NASA's International Space Station: Test Bed for Planetary Protection Protocol Development

Planetary Protection Workshop
NASA Ames Research Center
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Background

- **Wherever we go, we carry along micro-organisms that live in and on us**
  - Conventional wisdom says those critters would never survive the space environment
  - But ISS experiments have shown otherwise
    - Cyanobacteria survived outside the ISS for 548 days
    - Exposed Tardigrades reproduced after returning to Earth

- **What about the organisms that might leak/vent from crewed spacecraft?**
  - Do we even know what they are?
  - How long might our tiny hitch-hikers survive near a warm Mars Lander that periodically leaks/vents water or oxygen?
  - How might they mutate with long-duration exposure?
- **Unlike the Mars rovers that we cleaned once and sent on their way, crew will provide a constantly regenerating contaminant source**

Are we prepared to certify that we can meet planetary protection and contamination control requirements as we search for life at new destinations?

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New FY15 NASA JSC Project!

Develop Integrated Test & Analysis Plan

QUESTIONS

WHICH microbes are typically vented or leaked from crewed spacecraft?

HOW LONG can they survive?
- In destination environments?
- Near a warm spacecraft?
- Near oxygen or water vents?

HOW FAR can they travel?
- In Asteroid, Lunar or Mars environments

WHAT (if anything) should we do about it?
- Informs future designs & ops

PATH TO ANSWERS

SAMPLE what we have access to now
- Piggyback an ISS EVA: swab external ISS ECLSS vents
- Piggyback an EVA suit test to grab a sample of gas vented from the EVA suit

ANALYZE what we collect
- The same or different than what's *inside* ISS?
- Will it grow under destination conditions?
- Will it grow near simulated spacecraft (heat, moisture)?

MODEL transport mechanisms
- Under various destination conditions
- Impacts to destination science

DEVELOP recommendations
- How close can EVA crew or Habitat be to sensitive samples or regions?
- Does this drive closed loop life support systems?
- Should we expand (or can we relax?) cleanliness requirements?

Emphasis on what we can we do now with what we already have

We don't have to wait for SLS or Orion to swab ISS external vents and see what kinds of microbes are actually being vented from a crewed spacecraft

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Project Deliverable: Integrated Test & Analysis Plan

Goal: Integrate stakeholders to develop test/analysis that meets common goals w/out large investment

Individual stakeholders then pursue targeted funding to implement specific pieces of the plan

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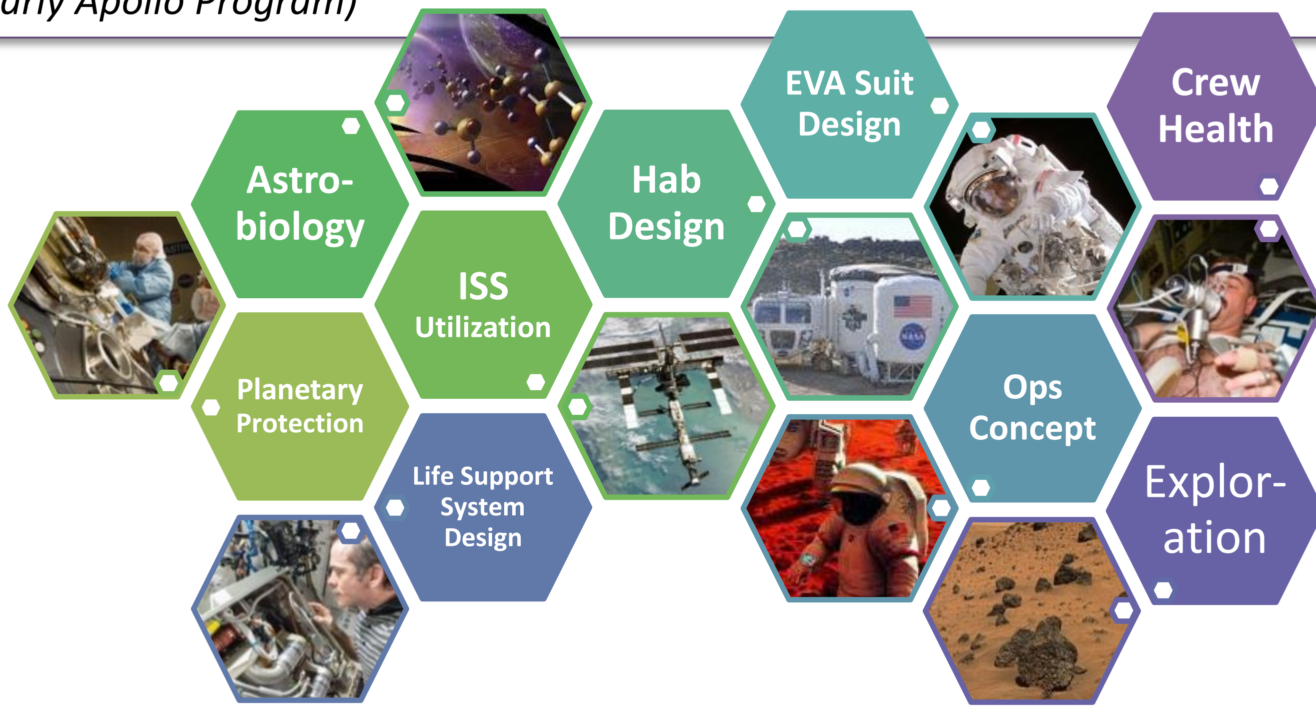
Project Benefits

