Planetary Protection Policy and Practice

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What is Planetary Protection (PP)?

- **An International Agreement**
- **A NASA Policy Directive**
- **A series of requirements which robotic planetary flight missions must meet in order to be in compliance with NASA policy.**

Goals:

Protect the scientific integrity of other solar system bodies for future exploration for life, remnants of past life, and the precursors of life (forward contamination)

Protect the Earth from possible hazards of returned extraterrestrial material (back contamination)

Sampling MER for microbial bioburden.

International Agreement on Planetary Contamination/Protection

- Article IX of the Outer Space Treaty of 1967:

  "...parties to the Treaty shall pursue studies of outer space including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter and, where necessary, shall adopt appropriate measures for this purpose..."

"Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies."

(entered into force, October 10, 1967)

Origin of Planetary Protection

- 1958: Council of U.S. National Academy of Sciences (NAS)
  - NAS calling for the conduct of planetary exploration in a fashion that "prevents contamination of celestial objects"
- 1959: NASA adopts first policy
  - Calling for "payloads which might impact a celestial body [to] be sterilized before launching"
- 1964: Committee on Space Research (COSPAR) resolution
  - Probability 10^{-4} or less for viable organism on lander or probe (anywhere!) and accidental impact by unsterilized flyby or orbiter $<3\times10^{-5}$
- 1966: COSPAR resolution
  - 10^{-3} limit of total probability of contamination of a "planet" by all missions during period of biological exploration

Origin of Planetary Protection (cont.)

- 1967: International treaty signed by U.S.
  - "Outer Space Treaty": "States parties to the treaty shall pursue studies of outer space... so as to avoid their harmful contamination and also adverse changes in the environment of the Earth"
- 1967: NASA PP policy adopting COSPAR 1966
  - NASA first version of 8020.7 and 8020.12
- 1981: NASA PP policy undergoes major revision
  - Drafted in 1981, not formalized until 1999
- 2002: COSPAR planetary protection policy adopted
  - Addressed Europa exploration and added concept of "special regions" for Mars
  - Introduced some new language about PP requirements for Mars life detection missions
- 2005 Updated version of NASA policy document, 8020.12C

http://nodis3.gsfc.nasa.gov/displayDir.cfm?Internal_ID=N_PR_8020_012C_&page_name=main

Planetary Protection Studies by the Space Studies Board

1992	*Biological Contamination of Mars: Issues and Recommendations,* which reported advice on measures to protect Mars from contamination by Earth organisms, as well as overall policy guidance.
1997	*Mars Sample Return: Issues and Recommendations*, which reported advice to NASA on Mars sample return missions.
1998	*Evaluating the Biological Potential in Returned Samples from Planetary Satellites and Small Solar System Bodies: Framework for Decision Making,* which reported advice on sample return missions from small bodies, including places like Europa, asteroids, and comets.
2000	*Preventing the Forward Contamination of Europa*, which reported advice on measures to be taken to prevent the contamination of Europa by Earth organisms.
2001	*The Quarantine and Certification of Martian Samples,* which reported recommendations on actions to be taken to implement containment and biohazard testing measures recommended in 1997.
2005	*Preventing the Forward Contamination of Mars,* to supercede the 1992 study, based on new knowledge returned since.

Planetary Protection Mission Constraints

- Depend on the nature of the mission and on the target body
- Constraints imposed for each specific mission/body take into account "current scientific knowledge about the target bodies through recommendations from both internal and external advisory groups, but most notably from the Space Studies Board of the National Academy of Sciences."
  - Implementation advice is given by the NASA Planetary Protection Advisory Committee
- Examples of specific measures include:
  - Constraints on spacecraft operating procedures
  - Spacecraft organic inventory and restrictions
  - Reduction of spacecraft biological contamination
  - Restrictions on the handling of returned samples
  - Documentation of spacecraft trajectories and spacecraft material archiving

Planetary Protection Mission Categories

PLANET PRIORITIES		MISSION TYPE	MISSION CATEGORY
A	Not of direct interest for understanding the process of chemical evolution. No protection of such planets is warranted (no requirements)	Any	I
B	Of significant interest relative to the process of chemical evolution, but only a remote chance that contamination by spacecraft could jeopardize future exploration.	Any	II
C	Of significant interest relative to the process of chemical evolution and/or the origin of life or for which scientific opinion provides a significant chance of contamination which could jeopardize a future biological experiment.	Flyby, Orbiter Lander, Probe	III IV
All	Any Solar System Body	Earth-Return “unrestricted-” or “restricted Earth-return”	V

