Mars 2018

Planetary Protection and Sample Integrity Focused Technology Development

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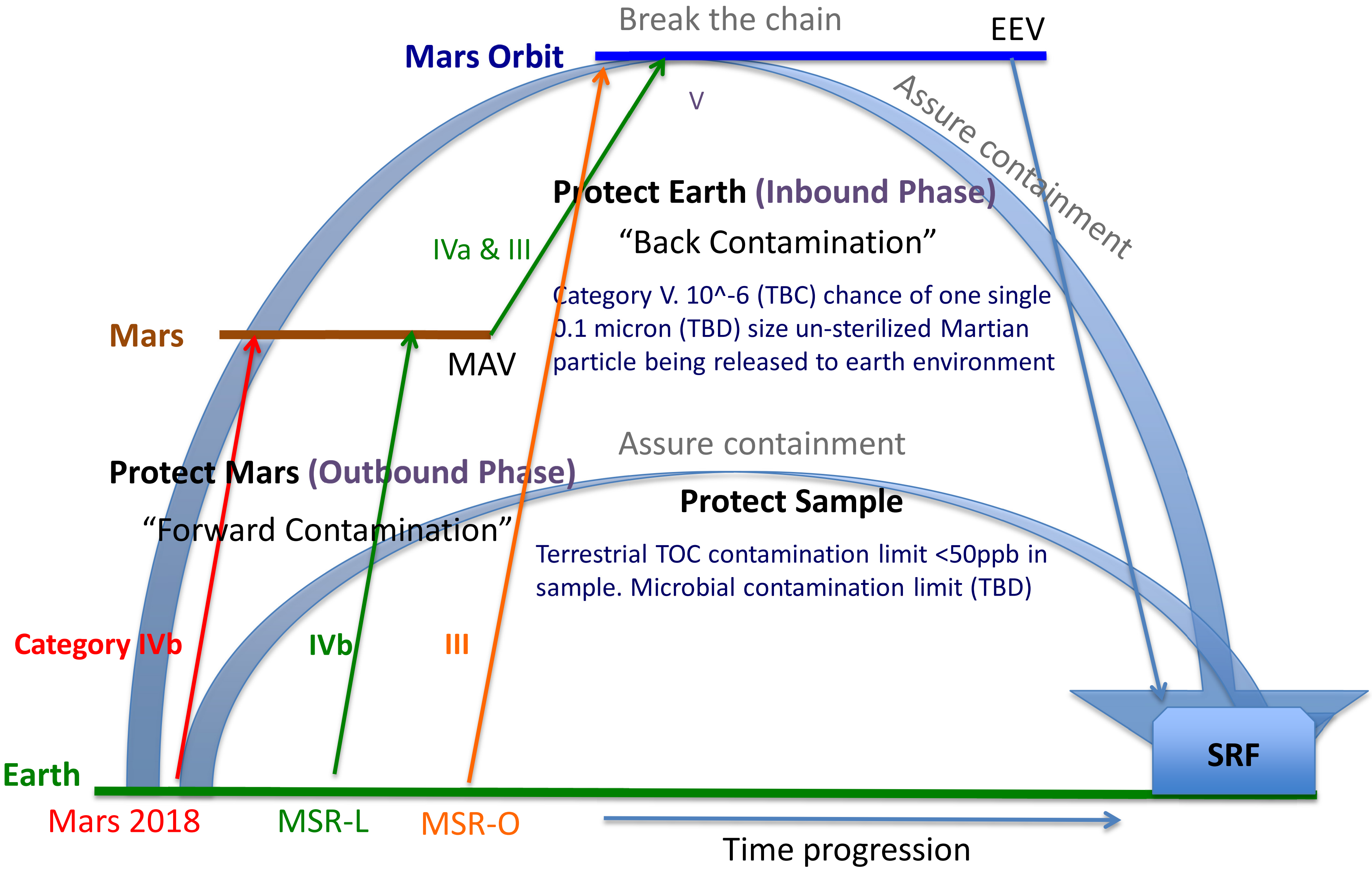
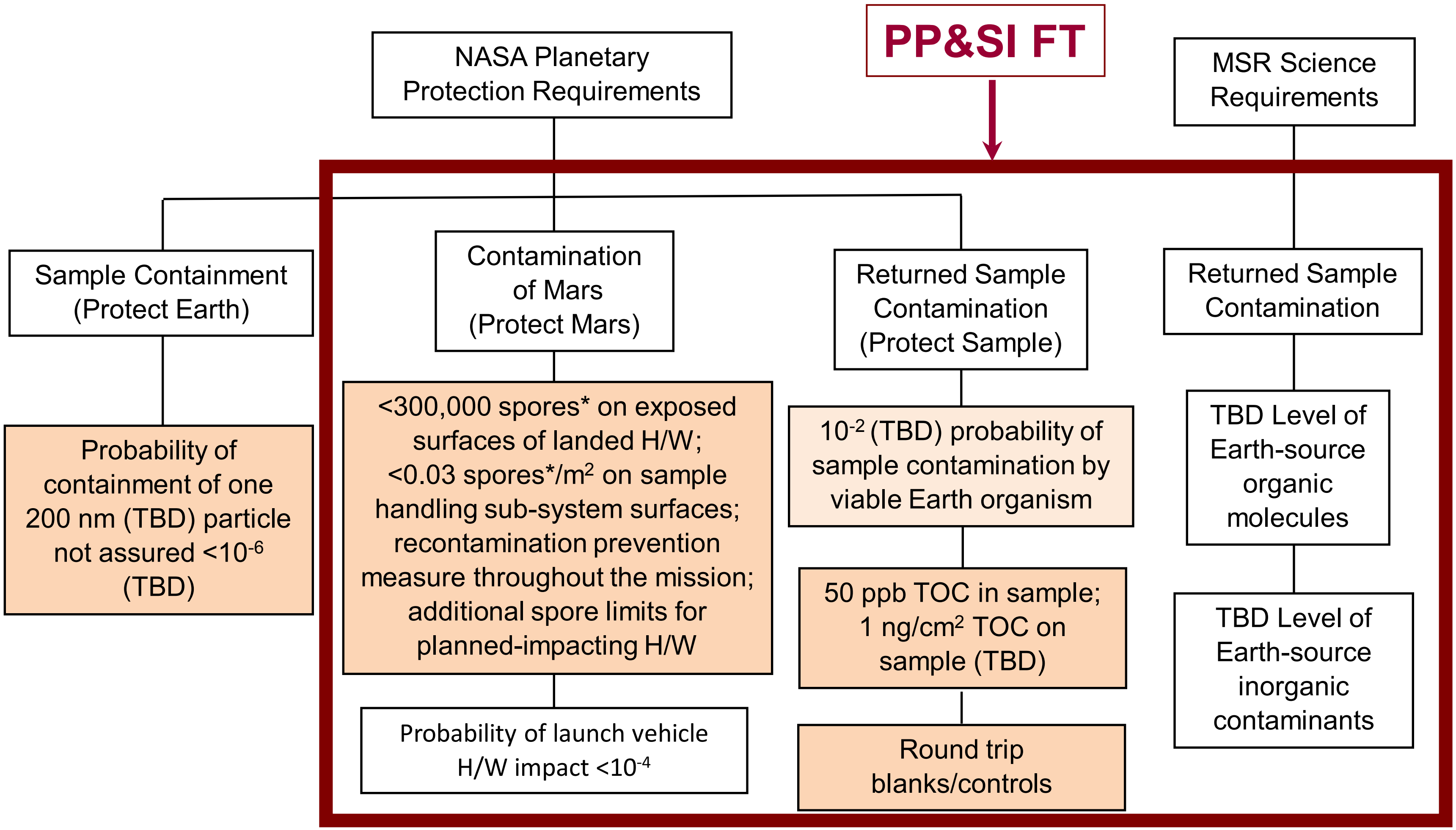
Outline

