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GNSS Interference Detection from Low Earth Orbit

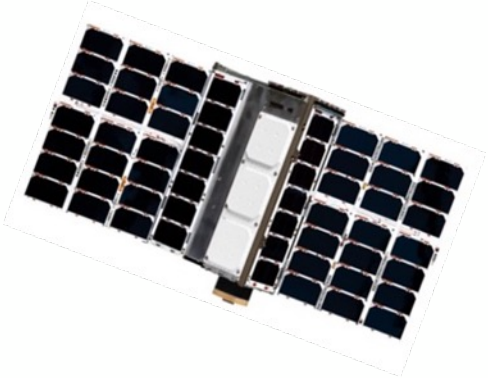
APRIL 15, 2024

Iain Goodridge Sr. Dr. RFGL Products, Spire Global

Introductions

Iain Goodridge

Sr. Dr. RFGL Products



Spire Global, Inc.

(NYSE: SPIR) is a US Company headquartered in Northern Virginia with over 400 employees

Agenda

Spire Overview

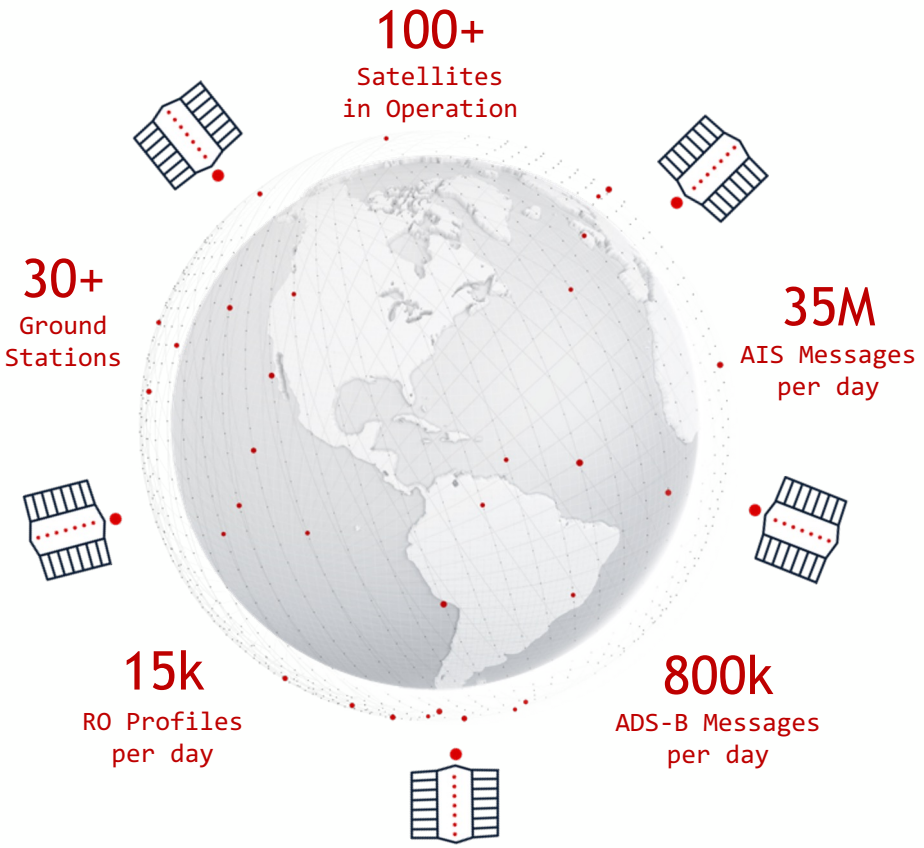
Geolocation of Terrestrial GNSS Jammers from Low Earth Orbit

Accessing the Data and Q&A

The Spire Constellation

The largest multipurpose constellation in the world

- The Low Earth Multi-Use Receiver (LEMUR) is Spire's 3U through 16U CubeSat platform used to track maritime, aviation, and weather activity from space
- We operate the world's largest RF sensing fleet and are the largest producer of radio occultation (RO) data
- Our data provides a global view with coverage in remote regions like over oceans and at the poles
- We are continuously launching improved sensors and upgrading them in-orbit
- We turn ideas into live data feeds from space in as little as 6-12 months



Global Ground Station Footprint

We own and operate the most geographically dispersed and largest network for ground stations, which allows us to repatriate our satellite-generated data at record speed

30+
Ground stations

70+
Antenna systems

Spire's Ground Station Network

Spire Market Sectors & Product Verticals

Maritime

Leveraging the International Maritime Organization AIS standard, Spire provides constantly-refreshed information on the state of the global waterways

Aviation

Sensing the ICAO-backed ADS-B standard, Spire is able to generate near real-time information on the movements of all civilian aircrafts across continents and oceans for a long suite of regulatory and operations applications

Critical Weather Data

Spire generates global space-based weather data at various vertical levels, with critical implications for severe weather events forecast, preparation and management

Weather Modeling

Spire generates unique data sets of Earth's surface and atmospheric layers using GNSS remote sensing techniques such as radio occultation and reflectometry

Soil Moisture

With our reflectometry data, Spire's satellites provide precision agriculture users with a quickly-refreshed database on the soil moisture level of their fields, enabling smart yield-critical decisions

Ionosphere

Spire constantly generates data on the local states of the Earth's ionosphere, the outermost atmospheric layer before outer space, with critical applications for telecoms, mobility and defense entities

Space Services

Spire offers access to its proven LEMUR platform for a wide range of sensing or telecom applications in a variety of all-inclusive packages

Radio Frequency Geospatial Intelligence

Spire offers provide comprehensive insights into global RF activity. Leveraging a vast network of satellite-based sensors and advanced analytics

