HSFL Contact
Email: info@hsfl.hawaii.edu
Phone: 808-956-3138 (Hawaii Space Grant)
In less than 60 years of space flight, the world has launched about 6500 satellites to space of which about 1000 are still operating…

- **The Economist (08/26/16)**
  - OneWeb: 648 microsats for communications
  - SpaceX: 4425 microsats for communications
  - Google: microsats 20 for remote sensing
  - Spire: 44 microsats for observation
  - BlackSky: 60 microsats for remote sensing

- **Demand for space launch and small sats has shifted from Government to commercial groups.**

- **Hawaii positioned for small space**
  - Dedicated small launch facility possible
  - Greater payload to orbit from US site
  - UH/HSFL infrastructure support for small sats

- **HSFL Objectives**
  - Foster an aerospace economy in Hawaii.
  - Provide catalyst for microsatellite industry in Hawaii.
  - Enable small launch opportunities from Hawaii.
  - Enable creation of high-tech/high paying jobs for Hawaii citizens.

- **Timely access to space is critical!**
HSFL Vertical Integration

**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.

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

**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.

**Launch Vehicle and Launch Support**
- **Pacific Missile Range Facility (PMRF)**
  - Local launch facility and mission support
  - Modify 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.

**Ground Station & Mission Ops**
- UHF/VHF/S-band stations at Kauai CC and Honolulu CC.
- Mission Ops Center @ POST 5th floor using COSMOS software.
HSFL Capabilities
**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>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>3U</td>
<td>6U</td>
<td>12U</td>
<td>50 kg</td>
<td>100 kg</td>
</tr>
<tr>
<td>Pointing</td>
<td>&lt;2°</td>
<td>&lt;2°</td>
<td>&lt;1°</td>
<td>&lt;1°</td>
<td>&lt;1°</td>
</tr>
<tr>
<td>Comm. Options</td>
<td>UHF, VHF, S-Band, X-Band, GlobalStar</td>
<td>UHF, VHF, S-Band, X-Band, GlobalStar</td>
<td>UHF, VHF, S-Band, X-Band, GlobalStar</td>
<td>UHF, VHF, S-Band, X-Band, GlobalStar</td>
<td>UHF, VHF, S-Band, X-Band, GlobalStar</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>
<tr>
<td>S/C ROM</td>
<td>$0.7M</td>
<td>$1.3M</td>
<td>$2.5M</td>
<td>$3.5M</td>
<td>$6M</td>
</tr>
<tr>
<td>1-Year Mission ROM</td>
<td>$1.5M</td>
<td>$2.3M</td>
<td>$4.0M</td>
<td>$6.5M</td>
<td>$12M</td>
</tr>
</tbody>
</table>

Note: Mission ROMs include US launch costs (Electron or Spaceflight Industries) plus 1 year Mission Ops

- HSFL microsat R&D missions for under $12M.
- 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.
HSFL Integration & Test Equipment

Intvac Thermal Vacuum Chamber
1.6 m I.D. x 2.25 m long, 10^{-8} Torr

Spin Balancer

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

ADCS Testbed (Astro-Fein)
Air-bearing platform for up to 100 kg satellites
Magnetic Field, Sun, GPS simulations
### HSFL Facilities

<table>
<thead>
<tr>
<th>Test Facility</th>
<th>Thermal Vacuum Chamber</th>
<th>Vibration Table</th>
<th>ADCS Test Facility</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Specs</strong></td>
<td>1.6 x 2.25 m, 10⁻⁸ Torr, -70° to 70°C</td>
<td>Tests objects 1.2m x 1.2m 5-2200 Hz to 7000 kgf; 14000 kgf shock</td>
<td>Air-bearing platform, Magnetic Field, Sun, GPS simulations, up to 100 kg satellite</td>
</tr>
<tr>
<td><strong>ROM Cost</strong></td>
<td>$18k/week</td>
<td>$5k/day</td>
<td>$26k/week</td>
</tr>
</tbody>
</table>

Final cost may include engineering time to prepare the facility.

- HSFL provides access to its small satellite test facilities
- Support from HSFL engineers
- Custom projects with custom quotes
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)
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
  - 90 spectral bands between 8-10.7 microns
  - Approx. 60 m data from an altitude of 500 km
  - General Purpose Imager
  - Resolution 2448x2050
  - Sensor Size: 2/3”
  - Monochrome and Color
  - Frame rate: 15 fps
HSFL Mission Ops Software: COSMOS

- **Comprehensive Open-architecture Solution for Mission Operations Systems (COSMOS)**
- Software ecosystem/framework to support spacecraft mission operations
- Set of tools:
  - Mission Planning & Scheduling Tool (MPST)
  - Mission Operations Support Tool (MOST)
  - Ground Segment Control Tool (GSCT)
  - Data Management Tool (DMT)
  - Flight Dynamics Tool (FDT)
  - Analysis Tools
  - Test Bed Control Tool (TBCT)
- Open architecture to enable modifications and adaptation to new missions and MOCs
- User-friendly interfaces and short learning curves for users and software integrators
HSFL Missions
HiakaSat (HS-50)