- Introduction
- MSR Planetary Protection Requirement (Draft)
- Technology Gap for Mars 2018
- PP&SI Focused Technology Plan

Planetary Protection Requirement Categories



Mars 2018 Planetary Protection and Sample Integrity (PP&SI) Focused Technology Scope



*spore definition per NPR 8020.12D

Draft requirement guideline by Planetary Protection Officer for MSR, taken as goal for technology development.

Planetary Protection Needs and Technology Gap

In situ life detection, caching, and sample return to Earth

PP Category V and IVb

In situ measurements

PP Category IVa (recent change)

Crashing risk only

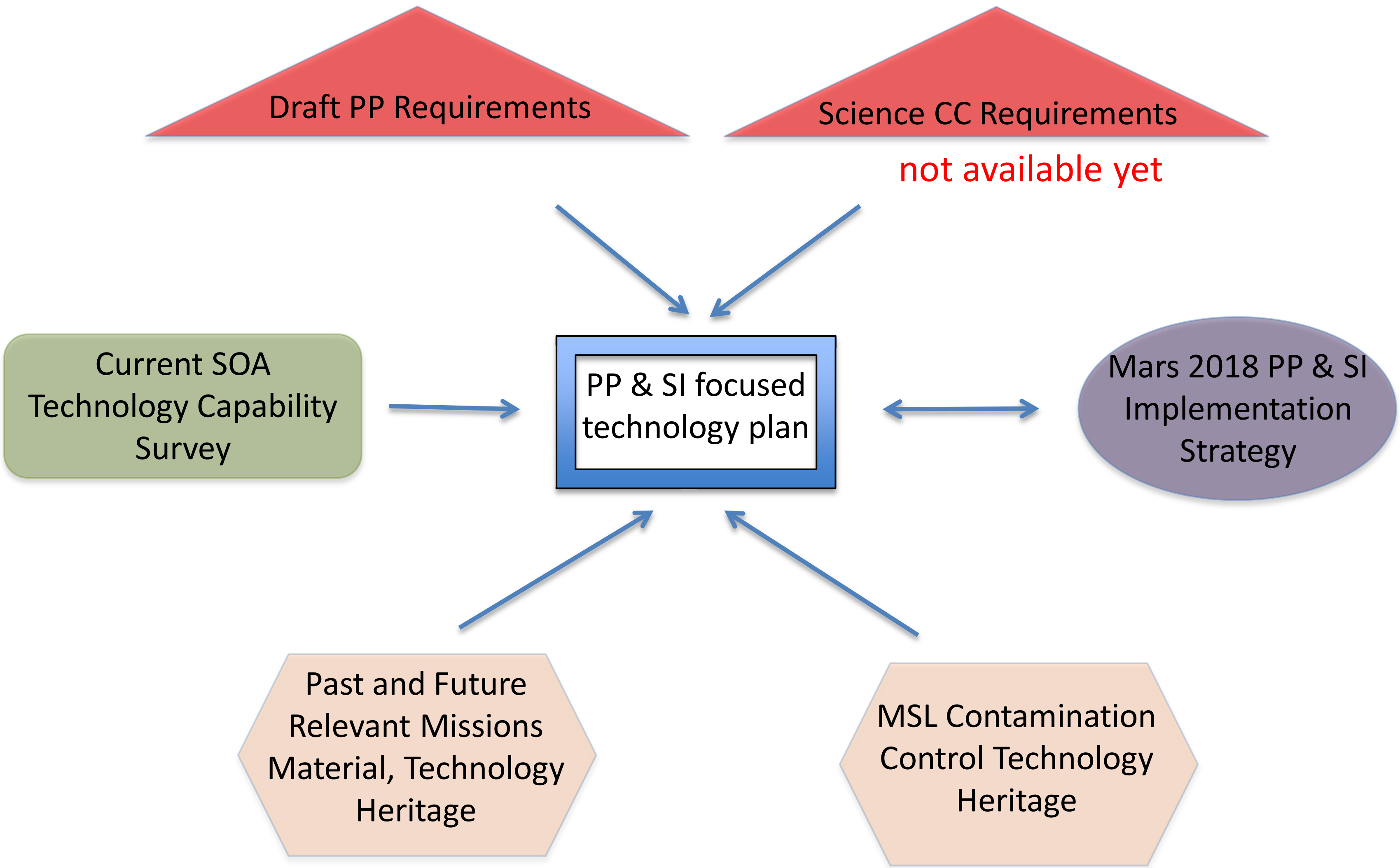
PP category III

Mars 2018 new PP requirements and needs

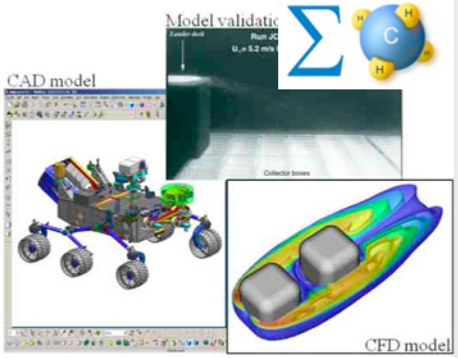
- Sample handling hardware remain sterile until the sampling activity is completed (Not in Category IVc or IVa)
- Total 50 *ng/g* TOC contamination in sample. (MSL CC requirements only restrict the organic contamination transfer from hardware surfaces)
- Microbial contamination limit in sample (TBD)
- 1 ng/cm^2 TOC (TBD) Sample contacting hardware cleanliness and recontamination prevention measures required throughout the mission operation. (MSL CC requirement is 100 ng/cm^2 without recontamination prevention requirements)
- Sample integrity through containment, sealing and reduce any contamination risk during sample storage on Mars
- Round-trip blanks/controls are required (MSL optional)
- NASA PPO approval before launch (MSL, project approval for organic contamination)

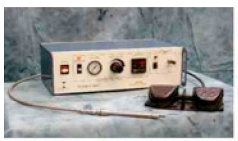
Technology and capability gaps in the areas of contamination risk assessment, cleaning, sterilization, validation, and containment.

