DepthX - from Autonomous Underwater Robot Explorer*

By
Ernest Franke[1], Michael Rigney[1], William C. Stone[2], and Marcus O. Gary[3]

Search and Discovery Article #40311 (2008)
Posted November 13, 2008

Adapted from oral presentation at AAPG Annual Convention, San Antonio, Texas, April 20-23, 2008

[1]Southwest Research Institute, San Antonio, TX (efranke@swri.edu)
[2]Stone Aerospace/PSC Inc., Austin, TX
[3]The University of Texas, Austin, TX

Abstract

The DEep Phreatic THermal eXplorer (DepthX) is an autonomous robot developed to investigate and test concepts for exploring liquid water oceans on Europa, the fifth moon of Jupiter. The oceans on Europa are covered by an ice layer several kilometers thick and may have channels or cracks that are much more difficult to explore than large open spaces. The DepthX project was funded by NASA to investigate techniques for a future mission to Europa. Although much of the NASA interest is directed toward the search for life, many of the techniques investigated have applications in exploration for other resources.

The DepthX robot is battery powered with multiple computers dedicated to various tasks. High resolution sonar and inertial sensors are used to map the environment and navigate in confined spaces while learning a safe return path. Water chemistry sensors measure temperature, pH, salinity, sulphide, and conductivity to identify locations where energy gradients may support life. When such a location is found, the robot can maneuver near the wall, capture images from two video cameras and use image analysis to identify significant visual patterns. A video microscope searches for microbial activity. The DepthX robot also includes a probe arm that can be extended to a wall and a solid sampler to capture core samples at locations identified by software algorithms for return and analysis.

Autonomous operation of the DepthX robot was tested at Sistema Zacatón, near Tampico, Mexico in May, 2007. The robot successfully explored cenote Zacatón to a depth of 1100 feet, mapping the cave walls and returning samples.

DepthX – An Autonomous Underwater Robot Explorer

Ernest Franke[1], Michael Rigney[1], William Stone[2], Marcus Gary[3]

1. Southwest Research Institute, 2. Stone Aerospace, 3. The University of Texas, Austin

NASA

STONE AeroSPACE

Southwest Research Institute

THE UNIVERSITY OF TEXAS AT AUSTIN

Colorado
University of Colorado at Boulder

THE UNIVERSITY OF ARIZONA
TUCSON ARIZONA

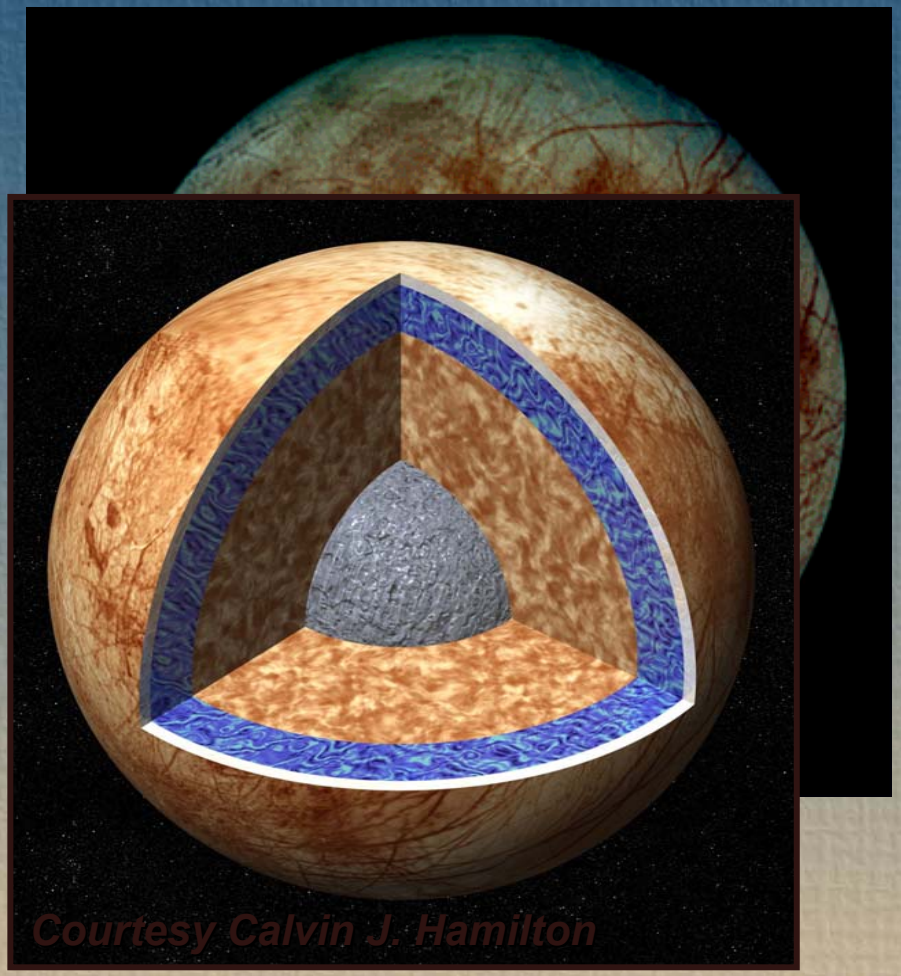
Carnegie Mellon

DepthX:
Deep Phreatic Thermal Explorer

Autonomous robot developed
to investigate and test concepts
for exploring liquid water
oceans on Europa and to
search for extra-terrestrial life

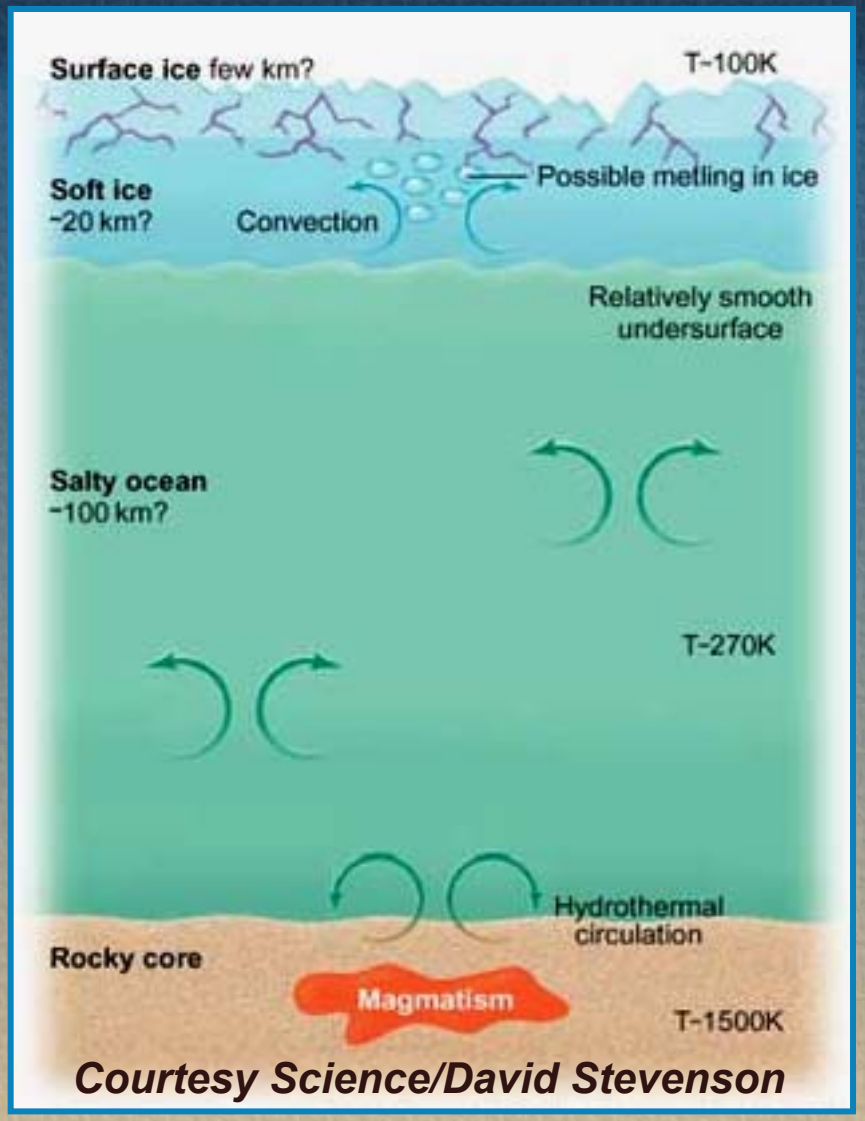
Europa — the Ocean Moon

- Jupiter's 6th Moon (Near Earth-Moon Size)
- There is Strong Evidence for Liquid Water Oceans Covered by a Layer of Ice Several Miles Thick



