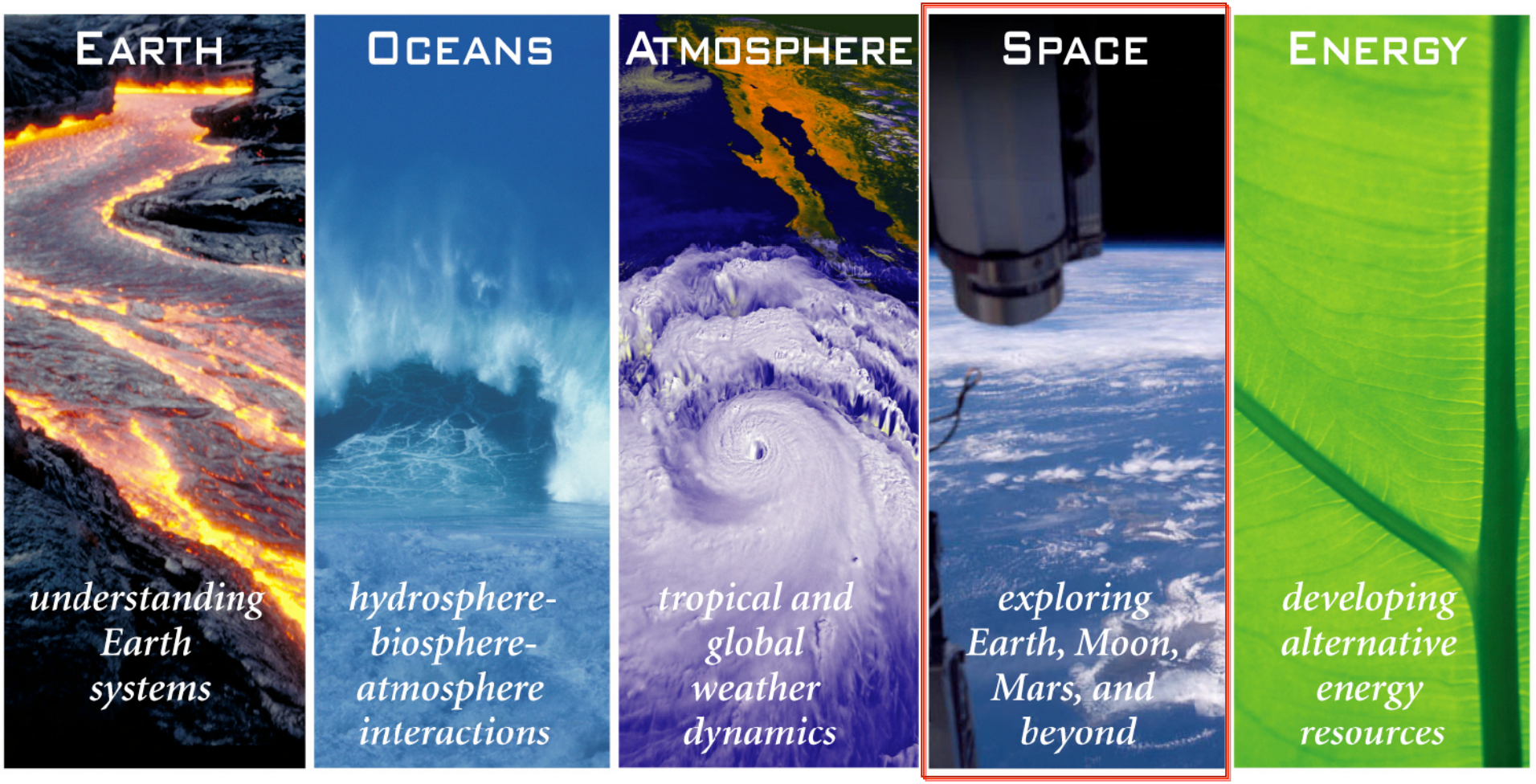
Brian Taylor, Dean, School of Ocean & Earth Science & Technology

soest

enabling a healthy public, economy, and planet
through an integrated, comprehensive, & sustained
system of Earth observation, research & education



