Machinery/Automation

Mobile Robot for Exploring Cold Liquid/Solid Environments

This tethered robot could float, swim, crawl, and sample environmental materials.

NASA's Jet Propulsion Laboratory, Pasadena, California

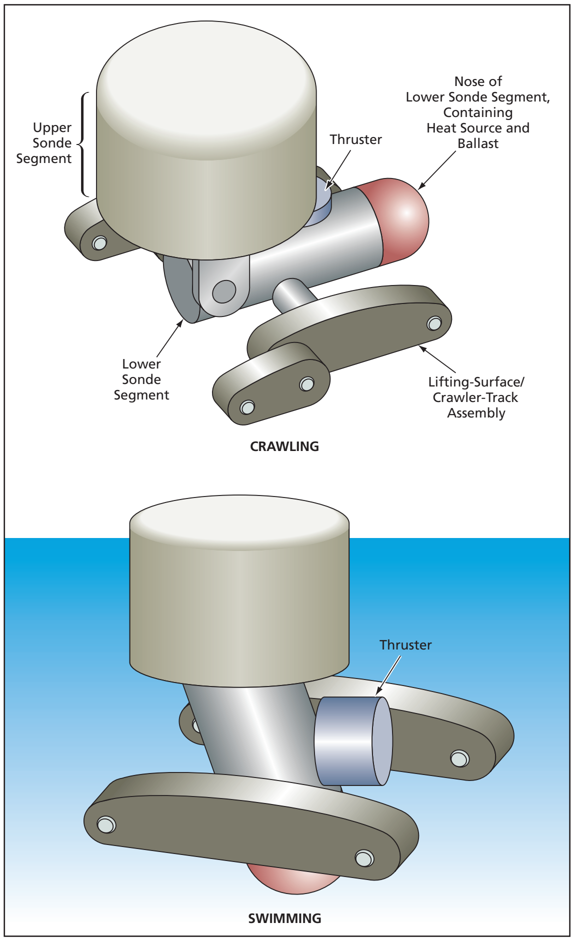
The Planetary Autonomous Amphibious Robotic Vehicle (PAARV), now at the prototype stage of development, was originally intended for use in acquiring and analyzing samples of solid, liquid, and gaseous materials in cold environments on the shores and surfaces, and at shallow depths below the surfaces, of lakes and oceans on remote planets. The PAARV also could be adapted for use on Earth in similar exploration of cold environments in and near Arctic and Antarctic oceans and glacial and sub-glacial lakes.

The PAARV design is based partly on the design of prior ice-penetrating exploratory robots and partly on the designs of drop sondes heretofore used on Earth for scientific and military purposes. Like a sonde, the PAARV is designed to be connected to a carrier vehicle (e.g., a balloon, aircraft, or vessel in a terrestrial setting) by a tether, through which the carrier vehicle would provide power and would relay data communications between the PAARV and an external or remote control station. Like a sonde, the PAARV could be lowered from the carrier vehicle into an ocean or lake environment to be explored. Unlike a sonde, the PAARV would be capable of swimming and of crawling along the bottom, and crawling out of the ocean or lake and moving to a designated site of scientific interest on the shore.

As now envisioned, the fully developed PAARV (see figure) would include an upper sonde segment and a lower sonde segment. Protruding from the lower sonde segment would be two assemblies containing both lifting surfaces (for control of attitude during descent and swimming) and crawler tracks. These assemblies could be rotated to align them parallel, perpendicular, or at an oblique angle with respect to the longitudinal axis of the lower sonde segment. Also protruding from the lower sonde segment, at a point above the center of gravity, would be a thruster for swimming.

The upper sonde segment would be cylindrical, approximately 30 cm in diameter and 20 cm high. This segment would contain a tether-management-and-actuation subsystem; buoyancy-control chambers; a subsystem of pumps, actuators, and valves; a chamber holding compressed gas; and a chamber containing a heater. The upper sonde segment would be attached to the lower sonde segment via a single-joint actuator that effects rotation about an axis perpendicular to the longitudinal axes of the sonde segments.

The lower sonde segment would be approximately 60 cm long and 15 cm in diameter. Either a general-purpose radioisotope heat source or a mass of phase-change heat-storage material would be located in the nose (lower and outer end) of the lower sonde segment to keep instruments warm in the cold environment. The sonde would have a dual-walled shell with insulation to reduce the loss of heat. The heat source in the nose also would serve as ballast to maintain stability like that of a traditional ocean buoy.



The **PAARV** is shown here in two of its many possible crawling and swimming configurations.

When the PAARV was initially lowered from the carrier vehicle, the upper and lower sonde segments and the lifting-surface/crawler-track assemblies would be aligned collinearly so that the PAARV would float in a nominal vertical orientation like a buoy. Once the buoyancy chambers started to fill, the tether would be paid out from the top sonde segment as the PAARV descended. Upon arrival at a depth designated for swimming, the thruster would be activated and relative alignments of the upper and lower sonde segments and the lifting-surface/crawler-track assemblies varied as needed for steering. Upon contact with the bottom, the lower sonde segment and the lifting-surface/crawler-track assemblies would be turned to a nominally horizontal orientation with the upper sonde segment in a nominally vertical orientation, and the crawler tracks would then be activated.

A sampling needle could be extended from the lower side of the lower sonde segment into the bottom of the ocean or lake, where it would adsorb bottom material. The needle would then be retracted, then heated to desorb the material for analysis by instruments in the lower sonde segment. The data from the analyses would be relayed to the external control station via the tether.