Europa

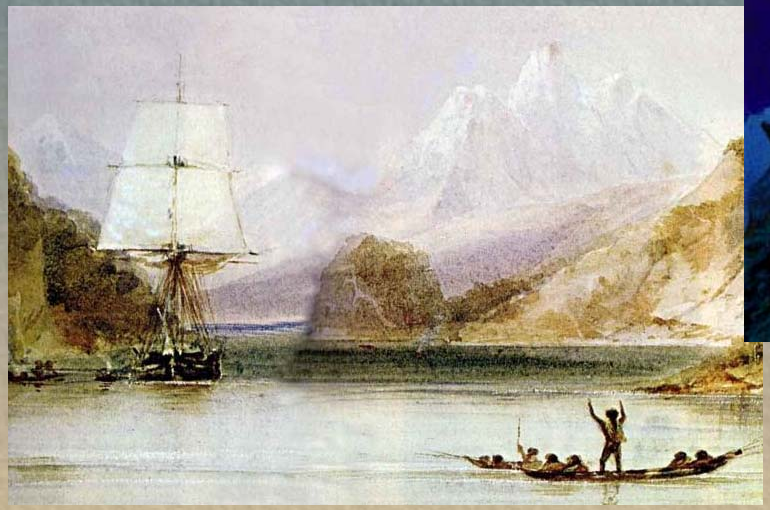
- Water Temperature Maintained by Gravitational Effects of Jupiter
- Many space scientists consider Europa a promising site for extraterrestrial life
- NASA planning future exploration missions



Courtesy Science/David Stevenson

Autonomous Search for Life

- Autonomous Robot, a “Field Biologist”
- Explore the Ocean
- Search for Life
- Return Data to Earth

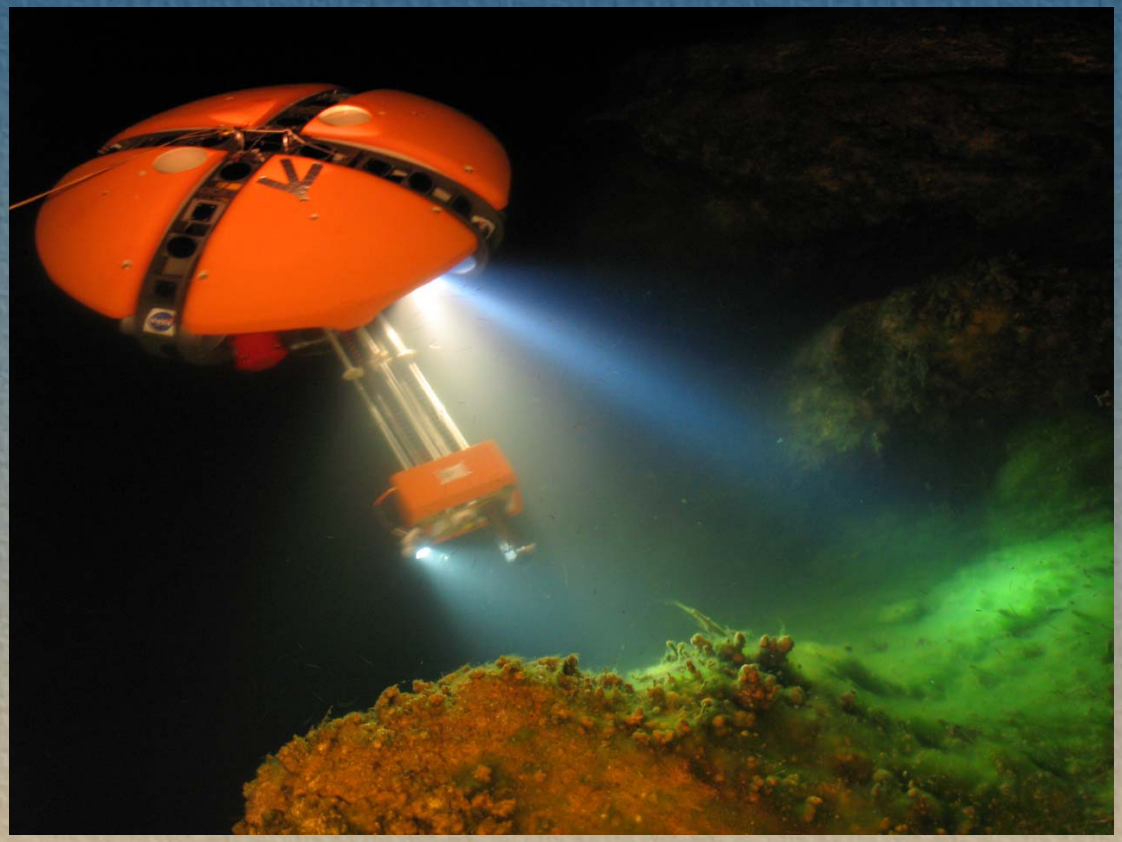


Field Biologist Activities

- Suitable Locations
  - Water
  - Energy Sources
- Visual Sensing
  - Patterns, color
  - Motion
- Chemical Sensing
  - Odor, sulfides
- Collect Samples
- Lab Testing

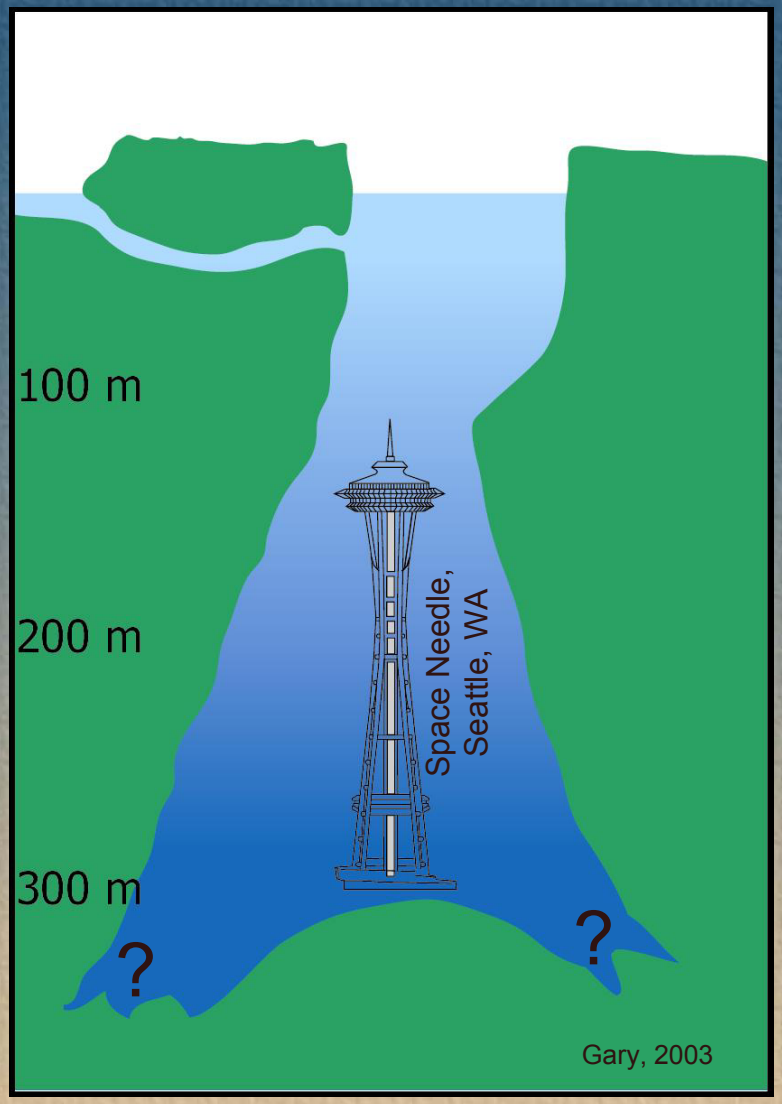
DepthX Goal - Develop Technology for Autonomous Search for Life

- Goal 1 – Navigate Through Unexplored Underwater Regions, Generate Map, Return
- Goal 2 – Identify Locations Likely to Support Life, Search for Life Forms, Collect Specimens and Return Them




