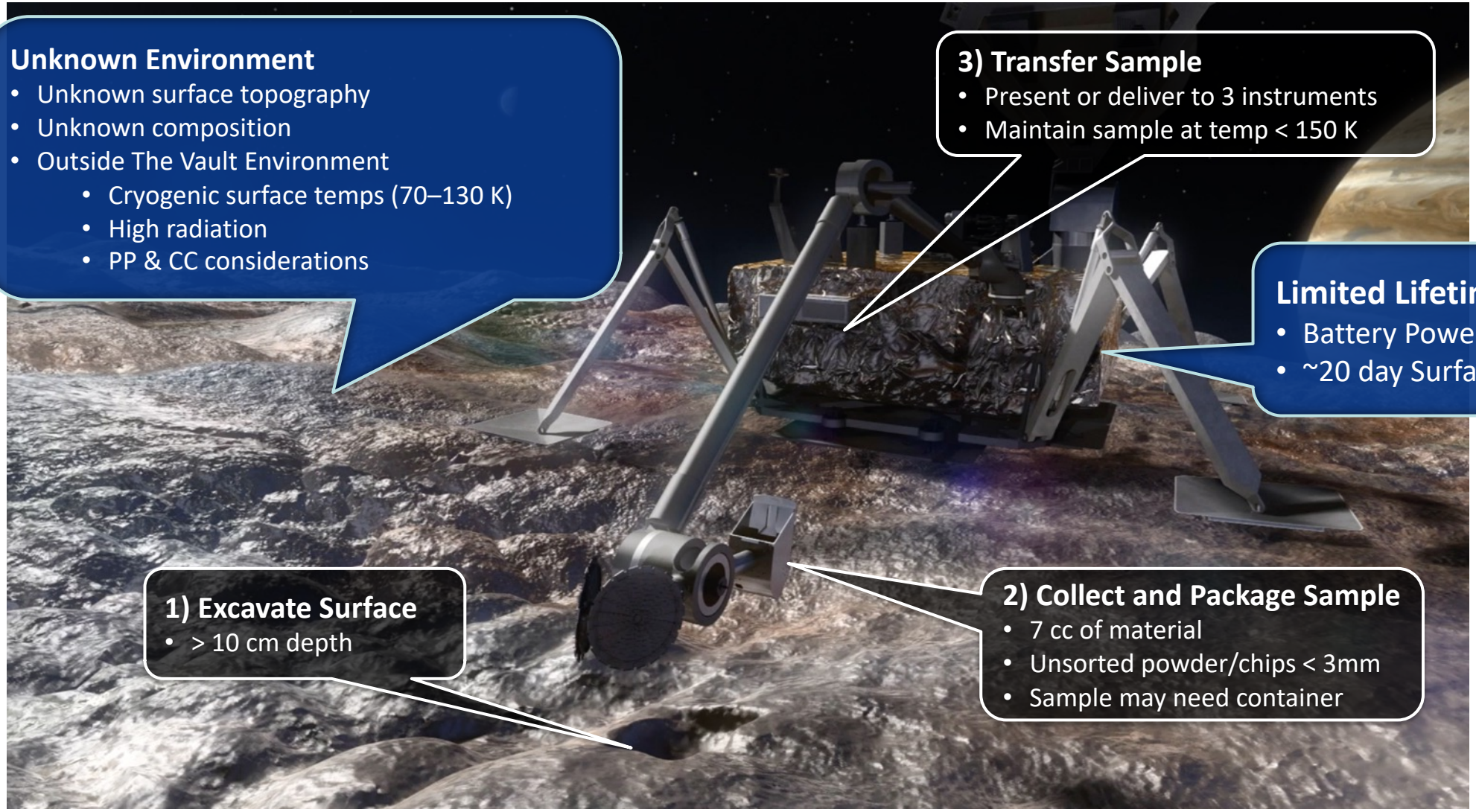
Sampling Chain Development Status

Sampling Team

Jet Propulsion Laboratory, California Institute of Technology

Jet Propulsion Laboratory
California Institute of Technology

Sampling System Mission Concept



Unknown Environment
- Unknown surface topography
- Unknown composition
- Outside The Vault Environment
  - Cryogenic surface temps (70–130 K)
  - High radiation
  - PP & CC considerations

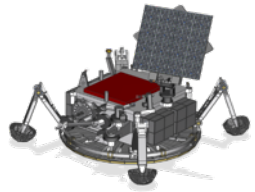
3) Transfer Sample
- Present or deliver to 3 instruments
- Maintain sample at temp < 150 K

Limited Lifetime
- Battery Powered
- ~20 day Surface Phase

1) Excavate Surface
- > 10 cm depth

2) Collect and Package Sample
- 7 cc of material
- Unsorted powder/chips < 3mm
- Sample may need container

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



TOPOGRAPHY

Topographical roughness presents different challenges at different scales

Salt Flats

Beach

Gravel Bed

Cobblestone Street

Devil's Golf Course

Chilean Penitentes

MATERIAL COMPOSITION

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

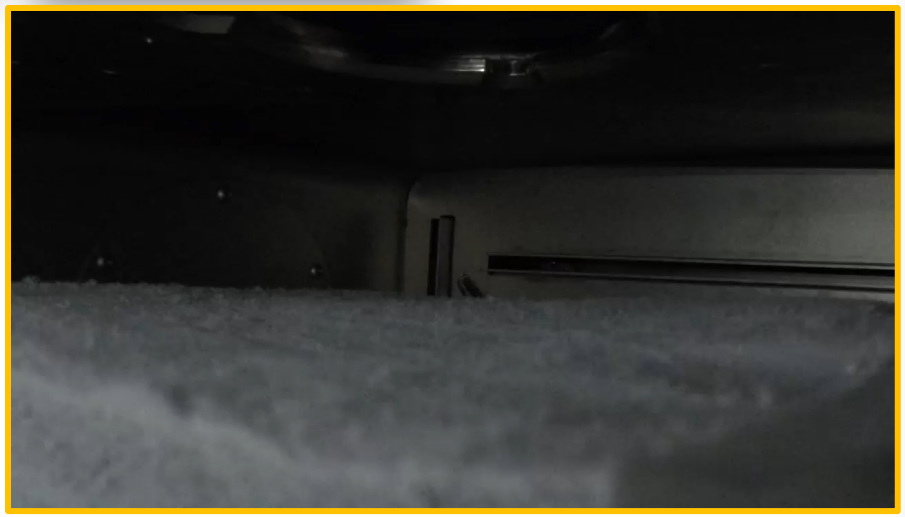
MMS Dust	Minus 30 Sand	Loose Ice	Comet Simulant	Grill Brick	Lake Koehn Evaporite	250 K	190 K	123 K	Saltwater Ice	Composite Cryogenic Ice	Kramer Massive Mudstone
						Water Ice					
• Granular and loose materials			• Low compressive strength, porous			• Ices, fractured, salty				• Heterogenous, tough	

