Capability statement for constellr

constellr Surface Temperature product specifications
Data stream of the **Hi**gh-resolution **V**ersatile **E**cosphere monitoring mission:
HiVE-Data stream

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Table of Contents

1 Business Information

constellr is a European technology company which provides worldwide mission-critical intelligence for climate resilience and sovereign decision-making, including the detection of events like drought, heat, crop stress, flood and fire. Aiming to serve diverse sectors including defense & intelligence, infrastructure, urban, and agricultural monitoring, constellr's data contribute to global food security, crisis prevention and climate resilience. Selected as a contributing mission to the European Copernicus Programme and having completed an in-orbit-demonstration on the ISS, constellr uses proprietary space technology for high-resolution and high-precision temperature measurement. As a vital environmental factor, temperature allows to gain valuable information about urban heat, crop growth, infrastructure status, and industrial activity with unprecedented accuracy.

2 Proprietary Technology: HiVE Mission

constellr has been building a proprietary satellite constellation to measure land surface temperature (LST) utilizing long wave infrared (LWIR) sensor payloads. We have thermal data (8-12μm) at different processing levels, with spatial resolution of 5-30m per pixel. Aligned to the thermal data, we are offering multispectral data covering the spectral range of 400-1000nm in 10 bands. Tasking and pointing capabilities enable average revisit times of 1.5 days with the first two satellites and sub-daily revisit with 3 or more satellites. It is planned for the constellation to be scaled up to 30 satellites by 2032. Detailed specifications are listed in chapter 4.

Named the **"High precision Versatile Ecosphere" (HiVE) mission**, our constellation's key objective is to support the security and resilience of global food supply chains, enhance urban climate resilience, and support environmental monitoring in the face of climate change.

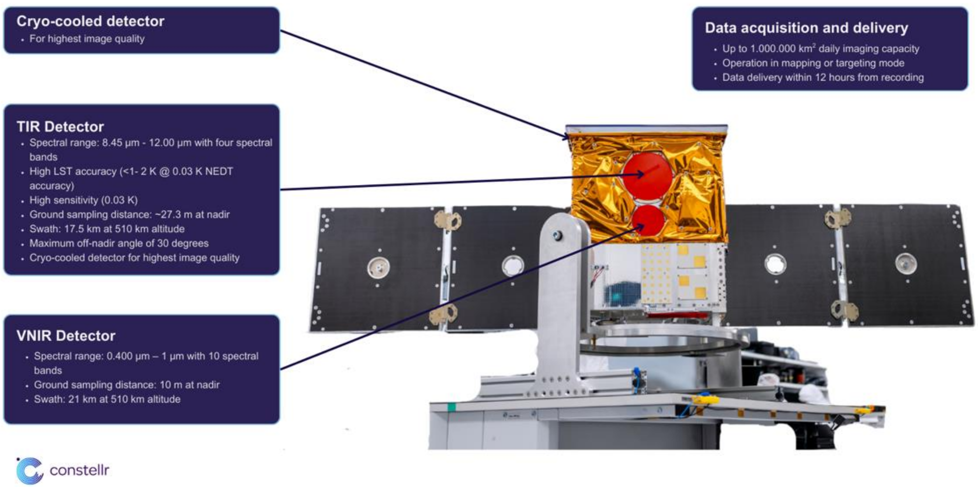

Figure 1: Visualization of the first generation of SkyBee satellites of the HiVE constellation.

The core IP and unique competitive advantage is a quantum leap in payload cost efficiency, leveraging our patented virtual calibration technology. Employing thermally stabilized optical systems, cryo-cooled sensors, and a cooperative approach with existing space infrastructure, this allows for measurement accuracy comparable to large satellites on a microsatellite platform. Figure 1 shows a visualization of the first generation of HiVE satellites currently in operations.

Our launch schedule is:

- SkyBee1 launch: January 2025
- SkyBee2 launch: June 2025
- SkyBee3 launch: Q3 2026 (planned)
- Second Generation: 2028 (planned)

constellr operates its own ground segment infrastructure including mission operation systems, image processing, and data platform for customer access (Figure 2).

