Jet Propulsion Laboratory
California Institute of Technology

Planning for Potential Future Missions of MSR: Interfacing and Complementary Science

Lindsay Hays

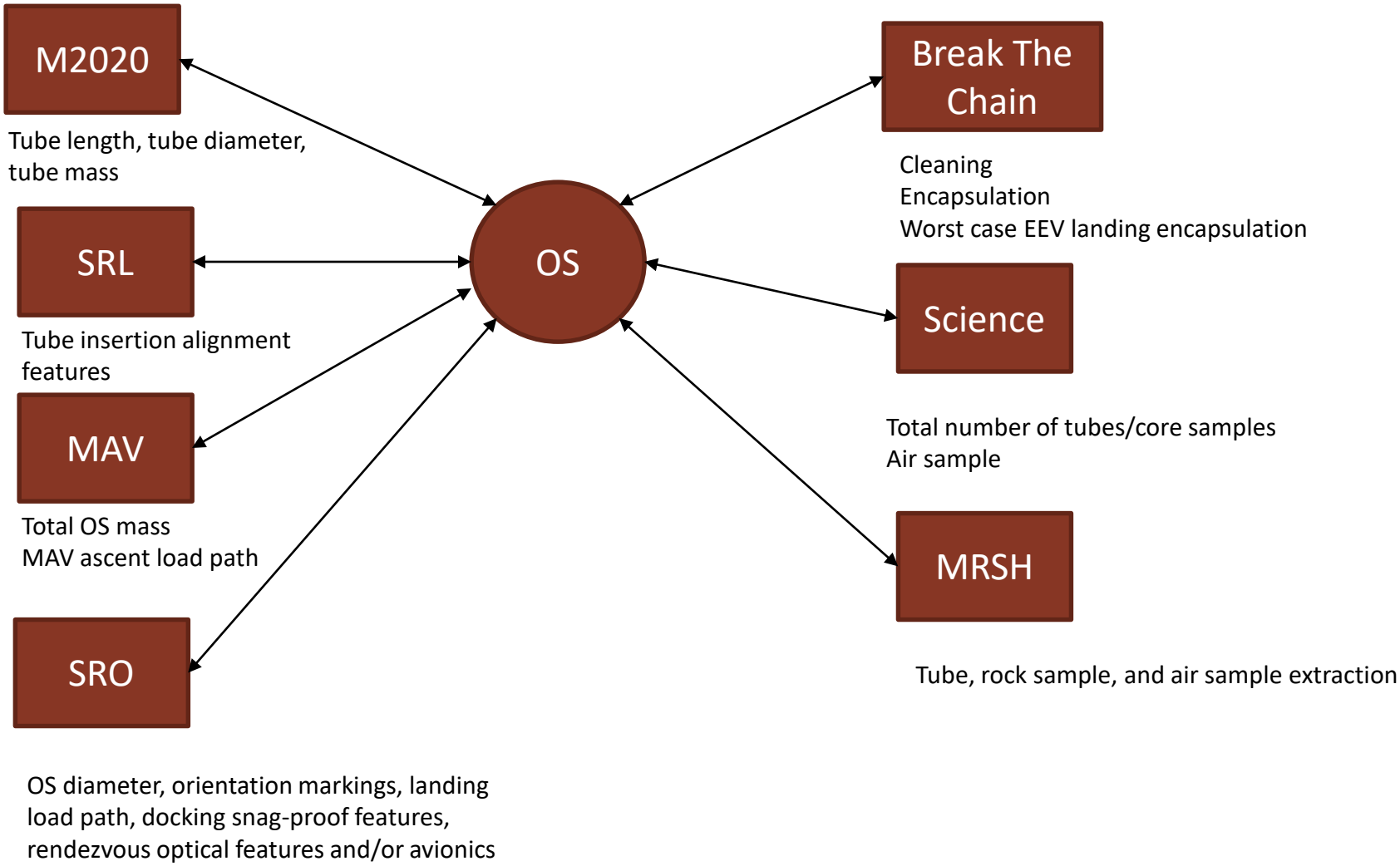
Jet Propulsion Laboratory/Caltech

Interfacing with Future Missions

Design

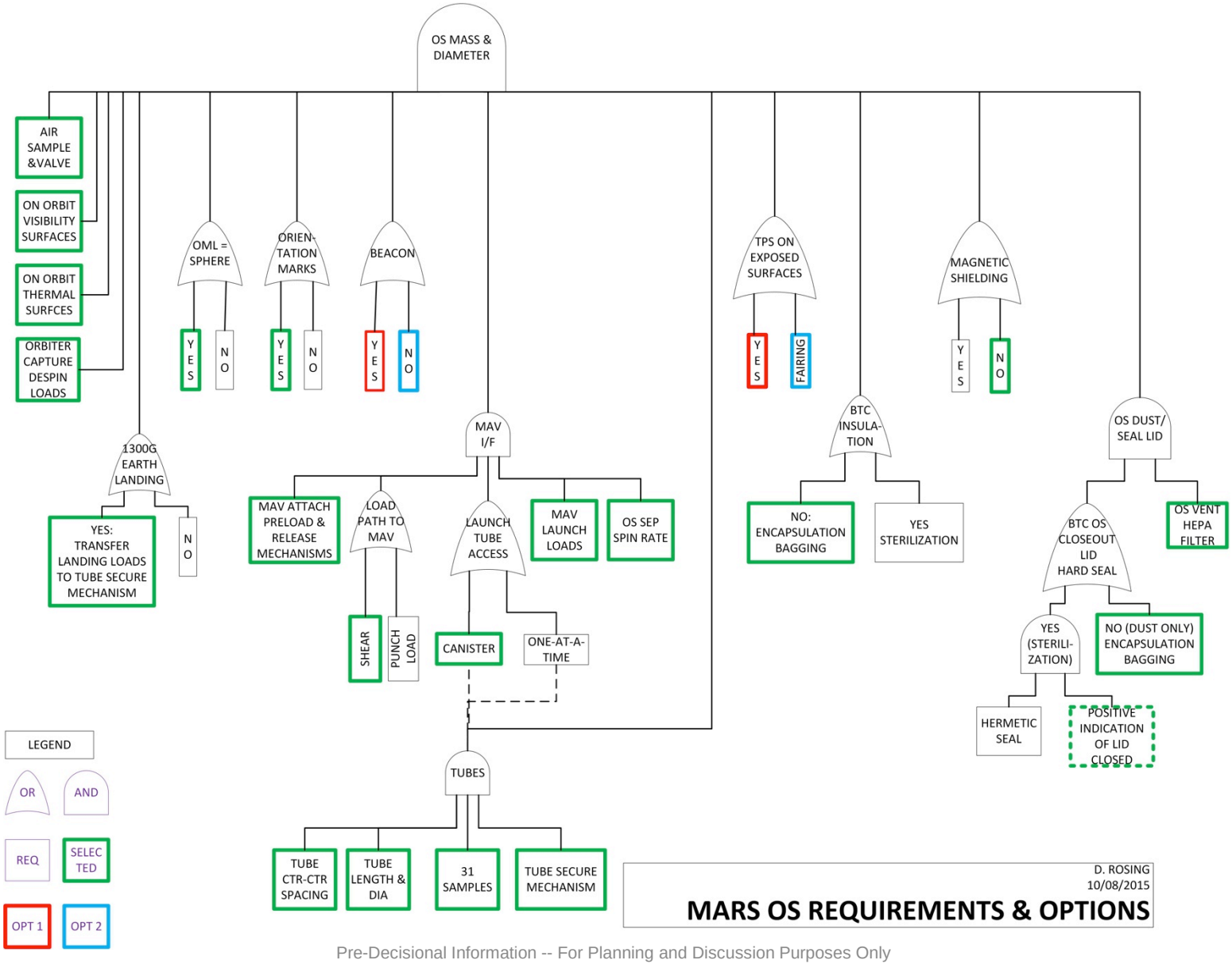
- Advanced Development Team - proxy for potential future MSR projects
  - Addressing and setting requirements for interface hardware
    - Orbiting sample container (OS)
    - Tubes
  - Testing of articles to prove that the samples survive environments consistent with a range of future MSR architectures

