Three steps to Microrobotics

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1^{st} Step:

Study on Curation Facility for Planetary Samples

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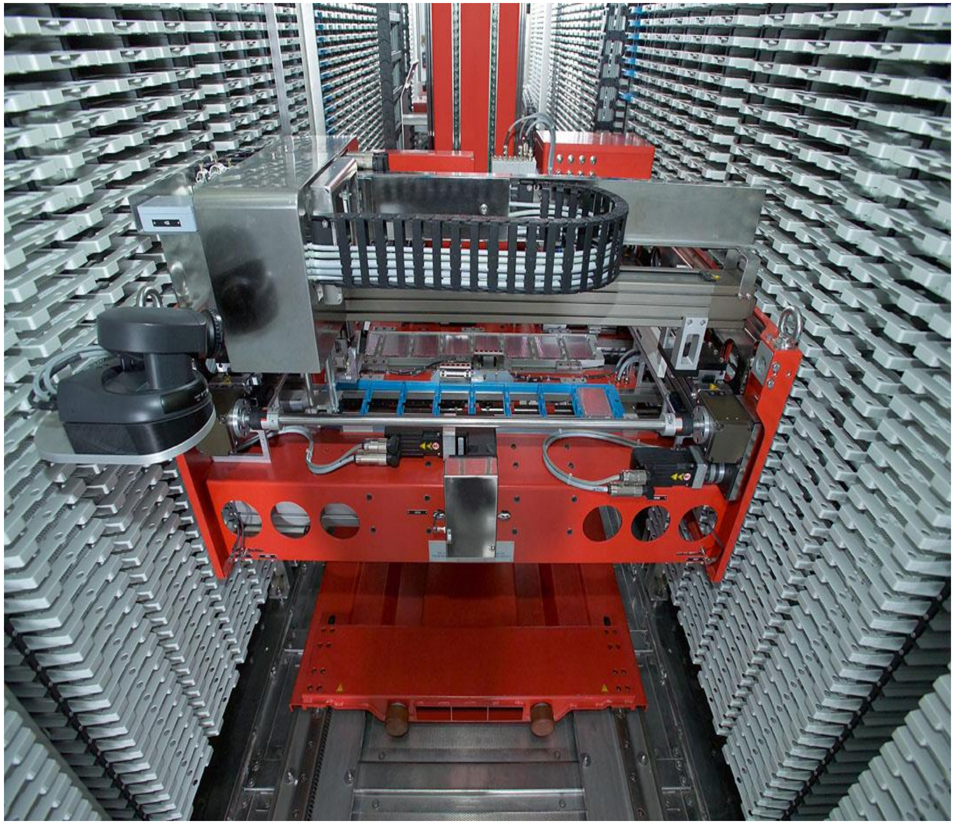
Solution

- Try to solve primary containment as reliably as possible.
- From this it can be concluded that volumes of primary containments and number of transfers between primary containments should be minimized.
- Keep a selection of samples at original atmospheric conditions (e.g. Mars like conditions: 12 mbar, CO_2,….)

Possible Synergies

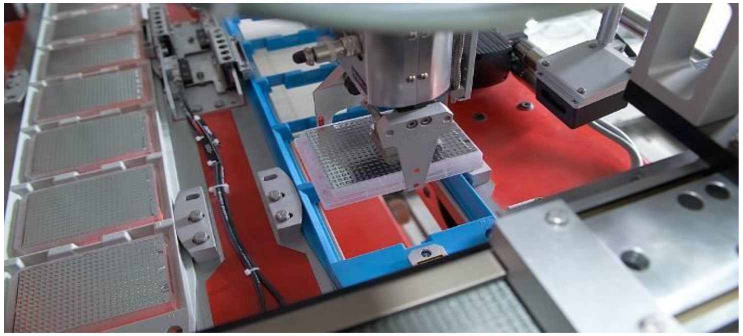
- Airthight boxes instead of glove boxes, plastic isolators and personnel protection suites.
- Robotics, including μ–robotics
- Fully automated storage systems at appropriate conditions