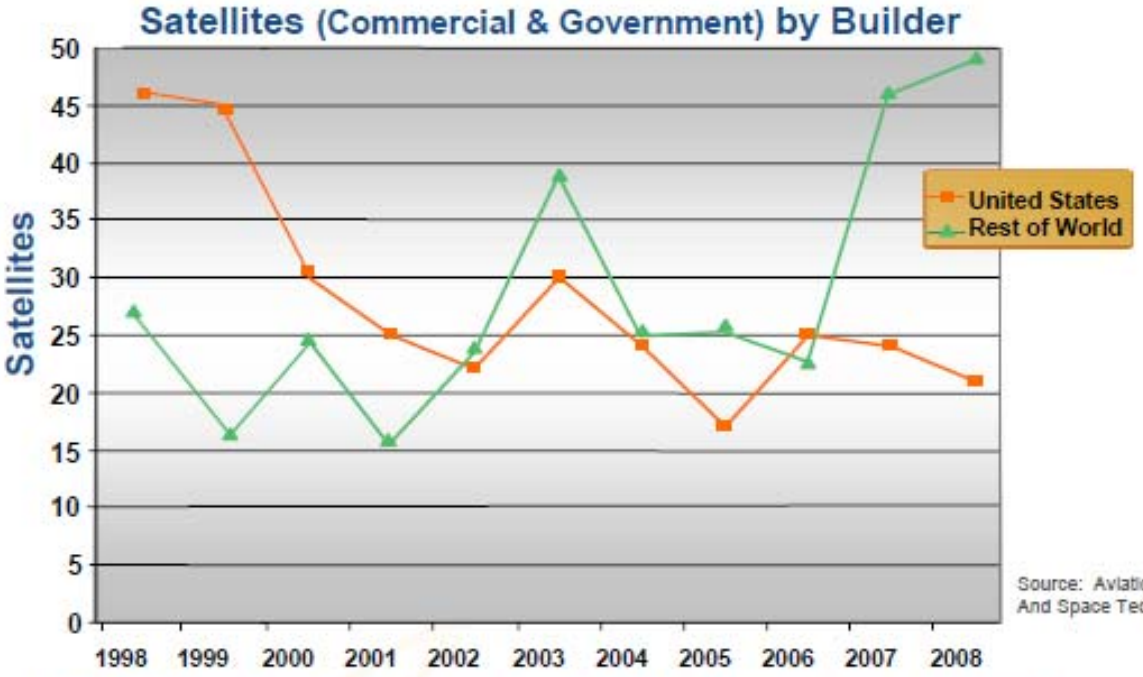
Innovative Satellite Launch Program

From National Reconnaissance Office Study:

UNCLASSIFIED

State of U. S. Space Industry

- **U.S. does not drive the satellite market**
  - > 40 Countries w/ Space Programs



Source: Aviation Week And Space Technology

- **Commercial only statistics are worse**

U.S. SHARE OF THE WORLD SATELLITE MARKET WENT FROM 68% IN 1998 TO 29% IN 2008 WHILE OVERALL SATELLITE DEMAND REMAINED STEADY

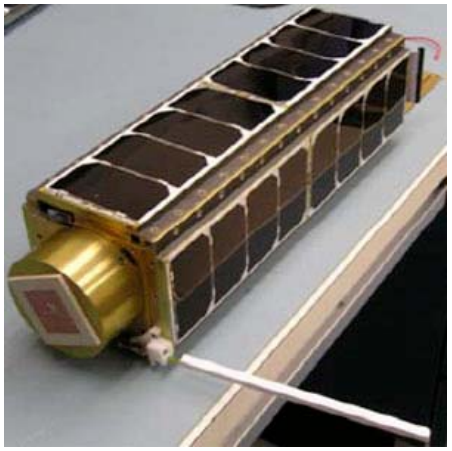
UNCLASSIFIED

Due to High Mission-Related Costs, US Technology Lead in Space Dwindles.

Growing Interest in "Rapid, Low-Cost" Space

- Change the economics: Smaller, Cheaper
  - Current satellite & launch cost for "big" satellite ~$1B ($500M-$1500M)
  - Current small satellite & launch cost ~ $140M
  - Develop low-cost small satellites & satellite rideshare launches
- Develop New Space Technology
  - NRO, Boeing & Air Force investing in CubeSats
  - Operationally Responsive Space Office (DoD) & NASA (Ames & Office of Chief Technologist) promoting small satellite development.
    - Advance Tech Readiness Levels for critical technologies
    - Accept experimental missions for iterative R&D.
    - Return to 60's mentality: failure is part of learning process
- Rapid Response Launch Plan
  - For Disaster Management & On-orbit Asset Replacement
  - Pre-stage, Modular, "Ship & Shoot"
  - Build redundancy with Constellations of small sats.

