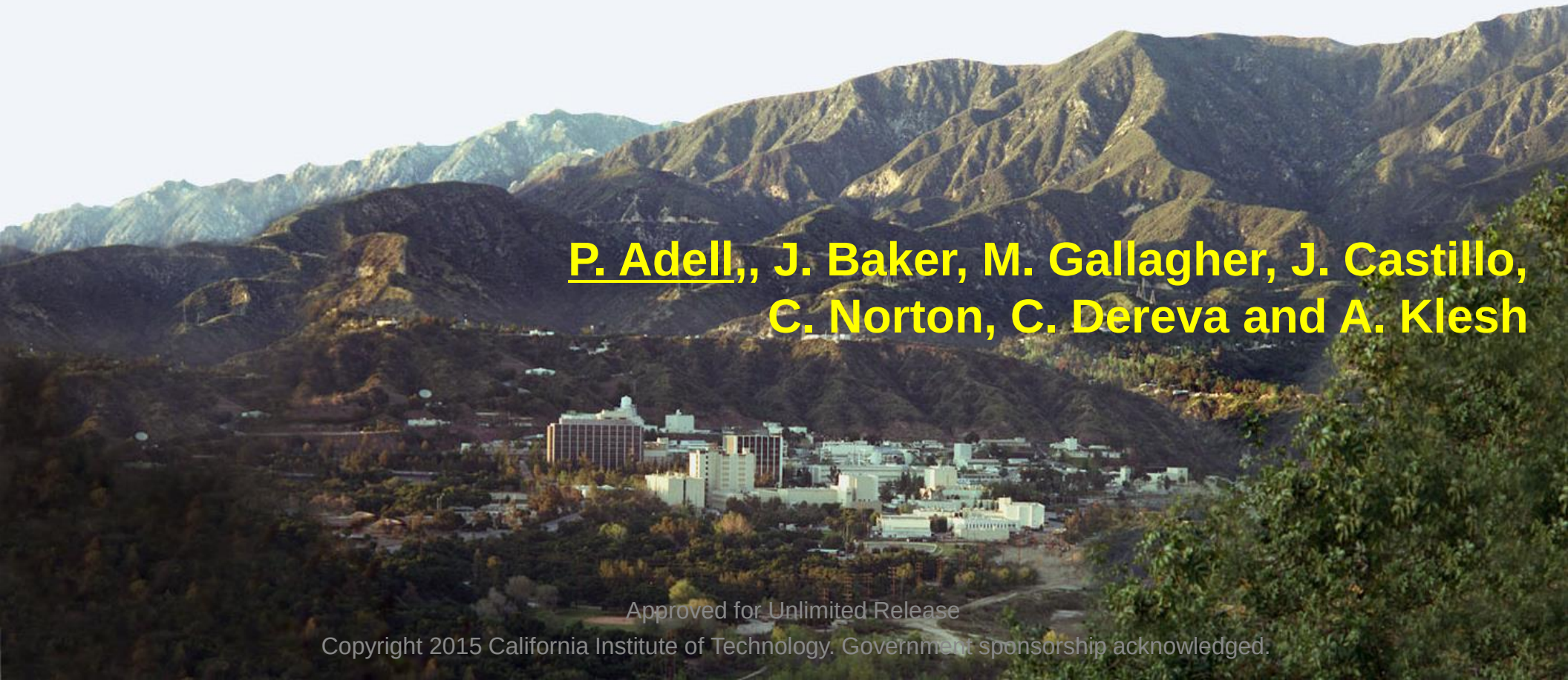
Jet Propulsion Laboratory
California Institute of Technology

