How (not) to lose communication with your submersible on Europa: An experimental study for characterizing the shear performance of tethers under confinement in ice

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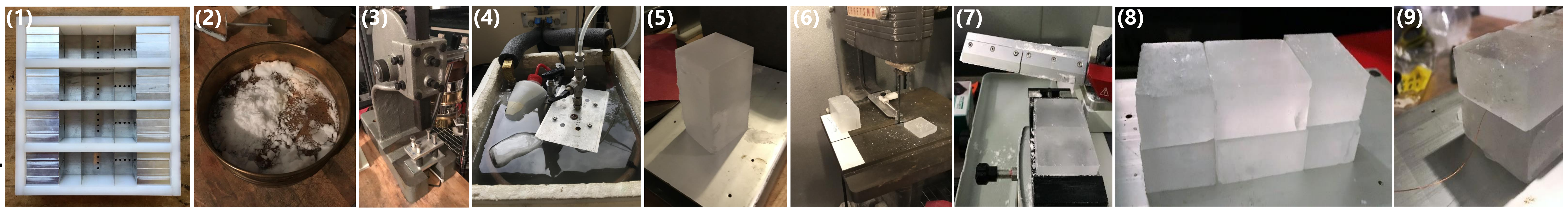
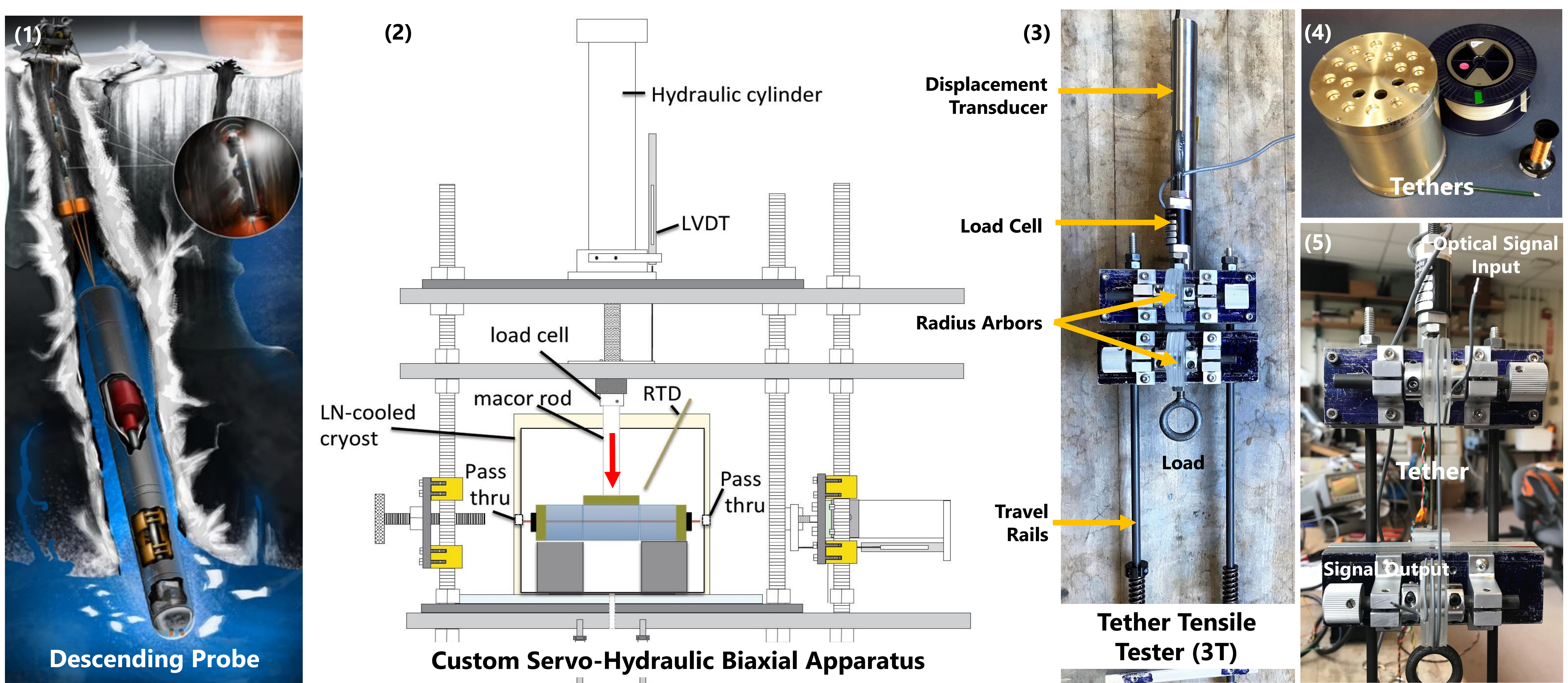
Sample Fabrication



(1) Multi Sample Die (2) Sieving shaved ice (3) Pressing ice (4) Flooding (5) Ice Block (6) Sawing for Microscopy (7) Microtome Ice Blocks (8) Create Ice Block Assembly (9) Insert Tether

Figure 1: Polycrystalline ice blocks of controlled grain size, porosity & impurity content are fabricated using a modified "standard ice" protocol [Cole, 1979] (1-6). Tethers currently employed for polar submersible exploration are embedded in the ice & retained in tension (7-9)

Mission Architecture & Test Apparatus



Singh et al. (in preparation)

Figure 2: (1) Future exploration of ocean world interiors can utilize micro-tether systems. Europa's observed thermo-mechanical properties are replicated to investigate (4) various tethers in ice with a (2) custom biaxial cryogenic deformation rig and (3,5) Tether Tensile Tester (T3) apparatus