UH Kumu A'o CubeSat



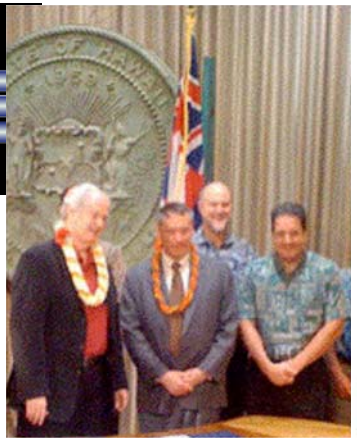
NASA's PharmaSat

SOEST - College of Engineering

The mission of HSFL is to:

- *promote innovative engineering & science research for terrestrial and planetary space missions*
- *develop, launch, and operate small spacecraft from the Hawaiian Islands to accelerate the validation of new space technologies*
- *provide workforce training in all aspects of unmanned space missions*
- *promote synergistic collaborations between educational, governmental, & corporate institutions interested in space exploration*

Spacecraft
Instrument
Integrate & Test
Launch Vehicle
Launch Support
Ground Station
Operations
Data



First HSFL Program: LEONIDAS

- Objectives:
  - Conduct two demonstration space launches from the Navy's Pacific Missile Range Facility in Hawaii using a low cost launch system.
  - Create workforce training opportunities.
  - Increase access to space for DoD, NASA, and University payloads – including short-duration technology demonstration missions.
- Hawaii Congressionally directed program supported in the FY07-present Defense Appropriations Bills
  - LEONIDAS = Low Earth Orbiting Nanosatellite Integrated Defense Autonomous System
  - Funded through the Operationally Responsive Space Office
  - UH's Hawaii Space Flight Laboratory (HSFL) is the prime contractor
  - **SPARK** Launch Vehicle (Space-borne Payload Assist Rocket Kauai) based on redesigned Sandia National Lab's Strypi ballistic rocket.
  - Scout rail launcher from VAFB rebuilt & extended

LEONIDAS Leverages Exceptional Expertise

DoD Office of Operationally Responsive Space (ORS)
Government Contracting Agency
Director – Dr. Peter Wegner
LEONIDAS PMs – Dr. Mark Franz, Mr. Steven Buckley

University of Hawaii – Hawaii Space Flight Laboratory (HSFL)
Prime Contractor
Program Manager – Dr. Luke Flynn

Sandia National Laboratories (SNL)
HSFL's Launch Systems Contractor
Project Lead– Mr. Todd Criel

Aerojet, a GenCorp Inc. company
SPARK Solid Rocket Motor Provider
Managers– Mr. Mark Kaufman, Mr. John Napior

USN Pacific Missile Range Facility (PMRF)
Launch Site & Range Safety
Commander – Capt. Nicholas Mongillo

White Sands Missile Range (WSMR)
Scout/SPARK Erector Modifications
Project Lead – Mr. Sal Rodriguez

NASA Ames Research Center (ARC)
Launch Vehicle Payload Adapter
Program Manager – Mr. John Hines

SPARK Launch Vehicle

Redesign Sandia Strypi

- Three-stage solid propellant motor stack.
- Leverage heritage devices that have flown on other rockets.
- Fin & spin stabilized vehicle, with attitude control system.
- Payload objective: 250kg to 400km Sun-synchronous Orbit from Kauai. Higher payload mass can be achieved to lower inclination orbits.

Aerojet Corp. – Strategic Alliance Agreement signed with UH in October, 2010 to provide all 3 motor stages

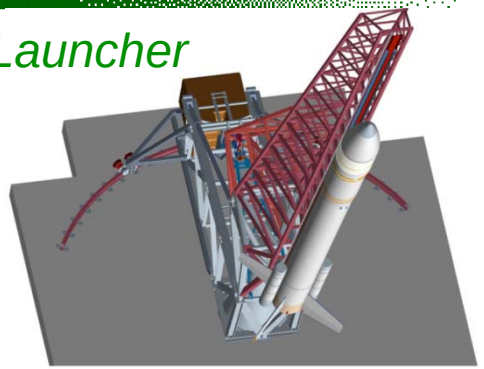
- Optimized motor design: exceeds payload objectives.
- Maximize performance & minimize cost by simplifying design & manufacturing process.
- Meet quick response launch requirement

