Spire for Third Party Mission Programme

Revision History

Rev	Date	Description	Written By	Approved By
1A	2020-05-15	Initial Release to Customer	Dan Isaac Marcus Tallhamn	DI

Contents

1. Introduction

This document is a guide to describe Spire's earth information mission, the data product catalogue and data product information provided by Spire Global through the Earthnet programme.

2. Mission Description

2.1. Spire Constellation

Spire Global is a satellite-powered data company that uses a large, distributed constellation of multi-payload nanosatellites to persistently collect global radio frequency data in near-real-time. The company leverages proprietary software-defined radio technology to both collect radio frequency signals and extract information and intelligence from the RF spectrum.

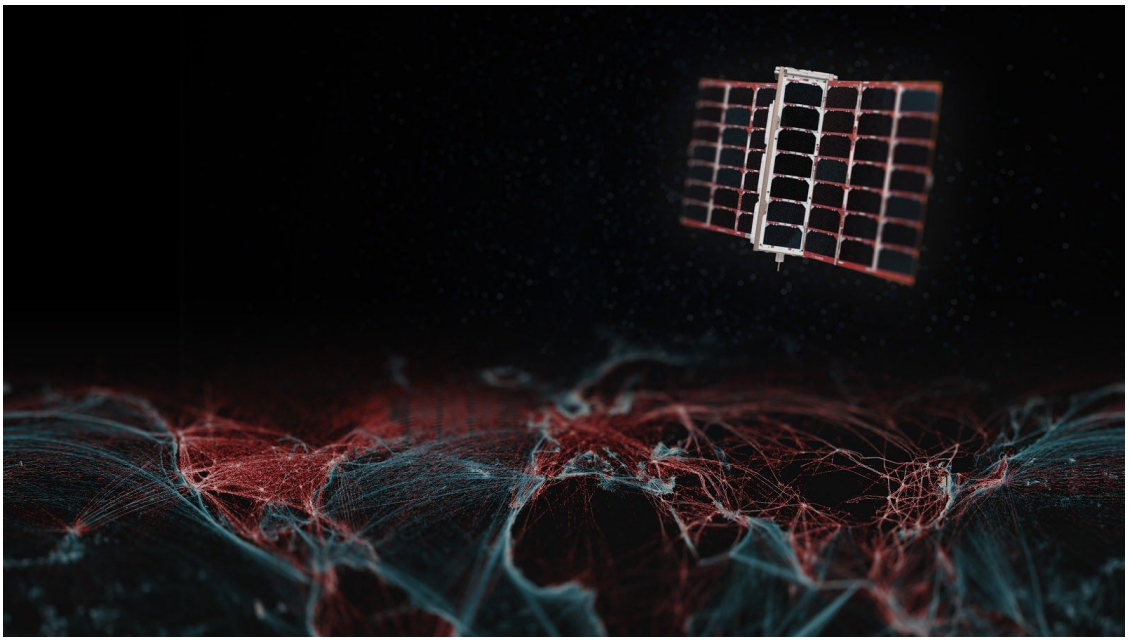


Figure 1 - View of Spire satellite

Spire's constellation of over 90 satellites, currently in operation, operate in a variety of Low Earth Orbits:

- Equatorial - 4 Satellites
- SSO - 56 Satellites
- 51.6 degrees inclination - 33 Satellites
- 83/85 degrees inclination - 4 Satellites
- 37 degrees inclination - 4 Satellites

Spire satellites are equipped with the following sensors:

- Automatic Identification System (AIS)
- Automatic Dependent Surveillance-Broadcast (ADS-B)
- Global Navigation Satellite System Earth Observation (GNSS-EO)

