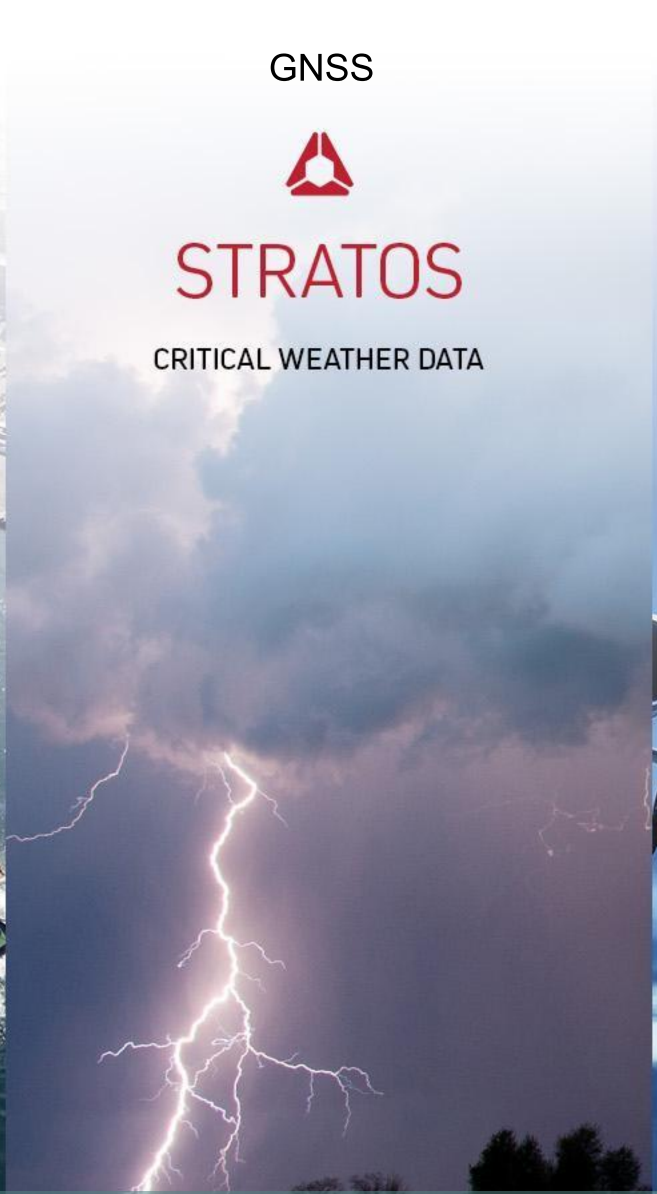
SPIRE CONSTELLATION

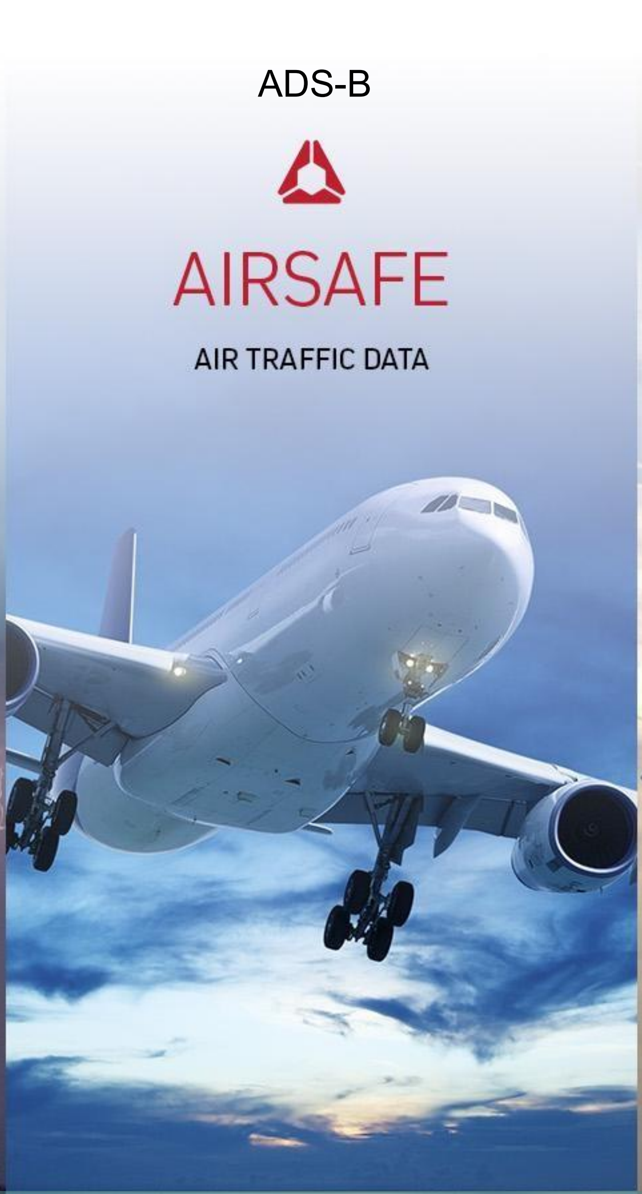


Snapshot of Spire satellites in orbit. Pink areas cover the Earth surface where there is a direct line of sight to at least one Spire satellite

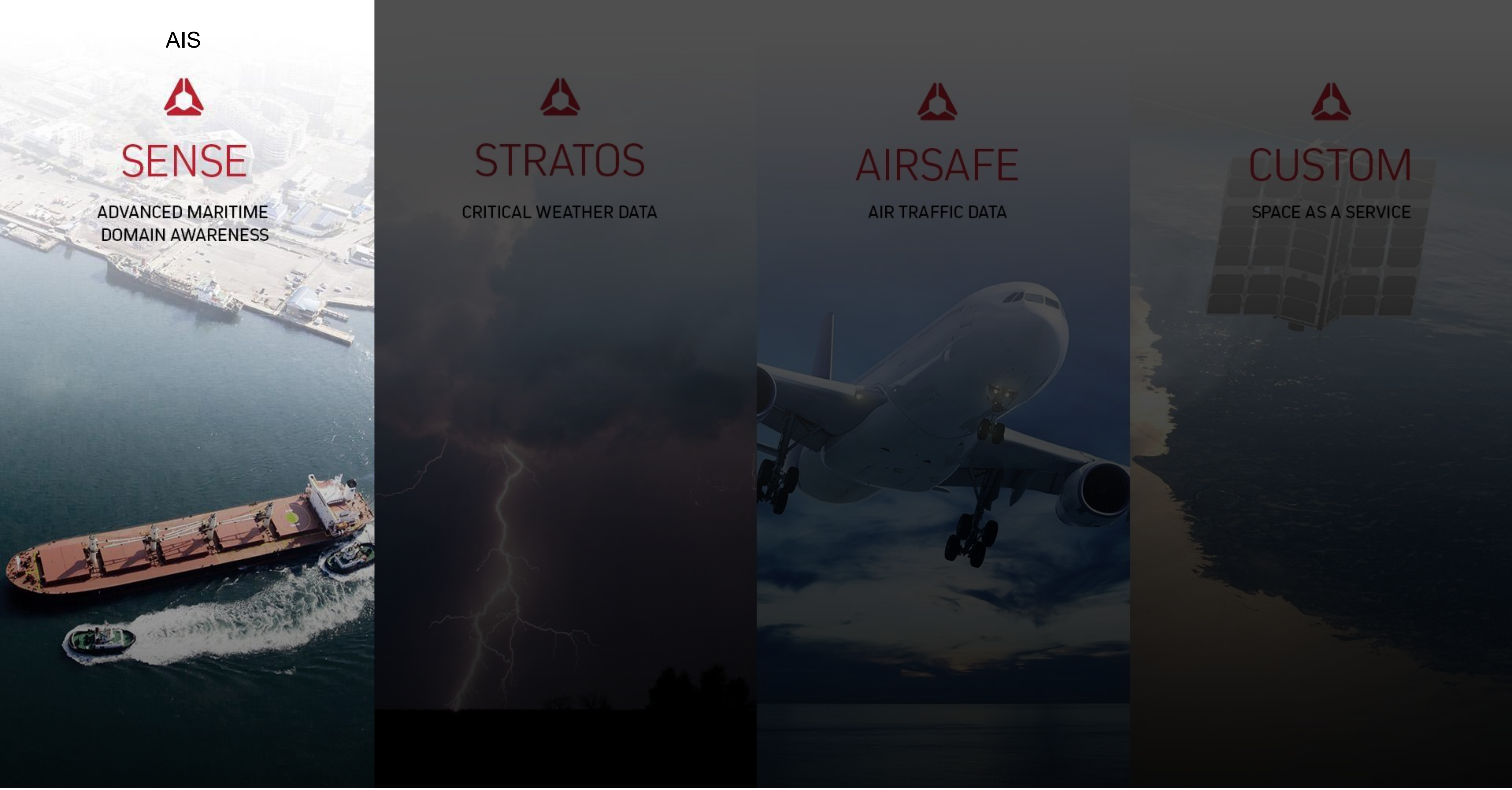
- Currently 60+ satellites in 400-650 km orbits
- Mainly sun synchronous or 51.6 deg inc (ISS) orbits
- Some new launches at ~85 deg inc







SPIRE’S CURRENT PNT PAYLOADS & PRODUCTS


AIS
SENSE
ADVANCED MARITIME DOMAIN AWARENESS
STRATOS
CRITICAL WEATHER DATA
AIRSAFE
AIR TRAFFIC DATA
CUSTOM
SPACE AS A SERVICE

spire

SATELLITE-AIS VESSEL TRACKING

- AIS = Automatic Identification System
- Globally used by maritime vessels to broadcast position information over VHF radio channels (162 MHz)
- Traditionally terrestrial tracking near ports, but satellite-AIS (S-AIS) now used to track vessels world-wide from space
- Spire’s first commercial payload was an AIS receiver and each satellite carries this payload
- S-AIS product known as “Spire Sense”

spire

SPIRE SENSE (S-AIS) BY THE NUMBERS

Spire Vessel & Message Counts

180K+ **Unique Vessels / Day**

(Satellite + Terrestrial)

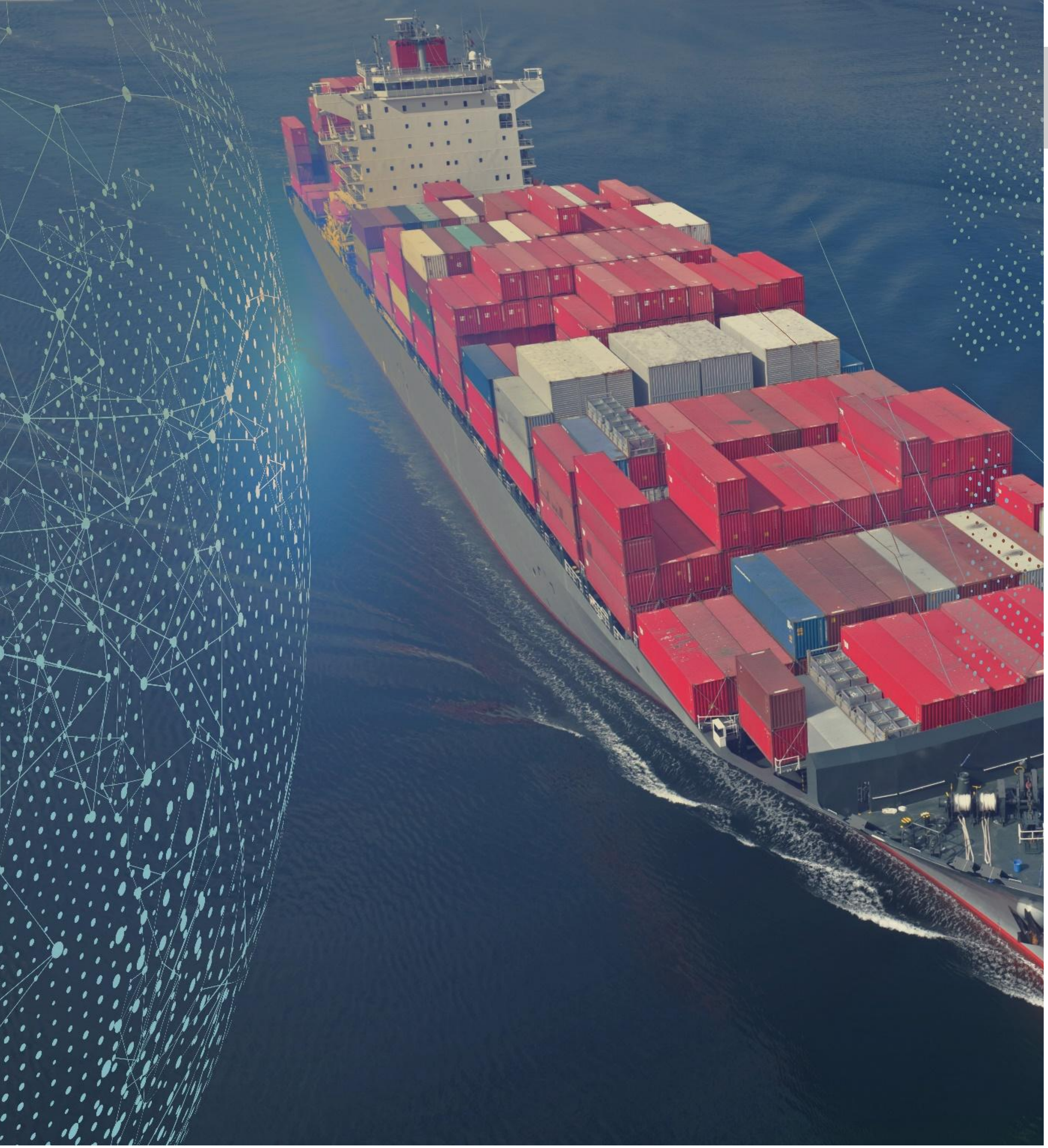
30M+ **Total Messages / Day**

(Satellite + Terrestrial)

What fields are in each AIS Message?

- NMEA
- MMSI
- IMO
- Message Type
- Message Timestamp
- System Ingestion Timestamp
- Collection Type (satellite or terrestrial)
- Message Description
- Intermediary Message Source
- Message ID
- Country Flag
- Country Flag Short Code
- Longitude
- Latitude
- Position (GeoJSON)
- GPS Accuracy
- Course
- Heading
- Speed
- Destination
- ETA
- Status
- Draught
- Vessel Name
- Vessel Length
- Vessel Width
- Ship & Cargo Type
- Ship Type
- Call Sign

spire



MARITIME DOMAIN AWARENESS

A Complete Understanding of Global Shipping:

- **Financial Services**
  - Accurate pulse of worlds commodity markets
- **Logistics**
  - Port operations and supply chain optimization
- **Fleet Management**
  - Fuel optimization, ETA , digital navigation, alerts
- **Oil & Gas**
  - Monitoring & insight into the off share market
- **Environmental**
  - Monitor protected areas / polar monitoring
- **Security**
  - Piracy identification and ship routing
- **Defense**
  - Monitoring, identifying anomalies in EEZ zones
- **Illegal Fishing**
  - Extend surveillance, correlate with SAR images
- **Search and Rescue**
  - Pinpoint vessels in distress / identify nearby vessels to assist

EXAMPLE: IDENTIFYING SPIES & SPOOFING

Problem:

Need to identify Spoofing and Spying Vessels in the strategically important Arctic. Before Spire, very little data existed from this region.

