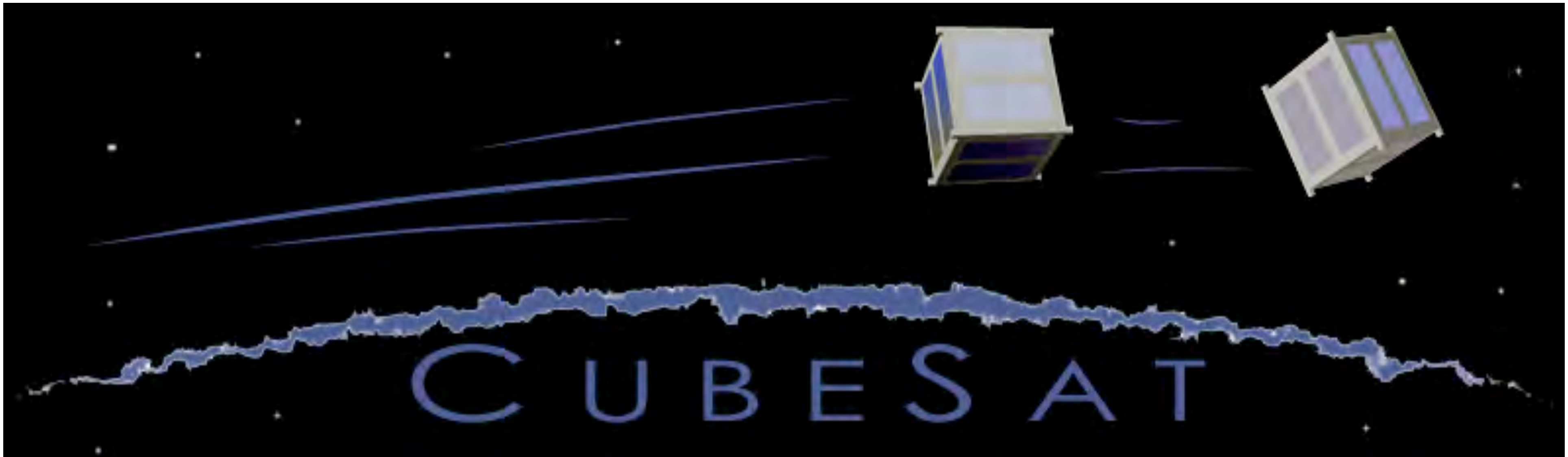

Strategies for Successful CubeSat Development

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Cal Poly, San Luis Obispo

CEDAR Workshop

July, 2009

Some CubeSat Facts

- Over 100 Developers Worldwide
  - Including Government, Industry & Academia
- 28 CubeSats in LEO (44 Launched)
- Dedicated Workshops/Meetings
- CubeSat Industrial Suppliers

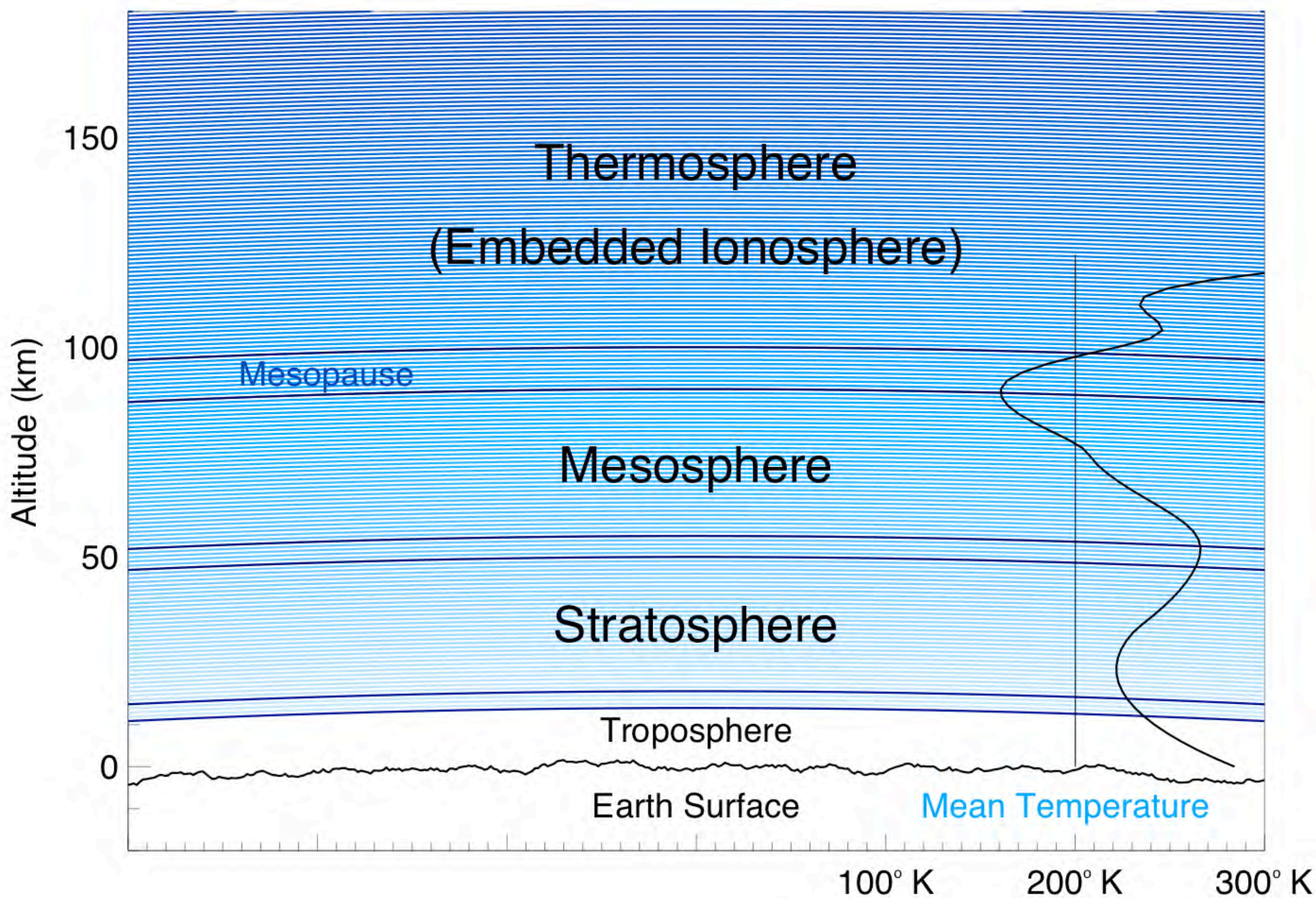
Ongoing CubeSat Activities

- CubeSat Access to More Launch Vehicles
  - SpaceX, Orbital, ULA, PLV, VEGA
  - **Launches Available**
- GENSO
  - University Ground Station Network
  - Addressing Data Download
- University Launches
  - ESA (VEGA), NASA, NSF
- Government CubeSat Activities
  - NASA, NRO, ARMY, NSF. . .
  - **Funding Available**

- **NSF Focus = Space Weather**

Space Weather Interests

Space Weather Interests



Space Weather CubeSats

Org	Mission	Description	Size	Domain	Focus
GSFC	WINC	Neutral & Ion mass and winds	3U	Particles	Thermosphere
MSU	Explorer’	Dosimeter	1U	Particles	Thermosphere
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SRI/UM	RAX	UHF Radar receiver	3U	Fields	Auroral Ionosphere

CubeSat Initial Objectives

- Started in 1999: Stanford-Cal Poly Team
- Facilitate Access to Space:
  - Rapid Development Time (1-2 years, Student Career)
  - Low-Cost
  - Launch Vehicle Flexibility
- Use Standards
- University Projects
- Industry Testbed

