The International Astrobiology Workshop 2013
(The 6th Japan Astrobiology Network Annual Meeting)

TANPOPO: ASTROBIOLOGY EXPOSURE AND MICROMETEOROID CAPTURE, A SAMPLE RETURN EXPERIMENT TO TEST QUASI-PANSEPERMIA HYPOTHESIS ONBOARD THE ISS-KIBO EXPOSED FACILITY

November 29th, 2013
JAXA/ISAS Sagamihara Campus, Kanagawa, Japan

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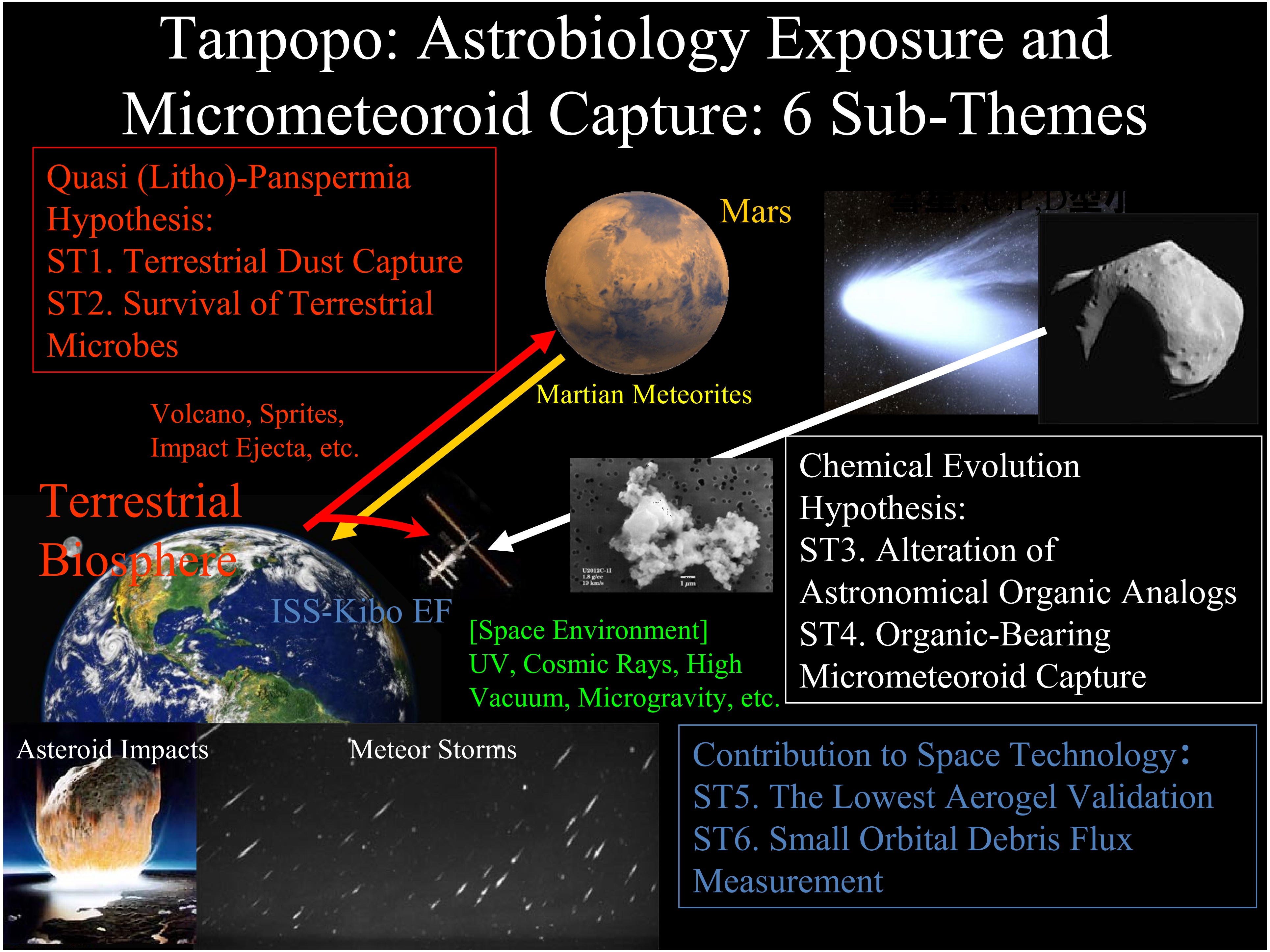
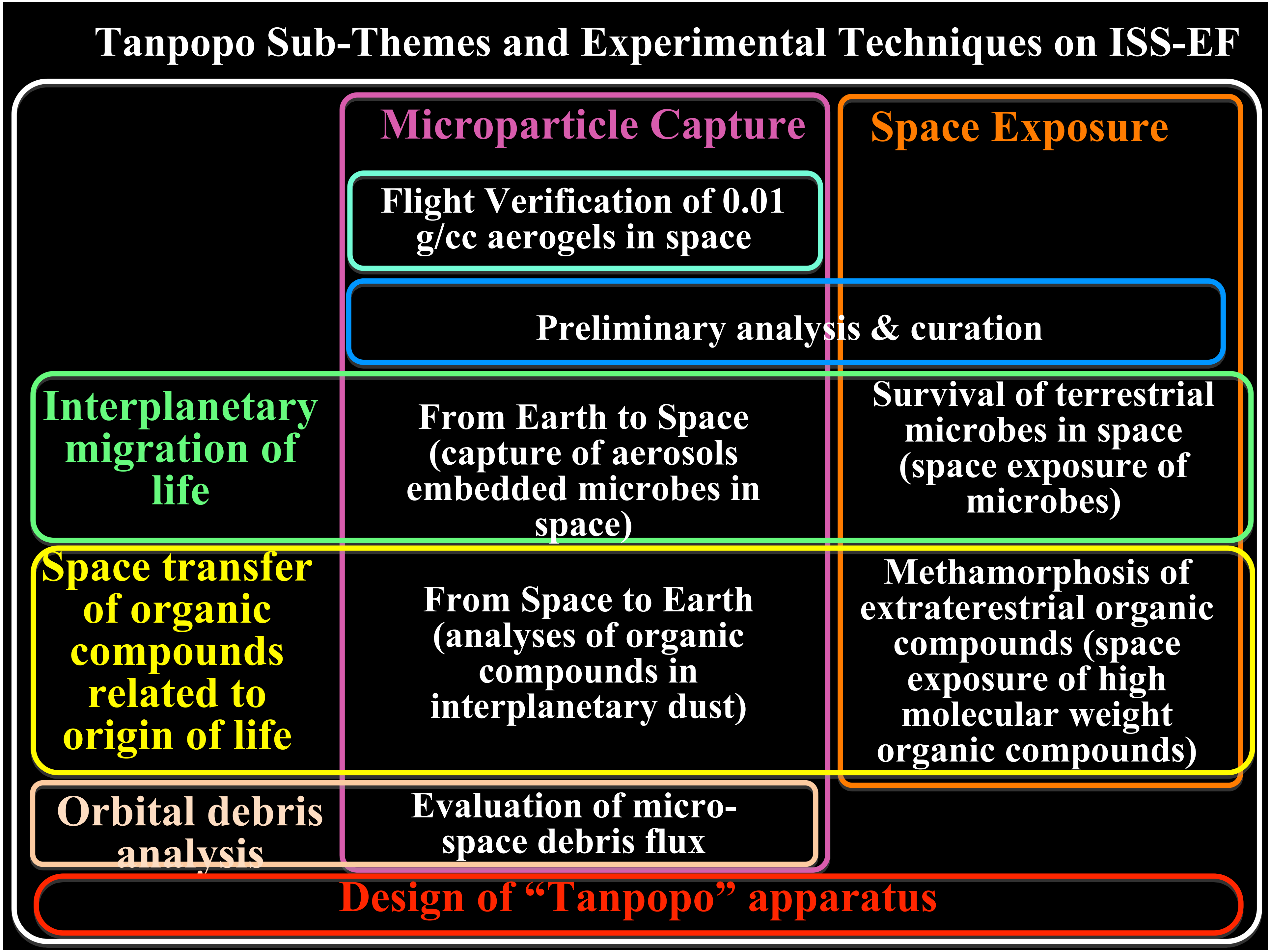
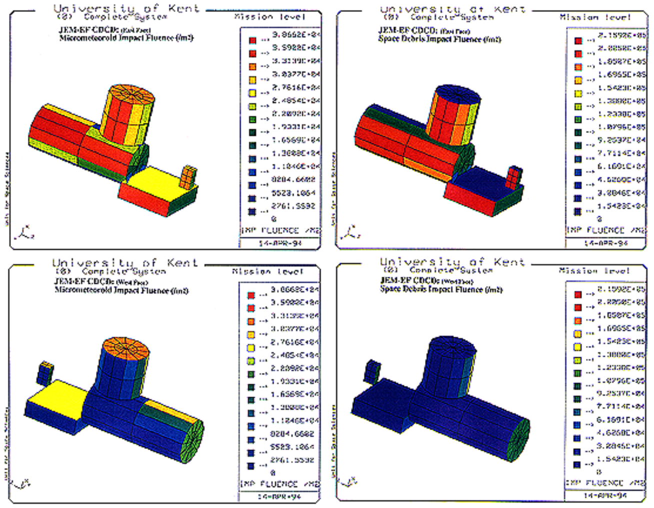
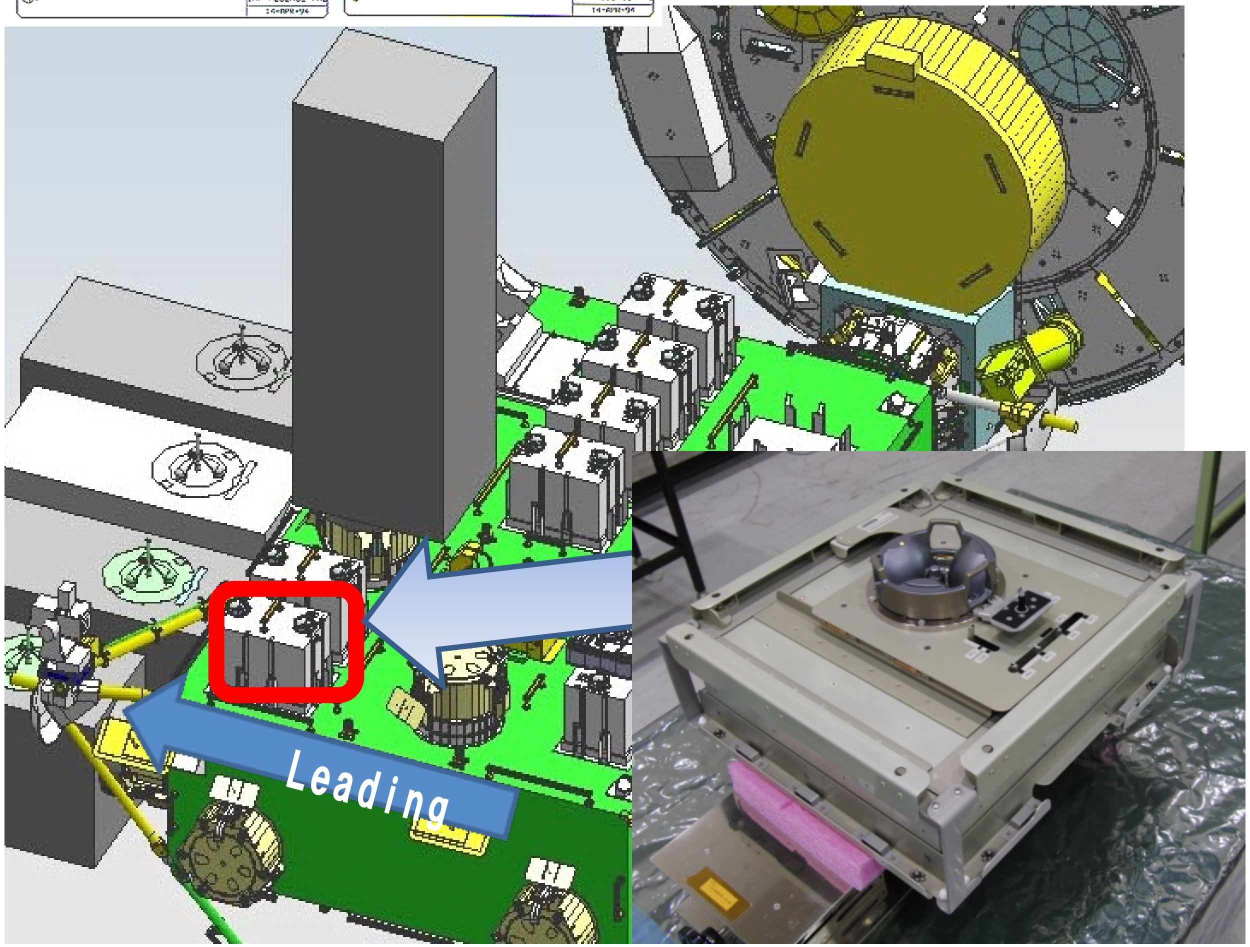
(1: JAXA/ISAS, 2: Tokyo University of Pharmacy and Life Science, 3: Yokohama National University, 4: Osaka University, 5: Fukuoka Institute of Technology,6: Chiba University, 7: JAXA/Aerospace Research and Development Directorate, 8: University of Aizu, 9: Tokyo University of Technology, 10: Nagaoka University of Technology, 11: National Institute of Radiological Sciences)

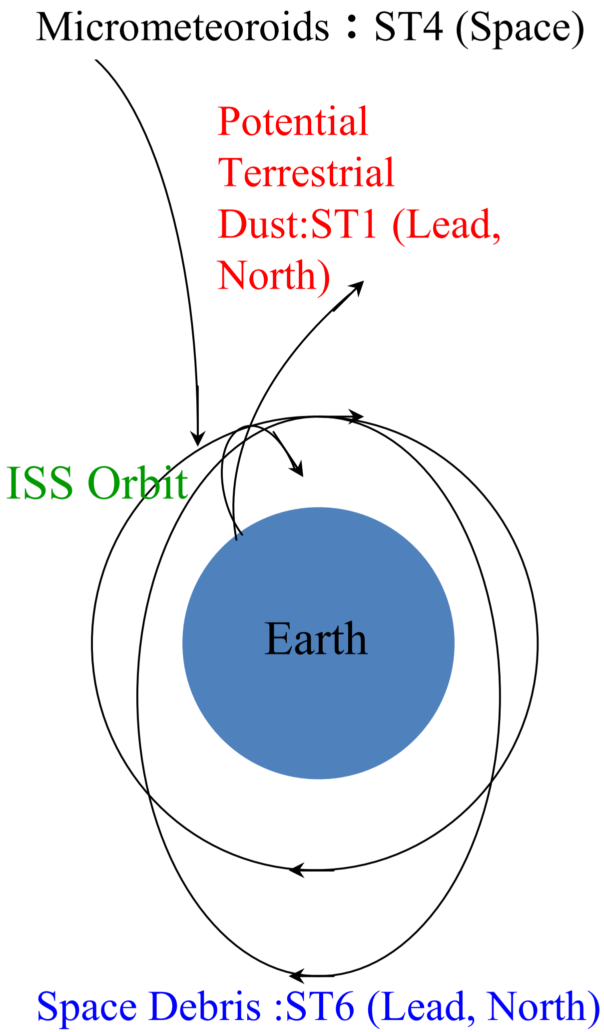

Tanpopo: Astrobiology Exposure and Micrometeoroid Capture: 6 Sub-Themes
Quasi (Litho)-Panspermia Hypothesis:
ST1. Terrestrial Dust Capture
ST2. Survival of Terrestrial Microbes
Mars
Martian Meteorites
Volcano, Sprites, Impact Ejecta, etc.
Terrestrial Biosphere
ISS-Kibo EF
[Space Environment]
UV, Cosmic Rays, High Vacuum, Microgravity, etc.
Chemical Evolution Hypothesis:
ST3. Alteration of Astronomical Organic Analogs
ST4. Organic-Bearing Micrometeoroid Capture
Asteroid Impacts
Meteor Storms
Contribution to Space Technology:
ST5. The Lowest Aerogel Validation
ST6. Small Orbital Debris Flux Measurement


Tanpopo Sub-Themes and Experimental Techniques on ISS-EF
Microparticle Capture
Space Exposure
Flight Verification of 0.01 g/cc aerogels in space
Preliminary analysis & curation
Interplanetary migration of life
From Earth to Space (capture of aerosols embedded microbes in space)
Survival of terrestrial microbes in space (space exposure of microbes)
Space transfer of organic compounds related to origin of life
From Space to Earth (analyses of organic compounds in interplanetary dust)
Methamorphosis of extraterestrial organic compounds (space exposure of high molecular weight organic compounds)
Orbital debris analysis
Evaluation of micro-space debris flux
Design of "Tanpopo" apparatus

