The Benefits and Uses of Very Small Spacecraft

4th Annual Cubesat Developer's Workshop

Huntington Beach

April 20, 2007

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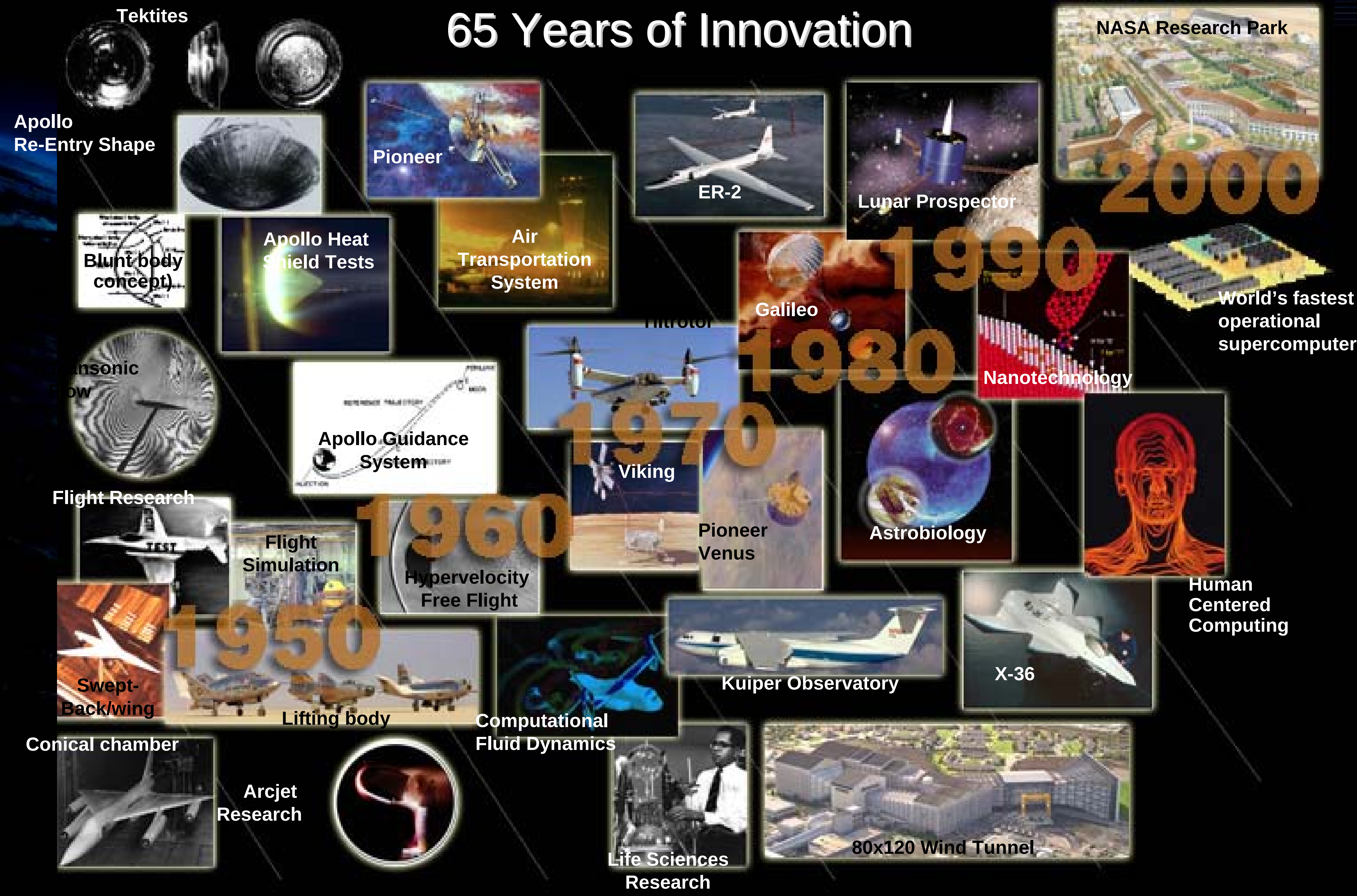
Director, NASA Ames Research Center

