Space Mission Development Capabilities
Hawaii Space Flight Laboratory

HSFL Overview Presentation
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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.
HSFL Overview: Vertical Integration

Spacecraft
- Partner with NASA Centers and others to advance small spacecraft design.
- 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.

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 low-Earth orbit (400 km).
- Heritage working with PMRF as on-site vehicle integrator and launch agent.

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

Instruments
- The HSFL can call on a diverse group of instrument-developing faculty from HIGP and SOEST.
- A number of businesses in Hawaii also develop a wide array of instrumentation. The HSFL will partner with these organizations to provide technology demonstration opportunities.
- NASA Centers (Ames and JPL) are interested in joint technology missions.

Ground Station & Mission Operations
- UH/HSFL maintains UHF/VHF receiving stations with Kauai CC and Honolulu CC staff.
- Ground station provides command and control broadcast as well as data downlink capabilities.
- Mission Ops Center POST 5th floor using COSMOS software.
Intlvac 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 150 kg satellites
Magnetic Field, Sun, GPS simulations
# HSFL Facilities Usage

<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° - 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>
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<tr>
<td><strong>1-Week ROM Cost</strong></td>
<td>$18k</td>
<td>$19k</td>
<td>$26k</td>
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**SUMMARY:**

- HSFL provides access to its small satellite test facilities
- Support from HSFL engineers
- Custom projects with custom quotes

ROM cost includes engineering time to prepare the facility.
HSFL Ground Stations

Affiliated Ground Stations:
- Alaska Space Facility (S-band)
- Surrey Space Centre/SSTL (UHF/VHF/S-band)

Honolulu Community College
X-band

Kauai Community College
UHF/VHF/S-band

UH Manoa – NRL MC3 GS
UHF/S-band
HSFL Mission Ops Software

- Comprehensive Open-architecture Solution for Mission Operations Systems (COSMOS)

- Software 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
ORS-4 Mission: 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
  - 1st stage motor issue

- ORS-4 Takeaways:
  - HSFL receives $29M contract
  - $5.1M in salaries
  - $3.9M in overhead to UH
  - 130 Hawaii students receive training/experience with HiakaSat
  - HSFL partnerships for future microsat work
  - X-Bow commercial follow-on missions
ORS-4 Mission: November 3, 2015
SUMMARY:

- 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.
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**
  – 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**
  – 2015 numbers: 500 educators and 4000 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, FIRST, Brushbots.
  – Windward Aerospace Lab and Activities.
On average, HSGC 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.
- **IMUA Project: $500K NASA Grant won by Community Colleges.** 2 successful suborbital launches in 2015 and 2016 involving Windward, Kauai, Honolulu, and Kapiolani CC’s.

**Diversity in Research**

- 48% of HSGC Research Fellowships go to Underrepresented Students
- 27% of HSGC awards go to women. This needs to be higher.
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 2017
  - Planetary Exploration Technology (PET) certificate program to be offered from Fall 2017.
  - 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.
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. Space mission operations (New Course)  
    Once the satellite is in orbit, or the rover is on the surface, how do we control it? How do we communicate with it? How does it communicate with us? How does it send our data back? How do we get the data to scientists?

11. Senior Capstone Mission (New Course)  
    Interdisciplinary deep dive including science and technology students working on a mission concept.
Research: Instrumentation

• **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

• **General Purpose Imager**
  – Resolution 2448x2050
  – Sensor Size: 2/3”
  – Monochrome and Color
  – Frame rate: 15 fps

• **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
Research: Attitude Control

- Helmholtz Cage
- Sun simulator
- Motion tracking system
- ADCS hardware Satellite testbed
- Air bearing platform
- Testbed control software
- GPS simulator
Research: Mission Operations
Research: Distributed Architectures
NASA Solicitations

• STMD
  – NASA Innovative Advanced Concepts (NIAC)
  – Small Spacecraft Technology Program (SSTP)
  – Space Technology Research Grants
  – Technology Demonstration Missions (TDM)

• SMD ROSES
  – A.41 “Advanced Information Systems Technology (AIST)”
  – D.13 “Astrophysics Explorers”
    • MIDEX
    • SMEX
    • UNEX*
    • MO

* Not currently funded
HSFL Summary

• Mission Schedule
  – August 2015: Project IMUA suborbital launch from NASA Wallops: successful launch of Pip
  – November 2015: ORS-4 Mission, orbital launch from PMRF: unsuccessful launch of HiakaSat
  – August 17, 2016: Project IMUA suborbital launch from NASA Wallops, multi-functional CC payload
  – April 2017: HSFL student mission, suborbital launch of new on-board computer, scheduled from Spaceport America, New Mexico.
  – June 2018: X-Bow orbital launch from PMRF
  – March 2018: NEUTRON-1 launch: NASA CLI launch to 550km.

• Summary Points
  – HSFL works towards vertically integrated small satellite ISR solutions for under $12M (including dedicated launch on RocketLab Electron).
  – HSFL is building 3-U Cubesats and larger satellites capable of accommodating rideshare payloads.
  – HSFL Integration and Test Facility is fully functional and staffed by a team that successfully delivered HiakaSat according to NASA and Air Force standards.
  – HSFL offers mission support including ground station coverage and tailored mission operations solutions.