Accommodation Position and Pointing Faces on Kibo-EF

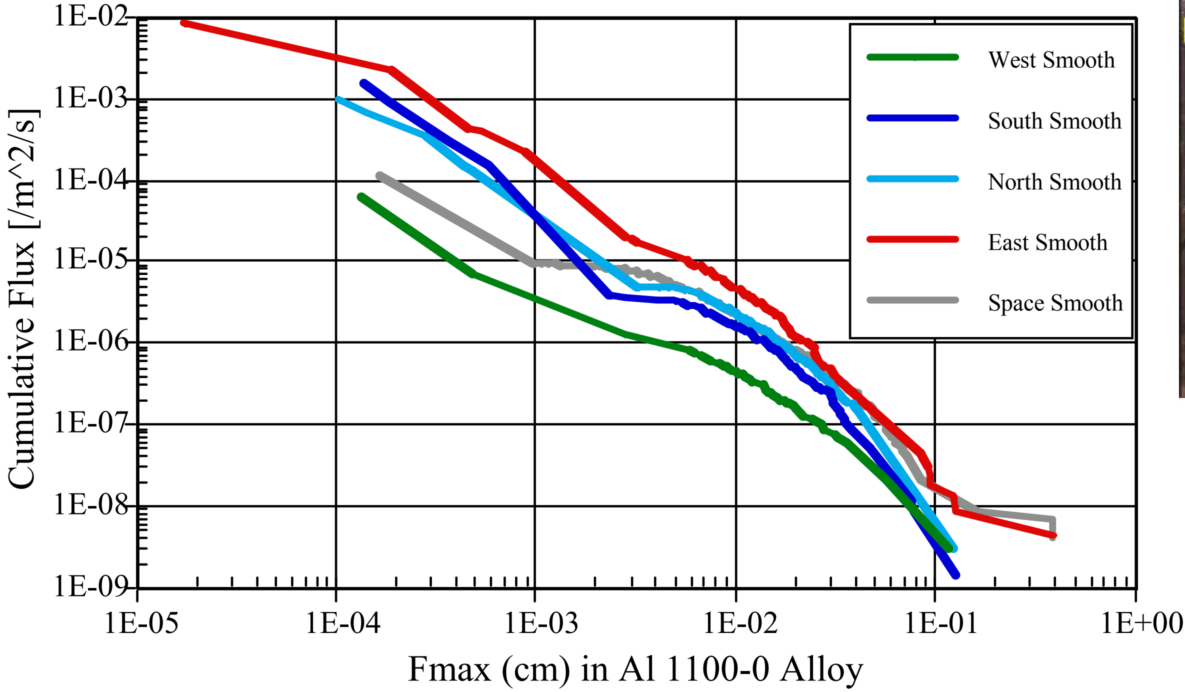




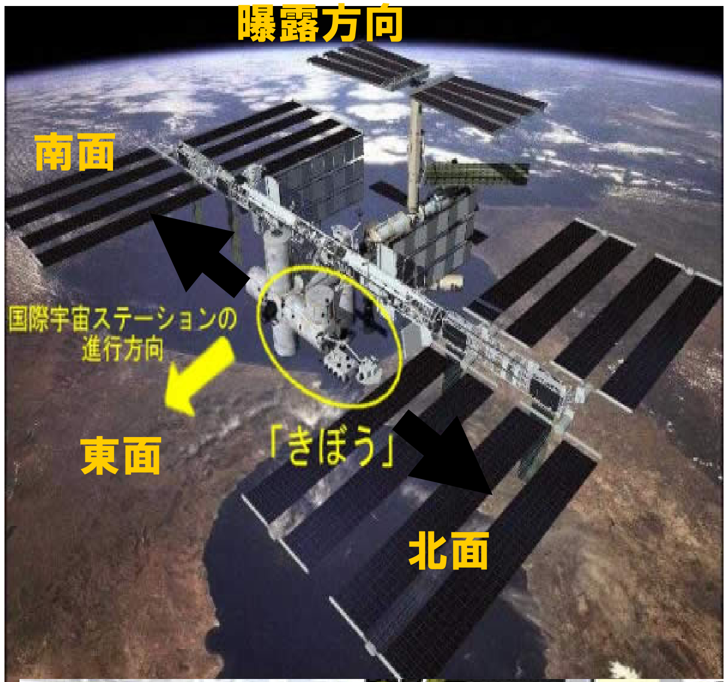


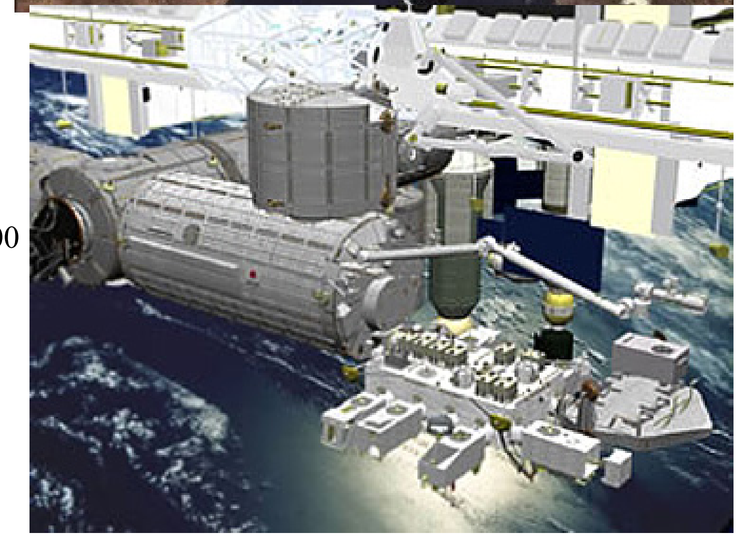
Meteoroid and Debris Impact Flux（D>10μm)

Meteoroids	～25/panel/year
Debris	13 ～ 130/panel/year

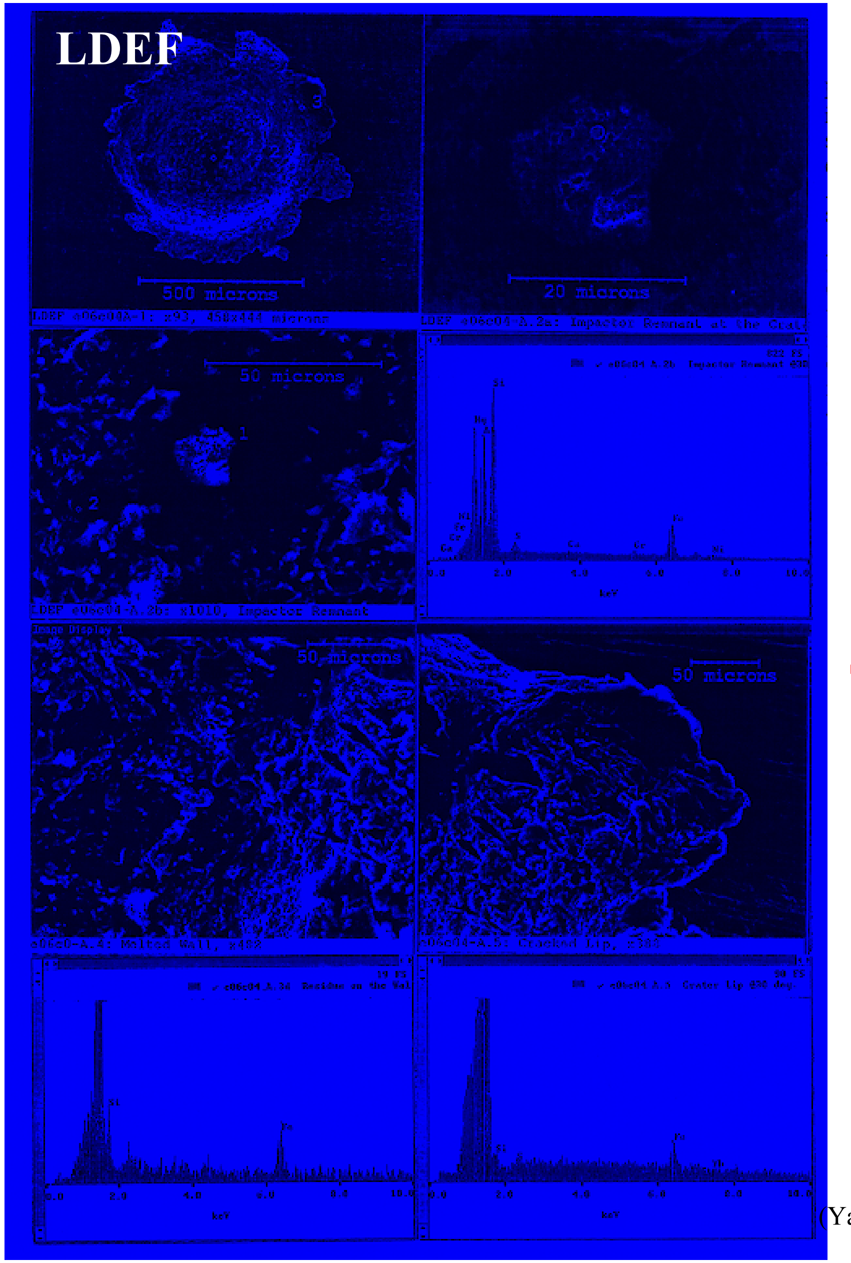


Yano, 1995

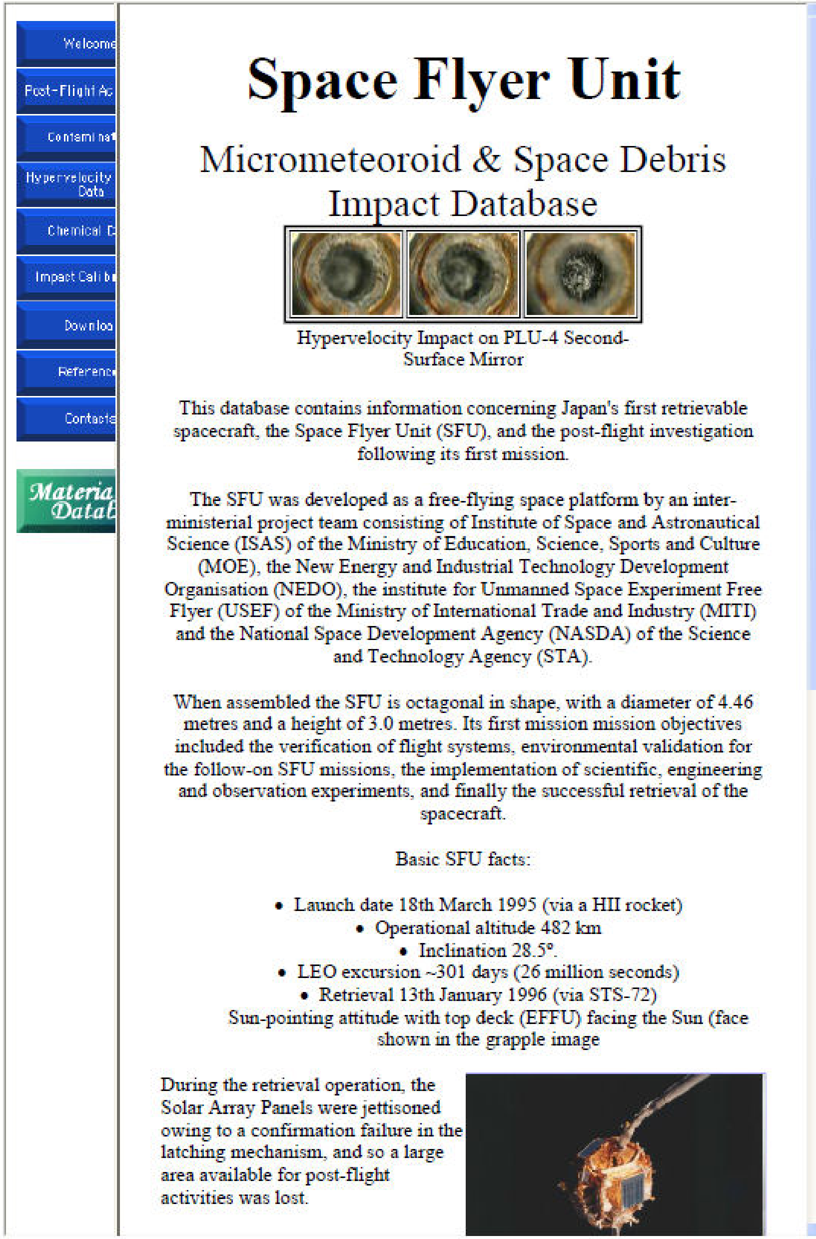




Past Impact Residue Analysis on Metal Foils/Plates to Database



(Yano, 1995)



Welcome
Post-Flight Ac
Contaminat
Hypervelocity Data
Chemical D
Impact Calibr
Downloa
Reference
Contacts
Materia Datab

Space Flyer Unit

Micrometeoroid & Space Debris Impact Database

Hypervelocity Impact on PLU-4 Second-Surface Mirror

This database contains information concerning Japan's first retrievable spacecraft, the Space Flyer Unit (SFU), and the post-flight investigation following its first mission.

The SFU was developed as a free-flying space platform by an inter-ministerial project team consisting of Institute of Space and Astronautical Science (ISAS) of the Ministry of Education, Science, Sports and Culture (MOE), the New Energy and Industrial Technology Development Organisation (NEDO), the institute for Unmanned Space Experiment Free Flyer (USEF) of the Ministry of International Trade and Industry (MITI) and the National Space Development Agency (NASDA) of the Science and Technology Agency (STA).

When assembled the SFU is octagonal in shape, with a diameter of 4.46 metres and a height of 3.0 metres. Its first mission mission objectives included the verification of flight systems, environmental validation for the follow-on SFU missions, the implementation of scientific, engineering and observation experiments, and finally the successful retrieval of the spacecraft.

Basic SFU facts:

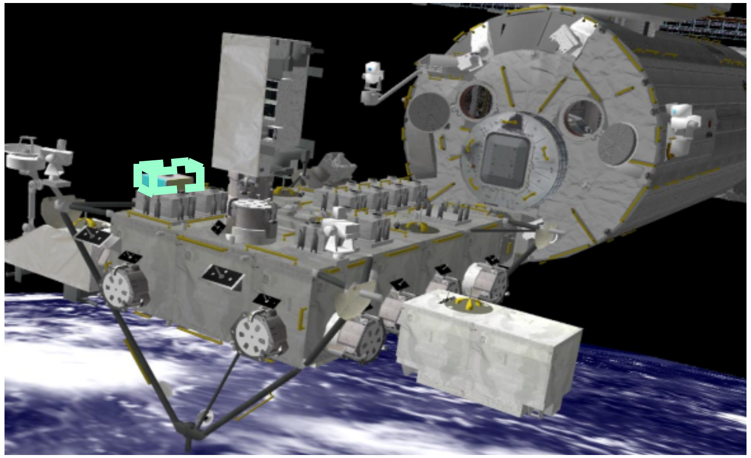
- Launch date 18th March 1995 (via a HII rocket)
- Operational altitude 482 km
- Inclination 28.5°.
- LEO excursion ~301 days (26 million seconds)
- Retrieval 13th January 1996 (via STS-72)

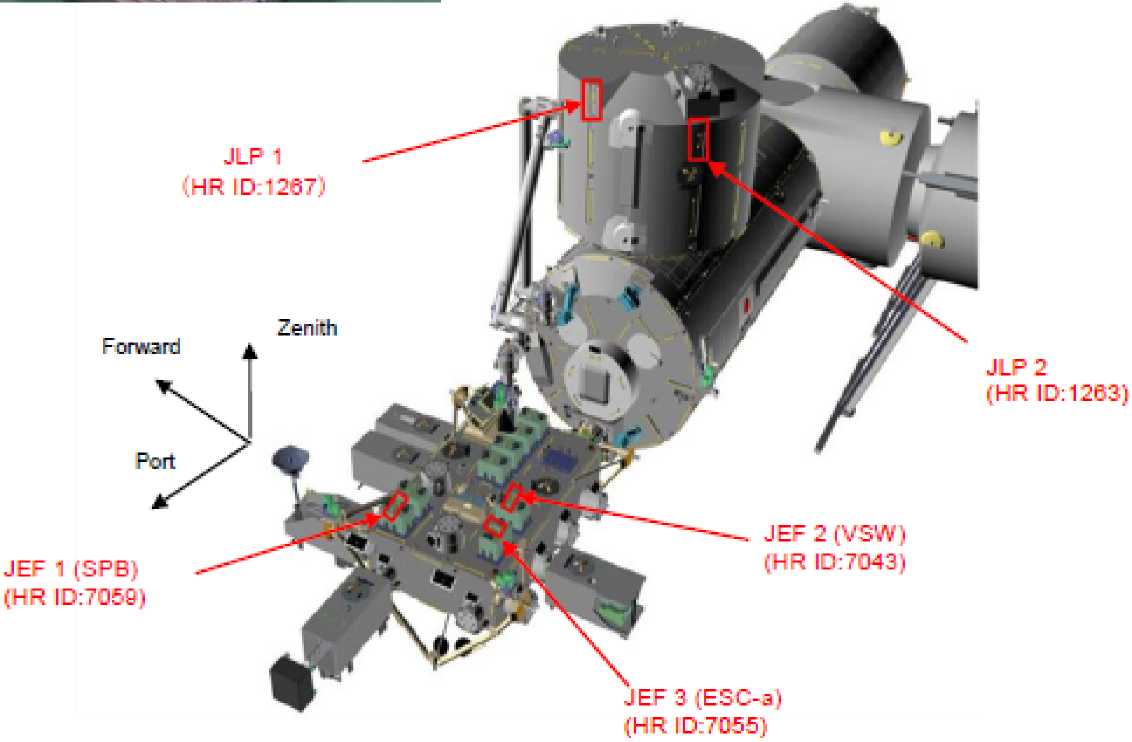
Sun-pointing attitude with top deck (EFFU) facing the Sun (face shown in the grapple image

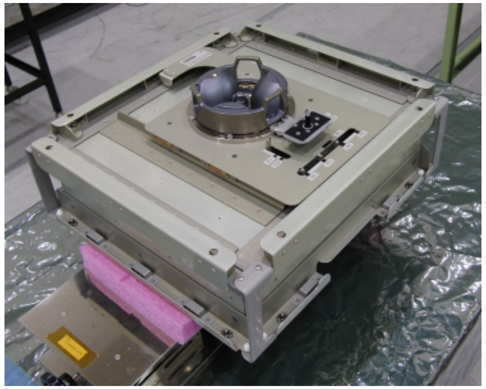
During the retrieval operation, the Solar Array Panels were jettisoned owing to a confirmation failure in the latching mechanism, and so a large area available for post-flight activities was lost.

