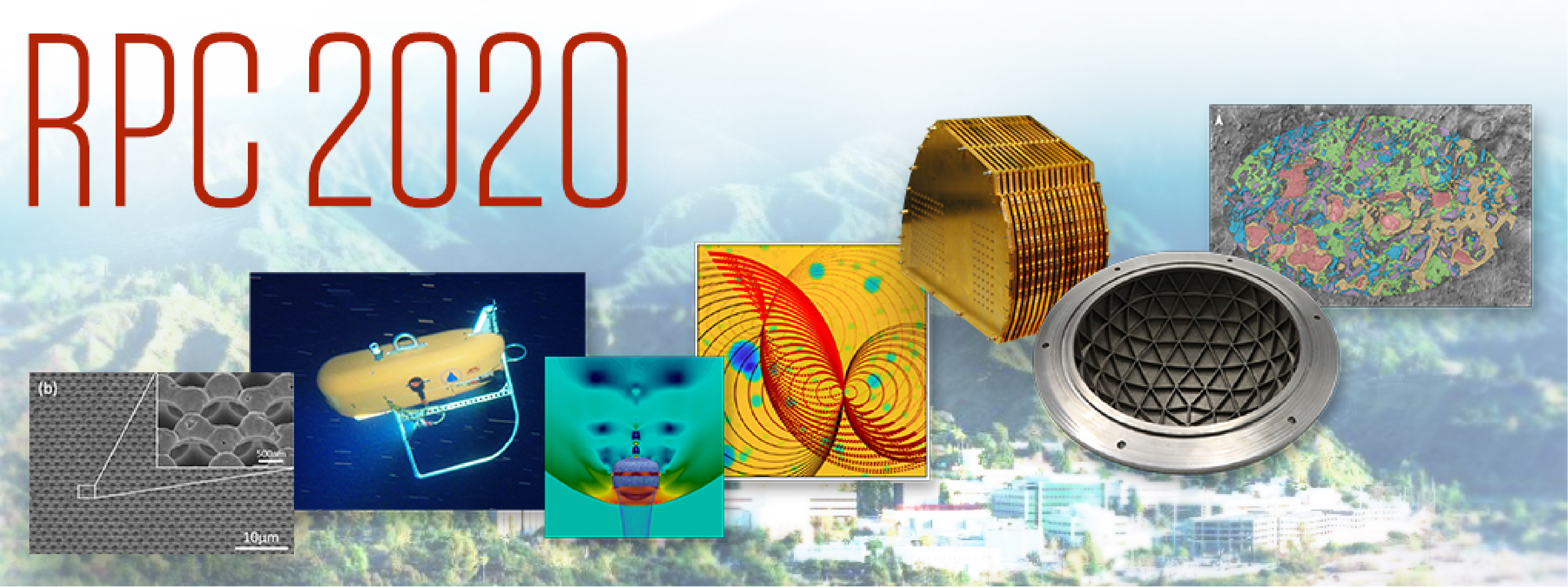

Virtual Research Presentation Conference

Capillary Action Freeze Entrencher (CAFE)

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Program: Spontaneous Concept

Assigned Presentation #RPC-169

Jet Propulsion Laboratory
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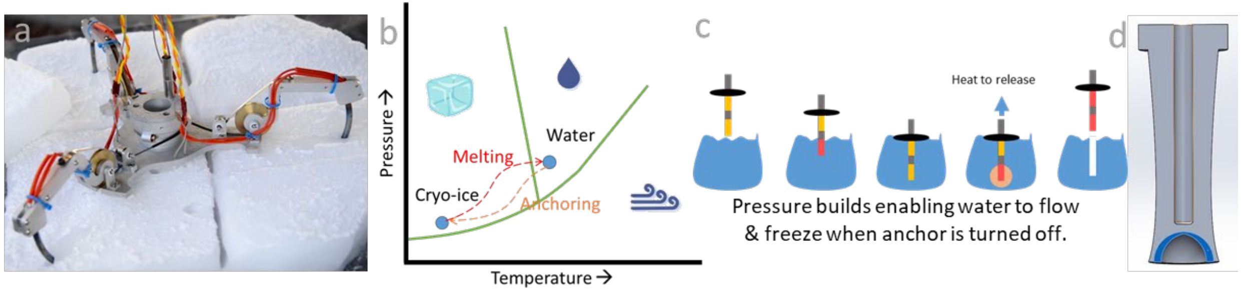
Tutorial Introduction

Abstract

The goal of this task is to improve ice anchoring robustness, reduce power consumption, and mass requirements to a third of current architectures. Current mobility architectures require three points of contact with a large gripping hand to react with all degrees of freedom and ensure a strong foothold. With JPL's recent development of 3d printable locally porous structures, a cryo-ice melt-gripper can provide capillary paths for the liquid water to wick inside of. Once the water refreezes, the anchor will create additional locking moments, allowing a single gripper to react on all six degrees of freedom.



(a) A traditional ice-gripping architecture requiring three points of contact. (b) A representative phase diagram for water showing the anticipate melt/freeze path for the gripper. (c) Schematic of the anchoring/removal process. (d) Concept anchor with solid material colored gray and porous in blue.

