HIBER GLOBAL NON-GEOSTATIONARY SATELLITE SYSTEM

ATTACHMENT A
Technical Annex to Supplement Schedule S

A. SCOPE AND PURPOSE

This attachment contains the information required by 47 C.F.R. § 25.114(d) and other Part 25 rules that cannot be captured by the Schedule S Software.

B. GENERAL DESCRIPTION OF OVERALL SYSTEM FACILITIES, OPERATIONS AND SERVICES AND EXPLANATION OF HOW UPLINK FREQUENCY BANDS ARE CONNECTED TO DOWNLINK FREQUENCY BANDS (§ 25.114(D)(1))

Hiber intends to operate its constellation at an altitude of approximately 600 km. Hiber has completed construction of its first two 6U satellites in partnership with Innovative Solutions in Space B.V. ("Innovative Solutions"), a Netherlands-based company. These two satellites are currently slated for launch in 2018, with the first scheduled for October 2018 by the Indian Space Research Organisation and the second in November 2018 on a scheduled SpaceX launch.[1] Hiber then intends to expand its constellation to 24 satellites over the course of five years. The two satellites that have been constructed are 6U in size with a total mass of 7.23 kg. A third 6U satellite is in the planning phase. Hiber is exploring the use of smaller 3U satellites as the network is built out. These 3U satellites will have a total mass of approximately 4.5 kg. Although smaller in size, the 3U satellites will use the same antenna as the 6U satellites and will therefore be technically identical as defined in the Commission's rules.[2]

The satellites will operate in a total of 8 orbital planes, with the following parameters:

- Inclination: 97.8 degrees for each plane
- Orbital period: 1h 37min
- Apogee: 600km
- Perigee: 600km
- Argument(s) of perigee: 0
- Active service arc(s) : the satellites will provide service during the whole orbit
- Right ascension of the ascending node(s)

Orbital Plane	1	2	3	4	5	6	7	8
RAAN (°)	0	22.5	45	67.5	90	112.5	135	157.5

- For each satellite in each orbital plane, the initial phase angle at the reference time is

Satellite	1	2	3
Initial Phase Angle (°)	0	120	240

[1] The launches were originally scheduled to occur in July and August 2018, respectively, but were postponed by the launch providers, postponements over which Hiber has no control.

[2] 47 C.F.R. § 25.114(a)(2).

Mission

Associated with Hiber's constellation are user modems ("earth stations") that will be located throughout the Earth's surface and two ground stations that are located in Europe, in Svalbard, Norway and Delft, Netherlands. Hiber's satellite payloads will provide a link between the user terminals, which are earth stations combining a modem and antenna, and the Hiber customer portal, according to the following steps:

- The satellite payload sends a broadcast to synchronize and update the earth stations.
- The earth stations send user data to the satellite payload.
- The satellite payload processes the received data.
- The satellite payload sends the data to ground stations when it is located directly over the ground station.
- The ground stations transfer the data to the Hiber user web portal via a secure internet link. The user then retrieves the information from the portal. No information will be transmitted back to the earth station other than the broadcast data.

To ensure its mission, the satellite uses three different communication links:

- **Service Links:** The link between earth stations and the satellite is established by a helicoidal antenna.[3] Each satellite can receive data from the earth stations through a 399.9-400.05 MHz (Earth-to-space) frequency band and can broadcast via a 400.15-401 MHz (space-to-Earth) frequency band to the earth stations. The earth stations can transmit messages up to 1400 bits in size and the duration of each transmission will last no longer than 400 milliseconds. The satellites can broadcast firmware updates and other broadcast data to the earth stations. The length and intervals of such broadcasts are configurable by Hiber. The size of the transmissions could range from a few bytes to a few hundred kilobytes and intervals from 5 to 30 seconds.
    - For the service uplink, Hiber will operate in the 150 kHz channel bandwidth in the 399.9-400.05 MHz band. The uplink transmissions will use Code Division Multiple Access (CDMA) spread spectrum.
    - For the broadcast service downlinks, the allocated bandwidth is 100 kHz, using Gaussian Minimum Shift Keying (GFSK) modulation. In this downlink, Hiber is capable of limiting its usage to 100 kHz.

