An overview of the Hawaii Space Flight Laboratory

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The **Hawaii Space Flight Laboratory** (HSFL) was established in 2007 at the **University of Hawaii at Manoa** as an Aerospace Workforce Development Program.

- HSFL was conceived as a collaboration between the [School of Ocean and Earth Science and Technology](http://www.soest.hawaii.edu) (SOEST) and the [College of Engineering](http://engineering.hawaii.edu) (CoE). It is currently embedded as a laboratory of the [Hawai‘i Institute of Geophysics and Planetology](http://www.higp.hawaii.edu) (HIGP) and is also directly connected to the [Hawai‘i Space Grant Consortium](http://spacegrant.org) to support students and space related projects.

- As a **multidisciplinary research and education center**, HSFL brings together individuals from various areas of research in sciences and engineering to work on the exploration and understanding of space. HSFL enables the University of Hawaii and other national organizations to design, build, launch and operate microsatellites in the 1-100 kg range that can be configured for a variety of science and educational objectives.

[HIGP Outreach Video](http://www.higp.hawaii.edu/hsfl/hsfl-outreach-video.html)
HSFL works with researchers at UH and other organizations to develop space mission concepts in diverse areas such as:

- **Earth Science research**
  - HIGP and HSFL have developed SmallSat missions using Hyperspectral Thermal Imaging for Earth Observation (HiakaSat, HyTI) in applications such as geological sciences for mapping of different minerals, volcanic hazard assessments and a series of other remote sensing applications.

- **Particle Physics research**
  - Neutron-1 is a collaboration between ASU and HSFL to measure low energy neutron flux in a low Earth orbit (LEO) environment using the Luna-H Map detector.

- **Solar Physics research**
  - HSFL and the Institute for Astronomy (IfA) are working on SmallSat concepts that can continuously observe the sun from orbit by exponentially increasing the science return compared to solar eclipse ground observations. Collaboration with Shadia Habbal and team.

- **Exoplanet research**
  - SmallSats orbiting in LEO have an extreme advantage over ground observations to detect the tiny variations in the signal coming from exoplanets. HSFL is working with IfA to develop new exoplanet search mission concepts. Collaboration with Michael Bottom and team.

Special filters enable scientists to measure different temperatures in the corona during total solar eclipses, such as this one seen in Mitchell, Oregon, on August 21, 2017. The red light is emitted by charged iron particles at 1.8 million degrees Fahrenheit and the green are those at 3.6 million degrees Fahrenheit. Credit: M. Druckmuller and published in Habbal et al. 2021

Images of disks and low-mass companions to stars taken from Mauna Kea. High-contrast imaging is the most promising way of studying planets at intermediate to large separations from their host stars.
HSFL Partners and Collaborators

We would like to add your organization to this list ...
HSFL Capabilities
1. Spacecraft
   - Design, build, launch, and operate 1-100 kg small satellites for science and education tasks.
   - Support technology validation missions as well as other University missions.

2. Integration and Test
   - Clean rooms to assemble & test satellites:
     - Systems integration
     - Thermal-vacuum testing
     - Vibration/shock testing
     - Payload spin balancing
     - Attitude control testing

3. Instruments
   - UH has diverse instrument-developing faculty from HIGP and SOEST.
   - Partnerships with organizations to provide technology demonstration opportunities. Also NASA centers and JPL are interested in joint technology missions.

4. Launch Vehicle and Launch Support
   - Pacific Missile Range Facility (PMRF)
     - Local launch facility and mission support
     - Modified existing PMRF launch pad for rail-fitted and modified VAFB Scout launcher.
   - Kauai Test Facility (KTF)/Sandia National Lab
     - Experience with solid rockets and missile design. Use Super-Strypi launch vehicle.
     - Can lift ~270 kg (594 pounds) to 400 km (LEO).
     - Heritage working with PMRF as on-site vehicle integrator and launch agent.

5. Ground Station & Mission Ops
   - UHF/VHF/S-band stations at Kauai and Honolulu CC.
   - Mission Ops Center @ POST 5th floor using COSMOS software.
   - HSFL also supports the DoD MC3 network.
### HSFL Satellite Platforms

