[2017-k-03]

Results from the Tanpopo Capture Panels: Using Silica Aerogel for Retrieving Cosmic Dust from Low-Earth Orbits

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On behalf of the Tanpopo Team

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Outline

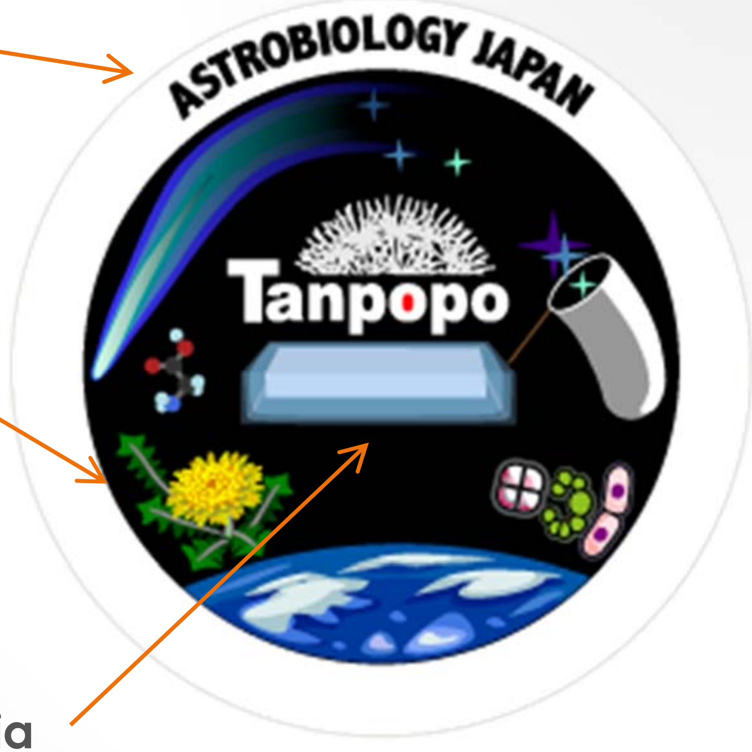
- **Introduction**
  - Astrobiology mission: Tanpopo
  - Silica aerogel: Intact cosmic dust capture media
- **Development of Capture Panels**
  - Capture panel design
  - Capture panel assembly
- **Post-flight Handling/Analysis of Aerogel**
  - Aerogel holder design
  - Preliminary aerogel analysis

Introduction

Tanpopo Mission

- **Japan's first astrobiology mission in space [International Space Station]**
  - Proposed in 2007
- **Test of interplanetary transfer of life or its precursor**
  - Tanpopo [in Japanese] = Dandelion
  - Spread of dandelion's seeds on Earth → Transfer of life in space
- **Multifaceted sample return mission**
  - **Cosmic dust capture experiment** **by silica aerogel as intact capture media**
    - **Microbes** in terrestrial dust
    - **Organic compounds** in interplanetary dust
    - **Space debris**
  - **Space exposure experiment**
    - Terrestrial microbes + organic compounds

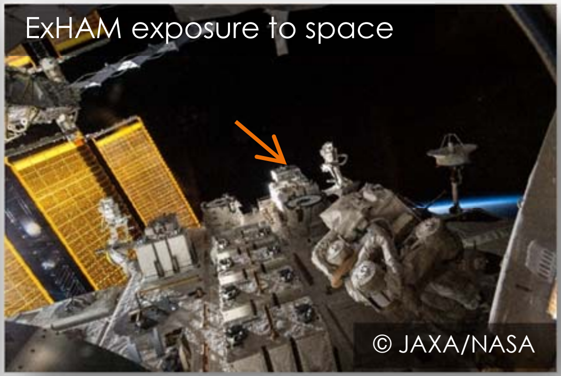
    A. Yamagishi *et al.*, 2017-k-04.