OS is the node that interacts with every stage of the potential MSR campaign



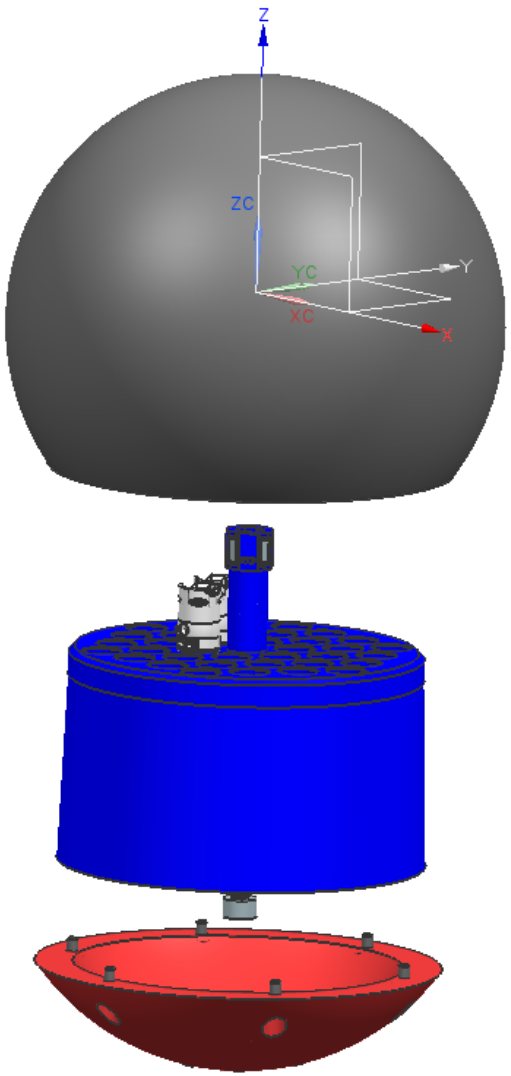
Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

Multiple requirements on the OS



Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

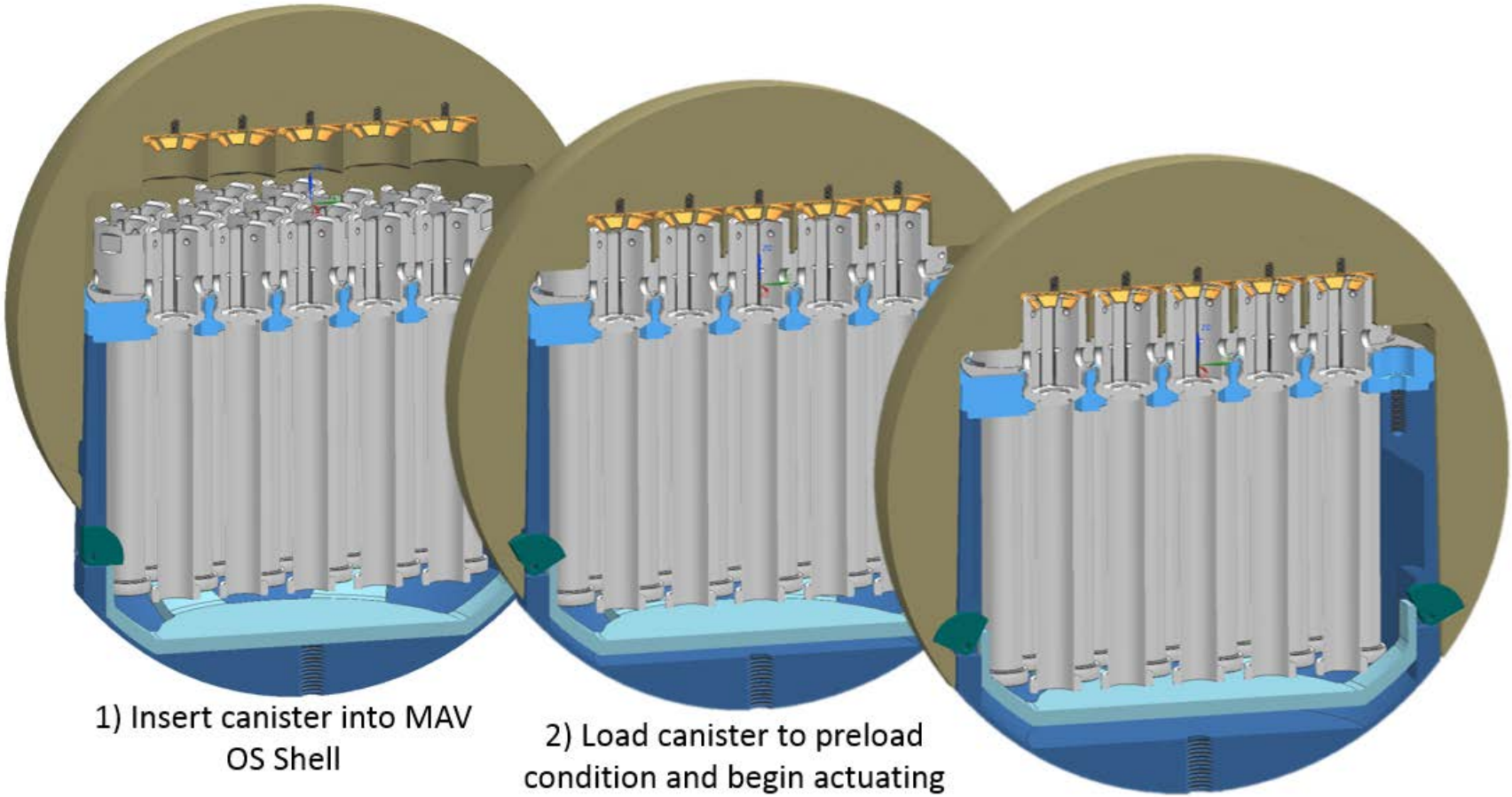
Current ADT Design of OS



Three piece design for OS allows the samples to be individually secured in a canister and then loaded onto the OS (already within the MAV) as a single piece.

Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

Tube insertion into OS



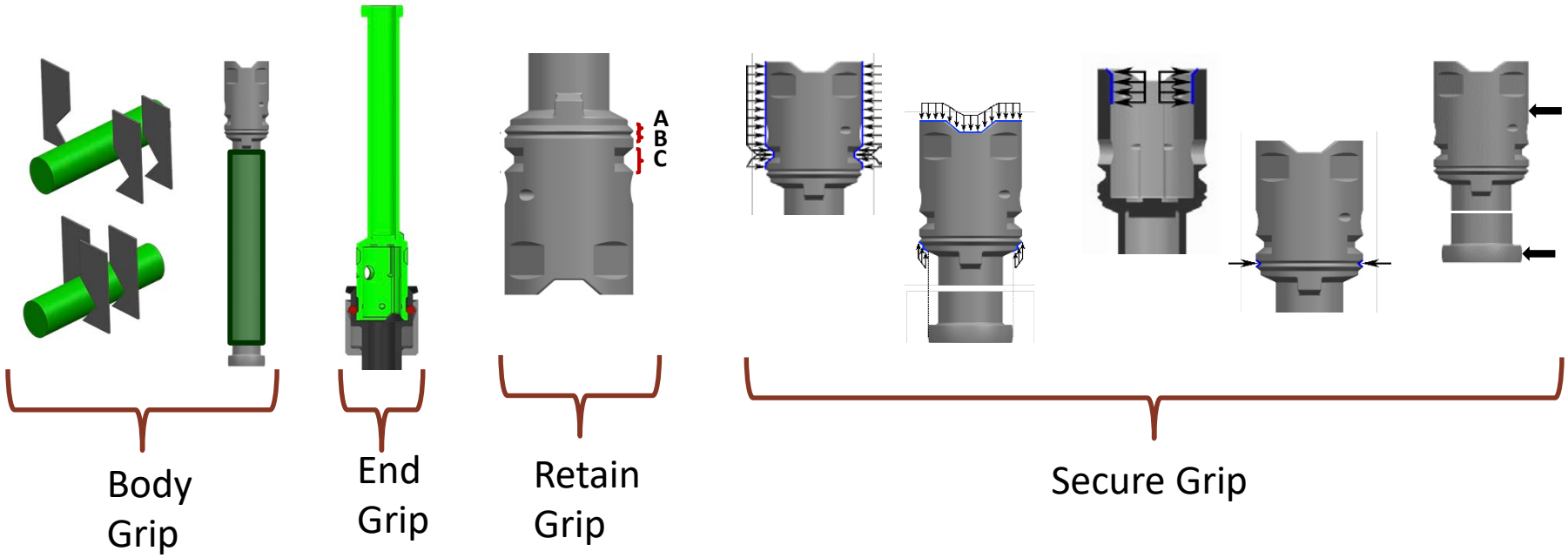
1) Insert canister into MAV OS Shell

2) Load canister to preload condition and begin actuating latches

3) Complete latch actuation; preloading sample tubes in OS and securing canister into MAV

Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

Tube interface options



Multiple different features on the tube allow for picking up, manipulating, and securing the tubes during different stages of the sample collection and return process.

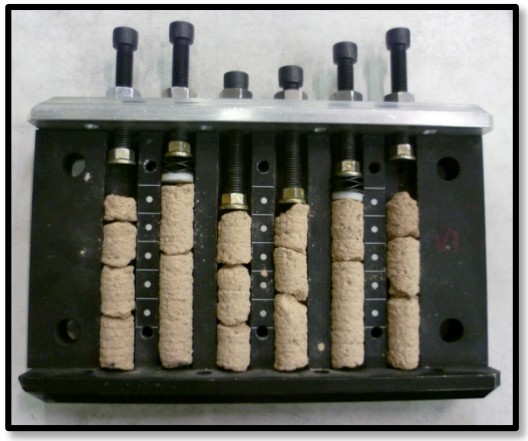
Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

Sample integrity testing

Two anticipated sources of stress

1. **Random vibration environment for Mars Ascent Vehicle (MAV)**
2. **Passive Earth Entry Vehicle (EEV) design for planetary protection Results in "hard" impact at Earth**
   - Soft soil impact of 2500 g's (science target)
   - Hard surface impact of 3500 g's (containment target)

Test Setup: Clamshell Design
- Holds 6 rock cores each
- Accommodates varying core lengths
- Multiple approaches to retaining the samples
  - Variable headspace
  - No headspace
  - Secured via a spring (~20N preload)



Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

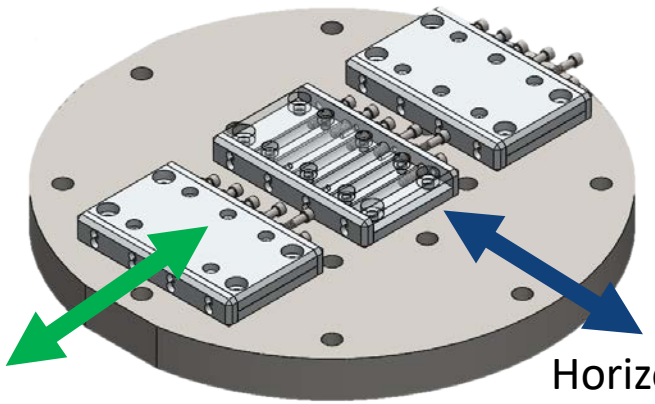
Two anticipated sources of stress

Test Setup for Vibration testing:

- Small shake table in JPL's Environmental Test Laboratory
- 3 clamshells are mounted to a circular vibration mount
- Samples can be vibrated in horizontal, vertical, and skew (45°) axes
- [Vertical = along length of core]

Test Setup for Impact testing:

- 100 lb aluminum alloy drop block
- 7 meter drop height onto cork
- Achieves ~3000 g's max deceleration
- Accommodates 3 clamshells per drop:
  - Vertical (along length of core)
  - Horizontal
  - Skew (45°)



Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

Mars Analog Rock Selection

Not Lithified (Regolith)	Very Weakly Lithified	Weakly Lithified	Medium Strength	Strong	Very Strong	Extremely Strong

<u>Old Dutch Pumice</u>

- Weak (~1-10 MPa compressive strength)
- Unaltered igneous (pyroclastic)
- Mechanically consistent

<u>China Ranch Gypsum</u>

- Medium (~10-80 MPa compressive strength)
- Hydrated sulfate
- Higher biosignature preservation

