

Sampling Chain Development Status

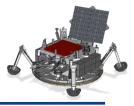
Sampling Team

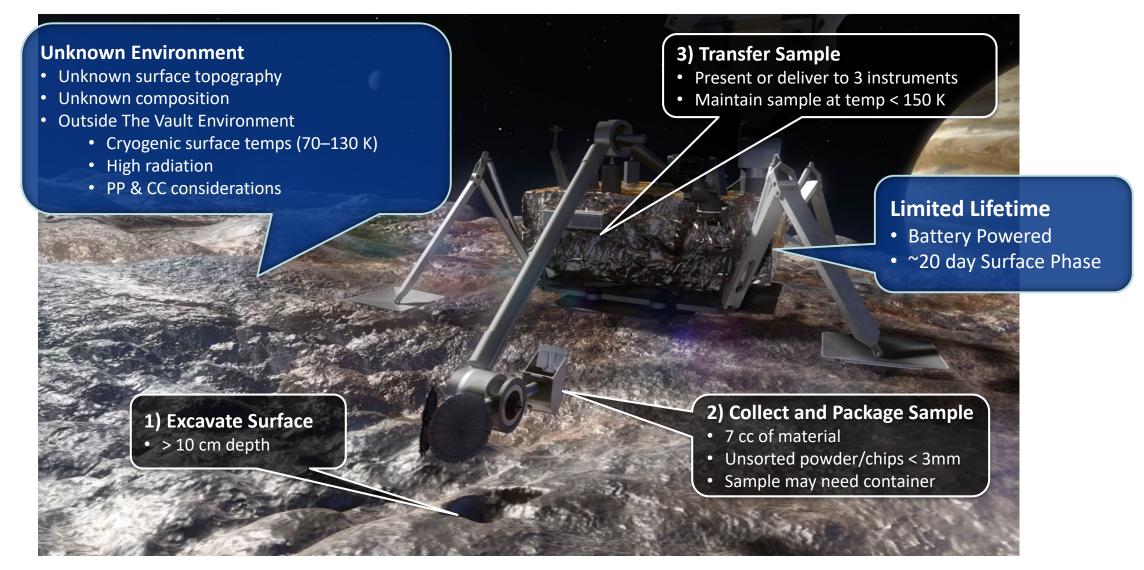
Jet Propulsion Laboratory, California Institute of Technology





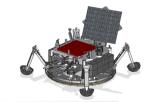
Sampling System Mission Concept







Need to be *Capabilities Based* for a Wide Range of Challenges



Topographical roughness presents different challenges at different scales

TOPOGRAPHY













Salt Flats

Beach

Gravel Bed

Cobblestone Street

Devil's Golf Course

Chilean Penitentes

"Hard to sample" is relative – each material has its own challenges associated

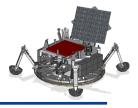
MATERIAL COMPOSITION

Granular and loose materials			Low compressive strength, porous			Ices, fractured, salty			Heterogenous, tough		
MMS Dust	Minus 30 Sand	Loose Ice	Comet Simulant	Grill Brick	Lake Koehn Evaporite	250 K	190 K Water Ic	123 K e	Saltwater Ice	Composite Cryogenic Ice	Kramer Massive Mudstone
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Reference Terrains will be defined by TSD