- Build relationships between stakeholder communities
- Conceptual designs of forward contamination sampling tools/techniques for use at any destination
  Potential ISS utilization with minimal cost/operational impact
- Provides a clear path to chip away at uncertainties associated with Forward Contamination
- Relatively low-risk opportunity to practice planetary protection operations *(something we haven't had to do since early Apollo Program)*



Helps Inform future spacecraft and suit designs *now*, so we can avoid redesign costs later

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Collaboration: 8 JSC Orgs + 3 Centers + 2 External Orgs

Discipline	Project Team Members	
Project Administration	Michelle Rucker	
Microbiology	Dr. Doug Botkin	Dr. Kasthuri Venkateswaran
	Dr. Andy Schuerger	Dr. Mark Lupisella
	Dr. Duane Pierson	Dr. Mark Ott
	Dr. Bekki Bruce	Dr. Sarah Castro
Flight Crew	Dr. Stan Love	
Planetary Protection and Surface Operations	James Johnson	Dr. Margaret Race
	Dr. Brian Glass	Dr. Mary Sue Bell
Environmental Control and Life Support	Jason Dake	Larry Spector
	Joe Chambliss	
Extravehicular Activity (EVA)	Drew Hood	Jesse Buffington
	Chris Vande Zande	Natalie Mary
Modeling	Dr. Bob Shelton	

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Project Status

☑ **Surveyed ISS U.S. Segment Life Support System vents**

- Cabin air relief valves, carbon dioxide removal system, cabin pressure equalization vents, condensate water vents, vacuum system vents
- These systems are more likely to contain micro-organisms than other types of vents (propulsion system, for example)

Sample of vent survey

No.	System	Location	Primary Vented Products	Use Frequency	
				Current	Past
1A	CDRA (Carbon Dioxide Removal)	Node 3	CO_2	Daily	Daily
1B		Lab			
2	OGA (Oxygen Generation Assembly)	Node 3	H_2	Daily	Daily
3	Sabatier (same vent as OGA)	Node 3	CH_4, CO_2	Intermit.	Daily
4	PPRV (Positive Pressure Relief Valve)	Node 3 Aft	Cabin Air	None	Rarely (maybe actuated during launch)

☑ **Established figures of merit to prioritize vents for EVA sampling**

☑ Prioritized the vent list

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Figures of Merit for ISS Vent Sampling Prioritization

Figure of Merit	Figures of Merit Rationale
Accessibility	1. Piggy-back onto a planned EVA, rather than use robotic assets (robot arm or purpose-built robot). *Rationale: assume robotics would add unnecessary cost and complexity.* 2. Sample location must be EVA accessible. *Rationale: EVA crew has to get close enough to sample, but we could use extension tools if necessary.* 3. Given the choice between sampling a single sampling location that may be off the planned EVA route vs. several locations on the planned EVA route, more is better 4. Ability to sample during venting is of interest.
Product Type	1. Vent products that were in direct contact with crew (i.e. cabin air) are more likely to contain organisms of interest than things that were isolated from the crew (such as combustion products) 2. Vent products from exploration-like systems are more pertinent than products from systems that would not be used for deep space exploration
Mass of Vent Product	*1. Combo of vented products and accessibility: can we get the right size sample container near the sample location* 2. More is better.
Local Environment	1. Sample locations with relatively benign local conditions (i.e. warm surfaces, shielded from direct UV exposure), may be more likely to support microbial growth than locations with harsher local environmental conditions