Designed to Reduce Cost, Simplify Launch & Increase Reliability

Launch Site: Pacific Missile Range Facility

- Pacific Missile Range Facility
  - Existing launch range on Kauai.
  - Partnering with UH and ORS
    - Provide Range Safety support
    - Professional execution & supervision of LEONIDAS launches
- SPARK Rail Launch System
  - Rail imparts stability & directional control for rocket launch.
  - Adjusting launcher trajectory allows multiple orbit tracks.
  - Launcher design enables economical deployment at complimentary sites.
- Polar & Sun-synchronous launch options from PMRF (Kauai)

SPARK Launcher



Economic Growth & Workforce Development

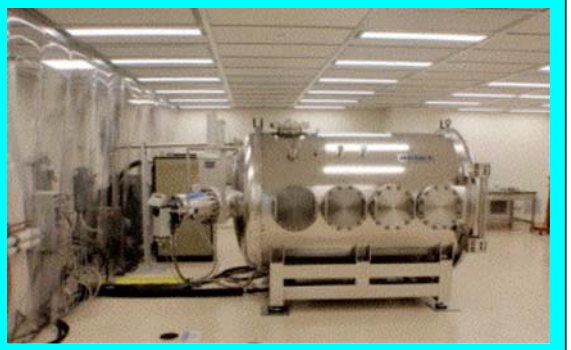
- UH, Hawaii Space Flight Lab, has developed a complete small satellite workforce development program that provides the State a new pathway for economic growth.
- Niche companies will be spun-off in Hawaii.
  - UH & Aerojet will form a launch vehicle integration and launch services partnership.
  - UH & a future partner could spin-off a small satellite development company.
- Mission Support Tools will be maintained at UH to provide necessary infrastructure for UH and Hawaii commercial space research.
  - Clean room facilities for satellite integration.
  - Large thermal-vacuum chamber & vibration table for satellite testing.
  - Spin-balance table for payload integration and processing
- Unprecedented educational training opportunities in all aspects of space mission operations; engineering, science & technology development.
  - Kauai CC: program management & telemetry
  - Windward CC: education & outreach through aerospace center
  - UH Hilo: (future) software & automation
  - System-wide u/grad & high school Space Grant program

CC's: technical Associate Degrees
4-yr: Bachelor's & Graduate Degrees

Enablers: Mission Support Tools

Payload Integration, Test, Launch Prep

- Clean rooms to assemble satellites.
  - –Systems integration
  - –Thermal/ vacuum test
  - –Vibration/ shock testing



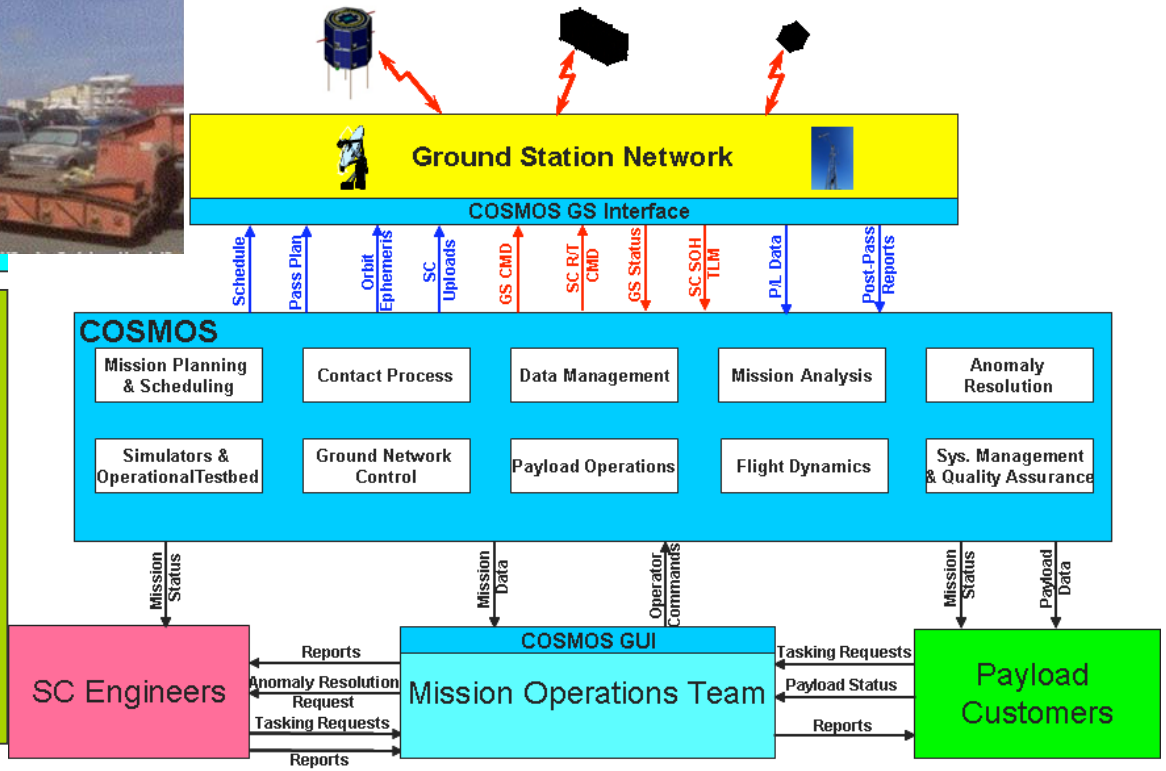
- Payload Spin Balancer for integrating multiple rideshare small sats in a single mission

