

# Final Report of the COSPAR Planetary Protection Knowledge Gaps for Human Mars Missions Workshop Series and Paths to Knowledge Gap Closure

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### Overview



- Introduction to Planetary Protection for Crewed Mars Missions
- Review of the Workshop Process and Findings on Knowledge Gaps
- Updates Strategy for Addressing Knowledge Gaps
- Contamination Threat Assessment for a Crewed Mission Concept
- Summary







The Outer Space Treaty of 1967

International Responsibility

#### Article VI:

States Parties to the Treaty shall bear international responsibility for national activities in outer space, including the moon and other celestial bodies, whether such activities are carried on by governmental agencies or by nongovernmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Treaty

## Article IX:

**Planetary Protection** 

States 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

#### Committee on Space Research (COSPAR)

- Panel on Planetary Protection forms international consensus guidelines
- Defines PP Categories I V based on target body and mission type

#### NASA

- Implements Planetary Protection Policy to achieve compliance for NASA Missions
- Supports FAA in planetary protection compliance evaluation for Non-NASA Missions
- Maintains US conformity with the provisions in the OS Treaty

 Supports the sciencebased international consensus process
 Develops new guidelines and provides significant input to COSPAR







Types of Planetary Bodies	Mission Type	Misson Category
Not of direct interest for understanding the process of chemical evolution. No protection of such planets is warranted.	Any	Ι
Of significant interest relative to the process of chemical evolution, but only a remote chance that contamination by spacecraft could jeopardize future exploration. Documentation is required.	Any	II IIa, IIb (Moon)
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. Substantial documentation and mitigation is required.	Flyby, Orbiter Mars, Europa, Enceladus	III
As above	Lander, Probe Mars, Europa, Enceladus	IV IVa, IVb, IVc (Mars)
Any solar system body. Unrestricted applies only to bodies deemed by scientific opinion to have no indigenous life forms.	Earth Return Restricted or Unrestricted	V



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#### Planetary Protection Implementation for Robotic Missions





#### Typical implementation - Orbiter:

- Probability of Mars impact assessment for launcher upper stage and spacecraft
- Launch, cruise to Mars, MOI and orbital mission phases
- · Hardware, software and operational reliability
- Micrometeoroid impact and effect analysis

Alternative approach is bioburden control of spacecraft, including break-up/burn-up analysis, to meet and impacted numeric bioburden limit



Typical implementation - Lander:

- Bioburden reduction of flight hardware using solvent cleaning, dry heat, ionizing radiation and gases
- Recontamination prevention using flight and nonflight filters and barrier systems
- Bioburden control of assembly, test and launch operations
- Bioburden verification with assays

Intent is to meet numeric bioburden limit (with the limit being more stringent for IVb/c missions)





- a. "Safeguarding the Earth from potential back[ward] contamination is the highest planetary protection priority in Mars exploration."
- b. "The greater capability that human explorers can contribute to the astrobiological exploration of Mars is only valid if human-associated contamination is controlled and understood."
- c. "For a landed [human] mission conducting surface operations, it will not be possible for all human-associated processes and mission operations to be conducted within entirely closed systems."
- d. "[Humans] exploring Mars, and/or their support systems, will inevitably be exposed to Martian materials."

(Originally excerpted as "guidance" from COSPAR 2008 policy language)





## **COSPAR** guidelines for crewed missions

Current guidelines, in place since 2008, address:

- Forward contamination
  - Orders of magnitude greater threat than robotic missions – crew as "biogenerators"
  - Crewed spacecraft systems are not sealed
- Backward contamination
  - Want the crew to return home
  - Earth's biosphere must be protected
- ... But do not yet provide enough detail for engineering design requirements