Ames Research Center

65 Years of Innovation



NASA's Missions

Exploration
- Local space environment
- Return to the Moon
- Manned presence on Mars (future)

Science
- Understand the nature of the solar system and universe
- Near Earth Objects (NEO)
- Lunar sciences

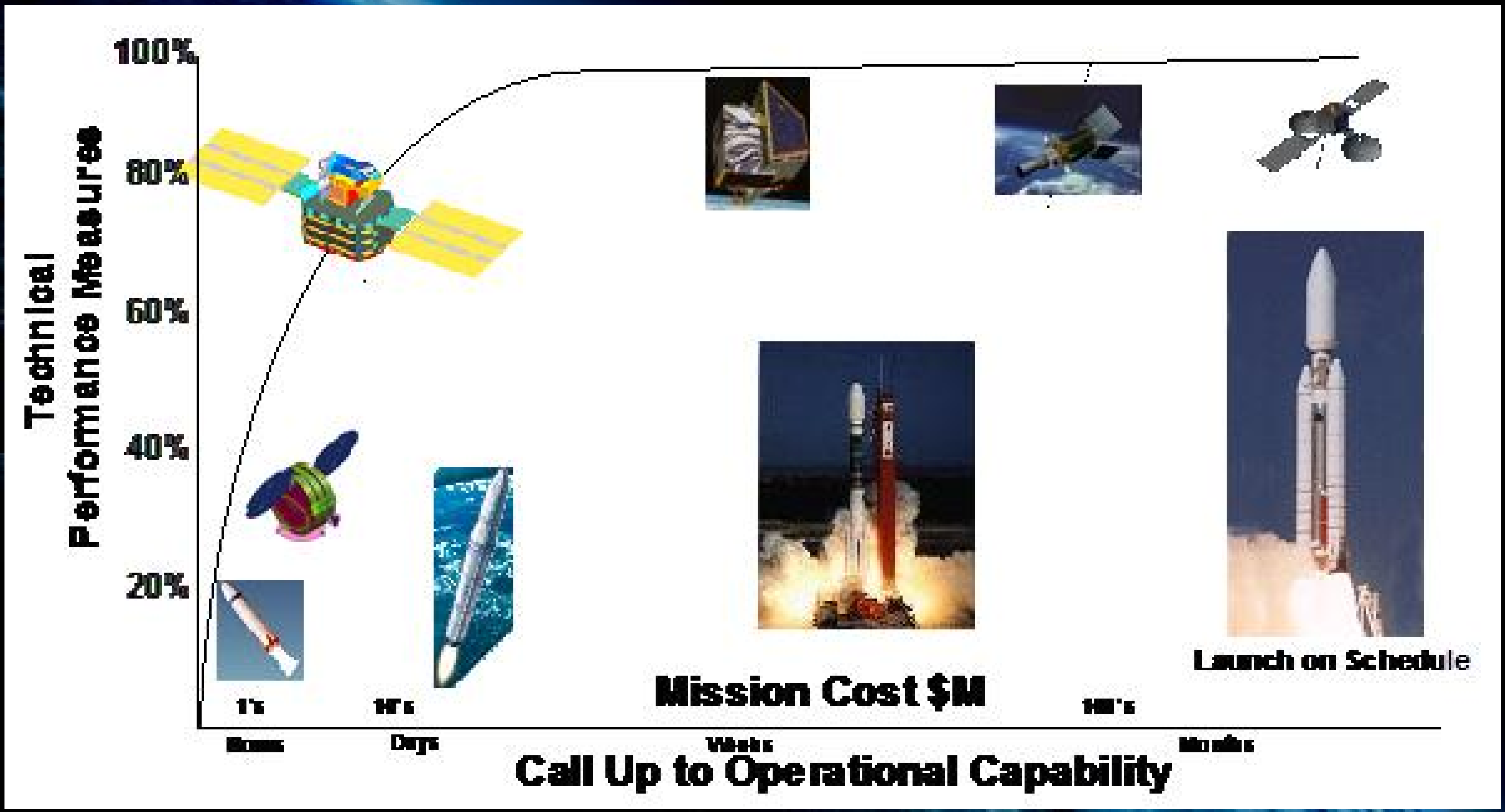
ARC Small Spacecraft Division

- Develop spacecraft and related systems to make access to space routine [<u>**VENTURE CLASS**</u>]
  - Common, reusable architectures
  - Place emphasis on payloads and science missions
- Secure and provide methods to access space reliably, frequently
  - Small space systems
  - Secondary payloads
- Reduce overall mission costs
  - Goal: Maintain or increase scientific and exploration return while reducing life cycle costs

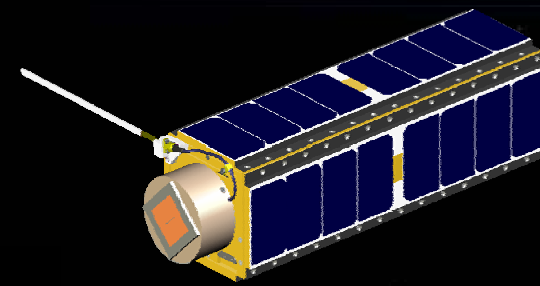
Small, Low Cost, Fast Missions

Developing three efforts:

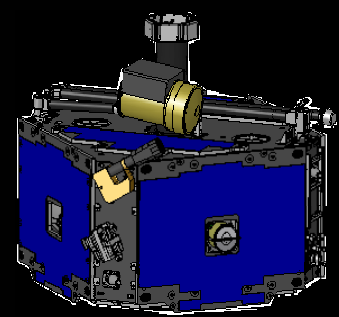
- **Mission Design Center (MDC)**
