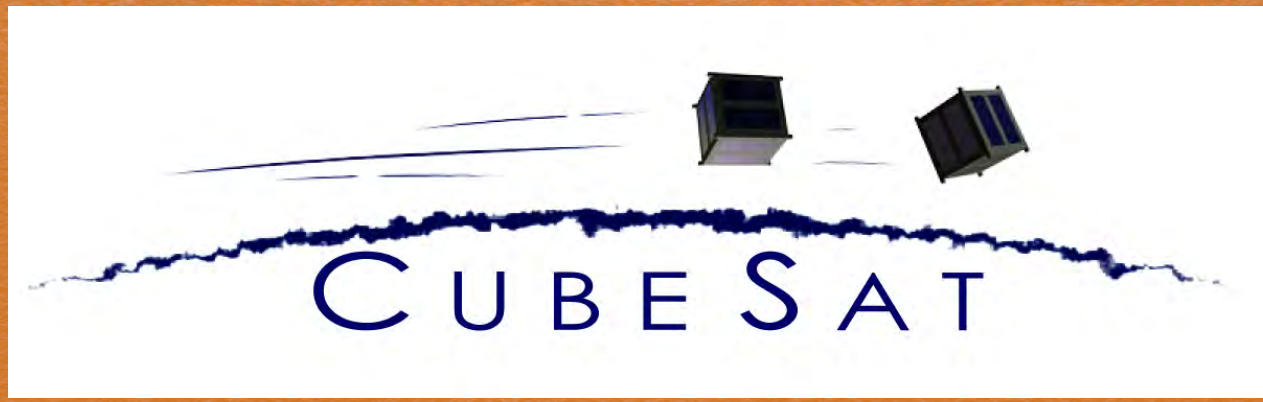
CubeSat Program Status



Jordi Puig-Suari

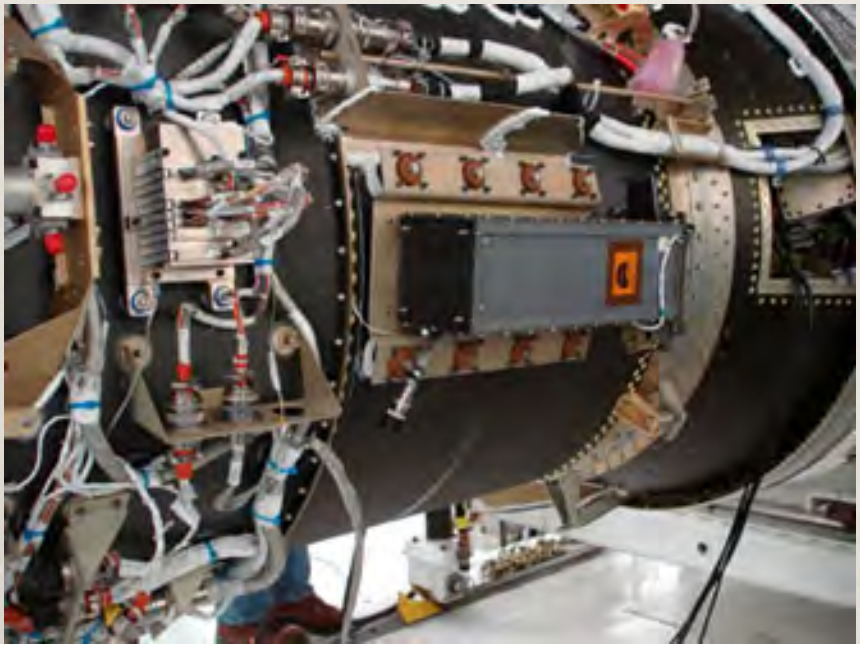
Cal Poly

ISU SSP11

July 2011

Cal Poly CubeSat Activities

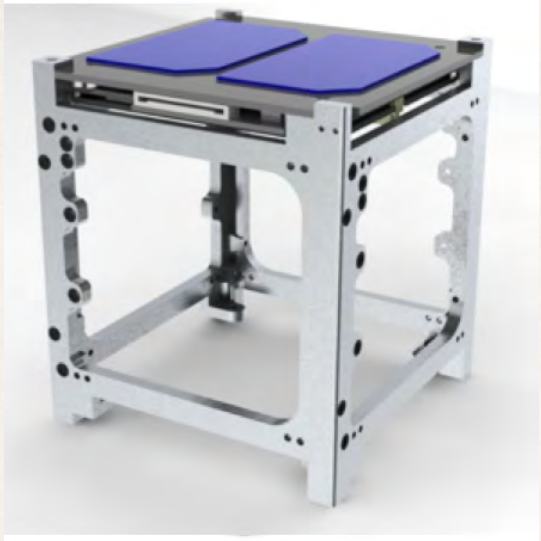
* Maintain/Evolve CubeSat Standard
  * Support Developer Community
* Develop CubeSat Access (P-POD)
  * Focus on US Launch Vehicles
* P-POD Integration Services for any type of user



Cal Poly PolySat Activities

* Develop Student CubeSats
* Focus on Improved 1U Bus Performance
  * Electronic Miniaturization
  * Collaboration with Payload Developers
* CP series (5 Launched, 3 in-Orbit, 2 in development)

Advanced CubeSat Avionics

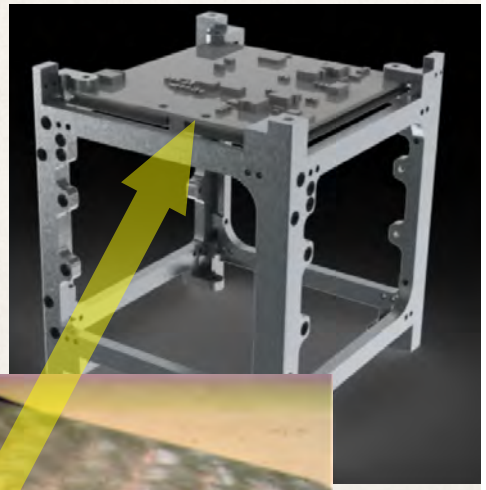


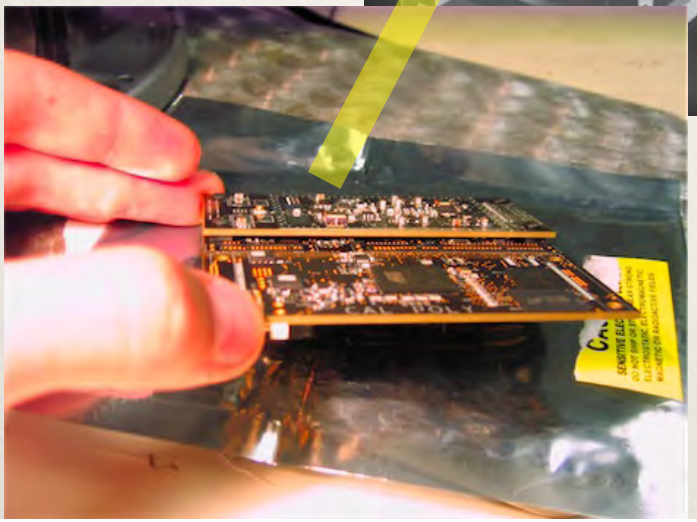
High-Performance Custom System

- ★400Mhz Arm processor
  - ★>512MB of storage & 64MB RAM
  - ★<0.6 Watts
- ★Custom Linux Build
- ★Integrated power regulation system and sensor suite
- ★Low profile UHF RF daughterboard
  - ★2W RF output up to 150kbps

CubeSat Mission Enabler

- ★Minimum bus volume
  - ★Avionics/EPS/Comm in 9cmx9cmx2cm
  - ★Custom efficient structure available
- ★Fast software development
  - ★Open source OS/drivers
  - ★Simple development platform





Student Satellites: Education Tools

Multidisciplinary!