<table>
<thead>
<tr>
<th>Class</th>
<th>HS-3</th>
<th>HS-6</th>
<th>HS-12</th>
<th>HS-50</th>
<th>HS-100</th>
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<tbody>
<tr>
<td>Size</td>
<td>3U</td>
<td>6U</td>
<td>12U</td>
<td>50 kg</td>
<td>100 kg</td>
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<tr>
<td>Pointing</td>
<td>0.1 - 2°</td>
<td>0.1 - 2°</td>
<td>0.1 - 1°</td>
<td>0.1 - 1°</td>
<td>0.1 - 1°</td>
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<tr>
<td>Comm. Options</td>
<td>UHF, VHF, S-Band, X-Band, GlobalStar/Iridium</td>
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<td>UHF, VHF, S-Band, X-Band, GlobalStar/Iridium</td>
</tr>
<tr>
<td>Payload</td>
<td>1 kg, 1W</td>
<td>2 kg, 5W</td>
<td>4 kg, 10W</td>
<td>10 kg, 10-20W</td>
<td>30 kg, 20-30W</td>
</tr>
</tbody>
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- Design/Proposal Phase through delivery and ops.
- HSFL accepts risk to test new space technologies while training workforce.
- HSFL Integration and Test Facility available to industry partners.
- HSFL tailored mission operations solutions with COSMOS.
Intivac Thermal Vacuum Chamber
1.6 m I.D. x 2.25 m long, 10⁻⁸ Torr

Vibration and Shock Table
Tests objects 1.2 x 1.2m
5-2200 Hz to 7000 kgf; 14000 kgf shock

Spin Balancer

Attitude Control Test Facility
ADCS testing for 1-100 kg satellites
Magnetic Field, Sun, Nadir, GPS and Star tracker stimulators

Spacecraft Avionics Development Equipment/Facilities
Machine Shop, PCB prototyping and repair equipment, etc.

Class 10,000 cleanroom
Located in the basement of the POST building.
HIGP/HSFL Instruments

- **Space Ultra-Compact Hyper-Spectral Imaging (SUCHI)**
  - Fabry-Perot FTIR
  - Uncooled 320x256 microbolometer array
  - Sensitivity 20 mK or better at 30 Hz frame rates, F1.4
  - Approx. 220 m ground resolution from 500 km
  - 7 wave channels between 7 and 14 μm

- **Thermal Hyperspectral Imager**
  - Uncooled 320x256 microbolometer array
  - Sagnac Interferometer
  - Approx. 120 m data from an altitude of 500 km
  - 40 spectral bands between 8-14 microns, with peak SNR of 1000:1

- **Thermal Infra-Red Compact Imaging Spectrometer (TIRCIS)**
  - Fabry-Perot interferometer
  - Uncooled microbolometer array
  - Approx. 120 m data from an altitude of 500 km
  - 90 spectral bands between 7.5-14 microns
  - Mass <10 kg, Dims. 53 cm × 25 cm × 22 cm

- **CubeSat Infrared Hyperspectral Imager**
  - Fabry-Perot interferometer
  - Cryocooled
  - 25 spectral bands between 8-10.7 microns
  - Approx. 60 m data from an altitude of 500 km
  - General Purpose Imager
  - Resolution 640x520
  - Sensor Size: 2/3”
  - Monochrome and Color
  - Frame rate: 139 fps
Super Strypi Launch Vehicle: ORS-4 Mission

- **Super Strypi** is expendable launch system developed in collaboration between University of Hawaii (HSFL), Sandia National Labs and Aerojet Rocketdyne
  - 1st Launch: November 3, 2015
- **HSFL mission partner for rail and microsat development.**
  - Largest rail launcher in the world built and successful
  - HiakaSat 50-kg microsat delivered by NASA and Air Force standards.
- **ORS-4 terminates ~60 seconds into flight**
- **ORS-4 Takeaways:**
  - HSFL receives $29M contract
    - $5.1M in salaries
    - $4.0M in overhead return to UH
  - 130 Hawaii students received training/experience with HiakaSat
  - HSFL partnerships for future microsat work
  - X-Bow commercial follow-on missions

[Link to UH News Video 2015-11-10](#)
Sample Orbital Trajectories from Hawaii

Courtesy X-Bow Launch Systems, Inc.
HSFL Ground Stations

Honolulu Community College
X-band

Kauai Community College
UHF/VHF/S-band

UH Manoa – NRL MC3 GS
UHF/S-band

Affiliated Ground Stations:
Alaska Space Facility (S-band)
Surrey Space Centre/SSTL (UHF/VHF/S-band)
HSFL Mission Ops Software: COSMOS