Cenote Zacaton, Mexico
(Courtesy Google Earth)
Monterrey
Cenote
Zacaton
Tampico

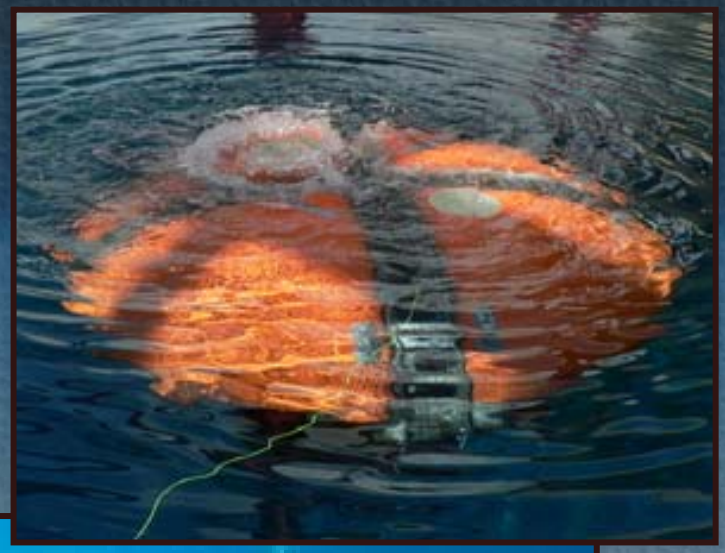
Cenote Zacaton



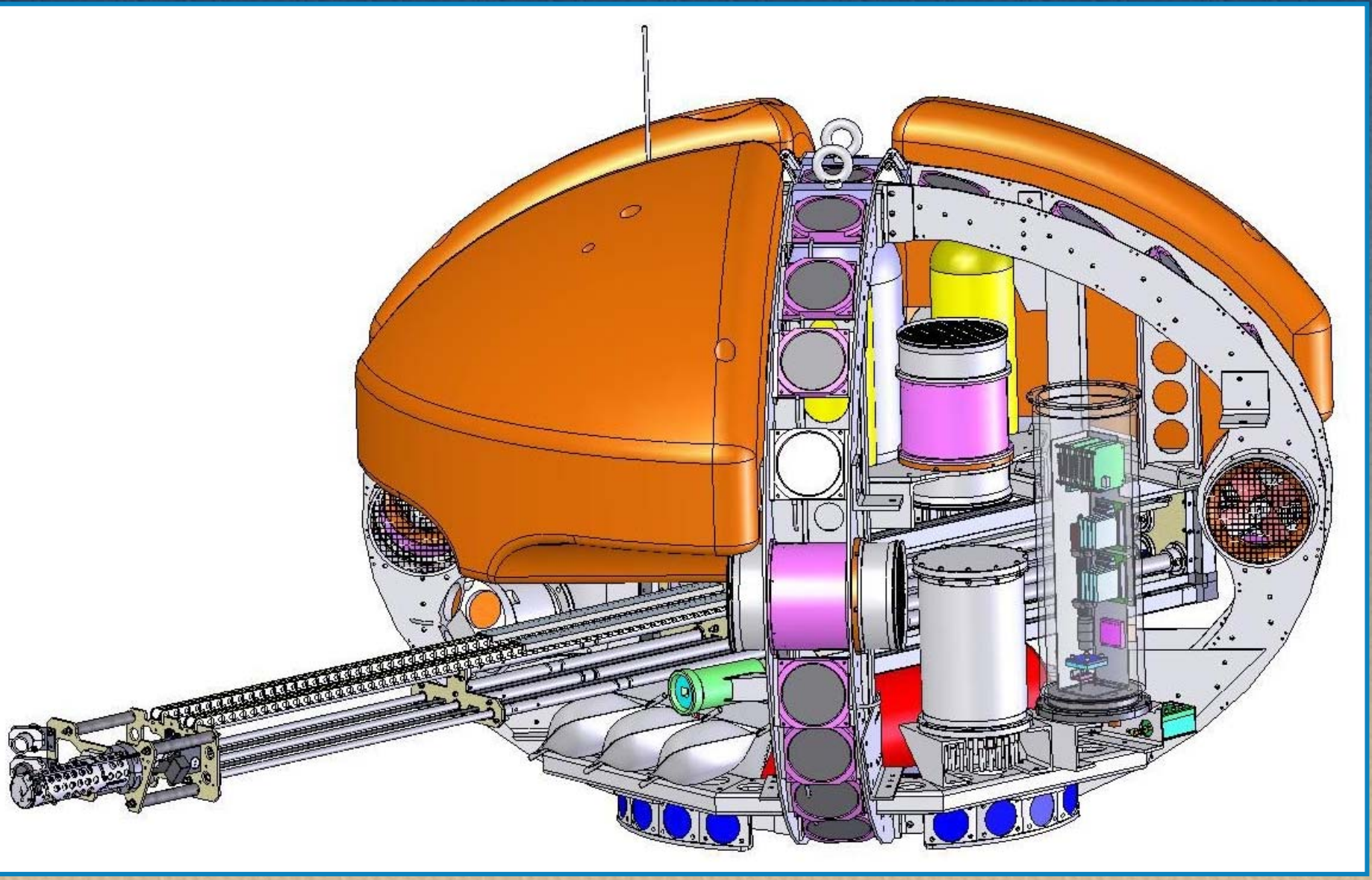
Hypothesized Profile
based on limited spatial data
(wire drop sounding)

DepthX Vehicle

- Neutral Buoyancy, 3,000 Ft. Design Depth
- Battery Powered, 8-Hour Missions
- Navigation by Inertial Measurements and Sonar Mapping of Cave Walls

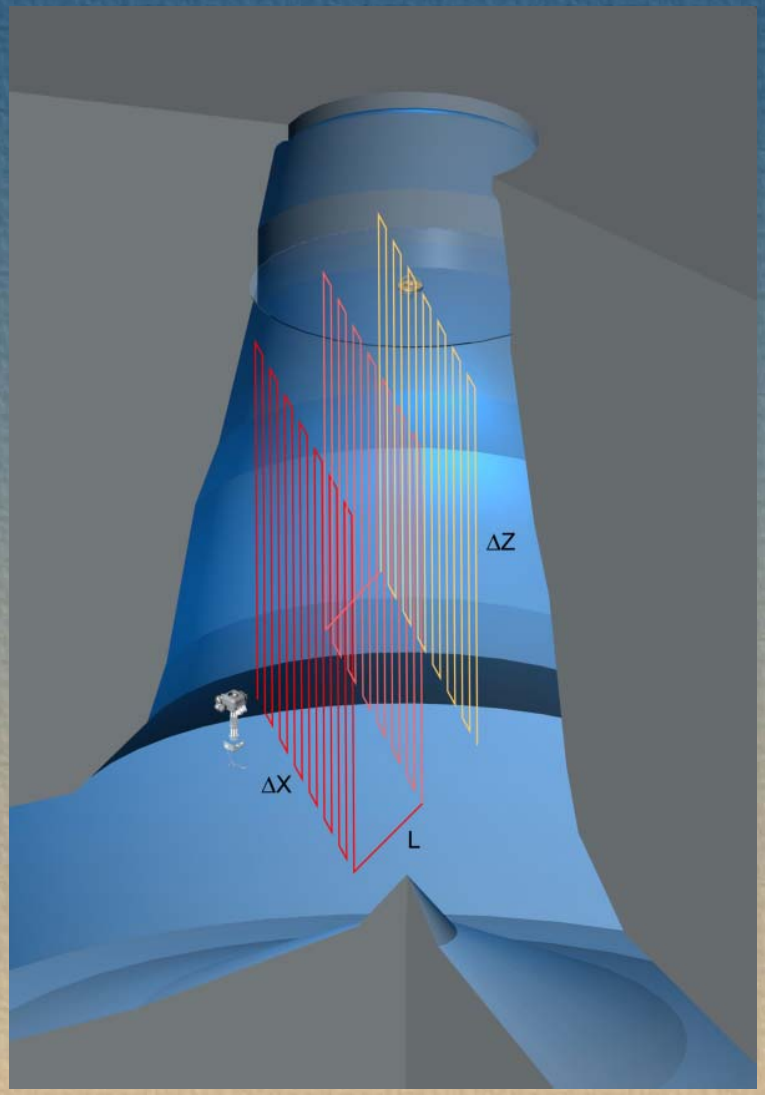


DepthX Vehicle Design



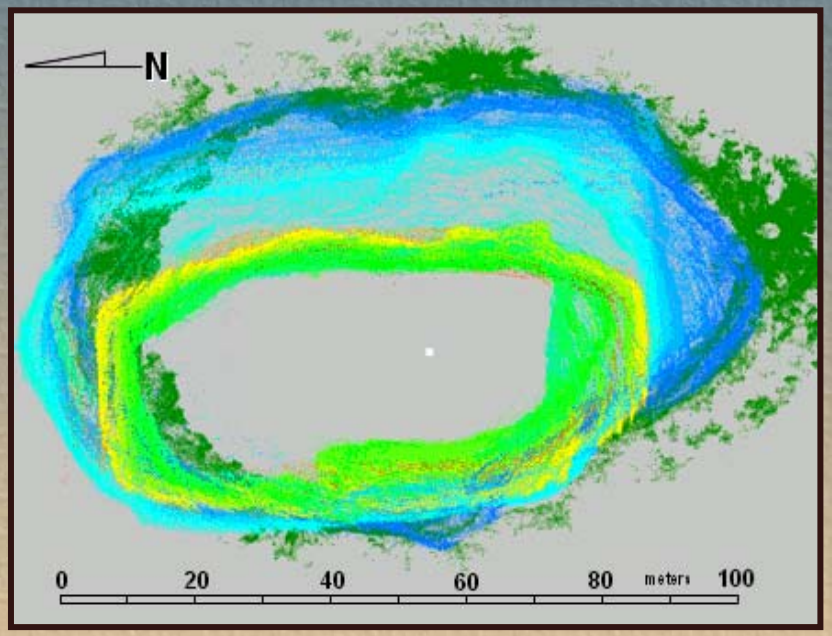
Step 1 — Find Locations Suitable for Life, Sources of Energy