- HiakaSat (Hyperspectral Imaging, Aeronautical Kinematic Analysis Satellite), is a microsat mission developed by faculty and students of the University of Hawaii.
- Launch: Fall 2015
- Lifetime: 1-2 year
- Mass: 55 kg
- Instrument: The Space Ultra-Compact Hyperspectral Imager (SUCHI) using a Fabry Perot interferometer
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 receive training/experience with HiakaSat
  - HSFL partnerships for future microsat work
  - X-Bow commercial follow-on missions
Super Strypi Launch Vehicle: ORS-4 Mission

UH News Video 2015-11-10
Sample Orbital Trajectories from Hawaii

Courtesy X-Bow Launch Systems, Inc.
HSFL Current CubeSat Missions

NEUTRON-1 (3U)
- **ELaNa 25 Launch**
- Goal: Measure low energy neutron flux in LEO.
- Team: HSFL, ASU
- Expected Launch: Fall 2019

HyTI: Hyperspectral Thermal Imager (6U)
- **NASA InVEST Award**
- Goal: Test the next generation of high spatial, spectral and temporal resolution thermal infrared imagery.
- Team: UH (HIGP, HSFL), JPL, SaraniaSat
- Expected Launch: 2021
Educational Outreach
On average, Hawaii Space Grant Consortium 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.
- ~ 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
- 30% of HSGC awards go to women. This needs to be higher.
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 Members**
  - **Educational**: UH-Hilo, Hawaii CC, UH Maui College, Kauai CC, Windward CC, Honolulu CC, Kapiolani CC, Leeward CC, UH-Manoa, UGuam.
  - **Corporate**: Strategic Theories Unlimited (Kauai), Hawaiian Electric Company (Oahu).

- **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 register 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.
Workforce Development

- Distributed campus approach to workforce development.
  - CC’s provide technical Associate Degrees
  - 4-yr provide depth in Bachelor’s Degrees
- Present Status and Future Plan:
  - **Kauai**: Small satellite communications and electronics fabrication, CubeSat development
  - **Maui**: Space debris surveillance and removal – NASA JSC interest
  - **Hawaii**: Software development for small satellites, test bed for HSFL lunar rovers
  - **Oahu**: CanSat and IMUA development at HCC, WCC, Kauai CC, Kap CC (won national award for CanSat); satellite data reception at Kauai CC, HCC, and UH-Manoa; mission control at UH-Manoa, small sat development at UH-Manoa; flight software, range safety, launch support at UH-Hilo and PISCES.
Undergraduate Engagement

- HSFL Missions provide unique hands-on research experiences for hundreds of students.
- Planetary Exploration Technology Track – Fall 2019
  - Planetary Exploration Technology (PET) certificate program to be offered from Spring 2020.
  - Classes at 200-400 level team-taught by the faculty of the Hawai‘i Institute of Geophysics and Planetology (HIGP/SOEST).
  - Current plan includes **11 distinct course offerings**, with 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).
  - Mixture of laboratory classes, HI-focused classes, field-classes, and classroom instruction.
  - Technology branch requires experienced engineering support. Propose 5 years for 3 0.5FTE engineering lecturers. The engineers currently work for HSFL.
New Track Starting in the Spring 2020

1. History of solar system exploration (Existing course)
   Why (the science) and how (the engineering and technology) humans have explored our planetary neighborhood

2. Cosmochemistry (Existing course)
   What are the physical and chemical processes that formed the materials we now observe in our Solar System?

3. Hawai’i as a planetary analog (New Course)
   Many processes that shaped the surfaces of Mars, the Moon, Mercury, and Venus, can be observed right here, in Hawai’i

4. Planetary surfaces and atmospheres (Existing course)
   The physical and chemical processes that produce the surface geology and atmospheres of the planets

5. Planetary interiors (Existing course)
   What can high pressure mineral physics experiments, conducted at HIGP, tell us about planetary interiors?

6. Extraterrestrial materials analysis (New Course)
   HIGP has some of the best facilities in the world for analyzing extraterrestrial materials, such as meteorites, interplanetary dust particles and comet dust. Students will learn how our FEI Titan Transmission Electron Microscope and our Cameca ims 1280 ion microprobe are used to probe the origins of our Solar System

7. Remote sensing of planetary surfaces (Existing course)
   We send satellites with imaging cameras to orbit the planets. How do they work, and how do we analyze the data collected?

8. Instrumentation for planetary exploration (New Course)
   How do we design and build the instruments carried on board the satellites, landers, and rovers that we send into space?

9. Space mission design (New Course)
   A space mission seeks to answer a science question using instruments carried onboard a satellite, and launched into space on a rocket. What elements of design, engineering, management, and budget are important to designing a successful mission?

