

Ocean World sampling and data communication through significant ice depths

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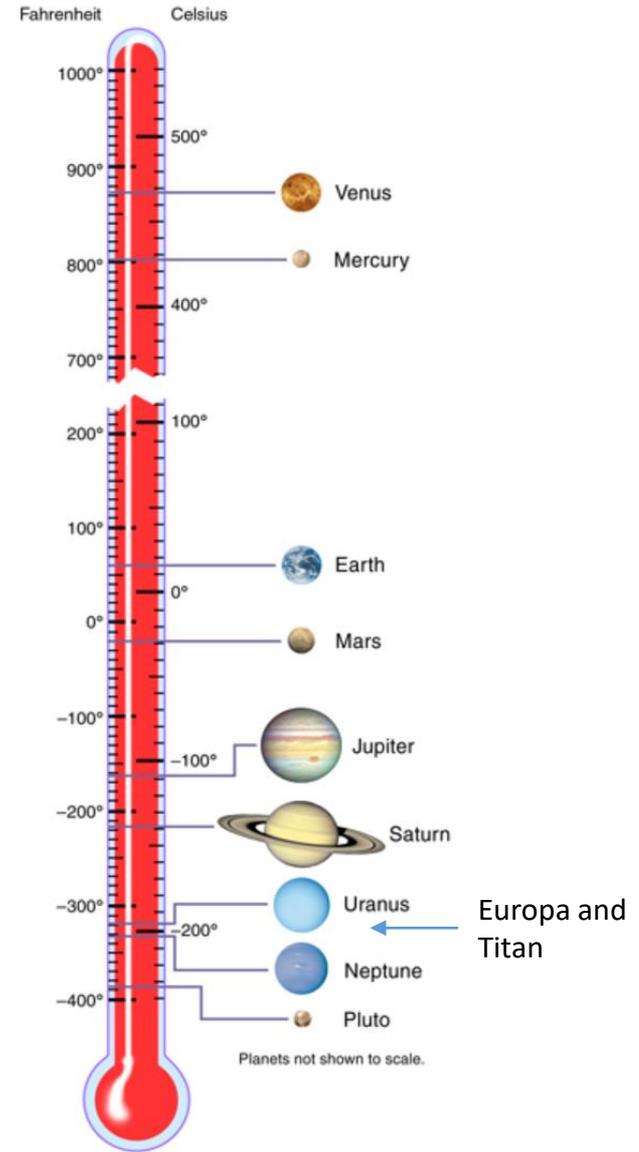
Outer Planets Assessment Group (OPAG)

Atlanta, GA Feb. 22 – 23, 2017

<http://www.lpi.usra.edu/opag/meetings/feb2017/draft-agenda.pdf>

Outline

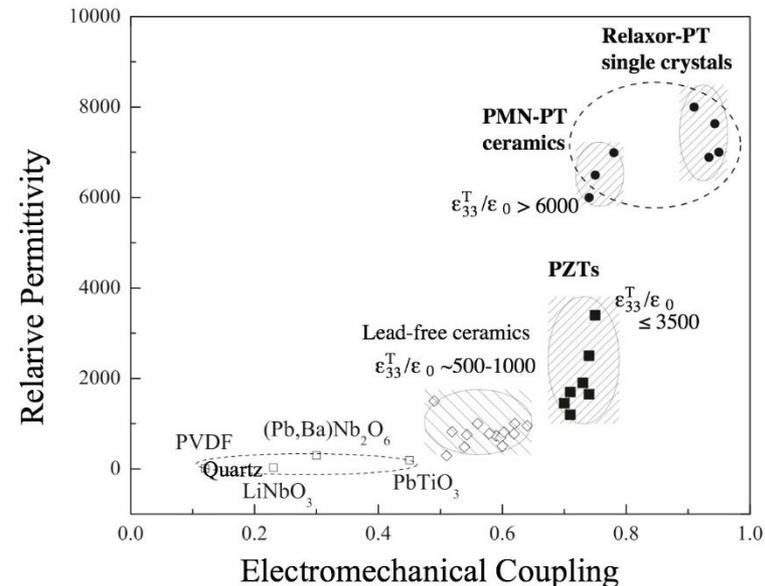
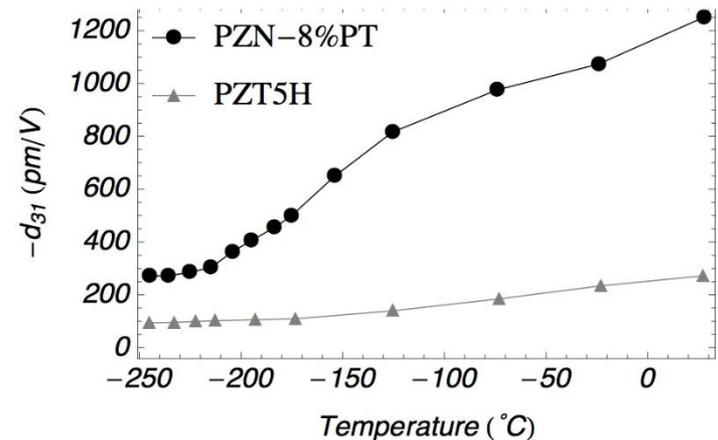
- Cryogenic temperature piezoelectric materials
- Piezoelectric driven devices
 - Sample conveyer
 - Linear inch-worm motors
 - Rotary motors
 - Piezoelectric hammer drills
 - Piezoelectric rotary hammer drills
 - Piezoelectric sonar
 - Piezoelectric acoustic communication
- Other NDEAA developments