[3] Additional information regarding the 400 MHz antenna is provided as a separate attachment. Helical Communication Technologies, *Feasibility Report on Various 400 MHz RHCP Antenna Configurations* (Jul. 24, 2017).

- **Feeder Link:** The payload data gathered from the earth stations is sent from the satellite to the ground stations via a link established by an S-Band patch antenna, which operates in the 2200-2290 MHz (space-to-Earth) frequency range. This link will be active only while the satellites are directly over the ground stations, which are located in Svalbard, Norway and Delft, Netherlands. The link will not be used within or near the United States or its territories.

- **TT&C:** The link for TT&C operations, which operates between the satellite and ground stations, is established by two half-length dipole antennas, operating in the 401-402 MHz (space-to-Earth) frequency band and 148-149.9 (Earth-to-space) frequency band. These links will be active only while the satellites pass over the abovementioned European ground stations. The feeder link will not be used within the United States or its territories.

Satellite design

The satellites consist of the following sub-systems:

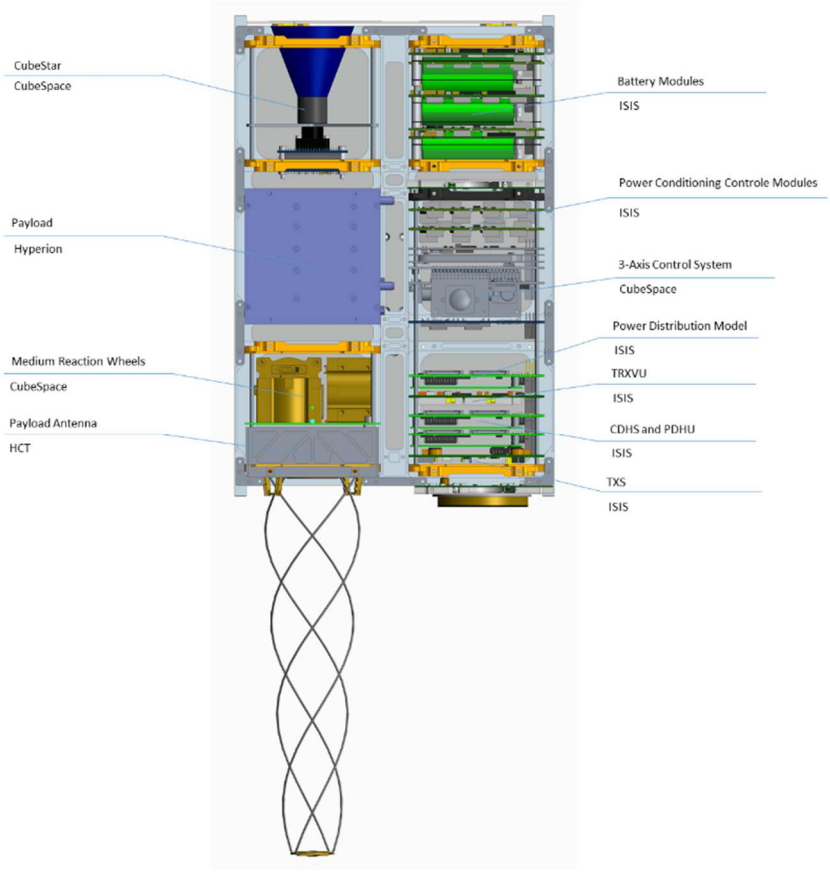
- Attitude Determination and Control, including a star tracker, reaction wheels and magnetorquers

- Power Supply, including batteries, solar arrays, power control and distribution modules

- Communication Systems, including transceivers and antennas

- Payload

The figure below depicts the layout of the satellites:



C. TT&C FUNCTIONS

Telemetry sent from the satellite to ground stations allows verification and monitoring of the health and correct functioning of each system on board. Two half-dipole antennas, operating in the 401-402 MHz (space-to-Earth) band, send telemetry data to the ground. The ground stations are located in Svalbard, Norway and Delft, Netherlands.

Telecommand sent from the ground allows for control of the satellite, including updating the onboard computer (OBC), and synchronizing and configuring automatic tasks. Telecommand is transmitted using the same antennas and transceiver as used for telemetry, but is conducted in the 148-149.9 (Earth-to-space) MHz band.