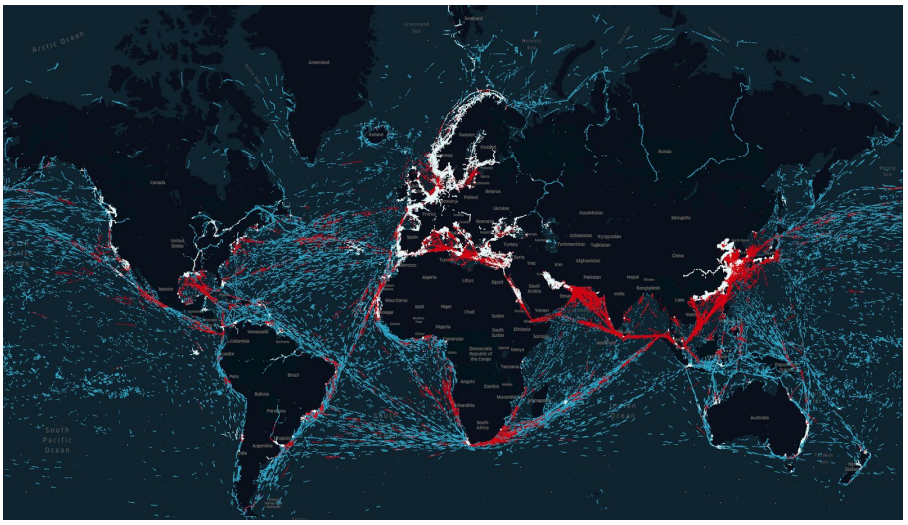
Data is downloaded from each spacecraft through Spire's own global ground station network. Spire uses this 'raw data' to produce high-value information products.

3. Data Catalogue

The following table provides a description of Spire's data products as furnished for the EO TPM programme:

Table 1 - Data Catalogue

AIS Data	
High-level description	The automatic identification system (AIS) is an automatic tracking system that uses transponders on ships and is used by vessel traffic services. Spire data includes satellite AIS (S-AIS) as observed by Spire satellites and terrestrial AIS (T-AIS) from third party sensor stations. Spire AIS data can be served as a 'live' stream: Global AIS messages (estimated today to be 40 million messages/day) pushed to the end-user. Or as historic data, dating back to December 2018.
Sensor technical details	Spire has different AIS payload variants onboard the LEMUR2 satellites. These are all SDRs capable of receiving AIS messages according to ITU-R M.1371-5. They are fed by a near omni-directional dipole and support operation on all four designated channels, one pair at a time depending on satellite tasking: ● AIS 1 and AIS 2 channels at 161.975 MHz and 162.025 MHz), or ● long-range AIS channels at 156.775 MHz and 156.825 MHz. Received messages are augmented with metadata, including a timestamp and reception channel, and later downlinked to the ground segment in a compressed format.
Coverage	Near global
Daily Data Size	[Currently circa] Satellite-AIS: Up to 1 GB compressed Terrestrial-AIS: Up to 10 GB compressed As the Spire fleet of satellites grows, the volume of data will increase accordingly.
Content	**.parquet.gz files** The AIS files contain both the raw NMEA message and added post-processing data for each message. Data is presented in a GZIP-compressed file - PARQUET format and contains time-series data on received AIS messages.
Data Format	See the following specifications on AIS messages format: https://gpsd.gitlab.io/gpsd/AIVDM.html https://www.navcen.uscg.gov/?pageName=AISmain