Structure:

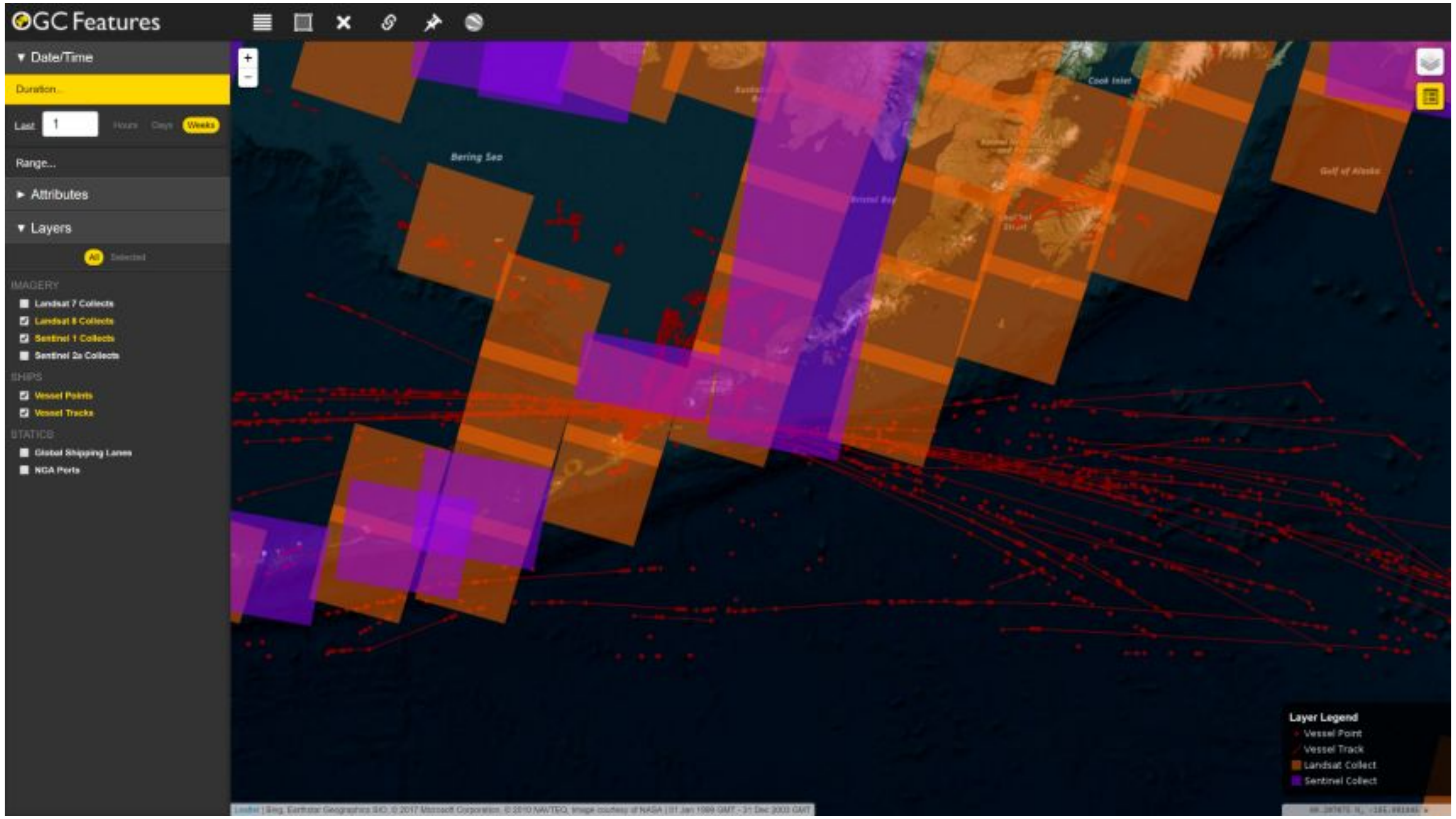
Collaboration between Spire (data), Ball Aerospace (UI), and DDI (analytics).

Goals:

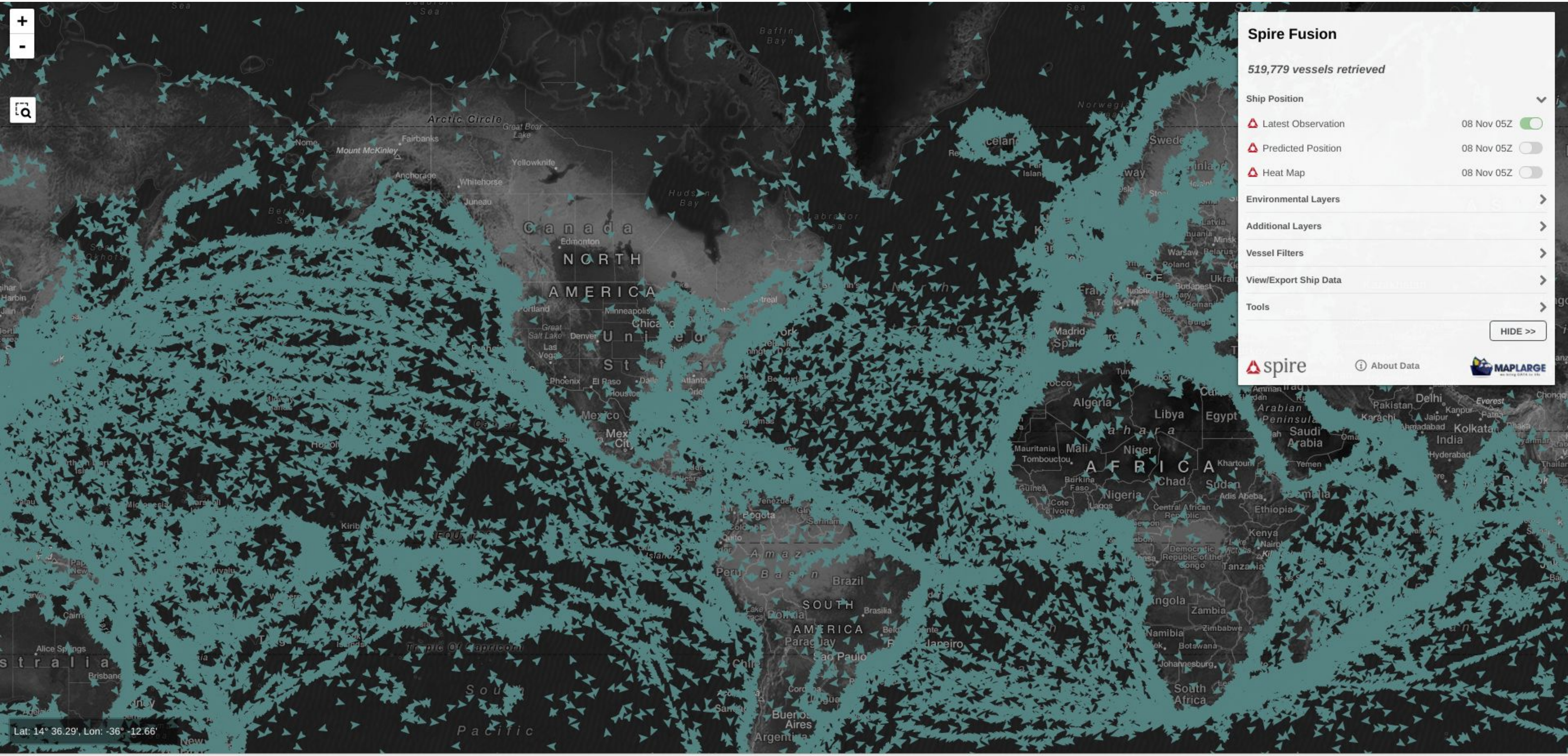
Use AIS data to establish models of normal vessel behavior in the Arctic or “patterns of life,” which can be leveraged to **detect anomalous vessel movements**.

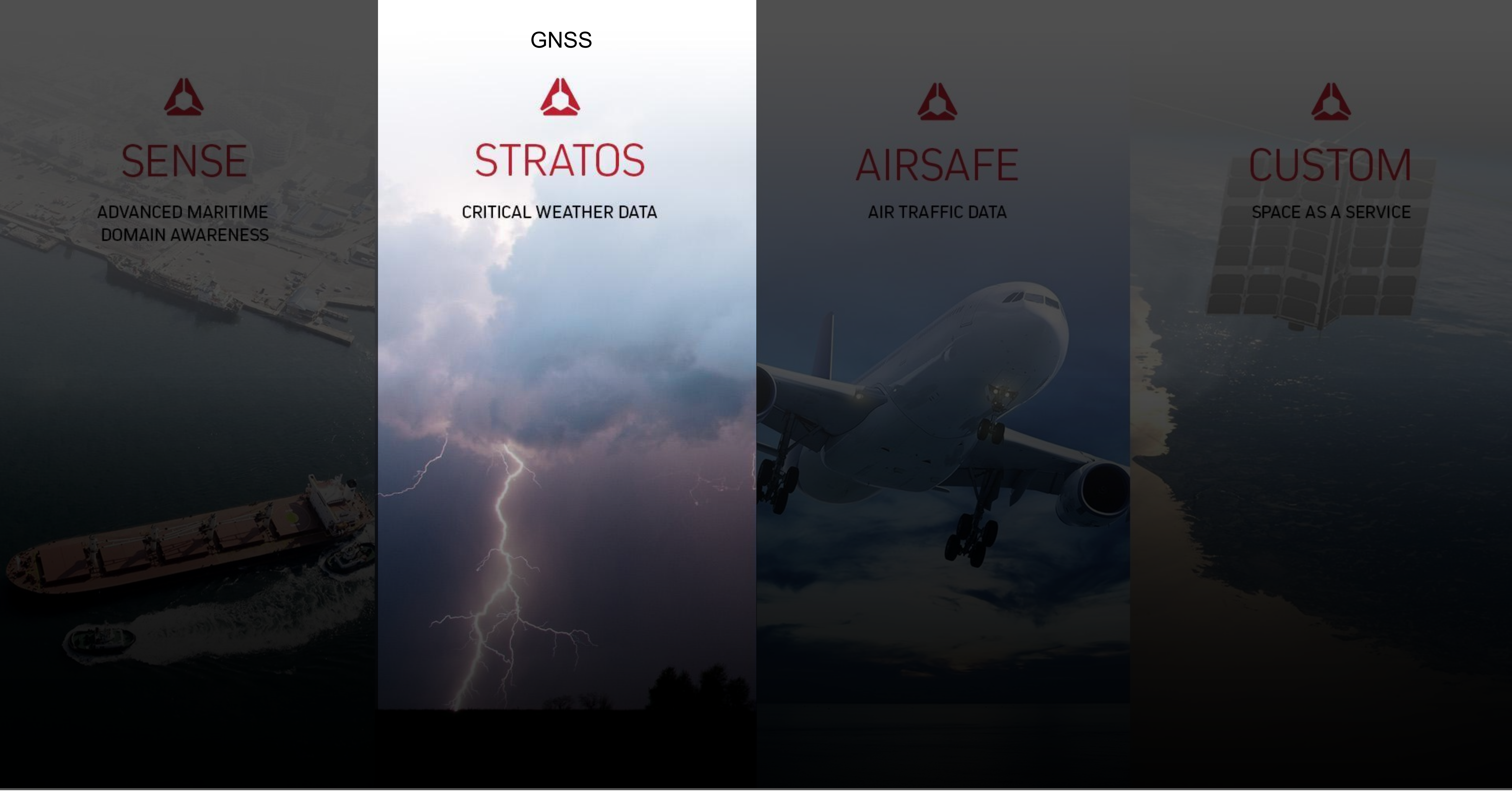
Methods:

Correlate RF-based AIS vessel tracking data to other types of GEOINT data, such as optical and/or SAR imagery, to **validate and verify the presence and location of shipping vessels**.

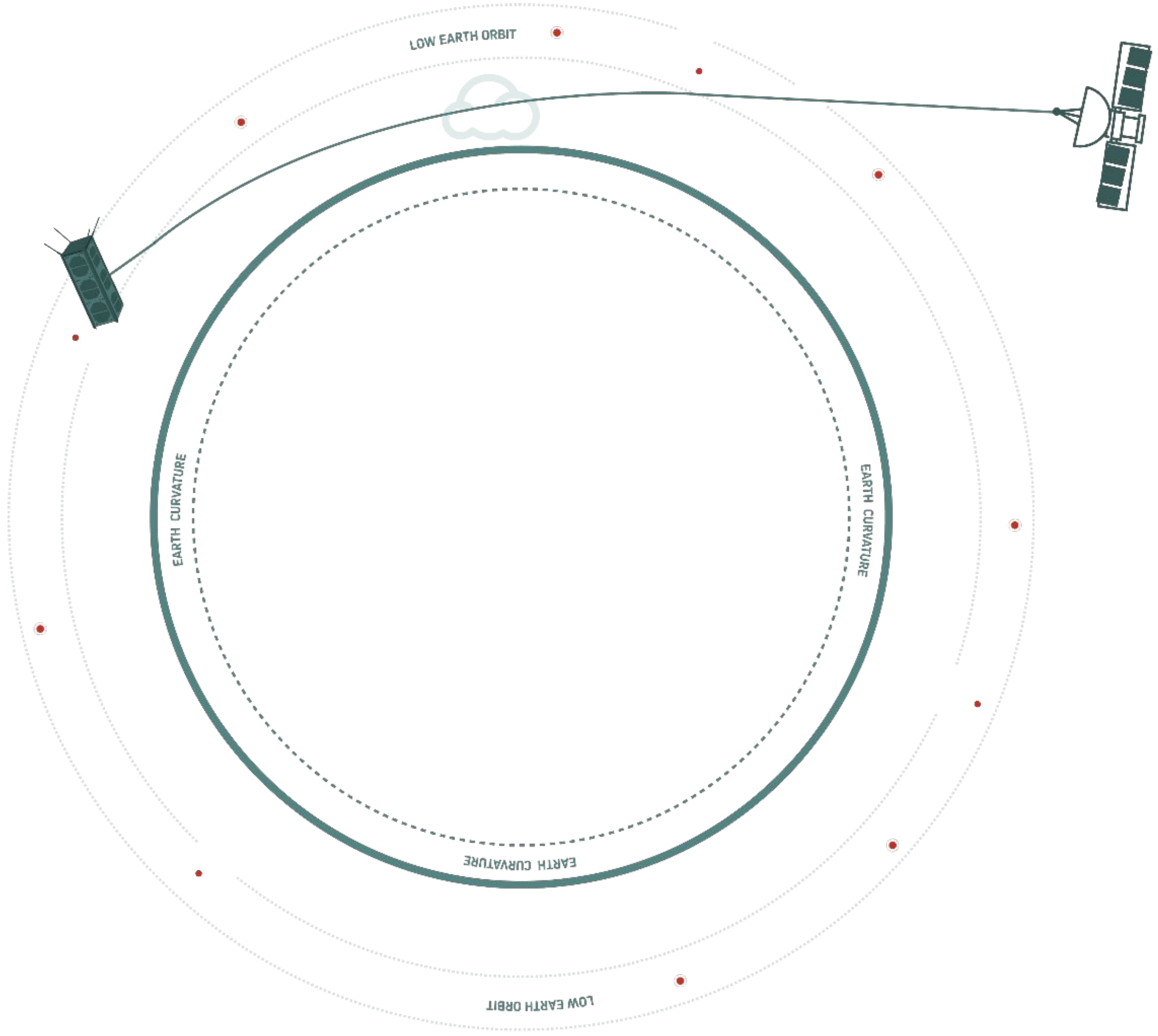


Landsat 8 (multi-spectral imagery) and Sentinel 1 (SAR) footprints overlay with Spire AIS messages (red dots) displayed in Ball’s UI. AIS facilitates powerful filter to "weed out" costly analysis of traditional GEOINT data.