Surface Simulant R&D



Compositions & Recipes











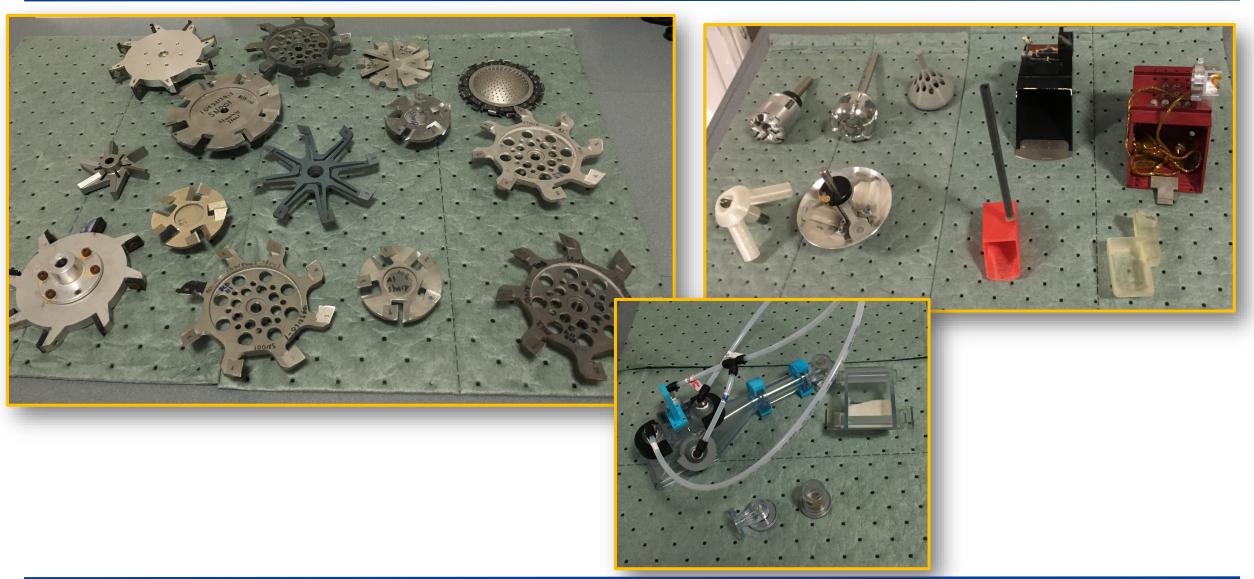
Mechanical Properties Testing





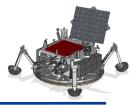
Developmental Hardware

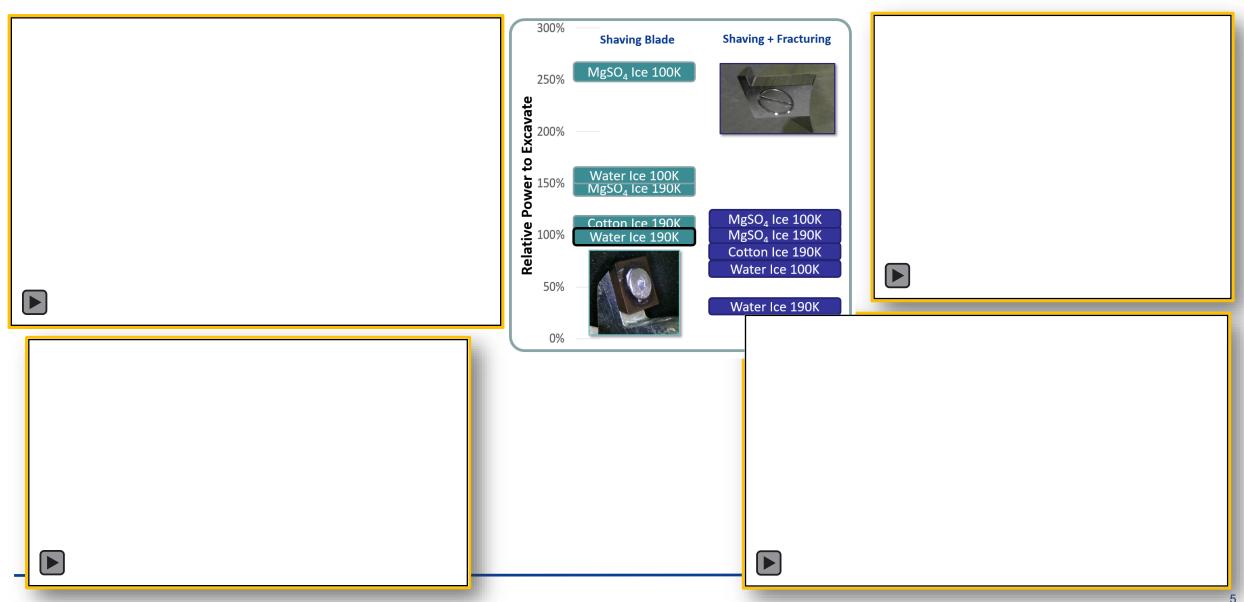






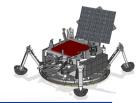
Excavation Tools Tested in Varied Terrains