The TT&C system will be the most actively utilized during launch and safe modes. Hiber's ground station network will ensure frequent contact with the satellite as it passes over at least one ground station approximately 15 times per day. When there is no contact, the satellite is able to act autonomously and effectuate automatic tasks.

D. PREDICTED SATELLITE ANTENNA GAIN CONTOURS (25.114(C)(4)(VI)(B))

The predicted antenna gain contours were implemented using MATLAB. The antenna implemented is the HCT with center frequency 0.401 GHz or 401 MHz. The earth station depicted below is located in Delft Zuid, Netherlands.

Latitude = 51.9885546;
Longitude = 4.3629348;
H = 30; (Height of the Ground Station)
Inclination Angle = 97.8 (degrees)

Figures 1 through 2 in this Attachment depict the Quad Helical antenna gain contours over the earth stations for the 401 MHz center frequency.

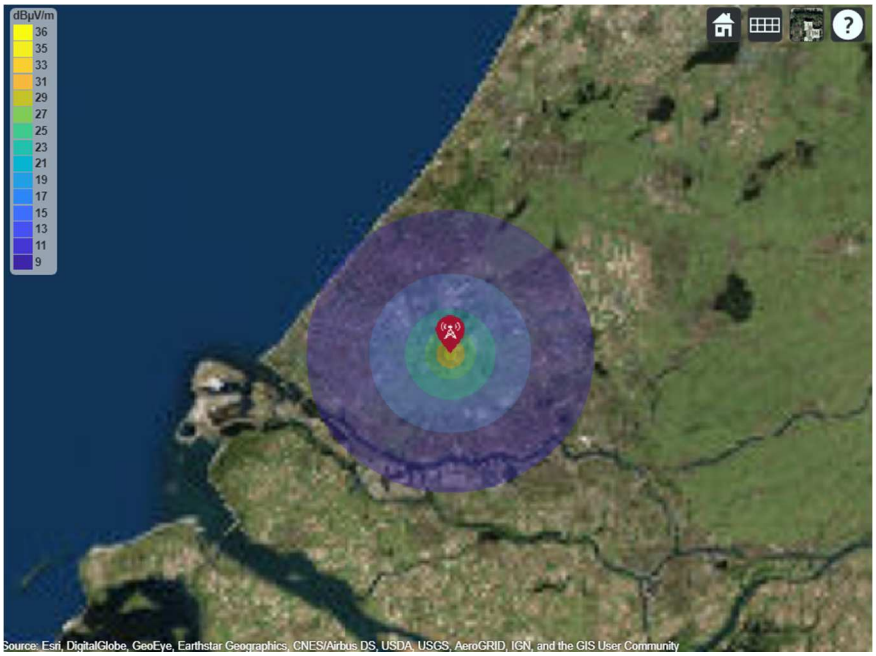


Figure 1 Predicted Antenna Gain Contour

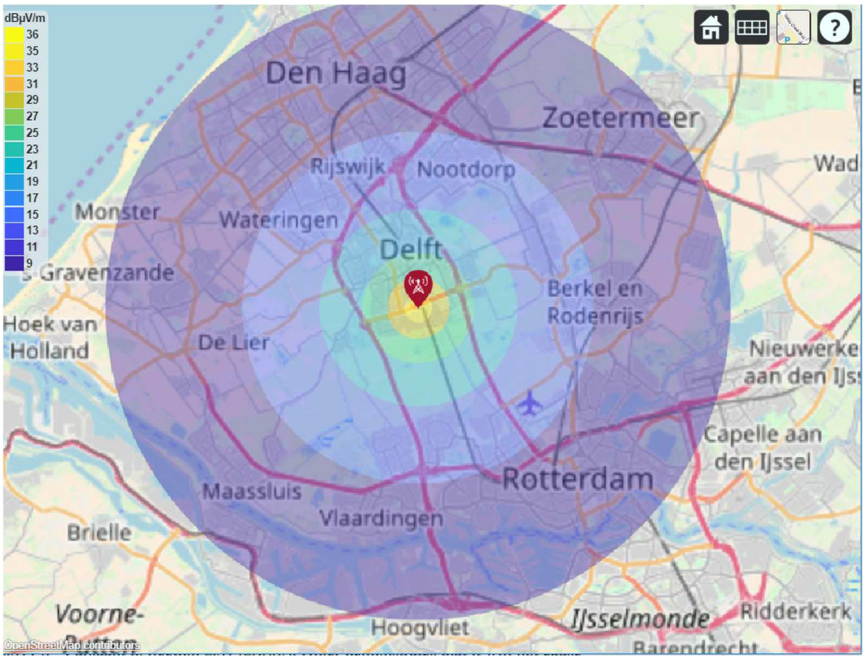


Figure 2 Predicted Antenna Gain Contour

E. COORDINATION WITH OTHER SYSTEMS OPERATING IN THE SAME FREQUENCY BANDS

Pursuant to Section 25.142(a) of the Commission's rules, Hiber describes its proposed NVNG MSS operations and the relevant technical and operational aspects of the systems as required by Section 25.114.[4] Pursuant to Section 25.142(b)(3), Hiber demonstrates that it will not cause unacceptable interference to any NVNG MSS system authorized to construct or operate in the frequency bands in which Hiber proposes to operate.[5]

a. Coordination between systems operating in the 399.9-400.05 MHz (Earth-to-space) frequency band

Hiber's proposed spread spectrum CDMA operations in the 399.9-400.05 MHz band are consistent with the U.S. Table of Frequency Allocations. Section 25.142(b)(3) of the Commission's rules requires coordination among NVNG MSS systems. However, the FCC noted in 2013 that since the NVNG MSS rules were adopted, no MSS systems have been deployed or authorized in the 399.9-400.05 MHZ band.[6] Presently, there are no NVNG MSS systems authorized under Part 25 of the Commission's to operate service links in the 399.99-

[4] *See* 47 C.F.R. § 25.114; 25.142(a).

[5] *Id.* § 25.142(b)(3).

[6] *See Amendment of Part 2 of the Commission's Rules for Federal Earth Stations Communicating with Non-Federal Fixed Satellite Service Space Stations*, Notice of Proposed Rulemaking and Notice of Inquiry, 28 FCC Rcd 6698 ¶ 68 (2013).