Reference Terrains will be defined by TSD

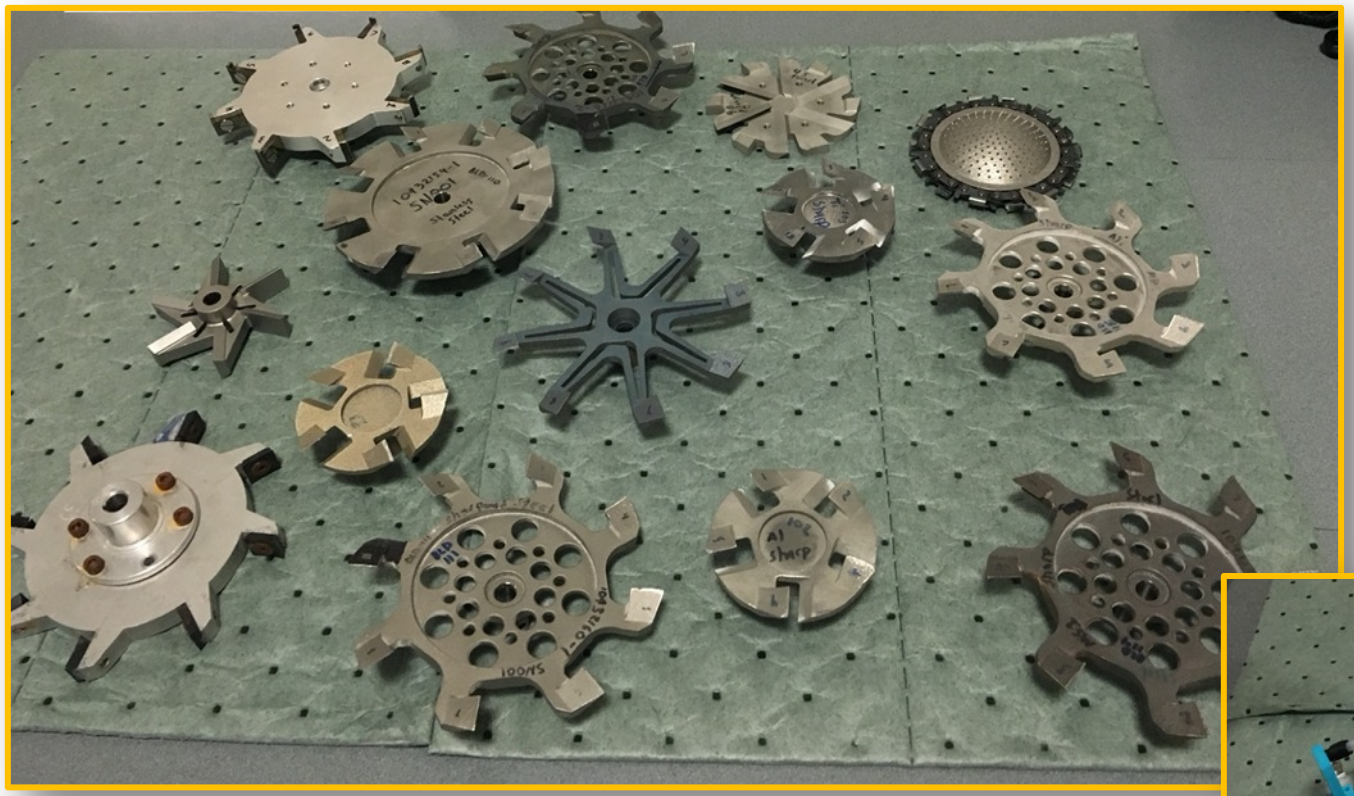
Surface Simulant R&D

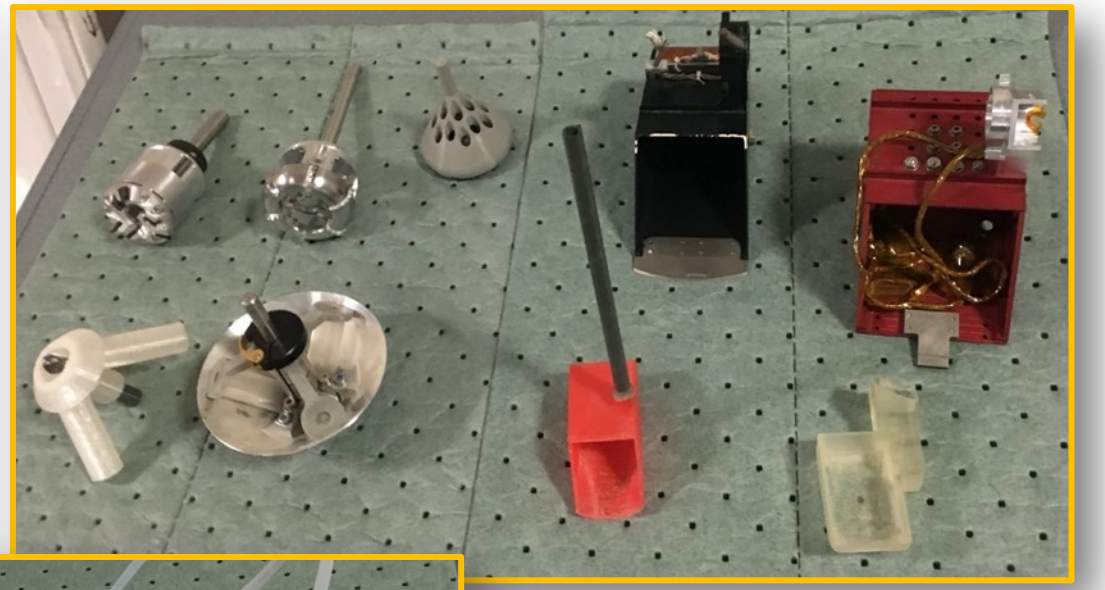
Compositions & Recipes

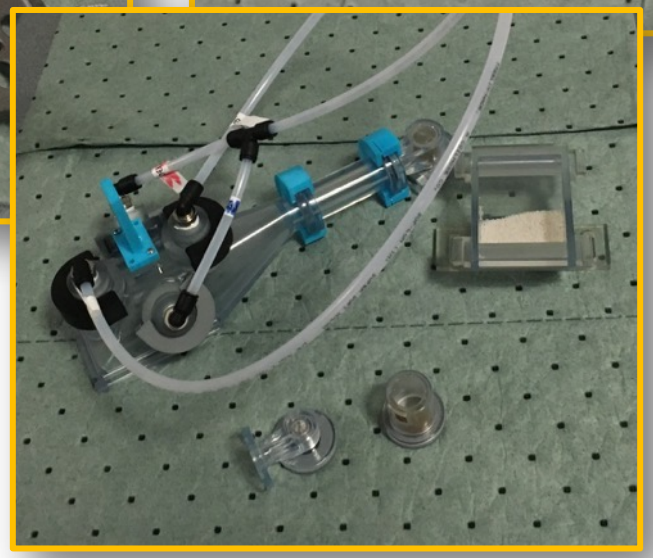
Mechanical Properties Testing



