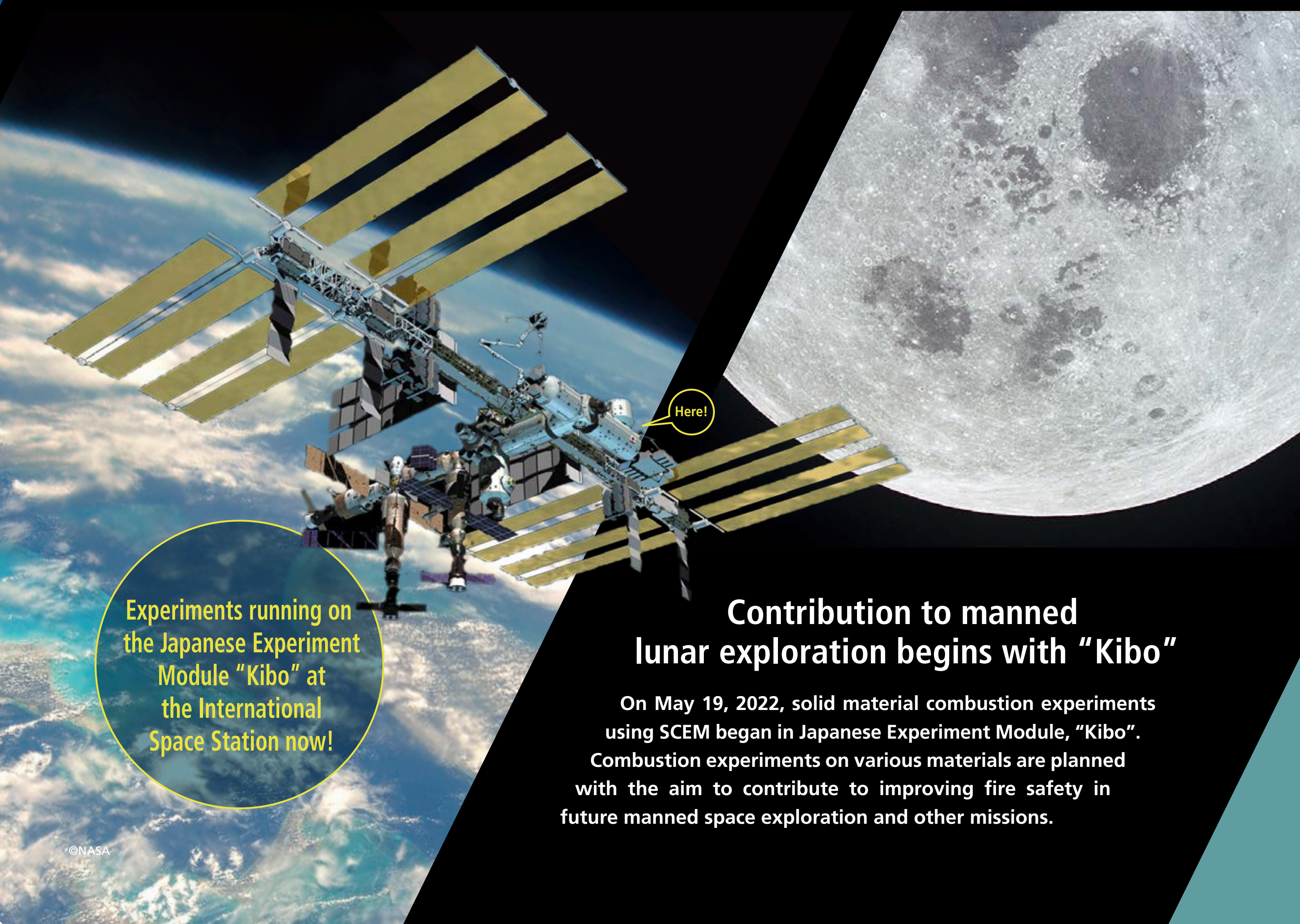
Solid Combustion Experiment Module

SCEM



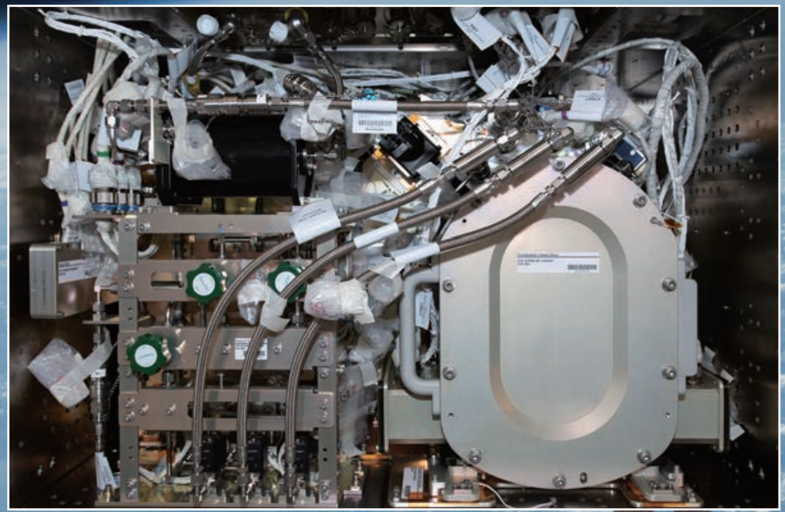
Experiments running on the Japanese Experiment Module "Kibo" at the International Space Station now!

Contribution to manned lunar exploration begins with "Kibo"

On May 19, 2022, solid material combustion experiments using SCEM began in Japanese Experiment Module, "Kibo". Combustion experiments on various materials are planned with the aim to contribute to improving fire safety in future manned space exploration and other missions.

Clarifying and verifying combustion characteristics of solid materials that change due to gravity

Have you ever seen a video of a candle burning in a spacecraft?
Combustion phenomena are strongly affected by buoyancy-driven convection due to gravity, so there are significant differences between Earth and space. Furthermore, common sense on Earth does not apply to the flammability of materials in space, which is closely related to preventing fires inside spacecraft.
Japanese Experiment Module, “Kibo”, in the International Space Station (ISS) has an experimental system for investigating the combustion characteristics of various solid materials in a microgravity environment in detail.



SCEM installed on board in the “Kibo” module

Using JAXA’s SCEM...

It is possible to observe the combustion behavior of materials in a quiescent atmosphere or in an extremely slow surrounding airflow, which is difficult to evaluate on Earth, and this allows for repeatedly obtaining quantitative data on combustion characteristics related to ignition, flame spread, and extinction by changing the atmospheric pressure, oxygen concentration, and surrounding airflow velocity.

