How can African universities join the mission of Lunar and beyond?

Interactive Panel Discussion

The 10th UNISEC-Global Meeting
28 November 2024

Image credits: ispace, inc.

How can African universities join the mission of Lunar and beyond?

SPEAKERS

Arno Barnard

Senior Lecturer
Stellenbosch University
South Africa

Ryu Funase

Associate Professor
Univ. of Tokyo & JAXA
Japan

Ertan Umit

Payload system engineer
ispace, inc.
Luxembourg

Mohammed Khalil Ibrahim

Senior Lecturer
EGYPT-JAPAN University of Science and Technology
Egypt

MODERATOR

Maximilien Berthet

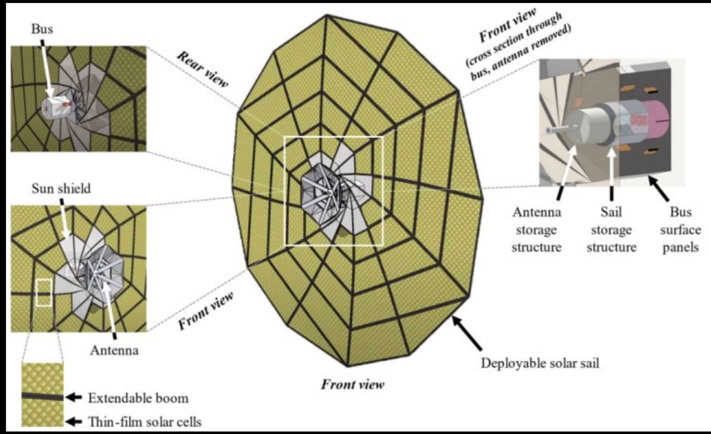
Assistant Professor
University of Tokyo
Japan

PANELS

1. Individual presentations – 25mins
2. Challenges & opportunities of university deep space missions (Why do it?) – 20mins
3. Advice to deep space pioneers in African universities (How to do it?) – 20mins
4. Q&A with audience – 20mins
5. Closing – 5mins

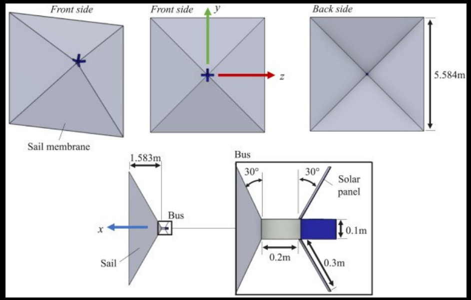
Panel 1:
Individual presentations

Research interest: Small satellite mission design

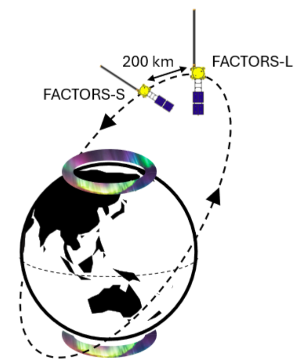


Enceladus plume sampling mission concept with small satellite ([Berthet, García, et al.](), *JESA*, **1**, 100, 2023)

Collaborative CubeSat mission concept between Japan and Cambodia ([Berthet, Sakal, et al.](), 35th Small Sat. Conf., 2021)

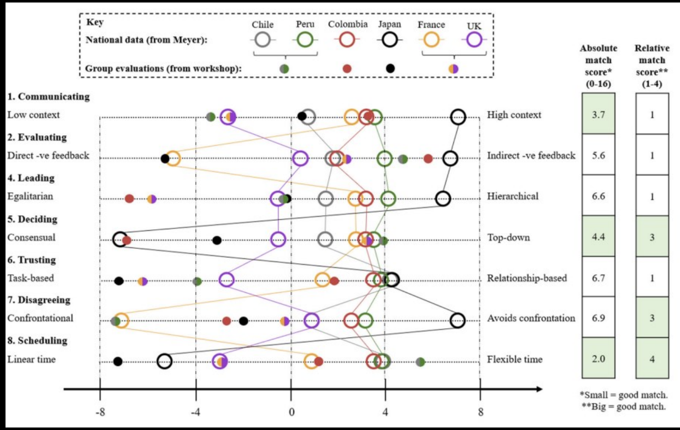


Sunflower type solar sail mission concept for Earth observation ([Berthet & Suzuki](), *Acta Astronaut.*, **213**, 2023)