PP Categories for Mars Landed Missions w/Current Representative Requirements

Cat IV: Lander or probe to Mars, a planet of significant interest

Cat V: Earth return

IVa

- No extant life detection experiments
- Bioburden reduction required to
  - $< 3 \times 10^5$ cultivable aerobic spores per landing event &
  - <300 cultivable aerobic spores / sq meter*
- Verify by bioassay

IVb

- Extant life detection experiments
- Bioburden reduction required
- Verify pre-sterilization cleanliness by bioassay
- Surface sterilization required
- Bioshield to prevent recontamination

IVc

- Investigate martian special regions
- Not driven by life detection experiments
- Bioburden reduction required
- Range of implementation options (system vs subsystem; surface vs bulk)
- Bioshield

V

- Stringent measures to prohibit unplanned Earth impact
- Returned hardware sterile
- Containment of any sample
- Microbial reduction
- Microbial assay
- Microbial archive
- Sample quarantine and assessment (sample receiving facility)

***<300 cultivable aerobic spores/m^2 ≈ <300,000 viable organisms/m^2 of all types**

Viking going into the oven

COSPAR Policy for Mars Sample Return (2002)

Classified Category V, "Restricted Earth return"

- Outbound leg of the mission shall meet Category IVb requirements [effectively sterile]
  - Avoid "false positive" indications in a life-detection and hazard-determination protocol
- Sample container must be sealed after sample acquisition.
  - Redundant, fail-safe containment with a method for verification of its operation before Earth-return
  - Integrity of the flight containment system shall be maintained until the sample is transferred to containment
- The mission and the spacecraft design must provide a method to "break the chain of contact" with Mars.
  - Uncontained hardware that contacted Mars, directly or indirectly, shall not be returned to Earth
  - Isolation from Mars shall be provided during sample container loading into the containment system, launch from Mars, and any transfer operations

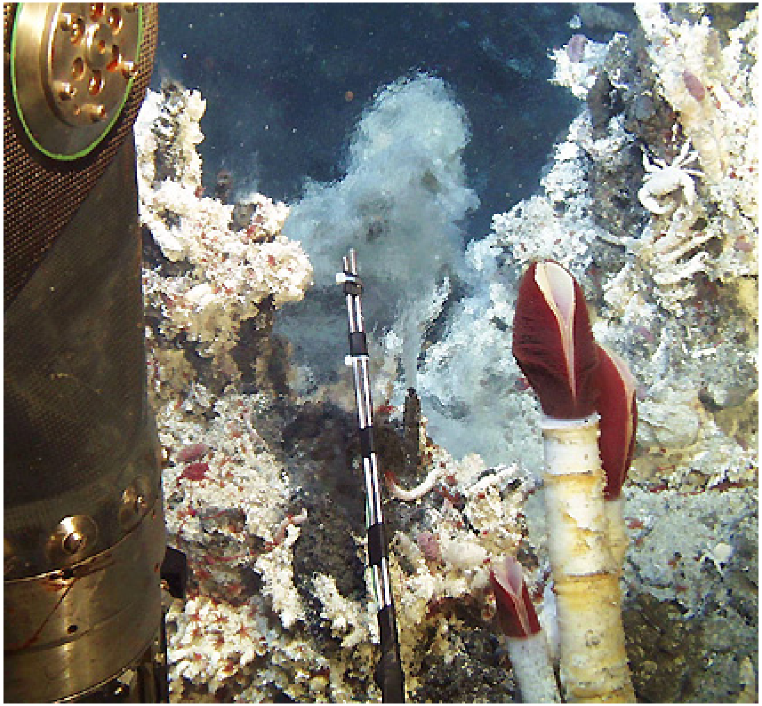
COSPAR Policy for Mars Sample Return (2002; cont.)