Ground Stations

- UH/HSFL maintains UHF/VHF receiving stations with Kauai CC
- Ground station provides command & control broadcast & data downlink capabilities.
- HSFL partnering with Alaska & European receiving stations for greater data downlink capability.

Mission Operations from UH Campus

- can track multiple small satellites.
- working on a NASA Ames project to develop a Mission Operations System to:
  - command & control multiple spacecraft.
  - run autonomously
  - be a standard adopted by NASA Ames and other Universities.



UH-Aerojet Partnership: Launch Services Provider

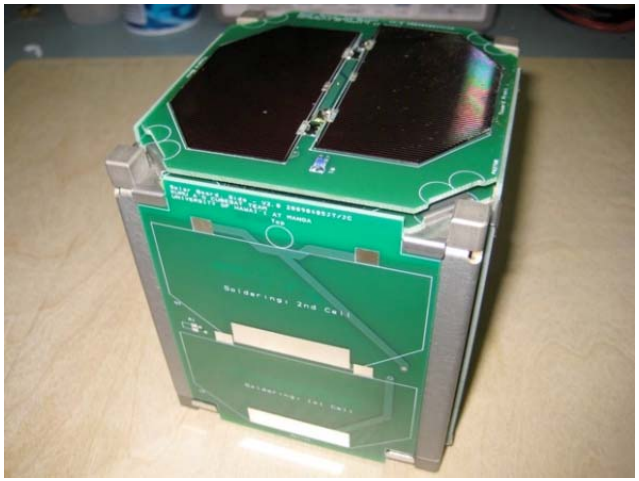
- 501(c)3 LLC being planned to benefit:
  - Aerojet: Increase solid rocket motor production,
    Hawaii “skunkworks” for new R&D
  - UH: Workforce training,
    Self-funded Science & Engineering Missions
  - Joint: Lower Overhead & Costs
    Handle Risk Management
    Hold Intellectual Property