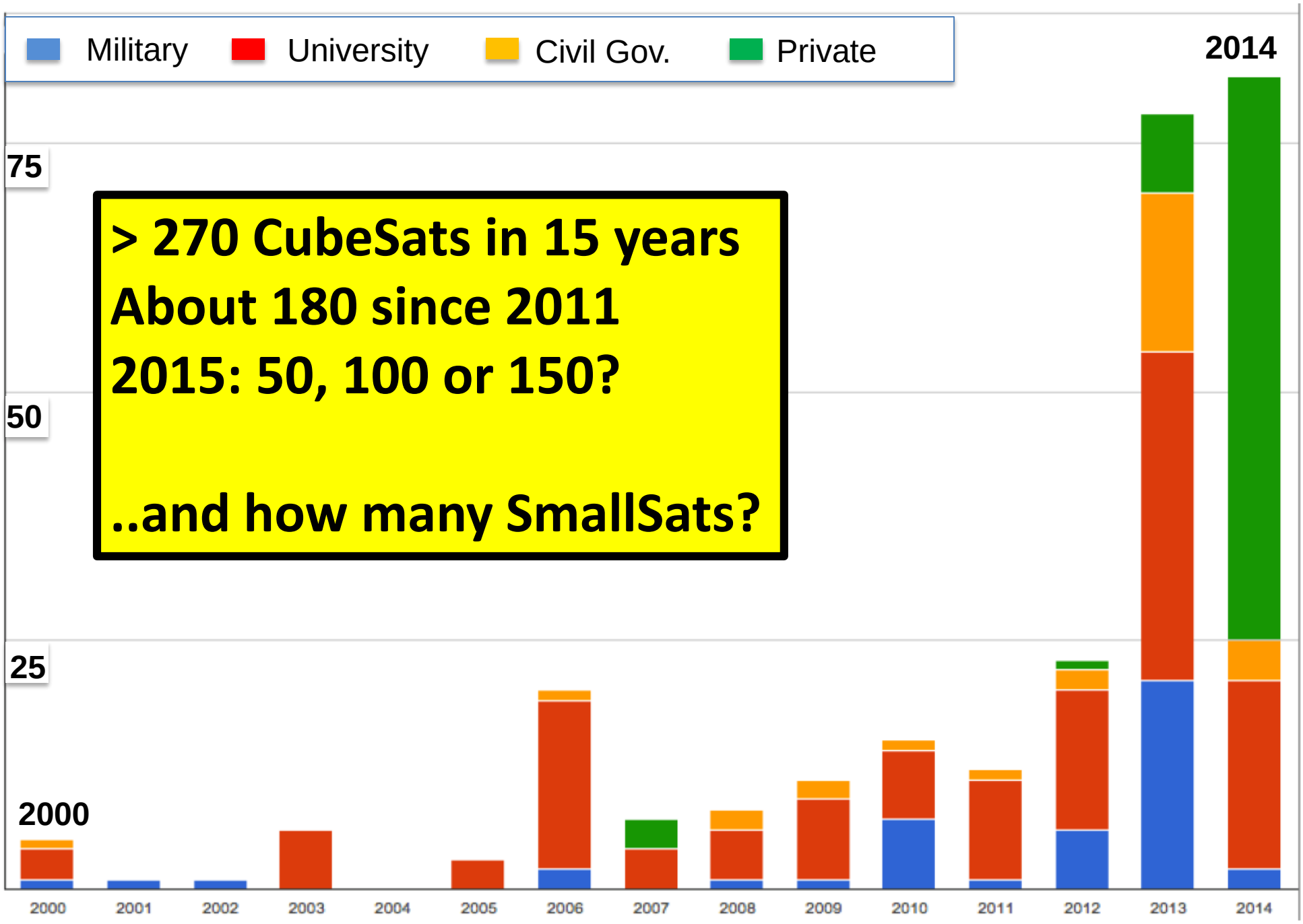
CubeSat/SmallSat Initiatives

From Earth to Beyond LEO



P. Adell,, J. Baker, M. Gallagher, J. Castillo, C. Norton, C. Dereva and A. Klesh

It is Raining CubeSats!!!



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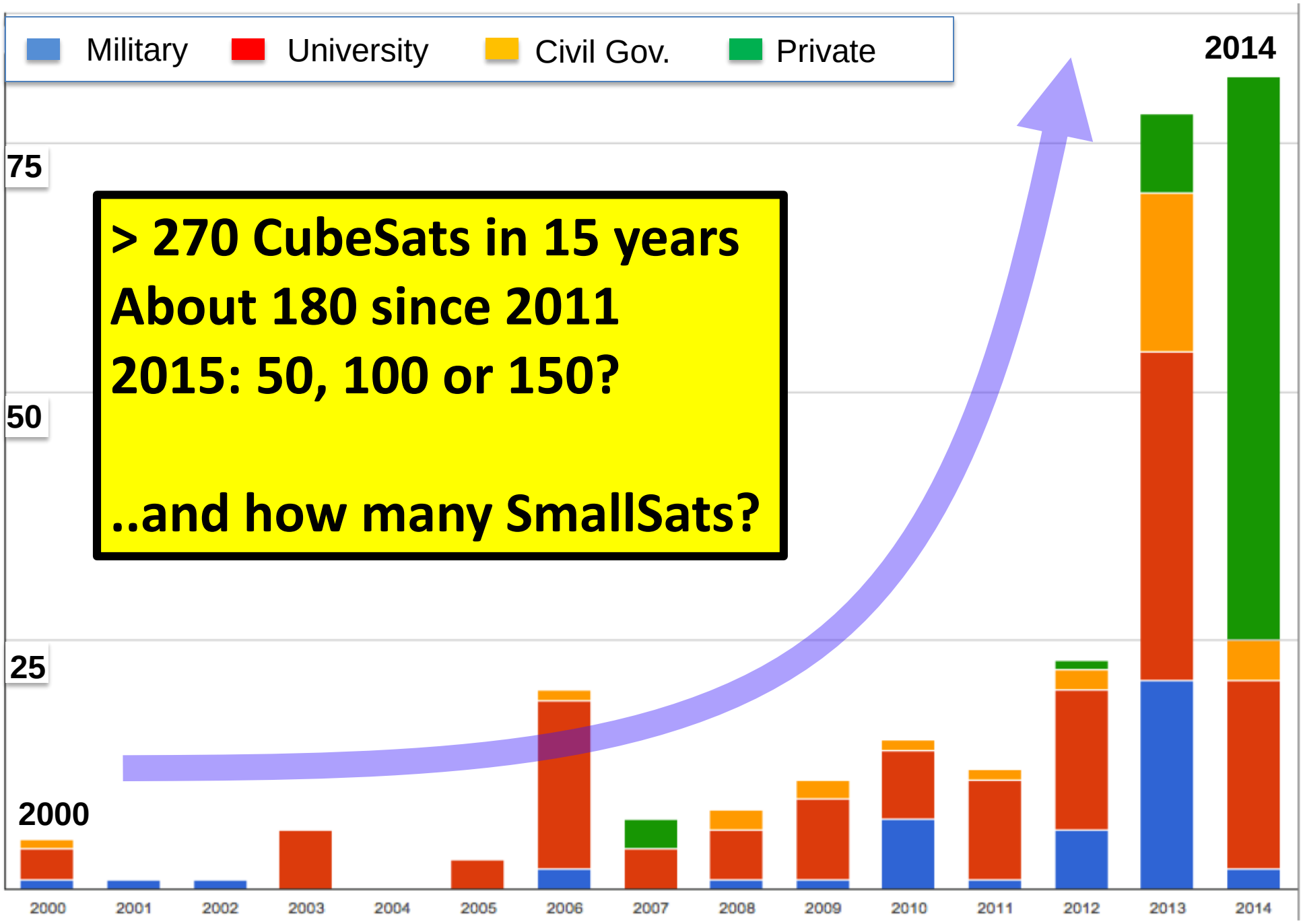