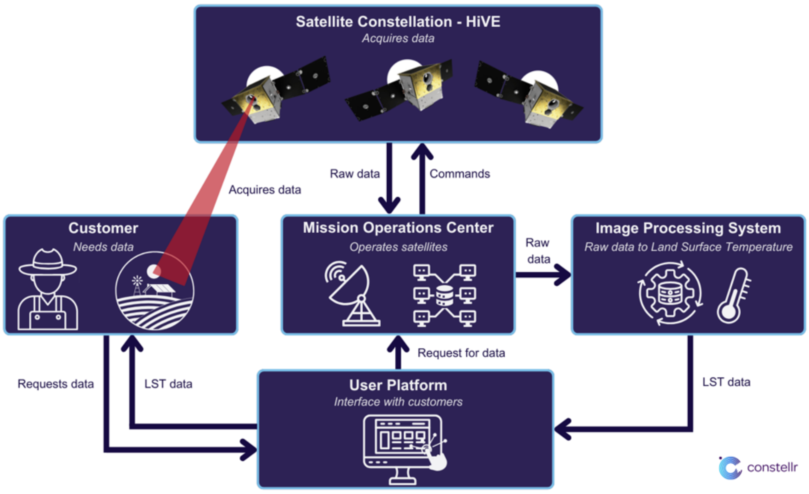

Figure 2: Infrastructure - constellr operates a constellation of satellites.

The HiVE data quality is ensured by defined high standards for all Cal/Val activities. The HiVE Cal/ Val activities are supported by ESA within the ESA programs InCubed and Copernicus Contributing Mission (CCM). Followed by an extensive laboratory characterization of the instrument, the HiVE satellites have been characterized during an approx. 3 months in-orbit commissioning phase. During that phase cross calibration with other sensors and vicarious calibration using reference data and locations at the earth and sea surface are performed. Based on the sensor performance and systems stability on-going Cal/Val activities are planned for the regular operation mode.

Besides a constellr internal validation the data quality will be evaluated independently by the ESA Mission performance cluster for the data levels (L1A, L1C, L2) within CCM. Sharing data with the scientific community for use cases specific data is planned with constellr's scientific advisory board members.

3 Product Offering

3.1 LST*precision*

LST*precision* is derived from the high-resolution measurements acquired by the SkyBee satellite instruments of constellr's HiVE constellation. Following an advanced calibration and validation (cal/val) procedures, ensuring highly accurate and well

georeferenced radiance data, a sequence of processing steps is applied to generate the full LST*precision* product (Table 1).
With partners, level 3+ analytics products can be developed and provided in the future.

Table 1: Product offerings from HiVE constellation

Product Area	Product level by constellr HiVE
Land and Surface Hydrology	
Surface Reflectance (aligned to TIR sensor)	Level 2 Surface Reflectance, geometrically co-registered to Sentinel-2
Surface Temperature	Level 2 land surface temperature (LST) at 30m spatial resolution, geometrically co-registered to Sentinel-2
Oceans, Inland Water Bodies, and Coasts	
Water Temperature	Level 2 Sea surface temperature at 30m up to 20km off coast, at 500m open water, geometrically co-registered to Sentinel-2

3.2 LST*zoom*

LST*zoom* is optimized for localized analysis where fine spatial detail is critical, such as thermal footprints for defence and intelligence and for infrastructure and industrial hotspots. It is based on our LST*precision* product with an additional sharpening algorithm applied to it, increasing the spatial resolution to 10m.

LST*zoom* is generated by training a Machine Learning model, that learns a mapping between high-resolution VNIR data (10 m) and coarser resolution temperature of the land surface (30 m). It aims to upscale the spatial resolution of LST while preserving accuracy, consistency, and capture the geometric features present in the VNIR data.

3.3 LST*fusion*

LST*fusion* is an advanced LST fusion product, integrating multiple satellite observations across different resolutions and times into a seamless, high-resolution (30m) and temporally harmonized dataset, offered daily at 11am local solar time.

The solution combines dynamic diurnal cycle modelling, leveraging EO data and thermal knowledge, with an innovative data assimilation framework. This approach merges model predictions and real-world observations to deliver high-precision LST estimates. LST*fusion* also supports future data products like LSTM, TRISHNA, and SBG LST, ensuring adaptability and scalability.

