MARS$_{DROP}$: Getting Miniature Instruments to the Surface of Mars as Secondary Payloads

Affordable microlander concept that could take instruments to difficult sites inaccessible to large landers and rovers

Full-size and flight-weight MarsDrop Lander prototype (on table) and parawing (in hands) were dropped from 30 km in deploy-ment tests, demonstrating a key element of this concept.

Photo by Lori Paul

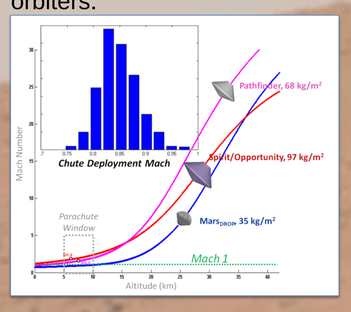
Robert L. Staehle[1], Matthew A. Eby[2], Jared J. Lang[2], Jeffrey A. Lang[2], Rebecca M. E. Williams[3], Justin S. Boland[1], Rebecca Castano[1], Marc S. Lane[1], Chris A. Lindensmith[1], Sara Spangelo[1].

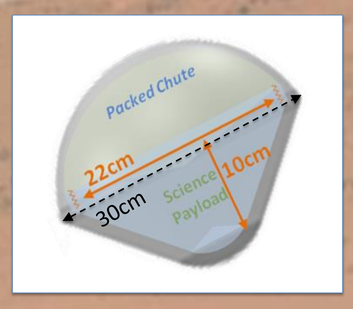
[1]Jet Propulsion Laboratory, California Institute of Technology (4800 Oak Grove Drive, Pasadena, California 91109, robert.l.staehle@jpl.nasa.gov)

[2]The Aerospace Corporation (2310 El Segundo Blvd., El Segundo, CA 90245, matthew.eby@aero.org

[3]Planetary Science Institute (1700 East Fort Lowell, Suite 106, Tucson, AZ 85719, williams@psi.edu

- Nearly all Mars missions fly with excess Cruise Stage mass capabilities, often >>100 kg. MarsDrop mass on host mission, including deployment hardware, is ~10 kg.
- Aerospace Corp. has successfully flown the Re-entry Breakup Recorder (REBR) three times from Earth orbit down. MarsDrop would use the identical aeroshell.
- The 9 km/sec Earth entry velocity creates much harsher conditions than ~7 km/sec Mars direct-entry missions and 3.5 km/sec from orbiters.

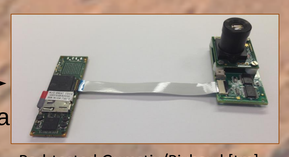




- REBR's small size (30 cm diameter) provides a low ballistic coefficient, meaning that it decelerates to subsonic velocity several kilometers above Mars' surface.

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

- Subsonic deployment would enable a simpler and lighter drag device that has been tested at full scale 30 km above Earth.
- Parawing would descend at a 3:1 glide ratio at Earth and Mars. At Mars, descent time is ~7-15 minutes; with ~7 m/sec vertical velocity at touchdown.
- Total touchdown velocity ~20 m/sec; fully survivable by today's consumer electronics with crushable heat shield support structure. Landing would be a shock/tumble/roll over 10's of meters.
- *But wait; there's more…* Precision Landing
  - Precision landing capability could be added after first "Science Demonstration Mission."
  - Multiple scientific targets of interest, e.g., RSL's, would be selected within landing error ellipse, each ranked for science value.
  - After parawing deploys, a descent camera would locate targets sites within range + control authority. Onboard software chooses best site, then terrain-relative nav using scene-matching from historical orbital imagery drives actuators on parawing lanyards for left/right/descent rate control.