Data shown below can be obtained

The experimental data shown below can be obtained in space experiments at “Kibo” under conditions that simulate the intravehicular environment.

- Position and shape of flames spreading over materials, and changes in surface temperature of materials
- Limiting oxygen concentration for sustaining flame spread over materials and its dependence on ambient flow velocity and atmospheric pressure
- The limiting current and ignition delay time for spontaneous ignition of insulated electric wires
- Thermal decomposition and smoke generation characteristics of materials when heated by a heat source

What we aim for in space

By suppressing buoyancy convection and obtaining data on the combustion characteristics of solid materials in an environment simulating the inside of spacecraft, we aim to produce scientific results regarding the effects of gravity on the flammability of materials. This can also be used to develop the technologies to evaluate the flammability of materials in low-gravity environments, such as microgravity environments and the lunar surface, on Earth, and to demonstrate on-orbit flame retardancy of materials to be used in space.

1 Materials used in space must be flame-resistant

The inside of manned spacecraft such as the ISS is a closed environment with no way to escape. In such case fire hazard is one of the most dangerous events that must be avoided. Therefore, the materials used are required to have a certain level of flame retardancy.
Until now, tests for evaluating the flammability of materials have been conducted on Earth in accordance with methods established by NASA, and the results have determined whether or not they can be used inside spacecraft.