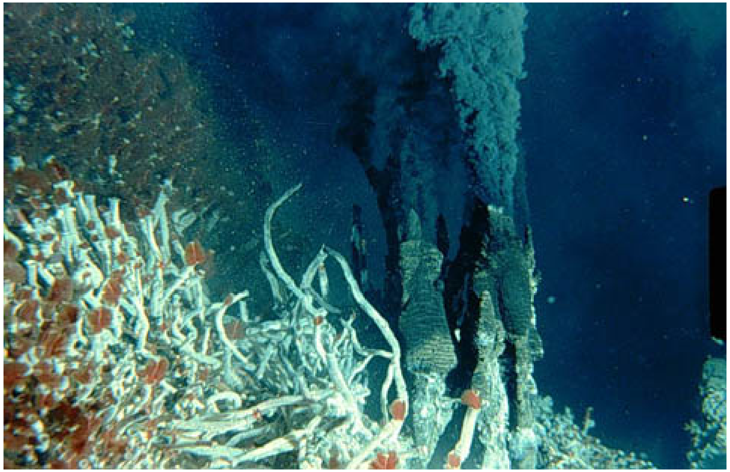
- Reviews and approval of the continuation of the flight mission shall be required at three stages:
  1) Prior to launch from Earth;
  2) Prior to leaving Mars for return to Earth; and
  3) Prior to commitment to Earth re-entry
- A program of life detection and biohazard testing, or a proven sterilization process, shall be undertaken as an absolute precondition for the controlled distribution of any portion of the sample.

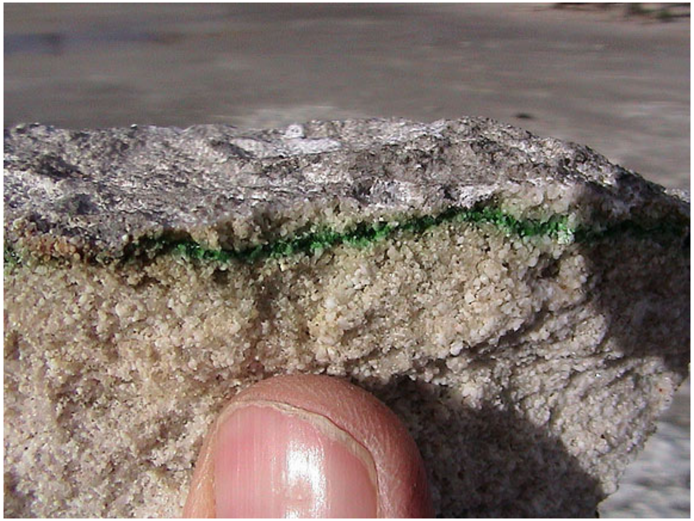
Genesis

Stardust

Extreme life on Earth





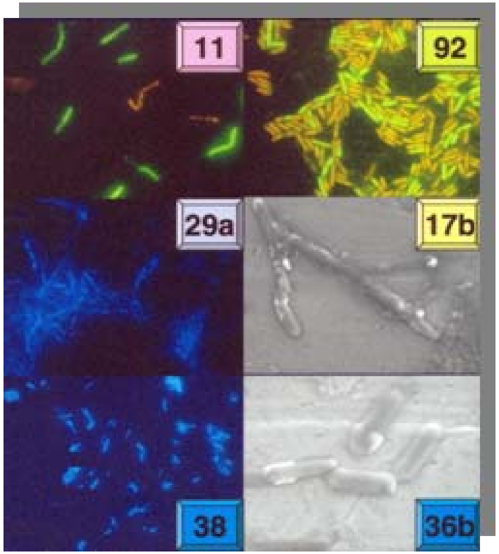


Planetary protection provisions are important, not because we expect to find these things out *there*, but because we didn't expect to find them *here!*

Technology Development to support Planetary Protection

JPL's Biotechnology and Planetary Protection group is actively developing advanced technologies including:

- **Detection** technologies for bioburden measurement
- **Cleaning** technologies for flight hardware materials
- **Sterilization** technologies for bioburden reduction
- **Maintaining** hardware cleanliness (bio-barriers)
- **Validation** technologies for bioburden measurement
- **Monitoring** technologies for all of the above
- **Archiving** methods for hardware and biologic materials
- **Modeling** of planetary protection events