Designed to simplify complex workflows, LST*fusion* transforms fragmented data into actionable insights. It provides a reliable, consistent view of Earth's surface temperature, empowering users to make informed decisions and drive meaningful impact across industries.

3.4 Comparison of LST Product Lines

constellr's LST data products can be used in a complementary manner, the key differences and similarities are listed in the following Table 2.

Table 2: LST data products comparison[1]

Features	Harmonized LST	LST HiVE	
Product name	LST*fusion*	LST*precision*	LST*zoom*
Spatial resolution[2]	30m	30m	10m
Scene size	110km x 110km	15km x 15km	
Frequency[3]	2025: daily 2026: hourly 2027: forecast	2025: 1.5-3 days 2026: sub-daily	
Coverage	worldwide	worldwide tasking, up to 1.000.000 km² daily imaging capacity	
Local acquisition time[4]	2025: Data delivery for 11:00 am 2026: hourly	2025 Q3: 10:30 am & 1:30 pm 2025 Q4: 01:30 am/pm, 10:30h am/pm	
Type of images	2025: day imagery 2026: day and night imagery	2025 Q3: day imagery 2025 Q4: day and night imagery	
Acquisition angle	not applicable	up to 30°	
Temperature accuracy[6]	<5K	<1-2K with 0.03K NEDT	<3K
Spatial accuracy	< 1px	< 1px	<1 px
Data availability	2014 – ongoing[5]	Q3 2025 - ongoing	
Latency[7]	not applicable	2025: <3 days 2026: <12 hrs 2027: <5 h	
Data access	API or download		
Calibration & validation	in-situ data validation following CEOS standards Patented cross calibration of HiVE with highly accurate calibrated public missions		

1. Performances are only warranted for daytime observations of land surfaces (for islands only if larger than 100 km^2) between 50°S and 55°N. All numbers are cloud coverage dependent.
2. Defined as resampled pixel size of Land Surface Temperature (LST) products. For LSTprecision and LSTzoom native nadir looking Ground Sampling Distance (GSD) at 510km altitude is 27.3 m for Thermal Infrared data, while GSD for LSTfusion varies with different input data sources. GSD defined as a pixel projection on ground. For LSTzoom higher resolution VNIR bands are used for sharpening to 10m.
3. For LSTprecision and LSTzoom frequency relates to the geometric revisit time, defined as the mean number of observation opportunities over a period of 3 months. In 2025 < 4 days is equatorial, < 3 days at ± 40o+ latitudes and < 2 days between ± 60o and ± 80o latitude. For LSTfusion frequency defines the regularity with which data output is delivered.
4. Defined as solar local time, which is time based on the Sun's actual position in the sky at your location, without considering time zones or daylight saving shifts.
5. Because LSTfusion combines data from multiple satellites it can deliver Land Surface Temperature maps starting from 2014 using archived imagery.
6. Defined as absolute temperature error. Value defined at Mid-Latitude Summer atmosphere, ground temperature of 295K, ground cover with emissivity 0.98. High atmospheric water vapour may lead to local deviations in temperature accuracy. The Noise Equivalent Temperature Difference (NETD) is defined as the minimum resolvable temperature difference.
7. Defined as the time between image acquisition by a satellite and delivery of LST data corresponding to the acquisition. 2σ (95%) over 1000 deliveries.

Detailed specifications of LST HiVE and the HiVE mission can be found in section 4 and Table 4.

4 Company Background

constellr is a European technology company with proprietary space infrastructure that provides global monitoring services to a range of applications across industries. Founded in 2020 as a spin-off of Fraunhofer, Europe's largest organization for applied research, research into our patented technology already commenced in 2016. Table 3 lists key milestones in chronological order.

constellr's vision is to become the global leader in thermal intelligence, providing actionable insights that redefine strategic decision-making for global resilience. Through the creation and continued development of our thermal products, we offer a near-real-time, high-resolution thermal data of the planet. This data contributes to enabling smarter decision-making across industries – from security & defense to urban planning and agriculture, from financial sectors to climate resilience.

constellr's purpose is rooted in enabling strategic insights for economic resilience, climate and national security, with a strong focus on supporting global food security. Harnessing our constellation of thermal-imaging satellites, we develop products to deliver mission-critical intelligence for sovereign decision-making, to enable agriculture to be more efficient, with farmers able to optimize water use and improve yields through regenerative practices. Urban planners and public authorities leverage our information to build more climate-resilient cities, and industries actively monitor and mitigate their environmental impact. This data-driven transformation will eventually extend to finance and insurance, where predictive analytics powered by our insights protect assets and enhance decision-making.