## Assessment of Knowledge Gaps for future crewed missions



2015	2016	2018	2018 & beyond
NASA Workshop at Ames	1 <sup>st</sup> COSPAR Meeting at LPI	2 <sup>nd</sup> COSPAR Meeting at LPI	COSPAR Working Meeting on Contamination Transport on Mars at LPI, May 2018 COSPAR Working Meeting on Microbial Monitoring & Health at LPI, May 2019 COSPAR Virtual Working Meeting on Spacecraft Systems, May 2020 COSPAR Virtual Working Meeting on Spacecraft Systems, Dec 2022
Identification of Planetary Protection Knowledge Gaps for human missions to Mars What Knowledge	Refinement and prioritization of Planetary Protection Knowledge Gaps for human missions to Mars	Mission Opportunity identification for addressing Planetary Protection Knowledge Gaps for human missions to Mars	Measurements and Payload/Operation Concepts for addressing Planetary Protection Knowledge Gaps for human missions to Mars
Gaps			measurements

...to establish the <u>right</u> quantitative and implementable planetary protection requirements for safe and sustainable exploration and utilization of Mars.





## Assessment of Knowledge Gaps for future crewed missions



2015	2016	2018	2018 & beyor	nd
NASA Workshop at Ames	1 <sup>st</sup> COSPAR Meeting at LPI	2 <sup>nd</sup> COSPAR Meeting at LPI	COSPAR Working Mee Transport on Mars at LF COSPAR Working Mee & Health at LPI, May 20 COSPAR Virtual Workin Systems, May 2020 COSPAR Virtual Workin Systems, Dec 2022	eting on Contamination PI, May 2018 ting on Microbial Monitoring 019 ng Meeting on Spacecraft ng Meeting on Spacecraft
Identification of Planetary Protection Knowledge Gaps for human missions to Mars What Knowledge Gaps	Refinement and prioritization of Planetary Protection Knowledge Gaps for human missions to Mars in what order	Mission Opportunity identification for addressing Planetary Protection Knowledge Gaps for human missions to Mars using what missions	Measurements and Payload/Operation Concepts for addressing Planetary Protection Knowledge Gaps for human missions to Mars	Spry, J. A., et al. (2024). Planetary Protection Knowledge Gap Closure Enabling Crewed Missions to Mars. <i>Astrobiology</i> , 24(3), 230–274. https://doi.org/10.1089/ast

...to establish the <u>right</u> quantitative and implementable planetary protection requirements for safe and sustainable exploration and utilization of Mars.







- Human spaceflight hardware leaks (in nominal and off-nominal operation), so the old robotic paradigm of managing a fixed bioload is inappropriate.
- The introduction of a maintained temperate terrestrial environment at the Martian surface affords the opportunity for many more organisms (in type and quantity) to escape into the Martian environment.
- This exploration is taking place in a post-Mars Sample Return (MSR) context where Martian life was NOT (yet?) discovered at the Martian surface/shallow subsurface in returned Mars material, but we know a lot more about Mars from those samples.
- Knowledge gaps need to be understood and preferably closed before launch to protect science return and the Earth.

\* Developed as ground rules for the 2020 COSPAR "4<sup>th</sup> Workshop on Refining Planetary Protection Requirements for Human Missions" – see the Conference Documents section at https://sma.nasa.gov/sma-disciplines/planetary-protection



### Knowledge Gap Areas

# NASA

### Microbial and human health monitoring

- Evaluation and monitoring of microbial communities associated with human systems, both for their initial state and changes over time
- Technology and operations for contamination control
  - Designs, methods and procedures for controlling contamination release of human spacecraft systems

## Natural transport of contamination on Mars

 Understanding the environmental processes on Mars that contribute to transport, survival and replication of microbes released by human activities











Microbial & Human Health Monitoring
1A. Microbial monitoring of the environment
1B. Microbial monitoring of humans
1C. Mitigation of microbial growth in spacecraft systems
1D. Operational guidelines for planetary protection and crew health
Technology & Operations for Contamination Control
2A. Bioburden/transport/operations during short vs. long stays
2B. Microbial/organic releases from humans and support systems
2C. Protocols for decontamination & verification procedures
2D. Design of quarantine facilities/methodologies at different mission phases
2E. Martian environmental conditions variation over time with respect to growth of Earth microorganisms
2F. Research needed to make ISRU & planetary protection goals compatible
2G. Acceptable contamination level from wastes left behind, including constraints on vented materials
ORIGINAL 2H. DELETED (merged with 2B.)
2I. Approaches to achieve 'Break the chain'' requirements
2J. Global distribution/depth of subsurface ice and evidence of extant life
2K. Evolution of planetary protection requirements/goals from robotic precursor through to human missions & exploration zones
Natural Transport of Contamination on Mars
3A. Measurements/models needed to determine atmospheric transport of contaminants
3B. Measurements/models for subsurface transport of contaminants
3C. Effect of biocidal factors on survival/growth/adaptation of microorganisms
3D. Determination of acceptable contamination rates & thresholds
3E. Protection mechanisms for organisms on Mars
3F. Degradation of landed materials by Martian environment
3G. Induced environmental conditions around structures
3H. Sensitivity of non-culturable species to biocidal factors