Spire Frequency Collection Bands

Frequency range	Signal	Illustrative use case
VHF (30-300MHz)	AIS	Detection of vessels breaching international sanctions
L1/L2/L5 - band (1.1-1.5GHz)	GNSS	Localization of GNSS jammers & spoofers in contested areas
L - band (1-2GHz)	ADS-B, Satellite phones	Detection and geolocation of potential criminal activities
S - band (2-4GHz)	Sat. Comm, WiFi, wireless cellular	Tracking of vessels with their AIS transmitters turned off and of illegal activities in remote areas
X / S - band (3 and 9.4 GHz)	Maritime radar	
Ku - band (12-18GHz)	Sat. Comm. (D/L), broadcast, Starlink	Spectrum usage and coverage
Ka - band (27-40GHz)	Sat. Comm., military radar, P2P wireless	Identification and geolocation of military assets

Active/on-orbit

Under development

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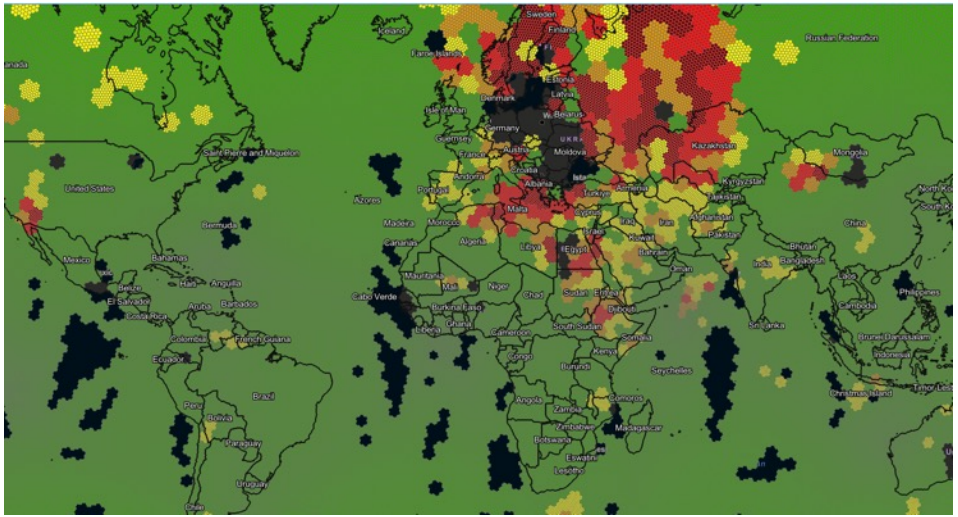
Accessing the Data and Q&A

Spire GNSS Monitoring

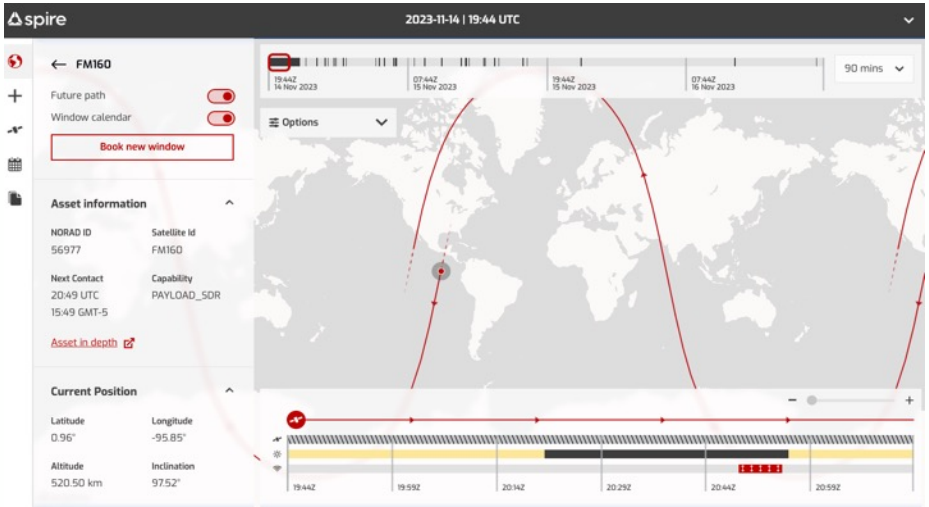
Extracted from ADS-B



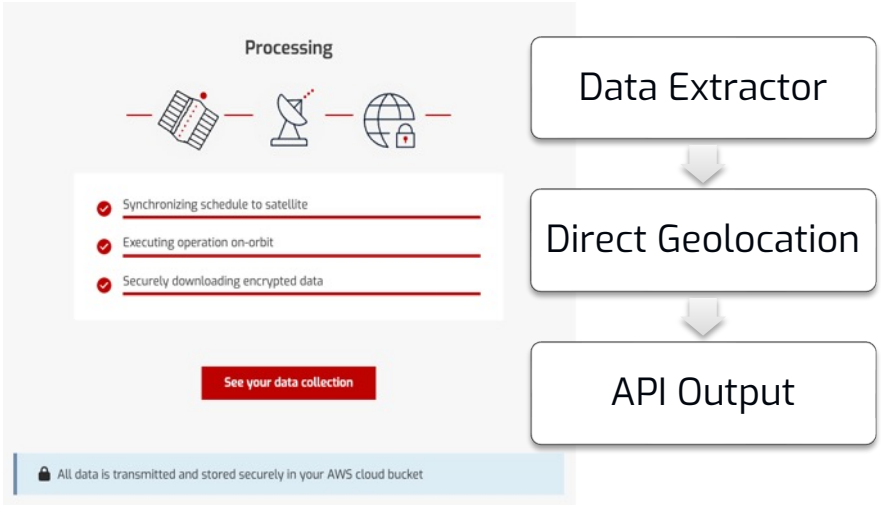
Extracted from GNSS-R Noise

Automated RFGL TCPED Engine

Tasking of Spire Satellites using web-based console or API to acquire Raw IF/IQ



Raw IQ downlinked to cloud infrastructure, processed, & geolocated within 24 hours



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Space-based GNSS interference monitoring has the potential to offer continuous global situational awareness and interference characterization.

