Finding Life on Mars Using CubeSat Hardware??

2018 May 1
CubeSat Developers Spring Workshop
CalPoly San Luis Obispo, California

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[1]Jet Propulsion Laboratory-California Institute of Technology
[2]NASA Ames Research Center, [3]The Aerospace Corporation, [4]Swarm Technologies

4/24/18

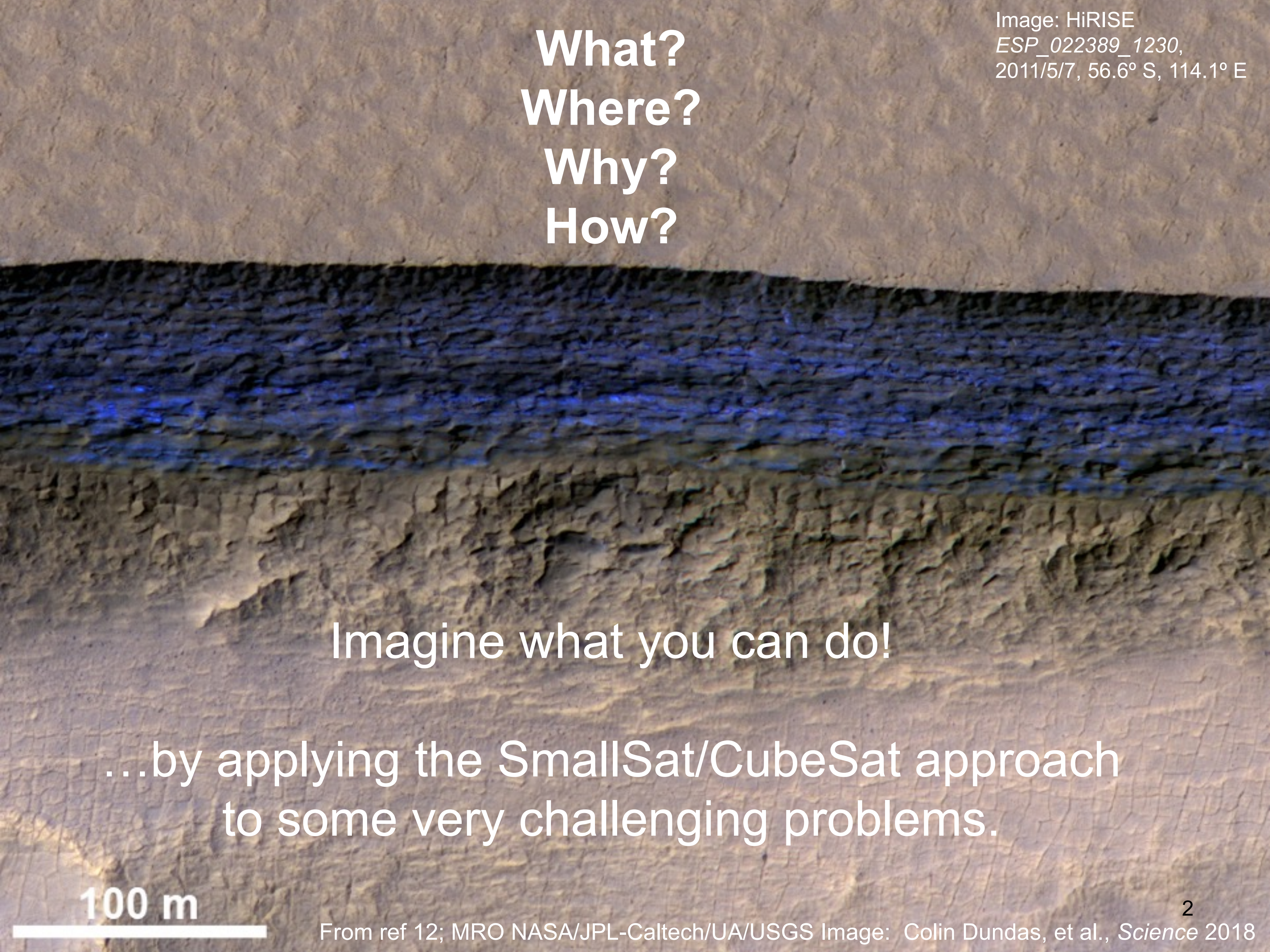


Image: HiRISE
ESP_022389_1230,
2011/5/7, 56.6º S, 114.1º E

What?
Where?
Why?
How?

Imagine what you can do!

…by applying the SmallSat/CubeSat approach
to some very challenging problems.

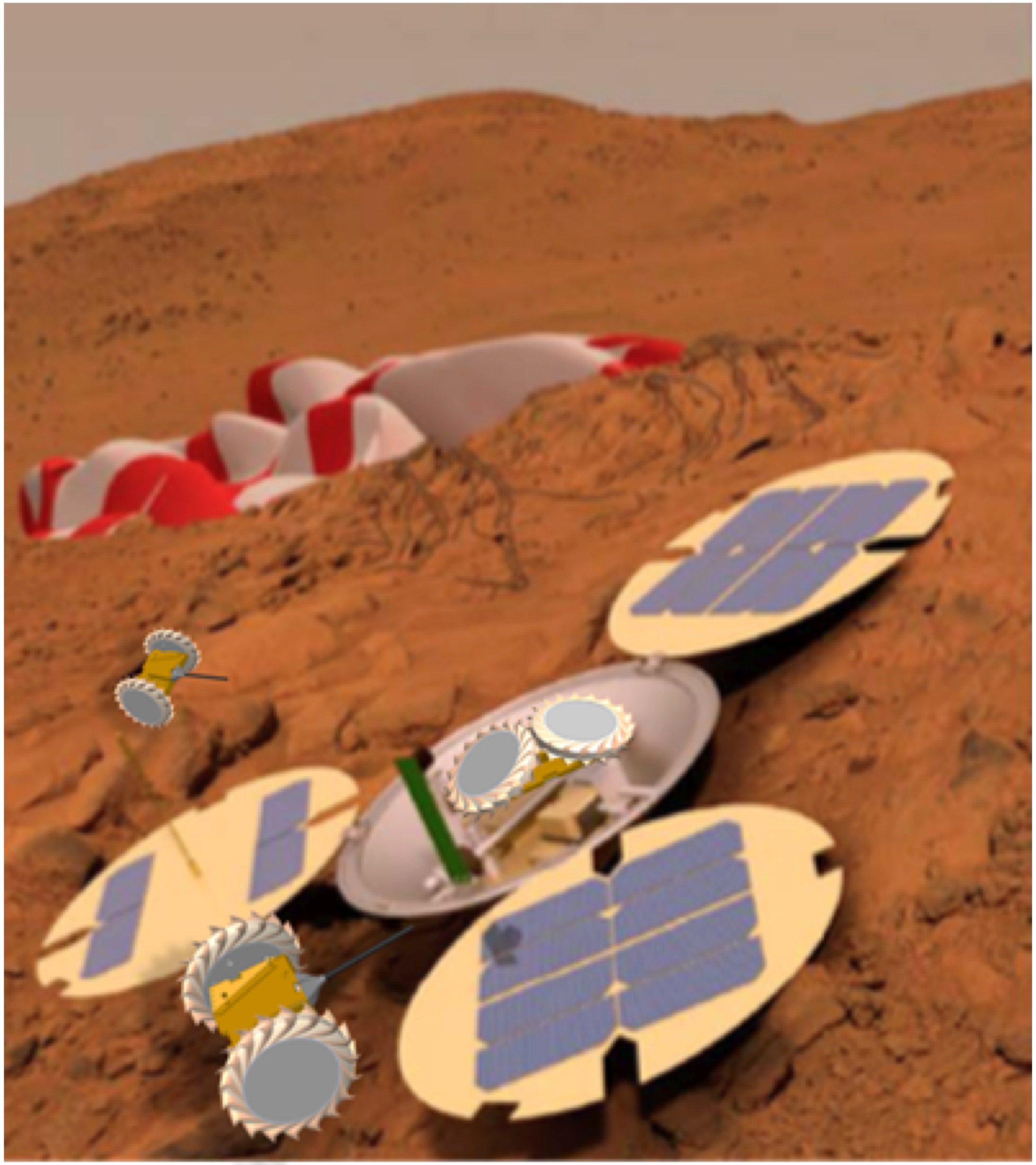
From ref 12; MRO NASA/JPL-Caltech/UA/USGS Image: Colin Dundas, et al., *Science* 2018