The temperature at various bodies in the Solar System

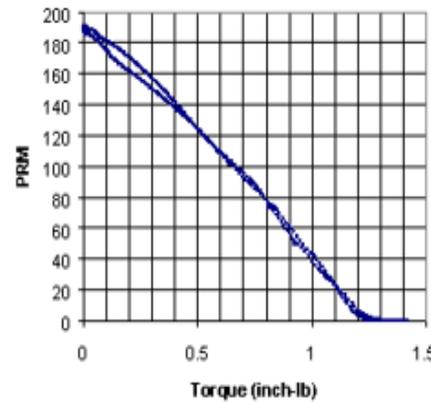
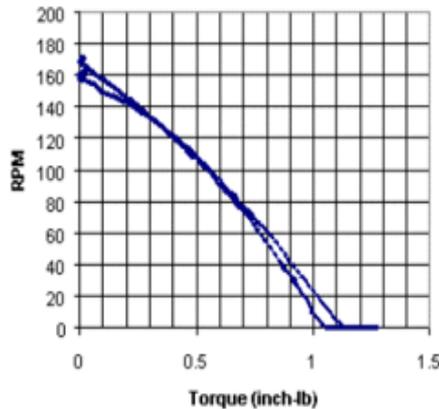
Piezoelectric transducers applicable at cryogenic temperatures

- Conventional piezoelectric materials, represented by PZT, lose most of their piezoelectric activity at cryogenic temperatures.
 - For example, the piezoelectric strain coefficient of soft PZT decreases from 760 pm/V (picometer per volt) to 220 pm/V when the operating temperature decreases from 300K to 30K.
- Studies of relaxor-ferroelectric based single crystals have revealed their extremely high piezoelectric coefficient at cryogenic temperatures, e.g., d_{33} of single crystal piezoelectrics (PMN-PT or PZN-PT) at 30 K is almost equal to d_{33} of PZT-5A at room temperature, indicating great promise for cryogenic applications.
 - This high piezoelectric coefficient implies that similar acoustic sources for a transducer can be achieved by replacing conventional PZT material with relaxor-ferroelectric single crystal at cryogenic temperatures.

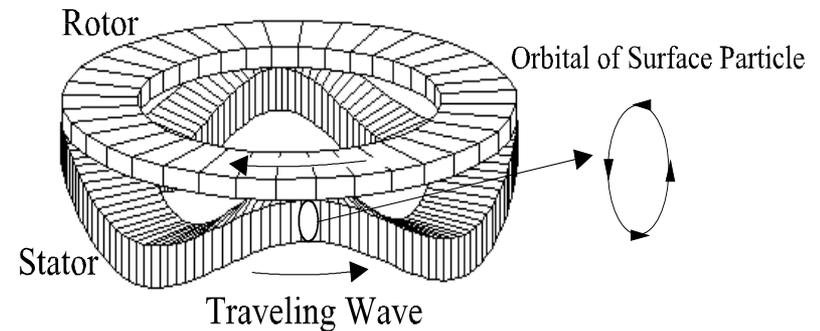


Rotary motors

Cryovac testing of the developed (traveling wave) piezoelectric motor



(a) Before test (b) After 231 temperature cycles
Temperature cyclic test

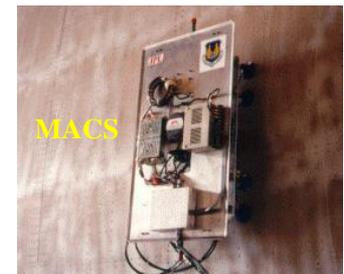
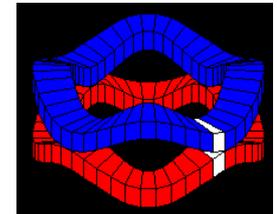
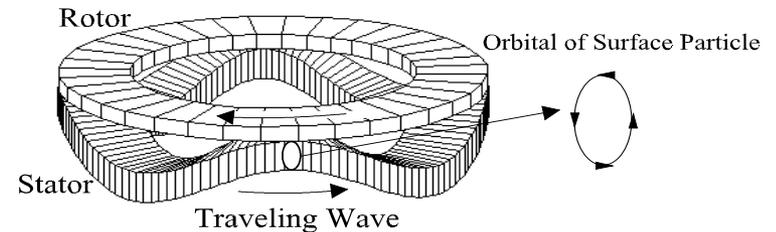


Principle of Operation of a Rotary
Traveling Wave Motor.

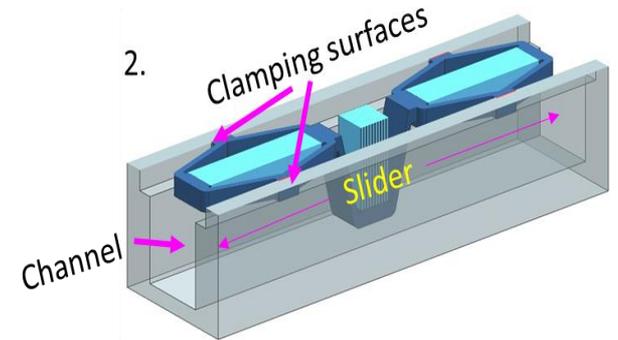
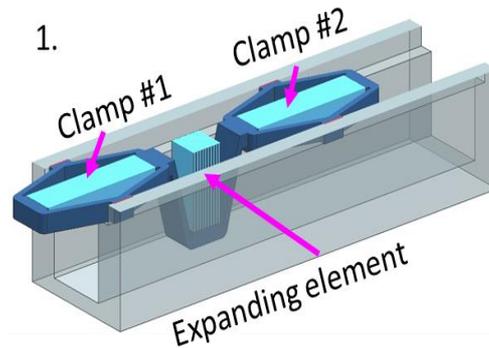
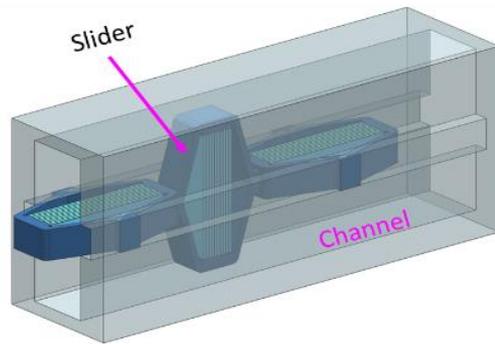
The developed motor survived a total exposure of 336 hours at cryovac test conditions of 65 hour at -80°C and 25-mTorr plus 271 hours at -150°C and 16-mTorr).

