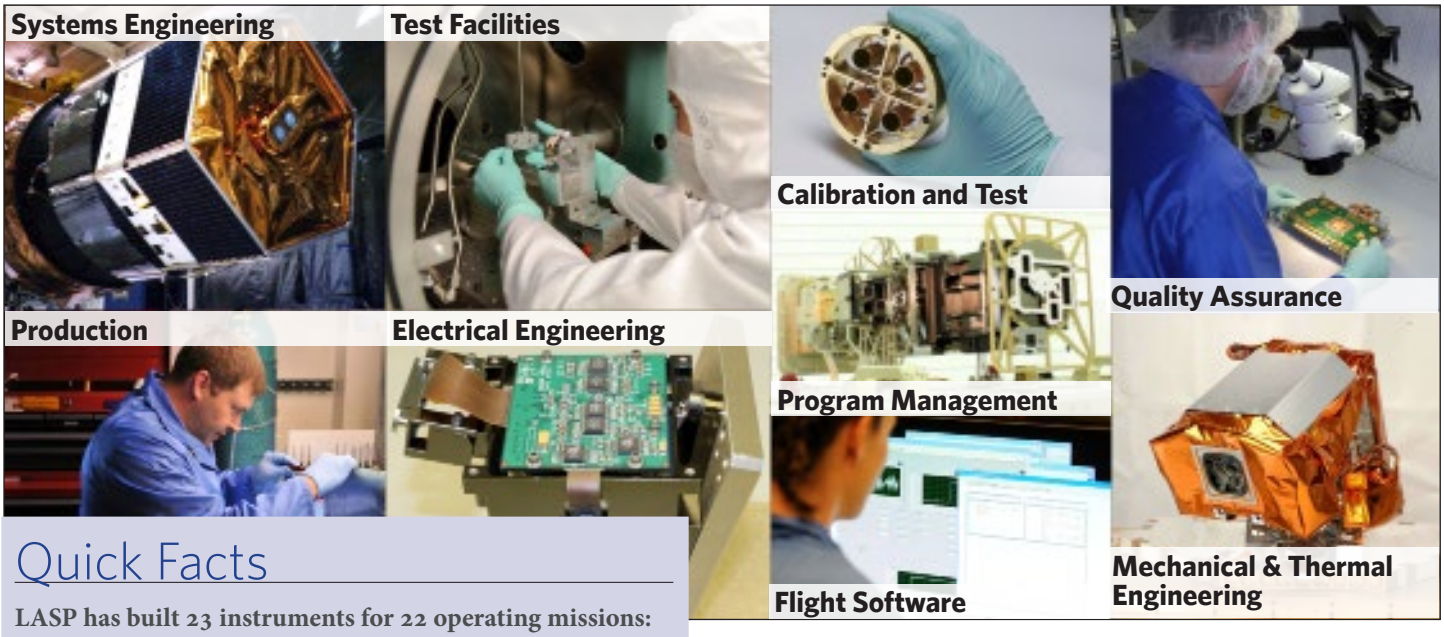
Engineering Capabilities

Laboratory for Atmospheric and Space Physics
University of Colorado Boulder



Quick Facts

LASP has built 23 instruments for 22 operating missions: AIM, CSIM, GOES-16 & 17, GOLD, MAVEN, MMS, New Horizons, Parker Solar Probe, SDO, THEMIS/ARTEMIS, TIMED, TSIS-1 SIM & TIM, Voyager I & II

LASP is developing 25 instruments for 21 missions: NASA: AEPEX, CIRBE, CLARREO Pathfinder, CTIM, CUTE, DALI/EDA, ESCAPE, Europa Clipper SUDA, EVC-1 Libera, IMAP IDEX, INSPIRESat-1 DAXSS, INSPIRESat-4 OWLS, LSITP, SPRITE, TSIS-2; NOAA: GOES-T & U EXIS; UAE: Emirates Mars Mission; NSF: CANVAS, VISORS; ESA: Daedalus / EFI

LASP has experience on NASA, NOAA, and Air Force contracts, as well as commercial partnerships.

