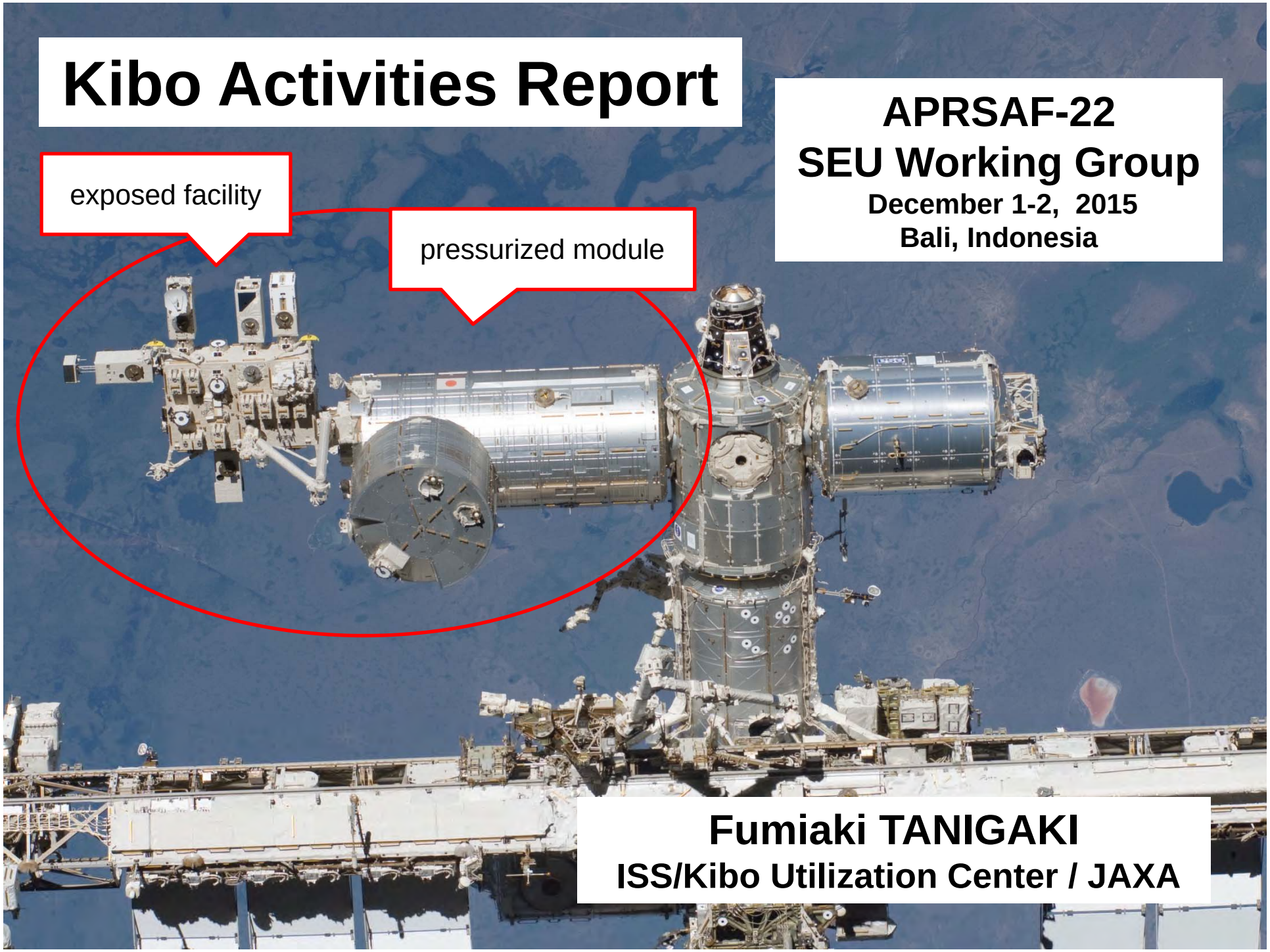
Kibo Activities Report

APRSAF-22
SEU Working Group
December 1-2, 2015
Bali, Indonesia



Fumiaki TANIGAKI
ISS/Kibo Utilization Center / JAXA

Initiatives of JAXA ISS Utilization

- JAXA is required to show the effectiveness of the ISS utilization and its future direction.
- JAXA established “Initiatives of ISS Utilization”.
- JAXA emphasizes five fields of Kibo usage for convincing benefit.

Initiatives of JAXA ISS Utilization

Scientific Research

- Kibo as “the National Laboratory”
- Japan’s national research strategy
  - Osteoclast
  - Muscle Atrophy
    → Rodent Research and Mouse Habitat

Commercial Usage

- Expand range of ISS commercial usage
- Create benefit and social innovation
  - Protein Crystal Growth (PCG) Experiment
  - CubeSat Deployment

Preparing for Future Exploration

- Technology development for future exploration
  - ECLSS
  - Radiation Measurement

Activities with International Society

- Promote human resource development activities and Kibo utilization of Asian countries

Space Education

- ISS experiments for students
- Communication events from ISS
- Reporting events from ISS

Kibo Life Science Researches

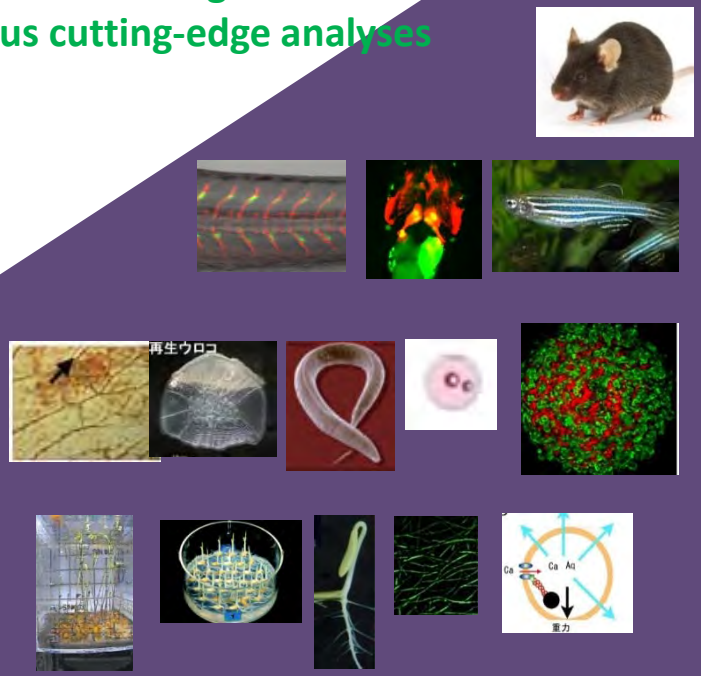
Human

Rapid changes: bone loss, muscle atrophy etc.

Ethical, experimental limitations

- ✓ Biological effect (gravity, radiation)
- ✓ Genetic, tissue analysis
- ✓ Accumulation of ground data
- ✓ Various cutting-edge analyses

Model organism



Expand Kibo life science research

Human Exploration

Building-up scientific knowledge bases to expand human activity into space

Strategic national lifescience researches

Epigenomic changes due to environmental factors

Regenerative medicine

Pathway analysis for drug

Aging mechanism

Fundamental researches

Gravitational biology

~2009 — 2015 — 2020

Major Equipments for Kibo Life Science

CBEF (Incubator)
Provide Temp./Humidity and CO_2 Controlled environment for plants, cells and small animals. Have a Centrifuge for comparative experiment between micro-G and various-G.


CBEF

Fluorescence Microscope
possible to observe the sample on the ground in real time


Microscope

Aquatic Habitat (AQH)

Mouse Habit Unit (MHU), <1st experiment in 2016>

[All image credit:JAXA]

MELFI/FROST (Freezer, Refrigerator)
Provide cold environment (-90, -26, +4 deg C for MELFI, ~ -70 deg C for FROST) for samples, reagent, etc.


MELFI


FROST

Chemical Fixation Equipments
Fixation apparatus for post-experiment samples (plants, cells, etc.) for return.