Small satellite formation flight for study of Earth aurora ([Berthet, Maru, et al.](), Astrodynamics Symp., 2024)

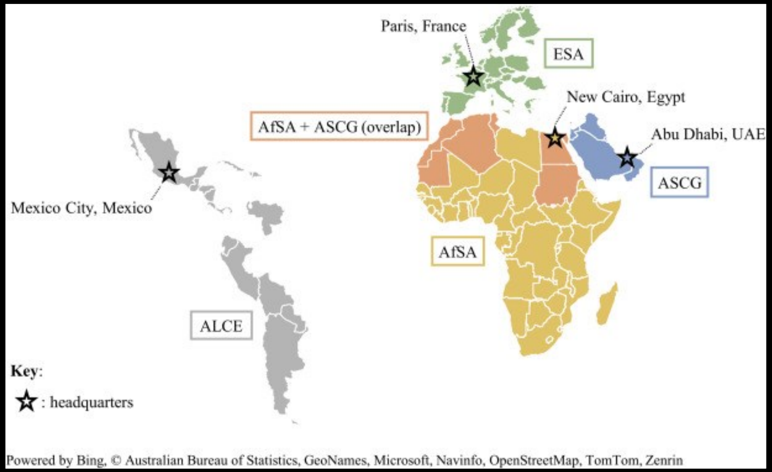
Teamworking in small & diverse space projects ([Berthet, García, et al.](), *JESA*, **2**, 127, 2024)

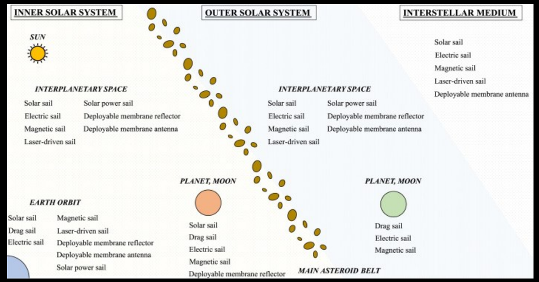


Research interest: Space history and policy

Country-first satellites (Berthet et al., *PAS*, **146**, 2024)

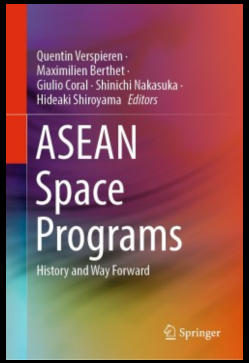
Regional space cooperation (Berthet & Corrado, *Space Policy*, **68**, 2024; Berthet & Corrado, *Space Policy*, 2024)



