Establishing and Monitoring an Aseptic Workspace for Building the MOMA Mass Spectrometer

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Exomars 2020 & Mars Organic Molecule Analyzer (MOMA):

- Exomars 2020- an ESA lander and rover:
  - Scheduled Launch Date: July 2020
  - **Life detection mission**
  - Samples will be collected up to 2m below the surface by a drill

- Mars Organic Molecule Analyzer (MOMA) is an instrument suite on rover
  - **Mass Spectrometer (MS) – NASA/GSFC**
  - Sample Ovens – MPS
  - Gas Chromatograph (GC) – LISA and LATMOS
  - Laser Desorption (LD) – LZH

The ExoMars rover. Credit: ESA
**MOMA Hardware bioburden requirements**

- **Sample path (Ultra Clean Zone):**
  
  \[ <0.03 \text{ spores/m}^2 \]
  
  - Accessible areas:
    - Base of MS
    - Internal surface of pseudo-Ultra Clean Zone (pUCZ)
  
  - Inaccessible areas:
    - Internal surfaces of Mass Spectrometer (MS)
    - Internal surfaces of Wide Range Pump (WRP)
    - Internal surfaces of Gas Processing System (GPS)
  
- **Surfaces not in contact with sample path:**
  
  \[ 300-1000 \text{ spores/m}^2 \]
  
  - Exterior of MS, pUCZ, WRP, GPS,
  - Internal and external surfaces of electronics boxes
Establishing clean working space and handling for MOMA-MS

- Three cleanrooms used during build, integration, and testing
  - Aseptic Assembly Cleanroom:
    - Smallest cleanroom
    - Highest and continual bioburden control
  - Integration and Test Cleanroom:
    - Largest MOMA cleanroom, additional ULPA filter tent for sensitive integration steps
    - Bioburden control to be added as needed
  - Vacuum chamber with clean tent: and Mars environment testing:
    - Custom vacuum chamber for Mars environmental testing
    - Bioburden control to be added as needed
Aseptic Assembly Cleanroom

- Daily
  - Mop with weekly alternations between 70% IPA and 7.5% H₂O₂
  - Wipe critical surfaces with sterile 70% IPA
- Twice a week:
  - Wipe horizontal surfaces with 100% IPA
  - Replace all garments
  - Run UV-C lamps

- Certified ISO class 7
- Maintains close to ISO 5
Ultraviolet Light treatment of MOMA assembly cleanroom

- Ultraviolet-C (UV-C 100-290nm), 250-260nm is germicidal
  - Kills by crosslinking DNA, which prevents the organisms from faithfully replicating its DNA
- 22,000 μWs/cm² is a sufficient energy dose to kill 99% of most common bacteria and bacterial spores on an exposed surface
- UV-C lamps (253nm) installed in cleanroom ceiling and on wall of assembly clean bench
- UV-C intensity at the floor of the cleanroom was measured at 30 μW/cm², 15 min exposure to reach 22,000 μWs/cm²
Biocidal mopping

• Cleanroom mopped daily (M-F) with either 70% IPA or 7.5% H$_2$O$_2$
  • Alternate between IPA and H$_2$O$_2$ weekly
  • Selected for biocidal action without leaving a residue

• Different biocidal mechanisms to prevent selecting for resistant organisms
  • 70% IPA denatures proteins
    • 70% IPA is a more effective biocide than 100% IPA
  • 7.5% H$_2$O$_2$ disinfects by oxygen radical damage to DNA and proteins
Integration and Testing Cleanroom

- Daily:
  - Vacuum
- Twice a week:
  - Mop with 5% IPA
  - Wipe horizontal surfaces with 100% IPA
  - Replace all garments
- Bioburden control to be instituted as necessary:
  - During sample path exposure post DHMR

- Room certified ISO Class 7
- ULPA tent: ISO Class 4 >99% of the time.
Bioburden Monitoring of Cleanrooms and Hardware

• MOMA Planetary Protection Lab
  • New capability at Goddard Space Flight Center to support MOMA-MS
  • On-site planetary protection assay support allows closer monitoring and faster results

• Lab Development
  • Initial lab setup from July 2014, first MOMA-MS hardware samples processed November 2014
  • “All operations involving the manipulation of sterile items and sample processing shall be performed in laminar flow environments meeting at least Class 100 air cleanliness requirements” -NASA-HDBK-6022
  • Biological safety Cabinet class II type A2
    • Meets ISO Class 5/Class 100 conditions
    • Provides both product and personnel protection
    • 70% air recirculation, HEPA filtration for cabinet and exhaust
Planetary Protection functionalities:
- Rapid assay (ATP) (5min)
- Testing airborne microbes (4 days)
- Standard swab assay (4 days)
- Active air sampling (4 days)
- Autoclave sterility verification (2 days)

Short term capacity expansion:
- Wipe assay for larger surface areas
- DHMR (Dry Heat Microbial Reduction) verification
- Biodiversity testing
Facility bioburden monitoring