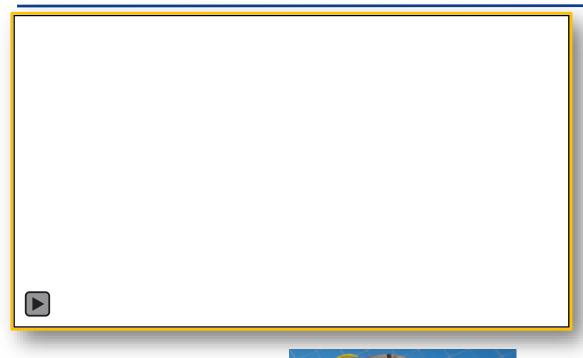




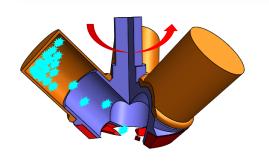


Centrifugal Collection Devices

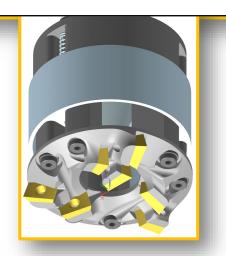








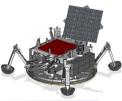


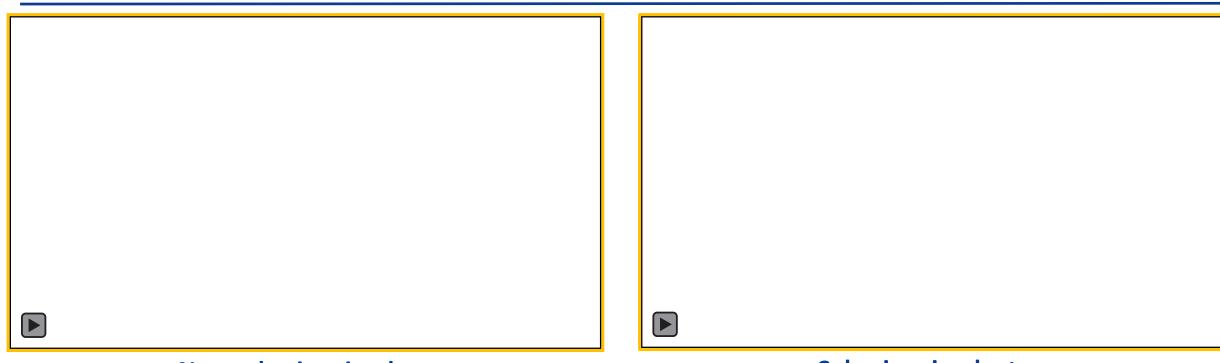




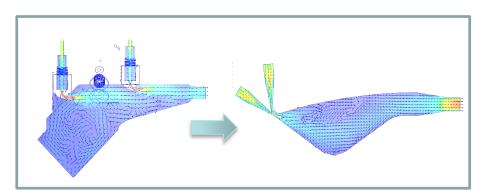


Pneumatic Transfer





Non-cohesive simulant

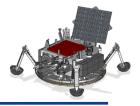


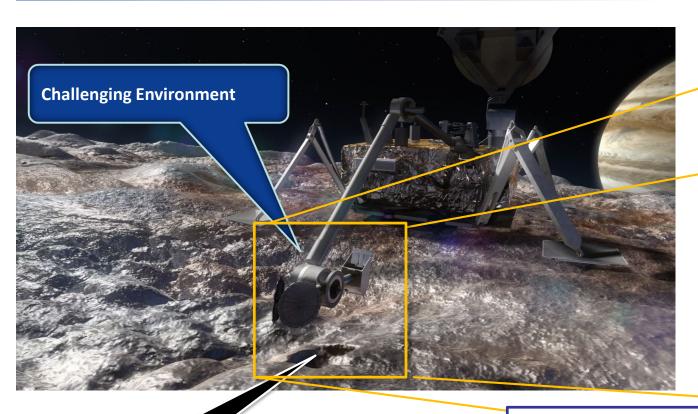
Cohesive simulant





How Do Icy Materials Behave in CryoVac?