Spacecraft Design

Subsystem Development

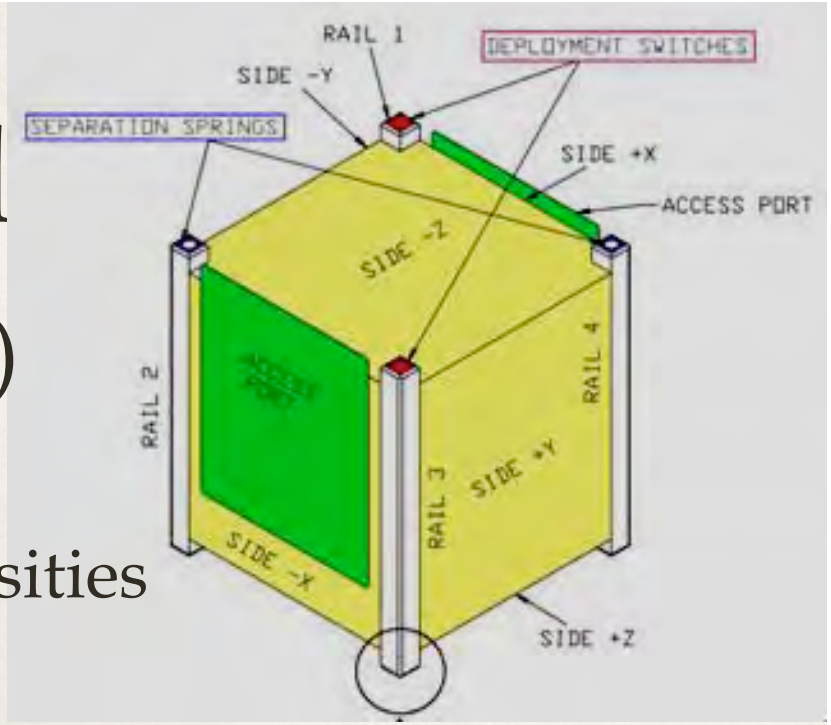
System Integration & Testing

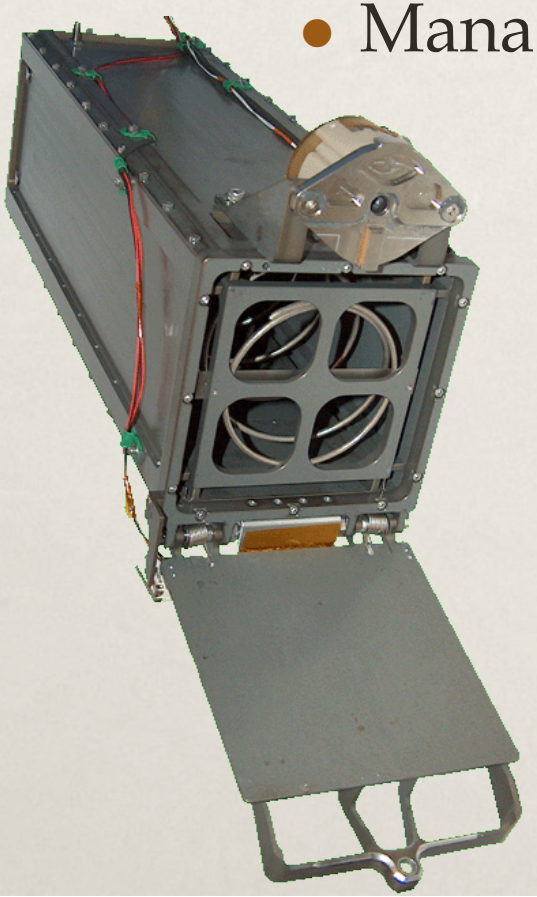
CubeSat Initial Objectives

* 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 Led Program

CubeSat Standard

- PicoSatellite (Small)
- Simple Standard
  - Manageable by universities



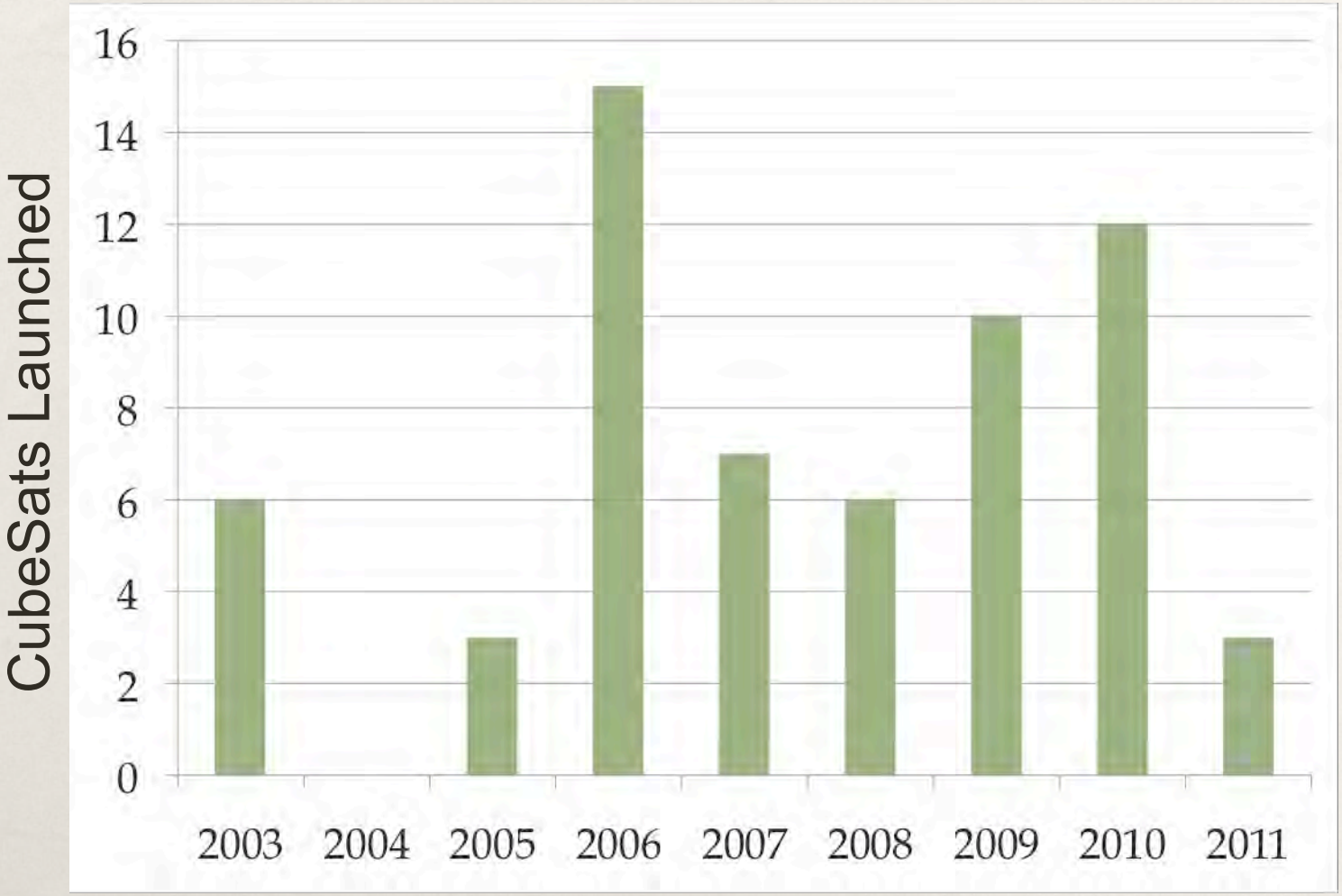


- P-POD Deployer
  - Protect Primary & Launch Vehicle
  - Launch Vehicle Flexibility
  - Simplicity
  - 3 CubeSats (or 3U spacecraft)
- Risk Containment

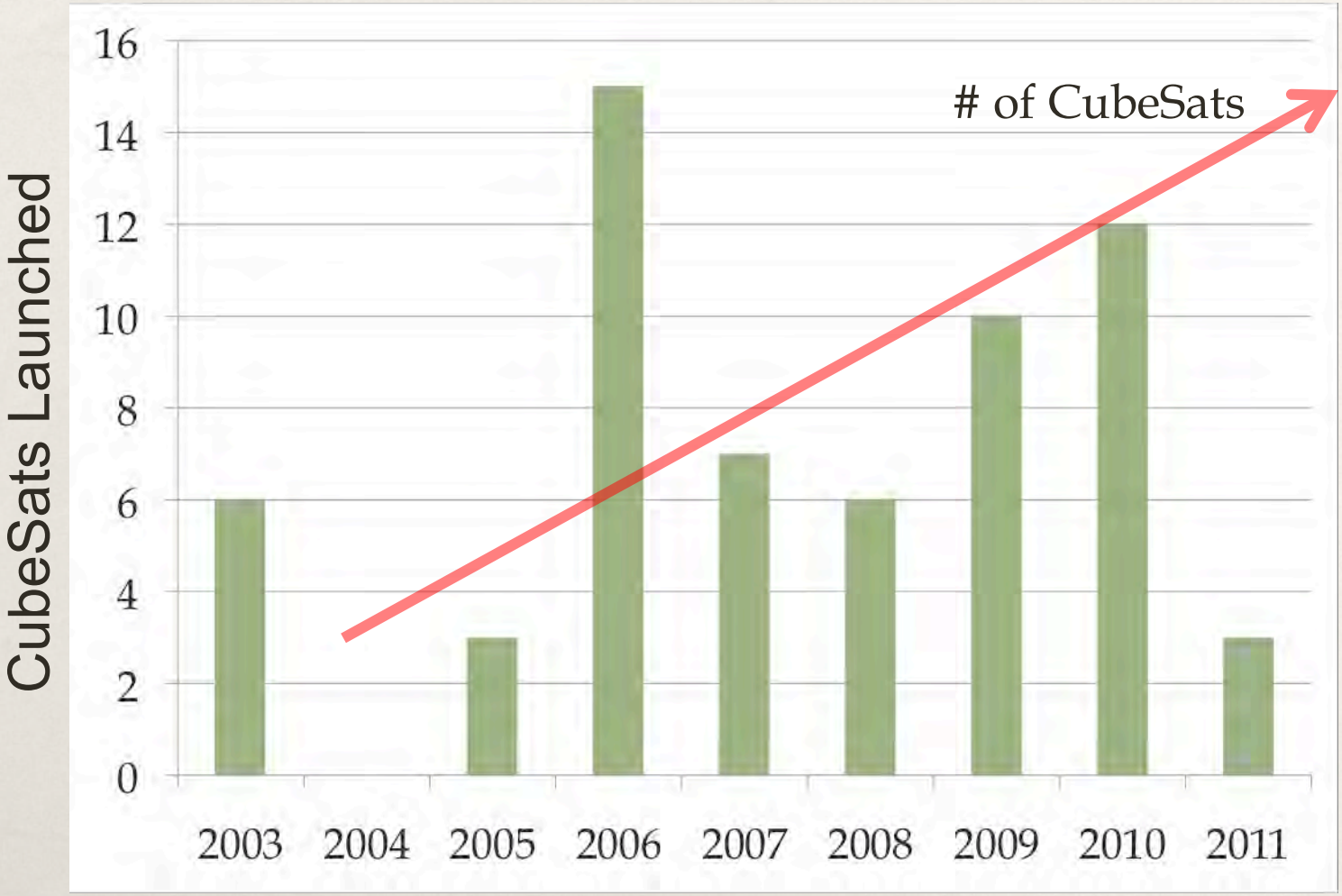
Results

* 44 CubeSats in LEO (63 Launched)
* 10 Different Launch Vehicles
  * U.S., Russia, India
  * 3 more vehicles manifested
* Large Developer Community
  * University/Gov/Industry
  * New Players
* CubeSat Industrial Suppliers
  * Pumpkin, Clyde, ISIS, Tyvak
* Government Support

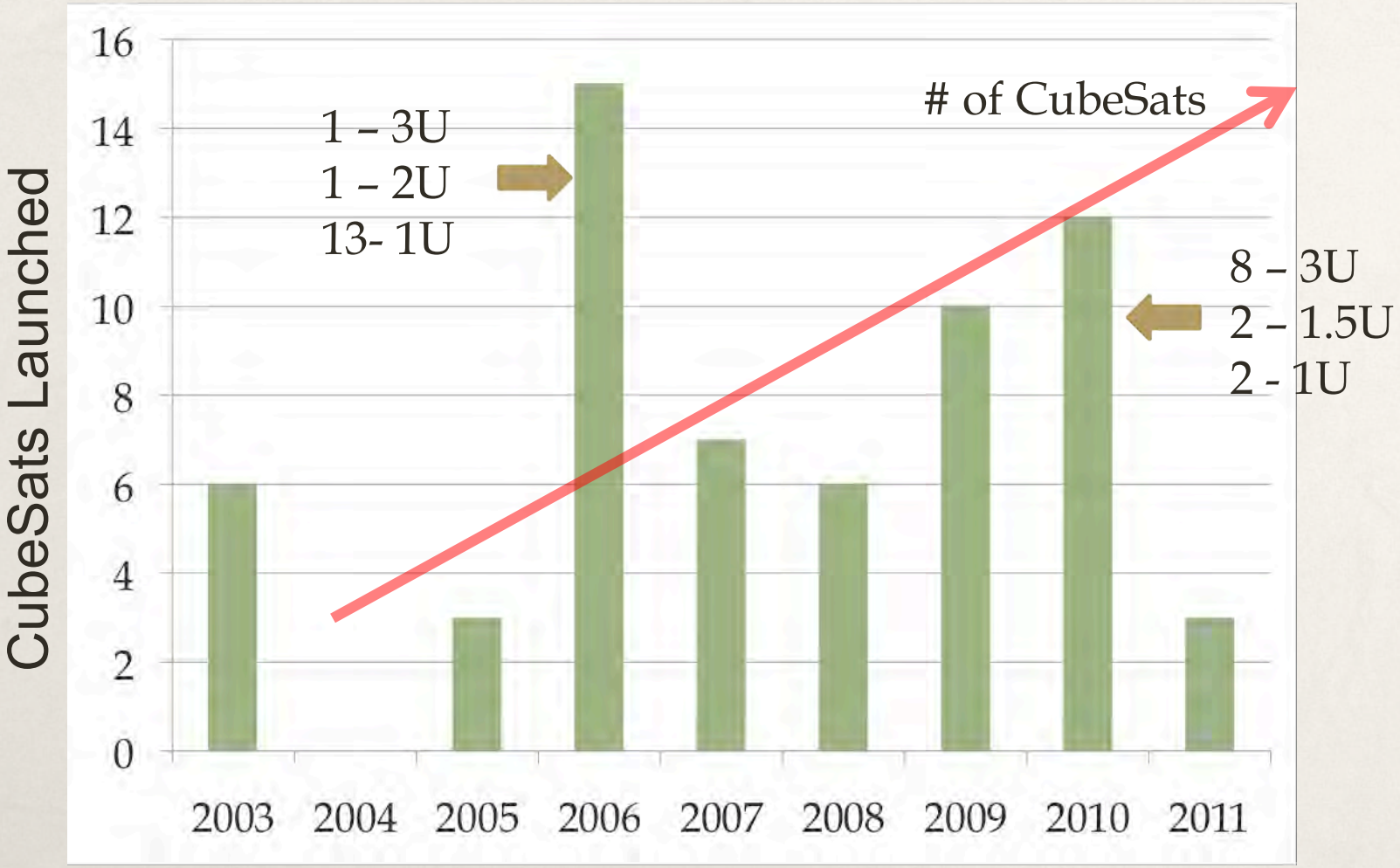
Trends


CubeSats Launched
16
14
12
10
8
6
4
2
0
2003
2004
2005
2006
2007
2008
2009
2010
2011