- **Comprehensive Open-architecture Solution for Mission Operations Systems (COSMOS)**
  - [https://www.hsfl.hawaii.edu/projects/cosmos/](https://www.hsfl.hawaii.edu/projects/cosmos/)
  - [https://hsfl.github.io/cosmos-docs/](https://hsfl.github.io/cosmos-docs/)
- NASA EPSCoR funded
- Software ecosystem/framework to support spacecraft mission operations
- **Set of tools:**
  - Mission Planning & Scheduling Tool (MPST) -> COSMOS Web
  - Mission Operations Support Tool (MOST) -> COSMOS Web
  - Ground Segment Control Tool (GSCT) -> COSMOS Core
  - Data Management Tool (DMT) -> COSMOS Core / COSMOS Web
  - Flight Dynamics Tool (FDT) -> NA / COSMOS Web
  - Analysis Tools -> COSMOS Core
  - Test Bed Control Tool (TBCT) -> NA
  - COSMOS Executive Operator (CEO) -> COSMOS Web
- Open architecture to enable modifications and adaptation to new missions and MOCs
- User-friendly interfaces and short learning curves for users and software integrators
Space Missions
HiakaSat (HS-50)

- Fully qualified and delivered to Air Force in 2015
- HiakaSat (Hyperspectral Imaging, Aeronautical Kinematic Analysis Satellite), is a microsat mission developed by faculty and students of the University of Hawaii
- Design Lifetime: 2 year
- Mass: 55 kg
- Instrument: The Space Ultra-Compact Hyperspectral Imager (SUCHI) using a Fabry Perot interferometer
HSFL Current CubeSat Missions

NEUTRON-1 (3U)

- [ElNa 31 Launch](#)
- Goal: Measure low energy neutron flux in LEO
- Team: HSFL, ASU
- Launched: Fall 2020

HyTI: Hyperspectral Thermal Imager (6U)

- [NASA InVEST Award](#) of ~$5.5M
- Goal: Test the next generation of high spatial, spectral and temporal resolution thermal infrared imagery. Cryocooled detector.
- Team: UH (HIGP, HSFL), JPL, SaraniaSat, others.
- Expected Launch: Q1-Q2 2022
Neutron-1 COTS ADCS Testing and Research

Validate and Test Commercial Off the Shelf ADCS Solutions such as the CubeADCS shown below.
Neutron-1 Launched from ISS on Nov 5, 2020
HyTI Mission Goals

To demonstrate high spectral, high spatial, and high SNR long-wave infrared imaging, and high performance on-board computing to process the resulting data, on a 6U CubeSat platform.

1. HIGP Fabry-Perot LWIR imaging interferometer (TRL$_{in} = 4$)

2. JPL T2SLS Barrier InfraRed Detector (BIRD) focal plane array (TRL$_{in} = 5$)

3. Unibap Deep Delphi iX5 heterogeneous onboard computer (TRL$_{in} = 5$)
Education

- Outreach
- Undergraduate Research
- Earth and Planetary Education Technology
- Concentration in Aerospace Engineering
- Graduate Education
Hawaii Space Grant Overview

- **NASA Space Grant and EPSCoR Programs**
  - **Space Grant**: Workforce Development for US citizens.
  - **EPSCoR**: Research Infrastructure Development.
  - **HSFL**: Created as workforce and infrastructure development project.

- **Hawaii Space Grant Consortium (HSGC) Members**
  - **Educational**: UH-Hilo, Hawaii CC, UH Maui College, Kauai CC, Windward CC, Honolulu CC, Kapiolani CC, Leeward CC, UH-Manoa, U Guam.
  - **Corporate**: Pacific International Space Center for Exploration Systems (PISCES), Kamehameha Schools

- **Space Grant Pipelines – NASA focused**
  - Remote sensing, engineering, space science
  - Undergraduate research focus but starting at K-12

- **K-12 Activities reach thousands of students and parents**
  - 2017 numbers: 1,447 educators and 20,298 students.
  - Astronaut Appreciation Days – Honolulu and Hilo – 600 student/parent pairs registered in hours.
  - FESTival Nights – Classroom visits in evenings
  - Robotics after school programs: VEX-IQ (300 teams State-wide), FIRST, Brushbots.
  - Windward Aerospace Lab and Activities.
Undergraduate Research

The Hawaii Space Grant Consortium University Research Internship program (HSGC URI) engages **150 undergraduate students per year** with unique research experiences with UH System faculty mentors.

- ~ 75 HSGC research projects have a NASA science focus.
- ~130 HSFL students helped to design and build HiakaSat.
- ~100 HSFL students helped to design, build, and test Neutron-1
- ~ 55 students continue to work on satellite related projects each year.
- HSGC mentors come from a wide array of departments and campuses.

**Diversity in Research**

- 53% of HSGC Research Fellowships go to Underrepresented Students
- 33% of HSGC awards go to women.
Undergraduate Engagement

HSFL Missions provide unique hands-on research experiences for hundreds of students.