LASP has launched 200 sub-orbital rocket experiments.

Full Lifecycle Program Management

- Science requirements definition to publication of data
- Hardware and software design, build, test, and delivery
- Financial and schedule management

Systems Engineering

- Requirements development and verification
- Interface control
- System analyses
- Resource tracking and management

Quality Assurance

- ISO 9001:2008 compliant
- Inspections for compliance to NASA and industry standards
- Safety, ESD, and contamination control

EEE Parts Engineering and Procurement

- Ensuring EEE part mission assurance requirements are met for design, quality, radiation and traceability

Electrical Engineering

- Low noise, high precision detector interface electronics
- Complex DSP and SoC FPGA design
- Custom low and high voltage power conversion
- Open-loop and precision closed-loop control

Flight Software

- Embedded systems to control flight instruments and spacecraft
- Ground systems such as S/C simulator software, telemetry analysis software, and FPGA diagnostics software
- Custom time slice architecture and VX Works RTOS
- NPR 7150.2 A compliant

Mechanical and Thermal Engineering

- Optical and electromagnetic fields instrument design, analysis, and test
- One-time and extended life mechanisms and gimbaled platforms
- Thermal control design and testing of detector, payload, and spacecraft systems
- Spacecraft structures, kinematic mounts and vibration isolation, electronics packaging

In-House Production Operations

- Workmanship certified assembly and polymerics technicians
- CNC machining with CMM verification capabilities

Calibration and Test

- Optical design and detector development for X-ray to infrared wavelengths
- Full characterization capability with NIST-traceable calibration standards
- Vacuum and thermal environmental testing facilities

Industry products and services

- **Test Facilities—**Thermal vacuum and bake-out tanks are available to external customers (see BEMCO and BOT pages)
- **Astrolabe Spacecraft Bus**—highly configurable to support your mission needs (see Astrolabe page). Contact pete.withnell@lasp.colorado.edu

Bemco Facility

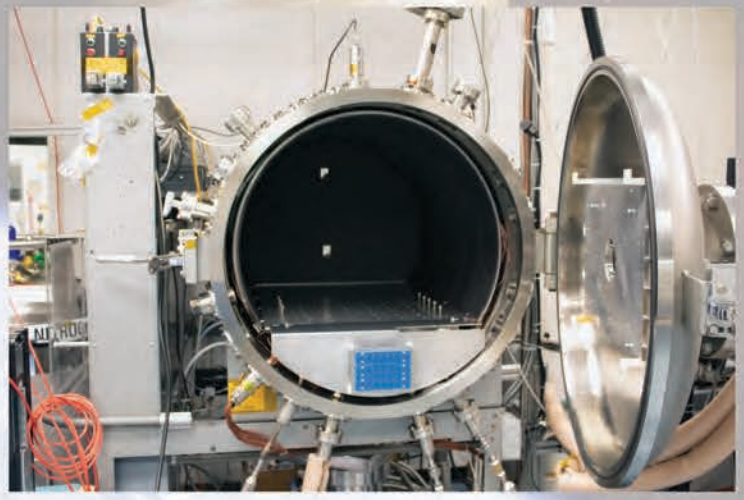
LASP thermal vacuum chambers are state of the art testing facilities that allow the end user complete customization with their test and chamber. Described in this brochure, the Bemco test facility is an optimum facility for smaller instruments and CubeSATs. The facility is comprised of two separate chambers built into one vessel. The choice of which chamber is most appropriate depends on the testing needs.

Bemco East chamber operations occur in an ISO 7 clean room allowing testing of highly sensitive items, while the mechanical parts remain in our control room for this chamber. For less sensitive items, Bemco West opens into the control room resulting in much quicker operation and turnaround.

Both chambers are thermal controlled using recirculating chillers that flow Galden HT-90 through an aluminum platen. In addition to this, Bemco West also has a shroud that encompasses the ceiling of the chamber. This is thermal controlled using LN2 and polyimide heater patches. The total encompassing thermal control of Bemco West allows for quicker cycling time to efficiently run a TVAC schedule.