Europa Signals Through The Ice (STI)

Micro-tethers offer unparalleled data transfer rates (for minimal size, mass & power) and sufficient length, but **can they survive under Europa's expected thermo-mechanical conditions?**

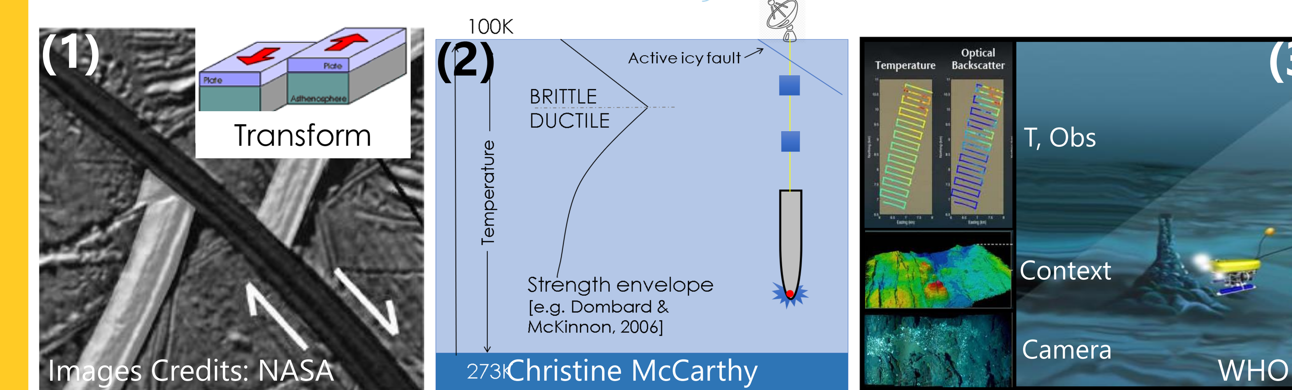


Figure 3: (1-3) Micro-tethers need to survive 10s of km in Europa's interior, while maintaining pathway for robust communication with surface lander

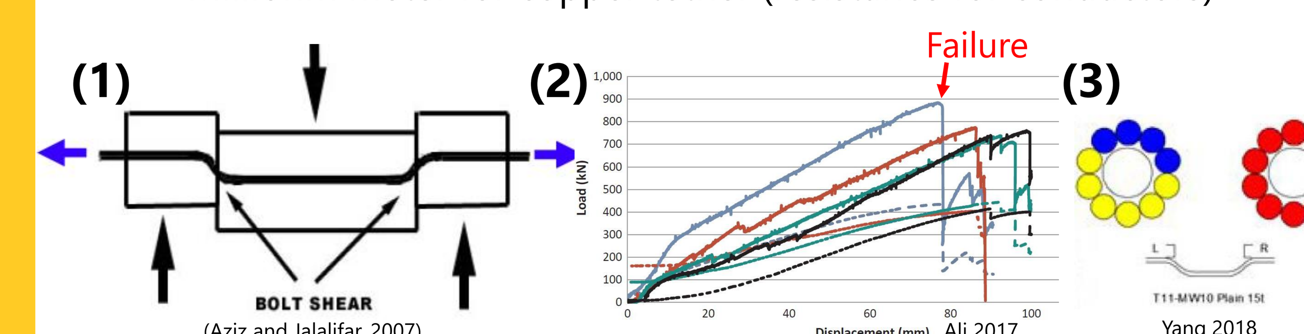
OBJECTIVE

Characterize viability of employing tethers with a laboratory setup simulating Europa's shearing & fault conditions

1. Measure strength, communication performance & deployment
2. Calibrate optical working strength & ultimate tensile strength
3. Identify failure modes using microscopic characterization

METHODS & TESTS

1. Testing includes shearing across 2 icy "faults" between 3 forcing ice blocks for various tethers at (Europa-based) parameters of:
   - Shear Stress | Velocity | Temperature | Ice Composition
2. Testing ices at 100-250K with tethers for velocities 10^{-7}-10^{-3} m/s, using biaxial cryogenic deformation apparatus:
   - Normal stress (100 kPa) maintained & vertical piston driven (constant shear rate) until optical and/or mechanical failure
   - Identify effects of pre-tension using load cells
3. Characterize communication performance (T3 & Biaxial):
   - Optical Backscatter Reflectometer for fibers (power loss & strain)
   - Milliohm meter for copper tether (resistance for conductors)



Characterize Tethers under Shear — Load vs Displacement Plot — Failure Modes

Figure 4: Expected deliverables for laboratory component of Europa STI

RESULTS

1. Establish properties for tethers in Europa-like ice/environment
2. Map out viable stress regimes for communication

Tether	Diameter (mm)	Max. Tensile Load (N)	Max. Shear Load (N)	Shear Displacement at Max. Shear	Mass (kg/20km)	Working Strength (kN)	Optical Working Strength	Bending Radius (mm)
Linden STFOC	0.965	220	?	?	18	?	?	38
Linden HSFOC	1.9	1100	?	?	72	133 (FOMC)	?	?
Bare Fiber	0.25	~10	?	?	1.282	8	?	?
XBT Cu Ribbon	0.113 x 2	< 10	?	?	4	?	?	?

Table 1: Europa STI will establish optical & shear properties of tethers

FUTURE TESTS: Freeze-In & Long Duration Cold Tests | Heating | Tether Fatigue (normal stress) w/o Ice | Shear on Tethers w/o Ice

Europa STI will enable development of tethered communication techniques to operate in the harsh conditions of Ocean World Interiors

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