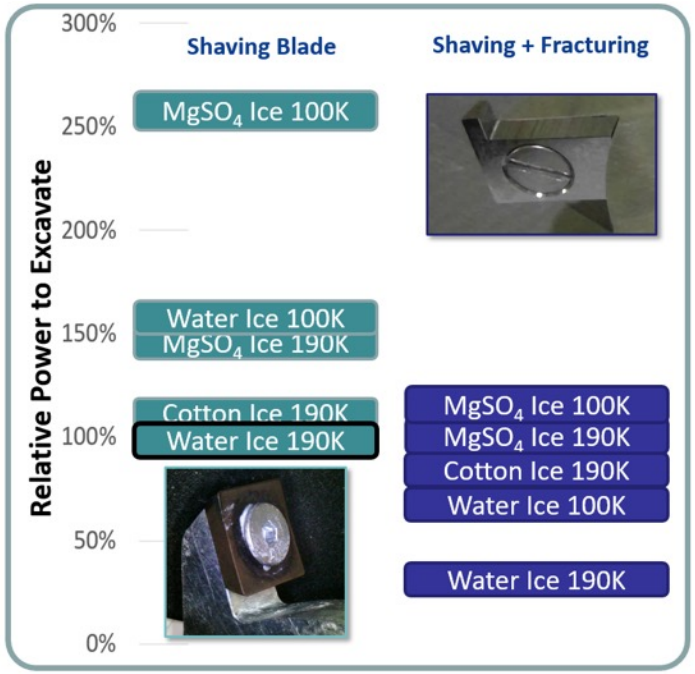
Developmental Hardware



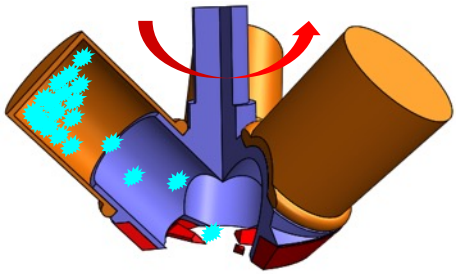


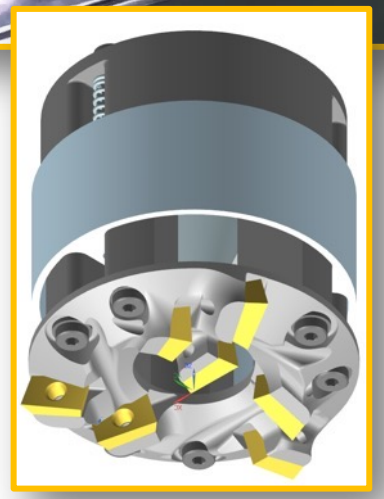


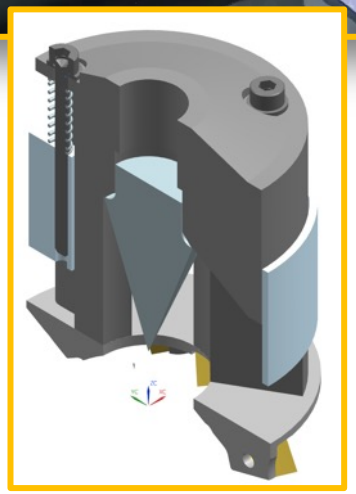
Excavation Tools Tested in Varied Terrains