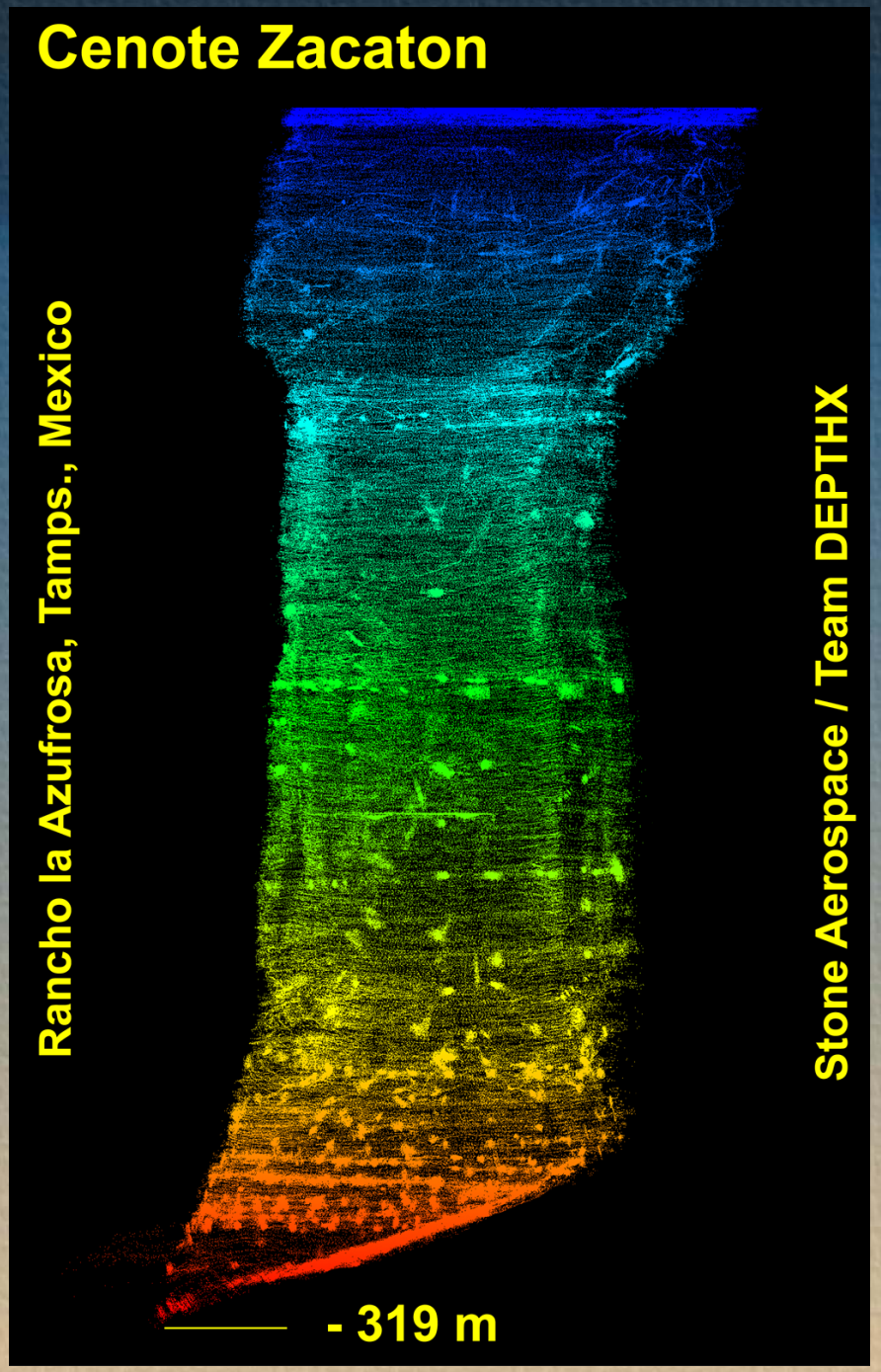
- Map Volume
- Map Environment Using Multiple Sensors
- Identify Locations That Could Support Life
  - Gradient in environmental variable



Sonar Map Data

- Near Cylindrical, Vertical Water Column, 150-Foot Diameter
- 1,099 Feet Deep
- No Side Passages Found





Environmental Sensing

Hydrotech

- Temperature
- pH
- Oxygen Redox Potential
- Dissolved Oxygen
- Specific Conductance
- Salinity

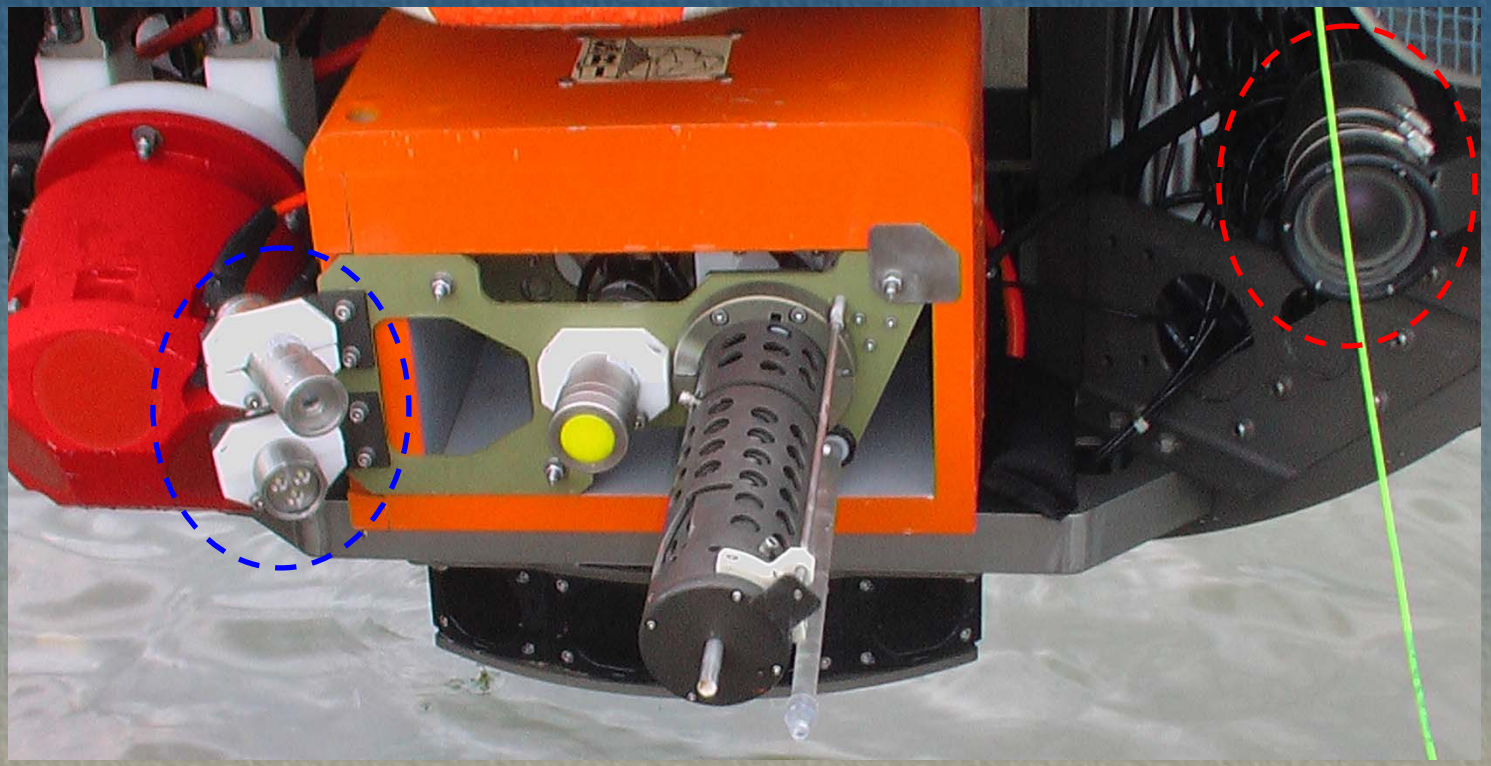
Weiss Research

- Sulfide

Step 2 — Conduct More Detailed Search at Promising Locations

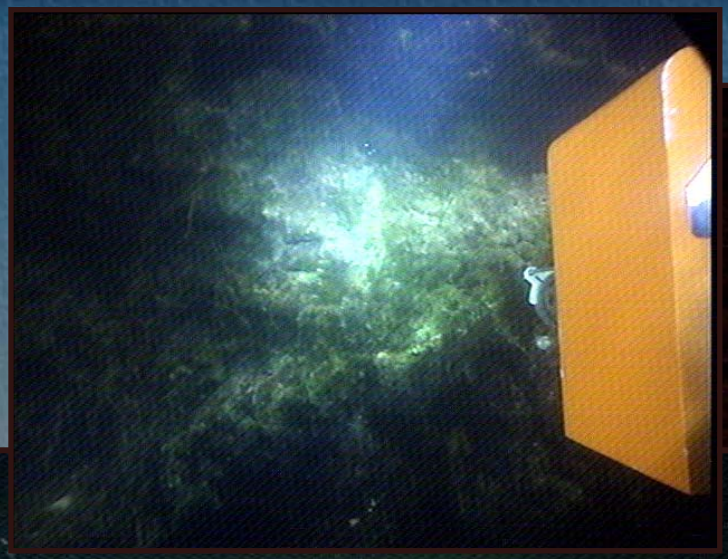
- Process Environmental Data
  - Locate High Gradients
  - Follow Thermocline or Chemocline to Cenote Wall
- Capture Video Images of Wall
  - Process Images, Classify
- Capture Flow Cell Microscope Images
  - Process Images, Classify
- Image Analysis and Motion Detection
  - Algorithms Identify Unusual Patterns Indicating Life
- Select Locations for Sampling