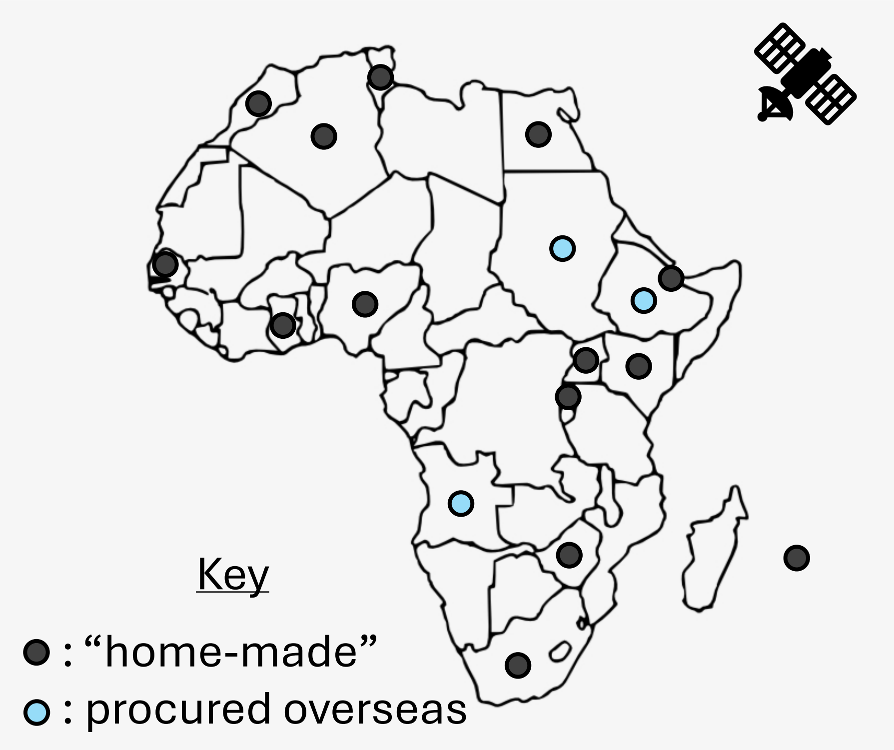


Space sails for meeting global space exploration goals (Berthet et al., *PAS*, **150**, 2024)

History of space development in ASEAN (Verspieren, Berthet, et al., *ASEAN Space Programs*, 2022)