Ultrasonic motors (USM) advantages

- Low speed and direct drive
- Order of magnitude higher torque density than electromagnetic motors
- Unique configurations: Pancake as well as annular shape for electronic packaging
- Lower cost, easy to miniaturize and to mass produce
- Inherently backdrivable (self braking)
- Not affected by magnetic field or radiation



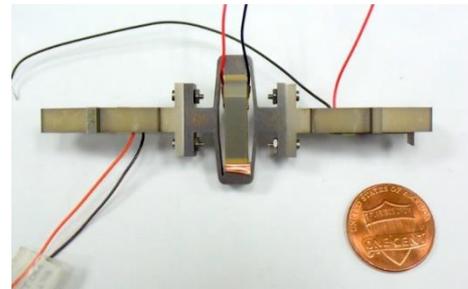
Linear motor



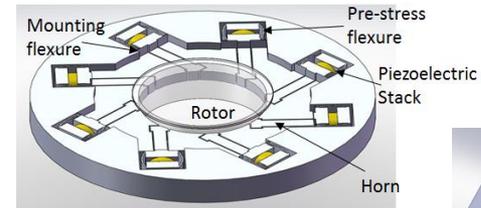
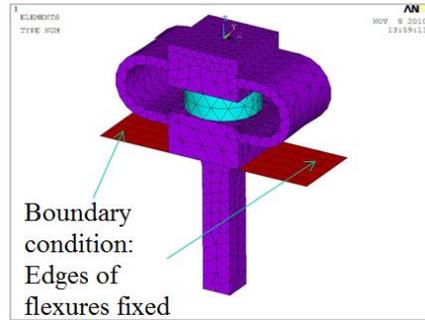
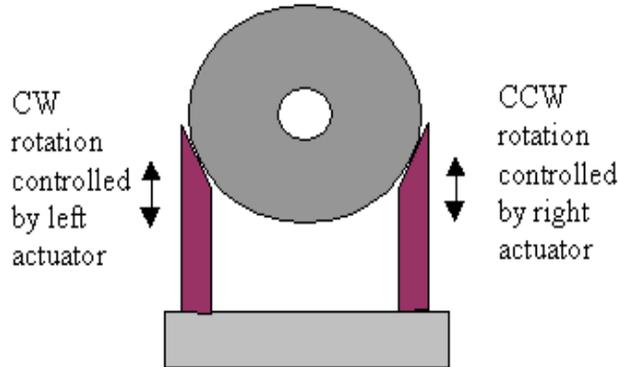
Configuration of a flextensional piezoelectric inch-worm motor.

A step in the translation of the slider inside the channel that makes up the motor.

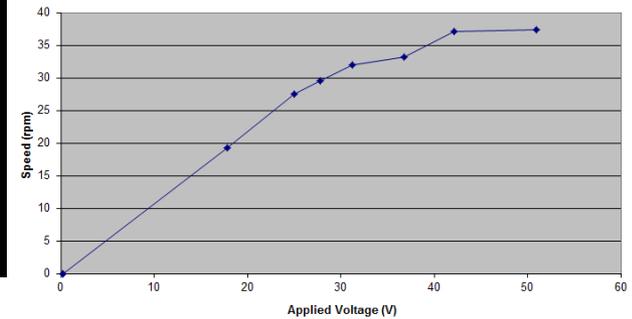
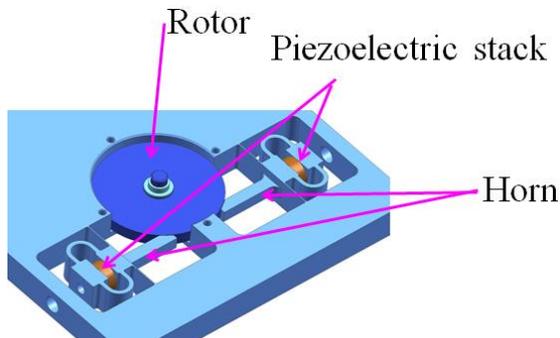
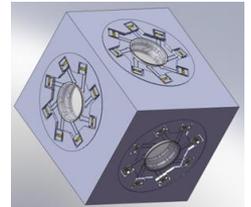
The fabricated piezoelectric inch-worm motor.