CITADEL

Surface Interaction

Early Test Objectives:

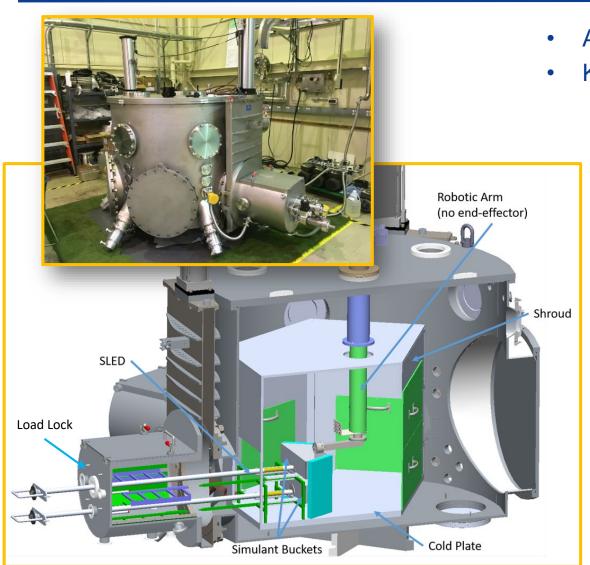
- Sample Thermal Integrity Testing
- Collection Tool Ice Interaction & Chip Dynamics
- Sample Transfer
- Initial material & component shakeout



CyroVac Test Venue

Cryogenic Ice Transfer, Acquisition Development, and Excavation Laboratory





- Aka CITADEL
- Key Features
 - In commissioning; Initial testing Summer 2019
 - ~3.5'x2'x3' inside shroud; Cryo down to ~70K; Vacuum < 10E-5 torr
 - Test Venue Objectives:
 - Observe and characterize behavior of cryogenic cuttings
 - Test end-to-end Excavation -> Collection -> Transfer, including verification of 150K Sample temperature requirement
 - Comparison testing to prove out adequacy of ambient simulants (and/or identify specific shortcomings to mitigate)
 - · Test sample integrity sensors
 - Accommodate up to 6 test material blocks inserted thru loadlocks to enable test simulant reconfig within <1 day
 - Expect ~4 days for full reconfig between test campaigns
 - 190K and 130K freezers immediately adjacent to testbed. Samples can be loaded into side loadlocks while isolated from main chamber
 - Current arm is only 2-DOF, planned upgrades to more DOF and more flight-like configuration
 - Test data products include multiple-angle video, motor telemetry, force/torque measurements, chamber pressure and temperature, cuttings properties



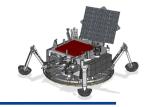
Tour Inside CITADEL



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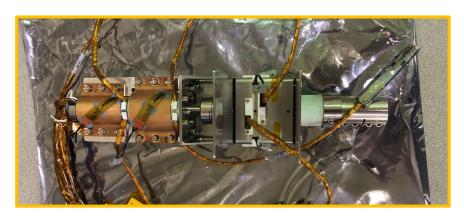


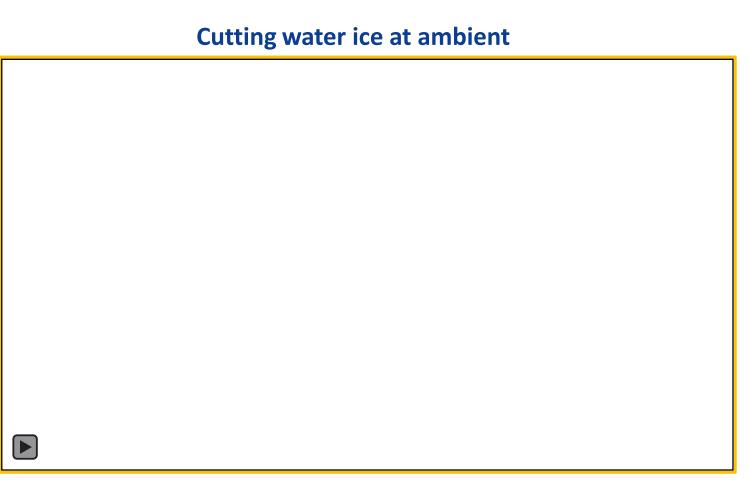
CITADEL Current Status



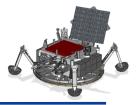
 Proceeding with final tasks to cut ice at cryo-vac conditions. Coming later this summer!