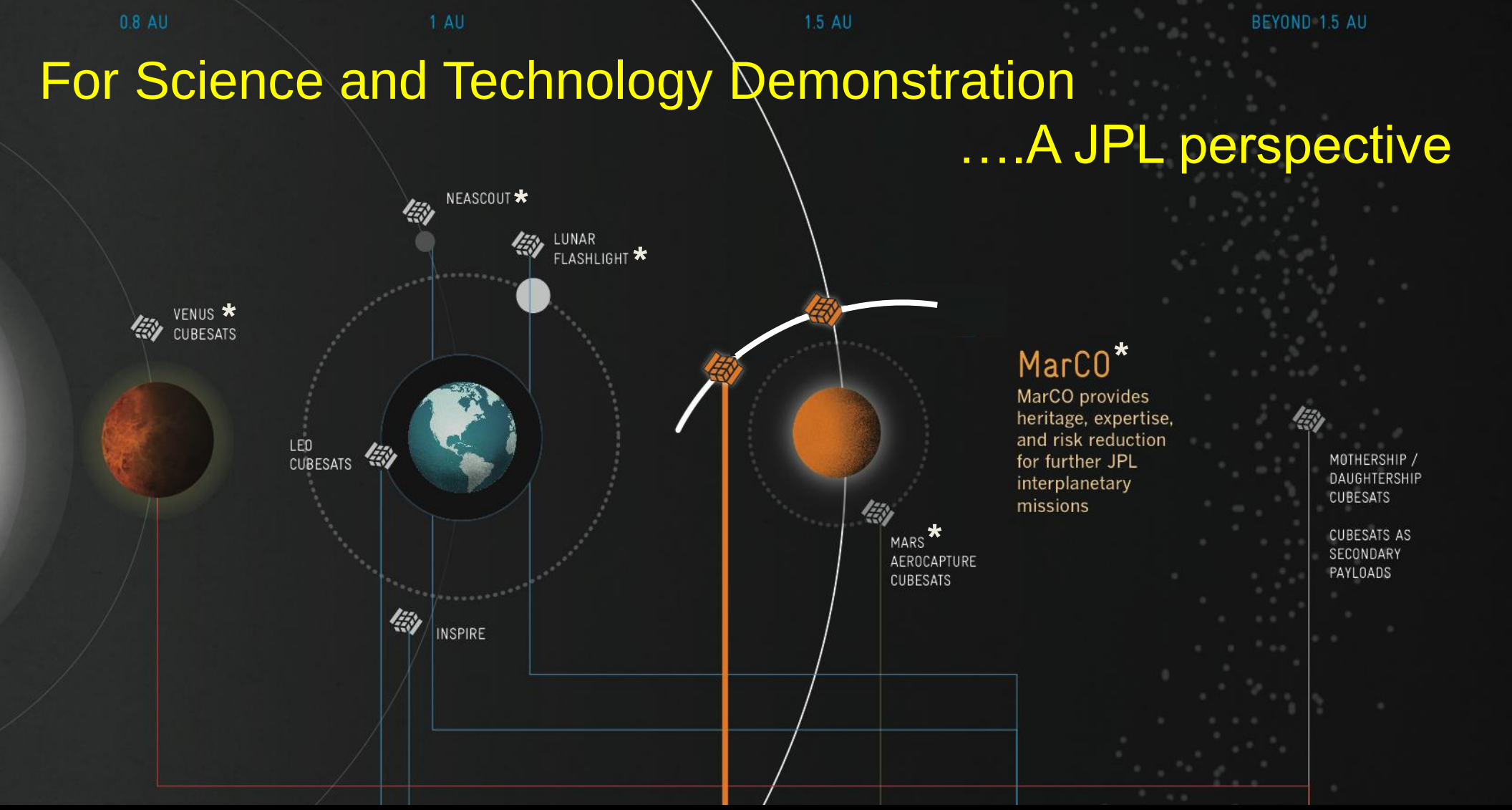
SmallSats, For What Purpose?