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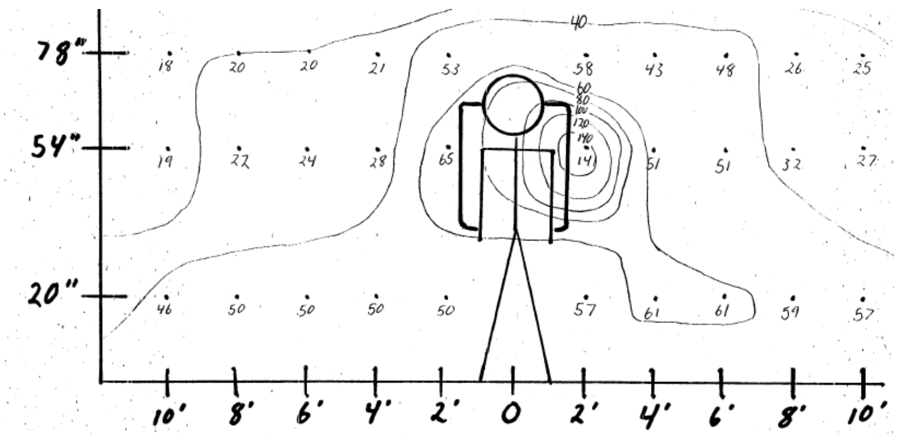
Project Status

- **Develop EVA vent sampling tools**
  - Evaluating Russian EVA sample kit vs. design/build something from scratch
  - *Forward Work: develop EVA sample kit requirements*
- **Develop EVA vent sampling procedures**
  - For piggyback onto planned EVAs as an if-time-permits task
  - *Forward Work: Develop a procedure sequence that can be easily dropped into a larger EVA procedure as opportunities arise*
- **Characterize EVA suit**
  - Engaged EVA community
  - Discussed areas most likely to shed contaminants from suit
  - *Forward Work: develop EVA suit sampling plan to piggyback onto suit development tests*

1997 Suit Vicinity Pressure Profile Test



This year's goal is only to develop the integrated test and analysis plans

- ***Implement individual test & analysis pieces in subsequent years***

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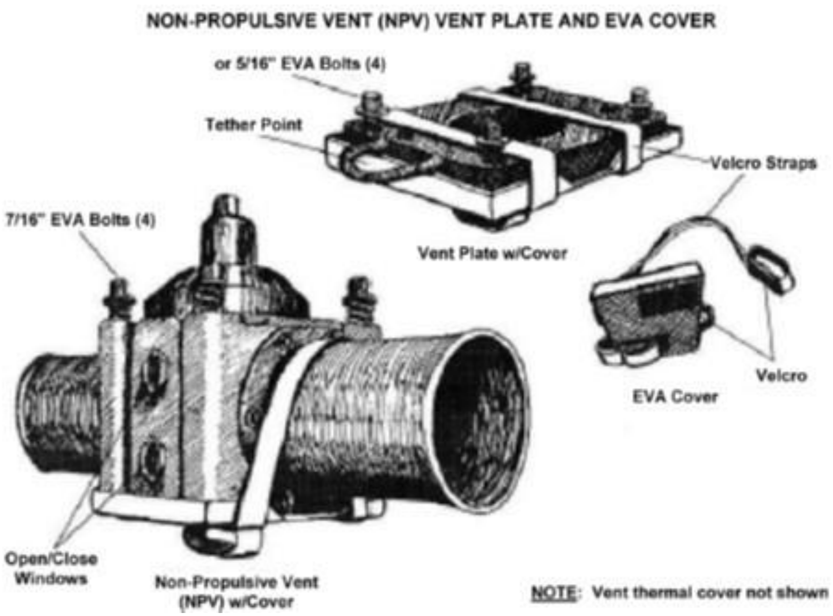
Opportunity

- **During ISS ECLS vent survey, an opportunity presented itself**
- **Node 3 Non-Propulsive Vent (NPV) was removed during February 25 EVA**
  - — Replaced with a Cover Plate
  - — NPV sits on top of cabin Vent Relief Valve which vents crew cabin air
  - — NPV was launched with Node 3 in 2010
  - — NPV will return to ISS exterior in a few months



Why go outside next year to sample this NPV when we could do it inside now?