Piezo-Barth Motor

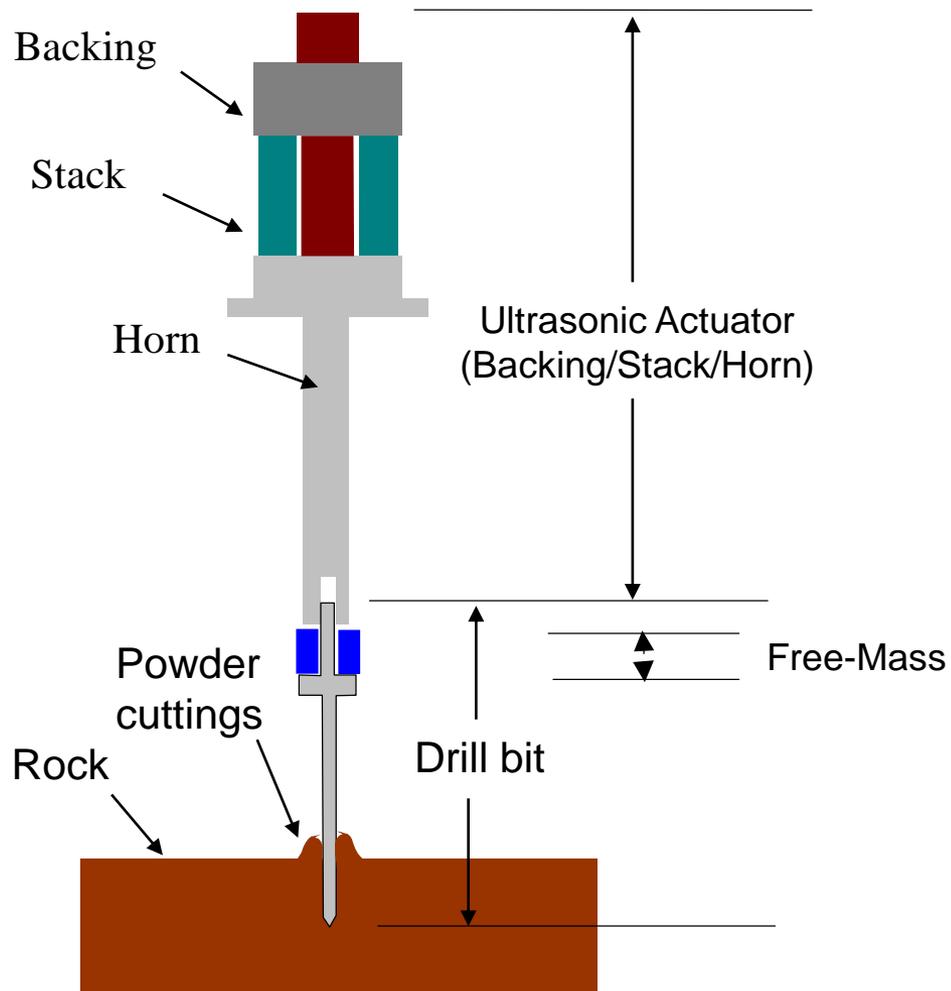


Unidirectional, bidirectional and 3D motor designs

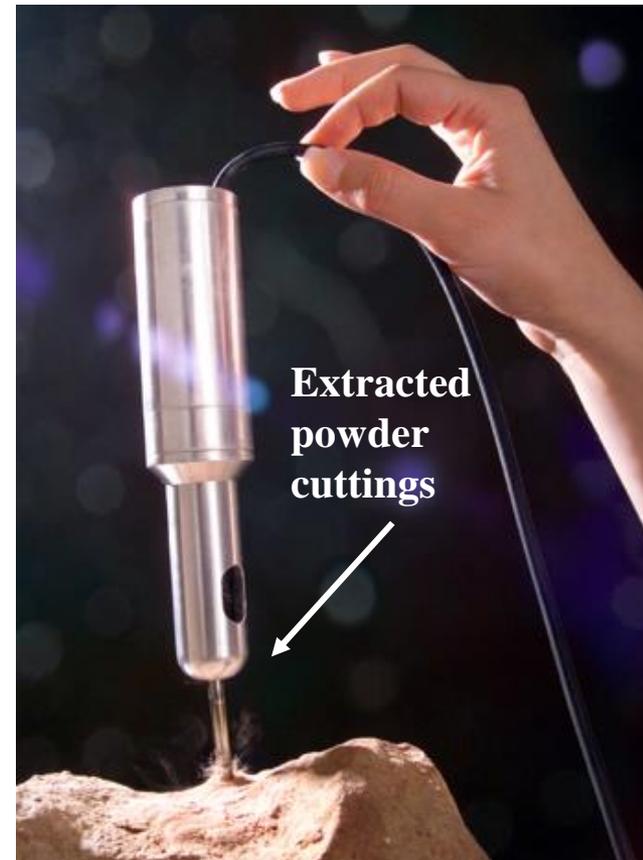


NTR REF: S. Sherrit, X. Bao, M. Badescu, Y. Bar-Cohen, P. Ostlund, P. Allen, and D. Geiyer, "Planar Rotary Piezoelectric Motor using Ultrasonic Horns," NTR Docket No. **47813**, (2010)

Ultrasonic/Sonic Driller/Corer (USDC)



2000  100 award



USDC



USDC

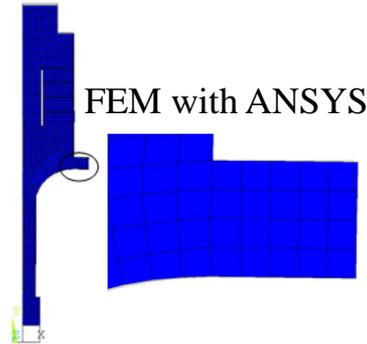
USDC anchor – operates forward and backward. Supported the steep terrain rover



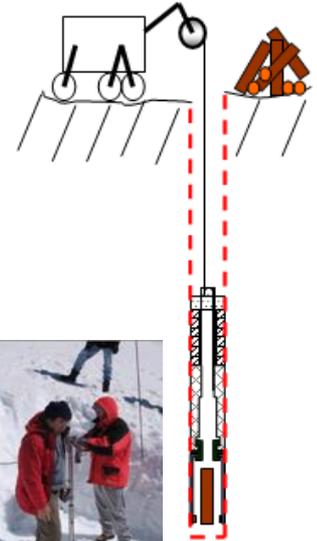
Packed soil penetrator



Ultrasonic Rock Abrasion Tool (URAT)