Fixation equipment

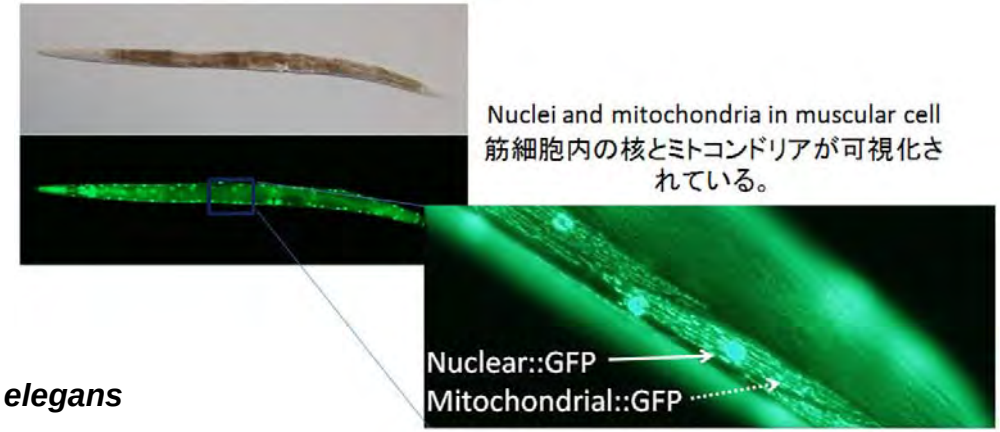
Scientific Research

(in pressurized module)

Biology Experiments (*C. elegans*)

- **A transgenerational experiment (~4th generation) for epigenetics research using *C. elegans* ("Epigenetics") was completed in February 2015. [PI: Higashitani]**
- **Alteration of *C. elegans* muscle fiber was investigated in April 2015. The nuclei and mitochondria in *C. elegans* muscle are visualized by GFP. The fixed samples will be returned by SpX-6 in May 2015 for analysis. ("Nematode muscle") [PI: Higashitani]**
- **70 days observation of *C. elegans* life cycle lasts until June 2015 in order to study the effects of space flight on aging. ("Space Aging") [PI: Honda]**

C. elegans



Scientific Research

(in pressurized module)

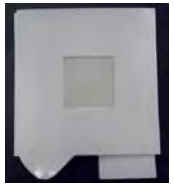
Plant Experiments

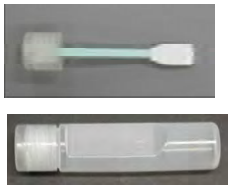
- **Investigation of helical growth of the morning glory and the rice was conducted in February 2015 ("Pant rotation") [PI:Takahashi].**
- **Microscopic observation of cortical microtubules on plant stems was completed in April 2015 ("Aniso Tuble") [PI:Soga].**

[image credit:JAXA]

Microbial Monitoring in KIBO

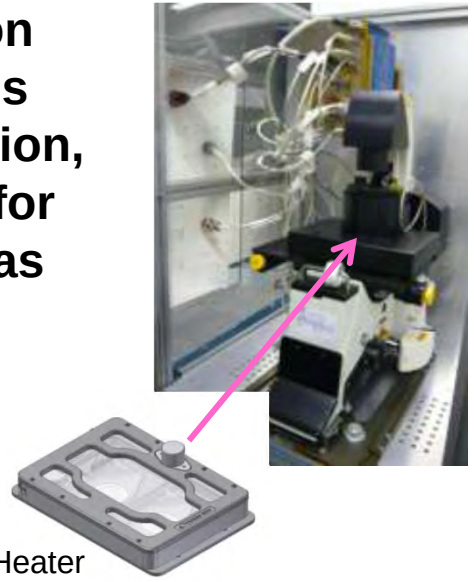
- **2nd sampling of Microbial monitoring experiment was conducted in Sept. 2015 ("Microbe-IV") [PI:Nasu]**





Fluorescence Microscope

- **For the observation of mammalian cells in 37 deg.C condition, a new heater unit for the microscope was launched and its check out was completed in May 2015.**



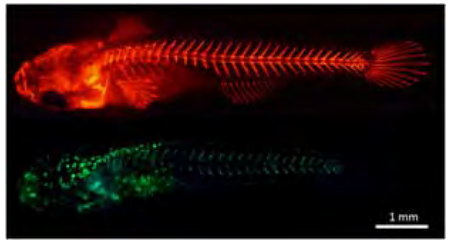
Stage Heater

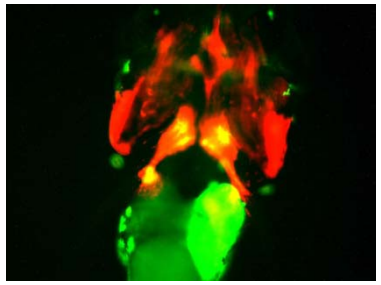
Scientific Research

(in pressurized module)

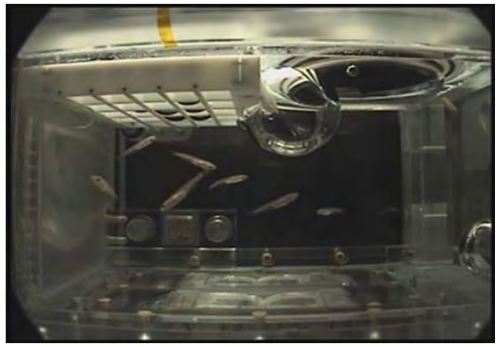
Medaka Osteoclast

- **Study Medaka fish bone to find microgravity's effect on osteoclast (bone resorption cells). [PI:Kudo]**
- **The experiments were conducted in 2012 and 2014.**





Transgenic Medaka:
the bone-create cells (osteoblast) are in red, and bone-break cells (osteoclast) are in green.

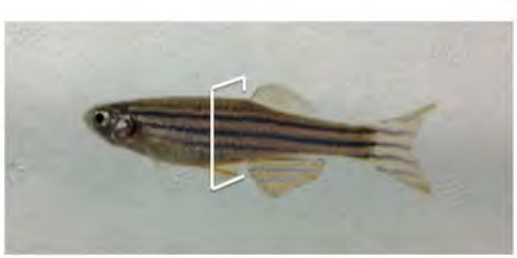


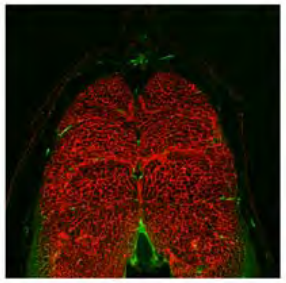
Medaka in the Aquatic Habitat (AQH)

[All image credit:JAXA]

Zebrafish Muscle

- **Study Zebrafish muscle to find whether muscle atrophy occurs in microgravity, and how the mechanism works. [PI:Sehara]**
- **18 Zebrafish were launched by Soyuz in Sep. 2014 and had been bred for 43 days. Part of the fish were returned in living condition for the first time by Russian Soyuz vehicle. The fixed samples were returned by SpX-5 in Feb. 2015.**