Both chambers come fitted with a thermocouple array to easily fit the chamber with test hardware. To avoid any possible contamination, they also contain a heat sink that is controlled using LN2.

Below is a quick reference of each chamber listing the equipment, dimensions, and limits.



Temperature Range: -165 to +140 °C (shroud and platen capability configuration dependent)
Interior Dimensions: 20"h x 22"w x 35"d
Platen Bolt Pattern: Tapped for ¼-20 bolts with center spacing of 2.5"

Bemco West

- Cryo-Torr 8 HV pump
- MKS 972B DualMag all-range pressure transducer
- MKS PDR900 pressure gauge controller
- SRS RGA 200
- Can be set up with QCM Research MARK 20 TQCM or MARK 18 CQCM

Temperature Range: -65 to +70 °C
Interior Dimensions (over platen): 20"h x 18.5"w x 48"d
Platen Bolt Pattern: Tapped for #10-32 bolts with center spacing of 2.3"

Bemco East

- Cryo-Torr 8 HV pump
- Ion gauge with high voltage interlock
- SRS RGA 200
- Can be set up with QCM Research MARK 20 TQCM or MARK 18 CQCM

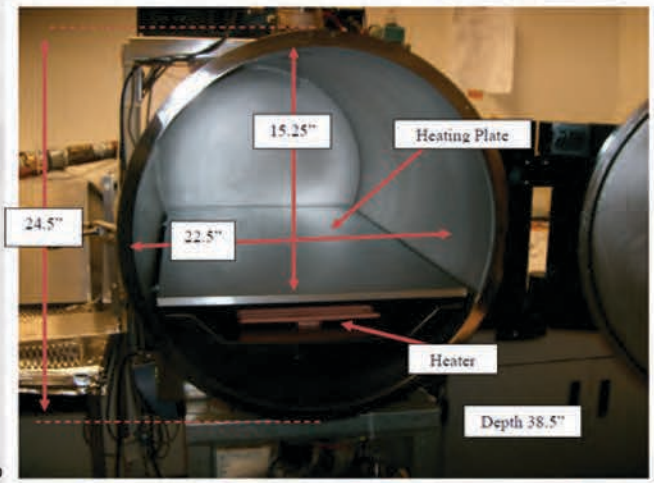
LASP

Bake Out Facility

The Bake Out Tanks (BOT) are a series of vacuum chambers with thermal control capabilities used to heat items under vacuum and determine the cleanliness of the items. There are two different chambers each with a different size and capability. Both chambers have the ability to be run with an LN2 cold plate to either increase pumping speed or act as a safeguard against contamination. Typically all bake out runs are "sniffed" with a mass spectrometry of the residual gas in the chamber to check the cleanliness of the parts being baked. The residual gas is analyzed and determined whether or not the part meets a passing criteria from the mass spectrum read out.

The BOT facility is also capable of measuring the outgassing rate of a part or just a test material to determine if it is a viable option for vacuum operations. This is accomplished through TQCM or CQCM measurements. This option is available on both BOT chambers.

The BOT chambers can be configured to do more than just bake out. The chambers have high adaptability for any test and can be put in numerous configurations to meet any vacuum testing need.



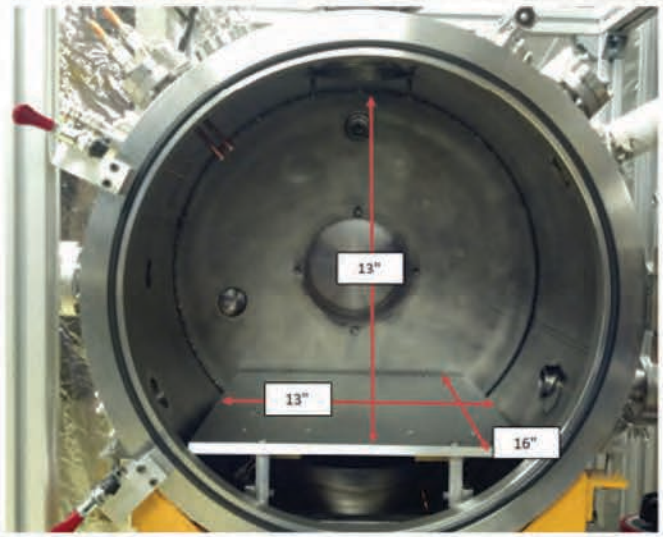
Temperature Range:
30 - 105 °C
Interior Dimensions:
15.25"h x 22.5"w x 38.5"d