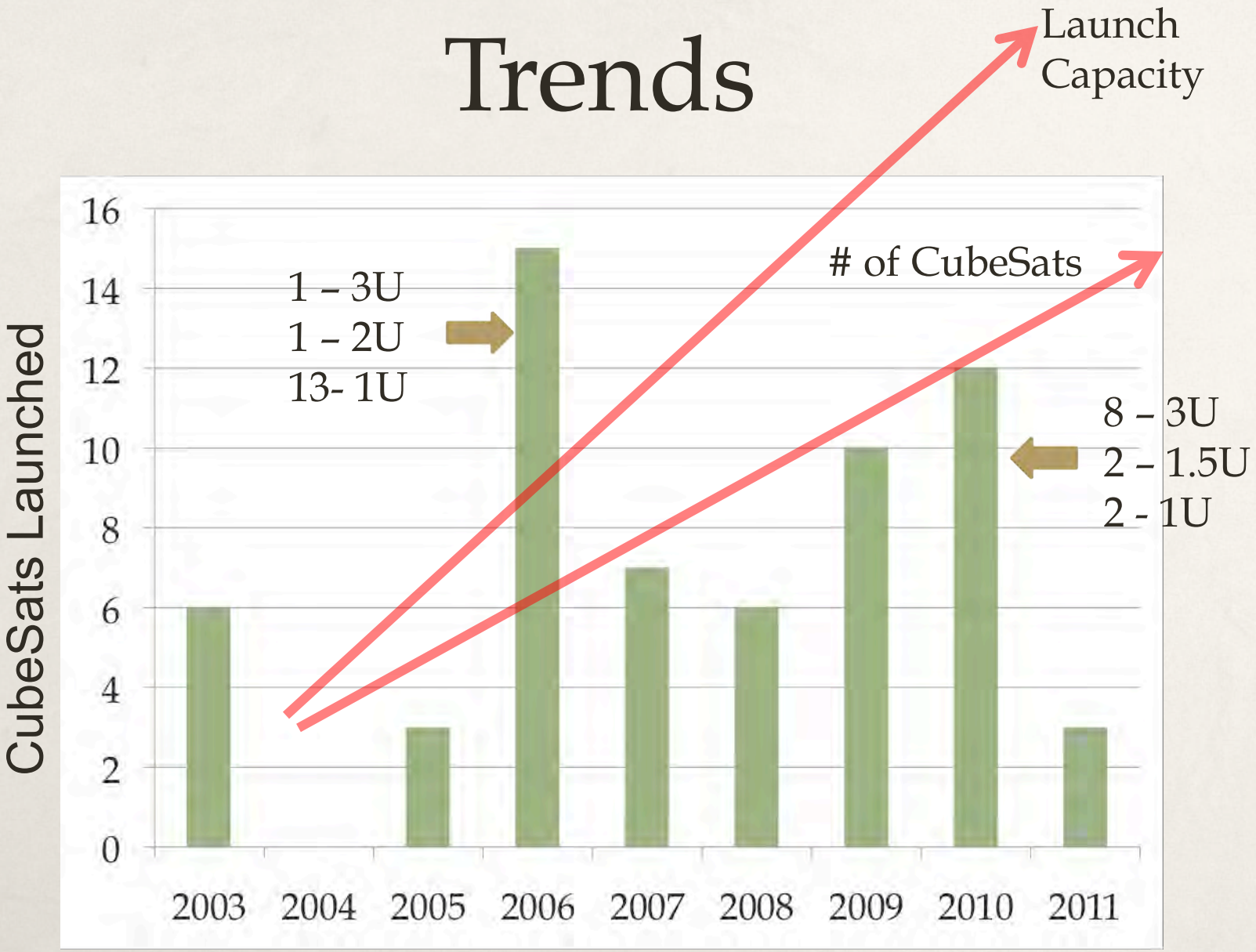
Trends


CubeSats Launched
16
14
12
10
8
6
4
2
0
2003
2004
2005
2006
2007
2008
2009
2010
2011
# of CubeSats

Trends


CubeSats Launched
16
14
12
10
8
6
4
2
0
2003
2004
2005
2006
2007
2008
2009
2010
2011
1 – 3U
1 – 2U
13- 1U
# of CubeSats
8 – 3U
2 – 1.5U
2 - 1U

Trends

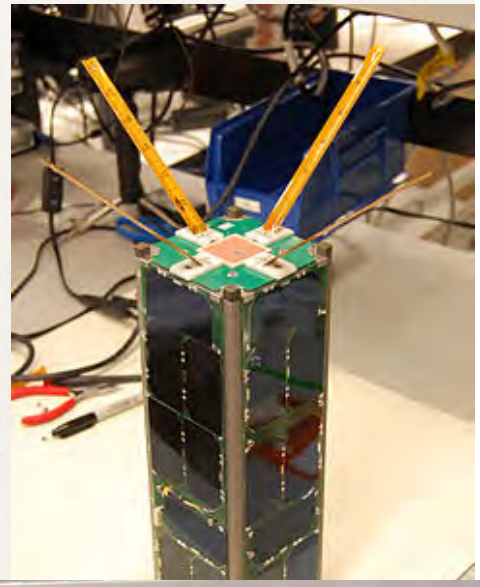

Launch Capacity
# of CubeSats
CubeSats Launched
16
14
12
10
8
6
4
2
0
1 – 3U
1 – 2U
13- 1U
8 – 3U
2 – 1.5U
2 - 1U
2003
2004
2005
2006
2007
2008
2009
2010
2011

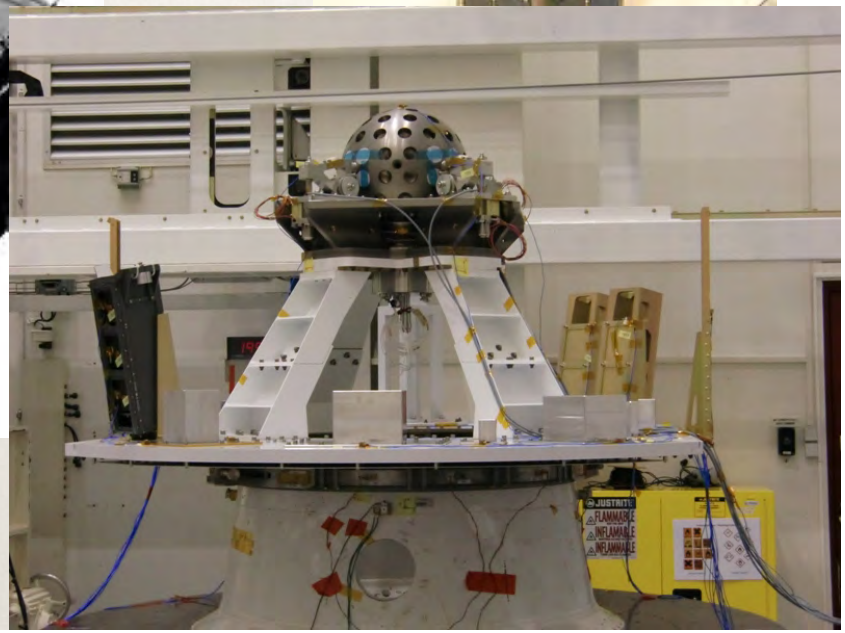
Lessons Learned

* **SPACECRAFT STANDARDS CAN WORK!!**
  * Repetition minimizes design, analysis, and testing
  * Large Developer Community
  * Spacecraft/Launch Vehicle Decoupling
    * Standard Independent of Launch Vehicle
    * Spacecraft Development without Launch
    * LV Manifest without Firm Spacecraft
    * Transfer spacecraft between LV
* **But It is Still Rocket Science**
  * Integration, Test & QA
  * Large numbers of Spacecraft

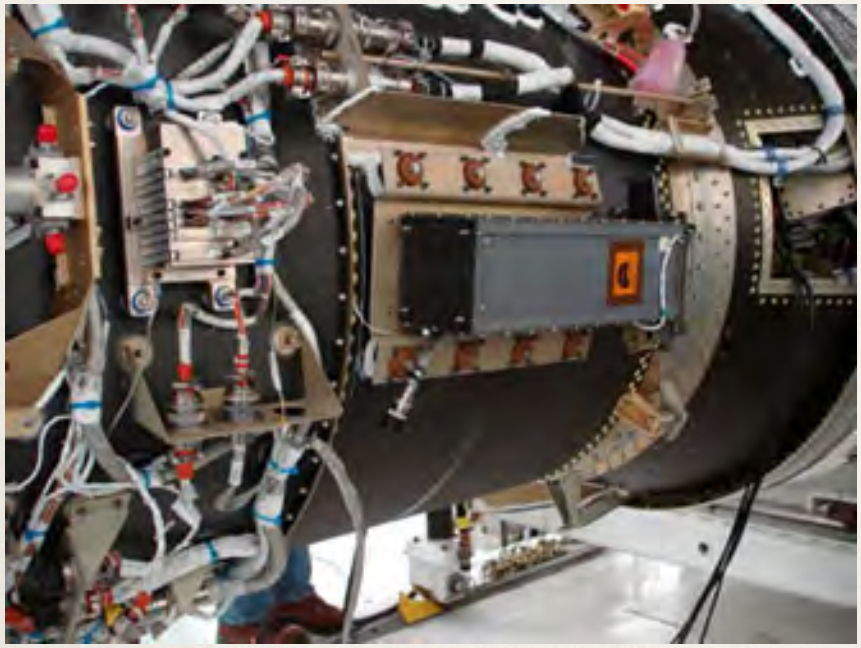
New Developments

* Mission Funding Opportunities
  * Military: NRO, Army, Air Force
  * Science: ESA, NASA, NSF (Space Weather)
* Education
  * NASA ELaNa
  * ESA Vega
* New Vehicles
  * Athena
  * VEGA
  * Delta II
  * Atlas V



