HSLU Lucerne University of Applied Sciences and Arts

Visual Servoing Testbed (VSTB)

A low-cost validation and development platform for teams developing camera-based visual servoing systems, from pose estimation and GNC algorithms to embedded firmware and camera hardware.

FH Zentralschweiz

Purpose

VSTB provides a hardware- and camera-in-the-loop environment for validating passive visible-light visual servoing systems for space and other applications under realistic conditions. It supports orbital rendezvous, proximity operations, and other closed-loop camera-based control applications, enabling realistic testing of camera hardware, embedded firmware, pose estimation, and closed-loop GNC integration without requiring complex mechanical motion systems. VSTB offers a compact, modular alternative for testing throughout the development lifecycle, from early algorithm, hardware, and firmware prototyping to final system validation.

Key Capabilities

- **Hardware- and camera-in-the-loop testing** without mechanical moving parts
- **Closed-loop rendezvous simulation** for joint validation of GNC and pose estimation algorithms
- **High-fidelity image presentation** using a 4K OLED display with high refresh rate, low response time, HDR support, high peak brightness, and ΔE < 1 color performance
- **Flexible optical setup** with adjustable display distance up to 1 m, supporting full-screen operation for camera optics with horizontal field of view ≥ 35°
- **Controlled illumination conditions** using a light-absorbing dark enclosure for deterministic and repeatable testing
- **Modular architecture** enabling drop-in replacement of devices under test
- **MQTT-based interfaces** for simple integration of custom components
- **Camera calibration workflow** for domain-gap minimization
- **Camera-in-the-loop dataset generation** for algorithm development, testing, and benchmarking

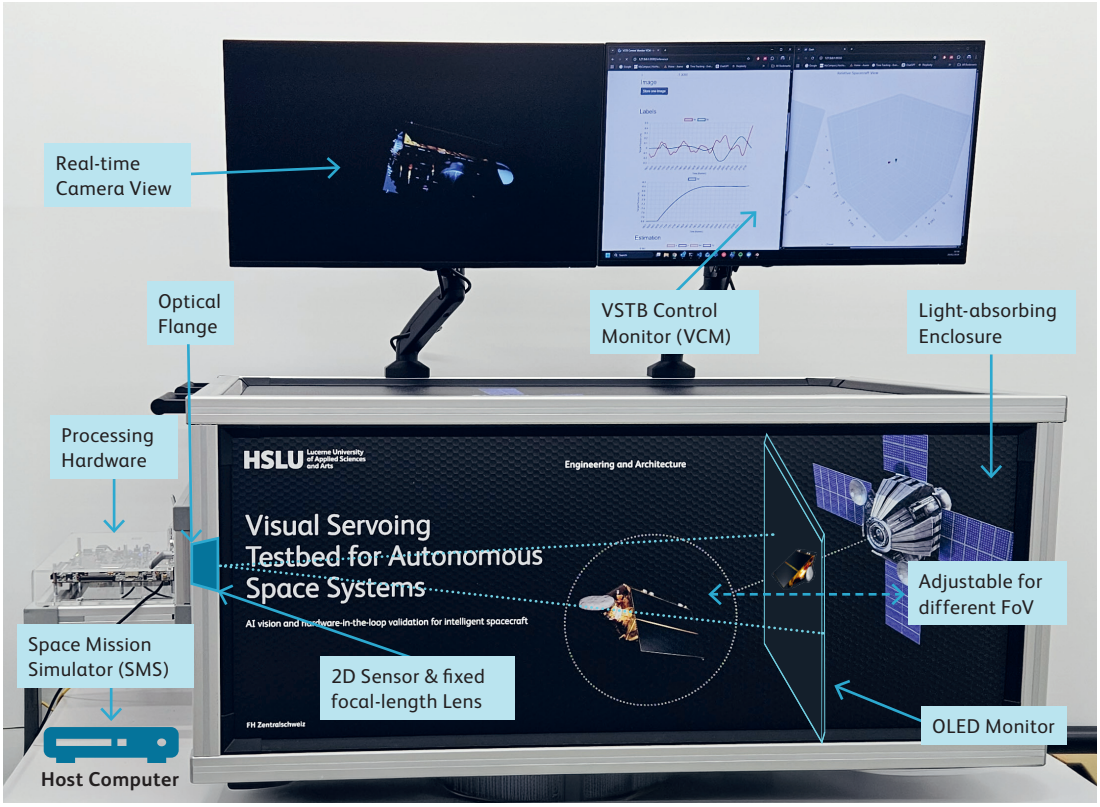
Setup

VSTB is built around a compact, light-absorbing dark enclosure measuring **1592 × 565 × 785 mm**. The enclosure fits through a standard door and can be transported in a mini-van.

Inside, a high-resolution OLED display presents synthetic camera scenes generated from the simulation state. A flexible camera mount and optical flange allow custom camera hardware to be installed while keeping the hardware accessible for development and debugging. The display position can be adjusted to accommodate different optical configurations and camera fields of view.

Components

Component	Function
Space Mission Simulator	Closed-loop simulation environment based on pykep for rendezvous and proximity-operation scenarios
Synthetic Image Rendering	Real-time rendering of camera scenes based on simulation states
Image Display	31.5-inch 4K UHD Asus ProArt OLED display with up to 240 Hz refresh rate, 0.1 ms response time, HDR support, 1000 nits peak brightness, and ΔE < 1 color performance
Device under Test	Adjustible interfaces to accomodate custom camera and processing hardware
Mechanical Setup	Adjustable display distance up to 1 m; full-screen operation suitable for camera optics with horizontal field of view ≥ 35°; Light-absorbing enclosure with external dimensions 1592 × 565 × 785 mm



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06-2026