- Four course 15 credit interdisciplinary certificate program based in HIGP is usually taught over four consecutive semesters.
- Started in the 2020 spring semester.
- Classes at 200-400 level team-taught by the faculty of the Hawai’i Institute of Geophysics and Planetology (HIGP/SOEST).
- EPET courses are a mixture of basic science and technology/engineering focused classes designed to appeal to Earth Science and Engineering undergraduates with an interest in the science and technology of planetary exploration, as well as physicists, chemists, and biologists with an interest in applications for their science.
- Courses are strongly focused on teaching via hands-on research experience, in both the laboratory and the field, and using state-of-the-art equipment and facilities, by HIGP faculty who are world-leaders in the field (as reflected in the ~$10M pa in extramural funding HIGP receives).
- The course sequence is designed for different delivery modes that allow the certificate to be completed within a single academic year and/or off-campus.
Undergraduate Engagement

Aerospace Engineering concentration of the department of Mechanical engineering program – Spring 2022

- The aerospace engineering concentration in mechanical engineering was jointly developed by HIGP/HSFL and the department of mechanical engineering. The concentration contains at its core the four courses and 15 credits of the EPET program. The courses are officially cross listed.
- The aerospace concentration will officially start in the 2022 spring semester.
- The EPET/ME classes are team-taught by the faculty of the Hawai‘i Institute of Geophysics and Planetology (HIGP/SOEST).

Graduate Education

HSFL and HIGP faculty provide Masters and PhD degree research in Earth and Planetary Exploration in cooperation with the Department of Earth Sciences. HSGC offers Masters apprenticeship and Doctoral Fellowship support in areas of NASA strategic priorities.

VIP Aerospace Technologies Students built a 2 stage rocket that won 2nd place on FAR competition.
EPET/ME Course Descriptions:

The EPET/ME course sequence has an introductory course that can be substituted by other courses that are earth and space science related. The remaining courses are 4 credit lecture/ laboratory courses. EPET/ME 301 has both strong science and some design components, whereas EPET/ME 400 and 401 are upper division design courses.

- **EPET/ME 201 Space Exploration (3)** Introduction to the science or engineering of Solar System exploration. Covers science instruments, mission trajectories (fly-by, orbit, or lander), and science and engineering constraints imposed on spacecraft design. Lectures, discussions, class projects. A-F only. (Spring only)

- **EPET/ME 301 Space Science and Instrumentation (4)** Essential techniques for remote compositional analysis of planets; understanding spectroscopy, mineralogy, and geochemistry of planetary surfaces and their measurement. Design of space flight instrumentation. A-F only. Pre: EPET/ME 201, or ERTH 101 and ERTH 101L and ERTH 105, or ERTH 101 and ERTH 107; and CHEM 161 and PHYS 272. (Fall only)

- **EPET/ME 400 Space Mission Design (4)** Will cover all aspects of spacecraft design, subsystems, science payload, systems engineering, project management, and budgets that are important to producing a fully successful mission. A-F only. Pre: EPET /ME 301. (Spring only)

- **EPET/ME 401 Capstone Project: Producing a Science Satellite (4)** Develops a space mission with a multidisciplinary team of engineers and scientists using concurrent science and engineering methodologies. Will build a small spacecraft and payload. The project will seek to answer important science questions. A-F only. Pre: EPET/ME 400. (Fall only)
Artemis CubeSat Kit

- NASA Funded $500k to develop foundation enabler including hardware and undergraduate curriculum for students
- Cost < $5k
- Tied into the EPET / ME 400 and 401 classes
- Tied with the UHM Vertically Integrated Project Ke Ao CubeSat project
- Can support new tech demonstrations in orbit
Research and Development Projects
High Altitude UAS Project

- HSFL and ARL working on very High altitude UAS project with HAPSMobile
  - Sunglider is a Solar-powered unmanned aircraft
  - Up to 20 km (65k feet)
  - Regional coverage for up to 1 year
- HAPSMobile is 10% Aerovironment and 90% Softbank (Japan).
- Google interest boosts company value
- Launch point for up to 500 UAS that can globally locate in 5 days
- SOEST/HSFL research interests for regional disaster monitoring and laser comm node
GNC/ADCS Development, Testing and Validation

- HSFL’s state-of-the-art testbed closely replicates the space environment to test and verify ADCS functionality and algorithms
- Testing capability for ADC Systems sized from CubeSats (<10kg) up to 100kg MicroSats
- Air bearing platform with motorized calibration system
- Testing of Sensors and actuators:
  - Sun Sensors
  - Nadir Sensors
  - Star trackers
  - Magnetometers
  - GPS
  - Reaction Wheels
  - Torque Rods, etc.
High Precision Star Tracker for Small Satellites