ExHAM on ISS-Kibo EF Handrails

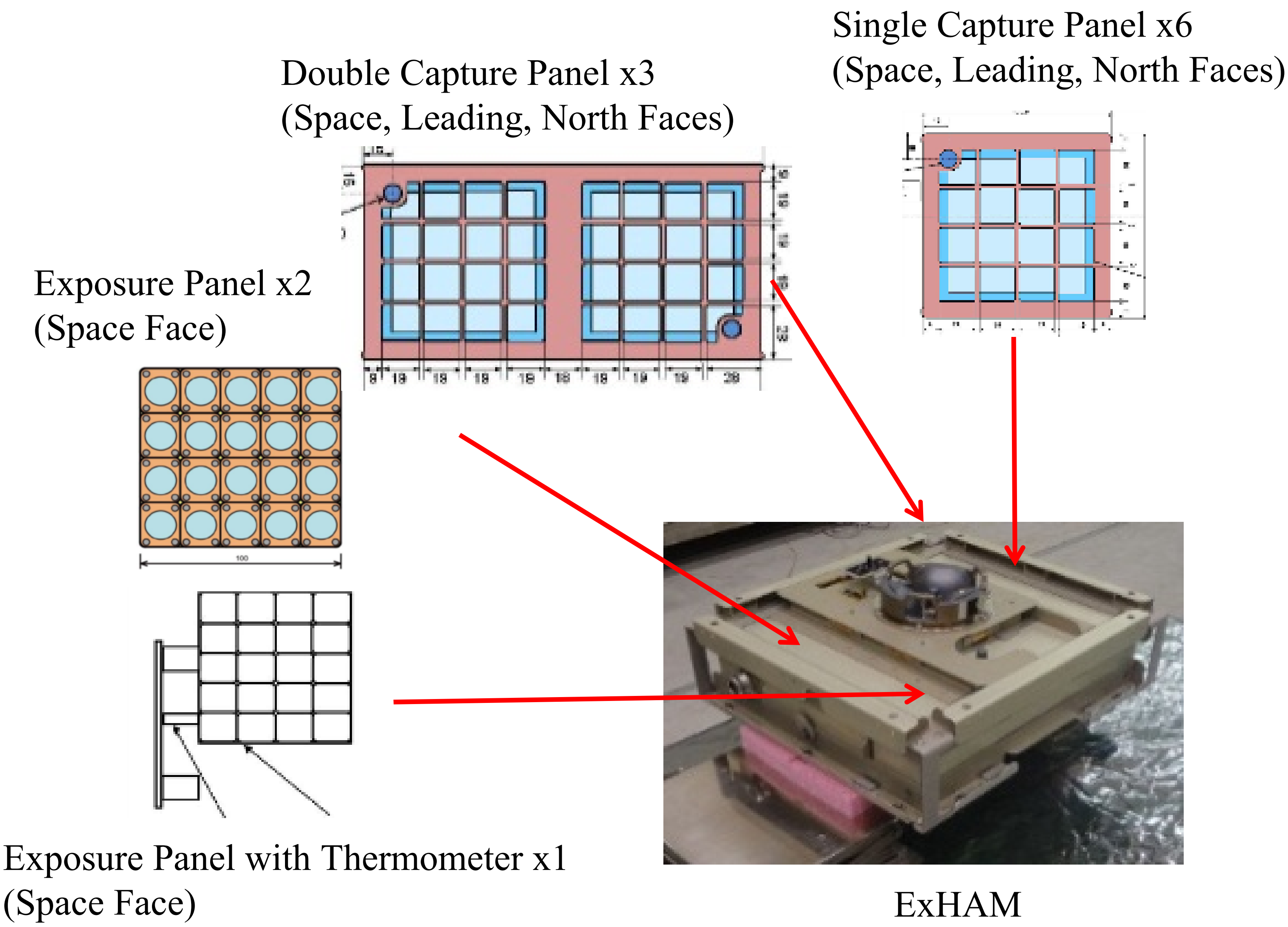
(Exposed Facility Handrail Attachment Mechanism)



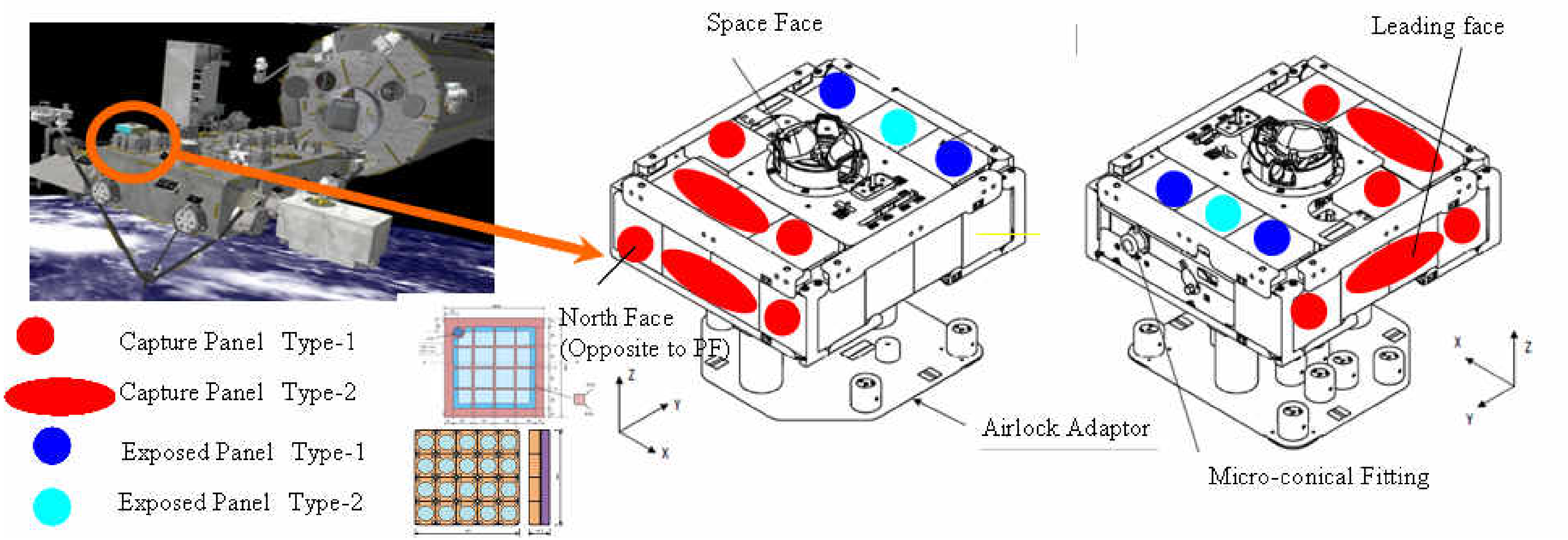




Tanpopo System Architecture

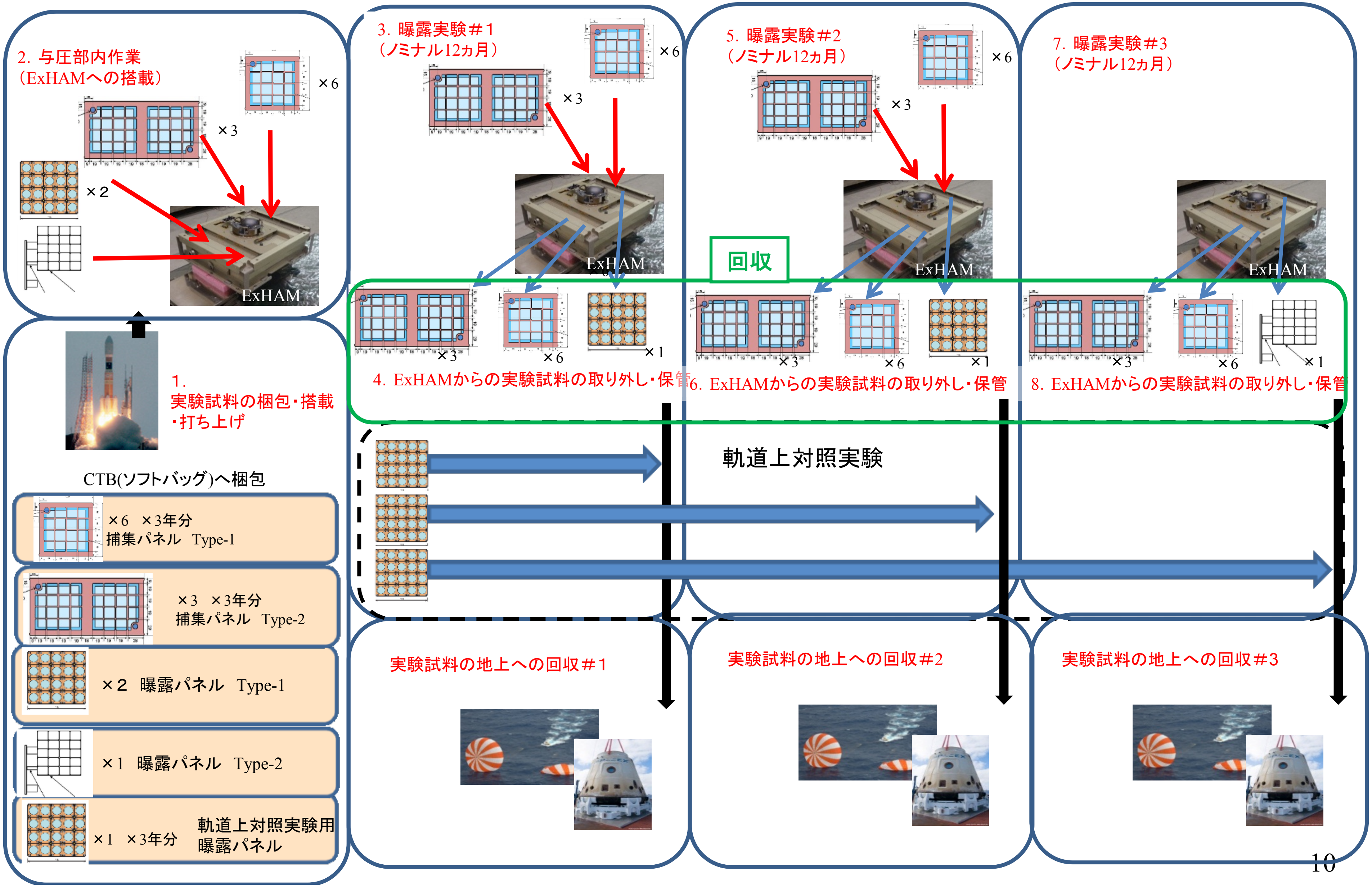


Locations of the Exposure Panels and the Capture Panels on the EXHAM

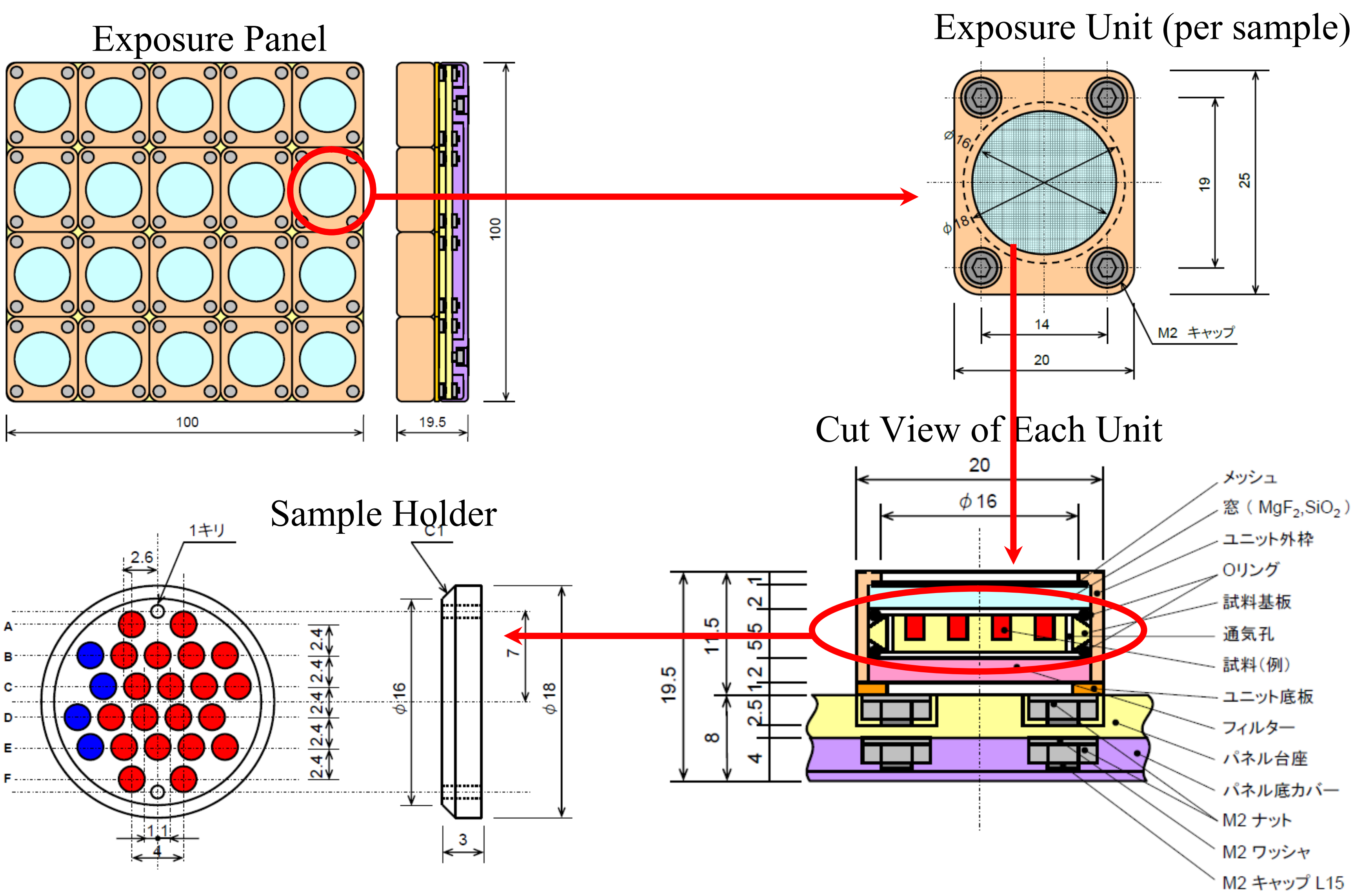


Sub-themes	Main Exposed Faces	Panels	Exchange frequency
ST1: Potentially Terrestrial Life-bearing Aerosols Capture	Leading, North (Anti-Pressurized Facility)	Capture	Every Year, up to 3 times
ST2: Terrestrial Microbe Exposure	Space	Exposure	1 tray after 1st, 2nd, 3rd years
ST3: Astronomical Organic Analog Exposure	Space	Exposure	1 tray after 1st, 2nd, 3rd years
ST4: Organic-bearing Micrometeoroid Capture	Space, North (Anti-Pressurized Facility)	Capture	Every Year, up to 3 times
ST5: Lowest Density Space-borne Aerogel Verification	Space, Leading, North (Anti-Pressurized Facility)	Capture	Every Year, up to 3 times
ST6: Orbital Debris Flux Evaluation	Leading, North (Anti-Pressurized Facility)	Capture	Every Year, up to 3 times

In-Orbit Operation Scenario



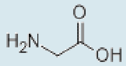
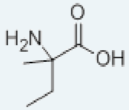
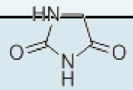
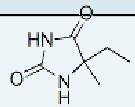
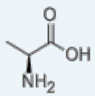
Dimension and Structure of Exposure Panel



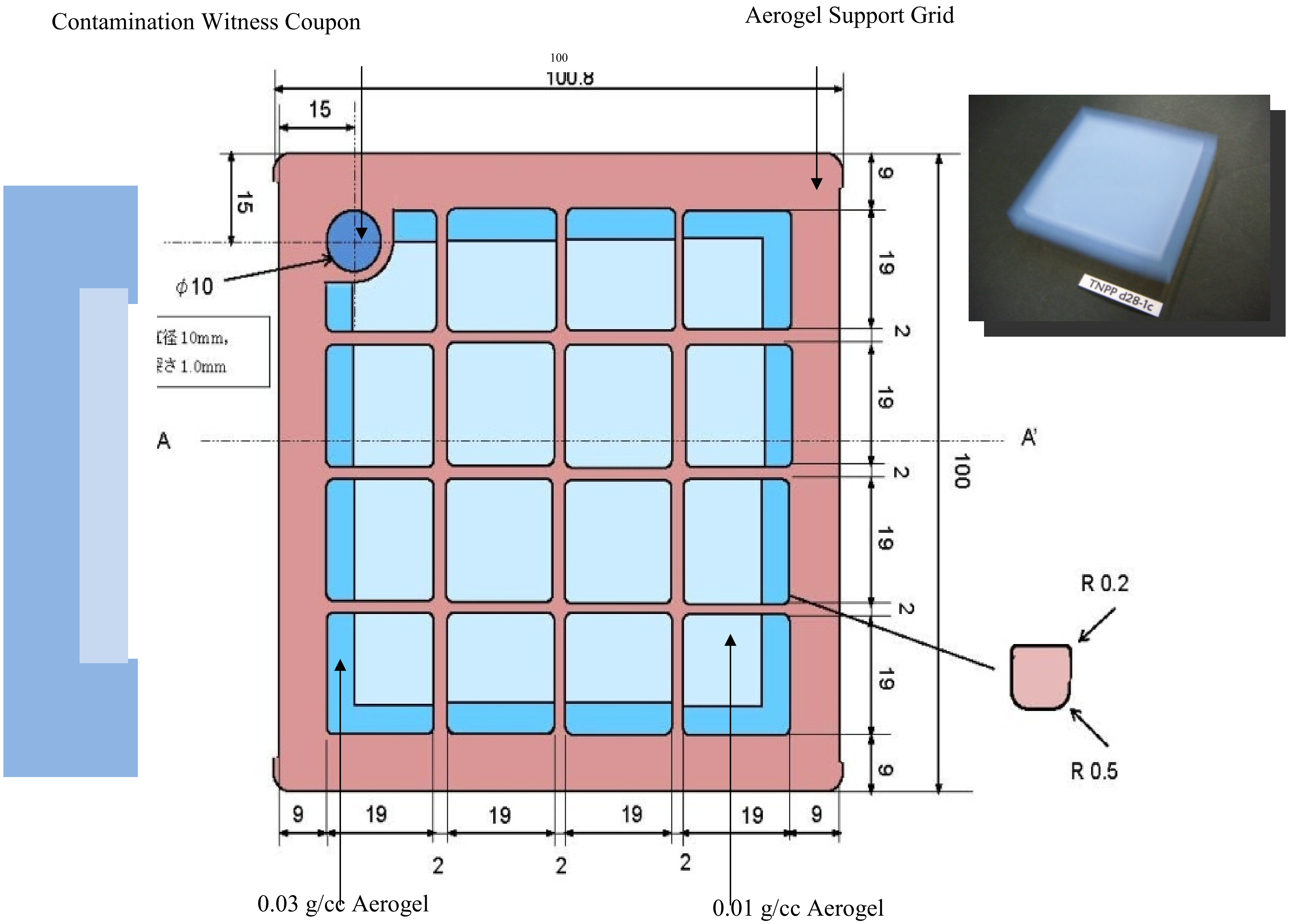
Candidate Microbes for Space Exposure Experiments

Species (strain)		Window			Characteristics of microbes
		MgF_2 (>110 nm)	Quartz (>170 nm)	Complete shielding	
Deinococcus radiodurans	R1	○	○	○	Radio- and UV- tolerant bacteria. This strain is treated as wild type of this species.
	KH311	○		○	Defective mutant strain of *D. radiodurans* on the nonhomologous end joining repair (mutant of pprA)
	UVS78	○		○	Defective mutant strain of *D. radiodurans* on the nucleotide excision repair (mutant strain of uvrA and uvdE)
	rec30	○		○	Defective mutant strain of *D. radiodurans* on the homologous recombination (mutant strain of recA)
Deinococcus aerius TR0125		○		○	Deinococci isolated at high altitude. Radio- and UV- tolerant bacteria.
Deinococcus aetherius ST0316		○		○	
Nostoc sp. HK-01		○		○	Terrestrial cyanobacteria
Schizosaccharomyces pombe JY3				○	Spore-forming (fission yeast, Eukaryote)

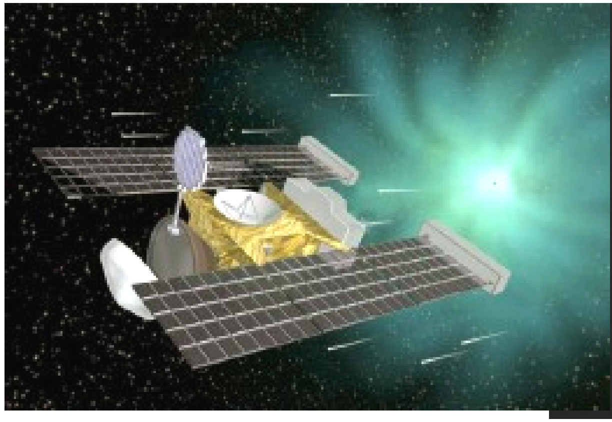
Candidates of organic compounds for space exposure (These will be covered with MgF_2 window, quartz window, and stainless steel)

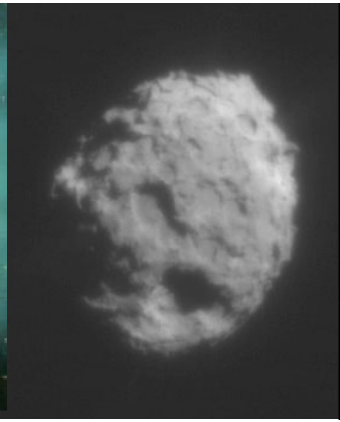
Compound name	Chemical formula	Structural diagram	Characteristics of compounds
Glycine	$C_2H_5NO_2$		Measuring stability and metamorphosis of glycine that is abundant in both organisms and meteorites. This compound has desorbing proton at the alpha position. The stability of this compound is compared with that of isovaline which does not have such proton and is known to show the bias of ratio of enantiomers.
Isovaline	$C_5H_{12}NO_2$		Measuring stability and metamorphosis of isovaline that is known to show the bias of ratio of enantiomers in meteorites. This compound is thought to be more stable than usual amino acids, as it does not carry desorbing proton at alpha position. In addition, this compound is abundant in carbonaceous meteorites, so that it is important to discuss the origin of homochirality.
Hydantoin	$C_3H_4N_2O_2$		Hydoantoin is the low-molecular-weight precursor of glycine. Its stability will be compared with glycine (precursor and amino acid) and methylethylhydantoin (presence/absence of alpha-proton).
Methylethyl-hydantoin	$C_6H_{10}N_2O_2$		Methylethylhydantoin is the low-molecular-weight precursor of isovaline. This compound does not have desorbing proton at alpha position, so that this compound is thought to be more stable than hydantoin.
Simulated interplanetary molecules	Complex organic compounds formed from the mixture of CO, NH_3, and H_2O by irradiation of heavy ion beam		Precursor of amino acids. The stability of complex organic compounds that might be provided from the interstellar molecule cloud will be compared with the low-molecular-weight precursors and amino acids.
Alanine	$C_3H_7NO_2$		Degradation and chiral inversion of alanine as well as peptide synthesis under the VUV (>110 nm) irradiation will be analyzed. The sample covered with quartz window will be used as the integral VUV dosimeter. (Dr. K. Nakagawa at Kobe Univ.)
Meteorite powder			The stability and metamorphosis of organic compounds in meteorites will be analyzed. (Dr. H. Yabuta at Osaka Univ.)