- **Process development, toolsets**
- **Near term flight experiments demonstrating "What Is Possible Today"**



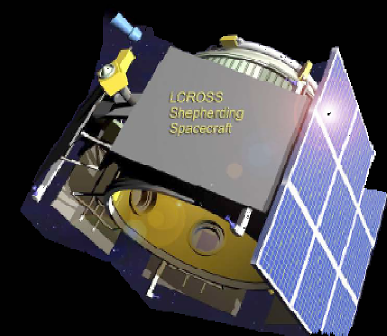
Small Spacecraft Projects



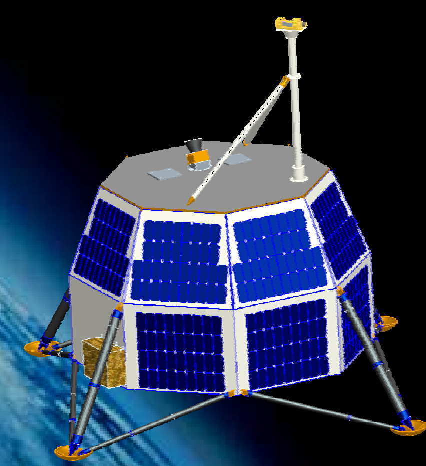
- GeneSat and GeneBox (flown)



- Lunar Science Orbiter (LSO - proposed)



- Lunar Crater Observation Sensing Satellite (LCROSS - in development)

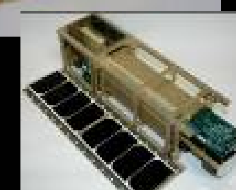


- Common Bus (lunar lander concept shown)

Benefits of Cubesats

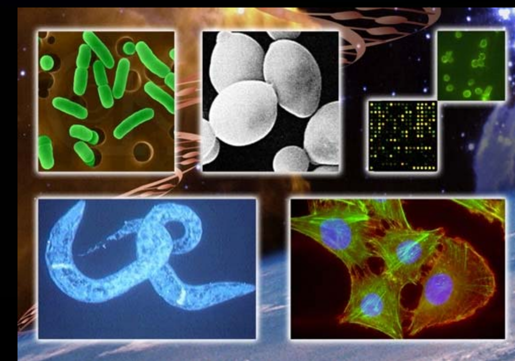
- Existing Cubesat standard(s)
  - Large, open development community
  - Wealth of ideas, approaches
  - Flight proven platform interfaces and accommodations
- Low cost
  - Small size and mass
  - Secondary payload accommodations
  - Repeatable missions, multiple spacecraft possible
  - Affordable operations
- Expanding capabilities
  - Ideal test bed for new technologies
  - Wide variety of mission architectures supportable