Affordable Mission Architecture to Search for Recent or Extant Martian Life

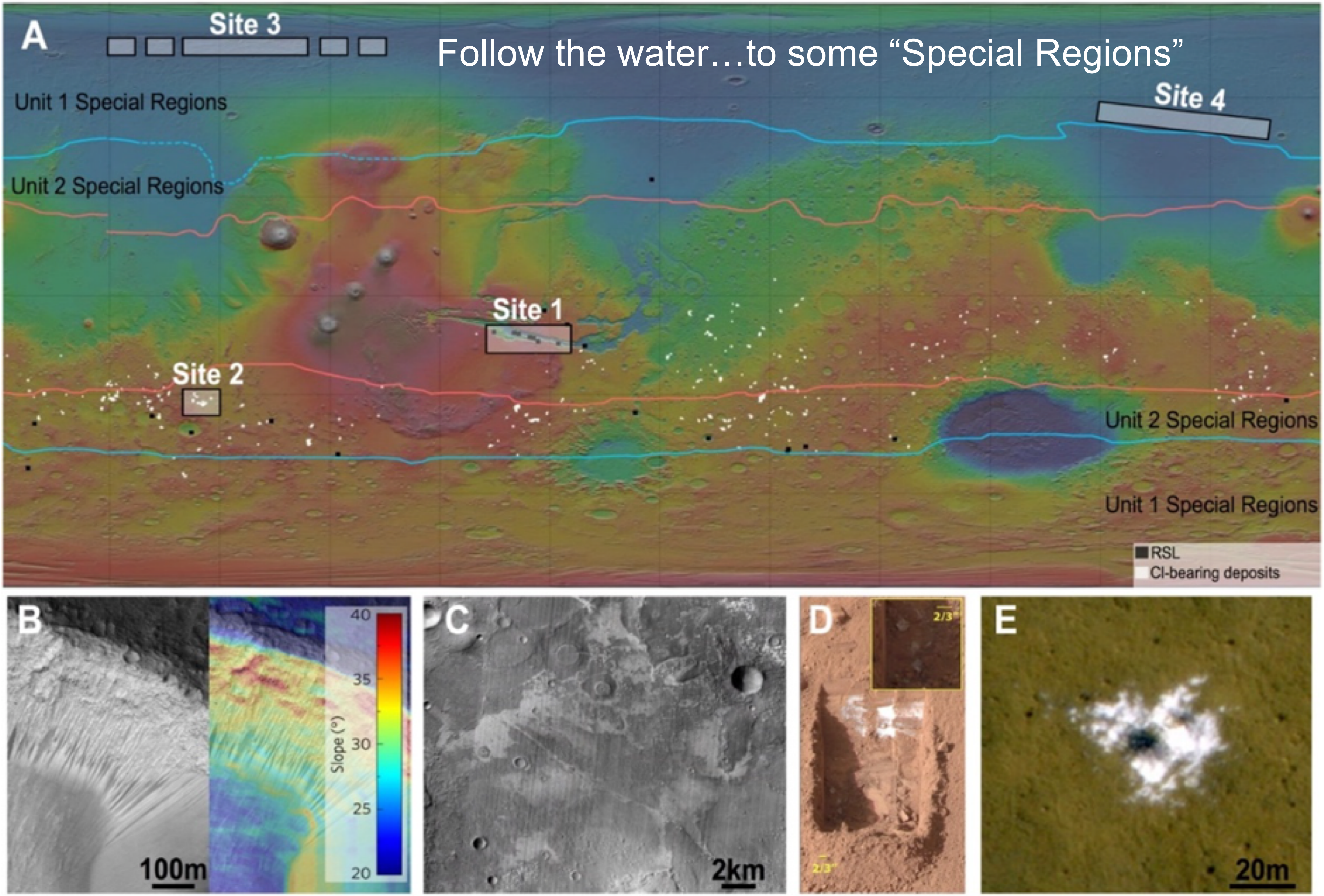
NASA Innovative Advanced Concepts (NIAC) 2017 proposal

PI = Robert L. Staehle;
Co-Is, Collaborators, & Other Professionals as on title slide

After a bounce-and-tumble landing, petals deploy from a microlander, followed by 3 PUFFERs to retrieve samples for biosignature measurements.



Aerospace Corp. artist's concept.



Site 1: RSL on crater slopes

Site 2: Cl-bearing deposits

Site 3: Polar ground ice

Site 4: Mid-latitudes ground ice

4/24/18

Potential Benefits

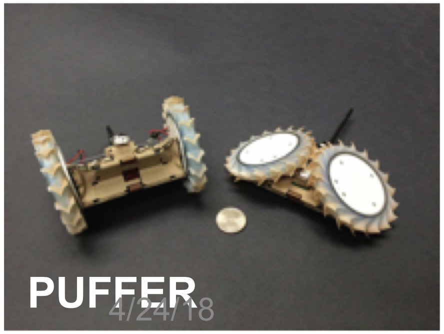
- Search for signs of life, if present, at the most likely surface expressions, before astronauts arrive and their waste blows everywhere.
- No current Mars surface mission architecture can affordably go to several locations with duplicate mini-instrument packages.
- No current mission architecture can access steep slopes where recurring slope lineae (RSL) and exposed ice layers are found, but MarsDrop can glide there to deploy PUFFERs that retrieve samples from possible “wet” locations to instruments.
- Planetary protection requirements for entering “Special Regions,” ~defined by the potential of liquid water & brines, require stringent sterilization procedures that no current architecture is capable of.
- Enable focused life-detection investigations to be carried as secondary payloads on primary Mars missions, to be dispersed to the most promising sites that could harbor life.

Composite of Earth and Mars images from NASA/JPL, Aerospace Corp. Lori Paul.

Enabling system/technology elements

1. MarsDrop microlanders[1], concept based on Reentry Breakup Recorder (REBR)[2, 3 ,4] plus steerable parawing and navigate-to-target video processing and terrain-relative control.
2. Pop Up Flat Folding Exploration Rovers (PUFFER),[5] a concept to find and retrieve samples to microlander.
3. Robotic Arm based on Miniature In-vivo Surgical Robot[6] to move soil samples.
4. Digital Holographic Microscope (DHM)[7,8] and image processing software and video processing to detect and track any organism motility.
5. Amino Acid Chirality Differentiator (AACD) electrochemical and electro-optical instrumentation to search for amino acid biosignatures.[9]
6. Semi-autonomous navigation and investigation operations software[10] to enable mission
7. operations with modest ground teams across simultaneous investigations at multiple sites.
8. Sterilization/cleaning of all hardware elements, allowing exploration of Special Regions.[11]

Mutual trades among these technology advancements to converge upon a smallsat-based mission architecture to be overlaid as secondary payloads on the schedule of primary Mars missions for a modest additional cost.