Luke Flynn
HSFL Director

Mark & Amber Kaufman
Aerojet Exec Dir Strategic Programs

UH Technology on LEONIDAS Missions

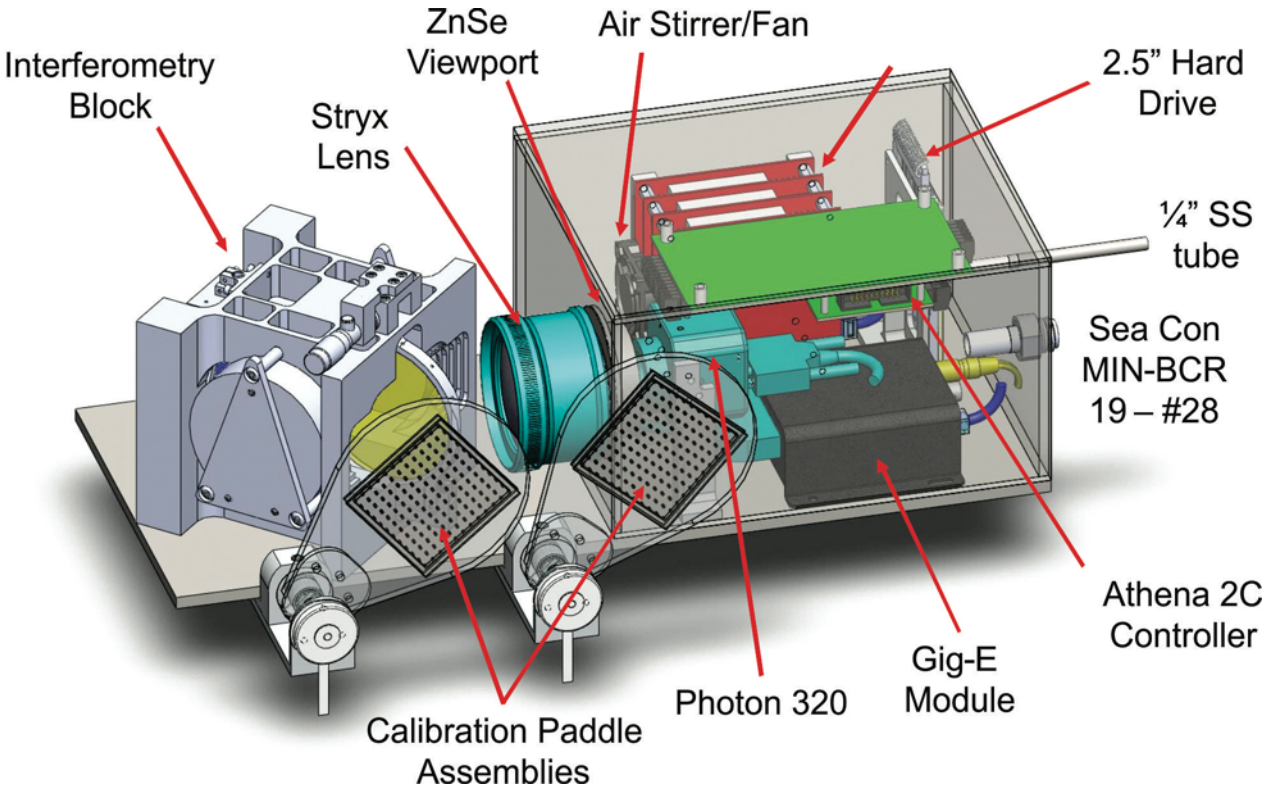
- Kumu A'o CubeSat
- Purpose: Technology readiness level advancement of new flight components
- To be Launched on 1st mission
- Built by CoE undergraduate students – mostly Hawaiian



- HawaiiSat-1
- Purpose: Thermal and visible imaging payloads to study Earth
- To be launched on 2nd mission
- Built by CoE and SOEST faculty, and CoE Grad Students
- Partnership with NASA Ames

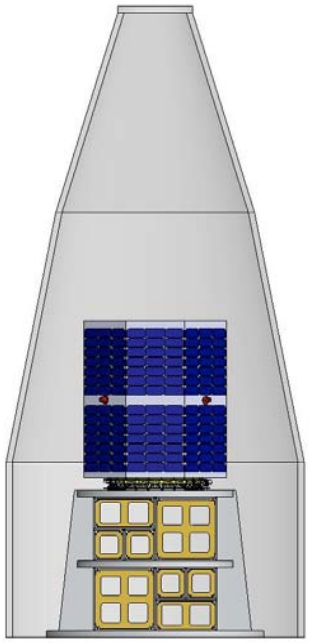
Thermal Hyperspectral Imager (THI)

Designed & built at the Hawaii Institute of Geophysics & Planetology, funded by NASA

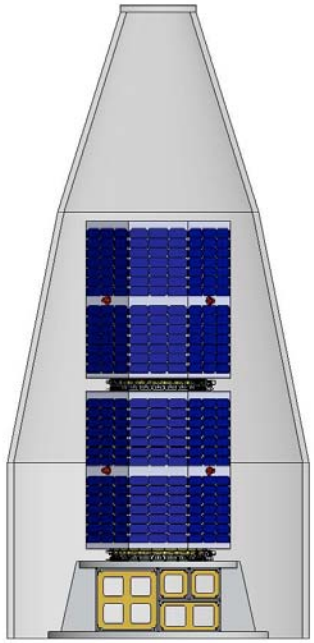


- Measures the thermal energy emitted by Earth’s surface in 30 wavebands 7.5-13.5 microns
- Applications include:
  - monitoring active volcanoes, wildfires & urban heat islands
  - monitoring atmospheric trace gases (e.g. methane)
  - detecting groundwater discharges into coastal waters