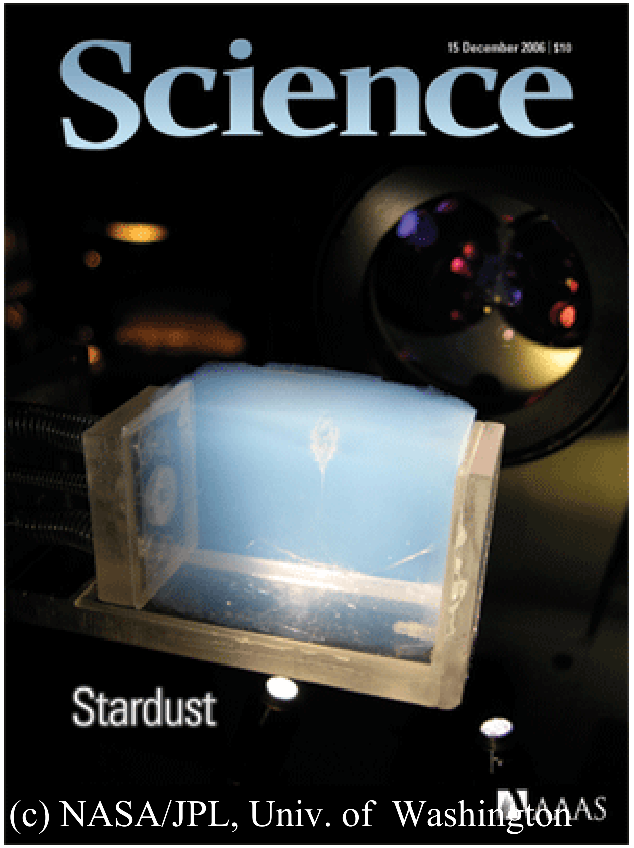
Dimension and Design of Capture Panel (mm)



Stardust, Cometary Coma Sample Return with Aerogels





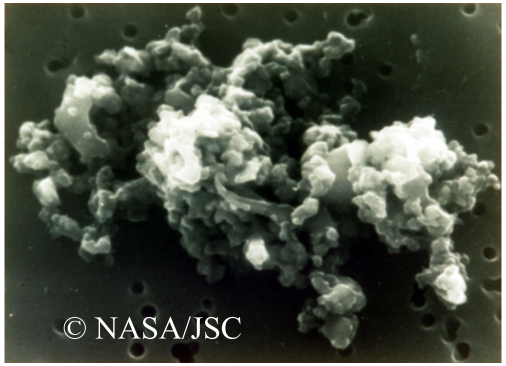


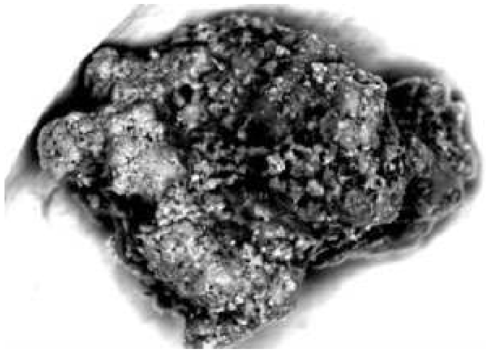
(c) NASA/JPL, Univ. of Washington

- Comet Wild/2 coma flyby
- Launch: Feb. 1999
- Interstellar Capture: 2002
- Cometary Capture: Jan. 2004
- Earth Return: Jan. 2006
- Curation: NASA/JSC
- "Intact" capture of hypervelocity impacted dust(6.1 km/s) into 0.03 g/cc aerogel
- Collected cometary dust of > 15 μm x > >1000 particles

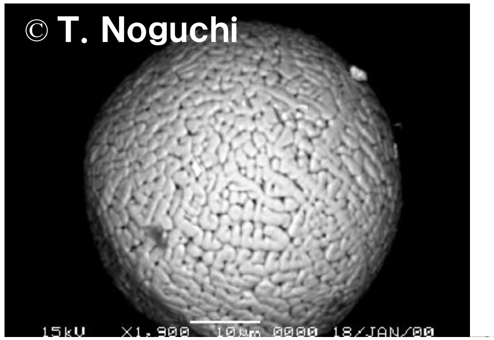
New Era of Astromaterial Research with the Ground Truth