Example Dual-Satellite Capture

Simultaneous collections of raw IF samples centered at GPS L1 and L2 can be performed. These raw samples along with the onboard navigation solution are used for geolocation.

Ground tracks of the satellites during two 60-second simultaneous captures from April 2022.

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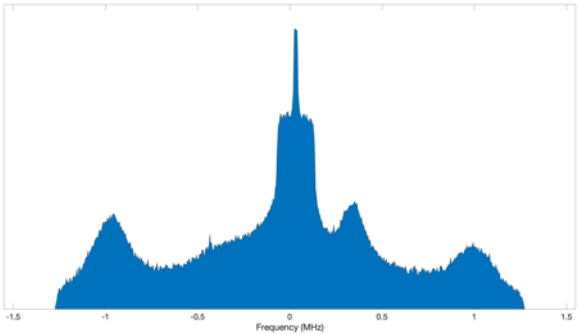
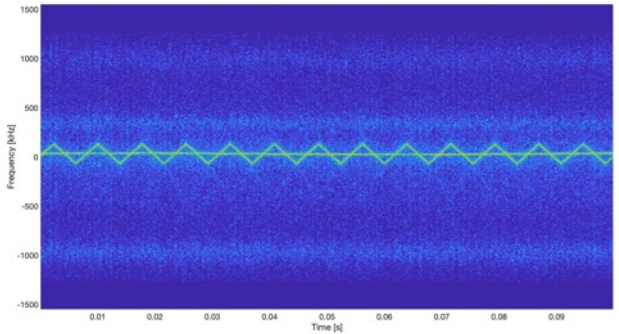
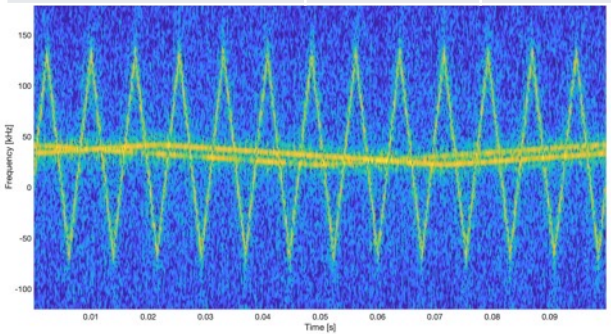
	Bandwidth	Period
Higher BW Chirp Jammer	200 kHz	8 ms
Lower BW Chirp Jammer	20 kHz	100 ms

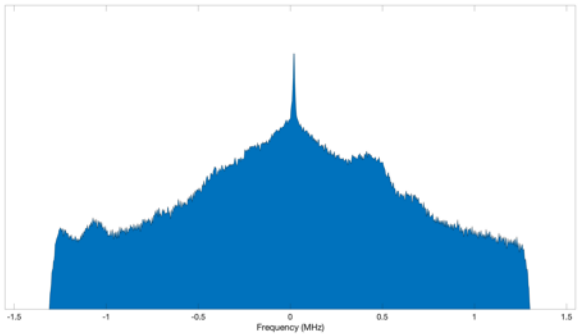
GPS L1

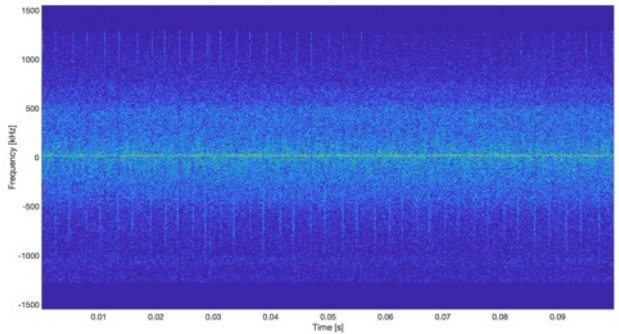


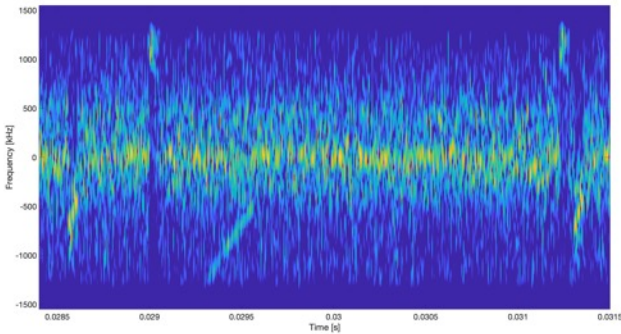




GPS L2







There is composite wideband interference on both GPS L1 and L2. There are powerful chirp jammers on L1. In addition to GNSS jammers, long range radars are visible on L2.