CubeSat Concept

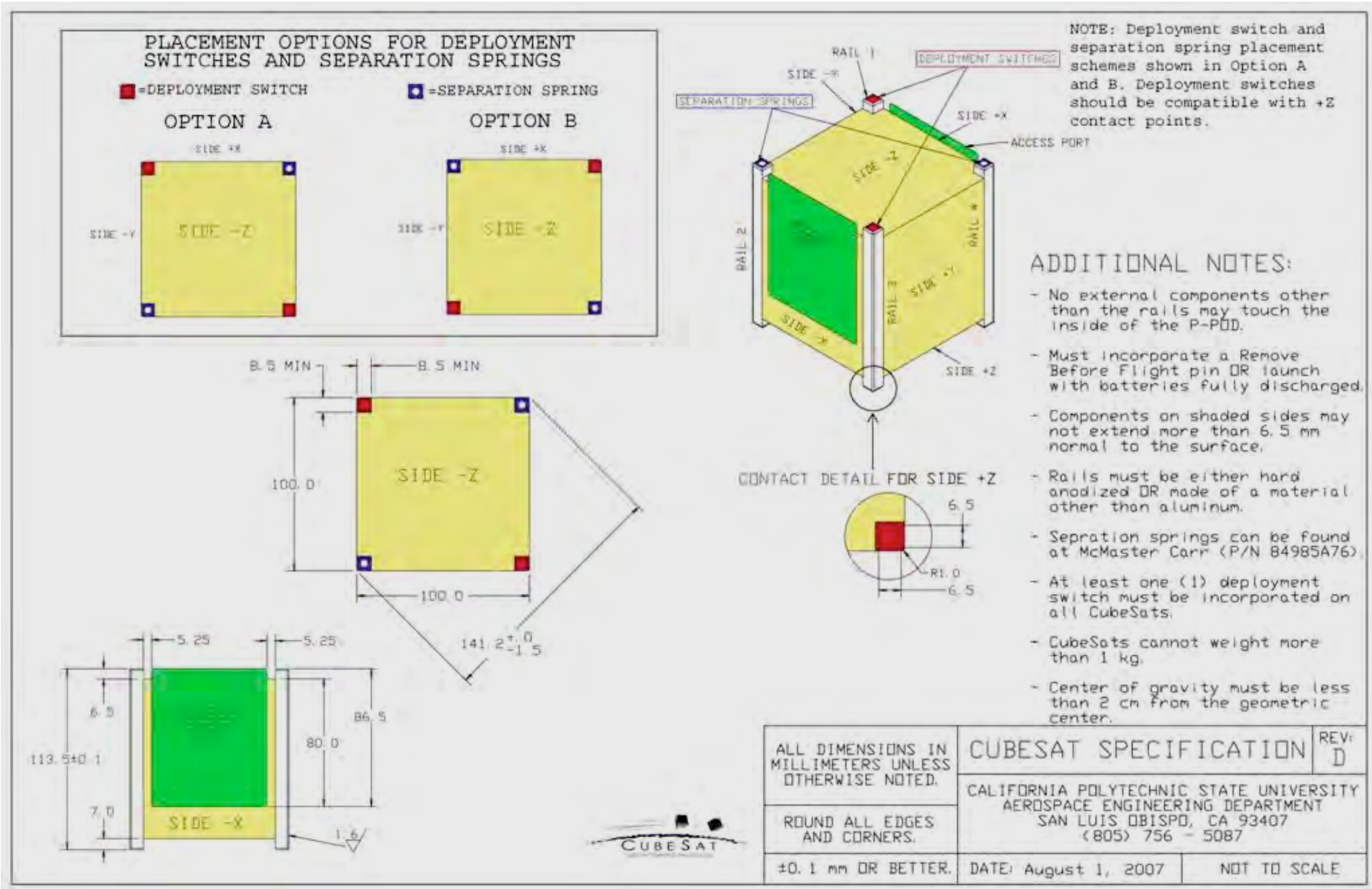
- PicoSatellite (Small)
- Simple Standard
  - Manageable by universities
- Standard Based On
  - Space environment
  - Size of available COTS components
    (Solar cells, batteries, transceivers, etc.)
  - Self-imposed safety standards
  - Deployer dimensions and features

The P-POD

- Mission Objectives
  - Protect LV and primary payload
  - Safe/reliable deployment
  - Compatibility with many LV
  - Simplicity
- Payload: 3 Single CubeSats
- Tubular Frame
- Spring Assisted Ejection
- Standard Deployment System
  - NEA Electronics
- Deployment Detection Switch

