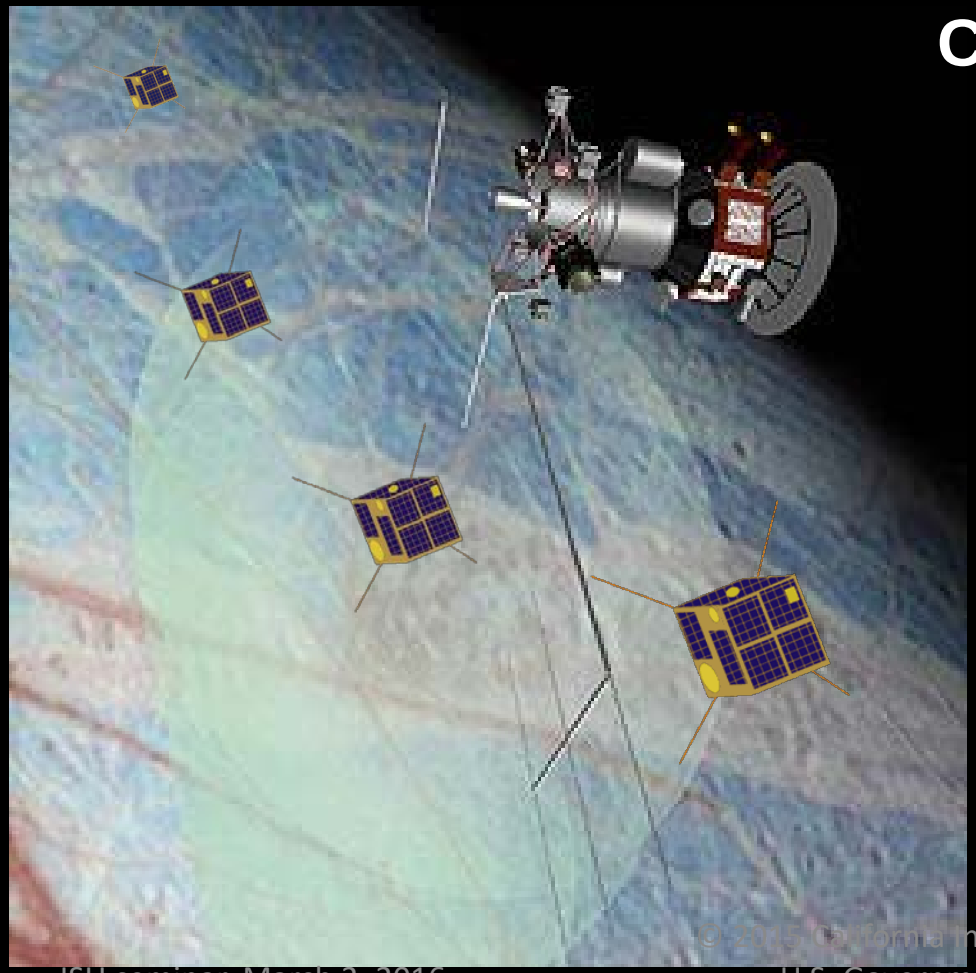
The future of cubesats

Tony Freeman
Manager, Innovation Foundry
Jet Propulsion Laboratory
California Institute of Technology



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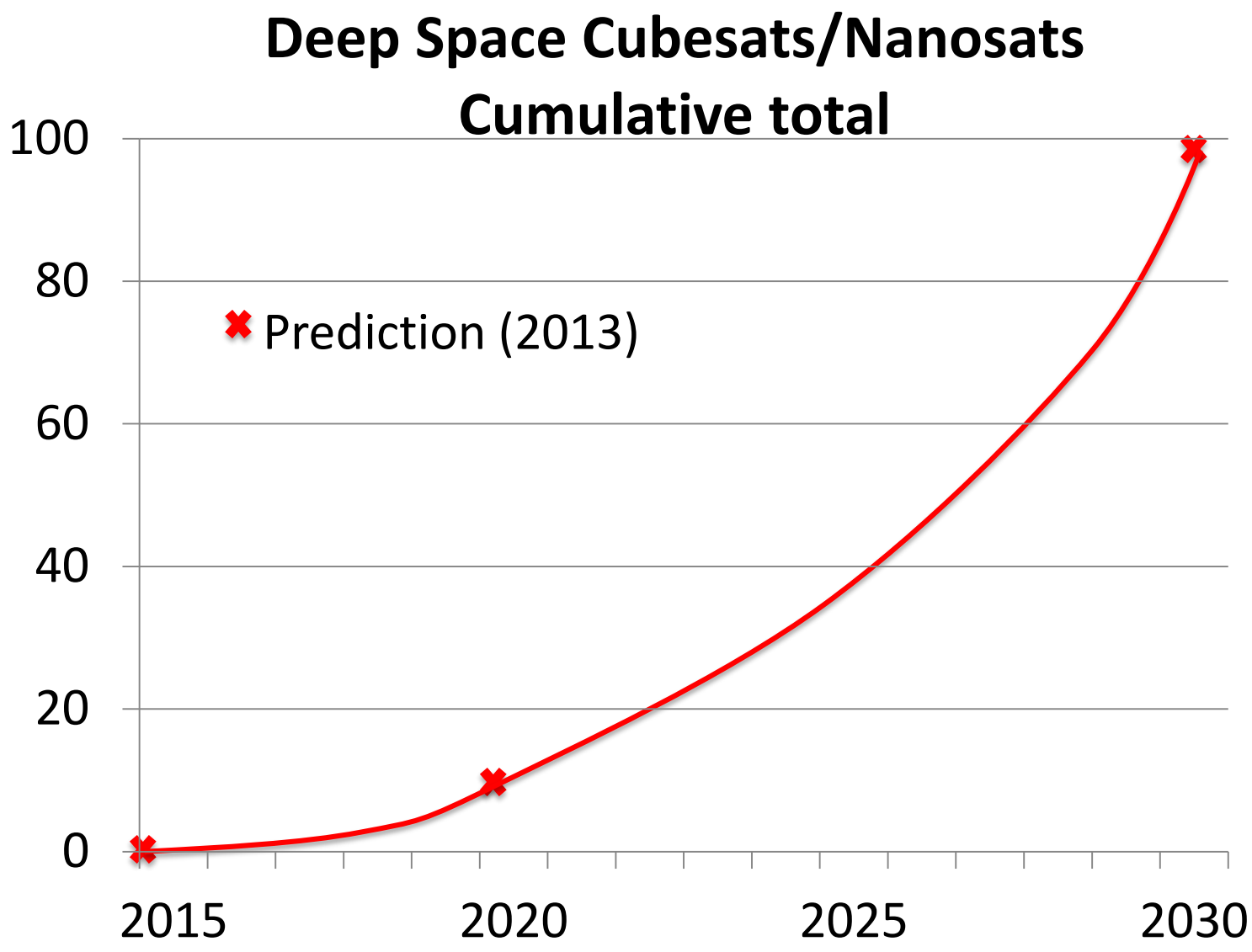
Prediction from 2013



Pre-Decisional – for Planning and Discussion Purposes Only
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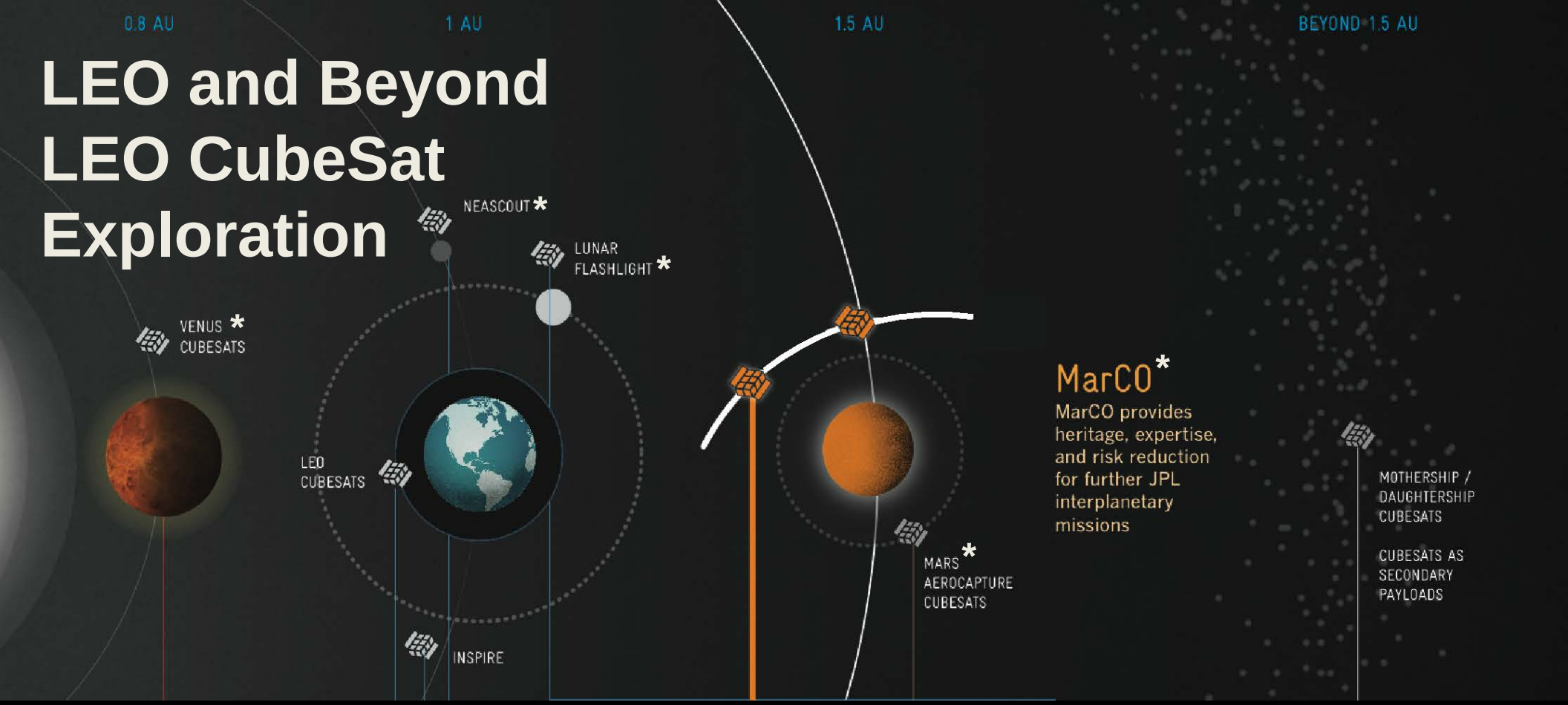
LEO and Beyond LEO CubeSat Exploration



Known Challenges

- Propulsion
- Communications and Navigation
- 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

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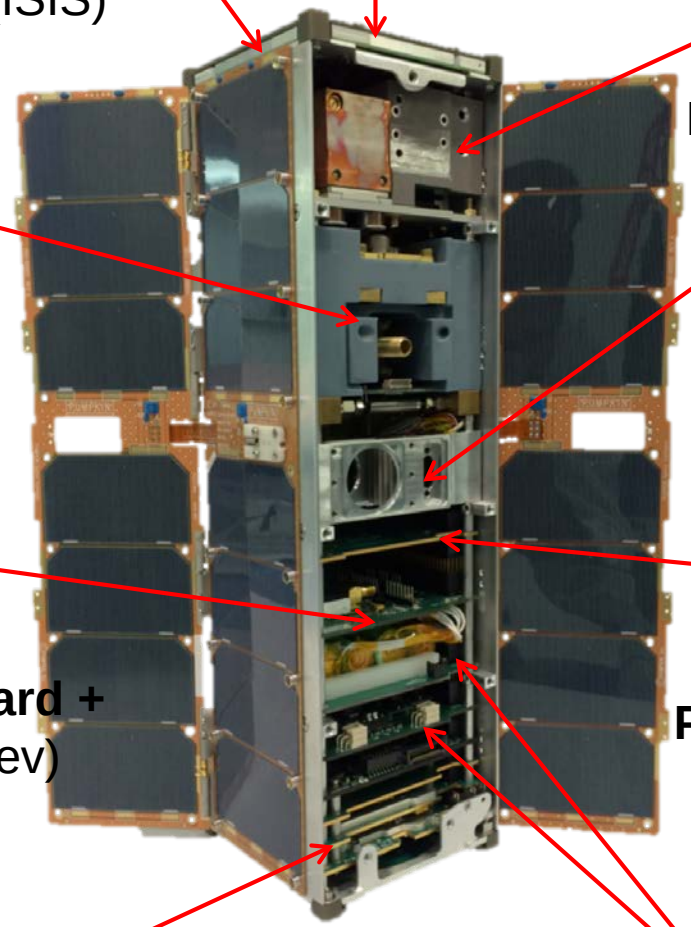
INSPIRE - Design Overview

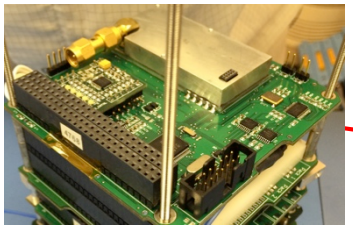
Flight-qualified and Ready in 2014



X-Band Patch Antennas (JPL)
[two sets]

UHF Antenna
(ISIS)

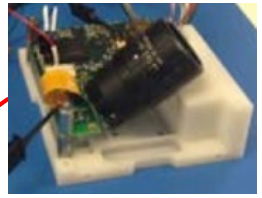
Cold-Gas ACS
(U. Texas)



C&DH + Watchdog Board + Lithium UHF (AstroDev)

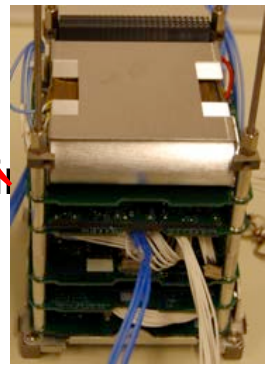
Nav/Comm X-Band Radio (JPL)

Magnetometer (JPL)



Star Tracker
(Blue Canyon)

Processing Board
(CalPoly / Tyvak)



Deployable Solar Panels (Pumpkin
Structure (JPL)

Electrical Power System + Battery Board (U. Michigan)

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INSPIRE Flight Systems

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JPL's Innovation Foundry

- JPL supports the science community to ideate, mature, and propose concepts for new NASA missions
- JPL continuously "system engineers" requirements and solutions to develop compelling new missions
- The JPL Innovation Foundry is our integrated formulation lifecycle enterprise