Once the bottom sampling was complete, the PAARV would increase its buoyancy by displacing liquid from the buoyancy-control chambers and would reel the tether back in. An onboard guidance, navigation, and control system coupled with acoustic range sensors would enable the vehicle to move slowly toward shore as it ascended. Upon contact with ascending slope, the crawler tracks would be rotated to the angle of the slope and the crawler tracks would be activated. Once out of the water, the PAARV would crawl to a location of interest designated by coordinates provided by cameras on the carrier vehicle or an aircraft overhead. The sampling process would be repeated at the location of interest.

This work was done by Charles Bergh and Wayne Zimmerman of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1)*
NPO-40731

System Would Acquire Core and Powder Samples of Rocks

A sampling system would be built around an ultrasonic/sonic drill corer.

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A system for automated sampling of rocks, ice, and similar hard materials at and immediately below the surface of the ground is undergoing development. The system, denoted a sample preparation, acquisition, handling, and delivery (SPAHD) device, would be mounted on a robotic exploratory vehicle that would traverse the terrain of interest on the Earth or on a remote planet. The SPAHD device would probe the ground to obtain data for optimization of sampling, prepare the surface, acquire samples in the form(s) of cores and/or powdered cuttings, and deliver the samples to a selected location for analysis and/or storage.

The SPAHD device would be built around an ultrasonic/sonic drill corer (USDC) — an apparatus that was reported in "Ultrasonic/Sonic Drill/ Corers With Integrated Sensors" (NPO-20856), *NASA Tech Briefs*, Vol. 25, No. 1 (January 2001), page 38. To recapitulate: A USDC includes a hollow drill bit or corer, in which combinations of ultrasonic and sonic vibrations are excited by an electronically driven piezoelectric actuator. The corer can be instrumented with a variety of sensors (and/or the drill bit or corer can be used as an acoustic-impedance sensor) for both probing the drilled material and acquiring feedback for control of the excitation. The USDC advances into the material of interest by means of a hammering action and a resulting chiseling action at the tip of the corer. The hammering and chiseling actions are so effective that unlike in conventional twist drilling, a negligible amount of axial force is needed to make the USDC advance into the material. Also unlike a conventional twist drill, the USDC operates without need for torsional restraint, lubricant, or a sharp bit.

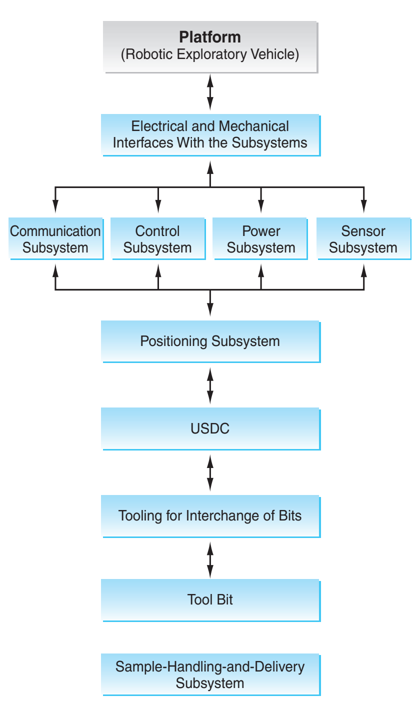

Figure 1. A **SPAHD Device** would be a highly integrated system containing specially designed mechanisms and electronic circuits working together to perform multiple functions, including probing, preparation of surfaces, acquisition of core and powder samples, and manipulation and delivery of the samples. The relative positions in this block diagram indicate approximate mechanical and electrical relationships among subsystems and components.

In addition to a USDC, the SPAHD device (see Figure 1) would include sensor, control, and communication subsystems; a subsystem for positioning the USDC at the desired position and orientation on the ground; a set of interchangeable USDC bits; a tool rack to store the bits; and mechanisms for manipulating and delivering samples. The bits would be attached to, and detached from, a resonator horn of the piezoelectric actuator by means of simple-to-operate snap-on/snap-off mechanisms. The set of bits would include a probing bit, bits for cutting cores and collecting powdered cuttings, bits for extracting the cores after they have been cut (see Figure 2), and an ultrasonic rock abrasion tool (URAT) bit [described in "Ultrasoni-cally Actuated Tools for Abrading Rock Surfaces" (NPO-30403), *NASA Tech Briefs*, Vol. 30, No. 7 (July, 2006), page 58.

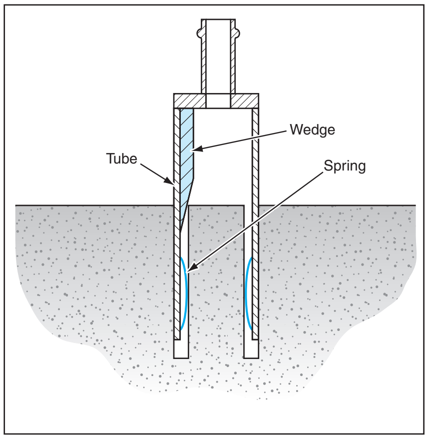

Figure 2. An **Extraction Bit** is one example of special-purpose bits that would be included in a SPAHD device. This bit would be inserted around a recently cut core. The wedge in the bit would introduce a transverse force that would cause the core to break off somewhere near its root. The springs in the bit would then retain the core so that the core could be lifted out of the hole.

This work was done by Yoseph Bar-Cohen, James Randolph, Xiaoqi Bao, Stewart Sherrit, Chuck Ritz, and Greg Cook of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
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