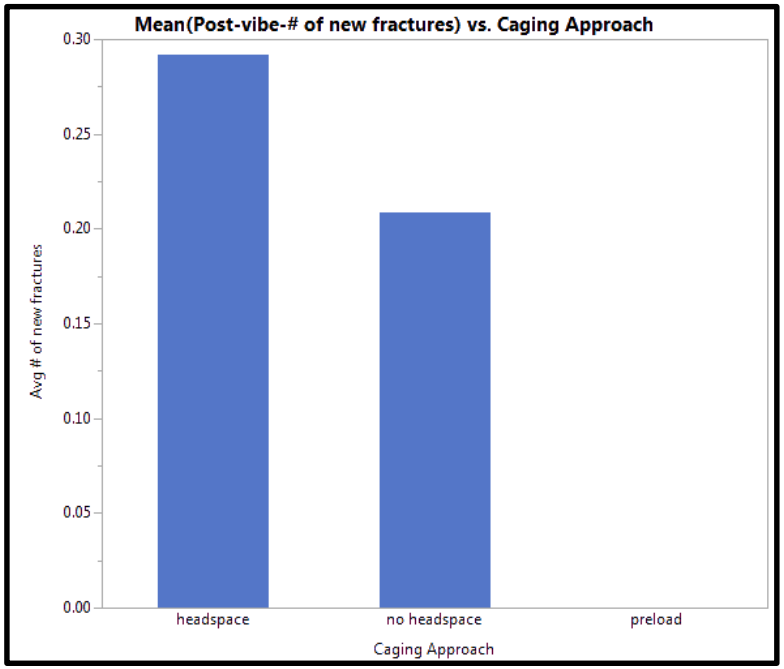
<u>Bishop Tuff</u>

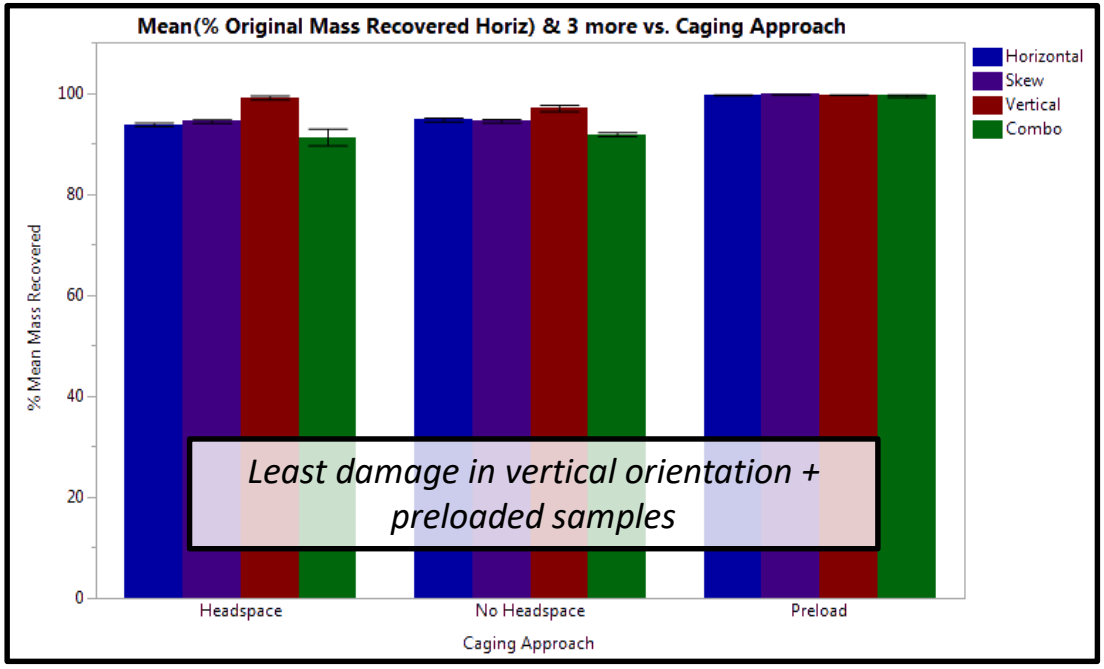
- Medium strength
- Volcanic ash flow
- Similar mechanical properties
- Relatively water-insensitive

Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

Mars Analog Core Testing: Vibration

- Vibration tests conducted on Mars Analog rock: Bishop Tuff
  - 72 cores tested
  - 20-2000 Hz, 21.37 G_{rms}, 3 minute duration
  - 18 cores each individually in horizontal, vertical, and skew configurations
  - 18 cores exposed to horizontal + vertical (cumulative)
  - Sample retention: 12mm headspace, No headspace, 20N preload

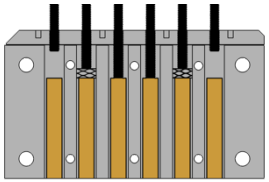




Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

Mars Analog Core Testing: Impact

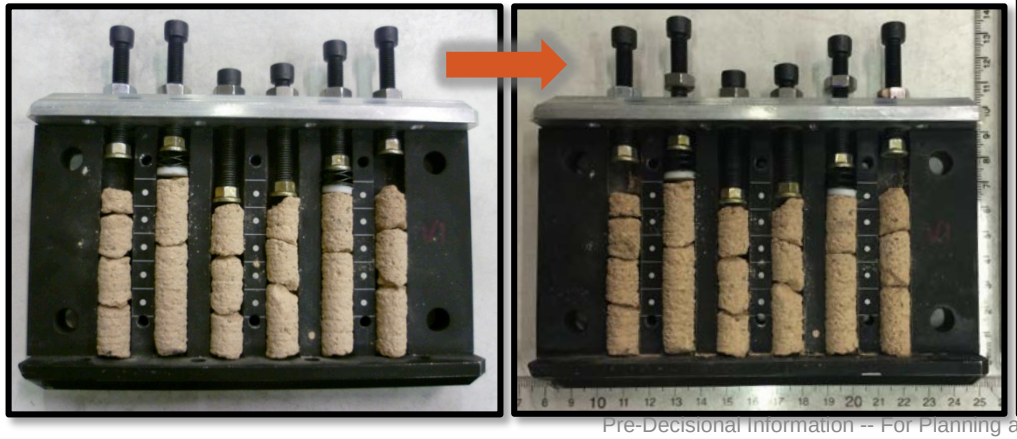
- Impact tests conducted on Mars Analog rocks: Bishop Tuff
  - 36 cores tested for each rock type (3 total drops at 3000 g impact deceleration)
  - 18 cores each in horizontal and vertical configurations
  - 3 approaches tested for sample retention:
    - 12mm headspace
    - No headspace
    - No headspace + 20N preload

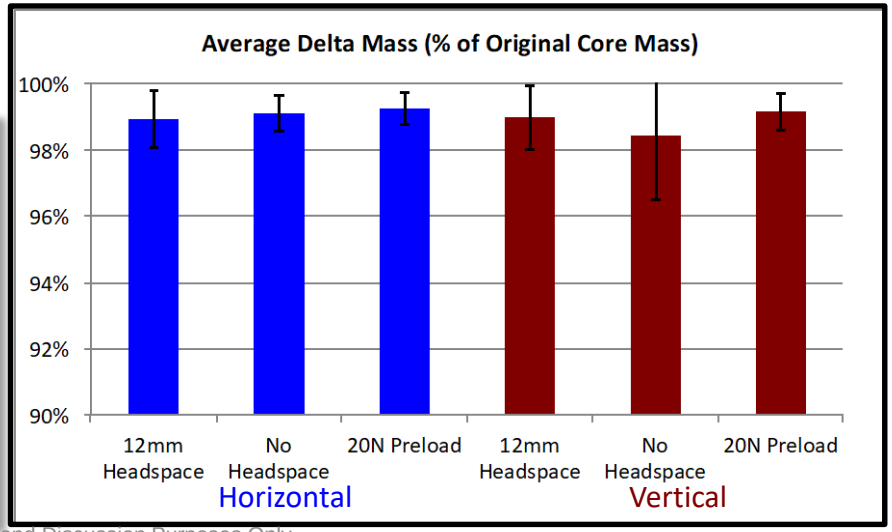


- <u>Bishop Tuff</u>: Little damage seen across all orientations & sample retention approaches

- Caveat: while drop tower achieves maximum likely peak deceleration, the overall energy imparted is less (lower impact velocity)