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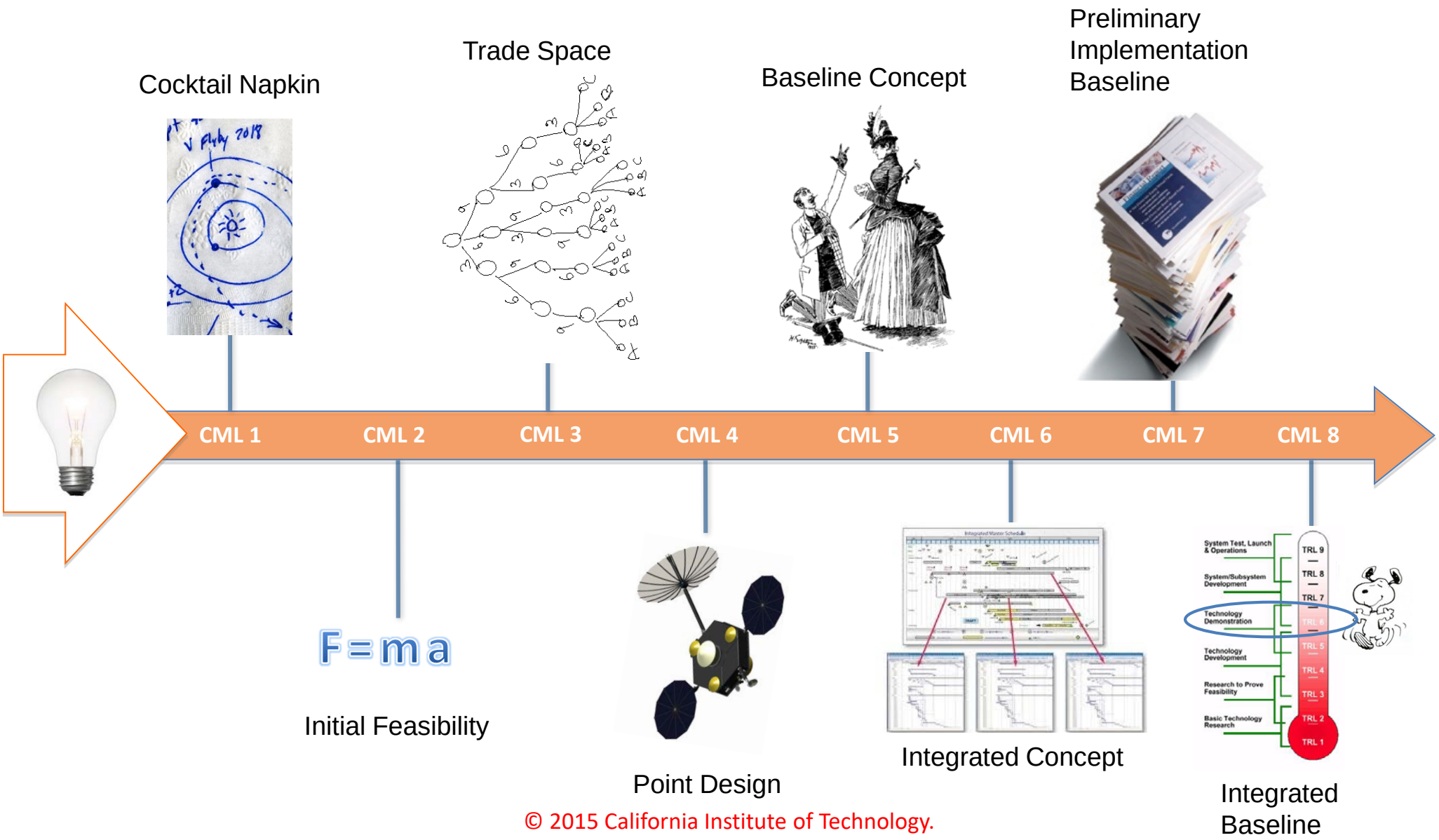
Concept Maturity Levels: A Standard Scale



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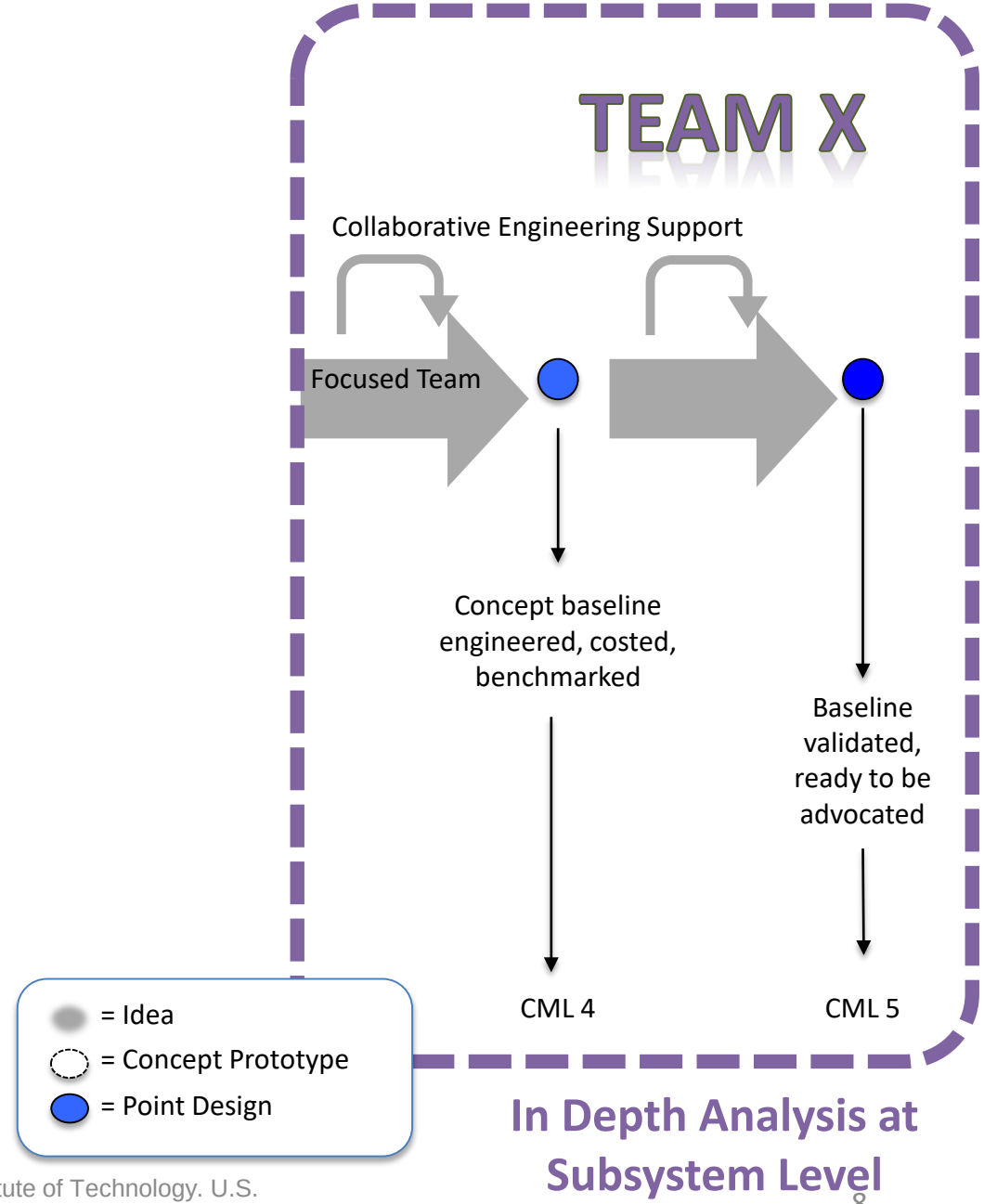
Progression of a Concept Through the CMLs



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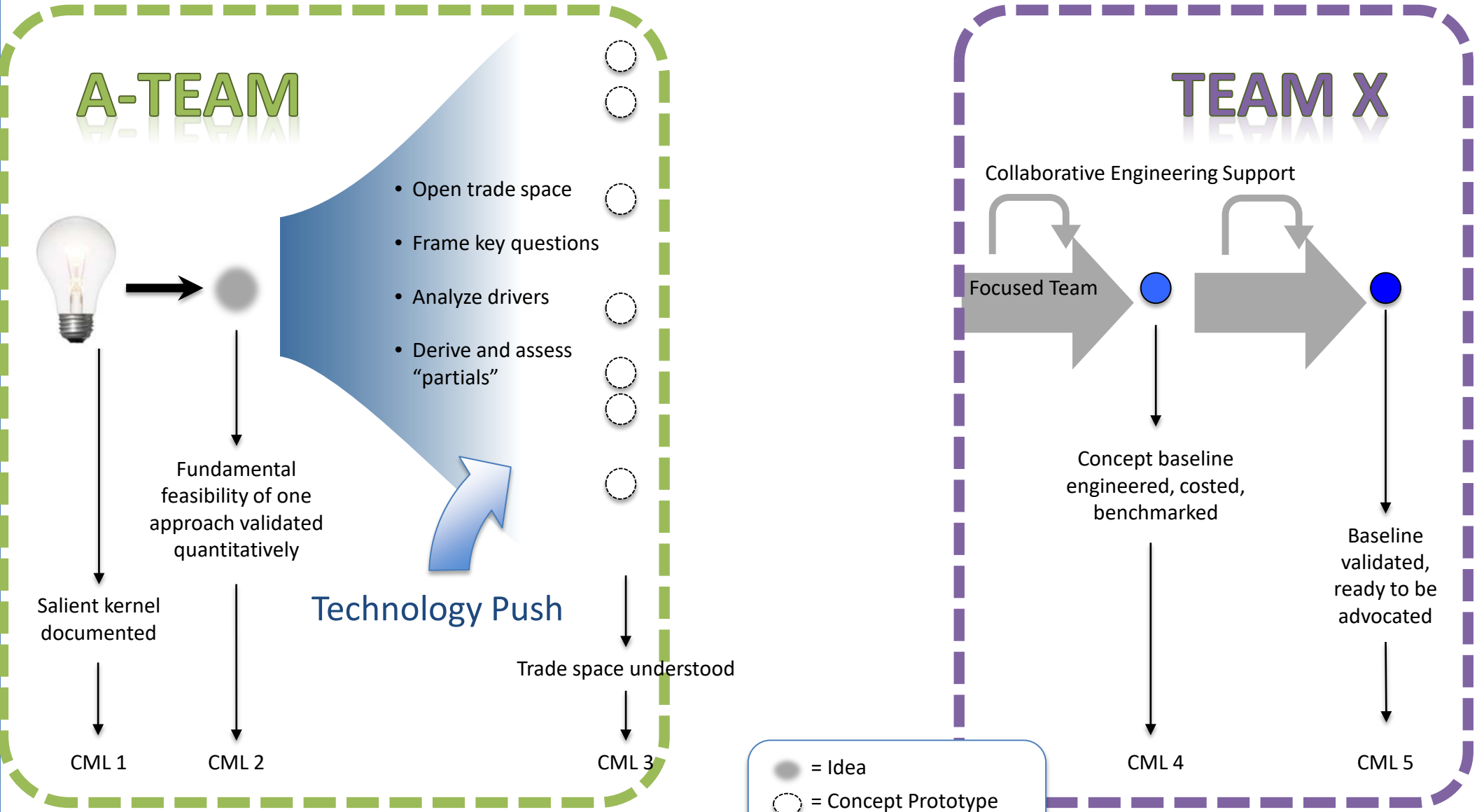
Progression of a Concept Through the CMLs



A Facilitated Conversation at the Architecture and System Level

In Depth Analysis at Subsystem Level

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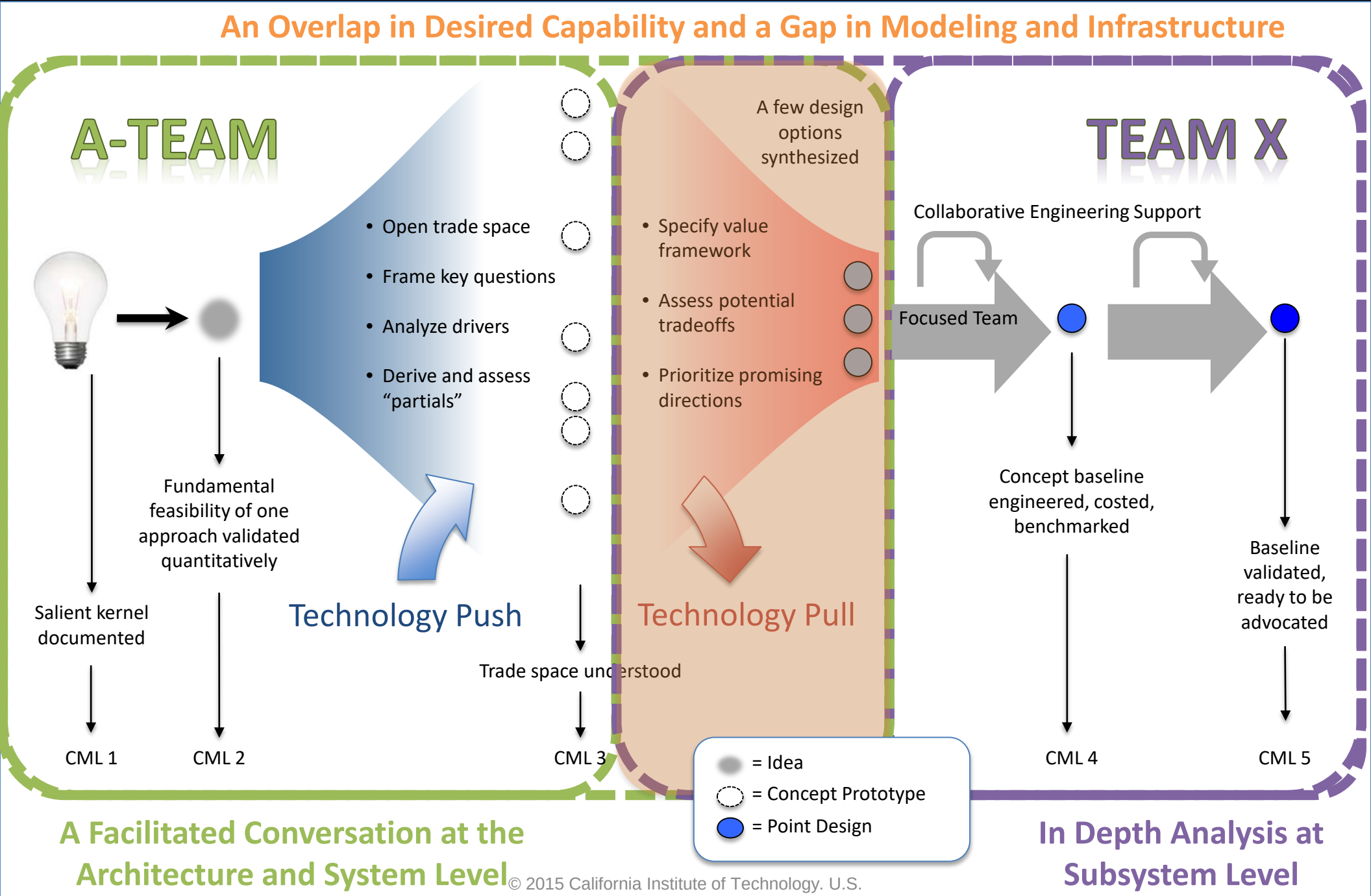
Progression of a Concept Through the CMLs