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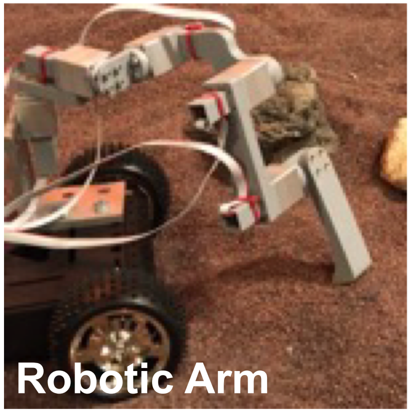
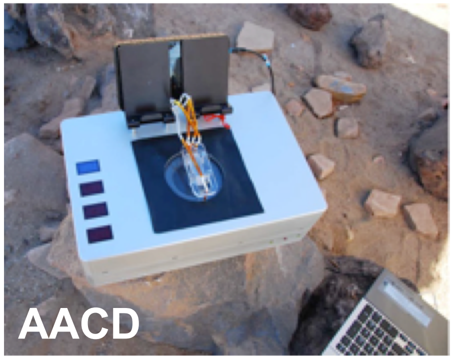
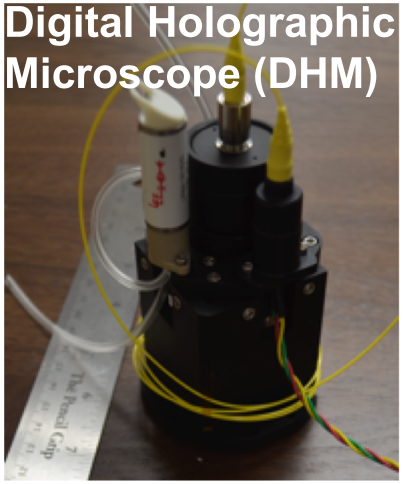
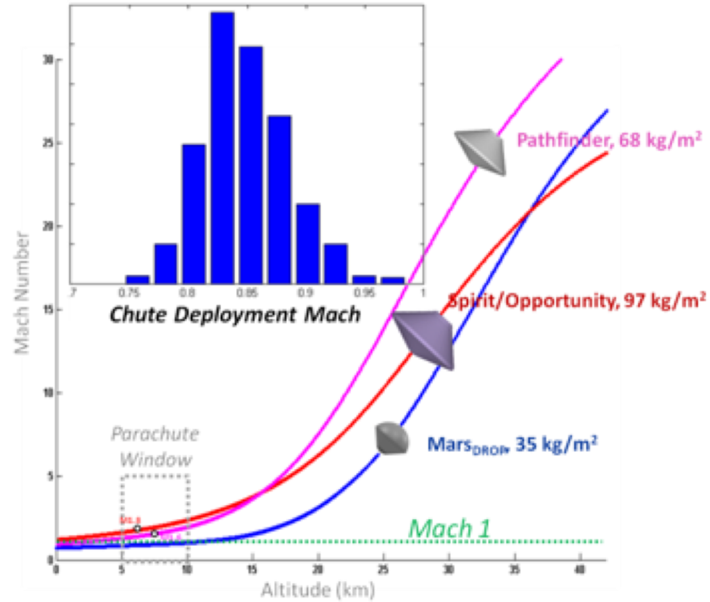


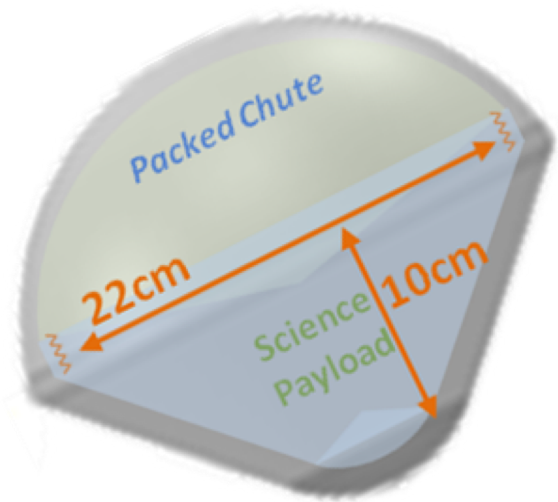




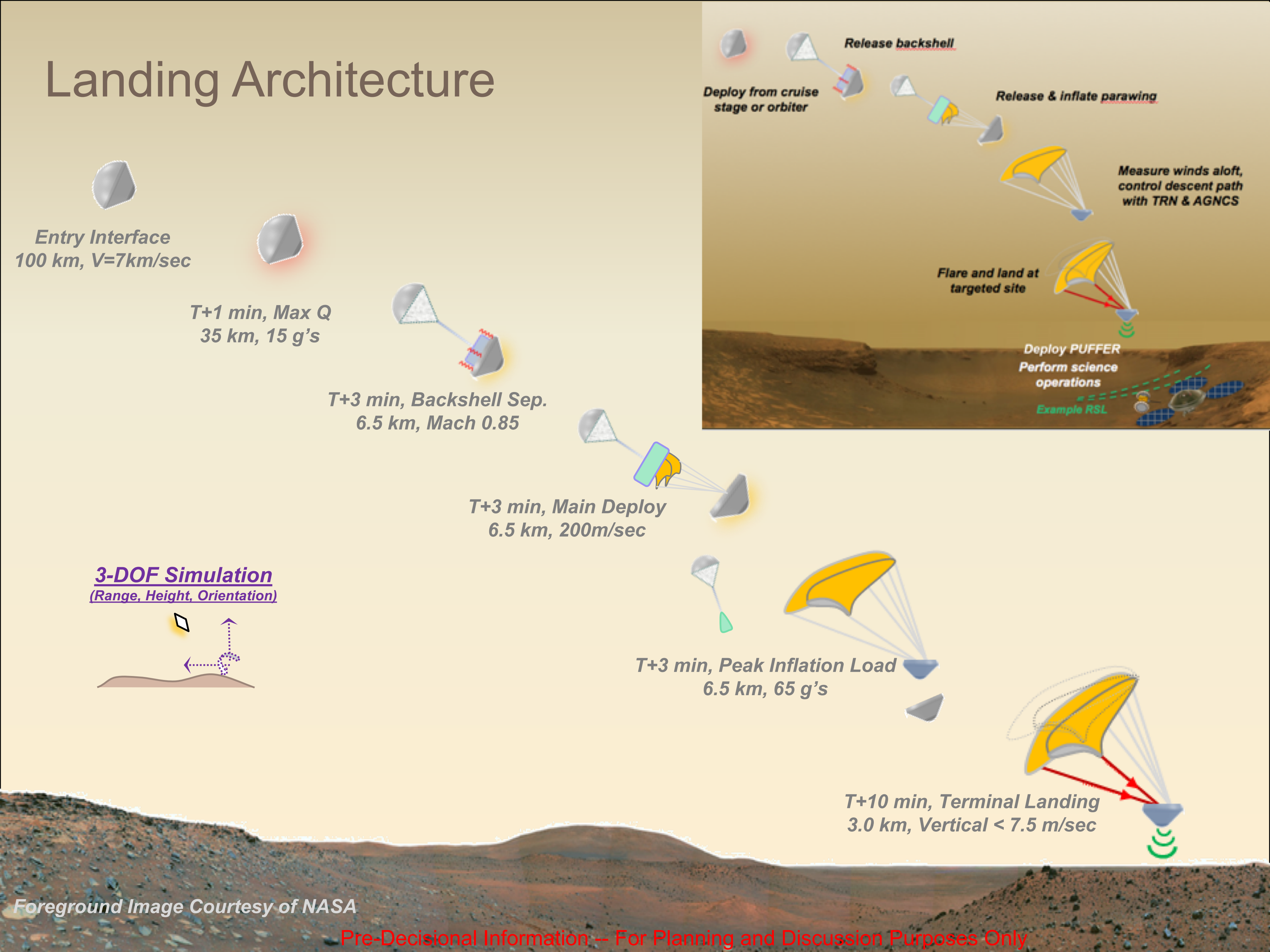
Capability Summary (conceptual)

- Probe is largely inert ballast from the host standpoint, added burden of 10 kg per probe.
- Probe shape derived from REBR/DS2, provides passive entry stability.
- Entry mass limited by the need to provide a subsonic parachute deployment
  - *3-4 kg probe entry mass*
  - *Accommodates a ~1 kg science payload*
- Packed parawing preserves a significant portion of the volume for a landed payload.
- Parawing is steerable, opening the way for targeted landing.