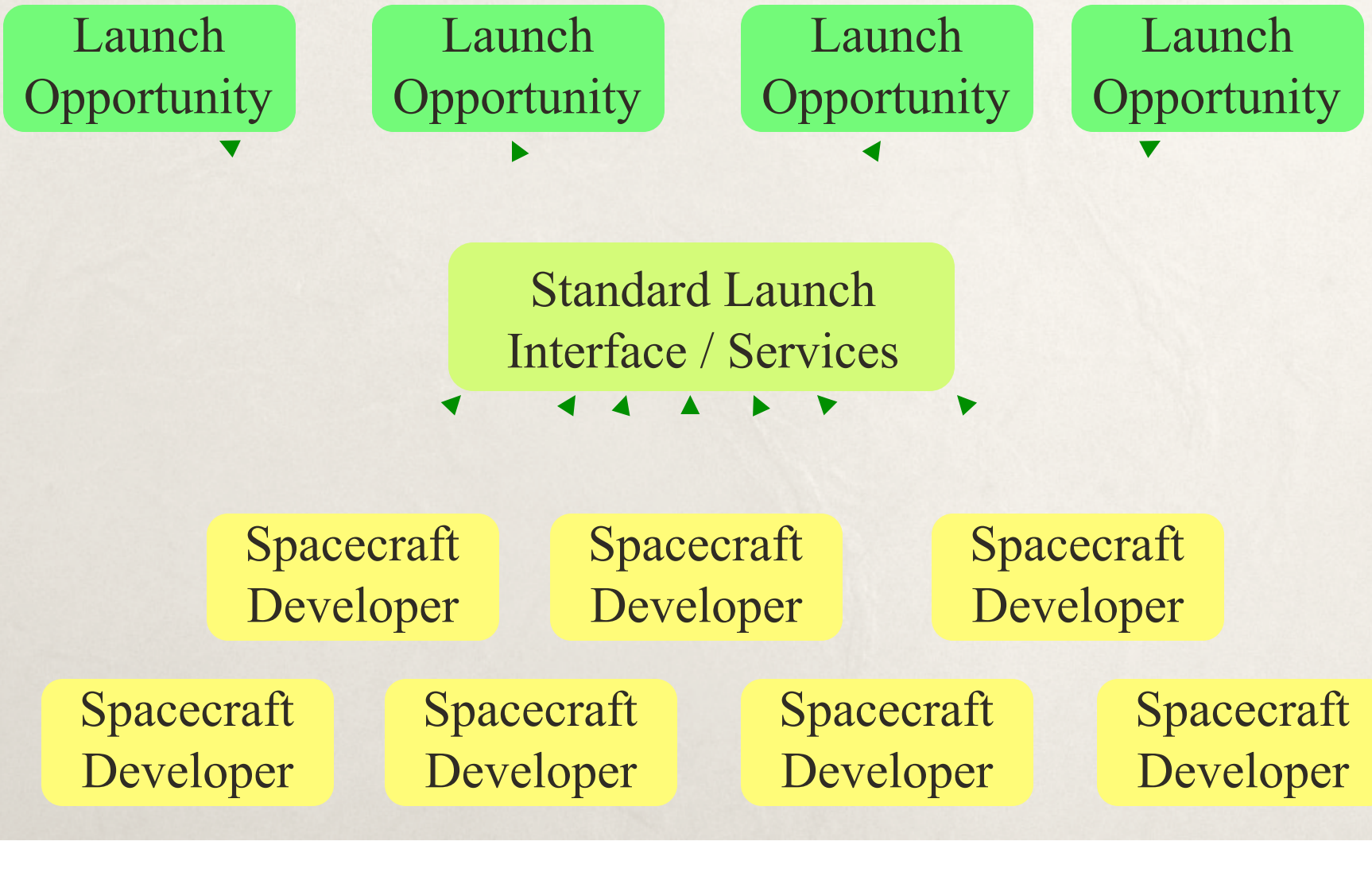


Future Evolution

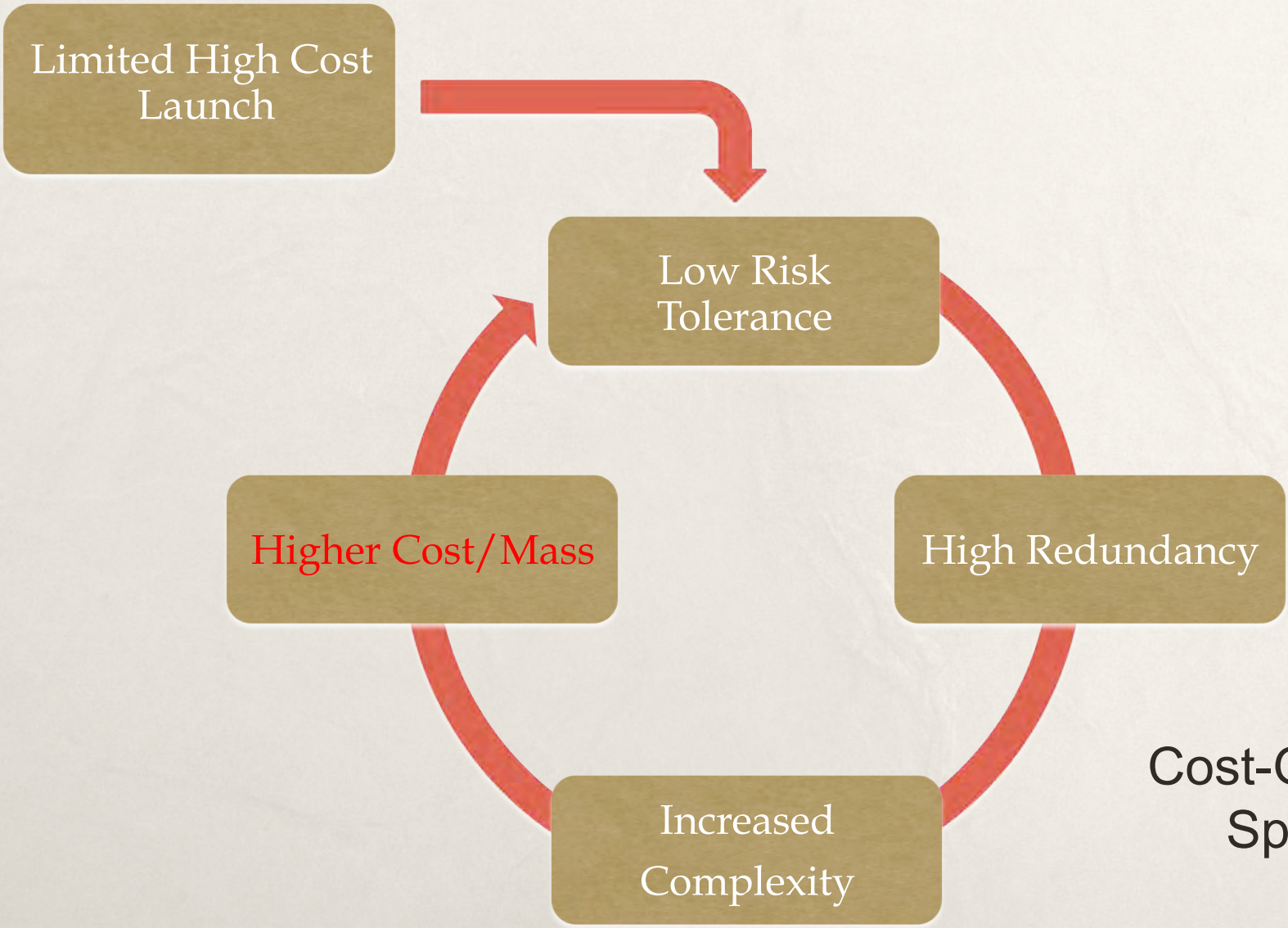


* Grow
  * AMES 6U (20x30)
  * Increase Mass (1.33kg)
* Shrink
  * PocketQub
  * (1/n) U CubeSat
* Maintain Standardization
  * Simple Launch Vehicle Integration
  * Maintain Risk Containment
* New Launch Accommodations