Compared to existing solutions, constellr delivers more reliable information, in time to act. Its space-proven technology enables the provision of accurate information in a globally scalable way and tailored to the needs of the agriculture sector. Furthermore, constellr is proud to be backed by the European Commission and the European Space Agency. This support is a testament to the company's exceptional technology and its commitment to delivering reliable, timely, and accurate information to the agriculture industry.

Table 3: Development of constellr key company milestones

Year	Milestones
2025	• Launch of **first HiVE satellite in January 2025** • Launch of **second HiVE satellite in June 2025**.
2024	• Commencement of full commercial services based on proprietary data. • Internationalization to France and the US.
2023	• **Selected as Copernicus Contributing Mission, five-year contract.** • Awarded EIC Accelerator grant for development of second generation of satellites**.** • Commencement of early commercial activities based on processing of publicly available thermal data. • Team grown to > 80 persons.
2022	• **Camera operated successfully on the International Space Station to validate our technology**. • Acquisition of hyperspectral company Scanworld. Established constellr Belgium SA.
2021	• Initiated R&D collaboration with ESA, OHB and Fraunhofer for first generation HiVE satellites.
2020	• constellr founded on a strong, patented IP base.
2016	• Development of core IP started at Fraunhofer.

4.1 Key Innovation

constellr's key innovation is a patented architecture to enable high-quality infrared imaging on microsatellites. So far, this was only possible with bus-sized systems costing hundreds of millions of Euros. Using our pioneering technology, we can reduce the cost of the satellites by a factor of around 30 at comparable performance levels.

There are three key innovations related to our core expertise to (1) deliver precise information, (2) near real-time LST retrieval, and (3) the advanced processing algorithms and fusion of data sources to improve and extend the constellr LST products.

- **(1) "Virtual calibration"** described an approach to enable both, high precision and high accuracy without any reference temperature measurements onboard the satellite. Instead of using complex mechanisms, which require additional mass and volume on the satellite, virtual calibration uses existing space and ground hardware to calibrate against, thereby substantially reducing the power, mass, and volume requirements for the satellite, effectively enabling the use of Microsatellite platforms.

- **(2) "Near real-time LST retrieval"** through the constellr processing chain. This precision is achieved through dynamic emissivity estimation, usage of highly precise water vapor predictions from atmospheric models, and real-time execution of cutting-edge atmospheric transmission models. The core LST retrieval method is designed to use flexible LWIR (Long-wave infrared) data inputs, allowing for easy instrument upgrades across the constellation while maintaining consistent LST products throughout the mission.
- **(3) "The constellr harmonized LST data product**" delivers precise global LST measurements by leveraging constellr's advanced processing chain and existing open LWIR data. The constellr LST product stands out with its higher sharpness compared to existing standard 30m LST products, achieved by using constellr's proprietary algorithm for optimized high resolution dynamic emissivity estimation. With constellr LST, users can customize their area of interest anywhere on Earth and for any time range, providing unparalleled flexibility and accuracy not yet covered by the HiVE satellites.

4.2 Our Team

Since our founding in 2020, we have also expanded to an 80+-strong team, which has an undeniably impressive track record, with deep scientific roots, many years of startup growth experience, and contributions to dozens of space missions, including several satellite constellations. We combine experience from the insurance and finance sectors, agronomy, digital product development, data science and processing, and aerospace engineering.

We have been able to hire talented individuals from some of the world's top research entities and industrial stakeholders, i.e. key constellr personnel previously worked at organizations such as ESA, OHB, Planet Labs, Fraunhofer, BASF, and Munich Re. Furthermore, constellr's management team balances start-up drive with academic excellence and complementary backgrounds in natural sciences, aerospace engineering, finance, economics, agriculture, and environmental governance.

