

# VeggieH – Seeing the living Earth change in 3D

## Phase-0 study for a next generation space-borne Lidar mission

VeggieH is a proposed next-generation satellite mission that combines the power of LiDAR and multispectral imaging to deliver unprecedented, repeated measurements of the structure and condition of vegetation and land surfaces worldwide. These observations will transform our ability to track carbon stocks, understand ecosystem dynamics and detect critical changes across the land surface related to hazards, resources and infrastructures.

VeggieH was one of only [six innovative ideas](#) selected in a 2024 call to strengthen Germany's role in the global space sector with a focus on Earth Observation. The mission aims to tackle urgent ecological challenges, from climate change to biodiversity loss, by providing accurate, repeated, and more detailed data on our planet's vegetation. By combining advanced laser technology with multispectral imaging,

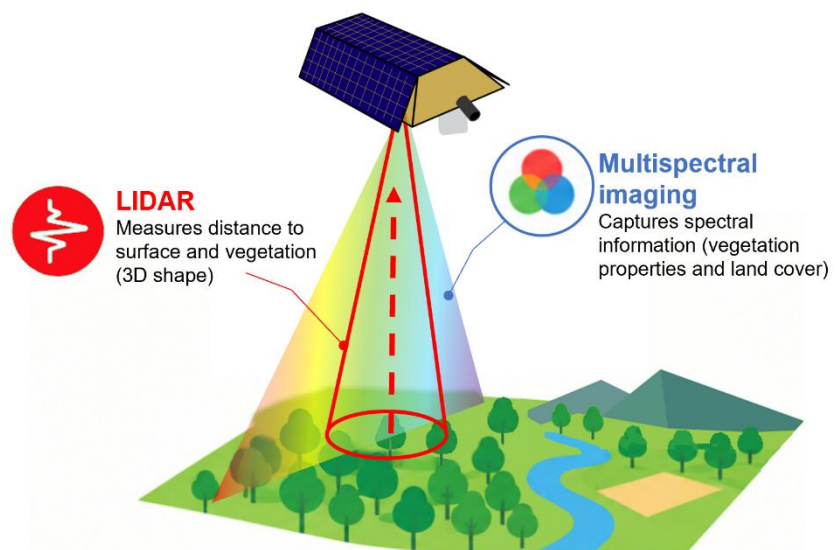


Figure 1: Illustration of the VeggieH mission.

VeggieH promises to deliver the 3-dimensional view (as illustrated in Figure 1), which is needed to observe changes in our forests and support global sustainability goals like the European Green Deal.

This document shares the results of an initial feasibility study funded by the German Aerospace Center (DLR). Launched in late 2025, this 11-month project brought together a team of experts from industry and top research institutions, initiated and lead by [Airbus Defence and Space GmbH](#) with contributions by [Helmholtz Center for Geosciences \(GFZ\)](#), [Ludwig-Maximilians Universität München \(LMU\)](#), [Fraunhofer Institute of Laser Technology \(ILT\)](#) and [Von Hoerner & Sulger \(vH&S\)](#).

### Why do we need 3-dimensional vegetation and land surface monitoring?

In a workshop organized by ESA in 2024 the need for new innovative Lidar concepts for vegetation monitoring was analyzed by international experts and the option of a combination with other sensors was discussed (Liu et al. 2025). To ensure the proposed VeggieH satellite mission meets practical scientific requirements, a survey of researchers working with spaceborne LiDAR was conducted as part of the feasibility study. The results highlighted a critical need for consistent, long-term vegetation

structural data spanning multiple growing seasons (Favrichon et al. 2026), ideally with global coverage (as highlighted for example by Friedlingstein et al. 2025). To effectively monitor biomass, natural hazards, agricultural processes, and resources many contributing factors need to be considered. For the VeggieH mission concept the following requirements were prioritized: Vegetation structure data should have high vertical accuracy of less than 10 cm, to enable monitoring of regrowth, short vegetation and crops and precise geolocation to enable the repeated identification of individual tree stands. Furthermore, reliable structural measurements and accurate ground detection, regardless of canopy density, are essential, as is the ability to detect structures below 2.5 meters for agricultural and infrastructure monitoring. To provide spatial context for full-waveform LiDAR measurements, users emphasized the need for integrated multispectral imaging and stereographic sensors capable of generating high-resolution canopy height models and capturing small-scale disturbances. Finally, this new mission must ensure interoperability with existing datasets, such as provided by GEDI and Sentinel-2, while firmly establishing European technological sovereignty in spaceborne LiDAR.