400.05 MHz band.[7] Pursuant to Agenda Item 1.2, which will be considered at World Radiocommunication Conference (WRC) in 2019, the relevant working parties under the ITU may propose to limit EIRP in this band to a value around 5 dBW.[8] Hiber's operations are envisaged to comply with the eventually adopted limit.

b. Coordination with other services in the 400.15-401 MHz band (25.142)

Hiber proposes to operate its service links in the 400.15-401 MHz (space-to-Earth) frequency band. The Commission adopted a sharing plan for NVNG MSS operations in this band and authorized Orbcomm to operate in certain portions of this band on a primary basis.[9] As noted above, Hiber's broadcast service downlinks will operate in 100 kHz channels, using GFSK modulation. Interference between Hiber's satellites and those of other systems in this band is unlikely because the Hiber's system will transmit only in short bursts of approximately 400 milliseconds while in view of a satellite passing overhead. Hiber will start transmitting between its satellites and ground stations once a day and will increase over time to approximately 100 times a day over four years.

Hiber is capable of sharing with Orbcomm for several reasons. First, it should be noted that Orbcomm is authorized to operate on a primary basis in the 400.15-400.505 and 400.645-401 MHz portion of this band. Its operations on frequencies other "than its primary assigned frequencies are on a non-harmful interference basis with respect to any other lawfully operating radiofrequency operations.[10] Orbcomm's operations in the 400.505-400.645 MHz band are subject to sharing with future licensees.[11] With a downlink channel of only 100 kHz, Hiber's operations can operate on at least 100 kHz in the 400.15-401 MHz band in the portion of the band in which Orbcomm is required to operate on a non-interference basis with other services. Furthermore, as noted above, Hiber's satellites only transmit to the earth stations in short bursts when the satellite is directly overhead. As a result, Hiber expects to be able to share with Orbcomm in additional portions of the band. Thus, Hiber believes it will be able to coordinate successfully with Orbcomm and any other users in the band.

Further, we note that the Commission requires operations in the 400.15-401 MHz band to time share with Department of Defense ("DoD") satellite operations. Hiber is capable of complying

[7] Spire has an application pending to provide TT&C in the 399.9-400.05 MHz band, Spire Global, Inc., Phase IB/IC and Phase II Space Station License Amendment Application, IBFS File No. SAT-AMD-20161114-00107 (filed Jan. 2, 2018).