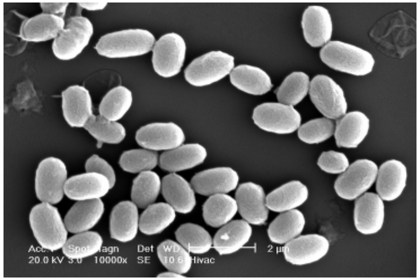
Isolates of cultivable species from SAF

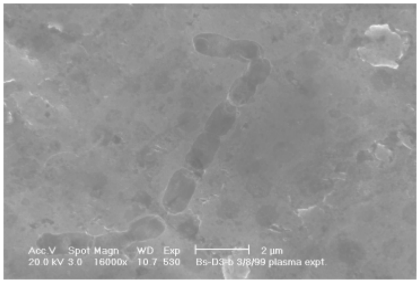
In addition to performing basic science research to support these efforts

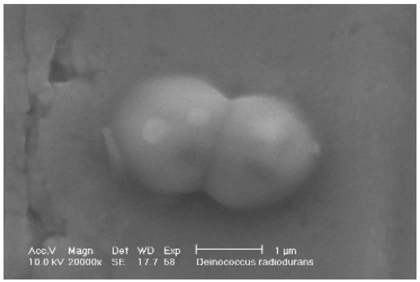
Microbial Diversity Studies

Purpose:

1) Identify sterilization resistances
2) Determine background level of contamination in spacecraft assembly areas
3) Catalogue microbial species

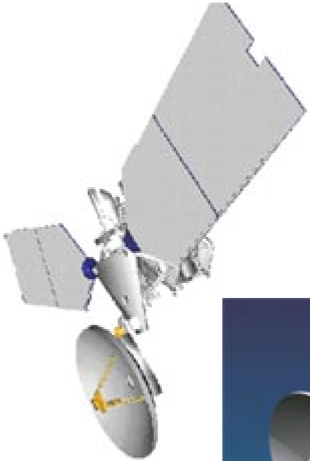


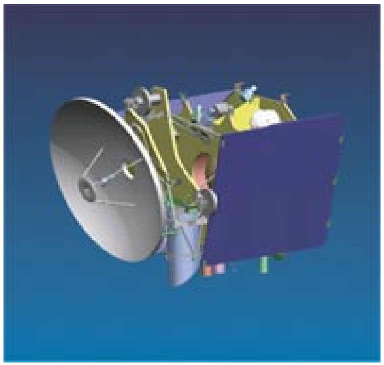




Caltech is applying for a full patent on *B. pumilus SAFR-032*, a bacterium that possesses unusual UV resistance.

Mars Reconnaissance Orbiter
Dr. Kasthuri Venkateswaran





Objectives: Characterize the microbial burden and community of the Mars Reconnaissance Orbiter (MRO) and its assembly facility surfaces using both culture dependent and independent methods.

Isolate extremophilic microbes and determine their potential to survive extraterrestrial conditions. Employ state-of-the-art techniques to detect the presence of non-cultivable, extremophilic microbes.

Significance: This study will help NASA to better understand the potential for both forward and back contamination, allowing refinement to planetary protection programs for future near-term Mars landers, rovers, orbiters, as well as outer planet missions, and detection of novel microbes on the spacecraft and associated environments will enable modified cleaning and sterilization technologies.

Recent Work:

Isolation of extremophilic microbes was carried out by exposing aliquots of samples to several extreme conditions.

- Tested for tolerance to UV light, H_2O_2, anaerobic condition, high T (~65°C), low T (~4°C), high pH (~11), low pH (~3) and NaCl (~25%).
- Isolates tolerant to each kind of stress were identified, characterized, and archived.

Identified three extremophilic isolates believed to be novel (based on 16s rRNA gene analysis)

Further characterization is in progress, as well as a manuscript reporting these findings

Hydrogen Peroxide Sterilization Process Certification
Shirley Chung

Hydrogen Peroxide Sterilizer
Steris MD2000

Objectives:

Generate experimental data necessary to validate the bioburden reduction effectiveness of vapor phase hydrogen peroxide. Provide data which would enable certification of this method as a NASA approved sterilization technique.