Spire Fusion
519,779 vessels retrieved
Ship Position
Latest Observation 08 Nov 05Z
Predicted Position 08 Nov 05Z
Heat Map 08 Nov 05Z
Environmental Layers
Additional Layers
Vessel Filters
View/Export Ship Data
Tools
HIDE >>
spire
About Data
MAPLARGE
Lat: 14° 36.29', Lon: -36° -12.66'


GNSS
SENSE
ADVANCED MARITIME DOMAIN AWARENESS
STRATOS
CRITICAL WEATHER DATA
AIRSAFE
AIR TRAFFIC DATA
CUSTOM
SPACE AS A SERVICE

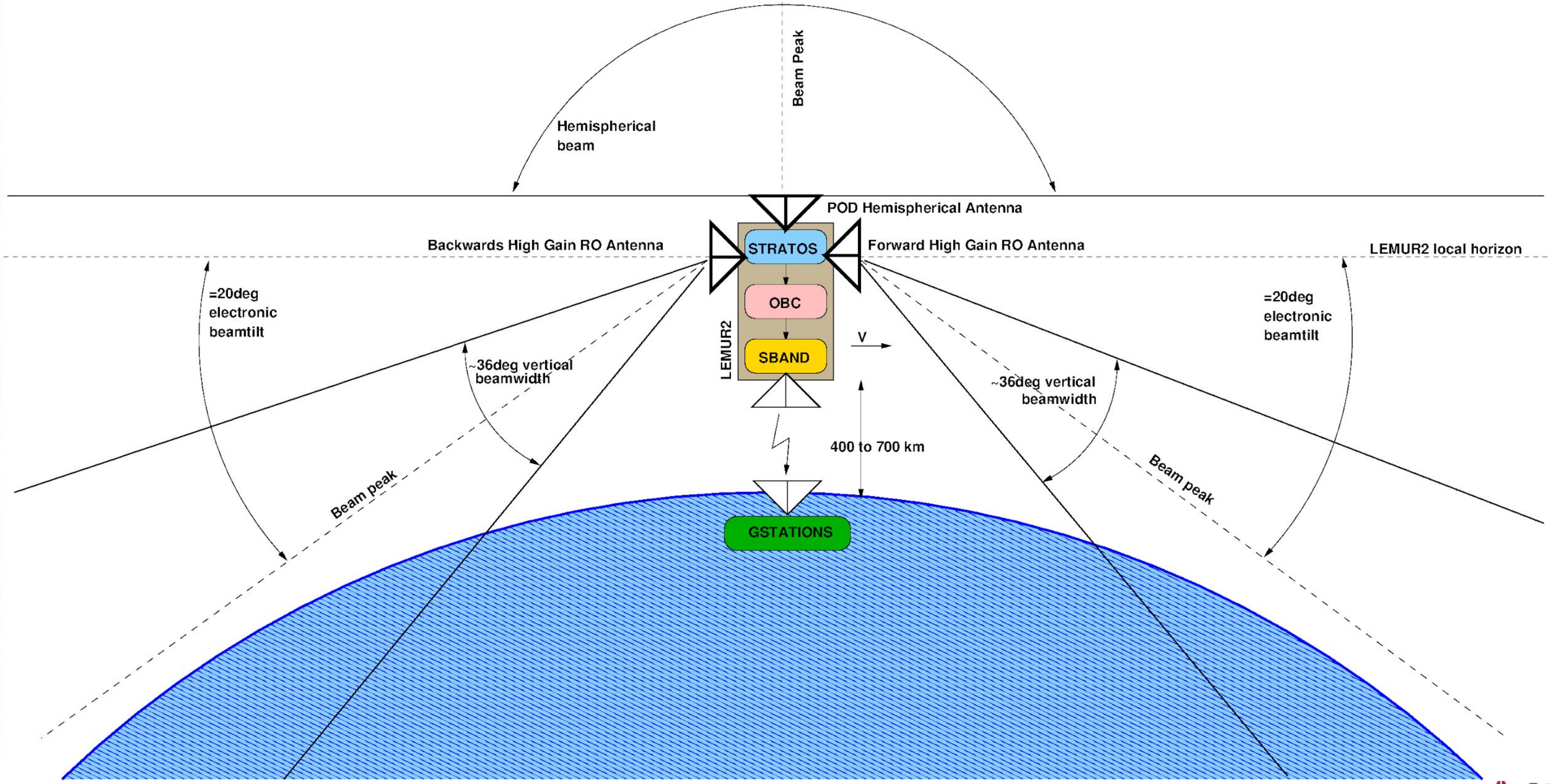
STRATOS: ENABLING GNSS SCIENCE



STRATOS is the Spire GNSS receiver for remote sensing & precision orbit determination

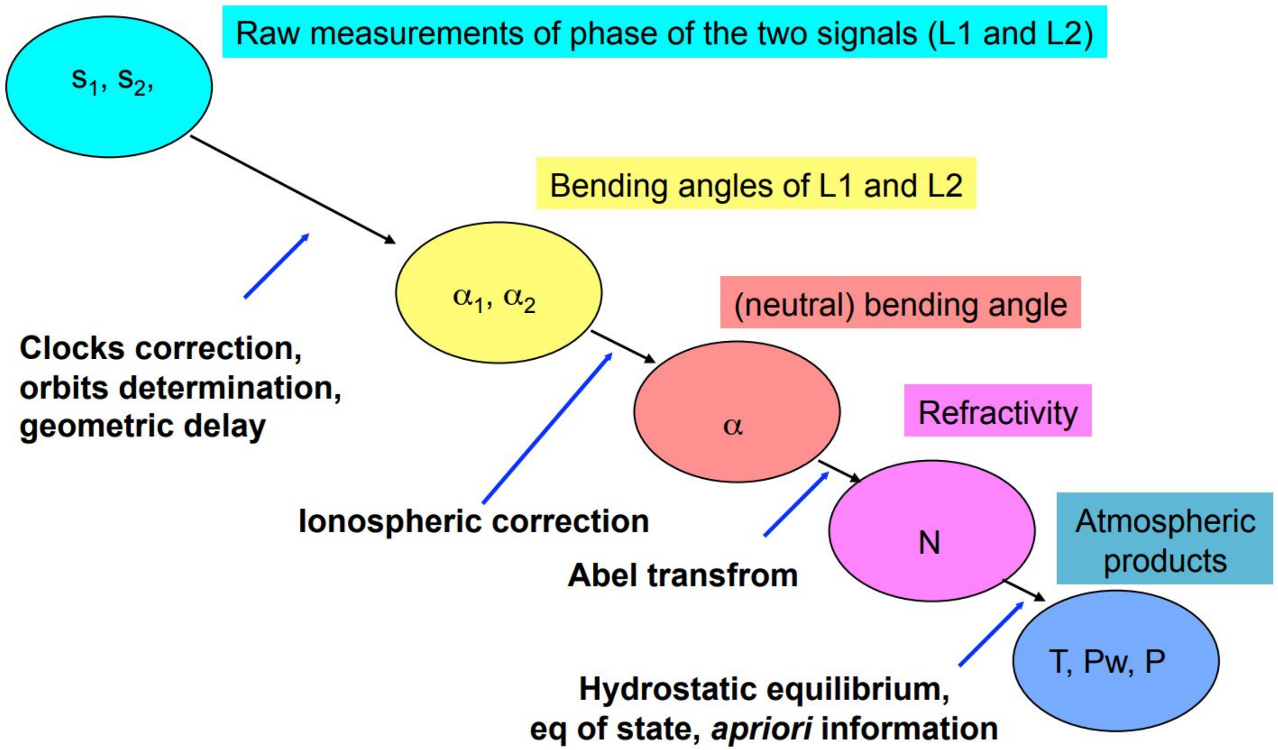
- Performs POD using zenith L1, L2 antenna
- Performs radio occultation (RO) on high-gain, side-mounted L1, L2 antennas
- Currently enables atmospheric & ionospheric remote sensing
- Applications: weather model assimilation of RO, space weather monitoring, ionosphere corrections for navigation, thermospheric density (POD)
- Currently modifying STRATOS for passive bistatic radar (GNSS-R) applications

SPIRE GNSS RO OBSERVING GEOMETRY

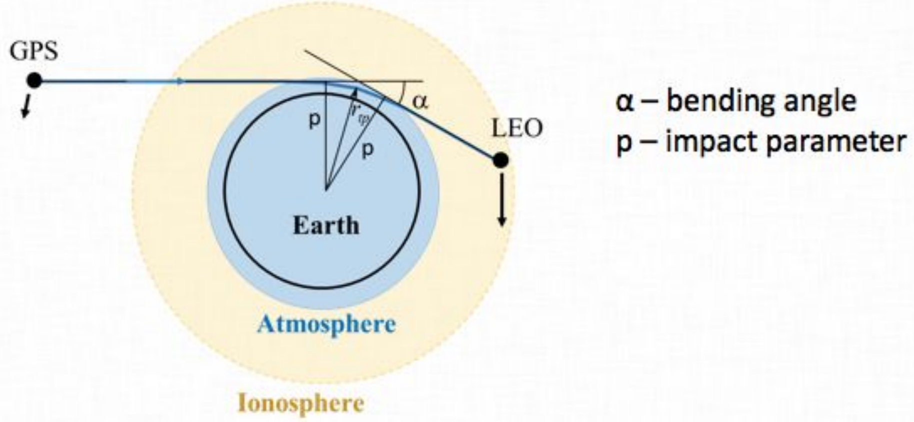


GNSS RADIO OCCULTATION

Excess phase observations on dual-freq GNSS signals due to iono/atmospheric refraction



(Cucurull, 2009)

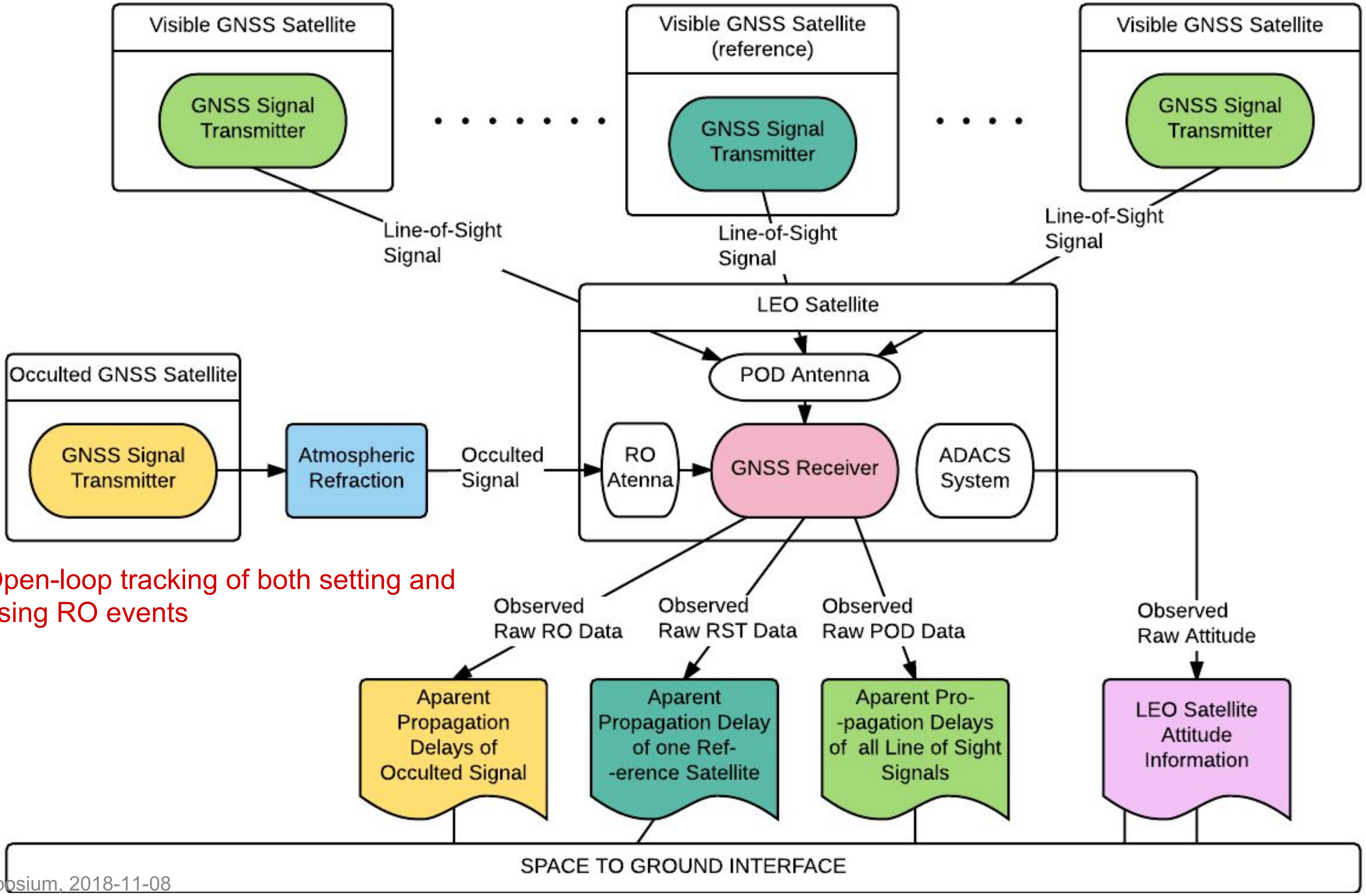


$$N = 77.6\frac{P}{T} + 3.73 \cdot 10^5 \frac{P_w}{T^2} - 4.03 \cdot 10^7 \frac{n_e}{f^2}$$

Occultation diagram illustrating the definition of bending angle and impact parameter. Bending angle profiles as function of impact parameter allow for the derivation of atmospheric refractivity (N) profiles as a function of altitude. The relation between refractivity and temperature (T) as well as pressure (P), water vapor (P_w) and ionospheric electron density (n_e).