- Bioburden swabs in assembly and I&T cleanrooms
  - General viable microbe screen (not spore specific)
  - Swab a 25cm$^2$ area on work surface with a damp flocked nylon swab
  - Sample transported in 2.5ml sterile water
  - Processed by ESA protocol: ECSS-Q-ST-70-55C

(ECSS-Q-ST-70-55C, D.2.1)
Consistently low viable microbe counts

Aseptic Assembly Cleanroom

Integration and Test Cleanroom
Airborne microbial monitoring

- Passive monitoring: Allowing airborne microbes to settle onto a plate surface
  - Requires review in NASA cleanrooms because of high volatile content of plates
- Active monitoring: pulling air through a filter which is later transferred to a plate
  - Used in MOMA cleanrooms:
    - Almost no growth seen in weekly cleanroom samples
  - Used to monitor immediate environment during highly sensitive activities
ATP rapid Bioburden Assessment

- Pre-wet swab is used to sample a surface, swished in the reactant buffer
  - ATP is the energy carrying molecule in all cell types
  - ATP in the sample will react with the luciferase and luciferin in the buffer and produce light
  - Less than 5 minutes to sample
- Pre-wet swab contains Chlorhexidine digluconate
  - Not to be used on sensitive hardware
  - Removable by 70% IPA wiping
Critical work surfaces in assembly cleanroom have very low ATP bioburden.

**Asseptic Assembly Cleanroom**

- **Relative Light Units (RLU)**
- Jul-14 to Jun-16
- **Pass**
  - Assembly Bench
  - Floor
  - Pass

**Integration and Test Cleanroom**

- **Relative Light Units (RLU)**
- Jul-14 to Jun-16
- **Pass**
  - Integration table
  - Floor
  - Pass
Determining risk from ATP readings

- Most cleanroom and hardware samples do not have any CFU
  - 99% of environmental microorganisms do not grow in a laboratory setting
  - <15% of cleanroom samples had CFU within 72h
  - RLU and CFU does not directly correlate in environmental samples

### Laboratory Experiment

<table>
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<th>RLU Range</th>
<th># Samples</th>
<th># with CFU</th>
<th>% Positive</th>
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<td>1000-5000</td>
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</tbody>
</table>

### Environmental Monitoring

- Aseptic Aseembly
- Integration and Testing
- Positive control
Three cleanliness categories:
- Sample path - <0.03 CFU/m²
- External non sample path surfaces - <300 CFU/m²
- Surfaces in closed non-sample path volumes - <1000 CFU/m²

Non sample path surfaces:
- Sampled for heat resistant spores using standard swab assay before last access
  - External non sample path surfaces - sampled before shipping
  - Surfaces in closed non sample path volumes - sampled before final closeout

Sample path
- Sampled for heat resistant spores using standard swab assay before sterilization
- Terminal sterilization by Dry Heat Microbial Reduction (DHMR)
  - 110°C bake for 60 hours
- Any and all post DHMR handling must occur in an aseptic ISO Class 5 workspace
Post DHMR handling and cleanroom maintenance

• All sample path bioburden testing occurs prior to final access before DHMR
  • Post DHMR testing risks recontamination of the surface, and bioburden will be below limit of detection

• Any access to sample path post DHMR must occur in an aseptic ISO Class 5 environment
  • Train all team members interacting with the sample path in aseptic processing
  • Sterile garments, gloves, and tools required
  • Workspace cleaned and tested for bioburden before work, actively monitored with air bioburden sampler
Post DHMR Tool Sterilization

- After precision cleaning and white light inspection, compatible tools will be sterilized
  - Autoclave sterilization: 20 min 121°C, 100 kPa
  - DHMR: 60 min, 165 °C
- Biological indicators used to ensure sterilization
- Tools not compatible with sterilization will not be used in direct contact with sample path surfaces post DHMR
Post DHMR Sterile Tool Handling

- Must only be exposed to ISO Class 5 or cleaner aseptic conditions
- Must be handled wearing sterile gowning
- Only wiped with sterile wipes
- Must only be set on sterile surfaces, sterile fields
- Must be opened by an assistant who is not handling sterile items
- Packages of foil will be sterilized for sterile fields (working surfaces)
- Sterile fields are single use and only for the continuous working session
Personnel management

- One day Planetary Protection/aseptic processing training for all personnel working directly with flight hardware
- Single use sterile cleanroom coveralls, hood, and gloves
- Two person system to manage sterile tools (pass sterile tool into workspace as needed)

Sample path work only in an aseptic ISO Class 5 environment that has been verified by bioassay

No tools that have not been sterilized in contact with Sample path
Summary

• MOMA-MS planetary protection requirements require the establishment of aseptic work spaces during assembly, integration, and testing
  • Three cleanrooms will be used at GSFC
  • Aseptic Assembly cleanroom is currently maintained with additional bioburden control steps: very low level of biological contamination
  • Integration and Testing cleanroom has not had additional bioburden control steps instituted: higher level of biological contamination
• Planetary Protection laboratory at GSFC developed to support onsite bioassay processing
• After DHMR exposures of sample path will be limited
  • Open only in a monitored aseptic work space
  • Handled only with sterile garments, sterile tools
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