FEM with ANSYS



Gopher was field tested in Mt. Hood and Antarctica



Quiet drill



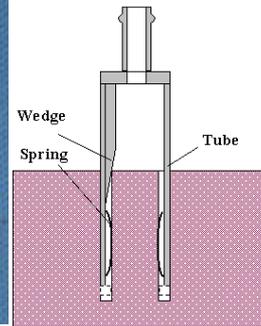
High temperatures



Low



Folded horn

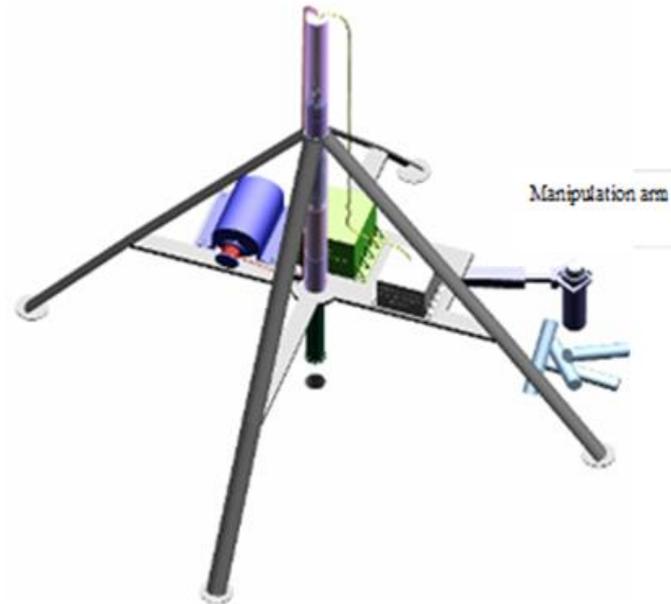
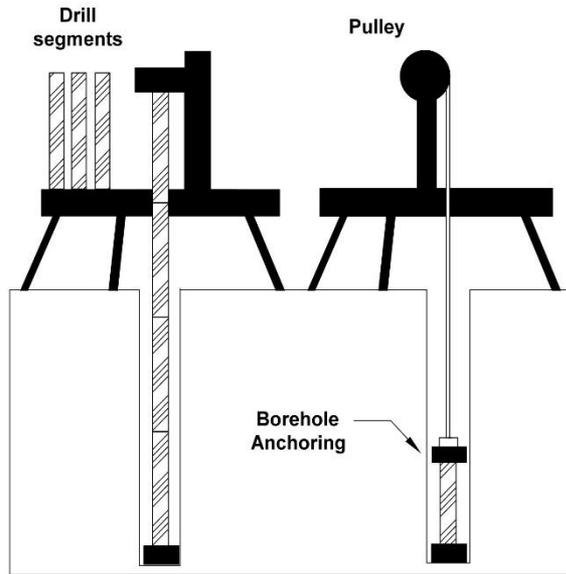


All-in-one bit

Wireline drill – reaching great depth

Conventional Approach

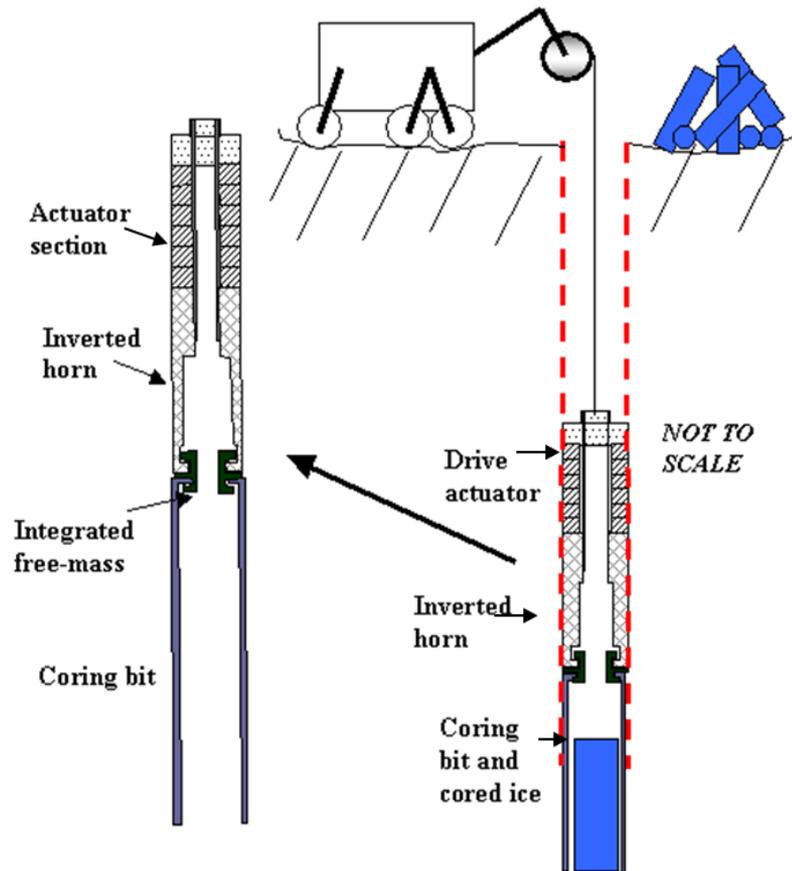
Wireline Approach



Rotary-hammer for efficient, dry drilling

- Piezoelectric actuator – hammers the bit and provides effective fracturing mechanism
- Electrical motors - provides cuttings removal via rotation, linear feed for weight on bit control, and anchoring