- For technology demonstrations in relevant environments
- For focused science objectives and enable new science via novel architectures
- Solidify the partnership between space, academia and industry
- For global activities monitoring (imaging and communication)
- For hands-on training opportunities for young professionals
  - Strengthen the expertise of early career engineers
  - Prepare potential principal investigators for bigger missions

Vision is to develop focused, low-cost missions on a broad range of science and commercial applications

For Science and Technology Demonstration

….A JPL perspective



Known Challenges

- Propulsion, Communications
- Environments, Power, ADACS
- Thermal, Energy storage
- Proximity operations and autonomy

Less Obvious Challenges

- Mission assurance and reliability
- Multi-mission ground operation systems
- Planetary protection, Hazard avoidance
- Flight software standards

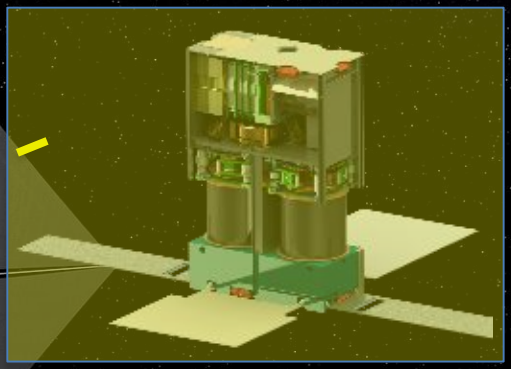
*Proposed Mission - Pre-Decisional – for Planning and Discussion Purposes Only

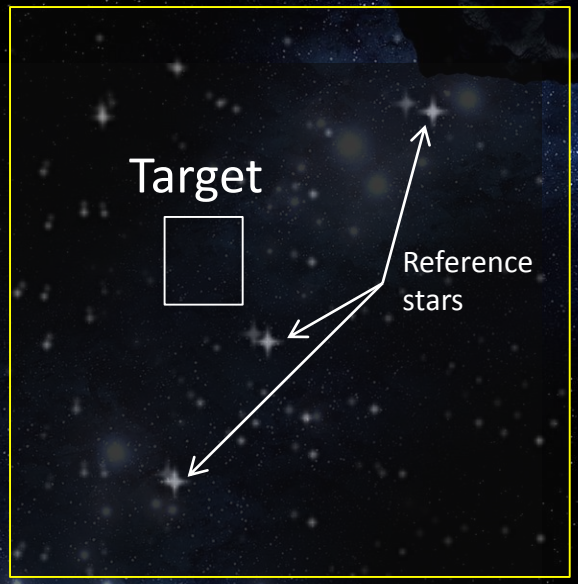
NEA Scout* (MSFC/JPL)

Near Earth Asteroid Reconnaissance via Imaging

Target Reconnaissance with Medium Field Imaging

Volume, global shape, rotational properties, and local environment characterization