Landing Architecture

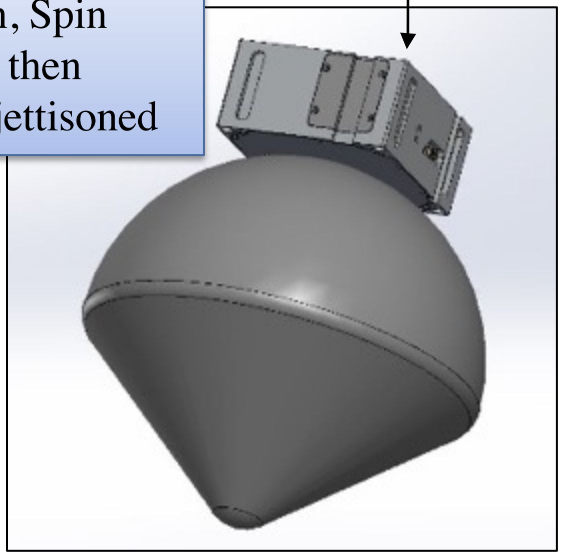


Going to Mars on Earth

Flight	Test Objective	Setup	Drop Altitude	Chute Deploy V	Chute Deploy Q	Canopy Condition	Test Result
MARS$_{DROP}$ 0 *(May 2013)*	Launch, Tracking, Recovery	Only Flight Computer	104,000	N/A	N/A	N/A	Experimental Setup Checked
MARS$_{DROP}$ 1 *(May 2013)*	Parawing Deployment	Chute Bomb	80,000	-	-	-	Electrical Short-No Parawing Deployment
MARS$_{DROP}$ 2 *(Sept. 2013)*	Parawing Deployment	Chute Bomb	100,500	300 mph	200 Pa (On Target)	No Damage	Successful Inflation, Backshell Tangled with Lines Post Deployment
MARS$_{DROP}$ 3 *(Feb. 2014)*	Capsule Demonstration	Capsule	115,000	500 mph	410 Pa (Overtest)	No Damage	Capsule Oriented Backwards-Canopy Inverted at Deployment
MARS$_{DROP}$ 4 *(May 2014)*	Capsule Demonstration	Capsule	114,000	550 mph	580 Pa (Overtest)	Minor Damage-Wing Tip Line Snapped	Successful Inflation & Deployment from Capsule-New Packing Procedure Verified
MARS$_{DROP}$ 5 *(Sept 2014)*	Capsule Demonstration	Capsule	111,000	400 mph		No Damage	Successful Inflation & Deployment from Capsule-AoA Too High

Phases & Configuration (conceptual)

1) Deployment, Orientation, Spin Initialized, then Backpack jettisoned

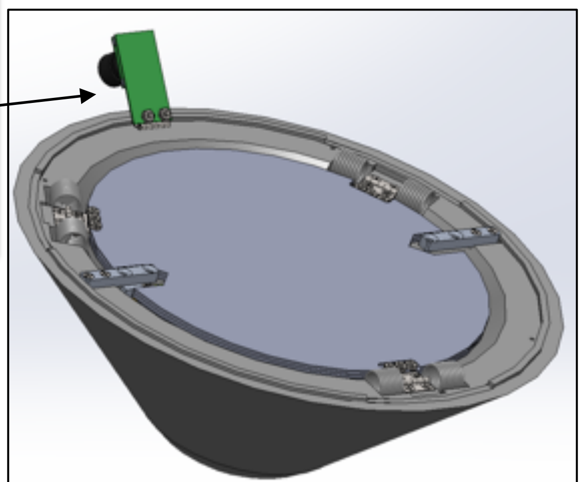


1) **Deployment:** *Backpack Unit* is 0.5 U XACT BCT (includes batteries) module to sense & control attitude, then impart spin (~2 rpm) required for stability through entry; jettisoned at entry interface

2) **Entry:** Maximum deceleration ~12 g's and heating ~150 W/cm^2 at ~40 km altitude from Mars surface

2) Entry, jettison Backshell, then Parawing & Descent Camera deployed

(lines to parawing not shown)



Representative descent characteristics for Mars Microprobe (Mars$_{DROP}$ is very similar with β=36.4 kg/m^2 with Current Best Estimate mass)

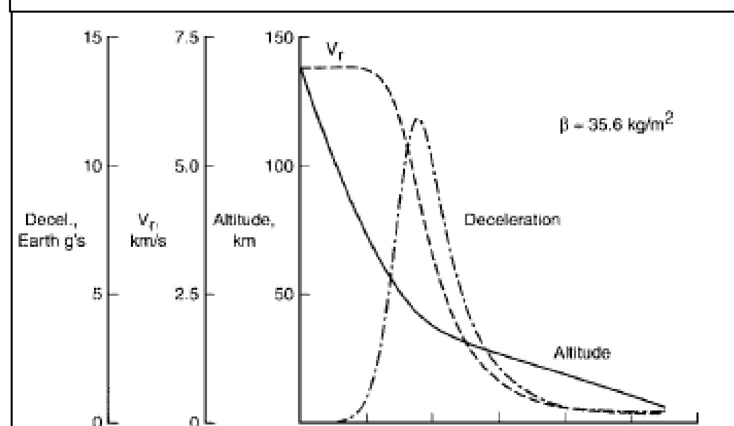
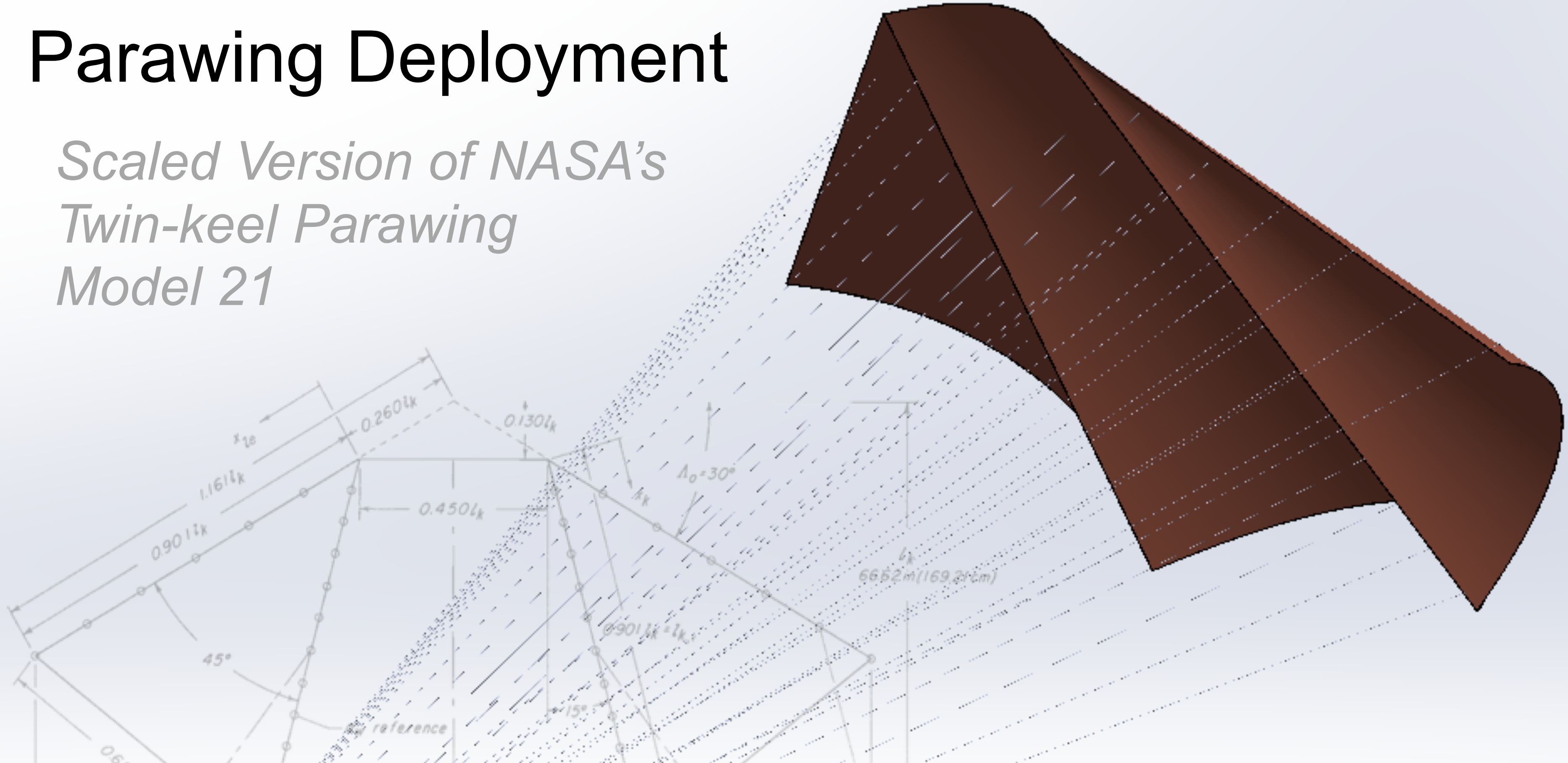
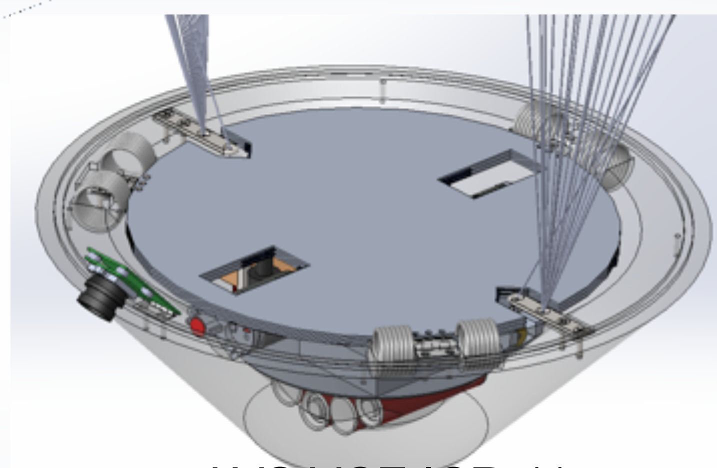


