Scientific Commission E

Astrophysics from Space

NISS onboard NEXTSat-1

Korea Astronomy and Space Science Institute (KASI) has been putting in efforts to develop infrared space instruments for the measurement of extragalactic background light (EBL). To address the origin of the large-scale fluctuation of EBL, KASI developed the Near-infrared Imaging Spectrometer for Star formation history (NISS) onboard NEXTSat-1. The unique capability of near-infrared imaging spectroscopy (Figure 1) is optimized to study scientific objectives, i.e., the origin of the fluctuation spectrum of EBL and the star formation in the local Universe through the spectral mapping of astronomical objects (e.g., nearby galaxies, star-forming regions, galaxy cluster, deep fields). System calibration was performed by utilizing our constructed test facility. The NISS was launched in 2018, and its scientific operation ended in June 2019. Currently, the NISS data are being analyzed. The NISS demonstrated the infrared imaging spectroscopy in space and performed the near IR imaging spectroscopic survey for star-forming regions, nearby galaxies, extragalactic deep fields, and so on (Figure 1). The performance of the infrared imaging spectroscopy matched the design specification.

International Collaboration Mission, SPHEREx

Based on the heritage of the NISS, KASI has been collaborating for SPHEREx (Figure 2), the first all-sky infrared spectro-photometric surveyor, as the NASA Medium Explorer (MIDEX) mission (PI institute: Caltech). Compared with the NISS, the SPHEREx accommodates a higher spectral/spatial resolution and a wider field of view to achieve three major scientific goals such as the origin of our Universe, the evolution of galaxies, and the Galactic ice survey. KASI is SPHEREx's unique international partner and contributes to the SPHEREx project in the development of the calibration facility and scientific research.

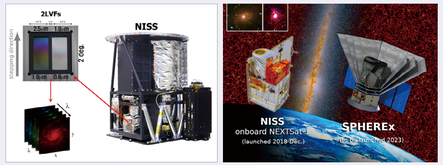


Figure 1. The NISS (right), its Linear Variable Filters (LVFs, upper-left), and an example output spectral map of a galaxy from the LVFs (lower-left).
Figure 2. NISS and SPHEREx. The insets show the M33 galaxy and the Orion cloud images captured with NISS's LVFs.

Scientific Commission F

Life Sciences as Related to Space

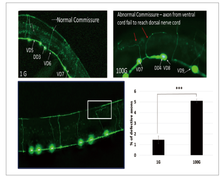
Genetics, development and physiology of animal models in altered gravity (Yonsei Univ.)

Yonsei Univ. (Team Leader Prof. J.I. Lee) is using *C. elegans* to elucidate the effects of hypergravity, simulated microgravity and space microgravity on neuron development and immune function at the genetic level. They have shown that the development of motor neurons is hindered by high gravity due to the compression of tissues blocking migration pathways. They have also shown that the proper development of the delicate dendritic endings of touch-sensing neurons are affected by high gravity. They are currently investigating the effects that space microgravity has on neuron development via experiments aboard the International Space Station.

Hypergravity hinders proper neuron development by compressing rigid tissue layers in nematode C. elegans

To study the effect of hypergravity on *C. elegans* biology, Prof. Lee's team used a tabletop centrifuge to create a gravity force and designed a small worm cultivation tube from a 1.5 cm centrifuge tube filled with agar and seeded it with OP50 E. coli bacteria on top : the food of the nematode. To visualize the DD/VD motor neurons, they used a *C. elegans* transgenic strain that expresses GFP under the control of the unc-25 gene promoter. Eggs containing developing embryos were placed in the cultivation tube, and either spun in the centrifuge to induce a high gravity force of 100G or placed in a 20C incubator as a 1G gravity control. At 1G, most of the animals showed normal DD/VD commissural projections that reached the dorsal nerve cord. However, in animals exposed to 100G hypergravity for 60 h, defective axonal projections could be seen more frequently. Axonal defects occurred at a frequency of 1.5% ± 0.36. In 100G, defects occurred at a rate of 5.1% ± 0.17, an over three-fold increase compared to 1G (Fig. 1).