The Vision: Getting Closer

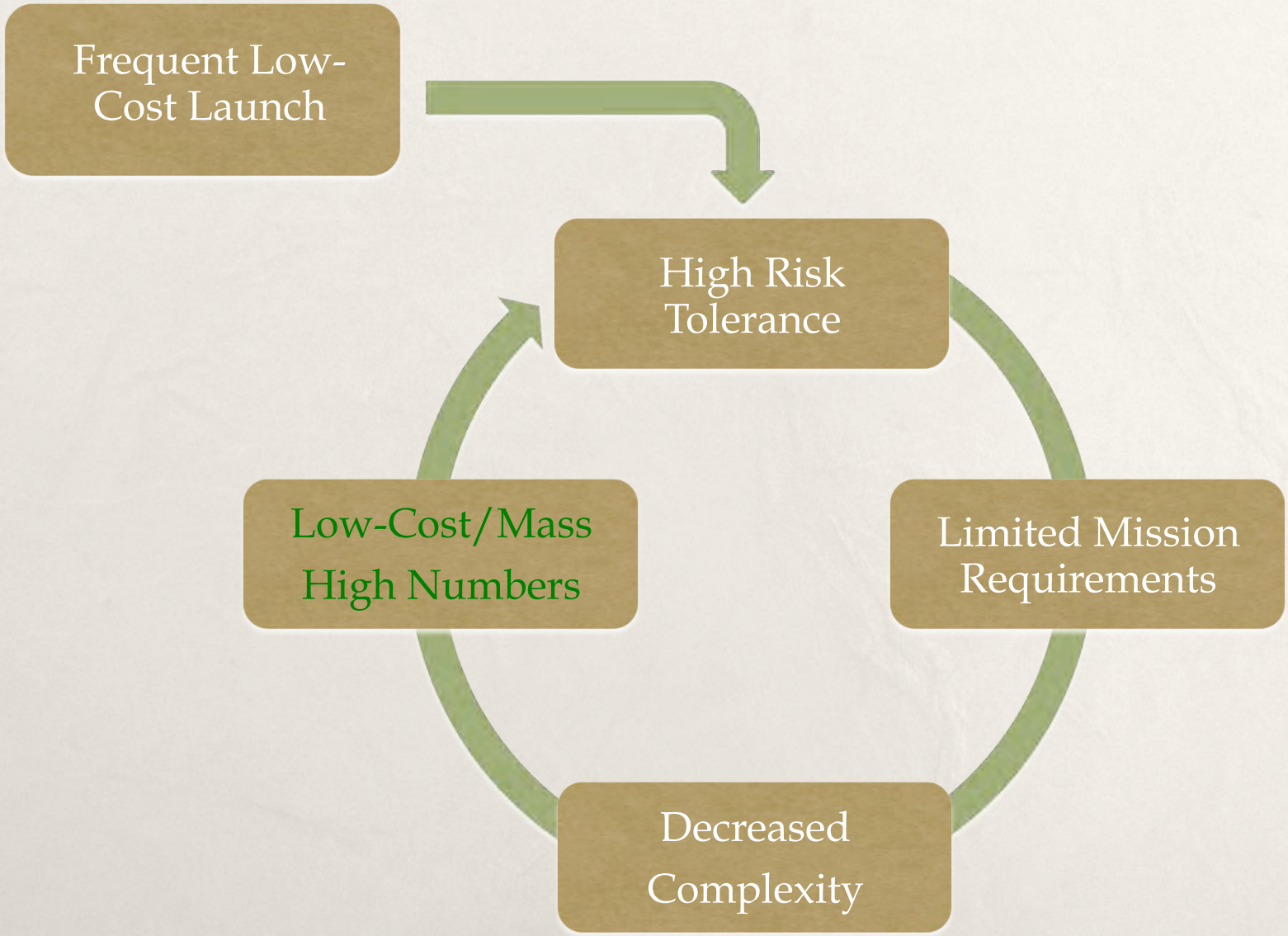


Traditional Space

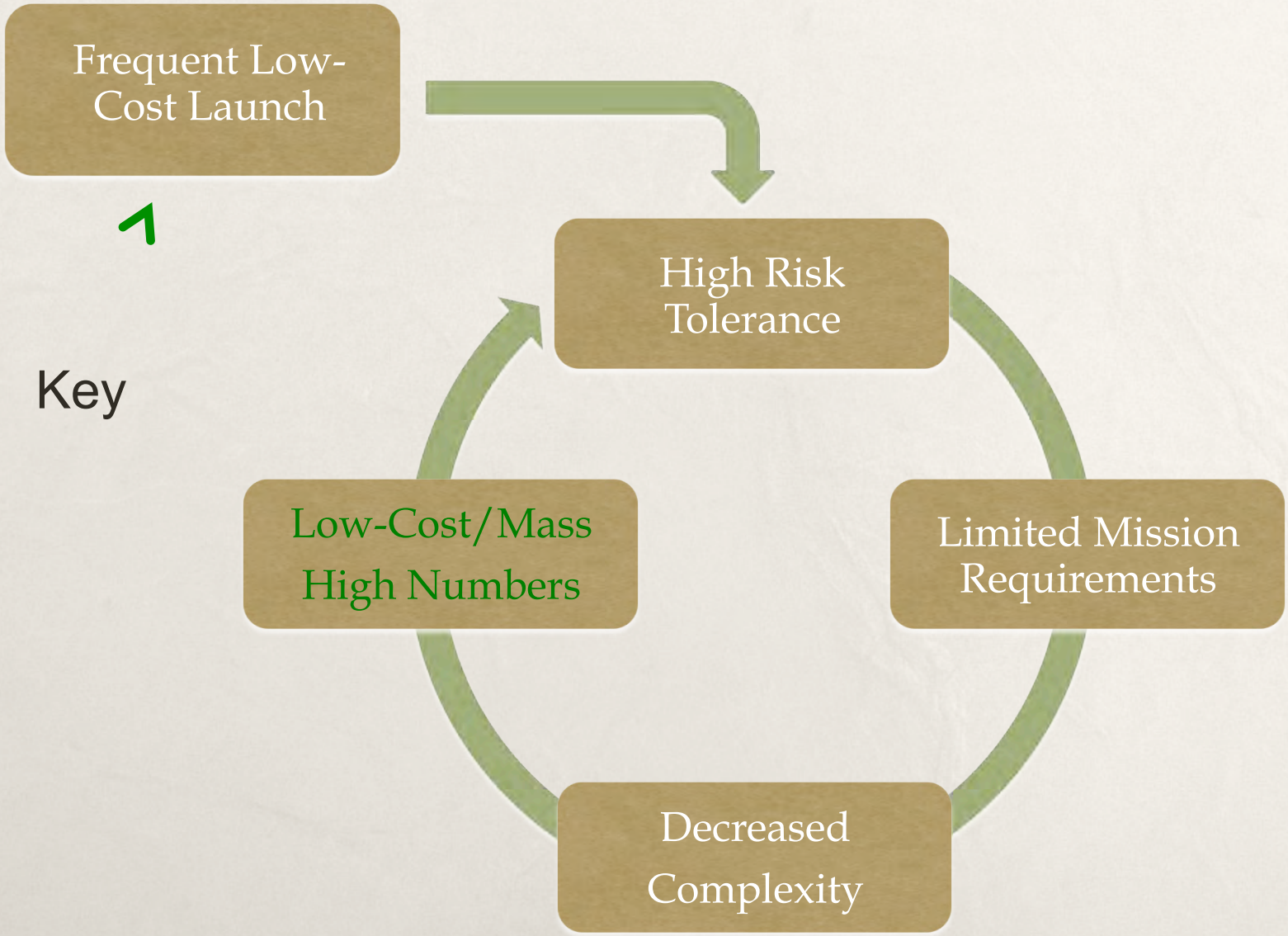


Cost-Growth Spiral

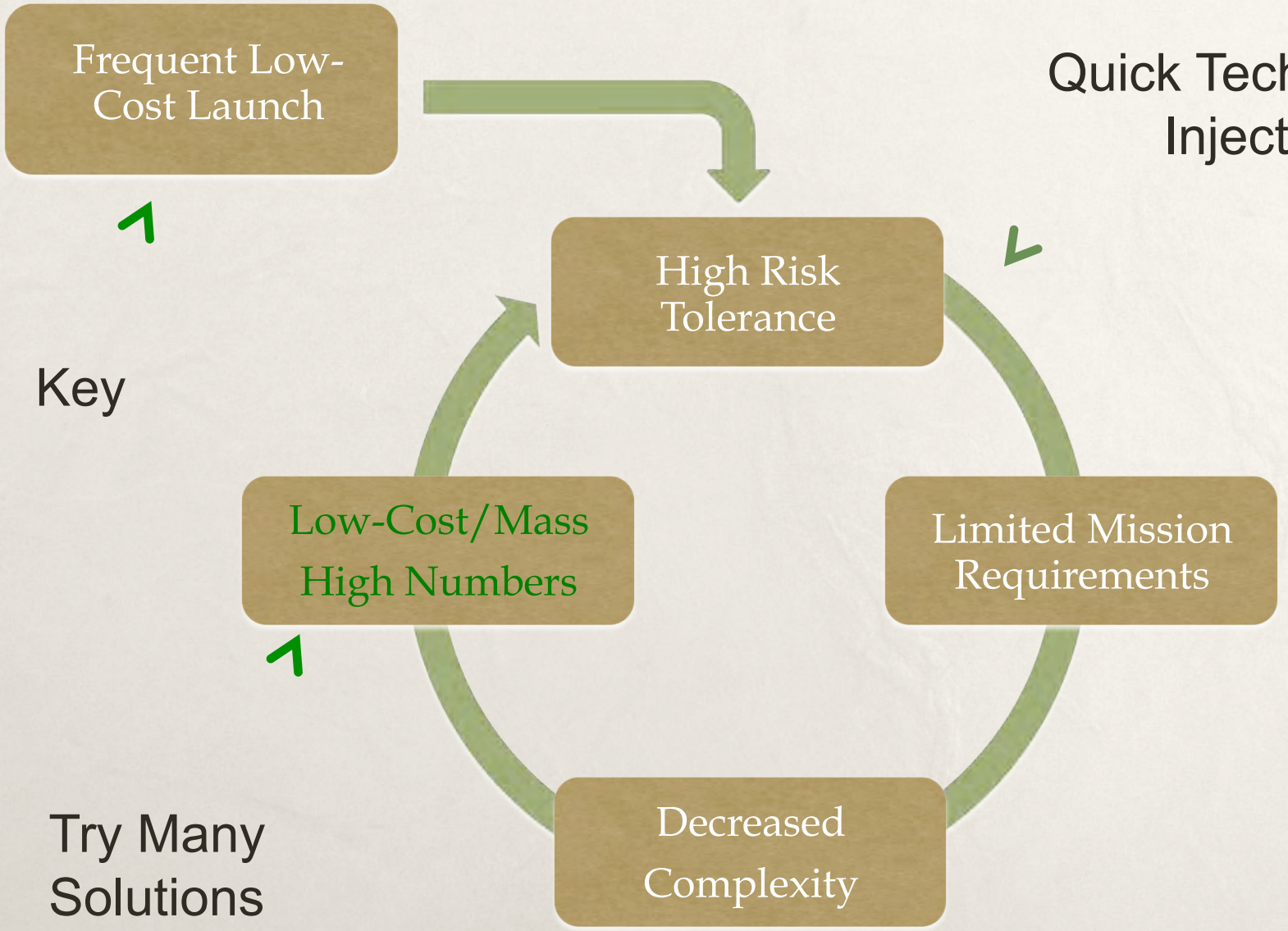
Standardized Small Space



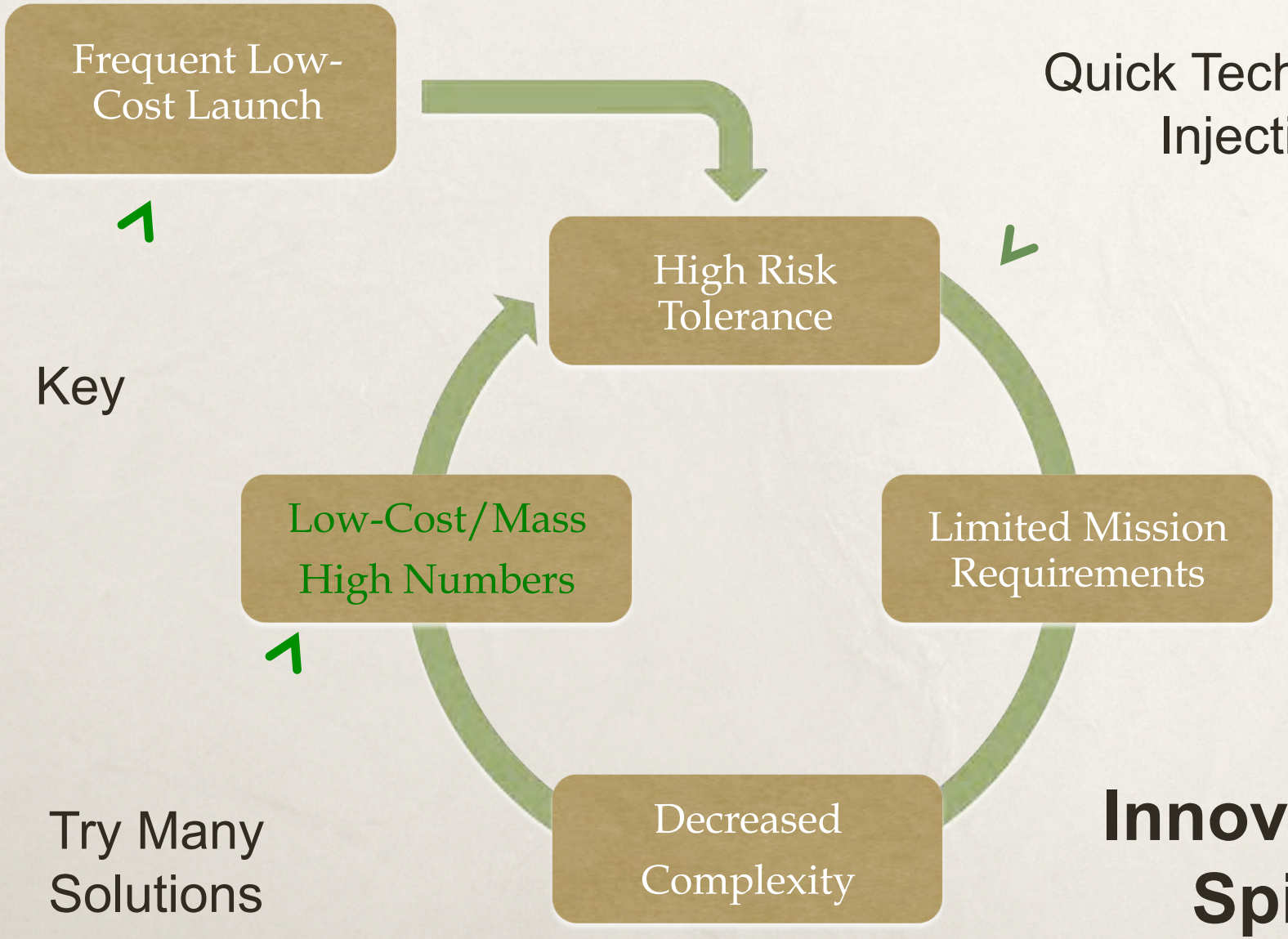
Standardized Small Space



Standardized Small Space



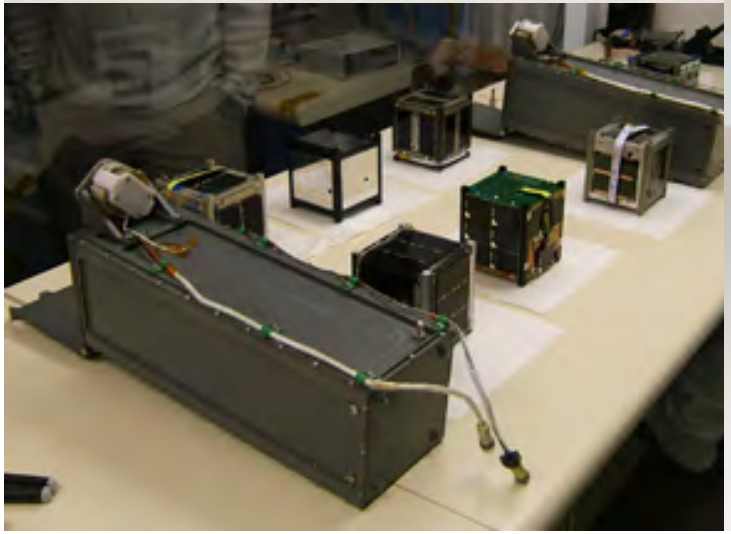
Standardized Small Space

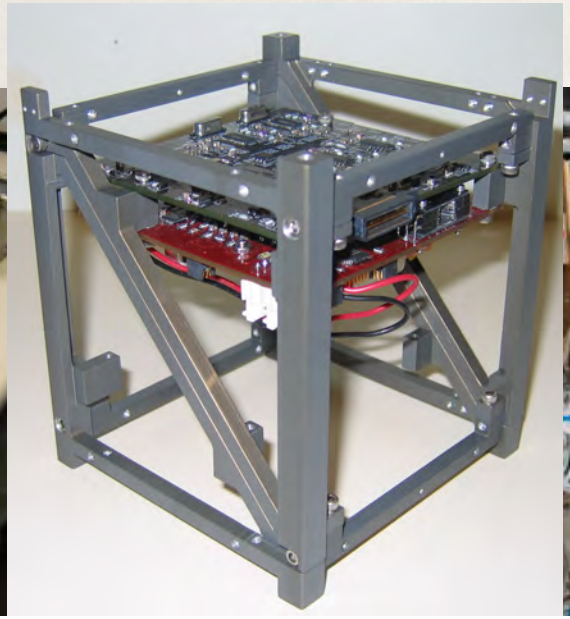


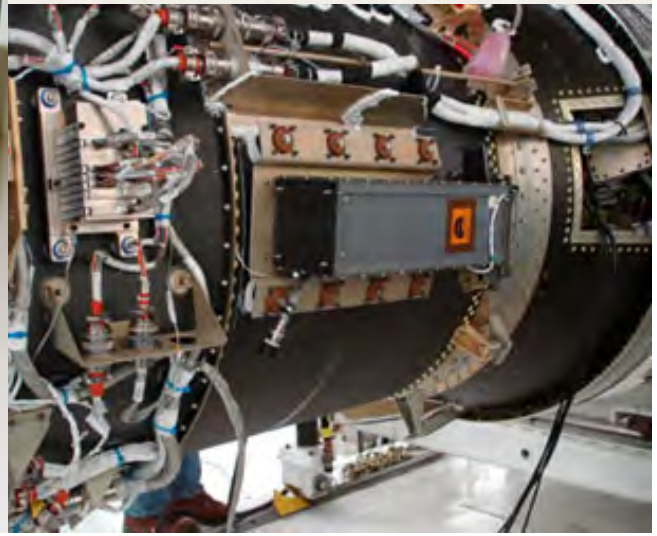
The CubeSat Challenge