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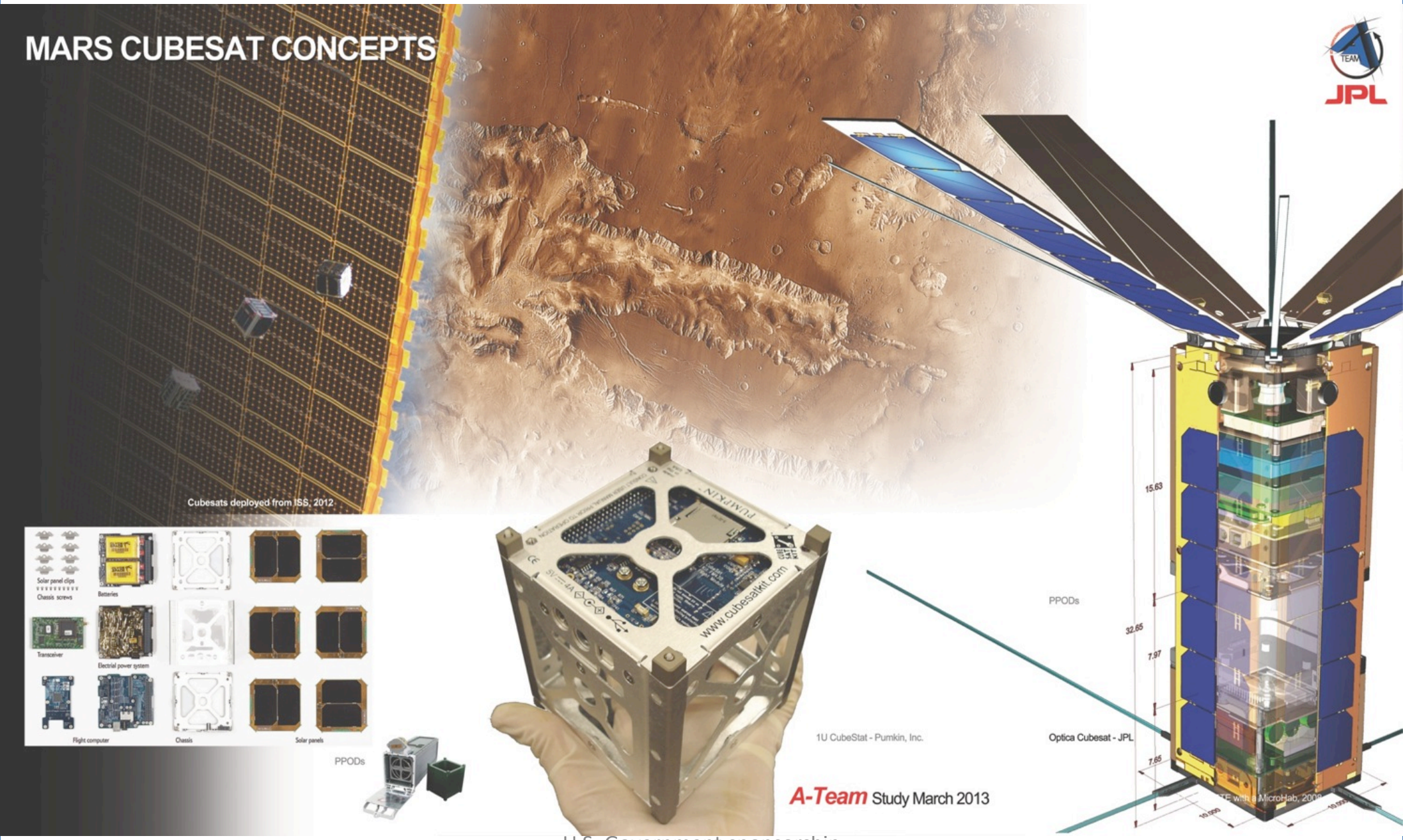
Mars CubeSats – A-Team Study



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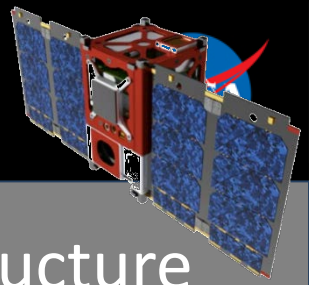
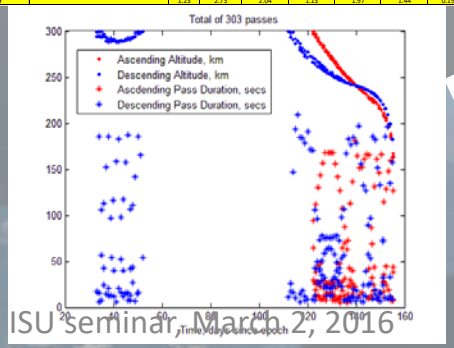
Team Xc – Fast Formulation

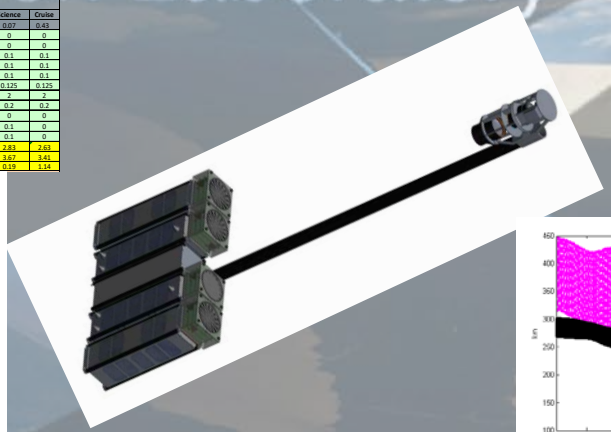


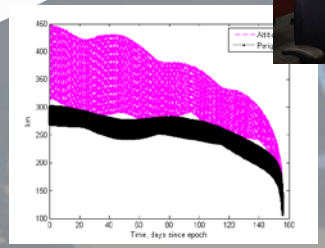
Agile, collaborative design team built on Team X infrastructure

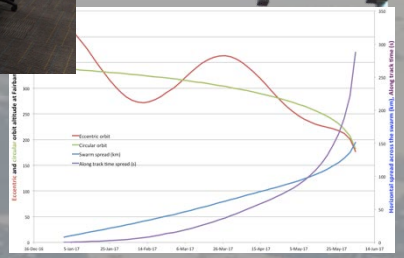
- Fast turnaround for mission concepts and studies (~2 weeks)
- Quickly assess feasibility, trade space, point designs, ops concept
- Product is more of a design than a concept

ICSP Power Modes		Setup Phase			Day in life				
		Beacon	Stabilization	Deployment	GPS	Recharge	Downlink	Science	Cruise
	Mode Durations (hrs)	1.00	1.00	0.17	0.25	0.75	0.10	0.07	0.43
Mechanical	Antenna Deployment	0	0	2	0	0	0	0	0
	Solar Panel Deployment	0	0	9	0	0	0	0	0
Avionics	GomSpace Battery	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Michigan C&DH	0.1	0.1	0.1	0	0	0.1	0.1	0.1
	Novatel GPS	0.1	0.1	0.1	2	0.1	0.1	0.1	0.1
	GomSpace EPS	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
ACS	BCT XACT	0.5	2	0.5	2	2	2	2	2
Telecom	L3 Cadet S band	0.3	0.3	0.3	0.3	0.3	12	0.2	0.2
	Patch Antenn	0	0	0	0	0	0	0	0
Instruments	Faraday cup	0	0	0	0	0	0	0.1	0
	Magnetometer	0	0	0	0	0	0	0.1	0
Total W		1.23	2.73	12.23	4.53	2.63	14.43	2.83	2.63
Total W+Cont (30%)		1.59	3.54	15.89	5.88	3.41	18.75	3.67	3.41
Total W-hr		1.23	2.73	2.04	1.13	1.97	1.44	0.19	1.14









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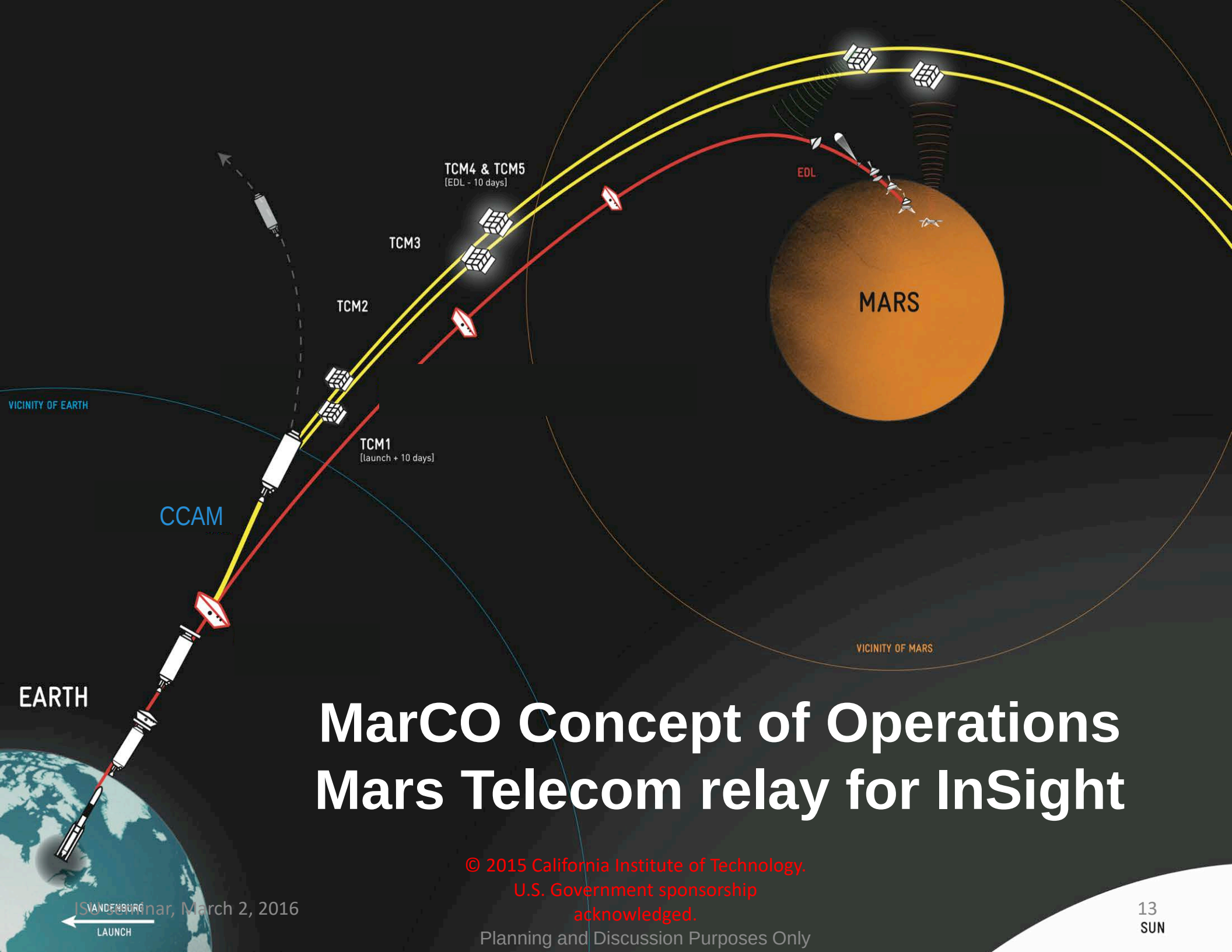

MarCO Concept of Operations
Mars Telecom relay for InSight

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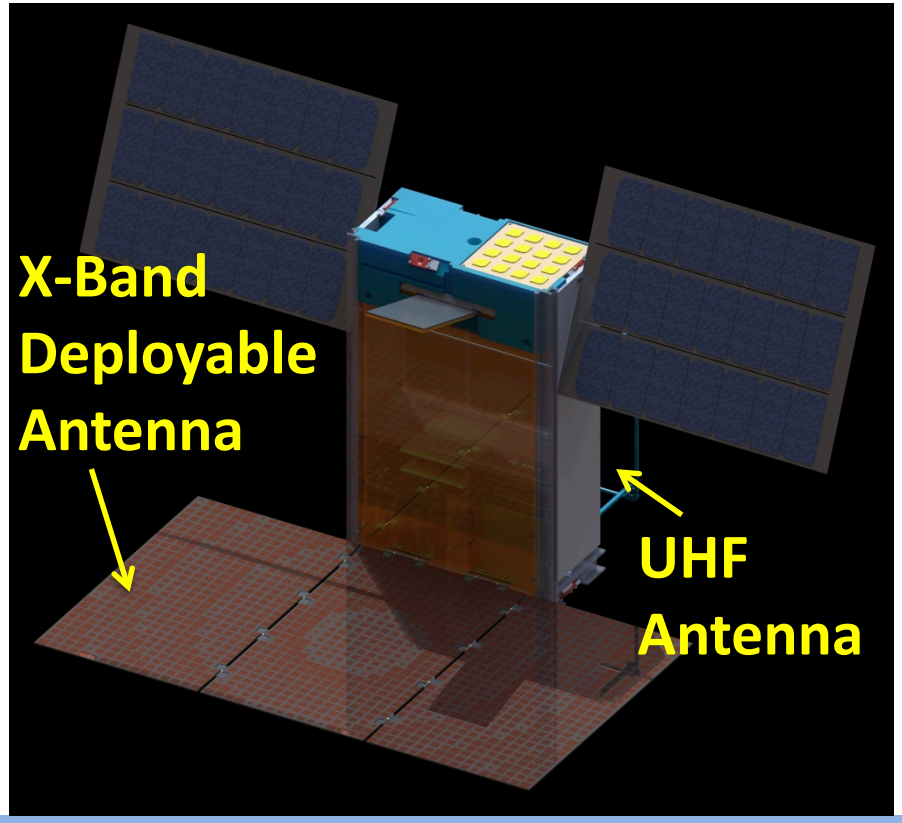
Planning and Discussion Purposes Only