- NASA STTR (Creare LLC, HSFL)
- Demonstrate and test in a representative environment a miniature, high accuracy attitude determination system (ADS) for use on small satellites
- Folded-optic star tracker
  - multiple reflective surfaces to significantly reduce the length of a telescopic lens.
- Sample Applications:
  - formation flying
  - precision pointing for laser-based communication systems

Image credit: AAReST project. KECK Institute

Image credit: Creare, LLC
Mission Adaptable Software Defined Radio

- SWaP-C ground systems solution that is highly mobile, reconfigurable, and easily integrated into existing satellite systems to support both new and current space missions for SSC Pacific
- Use the MC3 ground site in collaboration with Naval Postgraduate School to demonstrate space-to-ground link
- Use Software Communications Architecture (SCA) version 4
- SDR USRP E310
Multi-Satellite Mission Operations

- COSMOS Executive Operator (CEO) demonstrating the Operation 10’s of satellites
- Multi satellite physics (simulated and real time)
- Multi satellite operations rehearsals (simulated and real time)
- Swarm Operations algorithm development
- Space Operations Resource Management (satellites, operators, servers, databases, etc.)
Distributed Space Architectures

- Multi-Agent Robotic Systems
  - Autonomy
  - Optimal Control
  - Collision Avoidance
  - Guidance Navigation and Control (GNC)
  - Attitude Determination and Control (ADCS)
  - Time Synchronization
  - Real Time Pose Estimation
  - Rendezvous and Docking Algorithms

- Potential Future Applications (examples)
  - Large Self-Assembling Space Telescopes
  - Large Space Solar Farms

*Image Credit: Keck Institute*
Rapid Space Mission Design

- COSMOS (open source) for Rapid Space Mission Design
- Reduce design trades studies from months to weeks
- Train students in mission design tools and fundamental concepts
- Leverage Design Tools for satellite I&T activities
Inter-Vehicle Operations

- Empower Scientific and Operational capabilities using distributed systems
- Integrated vehicle operations
  - Water
  - Air
  - Space
- Facilitate Sensor exchange between research groups
- Strategic Collaborations between UH and other relevant partners (i.e. LSTS)
- Student involvement with hands-on and relevant research in Multi-Agent Robotic Systems
- Long Range Remote Raman Spectroscopy

SmallSat with Large Scale Observation Capabilities

Compact remote Raman + LIBS system developed at the University of Hawaii using 76mm diameter telescope

Autonomous UAS
New Projects and Potential Synergies

Optical Communications
- High data rate optical comms capability using UH-Maui College (Haleakala, Maui) and Kauai Community College (Pacific Missile Range Facility site).

UAVs
- UAVs serve as a tech demo platform for Small Satellites technology (instruments, subsystem components, operations software, control algorithms)

Advanced Visualization
- Immersive Mission Design and Data visualization tools with COSMOS (Lava Lab)
Moonshot Missions!

- Lunar orbit: RockSat mapper proposed by HIGP
- Lunar Mission:
  - 500 kg to LEO from East Hawaii = 250 kg to lunar orbit = 125 kg to lunar surface
  - Mass limit of ~ 100 kg
  - Rover design and construction through national and international competitions
  - PISCES: Rover testing on the Big Island
  - PISCES: State and NASA STTR funds for basalt sintering and printing projects
  - HIGP provides instrumentation package
- Cost of small launch delivery system ~$20-25M
- Tentative mission costs ~$40M
HSFL Summary

● Developing Aerospace Workforce and Infrastructure in Hawaii
  ○ Small Satellite Platforms and Technology
  ○ Space Science Research
  ○ Super Strypi and launch vehicles
  ○ End-to-end Mission Operations

● HSFL Integration and Test Facilities
  ○ Staffed to support testing and partnerships with commercial and government entities

● Mission support
  ○ Mid Pacific Ground station coverage and tailored mission operations solutions
Thank You! We’d love to work with you!
How to collaborate with and support HSFL

- Collaborative Research / Grants
  - NASA, NSF, DoD, DoE, ...
  - *UH is a Minority Serving Institution*
- Launch opportunities
  - “free” CubeSat launches through NASA CSLI (CubeSat Launch Initiative).
- SBIR/STTR Projects
- Students Scholarships
- Internships Opportunities
- Satellite Components (EM/FM)
- Ground Station Components
- Lab Equipment
- **UH Foundation**
  - direct student support
  - direct project support