



Aseptic Assembly of SmallSat Spacecraft for Europa Exploration

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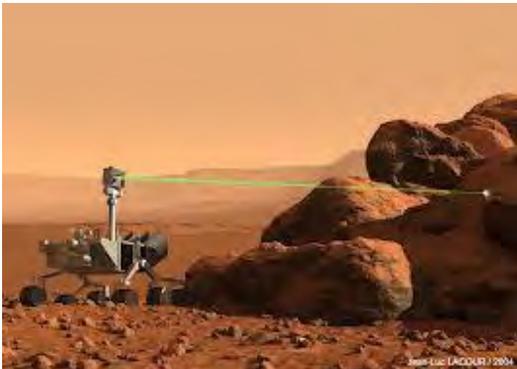
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Planetary Protection Objectives

- Protect the future exploration of other solar system bodies for life, remnants of past life, and the precursors of life (forward contamination)
 - Protect the science
 - Protect the environment
- Protect the Earth from possible hazards of returned extraterrestrial material (back contamination)



Planetary Protection Mission Categories

TYPES OF PLANETARY BODIES	MISSION TYPE	MISSION CATEGORY
Not of direct interest for understanding the process of chemical evolution. No protection of such planets is warranted (no requirements)	Any	I
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
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	III
	Lander, Probe	IV
Any Solar System Body	Earth-Return (Can be “unrestricted” or “restricted Earth-return”)	V

Mission categories are determined based on the target body explored, mission type and mission purpose

Category III/IV Requirements for Icy Bodies

Category III and IV. Requirements for Europa/Enceladus flybys, orbiters and landers, including bioburden reduction, shall be applied in order to reduce the probability of inadvertent contamination of an European ocean to less than 1×10^{-4} per mission. These requirements will be refined in future years, but the calculation of this probability should include a conservative estimate of poorly known parameters, and address the following factors, at a minimum:

- Bioburden at launch
- Cruise survival for contaminating organisms
- Organism survival in the radiation environment adjacent to Europa
- Probability of surviving impact/landing on Europa
- The mechanisms of transport to the European subsurface

Microbial Reduction Processes



Phoenix Subsystem-level Sterilization

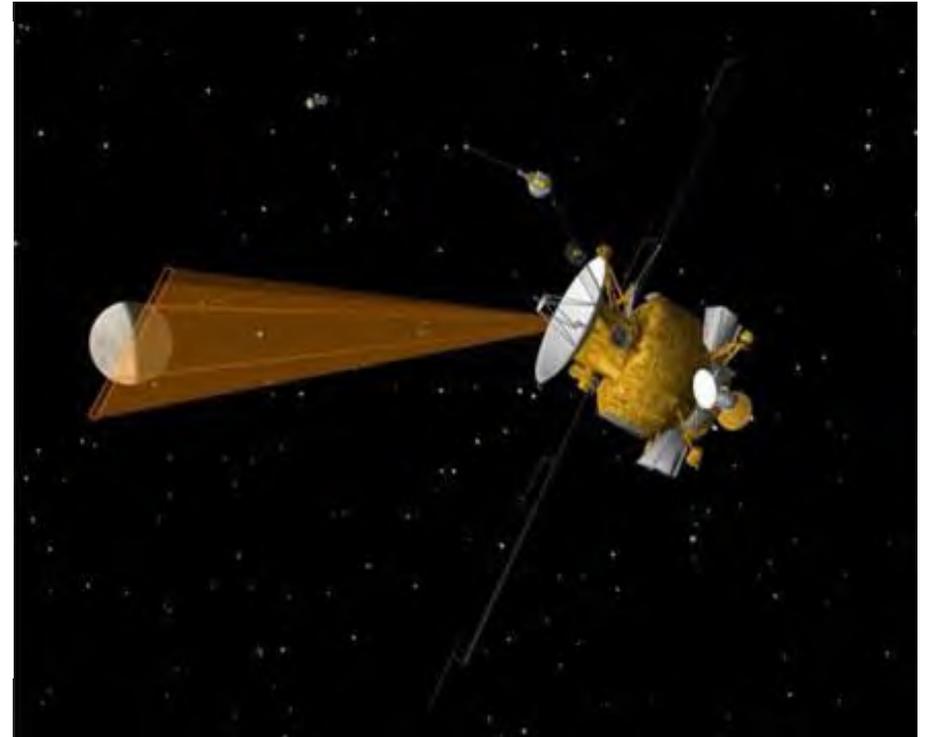
Viking Terminal Sterilization



Microbial Reduction Processes

The Europa Clipper Mission would:

- Require all components to be compatible with the DHMR environment
- Implement system level DHMR sterilization at KSC



The Europa Study Planetary Protection baseline plan would be extended duration Dry Heat Microbial Reduction (DHMR) at the system level

Dry Heat Microbial Reduction



- DHMR Process

- Standard process specs exist
- No assays required (but pre-treatment assays may be used for accounting)
- Optimal in range 110 °C to 125 °C (50 to 5 hours)
- Up to 4 log microbial reduction credit for process temperatures \leq 125 °C

- Limitation

- Advanced materials, electronics, and other heat-sensitive equipment being used on spacecraft today could be damaged by such high-temperature treatment
- Time consuming and costly

- Solution

- Development of a low-temperature alternative sterilization process

Local Sterilization Technology for Aseptic Assembly

- Objective: Develop an alternative system sterilization approach to the Viking-like dry heat microbial reduction (DHMR) system sterilization method with the goal to obtain significant cost and schedule savings for flight hardware activities.
- Technical Approach:
 - Develop a low-temperature local sterilization technology for aseptic assembly of spacecraft hardware using the vapor hydrogen peroxide (VHP) sterilization method.
 - Enables application of the sterilization method to a variety of different hardware.
- Advantages:
 - Aseptic assembly will allow components to be sterilized using a variety of methods such that the integrated system will meet sterilization requirement without damage to heat sensitive parts of the hardware.
 - Aseptic assembly would allow different sterilization methods to be appropriately applied to specific components based on their properties ensuring the most comprehensive sterilization of the whole system while allowing a broader parts selection and material selection for engineering design.

Vapor Hydrogen Peroxide Sterilization

- The VHP process employs hydrogen peroxide vapor to destroy microbes
- It is widely used by the medical industry to sterilize surgical instruments and biomedical devices
- Considered as a low temperature complementary surface sterilization technique to the DHMR process.
- Standard process specs recently accepted by NASA and ESA
- Temperature range: 25°C to 45°C
- Relative humidity controlled between 3-50%
- Sterilization process time reduced dramatically from hours to minutes.
- May provide significant cost saving over DHMR, especially if system level sterilization is required.
- Can achieve two order of magnitude more bioburden reduction credit.

Aseptic Assembly Implications for Small Satellites

- Advantages for SmallSat Development
 - Allows custom tailoring of sterilization processes based on sensitivity of hardware.
 - Allows flexibility when design changes are introduced.
 - Supports sterile, yet incremental, clean assembly when handling compact spacecraft systems.



Major Satellite Components	
A	DC Probe
B	E-Field Sensor Payload
C	GPS Receiver
D	Science / ADCS Board
E	C&DH Processor Board
F	C&DH Motherboard
G	Power Board w/ Batteries
H	Radio Electronics and Board
I	Turnstile Antennas
J	DC Probe

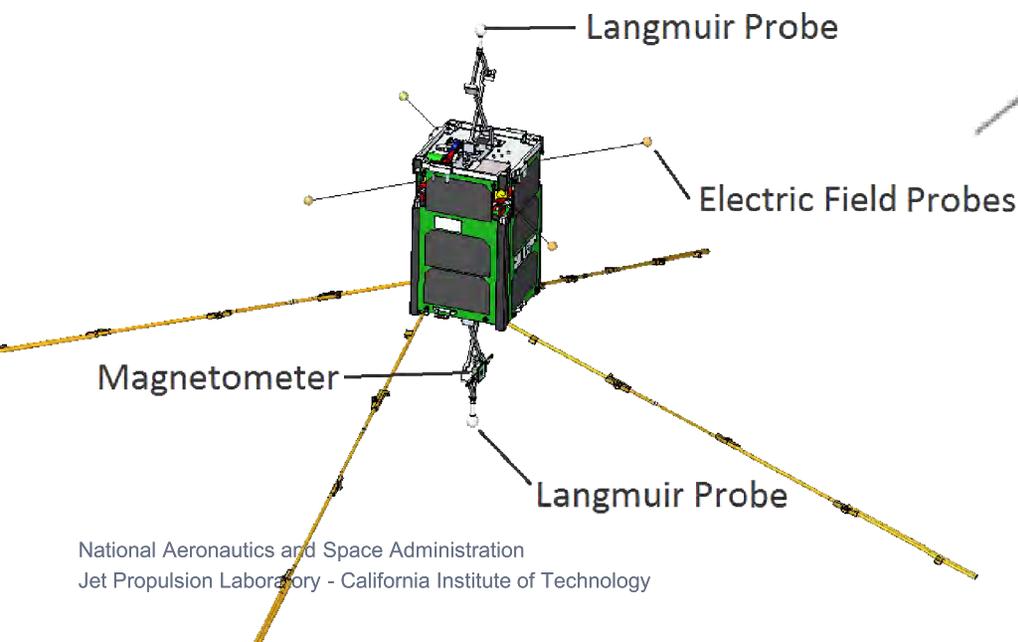


Illustration from Utah State DICE CubeSat

VHP Generator and Test Chambers



Steris VHP 1000 ARD was selected. The ARD was designed as a mobile system to be moved to different locations for room or laboratory (BSL) decontamination.