The CubeSat Standard

- Simple Document
- Shape and size & Interface to P-POD

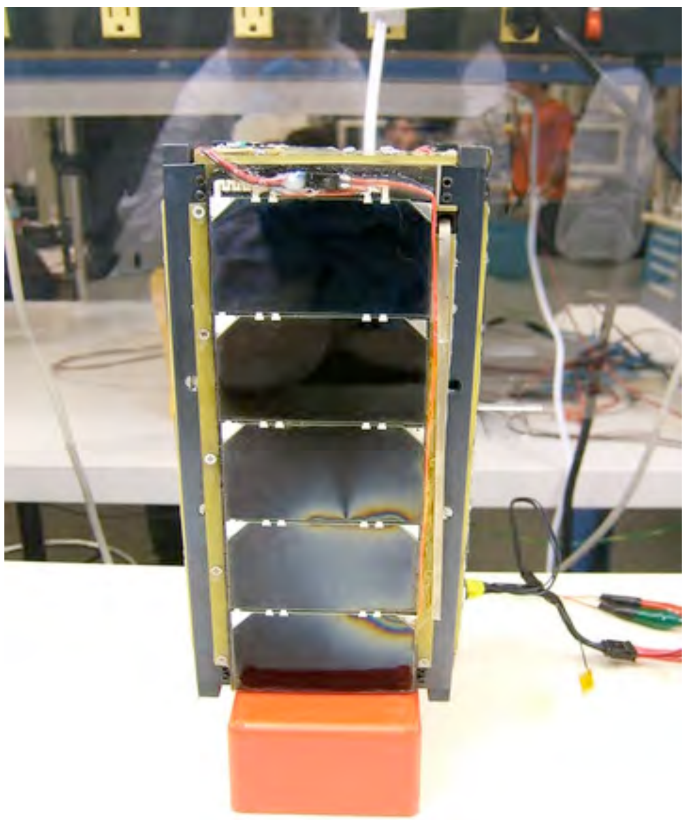


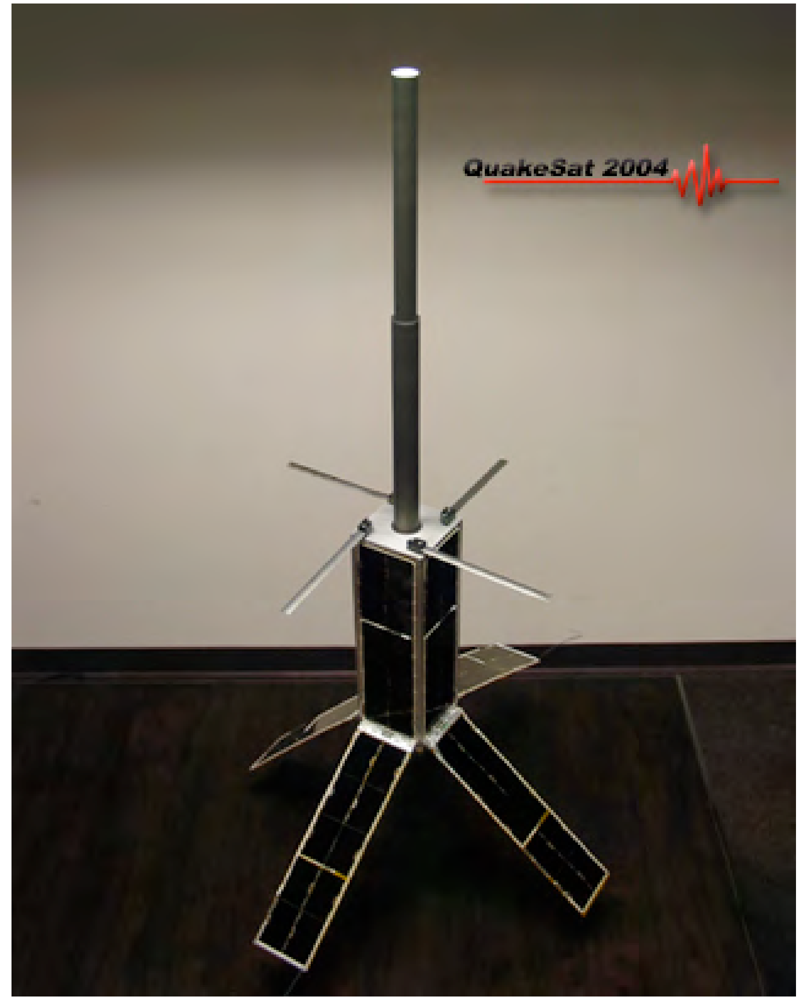
Variations on the Standard

- Double Cube: 10x10x20 cm   2.0 kg
- Triple Cube: 10x10x30 cm   3.0 kg
- Implemented from first CubeSat Flight (2003)
- **NO CHANGES to P-POD**
  - Maintains Launch vehicle Compatibility

Examples

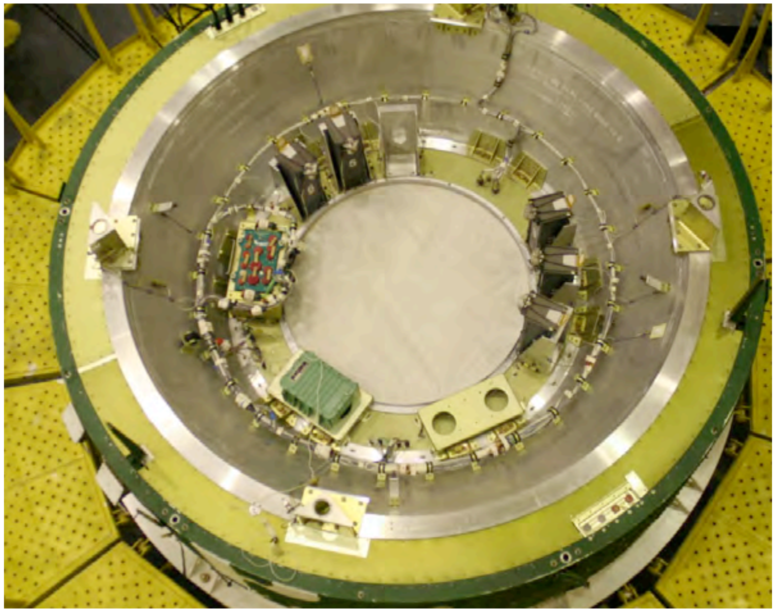
- Double (2U): Ion 1
  - Airglow photometer
  - University of Illinois

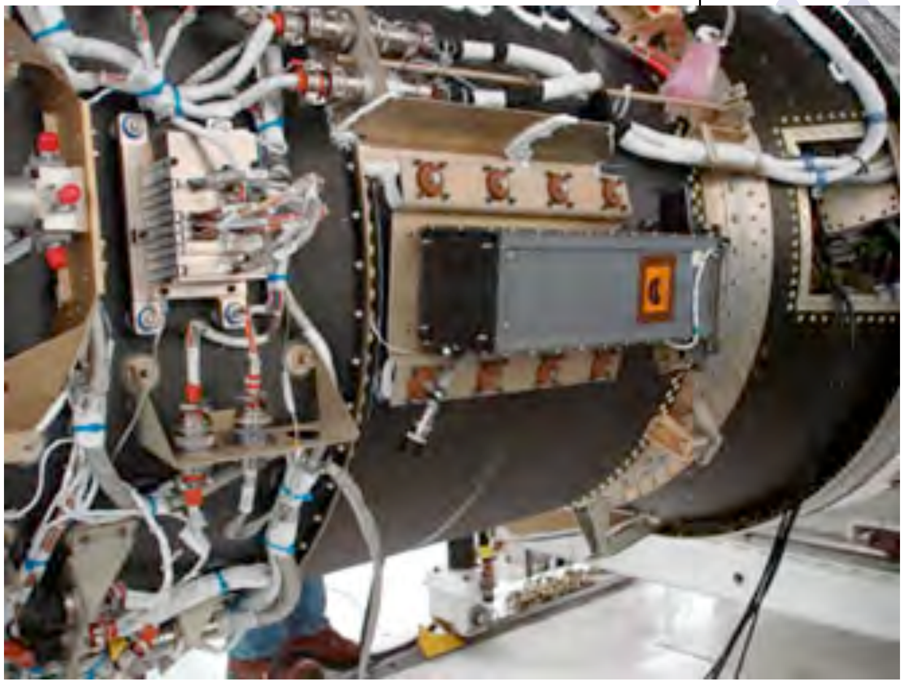




- Triple (3U): QuakeSat
  - ULF waves related to Earthquakes
  - Stanford/Quakefinder

P-POD Flight Heritage





- Rockot 2003
- Dnepr 2006 (Launch Failure) & 2007
- Minotaur 1 2006 & 2009
- Falcon 1 2008 (Failure) & 2009?
- Minotaur 4 2010

CubeSat is a Successful Standard, Why?

- Small & Low-Cost
  - Many Developers
- Hard-Standard
  - Physical Constraints
- Developer Community
- Advances in Miniature Electronics
- Primary/Launch Vehicle Protection
- Grass Roots Effort Lead by Universities
  - Industry & Government Joined Later

Lessons Learned
P-POD = Flexibility & Low Cost

- Multiple manifest: distribute launch costs over many customers
- Repetition minimizes design, analysis, and testing for subsequent missions
- Spacecraft Development Without Firm Launch
  - Standard Independent of Launch Vehicle
  - Fast Response to Launch Opportunities
- Possible to transfer spacecraft to a different LV if launch is delayed or canceled
- P-POD Protects CubeSat Developers

Current Challenges

- Moving from University to Industrial Model
  - Industry/Government Customers
  - Higher Performance/Cost Satellites
  - Increased Quality Required
  - Potential Cost Increases
- Must Maintain Access to Universities
  - Including New Developers
- Allow Risk (Failure)
- Support higher launch rates
  - Address orbital debris issues
  - Ground station capability
- Maintain standard model
- Coordinate Community

Big Space's View of CubeSats

- CubeSat Positives:
  - Available Launches
- CubeSat Negatives:
  - Limitations due to CubeSat Standard
  - Insufficient power, volume, mass, data rate, etc.
  - Not compatible with ***traditional*** missions
- Options:
  - Continue using traditional model
    - Wait for limited launch opportunities on large missions
    - Not possible to fly all instruments and get sufficient data
  - Find a way to use CubeSats

Alternative View

CubeSat's limitation is **mindset** not resources

- Need change in approach to scientific satellites that is compatible with CubeSat
- Limited Options + Limited Resources + Significant need = High Risk Unconventional Solutions