Rad-tested Gumstix/Pixhawk[tm]

- Sterilization could allow access to "special regions" where there may be liquid water:
  - Subject to further study, we expect MarsDrop can be assembled clean, then sterilized >111 C for >24 hrs.
  - Batteries are exception; can be sterilized by alternate method, then inserted into heat-sterilized MarsDrop lander during final assembly using sterile procedures.
  - Fully-assembled MarsDrop would then be placed into sterile shrink-wrap bio-barrier bag, and sealed for ground handling and integration with host mission.
  - Bio-barrier bag would burn off during Mars entry.

The Bottom Line*

Cost estimated to be 1 – 5 % that of primary (host) mission.

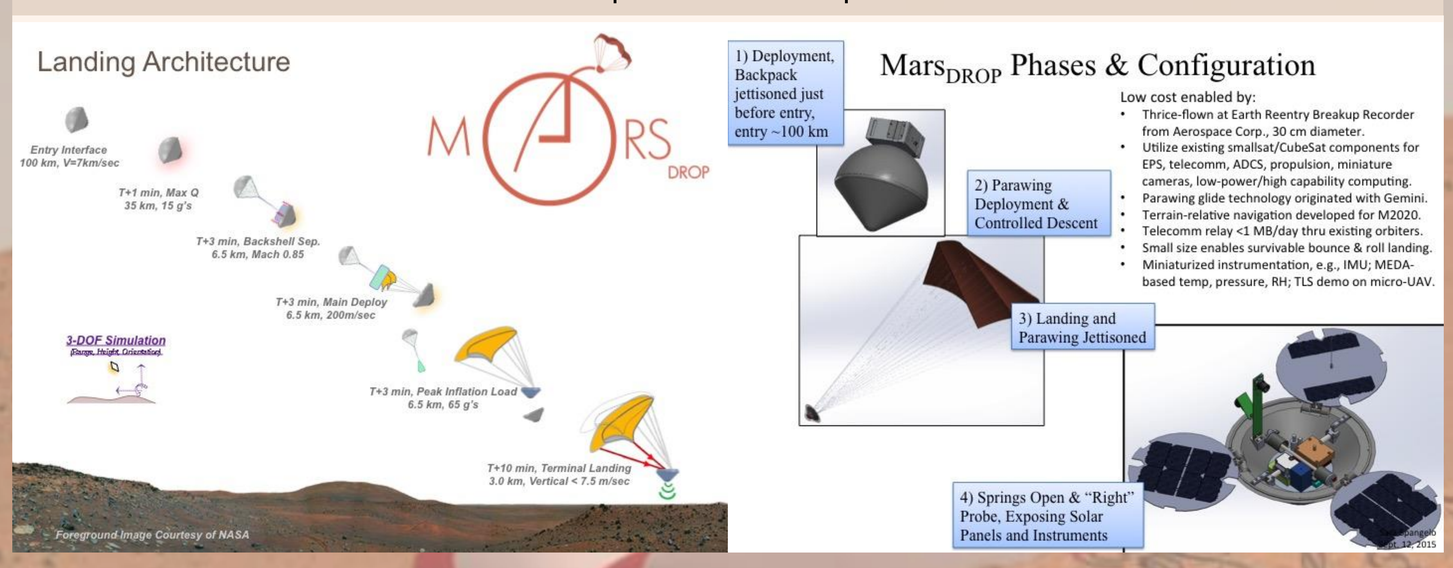
First unit "Science Demonstration Mission" estimated $20 – 30 M (including 35+% reserves, unreviewed), including deployment hardware.

Subsequent flight units expected ~$10 M each.