IDP, AMM, CS on Ground

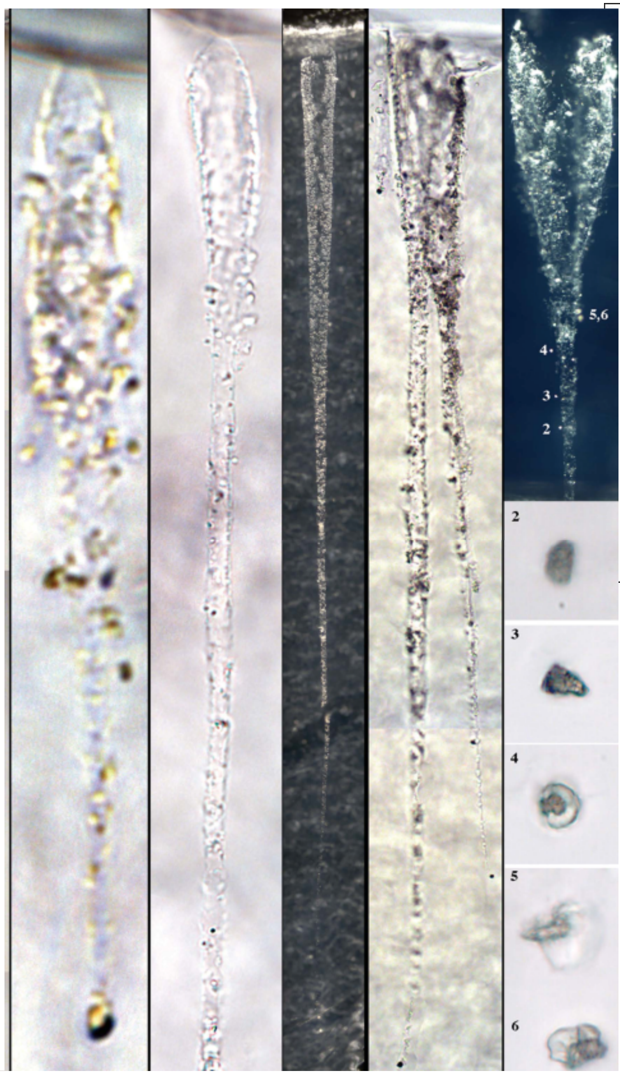




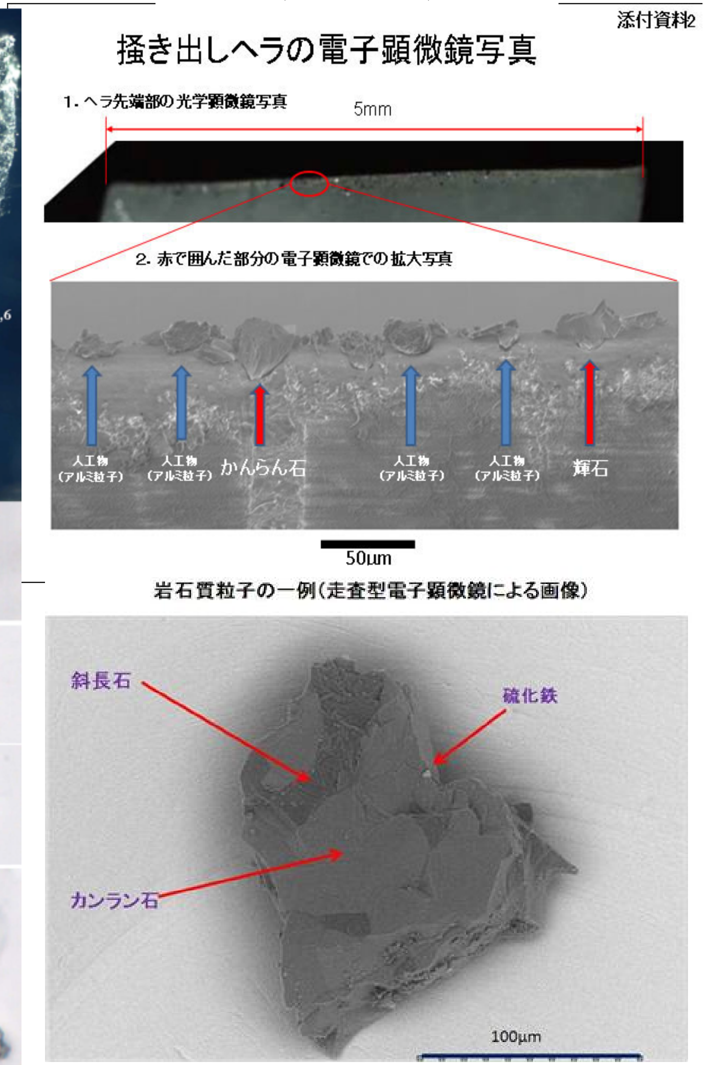
© Yano & Noguchi



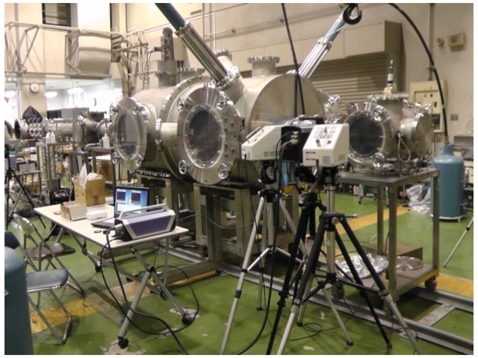
Stardust Samples（NASA）

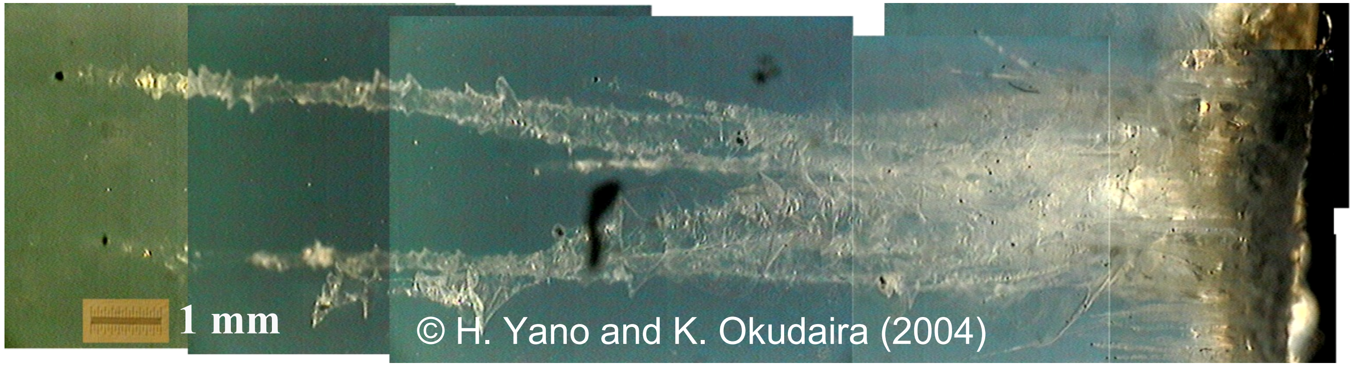


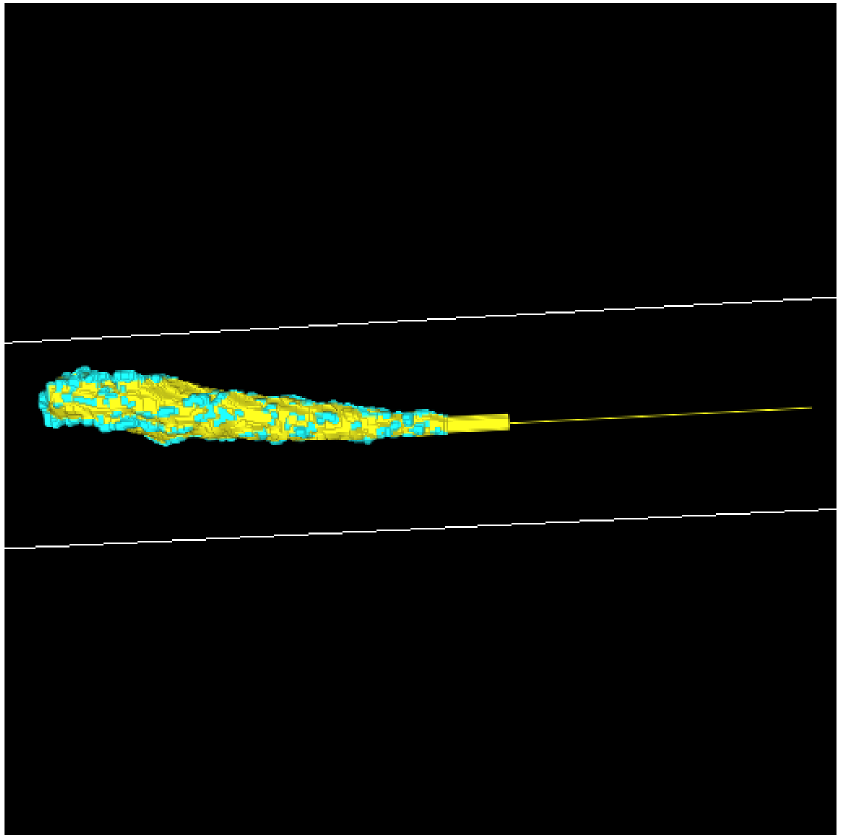
Hayabusa Samples （JAXA）

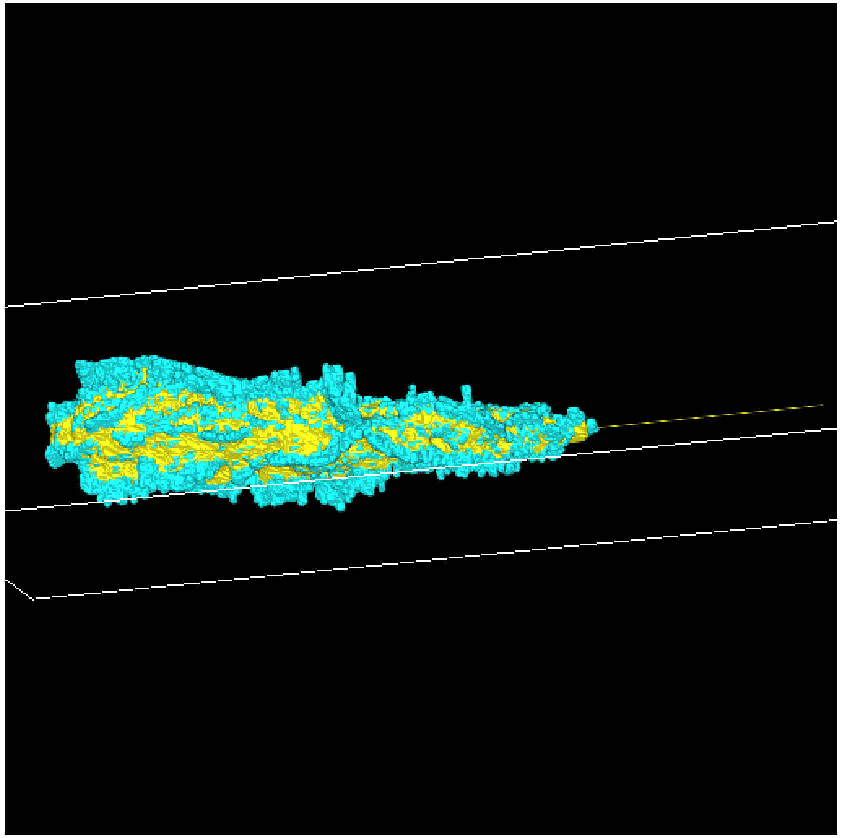


XCT Measurements of Crack Volume and Morphology







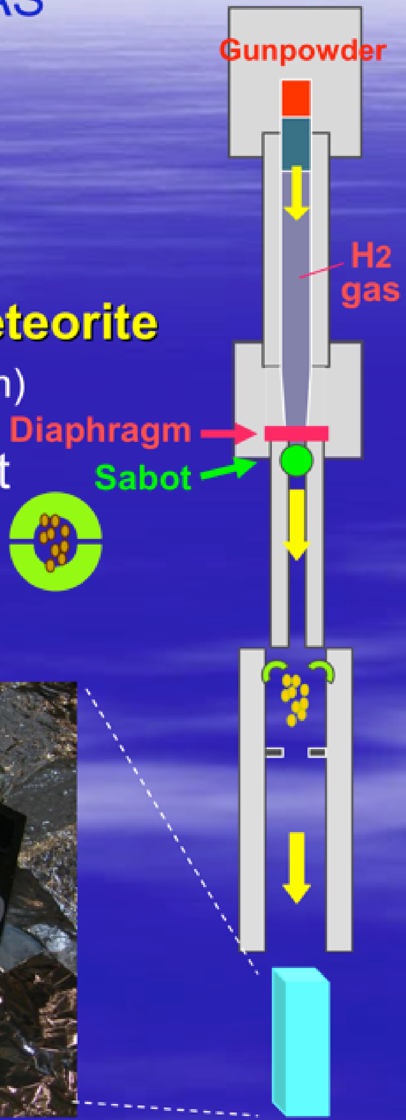


Hypervelocity impact experiment using a two stage light gas gun

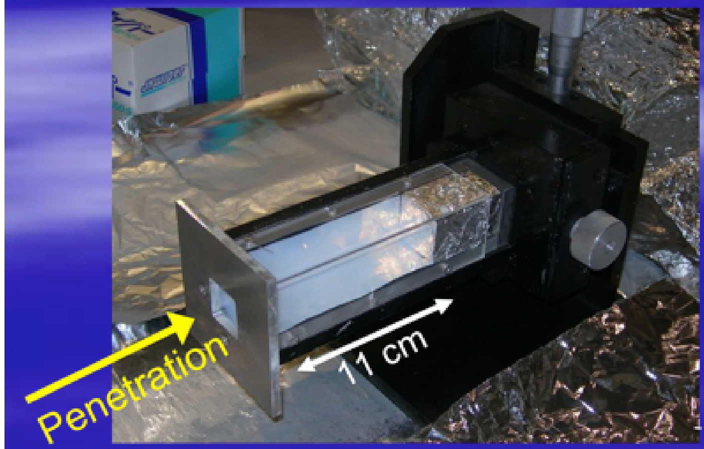
at JAXA/ISAS

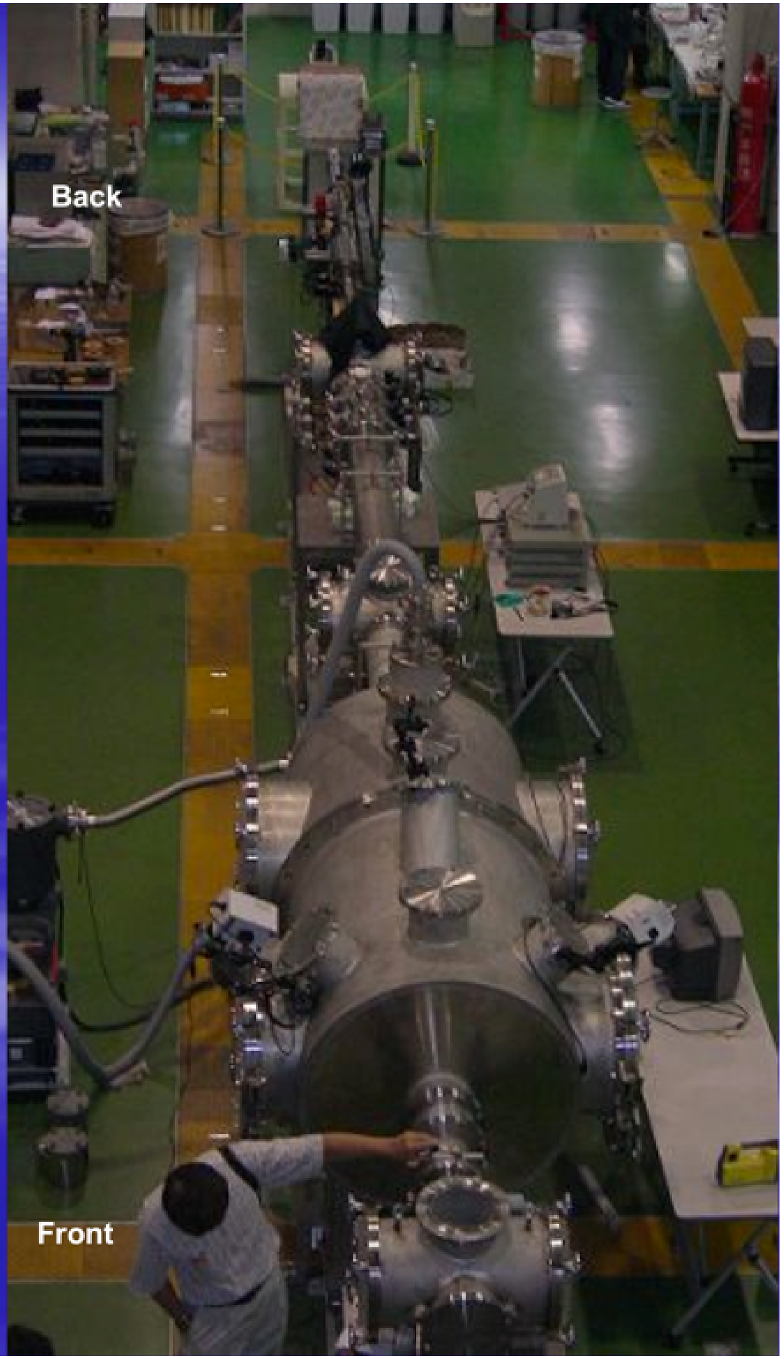
- Impact velocity: **4 km/s**
- Multiple particle shot
- Sample: **Murchison meteorite powder** 500 μg (30–100 μm)

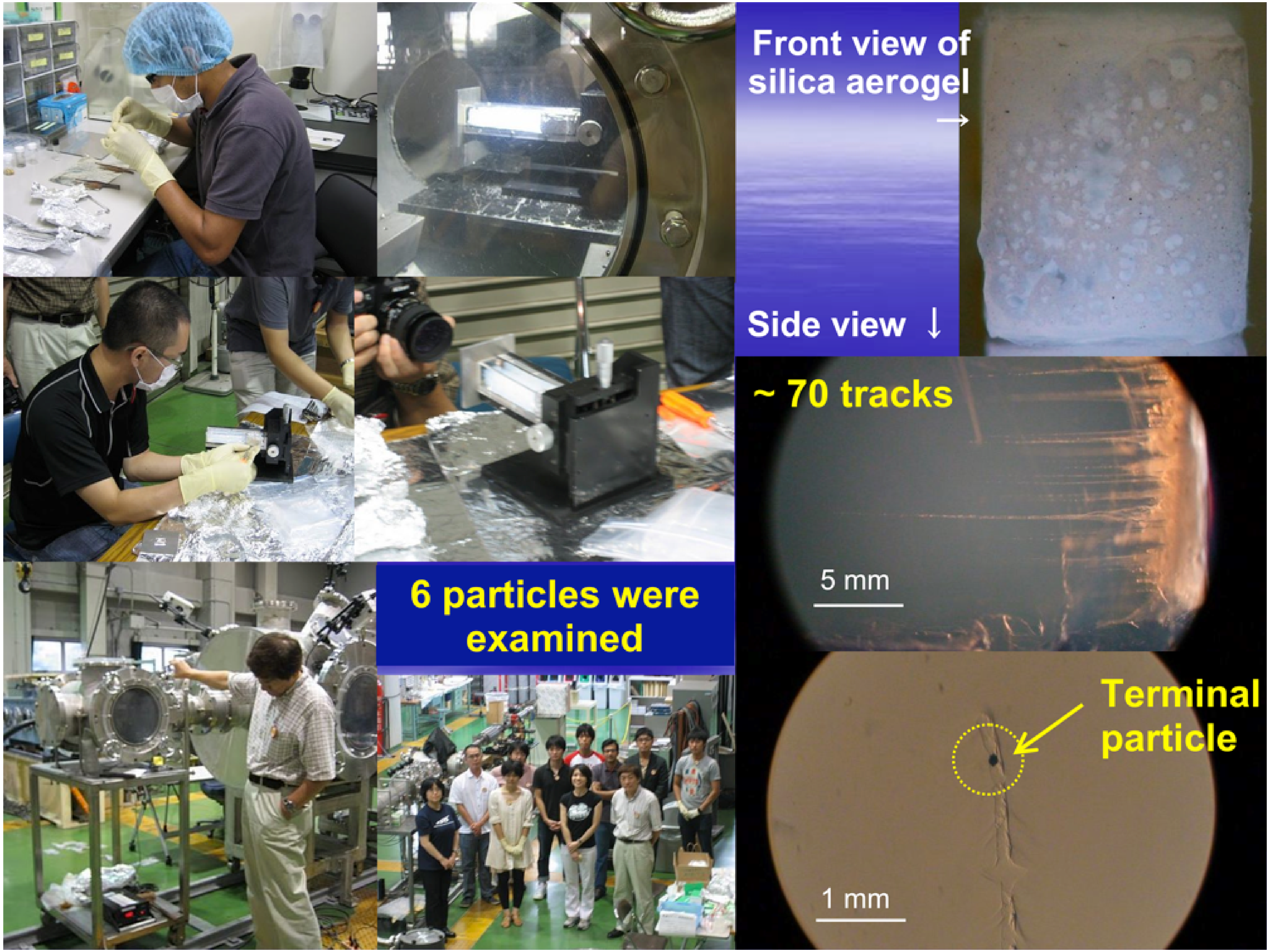
  in a polycarbonate sabot



Silica aerogel

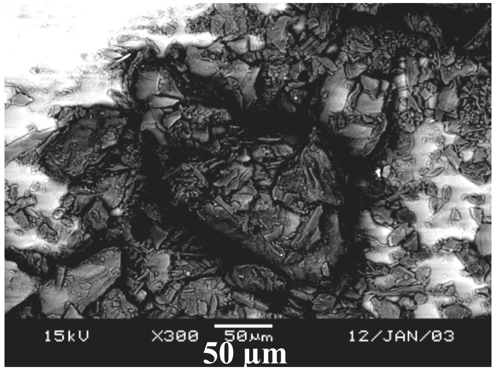


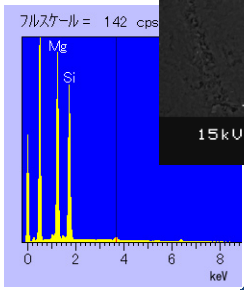



Front view of silica aerogel
Side view
~ 70 tracks
5 mm
6 particles were examined
Terminal particle
1 mm

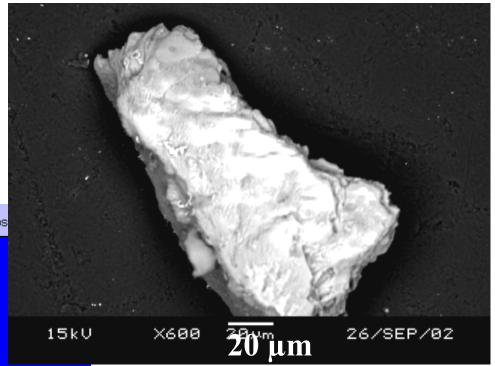
HVI Captured Dust Alteration by Aerogels (0.03 g/cc)

(Serpentine)
Before the shot

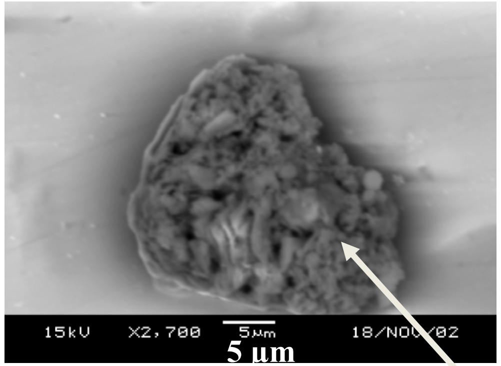




After extraction
(3.76km/s)

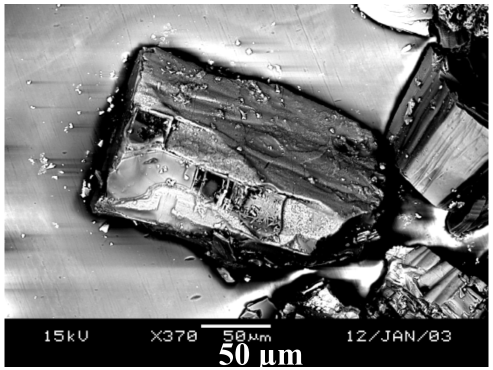


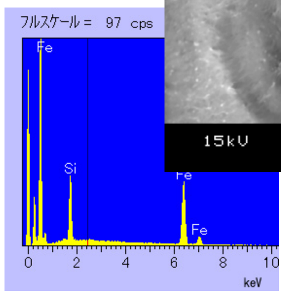
After extraction
(6.21km/s)



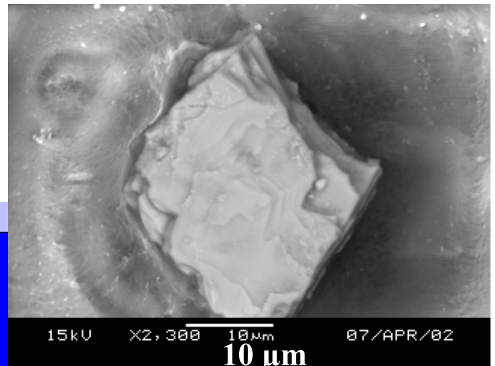
VESICULATED TEXTURE

(Cronstedtite)
Before the shot

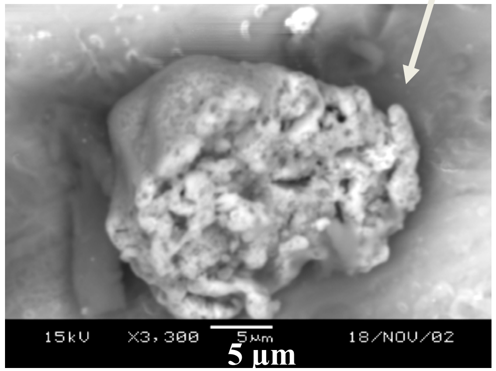




After extraction
(3.17km/s)

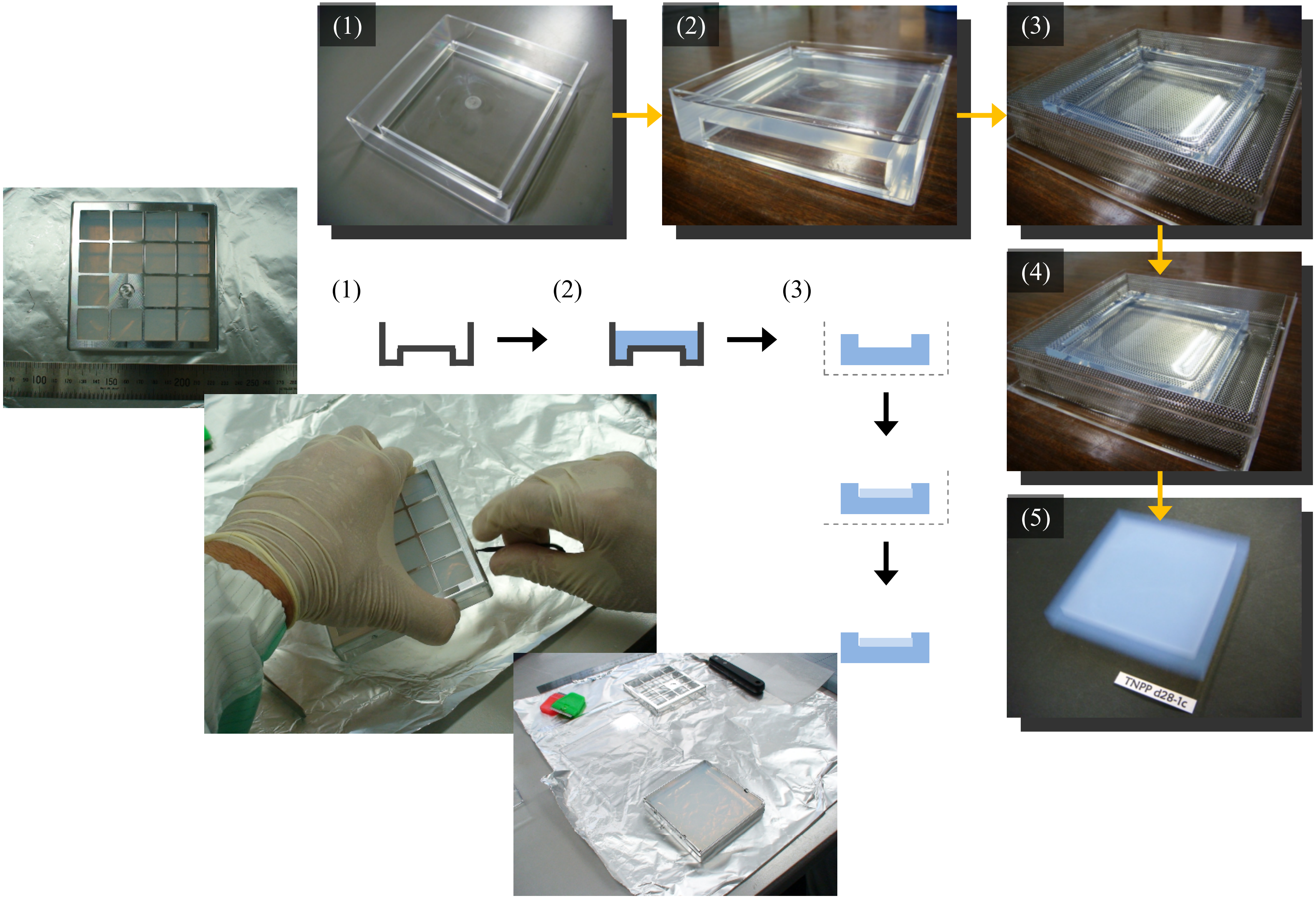


After extraction
(6.06km/s)



(Okudaira, et al., 2005)

How to Mold the Tanpopo Double-Layered Silica Aerogel



Post-Retrieval Flow Plan for ISAC-CP at ISAS:

Procedures 1-4 should be completed in the first 100 days after receiving the returned samples at LABAM

1) Photo-documentation (Capture Panel ---> aerogel tiles)

2) Sample selection

 2-1) Scan & Identification of track entry holes

 2-2) Identification of tracks

 2-3) Give ID to each track

 2-4) Position logging and archive database

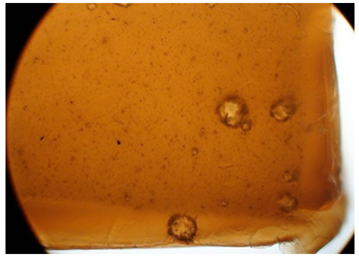
 2-5) Select high priority tracks to be extracted

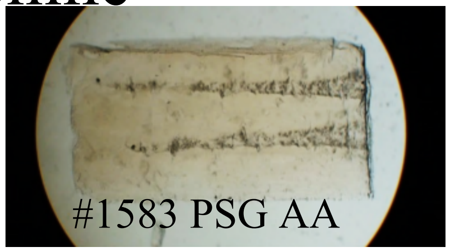
3) Extract “YOUKAN”s (keystones)