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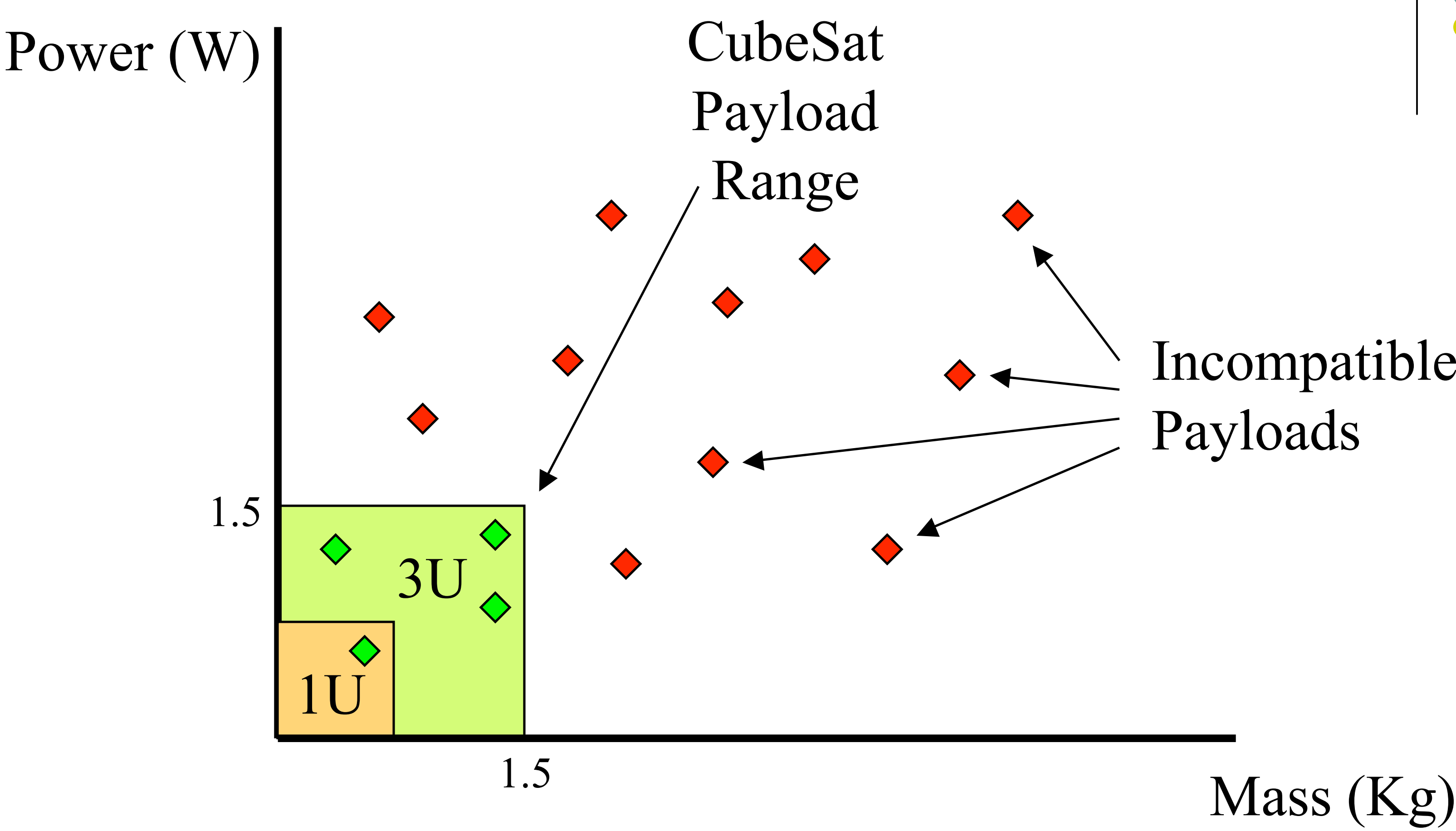
"Guerrilla Space"

Great science with limited resources is not new

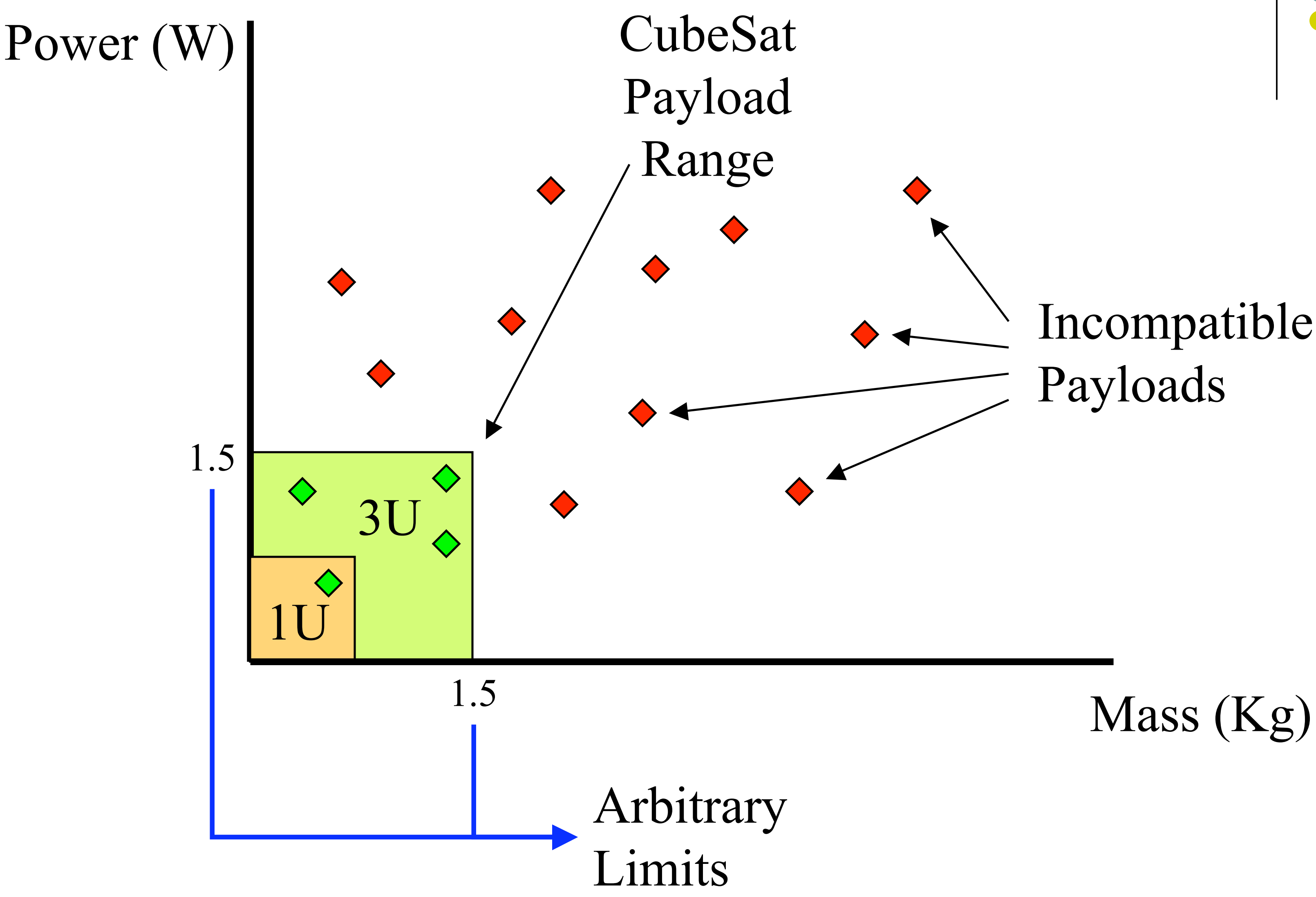
Patent Office Clerk
Albert Einstein

Big Space's View



CubeSat can only accommodate a few payloads

Big Space's View



Alternative View

Power limit is an operational constrain:

- Operational Solution= Reduce Payload Duty Cycle
  - Daily energy availability to payload ~10-30Whr
  - Battery density >150Whr/kg
- Payloads in the 10W range can run several hours per day