Beyond scientific needs, the diverse applications of the VeggieH mission align with broader regulatory frameworks defined by multiple European Union and United Nations policies. Regulators require precise structural data to accurately monitor forest degradation, help reduce illegal deforestation and to verify carbon stocks, moving beyond the limitations of traditional two-dimensional land-use statistics. Furthermore, the ability to measure three-dimensional structures and track spatial changes on the land surface fulfills legislative requirements for resource management. This can potentially support precise assessments of soil extraction, stockpile volumes, and surface deformation in remote mining areas.

Since both the user and policy needs substantially align, the mission creates a wide range of prospective applications. Improved global biomass estimations can be accurately extended well beyond tropical regions. Furthermore, the satellite's high revisit frequency over core areas enables the continuous monitoring of highly vulnerable ecosystems. This will further allow the development of advanced analytical methods that not only detect structural changes but also actively identify the specific drivers behind them, such as fire, logging, or biological pests. Additionally, the mission could provide important insights into forest structure by quantifying and mapping understory vegetation, a metric essential for managing temperate and Mediterranean forests facing severe climate pressures leading e.g., to increased susceptibility to forest fires among other applications. By offering continuous structural assessments, VeggieH will help bridge the long temporal gaps between large-scale, decadal campaigns like National Forest Inventories, providing actionable intermediate data that captures large-scale dynamics and enables rapid intervention. Beyond forestry, the mission will lay the groundwork for advanced applications in natural hazard monitoring, broad resource management, agricultural crop monitoring, and civil infrastructure assessment, similar to the outlined economic impact for the potential NASA EDGE mission (Garvin et al. 2026).

### What are the main goals of the VeggieH mission?

VeggieH combines high precision Lidar altimetry height measurements with high resolution multispectral imaging for tracking vegetation and topography change. Its main purpose is to improve monitoring of the Earth system and increase measurements and understanding of three-dimensional structural and bio-geochemical dynamics of the global carbon cycle, ecosystems, as well as critical land surface changes related to hazards and resources. The main objectives are summarized here:

- O1. Carbon + ecosystem dynamics:** Monitor carbon stock changes and ecosystem dynamics combining structural and biogeochemical repeat measurements.
- O2. Natural hazards and resources:** Coupling 3D topographic with land surface compositional data to improve assessments of natural hazard and land resources.

Additionally, the VeggieH mission is aiming to be a technology demonstrator for European based, end-to-end, high-precision Lidar-spectral sensing from space to catalyze new applications in science and resource monitoring

To fulfill these objectives the VeggieH mission will embark a combined Lidar and multispectral-imaging instrument, focus on repeat measurements and provide high vertical accuracy. Next to improved biomass estimates, which are an integral part of the quantification of the global carbon budget, VeggieH will serve a large variety of additional applications, for example natural hazard monitoring (forest disturbance, wild fire, land slide damage, flood monitoring), agriculture (crop monitoring, agroforestry) and resource management not only in forests, but also in the mining sector and hydrology. With its key features as shown in Figure 2 VeggieH is contributing to the improvement of critical gaps in available data of the current Copernicus and Earth Explorer programme in vegetation structure and land surface monitoring.

### What can VeggieH actually measure?

The VeggieH mission will feature one satellite with a combined Lidar and multispectral imaging capability. The swath of the multispectral imager will overlap with the Lidar footprint, which will be divided into several adjacent pixels. The satellite will collect data continuously along-track and provide Lidar-based canopy vertical profiles next to imaging data from up to eight spectral bands with high spatial resolution on a single focal plane, which together deliver direct measurements for improved biomass estimates. A main focus of the mission will be on repeat measurements for change monitoring. The orbit will allow several data acquisitions of the same ground locations evenly spaced throughout the year. The orbit will be defined to cover representative eco-systems worldwide,