Assessment focused in a "realistic" first crewed mission concept





 Ascent vehicle propellant, Fission Surface Power, and surface mobility/propellant transfer system PRE-DEPLOYED CREW ASCENT VEHICLE • Partially-fueled

3 CREW

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- Two crew land/live in pressurized rover
- Provides habitation and mobility for 30 days
- Supports science and exploration operations



A STANDARD





## The "Eye Chart": Visual of NASA Progress on Closing PP KGs



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COSPAR planetary protection KG parameters for a crewed Mars mission all in one table, with progress color-coded in the 3<sup>rd</sup> column

ley:	
	Knowledge Gap response approach is mature and/or
	addressable as policy
	Knowledge Gap response is actively being addressed
	and planetary protection application and outcome is clear
	Knowledge Gap response or path to closure is identified but
	planetary protection acceptability and/or outcome is not clear
	Knowledge Gap is not being addressed or work to
	closure is not started or new data acquisition is still needed

Note: not all KGs need to be closed for a viable PP Implementation strategy, but all need to be addressed and dispositioned in a risk-based approach



# Disposition of Planetary Protection KGs at the end of the COSPAR Meeting Series – 1) Microbial and Human Health Monitoring



Microbial & Human Health Monitoring	Parameter	Figure of Merit/Current Best Estimate	Notes
Knowledge Gaps			
1A. Microbial monitoring of the environment	Detection and monitoring of	TBD based on data from analog research to establish	MinION technology with appropriate front-end (sampling)
	microorganisms inside the habitat and in	baseline information and decision-making strategies	and back-end (bioinformatics) processing (Conclusion of
	the Mars environment		the 3 <sup>rd</sup> Meeting)
1B. Microbial monitoring of humans	Detection and monitoring of	TBD based on data from analog research to establish	MinION technology with appropriate front-end (sampling)
	microorganisms on/in crew	baseline information and decision-making strategies	and back-end (bioinformatics) processing (Conclusion of
			the 3 <sup>rd</sup> Meeting)
1C. Mitigation of microbial growth in spacecraft	Monitoring of microorganisms inside the	Establish (sub)-system requirements based on (sub)-system	Conclusion of 5 <sup>th</sup> Meeting
systems	habitat and establishment of action limits.	design and release limits (2B)	Ŭ
1D. Operational guidelines for planetary protection and	Ability to distinguish between benign and	TBD: Outcome dependent on 1A & 1B	MinION technology with appropriate front-end (sampling)
crew health	hazardous fluctuations in metagenome		and back-end (bioinformatics) processing. Discussion at
	data		the 3 <sup>rd</sup> Meeting.

- Needed technology is identified to be able to address KGs in Microbial & Human Health Monitoring
  - Demonstrated on ISS for crew monitoring
  - Data needs to be generated to create a framework for developing PP decision-making processes

Key:		
	Knowledge Gap response approach is mature and/or	
	Knowledge Gap response is actively being addressed	
	and planetary protection application and outcome is clear	
	Knowledge Gap response or path to closure is identified but planetary protection acceptability and/or outcome is not clear	
Knowledge Gap is not being addressed or work to		
	closure is not started or new data acquisition is still needed	



#### Microbial Monitoring Technologies for Planetary Protection







**Office of Planetary Protection** 



#### Disposition of Planetary Protection KGs at the end of the COSPAR Meeting Series – 3) Natural Transport of Contamination on Mars