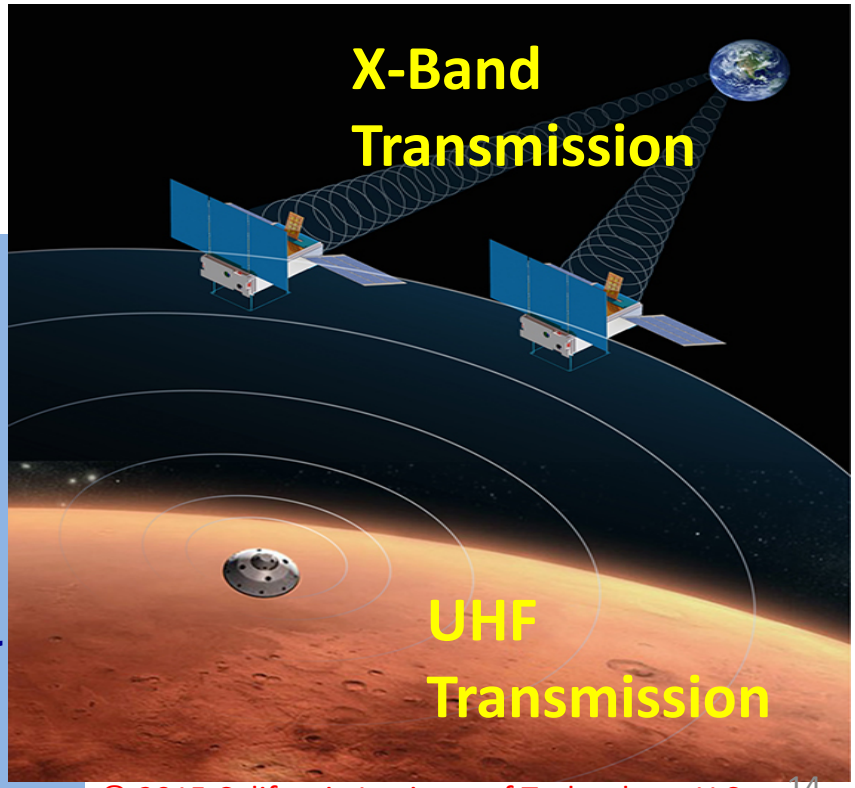
Mars Cube One

First Planetary CubeSat Mission



A Technology Demonstration of communications relay system

Interplanetary Travel
Fly-by Mars



- **Two redundant 6U CubeSats**
- **Formulated: Summer 2014**
- **Planned Launch: May 2018**
- **Arrival: Dec 2018**
- **Real-time relay of InSight EDL data**
  - **8 kbps UHF: InSight to MarCO**
  - **8 kbps X-band: MarCO to DSN**

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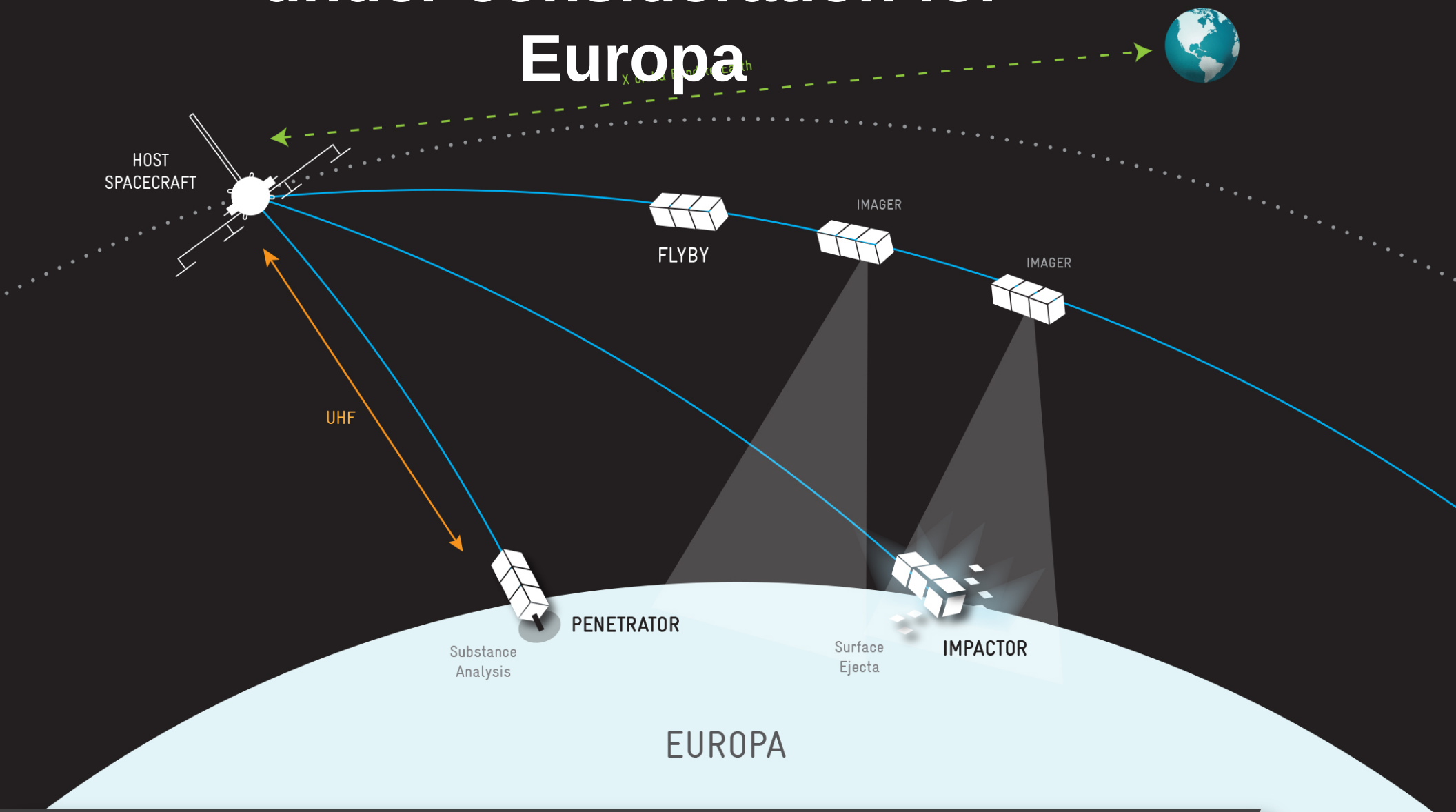
11 Cubesat "ride-alongs" under consideration for Europa

ExCSITE

Jet Propulsion Laboratory
California Institute of Technology



SPACECRAFT FORMATION	12 CUBESATS	FLYBY	DEPLOYMENT TRAJECTORY	HOST DEPLOYMENT	JOVIAN ENVIRONMENT	MISSION LIFETIME GOAL	3 YEARS

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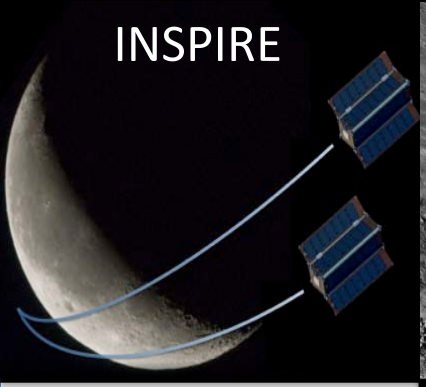
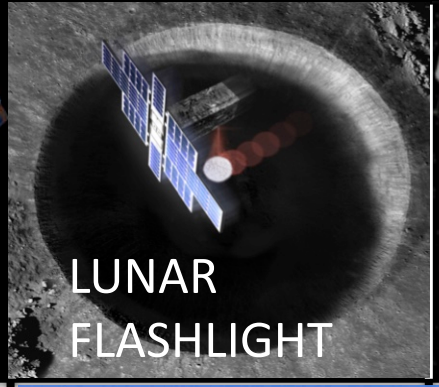
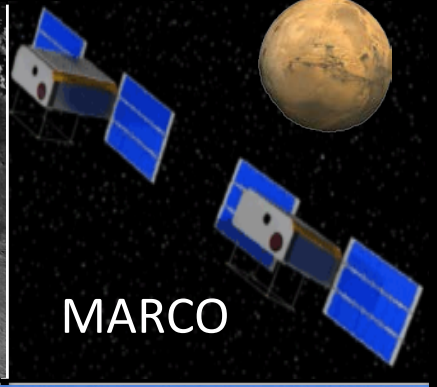
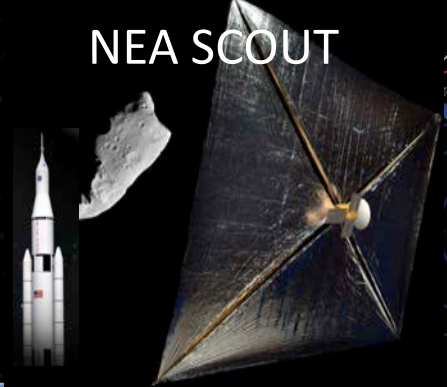
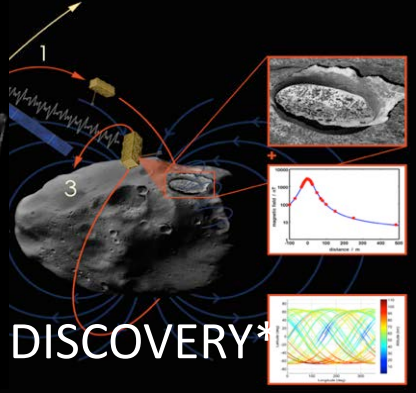

INSPIRE


LUNAR
FLASHLIGHT


MARCO

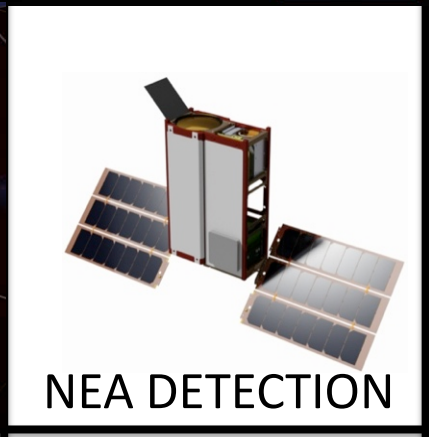

NEA SCOUT


DISCOVERY*

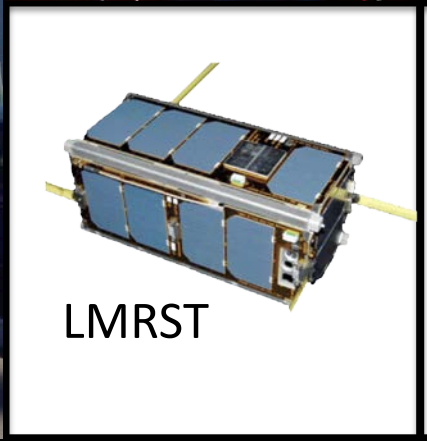
ASTERIA

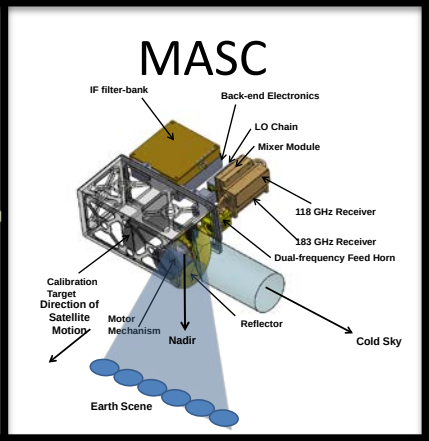
CubeSat Development Lab concepts and planned projects
CUBESAT

RELIC/ALFA-Cubed


NEA DETECTION

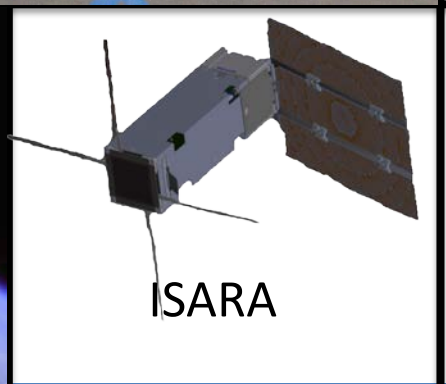
MCUBED/COVE2

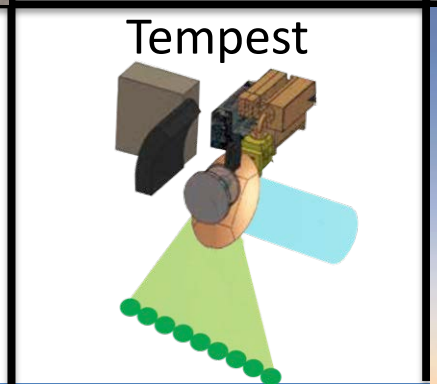

LMRST

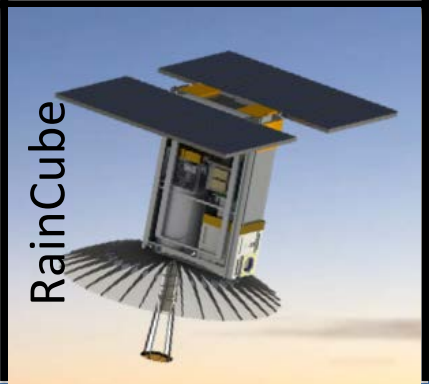

MASC
IF filter-bank
Back-end Electronics
LO Chain
Mixer Module
118 GHz Receiver
183 GHz Receiver
Dual-frequency Feed Horn
Calibration Target
Direction of Satellite Motion
Motor Mechanism
Nadir
Reflector
Cold Sky
Earth Scene