Drop #1, Vertical Orientation, 3000 g's, Before + After



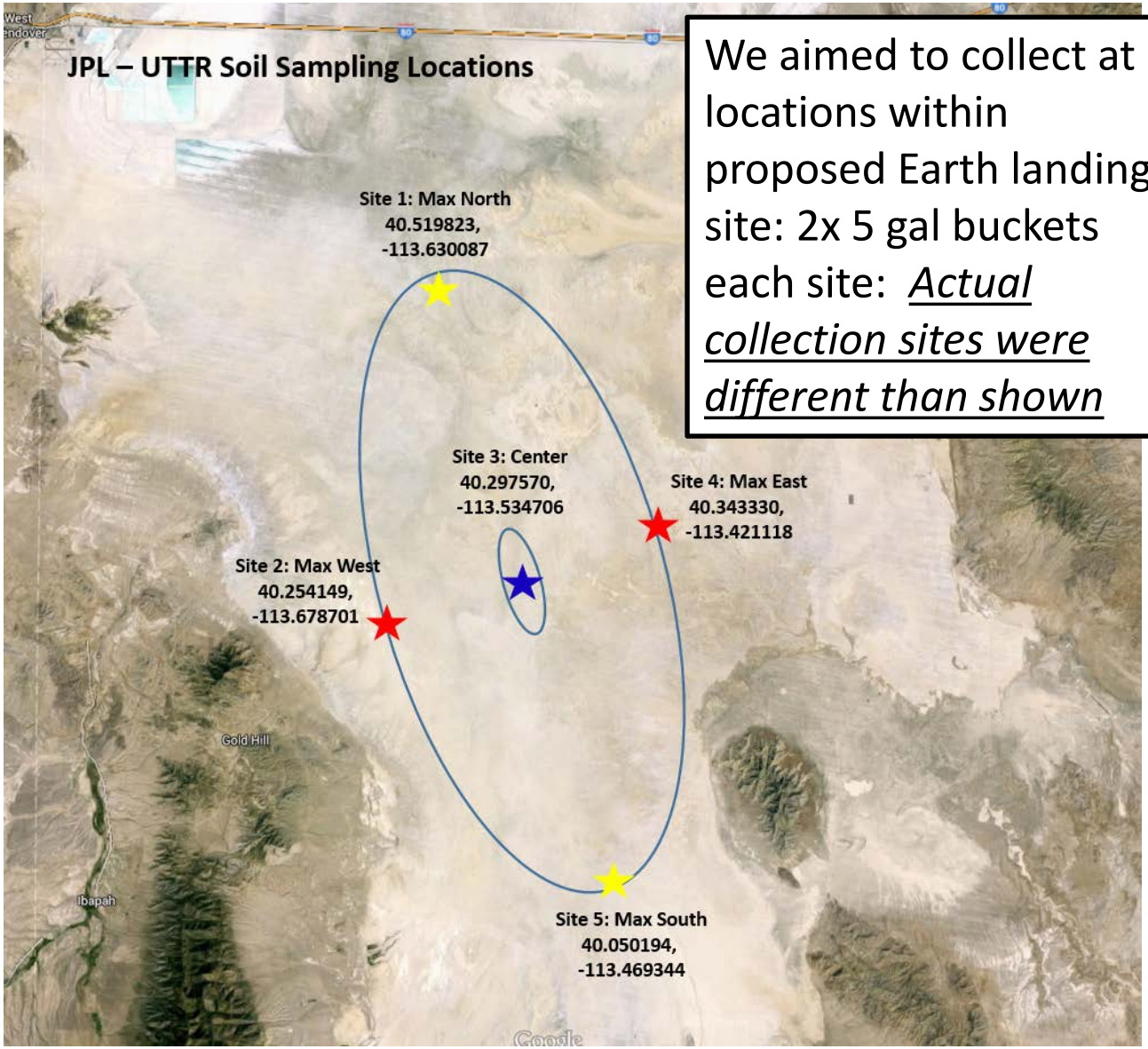


Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

Drop tower tests

- For impact testing of a notional design for a Earth Entry Vehicle (EEV) - allow for greater impact velocities and therefore better representation of expected impact pulse
  - What loads would the OS and the sample tubes see during the impact?
  - How would the material that the EEV impacts into affect these loads?
- Drop tower provides the ability to characterize this material
  - Anticipated EEV impacts velocity range: 30 – 70 m/s
  - Anticipated EEV mass range: 40 kg – 140 kg
- Modeled after Utah Test and Training Range – potential site for sample return landing
  - Used for Stardust and planned for OSIRIS-Rex
- Soil characteristics measured and compared to other soils
  - Use Rosamond, CA

UTTR Soil Collection Update



We aimed to collect at 5 locations within proposed Earth landing site: 2x 5 gal buckets each site: *Actual collection sites were different than shown*

Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

UTTR Soil Collection

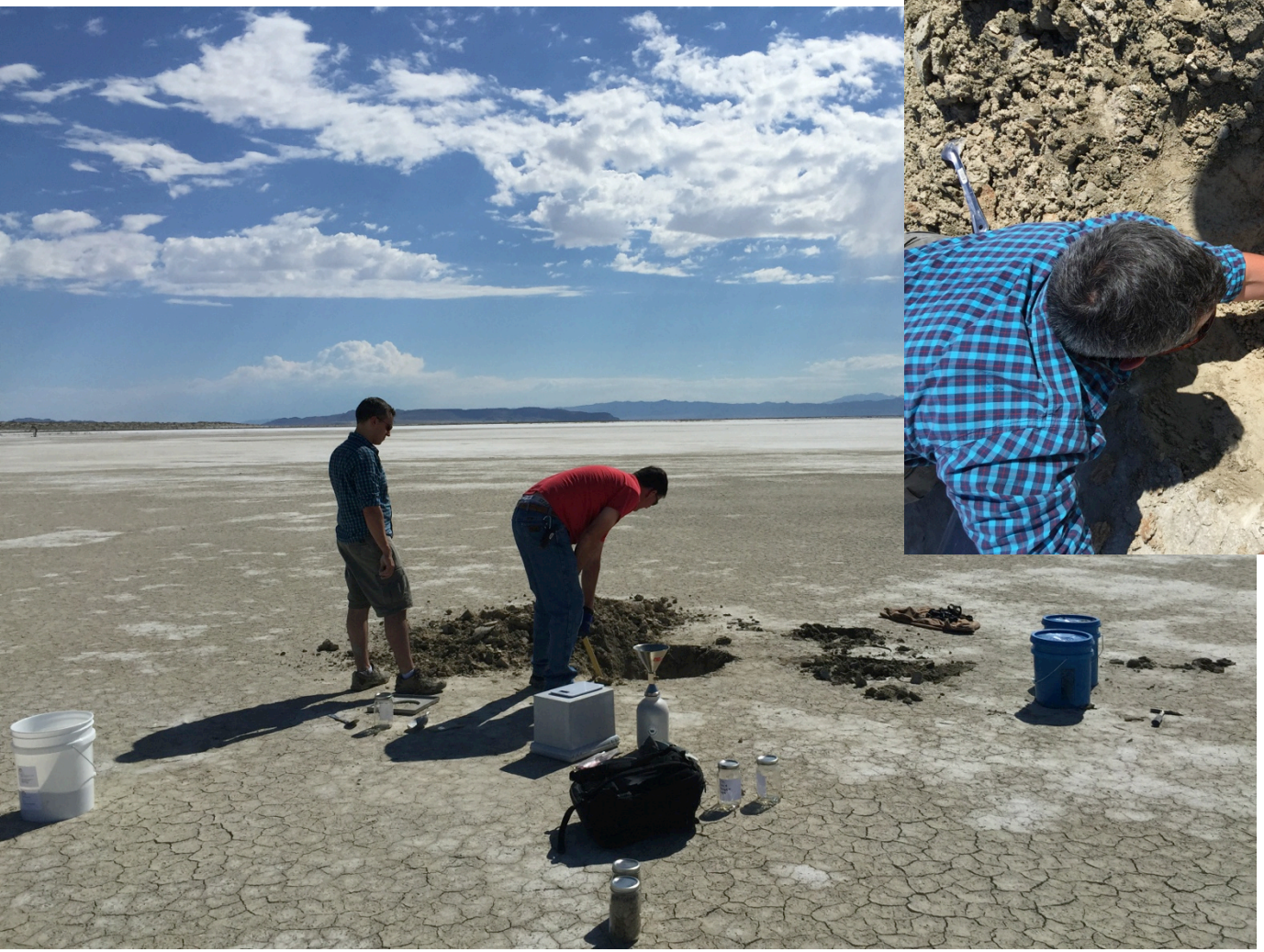
Primary Impact Ellipse Collection Site: 90% of landing ellipse is like this: Wet, No vegetation

Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

UTTR Soil Collection

Collection at primary site: At depth density measurements and surface collection

Water table less than 1 m below surface



Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

UTTR Soil Collection

5 impact ellipse collection sites: North Site (Dry, Most vegetated)

Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

UTTR Soil Collection

5 impact ellipse collection sits: West Site (Dry, Less vegetated)

Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

UTTR Soil Collection

5 impact ellipse collection site: East Site (Medium wet, Minimal vegetation)

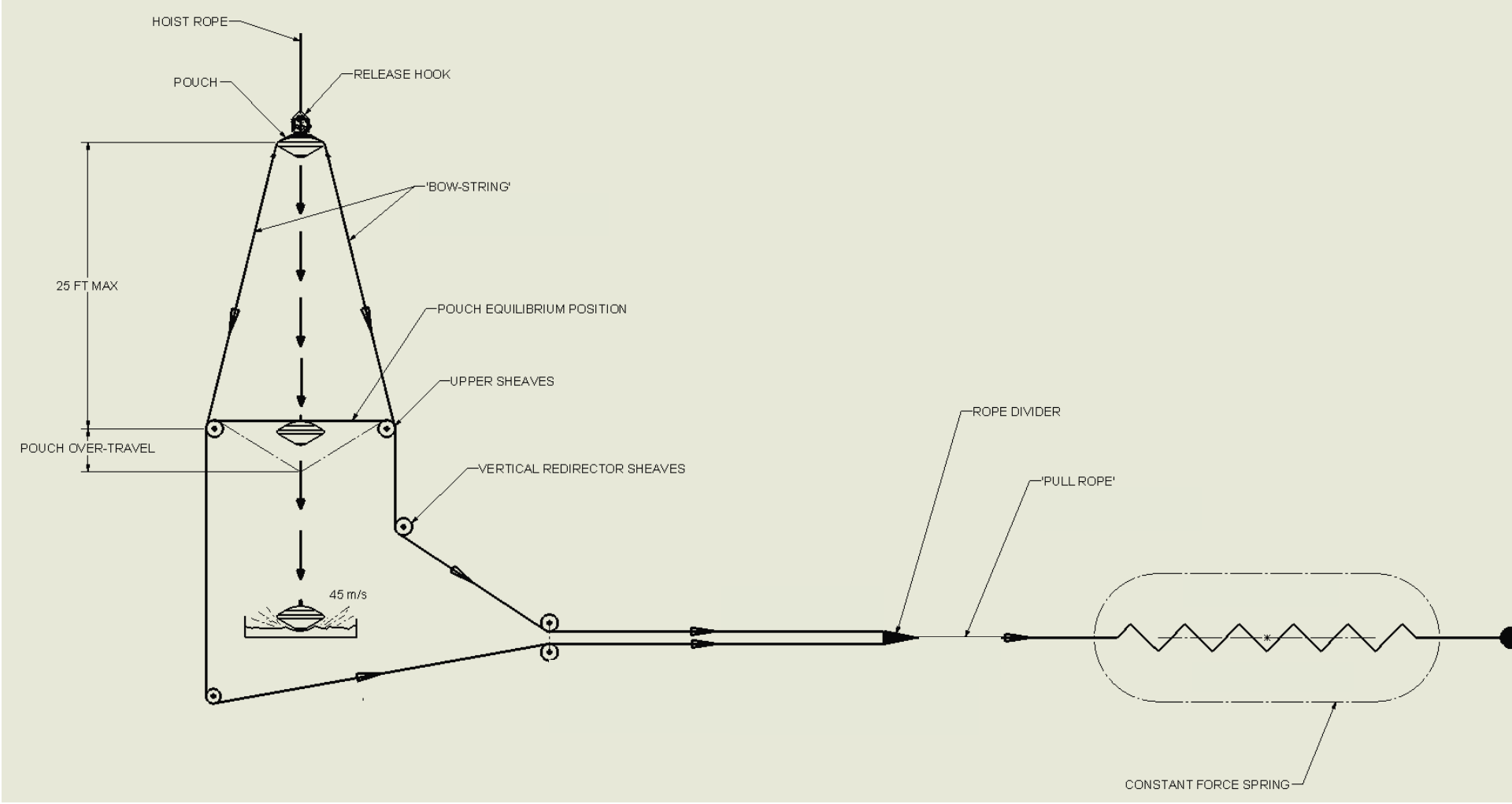
Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

UTTR Soil Collection

Sand Collection Site 10% area: (Dry, Fluffy, Hilly, Vegetated)

Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

Drop tower schematic

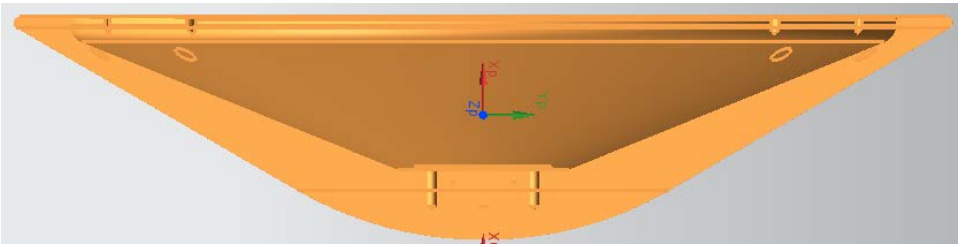


Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

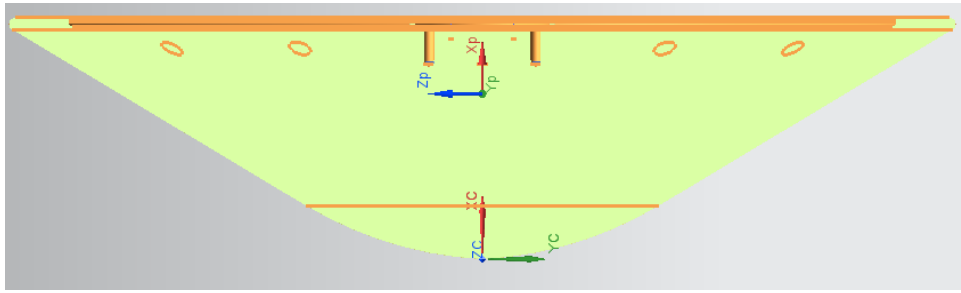
Sphere-Cone Penetrometers

Different penetrometers are being tested with different masses and geometry

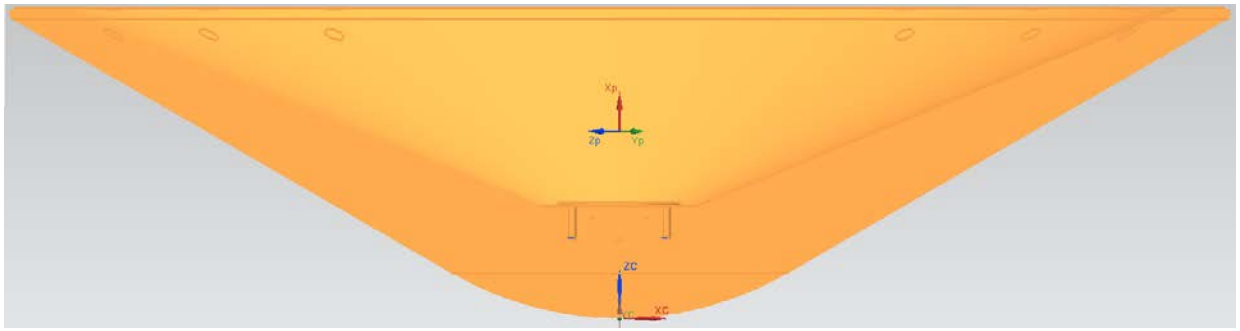
SC-A
Sphere-Cone Penetrometer ~ 40 kg
Diameter ~75cm
Height ~20cm



SC-B
Sphere-Cone Penetrometer ~ 90 kg
Diameter
Diameter ~75cm
Height ~20cm



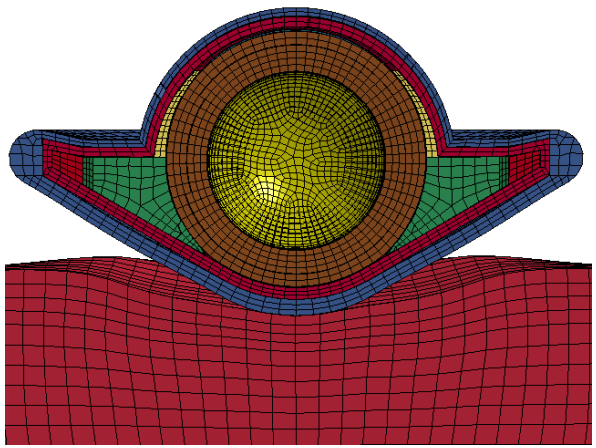
SC-C
Sphere-Cone Penetrometer
~ 140 kg
Diameter ~1m
Height ~30cm



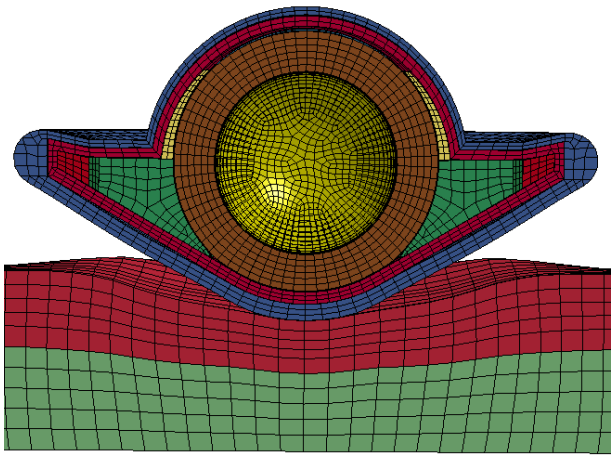
Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

SC-A type EEV Impact Results

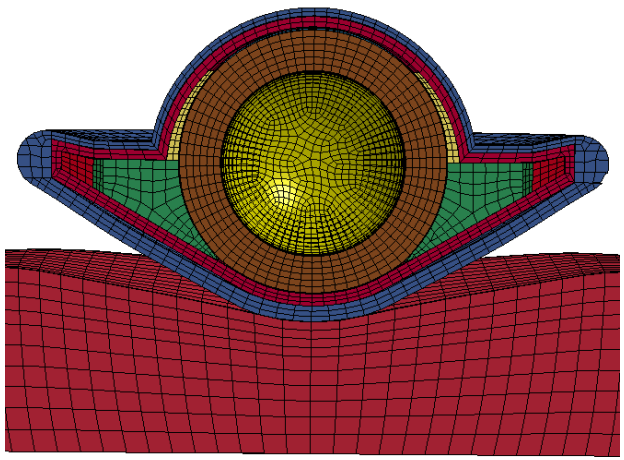
Dry Rosamond Soil



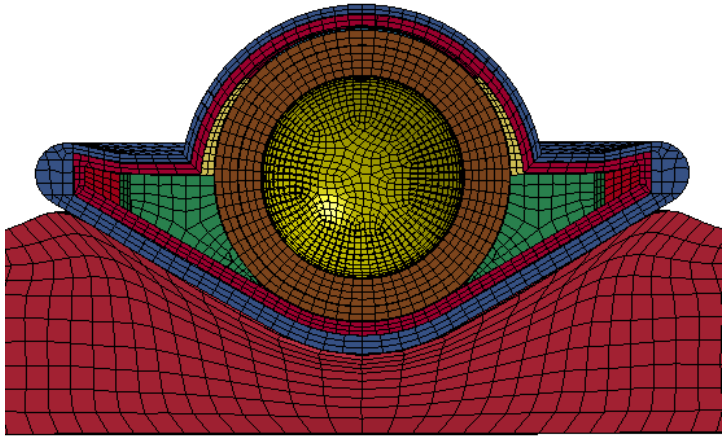
Hybrid Rosamond Soil



Saturated Rosamond Soil



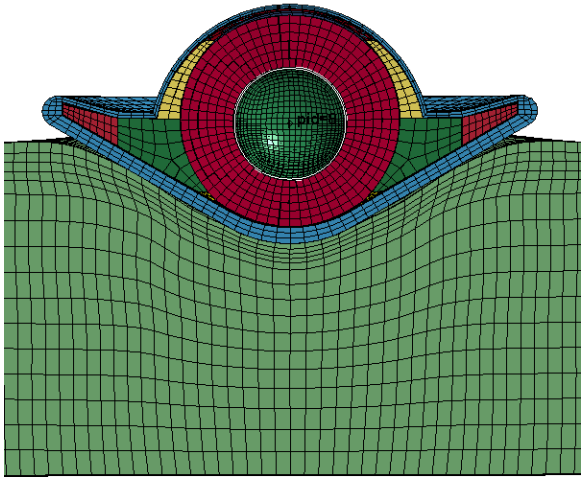
Previous Soil Model



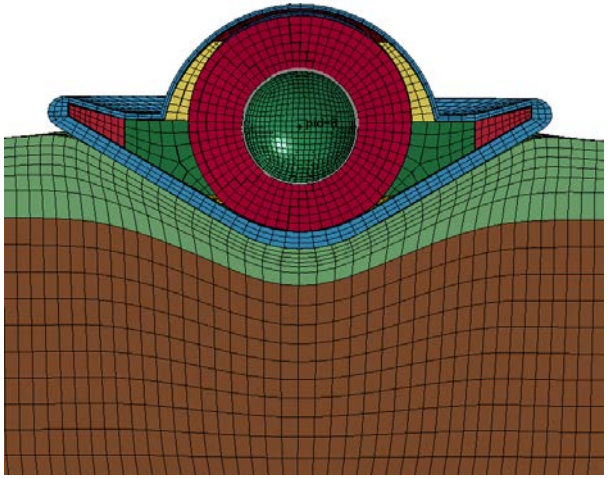
Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