Material flammability evaluation test (NASA standard)

2 Could solid material become more flammable in space?

Experiments in short-term microgravity environments using ground-based drop test facilities and space experiments conducted on the Space Shuttle and other spacecraft have revealed that the flammability of materials can be higher in a microgravity (μG) environment than in a gravity environment on Earth (1G). In other words, even if a material passes a flammability test on Earth, this may not possibly guarantee its flammability in the μG environment inside spacecraft.
The Artemis program, in which Japan is participating, is intended to conduct manned space exploration on the Moon, and in the 1/6 G environment of the Moon, it has been suggested that materials may be more flammable compared to 1G or μG. For this reason, there is a demand to establish a method for evaluating the flammability of materials that takes the effects of gravity into account.

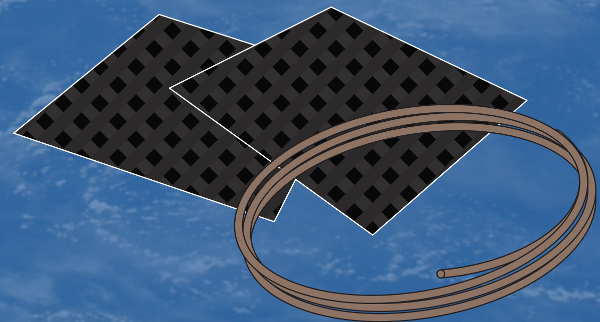
3 The key to properly evaluating the flammability of materials is “airflow”

Gravity-induced buoyancy convection of about 30 to 40 cm/s occurs near the flame on Earth. In contrast, buoyancy convection does not occur inside spacecraft, in a μG environment, but very slow airflow (of the order of a few cm/s) exists due to air conditioning and other factors. It is known that the flammability of materials is strongly affected by the surrounding airflows. On Earth, however, buoyancy convection becomes an obstacle to observe the combustion of materials in very slow airflows such as those inside spacecraft.
To cope with it, JAXA developed SCEM to conduct combustion experiments on materials under the quiescent or low ambient flow velocity conditions typical of spacecraft.

4 Expected outcomes

New flammability evaluation methods for expansive use of diverse materials

JAXA is developing a new approach to evaluate materials flammability less costly than the current method while properly considering the effects of gravity. When adopted internationally, this new approach is expected to expand the use of a variety of materials in manned space activities.



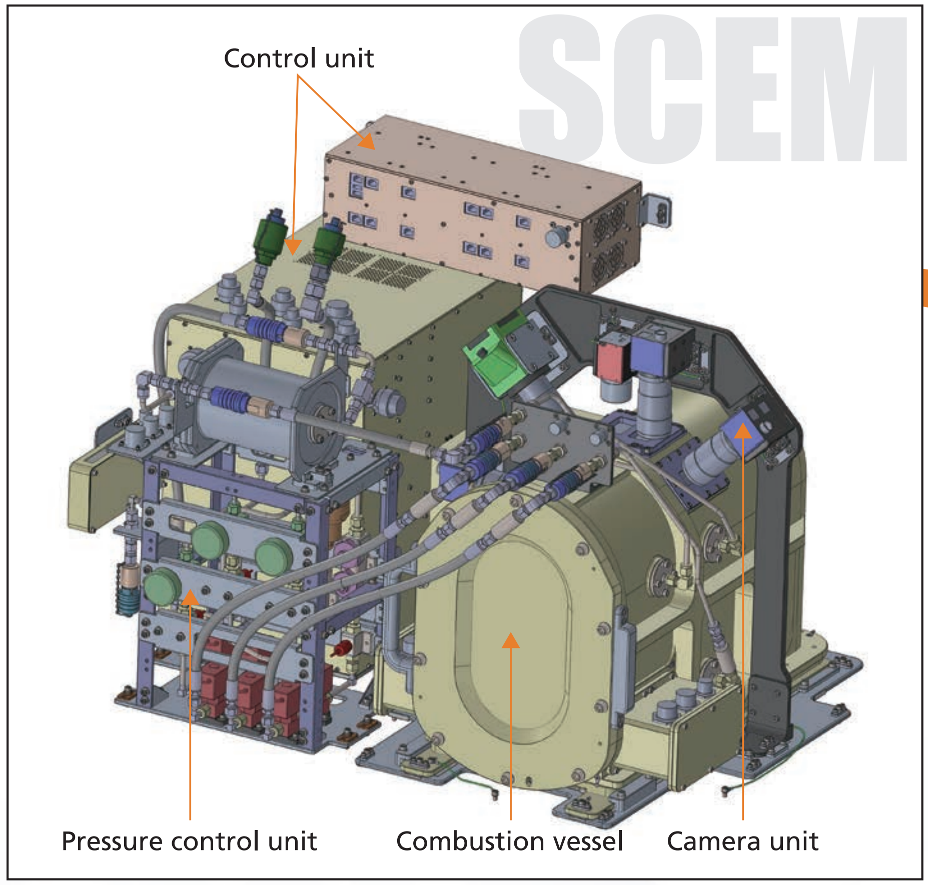
Materials used in spacecraft (image)