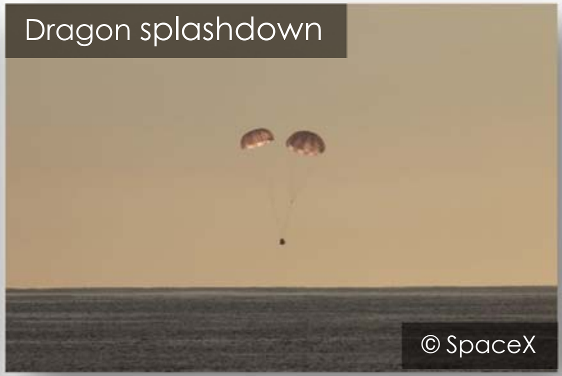


- **25+ institutes**
- **50+ collaborators**
  - Biologist
  - Chemist
  - Physicist
  - Planetary scientist
  - Engineer

Tanpopo Experiment Timeline

- **Rocket launched in Apr. 2015**
  - 2016, 2017, and 2018 samples
  - Arrival in the ISS
- **ExHAM exposed in May 2015**
  - Capture panels for 2016 attached to the ExHAM
- **ExHAM recovered in Jun. 2016**
  - CPs for 2016 restored in the Pressurized Module
- **Cargo spacecraft retrieved in Aug. 2016**
- **2016 sample analysis and 2017 sample exposure in progress**





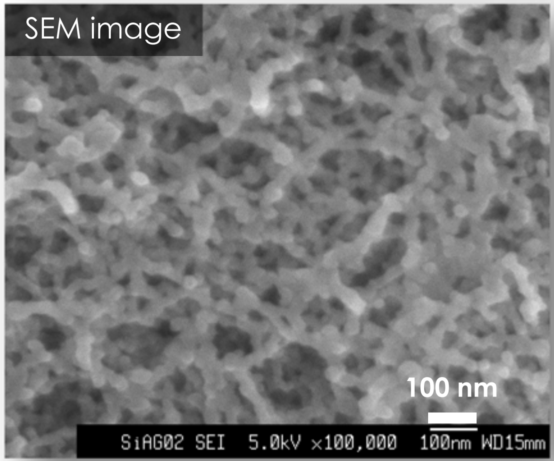
Silica Aerogel

- **Silica aerogel:**

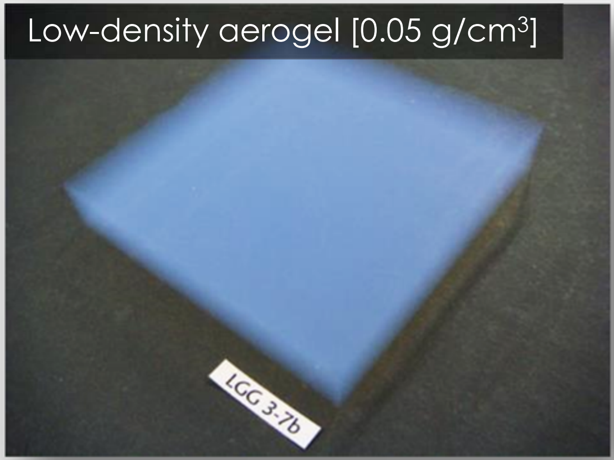
  Colloidal foam of nanoscale SiO_2 particles
  - **Transparent**
  - **Tunable bulk density** [0.01–1.0 g/cm^3]

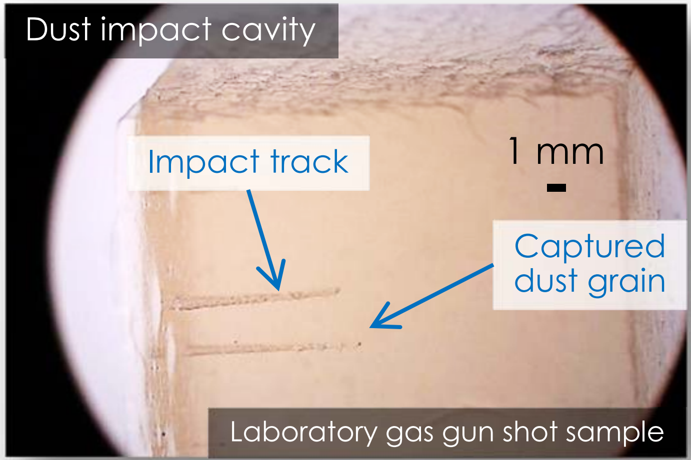
    Determined by the silica–air volume ratio

    M. Tabata et al., Nucl. Instrum. Methods A 623 (2010) 339.
  - Feasible surface modification → **Hydrophobic**



Promising medium to capture **cosmic dust** inside it
- **Micron size** [~10 μm dia.]
- **Hypervelocity** [Max. ~16 km/s in low-Earth orbits]