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

* Need change in approach to develop satellites compatible with CubeSat standard
* Limited Options + Limited Resources + Significant need = High-Risk Unconventional Solutions







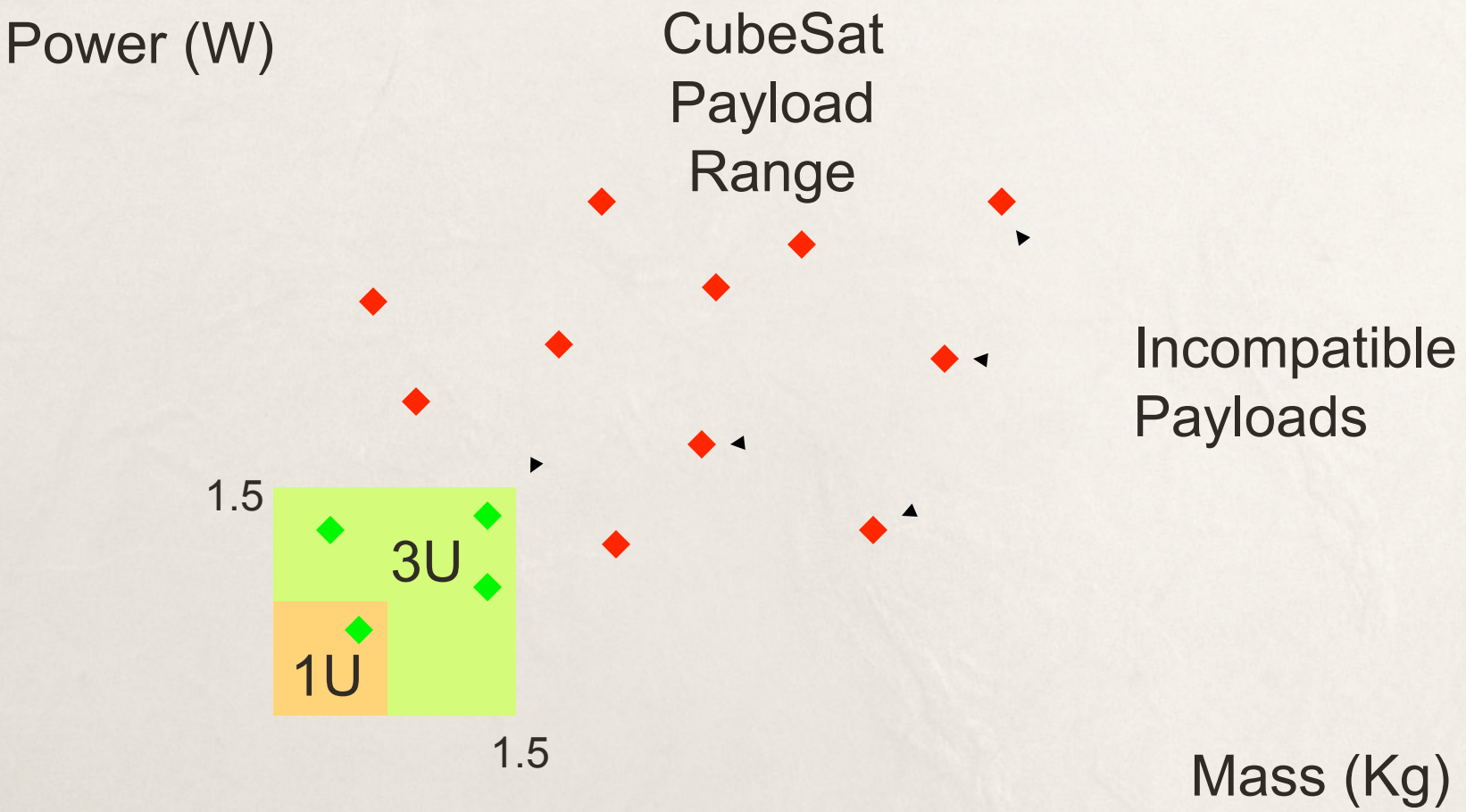
The CubeSat Challenge

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

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

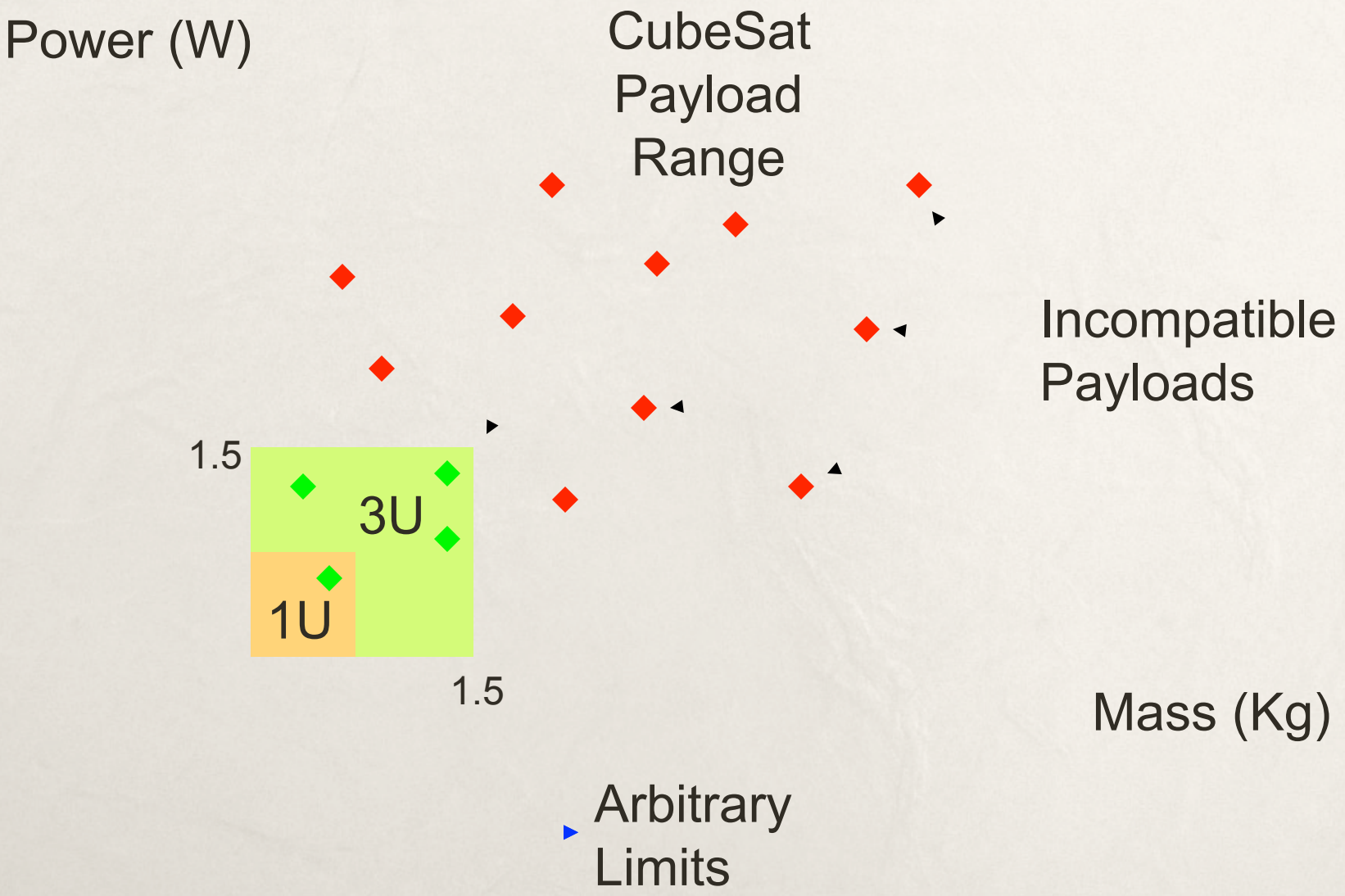
"Guerrilla Space"