BOT I

- Varian Tri-Scroll rough pump
- Pfeiffer D-35614 Asslar turbo pump
- Pfeiffer DCU 150 turbo controller
- MKS 972B DualMag all-range pressure transducer
- MKS PDR900 pressure guage controller
- Omega CN16DPT-445 PID controller
- SRS RGA 200
- Can be set up with QCM Research

The BOT facility also contains a substantial air bake oven that can be used to prebake items before bake out if they are consider to be significant contamination risks or if a part requires a desired cure process before bake out.

Below, each of the BOT chambers along with the oven described are shown with specific equipment used to operate the chamber and exact dimensions.



BOT III

- Oil free Tri-Scroll 300 rough pump
- Agilent 551 Navigator turbo pump
- Agilent V-550 turbo controller
- MKS 972B DualMag all-range pressure transducer
- MKS PDR900 pressure guage controller
- Omega CN16DPT-445 PID controller
- SRS RGA 200
- Can be set up with QCM Research MARK 20 TQCM or MARK 18 CQCM

Temperature Range:
30 - 150 °C
Interior Dimensions:
13"h x 13"w x 16"d

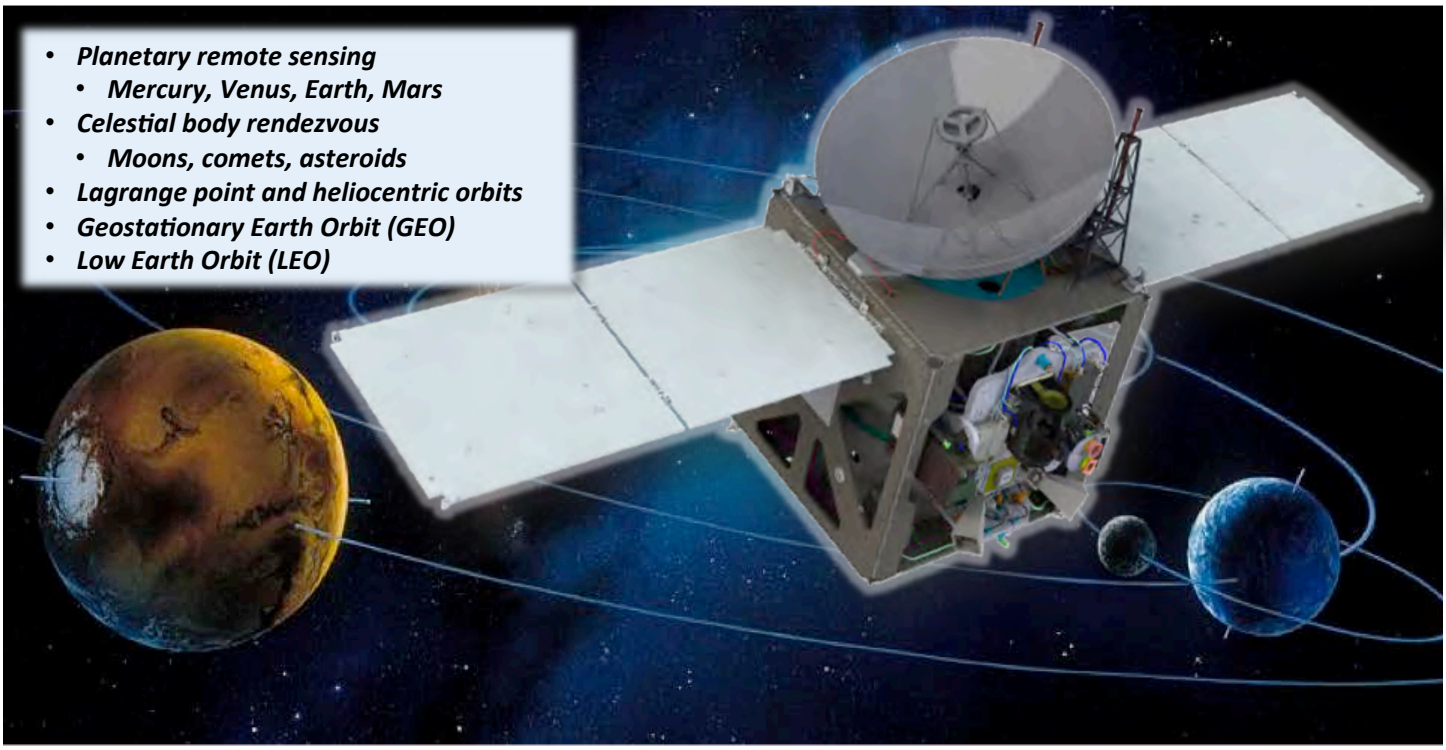
TARDIS

Temperature Range:
30 - 250 °C
Interior Dimensions:
61"h x 31.6"w x 25"d

The Astrolabe Bus

Astrolabe can take you where you want to go

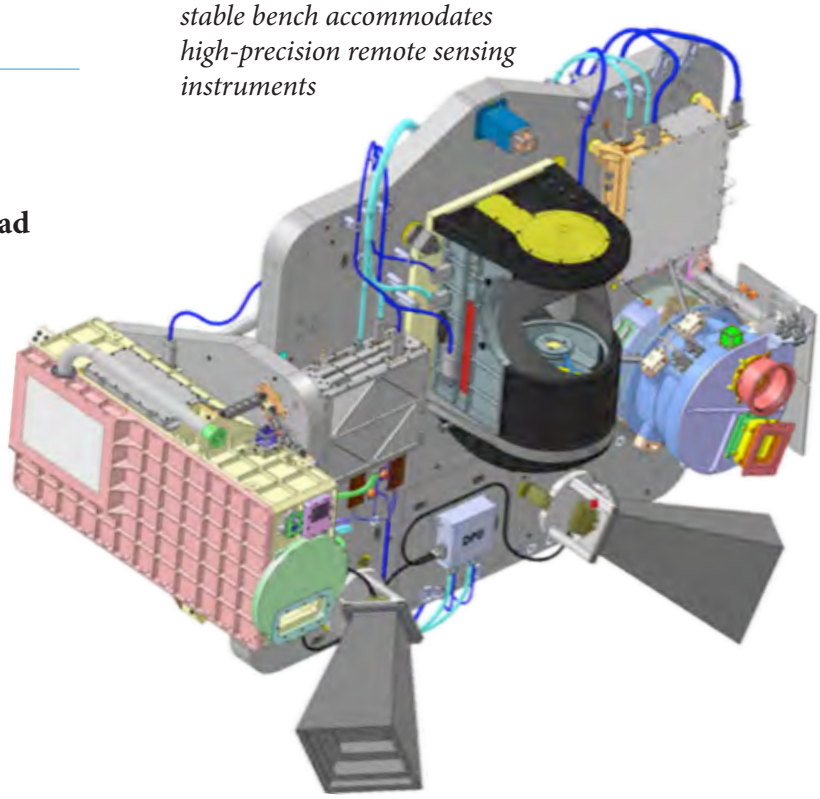
Laboratory for Atmospheric and Space Physics
University of Colorado **Boulder**



Instrument Accommodation (highly configurable)

- **Surface or kinematic mounting**
- **RS-422, LVDS, Spacewire, 1553 interfaces available**
- **Up to 500 kg available to instrument payload**
- **Up to 700 Watts available to instrument payload**
- **~1 Mbps data to Earth from deep space or 10's of Mbps from LEO or GEO**
- **Nadir, zenith, limb, solar pointing**
- **Scanning or stationary**
- **High precision pointing**
  - **Control: 6 arcmin**
  - **Knowledge: 1 arcmin**
  - **Jitter: 2 arcsec/3 sec**
- **Sun avoidance/Sun protection**
- **Thermally isolated or thermally sinked**
- **Precision thermal control available**