Natural Transport of Contamination on Mars Knowledge Gaps	Parameter	Figure of Merit/Current Best Estimate	Notes
3A. Measurements/models needed to determine	Measurements to establish a mesoscale predictive model	Air Pressure 4Hz cf MSL	Conclusion at the 2 <sup>nd</sup> Meeting (minimum specs quoted)
atmospheric transport of contaminants	(baseline performance levels assuming appropriate	Air Temp. 4Hz 150-300K +/-0.1K	
	instrument suite)	Ground Temp. 1/Hr 150-300K +/-1K	
		Wind (in 3D) 10Hz 0-50m/s +/-0.5m/s: 360deg +/-5deg	Contraction of the second s
		Humidity 1/Hr 0-100% +/-5%	
and the second		Upwelling shortwave & IR 1/hr w/ TBD Range & Accuracy	
	and the second	Downwelling Solar flux 4Hz w/ TBD Range & Accuracy	
		UV-C flux 4Hz with TBD Range & Accuracy	
and the second		Total dust opacity 4Hz 0-6 +/-0.03	
		Dust size & conc. $4Hz > 0.2um + -0.05um @ 1-5000/cm^{3}$	and the second se
		Dust saltation mass flux 4Hz >0.65um +/- 10um @1-30m/s	
3A. Measurements/models needed to determine	Instrument suite to establish a mesoscale predictive model	Few 10s of Kgs high fidelity instrument suite supported by	Conclusion at the 2 <sup>nd</sup> Meeting
atmospheric transport of contaminants		three low fidelity instrument suites	
3A. Measurements/models needed to determine	Application of a mesoscale predictive model	TBD time/distance concern for viable organisms in the	Discussion at the 2 <sup>nd</sup> Meeting
atmospheric transport of contaminants		Martian atmosphere/surface	, and the second s
3B. Measurements/models for subsurface transport of	Develop and prove drill sterilization strategies	TBD case-by-case development of planetary protection	Conclusion at the 2 <sup>nd</sup> Meeting
contaminants		compatible operational plan	
3B. Measurements/models for subsurface transport of	Analyze contamination pathways for sterile drilling	TBD time/distance/depth concern for viable organisms in the	Discussion at the 2 <sup>nd</sup> Meeting
contaminants		Martian subsurface	
20 Effect of this sidel for term on summing the store on	Effect of IN/ on termentain in directory anominant	Commission I and times	and a sub-

- Understanding the Natural Transport of Contamination on Mars allows us to answer the question "How much contamination is too much?"
  - Data needs to be generated to create models of transport at Mars (particularly for the aeolian distribution case)
  - Data is also needed on the ability of contaminant terrestrial microorganisms to survive in the Mars environment

3H. Sensitivity of non-culturable species to biocidal factors Demonstration of equivalent sensitivity compared to cultivable population Establishment of a factor (if not 1.0 cf 3C data) for lethality to allow assessments under 3D to be made





nission

nission

#### Disposition of Planetary Protection KGs at the end of the COSPAR Meeting Series – 2a) Technology & Ops for Contamination Control



Technology & Operations for Contamination	Parameter	Figure of Merit/Current Best Estimate	Notes
Control Knowledge Gaps		5	
2A. Bioburden/transport/ operations during short vs.	N/A	N/A	Since only short stay missions are considered, this KG was
long stays			left open. (Discussion at 4 <sup>th</sup> Meeting)
2B. Microbial/organic releases from humans and	Is it required for an airlock volume to be sterilized prior to egress.	Yes, degree of filtration/ sterilization processing TBD based on threat	Expectation that Hydrogen Peroxide vapor and UV
support systems		of organisms released	technologies might be suitable for this purpose. Conclusion
2B. Microbial/organic releases from humans and	Is it required for an airlock volume to be sterilized prior to ingress.	Yes, degree of filtration/ sterilization processing TBD based on threat	Expectation that Hydrogen Peroxide vapor and UV
support systems		of organisms released	technologies might be suitable for this purpose. Conclusion
2B. Microbial/organic releases from humans and	Is it required for suits/ tools/ instruments/ robots to be sterilized	Yes, if required for pristine sample acquisition/processing	Consideration that pass-through glove box technology with
support systems	prior to eqress		hydrogen peroxide technology might be suitable for this
2B. Microbial/organic releases from humans and	Is it required for suits/ tools/ instruments/ robots to be sterilized	Yes, if exposed to pristine/Special Region or unknown Mars	Consideration that pass-through glove box technology with
support systems	prior to ingress	environments/materials	hydrogen peroxide technology might be suitable for this
2C. Protocols for decontamination & verification	Bioburden reduction technology compatible with spaceflight systems	TBD based on data from analog research to establish performance	Conclusion of 5 <sup>th</sup> Meeting
procedures		of candidate technologies	