Traditional View

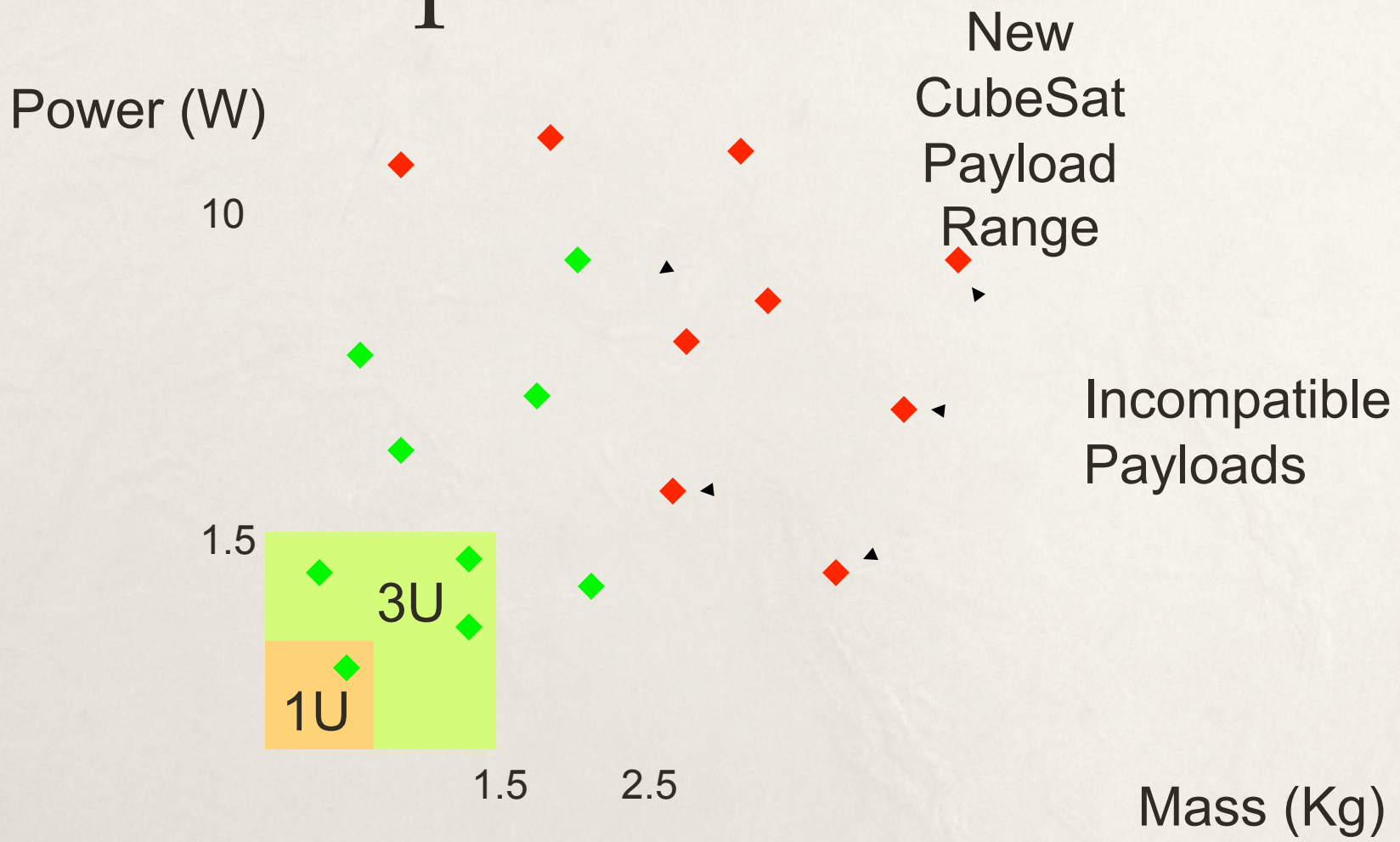


CubeSat can only accommodate a few payloads

Traditional View

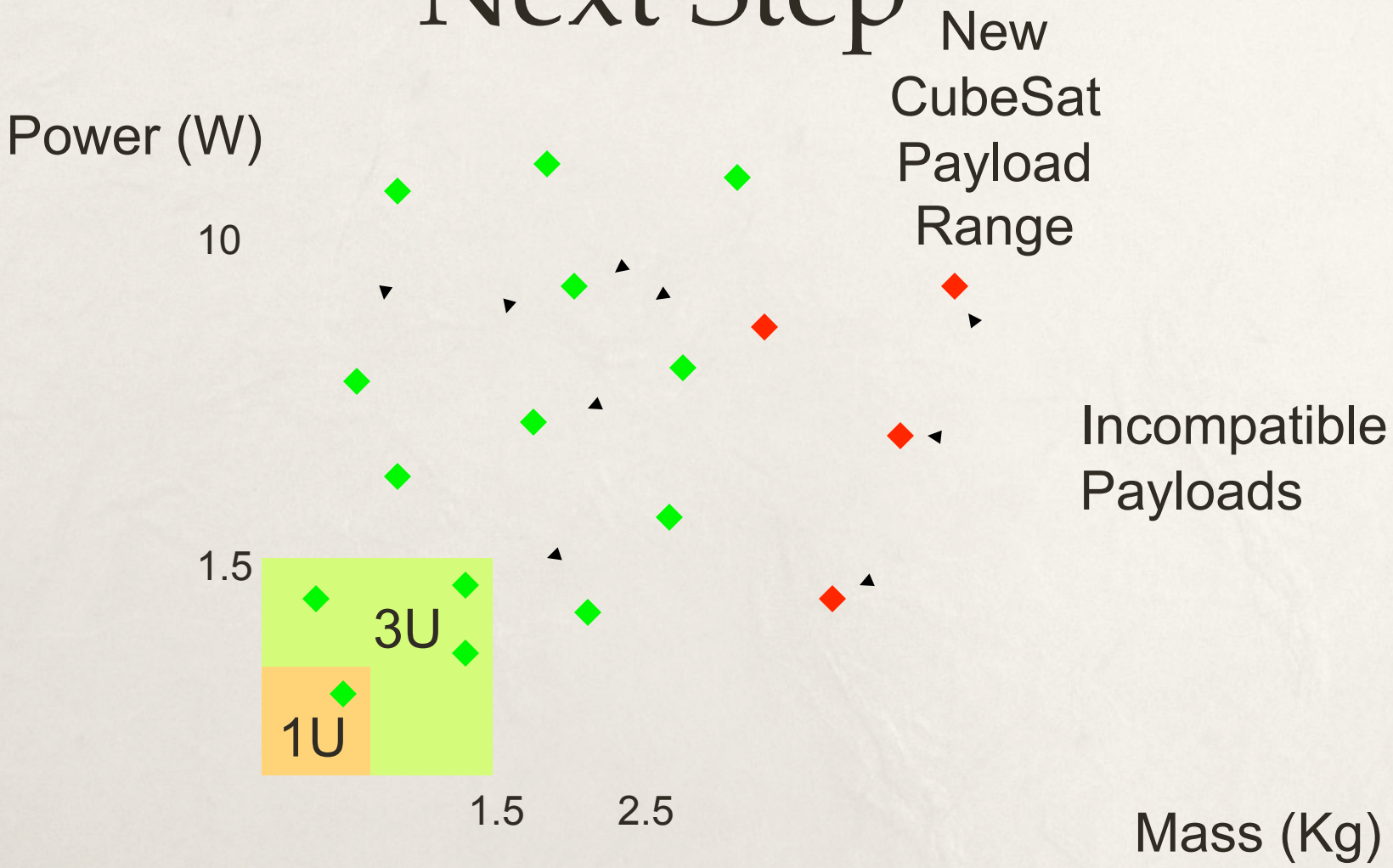


Improved View



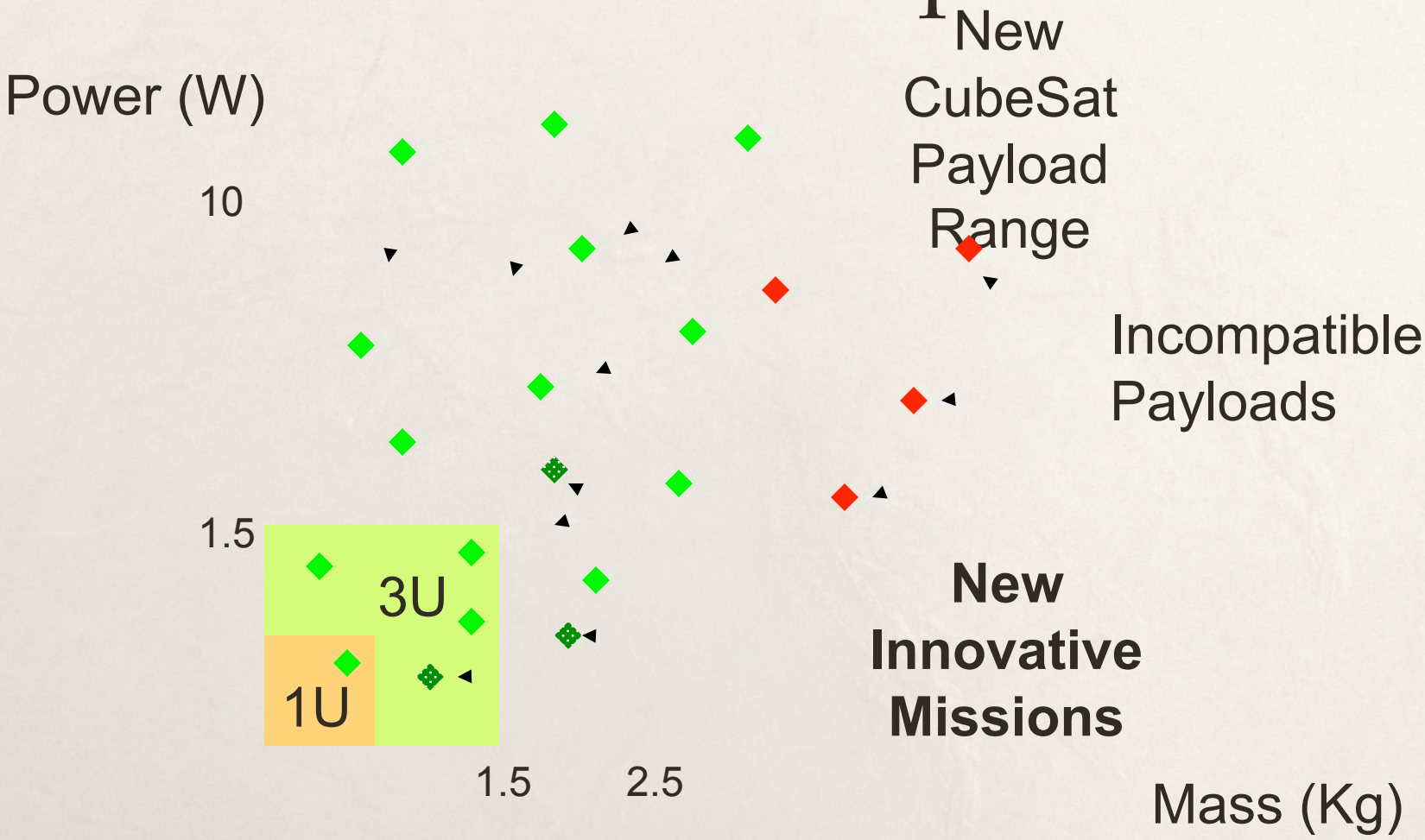
Increased Payload resources due to optimized bus and operations plan