The U/S Ice-Gopher

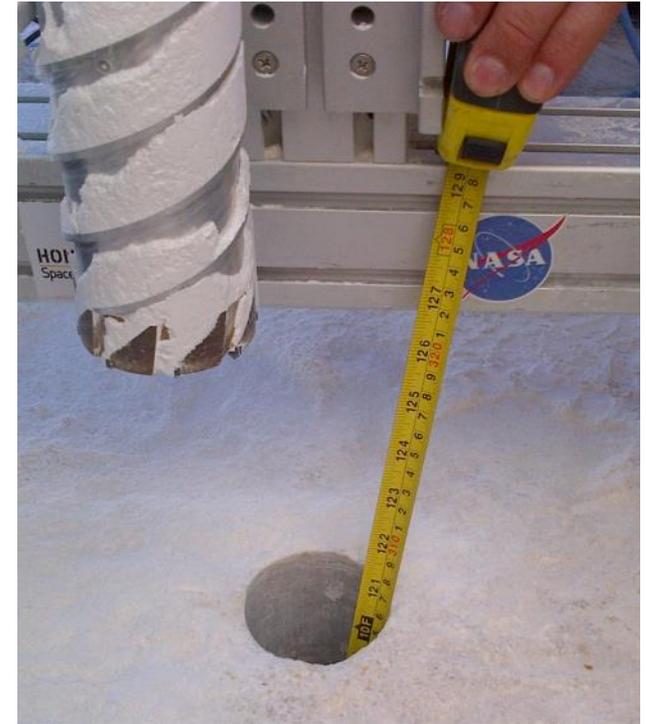
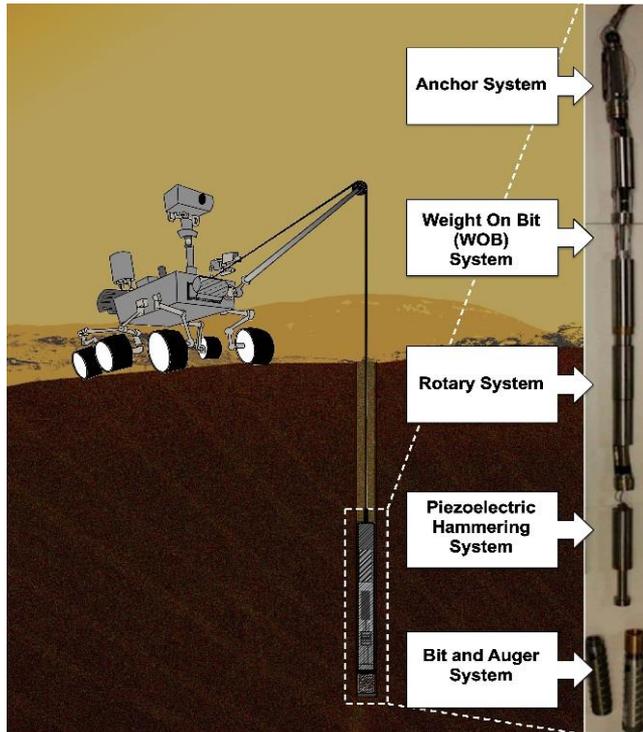


Sea ice drilled borehole entry



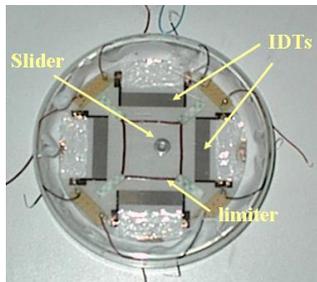
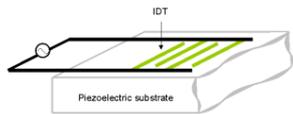
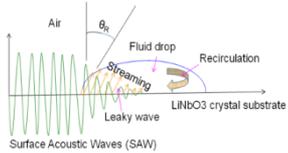
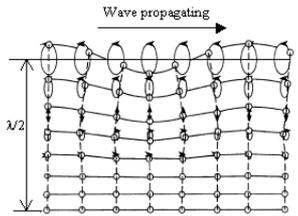
The gopher in the drilled hole

Field test (joint with Honeybee Robotics)

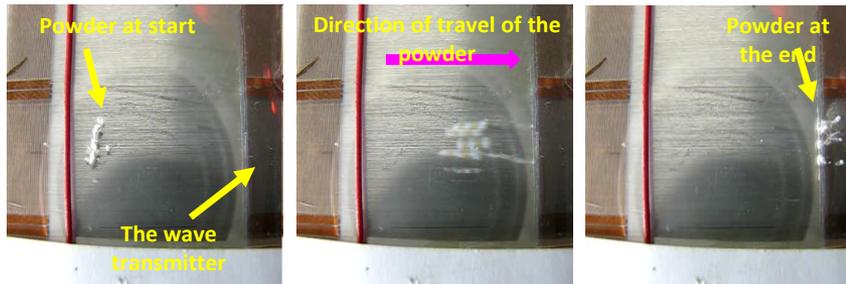


32 cores were extracted from a depth of 3.07 m

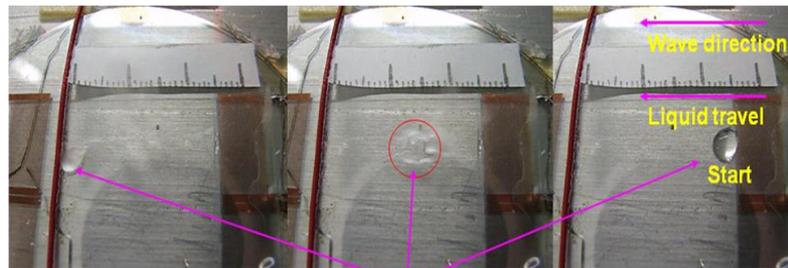
Beltless conveyer using Surface Acoustic Wave (SAW)



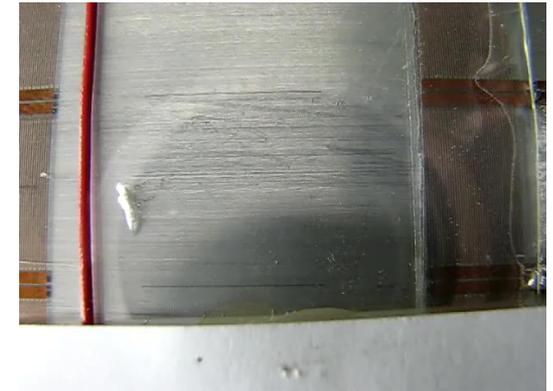
2D SAW motor



Snapshots from the travel of WCA 12 powder with 50% 7–8.5 μm particles.