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Direct Geolocation over Syria

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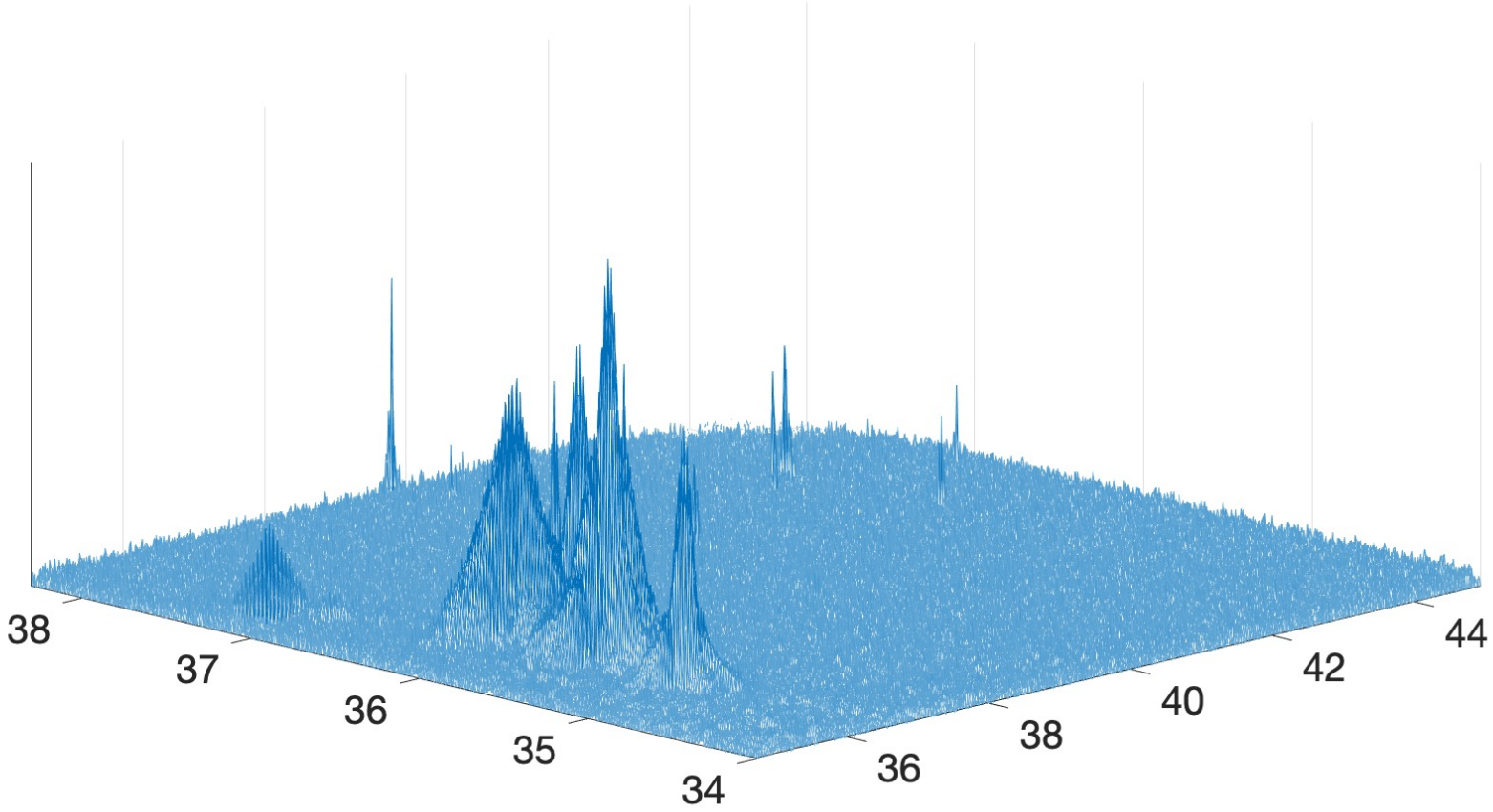
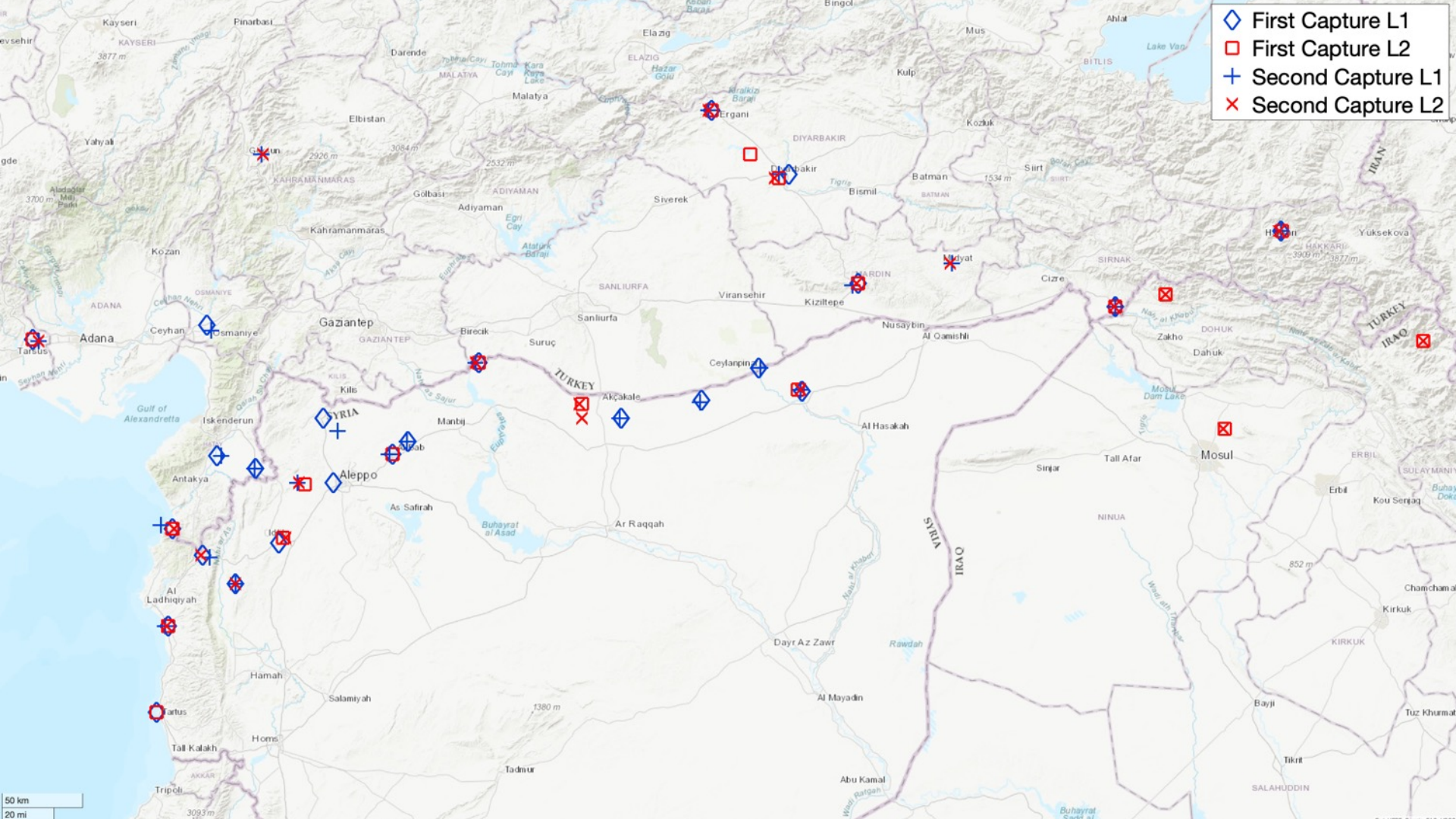
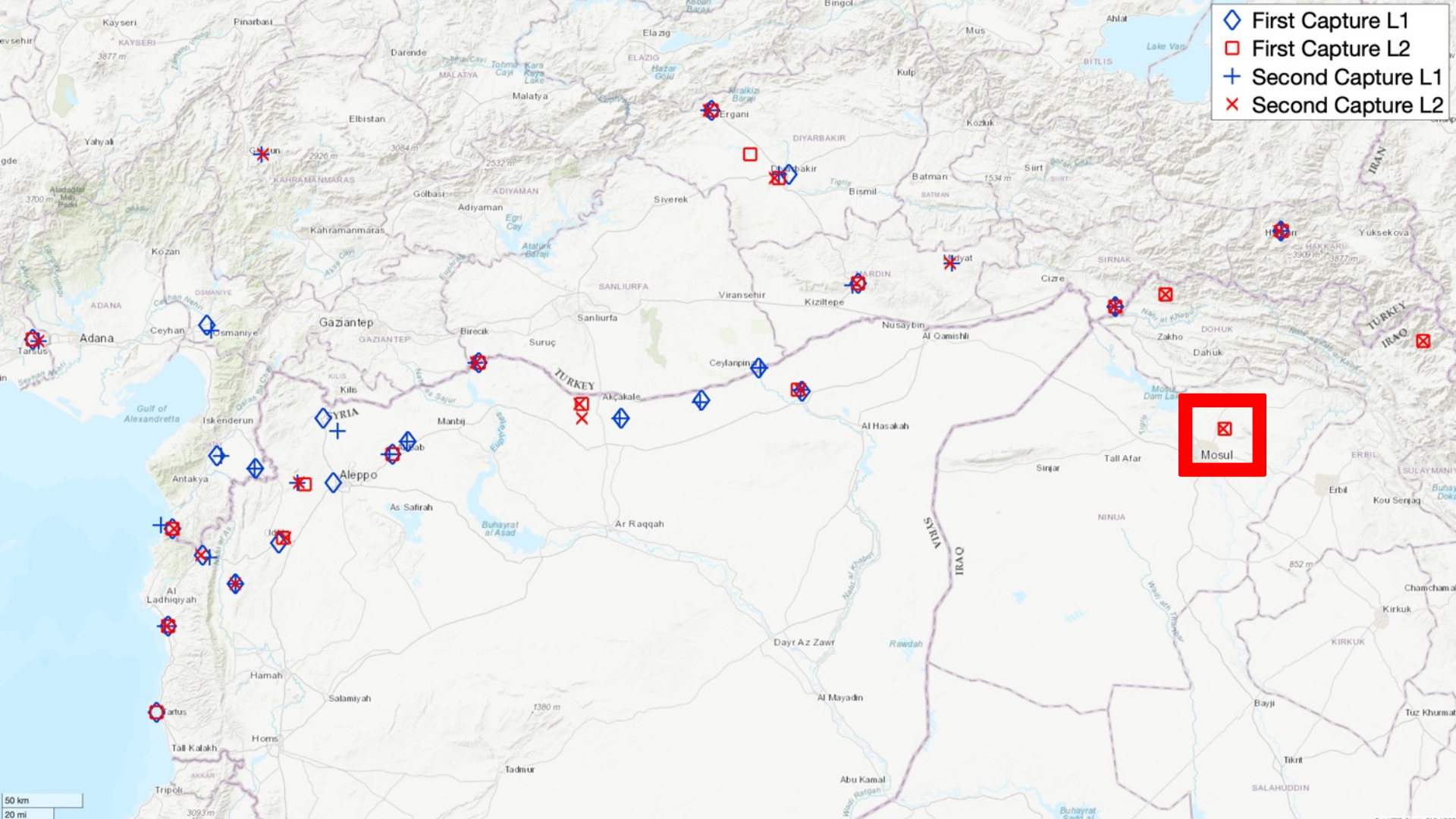
Direct Geolocation over Syria on L2