Next Step



Optimize Payloads for CubeSat Application

Additional Step: Identify new mission concepts

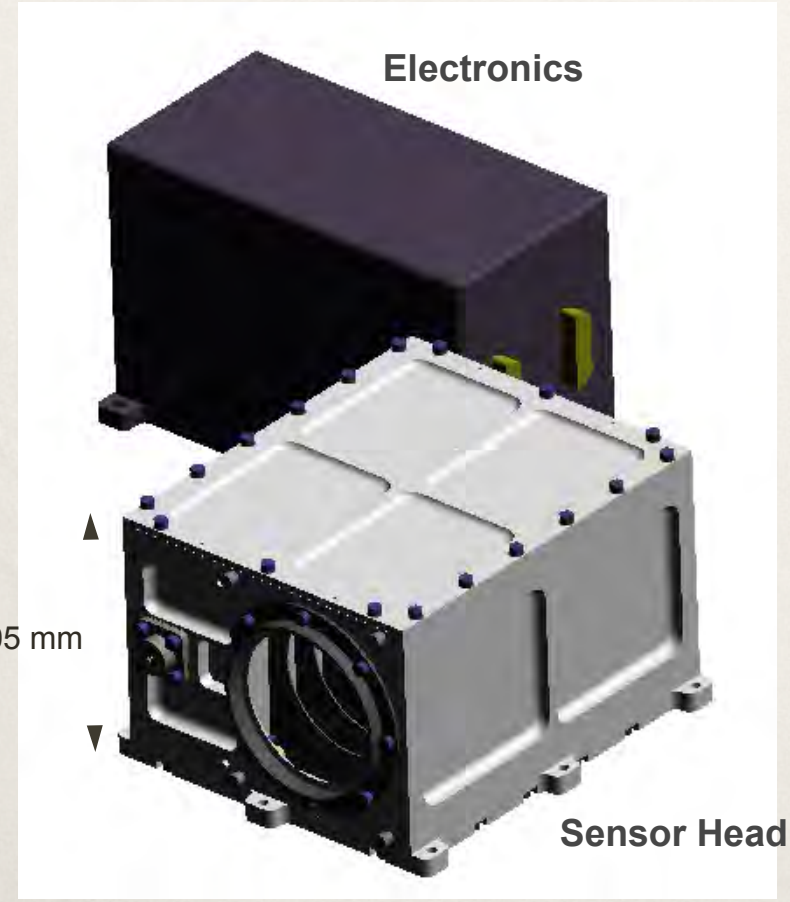


NSF CubeSat RFP was catalyst in Space Weather Community

Payload Optimization Example

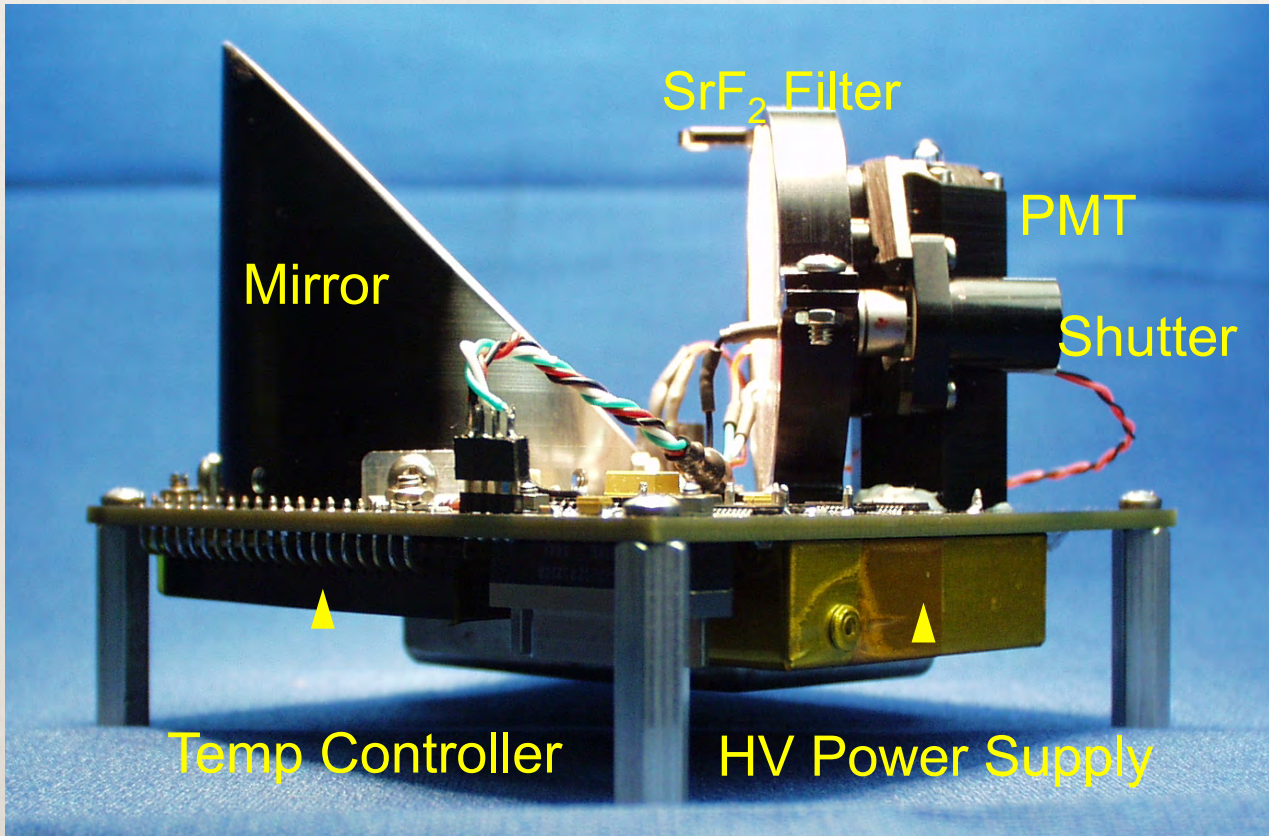
SRI's CubeSat Tiny Ionospheric Photometer (CTIP)

* 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



Lessons Learned in CubeSat Development

* Highly Integrated Payload/Bus System
  * Small multidisciplinary team
  * Take Advantage of Commercial Electronics Development
* Understand Complete Development Cycle
* Apply KISS principle
  * Minimal mission requirements (single instrument)
  * Minimum redundancy (Build 2 single-string CubeSats)
  * Simple operations model
* Flexible orbit missions Maximize Opportunities
* Traditional Spacecraft Development Approach May not Apply

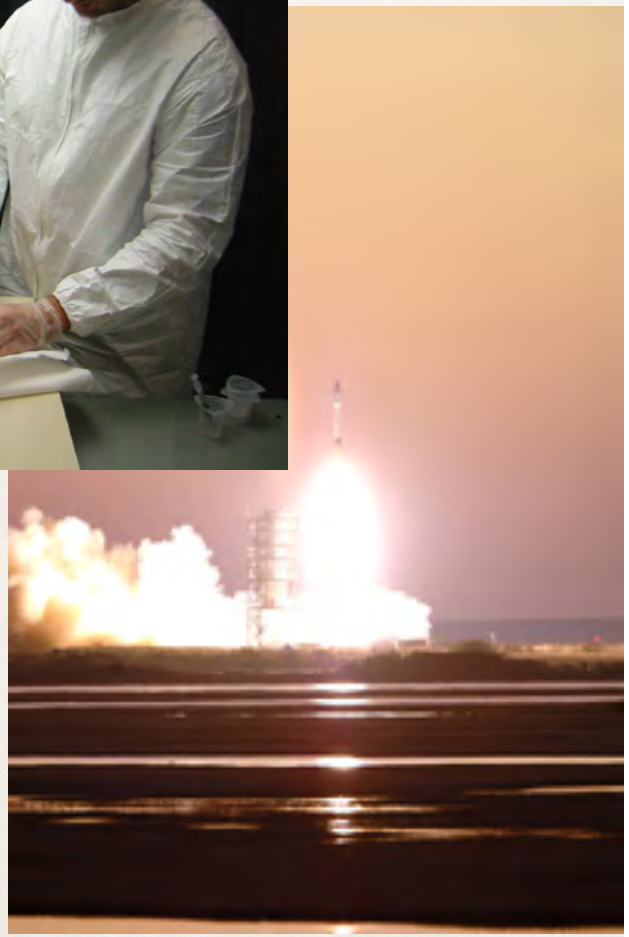
Lessons Learned in CubeSat Development

* Frequent Launches Accelerate Learning Curve
  * Fast lessons and improved next flight
  * Multi-mission development plan
    * NASA-AMES: GeneSat, PharmaSat, OREO, . . .
    * (XI-IV, XI-V, . . .) (UWE 1, UWE 2, . . .) (CP 1, 2, 3, . . .)
* Develop Spacecraft without Firm Launch
* Understand Regulation
* Fast Programs can Outrun Paperwork
* **BE CREATIVE!!**
* **ALLOW RISK!!**

Where are we going?

* Can Traditional Customers Embrace Risk on Missions?
* Can Big Space Move Down and Compete?
* Can Small Space Move up and Win?

Conclusion:



* CubeSat is Successful Standard
* Mindset is the biggest constraint
* Higher risk tolerance required
* Capability is increasing quickly
* Cannot follow standard spacecraft practices
* **Lessons apply to bigger spacecraft**