Image Acquisition



- Probe Camera
  - 1ft Field of View @ Solid Sampler
- Stage 1 Camera
  - 1m Field of View @ 1.5 m standoff

Wide-Field Camera Images



Probe Camera Images

Microscope Image Analysis

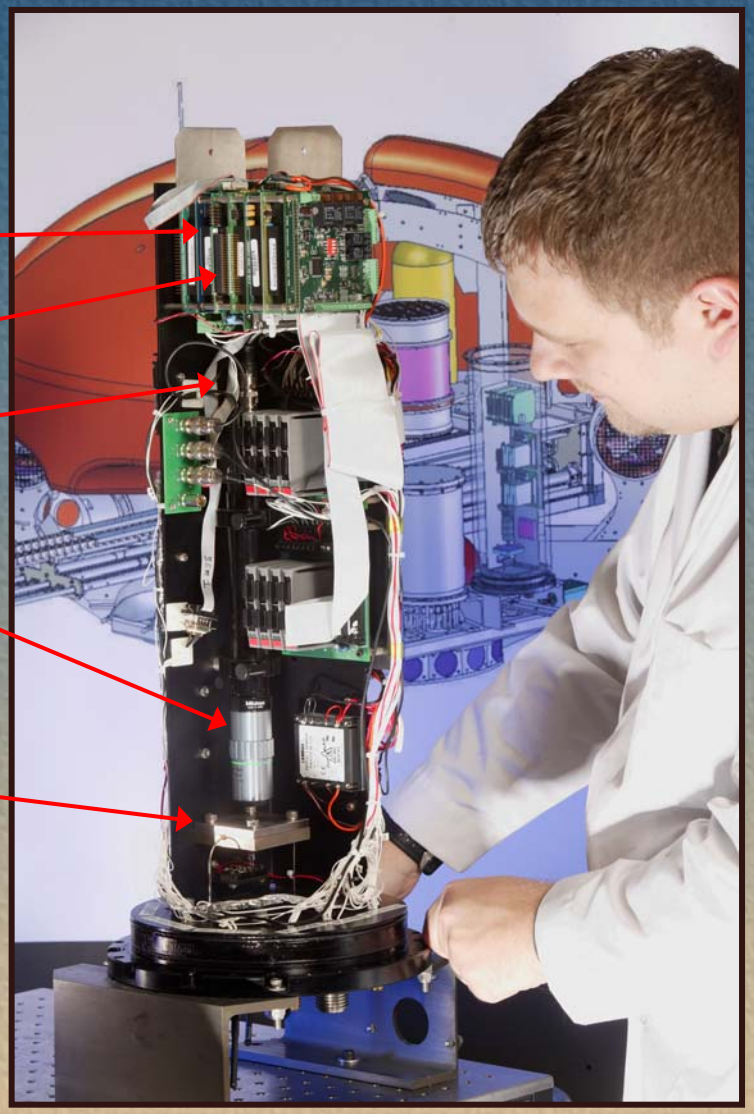
Computer

Frame Grabber

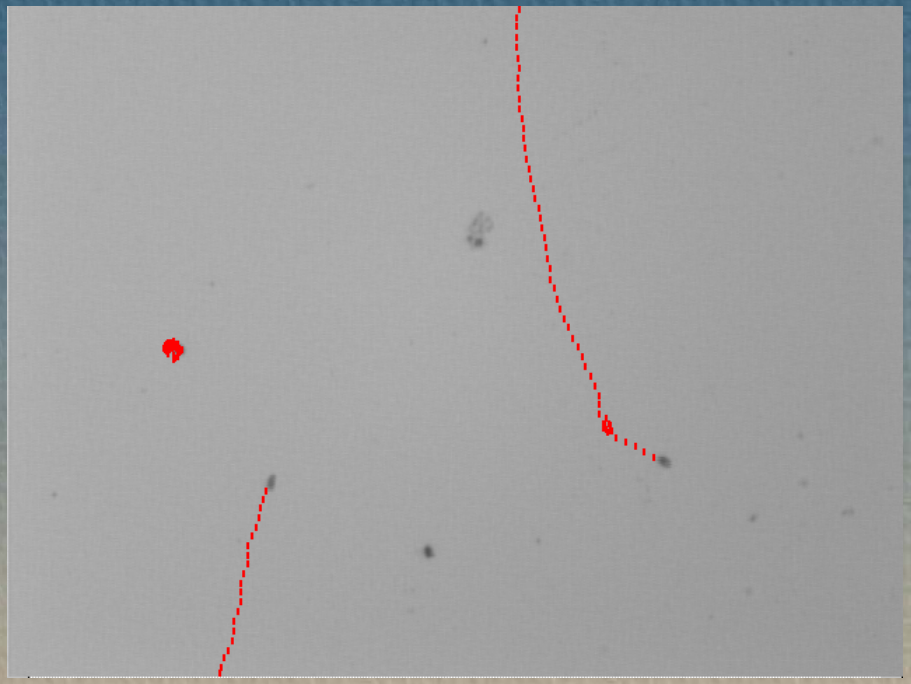
Camera

Microscope Objective

Flow Cell



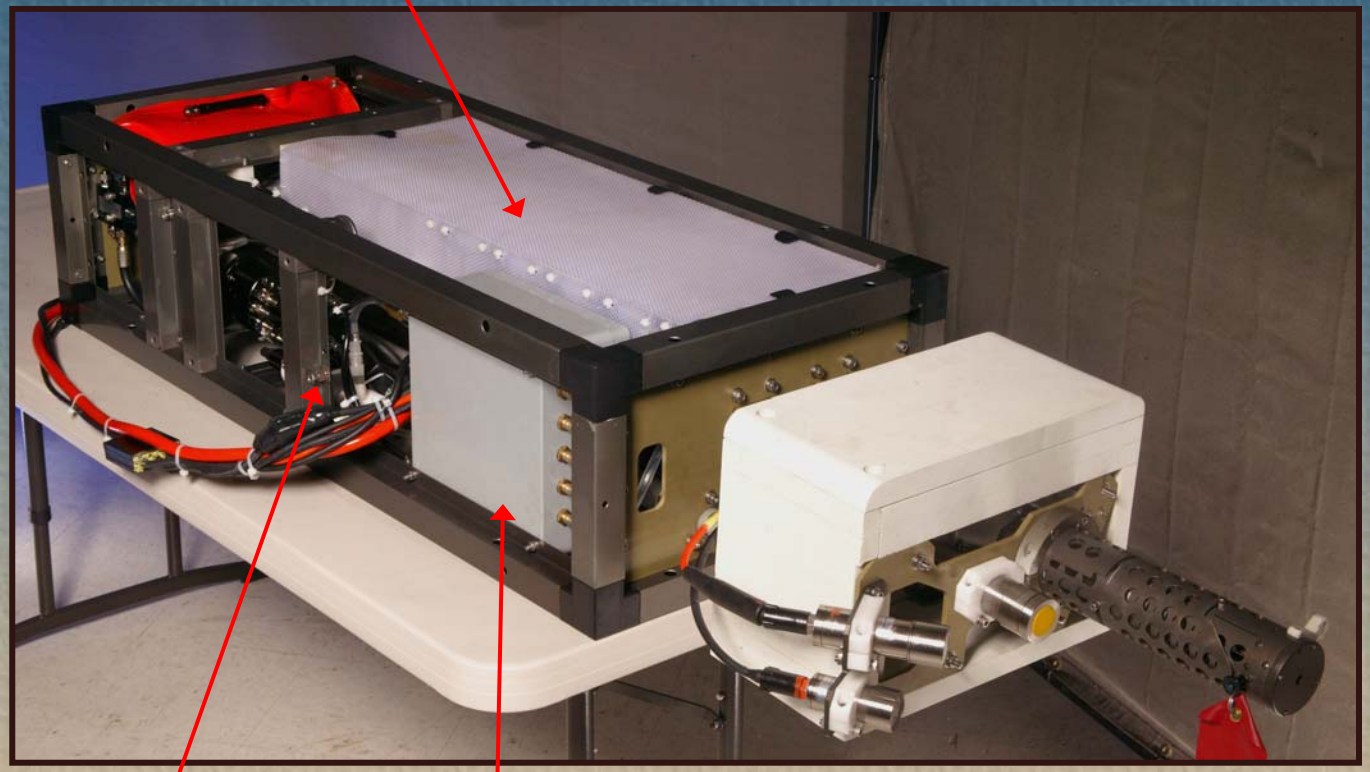
Motion Detection



Step 3 - Sample Collection

- When life detection finds something “interesting” on the wall
  - Extend probe to reach the wall, about 1.5 meter
  - Trigger a spring loaded tube to take a core from the wall
- Also collect samples of water
  - Turn on pump power to fill specimen bag(s)
  - Valves control which container is filled