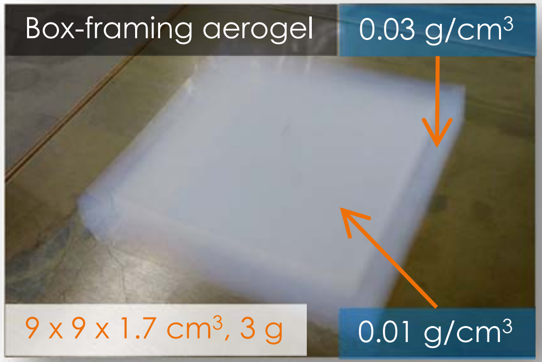


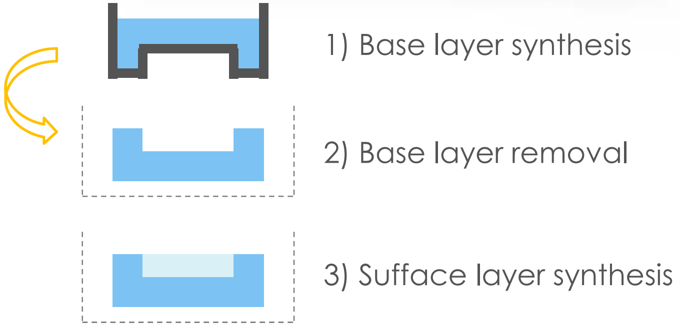


Development of the Capture Panels

Ultralow-density Double-layer Aerogel

- **0.01 g/cm³ ultralow-density aerogel**
  - World's lowest density used in space
  - M. Tabata *et al.*, Nucl. Instrum. Methods A 623 (2010) 339.
- **Double-layer [box-framing] aerogel**
  - **Surface layer: 0.01 g/cm³** [Very brittle]
    - **Capture** ~10 μm dust particles
  - **Base layer: 0.03 g/cm³** [Relatively tough]
    - **Protect** the surface layer from vibrations
    - Capture high-energy dust particles
  - Both the layers chemically combined
  - M. Tabata *et al.*, J. Sol–Gel Sci. Technol. 77 (2016) 325.
- **Contamination-controlled aerogel**
  - Sterilized tools
  - Clean booth [Class 1000]
  - Flight aerogel production in Mar.–Apr. 2013
  - M. Tabata *et al.*, Biol. Sci. Space 25 (2011) 7.

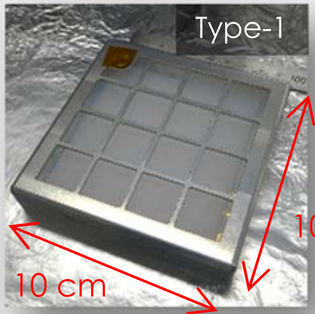


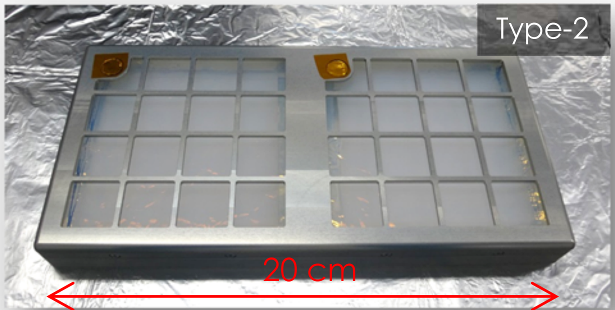


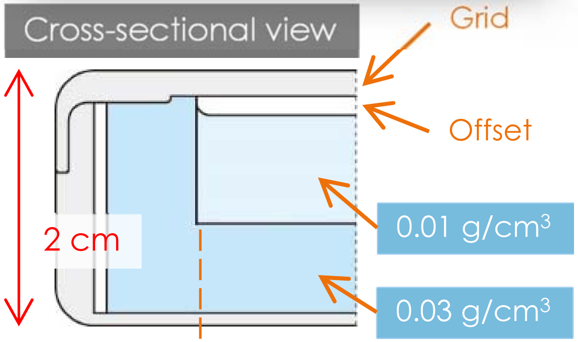
Capture Panel Design

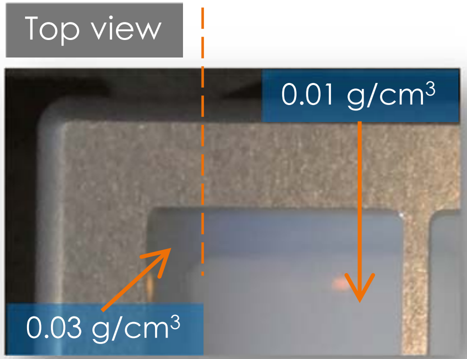
- **Aerogel + container = capture panel [CP]**
  - Type-1 panel: 1 unit
    Type-2 panel: Connected 2 units = 2 chambers
  - 12 units x 3 years =36 units
    - **Interface** with the ExHAM
    - **Withstand** rocket launch vibrations
    - **Maximize** the dust capture performance