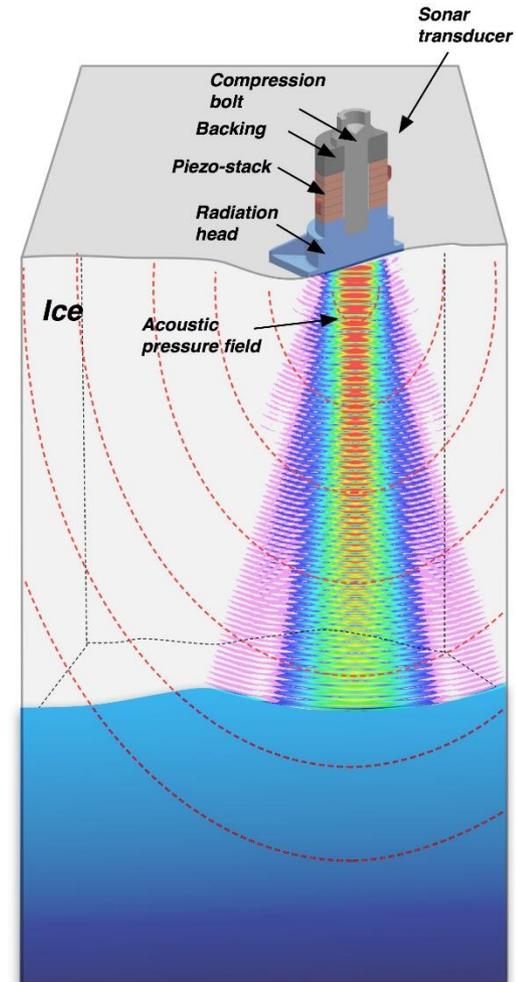
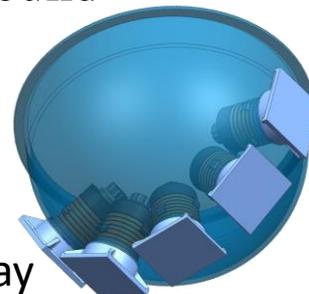
Snapshots from the travel of water droplet (the travel direction here is from right to left).



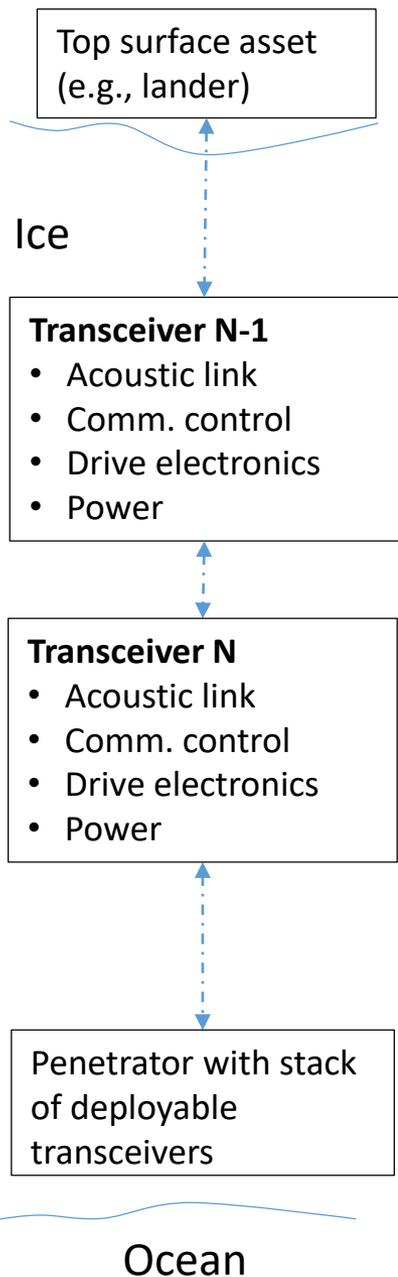
iSONAR - Acoustic analyzer of icy sub-surfaces of cold bodies in the solar system

- An iSONAR is being proposed as an analyzer for exploring Europa's subsurface as well as the investigation of Titan lakes' architecture.
- A sonar probe emits acoustic waves, which are reflected from discontinuities and subsurface layer interfaces depending on the transmitted power and acoustic properties.
- The emitted waves are reflected by interfaces where contrast in acoustic impedance (sound speed times the density) occurs.

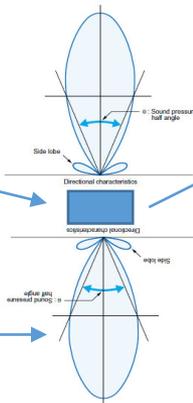
Sonar transducer array



Wireless Acoustic System (WAcS) for communication through thick ice

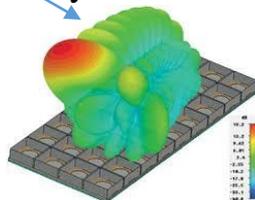


Acoustic transceiver



Directivity of the transmitted acoustic wave from a single transducer

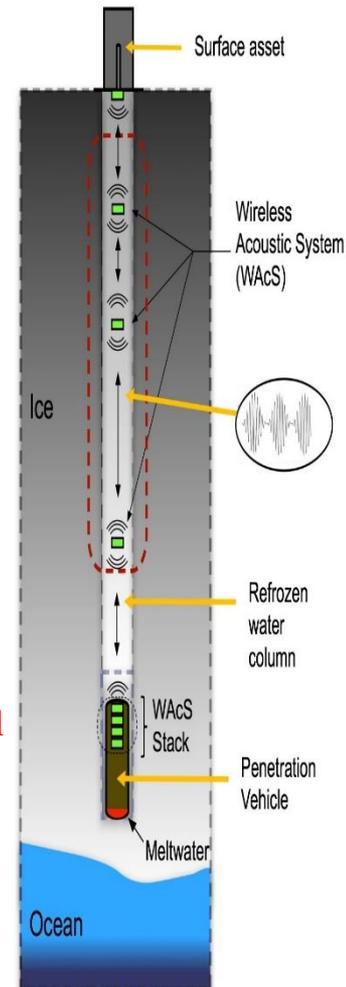
Transmitted acoustic field from a transducer array