Thermally and optically stable bench accommodates high-precision remote sensing instruments



Leveraging our 70 year history of successful space exploration, LASP achieves cost-effective mission and spacecraft customization through whole-system synthesis by our highly experienced systems engineering and program management teams, together with our world-renowned scientists and mission operations group. This unique combination of mission segments within a single organization creates the critical ethos necessary to produce a targeted, effective, and collaborative mission solution.

Astrolabe is a highly configurable bus that can accommodate deep-space, GEO, or LEO missions.

The Emirates Mars Mission (EMM) bus, the origins of Astrolabe, was a joint international effort between LASP and the Mohammad Bin Rashid Space Center in the United Arab Emirates.

- **Heritage components in custom solutions**
- **Parallel integration design maximizes available instrument development time**
- **Agile, responsive, inclusive, and payload-focused development team**
- **Highly test-driven development philosophy**
- **Significant experience developing high-performance pointing platforms**
- **Highly configurable fault-protection systems**
- **International collaboration: ITAR/EAR/Export control and licensing successfully implemented over three years**
- **On-site development labs, clean rooms, and thermal-vacuum testing chambers**

Spacecraft Overview

- **ADCS**
  - 3-axis stabilized, inertially pointed
  - Redundant star trackers and IRUs
  - 4 for 3 reaction wheels
  - 8 for 4 one-Newton RCS thrusters for reaction wheel desaturation, safe mode, and roll control during Delta-V maneuvers
- **Command and Data Handling**
  - Selectively redundant computer with extensive fault protection
  - Architecture supports a fully redundant configuration
- **Flight Software**
  - Based on NASA's open-source CFE-CFS software with mission-specific applications
- **Electrical Power Systems**
  - Direct energy transfer system
  - Deployable, non-articulating arrays, 12 strings; articulated arrays available
  - Lithium ion battery with m-for-n cell redundancy
  - Fully internally redundant Power Control Unit
- **Thermal**
  - Thermostatically and flight software controlled heaters (most redundant)
  - Multi-layer insulation (MLI)
  - Passive radiators
- **Telecom**
  - 1.85-meter high gain antenna
  - Spherical coverage low gain antennas
  - High-reliability deep-space X-band radio talking to NASA's DSN; Ka-band available for higher rate communications
  - 100-watt TWTA
- **Propulsion**
  - Regulated monopropellant hydrazine
  - 6 x 100 Newton Delta V thrusters for planetary orbit insertion or celestial body rendezvous
  - 8 x one-Newton RCS thrusters; larger thrusters available for greater maneuverability
- **Structure**
  - Central thrust cylinder with honeycomb composite panels
- **Launch Vehicle**
  - Compatible with any GEVS enveloped launch capability
  - Proven interface heritage with Mitsubishi Heavy Industries HIIA

Additional Services

Program Management—Adept at tailoring projects for customer-desired levels of engagement, reporting, and access

Mission Design and Navigation—Significant experience in implementing complex, interplanetary orbits and trajectories with partners

Mission, Spacecraft, and Instrument Systems Engineering—Broad experience architecting and implementing mission, spacecraft, and instrument solutions; all under one organizational group to foster collaboration and cohesion

Mission Operations—On-site mission operations experts and facilities implementing turn-key solutions with extensive experience flying both Earth-orbiting and deep-space missions

Data Systems—Hosted data centers, data processing experts, and web-based interactive data tools developers

For more info on Astrolabe and LASP engineering services, please contact:
Pete Withnell at 303-492-1326 or pete.withnell@lasp.colorado.edu.

The Laboratory for Atmospheric and Space Physics (LASP) combines all aspects of space exploration through our expertise in science, engineering, mission operations, and data management. As an institute at the University of Colorado Boulder, LASP includes students throughout our activities. Learn more at http://lasp.colorado.edu.

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