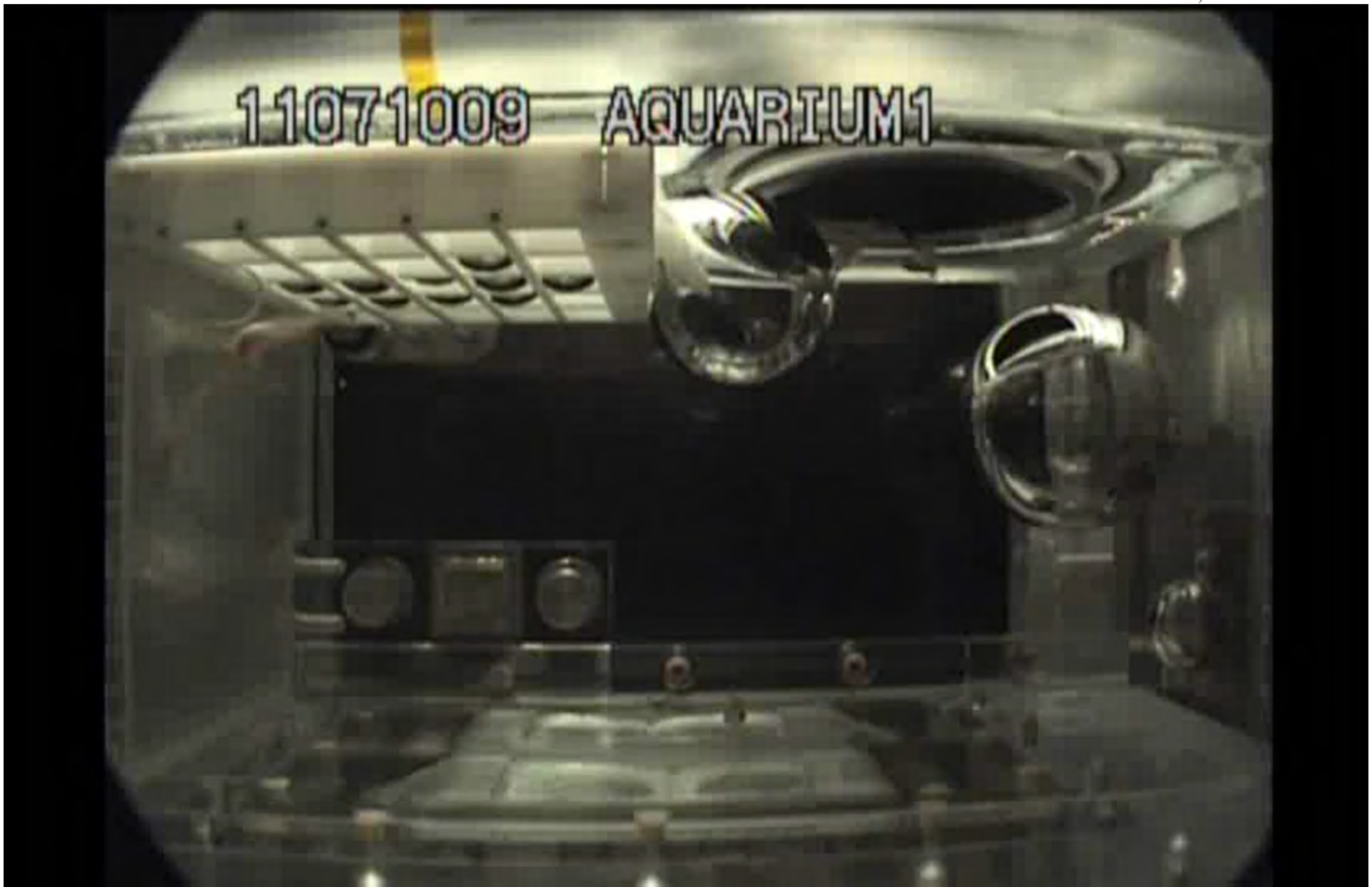


Transgenic Zebrafish and the surface of its muscle

[Image credit:JAXA]

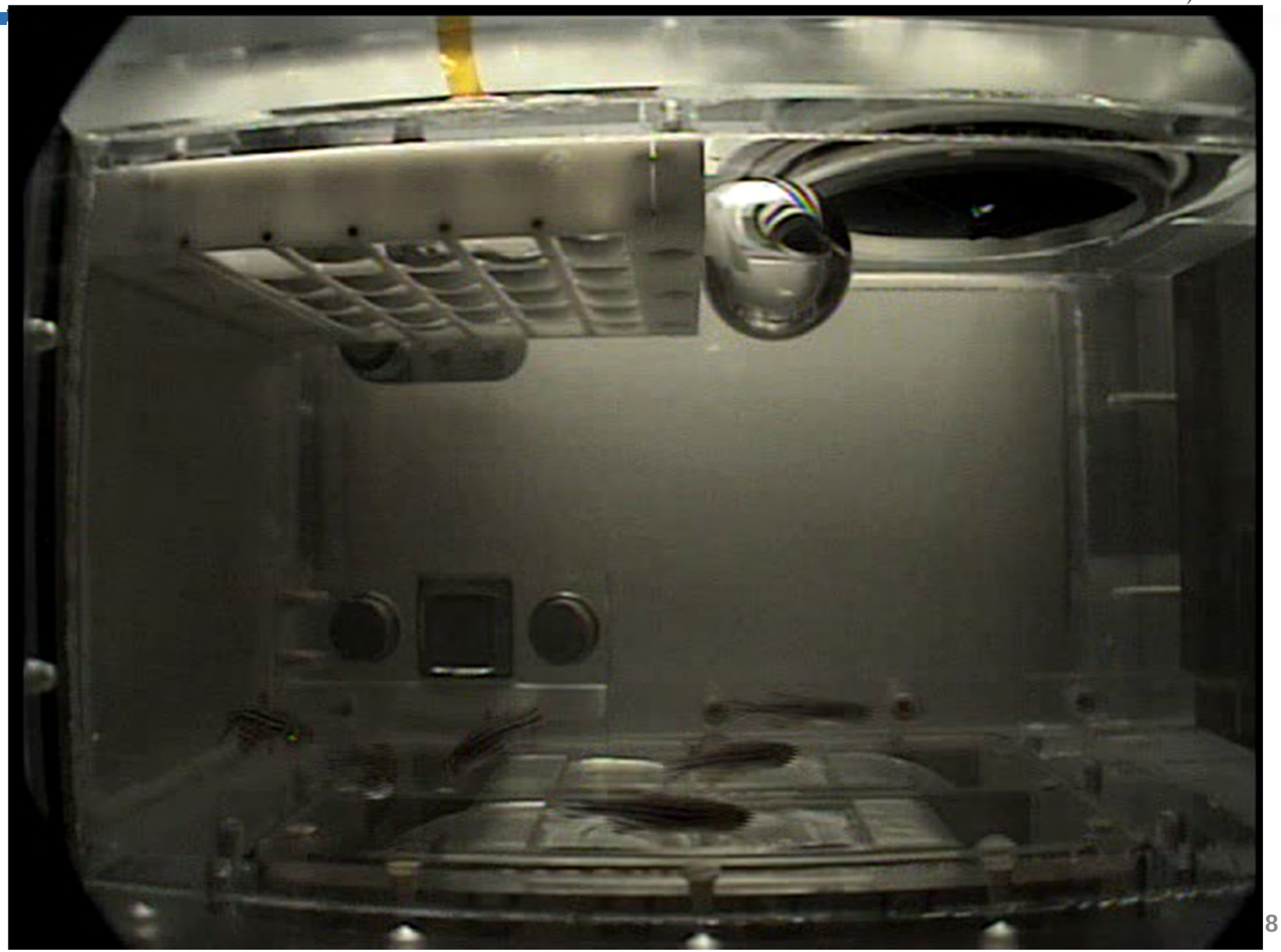
[image credit:JAXA]

Medaka fish onboard KIBO (day 13)



[image credit:JAXA]

Zebrafish onboard KIBO (day 21)



Scientific Research

(in pressurized module)

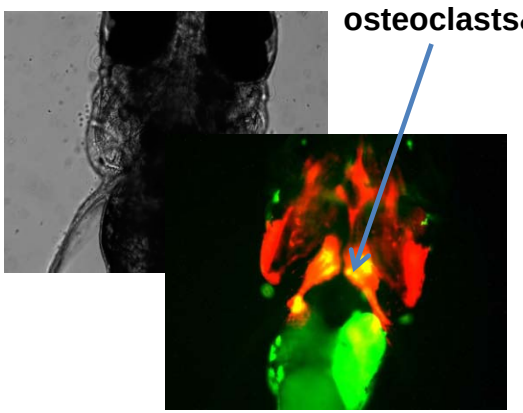
Medaka Osteoclast

Effect of Microgravity on Osteoclasts and the Analysis of the Gravity Sensing System in Medaka

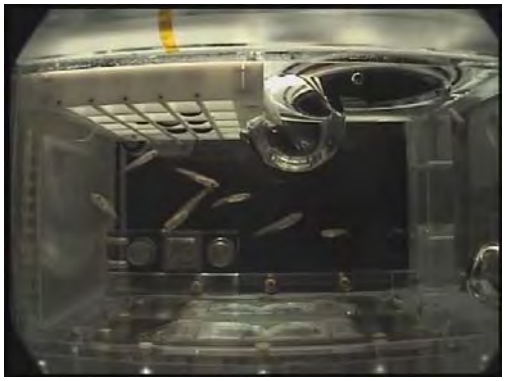
PI: Professor Akira Kudo, Tokyo Institute of Technology, et al.
Sponsoring Space Agency: JAXA

Research Objectives

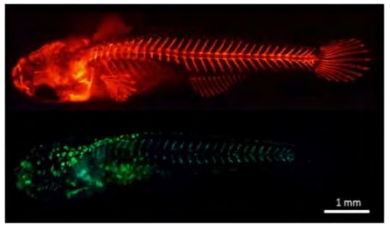
During space flight, bone mineral density is decreased by the influence of osteoclast activation. The molecular mechanism of this phenomenon is investigated in this study. In order to examine the effect of microgravity on osteoclast activation in space, this experiment performs *in vivo* imaging analyses of gene expression and cell mobility with embryonic and juvenile Medaka from osteoclast-specific transgenic lines. In combination with the long-term growth experiment (Medaka Osteoclast), the alteration of osteoclast activity in microgravity is studied microscopically and by means of gene expression analysis.