PP and SI Technology Plan Development Process



PP&SI Technology Investment Areas





I. ***Contamination risk assessment***
   - Quantitative contamination burden assessment of hardware
   - Contamination (biological and organic) transport measurement and modeling
   - Risk assessment of sample contamination

II. ***Surface sterilization and precision cleaning***
   - CO_2 cleaning, laser, plasma
   - Cleaning validation (microbes, molecules, particles)
   - SHEC cleaning

III. ***Re-contamination prevention***
   - Clean assembly
   - Contamination barrier
   - Organic sensor, getter

IV. ***Sample containment, sealing, sample integrity***
   - Material selection, compatibility to Martian samples
   - Sealing method and materials
   - Sample integrity

Area I: Contamination Risk Assessment

Description:

System Engineering approach to establish quantitatively the pathway of contamination transport from spacecraft hardware and environment to samples

- Quantitative organic and microbial contamination burden assessment of hardware
- Contamination (biological and organic) transport measurement
- Transport modeling, Integrated tool development
- Risk assessment of sample contamination

Objectives:

- Enable the Mars 2018 project to develop reliable implementation approaches including a set of flow-down requirements on outgassing material usage limits, hardware surface cleanliness levels, and hardware containment needs.
- Enable the project to demonstrate that it meets the PP sample organic and microbial contamination requirements

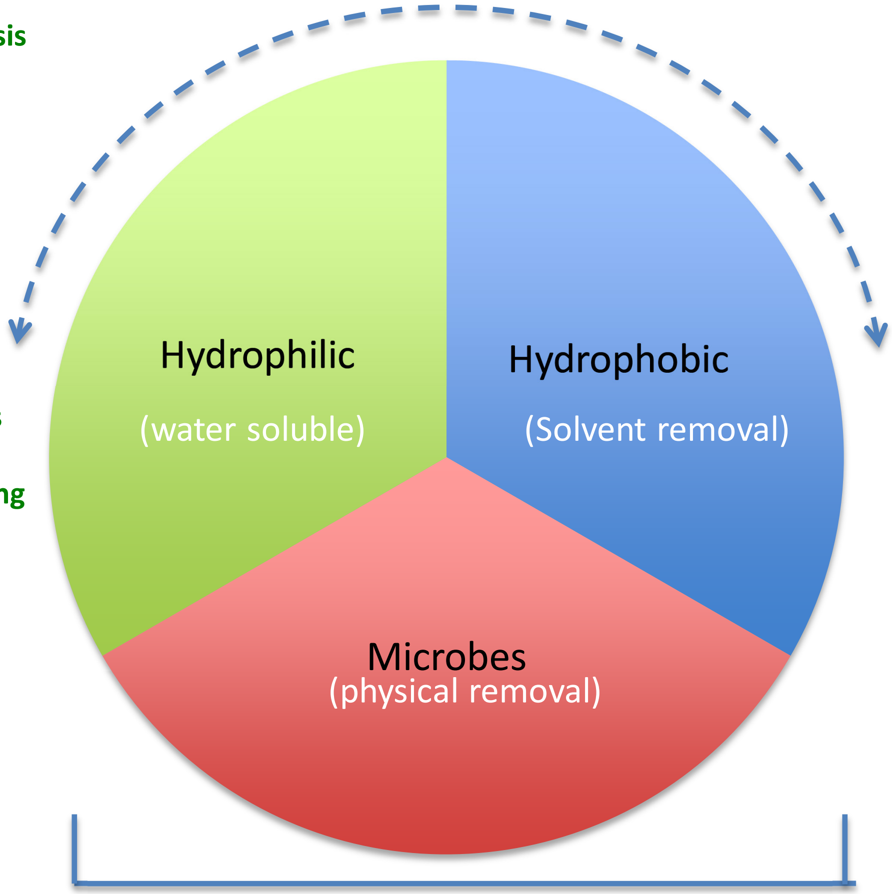
Total Organic Carbon Composition Chart

Molecular polarity

Amino Acid analysis
HPLC (1 ng/cm^2)
CE (pptr)

Water (80)

Amino acids
Amines or Amides
DNA
Hydroxyl containing compounds



GC (ppb, 1ng/cm^2)

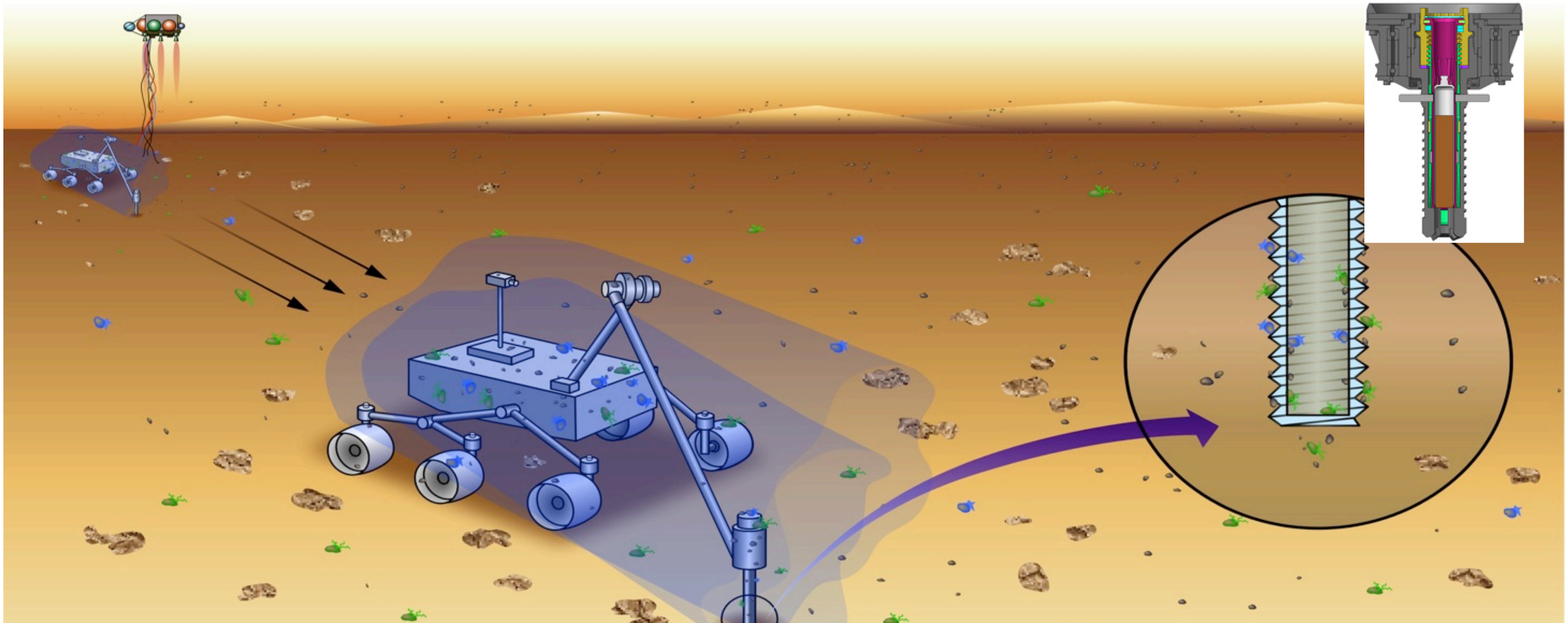
Hexane (1.88)
DCM (9.1)
Acetone (21)
IPA (18)