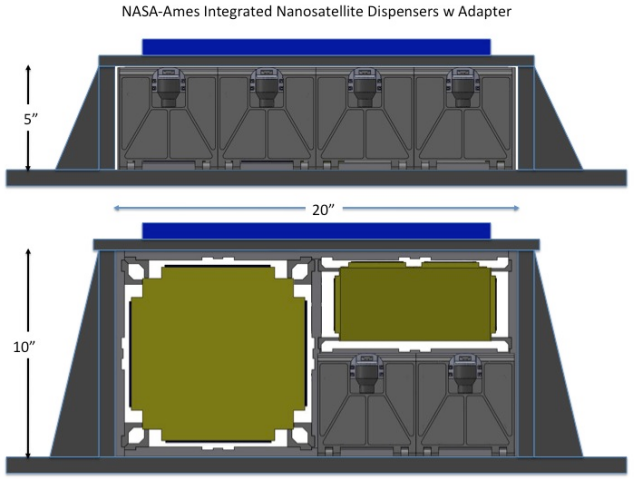
Rideshare Payload Configurations



1 small satellite, 2 PADs



2 small satellites, 1 PAD



- Large fairing capacity for multiple small satellites
- NASA Ames Payload Adapter and Deployer (PAD)
  - PAD can carry 24 1-u Cubesats or
    a combination of 1-u, 3-u, 6-u, & 12-u Cubesats