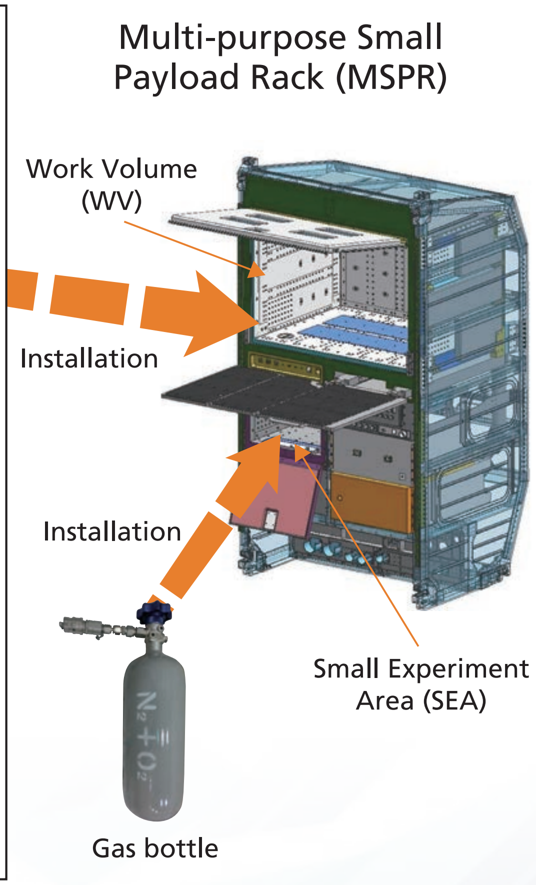
Firm footing in space markets through proven flame retardancy in manned space environments

Lunar base (image)

In the Artemis program’s manned exploration on the Moon, the internal environment of habitats and other facilities is expected to have conditions such as low pressure and high oxygen concentration, approximately 0.56 atmospheres with 34 % oxygen. Taking into account the gravity environment of 1/6 G, materials with high flame retardancy are also required. Using SCEM in orbit to demonstrate the suitability of certain materials for such an environment will establish these materials as the world leading de-facto standard for international use in future manned space missions to the Moon and beyond.

Introduction of SCEM





■ Combustion vessel

It is used for combustion experiments. By replacing the experiment insert (p5) installed inside the combustion vessel, various materials can be used for combustion experiments. The combustion phenomenon is observed with cameras through observation windows attached to the combustion vessel.

■ Camera unit

Five cameras are installed around the combustion vessel to observe combustion phenomena. The camera unit consists of three visible cameras, one high-speed camera, and one infrared camera. Still images and videos taken by each camera are transmitted to Earth by remote control.