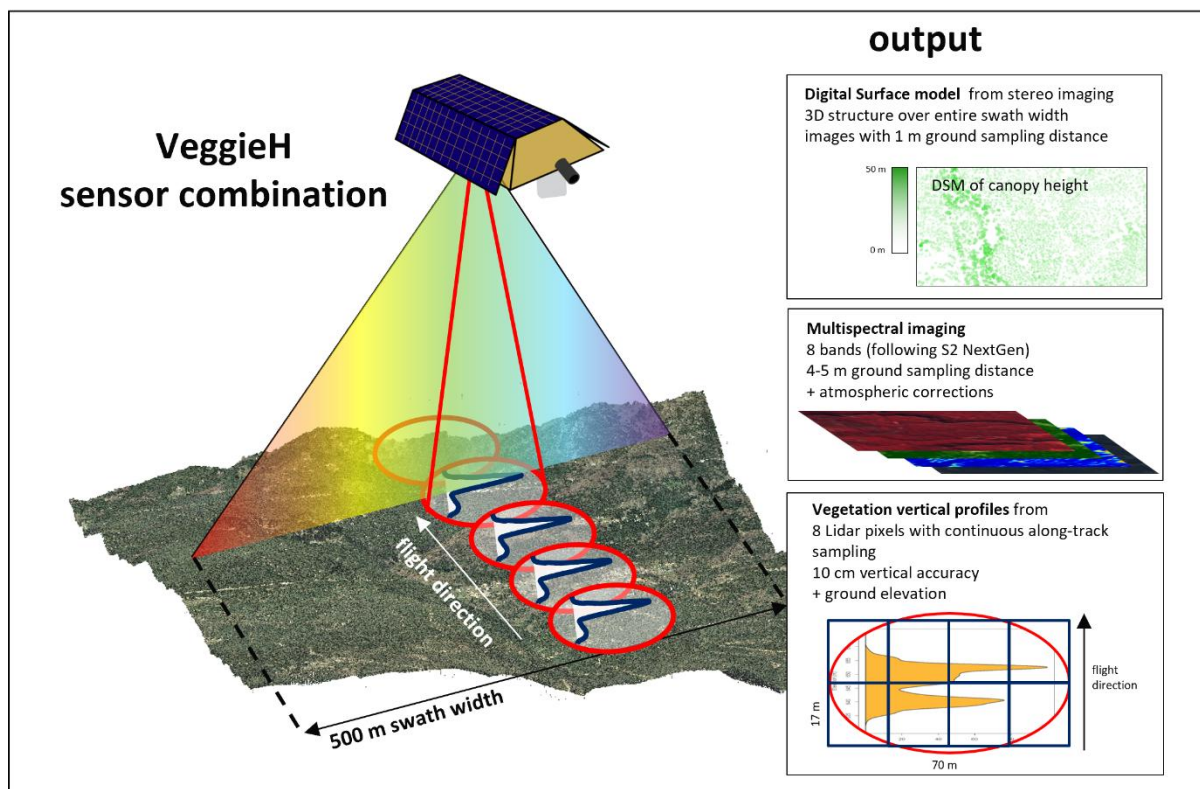


Figure 1: Schematic of VeggieH sensor combination and resulting data outputs.

including all major biogeographical regions and a large variety of eco-systems. Additionally, a pan-chromatic channel with very high spatial resolution ( $\leq 1$  m) will allow the detailed characterization of the footprint and its surrounding as well as the option to improve geolocation. It could potentially be combined with a second imager for stereo-imaging, subject to additional studies in the next phase. The

stereo-imaging would provide the potential to generate a digital surface model of changing surfaces and canopy cover over the entire swath width, with absolute height calibrated by the Lidar data. Figure 2 shows a schematic illustration of the sensor combination and each sensor output. The unique combination of Lidar-based structural data with multispectral imaging allows the derivation of established parameters from each of the sensors as well as new combined output products.

The mission will build on the experiences of current Lidar missions (i.e. GEDI) combined with recently improved laser technology (as used for the MERLIN mission(Wührer et al. 2019)) and integrate with the existing and planned Sentinel constellation to allow cross-calibration and data fusion. VeggieH will not reach an extensive coverage, but sample representative eco-systems covering the entire globe as well as specific study sites repeatedly.

**VeggieH concept summary:**

- **Laser ranging:**
  - continuous LiDAR spots with ~60m footprint split up into 2x3 pixels
  - systematic remeasurements with <30 day repeat cycle
  - basis frequency 300 Hz
  - laser energy: > 40 mJ (higher than GEDI)
  - goal of 0.1 m resolution for height measurements
- **Multispectral imaging:**
  - SWATH: ~300-500 m
  - 4 m spatial resolution on ground
  - 8-10 spectral bands following S2-NextGen + atmospheric corrections
- **Panchromatic imaging:**
  - SWATH: ~300-500 m
  - 1 m resolution on ground
  - potential for stereo capabilities with ~2 m resolution

### What are the next steps?

The scope of the Phase 0 study was to gather user and scientific needs, derive the corresponding mission requirements, and establish a system concept. Based on these requirements, the mission and instrument concept was developed by incorporating lessons learned from previous LiDAR projects. The design prioritizes solutions that minimize technological development risk. The proposed mission follows a classical development approach, utilizing high-performance instruments and platforms in compliance with ECSS development standards, similar to an ESA Earth Explorer mission. In a subsequent Phase A study, the instrument and platform strategies could be revisited once instrument sizing and final material selections are confirmed. Additional studies focusing on detailed requirements for stereo capabilities, global coverage, and LiDAR sensitivity, specifically the ability to detect the forest floor in densely vegetated areas, would be conducted to further optimize the instrument design. A comprehensive science plan and product description would also be developed.

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