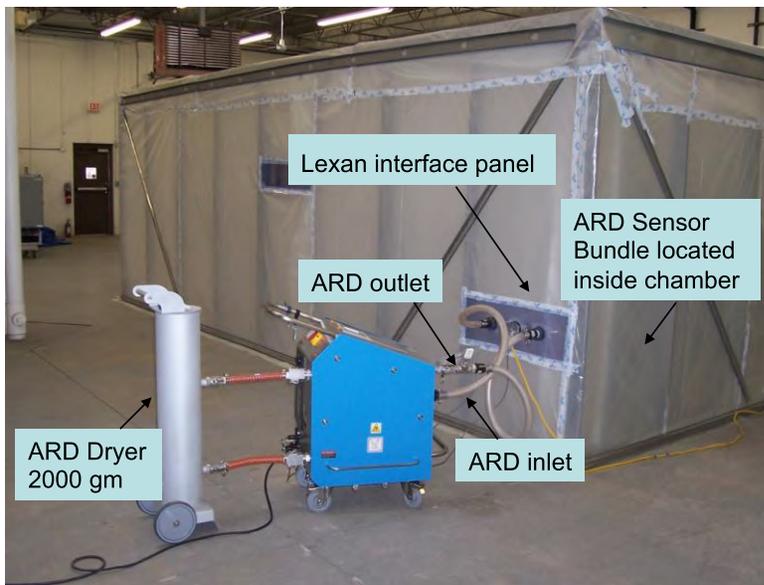
Rigid plastic walls test chamber



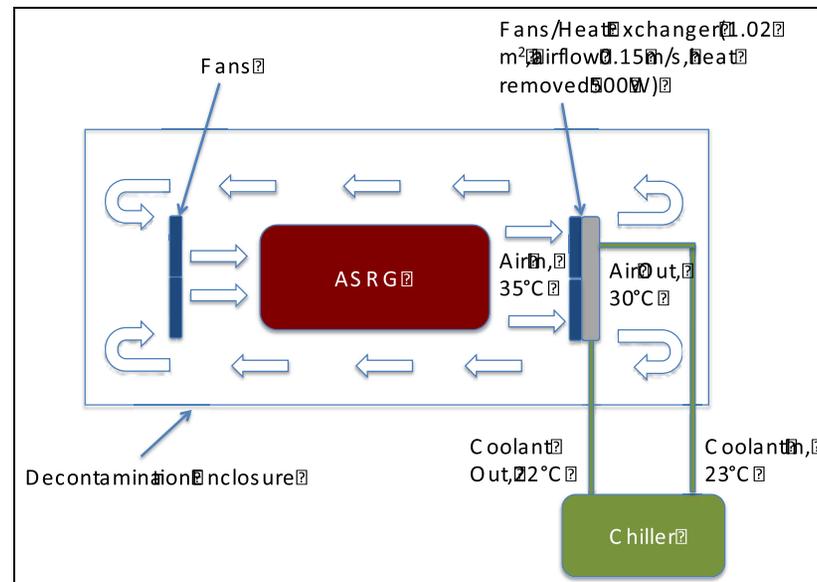
Flexible walls test chamber

Aseptic Assembly Potential Application

- Advanced Stirling Radioisotope Generator (ASRG) sterilization:
 - For a Europa Mission system-level sterilization by DHMR can't be used for the ASRGs due to a heat sensitive magnet. Aseptic Assembly provides an alternative way for system-level sterilization.



STERIS VHP 1000 ARD Connected with Test Enclosure



Fans/Heat Exchanger Layout

Aseptic Assembly vs Viking-like System Sterilization

	Viking-like System Sterilization	Aseptic Assembly
Sterilization Method	DHMR	VHP
Standard Process Specs	Yes	Yes
Temperature	110 - 125 °C	25 - 45 °C
Duration	50 hours	30 minutes
Relative Humidity	0.20%	3 - 50%
Bioburden Reduction Credit	4 orders of magnitude	6 orders of magnitude
Cost	expensive (\$25M for DHMR oven)	inexpensive (\$40K for ARD)