Water Sample Collection



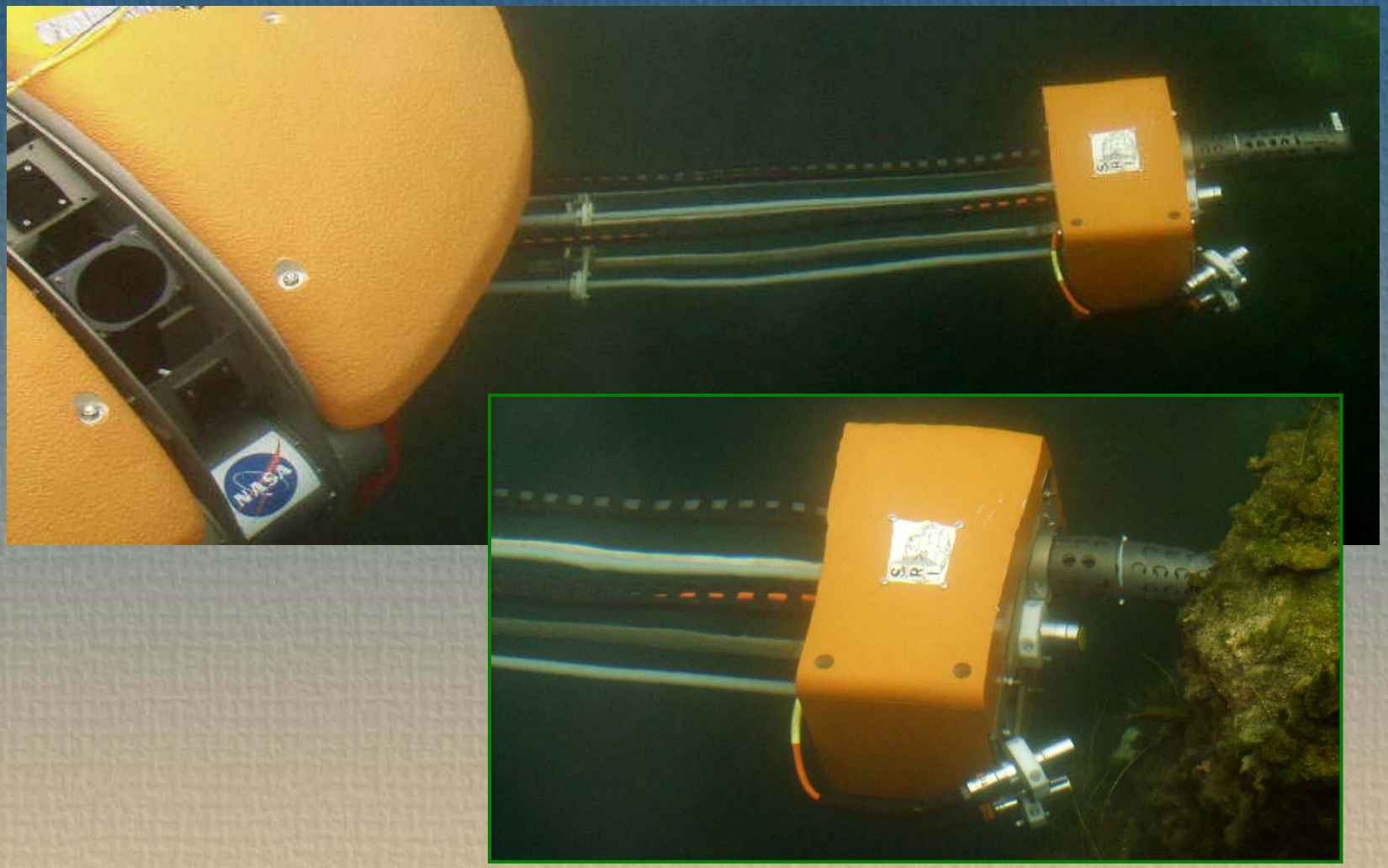
Water Sample Bags (5 x 2 litter)