[8] *See* Agenda Item 1.2 to consider the in-band power limits for earth stations operating in the mobile-satellite service, meteorological-satellite-service and Earth exploration-satellite service in the frequency bands 401-403 MHz and 399.9-400.05 MHz, in accordance with Resolution 765 [COM6/7](WRC-15).

[9] *See Amendment of Part 25 of the Commission's Rules to Establish Rules and Policies Pertaining to the Second Processing Round of the Non-Voice, Non-Geostationary Mobile Satellite Service*, Report and Order, 13 FCC Rcd 9111 (1997) ("*Sharing Order*"); *see also Applications by Orbcomm Corp. for Authority to Modify its Non-Voice, Non-Geostationary Satellite System*, Order and Authorization, 23 FCC Rcd 4804, 4813 ¶ 23 (2008).

[10] *Id.* at 4808 ¶ 11.

[11] *Id.* at 4813 ¶ 23.

with Section 25.260 of the Commission's rules, which requires NVNG MSS operators to time share their operations in this band with DoD satellites.[12] Hiber is capable of coordinating with the DoD satellite operations in the 400.15-401 MHz (space-to-Earth) frequency band.

c. Interference with other services in the 2200-2290 MHz band

Hiber's satellite constellation is designed so that the downlink feeder link communications from the satellite to the earth station will occur only when the satellite is in view of the earth station. Hiber intends to operate its feeder link downlinks only when its satellites are in view of its ground station located in Norway and the Netherlands. Hiber does not intend to operate in the 2200-2290 MHz frequency band over the United States or its possessions.

d. Power Flux Density Calculation[13]

The power flux density (PFD) limits specified in Section 25.208 of the Commission's rules do not apply to Hiber's operations. Rather, Section 25.142(a)(2) of the Commission's rules requires Hiber to identify the PFD produced at the Earth's surface by each space station of their system in the 400.15-401 MHz band apply to Hiber's proposed downlink operations.[14]

The results of power flux density calculations are included in the accompanying Schedule S. The following assumptions have been made:

- Channel bandwidth BWCh =100kHz
- Transmitter power Pt=10W
- An average antenna gain G = 1.4dBi
- Distance to Earth R = 600km
- Bandwidth of interest BWmsr=4kHz

Under the assumptions provided above, the PFD is -129.14 dBW/m^2/4kHz. This downlink PFD is less than the ITU-specified coordination trigger of -125 dBW/m^2/4kHz at the Earth's surface.[15]

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[12] 47 C.F.R. § 25.260.

[13] Additional information regarding Hiber's PFD calculations is provided as a separate attachment to this application.

[14] *Id.* § 25.142(a)(2).

[15] *See* 47 C.F.R. § 2.106 at International Footnote 5.264; ITU Radio Regulations, Coordination thresholds for sharing between MSS (space-to-Earth) and terrestrial services in the same frequency bands and between non-GSO MSS feeder links (space-to-Earth) and terrestrial services in the same frequency bands

e. Emission limitations.

Below is the specified spectrum mask for the Hiber service downlink in the 400.15-401 MHz band. This spectrum mask demonstrates that Hiber's satellites will comply with the out-of-band emission limitations specified in Section 25.202(f) of the Commission's rules. The Y axis in the depicted chart is dBC/4kHz while the X axis is megahertz.