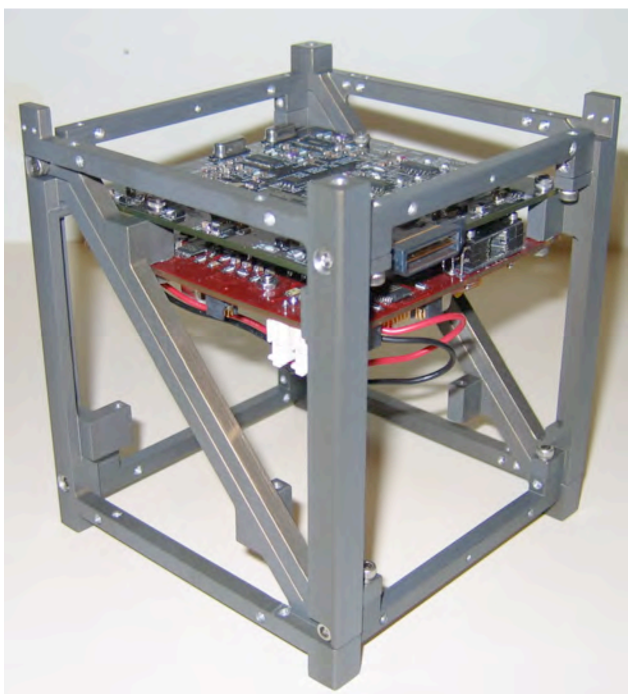
Mass and Power limits are also a function of bus parameters:

- Minimize bus requirements (Mass, Volume, Power)

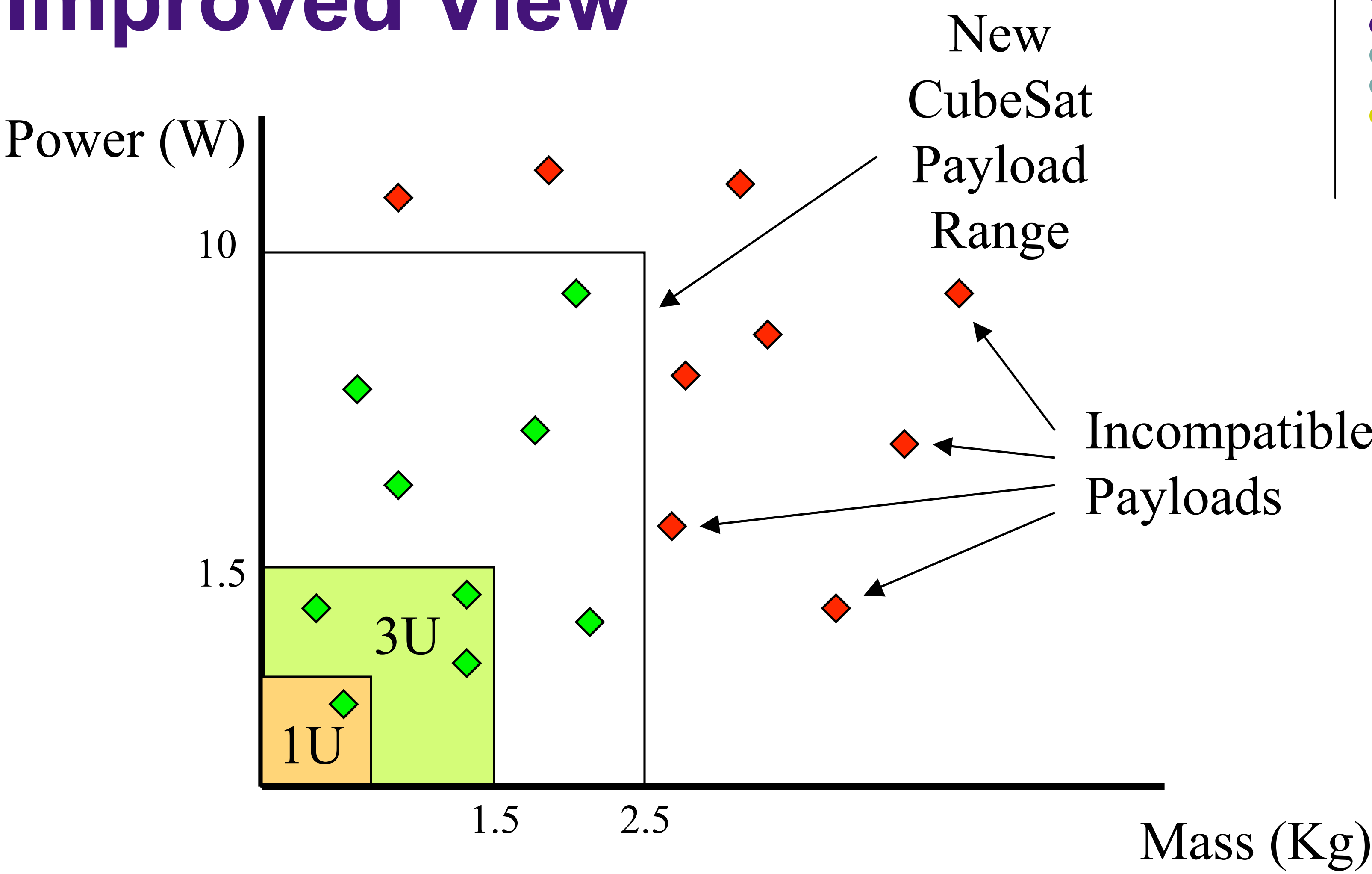
Optimized Bus Example

Cal Poly's CP X bus:

- All Bus Functions on 2 Multifunction PCB's
- Magnetic AD&C System on Sidepanels
- Software functionality replacing hardware