Intake

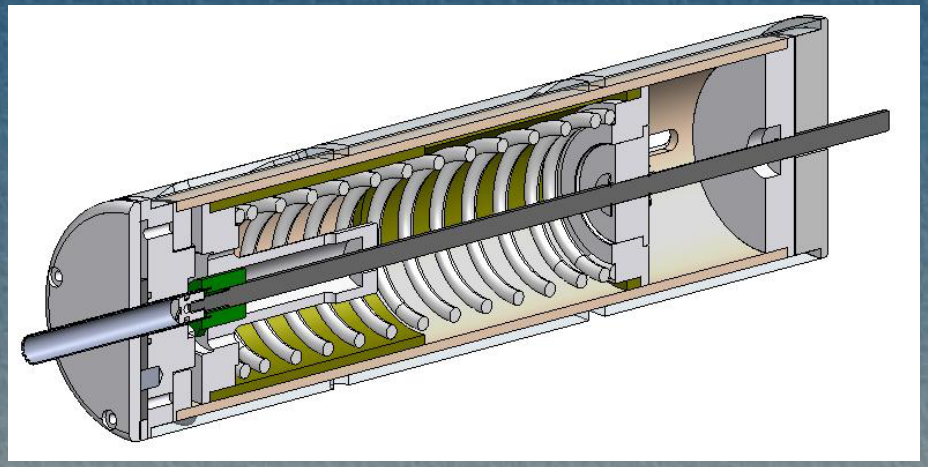
Pump

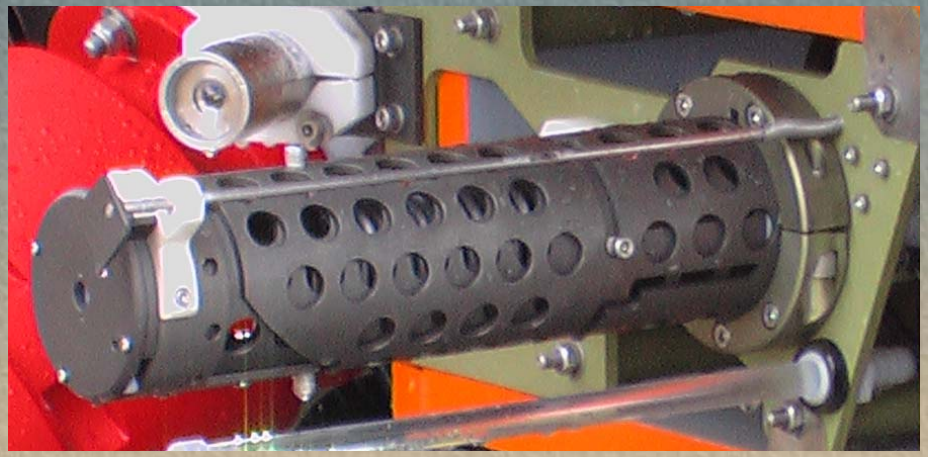
Valve Box

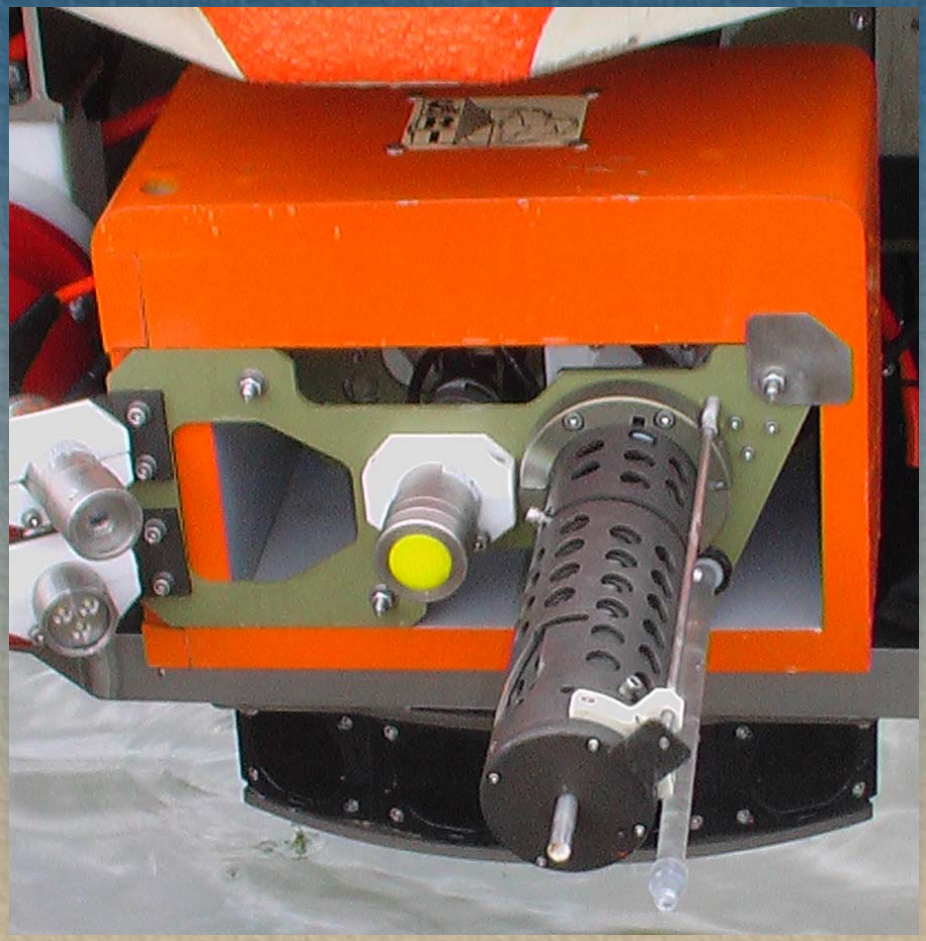
Solid Sampling – Arm Extension



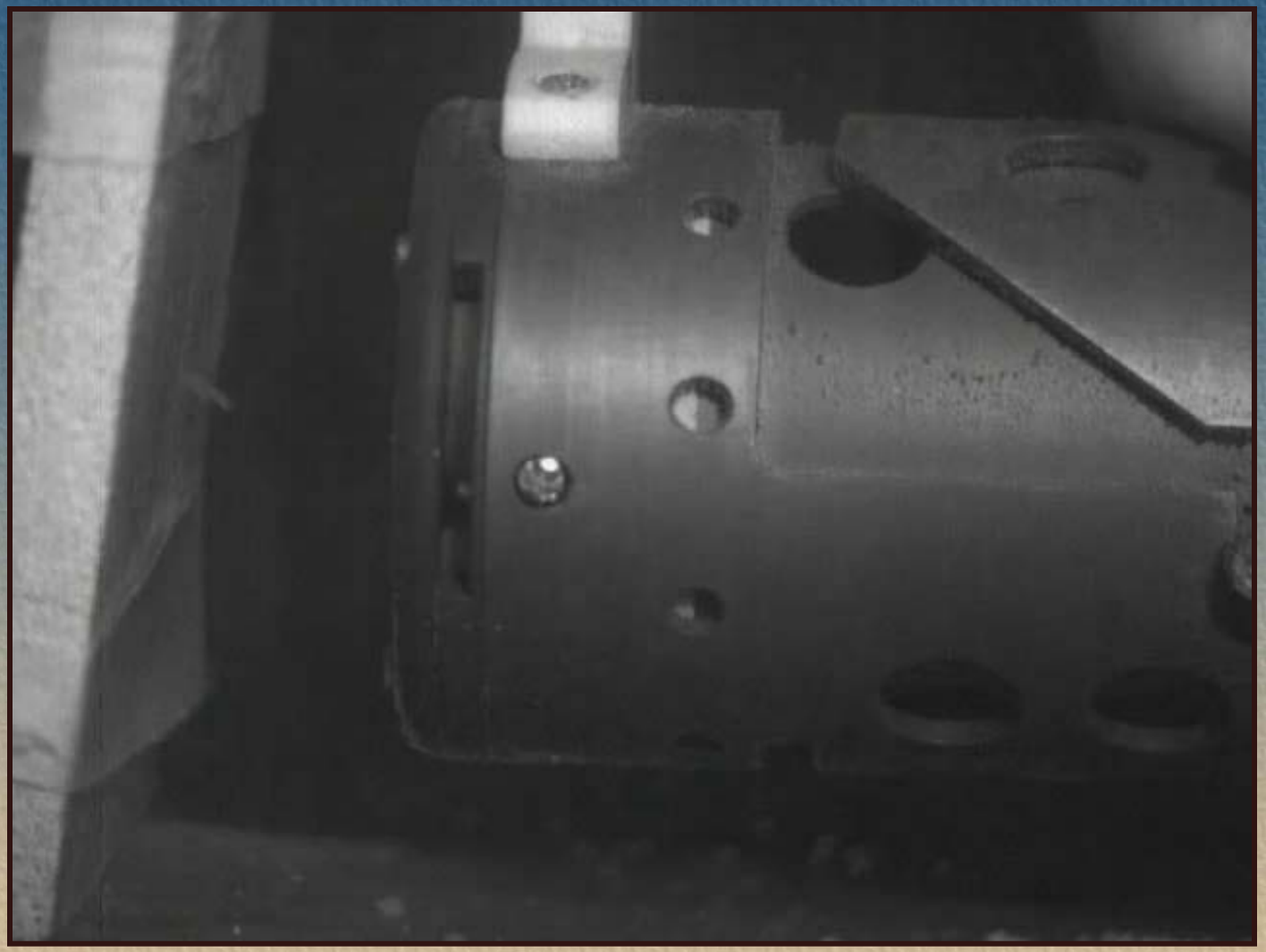
Solid Sampling – Coring Probe



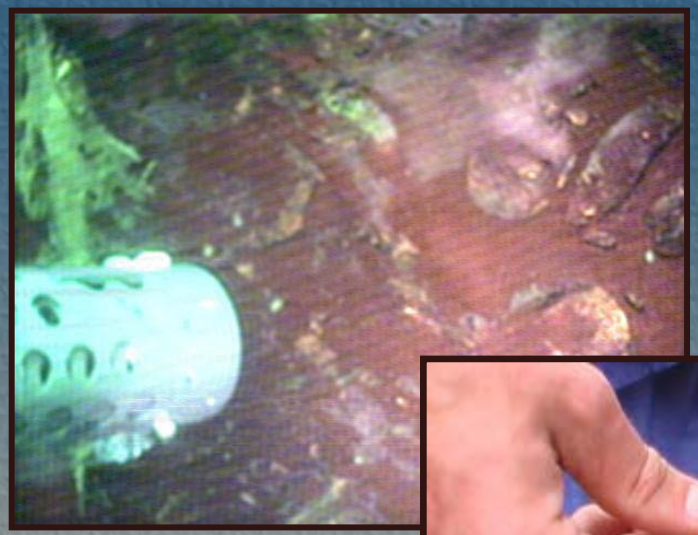


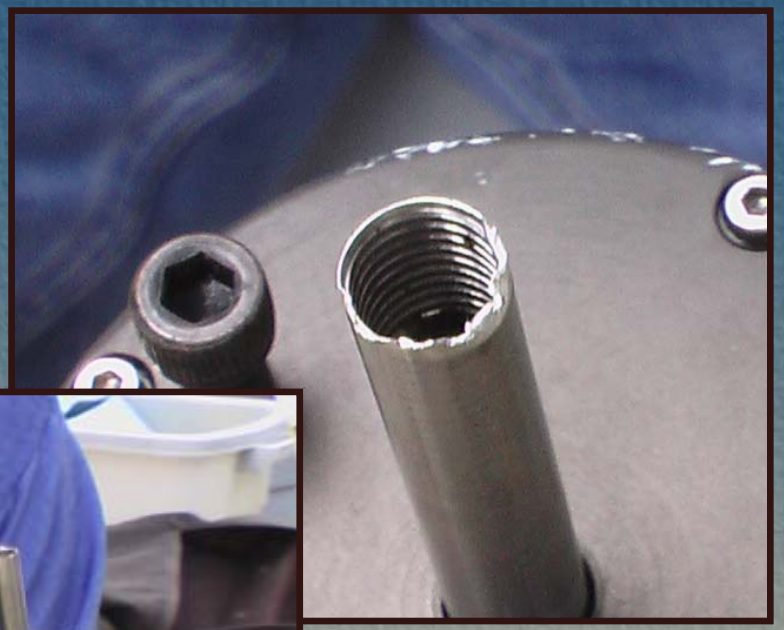


Solid Sampling Probe



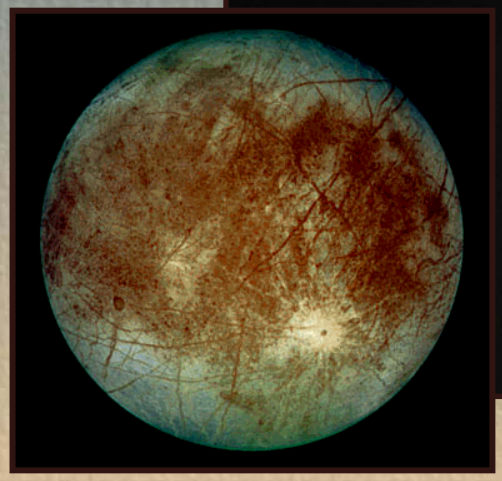
Retrieval of Solid Samples





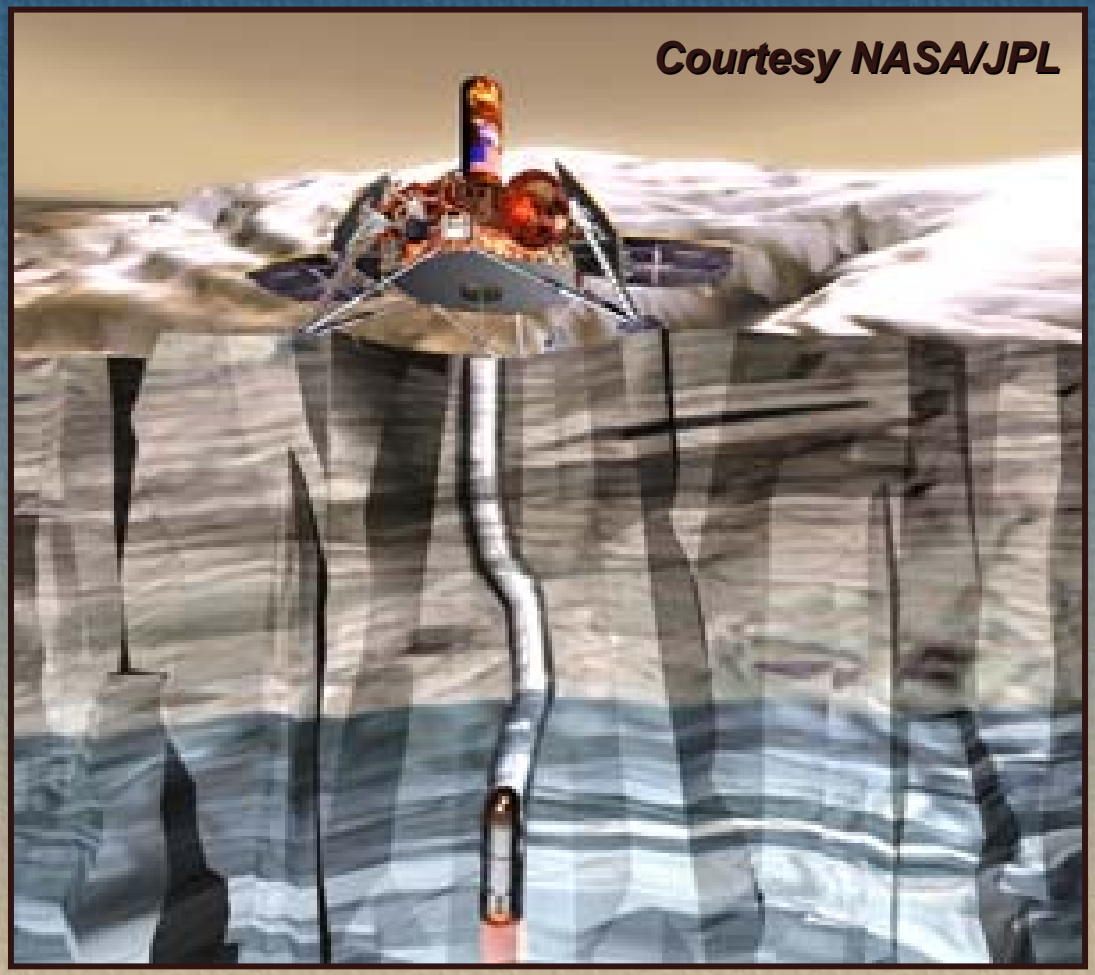
Accomplishments

- Exploration and Mapping
  - Hierarchical system architecture including decision making applicable to other autonomous systems and robots
  - SLAM (Simultaneous Location and Mapping) using inertial navigation and sonar wall signatures
- Autonomous Science Capability
  - Methods for sensors, image analysis, and decision making applicable to other autonomous systems, robots