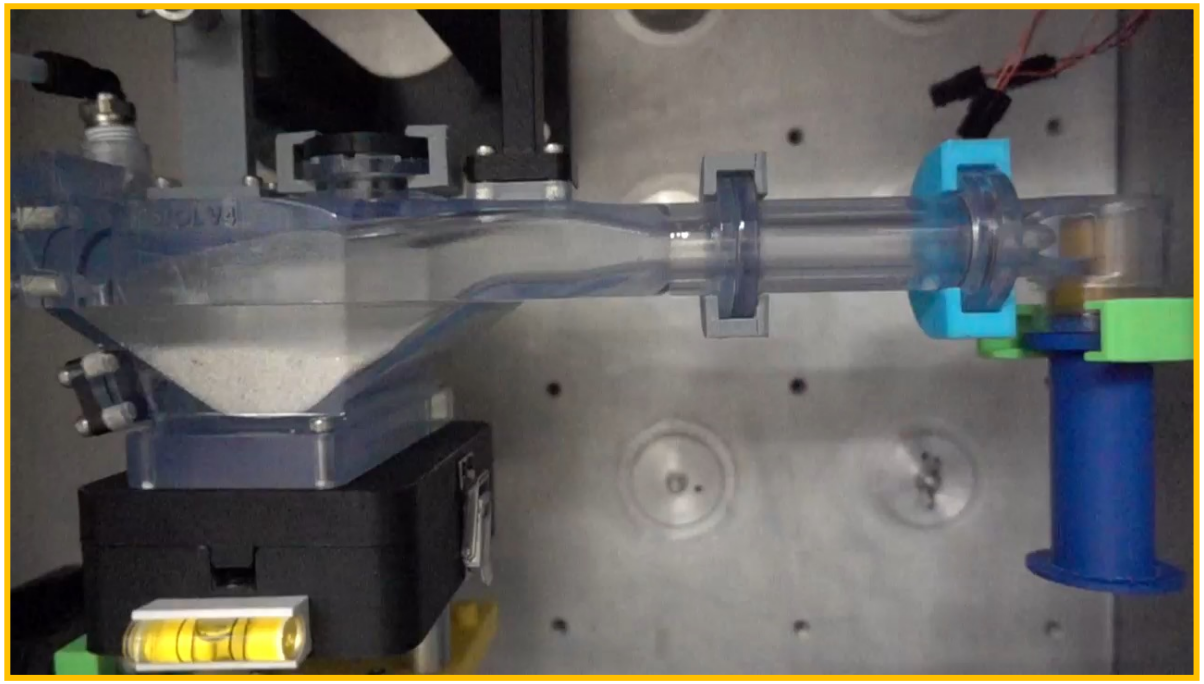
Centrifugal Collection Devices



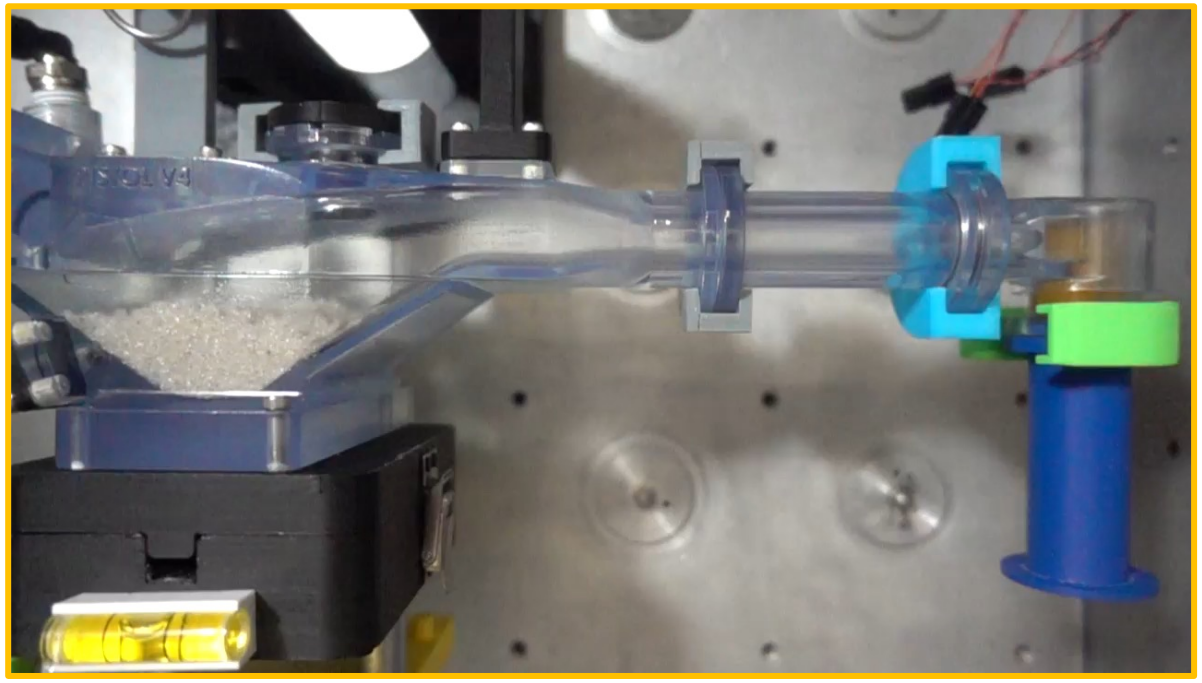




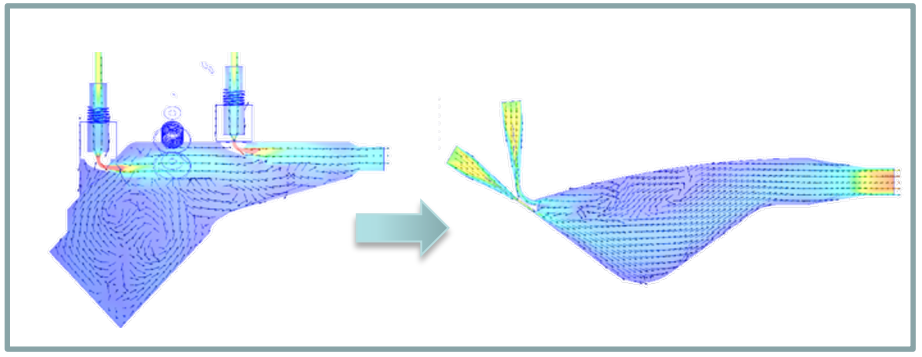
Pneumatic Transfer



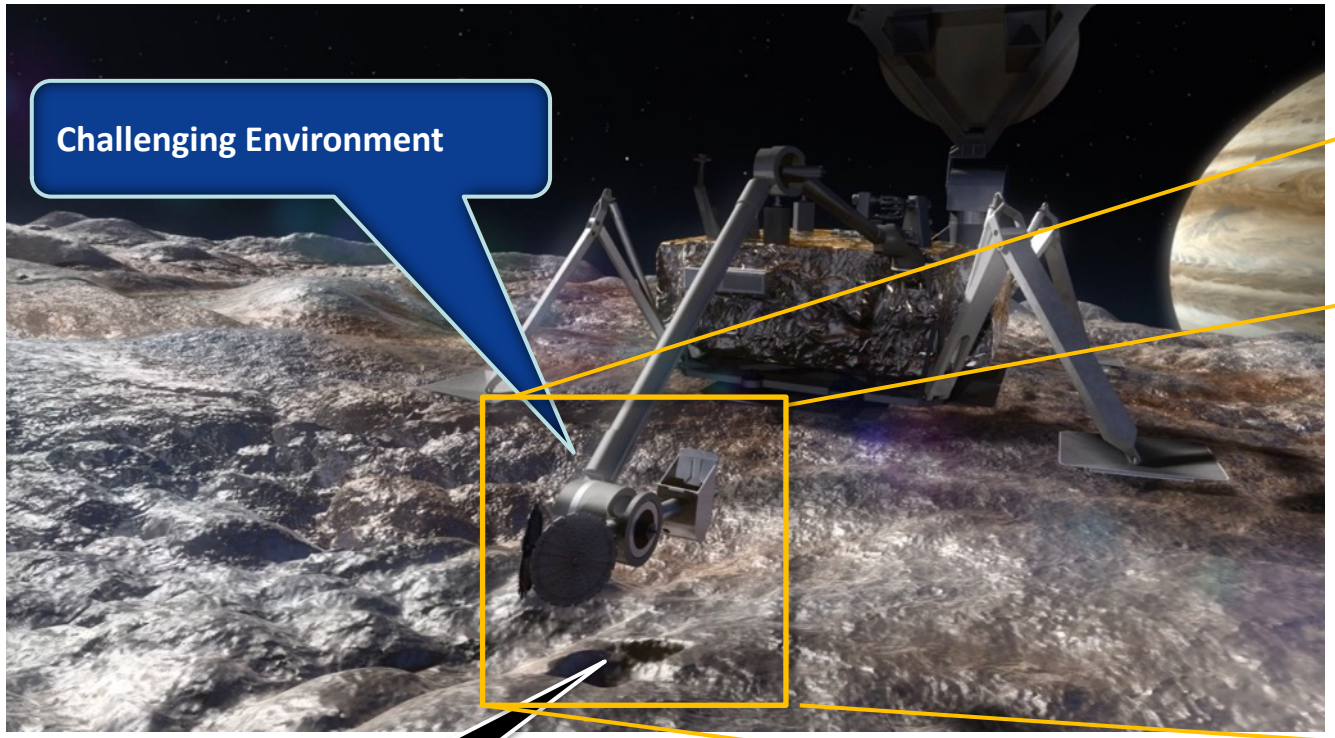