Figure reference: R. Braun et al., "Mars Microprobe Entry-to-Impact Analysis", JSR, 1999.

Parawing Deployment

Scaled Version of NASA's Twin-keel Parawing Model 21



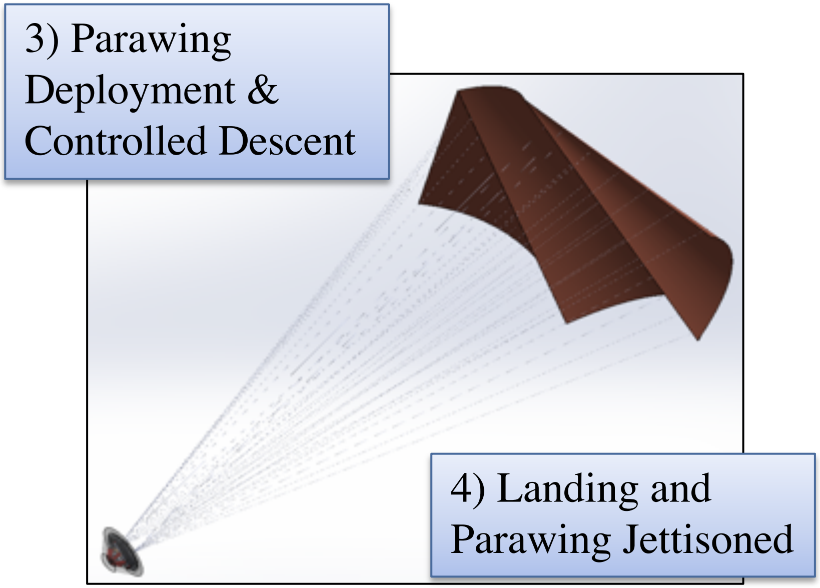


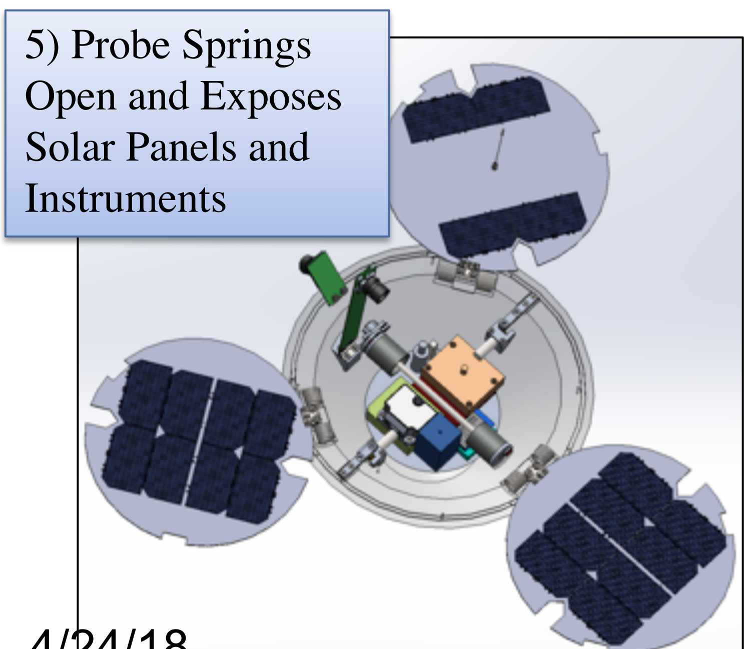
NASA Graph: Technical Note D-5965

Design Sizing Point

- *L/D = 3, CR=1.00*
- *Produces a 70° Glide Angle*

Phases & Configuration (conceptual)





3) Parawing Deployed: Parawing released to enable gliding and controlled descent.

Controlled Descent: Camera pointed at ground/ horizon for position/altitude determination.

On-board navigation algorithms control actuators that pull on wingtips to turn (one wingtip) or change glide angle (both wingtips).