  - Systems and devices for collecting liquid and solid samples
  - Several new species of microbes discovered in Zacaton

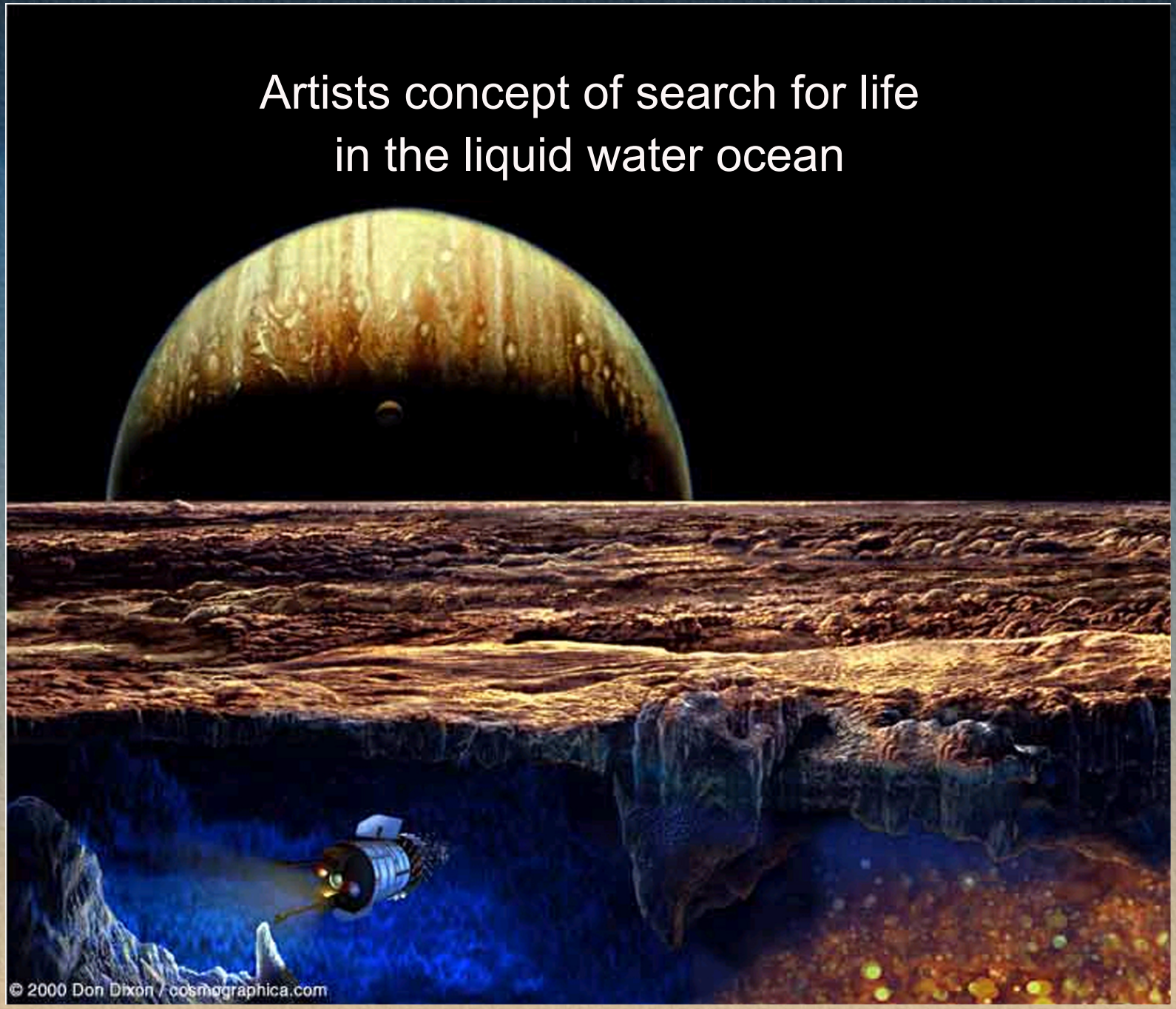


Reaching the ocean

- Early planning for exploration missions
- Lander with Nuclear Power Source
- Melt Access Hole Through Ice Layer
- Establish Base for exploration



Artists concept of search for life
in the liquid water ocean



Future Missions

Lake Bonney, Antarctica - Knowledge gained and some vehicle hardware will be used to explore and map an ice covered lake (Endurance)

- Europa –Autonomous underwater techniques will help explore and search for extraterrestrial life
- Titan – Autonomous underwater capability may be used to explore liquid methane lakes on Titan (largest of Saturn's moons)