GRIFEX

IPEX

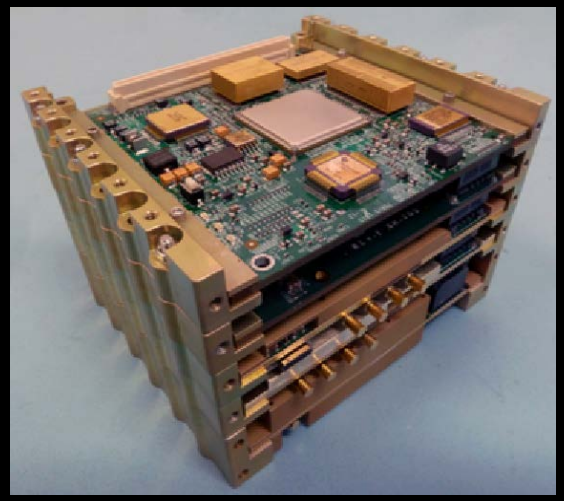

ISARA


Tempest

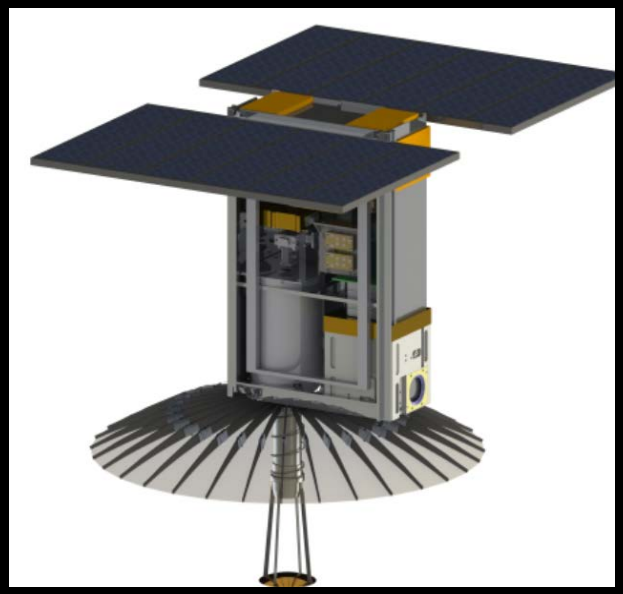

RainCube

JPL Technologies and Standards

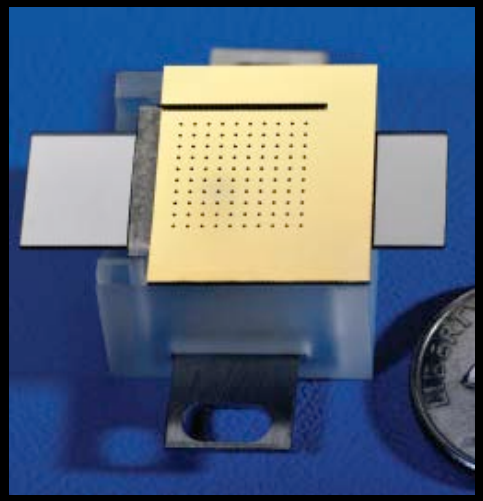
Deep SpaceTransponder



Deployable Reflector



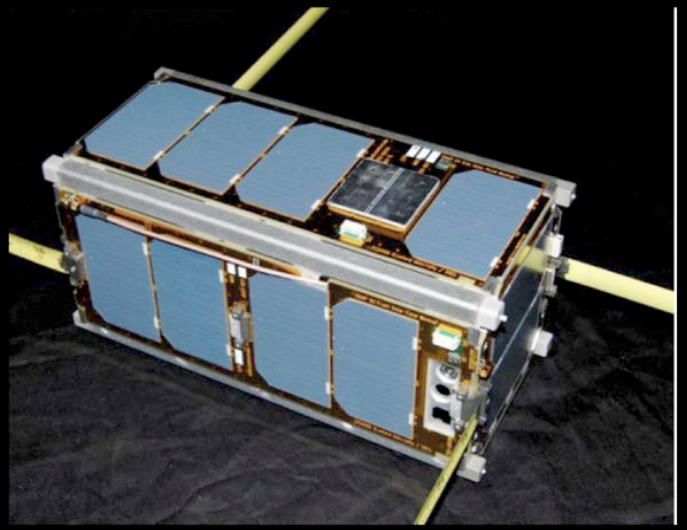
Micro-Electric Propulsion



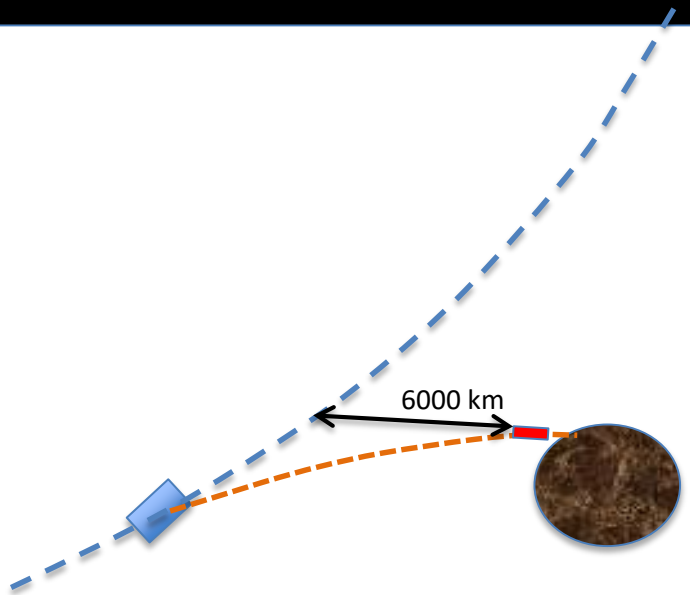
DSN Communications and Navigation Protocols

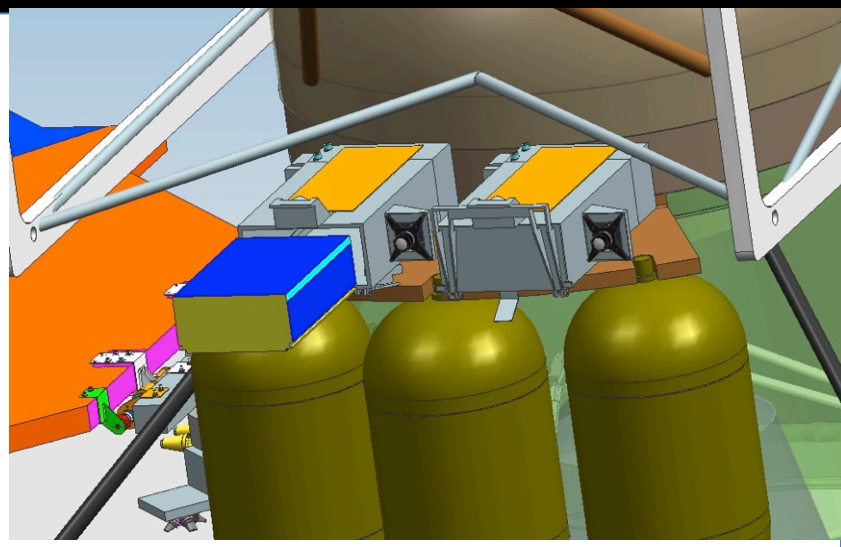
OnBoard Data Reduction

Low Mass Radio Transponder

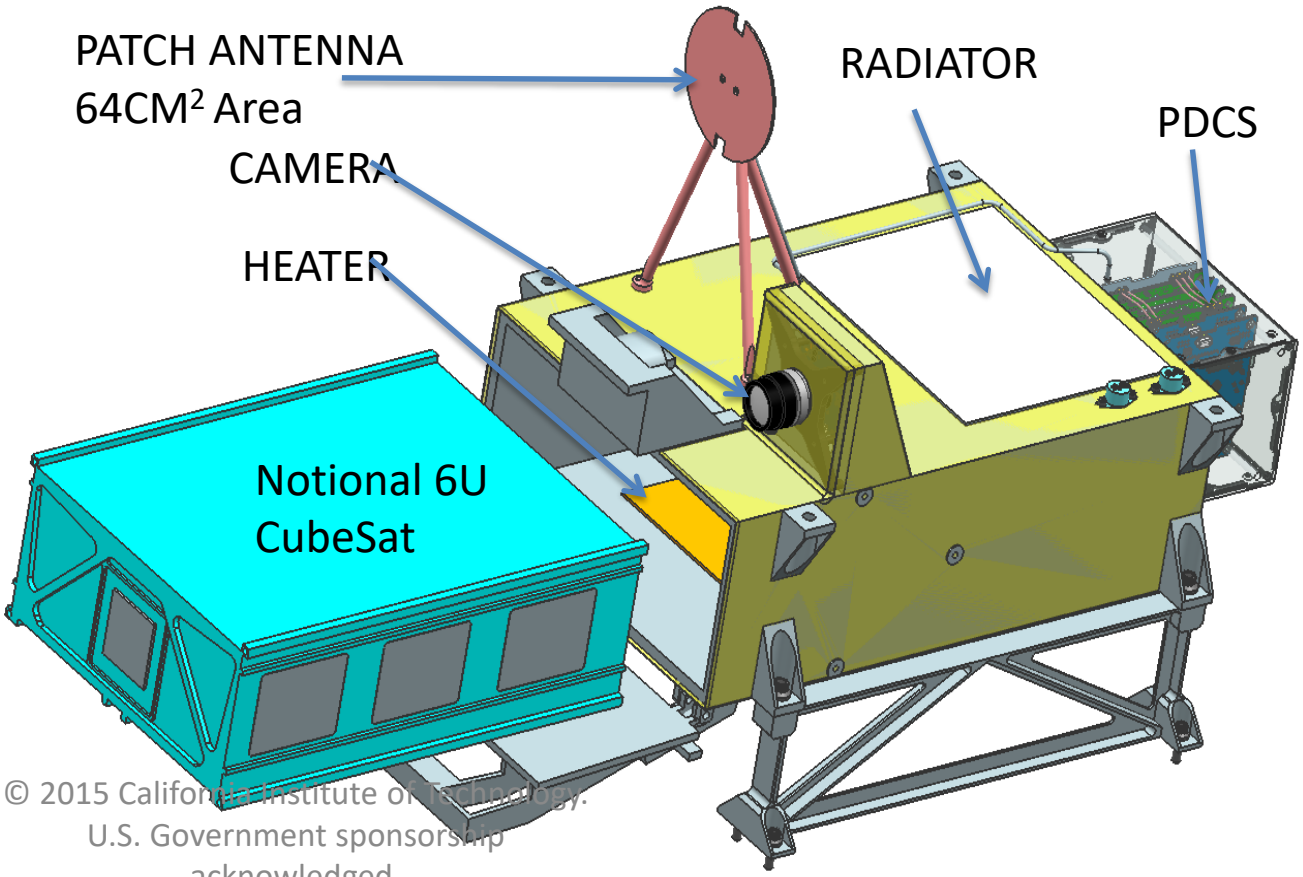


Deep Space P-POD Concept





Need a "standard" communications, storage & deep space deployment system for small satellites



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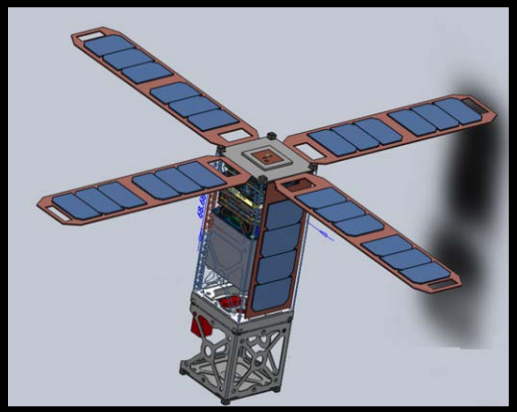
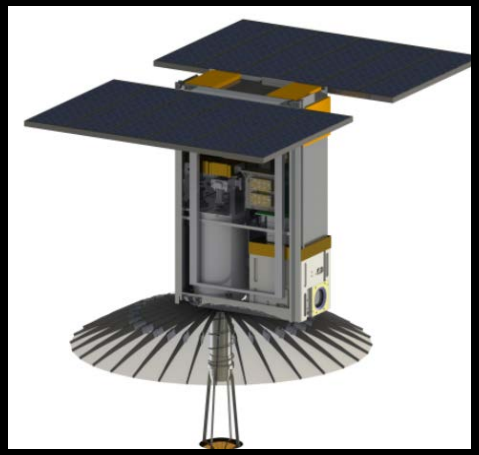
JPL Cubesat Instruments