■ Control unit

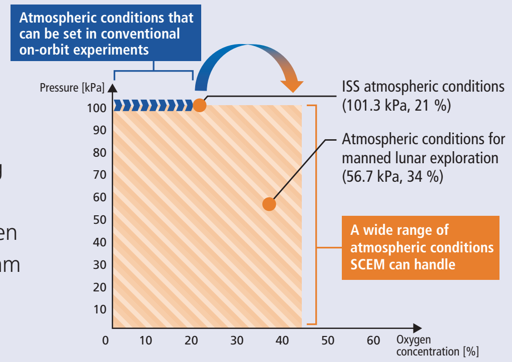
The control unit mainly supplies power to SCEM, controls the components, receives remote control signals from Earth, and transmits data to Earth. It is composed of a power supply and communication control unit that controls the entire system, and a camera control unit.

■ Pressure control unit

It is connected to the nitrogen and oxygen supply and exhaust pipes of the experimental rack, and the main function includes the adjustment of the pressure and oxygen concentration inside the combustion vessel, and exhaustion of gas after combustion. It also purifies exhaust gas with a filter filled with an adsorbent.

Contributions to manned lunar exploration!

- SCEM is the world's first on-orbit experimental device capable of conducting material combustion experiments under low-pressure and high-concentration oxygen conditions envisioned in the Artemis program
- The flame retardancy of materials possibly used for manned lunar exploration can be demonstrated in orbit

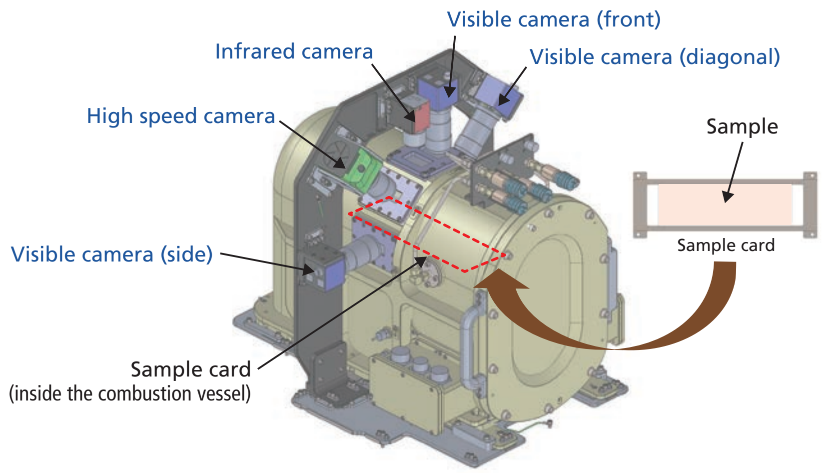


Atmospheric conditions that can be set with SCEM

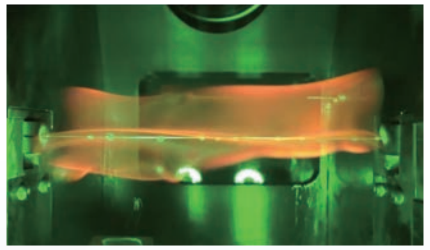
Lunar base (image)

Main Specifications

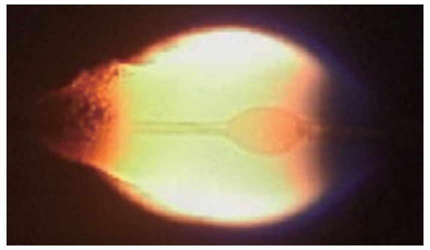
Item	Specification
Combustion vessel inner dimensions	220 mm (W) x 374 mm (H) x 548 mm (D)
Observation unit	• 3 visible cameras (resolution 3296 x 2472 px) Shooting speed: 21.8 fps (at maximum resolution) • 1 high speed camera Maximum shooting speed: 2000 fps (measured value) • 1 infrared camera (temperature range 20-500 °C)
Measurement function (inside the combustion vessel)	• Pressure 2ch (0-200 kPa abs) • Temperature 3ch (-40-180 °C) • Flow rate 1ch (0.125-2.5 m/s) • Oxygen concentration 1ch (0-40 %) • Carbon dioxide concentration 1ch (0-3 %)