Non-cohesive simulant



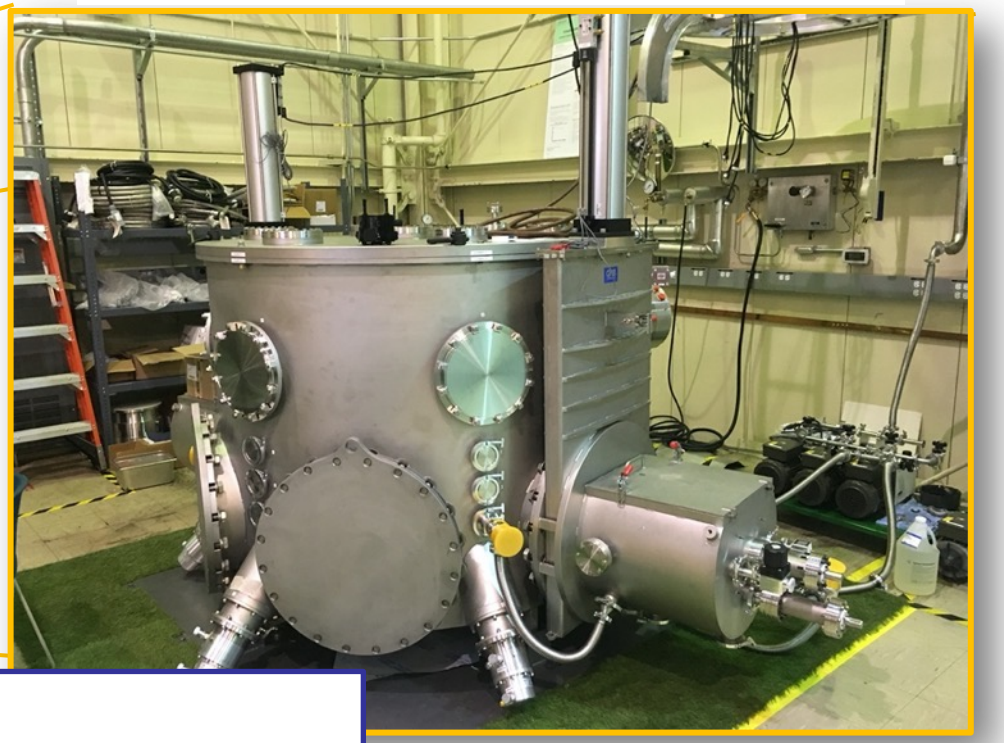
Cohesive simulant



How Do Icy Materials Behave in CryoVac?



CITADEL

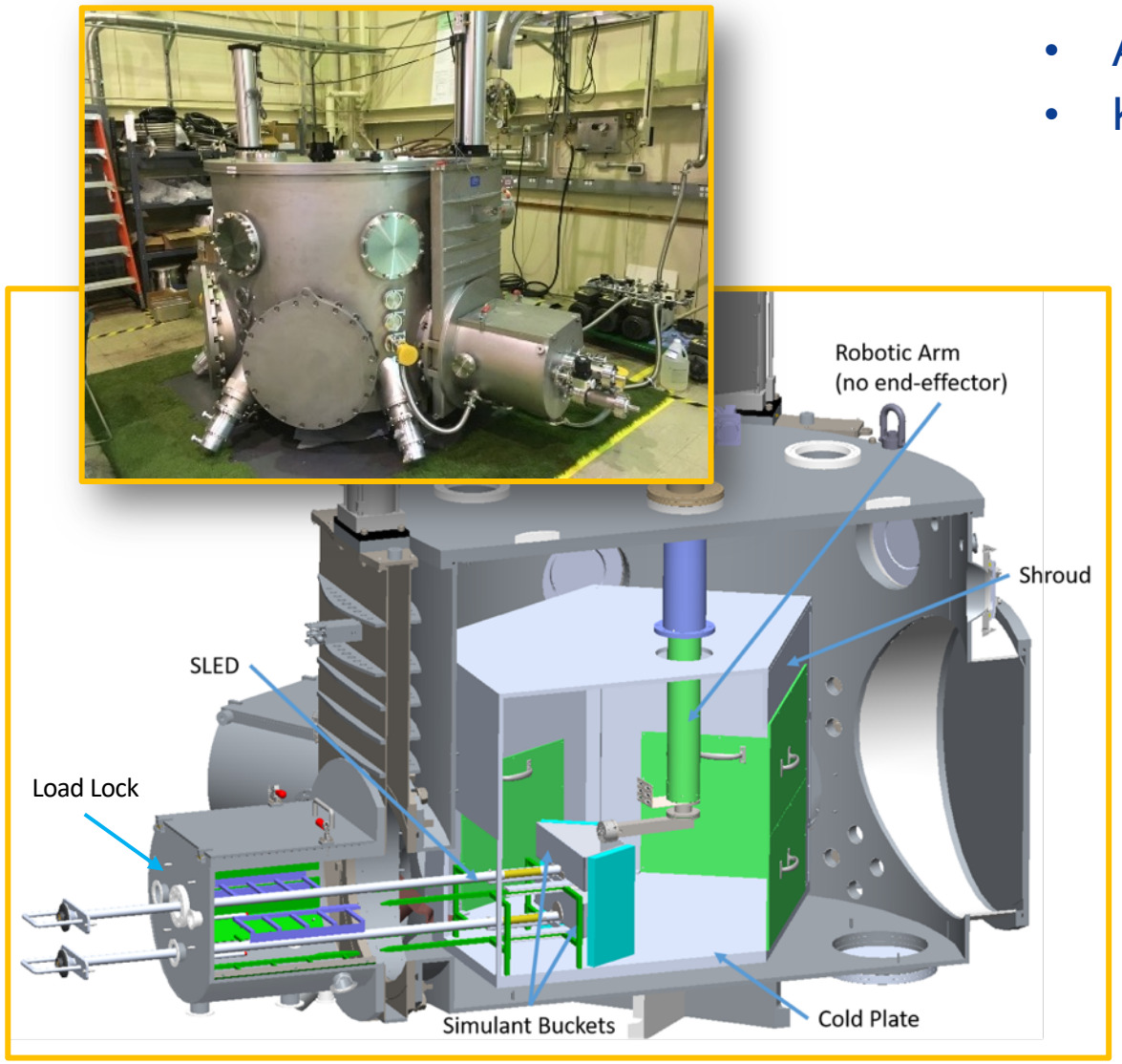


Early Test Objectives:

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

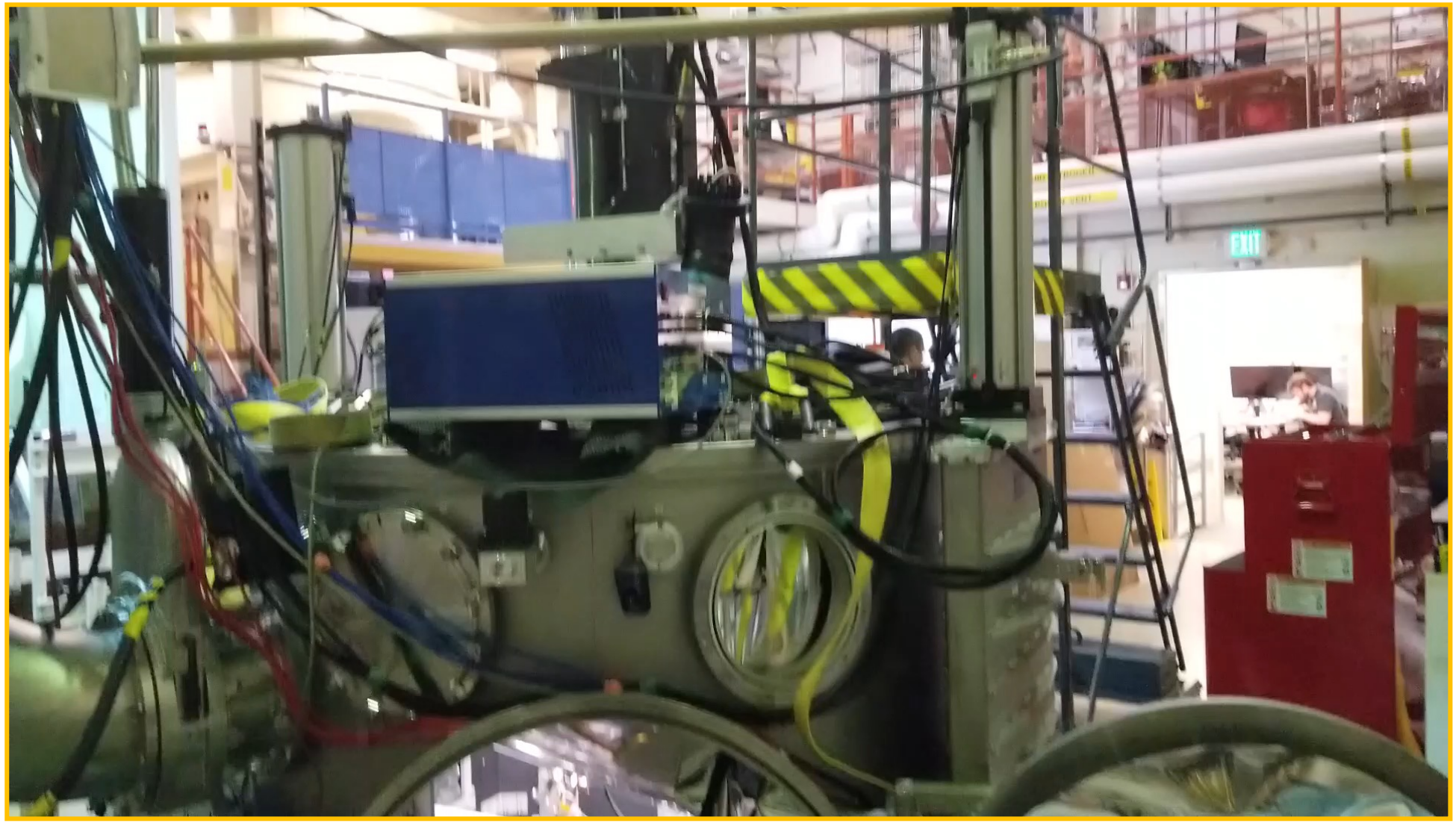
CyroVac Test Venue

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

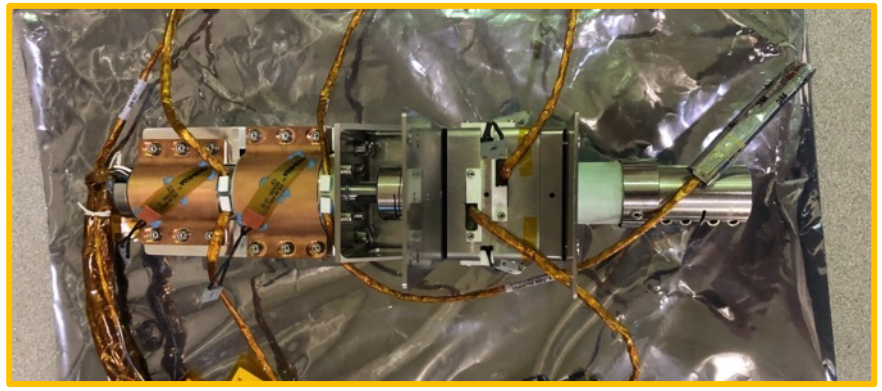
Tour Inside CITADEL



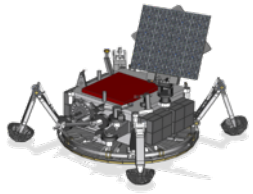
CITADEL Current Status

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

Thermal hardware on Tool motor

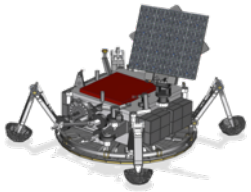


Cutting water ice at ambient



Thank You!