5 Detailed Specifications for HiVE

5.1 Overview

The HiVE Mission aims to deliver Land Surface Temperature (LST) data to users at a 1-day global temporal resolution, native 30 m spatial resolution (in the thermal infrared, TIR) and better than 2K absolute temperature accuracy. To this end, we design and operate a constellation of microsatellites in the 120 kg class, flying in constellation in the same (or similar) sun-synchronous orbital plane at an altitude of 510km. The HiVE constellation is deployed in orbit via a ride-share procured from a third-party launch provider.

Table 4: Detailed data specifications

Parameter	LWIR	VNIR
Launch Dates	Q1/2025 (#1), Q2/2025 (#2), Q3/2026 (#3)	
Orbit	SSO, 510 km	
Technology	Cryo-cooled, four-band LWIR	10 band MS VNIR
Bands	8.6 – 0.3 FWHM 9.2 – 0.3 FWHM 10.6 – 0.5 FWHM 11.75 – 0.5 FWHM	Sentinel-2 like
Swath width	17.5km	21km
GSD (nadir)	30m	10m
Data continuity of system generations	Band positions of previous generations aimed to be preserved, but extended in number of bands and GSD	
Calibration	On ground calibration Vicarious calibration Patented sensor cross calibration	On ground calibration Vicarious calibration
Validation	Image-Image Validation (e.g. Landsat LST, Sentinel-3) In-situ reference data Cal/Val activities supported by ESA Mission Performance Cluster	In-situ reference data (e.g. HYPERNETS)
Metadata and Data Format	Following CEOS ARD standard for LST Cloud Optimized GeoTiff / STAC	Following CEOS ARD standard for Surface Reflectance Cloud Optimized Geotiff / STAC

5.2 Mission Payload and Hardware

HiVE’s payload is composed of three main elements: a Thermal Infrared (TIR) Instrument, a Visible and Near Infrared (VNIR) Instrument, and a Data Processing Unit (DPU). A Thermal Control System that includes a Heater Control Unit, a Focus Motor Control Unit, and a radiator, is also part of the payload. The total payload mass is 29.17 kg, margins at subsystem and component levels included.

The TIR Instrument is HiVE’s payload core. It retrieves Land Surface Temperature (LST) data while the VNIR sensor is used for georeferencing, emissivity estimation, cloud detection and additional on ground biophysical parameter estimation. Both are push-frame imagers and record multiple spectral bands (4 and 10 respectively). The TIR imager is an actively cooled Long Wave Infrared Imager that uses a commercial Mercury-Cadmium-Telluride (MCT) sensor. It achieves a 28.9 m Ground Sampling Distance (GSD) and a 17.5 km swath width at an altitude of 510km.

The visible instrument is the COTS Simera Sense Multiscape100 camera. At an altitude of 510 km, the camera has a swath width of 21 km with a native Ground

Sampling Distance of 5 m (though baselined **10m with 2x2 binning**). Thus, the camera covers the complete swath of the TIR instrument and can be used for georeferencing.

5.3 Data Acquisition Modes

The instruments are designed as such that they can operate either in targeting mode (Nominal Case), where specific targets are pre-selected and then recorded within the field-of-regard, or in satellite mapping mode (Back-up Case), where continuous stripes are recorded. Both instruments have filter strips in the along-track direction to collect multiple spectral bands over the same spot on the ground (as seen Figure 3) simultaneously.