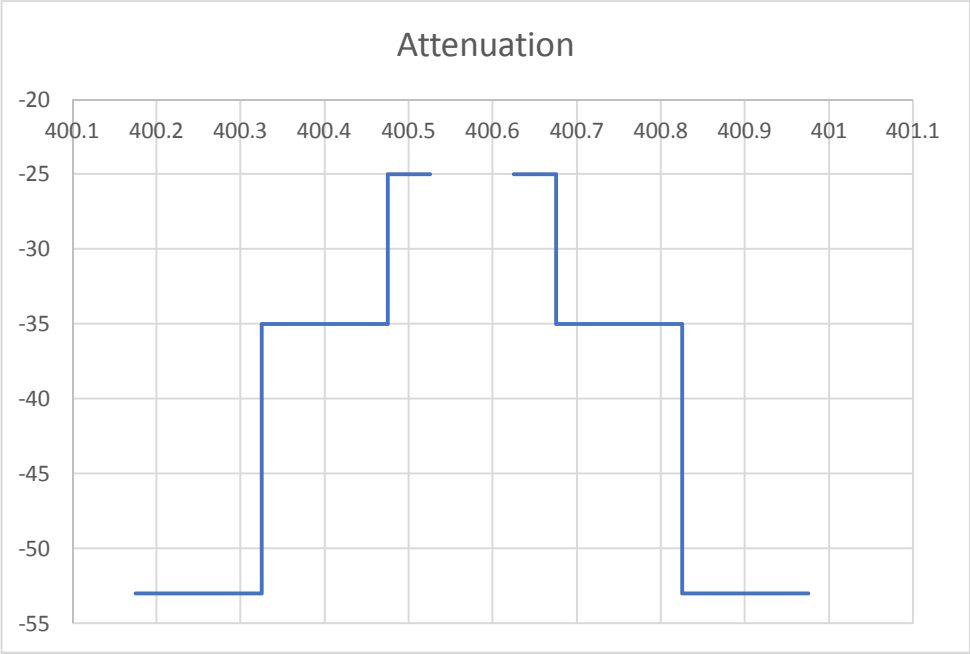

Figure 3 The FCC spectral mask for Hiber satellite.

F. CESSATION OF EMISSIONS (25.207)

Each satellite transmission chain can be individually turned off by ground telecommand, thereby causing cessation of emissions from the satellite, as required by 47 C.F.R. § 25.207.

G. ORBITAL DEBRIS MITIGATION (25.114(D)(14))

The Hiberband satellite constellation is authorized by the Agentschap Telecom/ Radiocommunications Agency Netherlands ("RA") for launch and operations. The RA requires its satellite licensees to adhere to the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space and the Inter-Agency Debris Coordination Space Debris

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and between RDSS (space-to-Earth) and terrestrial services in the same frequency bands, Appendix 5, Annex 1 ¶ 1.1.1.

Mitigation Guidelines, ITU Recommendation ITU-R S.1003. Accordingly, consistent with Section 25.114(d)(14)(v) of the Commission's rules, the RA conducts "direct and effective regulatory oversight" of orbital debris mitigation.[16] However, in an abundance of caution and to facilitate Commission review of this Petition, a detailed description of Hiber's orbital debris mitigation plan is provided below and in the attached Orbital Debris Assessment Report ("ODAR").

Hiber's satellites will be deployed from various commercial launch vehicles. Hiber has conducted an ODAR in compliance with NASA-STA-8719.14, Attachment A and has attached this ODAR as an Attachment to this application. The attached ODAR has been conducted for the 6U satellites in Hiber's constellation. The possible 3U satellites are still in the design phase and Hiber has not yet selected a manufacturer. Consequently, the ODAR has not been completed for the 3U satellites. If Hiber decides to move forward with use of 3U satellites in the future, Hiber will supplement its application with the ODAR for the 3U satellites once it is complete. Consistent with Section 25.114(d)(14)(i), Hiber will not undertake any planned release of debris during its operations.[17] Hiber has assessed the probability of the satellites becoming sources of debris by collision with both large and small objects using NASA's Debris Assessment Software and has found Hiber's constellation to be fully compliant.

Hiber also conducted a collision risk analysis using the DAS software for the *Assessment of Spacecraft Compliance with Requirement 4.7-1: Limit the risk of human casualty* scenario. As described in greater detail in the attached ODAR, Hiber is compliant with the casualty probability requirements which requires a probability of less than 1/10,000. In addition, Hiber will also engage the Joint Space Operations Center (JSpOC) to receive conjunction threat reports to better coordinate conjunction events.

[16] 47 C.F.R. §25.114(d)(14)(v).

[17] *Id*. § 25.114(d)(14)(i).

CERTIFICATION OF PERSON RESPONSIBLE FOR PREPARING ENGINEERING INFORMATION

I hereby certify that I am the technically qualified person responsible for preparation of the engineering information contained in this application, that I am familiar with Part 25 of the Commission's rules, that I have either prepared or reviewed the engineering information submitted in this application and that it is complete and accurate to the best of my knowledge and belief.

/s/ Maarten Engelen
Maarten Engelen
Chief Technology Officer
Magnitude Space B.V.