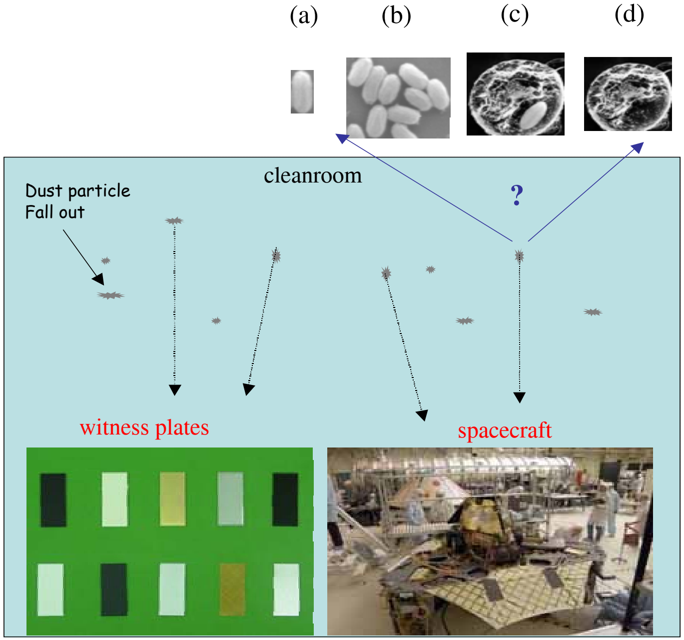
Significance:

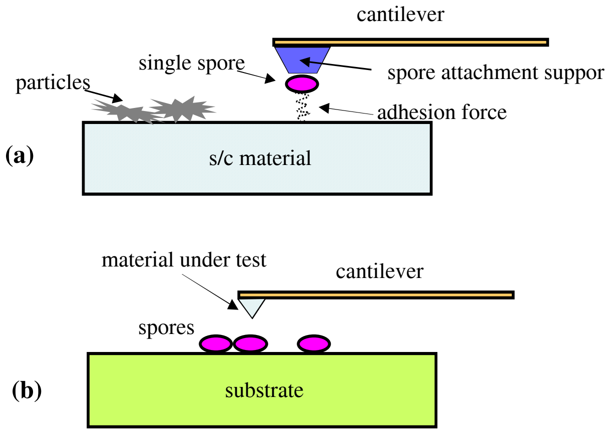
Offers an alternative low temperature technique to sterilize spacecraft components and systems to meet planetary protection requirements.

Recent work:

Recently determined humidity, concentration, time, temperature and substrate material which resulted in the most spore survivors.

Spore Adhesion for Contamination Transport Model
Dr. Ying Lin





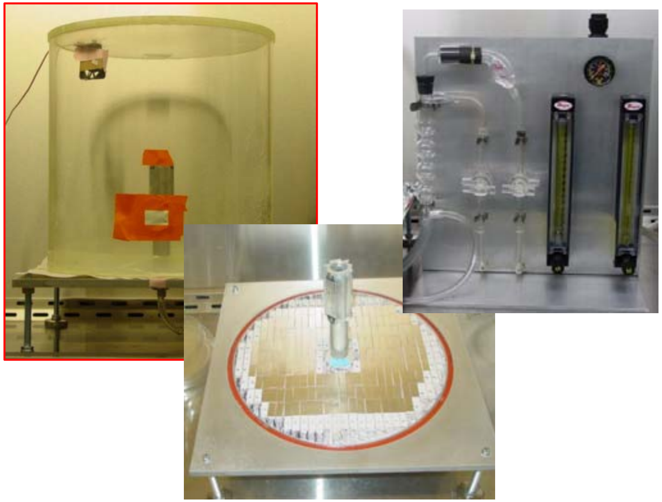
Objectives:

- To obtain knowledge and data sets of spore association and adhesion to dust particles and spacecraft necessary for developing high fidelity contamination transport models in support of Mars landing and sample return mission PP requirements.
- To understand spore association with dust particulates by measuring the number of spores on particles of various sizes in a clean room environment.
- To investigate spore adhesion to its carriers by AFM measurements of adhesion forces among spores, particles, and spacecraft material surfaces.

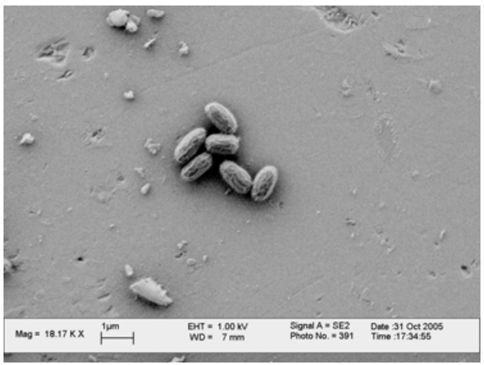
Significance:

- Contamination transport models are required to describe the transport of terrestrial microbes during in-situ planetary operations from lander to surface, from lander to sterilize sampling arms etc. Existing contamination transport models and simulations are mostly based on theories and assumptions. This work will provide data crucial for simulation results and predictions.