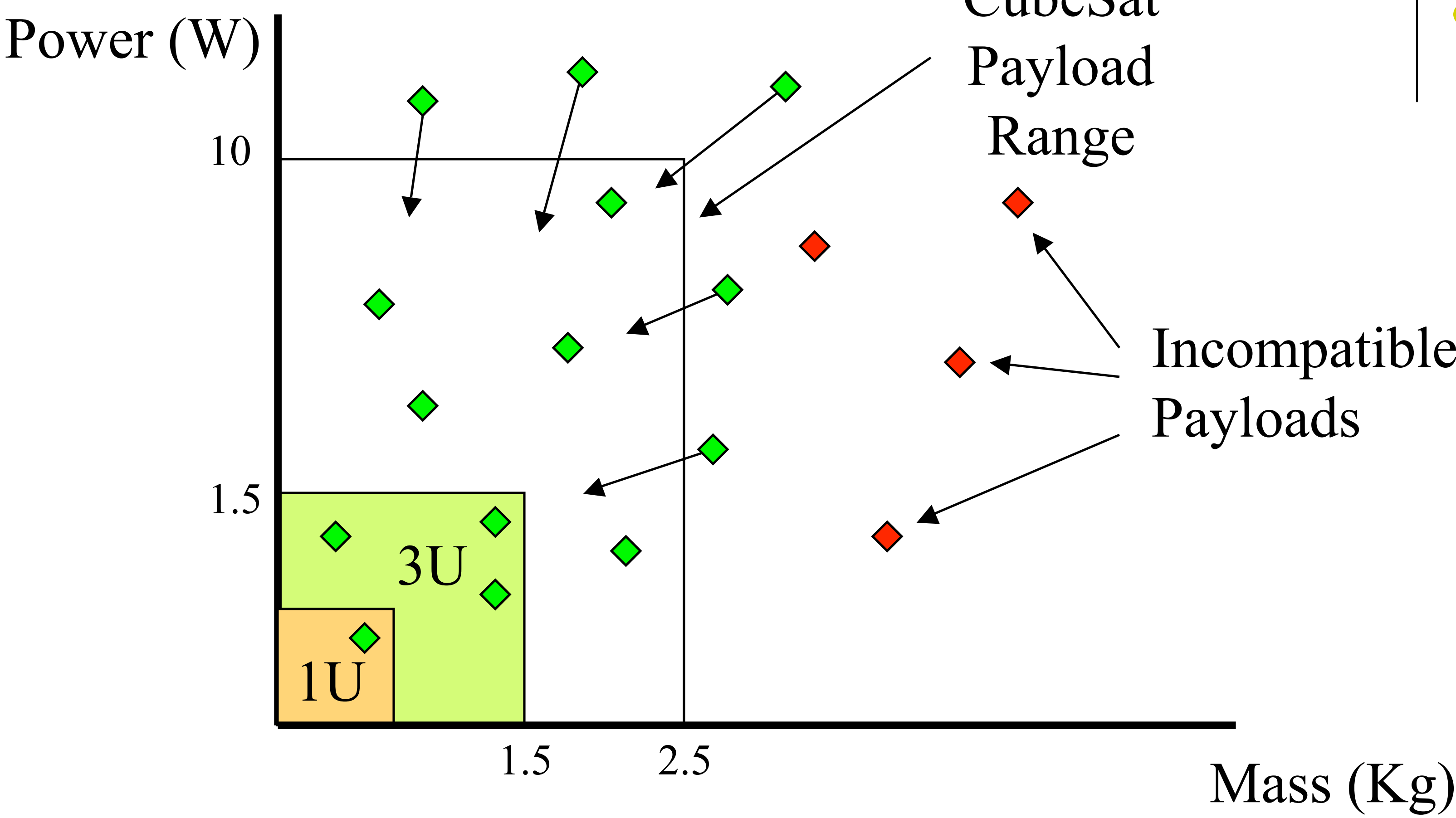


Improved View



Increased Payload resources due to optimized bus and operations plan

Next Step

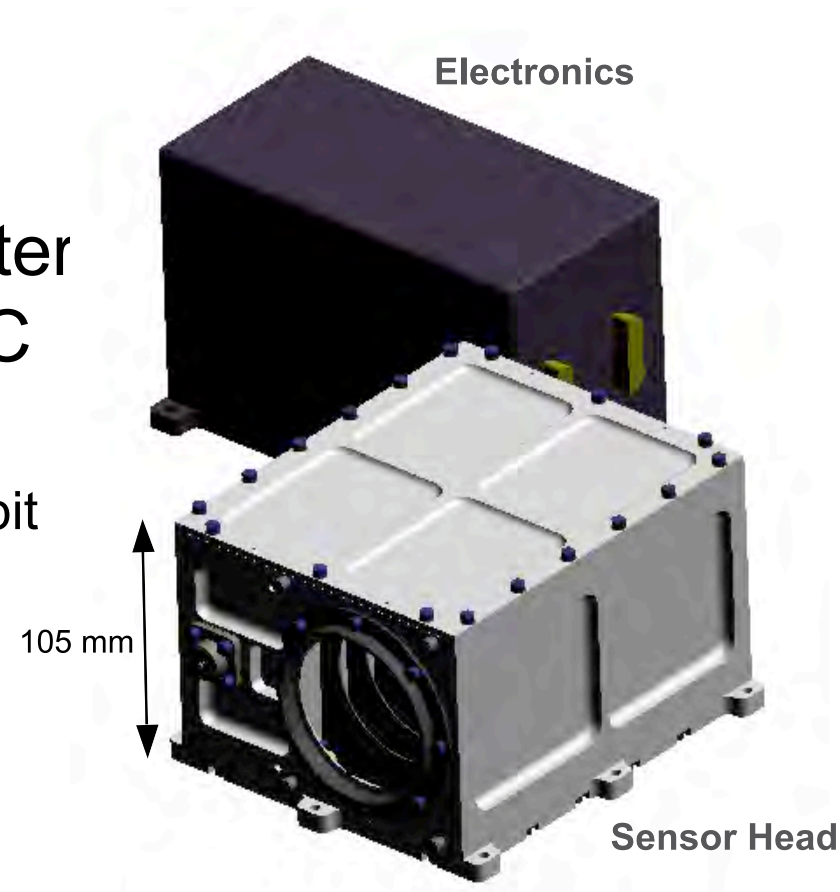


Optimize Payloads for CubeSat Application

Payload Optimization Example

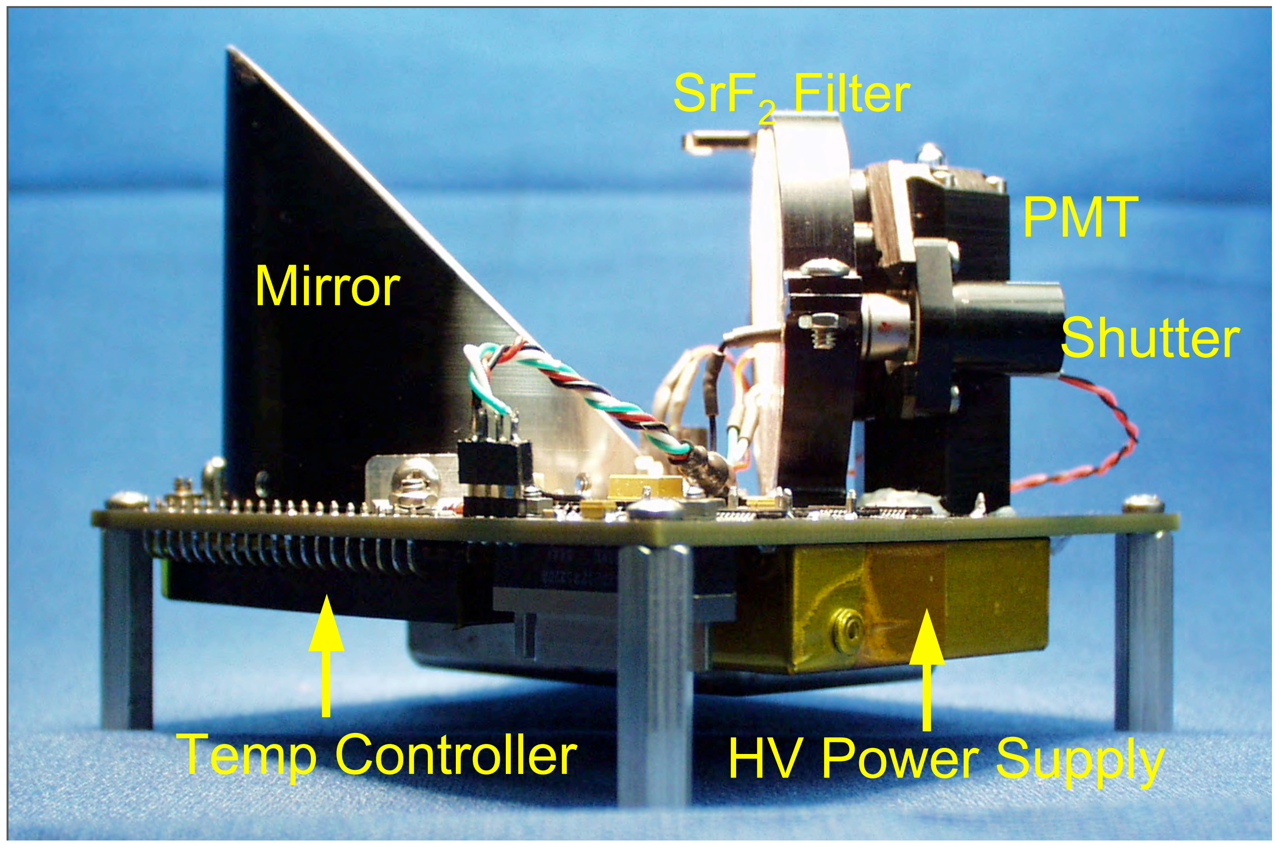
SRI's CubeSat Tiny Ionospheric Photometer (CTIP)