183 GHz radiometer



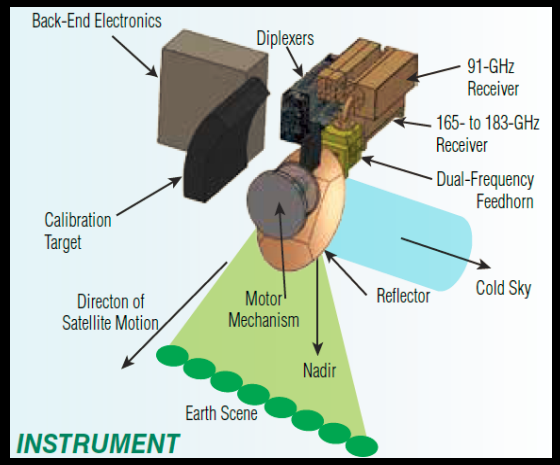
Astrometry Telescope

Raincube 35 GHz radar

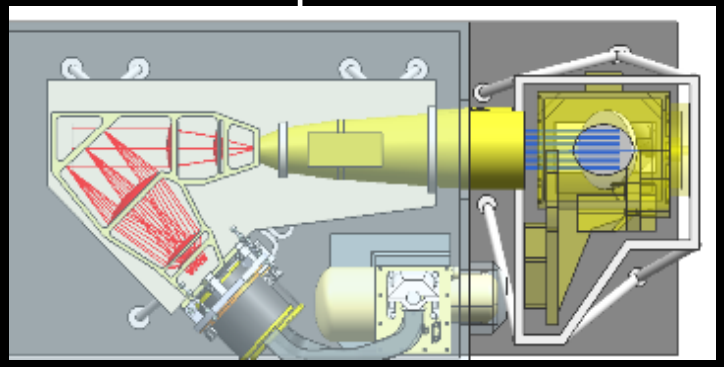


NIR Spectrometer

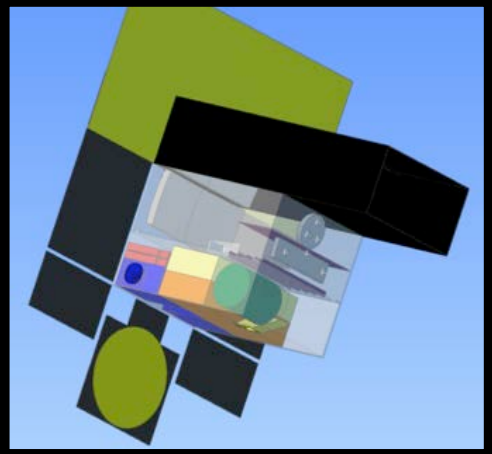
Multi-freq mm-wave radiometer



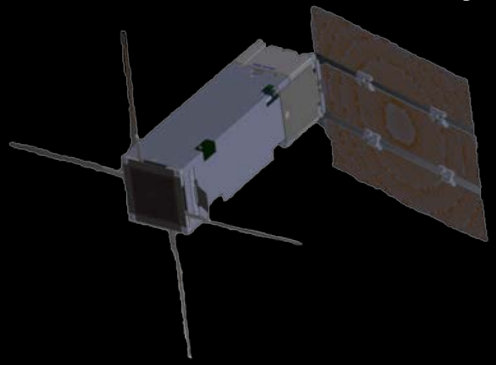
IR Atmospheric Sounder



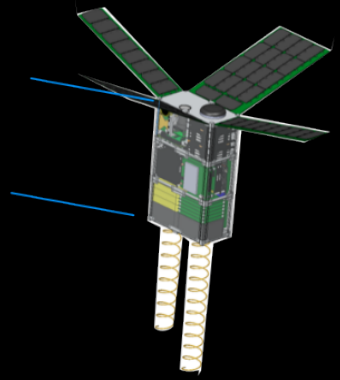
Multi-spectral Imager

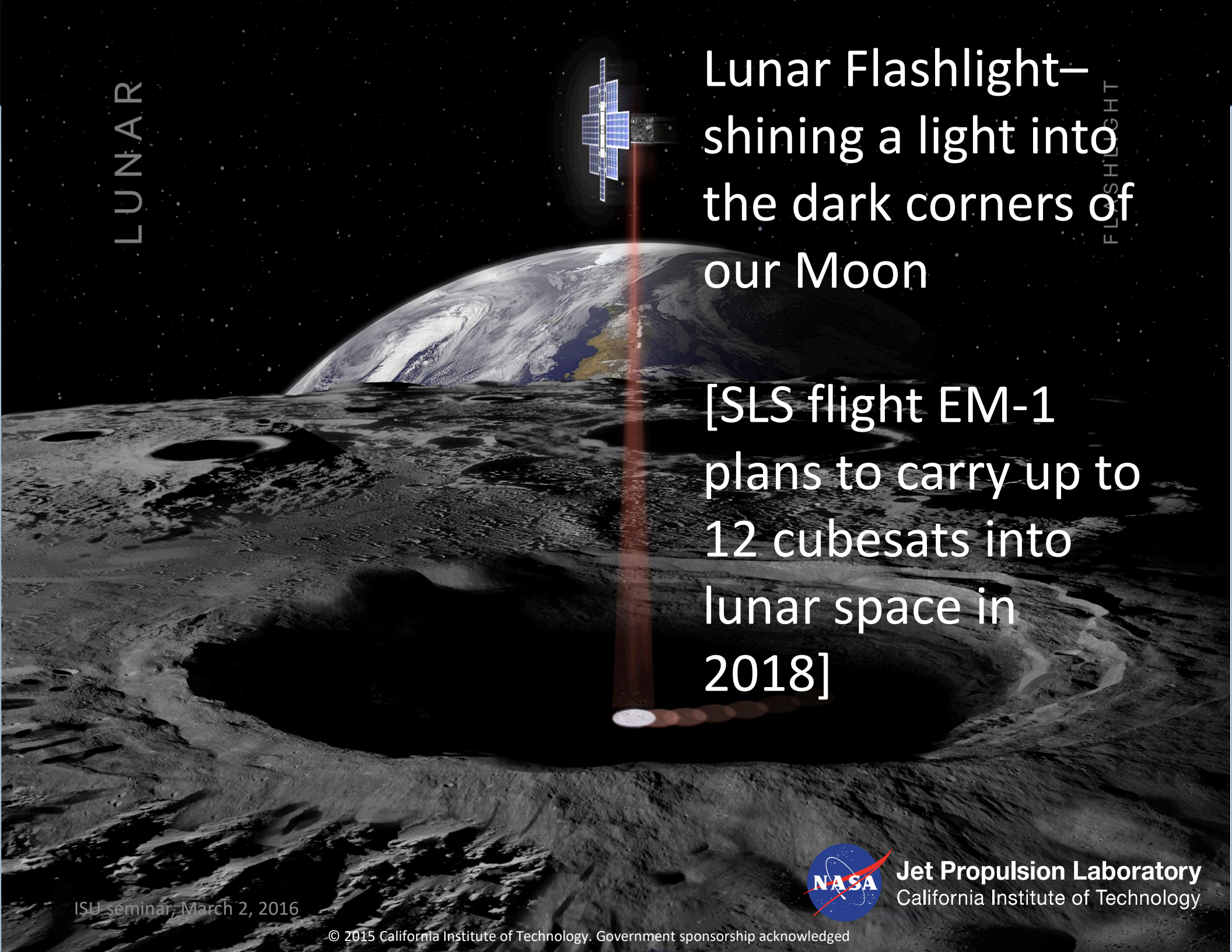


ISARA Reflectarray



Gravity (μGRACE)





Lunar Flashlight– shining a light into the dark corners of our Moon

[SLS flight EM-1 plans to carry up to 12 cubesats into lunar space in 2018]

Jet Propulsion Laboratory
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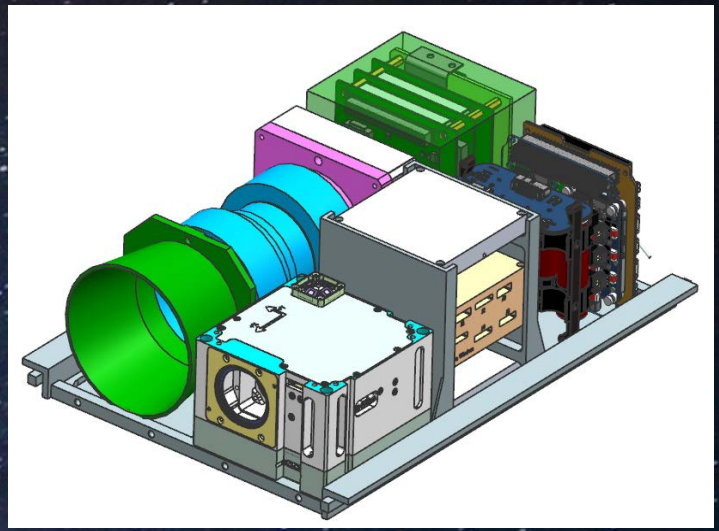
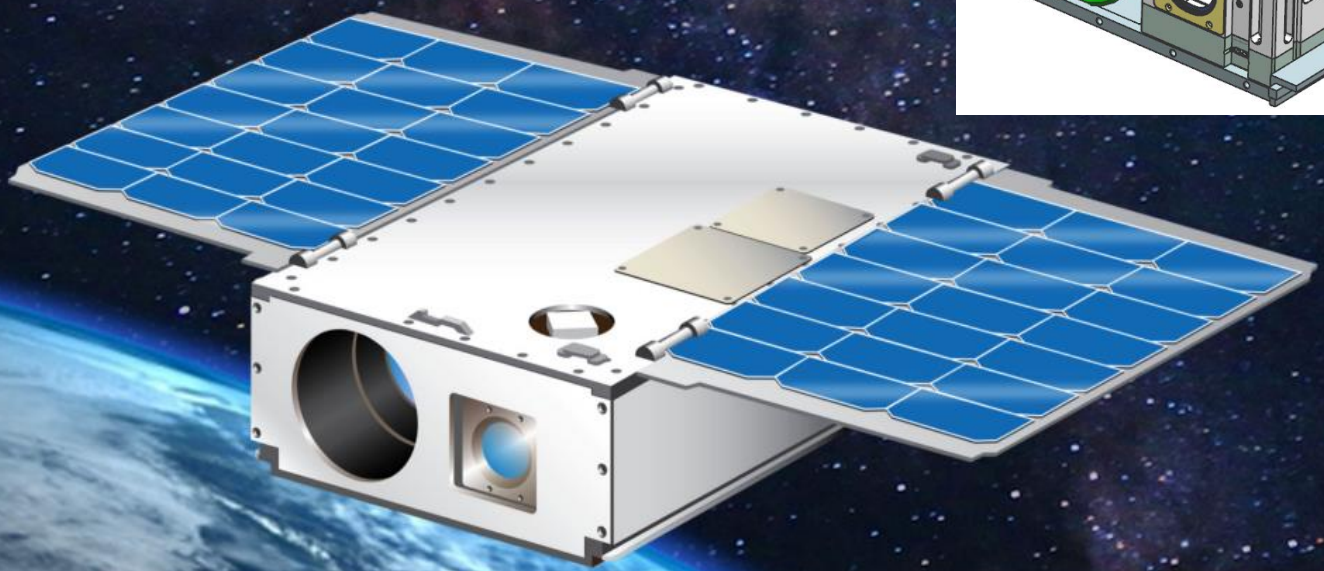
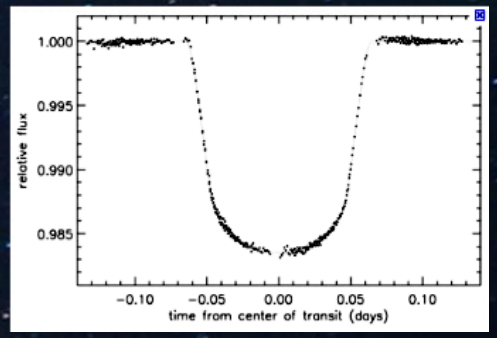
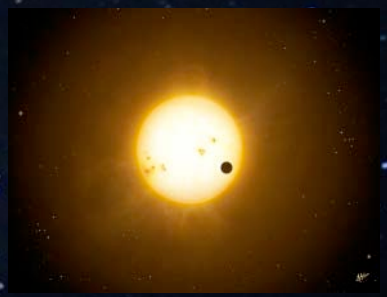
ASTERIA: Arcsecond Space Telescope Enabling Research in Astrophysics

Optically refined pointing gives 5 arcsec rms accuracy









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VERITAS - Proposed Discovery Mission

Implementation

PI: Sue Smrekar, JPL

Project Mgmt: JPL

Instruments:

- Radar (JPL + ASI)
- Spectrometer (DLR)
- Gravity (JPL + ASI)

MAVEN heritage S/C: LM

Carries DSOC, Cupid's Arrow TDO

Science

1) understand Venus' geologic evolution

2) determine what geologic processes are currently operating

3) find evidence for past or present water

Mission Profile

Launch: Nov 2021

Venus arrival: Feb 2024

Type IV E-E-V trajectory

Science Phase I: 4 months

Aerobraking: 7 months

Science Phase II: 2 years

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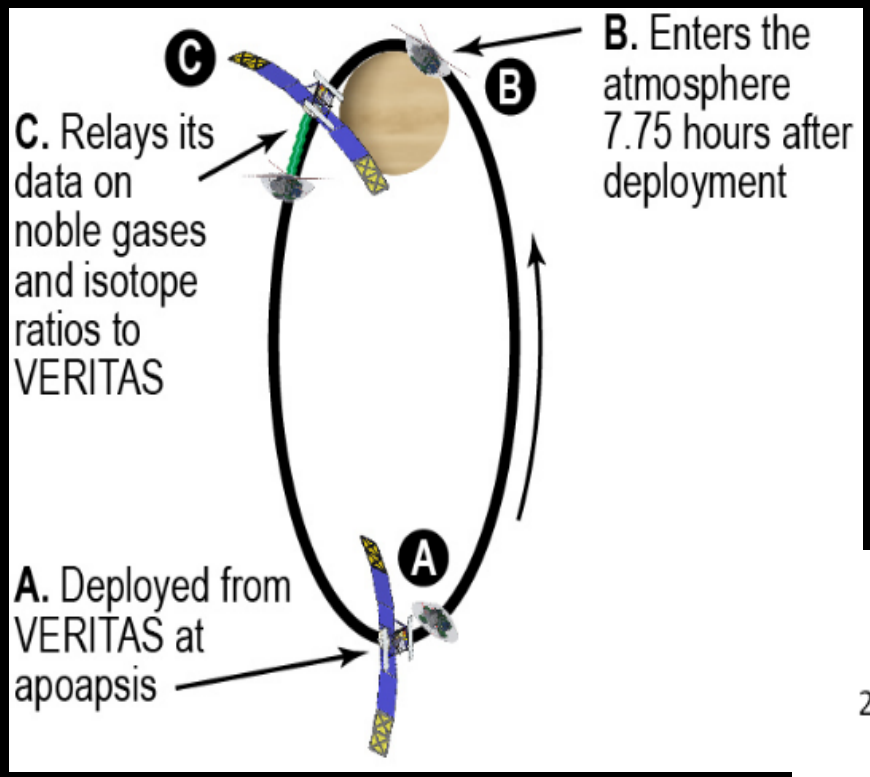
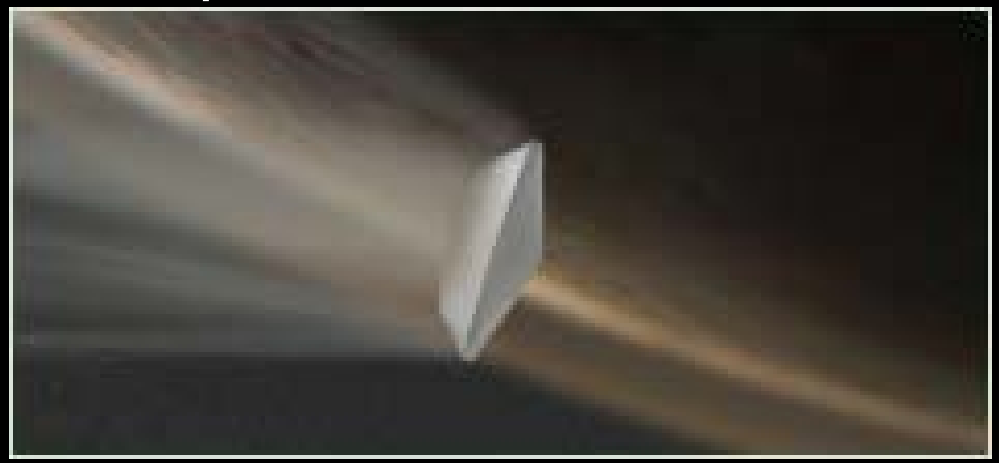
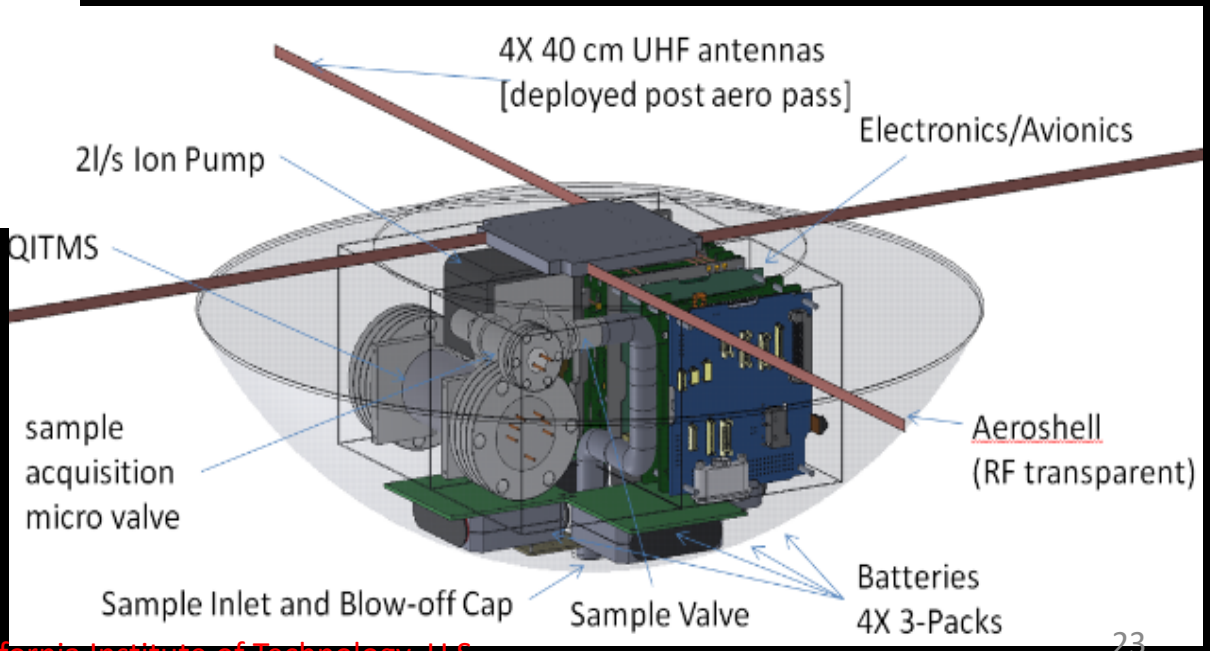
Proposed Cupid's Arrow Technology Demonstration