Ambient Testbeds



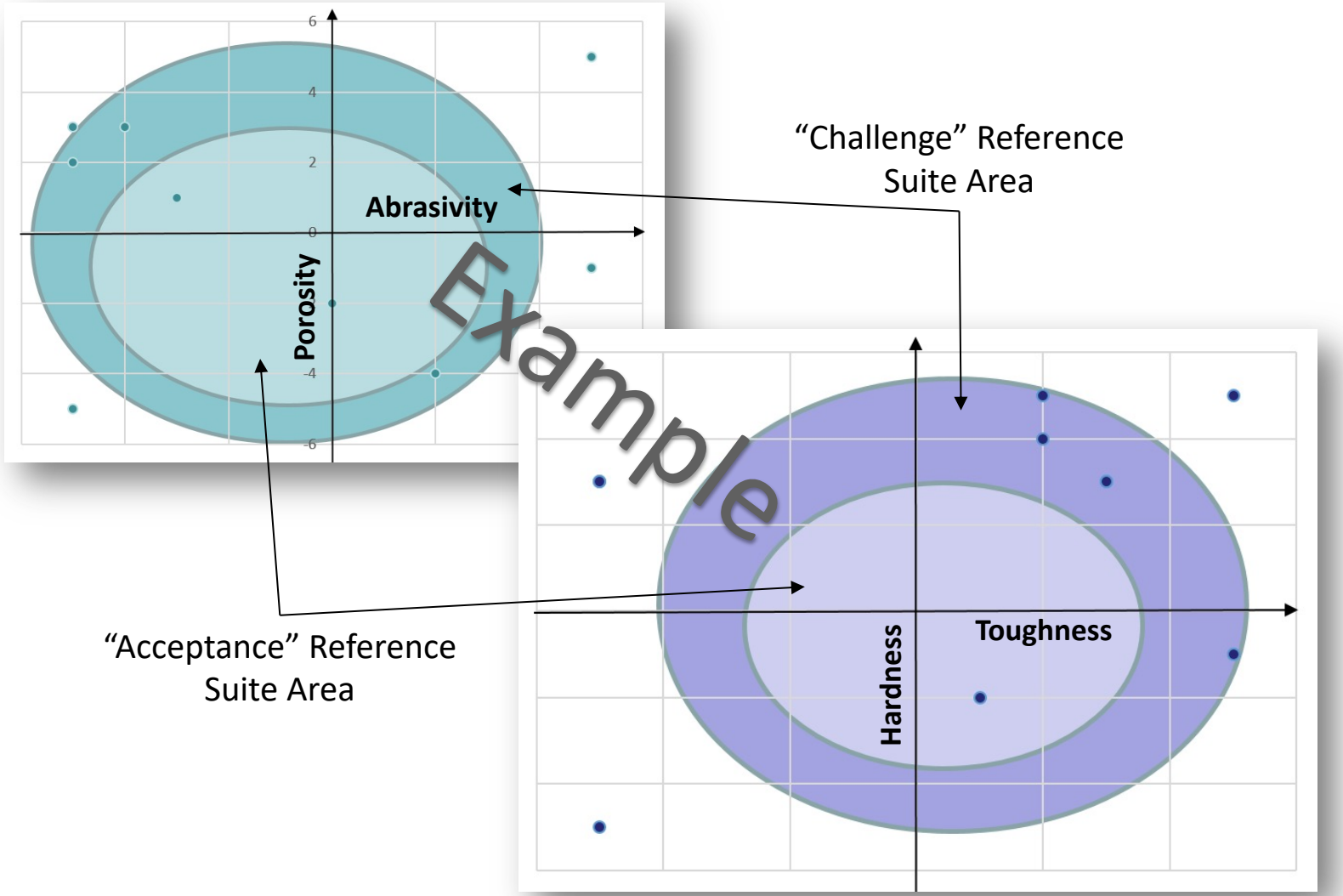
StORM

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 home-grown
  - 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)



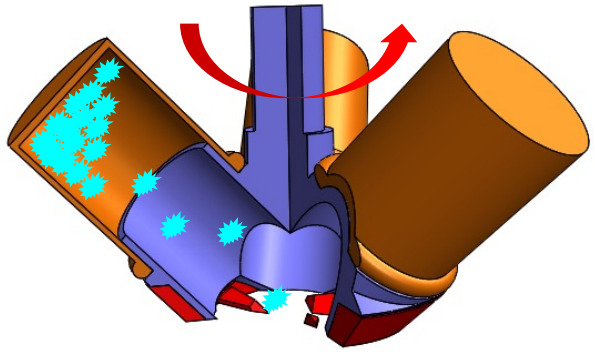
Surface Simulants

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
  - $MgSO_4$ ice
  - Various other impurities
- Key desired simulants not yet used
  - Ice with embedded temperature markers
  - Ice embedded with worst-case concentration of H_2SO_4 constituents
  - Exothermic clathrates

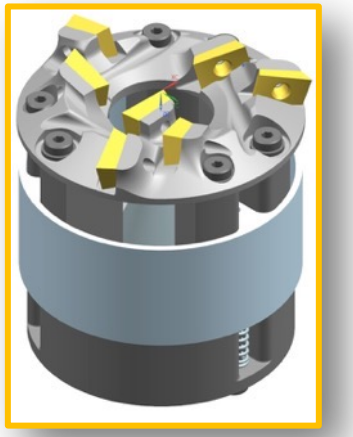
Collection Device Prototype #1

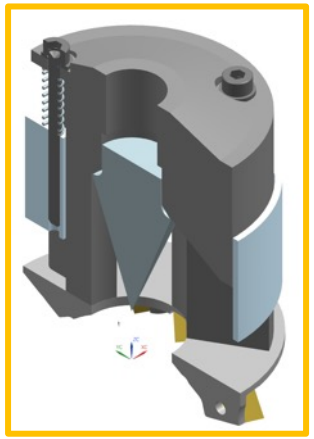
Centrifugal Collector Testing



- Characteristics
  - Sample is divided into separate detachable containers at time of collection
  - Containers need to be oversized to account for post-collection 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