10. Senior Capstone Mission (New Course)
    Interdisciplinary deep dive including science and technology students working on a mission concept.
Other HSFL Projects
HSFL Federal and State Projects

- **State Project: Easterly launch site from Hawaii by mid 2019.**
  - 11/16: Private site approved by W H Shipman Board of Directors.
  - 3/17: UH ARL support to start environmental work.
  - 6/17: FAA briefing in Washington DC to introduce commercial site in East Hawaii.
  - State of Hawaii budget for Joint Manufacturing Center in East Hawaii.
  - Commercial partners for site development.
  - Strong DoD support for site development that will allow access to orbit for low-cost, small satellite missions.

- **Federal FY 19 Proposal Request: Dual Use DoD/Commercial Equatorial Space Launch for Rapid Deployment**
  - Proposed Congressional additional funding of $8.0M to develop easterly launch site in Hawaii.
  - Congress has been looking for public/private partnerships. Remaining development funds would come from commercial partners.
  - Supported by HI and AK.
COTS ADCS Testing

Validate and Test Commercial Off the Shelf ADCS Solutions such as the CubeADCS show below

[Image Credit: CubeSpace]
High Precision Star Tracker for Small Satellites

● NASA STTR Phase I (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.
● Applications:
  ○ formation flying
  ○ precision pointing for laser-based communication systems
  ○ ...

Image credit: AAReST project. KECK Institute
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
Research Topics
GNC/ADC Systems

- 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.
CubeSat ADCS Testing

Initiate Nadir Pointing
Set Pitch Angle to 0 deg
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
Future Projects / Potential Synergies
New Projects and Potential Synergies

- **Small Satellites (new technologies)**
  - HSFL can provide test support for small sats and is interested to advance small sat technology. HSFL is part of a Minority Serving Institution and qualifies for “free” CubeSat launches through the [NASA CubeSat Launch Initiative](https://www.nasa.gov/mission_pages/cubesat/initiative.html).

- **Optical Communications**
  - HSFL is seeking to develop optical communications downlink capability using UH-Maui College (Haleakala, Maui) and Kauai Community College (Pacific Missile Range Facility site).
New Projects and Potential Synergies

● **UAVs**
  ○ HSFL works with the Applied Research Laboratory at UH-Manoa in UAV projects and instruments development.

● **Rapid Mission Design with Advanced Visualization**
  ○ HSFL COSMOS Mission Design Tool with Lava Lab.

● **Small Launch**
  ○ *HSFL is dedicated to expand small launch operations from Hawaii.*
Moon Missions!

- How to Get There: Lunar Atmosphere and Dust Environment Explorer (LADEE) and Moon Express
- 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 can provide instrumentation package
- Cost of small launch delivery system ~$20-25M
- Total mission costs ~$40M
In Conclusion ...
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>August: Project IMUA suborbital launch from NASA Wallops: successful launch of Pip &lt;br&gt; November: ORS-4 Mission, orbital launch from PMRF: unsuccessful launch of HiakaSat</td>
</tr>
<tr>
<td>2016</td>
<td>August: Project IMUA suborbital launch from NASA Wallops, multi-functional CC payload</td>
</tr>
<tr>
<td>2017</td>
<td>Work begins on NEUTRON-1 3U CubeSat &lt;br&gt; SSC Pacific CubeADCS testing project</td>
</tr>
<tr>
<td>2018</td>
<td>SSC Pacific Software Defined Radio Project &lt;br&gt; SSC Pacific Space Based Calibration Platform (Phase 1) &lt;br&gt; CREARE High Accuracy Star Tracker Testing &lt;br&gt; Environmental Analysis for Pacific Spaceport Complex - Hawaii &lt;br&gt; HyTI Mission Award</td>
</tr>
<tr>
<td>2019</td>
<td>SSC Pacific Software Defined Radio Project (Phase 2) &lt;br&gt; SSC Pacific Space Based Calibration Platform (Phase 2) &lt;br&gt; NEUTRON-1 CubeSat launch Fall 2019. NASA CLI launch to ISS &lt;br&gt; HyTI CubeSat development</td>
</tr>
<tr>
<td>2020</td>
<td>NEUTRON-1 Operations &lt;br&gt; Pacific Spaceport Complex - Hawaii operational &lt;br&gt; HyTI delivery</td>
</tr>
</tbody>
</table>
HSFL Summary

- Increasing high technology aerospace workforce and infrastructure in HI
  - Super Strypi
  - Small Satellite Platforms
  - End-to-end Mission Operations
- Integrated small satellite ISR solutions for under $12M (including dedicated launch on RocketLab Electron)
- Cubesats and larger satellites capable of accommodating rideshare payloads.
- HSFL Integration and Test Facility is fully functional and staffed to support testing and partnerships with commercial and government entities.
- Full mission support including ground station coverage and tailored mission operations solutions.
- USPACOM, USSOCOM, and Pacific Operational Science and Tech Results
  - Commercial small launch leveraged by DoD as needed.
  - Small satellite component testing and validation.
  - Small satellite mission development
HSFL Current Needs

- Continuous Student Support
- Scholarships/Internship support
- Satellite Parts
- Ground Station Upgrades
- Lab Equipment Upgrades

Ways to help
- Internships
- UH Foundation