Camera shooting direction relative to the test sample



Spontaneous ignition of an insulated electric wire sample due to overcurrent
(visible camera; aircraft experiment image)
©Hokkaido University



Flames spreading over an insulated electric wire sample
(visible camera; aircraft test image)
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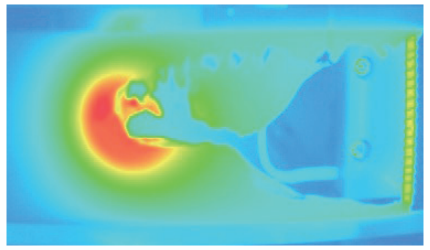


Surface temperature distribution during flame spread on a flat-plate material
(infrared camera)
©Hirosaki University/Gifu University/Hokkaido University/JAXA

Experiment flow in SCEM

STEP 1

Place an experiment insert in the combustion vessel.

STEP 2

Adjust the pressure and oxygen concentration inside the combustion vessel.

STEP 3

Set the sample in the experiment insert in the combustion position by remote control from Earth.

STEP 4

Turn on insert-fan to generate the required circulating flow rate within the combustion vessel. Ignite the sample either by using an electrically-heated wire or applying overcurrent.

STEP 5

Take pictures of the flame spread and ignition behavior on the sample using various types of cameras. Measure changes in the oxygen concentration and pressure during combustion with sensors. Transmit the captured images and data to Earth.

▶▶▶ **STEP 2** Repeat from STEP 2.

Astronauts will replace the experiment inserts and gas bottles.
©JAXA/NASA

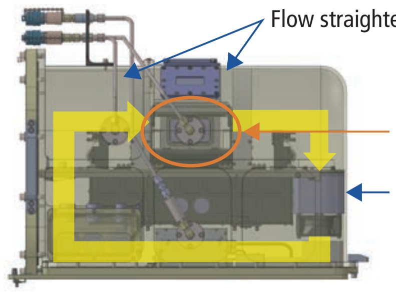
The experiment will be conducted by operating SCEM in orbit from the user operation area at the Tsukuba Space Center.

Experiment inserts available for SCEM

Experiment inserts

In SCEM, samples are placed in an experiment insert. By changing the experiment insert installed inside the combustion vessel, experiments on various samples can be performed. Currently, the following two types of experiment inserts are available.

The experiment insert is equipped with a Fan and Flow straightener, allowing the inside of the combustion vessel to be turned into a recirculating wind tunnel.



Experiment insert for insulated electric wire samples

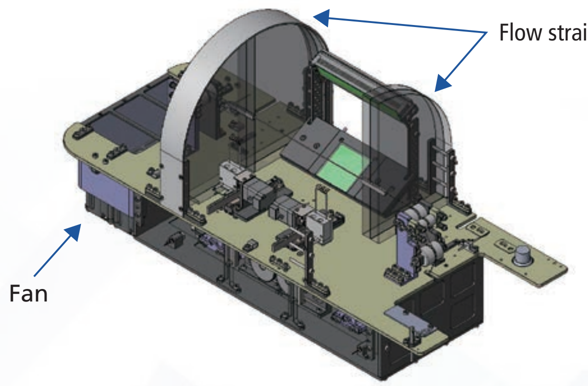
Ignition:
External ignition with electrically-heated wire, or spontaneous ignition by applying electric current
(achieved by selecting an electrically-heated wire or an energization electrode)

Supply of sample:
The sample wound on the sample reel is fed/wound by the sample feed mechanism.