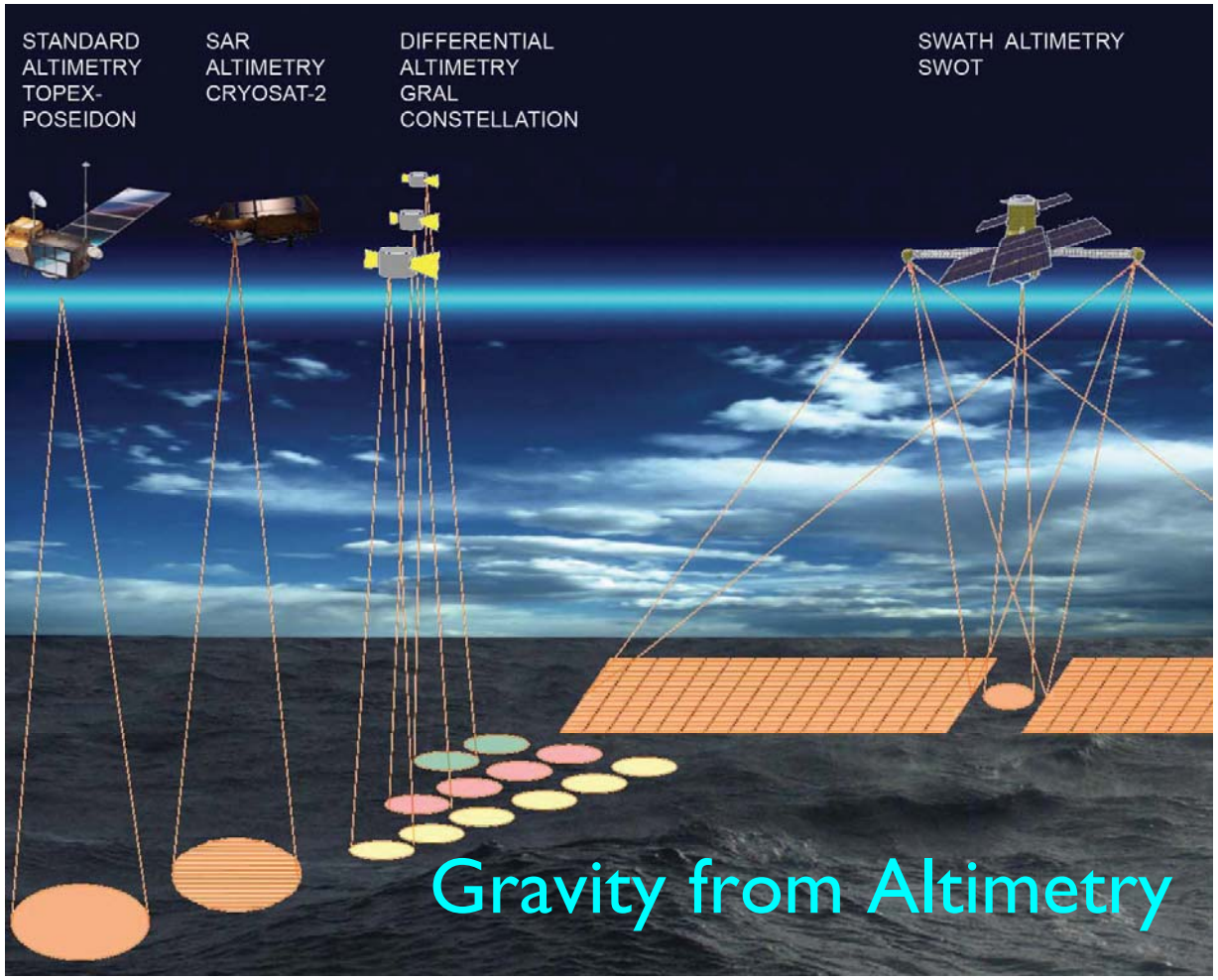
Small Sat Performance and Cost Models

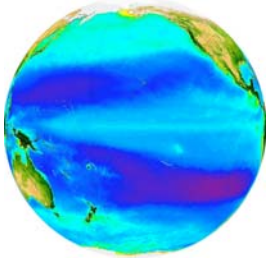
44 States currently build small satellites at over 80 Universities!

Spacecraft Size	Mass (kg)	S/C Volume (cm3)	Power (W)	Bus Cost ($K)	Launch Cost ($K)
1-u	1-2	10 x 10 x 10	2	20-30	40-60
3-u	5-6	10 x 10 x 30	4-5	100-200	250-300
6-u*	**12-15**	**10 x 20 x 30**	**12-15**	**400-500**	**750**
12-u*	**30-40**	**20 x 20 x 30**	**40**	**1000**	**1500**
HawaiiSat	60-80	60 x 60 x 70	100	2000	4500
Other	>80	larger	??	??	Up to 12000

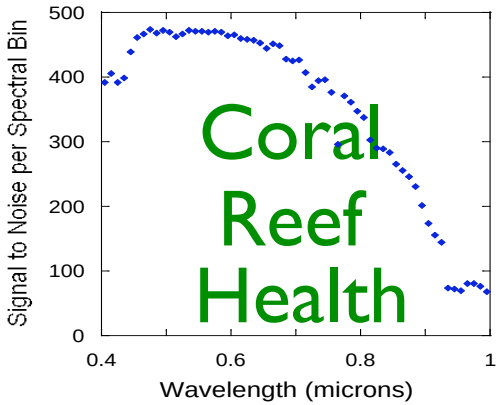
- Goal: Future 3-u CubeSat could be built and launched within the budget of a NASA EPSCoR Research Award ($750K over 3 years).
- * 6-u and 12-u CubeSats have not flown in orbit.

Constellations of small satellites





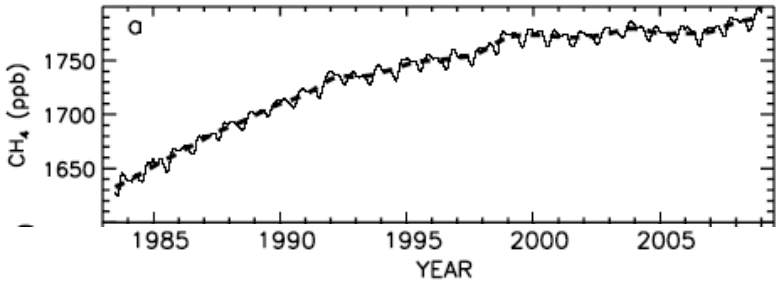
Ocean Color



Coral Reef Health

Space Weather

Water Vapor from GPS



Monitoring Methane

Innovative Satellite Launch Program

- HSFL - PMRF - Sandia NL - Aerojet - NASA-AMES working together are developing a game-changing satellite launch & deployment system:
  - High heritage, low risk
  - Capable of rapid response (< week)
  - Low-cost for small spacecraft
- Recurring launch costs at $10-12M (inclusive of range costs) are a fraction of current alternatives.
- This enables new paradigms of satellite development, cal/val, & deployment
  - (e.g., constellations of small satellites)
- “the sky is NOT the limit” - this promises a new economic driver & high-tech workforce for Hawaii
  - Watch for 1st launch in 2012