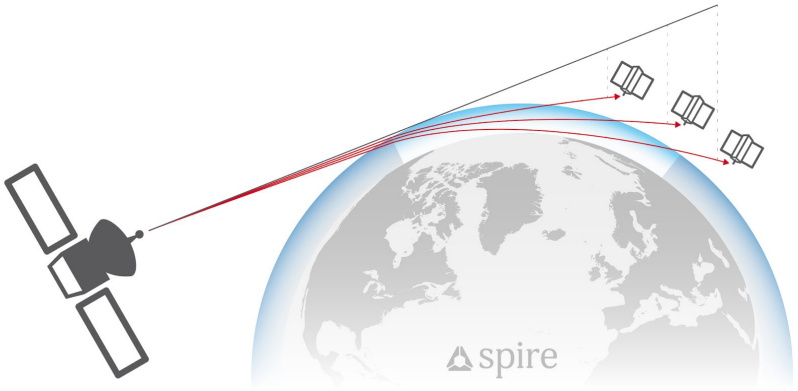
	Information on field names and field types can be provided upon request.
Method of delivery to Category-1 user	Historic AIS: S3 API Live AIS: Messages API
Graphic/Image	 Important note to users: Data points in blue correspond to S-AIS. Data points in white are T-AIS. Data in red corresponds to Dynamic AIS which is not included in the catalogue (only available commercially).
Automatic Dependent Surveillance - Broadcast (ADS-B) Data	
High-level description	Automatic Dependent Surveillance-Broadcast (ADS–B) is a surveillance technology in which an aircraft determines its position via satellite navigation and periodically broadcasts it, enabling it to be tracked. Spire data includes satellite ADS-B as observed by Spire satellites. Spire ADS-B data can be served as a 'live' stream, global ADS-B messages pushed to the end-user, or as historical data, dating back to December 2018.
Sensor technical details	Spire ADS-B payload receives 1090 MHz Mode-S Extended Squitter messages (DF17 and DF18) using SDR receiver on board of LEMUR2 satellites. The receiving antenna is a directional patch antenna with circular polarisation. The messages are received and stored in real time and time stamped by a clock synchronised from ground.
Coverage	Near global
Daily Data Size	[Currently circa] 800MB As the Spire fleet of satellites grows, the volume of data will increase accordingly.

Content	**.csv.gz files** The decompressed csv file contains a list of hexadecimal representations of ADS-B messages associated with the timestamp they were received on the satellite.
Data Format	Historical format: Target Update data is presented in GZIP-compressed CSV files. Live format: Target Update message Time: UTC timestamp of when the message was received (seconds from epoch)
Method of delivery to Category-1 user	Historical ADS-B: S3 API Live ADS-B: Streaming API
Graphic or image	
GNSS-Radio Occultation (GNSS-RO) Data	
High-level description	Atmospheric radio occultation (RO) relies on the detection of a change in a radio signal as it passes through a planet's atmosphere, i.e. as it is refracted by the atmosphere. GNSS radio occultation (GNSS-RO) is a type of radio occultation that harnesses the radio transmissions from Global Navigation Satellite System satellites, such as GPS or Galileo. Spire satellites perform GNSS-RO measurements on a continuous basis, globally, thus allowing researchers to have a global image of the Earth's atmospheric properties. Spire can provide RO data up to 30 days old or greater than 30 days old.
Sensor technical details	Currently, the main Earth observation instrument is the Spire STRATOS GNSS receiver instrument. It is an advanced, science-grade GNSS receiver, leveraging previous GNSS-RO receiver designs worldwide. It is an open loop L1, L2 receiver, utilizing less than 4 watts, with three RF inputs to allow both setting and rising occultation observations. This state-of-the-art receiver collected the first GNSS-RO profile by a commercial company, as well as the first open loop profile by a commercial company. It

	can collect from multiple GNSS constellations, including GPS, Galileo, GLONASS, and QZSS. The receiver tracks, on average, five-six dual frequency GPS signals for precision orbit determination (POD) at 1 Hz, as well as multiple simultaneous GNSS satellites at 50 Hz (rising or setting) for the GNSS-RO measurements.
Coverage	Global
A- POD Observation	
Content	**podObs*.rnx files** This file contains raw pseudorange, carrier phase, Doppler frequency, and signal-to-noise measurements for each observed GPS signal from a single Spire satellite. Data is currently output every second in time. These measurements are used to estimate the positions and velocities of each Spire satellite and also used to derive ionospheric total electron content data. **leoOrb*.sp3 files** This file contains the estimated position, velocity and receiver clock error of a given Spire satellite after processing of the POD observation file by the precise orbit determination software. The length of the file is typically at least 45 minutes long and thus, will overlap with multiple occultation events.
Format	**podObs*.rnx files** Data is presented in standard RINEX format (version 3.02). An example of RINEX version 3.02 format is shown below. The header contains such information as the satellite number, relevant antenna data, and GNSS observation types. The observations corresponding to each GNSS observational type for each time epoch are presented after the header. More information on formatting can be found in the RINEX: The Receiver Independent Exchange Format Version 3.02 document. **leoOrb*.sp3 files** The data are given in standard sp3 format (ftp://igs.org/pub/data/format/sp3_docu.txt). Under each time epoch, there are two lines beginning with ‘P’ and ‘V’. The first three values in the ‘P’ line contain the XYZ position coordinates with units of kilometers in a given orbital frame (‘IGS08’ as shown in the header in this example). The fourth value in the ‘P’ line refers to the estimated receiver clock error from true GPS time given in microseconds. The XYZ velocity coordinates are given in the ‘V’ line in units of decimeters/sec. The final value of the ‘V’ line refers to the estimated receiver clock error rate of change in units of 10-4 microseconds/sec, which is normally not estimated from the precise orbit determination software and thus set to 999999.999999.