 3-1) Define cutting lines of keystones

 3-2) Extract keystones with the “YOUKAN machine”

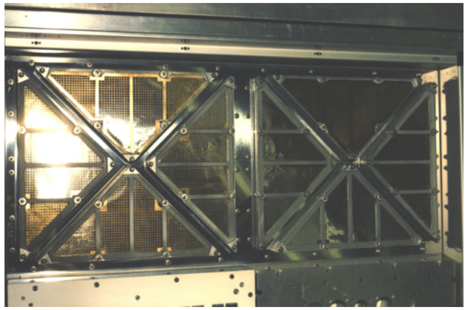
4) Allocate YOUKANs to respective sub-theme researchers

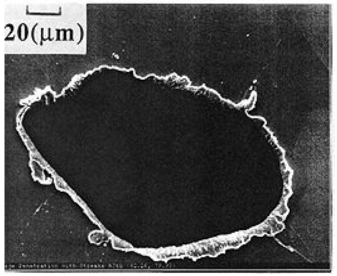


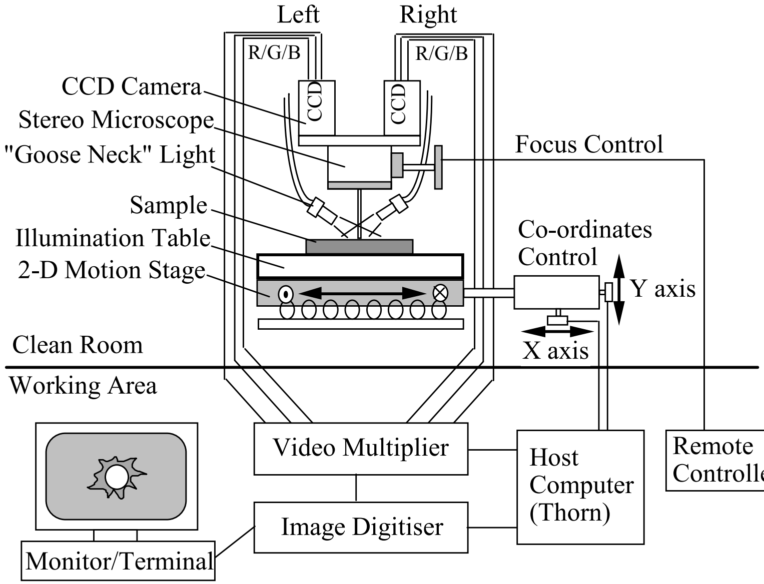


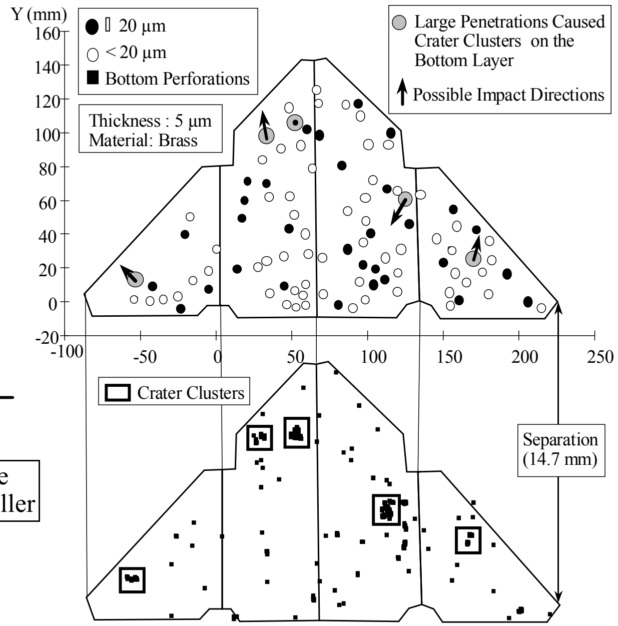
Past Examples of Optical Detection Systems of Retrieved Spacecraft

LDEF

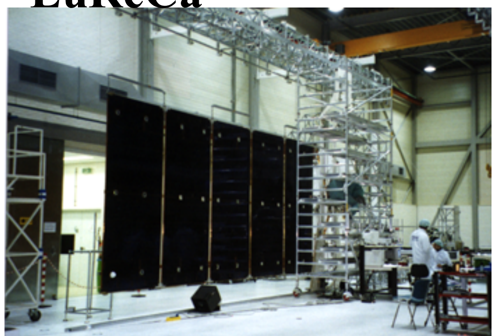


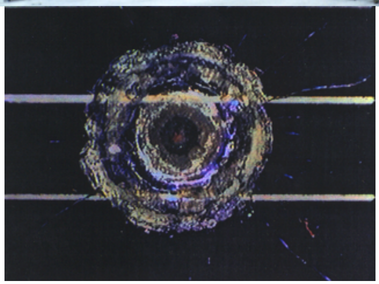


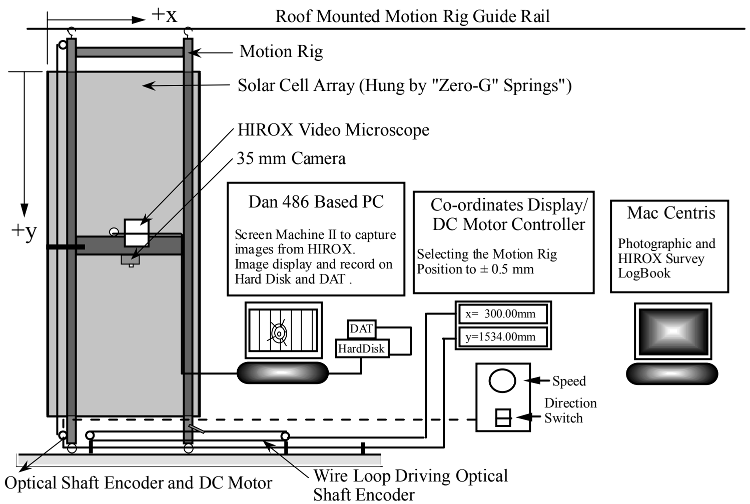


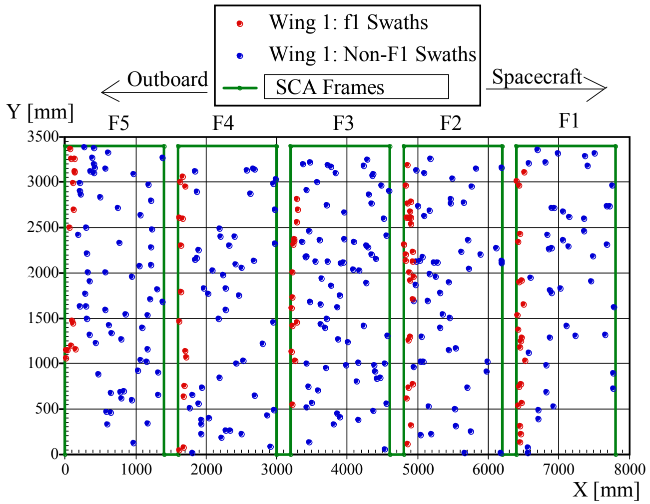


EuReCa



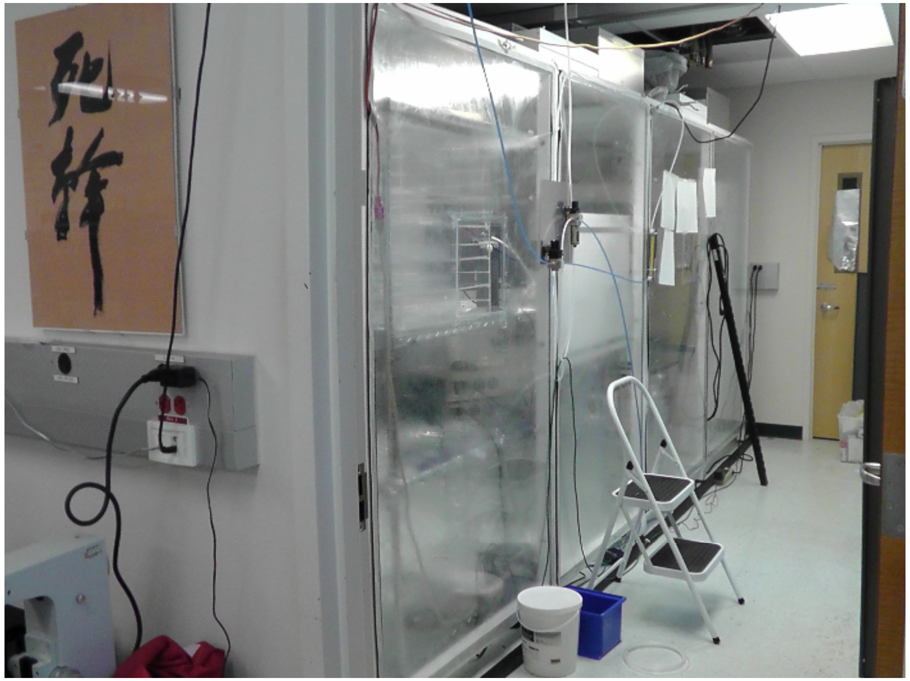


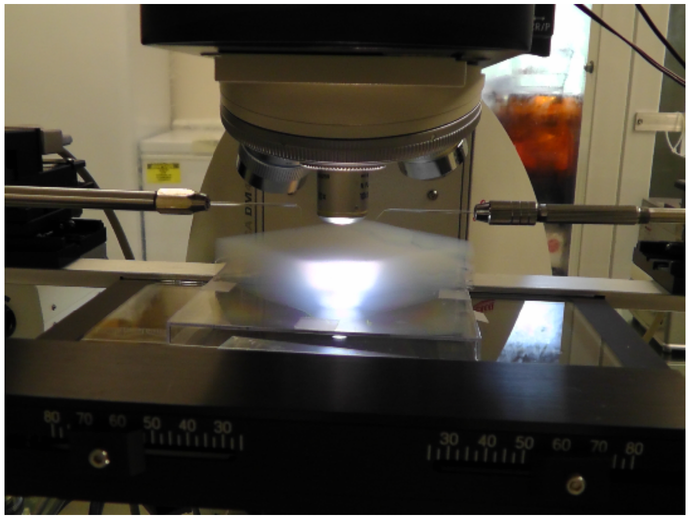




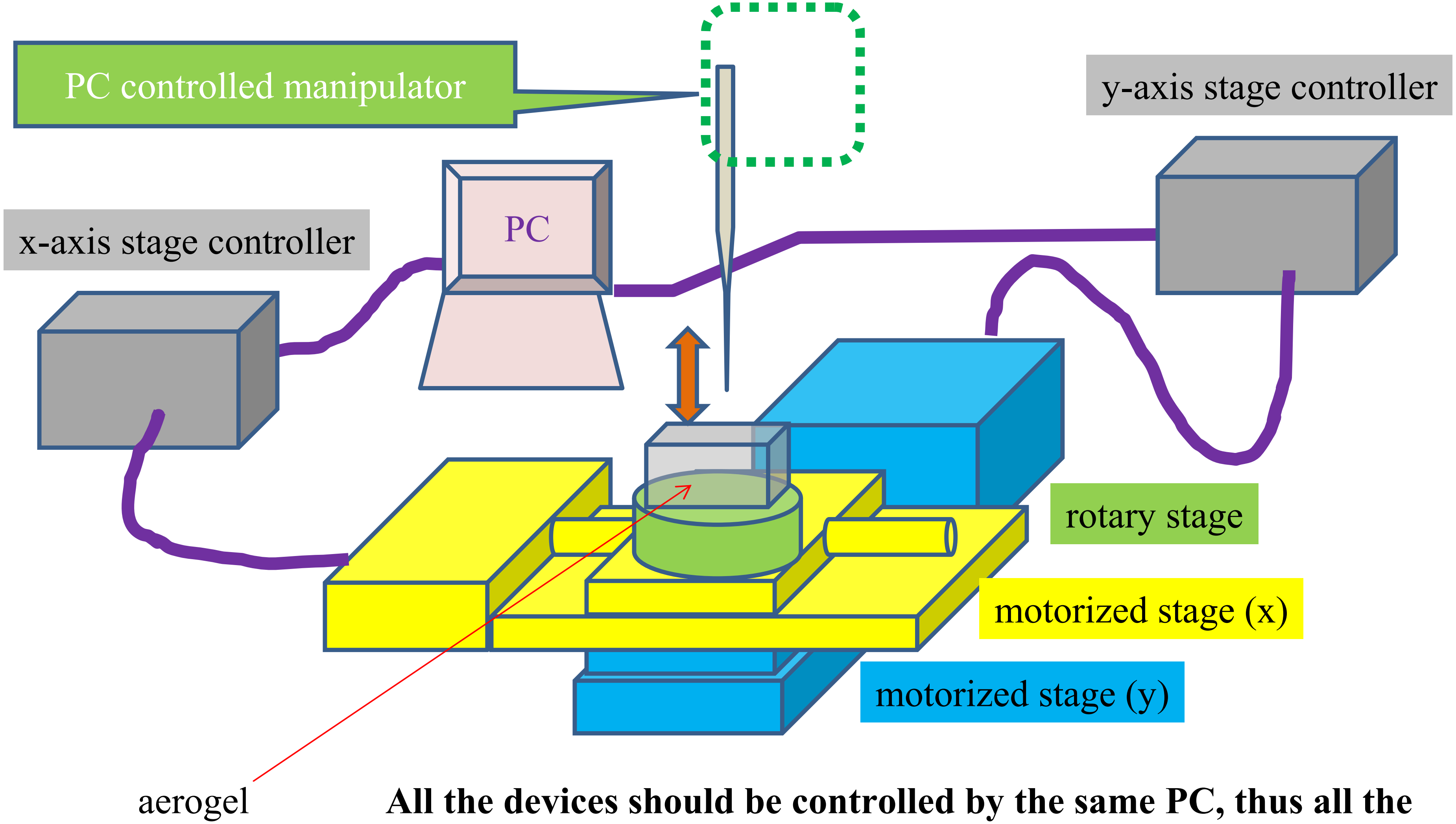
(Yano, 1995)

A Reference: Stardust Key Stone Machine at UC Berkeley SSL (Courtesy: A. Westphal)





Schematics of the ISAS “Youkan” Machine System



All the devices should be controlled by the same PC, thus all the program should be written by the same language. (prime candidate: C)

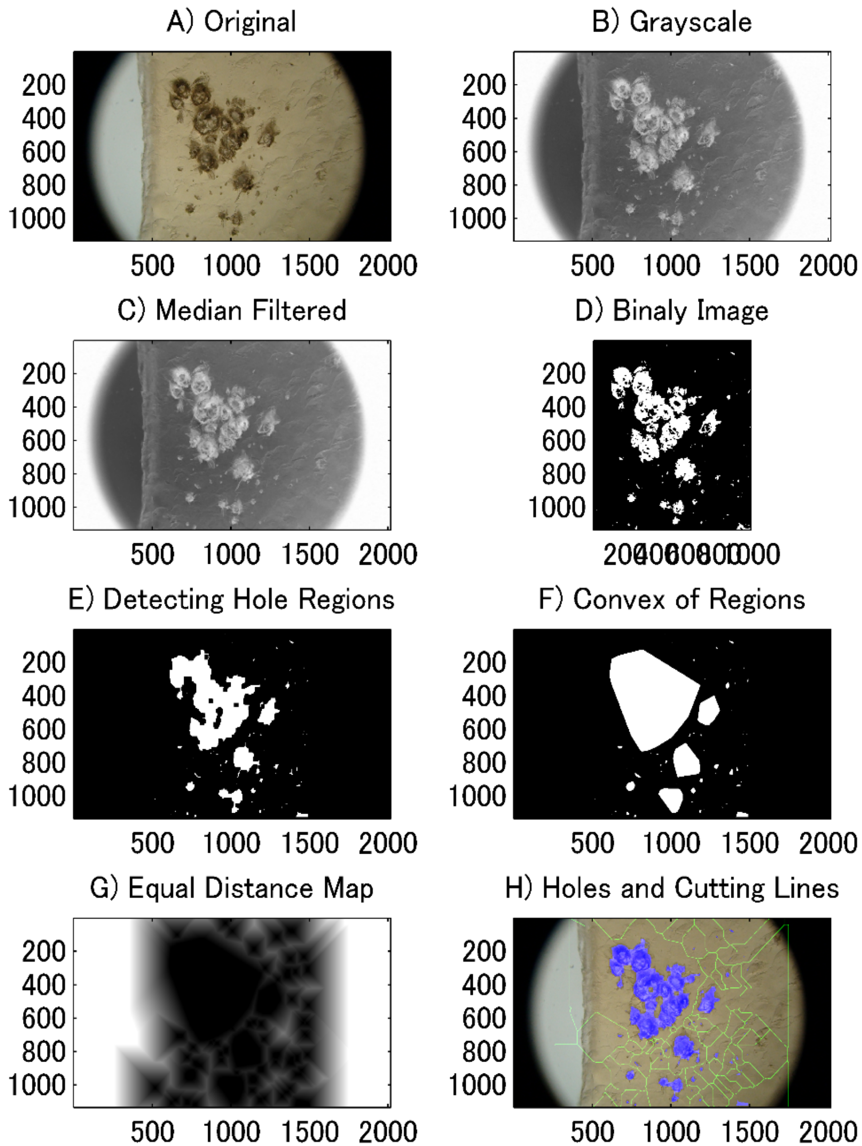
Algorithm for Identification of Track Entrance Holes