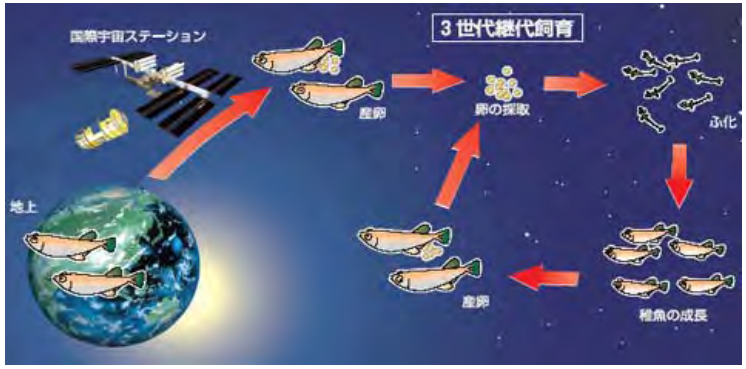
Fluorescence imaging of Medaka osteoclasts. [Image credit:JAXA]



Medaka (*Oryzias latipes*) in the Aquatic Habitat (AQH) [Image credit:JAXA]



Visible fluorescent bone cells glow in a Medaka fish. The cells that create bone are red, while those that break it down are green



Multigenerational research of model fish onboard the ISS. [Image credit:JAXA]

Results:

(1) Scientific Reports,
DOI：10.1038/srep14172
(2) Plos ONE,
DOI：10.1371/journal.pone.0138799

Space Applications: Elucidation of the molecular mechanism of bone mineral density decrease in space flight.

Earth Applications: Development of pharmaceuticals to treat senescent osteoporosis.

Scientific Research

(in pressurized module)

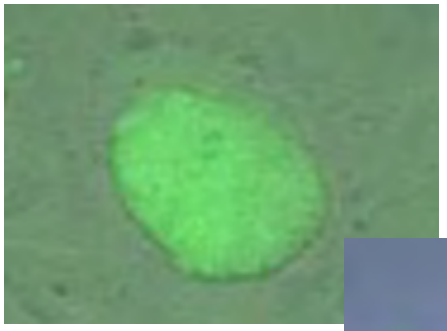
Stem Cell

Study on the Effect of Space Environment to Embryonic Stem Cells to Their Development

PI: Professor Takashi Morita, Osaka City University, Osaka, et al.
Sponsoring Space Agency: JAXA

Research Objectives:

Stem Cells is an investigation that uses embryonic mouse stem cells to study the effects of the space environment on their DNAs, chromosomes, and on their development into adult mice after return to Earth. Frozen stem cells are placed in the Kibo module for periods ranging from 6 to 36 months, and then returned to Earth where scientists will microinject them into 8-cell mouse embryos that will be implanted in female mice. Investigators will also look for double-strand DNA breaks and chromosome aberrations caused by space radiation



Mouse ES Cell

[Image credit:JAXA]

Cryo tubes in the Case

Stem Cells Sample Case

[Image credit:JAXA]

A "Stem Cells Sample Case" in a mock up of MELFI 1/2 box module

MELFI

Scientific Research

(in pressurized module)

Space Pup

Effect of space environment on mammalian reproduction

PI: Professor Teruhiko Wakayama,
Yamanashi University, et al.
Sponsoring Space Agency: JAXA

Research Objectives: Space Pup represents the first step towards studying the effects of space radiation on mammalian reproduction, which must be understood to sustain life beyond Earth. This starts by holding freeze-dried mouse sperm aboard the International Space Station for one, 12, and 24 months, and then fertilizing mouse eggs on Earth to produce mouse pups to study the effects of space radiation.

Ampoule
(in the case)

Space Pup Sample Case

A "Space Pup Sample Case" in MELFI

[image credit:JAXA]

Iinjecting male germ cells directly into an oocyte using microscope

Space Applications: Sustaining life beyond Earth either on space stations or other planets requires a clear understanding of how the space environment affects key phases of mammalian reproduction. So far only non-mammals have been used in reproductive studies in space. Studies using simulated microgravity on Earth showed birth rates due to poor placental development, indicating that microgravity has an adverse but unknown role in fertilization and gestation. Space Pup will help isolate radiation as a factor in long-term studies.

Earth Applications: The gestational period is highly sensitive to environmental factors, including radiation and potentially the effects of gravity. Results from this experiment should provide valuable information for the collection and preservation of mammalian reproductive tissue for a range of uses.

Scientific Research

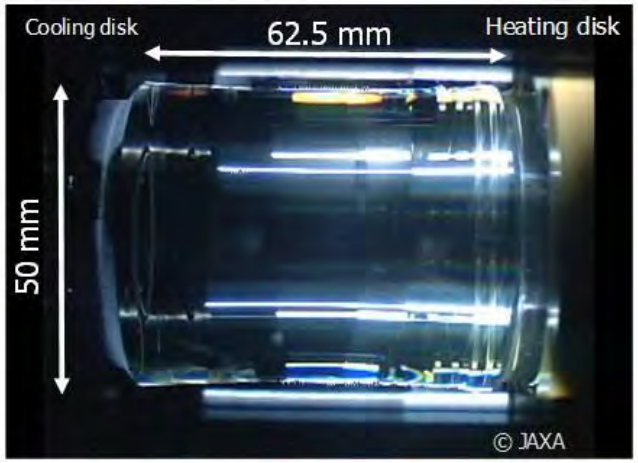
(in pressurized module)

Dynamic Surf

Experimental Assessment of Dynamic Surface Deformation Effects in Transition to Oscillatory Thermo capillary Flow in Liquid Bridge of High Prandtl Number Fluid

PI: Professor Yasuhiro Kamotani, Case Western Reserve University

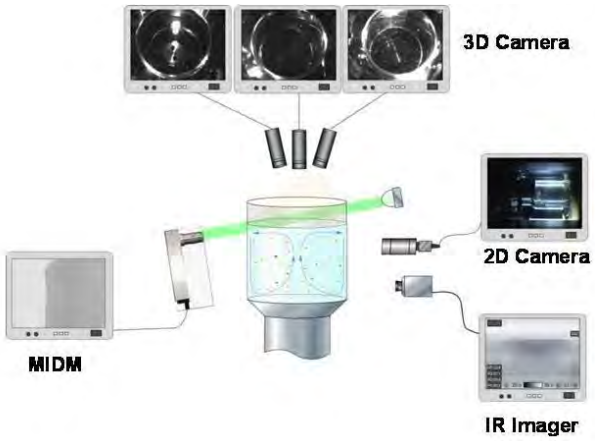
Sponsoring Space Agency: JAXA



Liquid bridge of silicone oil formed in Kibo [Image credit:JAXA]

Research Objectives

The Dynamic Surf investigation is part of a series of JAXA experiments that examine a specific type of heat transfer called Marangoni convection. This convection is produced by a difference in temperature between a liquid and a gas. By observing how a silicone-oil mixture changes when heated, scientists can learn how heat is transferred in microgravity, which could lead to better designs for fluid-based systems in space.