First Capture L1
First Capture L2
Second Capture L1
Second Capture L2
Kayseri
Pinarbasi
Darende
Elazig
Bingol
Mus
Ahlat
Malatya
Elbistan
Ergani
Kulp
Kozluk
Yahyali
Diyarbakir
Batman
Siirt
Bismil
Siverek
Golbasi
Adiyaman
Kahramanmaras
Kozan
Midyat
Hakkari
Yuksekova
Cizre
Viransehir
Kiziltepe
Sanliurfa
Gaziantep
Adana
Ceyhan
Osmaniye
Tarsus
Birecik
Suruç
Nusaybin
Al Qamishli
Zakho
Dahuk
Ceylanpin
Akçakale
TURKEY
SYRIA
IRAQ
IRAN
Kilis
Iskenderun
Gulf of Alexandretta
Manbij
Al Hasakah
Mosul
Tall Afar
Sinjar
Erbil
Kou Senjaq
Antakya
Aleppo
As Safirah
Ar Raqqah
Buhayrat al Asad
Al Ladhiqiyah
Hamah
Salamiyah
Dayr Az Zawr
Rawdah
Al Mayadin
Bayji
Kirkuk
Tuz Khurmatu
Tartus
Homs
Tall Kalakh
Tadmur
Abu Kamal
Tikrit
Tripoli
50 km
20 mi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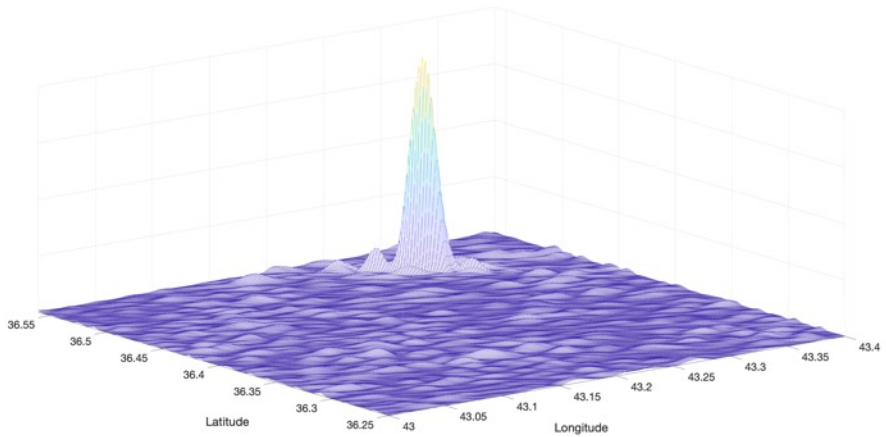
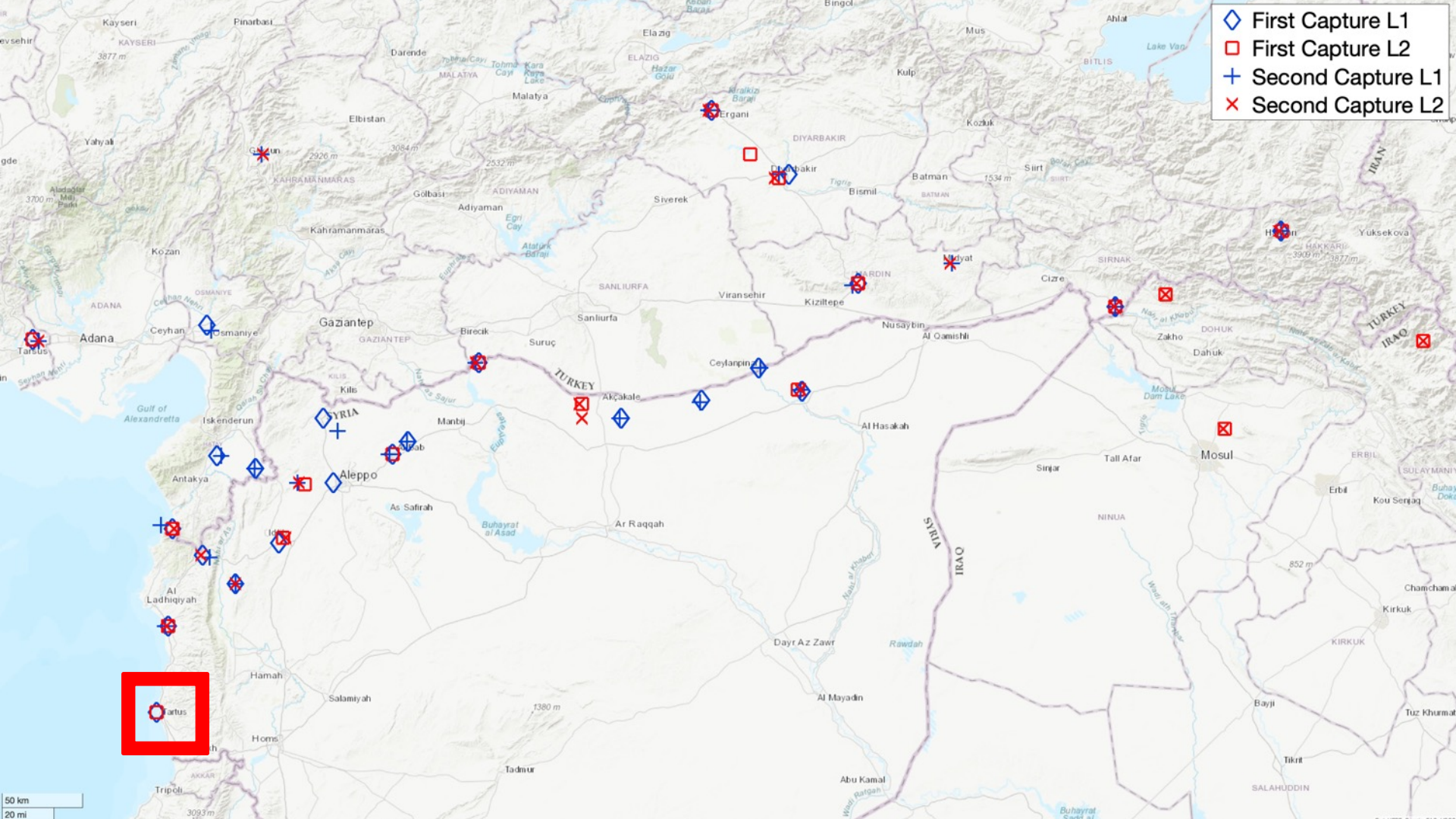
Homs
Tall Kalakh
Tadmur
Dayr Az Zawr
Al Mayadin
Abu Kamal
Bayji
Kirkuk
Tikrit
Yuksekova
Hakkari
Lake Van
Gulf of Alexandretta
TURKEY
SYRIA
IRAQ
IRAN
50 km
20 mi