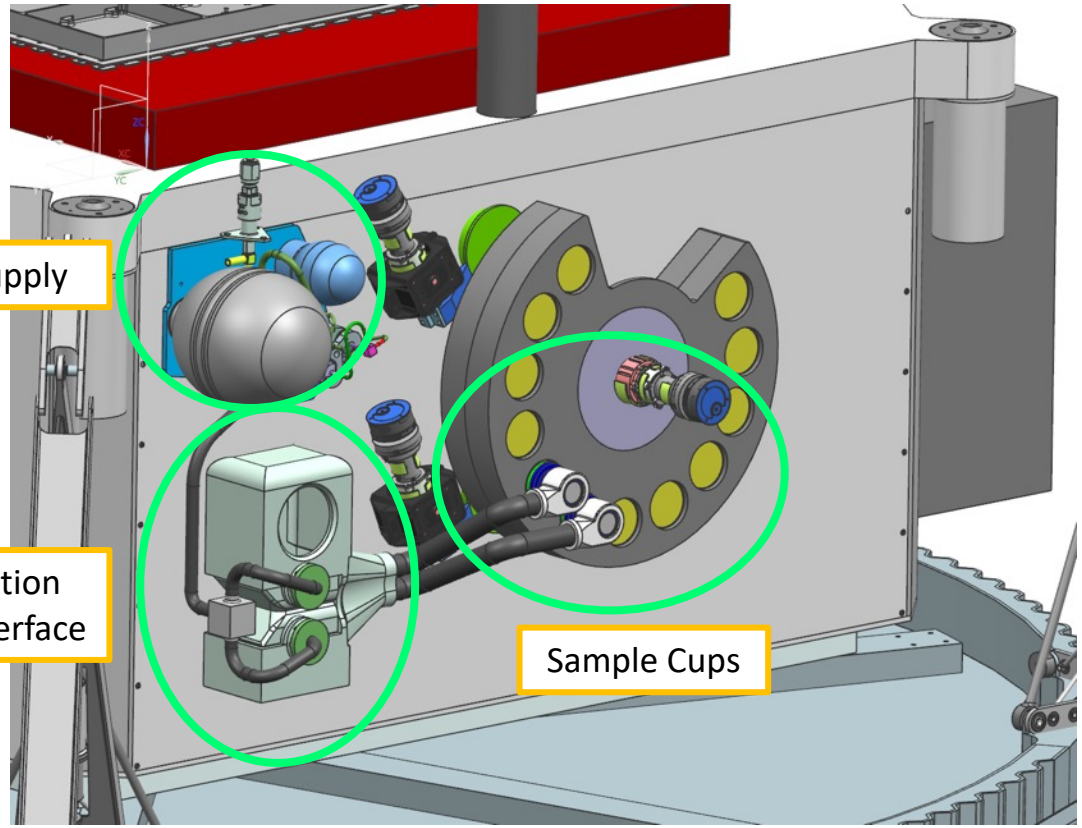
Collection Device Prototype #2





- 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

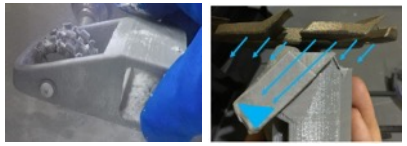
Pneumatic Transfer



- 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

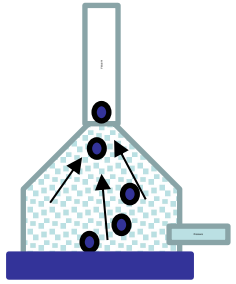


Capture the Rooster Tail

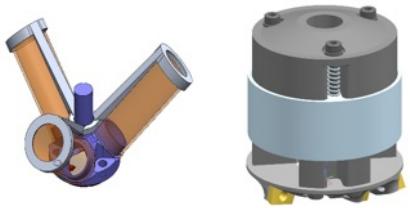
Scoop

Rasp

Auger



Pneumatics



Centrifugal Collectors

Not Yet Explored

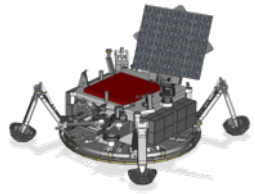
Traps – Sponge, Aerogel

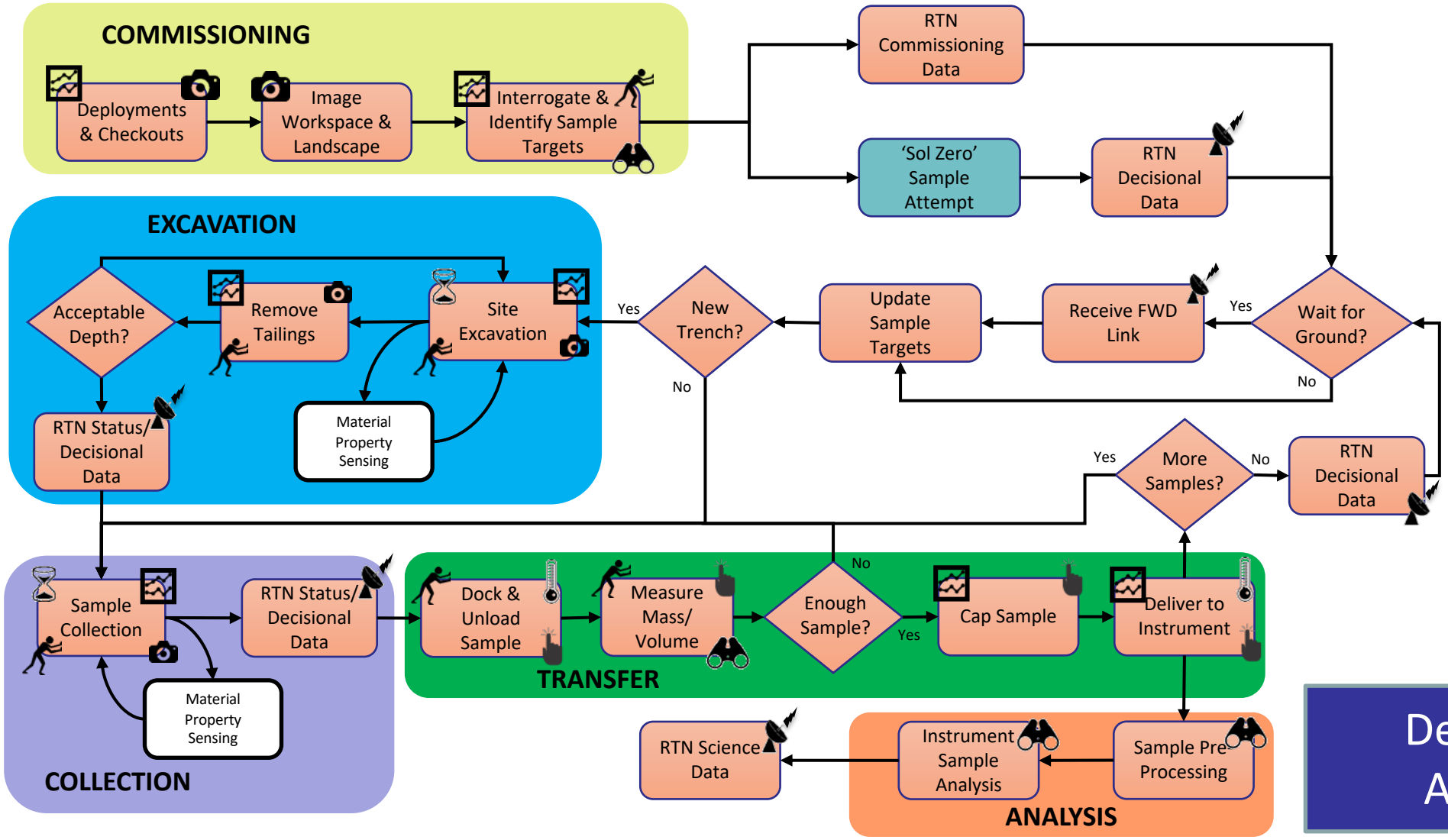
Conveyor

Sleeves

Cups

The Snake Chart: Tool for Conceptual Development & Communication





Dependent on Architecture