spire

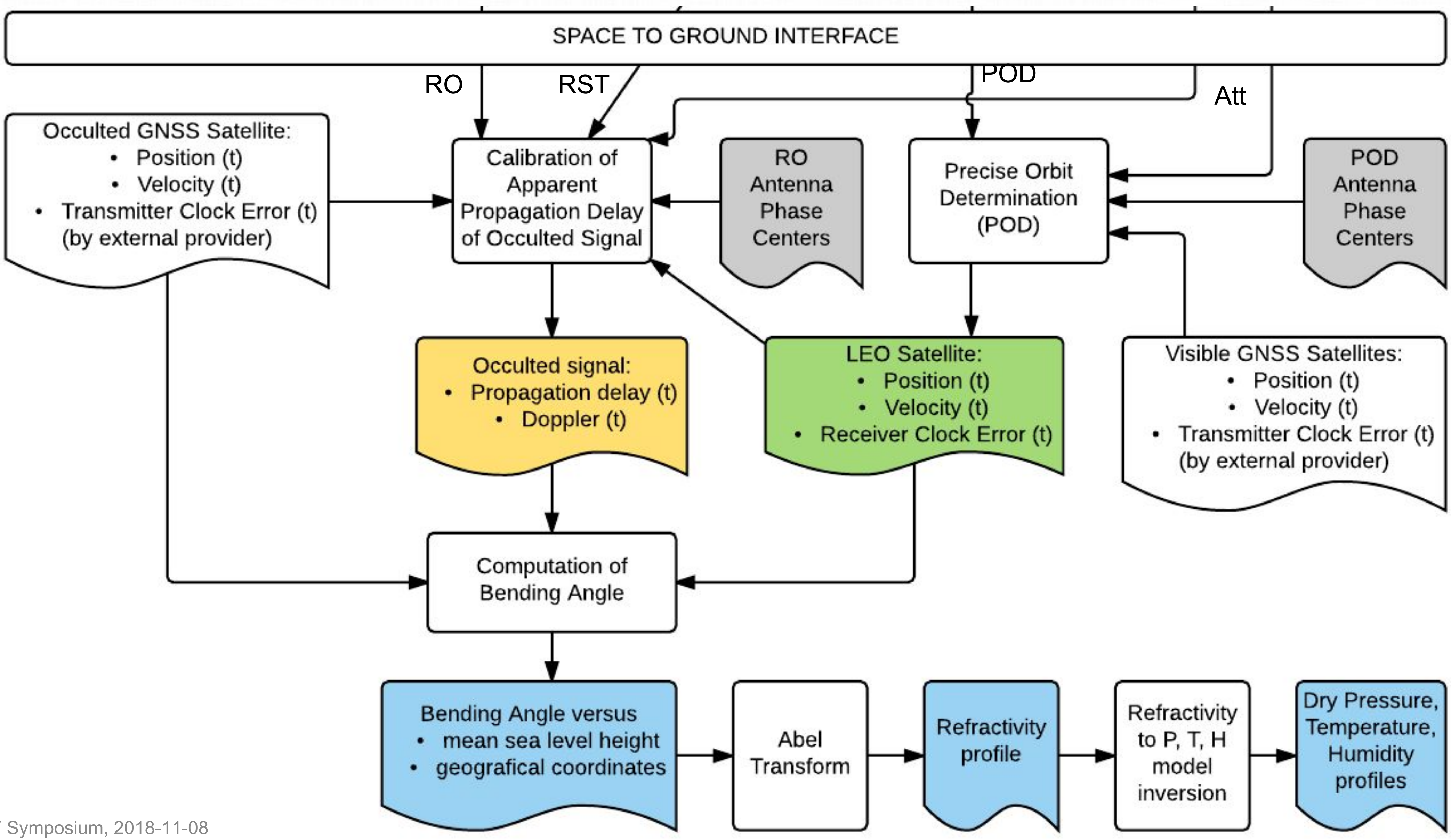
STRATOS RECEIVER RO CONOPS



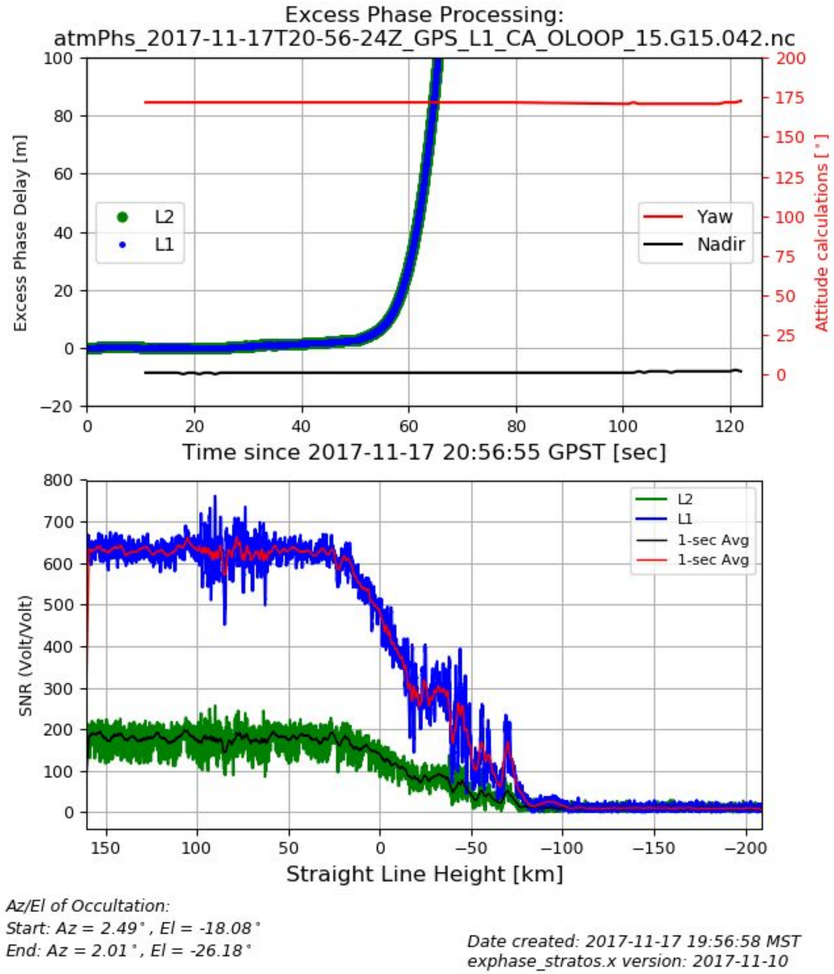
Open-loop tracking of both setting and rising RO events

spire

SPIRE SCIENCE RO PROCESSING



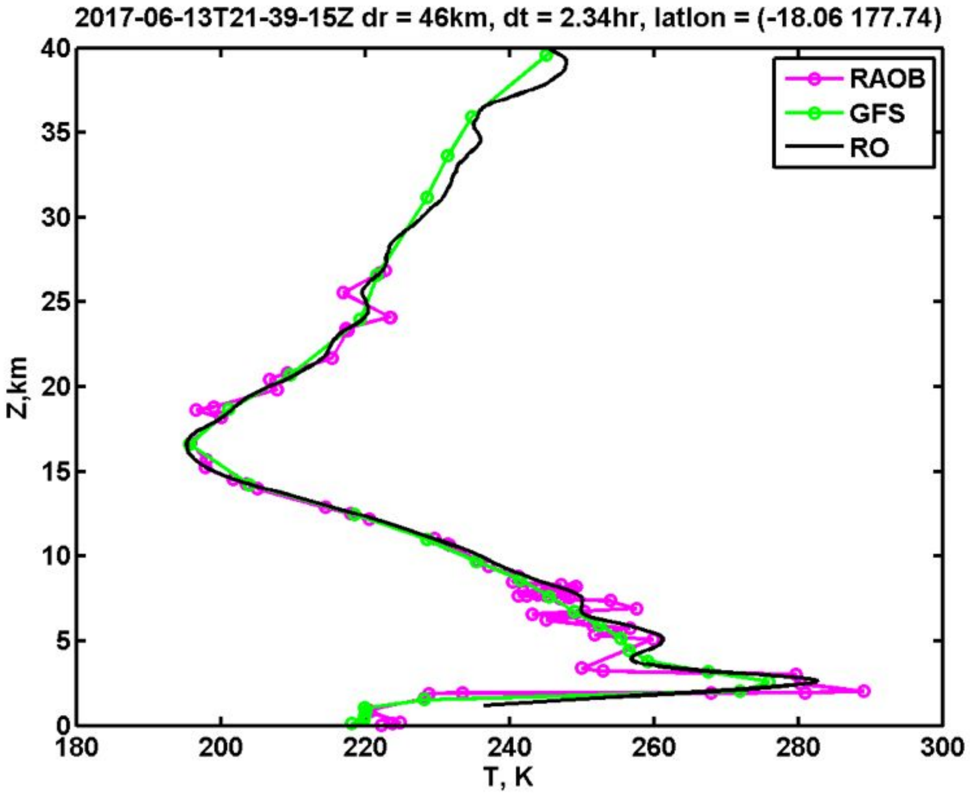
SPIRE SCIENCE RO PROCESSING



Output data from the excess phase processing step. The top plot shows the excess phase delay on the L1 and L2 frequencies as a function of time while the bottom plot shows the L1 and L2 SNR as a function of straight line height during the occultation event. Additionally, there are two lines (red, black) in the top plot which represent the pointing stability of the spacecraft during the occultation event.

GNSS obs

Weather data

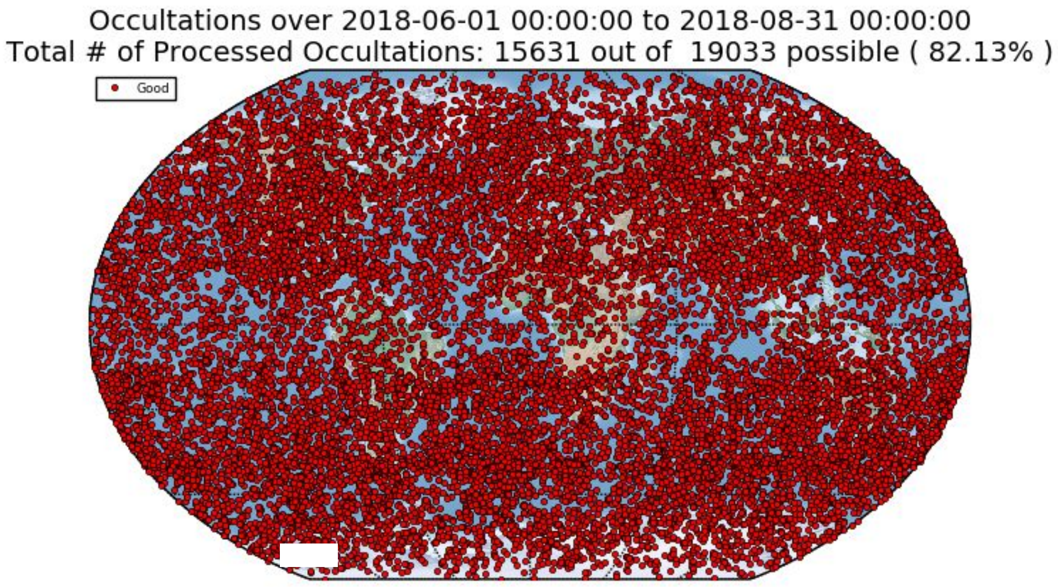


Example of a dry temperature profile derived from radio occultation data collected by a Spire satellite. The Spire observation is compared to a temperature profile predicted by the GFS weather model (GFS) and temperature data obtained from a nearby radiosonde (RAOB).

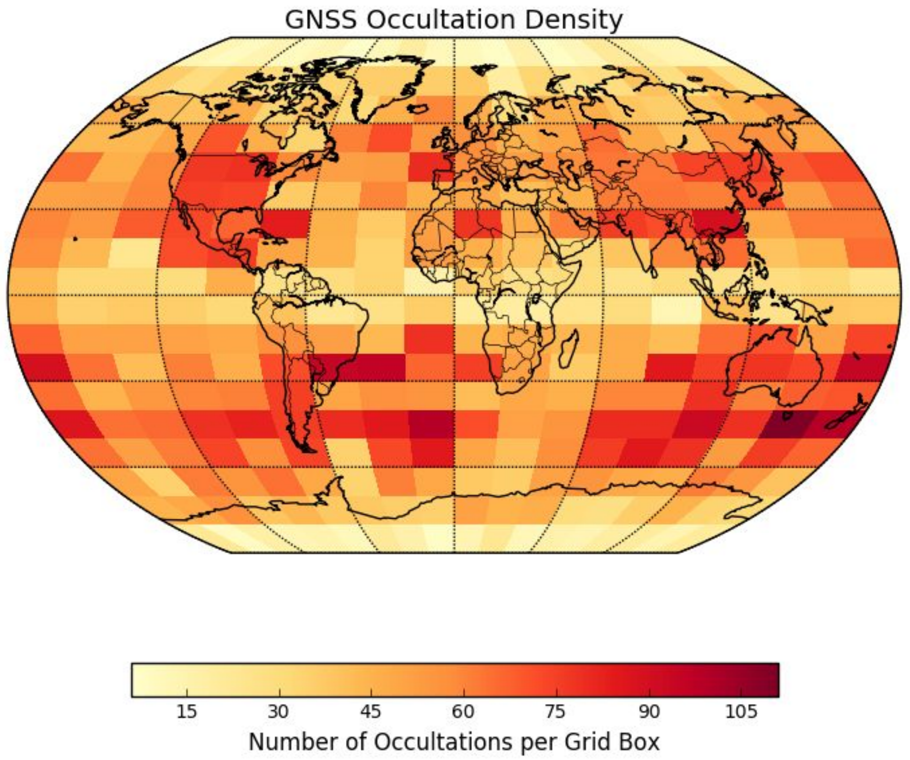
GNSS RADIO OCCULTATION OBS

- RO observables
  - L1a: GNSS L1/L2 signal excess phases
  - L1b: bending angle
  - L1c: refractivity profiles
  - L2: “dry” temperature, pressure (~6-70 km, although climatology dominates above ~50 km), “wet” temperature, pressure, water vapor pressure (< 6 km)
- Vertical sounding resolution: ~100 m
- Along-track resolution: ~200 km
- Across-track resolution: ~1 km
- Accuracy: ~0.5 K
- Assimilation of bending angle improves weather forecasts
- GNSS phase measurement = no drift, no calibration, no inter-instrument biases, no inter-constellation biases = *inherent climate quality*
- Globally distributed measurements over ocean/land/poles
- Spire collected its first RO data in June 2016 (first commercial RO)
- Collecting both rising & setting occultations
- Capable of collecting signals from GPS, GLONASS, Galileo, QZSS now; BDS in 2019
- Full in-house science processing system and customer API
- Operationally delivering RO and TEC data to multiple customers

SPIRE RO SAMPLING CHARACTERISTICS



Geographic locations of retrieved RO profiles



2D histogram of the geographic distribution of the RO profiles

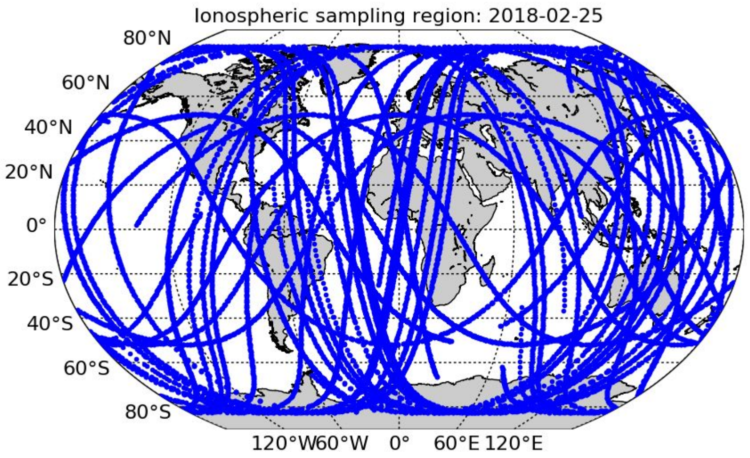
With four launches in the next two months, (*and many more in 2019*), RO density and coverage will dramatically increase