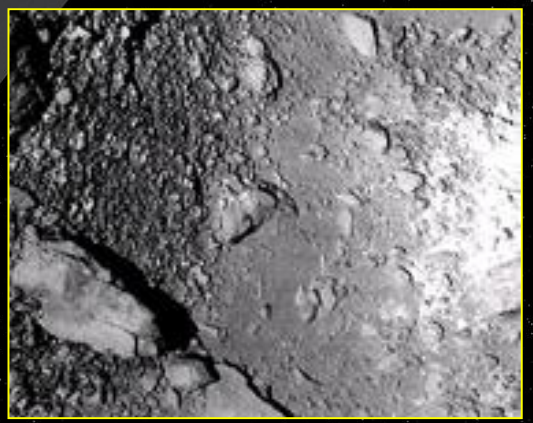


Target Detection and Approach with Wide-Field Imaging

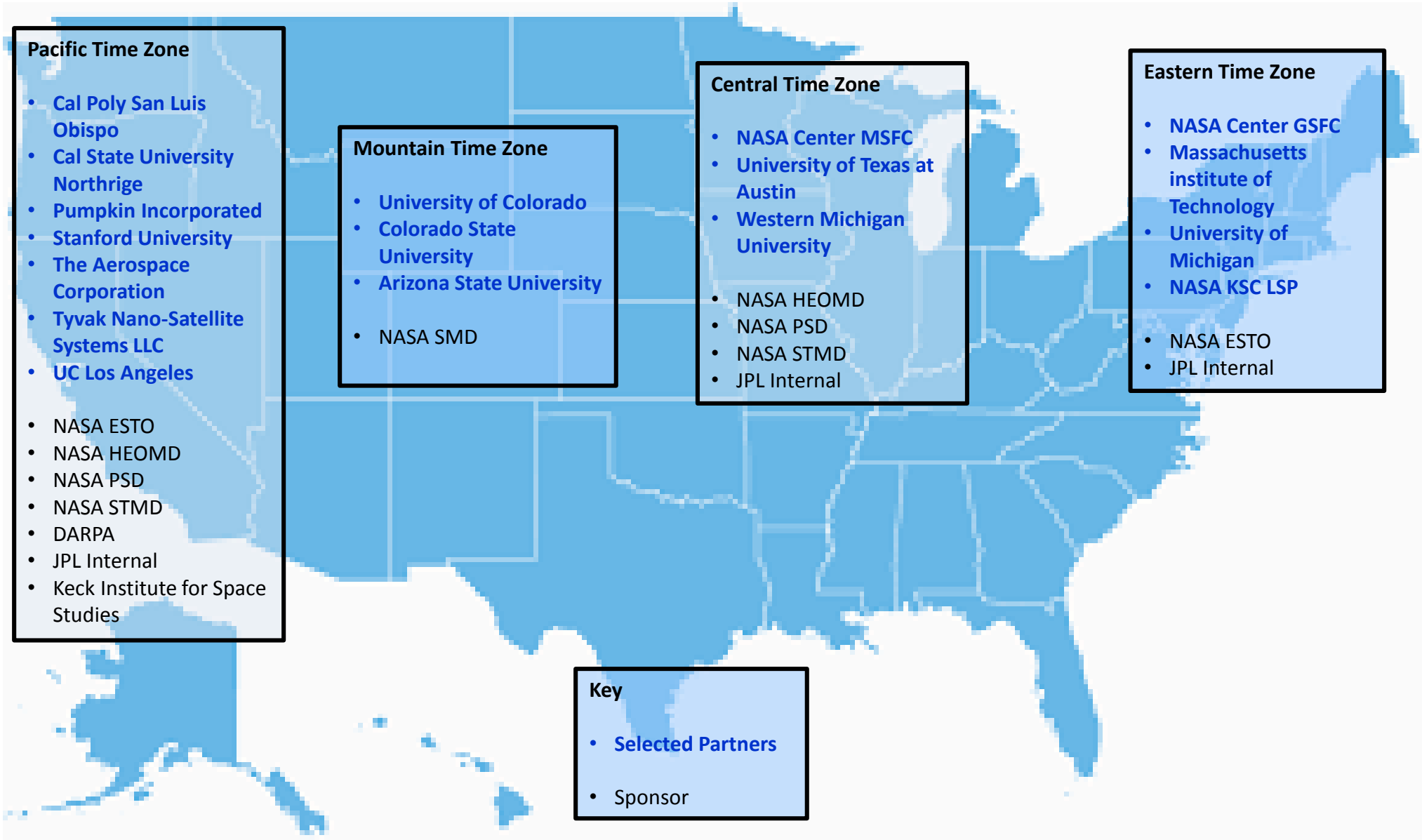
Ephemeris determination and color typing