Plate and Tube Handling Robot

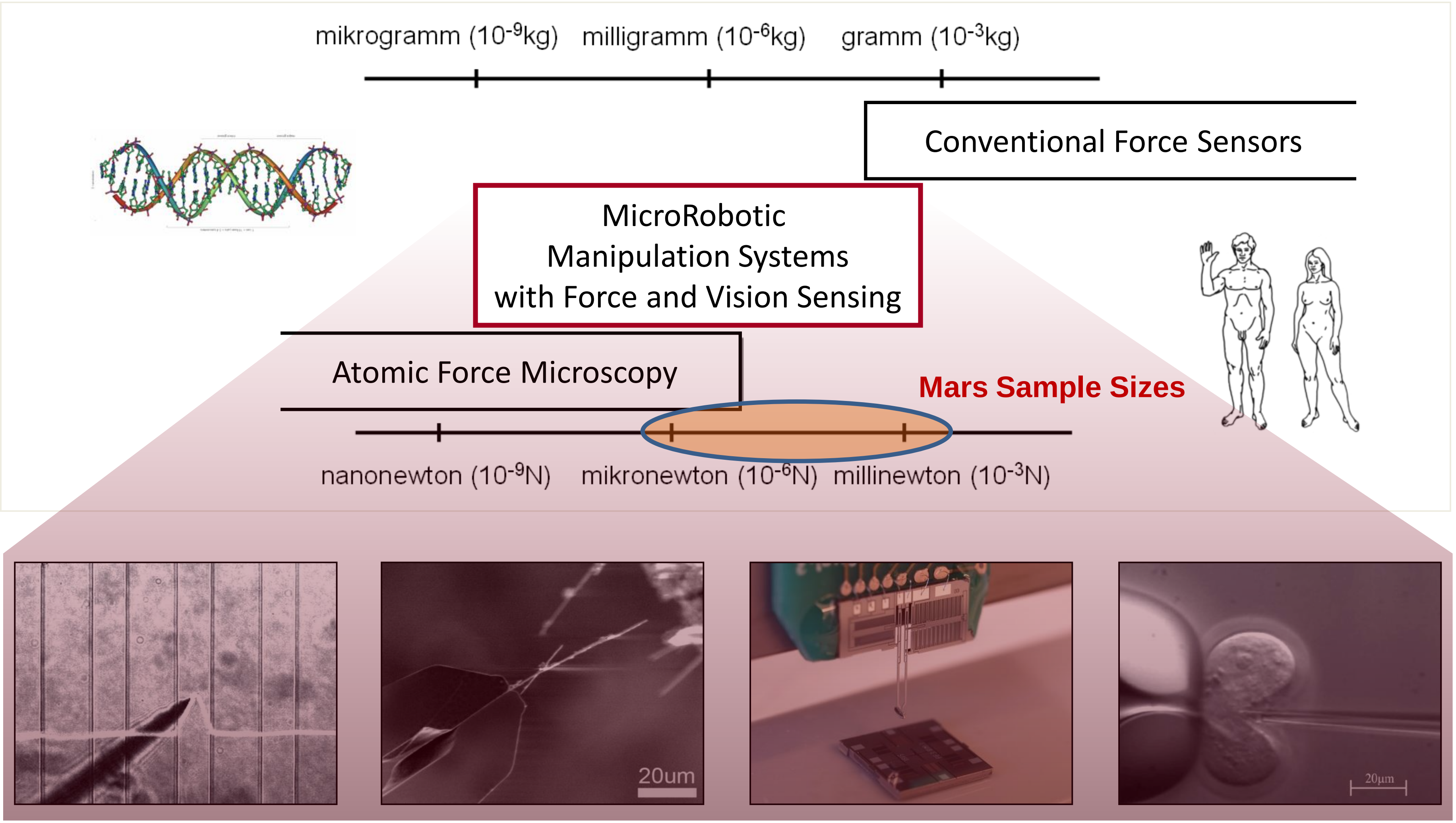


Details of trays, plate/rack gripper and tube puncher

Robot platform with tray and plate handling, barcode reading, tube puncher and remote controlled video camera