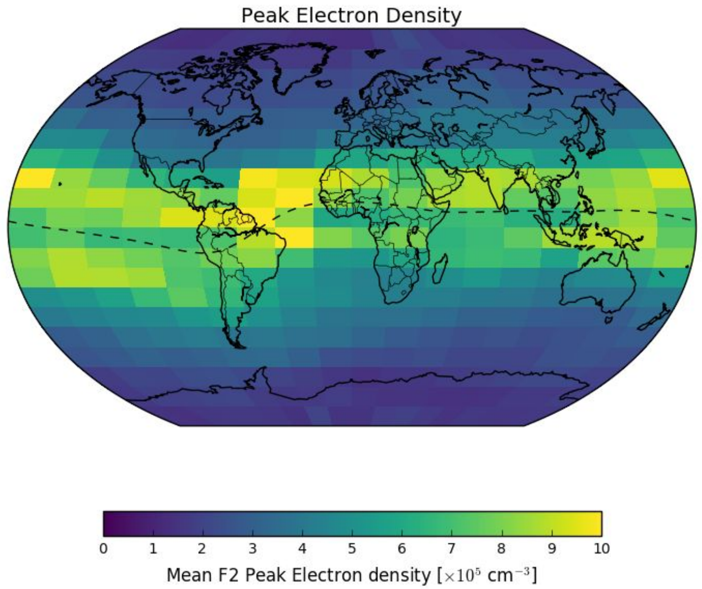
STRATOS GNSS IONOSPHERIC DATA

- Slant total electron content (TEC) and S_4 scintillation is collected along with RO
- Available globally, unlike land-based GNSS ionosphere measurements
- Applications include space weather monitoring, GNSS augmentation (real-time corrections)

STRATOS IONOSPHERE MEASUREMENTS

- Top-side ionospheric information can be derived from dual frequency GNSS signals
  - Slant total electron content (TEC)
  - Scintillation events
  - Electron density profiles
- Spire currently processes over 750,000 TEC samples each day
- Expected growth to 16M TEC with 60 STRATOS payloads
  - In data-denied areas
  - And with low-latency
- Assimilation into upper atmospheric models for improved space weather forecasting predictions

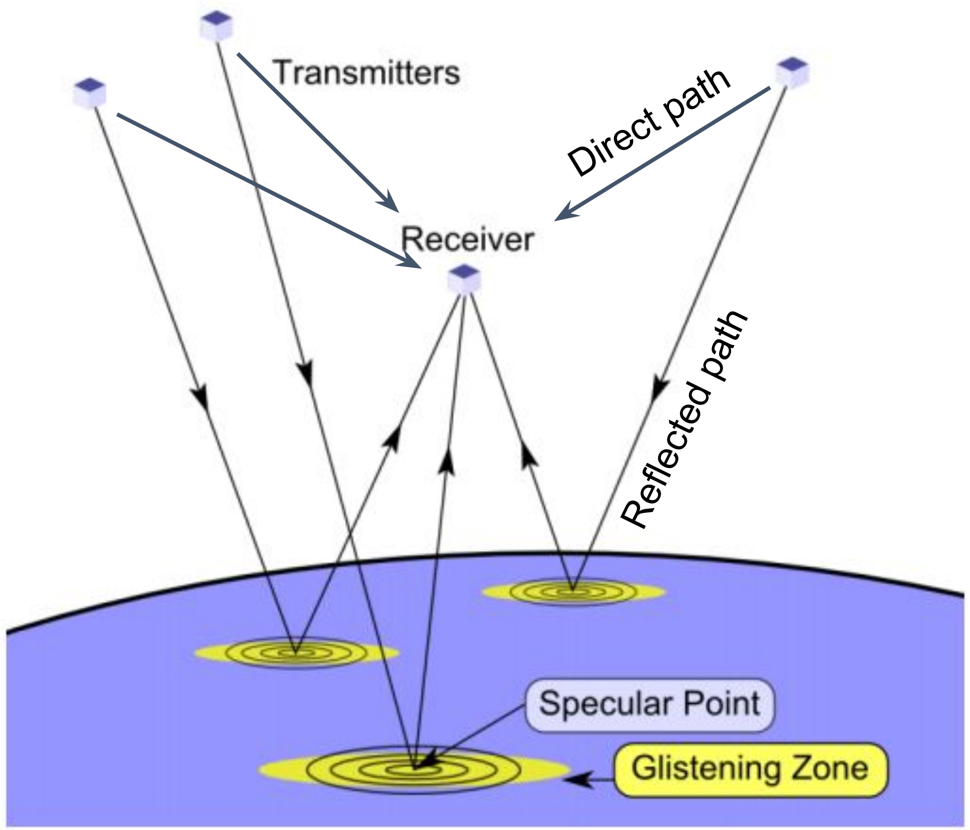


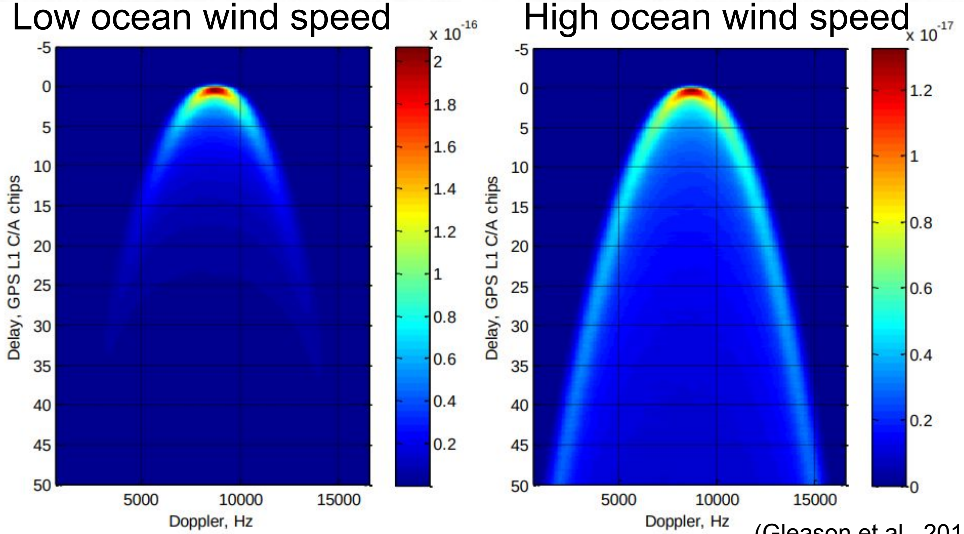


NEW MISSION:
GNSS PASSIVE BISTATIC RADAR (GNSS-R)

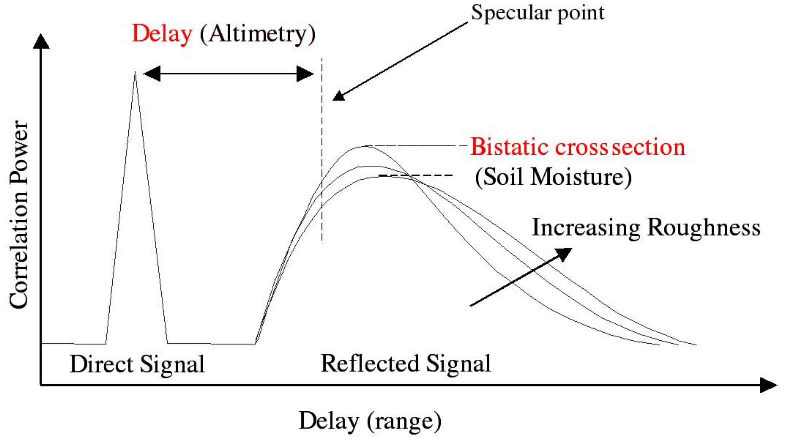
STRATOS GNSS BISTATIC RADAR

Passive bistatic radar using GNSS signals that estimates Earth surface properties through the radar scattering cross-section or delay observable



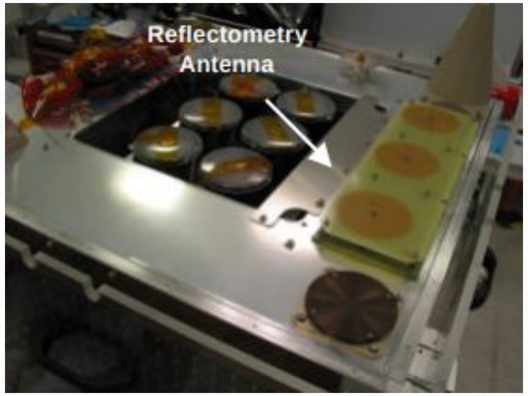


(Gleason et al., 2017)



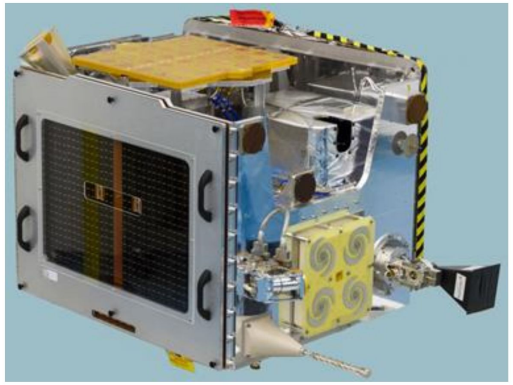
spire

GNSS BISTATIC RADAR HERITAGE



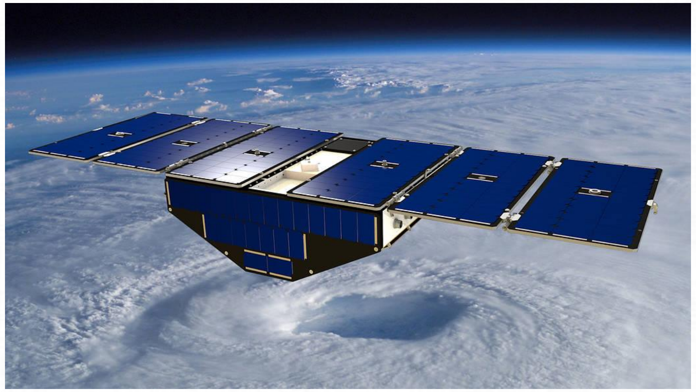
UK-DMC (SSTL)

- Collected very limited quantity of sampled IF data sets
- ~11.8 dBi antenna
- Proof of concept
- No calibration



TDS-1 (SSTL)

- Shared duty-cycle with other payloads
- Still operational (now collecting 100% duty cycle)
- ~13.3 dBi antenna
- Still proof of concept
- Problems w/ calibration



CYGNSS (NASA, U. Michigan)

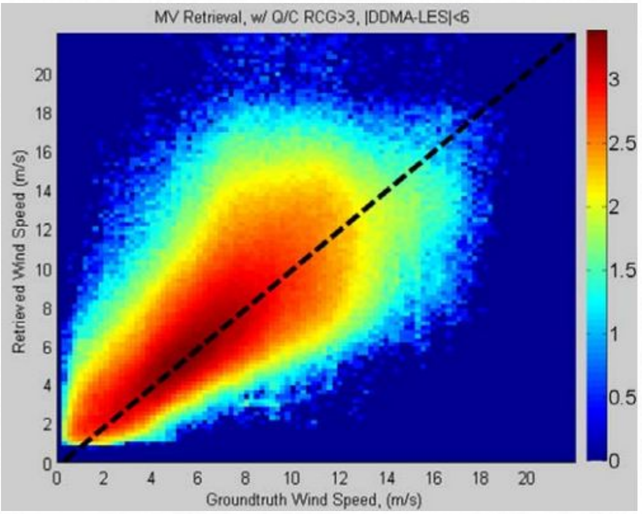
- Constellation of 8 sats
- Similar receiver as TDS-1
- ~14.6 dBi antenna
- Hurricane application
- Problems w/ calibration
- Nearing nominal mission lifetime

Spire is now designing and building GNSS-R missions

- Same STRATOS receiver as Spire RO payload
- Same POD antenna
- L1 LHCP deployable GNSS-R antennas
- Relative channel calibration
- Launch in 2019

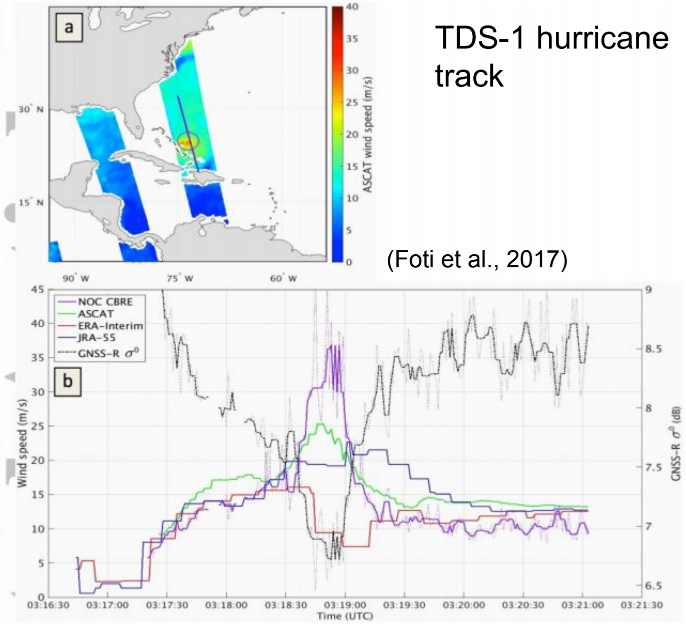
spire

GNSS BISTATIC RADAR APPLICATIONS



CYGNSS wind speed performance

(Ruf et al., 2017)

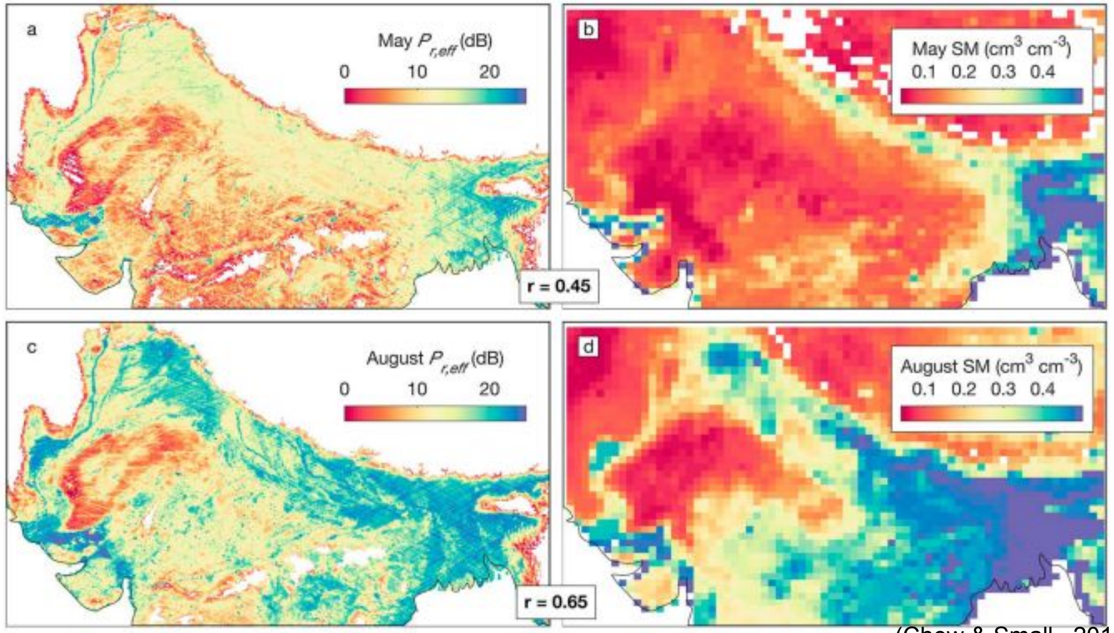


TDS-1 hurricane track

(Foti et al., 2017)