Close Proximity Imaging

Local morphology, regolith properties



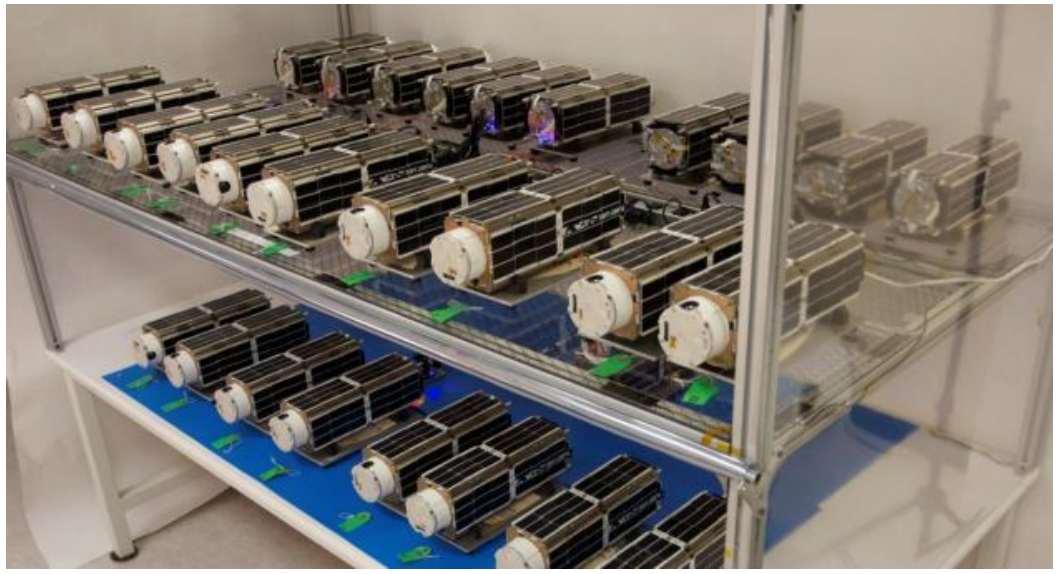
Selected Development Partners and Sponsor

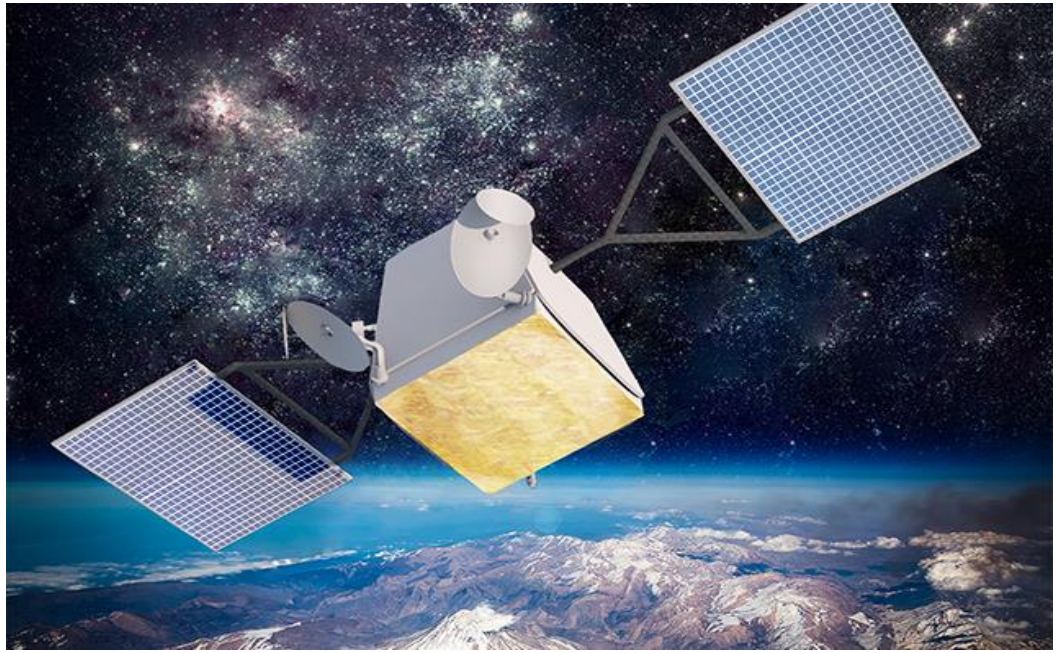


JPL is looking for international collaborations on CubeSats/SmallSats

Active Commercial Initiatives within the US

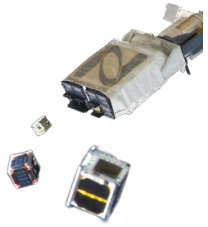
- Skybox
- PlanetLabs
- OneWeb





Monitoring global activities through imaging and communication

US Rideshare opportunities



Rideshare opportunity by Third party brokers/integrators

- Adaptive Launch Solutions (ALS)
- NanoRacks LLC
- SpaceFlight Inc.
- Trisept/Moog CSA Corporation
- Tyvak Nanosat Systems

Large US vehicles w/ secondary capabilities

- Antares (including Cygnus) **[Orbital]**
- Atlas V **[ULA)/Lockheed Martin Commercial Launch Services]**
- Delta IV **[ULA/Boeing Launch Services]**
- Falcon 9 (including Dragon and Surfboard) **[SpaceX]**
- Falcon Heavy (2015) **[SpaceX]**
- SLS (11 6U CubeSats slated for EM-1 2017) **[NASA]**

US Small Launchers

- ALASA [DARPA/Boeing]
- Athena II [Lockheed Martin]
- GO Launcher 1, 2 [Generation Orbit]
- LauncherOne [Virgin Galactic]
- Minotaur I, IV, V, VI, C [Orbital]
- Neptune [Interorbital]
- Pegasus [Orbital]
- SuperStrypi [Sandia National Labs]