M. Tabata *et al.*, Trans. JSASS Aerosp. Technol. Jpn. 12 (2014) Pk_29.









Assembly of the Capture Panels

- **Capture panels assembled in the Tanpopo clean room at ISAS** [Class 1000]
  - 36 units [18 type-1 panels, 9 type-2 panels] in Dec. 2014
- Assembly procedure:
  1. **Form** an aluminum sheet box
  2. **Place** an aerogel in the box
  3. **Install** the aerogel box in the panel
  4. **Attach** the lid
  5. **Attach** an panel cover

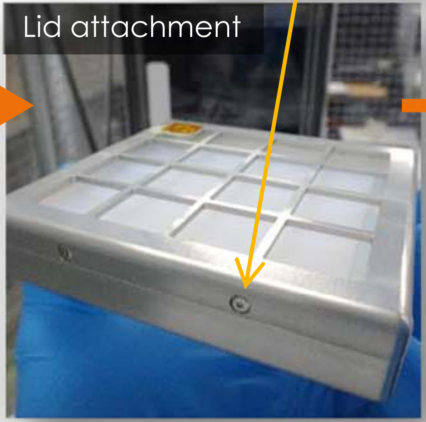

Aluminum sheet box


Aerogel in the box


Al sheet spacer


Aerogel box installation


Screws


Lid attachment

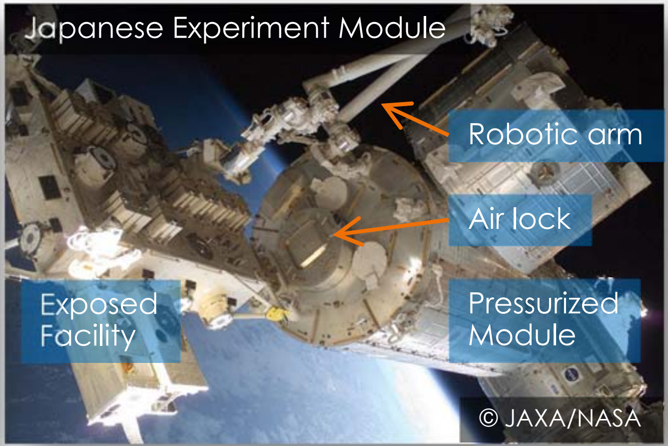

Panel cover attachment


Presenter in the Tanpopo clean room @ISAS/JAXA

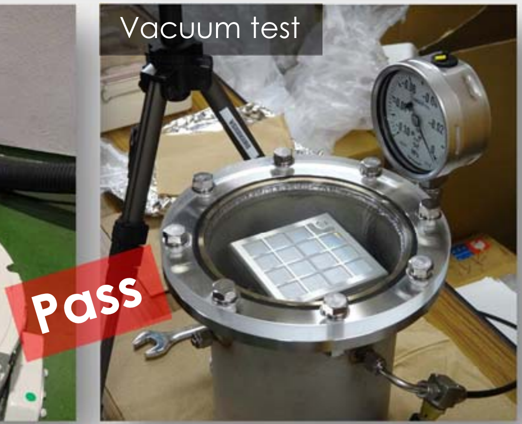
Flight Payload Acceptance Tests

- **Safety requirement for an ISS payload: Not to disintegrate aerogel segments, which can escape from the capture panel**

→ Potential risk to the ISS crew



- **Acceptance [sampling] tests:**
  - Vibration test
  - Vacuum test
    - Depressurization/repressurization w/ 1 kPa/s
  - Thermal test
    - From −135°C to 85°C



Post-flight Handling of the CPs

Post-flight Analysis Scheme

Initial analysis @ISAS/JAXA

1. Quick look
2. **Aerogel transfer from the CP to an aerogel holder**
3. X-ray CT scan @JAXA Chofu
4. Aerogel imaging by CLOXS
5. Dust impact track search
6. Keystone cutting by CLOXS