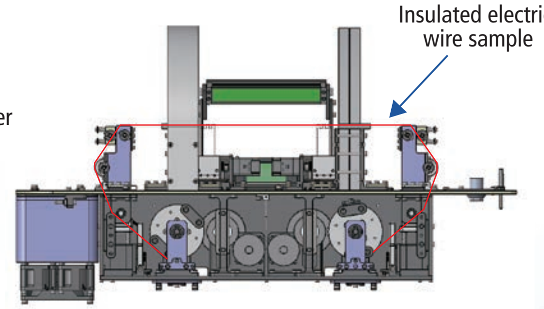
Replacement of sample:
Astronauts replace the samples by the sample reel.

Sample reel load capacity

1.1 mm or less in diameter
Minimum length: 3 m
Maximum length: 81 m
(However, this varies depending on the sample diameter)



*Some parts are not shown in this picture.
(To make the combustion area easier to see.)



Sample reel

Experiment insert for flat / rod shaped samples

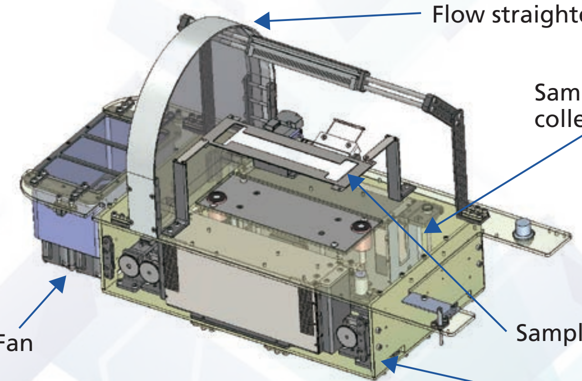
Ignition:
External ignition using an electrically-heated wire.

Supply of sample:
The sample cards loaded into the sample card holder are automatically loaded one by one into the space where the combustion experiment is conducted by the sample feed mechanism. After the experiment, the sample card is automatically stored in a collection holder.

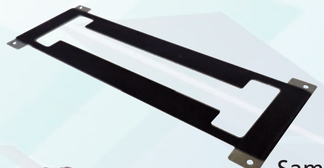
Replacement of sample:
Astronauts replace the samples by the sample card holder.

Sample card holder load capacity

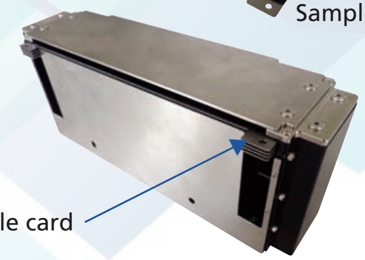
Sample size:
50 mm (W) x 4 mm (T) x 140 mm (L) (maximum value)
Number of sample cards:
30 (maximum for thin samples)
16 (maximum for samples of 4 mm in thickness)



*Some parts are not shown in this picture.
(To make the combustion area easier to see.)



Sample card



Sample card holder

Flow of space experiments

Solicitation — **Call for experiments**
JAXA is accepting space experiment proposals from universities, research institutes, and companies.
(For a specific limited period)

Selection — **Experiment selection**
JAXA will make the selection based on the details of the experiment and expected results.

Consider — **Consideration of samples and experiment conditions**
The toxicity of the samples and combustion gases will be examined to assess their safety as well as confirming their compatibility with the test device, and the experiment proposer and JAXA will work together to set detailed experiment conditions.

Preparation — **Preparation for space experiments**
Experiment sequence will be created for each experiment. The operation of the experiment sequence would be verified using the SCEM ground model.

Transportation — **Transport to the International Space Station**
The samples will be loaded into a sample holder / reel and transported to the International Space Station by spacecraft.

Experiment — **Experiments conducted at "Kibo"**
Data is acquired remotely from Earth. Astronauts replace the sample card holder and gas bottle.
The experiment can be monitored in real time at the Tsukuba Space Center.

Provide — **Provision of experiment data**
The acquired data will be handed over to the experiment proposer.

Japanese experiment module "Kibo" in the International Space Station is a laboratory where Japan can conduct unique research in space. JAXA provides full support so that many people involved in research and technological demonstration in the field of combustion can use "Kibo".