This activity mimics the kind of planetary protection situation we'll have to address for Mars: something breaks, we'll go outside to retrieve it, bring it inside to repair it, and send it back out again—ideally without exchanging Earth and Martian contaminants in the process

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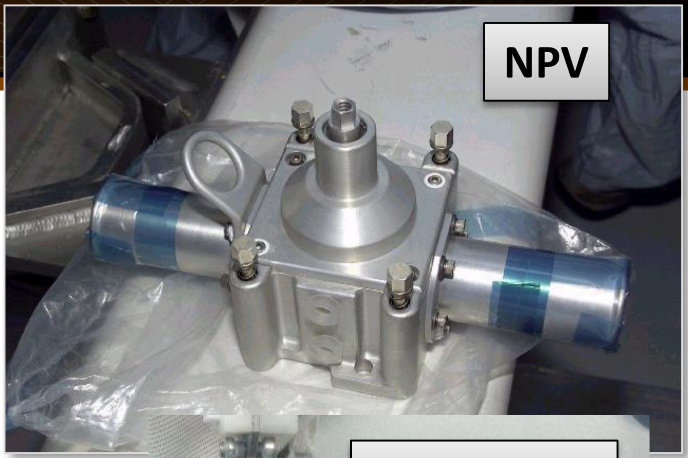
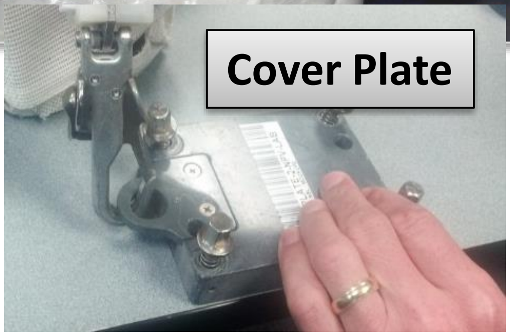
NPV Sampling





- **Potentially two opportunities!**
  - Both the NPV and Cover Plate
- **NPV Sampling priority**
  1. Inside diameter of one vent tube
  2. Internal Plunger face
- **Preference is molecular analysis**
  - Either sterile polyester wipe or SWAB tube
  - Lower priority: sample for culturable organisms on exterior and interior surface of NPV
- **Sampling made possible courtesy of Kasthuri Venkateswaran**
  - ISS Microbial Observatory project

We recognize this is not an optimal approach

Ideally, we would know the NPV baseline and sample it *before* it came inside. But this opportunity is about developing processes & procedures for a larger exploration effort

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Lessons Learned (So Far)

Trying to sample a specific item in a given time frame has flushed out issues that may not have been detected with a more generic approach

1. **We didn't have the right relationships in place to quickly react to a near-term opportunity**
   - — Hadn't yet approached the ISS Research Integration Control Board
   - — Hadn't yet coordinated with EVA and ISS operations community
2. **We don't have a good way to prepare external hardware to come inside a crewed pressure cabin**
   - — No EVA-compatible caps or tape to cover NPV openings of interest
   - — No EVA-compatible "clean" bags to place NPV into
   - Potential development opportunity: make-to-fit as needed
3. **We don't have a good place to do this work inside a crewed pressure cabin**
   - — Not an issue for ISS but where would we do this on Mars?
   - — If we use the Science Glovebox, how would we sterilize the Glovebox before/after working on a particular item?
   - Potential development opportunity

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Lessons Learned (So Far)

4. **Hardware may have unique "keep out zones" that drive the sampling method used**
   - NPV has an orifice in the vent tube that's just big enough to get a finger stuck and there may be sharp internal edges that pose a cut hazard to crew
   - NPV has seal surfaces and internal mechanisms that are sensitive to scratches
   - Q-tip type swab mitigates these issues vs. a larger fabric wipe, even though the fabric wipe was preferred by the scientists
5. **We don't have a ready supply of sampling equipment available**
   - Swabs/wipes on board ISS is dedicated for specific experiments
   - May take months to manifest/launch new equipment
   - What about Mars? How many sampling kits should we plan for?
6. **Unused sample kits are discarded on ISS**
   - Not enough space to store them, and loose equipment may be difficult to find later
   - Won't be practical to discard anything on Mars
   - Potential development opportunity: develop processes and procedures for salvaging unused portions of equipment kits for re-use