Carbonyl containing compounds
Benzene
Aromatic hydrocarbons
Non-aromatic hydrocarbon

TOC

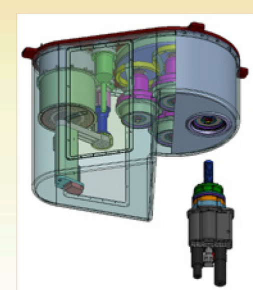
(Proportion is for illustration only)

Contamination Transport



There are at least three pathways by which contaminants can be transported into samples:

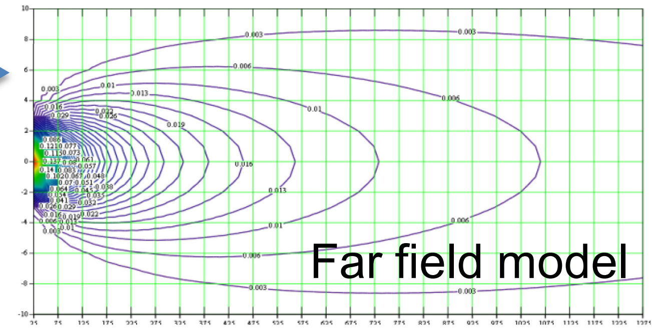
- Direct contact – microbial and molecular contaminants are transferred from the hardware surfaces to samples by direct contact.
- Particle transport – Microbes and molecular contaminant-containing particles are dislodged from spacecraft hardware surfaces by wind or by mechanical forces and are then carried by wind to the sampling ground or into the sample tube.
- VOC transport – outgassed volatile organic compounds from nonmetallic parts will diffuse or be carried by wind to condense on the sampling ground, sample contacting hardware, and samples.

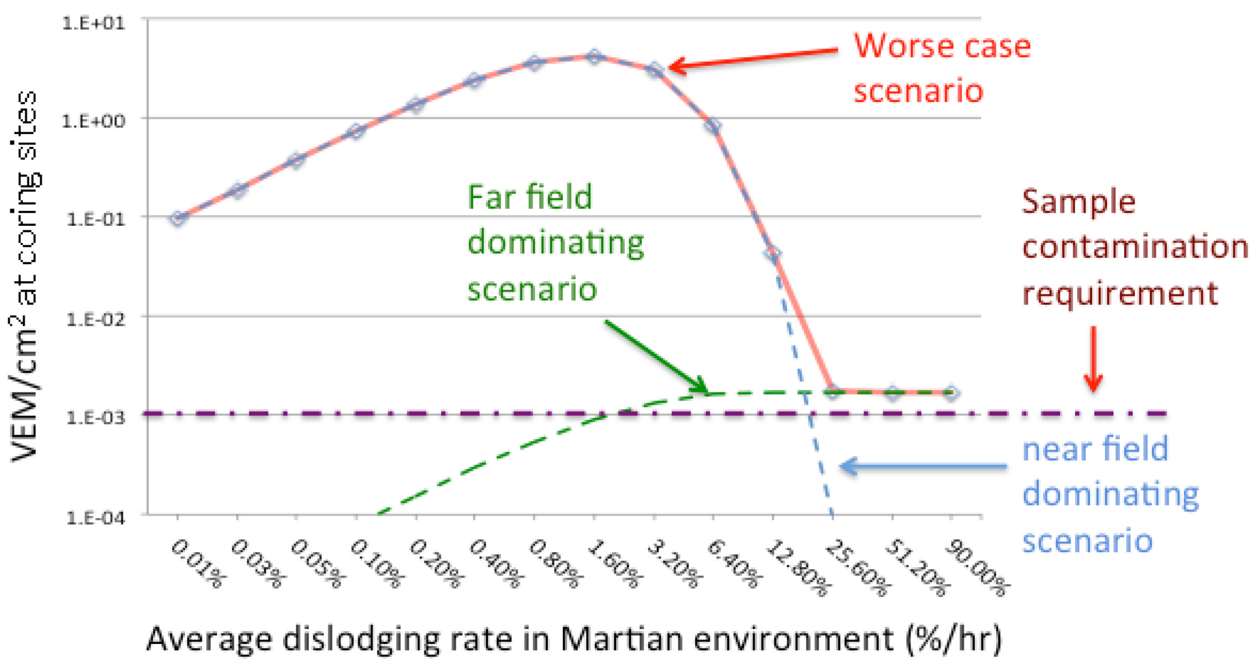


BOTE Risk Estimate in VEM Surface Density

Assumptions:

- Far field model under unidirectional wind of 7 m/s steady
- Rover moves 1 km away in the direction of the wind 48 hours after landing
- Another 24 hours at the sampling site
- Initial total spores on the rover is $3x10^5$ and the corresponding VEM $3x10^8$