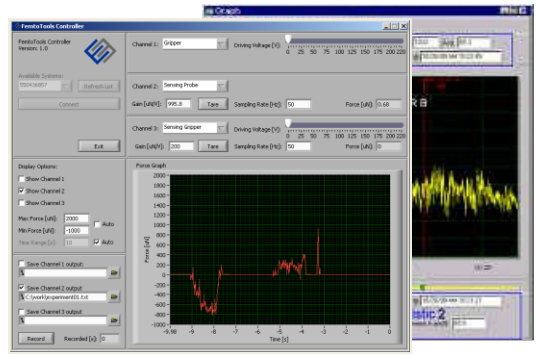


MicroRobotics for Remote Handling of Small Samples

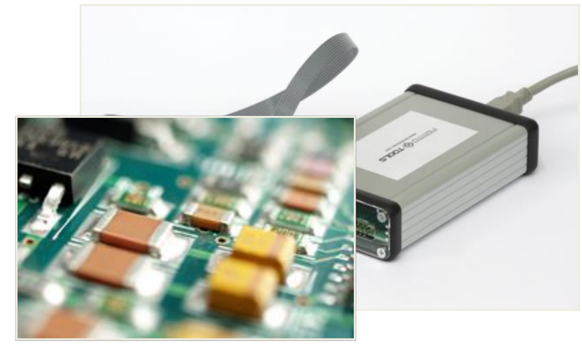


Complete Microrobotic Systems for Remote Handling of Small Samples

MEMS Sensors and Grippers



Software, GUIs, Automation



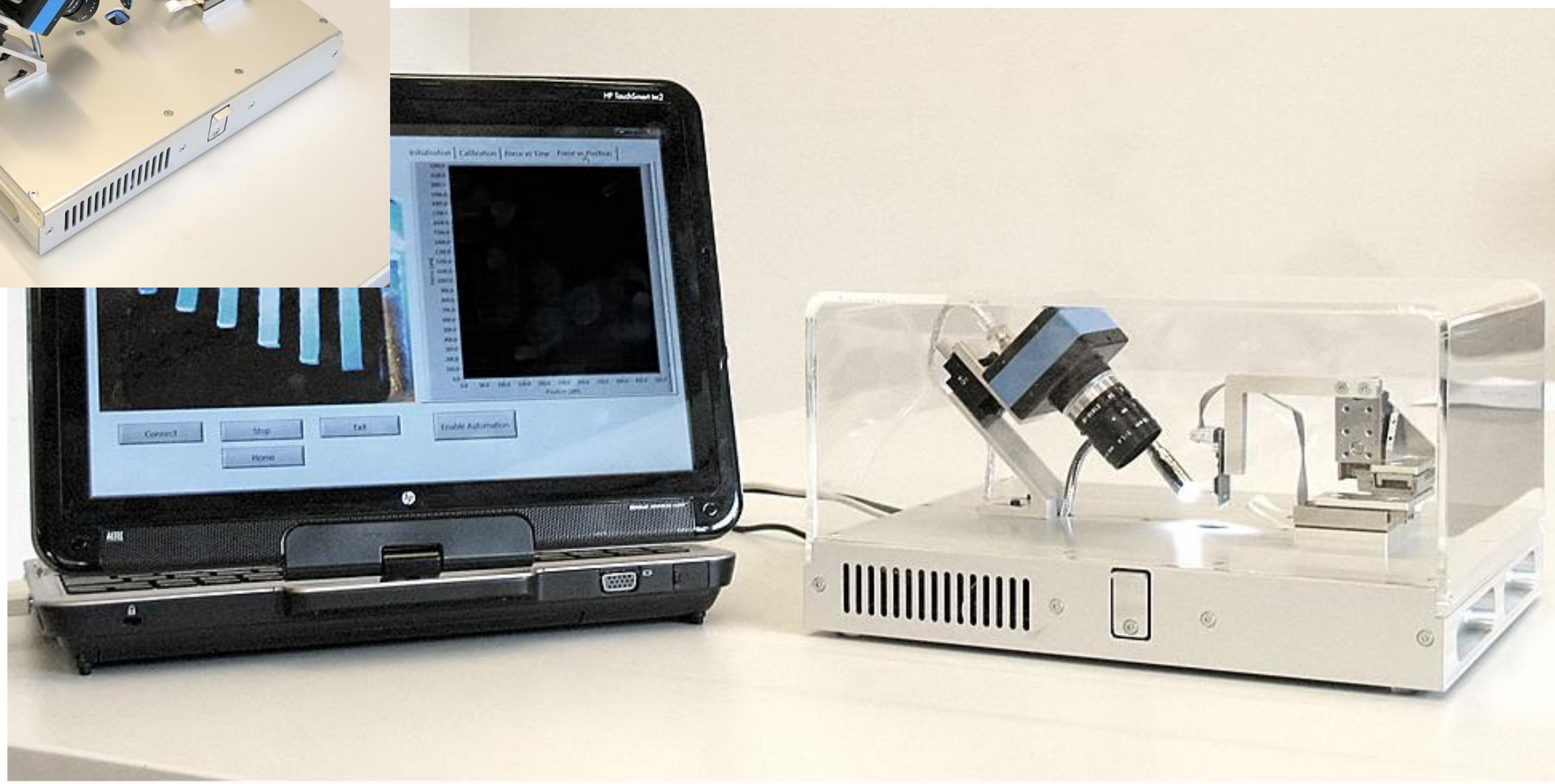
Electronics und data acquisition

Manipulators, Encoders

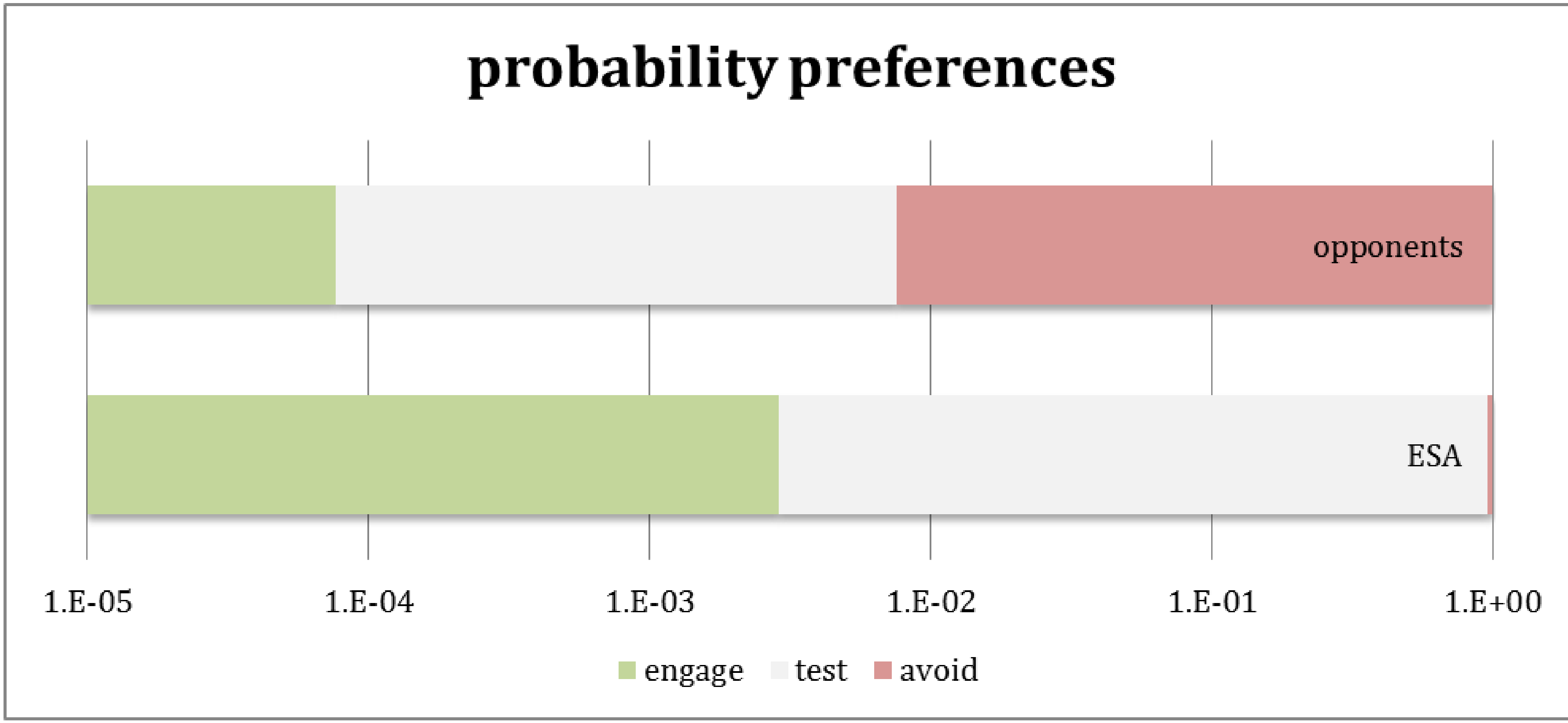
Automated and Remotely Teleoperated Systems

Microscopes, Microscope cameras

A MicroRobotic System for Each Sample Vessel



Probability to engage or avoid



2^{nd} Step:

Study on sub-sampling of Mars samples

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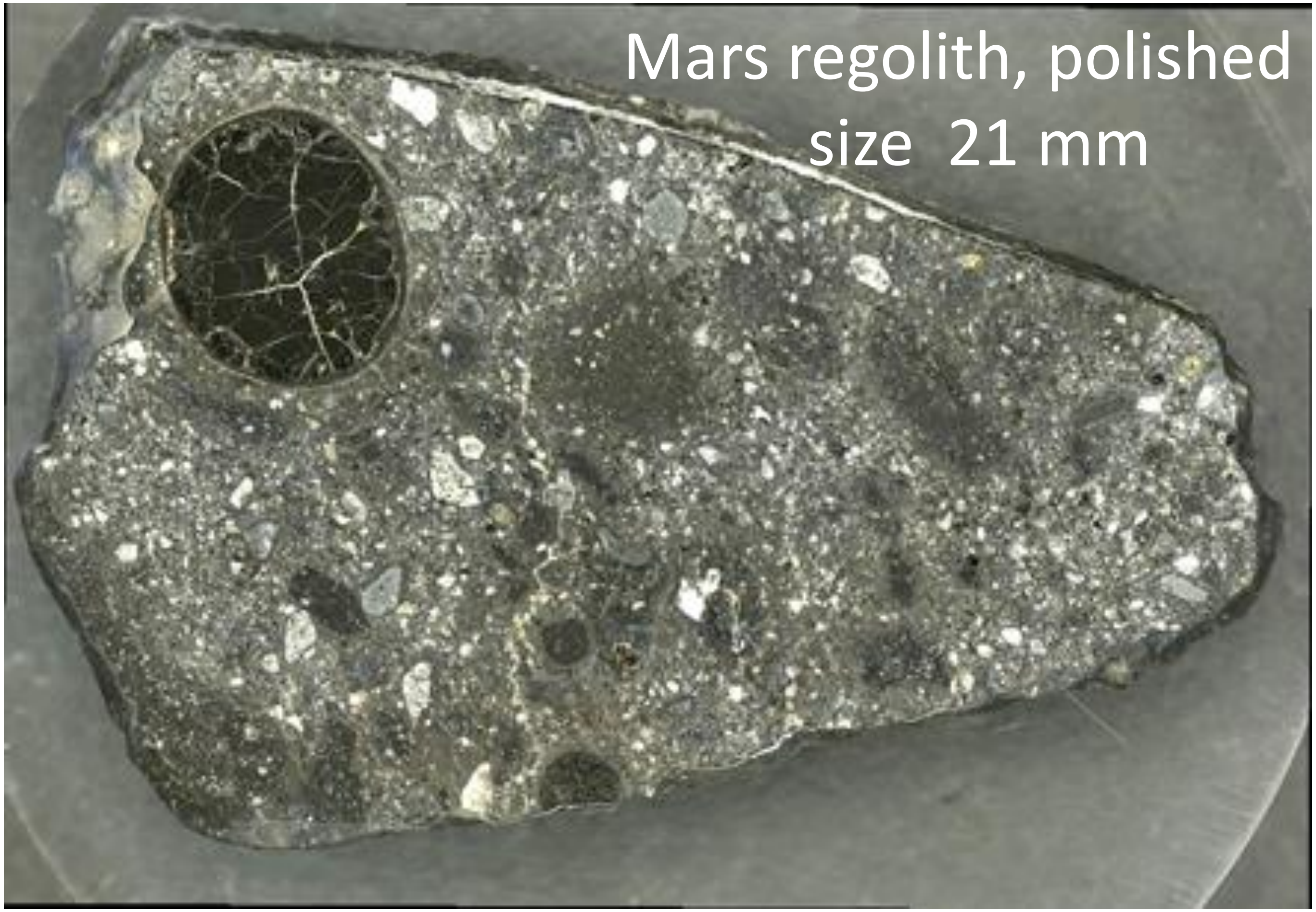
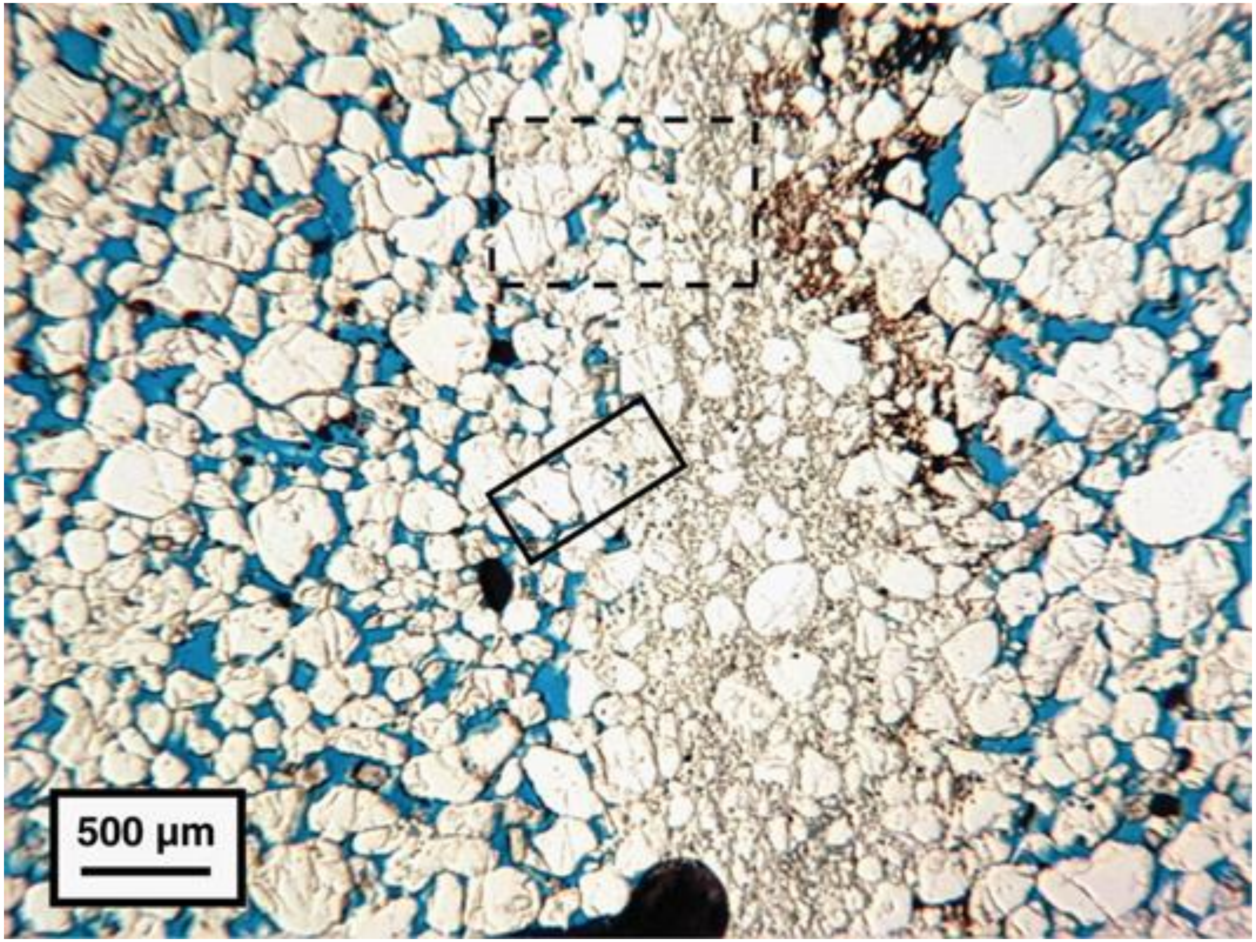
Interpretation of Evidence for Life in Mars Return Samples.