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Lessons Learned (So Far)

7. **Microbiologists want wetted swabs/wipes, but hardware owners worry about material compatibility**
   - Example: Concern that detergent solution could compromise seal lubricants
   - Wetted swabs may not be practical for EVA sampling
8. **No on-board sample analysis capability**
   - ISS samples are returned to Earth for analysis, but that's not practical at exploration destinations
   - Development opportunity
9. **Considerable coordination required**
   - EVA, Crew, Materials and Processes, Hardware Owners (both NASA and contractor), Research Control Board, Vehicle Control Board, microbiologists
   - Development opportunity: Given communications lag time to Mars, what would coordination look like if we had to take an unplanned sample?

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Project Summary

BACKGROUND

Some organisms can survive exposure to space environments!

Cyanobacteria survived 500+ days outside the ISS

Tardigrades survived extended exposure *and then reproduced*

We also know that all crewed, pressurized volumes will leak or vent

ISSUE

But we *don't* know what's actually leaking/venting from our current systems, how long those organisms could survive, or how far they may travel under destination conditions

Does proximity to a warm spacecraft matter?

How close can crew get without compromising science?

How far could our little hitchhikers spread?

The answers will drive element design (i.e. closed vs. open ECLS), where we place elements, and who/how we collect science samples

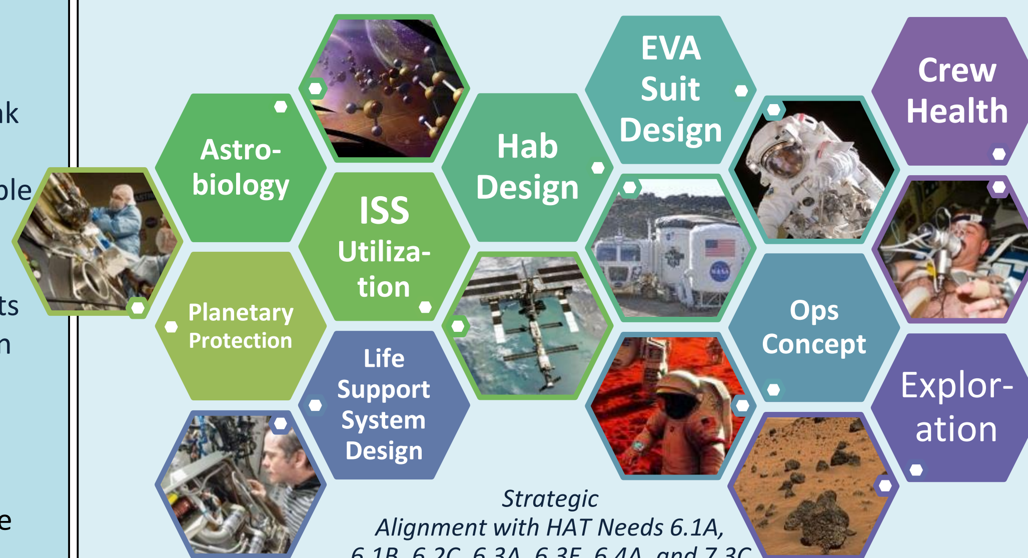
SOLUTION

Big Picture

1. Identify ways to characterize what is expected to vent/leak overboard – what can we do now, with what we have?
   - Swab ISS ECLS external vents, collect EVA suit vent sample
2. Develop analysis plan to study vented organisms under destination conditions (including spacecraft-induced)
3. Model transport mechanisms in destination environments
4. Assess impact on future operations and equipment design

Node 3 NPV Opportunity

- Provides an opportunity to exercise the processes and procedures we'll need for future exploration
- Data point will be interesting—but not expected conclusive
- Will provide a baseline for future EVA sampling



Strategic Alignment with HAT Needs 6.1A, 6.1B, 6.2C, 6.3A, 6.3E, 6.4A, and 7.3C

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Questions?

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