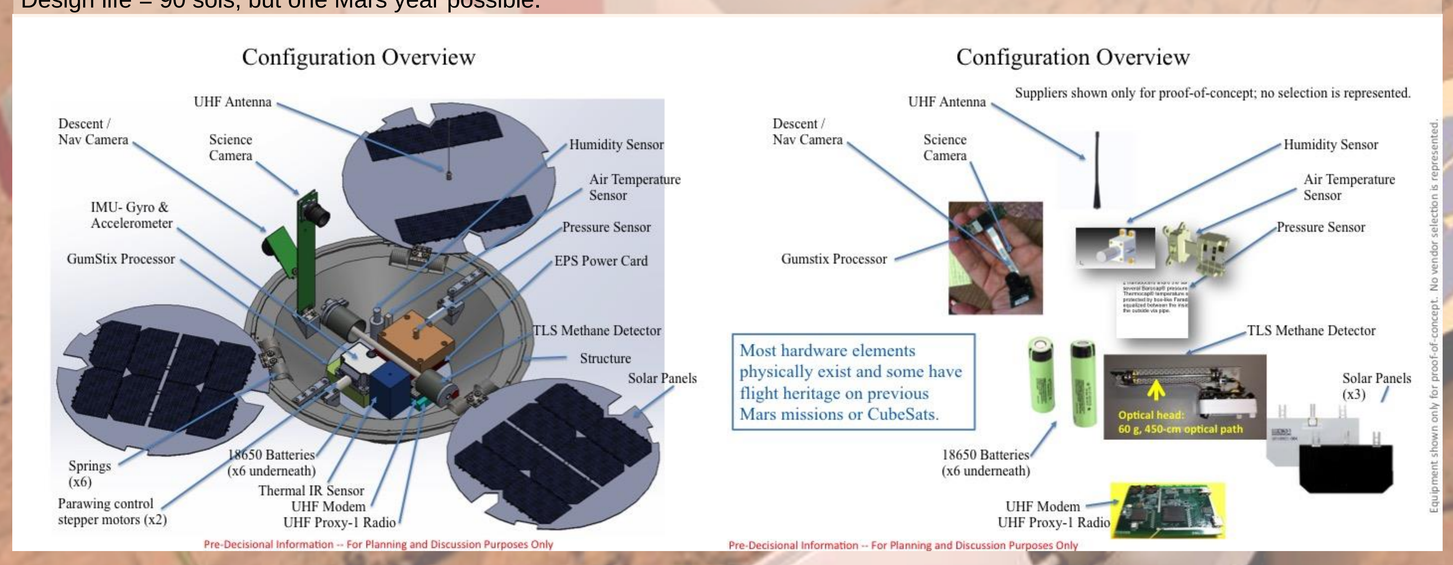
Where multiple identical units made for a single mission, copy cost estimated <<$10 M each, e.g., for network science.

*The cost information contained in this document is of a budgetary and planning nature and is intended for informational purposes only. It does not constitute a commitment on the part of JPL and/or Caltech.

Operations Concept



All components needed to comprise a functional lander are available today or soon, based on smallsat & CubeSat developments. Design life = 90 sols, but one Mars year possible.



After entry vehicle, parawing, and other equipment, there would be enough mass, power & volume available for a moderately sophisticated instrument suite. Strawman "Science Demonstration Mission" payload concept is ~300 g with camera, pressure, temperature and humidity sensors + tunable laser spectrometer sensitive to a few ppb CH_4.

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).

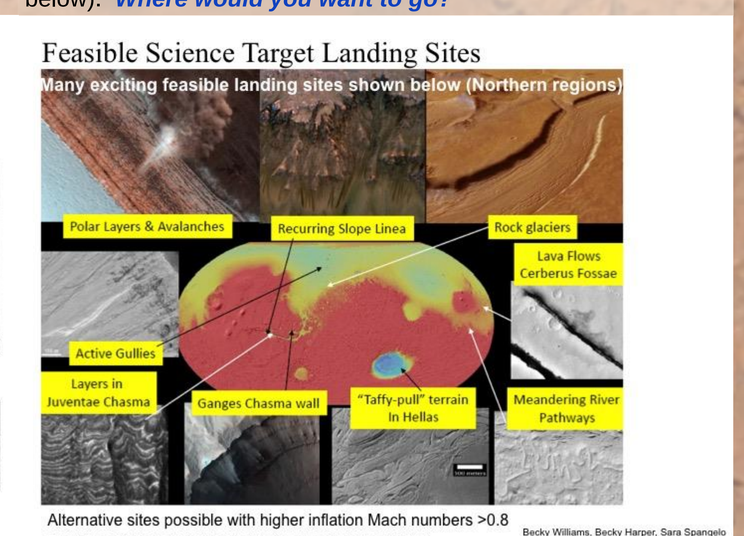
Pre-Decisional Information -- For Planning and Discussion Purposes Only