Optical microscopic image

Noise reduction

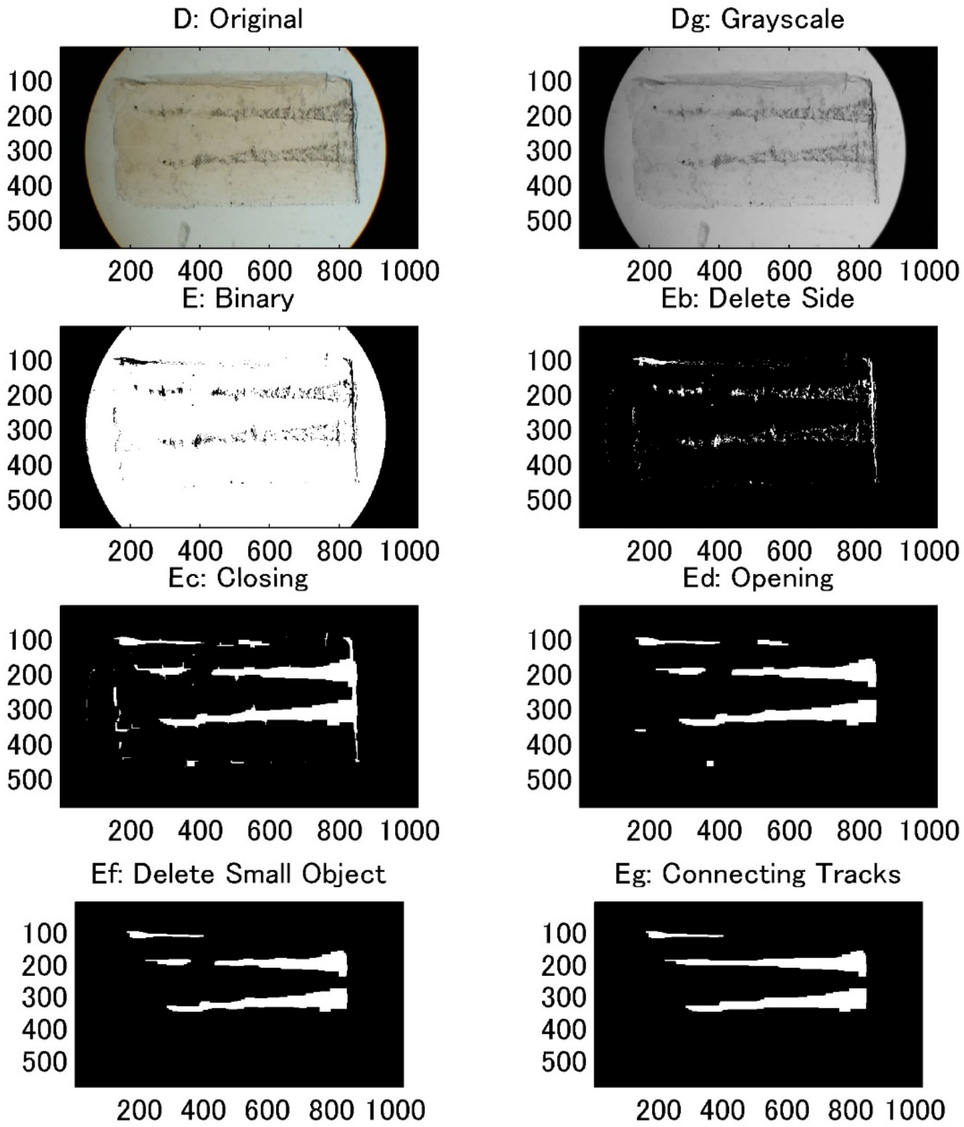
Identify track holes

Try to group the track entry holes



Define all the holes and their groups on the surface, as a first step for cutting Youkans (in progress)

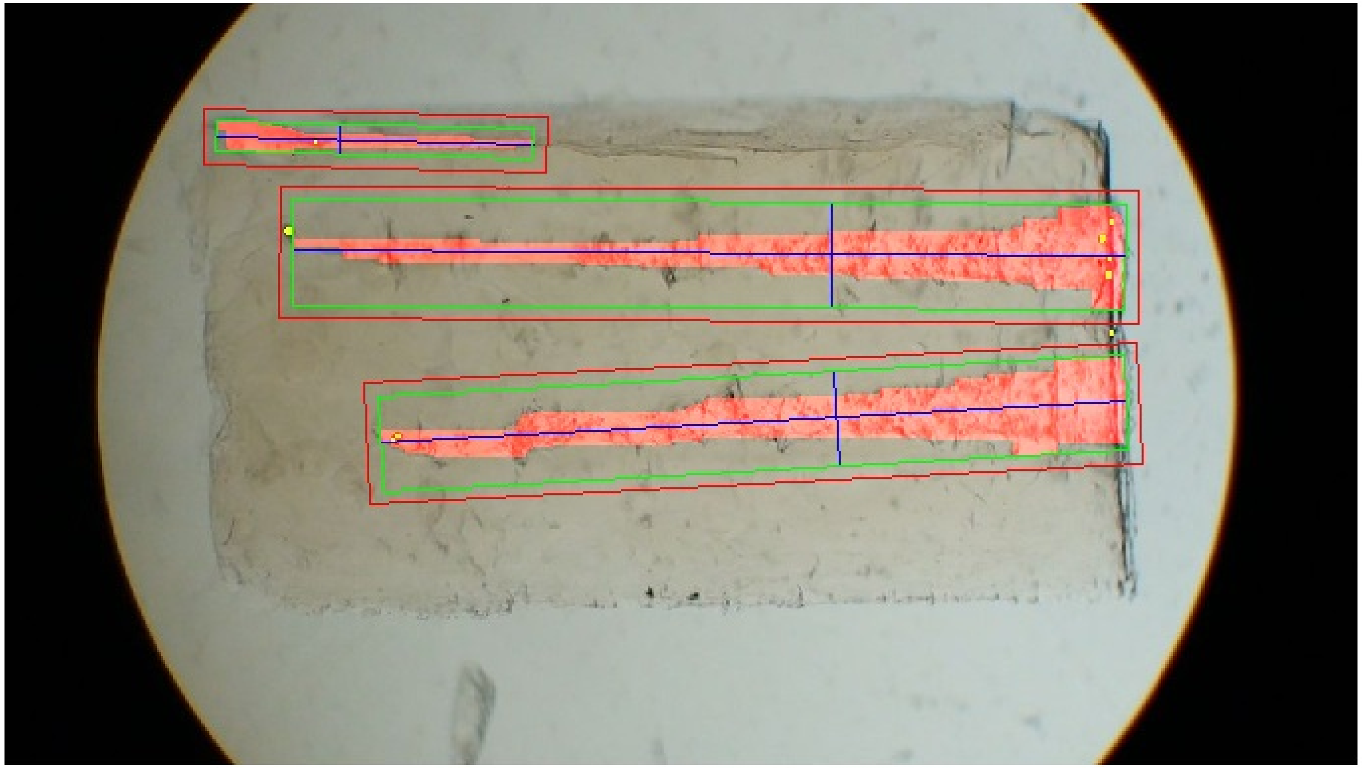
Algorithm for Identification of Tracks



Try to detect each track shape by image analytical techniques

Try to exclude “false (non-track)” areas on the image

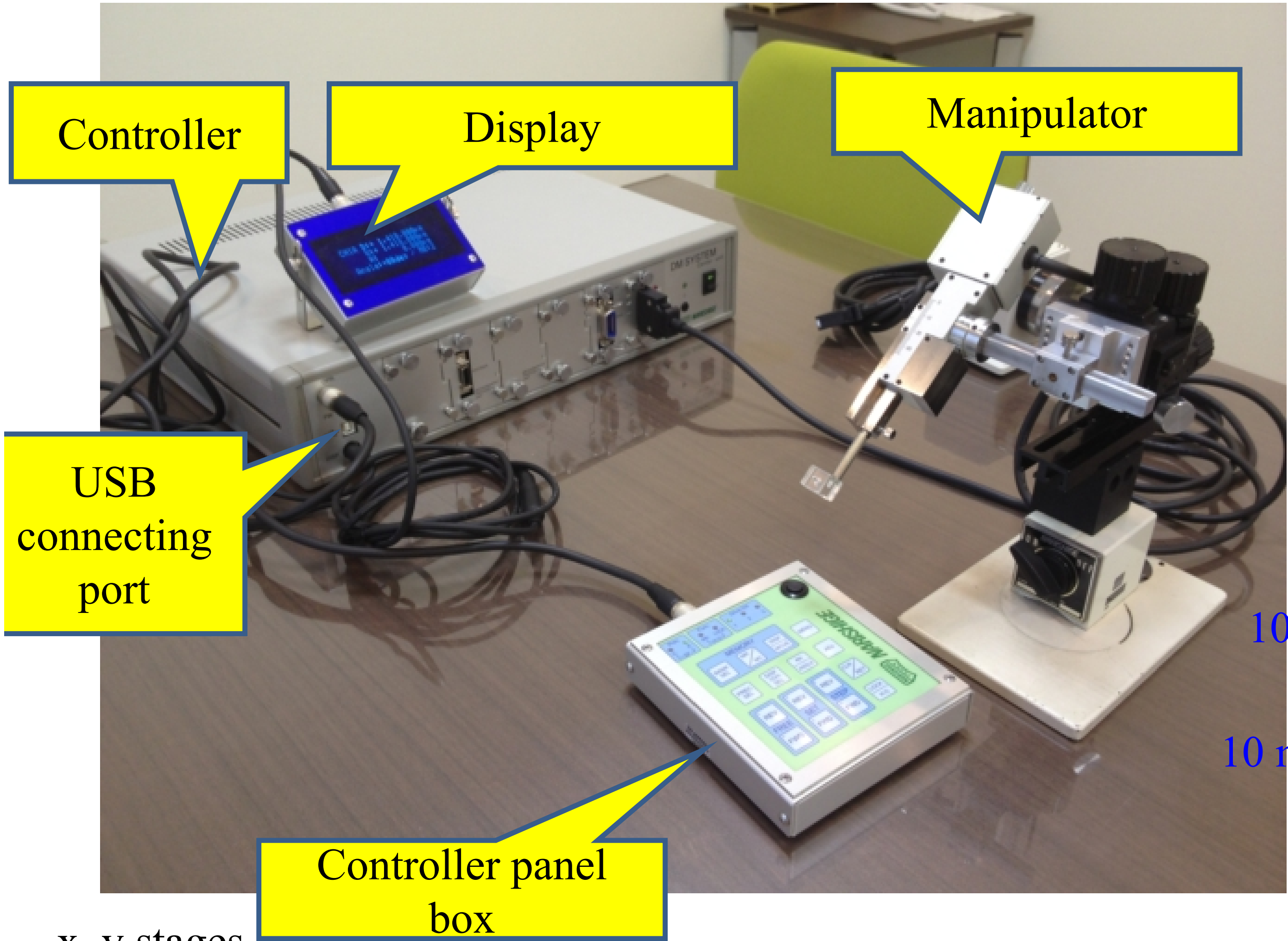
Define cutting lines of YOUKANs

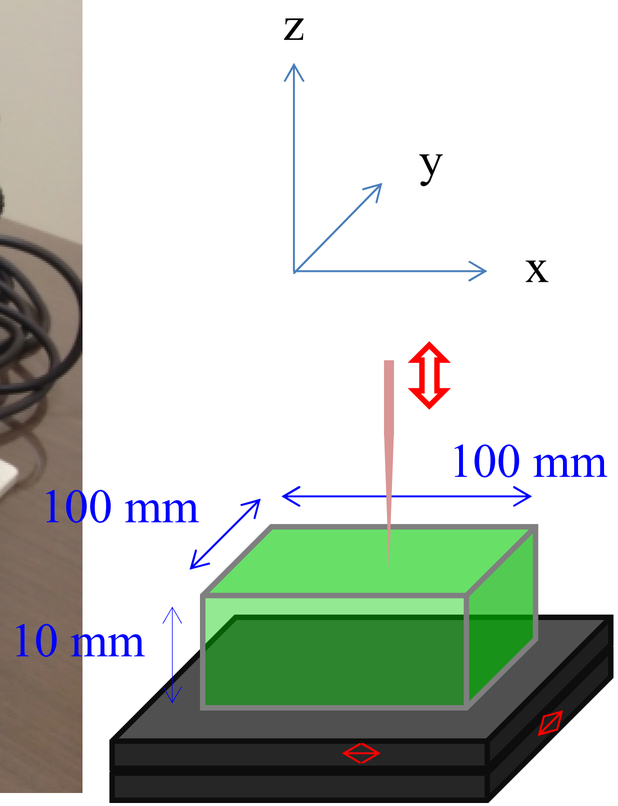


One result is shown.
Unsolved problems:
A false area (upper left) is remained.
Margins for terminal particles are necessary.

(in progress)

Manipulator Control System BBM Test

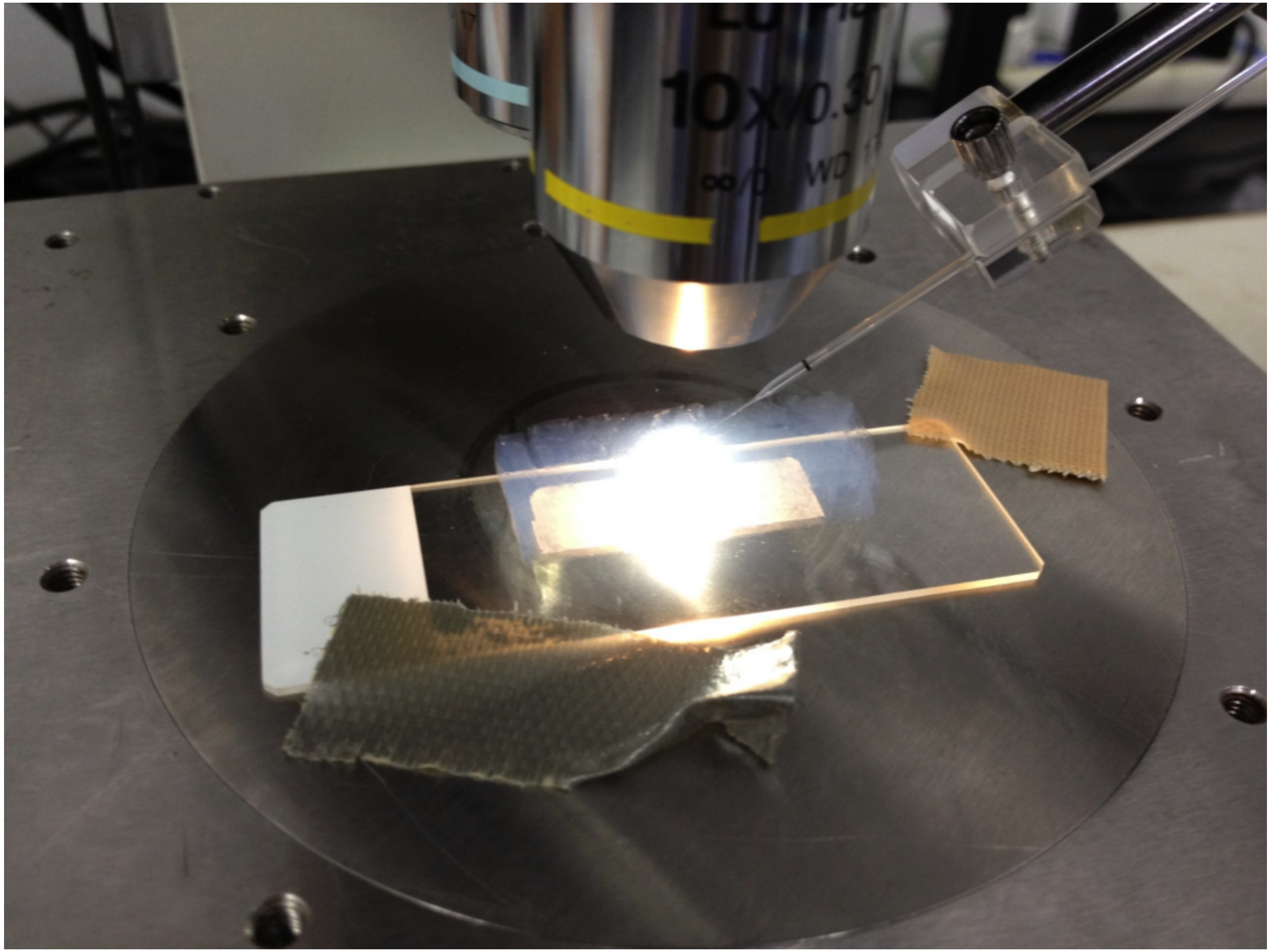




x, y stages
travel range: 100 mm
positional resolution: 10 µm
traveling velocity: maximal 10 mm s^{-1}

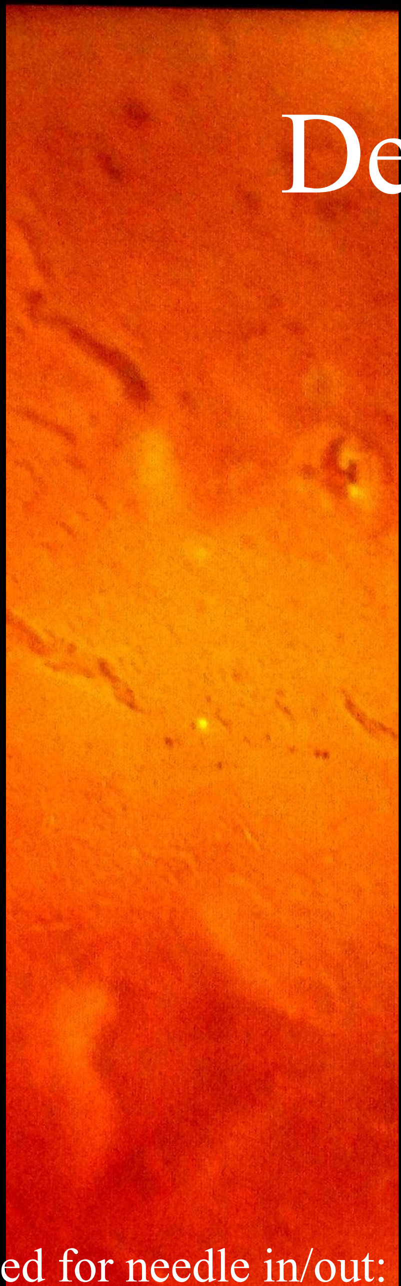
Manipulator
travel range: minimal 14.1 mm
positional resolution: 10 µm
traveling velocity: maximal 10 mm s^{-1}

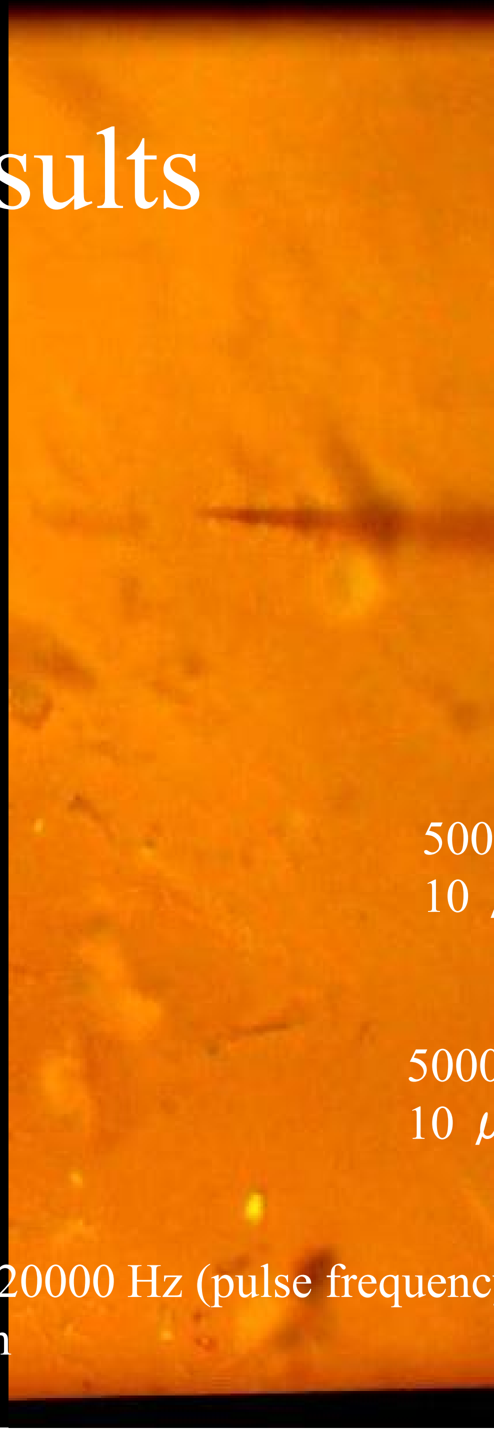
A Close-Up Image of the TNPP Aerogel and a Glass Needle