1. Drop-off



2. …Skims through Venus' atmosphere





3. …samples noble gases

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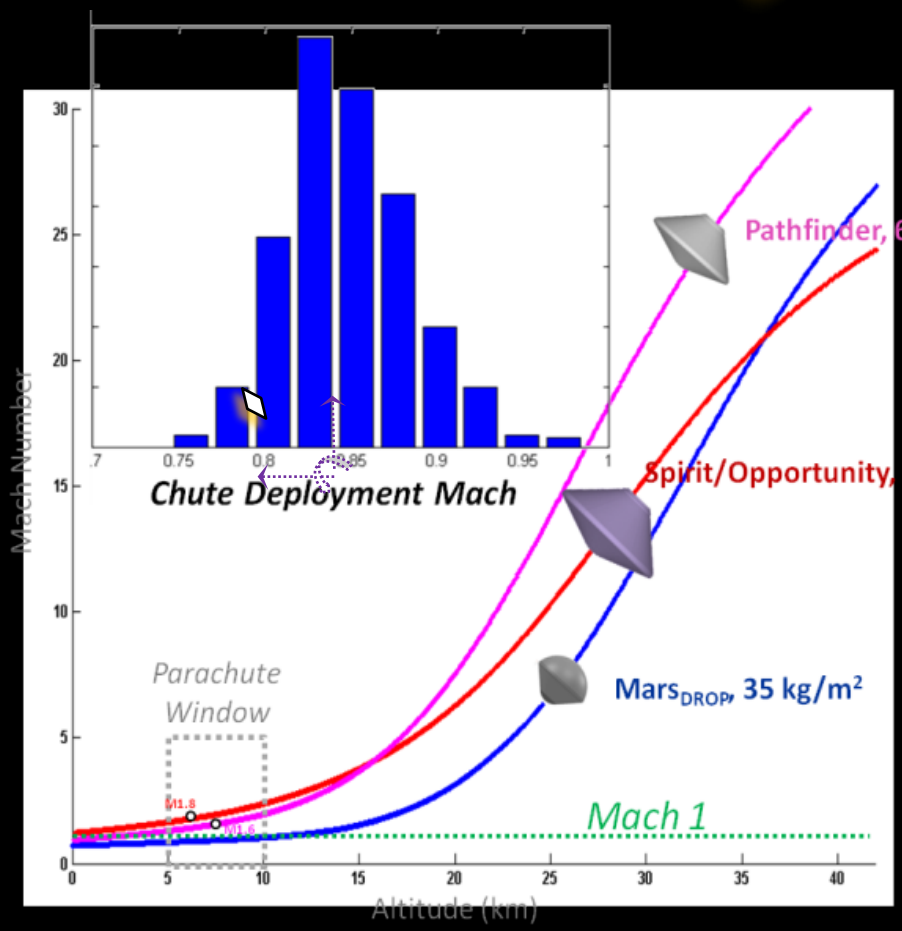
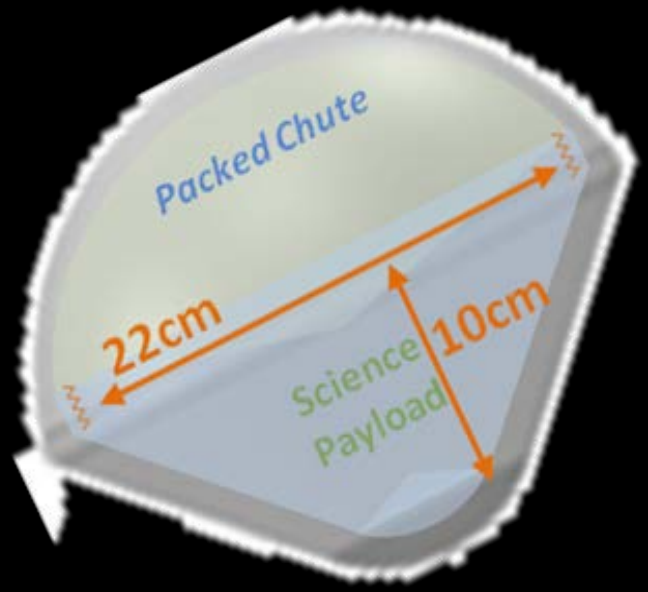
Jet Propulsion Laboratory
California Institute of Technology

MarsDrop Concept

AEROSPACE



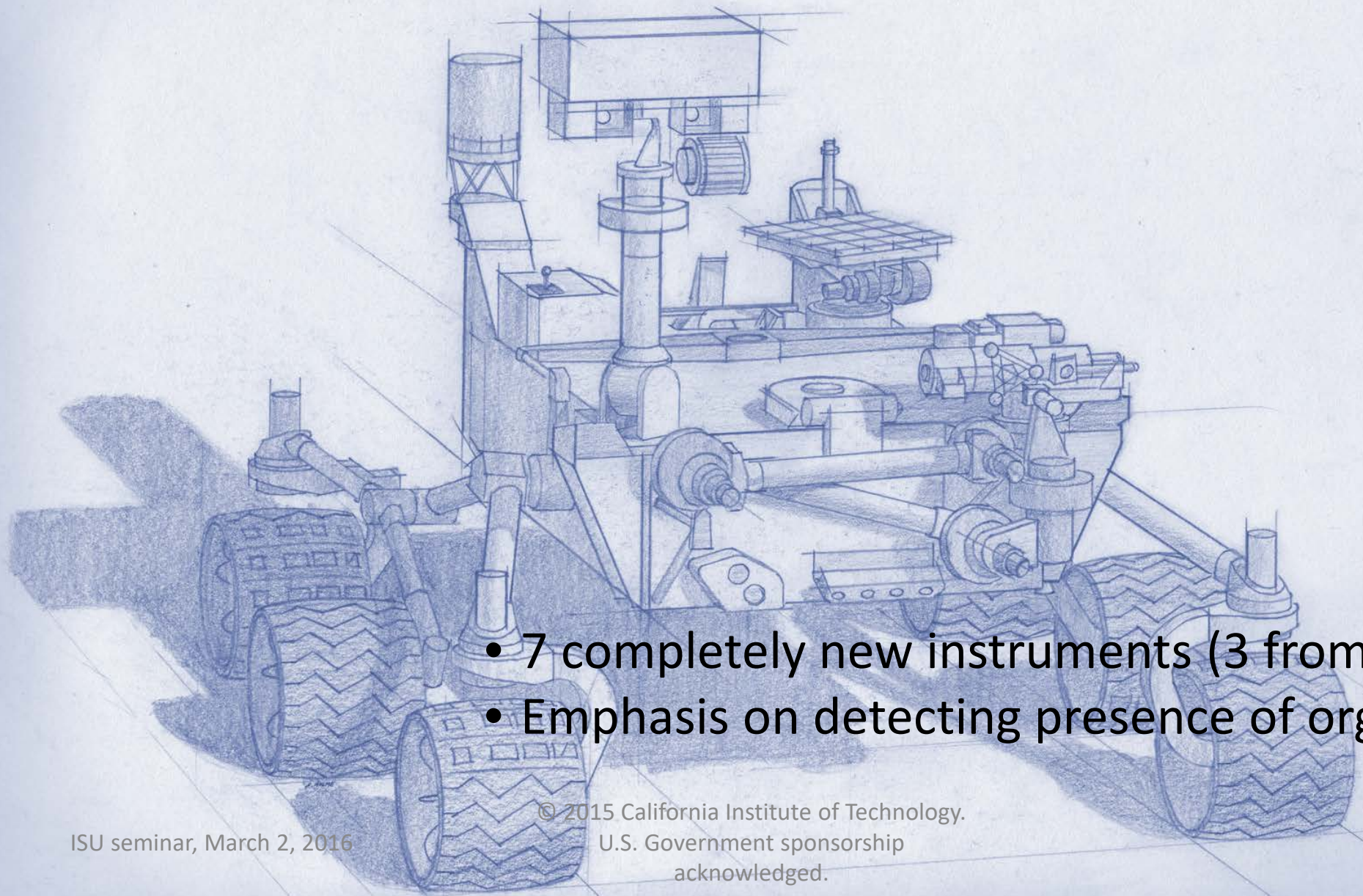


- Cubesat avionics enable insitu science at multiple landing sites

MARS DROP

Mars 2020 Rover

- Same chassis as Curiosity (2012)
- Same “terrifying” skycrane landing system



- 7 completely new instruments (3 from JPL)
- Emphasis on detecting presence of organics

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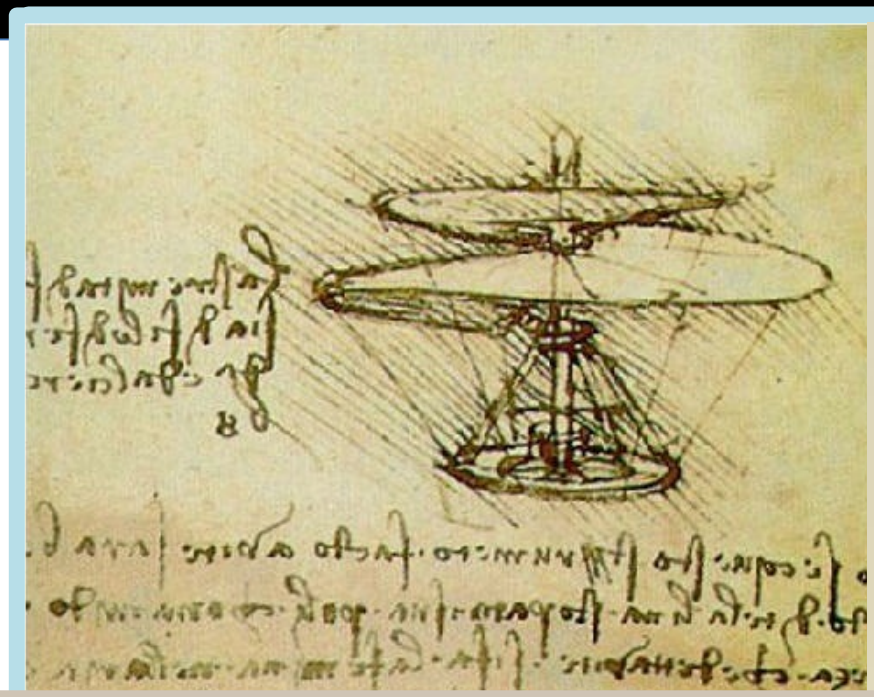
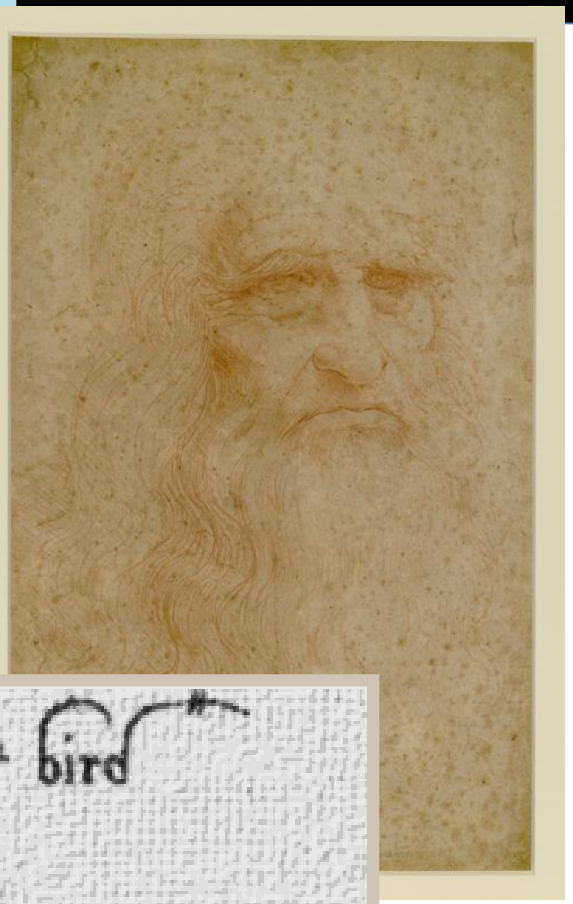
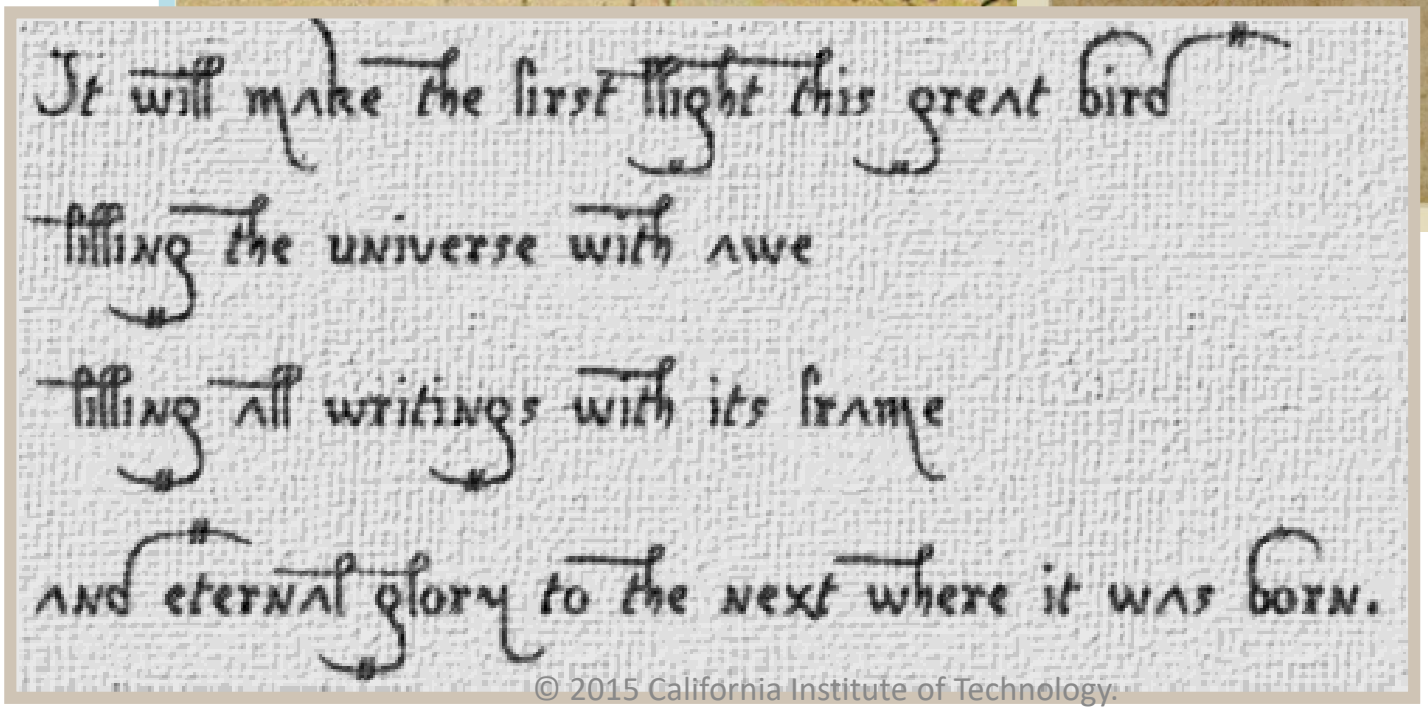
Helicopters on Mars?