Observation method of Marangoni convection (MIDM: Microscopic Imaging Displacement Meter) [Image credit:JAXA]

Space Applications: In the experiment, a silicone oil is suspended between two small solid disks. One of the disks is heated and another is cooled to create a difference in temperature across the liquid. The difference is gradually increased to cause the convective force known as Marangoni flow, and it becomes more complicated and turbulent. Understanding the physics of this convection will improve research in high-quality crystal growth, such as crystals used for semiconductors and optics, and in various micro-fluid applications, such as DNA examination.

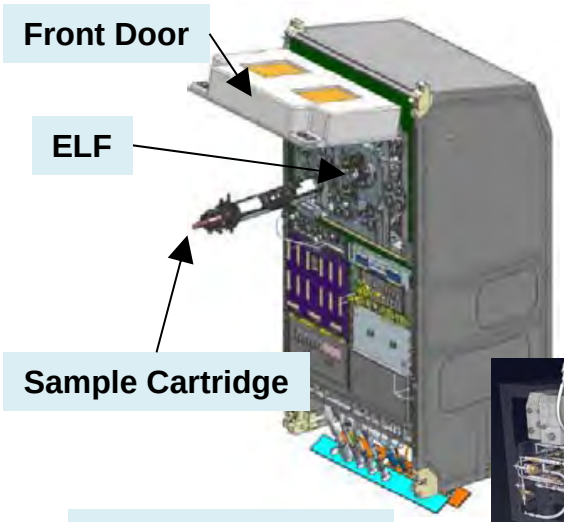
Earth Applications: Marangoni convection is important for heat exchangers, which use combinations of liquids and solids in heating and cooling systems. Understanding the turbulent forces that contribute to this type of convection could lead to better designs for spacecraft thermal management systems.

ELF “Electrostatic Levitation Furnace”

(launched in 2015)

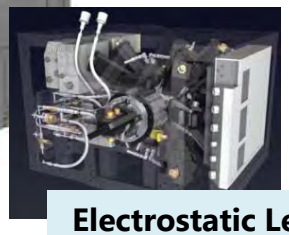
Facility Operations :

- **The ELF is assembled in the Work Volume of Multipurpose Small Payload Rack (MSPR) located in the Japanese Experiment Module (JEM) and Sample cartridge is installed into Chamber by crew.**
- **Following the initial checkout of the assembled hardware, the experiment and operation will start by ground operation.**
- **The sample is injected with rod, and charged/ position controlled/ heated and melted through electrodes and power lasers.**
- **The sample is measured and observed through sensors and cameras.**
- **Images and environmental data are downlinked and the samples are returned with sample holders to the ground for analysis.**



MSPR Structure

[Image credit:JAXA]



Electrostatic Levitation Furnace(ELF)

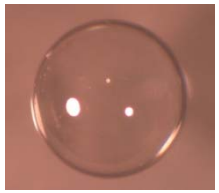
Capability Comparison

Specimen	Low Temperature	High Temperature
Conductor (Metal, Alloy)	Sound wave floating furnace (NASA)	Electromagnetic floating furnace(ESA)
Insulator (Oxide)		ELF (JAXA)

Levitation, Oscillation and melting Image on ground

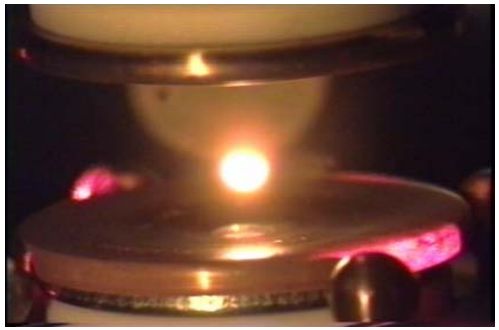
[Image credit:JAXA]

ELF for New Science & Technology

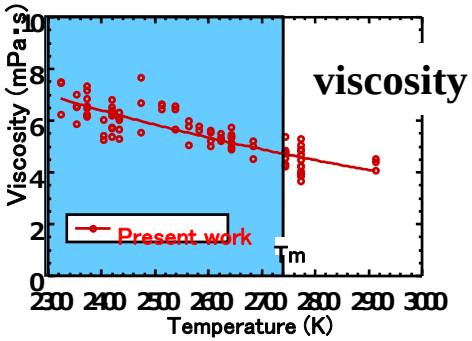


glasses with high refractive index

ELF



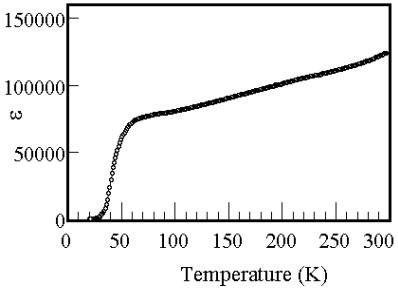
Above 2000K



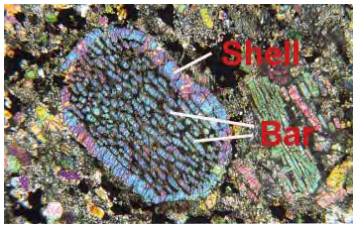
Thermophysical property measurements

New functional materials

ferroelectric materials



Planetary Science



reproduction of structure found in chondrule

High temperature thermal property

Structural analysis of molten metals

[All Image credit:JAXA]

Hybrid Muscle Training

The Effect of the Hybrid Training Method on the disuse atrophy of the musculoskeletal system of the astronauts staying in the International Space Station for a long term Initial verification in ISS

PI: Professor Naoto Shiba, Kurume University

Sponsoring Space Agency: JAXA

Objectives

Hybrid Training System (HTS) is used for one of an astronaut's upper limbs (the non-dominant arm) for four weeks, and his muscular strength and bulk are compared to those of his non-HTS arm (the dominant arm) to examine its orbital operation capability utility, as well as the preventive for muscle atrophy.

HTS (Hybrid Training System) can become a useful back-up for the standard training device in the ISS. It can also be a useful training device in small space ships for the exploration of the Moon and Mars.

Hybrid Training System (HTS) for ISS

[Image credit:JAXA]

Concept:

To provide motion resistance inside the human body instead of gravity.

Space Applications: **One benefit of this experiment is that muscle force of the exercised upper limb will be maintained or increased by HTS training. Moreover, it has potential benefits for the promotion of space medicine as well as human space flight.**

Earth Applications: **There are potential benefits to bed-rest patients, spin-offs in the field of clinical medicine and aging. These can eventually bring about substantial contributions to society.**

Scientific Research (on exposed facility)

MAXI

Monitor of All-sky X-ray Image

PI: Professor Masaru Matsuoka, Institute of Physical and Chemical Research, *et al.*

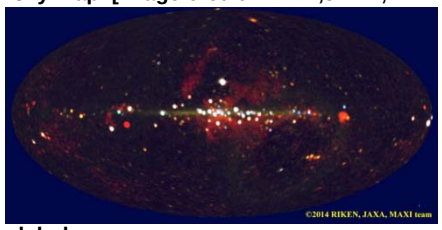
Sponsoring Space Agency: JAXA

Objectives

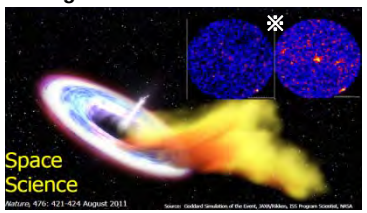
The MAXI investigation is designed to continuously monitor, through a systematic survey, X-ray sources and variabilities as the International Space Station (ISS) orbits Earth. MAXI is comprised of a couple highly sensitive X-ray detectors, the Gas Slit Camera (GSC) and the Solid-state Slit Camera (SSC). Besides the goal of performing a complete sky survey, this research helps to address fundamental astrophysics questions and allows researchers to better understand the current state and evolution of our Universe.

MAXI's highly sensitive X-ray slit camera is monitoring more than 1,000 X-ray sources in space, including black holes and neutron stars.

MAXI all-sky map [Image credit:RIKEN,JAXA,MAXI team]

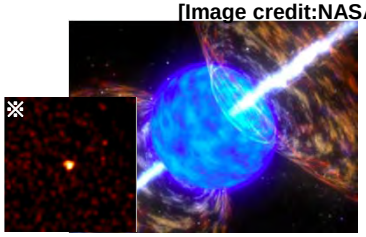


Onset of relativistic jet from a black hole consuming a star.