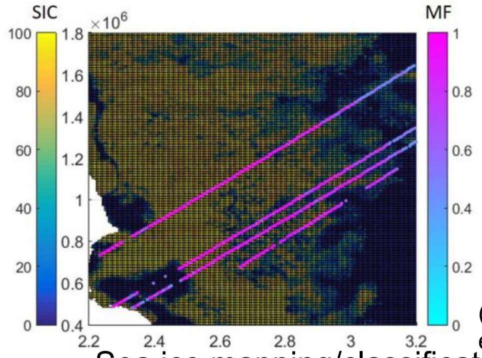
Ocean roughness and wind speed measurements 2-3 m/s RMSE (with hurricane penetration)

CYGNSS soil moisture SMAP soil moisture



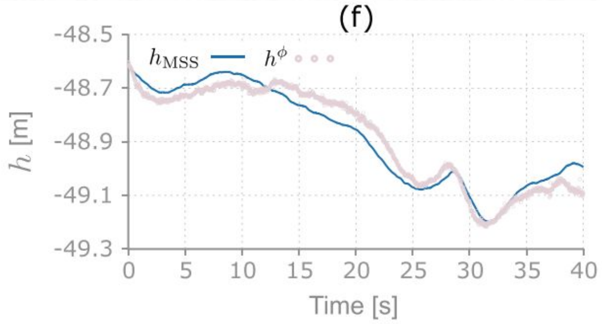
(Chew & Small., 2018)

Soil moisture measurements at potentially much finer (0.2-25 km) spatio/temporal resolution than SMAP

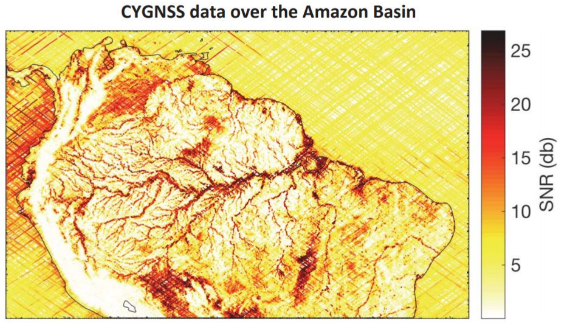


(Alonso-Arroyo et al., 2017)

Sea ice mapping/classification



Phase delay ocean alimetry (Li et al., 2017)



Wetlands/flood mapping (0.2 km) (Chew et al., 2018)

SPIRE EARTH OBS DATASETS & PLANS

2018 → **2019** →

GNSS-RO

- Atmospheric profiles (temp, pressure, water vapor)
- Ionosphere slant TEC, S_4
- Grazing angle altimetry (sea surface height)

GNSS-R

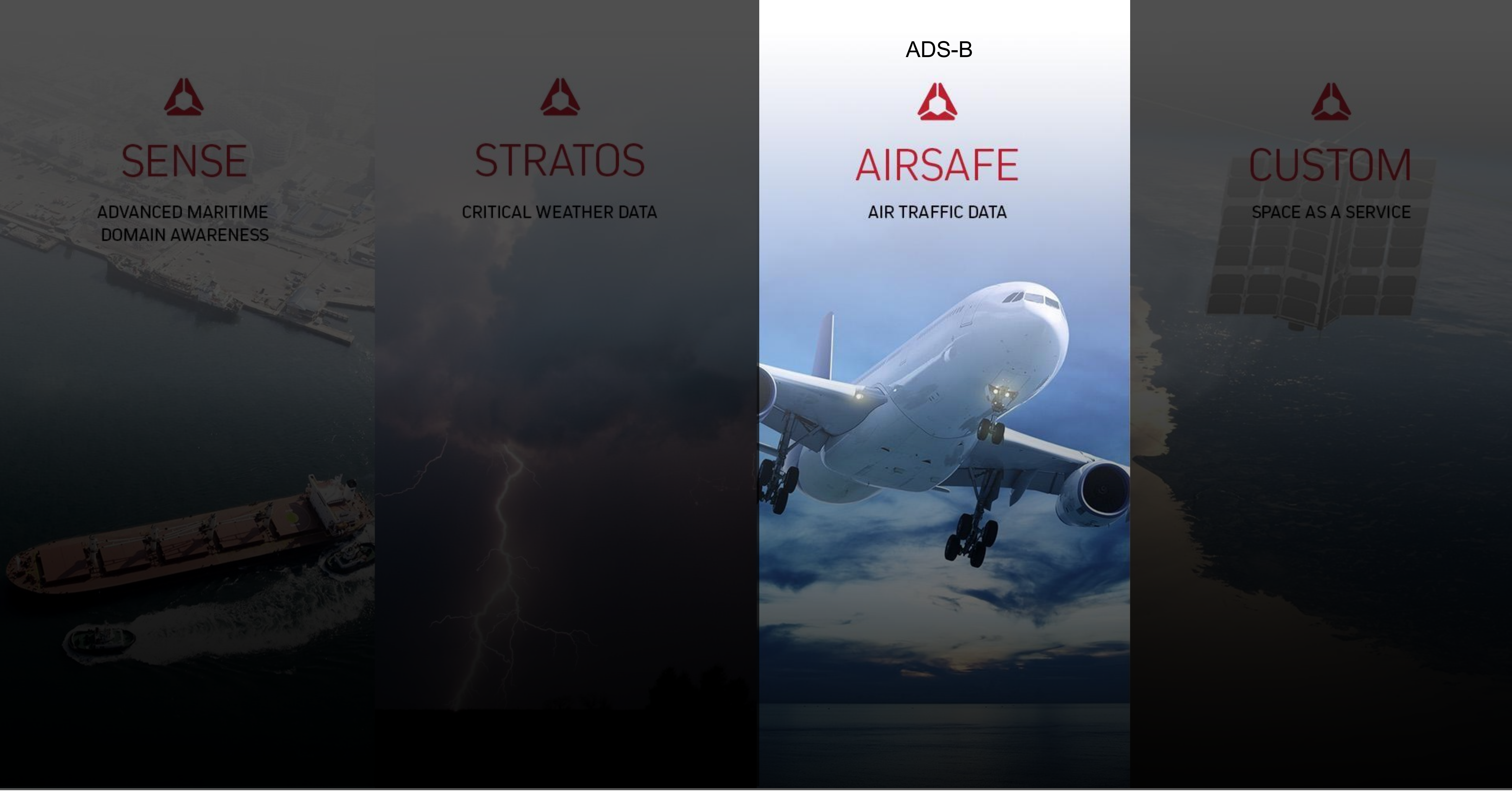
- Soil moisture
- Ocean wind/waves
- Sea ice
- Wetlands/flood inundation

New Spire-Designed Sensors

Hosted Payloads

Possible other signals of opportunity

- MUOS-based P-band reflections (root zone soil moisture & snow water equivalent)
- Ku-band reflections (coastal sea surface heights)


ADS-B
SENSE
ADVANCED MARITIME DOMAIN AWARENESS
STRATOS
CRITICAL WEATHER DATA
AIRSAFE
AIR TRAFFIC DATA
CUSTOM
SPACE AS A SERVICE

WHAT IS ADS-B?

Automatic (no human interaction)

Dependent (depends on aircraft navigation)

Surveillance (ATC technology)

Broadcast (periodic)

- Provides aircraft's position from GNSS (or inertial for older installations)
- Velocity, callsign, status
- Versions 0, 1 and 2 (DO-260/ED-102)
- Required in US by 2020 (DO-260B)

1090ES (1090 MHz extended squitter)

- Part of Mode-S secondary radar standard
- 112 bits (8 type/capability, 24 address, 24 CRC, 56 ADS-B)
- Full position in two messages (odd/even)
- Average rate 5.2 messages per second
- Lower and upper antenna alternation
- Uniform distribution in time

UAT (978 MHz) - Universal Access Transceiver

- ADS-B plus other services

TIS-B (Traffic Information Service)

FULFILLING ICAO MANDATE

Requirement to report latitude, longitude, altitude, and time every 15 minutes by Nov 8, 2018

Applies to:

- Airplanes with a seating capacity greater than nineteen
- Aircraft with a take-off mass of 45,500 kg when flying over oceanic areas
- Recommended operational use for all aircraft with a take-off mass of 27,000 kg

No strong recommendation on how to comply, but ADS-B will soon be required by most countries around the world

- Already required in Hong Kong, Vietnam, Sri Lanka, Singapore, Taiwan (2017), Australia (2017), and many more
- North American and Europe will require ADS-B Out by 2020

Technology Path to 1 minute latency by required date (2020)

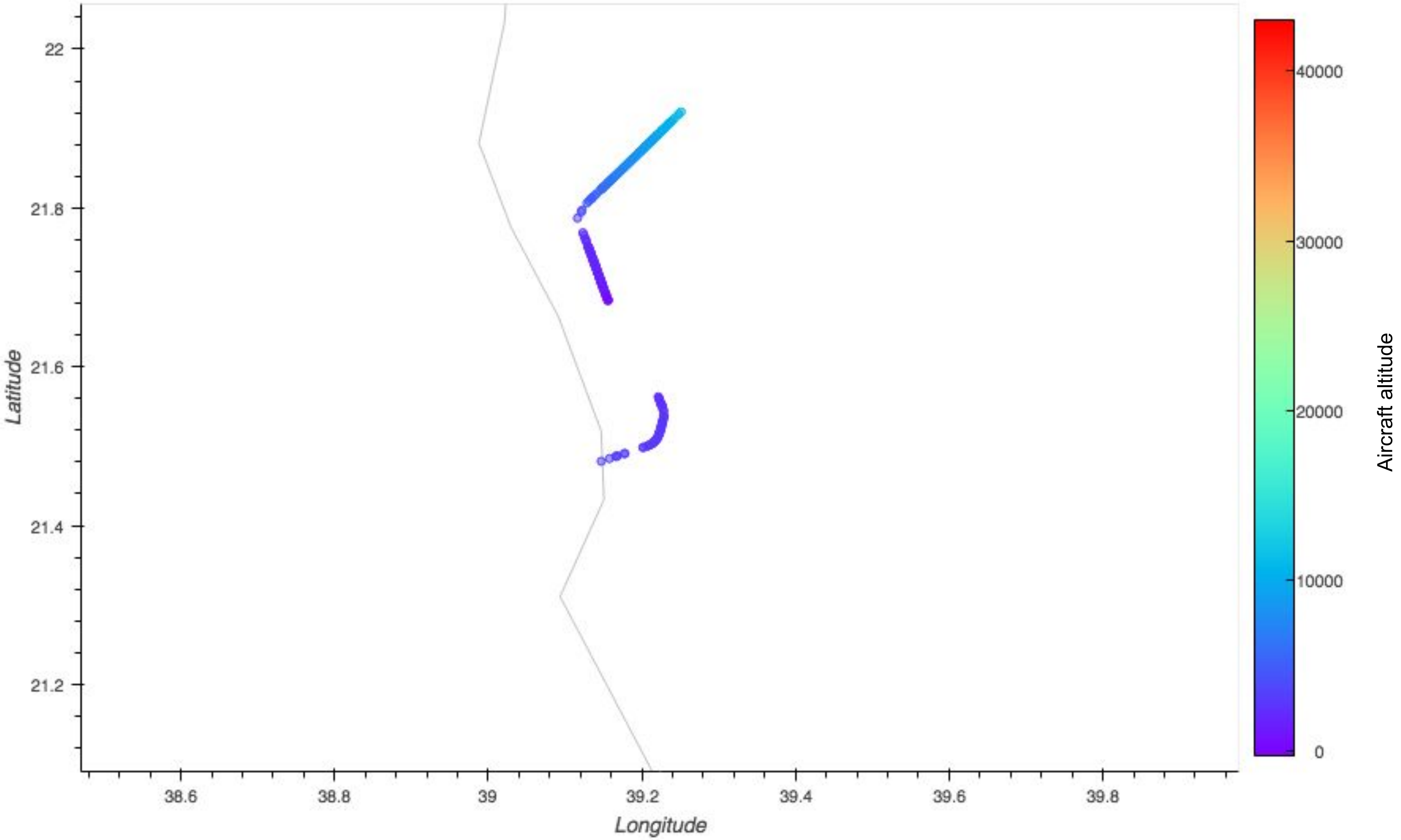
SPIRE ADS-B CONSTELLATION

- 4 active ADS-B satellites (as of Nov. 2018)
- Four segment antenna with tilted main beam
- State of the art software-defined ADS-B/AIS receiver
- ARM Cortex-9 / Xilinx Zynq 7000
- Yocto Linux
- ADS-B demodulation in FPGA
- Messages decoding and processing in CPU
- Peak capacity 7500 messages per minute per satellite
- Antenna footprint 2.5 million km^2
- Many ADS-B capable sats to be launched in coming months
- Following slides show recent early on-orbit ADS-B results

SPIRE SINGLE SATELLITE ADS-B RESULTS

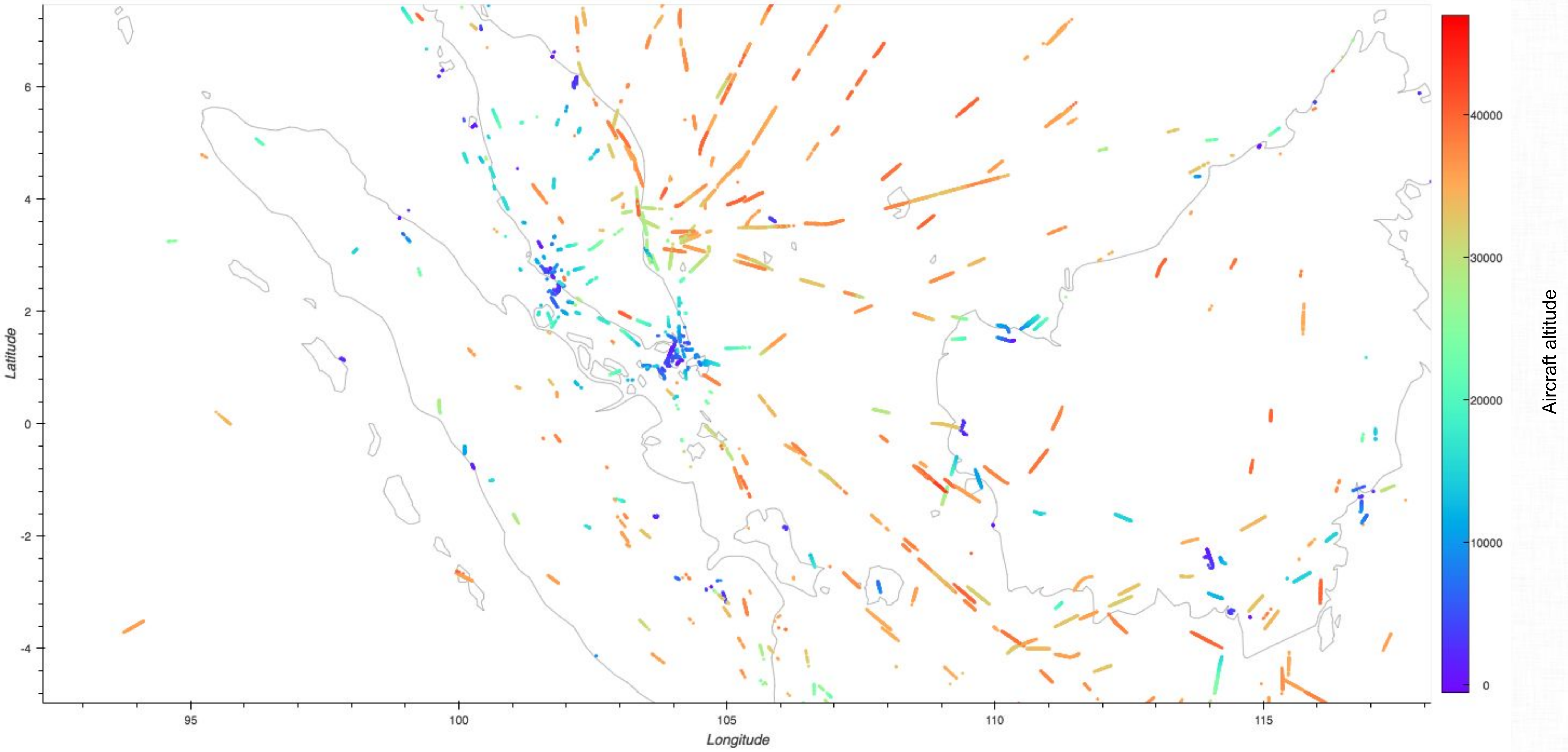
Data collection over recent 11 days, 1 hour per day: > 750K messages and > 250K positions
Subsequent plots are sub-regions of interest

AIRCRAFT LANDING/TAKE-OFF, JEDDAH, SAUDI ARABIA



The tracks are very close to the ground. The “missing piece” is a runway.