- The COSPAR meeting series considered Technology and Operations for the first crewed Mars mission, leading to paths forward to address:
  - Contamination from spacecraft systems
  - Mitigation of contamination
  - Waste handling
- The discussions and findings give confidence that these topics are a tractable problem set for an end-to-end planetary protection implementation solution.



#### Disposition of Planetary Protection KGs at the end of the COSPAR Meeting Series – 2b) Technology & Ops for Contamination Control



Technology & Operations for Contamination Control Knowledge Gaps	Parameter	Figure of Merit/Current Best Estimate	Notes
2D. Design of quarantine facilities/methodologies at different mission phases	Crew Quarantine	Crew quarantine considered as a unit (not as individuals)	Conclusion of 6 <sup>th</sup> Meeting
2D. Design of quarantine facilities/methodologies at different mission phases	Crew Quarantine	Crew isolated from Mars samples on mission Earth-return leg	Conclusion of 6 <sup>th</sup> Meeting
2D. Design of quarantine facilities/methodologies at different mission phases	Crew Quarantine	Crew isolated on return (21 days [tbd] cf. Apollo)	Conclusion of 6 <sup>th</sup> Meeting
2I. Approaches to achieve 'Break the chain" requirements	Pristine sample containment (defined as a sample that could be used to test for extant and (TBD) extinct Martian life	Consistent with current Special Region containment for "pristine" samples	Conclusion of 6 <sup>th</sup> Meeting
2I. Approaches to achieve 'Break the chain" requirements	"Regular" sample containment	TBD by policy for determining Consistent with current Special Region containment for "pristine" samples	Discussion in 6 <sup>th</sup> Meeting

- The Technology and Operations to address backward planetary protection for the first crewed mission reflects a conservative approach
  - Containment of Mars samples (even if a prior MSR mission detected no life)
  - Quarantine of crew on return





## **COSPAR** Perspective



COSPAR



Olsson-Francis, et al. (2023) Life Sciences in Space Research, 36, 27-35.



Office of Planetary Protection





- COSPAR as the source for policy and planning
- e.g. IMEWG as a venue for coordination and action





 Opportunities for collaboration on instruments, small missions, launch activities, data sharing, analog activities, etc. etc....







Updating of NASA's own PP policy and planning
 NASA-wide advocacy for KG closure activities



- Competitive Awards, e.g. ROSES, SBIRs, EPSCoR
- ESDMD Strategic Architecture Office guided work
- ESDMD Mars Campaign Office guided work
- Center-supported activities
- Coordination with other Tech Dev activities e.g., HERA, DRATS, CHAPEA
- Stakeholder Engagement (workshops, seminars etc.)



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# Returning to the "How Much is too Much?" Question: Contamination Assessment – Detailed Analysis