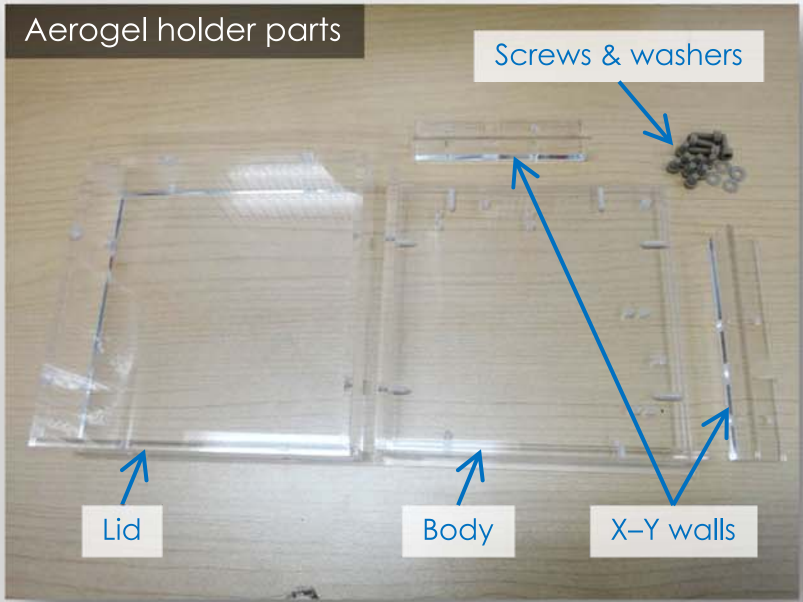
Aerogel segment containing dust grains

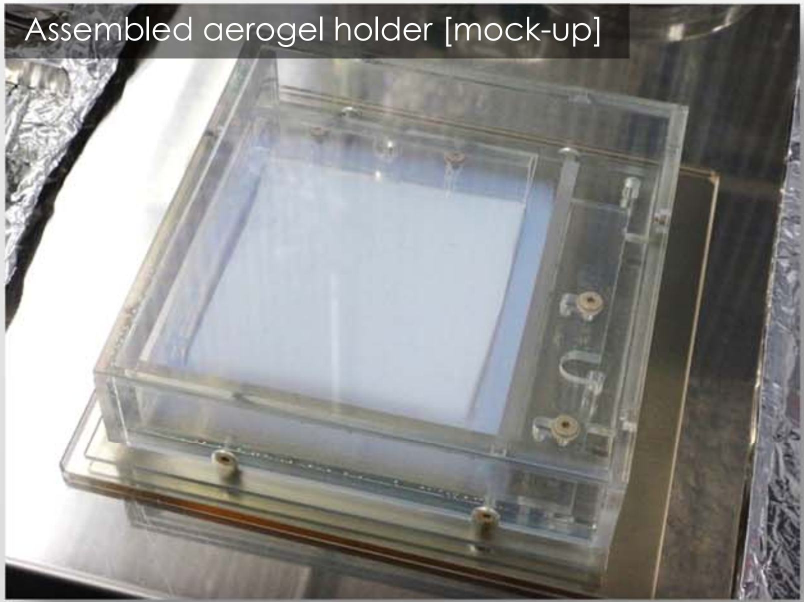
7. Keystone manual pickup

8. Keystone analysis @Individual institutes

Aerogel Holder

- **Aerogel holder [AH] designed for the post-flight analysis**
  - Body, lid, and adjustable X–Y walls for fixing the aerogel
  - Made of antistatic, transparent acrylic resin
    - **Seal** the container to prevent **biochemical contamination**
    - **Carry** the aerogel outside of the clean room → **XCT scan** at Chofu
    - **Observe** the aerogel through the lid → **Aerogel imaging** by CLOXS
    - **Interface** the aerogel to CLOXS → **Coordinate system** for DAQ