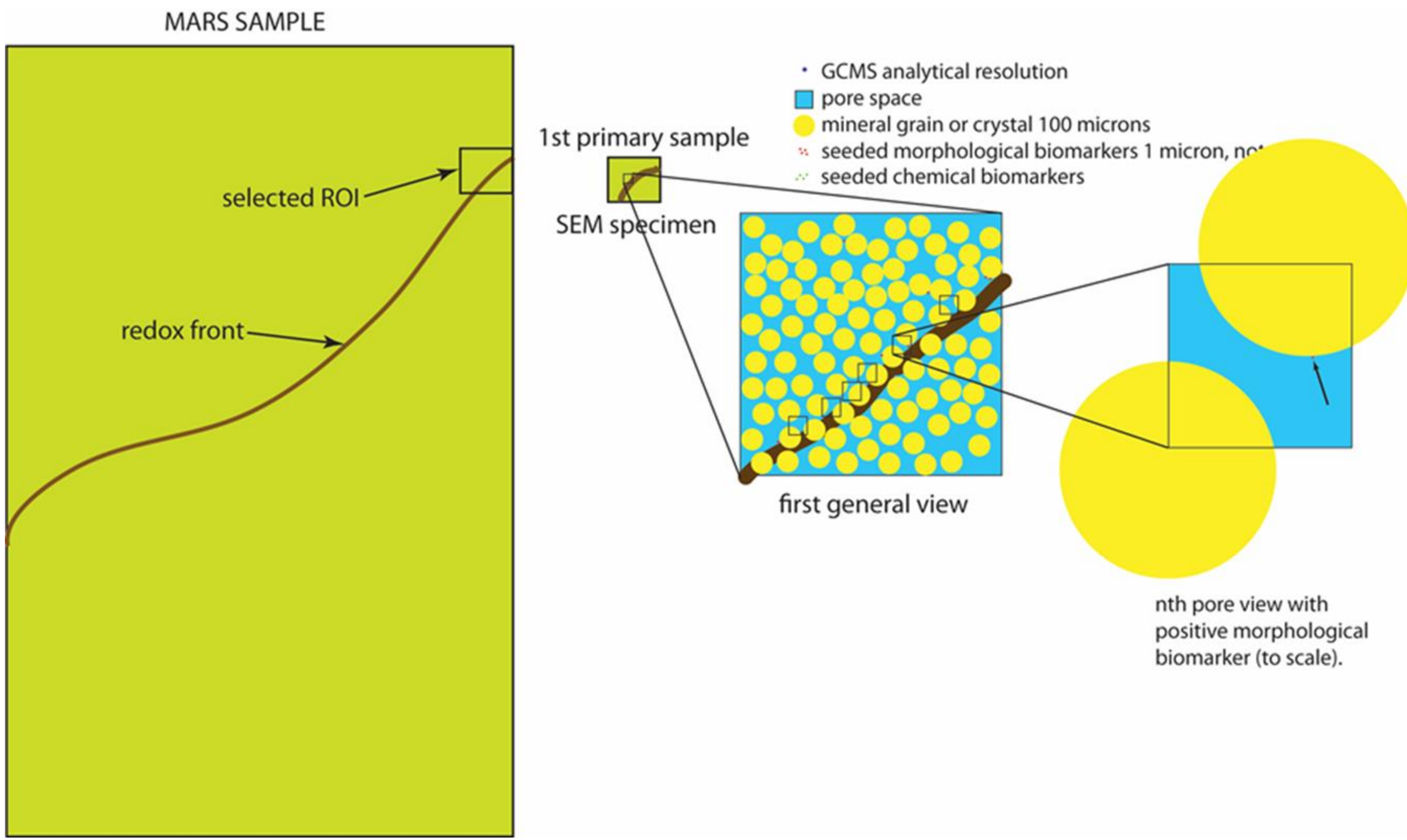
P. Mani, M. Heuer[1], B. Hoffmann, K. Milliken, J. West