							_
Item	Basis	Specification	Notional	Conversion factor	Start Condition:Day -3	End condition: Day 33	
		(if any)		(mass etc. to CFU)	(DST Hatch Closure)	(MAV Arrival at DST &	
						Waste left behind)	
Food for 36 days	0.294kg/crew/day reduced	<10000cfu/kg	10000cfu/kg	2.94kg/d	2116800	0	
	stock over time arrives with					TBD based on margin	
	lander 3					policy	
Crew Microbiome	constant, arrive with lander 3	1E+13/person	1E+13/person	2 crew	2.00E+13	2.00E+13	
Urine (0.320ml/d)	accumulates over time:	<10000/ml	1000/ml	1000ml = 1kg;	1920000	21120000	
	dropoffs at logistics/waste			320ml/d			
	transfer EVAs						
Solid (fecal) Waste (Kg)	0.3kg/crew/day accumulates	1E+14/kg	1E+14/kg	0.6kg/day	1.8E+14	1.98E+15	
	over time: dropoffs at						
	logistics/waste transfer EVAs						
Shed Waste (all	accumulates over time: skin	NA	TBD	Estimate to difficult,	NA	NA	
sources)	cells, hair, etc.: air filter			based on Ganesh et			
	dropoffs at logistics/waste			al 2019 and			
	transfer EVAs TBD			Checinska et al.			
				2015 + others: use			
				Equilibrated			
				Crewed			
Equilibrated Crewed	Assume PR is equilibrated to	8320000/m3 @>2um	10% of particles >2u	r Estimate, based on	8320000	8320000	
Environment (PR =10	ISO9 cleanliness by the time it	293000/m3 @>5um		Ganesh et al 2019			
m3)	reaches the Martian surface			and Checinska et al.			
				2015 + others			
Clothing	Starts clean, goes to	NA	400g	Whitehead et al.	(Assume sterilized)	9960000	
	dirty/waste		clothing/astronaut/	2023 dirty = 415			
			2days	bacteria/g/day			
			=30x400=12kg				
Hygiene Products 0.4L	Starts clean, goes to	100	100	400g, not cleaner th	a 2640	1095600	
	dirty/waste						
Drinking Water (36d?)	Starts clean ends up as urine	0	C	2.79L/d min.	0	(margin?)	

0

0 (margin?)

0

Breathable Air (36d?) Starts clean ends as



Breathable Air (36d?) Starts clean ends as

# Returning to the "How Much is too Much?" Question: Contamination Assessment – Key Takeaways



Item	Basis	Specification (if any)	Notional	Conversion factor (mass etc. to CFU)	Start Condition:Day -3 (DST Hatch Closure)	End condition: Day 33 (MAV Arrival at DST &		
						Waste left behind)		
Food for 36 days	0.294kg/crew/day reduced	<10000cfu/kg	10000cfu/kg	2.94kg/d	2116800	0		
	stock over time arrives with					IBD based on margin		
Crew Microbiome	constant, arrive with lander 3	1E+13/person	1E+13/person	2 crew	2.00E+13	2.00E+13		
Urine (						20000		
Key (	Contaminatic	on Risk A	ssessme	ent lake	aways:			
Solid (fe $\sim 20$ x	$x_{\rm H}/t_{\rm e} \sim 2.0 \ {\rm x10^{15}}$ Organisms introduced to Mars in 3-lander crewed mission							
	C C C C C C C C C C C C C C C C C C C							
Compr	ising:							
Shed W ~ 1.98	$^{d W} \sim 1.98 \times 10^{15}$ Organisms associated with solid (fecal) metabolic waste							
sources $\sim 20 \text{ y}$	$\sim 2.0 \times 10^{13}$ Organisms associated with the crew (who leave at EOM)							
	2.0 × 10 Organisms associated with the crew (who leave at LOW)							
~ 2.1 X	$\sim 2.1 \times 10^7$ Organisms associated with urine waste storage							
~ 2.29	$\sim 2.29 \times 10^8$ Organisms associated with pressurized/unpressurized hardware							
Equilibr $\sim 1.5 x$	$\sim 1.5 \times 10^7$ Organisms associated with other waste articles							
Environ								
m3) ~ 2.0 X	$\sim 2.0 \times 10^{\circ}$ Organisms associated with potential operational activities							
Clothin	dist /wasta		alathing (actronaut (	2022 dirty = 415		60000		
	dirty/waste		2days	2023  dirty = 415				
			=30x400=12kg					
Hygiene Products 0.4L	Starts clean, goes to	100	100	400g, not cleaner th	a 2640	1095600		
	dirty/waste							
Drinking Water (36d?)	Starts clean ends up as urine			2.79L/d min.	0	(margin?)		

0

0

0 (margin?)