Examples of SCEM usage

FLARE

Fundamental Research on International Standard of Fire Safety in Space -base for safety of future manned mission
Principal Investigator: Professor Fujita Osamu (Hokkaido University)

The on-orbit experiment in "Kibo" using SCEM began in May 2022. This was the first on-orbit experiment for SCEM.

Objectives

To clarify how the flammability limit conditions of solid materials change in a microgravity environment compared to the gravity environment on Earth, and create international standards for evaluating the flammability of materials in a microgravity environment.

Experiment samples

Plate samples: Filter paper, acrylic, flame-retardant fiber, etc.
Insulated electric wire samples: Polyethylene, flame-retardant fluorine resin

Image of flames spreading over a filter paper sample
©Hirosaki University/Gifu University/Hokkaido University/JAXA

FLARE-2

Evaluation of Flammability of Solid Materials in Space Habitation
Principal Investigator: Professor Takahashi Shuhei (Gifu University)

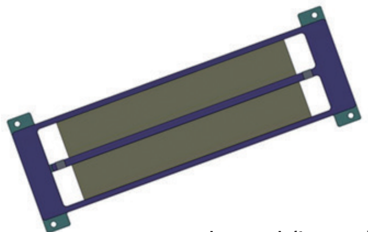
The next SCEM experiment planned after the FLARE experiment. A new sample card that can set two samples at the same time will be used.

Objectives

To expand the combustion model developed in FLARE to various materials such as thick materials and composite materials, as well as to low-pressure environments of manned lunar exploration.

Experiment samples

Flat-plate samples: Carbon fiber reinforced plastics, electronic circuit board materials, etc.
Rod-shaped samples: Polyethylene, acrylic



New sample card (image)

Q&A on Combustion Experiments at “Kibo”

Q What restrictions are there on samples used in combustion experiments?

A In addition to size restrictions, it is necessary to evaluate the toxicity of gases and solid particles generated during combustion, and to evaluate compatibility with materials used in experimental equipment. If the toxicity level is high or corrosive gases are generated, it may be difficult to conduct experiments using that sample. For other general points to note regarding space experiments, please contact Kibo Utilization Promotion Office.

Q I have a specific camera I'd like to use for observations. Can I use it?

A Evaluation of suitability for mounting on SCEM, safety, etc. is necessary. The camera must also be launched. Please contact Kibo Utilization Promotion Office for more information.

Q How many experiments can be performed on one Theme?

A The number of experiments is basically determined by the number of samples.
Each experiment-insert has a specific sample quantity. (For “insulated electric wire samples” and “flat- and rod-shaped samples”.)
The quantity of samples depends on the width and thickness of the samples.
When using many samples, astronauts will need to replace the sample card holders.

Q I'm interested in conducting combustion experiments at “Kibo”. What should I do?

A Please contact Kibo Utilization Promotion Office.

Q What will the cost and timeline for the experiment be?

A Cost and timeline depends on the selected framework of the space experiment. The experiment proposer will be responsible for expenses related to the realization of the experiment plan, preparation for the experiment, and analysis of the experiment results, etc. The period from selection to the implementation of the experiment at “Kibo” will vary depending on the content of the experiment.

Q Can this apparatus only be used for combustion experiments on solid materials?

A One of the major features of SCEM is that it can carry out different experiments by replacing the experiment inserts installed in the combustion vessel. Currently, we are investigating new experiment inserts for droplet combustion experiments using liquid fuels.

JAXA
National Research and Development Agency
Japan Aerospace Exploration Agency
Human Spaceflight Technology Directorate

Solid Combustion Experiment Module (SCEM)
https://humans-in-space.jaxa.jp/en/biz-lab/experiment/facility/pm/scem/

If you have any questions about this pamphlet
or about using “Kibo”, please contact:
Kibo Utilization Promotion Office z-kibo-promotion@ml.jaxa.jp

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