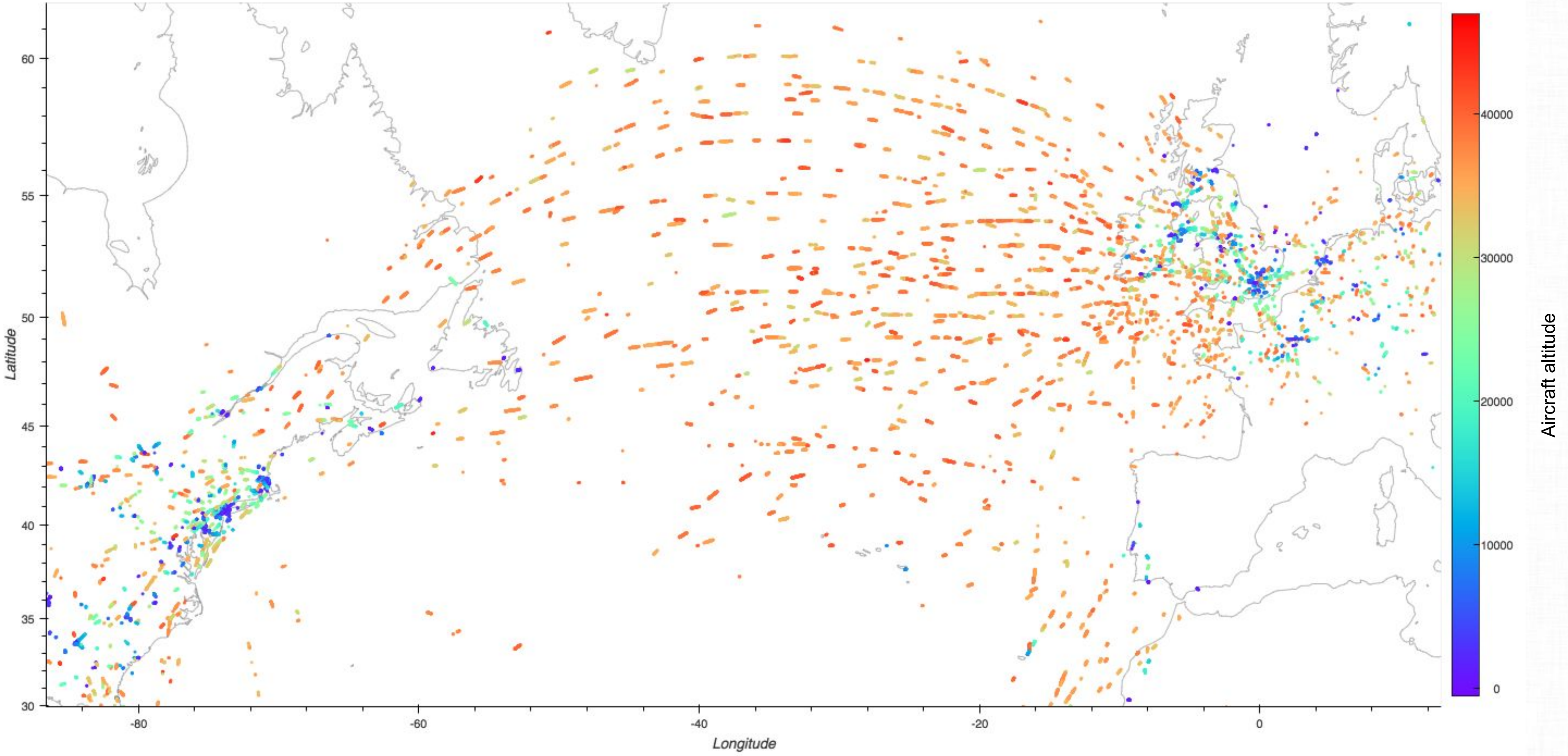
AIR TRAFFIC AT SINGAPORE



Singapore is the large blue area near ground level in the middle of the map.