## Summary

- The COSPAR Planetary Protection Policy and Guidelines include approaches for controlling forward and backward contamination at Mars.
- Approaches for robotic missions are well developed and have successfully guided exploration and preserved scientific integrity for over 50 years.
- Approaches for crewed missions are still in development, but require a paradigm shift from robotic methods.
- A path to achieving that shift is already identified through closure of knowledge gaps identified in the COSPAR workshop series.
- Work to develop a Knowledge-based Risk-informed Decision Making Process in under way.
- Knowledge gap closure will be a team effort with room for everyone to contribute!











## Questions?

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**Contamination\*** Unwanted material present on or in the spacecraft/spacecraft assembly environment or introduced into the environment of a solar system body.

**Expected:** There is a non-zero amount of contamination expected for spacecraft.

**Contamination Control:** Practice to control contamination of spacecraft & spacecraft assembly environments to acceptable limits.

#### Focuses on:

Particulate contamination, molecular contamination, & sometimes biological contamination.

#### **Contaminants of Concern:**

Not all contaminants are the same. Requirements depend on what the contamination is, where it is, and how much.

#### Harmful Contamination\*

Unwanted material on the surface of a solid material, or incorporated into a solid, liquid, or gas that damages the integrity of the study of chemical evolution and the origin of life at another solar system body, or that has negative consequences for humans and Earth's biosphere.

#### To Be Limited and Avoided:

What is the tipping point from "contamination" to "harmful contamination?"

#### Planetary Protection:

Practice to limit contamination of solar system bodies (Forward PP) and avoid harmful contamination of Earth (Backward PP).

**Focuses on:** Biological contamination & molecular contamination.

**Contaminants of Concern:** Biological – Spores & viable terrestrial organisms Molecular - ???

> \*Definitions from NASA-STD-8719.27 28







### **SCIENCE** Responsibility

- There's a cost of doing business. Exploration com All space activities will have some level of contam question is when does it become an issue?
- Day-to-day trade space for the scientific process experiments (e.g., signal to noise, limit of detection
  - Ability to interpret analytical results with me conclusions
  - Statistical significance uncertainty, what d low, stable, and well-characterized? (OCP I

## **PP** Responsibility

<ul> <li>There's a cost of doing business. Exploration comes at "some" cost.</li> <li>All space activities will have some level of contamination. The question is when does it become an issue?</li> <li>Day-to-day trade space for the scientific process and the design of experiments (e.g., signal to noise, limit of detection etc.).</li> <li>Ability to interpret analytical results with meaningful conclusions</li> <li>Statistical significance – uncertainty, what defines acceptably low, stable, and well-characterized? (OCP Report 2014)</li> </ul>	<ul> <li>PP Policy needed to help define objectives and develop performance metrics based on science need. (Assuming this is not a one size fits all answer.)</li> <li>PP Policy needs a balanced solution to enable science but does not replace science's role.</li> <li>Enables science by defining an internationally agreed upon set of practices.</li> <li>What defines this trip wire for science? <ul> <li>Limit of detection? Projected limit of detection?</li> </ul> </li> <li>Is this different for <ul> <li>Current mission(s)?</li> <li>Future missions? Is there a time dimension to project?</li> </ul> </li> <li>What's the balance point for science return vs. barriers to exploration? Can you plan for the unknowns or a bad day?</li> </ul>
What is the organic material of concern? Concentration of concern?	Knowns vs. Unknowns?



Contamination

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Harmful



## **Tech Dev – Crew KG Mitigation**





Group 1 – Microbial and human health monitoring





What systematic microbial monitoring is required ?



What monitoring is required on human missions ?



What is the mutation rate in flight ?









Group 1 – Microbial and human health monitoring



#### MORE SPECIFIC QUESTIONS

- Where is the right spot to monitor?
- How clean is clean enough?
- Can one be too clean?
- o Have we overlooked back contamination?
- How much knowledge is enough? 95%? 98%?
- How does one decide?
- How does one characterize the material that the crew is bringing back?
- How long do we need to treat returned samples as a biohazard?
- What if mutated Earth microbes are more dangerous than anything we find on Mars?
- Is there potential to use the Deep Space Gateway as a stopover point for Mars Sample Return and returning astronauts?





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## Tasks: Gap Id. 1A Microbial monitoring of the environment