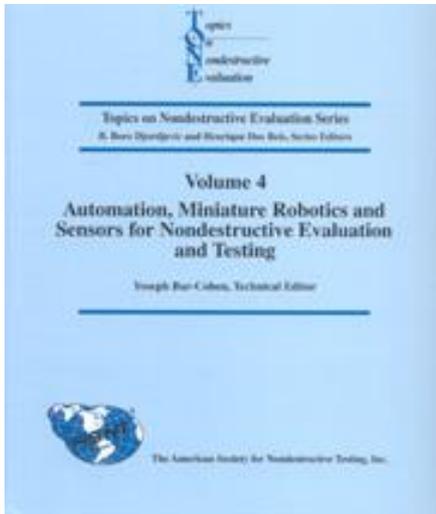


Transceivers

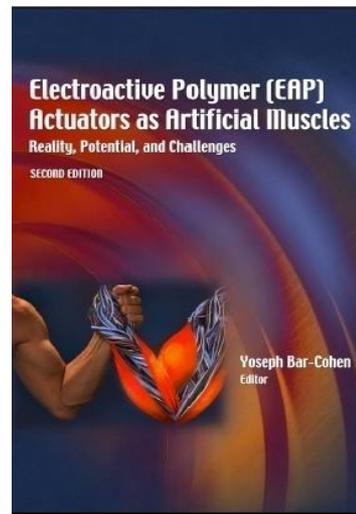


Cordless hydrothermal melting drill

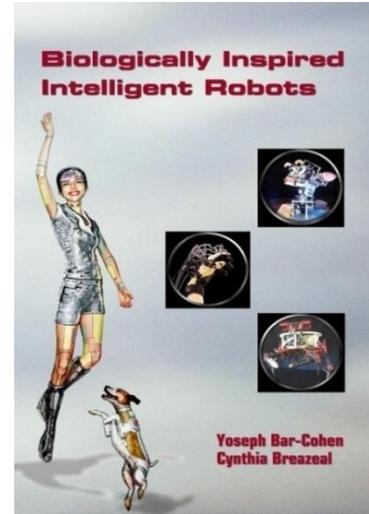




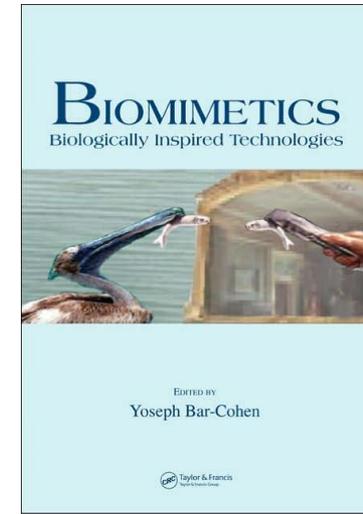
2000



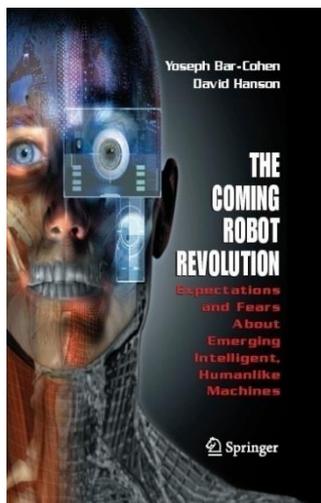
1st Ed. (2001)
2nd Ed. (2004)



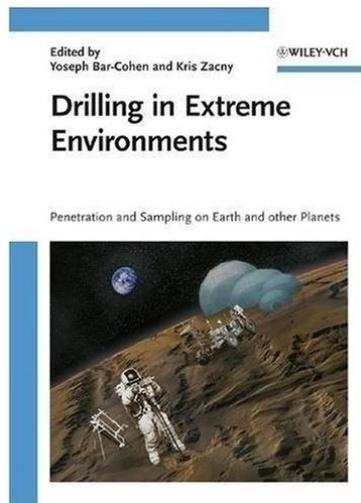
2003



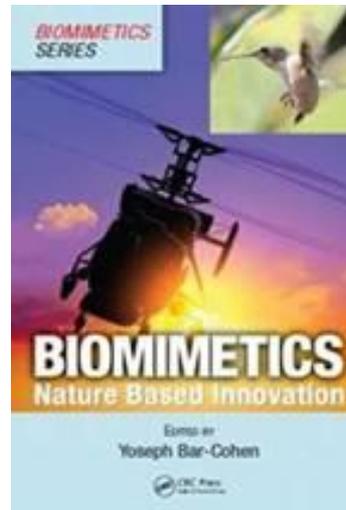
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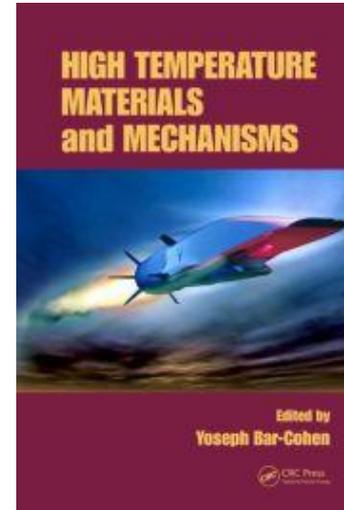
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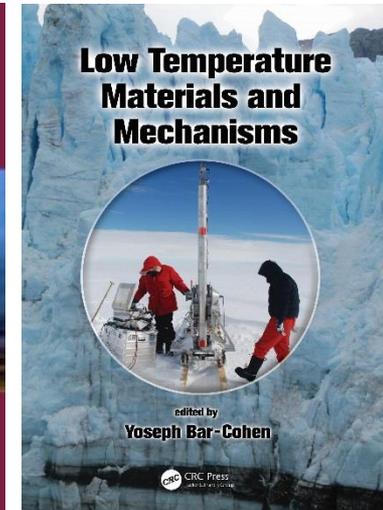
2009



2011



2014



2016

<http://ndea.jpl.nasa.gov/nasa-nde/yosi/yosi-books.htm>

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