Outside of Mosul, Iraq

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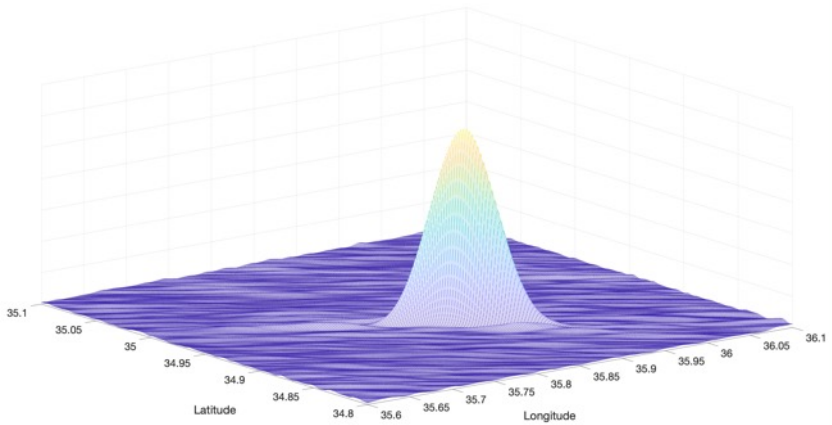
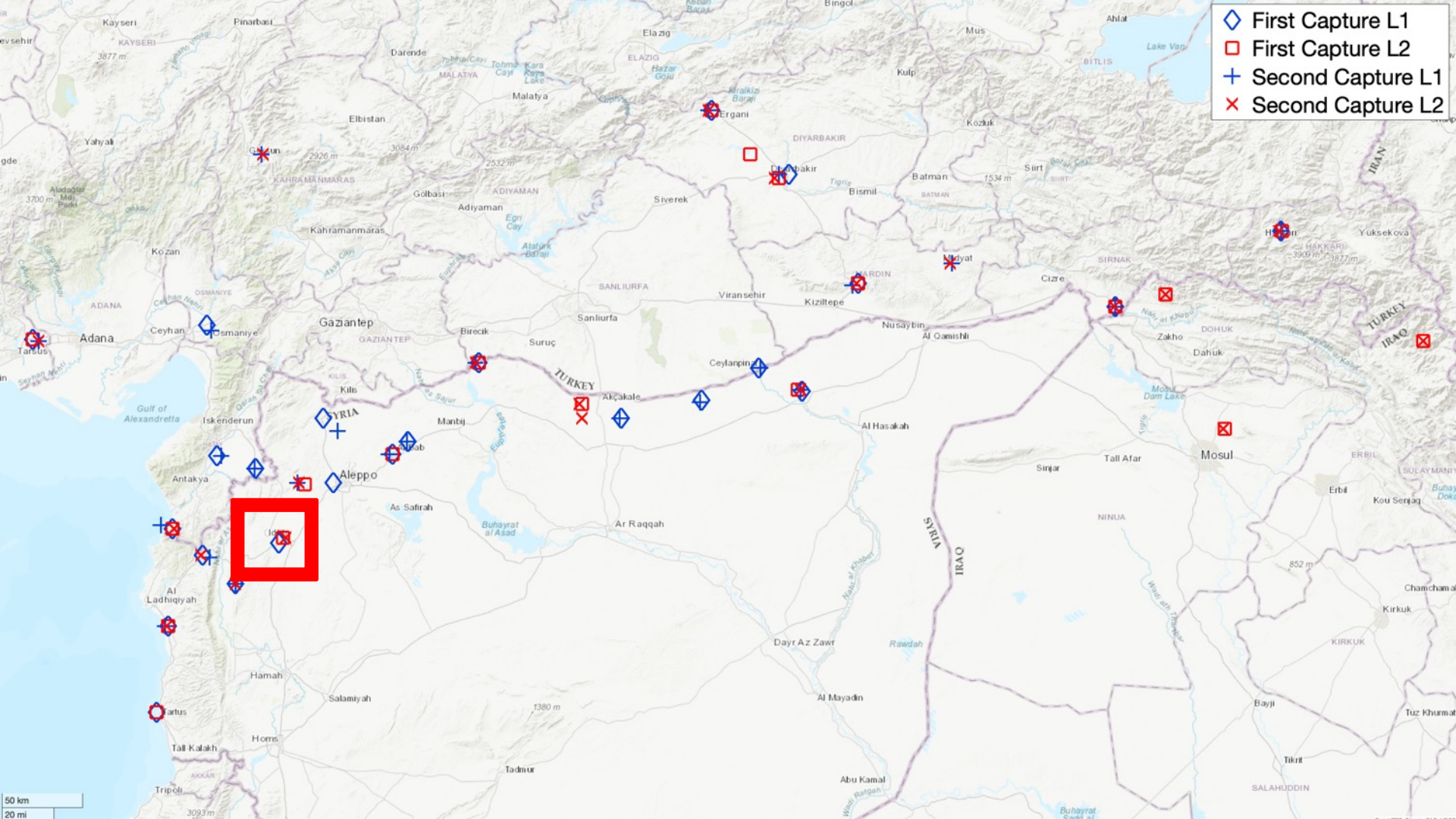
50 km
20 mi