Average Daily Data Size	[Currently circa] 300MB-1GB As the Spire fleet of satellites grows, the volume of data will increase accordingly.
B- Satellite Attitude Information	
Content	**leoAtt*.log files** File contains 1 Hz rate quaternion information measured from a single Spire satellite. Quaternion information is necessary to convert between the spacecraft-fixed body frame to the orbit local level frame defined in the header. This essentially describes the orientation of the satellite. Each time epoch contains one single quaternion.
Format	Attitude data are presented in an ASCII format adopted by CDAAC for COSMIC data. http://cdaac-www.cosmic.ucar.edu/cdaac/cgi_bin/fileFormats.cgi?type=leoAtt
Average Daily Data Size	[Currently circa] 5MB - 100MB As the Spire fleet of satellites grows, the volume of data will increase accordingly.
C- High-Rate Occultation Observation (RO)	
Content	**opnGns*ro.bin, opnGns*rst.bin files** File contains raw carrier phase measurements and open-loop model information obtained during an occultation event at 50 Hz sampling. This file can either contain raw measurements from the occulting satellite signal or the reference satellite signal, which is necessary to mitigate the effects of receiver clock error (see “Excess Phase Processing”). Each file contains measurements pertaining to only one signal frequency/type (i.e. GPS L1 vs. GPS L2). In general, for a given successful occultation event observed on a single Spire satellite, there should be two files containing raw measurements from the occulting GNSS satellite (one for each signal frequency) and two or more files containing raw phase data from one or more reference GNSS satellites.
Format	Data are presented in ‘opnGps’ format, which is a binary format created by the CDAAC for processing COSMIC radio occultation data. More information on this format can be found at: http://cdaac-www.cosmic.ucar.edu/cdaac/cgi_bin/fileFormats.cgi?type=opnGps
Average Daily Data Size	[Currently circa] 50MB - 1GB As the Spire fleet of satellites grows, the volume of data will increase

	accordingly.
D- Atmospheric Profiles	
Content	**atmPrf*.nc files** The file contains profiles of atmospheric dry pressure, dry temperature and neutral refractivity as a function of altitude produced from full processing of one occultation event. In addition to that the NetCDF file aggregates almost all outputs of RO processing: metadata, impact parameter, bending angle, standard deviation of bending angle, perigee point geolocation, RO azimuth angle, etc. atmPrf*.nc files can be considered as a replacement for BUFR files because it contains all the data stored in BUFR files and more. **bfrPrf*.bufr files** Each BUFR file contains derived profiles of dry pressure, dry temperature, refractivity and bending angle for each occultation.
Format	**atmPrf*.nc files** The data are presented in standard netCDF using the format defined for COSMIC atmospheric profiles (https://cdaac-www.cosmic.ucar.edu/cdaac/cgi_bin/fileFormats.cgi?type=atmPrf). **bfrPrf*.bufr files** Each file is in standard BUFR format, which is used by almost all operational meteorological services for assimilation of observational data into weather models. More information on the BUFR file format can be found in WMO FM94 (BUFR) Specification For Radio Occultation Data Version 2.4.
Average Daily Data Size	[Currently circa] 5MB - 100MB As the Spire fleet of satellites grows, the volume of data will increase accordingly. Near global coverage.
Additional information	
Method of delivery to Category-1 user	Up to 30 days RO and >30 days RO: S3 API

Graphic/Image	

End of Document