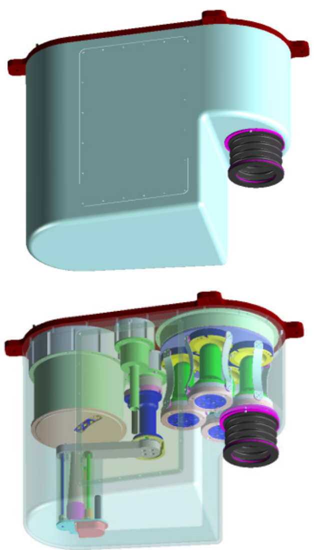


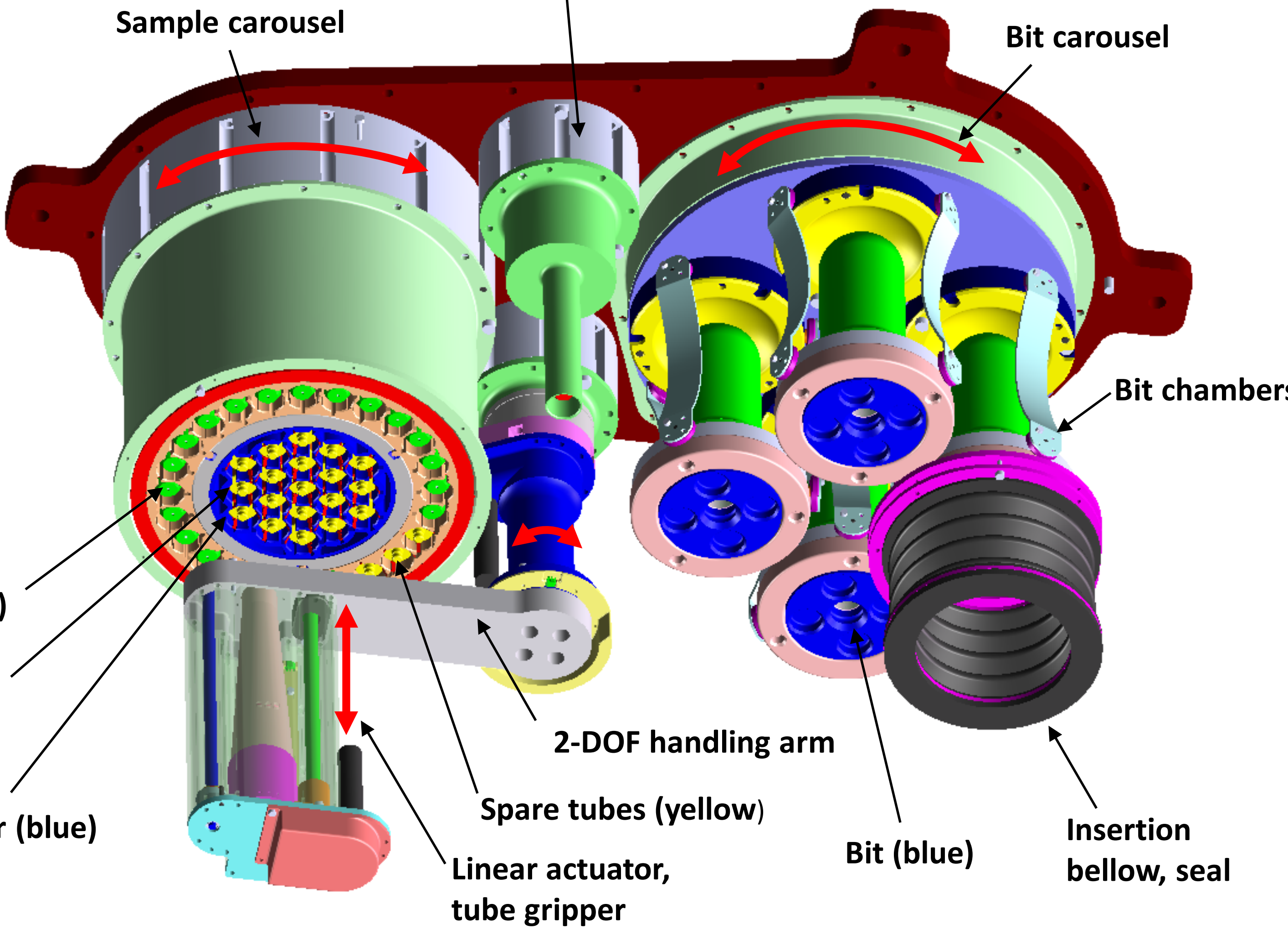
Key points illustrated:

- The simple BOTE estimate illustrates that the risk of sample contamination is not low.
- It also shows that understanding accurately the particles dislodgement and the Martian weather conditions are critical to the overall contamination risk.

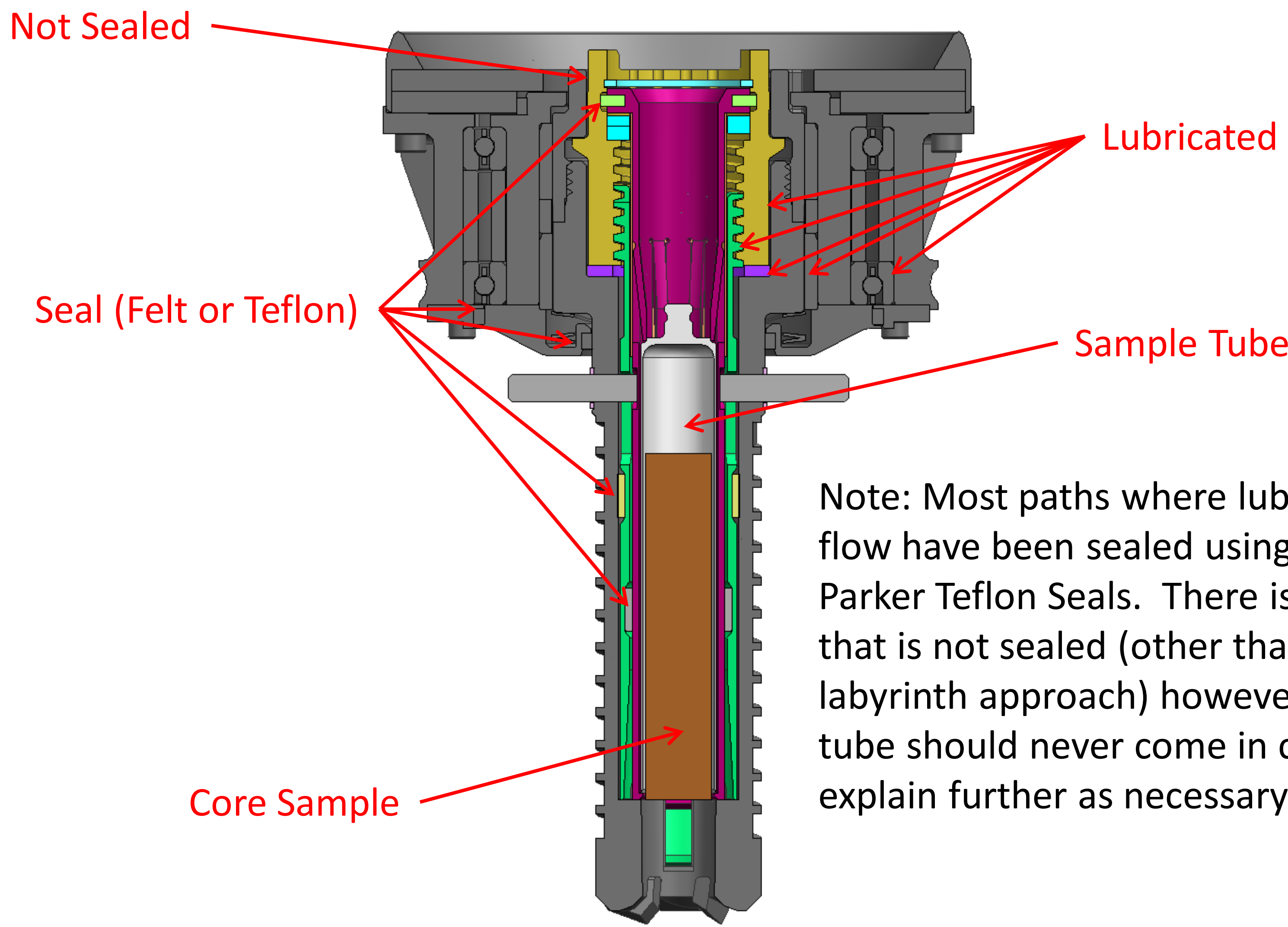
Sample Handling, Encapsulation, and Containerization (SHEC) Description

SHEC Subsystem (enclosed)





Drill Bit Lubrication



Note: Most paths where lubricant can flow have been sealed using Felt or Parker Teflon Seals. There is one path that is not sealed (other than utilizing a labyrinth approach) however the sample tube should never come in contact, can explain further as necessary.