Survey: Any of a variety of plausible instrumentation, serving a span of Science, can be accommodated

Instrument Type	Mass (g)	Power (mW)	Max Dimension (mm)	Example	Modification Required	Measurements & Remarks	JPL POC
Digital Video Holographic Microscope	300	8000 (peak)	150	DHM 2015, Greenland field test	Replace lenses w/ fiber for light mgmt (lab demo done). Shrink electronics and Mars-qual	Microscopic imaging to <1 um (bacteria-size) res, in "focus" throughout >0.5 mm depth-of-field. Detect & track any motility; autono-mously distinguish non-Brownian/non-flow.	Chris Lindensmith
Video Camera	74	600-1900	60	GoPro Hero3	Rad tolerance; modify for external control	720p, 960p, 1080p video with 3 FOVs up to ~150 deg. 5, 7, 10 MP pictures with 3 -10 fps.	Travis Imken/ Tim Goodsall
Legacy still camera	220	210	67	MER/MSL Hazcam & Navcam	Lander to provide input voltages and camera control	High heritage; scientific quality CCD still images up to every 5 sec. >20 units to Mars.	Marc Walch
SmartCam	<100	<1600	58	PIXHAWK	Low op temp, Rad tolerance.	Machine vision camera and processing to support glide-to-target guidance.	Justin Boland
uSeismometer	200	100	30	JPL Microdevices		Performance comparable to conventional terrestrial seismometer.	Rebecca Williams/ PSI, Sharon Kedar
Weather Monitor	≤1930	12,750 (peak)	140	REMS/MSL, Twins/InSIGHT	Adapt to the desired envelope.	Configuration is flexible and sensors can be added or subtracted/replaced + aerosol monitoring sensor via a dedicated camera.	Maneul de la Torre Juarez
Aerosol Properties Sensor	630	4300 (peak)	70	REMS/MSL, Twins/InSIGHT	Adapt to the desired envelope.	Camera from above + set of photodiodes; from Mars 2020	Manuel de la Torre Juarez
Multispectral Mirscopic Imager VNIR	240	3000 (60 sec.)	67	MER-MI Rosetta ROLIS Phoenix RAC	Wider FOV	Infer mineral grain composition at <1 mm scale. Operates day (panchromatic) or night (multispectral 0.4 to 1.0 microns).	R. Glenn Sellar
Multispectral Mirscopic Imager VSWIR	150	9000 (5 mins)	110	MIMI Mars 2020 proposal	Wider FOV ~30 x 30 xm. Consider COTS InGaAs camera	Infer mineral grain composition at <1 mm scale. Passively-cooled HgCdte - operates at night (multispectral 0.45 to 2.45 microns).	R. Glenn Sellar
Deep UV Fluorescence Imager	700	3000 (peak)	150	Lab demo	Communication/power from vehicle.	Organic detection. Small UV light sources dependent on current DARPA efforts.	Rohit Bhartia
Tunable Laser Spectrometer	400	400	100	CH_4 sniffer for PG&E	Miniaturized cell, electronics, low power laser packages.	CH_4 to 1 ppbv. Heritage from TLS-MSL and quadcopter versions.	Chris Webster, Lance Christensen

Other instrument selections possible, e.g., Digital Holographic Microscope. ***What instruments would you want to fly?***

Sites below -3.8 km MOLA initially achievable (see examples below). ***Where would you want to go?***



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Could your science investigation or instrument benefit from this architecture? We're happy to discuss:

Robert Staehle
robert.l.staehle@jpl.nasa.gov
+1 818 354-1176

Planetary Science Institute

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