To understand the mechanism of how gravity force affects motor neuron axon development, Prof. Lee's team performed a candidate genetic screen and looked for mutants that would suppress the hypergravity-induced axon defects (HIAD). They found that neuronal factors surprisingly did not alter HIAD. Instead, mutants of proteins that were localized to the muscle, epidermis and ECM suppressed HIAD (Fig. 2). These proteins, including UNC-70 spectrin, SMA-1 spectrin, UNC-54 myosin, VAB-10 spectraplakin, VAB-19 kank, UNC-52 perlecan, and ROL-6 collagen, were important in forming a hemidesmomal structure, called the fibrous organelle, that holds the muscle, epidermal, and cuticular tissue layers together. They surmised that hypergravity may compress these rigid tissue layers together hindering proper motor neuron axon migration, but loss of fibrous organelle proteins loosens the rigid structure of the tissues restoring normal axon migration and development (Fig 2). They are also investigating the effect of space microgravity in motor neuron development after sending *C. elegans* to space aboard the International Space Station in collaboration with the University of Exeter and the European Space Agency.



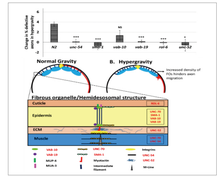


Figure 1. Hypergravity induces axon defects in motor neuron development in *C. elegans*. (left) **Figure 2.** Genetic analysis of hypergravity-induced axon defects. (right)

Scientific Commission G

Materials Science in Space

Developments of combined techniques with electrostatic levitation (ESL) and synchrotron X-ray diffraction for various liquids.

Geun Woo Lee's group (Frontier of Extreme Physics) in Korea Research Institute of Standards and Science (KRISS) has been developing electrostatic levitation (ESL) devices for materials studies at both ultra-high temperature and low temperature since 2008. This is a good test-bed for space-sciences which can be conducted on the international space station. In 2022, this group have significantly improved the repeatability and precision of density measurements for high melting temperature materials over 3000 K. Moreover, the ESL devices have been modified to investigate highly supersaturated aqueous solutions and a new phenomenon which is called multiple pathways of crystallization under extreme supersaturation with aqueous solutions has been found. In 2021, Dr. Lee's group has demonstrated highly supersaturated NaCl solutions and found an evidence of two-step nucleation of NaCl solution that has been predicted for over 20 years. This provides a new insight for non-classical nucleation theory for large communities, e.g., physics and chemistry, materials sciences, food, cosmetics, biology, and so on. These ESL devices have been combined with Synchrotron X-ray scattering at the Pohang Accelerator Laboratory (PAL) (1C-beamline) to investigate the structures of various materials as well as thermophysical properties.

Structure Analysis of CaO-SiO_2-Al_2O_3 Melts

At Korea University, Joonho Lee's group has studied the structure of aluminosilicate melts which is affected by the degree of polymerization, the fitting of cations and the nature of the network modifiers present in the melts. Dr. Lee's group performed density measurements of the levitated melts by using the aerodynamic levitation method, and the structure analysis with Raman spectroscopy. Structural modification results in the changes of the density and the thermal expansion coefficient.

Solidification study by aerodynamic levitation

At Inha University, Wonseung Cho's group has studied BaTiO3 by using aerodynamic levitation. The solidified BaTiO3 shows a compositional shift by heat treatment with Ti or TiO2 rich compositions. The effect of heat treatment on the microstructure of BaTiO3 shows ~400 nm BaTiO2 grains which is understood by the formation of Ba6Ti17O40 by atomic diffusion. This work will helpful to develop giant ferro-electric materials and high refractive glasses.

Figure 1. Combination of ESL and Synchrotron X-ray and Raman scattering **Figure 2.** Two-step nucleation in NaCl solution and crystallization of colloids **Figure 3.** Images of a slag drop in the aerodynamic levitation ((1)1773 K, (2) 1873 K, (3) 1973 K, and (4) 2073 K) **Figure 4.** SEM images of (a) surface of as-levitated BaTiO3 sample and (b) nucleation point at surface, (c) microstructure after heat treatment at 1000 °C-1 h, and (d) at 1000 °C-12 h (surface).

Scientific Commission H

Combustion Science and Fire Safety Research for Manned Space Exploration

Parabolic flight experiments to investigate the flame spread over wires under different gravitational fields (KARI & Chosun Univ.)

During manned space exploration to Mars, crew members are inevitably exposed to different gravity environments. In this study, the flame spread characteristics were investigated from the perspective of fire safety for a manned space module. To this end, a flame spread over thermally-thin optical fiber was experimentally investigated in a quiescent environment. An optical fiber with a thin combustible (polyethylene) layer was used as solid fuel. Noting that changes in gravitational field are essential during the manned space exploration to Mars, the effects of changes in gravitational field on flame spread were investigated using a series of parabolic flight campaigns provided by Zero G company. Parabolic flights provide approximately 20 second periods of reduced gravity ranging from Mars gravity to Microgravity (See Figure 1). The experimental results clearly show that the flame spread rate was much faster in the microgravity environment compared to that in Mars gravity environment followed by the earth gravity environment. These experimental findings provide important foundational understanding of the influence of gravity on the flame spread over thermally-thin combustibles that had yet to be previously studied.