Thermal hardware on Tool motor





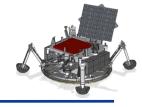




Thank You!



Ambient Testbeds







SFTB

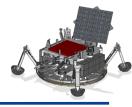


Two ambient robotic test venues

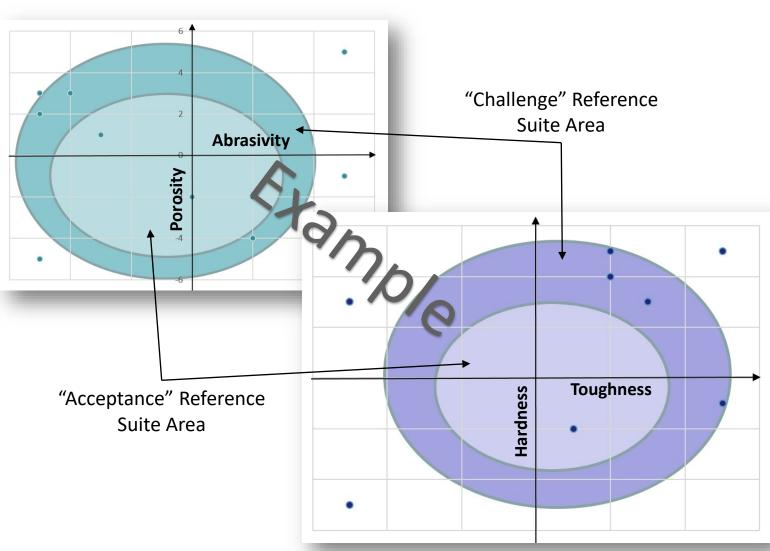
- StORM: Stiff Operationally-Flexible Robotic Manipulator
 - 6 DOF COTS robotic arm
 - Arm compliance and kinematics are not flightlike
 - Venue for characterization of Collection end effector prototypes
- SFTB: Sampling Functional Testbed
 - 5 DOF robotic arm
 - In commissioning, initial tests summer 2019
 - · Arm compliance and kinematics possibly more flightlike
 - Intended for study of sampling autonomy and ambient end-to-end sampling tests
- Interchangeable tools
- "Warm ice" and ambient test material venues
 - Collocated with -80C freezer for storage of ~
 30cmx25cmx15cm test material blocks
 - Samples can be held in LN2 bathtub
 - BUT testing with an icy simulant in ambient environment (even with LN2 bathtub) is often problematic
- Room ambient conditions for ease / speed of testing throughput and reconfiguration. << 1 day reconfig between tests



Engineered Surface Simulants

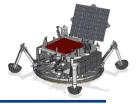


- Develop surface simulants (frozen & ambient) in R&D effort
 - Identify key material properties driving device design and performance
 - Properties can be traditional or homegrown
 - Properties can be lab-measured or Lander-measured
 - Develop repeatable "recipes" and processes (including infrastructure) for consistent testing
 - Factor in non-mechanical considerations such as testability, manufacturability, and probability of occurrence
- Mechanical properties, terrains, and boundaries defined in close coordination with science team and codified in TSD
- Philosophy encompasses all elements that interact with the Europa surface (e.g. Sampling, Landing/stability hardware, imaging, instruments)





Surface Simulants



Compositions & Recipes







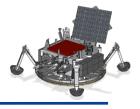


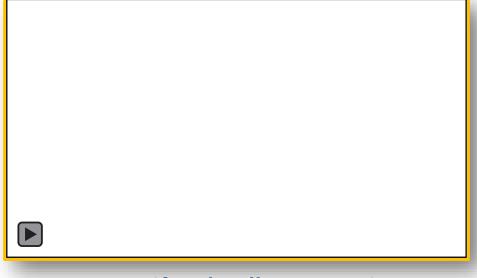


- Ambient simulants used to date (collection and transfer focused)
 - Sand
 - Sand with silicone oil different ratios to simulate "stickness"
 - Salt block
 - Mojave Mars Simulant cuttings
- Icy simulants used to date
 - Pure water ice
 - MgSO4 ice
 - Various other impurities
- Key desired simulants not yet used
 - Ice with embedded temperature markers
 - Ice embedded with worst-case concentration of H2SO4 constituents
 - Exothermic clathrates