CalPoly SLO PPOD



Genesat

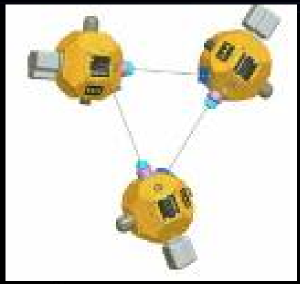
Roles of Cubesats



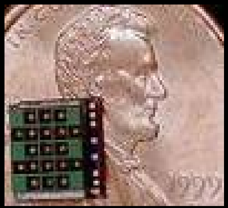
- Science and Exploration Missions
  - Space Biology
    - Radiation effects on biology
    - Lunar dust interactions
    - Effects of microgravity on biological systems
  - Space Sciences
    - Near Earth Objects
  - Astrobiology
    - Biological origins
    - Astrochemistry
    - Survey for habitable zones
  - Space Physics
    - Heliophysics
    - Space weather
  - Lunar Sciences

Roles of Cubesats

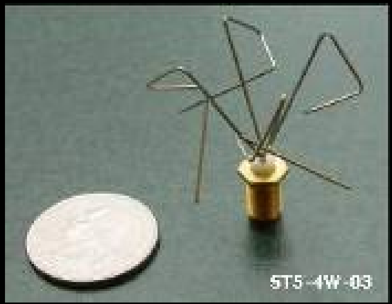
- Technology Demonstrations
  - Propulsion
  - Communications
  - Mass reduction - MEMS and smaller
  - Autonomous operations
  - Formation flying/constellations
  - Novel space architectures - tethers
  - Evolvable, reconfigurable satellites



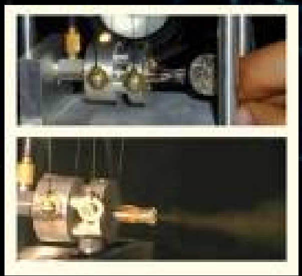
MIT



CalTech



NASA/ARC



LANL

Aerospace Corp

TUI

Advanced Nanosats

Advanced NanoSat Program Goals:

- **High Capability** Achieve 80% capability of larger spacecraft (100-150 kg class)
- **Low Recurring Costs** ~$ 1 M for bus
- **Leverage** Latest technology advancements & existing Ames Nanosat bus (GeneSat) for space validation of key sub-systems
- **Enable Space Exploration** Big science in a small, highly functional form factor

Advanced Nanosat X

- Delta-v > 300 m/s
- Sub-arc min pointing accuracy
- Ultra-low power commercial CPUs
- Micro/Nano based attitude position & tracking sensors
- Integrated GPS receiver/antenna


Sun Sensor


GPS Receiver


Mini Star Tracker

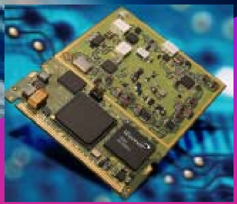

Nano Reaction Wheels

NASA Ames NanoSat
In-Space Validation of Key Technologies

Advanced Nanosat I

- High Data Rate Downlink (Gb/day)
- 30 arc-sec pointing accuracy
- High performance Avionics
- Nano-thruster validation
- <5 kg bus mass
- Mission Opps


High Performance, Low Power Computing

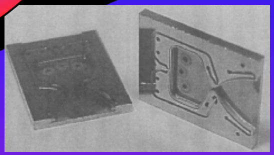

5.8 GHz Transceiver


Ultra light weight IMU

NASA Ames NanoSat
In-Space Validation of Key Technologies

Advanced Nanosat 2

- Delta-V >700 m/s
- 3-axis Stabilized, <10 arc-sec pointing
- Ultra-low power ADACS
- Advanced Multifunctional Materials
- <4 kg bus mass
- 6 W payload power
- 1 kg payload capability