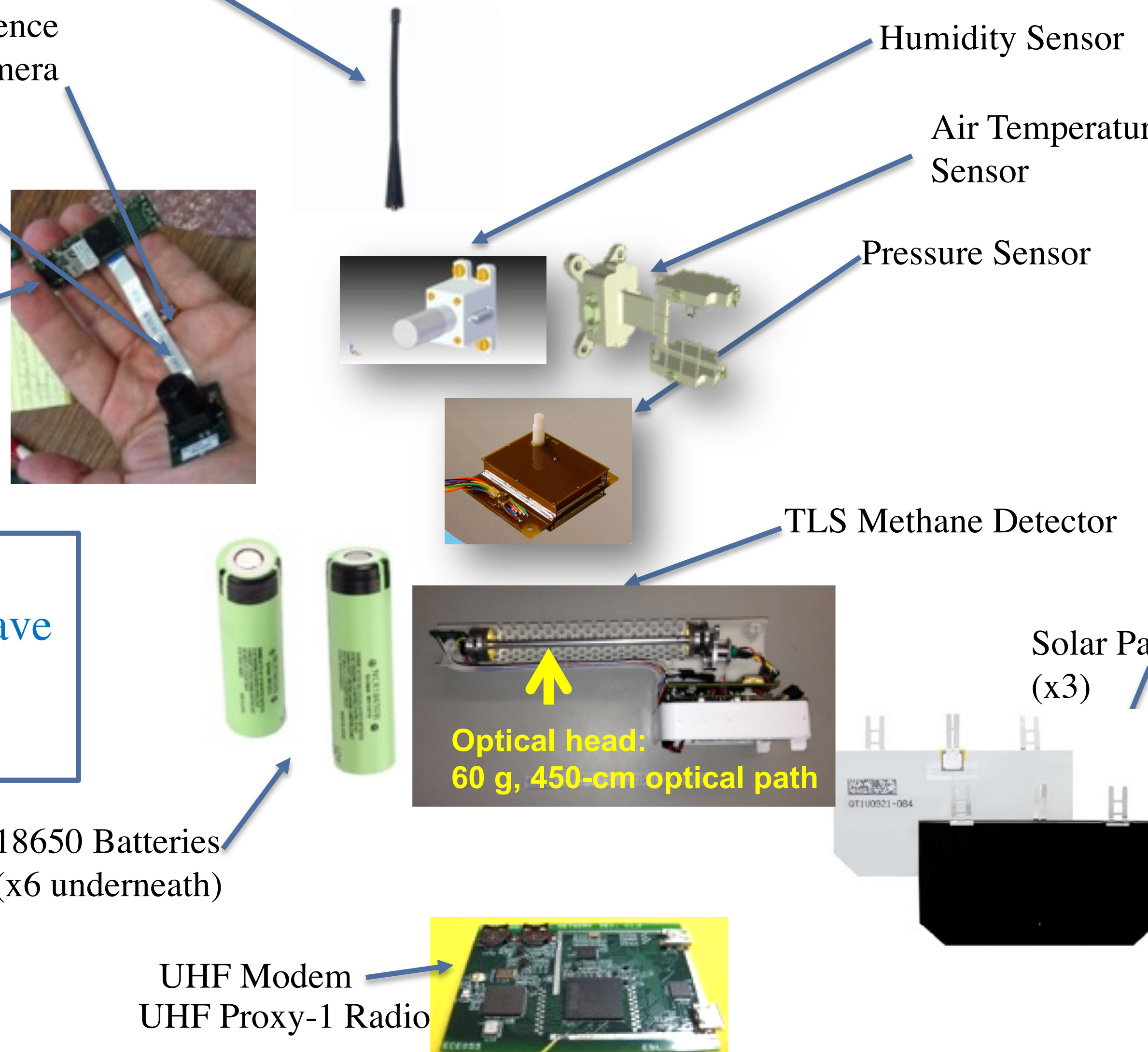
Nominally a ~3:1 glide ratio is achieved. The navigation system helps probe glide to pre-selected landing sites.

4) Landing: Expected speeds ~20 m/sec total, ~7 m/sec vertical, 18.7 m/sec horizontal, flare possible. Rolling expected and probe designed for expected impact forces (~300-500 g's).

5) Opening: Springs are powerful enough to "right" spacecraft regardless of landing orientation and expose "platters" to sky.

Configuration Overview

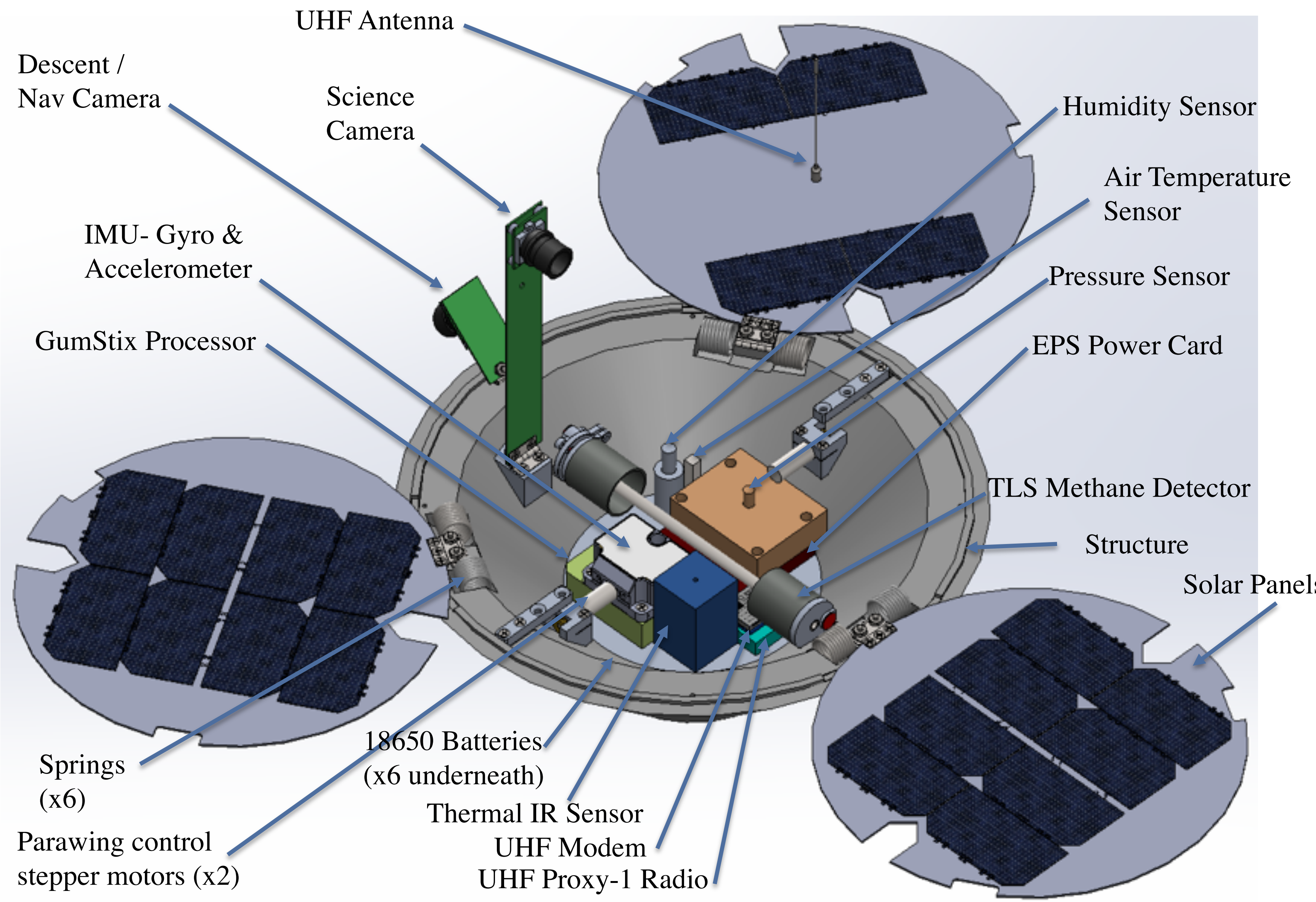
Suppliers shown only for proof-of-concept; no selection is represented.



Most hardware elements physically exist and many have flight heritage on previous Mars missions or CubeSats.

Equipment shown only for proof-of-concept. No vendor selection is represented.

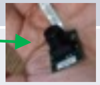
Configuration Overview

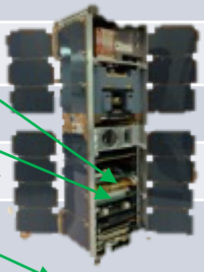


Master Equipment List

Suppliers shown only for proof-of-concept; no selection is represented.