[Image credit:NASA/Swift]

[Image credit:NASA]



X-rays afterglow of huge gamma-ray bursts

[Image credit of ※:RIKEN,JAXA,MAXI team]

SMILES

Superconducting Submillimeter-Wave Limb-Emission

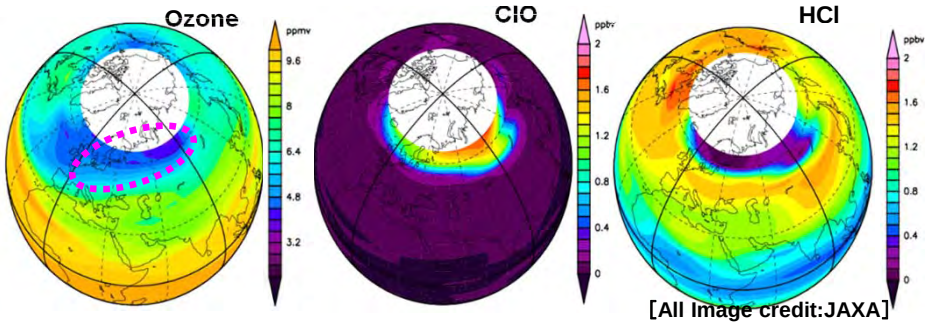
PI: Professor Masato Shiotani, Kyoto University,et al.

Sponsoring Space Agency: JAXA

finished

Objectives

The SMILES investigation is a highly sensitive, cryogenically cooled, radio wave receiver that measures atmospheric limb emissions. SMILES monitors and maps the global distributions of the high altitude trace gases and constituents related to the chemistry of the ozone layer. Observing and understanding the properties and evolution of the upper atmosphere allows researchers to better model Earth's atmosphere and possibly detect or predict environmental changes.



[All Image credit:JAXA]

On January 23, 2010, SMILES observed destruction of the ozone layer at an altitude of 22 km. Utilizing its high sensitivity, SMILES not only observed ozone depletion but also captured changes in chlorine compound levels over a single day.

Space Applications: The technologies of the cryogenic system used in SMILES will be taken over by future space science programs.

Earth Applications: The high sensitive observations of SMILES will gain a better understanding of processes controlling the stratospheric ozone chemistry and those related to climate change.

Scientific Research

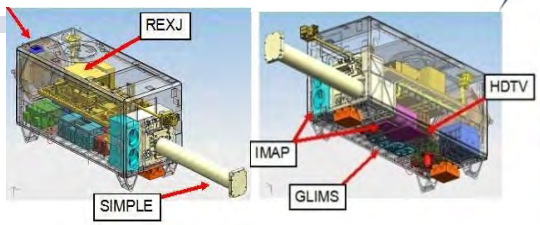
(on exposed facility)

MCE

Multi-mission Consolidated Equipment

Sponsoring Space Agency: JAXA

finished



Research Objectives:

- IMAP (Ionosphere,Mesosphere,upper Atmosphere, and Plasmasphere mapping) studies the energy and plasma activity and related global transportation near the rim of atmosphere, at the highest altitudes, using a visible light spectrometer.

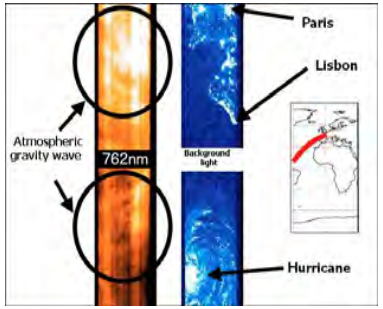
-GLIMS (Global Lightning and sprIte Measurements on JEM-EF) investigates the spatial distribution of lightning and plasma phenomena and their discharge characteristics throughout the atmosphere during night observation times.

-SIMPLE (Space Inflatable Membranes Pioneering Long-term Experiments) collects fundamental engineering data in orbit for inflatable space structures; with the expectation of applying such information to the design of future space structures.

-REXJ (Robot Experiment on JEM) demonstrates real-time ground control of a robotic system by providing validation data during robotic manipulation. This investigation is expected to lead to an application of an EVA assistant type robot.

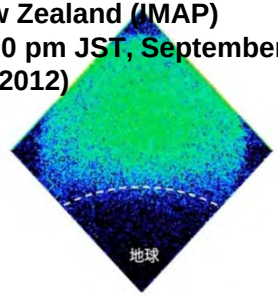
-HDTV acquires data for evaluating how long a COTS-HDTV (COTS HTDV Verification) survives in the orbit environment. This evaluation includes a validation for inexpensive space HDTV systems.

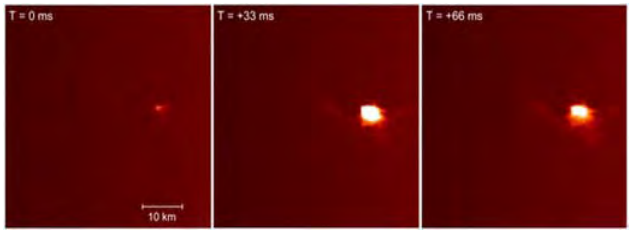
-A-IMAP makes imaging observation of the airglow and aurora using a digital camera operated by an astronaut to elucidate the structures and dynamics of the Earth's upper atmosphere. Coordinated observations with IMAP are carried out to investigate the common target.



Airglow at 762nm of wavelength (IMAP) (Sep. 25, 2012)

Resonant light scattering of He+ was obtained by EUVI. Observed over near New Zealand (IMAP) (4:00 pm JST, September 26, 2012)

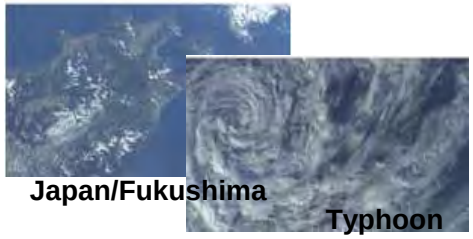




The upper-atmospheric lightning (GLIMS)

Inflatable membrane extension (SIMPLE)

Robotics operation experiment(REX-J)



Japan/Fukushima

Typhoon

High Definition Camera (COTS-HDTV)

［All Image credit:JAXA］

Scientific Research

(on exposed facility)

CALET

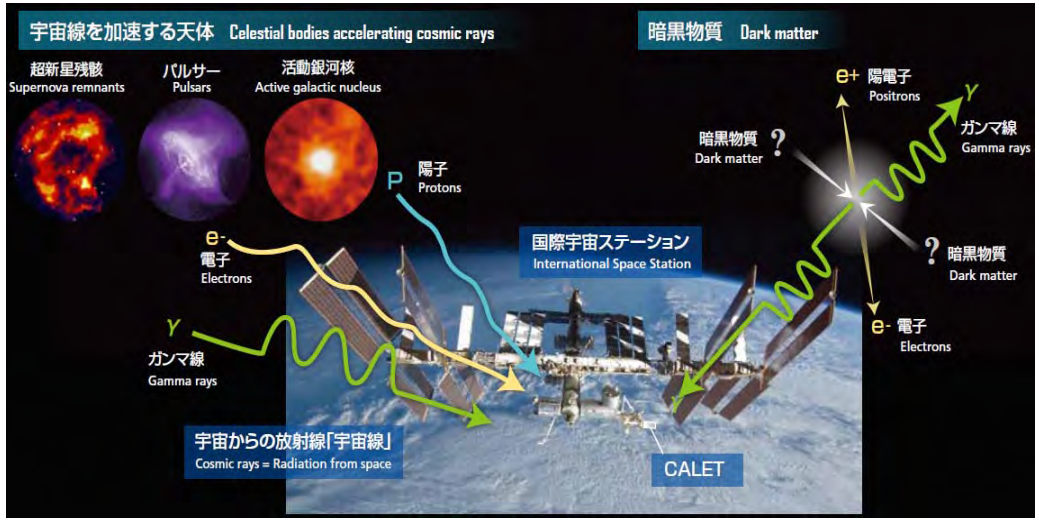
CALorimetric Electron Telescope

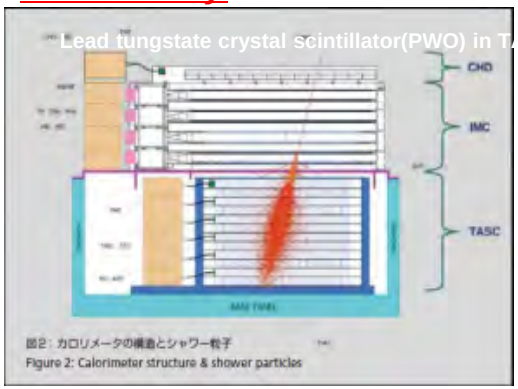
PI: Professor Shoji Torii, Waseda University, et al.