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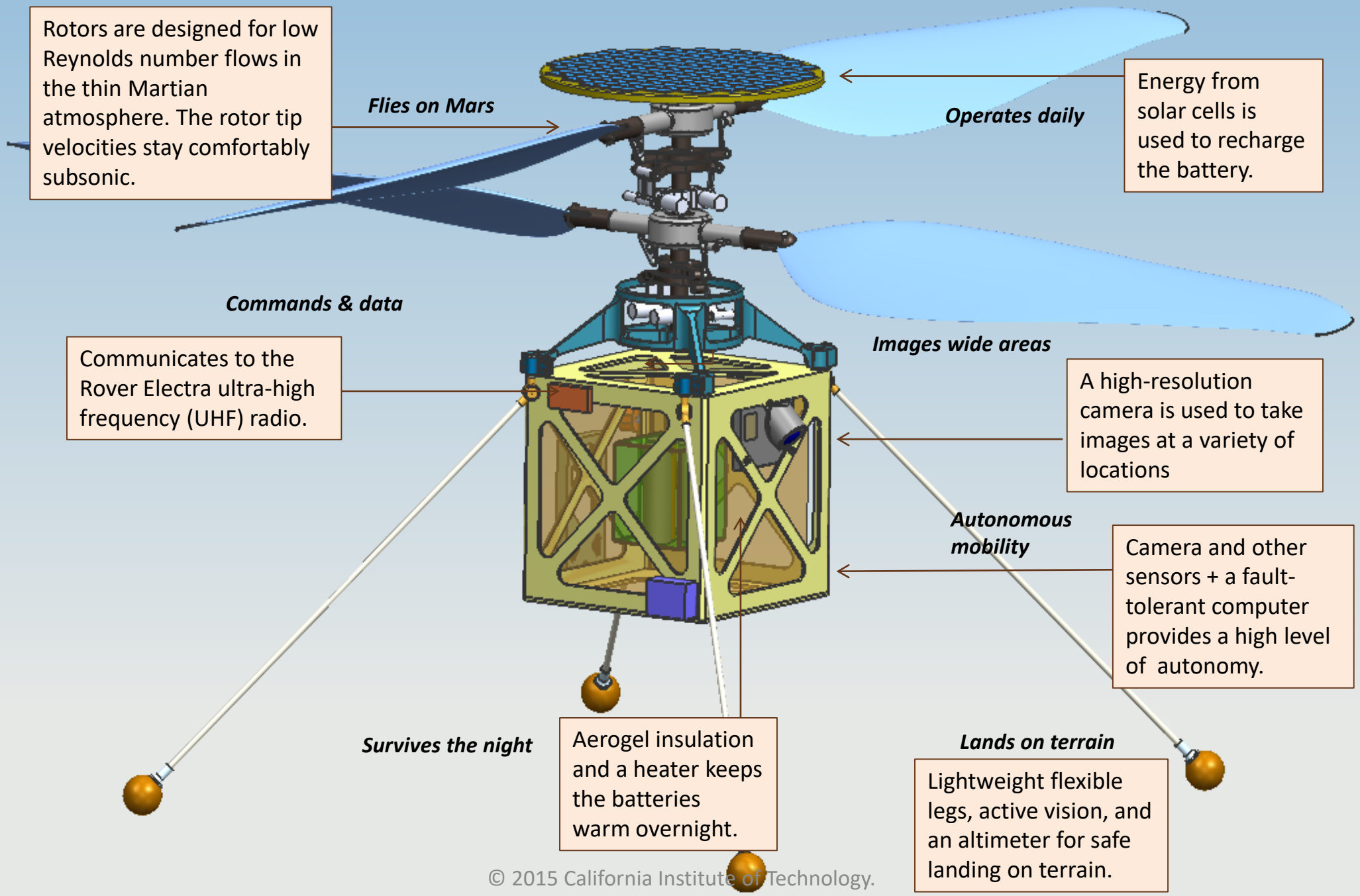
Mars Helicopter under Investigation



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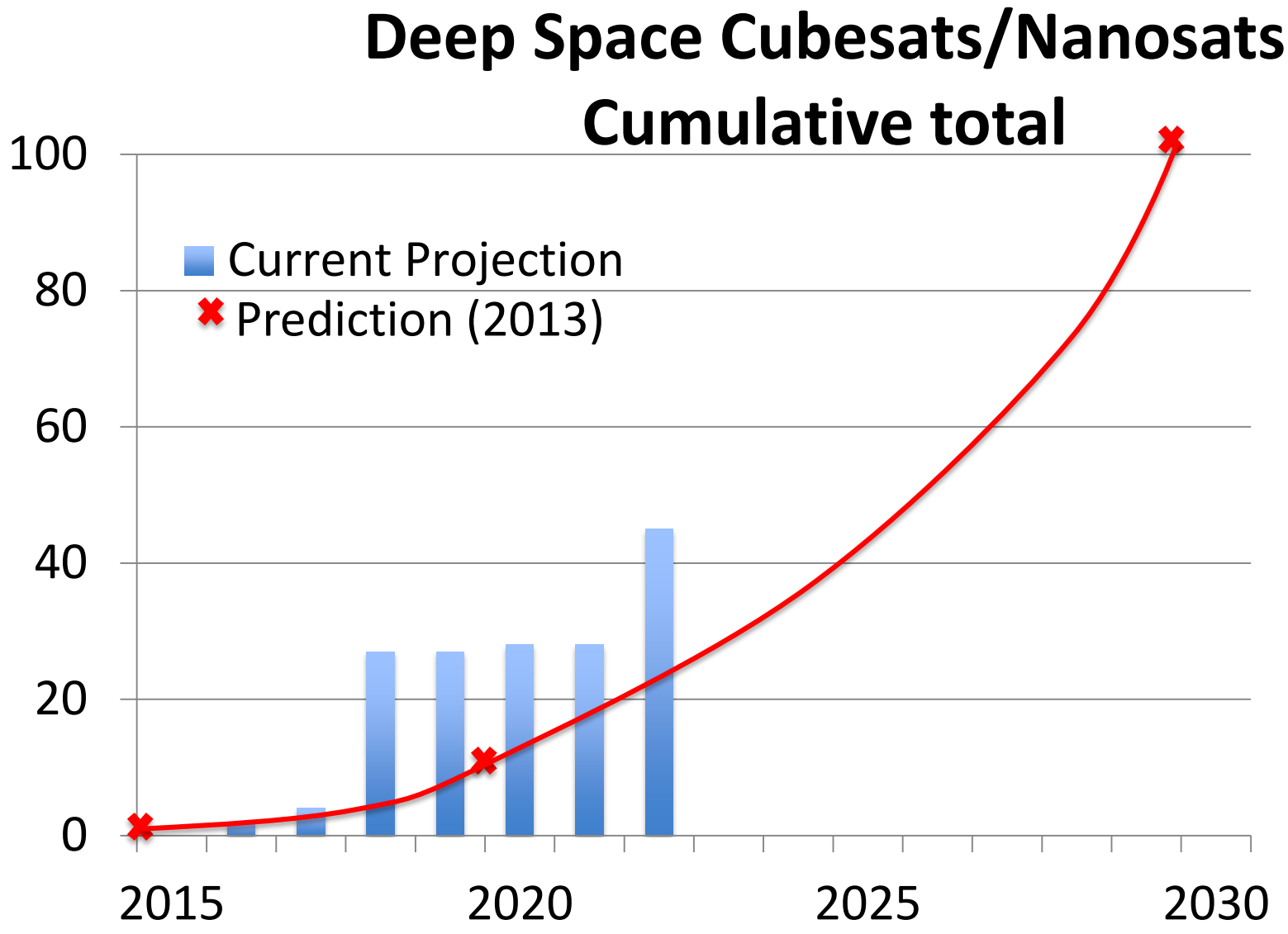
*Mission Concept - Pre-Decisional - For Planning and Discussion Purposes Only

Current Projection



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The Biggest Bottleneck

Earth Escape Launch Opportunities

Secondary Payload

ISS Delivery

Dedicated launch

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Conclusions

- Cubesat and nanosat spacecraft can enable ground-breaking, focused science missions
- As cubesats in LEO have experienced exponential growth, we believe we are poised on the edge of exponential growth in deep space cubesats and nanosats
- Earth Escape launch capabilities/opportunities are the main choke point

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www.jpl.nasa.gov/cubesats

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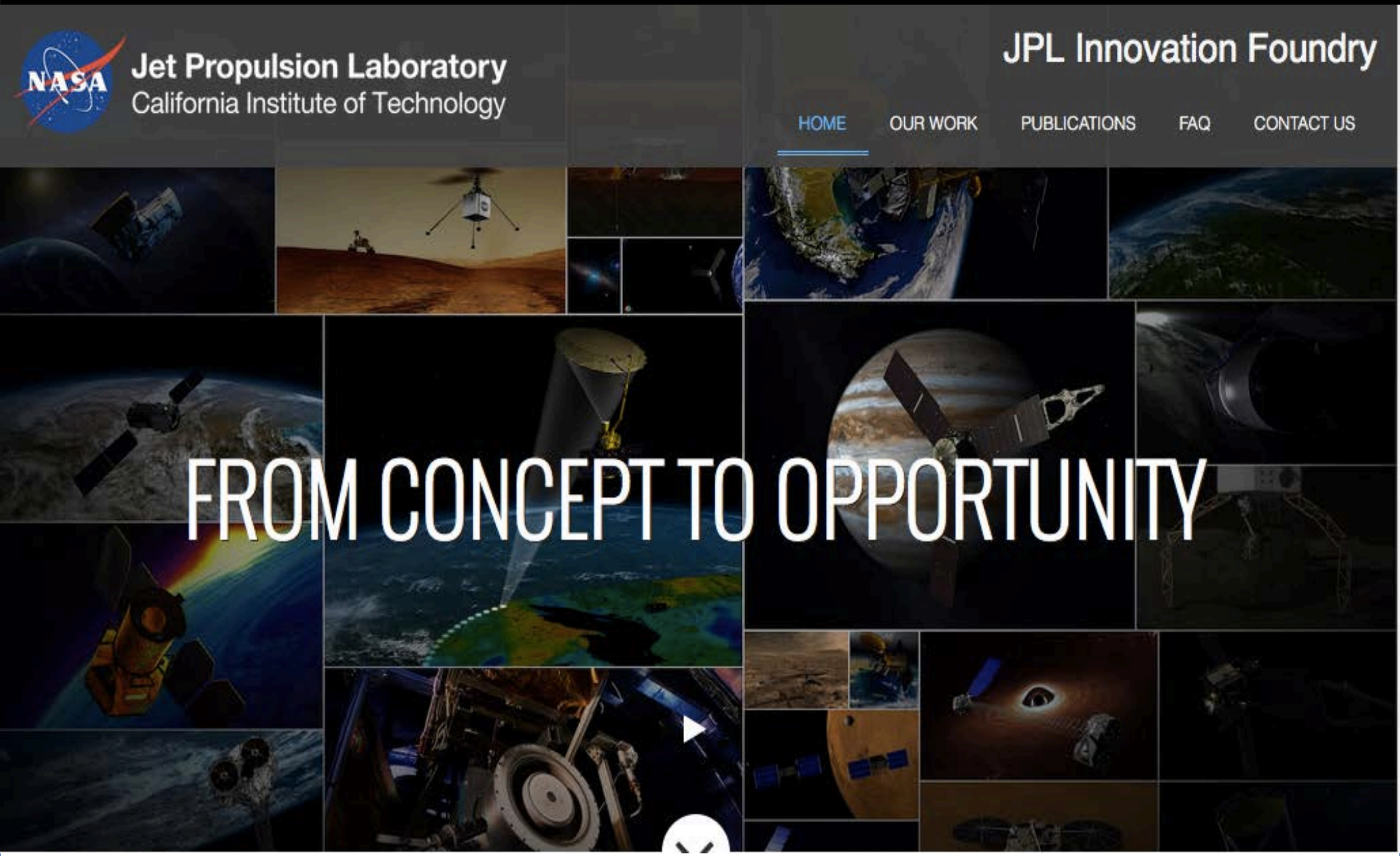
jplfoundry.jpl.nasa.gov



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