Subsystem	Components	Mass	Power	Heritage / Supplier
Entry & Descent	Aeroshield (1,200 g), Parawing (400 g), Stepper motors (2 x 10 g)	1,620 g	-	REBR/Aerospace Corp.
Payload	Methane Detector (Tunable Laser Spectrom-TLS)	100 g	0.67 W	MSL/ JPL
	Pressure, Air Temperature, and Humidity Sensors	113 g	0.43 W	MSL/ JPL, various
Payload/Navigation	Descent/Geology Camera (2 x 40g)	80 g	1 W	None*/ Aptina
Navigation	IMU (Gyro & Accelerometer)	10 g	0.1 W	Variable/ Blue Canyon Tech.
Power	Body-Mounted Solar Panels (20 x UJT Cells)	40 g	-	Variable/ Spectrolab
	Batteries (6x18650 Li Ions, ~16 W-hr each max)	270 g	-	INSPIRE/ Panasonic
	Electric Power System & Battery Board	80 g	-	RAX & INSPIRE/ JPL
Computing & Data Handling	Gumstix Flight Computer & Storage	10 g	0.5 W	IPEX/ Gumstix
Telecom	UHF Proxy-1 Radio	50 g	2 W	Variable/ JPL
	UHF Low Gain Antenna (Whip)	5 g	-	Variable/ JPL
Mechanical & Others	Shelf (68 g), Brackets (26 g), Wing Actuator (19 g), Springs (48 g), Hinges (7 g), Fasteners (20 g), Harnessing (50 g), and others (20 g)	256 g	-	Variable/ JPL
Thermal	Heaters (3 x 50 g), Aerogel (10 g)	160 g	2 W	Variable/ JPL
Sterilization	Sterilization Bag	100 g	-	Variable/ JPL
TOTAL	Total No Margin/ With 20% Margin	**2.9 kg/ 3.5 kg**	~3 W (avg)	-





*Radiation (~3.5 krad) and thermal testing will be performed to ensure reliability

Entry mass (3.5 kg) consistent w/ mass from Aerospace Corp. REBR flights from Earth orbit.

Note the Backpack (ACS & mechanical interfaces, spring for jettison) is an additional 0.7 kg/ 0.9 kg (30% margin).

- **Three years have passed since 2015 proof-of-concept set of components, not then qualified for the Mars environment…**
- **Now, independently, the Mars Helicopter technology demonstration is in-build and being qualified for possible launch aboard Mars2020.**

JPL artist's concept.

Pre-Decisional Information -- For Planning and Discussion Purposes Only

Enabling system/technology elements

1. <u>MarsDrop microlanders</u>[1], concept based on Reentry Breakup Recorder (REBR)[2, 3 ,4] plus steerable parawing and navigate-to-target video processing and terrain-relative control.
2. <u>Pop Up Flat Folding Exploration Rovers (PUFFER),</u>[5] a concept to find and retrieve samples to microlander.
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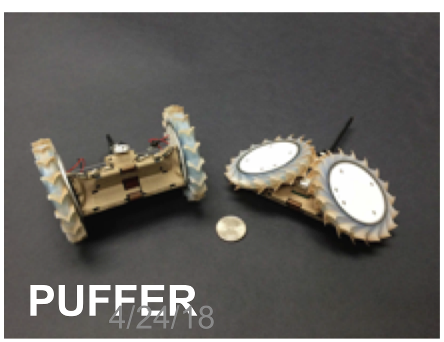
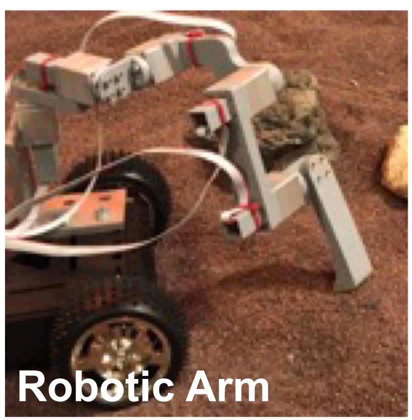
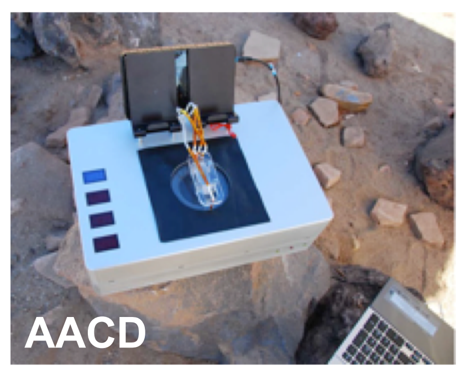
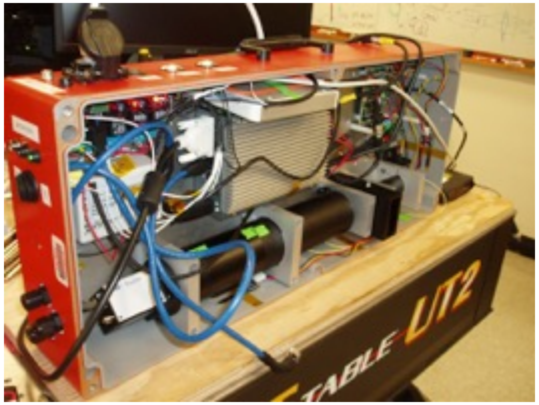






Looking for signs of life with a small instrument: Digital Holographic Microscope [Chris Lindensmith, et al.]