Sponsoring Space Agency: JAXA

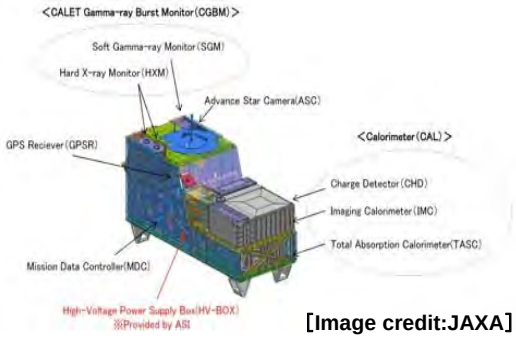
Research Objectives

CALorimetric Electron Telescope (CALET) is an astrophysics mission that searches for signatures of dark matter and provides the highest energy direct measurements of the cosmic ray electron spectrum in order to observe discrete sources of high energy particle acceleration in our local region of the Galaxy.





CALT Calorimeter structure and shower particles



[Image credit:JAXA]

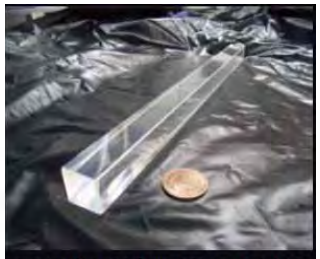


図3：タングステン酸鉛結晶シンチレータ(PWO)
Figure 3: Lead tungstate crystal scintillator (PWO)

Space Applications: CALET addresses many outstanding high-energy astrophysics questions such as the origin of cosmic rays, how cosmic ray accelerates and travels across the galaxy; the existence of dark matter and nearby cosmic-ray sources. An inventory of the highest-energy radiation encountered in space also helps in characterizing the radiation environment encountered by humans and space electronics, and the risks they face.

Earth Applications: CALET expects to provide an important window on the highest-energy phenomena in the galaxy by studying cosmic rays, and seeks the first experimental evidence of the presence of nearby cosmic-ray sources. CALET's long exposure in space may also yield evidence of rare interactions between matter and dark matter.

Commercial Usage

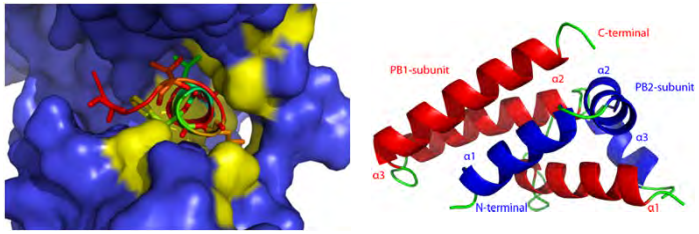
Scientific Research

With International Society

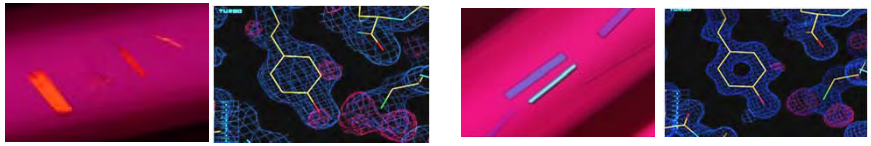
High Quality Protein Crystal Growth (PCG) Experiment

- Make high quality protein crystals under microgravity environment.
- Analysis by Japanese SPring-8 Synchrotron radiation facility give fine protein structure that is useful for designing new medicine.
- Universities and pharmaceutical companies have joined the research.

Influenza Virus RNA Polymerase



Prostaglandin D Synthase



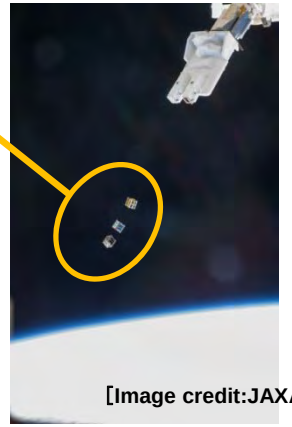
Ground **Space**

[Image credit:JAXA]

CubeSat Deployment from Kibo

- CubeSat deployment with JEM Small Satellite Orbital Deployer (J-SSOD), for commercial usage.
- For domestic and international commercial users.
- Brazilian CubeSat deployment was conducted in Feb. 2015.

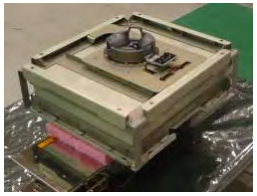
(Right) Deployed CubeSat
(Below) Vietnamese CubeSat "PicoDragon" in 2013



[Image credit:JAXA]

Exposed Handrail Attach Mechanism (ExHAM)

ExHAM, attached to a Kibo's handrail, with exposed materials can be used after 2015.



[Image credit:JAXA]

High-quality Protein Crystal Growth(PCG) Experiment

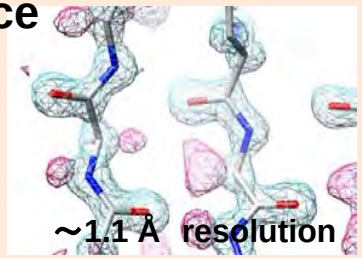
■The purpose of the experiments

- To obtain high-quality protein crystals under microgravity and to achieve more precise 3-D protein structures.
- Developing industrial applications as functional protein and drug designs based on protein structures.
- Contributing to structural biology by clarifying protein structures and functions.

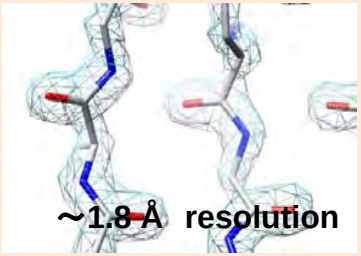
■Examples of Results

Nylon Oligomer Hydrolase (University of Hyogo)

Space

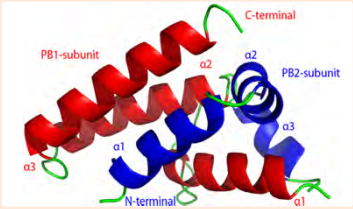


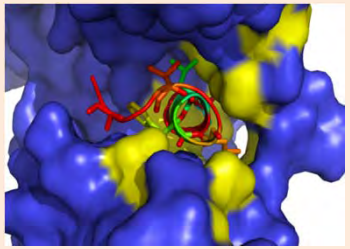
Ground



Create new enzymes and catalyze the synthesis of nylon-6 (reverse reaction) or other potential products.

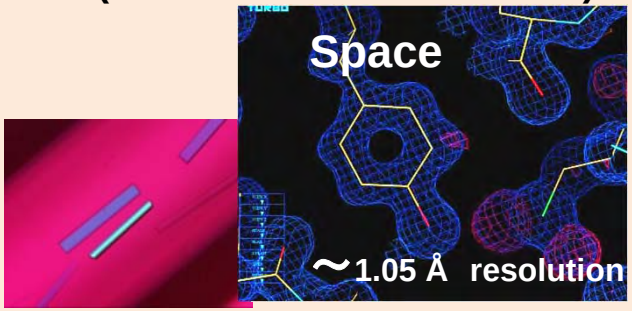
Influenza virus RNA polymerase (Yokohama City University)

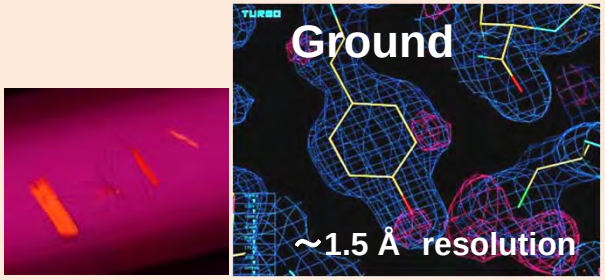




Structural insight into the RNA polymerase lead to the development of new medicine regardless of influenza viruses type.