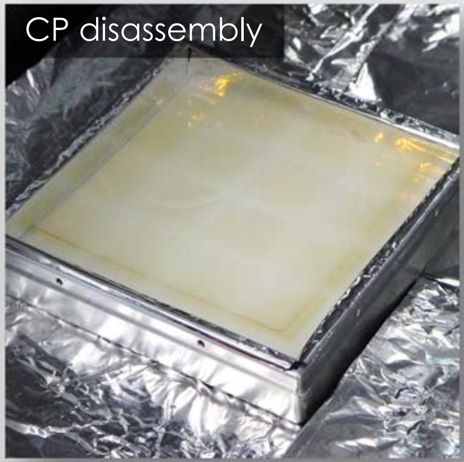




Aerogel Transfer from CP to AH

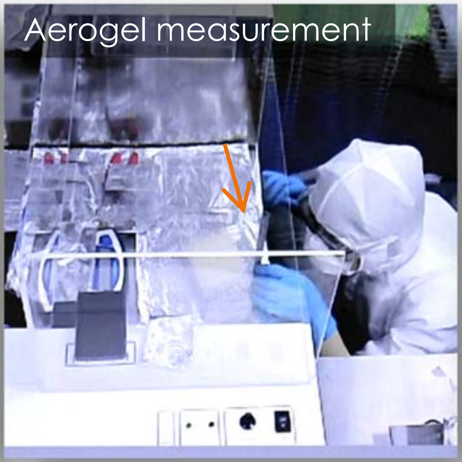
- **Aerogel tiles transferred from CPs to AHs inside a contamination-controlled environment** [ISO level 1]
  - 2016A samples: 8 tiles in Oct. 2016
  - 2016B samples: 3 tiles in Apr. 2017
- Transfer procedure:
  1. **Disassemble** the CP
  2. **Extract** the aerogel from the CP
  3. **Measure** the aerogel dimensions & weight
  4. **Assemble** the AH

Work area inside a tabletop open clean system [KOACH] in the Tanpopo clean room

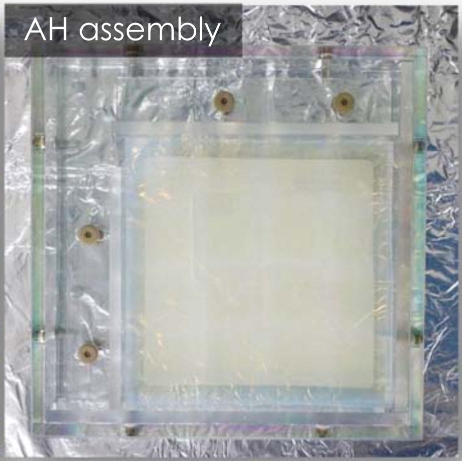


CP disassembly

Aerogel extraction



Aerogel measurement



AH assembly

Preliminary Aerogel Analysis

- **Demonstrated dust capture performance**

  H. Yano *et al.*, 2017-k-02.

  - >10 μm dust search

    → **Multiple particles and/or impact cavities confirmed on each aerogel**
  - Track terminus found in the 0.01 g/cm³ surface layer [for ~10 μm dust]

    → Consistent with results from a ground-based gas gun experiment

    → Ideal dust capture only inside the ultralow-density layer

- **Aerogel tile shrinkage**
  - Maximum 5% longitudinal shrinkage [~14% volume reduction]
  - Post-flight weight almost identical to pre-flight one [at 1–2% level]

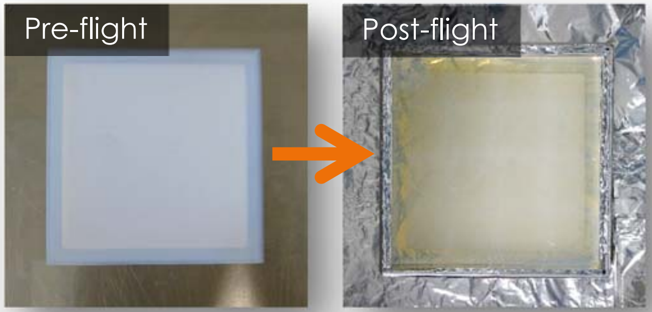
    → Possible slight density increase from the nominal density 0.01 g/cm³

    → **No significant degradation of the dust capture performance**

- **Aerogel surface yellow/brown discoloration**
  - **Possible surface denaturation in space**

    → Water contact angle to be measured [to test the hydrophobic feature]

    → Elemental analysis needed



M. Tabata *et al.*, "Results from Tanpopo Capture Panels," ISTS 2017, 6 June 2017, Matsuyama, Japan

Summary

- **Silica-aerogel-based intact cosmic dust collector, capture panels for the Tanpopo mission were developed and launched to the ISS.**
  - The 1st-year samples were successfully retrieved.
- **A dedicated aerogel holder for the initial analysis was designed, and the 1st-year aerogels were equipped.**
  - The initial analysis to search for the impact cavities on the aerogel was successful.

- **Multiple dust grains and/or impact tracks were confirmed on each aerogel.**
  - New space instrumentation technology employing the ultralow-density aerogel was demonstrated in near-Earth orbits.
  - The aerogel performance will be investigated in more detail. [e.g., comparison with gas gun experiments]