Cleaning to Achieve Sterility
Dr. Roger Kern



Spore Deposition Mechanism



A “sterile” surface that isn’t clean

Objectives:

Establish an alternative to dry heat sterilization by developing a method based on advanced cleaning techniques to remove spores, rather than killing them in place.

Significance:

A cleaning alternative to dry heat sterilization will save time, possibly be more compatible to spacecraft materials, and will be synergistic to achieving contamination control requirements.

Status:

1) Created a closed system Bacillus spore chamber to achieve a uniform deposition on test coupons (NTR write-up in progress)
2) Evaluated efficacy of six different cleaning methods
3) In the process of recommending modifications to current cleaning methods
4) Further characterization of the materials compatibility is underway

Bioassay Certification
Dr. Roger Kern and Dr. Norm Wainwright

Portable ATP instrument

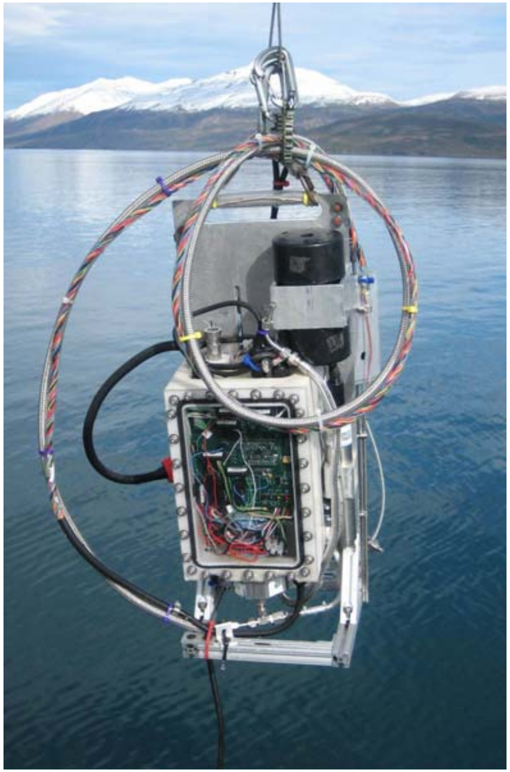
Objectives: Characterize and deliver two rapid enzyme-based bioburden detection assays, to be used as augmentations to the current NASA Standard Assay.

Significance: The Adenosine triphosphate (ATP) and Limulus amebocyte lysate (LAL) assays are intended for near term use, during spacecraft assembly, to permit the rapid (<1hr) detection of gross bioburden problems.

Handheld LPS instrument

Status: The work was recently completed and the results delivered to HQ. The Planetary Protection Officer is in the final stages of evaluating these methods for adoption as new standards.

Astrobiology Science Instrument Technology and Development
Dr. Kasthuri Venkateswaran



Field testing of the Hydrothermal Vent Biosampler (HVB) at the Eyjafjordur Fjord hydrothermal system near Akureyri, Icleand.

Objective: To develop a Hydrothermal Vent Biosampler (HVB) capable of collecting samples from discrete locations within a hydrothermal plume. Accurate analyses of hydrothermal microbial communities and the conditions under which they exist (extreme temperatures, pressures, etc.) greatly expands NASA's understanding of the limits of life on Earth. As these environments are potential analogs to those present elsewhere (e.g. the icy Jovian satellite, Europa), the development of effective sample collection systems is a critical step for future life detection missions.

Recent Work:

1) A functional sampler has been constructed and 'bench' evaluated at JPL.

2) Barometric tests (Scripps Institute of Oceanography, La Jolla, CA) demonstrated HVB operational at deep sea pressures (~100MPa = 6500m).

3) Dive tests (Monterey Bay Aquatic Research Institute (MBARI) and the Eyjafjordur Fjord hydrothermal system, Iceland) have demonstrated sample collection while in the fluid environment.

Status:

Upcoming field campaigns include Eyjafjordur Fjord, Iceland (Spring 06) and next available Japan Agency for Marine-Earth Science and Technology (JAMSTEC) cruise (Summer 06).