Prostaglandin D Synthase (Osaka Bioscience Institute)





A drug for muscle diseases was designed by pharmacists and its effect was confirmed with animal experiments.

High-quality Protein Crystal Growth(PCG) Experiment

[All image credit:JAXA/FSA]

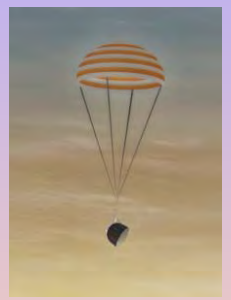
Soyuz/Progress

Crystallization in Kibo

Soyuz

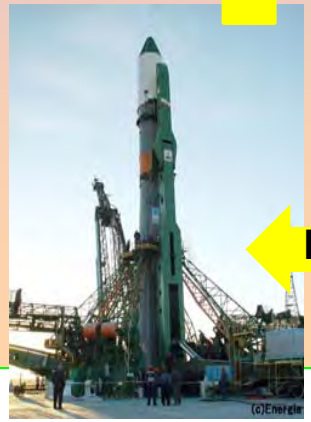
Launch

Return



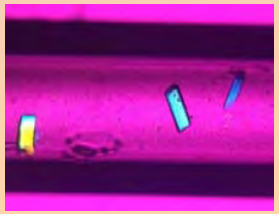
Concept of JAXA PCG

- User-friendly support system
- Application of accumulated know-how to maximize space crystallization



Loading

Protein Crystallization Facilities



Visual inspection and X-ray diffraction

Environmental Control and Life Support System (ECLSS)

- Water Recovery System:
  - Full scale model in ground test.
  - Subscale model in flight model development for flight.
  - Scheduled for launch in 2016.
- Air-Recycling System:
  - Applies a low-temperature reactor in CO2 deoxidization and water electrolysis.
  - Flight test of oxygen generation assembly on ISS is planned.

Radiation Measurement

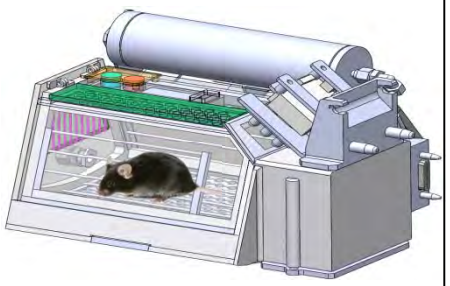
- Compact battery-less radiation dosimeter package and analysis system (PADLES)
- Measurement of radiation doses on ISS using PADLES
- Joint research with Roscosmos Matroshka-R

[Image credit:JAXA]

JAXA Rodent Research and Mouse Habitat Unit

- JAXA Rodent Research:

  To keep mice on board under μG and 1G environment to investigate the effect of the gravity environment on gene expression patterns.
- Mouse Habitat Unit (MHU):
  - Consists of 12 mouse cages with life support, environment control and observation system.
  - Launched in 2015. The first experiment will be conducted in 2016.



[Image credit:JAXA]

Activities with International Society

[All image credit:NASA/JAXA]

(1) Capacity Building through APRSAF

- **Plant Seed Observation Experiment（SSAF2013）**
  Seven Asian countries with over 1,300 students and teachers participated.
  In Malaysia, 39,000 people participated in a joint plant seed observation contest.
- **Microgravity Experiments by Parabolic Flights**
  Seven opportinities with students of Thailand, Malaysia and Vietnam.

- **Scientific Experiment Demonstration through APRSAF/Space Education WG**

(2) Collaboration with Asian Space Agencies

- **Protein Crystal Growth Experiments with Malaysia**
  Past six experiments lead theses and students getting degrees in Masters and Ph.D.

- **Vietnamese CubeSat "PicoDragon"**

(3) Natural Disaster Monitoring in Asia

(International Disaster Charter and Sentinel Asia)

- Registered in IDC in 2013. Delivering natural disaster monitoring data to Asia.

Flood in Thailand taken by Astronaut Furukawa. (Oct. 2011)

Forest fire in Sumatra (Jun. 2013)

Flood in Philippines caused by Typhoon#30 (Nov. 2013)

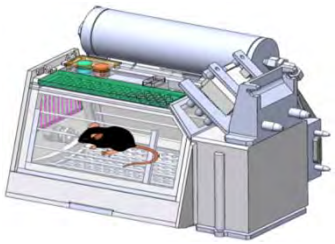
The Mission of Astronaut Yui in 2015

➢ Astronaut Kimiya Yui is now onboard the ISS.
(from July 2015 to December 2015)

< Missions of Astronaut Yui >

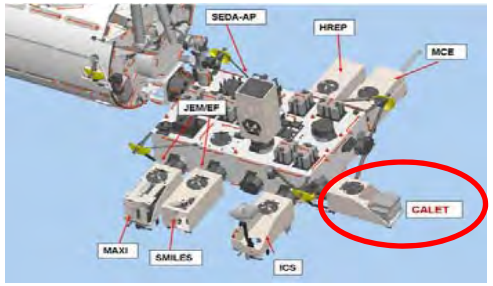
(1) Verification of the functions of the breeding and experimental device for small animals

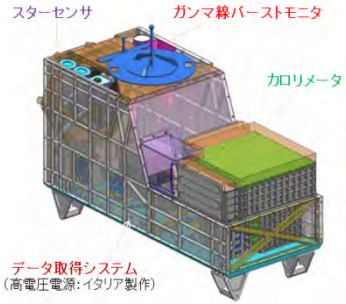
・Capability to breed healthy mice in orbit.
・The device enables the separate observation of 12 mice for approximately 30 days.



(2) CALET: observation of high-energy cosmic rays

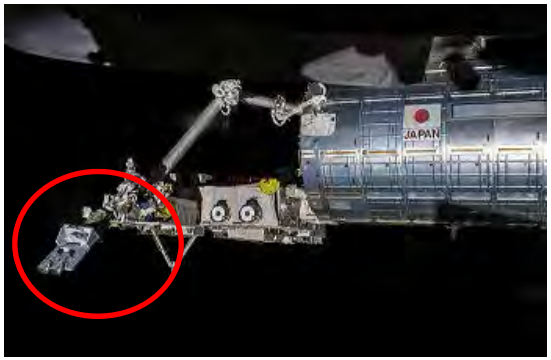
• Cosmic ray observatory seeking to unravel the mysteries of dark matter and cosmic rays, and venturing into the frontier of space science





(3) Deployment of microsatellites (SmallSat Deploy)

・SmallSat Deploy is a satellite deployment mission using the robotic arm.



And more...

[Image credit:JAXA]

Try Zero-G 2015 by Astronaut Yui

Asian Try Zero-G 2015 was successfully performed by Astronaut Kimiya Yui on Aug. 20th, 2015. The video was down-linked and distributed through internet.

http://iss.jaxa.jp/en/kuoa/news/yui_try_zero-g_2015.html

KUOA KIBO UTILIZATION OFFICE FOR ASIA

KUOA News

KUOA Programs

- Space Seeds for Asian Future (SSAF)
- Asian Students' Parabolic Experiment Contest
- The Japan-Korea Joint Seminar on Space Environment Utilization Research

Reference Materials

LINK

Kibo Experiment

JAXA Digital Archives

KIBO-ABC

Try Zero-G 2015 performed by JAXA astronaut Kimiya Yui

Last Updated: November 27, 2015

KIBO-ABC

Try Zero-G 2015 performed by JAXA astronaut Kimiya Yui, the following 6 proposals were selected out of 80 proposals. (Similar proposals were merged through the selection process.) He also gave us special message to Asian youth.

The next call for proposal of Try zero-G for Asia 2016 will be open very soon with renewal application.

Try Zero-G 2015 movies

Thumbnail	Title	Duration
	Astronaut Yui's opening remarks • Windows Media Player • MP4 file format	00:54
	Experiment 1: Spinning a ball on it's own axis with one finger (Proposed by students from Malaysia) • Windows Media Player	04:25

Thank you very much! Terima kasih