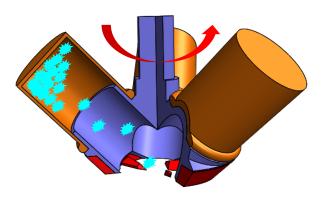


Collection Device Prototype #1





Centrifugal Collector Testing



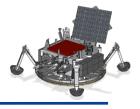


Characteristics

- Sample is divided into separate detachable containers at time of collection
- Containers need to be oversized to account for postcollection losses
- To date more focused on sample going in, not necessarily out
- Thoughts on transfer to dock
 - Post collection, end effector mates to the Dock to transfer full containers
 - Detachment interface is at each container inlet?
 - Detach whole end effector?
 - Push sample out of each container like a push pop?
 - If containers are removed, end effector then mates to pick up new containers
 - Require Arm motion to mate to different location on dock?
 - Or same location as detachment?
 - Other TBD



Collection Device Prototype #2







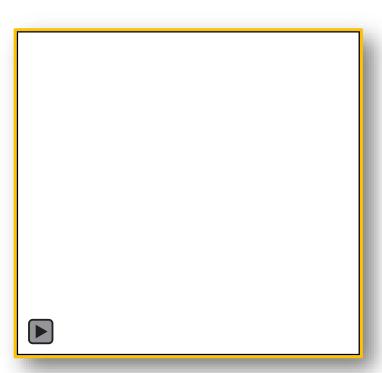


Characteristics

- Like a modified coring bit with a tooth in the middle to "chew up" the core
- Sample collected in empty space inside collection tool
- Sampled dumped into "coffee can"
- Thoughts on transfer to dock
 - Likely need a passive rotating interface between tool and dock
 - Tradeoff between precision of docking and size of features to push the sleeve

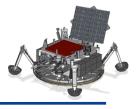


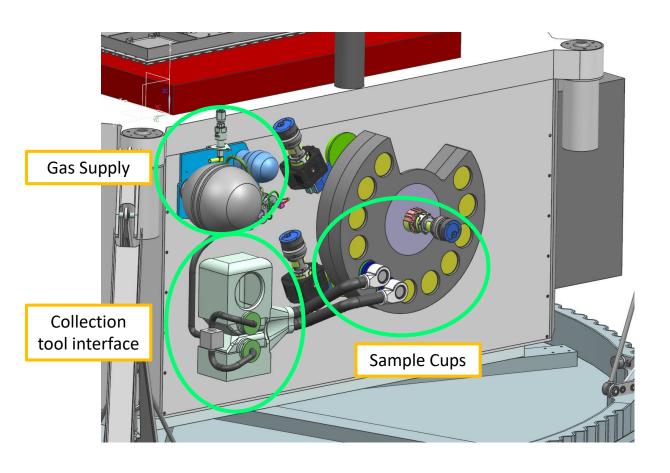






Pneumatic Transfer





Characteristics

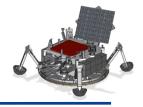
Sample transferred using pulses of gas

Thoughts

- Could transfer to one cup at a time
- Could use a manifold and transfer to multiple cups at once
- Deliver directly to instrument inlets?
- Many options to remove the sample from the gas flow
- Can work with various collection tools
- Could work with varying size transfer cups



Sample Collection Solution Space



Explored to Date





Capture the Rooster Tail



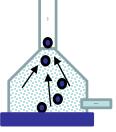
Scoop



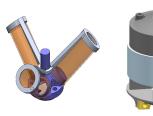




Auger



Pneumatics



Centrifugal Collectors

Not Yet Explored





Traps – Sponge, Aerogel



Conveyor



Sleeves



20



The Snake Chart:

Tool for Conceptual Development & Communication