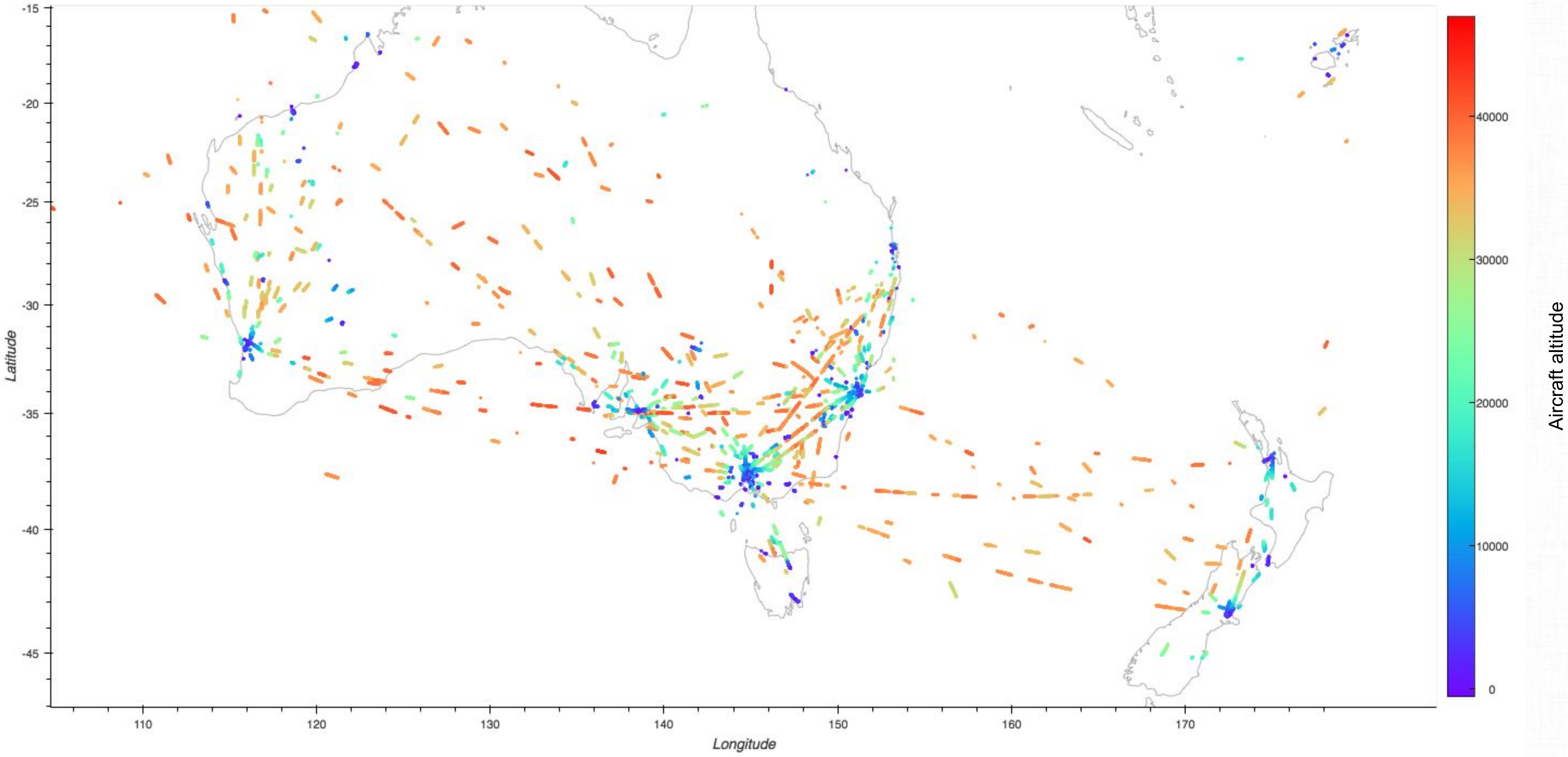
spire

TRANS-ATLANTIC AIR TRAFFIC

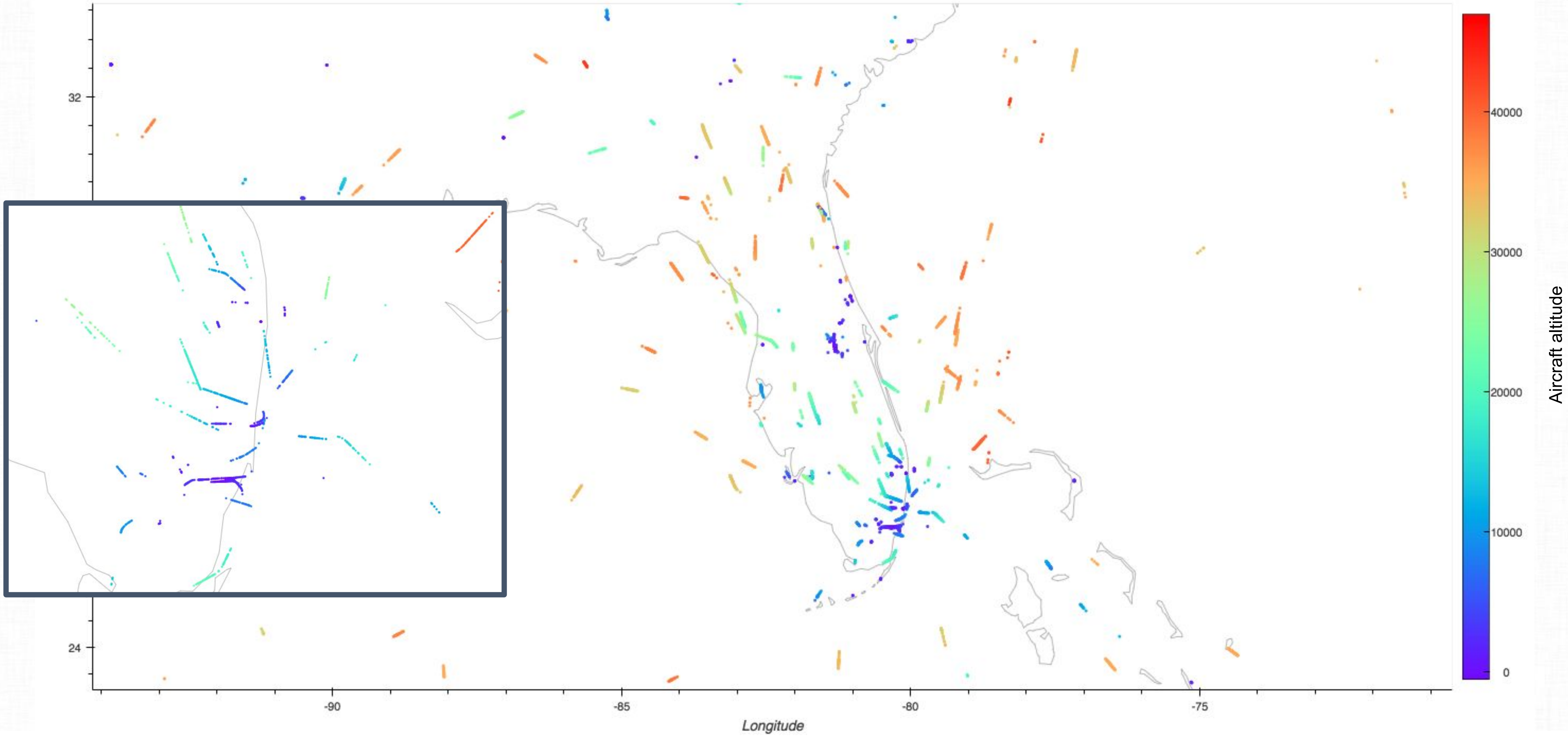


spire

AUSTRALIA & NEW ZEALAND

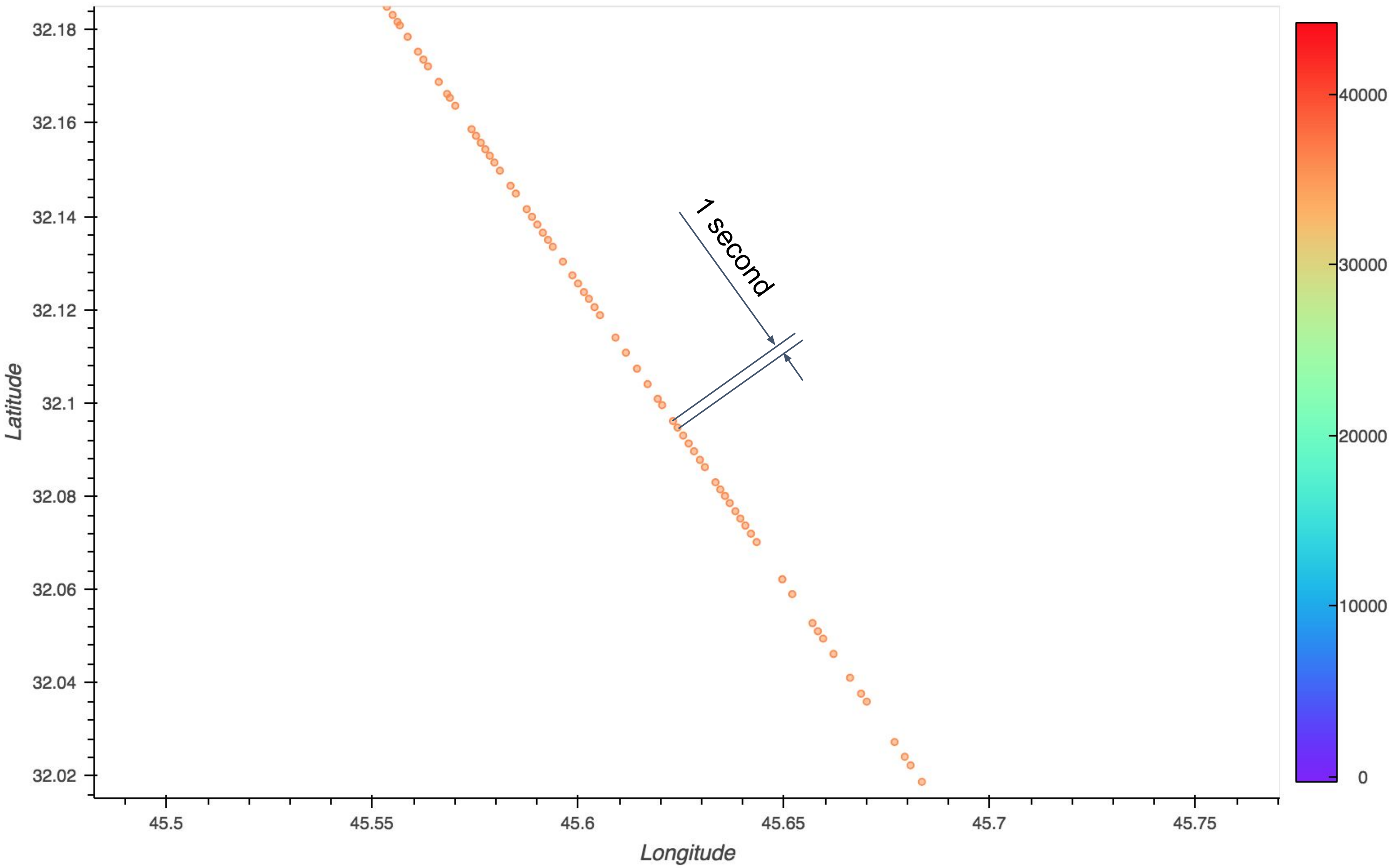


FLORIDA: MIAMI IN DETAIL



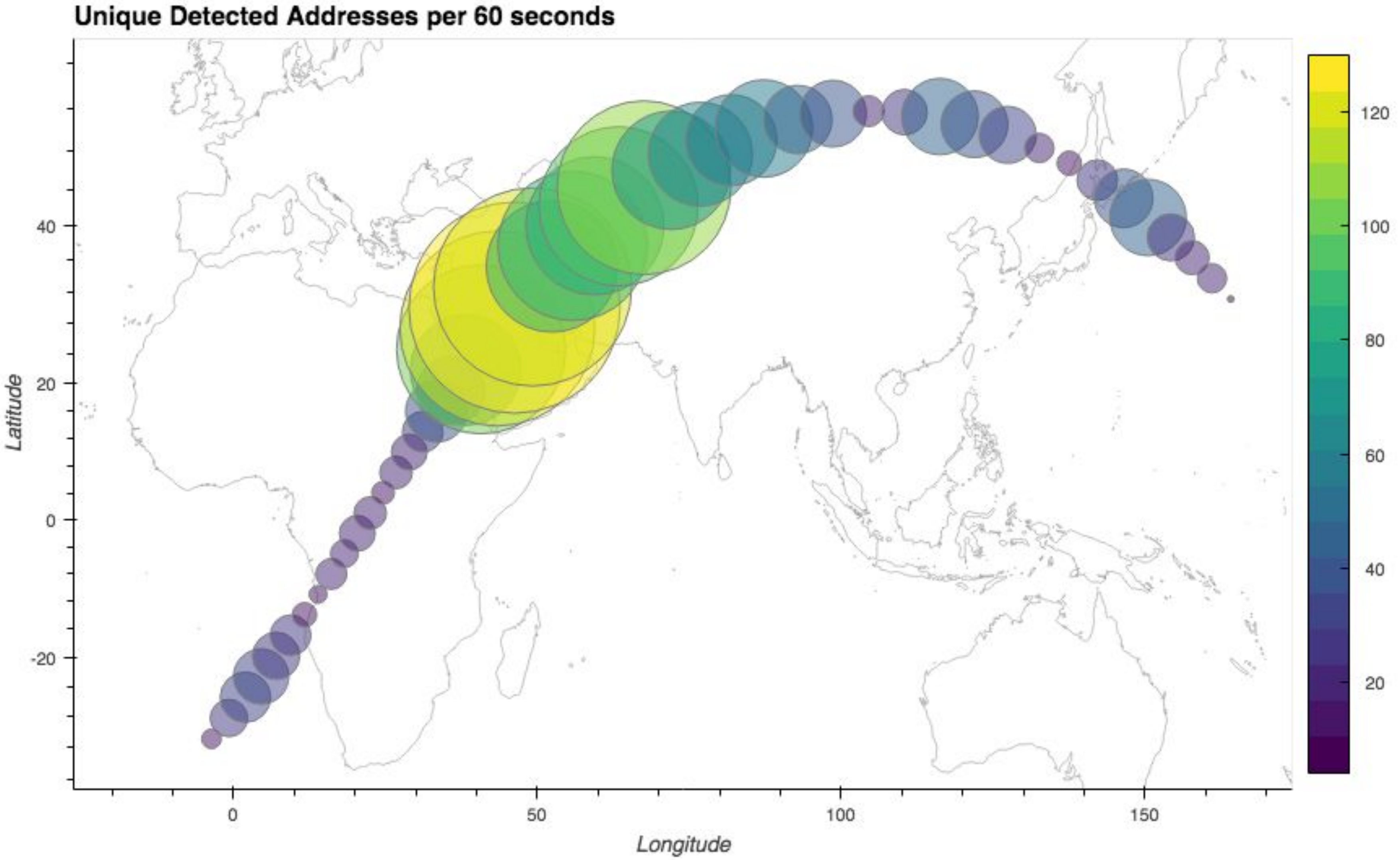
spire

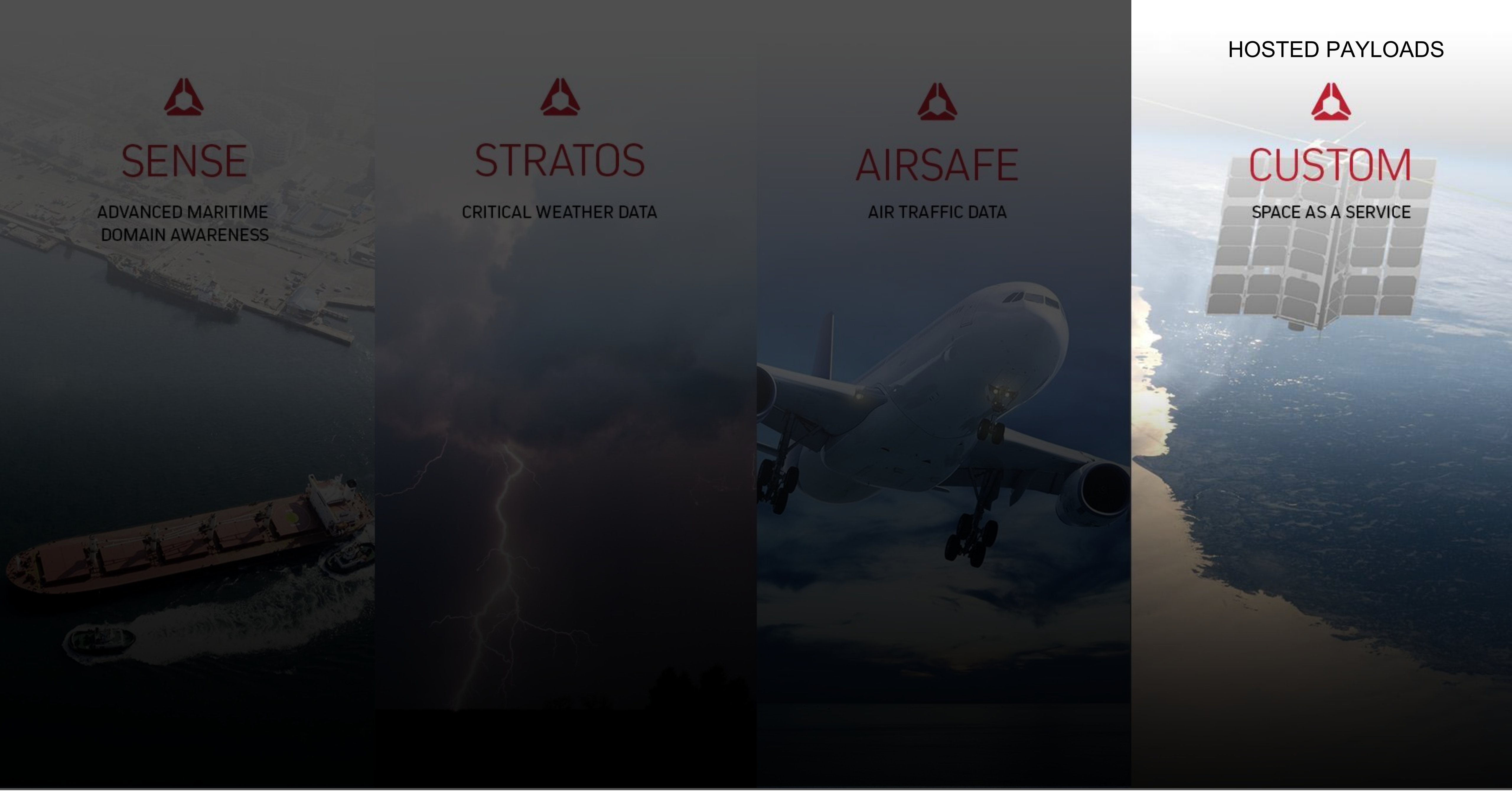
DETAIL OF AN AIRCRAFT TRACK



spire

ADS-B AIRCRAFT PER ORBIT ARC




HOSTED PAYLOADS
SENSE
ADVANCED MARITIME DOMAIN AWARENESS
STRATOS
CRITICAL WEATHER DATA
AIRSAFE
AIR TRAFFIC DATA
CUSTOM
SPACE AS A SERVICE

SPACE AS A SERVICE

- About 1U free space available on each satellite, on each launch
- Ability to get new payloads into orbit within 6 months
- High level ICD for space, volume, power, data-download volume available
- Service includes all testing, integration, licensing, launch, and operation for up to 2 years

spire

SPIRE GOAL: DOUBLE GDP GROWTH

- Growth, especially in some of the most underserved parts of the world, does actually solve problems
- Through assimilation of Spire satellite data into weather forecast models

spire

WEATHER FORECAST IMPROVEMENT YIELDS MAJOR RESULTS

1/3 of GDP Impacted By Weather[1]

Eradicate mitigatable losses, double global GDP growth!

1/10th of impact can be mitigated[2]

Mitigated Weather Losses = 3% of GDP per year

Current GDP Growth = 3% per year

[1] Dutton, 2002, BAMS, *"OPPORTUNITIES AND PRIORITIES IN A NEW ERA FOR WEATHER AND CLIMATE SERVICES"*
[2] Lazo 2011, AMS, *"US Economic Sensitivity to Weather Variability"*

spire

NEW SPACE CHANGES THE PARADIGM

Constellation Design 1.0	Constellation Design 2.0
Legacy Space	New Space
$1 Billion	**$0.1 Billion**
15 Years	**5 Years**
Iridium, Orbcomm, O3b, Disaster Monitoring Constellation, Globalstar, …	Spire, Planet, ?
Value found in: The Hardware	Value found in: **The Data**

You need to be 10x better or cheaper to create a new market.

Peter Drucker

spire

DRIVING DOWN ACCESS COST FOR THE PUBLIC

$3m

SPACENEWS magazine

HOME ISSUE + FEATURES COLUMNS + LOG IN | SUBSCRIBE SPACENEWS.COM

NOAA's Commercial Weather Data Pilot Takes Flight

Stephen Volz April 11, 2016, My Take

For decades, NOAA has had a robust, mutually beneficial relationship with our private sector aerospace industry partners. Commercial space services are rapidly changing and new approaches are emerging for the development and operation of satellites, drawing many more data service providers into the Earth observation market. To guide the agency's efforts to capitalize on the opportunities offered by these changes, NOAA released a policy framework earlier this year to acquire new satellite weather data from industry. NOAA's Commercial Space Policy outlines the tools NOAA will use in this effort as well as the principles to guide it.

Stephen Volz, assistant administrator for NOAA Satellite and Information Services. Credit: Kate patterson

We've expanded the role of our Office of Space Commerce to be a single point of entry for companies interested in working with us.

We will continue to hold industry roundtables to maintain an ongoing dialogue throughout the process. The key word is "dialogue;" we want to make a point of two-way, collaborative discussions to share information on needs, capabilities, and capacities.

The nation counts on the accuracy and timeliness of the data and services NOAA and its space agency partners have provided for more than 40 years. We must ensure any new data we acquire is useable and based on the best available science. We must maintain the standards outlined by NOAA's National Weather Service as we look to expand our observational capabilities, either through government deployed systems, international partnerships, or commercial solutions.

This isn't about government obstruction. It's about maintaining and improving the accuracy of our forecasts, watches and warnings. NOAA is committed to an open and transparent process, and we will communi-

$20m

WIRED How Smallsats Could Make a Big Difference for NASA and NOAA

SHARE
SHARE 153
TWEET
COMMENT
EMAIL

SARAH SCOLES SCIENCE 01.23.18 08:00 AM

HOW SMALLSATS COULD MAKE A BIG DIFFERENCE FOR NASA AND NOAA

An engineer at Spire, a smallsat company that got a NOAA contract in 2016, prepares a satellite for antenna testing. SPIRE

INFORMATION FROM SPACE has historically been the province of the rich and powerful. Big Earth-observing satellites can cost hundreds of millions of dollars to build and launch, and the price of their data scales accordingly. Scrappy scientific upstarts have, for a while, been building smallsats to get orbital data on the cheap. And while a single smallsat won't give a small company or nation-state all-seeing powers, if you put a bunch of them together to form a constellation, you can get rapidly refreshed information on the planet.

$6m

GOV.UK

Search

Departments Worldwide How government
Policies Publications Consultations Stati

Home

News story

UK Space Agency backs Spire as ESA space mission provider

The UK Space Agency has awarded more than £4 million to Spire Global to demonstrate cutting-edge space technology including 'parallel super-computing'.

Published 1 February 2018
From: Office of the Secretary of State for Scotland, UK Space Agency, The Rt Hon Lord Henley, and Lord Duncan of Springbank

Artist's impression of an ARTES programme mission. Credit: ESA.

Today's announcement by UK Government ministers Lord Henley and Lord Duncan, gives the green light to missions designed to showcase the technology and put UK companies into orbit faster and at a lower cost. The UK is the largest funder of the European Space Agency's Advanced Research in Telecommunications Satellites (ARTES) programme, which transforms research into successful commercial projects.

AVERAGE NASA MISSION COST OVER LAST 60 YEARS: >$3,000m

LOOKING FORWARD

TECHNOLOGY DEVELOPMENT

- Increased GNSS-RO capabilities: quantity, quality, Beidou
- Global ADS-B services
- Increases in satellite capability through constant iteration
  - Including increases in computational and downlink abilities
- Robust data & analytics services
- GNSS-R and other signals of opportunity missions launched

spire

Credit to Spire Teams:

David Manda, Svante Eriksson, Adam Dunbar, Sandy McDonald, Peter Platzer, Joel Spark, Jeroen Cappaert, Sarah Preston, Nick Allain, Vu Nguyen, Tim Duly, Vladimir Irisov… and the entire Spire Team.

For technical questions, please contact:

AIS: Svante Eriksson, svante.eriksson@spire.com

ADS-B: David Manda, david.manda@spire.com

GNSS: Dallas Masters, dallas.masters@spire.com

Thank you!