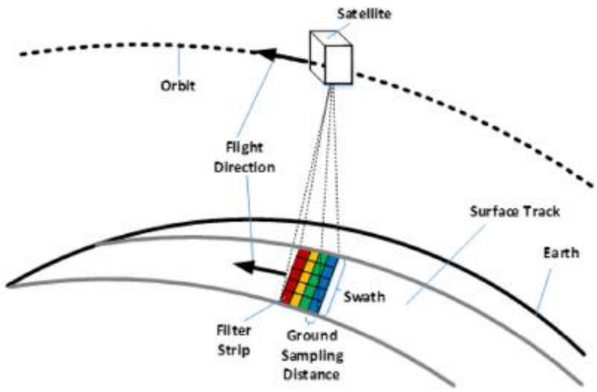

Figure 3: Spacecraft mission operations

Data from both instruments are transferred to the DPU which does the first post-processing of the recorded images, stores them on memory before directly sending them to the platform X-band transmitter for downlink to Earth. The data processing unit is further responsible for commanding the two instruments. The TIR imager has 4 bands between 8 μm and 12 μm while the VNIR imager will have 10 bands, matching Sentinel-2 bands.

5.4 Data Processing Levels

The data processing chain is following usual standards. Starting from raw data (L0) the internal calibration is applied to derive L1 top of atmosphere data. Neither geo-corrected nor band co-registered L1A data is processed using the internal orientation information of the sensor (intermediate non distributable result: L1B) and orthorectified based to a comparison of our VNIR data with Sentinel-2 reference scenes (L1C).

To derive L2 products constellr's proprietary LST retrieval algorithm is applied. In the process, the emissivity is estimated at the pixel level of the corresponding scene to consider the dynamic development of surface, while reducing artifacts and improving sharpness of the final LST data product.

The processing workflow is shown in Figure 4, including a Level 3 step which includes harmonizing 3rd party data from publicly available LWIR sources.

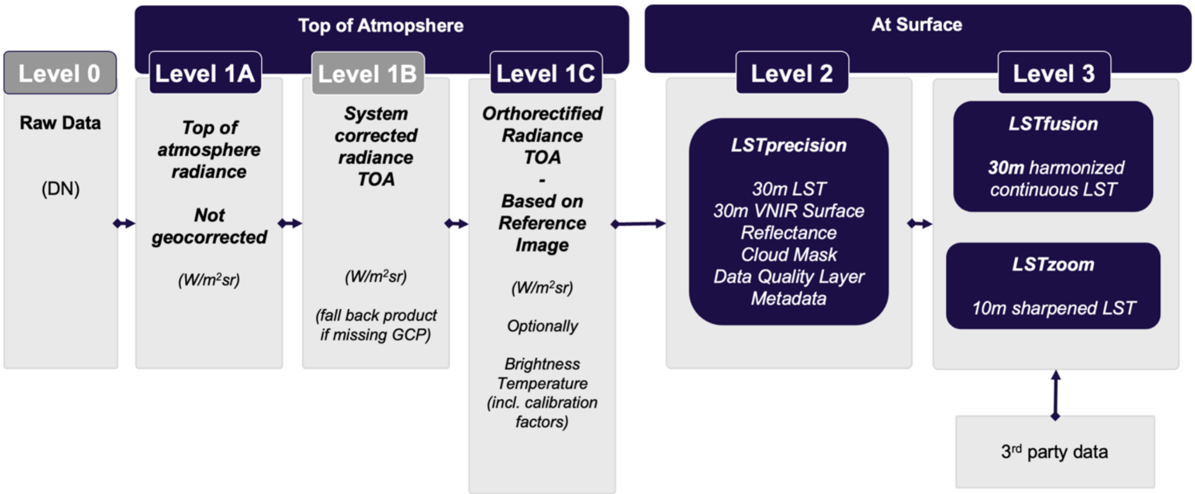

Figure 4: constellr HiVE image processing pipeline.

5.5 Data Delivery

constellr's Land Surface Temperature product comprises multiple files per scene. For each scene the user gets multiple files: one LST raster, a cloud mask, and metadata as well as VNIR data with surface reflectance as well as intermediary layers such as emissivity per thermal band. The LST raster holds for each pixel a temperature value in degree Kelvin. Additionally, the user is provided with a specification sheet of the product containing the details of the data.

6 Staying up to date

constellr maintains a Knowledge Center that provides direct access to product documentation, technical specifications, data resources, and usage examples. It is designed to support both decision-makers and technical teams by offering clear insights into our product portfolio, data interfaces, and integration pathways. The Knowledge Center is continuously updated to ensure users have the most current information, enabling effective adoption and application of our solutions.
https://constellr.github.io/product-lst/