A few points…

The primary payload market for small spacecraft is limited…technologies are being developed

Secondary payload arrangements provide far more options for immediate launch at high TRL

Rideshare opportunities by third party is growing

Seeing companies facilitating launch for customers being developed

Working on document standard interfaces and available rideshare adapters with allowable payload masses and volumes

Small Launchers

Technology	Description	Developer	TRL Status	Cost	Photos
ALASA DARPA program	Airbone launchers capable of boosting 45 Kg into LEO. Has initially contracted Lockheed, Virgin Galactic, Ventions LLC	**DARPA (boeing with FE15 Strike Eagle)**	**TR7** - flight test expected in 2015; **TRL 5** ALASA program in place to launch constellation of 24 CubeSats (imaging 1m resolution)	< $1M	
Super Strypi/SPARK	Small, three-stages, all-solid orbital expendable launcher with 250 Kg payload to 400 km SSO	**University of Hawaii, Sandia National Labs, Aerojet**	**TRL- 7** Flight planned for 2015	$12-16 M	
Pegasus	Air-Launched, three stages orbital vehicle, launcher with up to 450 Kg payload to LEO	**Orbital Science**	**TRL 9** - Launched successful IRIS missions: 26 consecutive fully successful mission 2016 - launch 8 NanoSats for NASA	<$40M	
Minotaur	Rocket Family currently with 580 Kg to LEO (Minotaur I) and 437 kg to TLI (Minotaur V)	**Orbital Science**	**TRL 9** - First Launch of Family in 2000 (Minotaur I 13 successful launches in LEO); launch of Minotaur V 2013 successful	<$30M	
GoLauncher 2	Air-Launched, single stage rocket delivering ~45 Kg to LEO (400km)	**Generation Orbit Launch Services, Space Propulsion Group**	**TRL 5** - Looking at a demonstration 2017	< $2M	
LauncherONe	Two stages rocket, 225 Kg to LEO or 120 kg to SSO	**Virgin Galactic**	**TRL 6**- Finalizing design and testing of key component (2016-17)	< $10M	
Neptune	Three stage micro-sat launch vehicle (30 ,40 or 70 Kg) into Polar LEO orbit	**InterOrbital Systems**	**TRL 8** - Successful test of common propulsion module 2014 with two Cubesats, a synergy moon payload (3 kms) - no release to orbit	< $1M	
Athena 2	revived in 2012 to deliver 50-180 Kg micro-sats in LEO orbits	**Lockheed Martin**	**TRL 9** - Many successful launches (1997-2001) plan launches 2015 (CubeSats are an option)	< $6M	

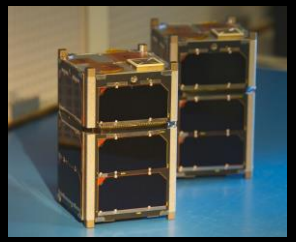
Many other developments are in progress but TRL levels are very low 3-4

ELaNa-X SMAP Launch with GRIFEX

January 31st, 2015 at 6:22 am PT

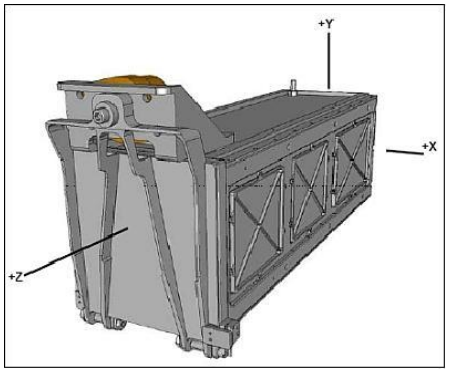
Part of NASA CSLI (CubeSat Launch Initiative)
https://www.nasa.gov/directorates/heo/home/CubeSats
ELANA I, II, ….,XIII are sustainable CubeSat launch capabilities within NASA and is expanding…