SC-C type EEV Impact Results

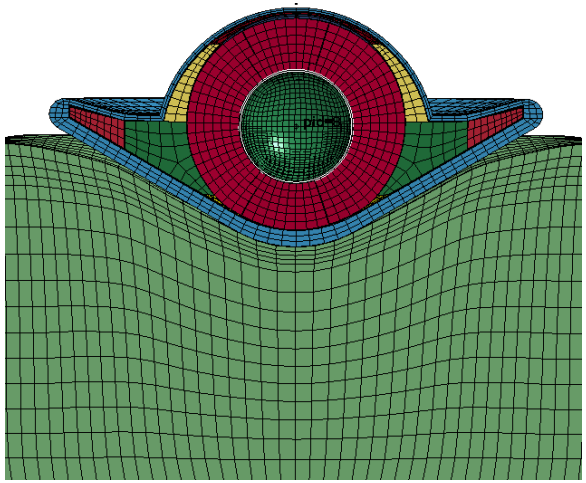
Dry Rosamond Soil



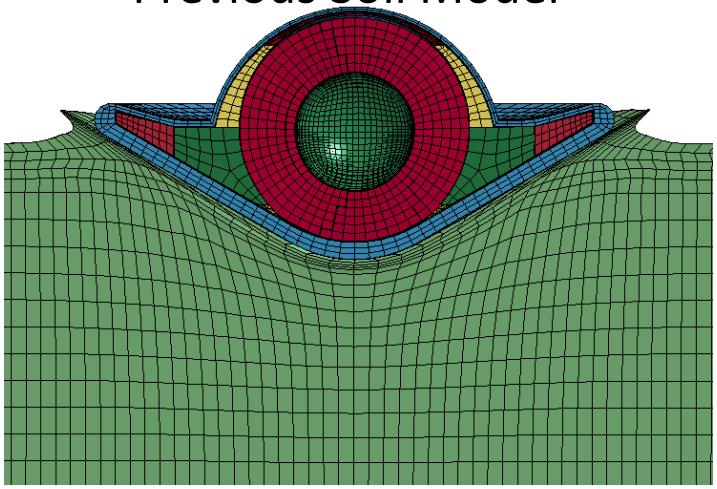
Hybrid Rosamond Soil



Saturated Rosamond Soil



Previous Soil Model



Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

Drop tower tests

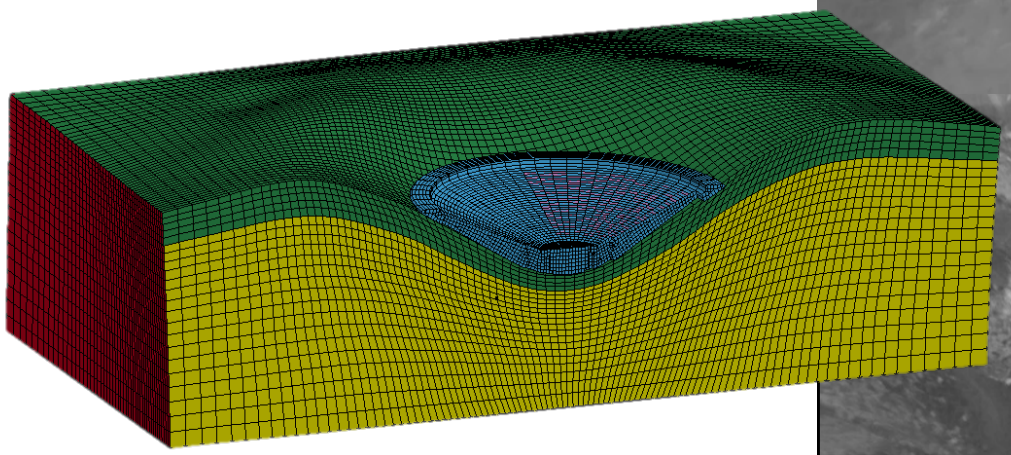
Test #	Impactor Mass (kg)	Impact Velocity (m/s)	Peak Acceleration (G)	Pull-back (ft)	Energy
1	15	20	400	--	3000
2	30	20	200	--	6000
3	40	30	550	16	19000
4	40	45	1000	16	40000
5	40	45	1200	16	40000
6	40	45	1400	16	40000
7	40	70	2000	28	90000
8	90	45	800	28	110000

Tested at different soil moistures

Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

Model Images

Test 5 and 6 are both very aggressive impacts – Soil ejecta becomes a concern in accurate modeling. Other modeling approaches and models could capture ejecta if found to be useful.



Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

Movies

Impact Test 7:

- SC-A
- New extended crossbow pullback
- Impact velocity very high ~70 m/s (~150 mph)
- Impact energy ~90 kJ
- Soil saturated to ~22%+ WC

Impact Test 8:

- SC-B
- New extended crossbow pullback
- Impact velocity high ~45 m/s (~100 mph)
- Impact energy ~110 kJ
- Soil saturated to ~27%+ WC (highest so far)

Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

Complementary Science

Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

Some considerations for complementary SRL science

- If the next lander/rover mission collects the samples deposited by M2020 it would have to go to the same location as M2020.
  - What more could be done in a place we have already sent a very capable rover to?
- The next mission would have to include mass and power allocations for a MAV to get the samples off the surface.
  - What could be done with limited mass and power?
- The next mission architecture is not set – there may be a landed element and/or a roving element, both of which may or may not survive the MAV launch.
  - What could be done while collecting samples?
  - Are there additional architecture ideas that have not been considered?
- Beyond pure science goals, are there overlaps with human exploration that could be added to the potential complementary instrument package?

Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology

Potential Complementary Science for Sample Return Lander

From MEPAG Goals Document

	Ranked sub-objective	Justification
High	Characterize lower atmosphere dust, water vapor, winds	High priority investigations largely unpursued by previous missions; cross-cutting with high priority Goal IV investigations; synergy with NEX-SAG mission concepts
	Volatiles and dust exchange between surface and atmospheric reservoirs	
	Characterize ancient habitable environments	Establish enhanced astrobiological context for returned samples
	Ancient biosignature preservation and degradation	
	Presence of ancient biosignatures	
	Determine the aspects of the atmospheric state that affect EDL	Medium and high priority investigations largely unpursued by previous missions
Medium	Regolith physical and chemical properties for human exploration	
	Characterize past and present geologic environments	M2020 expected to characterize the landing site
	Timing and processes of climate change	Investigations likely to be Goal I secondary accomplishments
	Manifestations of crust-mantle interactions	Best suited for sample return; InSight expected to make some progress
Low	Characterize atmospheric electricity	High priority sub-objective, low priority investigation
	Interpret physical and chemical records of past climate	Low priority sub-objective, low priority investigations
	Radiation and toxic dust hazards for human exploration	MSL currently making progress; toxic dust investigations perhaps more suited for Earth-based sample analysis
	Characterize airborne dust that could be hazardous to hardware and infrastructure	Low priority sub-objective, low priority investigations
	Quantitatively constrain the age and processes of accretion, differentiation, and thermal evolution of Mars	InSight expected to make significant progress

Pre-Decisional Information -- For Planning and Discussion Purposes Only
© 2016 California Institute of Technology