- Original Instrument: NRL Tiny Ionospheric Photometer System (TIPS) on COSMIC Satellite
  - 3000 cm^3, 2.3 Kg and 7.6 W Orbit Average

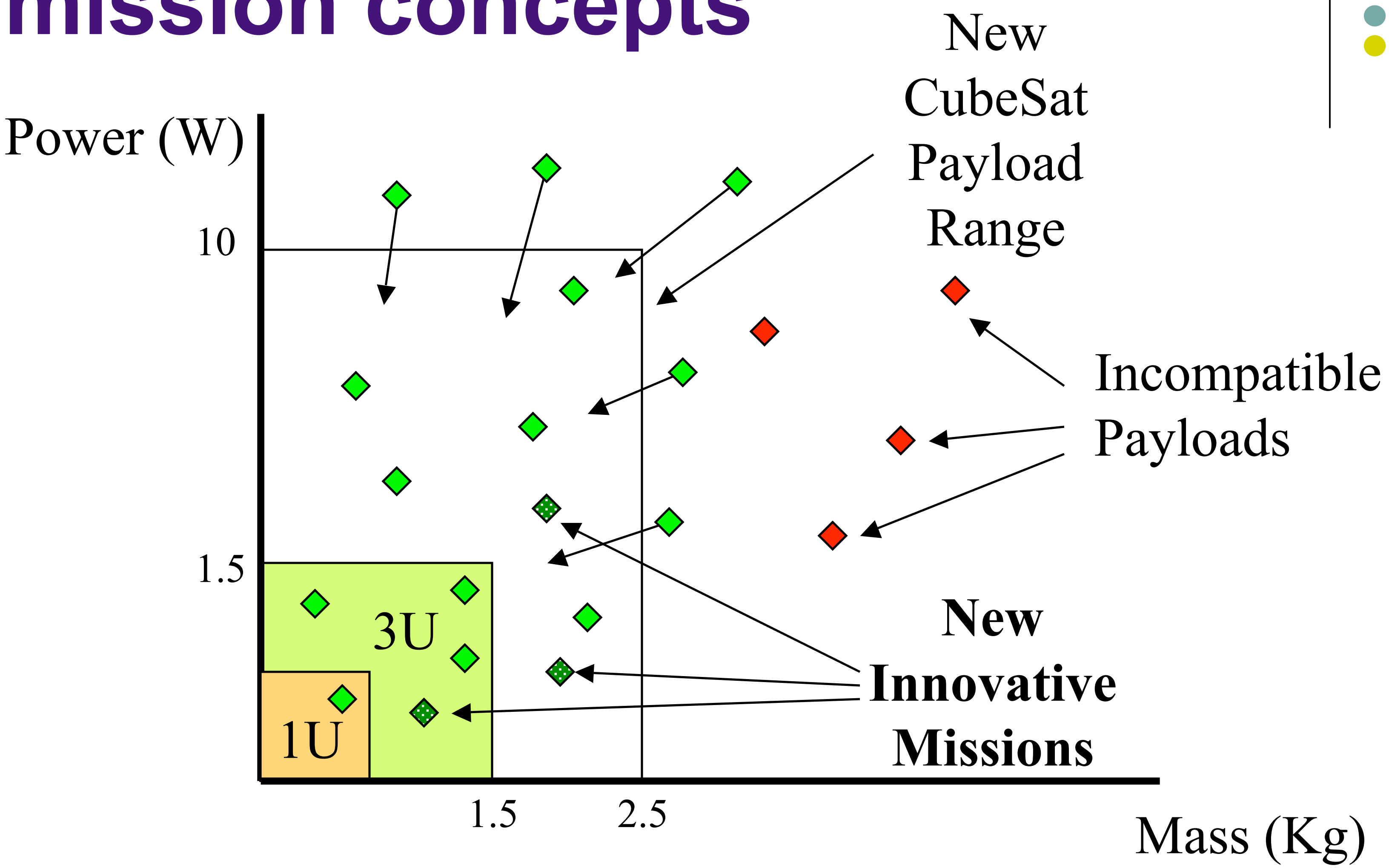


CubeSat Optimized Instrument

- CTIP: <1000 cm^3, <1 Kg and 2-3W Orbit Average
- Matches TIPS Performance

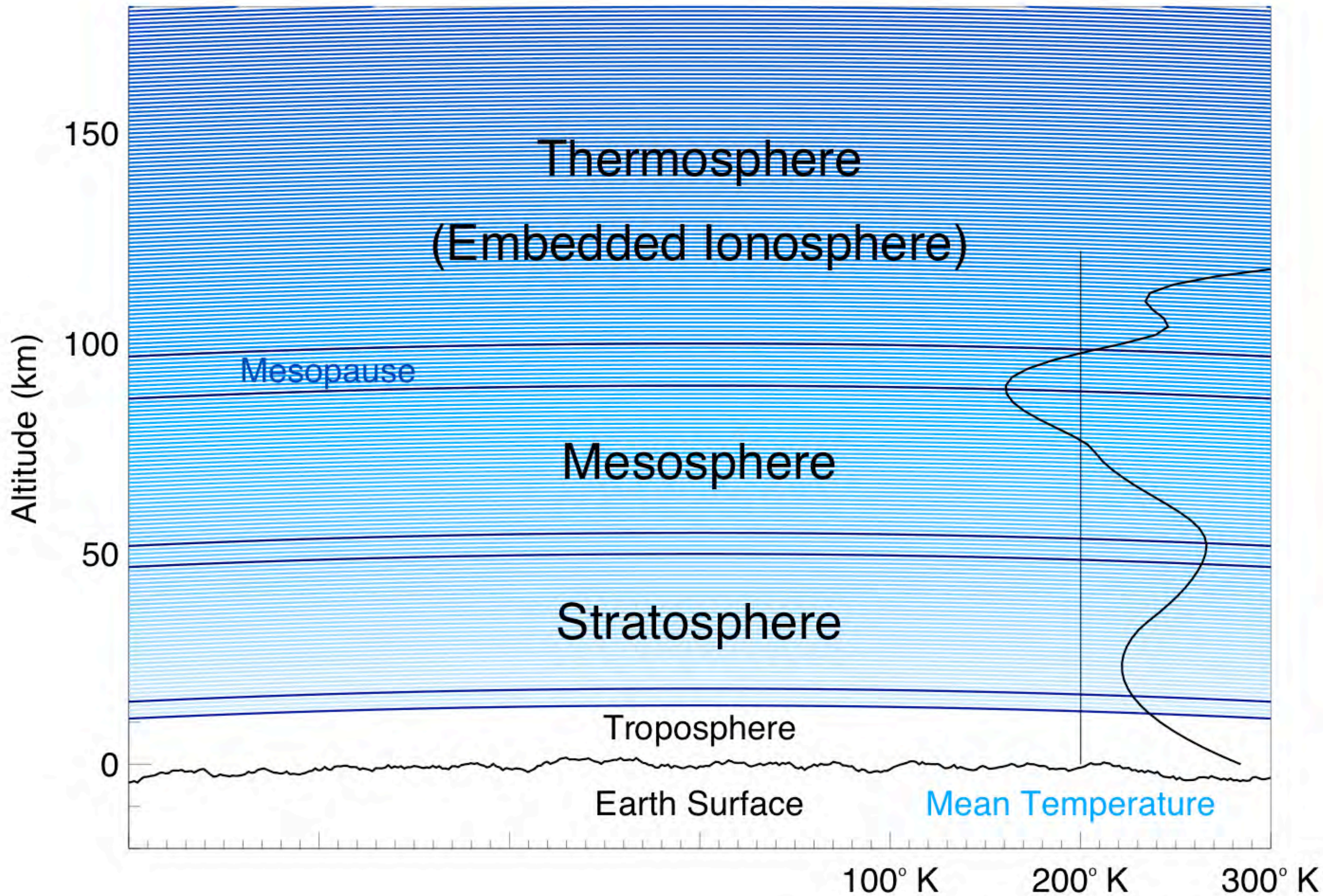


Additional Step: Identify new mission concepts



NSF CubeSat RFP was catalyst in Space Weather Community

Space Weather Interests



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Additional Lessons Learned in CubeSat Development