Micro-Propulsion


Nano-ACS Thrusters


High Capacity, Lightweight Batteries

Enables a Variety of Science Missions:

Precision Formation Flying
Remote Imaging- Earth/Lunar Science
Autonomous Satellite Maintenance
Space Physics & Astrophysics
Exploration- Lunar, NEOs, Comets

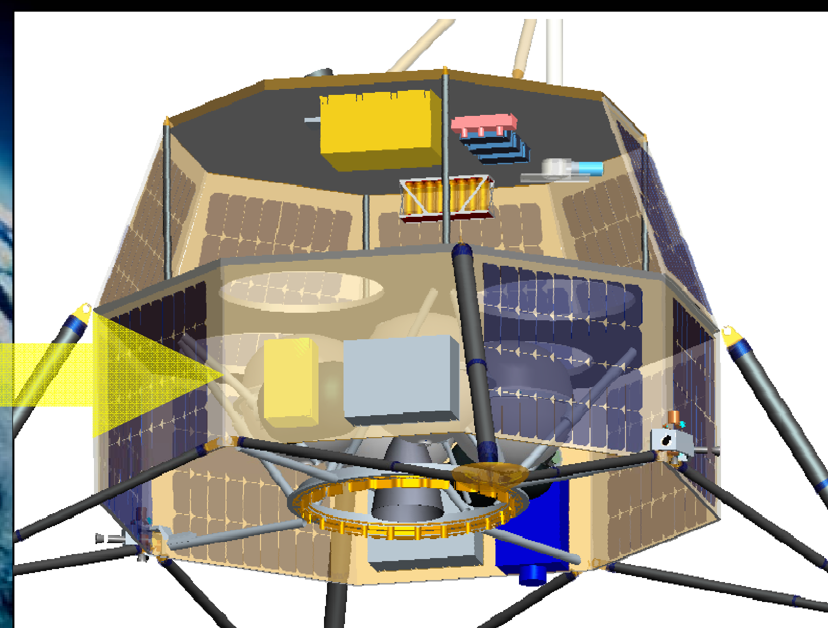
NANOSAT CAPABILITY

6-9 Months | **12 Months** | **12-15 Months** | **Month 18** | **18-24 Months**

Roles of Cubesats

- Payload packages on larger spacecraft
  - Flight heritage from Cubesat missions
  - Use Cubesat derived technologies to support other spacecraft missions
    - Lunar Orbiters
    - Lunar Landers

NASA/ARC GENEBOX

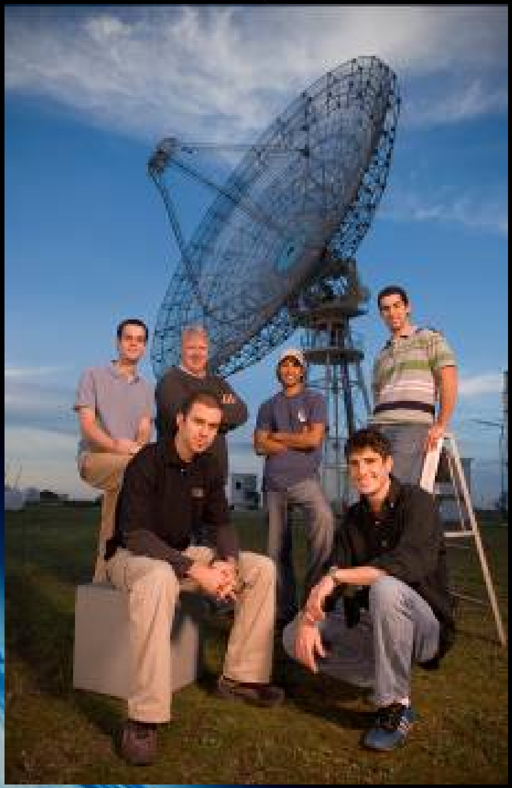


Roles of Cubesats

- Education and training
  - Space systems development and test
  - Systems Engineering
  - Operations