A nanosatellite as an ideal platform to study the fire safety for human spaceflight

This study investigates the feasibility of a nanosatellite (named as "Korea Microgravity Science Laboratory, KMSL") as a scientific platform to investigate the fire safety in space. The KMSL mission is designed and implemented to perform a series of flame spread experiments in microgravity inherently created during its on-orbit operation. The KMSL was selected as the final recipient satellite through a national CUBESAT competition in 2017 and has been funded by Korea Aerospace Research Institution (KARI) for implementation and fabrication.

The KMSL nanosatellite is a 3U sized CubeSat which includes a combustion scientific payload (Combustion Experiment Module, CEM) for flame spread experiments in microgravity. This payload is perfectly sealed and acts as a miniature science laboratory that enables a series of the scientific experiments to be conducted in a designed atmospheric environment during on-orbit operation. The objectives of these combustion experiments are to visualize a sequence of flame ignition, spread and extinction for given atmospheric environments in microgravity. The KMSL nanosatellite was successfully launched on a Soyuz rocket in March, 2021.

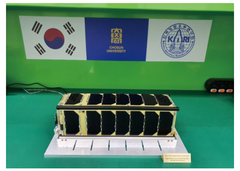


Figure 1. Combustion chamber and auxiliary devices (left) **Figure 2.** Flight Model of the KMSL nanosatellite (right)

Korean National Committee for COSPAR

COSPAR 2022

National Report

Republic of Korea

Scientific Commission A

Geostationary Environment Monitoring Spectrometer (GEMS) on GK2B

The First Air Quality Monitoring Mission from GEO

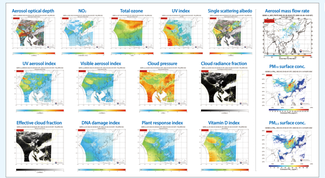
The first air quality monitoring mission, Geostationary Environment Monitoring Spectrometer(GEMS) was successfully launched on Feb 19th KST 2020. GEMS is a scanning UV-visible spectrometers with an unprecedented spatial and temporal resolution. Its spectral resolution is 0.6 nm over 300 – 500 nm, and its spatial resolution is 7 km x 8 km for gases and 3.5 km x 8 km for aerosols, covering Asia (latitude: 5S – 45 N, longitude: 75 E – 145 E). GEMS is to revolutionize air quality monitoring from space, which eventually contributes to top-down emission estimates and air quality forecasts.

GEMS Program

GEO-KOMPSAT(GK) series have been a key to Geostationary Earth Orbit(GEO) program as listed in the National Space Program of Korea.

GEMS Observation, Pandora Asia Network, and the three GEO Missions

Using a scanning UV-Visible spectrometer, it can contribute to providing a set of tropospheric column products over the Asia-Pacific region at a spatial resolution of ~ 8 km and a temporal resolution of one hour. Other products include NO_2, HCHO, SO_2, and aerosol optical depth. GEMS can scan a 5000 km East/ West area in less than 30 minutes with its state-of-the-art calibration skills and high spatial and spectral resolution. In geostationary orbit, GEMS collects images every 8 to 12 hours. Out of the 21 GEMS observation items, 14 items are currently being released in real time on the website of the Environmental Satellite Center (https://nesc.nier.go.kr). The other 7 items (aerosol effective height, stratospheric ozone, tropospheric ozone, surface reflectance, HCHO, CHOCHO, and tropospheric NO_2) will become available in 2022. Ground-based networks have started to be built as essential components in the validation of the GEMS missions, where Pandora, a ground-based UV-visible spectrometer, is a key instrument. Pandora Asia Network(PAN) was established to deploy 20 Pandora systems to 13 countries within the GEMS field of Regard, with the support of Korea International Cooperation Agency, United Nations Economic and Social Commission for Asia and the Pacific. NIER(National Institute of Environment Research) has released the policies on the data collected from GEMS and is planning to distribute the data to users through their network. Data distribution and capacity building is to be implemented through the Pan-Asia Partnership for Geospatial Air Quality information (PAPGAPI). As of 2022, three Pandoras have been installed in Thailand and Mongolia. 20 Pandora systems will have been installed in total by the end of 2022. GEMS is to be followed up by NASA's TEMPO over North America in 2022, and ESA's Sentinel-4 over Europe in 2023-2024. These three missions have similar observational capabilities to form GEO Air Quality(AQ) Constellation, as recognized by the Atmospheric Composition-Virtual Constellation of the Committee on Earth Observation Satellites. The three GEO AQ missions, together with environmental and meteorological measurements, will improve our understanding of the transport of air pollutants and chemical and physical processes by integrating multiplatform, cross-scale observational assets. The GEO AQ Constellation will be the first of its kind to monitor global air quality in a coordinated manner.