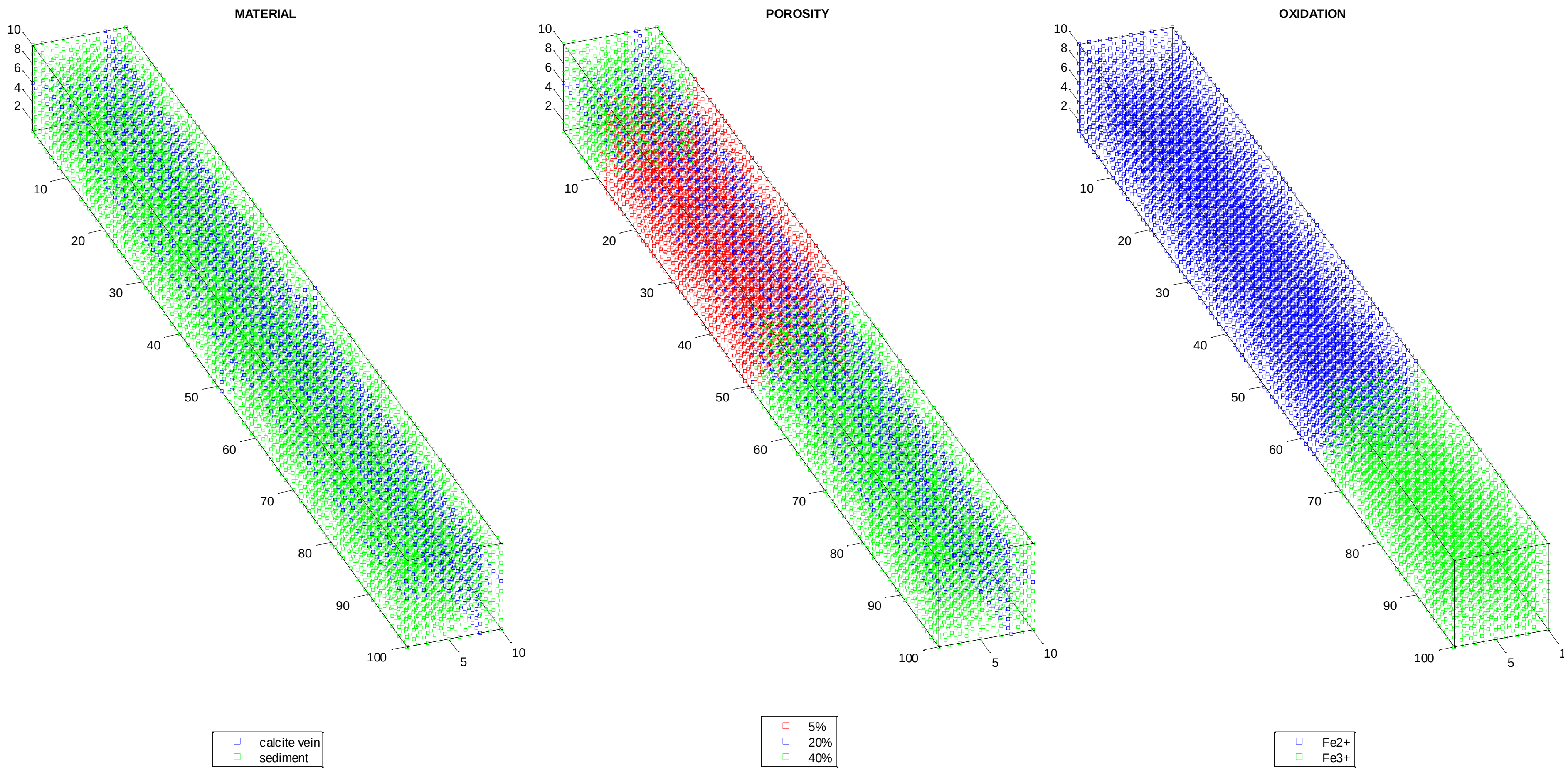
Heterogeneity and Porosity

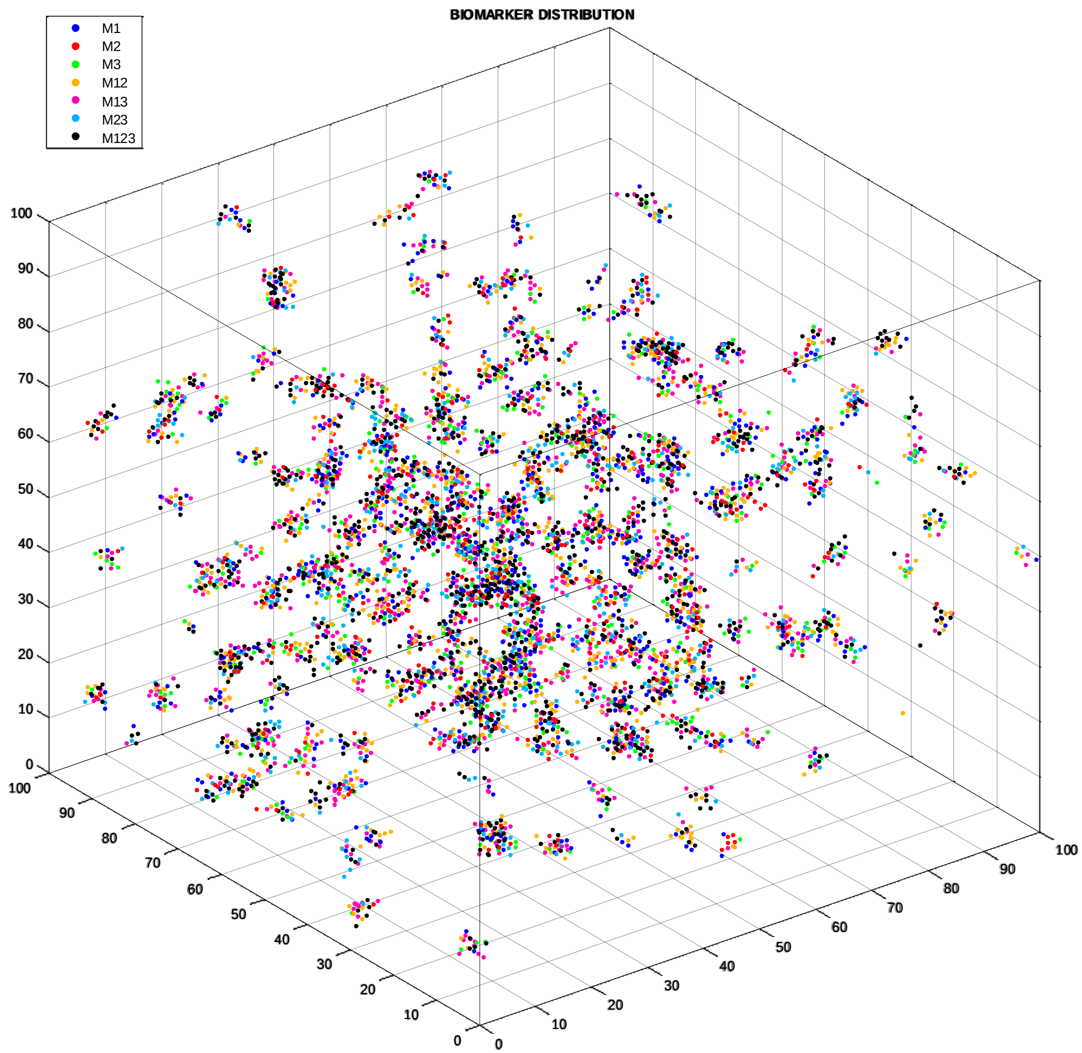


Virtual Mars Sample



Virtual drill core




BIOMARKER DISTRIBUTION
M1
M2
M3
M12
M13
M23
M123
0
10
20
30
40
50
60
70
80
90
100

List all possible test methods:

<u>Low-invasive methods</u>, non-destructive or requiring very small sub-samples (physical invasion in parentheses):

- **Optical imaging at different scales of untreated samples (visible light): shape, colour, texture**
- **Computer tomography (X-rays): shape and internal texture**
- **Gamma-spectroscopy (none): radioisotopes 40K, Th(series), U(series), 26Al, 60Co, 22Na etc.**
- **Mass determination (none): sample mass**
- **Raman and FT-IR spectroscopy (laser): mineralogy, presence of organics at high levels**
- **X-ray diffraction on single grains, fines (X-rays): mineralogy**
- **X-ray fluorescence (X-rays): major and some trace elements**
- **GC-MS, specific gas sensors (use of gas headspace): release of volatiles**

<u>More strongly invasive methods:</u>

- **Thin section preparation and optical microscopy, SEM, electron microprobe etc.**
- **X-ray diffraction on artificial powders (X-rays): mineralogy**

Here's Waldo: Computing the optimal search strategy for finding Waldo

national synonyms: Wally, Charlie, Walter, Ubaldo, Holger, Willy, Vallu, Wali

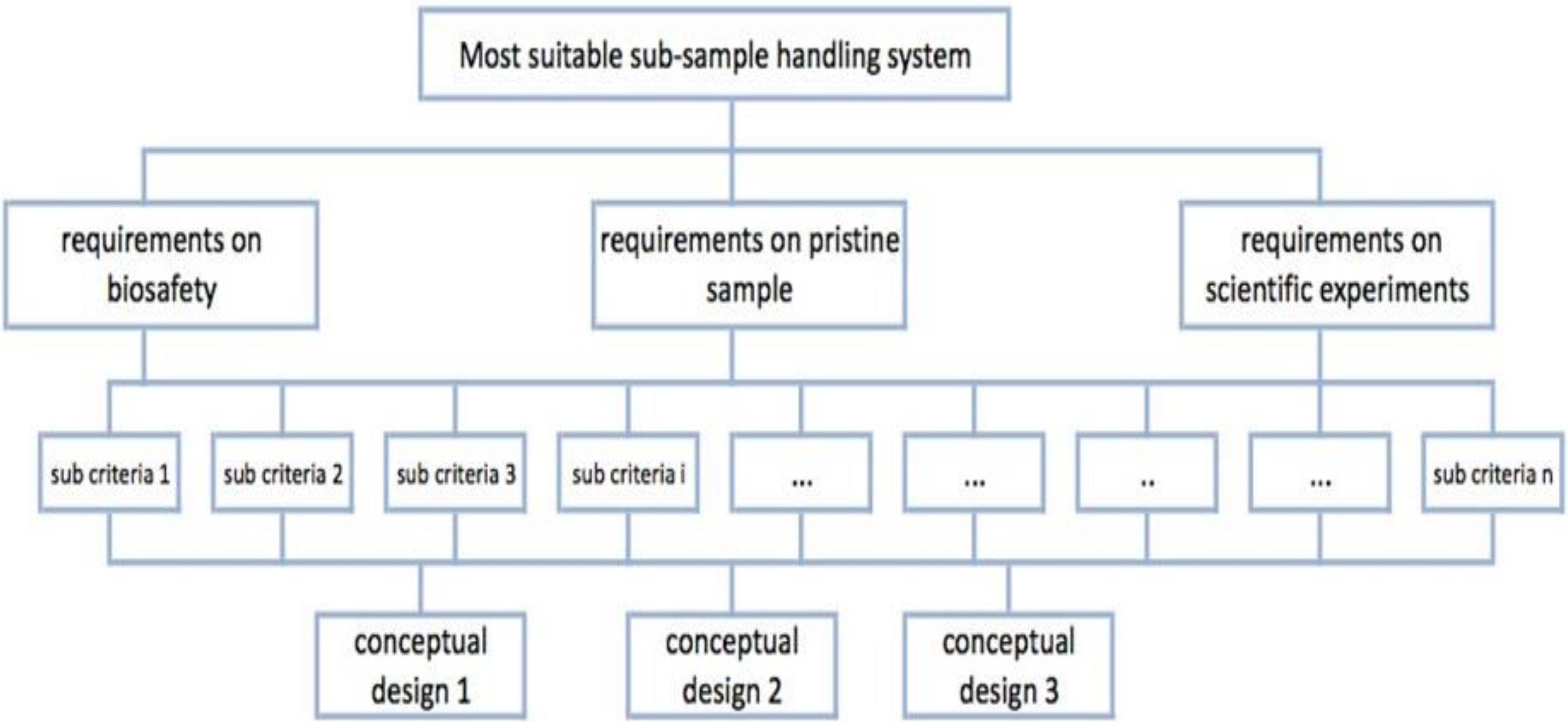
- Sensitivity = 99%
- Specificity = 99%
- Efficiency = 99%

- False Negative

  FN = 10^{-4}

$$p(\sim BM_t \mid s_t) = \frac{p(s_t \mid \sim BM_t)(1 - p(BM_t))}{p(s_t)} = \frac{p(s_t \mid \sim BM_t)(1 - p(BM_t))}{p(s_t \mid BM_t)\,p(BM_t) + p(s_t \mid \sim BM_t)(1 - p(BM_t))}$$