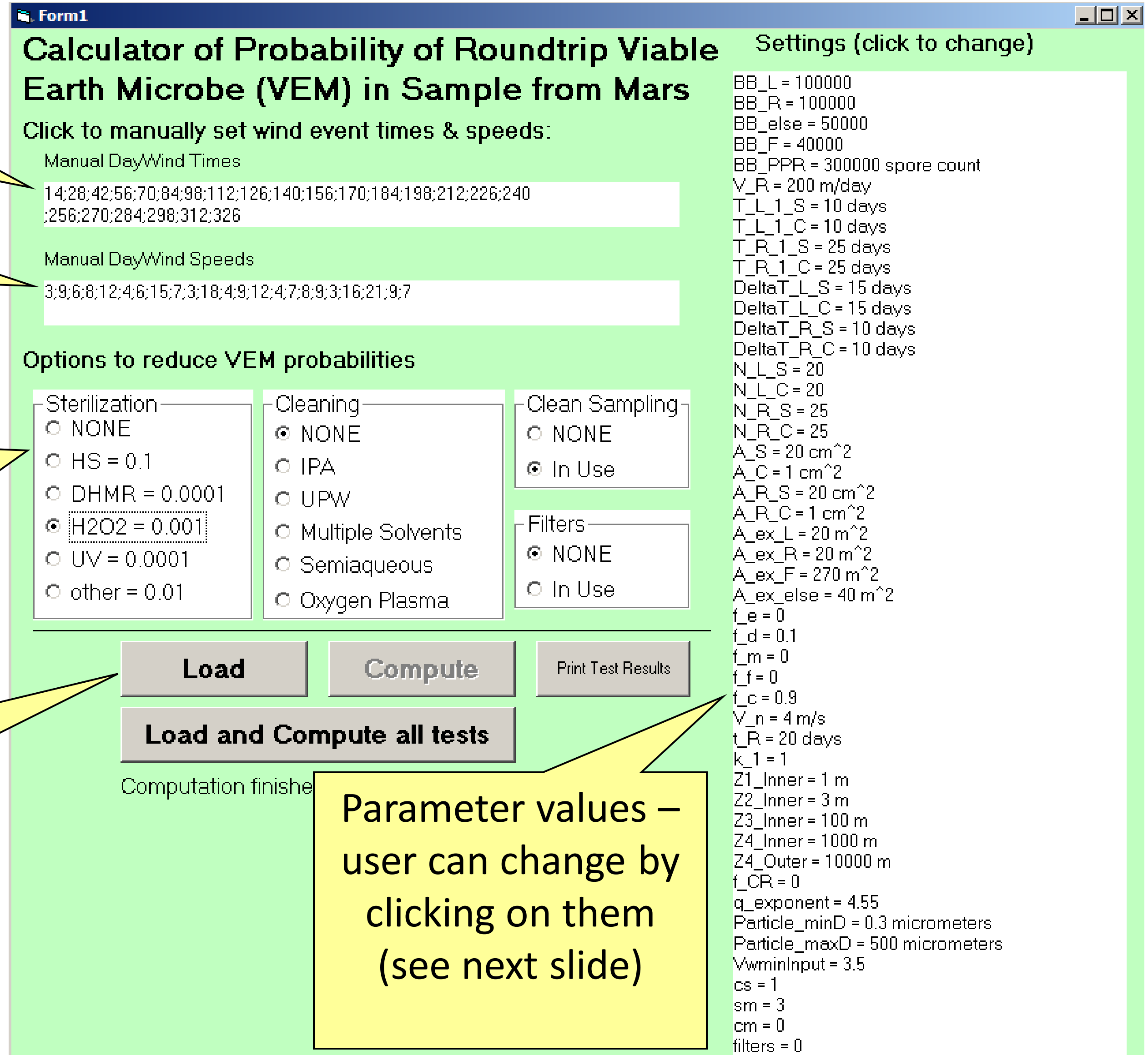
Interactive and Integrated Tool

Times of day wind events

Speeds of day wind events

Selection among sterilization options

Load settings from a row in a spreadsheet



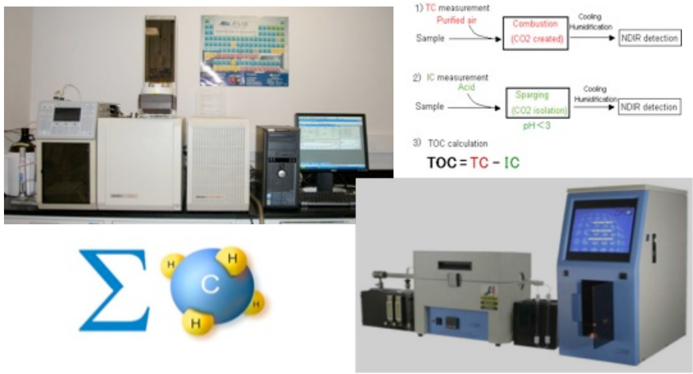
Parameter values – user can change by clicking on them (see next slide)

Focused Technology Program Needs to Address

Main areas include physical process understanding, model development and validation, and an end-to-end model integration.