Tartus Port, Syria



Imagery from BlackSky the day after the collect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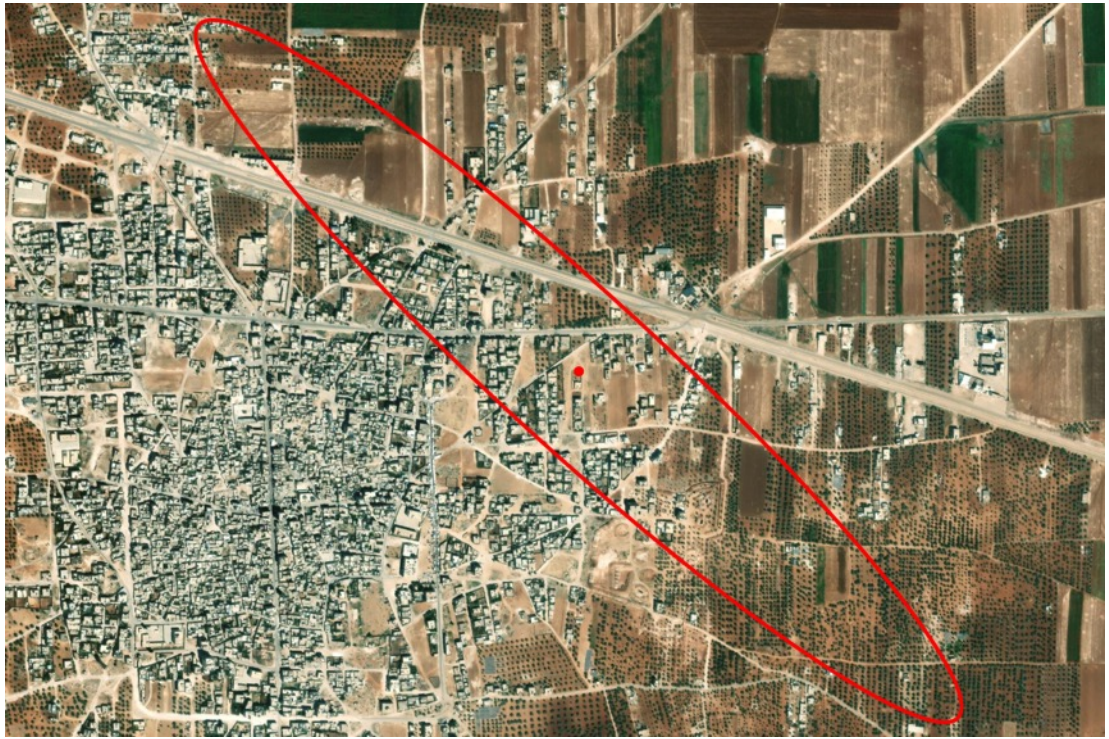
Bayji
Kirkuk
Tikrit
Tripoli
50 km
20 mi

Sarmin, Syria



95% Semi-major: 1019 m
95% Semi-minor: 153 m

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Takeaways

Deliberate persistent unauthorized wide-area GNSS interference is ongoing in multiple areas of the globe.

Time-synchronized LEO-based receivers provide unprecedented levels of GNSS interference detection and geolocation.

An emitter transmitting any arbitrary waveform can be geolocated with **sub-km accuracy.**

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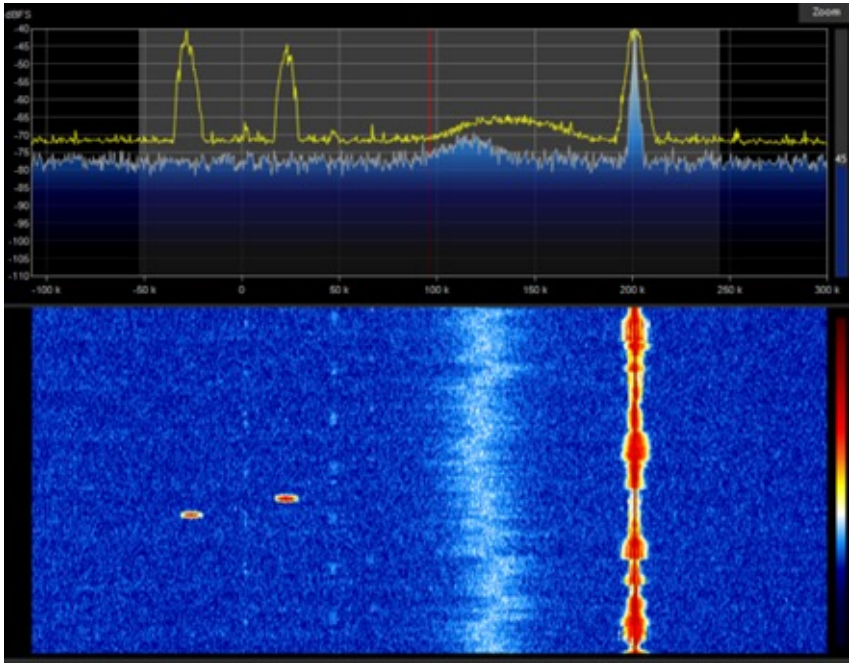
Accessing the Data and Q&A

Data Access Options

Archived daily collects / Custom AOI / Dedicated Constellations



- IF Collections: Using our existing assets.
- Geolocation Reports: Using our existing assets to then provide Geolocation reports.
- Space Services RF Constellations: These are large-scale end-to-end design, build, deploy, maintain of dedicated RF intelligence constellations spanning multiple years.
- Persistent RF Surveillance: GNSS band and eventually spanning to others RF bands.

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Q&A
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Thank you