The observation images and value added product of GEMS, (Expected) release dates of GEMS observation images

No.		Release plan of products (month/year)
1	Aerosol	AOD (March, 2021)
2		Single Scatter Albedo (October, 2021)
3, 4		UV/VIS Aerosol Index (October, 2021)
5		Aerosol Effective Height (November, 2022)
6	O3	Total Ozone (March, 2021)
7		Stratospheric Ozone (November, 2022)
8		Tropospheric Ozone (November, 2022)
9	Surface reflectance	Surface Reflectance (October, 2021)
10	Cloud	Cloud Centroid Pressure (October, 2021)
11		Effective Cloud Fraction (March, 2021)
12		Cloud Radiance Fraction (October, 2021)
13	VOCs	HCHO (June, 2022)
14		CHOCHO (June, 2022)
15	NO_2	Tropospheric NO_2 (June, 2022)
16		Total NO_2 (March, 2021)
17	SO_2	SO_2 (March, 2021)
18	UV	UV index (October, 2021)
19		Plant response rate (March, 2021)
20		DNA damage rate (March, 2021)
21		Vitamin D production rate (March, 2021)

Scientific Commission B

The Earth-Moon System, Planets, and Small Bodies of the Solar System

Korea Pathfinder Lunar Orbiter (KPLO) Mission

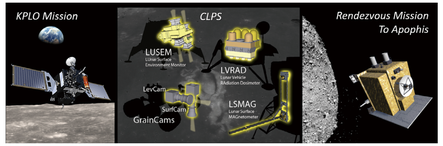
The Korea Pathfinder Lunar Orbiter (KPLO) mission is the first space exploration mission of the Republic of Korea beyond the Earth's orbit. The Korea Aerospace Research Institute (KARI) has launched a series of Korea Multi-Purpose Satellite (KOMPSAT) and Geostationary KOMPSAT (GEO-KOMPSAT) satellites and aims to perform a safe moon landing by 2030. KPLO is scheduled to be launched in August of 2022 using a Falcon-9 launch vehicle. After traveling to the Moon via a Ballistic Lunar Transfer (BLT) trajectory, KPLO will be inserted into mission orbit at an approximately 100 km altitude circular orbit. KPLO will carry out its mission around the moon for one year, and there may be an extended mission depending on the amount of fuel. KPLO is equipped with five science instruments (LUTI, PolCam, KMAG, KGRS, and ShadowCam) and one technology demonstration instrument (DTNPL).

CLPS Korea Project

Korea Astronomy and Space Science Institute (KASI) is developing science payloads to make observations on the lunar surface in situ as a part of Commercial Lunar Payload Services (CLPS) of National Aeronautics and Space Administration (NASA), USA, based on the KASI-NASA Exploration Working Group.
KASI has selected four payload instruments to fly onboard one or more CLPS landers that will be jointly developed by KASI and domestic universities and companies.

Apophis mission (Phase A)

The Rendezvous Mission to Apophis (RMA) is the first asteroid exploration mission proposed in Korea which is currently under pre-Phase A study. The 370 m-sized potentially hazardous asteroid Apophis is expected to approach as close as 31,600 km from the Earth's surface during the close encounter on April 13, 2029 UT. The science team will investigate the changes in spin states, surface topography and regolith distribution of Apophis which are expected to occur due to the tidal forces exerted by Earth during the approach. With a dedicated rendezvous mission to Apophis such as RMA, we should be able to fill in the knowledge gaps in our scientific understanding of tidal effects that can be beneficial for planetary defense in the event of a real threat.