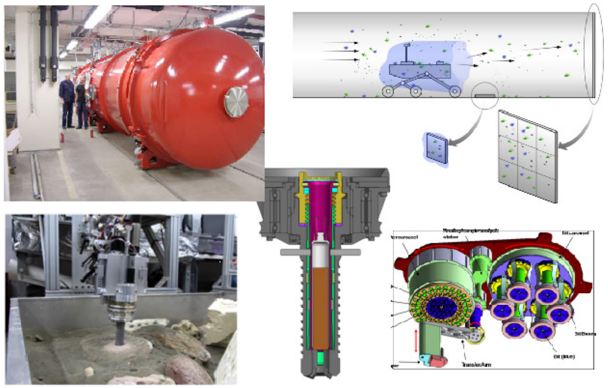
1. *Wind-induced particle dislodgement*
2. *Vibration-induced dislodgement*
3. *Direct coring tool contamination*
4. *Contamination inside the SHEC*
5. *Martian wind information*
6. *Special weather conditions*
7. *Far field transport models*
8. *Near field transport*
9. *Organic vapor transport*
10. *Quantify organic molecules-particle association*
11. *Spore-particle association*
13. The ratio of VEM to spores
14. *Particle size distribution*
15. *End to end model integration and analysis*

Planned Contamination Risk Assessment Tasks



Contamination Burden Assessment

- Develop strategies to quantitatively assess the total organic carbon (TOC) burden of spacecraft hardware.
- Quantitatively assess the total microbial burden of spacecraft hardware

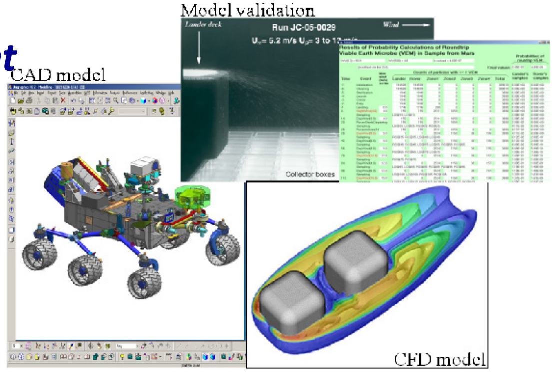


Contamination Transport Measurements

Objectives: Generate critical and realistic physical parameters that are necessary to develop a comprehensive end-to-end microbial and organic contamination transport model

Approach: by conducting experiments in testbeds including the Mars Wind Tunnel with drill, SHEC, and rover analogue, critical relevant interaction phenomena pertaining to particle and organic removal, transport will be measured.

Contaminant Transport Integrated Interactive Model Development



Objectives:

- Determine contaminant transport during surface operations in the Martian atmosphere to quantify spacecraft cleanliness requirements for surrounding area and samples.
- Develop an integrated interactive tool for assessing prognosis of meeting PP requirement

Area II: Surface sterilization and precision cleaning

Description:

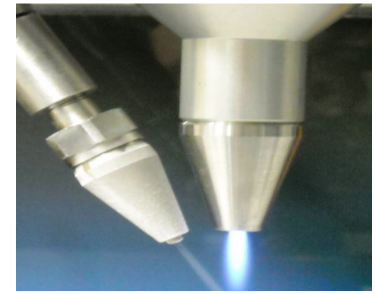
Develop precision cleaning technologies to achieve surface organic cleanliness and microbial sterilization. It also has potential for in situ cleaning applications

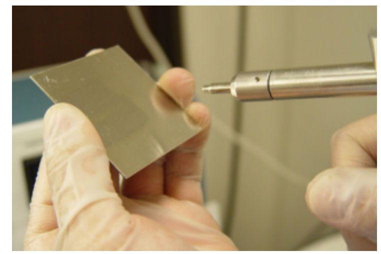
- CO_2 jet cleaning, Laser/plasma cleaning
- Cleaning validation (microbes, molecules, particles)
- SHEC cleaning

Objectives:

Enable the Mars 2018 project to successfully implement planetary protection (category IVb and sample contamination requirements) and mission science requirements

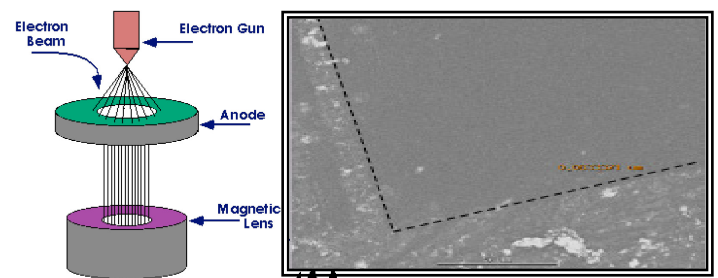
CO_2 Jet Cleaning

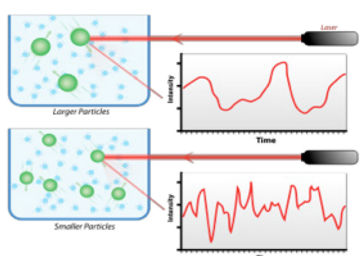




Objectives:

- Develop a cleaning method that will remove sub-micron particles by varying parameters such as CO_2 crystal size, speed of delivery onto surfaces
- Validate cleaning efficiency
- Develop a TRL 6 touch-up cleaning device
- Evaluate the possibility for in situ clean sampling applications on Mars





Cleaning Validation

Objectives:

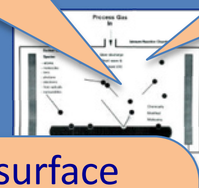
- Validate surface cleaning methods
- Design and build optical detection system for surface particle analysis
- Calibrate and measure detection sensitivity
- Distinguish contaminant types

A Possible PP Implementation Approach

Ultra-cleaning technologies are needed to achieve surface sterility and be organics clean; methods needed for all relevant material surface and geometry; cleaned parts must be protected from recontamination (use of glovebox or sealed bags free of contamination)

H
Duration: N/A
Cont. Source: N/A

…ning:
…nt: T… C…
…tion: N/A
…ource: N/A

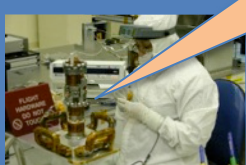


Cleaning validation (trace organics and submicron particles) methods are needed for verification

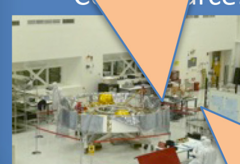
…embly:
…nt: TBD Class Cleanroom
Duration: 1 month
Cont. Source: handling of hardware, cleanroom environment

Clean assembly, touch-up surface cleaning, contamination barriers are required. Must actively monitor contamination transfer within the glovebox or barriers

Subsystem Level Ass…
Environment: … Cleanr…
Duration: 3 m…
Cont. Source: …ing of hardware, cleanroom environment

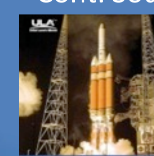


…:
…: TBD Class Cleanroom
…: 3 month
C…urce: handling of hardware, cleanroom environment



Clean assembly, touch-up surface cleaning (e.g. with hand-held CO2/plasma jet), contamination barriers are required

Duration: 10 minutes
Cont. Source: FOD due to vibe



Surface cleaning to sterility is needed after each assembly step and re-work

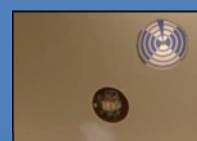
A

A Possible PP Implementation Approach (Con't)

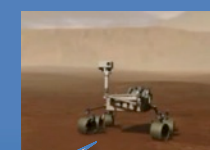
A

Cruise Stage
- Environment: Temp TBD, Hard Vacuum
- Duration: 6 months
- Cont. Source: N/A