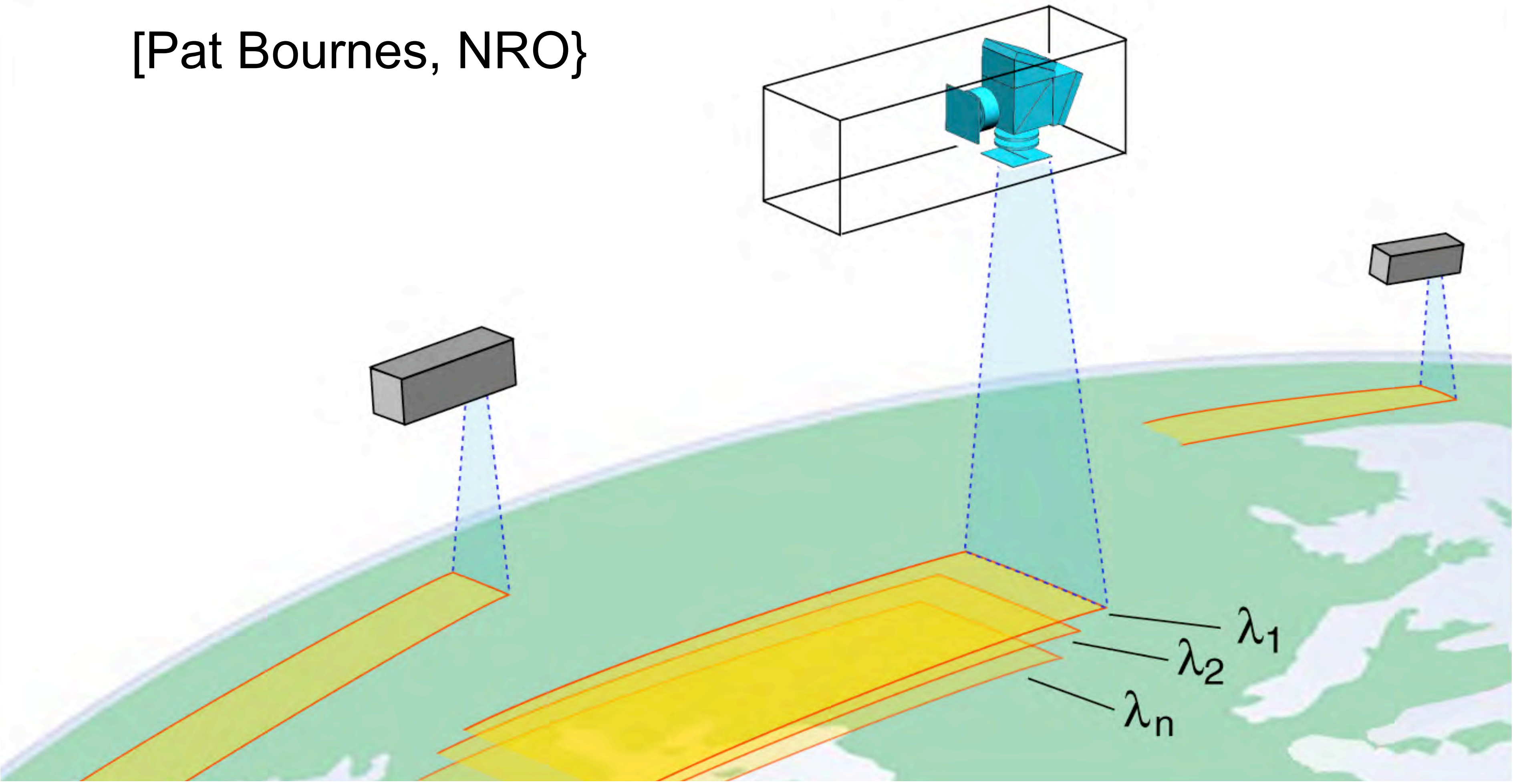
- Consider minimal mission requirements
  - Single instrument (multiple spacecraft)
- Apply KISS principle
  - Minimum redundancy (build 2 spacecraft)
  - Simple operations model
- Flexible orbit maximize launch opportunities
- Develop Spacecraft without Launch
- Become Familiar with CubeSat Standard
- Team with good engineering groups
- **BE CREATIVE** !!!!

Conclusion: CubeSats can do more

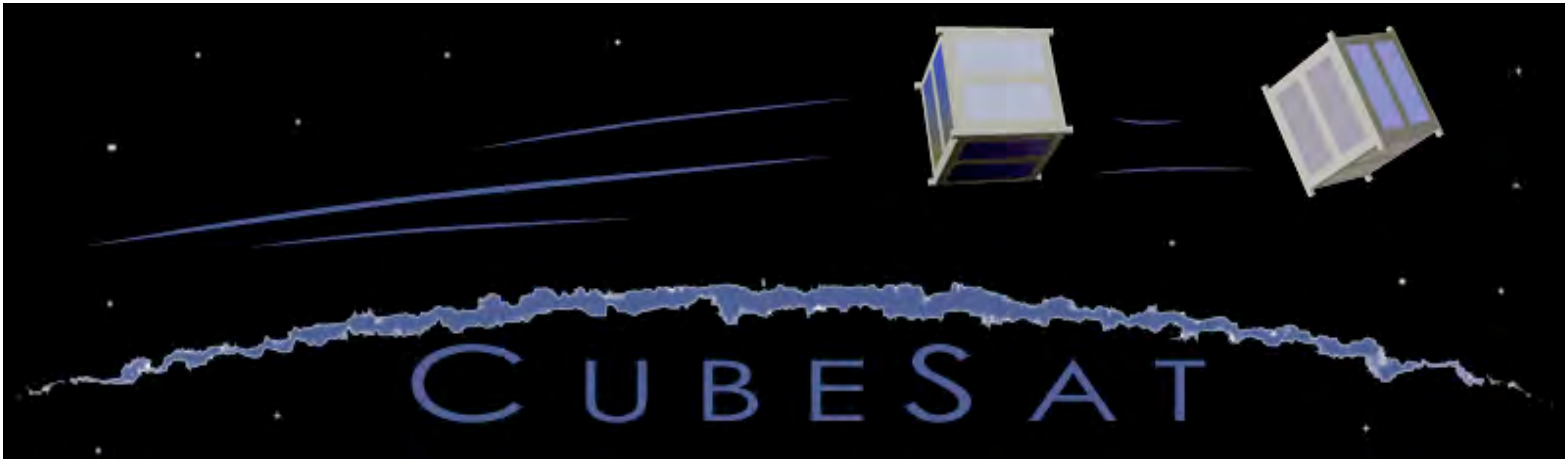
- Mindset is the biggest constraint
- Cannot follow standard spacecraft practices
- Higher risk tolerance required
- Frequent launches accelerate learning curve & provide redundancy
- Ideal for constellation applications

Think Outside the Box by thinking
“Inside the Cube.”

[Pat Bournes, NRO}



WWW.CUBESAT.ORG



Next CubeSat Workshop:
Cal Poly
April, 2010