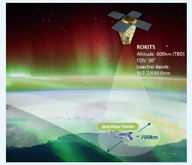


KPLO: Korea Pathfinder Lunar Orbiter (August, 2022), **CLPS:** Four Korean Scientific Payloads (2024 ~2025)
Apophis mission: Phase A study(2022), (Rendezvous, 2029)

Scientific Commission C

The Upper Atmospheres of the Earth and Planets including Reference Atmospheres

In recent years, South Korea has been developing various high-tech facilities with a focus on those associated with advanced information technologies, one of the main engines of the South Korean economy. However, these facilities are increasingly vulnerable to space weather events, such as solar flares and coronal mass ejections.
Reliable space weather information has thus become critical to the continued prosperity of the South Korean economy. To meet this urgent demand, space weather research in South Korea has become a rapidly developing discipline. Government-funded research institutes such as Korea Astronomy and Space Science Institute (KASI), Korea Polar Research Institute (KOPRI), and Korean Space Weather Center (KSWC) have taken an active role in space weather research and applications by monitoring the Sun and near-Earth space environment including the magnetosphere and the upper atmosphere, sponsoring robust national space science and meteorological programs as well as promoting efficient systems for the delivery of space weather information to the public. These institutes closely collaborate with each other and with domestic universities to provide students with various research opportunities such as field experiments, data analysis, and numerical modellings for the upper atmosphere.
KASI performs various ground- and space-based observations around the globe. In particular, the Republic of Korea Imaging Test System (ROKITS) project was recently initiated to develop a wide-field auroral/airglow imaging system for the first auroral observations from space in Korea (Figure 1). The main research activities at KOPRI are the ground-based observations for the various phenomena including the ionospheric densities and irregularities, neutral temperature and winds, aurora, gravity waves, etc. in the polar regions (Figure 2). KSWC of the National Radio Research Agency (RRA) is a national institute which is the official source for space weather alerts and warnings for Korea and also a Regional Warning Center of the International Space Environment Service (ISES).



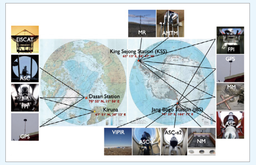


Figure 1. KASI recently initiated the ROKITS project to monitor aurora and airglow emissions from space. **Figure 2.** Various ground-based observations for the upper atmosphere are conducted by KOPRI in the polar region.

Scientific Commission D

Space Plasma in the Solar System, Including Planetary Magnetosphere

Solar Coronagraph Mission

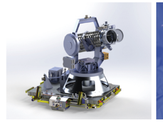
Korea Astronomy and Space Science Institute (KASI) has been developing the next generation coronagraph, Coronal Diagnostic Experiment (CODEX), in collaboration with NASA, which will be installed on the International Space Station (ISS). The coronagraph simultaneously measures the density, temperature, and speed of electrons in the corona. The goal of this mission is to discover the sources and acceleration mechanisms of the solar wind. KASI is currently developing a filter wheel, filters, main electronics, camera, and ground and ground/flight software for this mission. CODEX will be launched in 2023.

SNIPE Mission for Space Weather Research

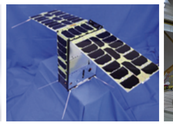
KASI has been developing the Small scale magNetospheric and Ionospheric Plasma Experiment (SNIPE) mission, which is a constellation of four identical 6U cubesats for space weather research. The goal of the SNIPE mission is to measure the spatial and temporal variations of the micro-scale plasma structures on the topside ionosphere including polar cap patches, field-aligned currents, radiation belt microbursts, and equatorial and mid-latitude plasma blobs and bubbles. The cubesat carries a Langmuir probe, a flux gate magnetometer, and a solid state telescope to measure the energetic electrons with energies of 100 – 400 keV. The flight model was completed in 2021 and is waiting for launch.

KSEM on GK2A

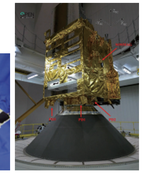
The Korean space environment monitor (KSEM) is a suite of instruments to monitor space weather in the geostationary orbit onboard the Korean geosynchronous satellite Geo-KOMPSAT-2A (GK2A). GK2A was launched on 4 December, 2018, and is located at the longitude of 128.2° East and KSEM has been measuring the space environment since then. KSEM has been developed by a group led by Prof. J. Seon at Kyung Hee University in collaboration with the Space Sciences Laboratory at UC Berkeley, Satrec Initiative Co., and ESTEC of European Space Agency. KSEM consists of three Particle Detectors (PDs), a Charging Monitor (CM), and a set of magnetometers (SOSMAG).



CODEX



SNIPE



KSEM on GK2A

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July 13–21 2024, BEXCO, Busan, Korea

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