Needle angle: ca 30 deg vs horizontal plane
Needle: prepared from silica glass tube using a puller

Demo Results





100 μm

10000 Hz in
5000 Hz out
50 μm step

20000 Hz in
10000 Hz out
50 μm step
total 300 μm

5000 Hz in/out
10 μm step

5000 Hz in/out
10 μm step

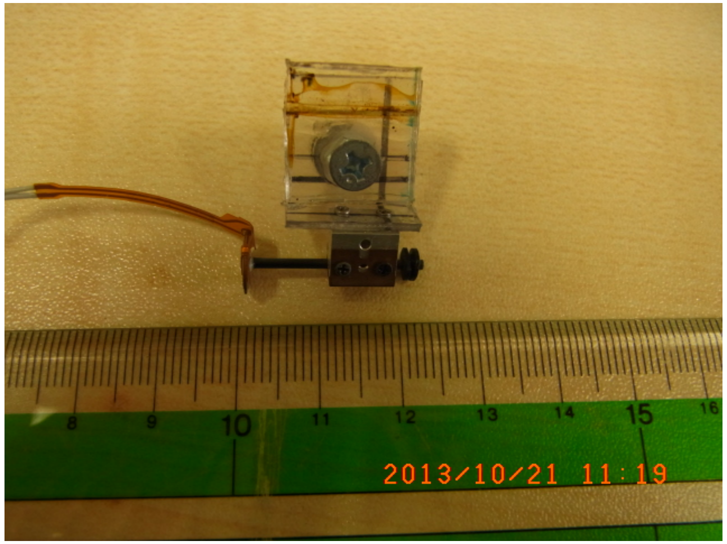
5000 Hz in/out
10 μm step

Speed for needle in/out: 5000, 10000 and 20000 Hz (pulse frequency: larger → faster)
Total length step of inserting: 50, 100 μm
Total length of inserting: 100, 300 μm

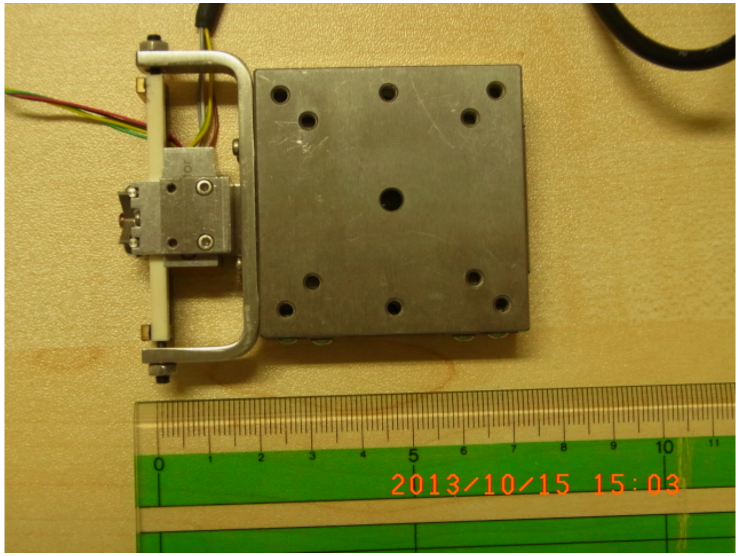
Motorized Stage and Integration Demo (On-Going)

Piezo-based

■Manipulator (Microminiature ultrasonic linear actuator,TULA series, Technohands Co. Ltd; resolution 1 μm)

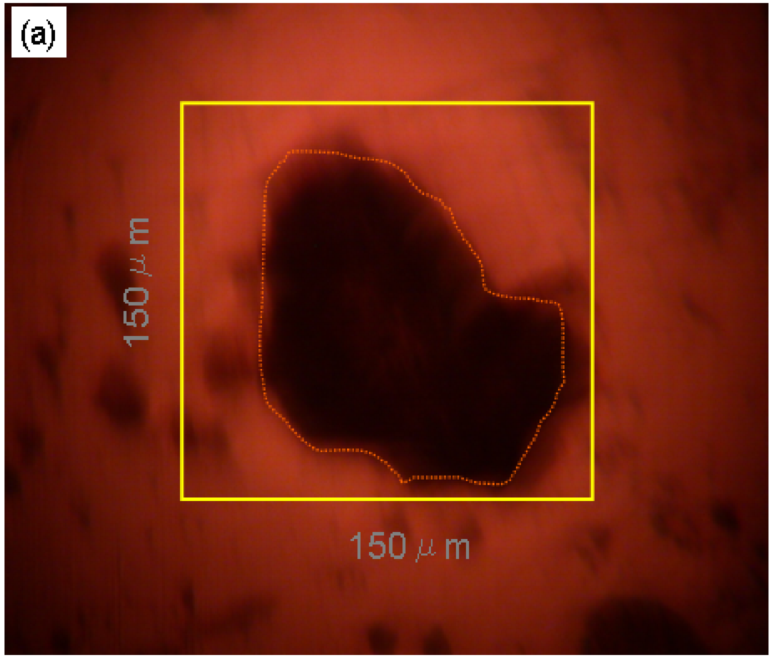


■Stage (High precision linear stage, Feinmess; resolution 0.1 μm)

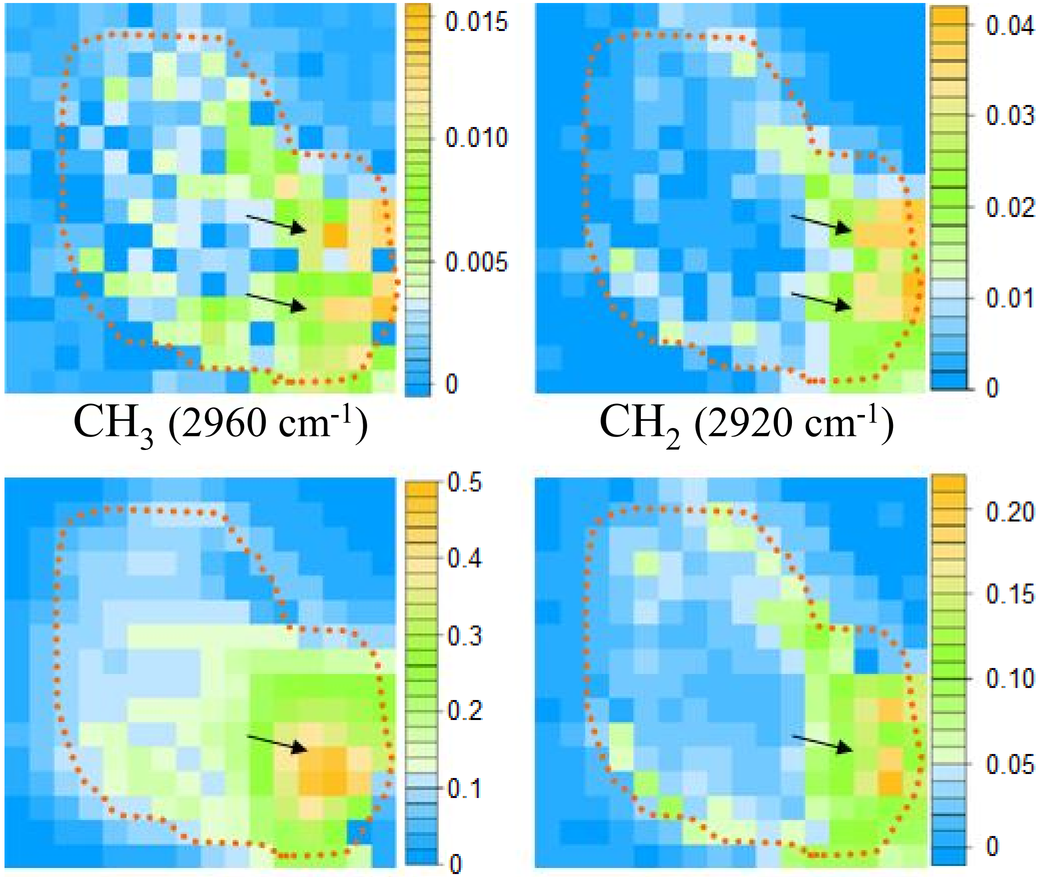


Possibly controllable using a single program

μ-FTIR imaging (Reflection) of A Terminal Particle



Murchison terminal particle (150 x 150 μm) extracted from the aerogel and pressed between two Al foils



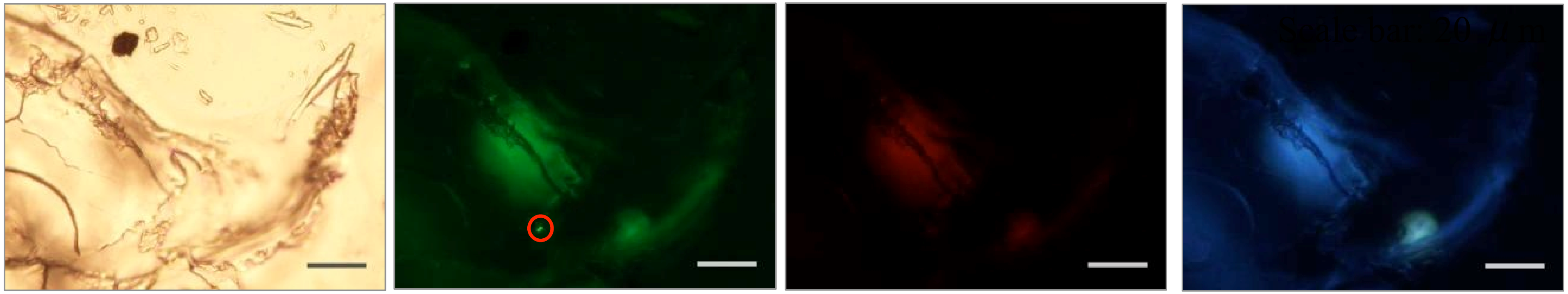
CH_3 (2960 cm^{-1}) CH_2 (2920 cm^{-1})

SiO (1100 cm^{-1}) OH (3600 cm^{-1})

- The regions of aliphatic carbons (CH_3 and CH_2) detected within the terminal particles indicates the survival of organics through the high velocity impact of 4 km/s

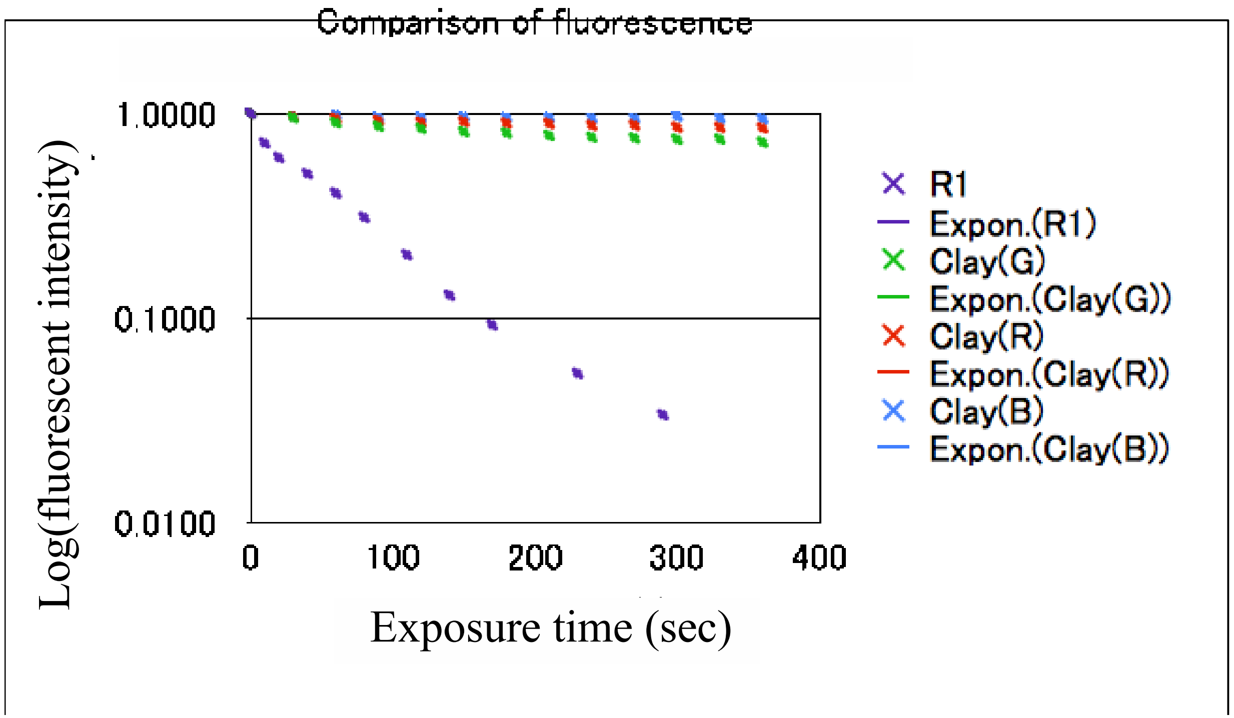
- Distributions of aliphatic carbon and phyllosilicates (SiO, OH) are similar to those in the pre-shot carbonaceous chondrite (Kebukawa et al. 2010)
  -> Mineral-organic relationship is not modified by high velocity impact

Microorganisms embedded in lucentite particles were accelerated (4 km/s). The track was stained with fluorescence dye. Fluorescent particles (green with SYBR Green) were detected in the aerogel.



Green fluorescence

Red fluorescence

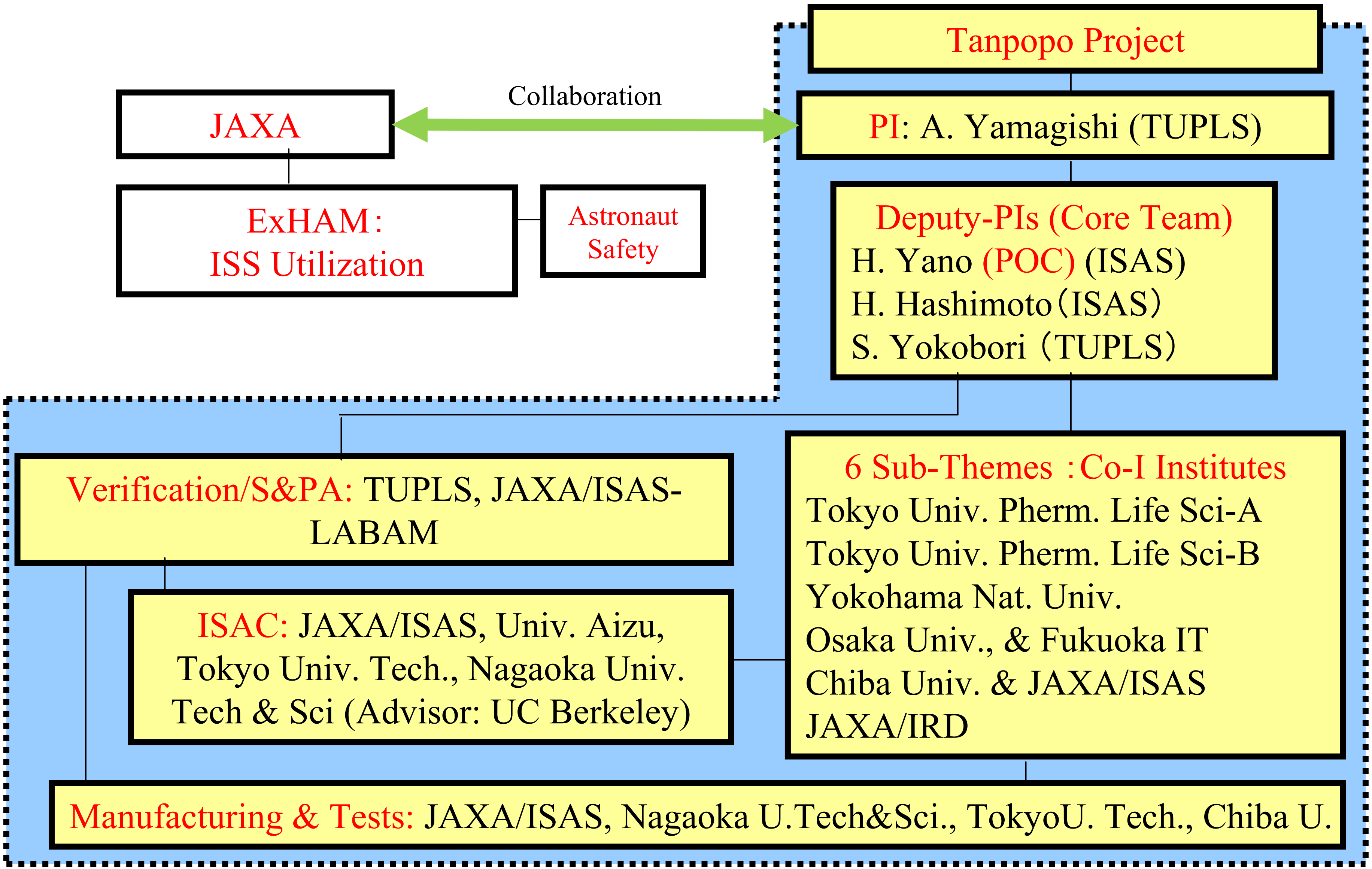


The fluorescence characteristics are different between *Deinococcus radiodurans* and Lucentite (clay material)

Bleaching of green fluorescence from stained *D. radiodurans* R1 is faster than fluorescence from the glass

Kawaguchi et al. (in preparation)

Tanpopo Team Organization



Tanpopo Development Schedule

2007-8 Selected as a Kibo-EF experiment candidate and conducted MDR/SRR/SDR
2008-9 Development of the 0.01 g/cc double-layer aerogels
2011-3 Development of ExHAM
2012 ISAC facility allocated at ISAS A1405
Youkan Machine concept design started
2013.09 Tanpopo granted as the formal Kibo-EF experiment to be allocated the flight increment to ISS (equivalent to delta MDR, PDR, Project formulation)

12 Tanpopo CDR
2014.03 Youkan Machine BBM to be completed
05 Tanpopo Flight Model to be completed
fall-2015 spring Flight to ISS and start the experiments

2015 Actual Youkan Machine manufacturing and ISAC dress rehearsal starts
2016 The first samples to be returned to ISAC Facility for YM operation
2017 The second samples to be returned to ISAC Facility for YM operation
2018 The third samples to be returned to ISAC Facility for YM operation
2019 Completion of the ISAC activities (detailed analyses will continue)