Problem Description

a) Context (Why this problem and why now)
   a) NASA has identified icy worlds as important locations for future planetary landers
   b) Icy surfaces pose unique challenges for gripping versus solid rock or dusty terrain
   c) JPL has created a unique method for creating multifunctional structures with integrated interconnected porosity

b) SOA (Comparison or advancement over current state-of-the-art)
   a) Current ice grippers require three points of contact react against all six degrees of freedom (3 translational/3 rotational)
   b) Traditional ice anchors due not work due to hardness of cryoice
   c) Simple heated anchors would require lots of energy to sublimate ice
   d) A properly designed ice anchor sunk into cold ice can prevent rotation and translation with a single anchor

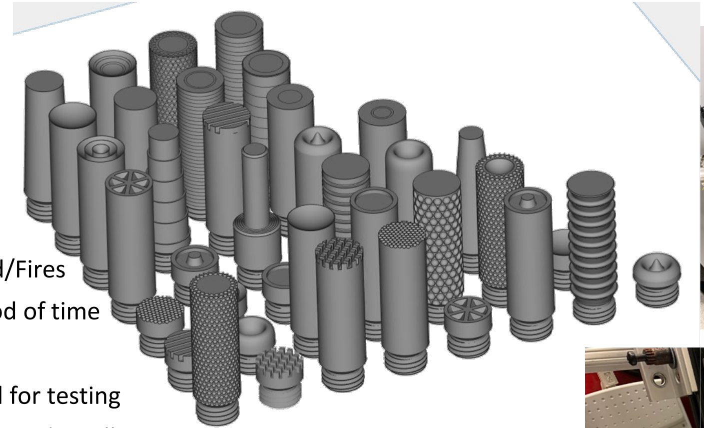
c) Relevance to NASA and JPL (Impact on current or future programs)
   a) The melt anchor system could enable compact mobility systems useful in a variety of environments
      a) Climbing narrow crevasses
      b) Low impact anchoring for low gravity environments such as Enceladus
   b) Can be integrated with a porous capillary liquid sampling system

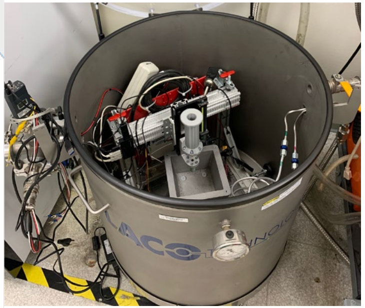
Methodology

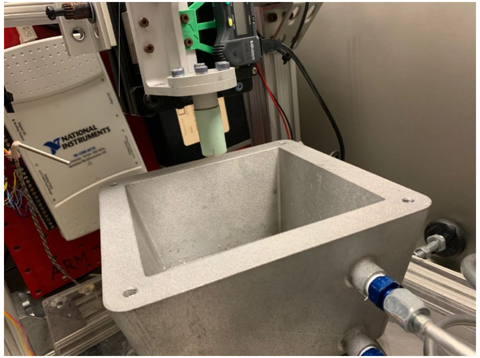
a) Formulation, theory or experiment description
   a) Build an environmental test chamber
      - Low enough pressure to sublimate ice
      - Integrated load cell
      - Contain a movable stage to position ice
      - Move anchor vertically with controllable loading
   b) Design a large assortment of ice anchors to optimize for resisting rotation, shear, pullout, and optimize for energy use

b) Innovation, advancement
   a) Demonstrate the ability to form liquid water in a cryoice vacuum environment
   b) Show single point anchoring to resist shear, rotation, and removal from ice environment
   c) Demonstrate low size, weight, and power compared to a traditional gripping system
   d) Customizability of anchor design for local environment (climbing ice crevasses, anchoring on a surface, low gravity, porous ice)

Results

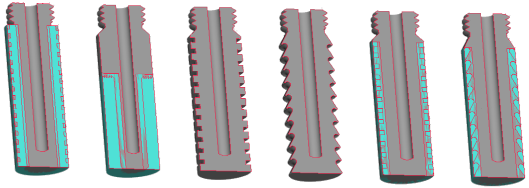






a) Accomplishments versus goals
   - a) Significant setbacks in accomplishing tasks due to Covid/Fires
     - a) Difficulty in accessing labs for an extended period of time
     - b) Delays in deliveries of parts
     - c) Unable to get final tray of ice anchors fabricated for testing
   - b) Were able to build, prepare, and program test chamber and ancillary equipment
   - c) Unable to perform tests due to repeated schedule slips. If funding would continue, could quickly complete the testing forecast for this task.

b) Next steps
   - a) Seek bridge funding to complete task
   - b) Develop PICASSO proposal for instrument idea developed during project
     - a) Low impact capillary pumping system with integrated low-power instruments.
       - Liquid conductivity (measuring total dissolved solids)
       - Particle count
       - Mechanical strength of ice
       - Rapid characterization
       - Concentration of particulates
       - Thermal properties of ice
       - Can double as mechanical anchor



Publications and References

None.