Martian Re-Entry
- Environment: Temp TBD, Hard Vac, Re-Entry Vibe
- Duration: 15 minutes
- Contamination: FOD due to vibe



Martian Roving
- Environment: Temp TBD, Pressure 10torr
- Duration: TBD years
- Cont. Source: N/A



B

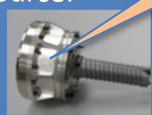
Procedures must be taken to avoid sampling area contamination from rest of (dirtier) lander or rover. Transport models (vapor, particle, contact) for Martian environments are needed for contamination risk analysis

A Possible PP Implementation Approach (Con't)

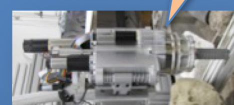
All coring and sample handling parts must be protected from recontamination from dirtier parts of the lander or rover. Need transport model and experimental verification

B

Insert clean sample tube in bit assy and remove Bit from SHEC
Environment: Temp TBD, Pressure 10torr
Duration: ~10 minutes
Cont. Source: N/A



Environment: Temp TBD, Pressure 10torr
Duration: ~2 hourse
Cont. Source: Cross-cont. from previous samples



Place Bit Assy into SHEC and remove sample Tube from Bit
Environment: Temp TBD, Pressure 10torr
Duration: ~10 hours
Cont. Source: Cross-cont. from previous samples

Req#1: no live microbes
Req#2: 50 ppb TOC
Modeling tools, experimental data are needed for requirements flow-down (e.g. limits on offgassing, outgassing rates, non-metallic materials used: amounts and locations, hardware surface cleanliness requirements)

Cap and Seal Sample T... Place in Sample Canis...
Environment:
Duration:
Cont. So...: ...from previous samples

...mple canister on Martian ...nd await Fetch Rover
...onment: Temp TBD, Pressure 10torr
...ion: ~5 years
... Source: Atmospheric dust, failed ...

Sample integrity, material compatibility

C

Area III: Re-contamination Prevention

Description:

Strategies for preventing re-contamination between hardware components.

- Clean assembly
- Contamination barriers
- Organic sensor, getter

Objectives:

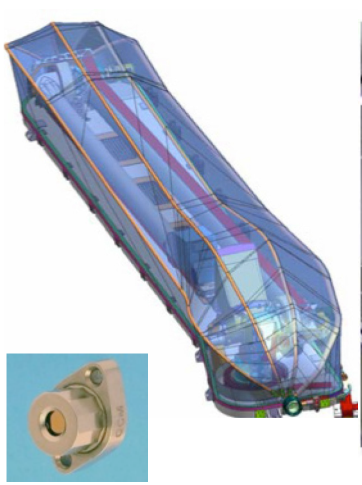
- Prevent contamination transport between hardware components (molecular and particulates)
- Protect cleaned sample contacting hardware from re-contamination during ground handling and sample acquisition on Mars
  - PP requirements (*MSR Campaign, Caching Mission, and MAV Mission, July 2011*) :
    - Surface molecular cleanliness of < 1-10 ng/cm^2 (TBD)
    - Surface microbial cleanliness < 0.03 $spores/m^2$
    - No particles > 200 nm in diameter (TBD)
- Prevent contamination of Martian sample from terrestrial contaminants carried by spacecraft
  - PP Requirement: < 50 ng/g of terrestrial organics transferred to Martian sample
  - Microbial contamination probability limit < 10^{-3} VEM (TBD)

Re-contamination Prevention Tasks

Implementation Strategies

- Clean assembly techniques (mini-environments)
  - Vacuum enclosure required for 1 ng/cm^2 cleanliness level
- Develop contamination barriers
  - Encapsulation on Earth and Mars
- Molecular sensors for monitoring of contaminants
- Develop custom filters and molecular getters
- Fly controls/blanks to monitor contamination health

Cross-Contamination Prevention Technologies



Objectives:

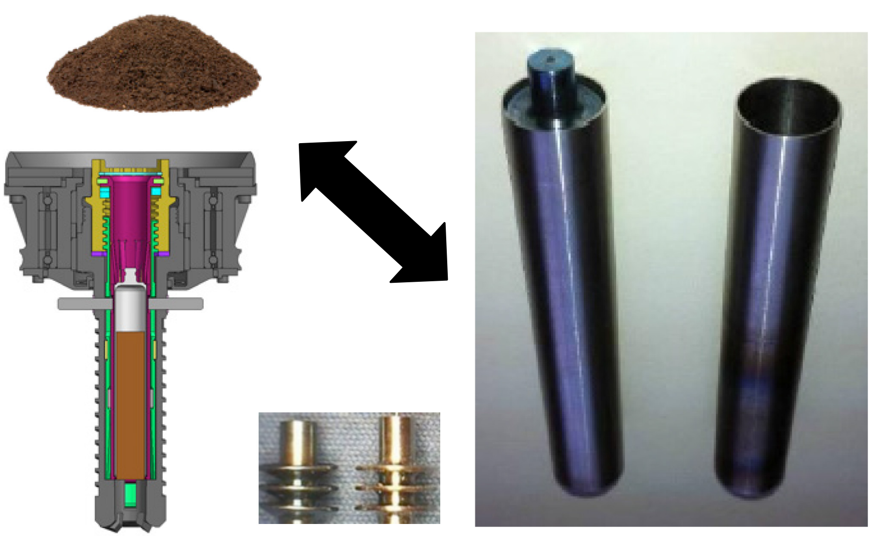
- Develop strategies to prevent re-contamination of hardware components
  - Clean assembly
  - Contamination barriers
  - Molecular sensors, getters

Area IV: Sample containment, sealing, sample integrity

Description:

Establish and test candidate material capabilities to samples by working with the caching and science teams to fulfill sample integrity science requirements for Mars 2018

- Material selection, compatibility to Martian samples, sample integrity
- Sealing method and materials



Sample Containment, Sealing, and Sample Integrity

Objectives:

- Define and deliver standard procedures for evaluating and recommending compatible materials.
- Evaluate sample/container interaction through chemical, mechanical, and physical compatibility tests using Martian analogue soils
- Assess material integrity against environmental factors
- Investigate materials and sealing techniques within constraints of the Martian environment
- Deliver a material lifetime prediction based on an Arrhenius–based model fit of the data

Summary

- Mars 2018 is a Cat V and IVb mission with corresponding PP requirements
- MSR PP requirements are sufficiently different from all previous Mars missions that new technology and capabilities are needed.
- Technology gaps for Mars 2018 have been identified and an investment portfolio developed
- Mars Focused Technology program will invest in four critical areas:
  - *Contamination risk assessment*
  - *Surface sterilization and precision cleaning*
  - *Cross contamination prevention*
  - *Sample containment, sealing, sample integrity*