ExoCube

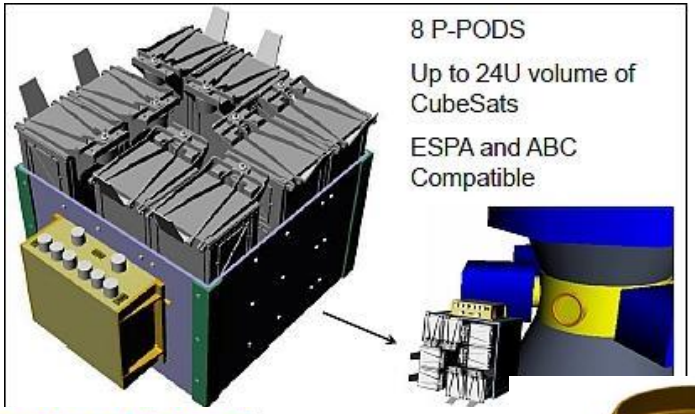

Firebird-2

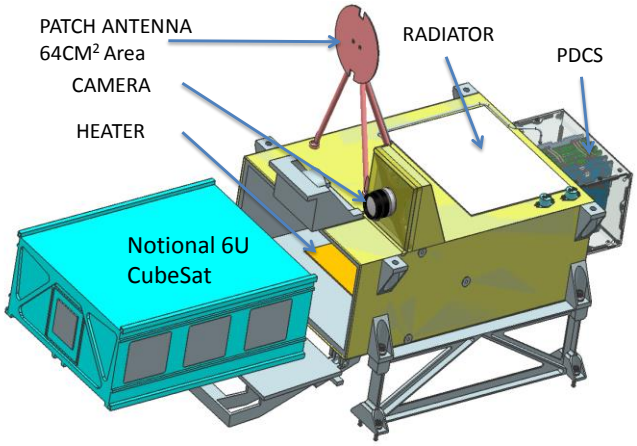

GRIFEX

Deployment for secondary payload interfaces



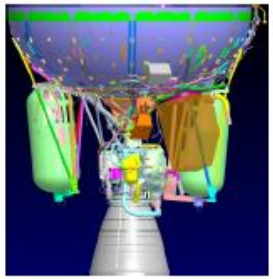
CalPoly P-Pod (Up to 3U)

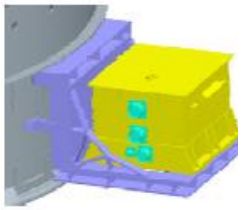




NASA-JPL 6U for deep space

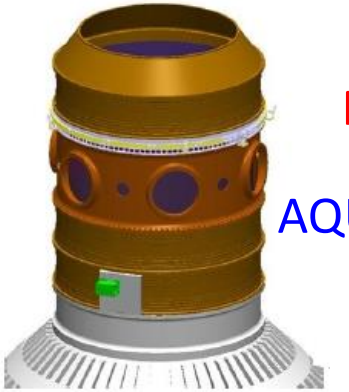
UTIAS X-Pod (1U + Custom)



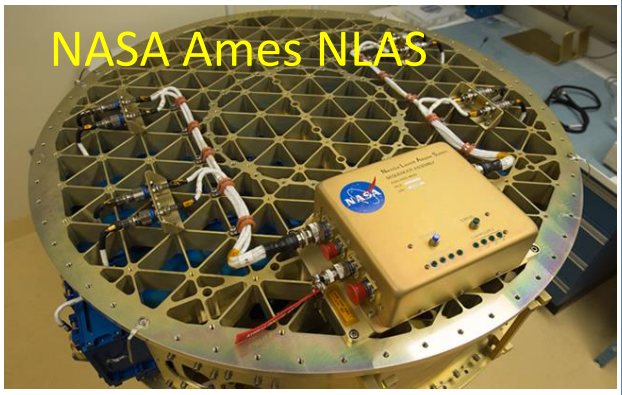


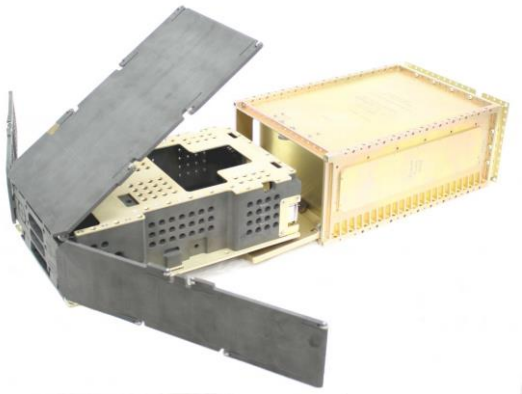
ABC
Aft Bulkhead Carrier

CAP
C-Adapter Platform



AQUILA





Planetary Systems CSD (6U)

Collaborate for a commercial manifest – need $10 M considering 18 mission/year using ESPA.

Potential Collaboration Opportunities

- **Space technology education and training**
  - Plan exchange of students (MS/PhD)
  - Welcome postdocs/scientists/professors/engineers
  - Encourage participation in workshops on interplanetary CubeSats/SmallSats
- **Execute technology demonstrations**
  - Collaborate to develop novel technology from either organizations into several CubeSat/SmallSat projects
  - Identify areas where complementarity can be leveraged (small instruments, sub-systems)
  - Secure ride opportunities between agencies (ESA VEGA, NASA CSLI, Piggybacking etc…)
- **Demonstrate new mission assurance standard approaches**
  - Develop an international mission assurance standard (COTS systems)
  - Converge toward cost effective and highly reliable CubeSat/SmallSat technologies
- **Enable new science**
  - Collaborate on future SmallSat/CubeSat missions (Europa, Mars, Earth or Asteroids)*
    - Encourage joint proposals (Discovery, New Frontiers, SMEX, Earth Venture…)
  - Develop innovative mission concepts exploiting advantages of NanoSpacecraft to complement existing mission opportunities