Santa Clara University

CalPoly SLO



SRI/Santa Clara

The Future of Cubesats

- Cubesats on every available launcher
  - Multiple opportunities per year
  - Launch supply >> Cubesat demand
- Multiple low cost NASA missions
  - Current focus is on 3U configuration
  - Other variations possible and under investigation
- Cubesat as a thesis or senior project at all the leading engineering universities
  - More solutions, more approaches, more ideas
  - Large familiarity with all things Cubesat
  - Common foundation for engineering education

Roadmap (notional)

2007	2008	2009	2010	2011

Missions/Science Disciplines

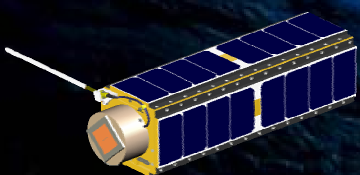
Space Biology

Astrobiology

Space Sciences / Space Physics

Technology Demonstration / Validation

Platforms



3U Cubesat

6U Cubesat

Microsatellite Sorties

Microsatellite Constellation

Launch Opportunities

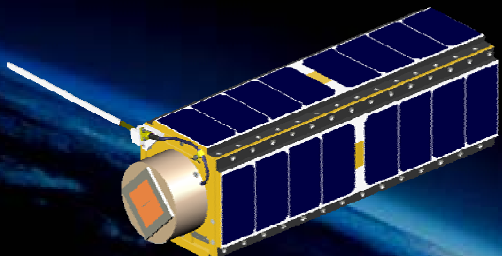
GeneBox; Flown 16 July 2006
GeneSat-1; Flown 16 Dec 2006
Pharmasat-1; Launch 10 Dec 2007

Overarching Goals:

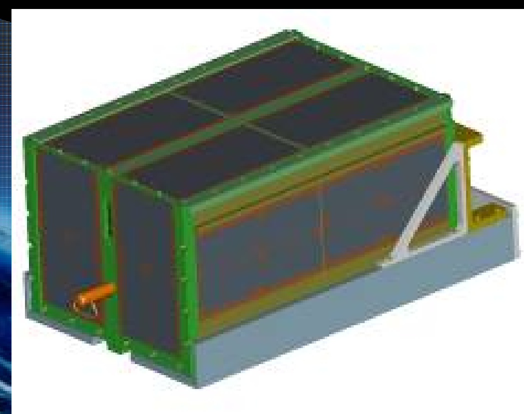
- Contribute substantially to NASA's missions
- Do big science in small spacecraft
- Provide rewarding, focused objectives for the Next Generation of space scientists and technologists

The Future of Cubesats

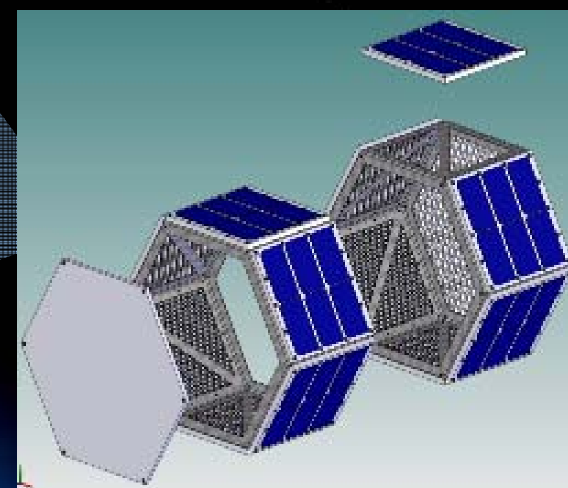
- What is the next “Cubesat standard”?



3U?



6U / 6U+/ 12U/?



University Nanosat?

- How can we advance the field?
  - Provide ‘Rides’?
  - Sponsor Contests?
  - …