Criteria Structure



Manipulators shall be able to fulfil:

- **science requirements**
- **biosafety requirements**
- **biosecurity requirements**
- **decontamination requirements**
- **sample handling requirements**
- **sample preparation requirements**
- **sample container unpacking requirements**
- **sample vessel handling requirements**
- **decontamination requirements**
- **containment requirements**
- **sub-sampling requirements**
- **curating requirements**
- **Sample protocol requirements**

3rd Step:

Road map for microrobotics

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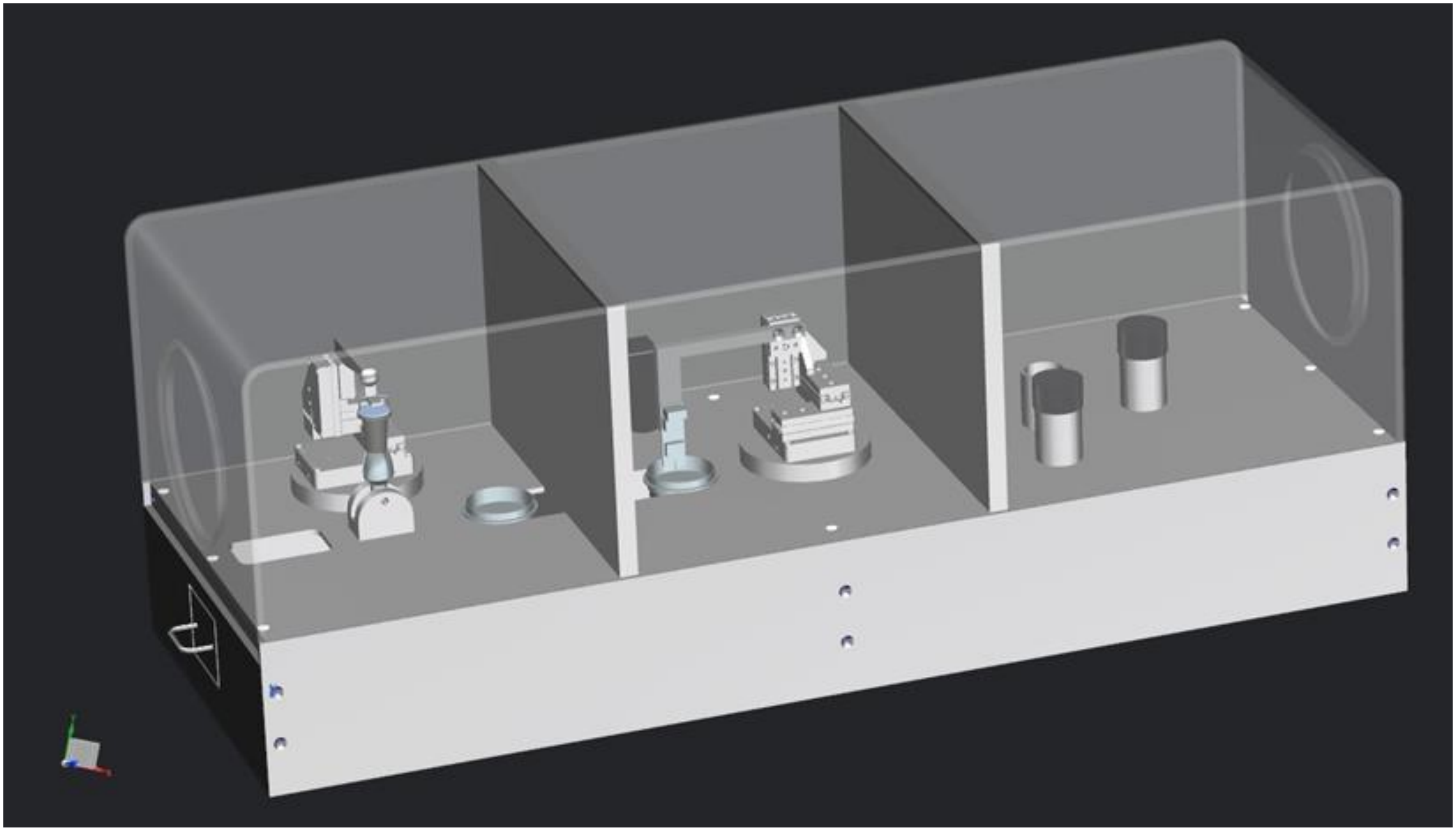
Key Technologies

- Microrobotic end effectors
- Micropositioner
- “Smart” sample holders
- Visualization system
- Martian soil testing and measurement systems
- Load-lock system and feedthrough technology
- Surface engineering
- Mars soil analog
- Martian environment chamber

Development Strategy

Modular system design
Handling and testing sequence
Microrobotic sub-systems
Resistance of material
Electrostatic and magnetic field impact
System and sub-system test
Treatment of surfaces
Cleaning of minienvironment to ultra clean conditions
Marsian environment chamber and system interfaces
System integration and test
User software and automation
Minienvironment life time and maintenance

Proposal of a 3 chamber system



Commercial Microrobotic Players

Nanosurf AG
Femtotools GmbH
Mecartex SA
Aeon Scientific AG
Attocube Systems AG
SmarAct GmbH
Kleindiek Nanotechnik GmbH
Physik Instrumente GmbH

Piezosystem Jena GmbH
miCos GmbH
Klocke Nanotechnik GmbH
Zyvex Instruments LLC
MEMS Precision Instruments
Newport Corporation
Aerotech Inc.

Microrobotic Research Institutes

Institute of Robotics and Intelligent Systems
The Sensors, Actuators and Microsystems Laboratory
Labortoire de Systèmes Robotiques
CSEM, Switzerland
Nanointegration group
Division Microrobotics and Control Engineering
Institute for Electronic Nano Systems ENAS
Institute for Silicon Technology
Research group Micro and Nano Engineering
Femto-ST

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Conclusions

R & D activity is essential to develop this new technology to an advanced level to handle Mars samples without risk for staff and the environment and without compromising the pristine state of the sample for a long storage time.