Carry-on size 2014



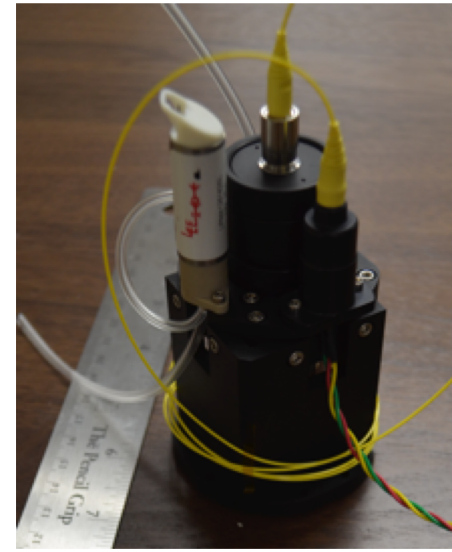
FOV = 360 um wide

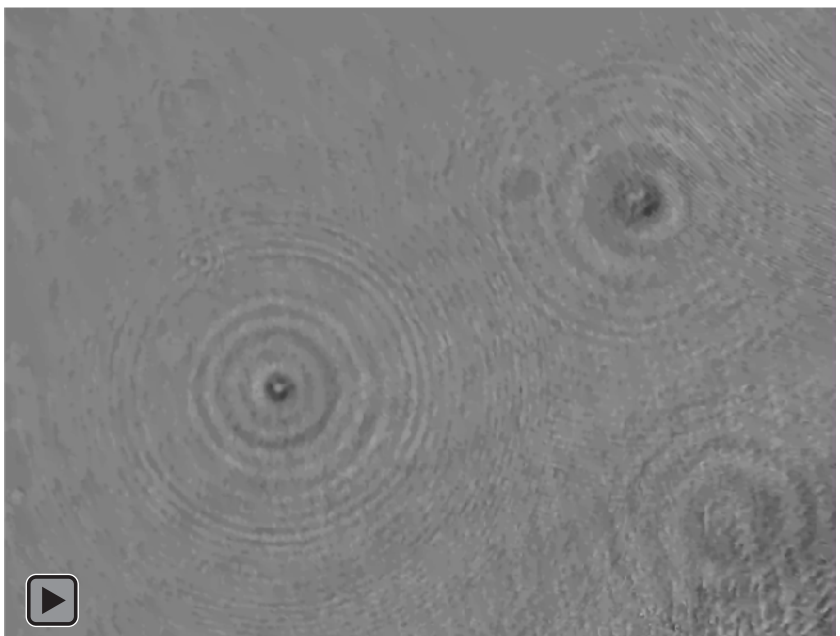
Ice melt, Nuuk, Greenland

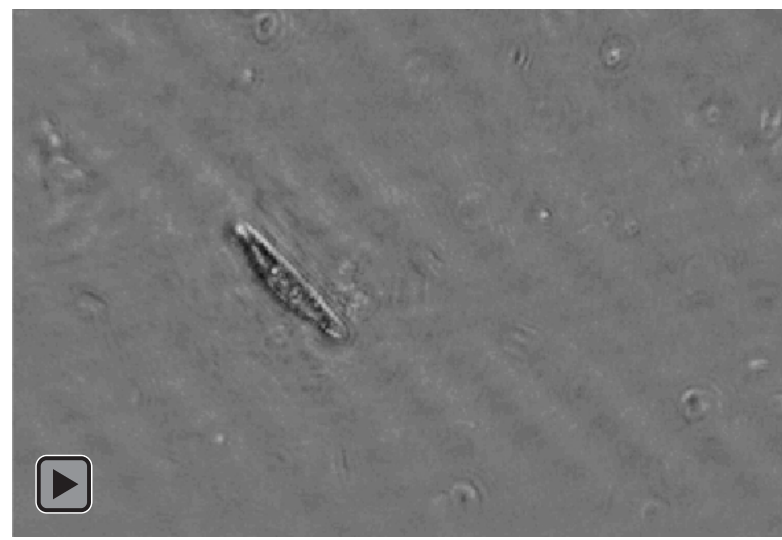
60x25x12 cm

Brine pool, Badwater, Death Valley, CA

Soda-can size 2017



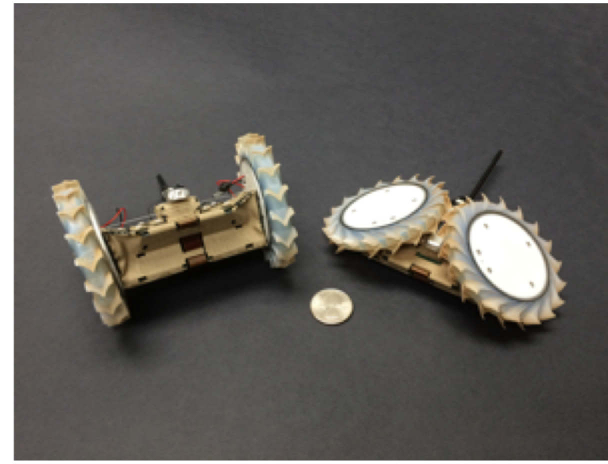


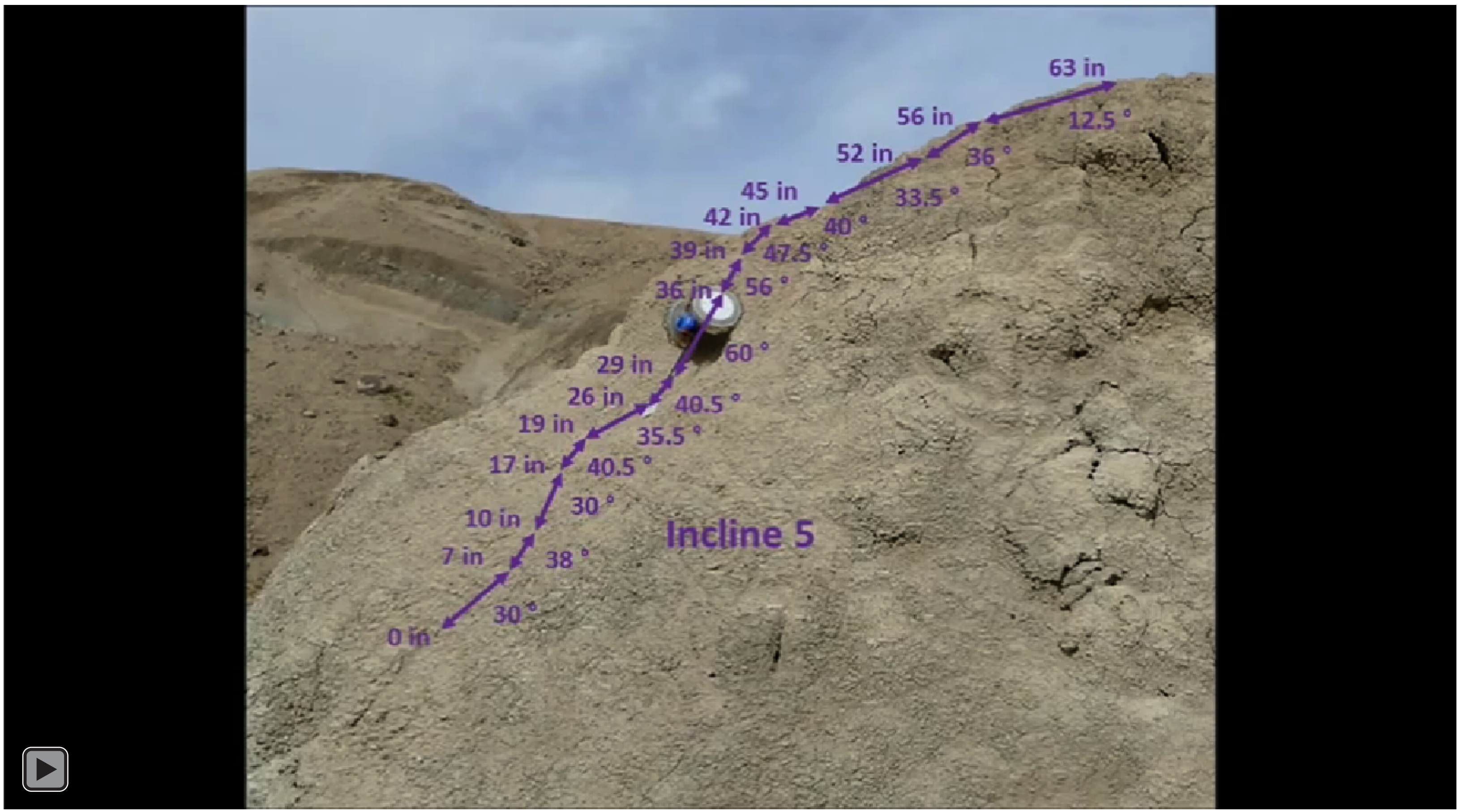


Early concept: MarsDrop microlander, micro-robot arm & Digital Holographic Microscope (all mockups)

Pop-Up Flat-Folding Exploration Robot (PUFFER)

Jaakko Karras, Kalind Carpenter, et al., Jet Propulsion Laboratory. 2017





The reviewers loved it….

"This is a proposal to create a new way of landing on and exploring the surface of Mars in order to facilitate the search for life there. ... Certainly the searches of previous landers have focused primarily on geology, … As this proposal makes clear, this stays away from areas that might be more favorable to life."

"It is a strongly motivated proposal because the search for life on Mars is probably the most interesting mission that NASA has undertaken in recent decades. …"

"This proposal lays out an understanding of the many issues that have to be addressed. The approach used is to address them all rapidly in parallel and to come to conclusions about the right course of action. Certainly the large team of 14 people seems quite qualified to address the issues. This gives confidence that the study will be properly executed."

The reviewers loved it….NOT!

"The success of this new method of landing on and exploring Mars for life depends upon a succession of major technological successes. This proposal is an N-miracle idea, where N miracles have to occur for the mission to succeed. If N were 1 or 2, it would be credible for the solicitation, but this proposal has N>3. This is not particularly appropriate for this solicitation." …

"To realize this mission, multiple concerns abound: development in miniaturizing instruments, Pop Up Flat Folding Exploration Rovers (PUFFER) autonomy, High-Performance Space Computer (HPSC), communications, power, battery density, Terrain-Relative Navigation (TRN), and Entry, Descent & Landing (EDL)."

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Imagine what you can do!

…by applying the SmallSat/CubeSat approach to some very challenging problems.

Thank you!
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Robert Staehle
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