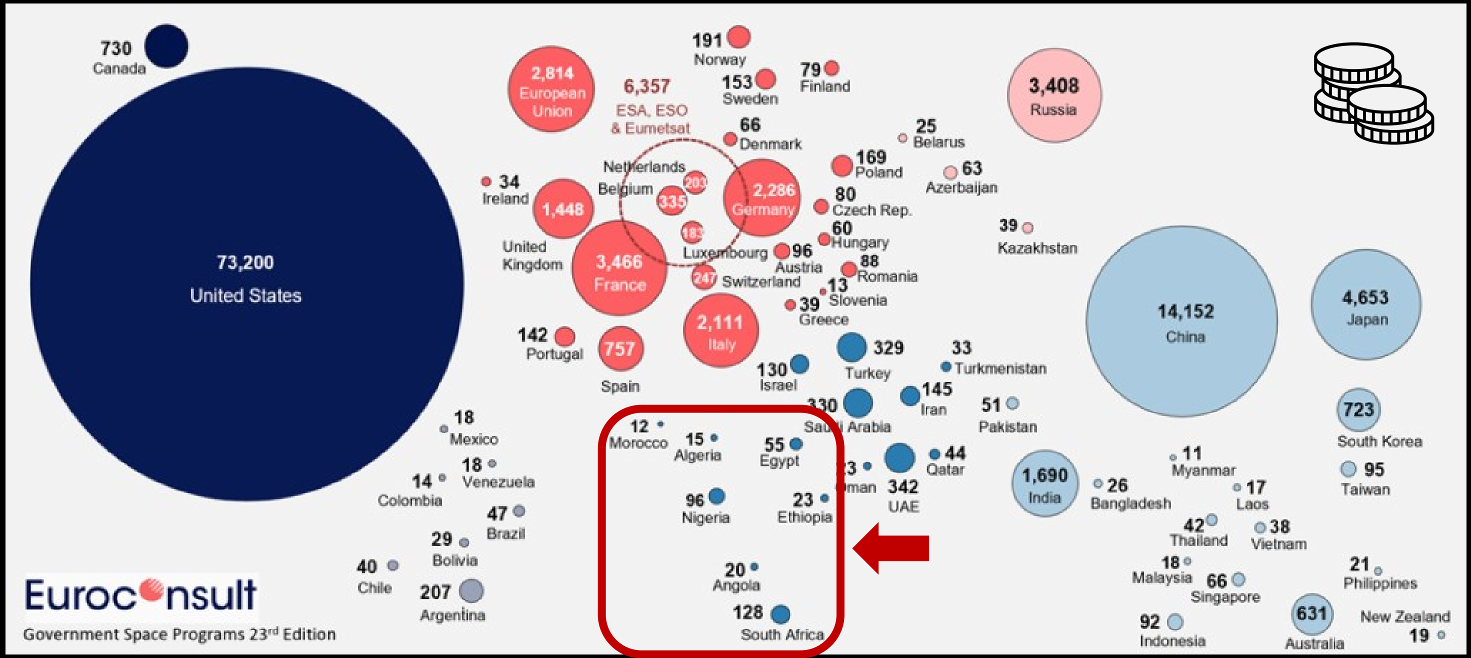


Status of space in Africa



Satellite technology in Africa

17 countries have launched satellite(s)
~ 62 satellites launched as of Nov. 2024



Space economy in Africa

USD 460 million government spending in 2024
Space market valued at USD 22.6 billion

(Source: African Space Industry Annual Report, 2024, Space in Africa)

UNISEC GLOBAL
University Space Engineering Consortium

Status of space in Africa

World-leading African universities (top 600)

(Source: Combination of QS World University Rankings 2025 & THE World University Rankings 2025)

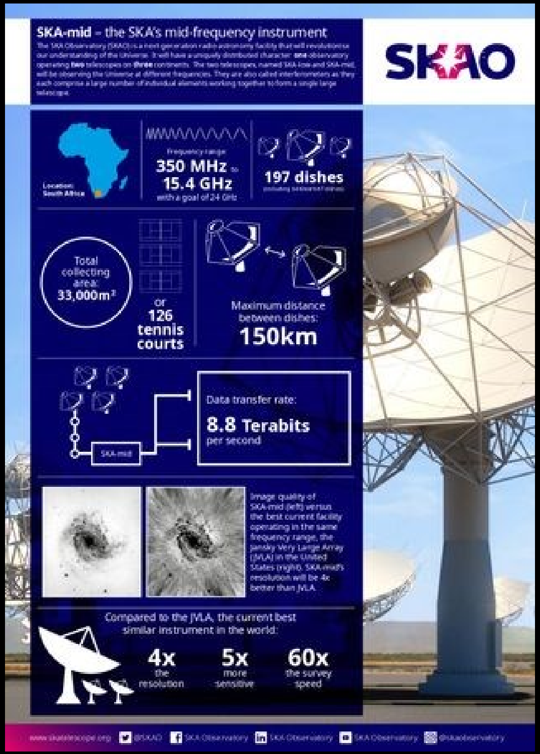
Aerospace Systems Research Institute

Example of a university-led initiative: Phoenix Hybrid Sounding Rocket Program

(Source: UKZN)

Education & research in science, technology, and innovation (STI)

Status of space in Africa



Square Kilometer Array

(Source: SKAO)

Space weather center, magnetic technology

(Source: SANSA)

Antenna facility in support of the Artemis Program, for spacecraft tracking and communications

(Source: SANSA)

Ground infrastructure

Arno Barnard

Senior Lecturer
Stellenbosch University
South Africa

1. Arno Barnard

- 1999 SUNSAT Launch -> Undergraduate project 30W Fail-safe Micro-Satellite Power Supply
- 1999-2001 SUNSAT Ground station operations and maintenance
- 2000-2001 Masters degree -> New generation OBC for Microsatellite
- 2003-2009 Manager of Electronic Systems Laboratory -> Guiding students and supporting research projects
- 2003-2005 SUNSAT2? (had many names) new generation subsystem prototype development
- 2006 Main engineer for SumbandilaSat University Experiments Payload
- 2010-Now Full-time academic in E&E Engineering
- 2016-2017 Gravity wave experiment on ZA-Aerosat
- 2020 PhD in Single Events Effect testing using protons

- Current projects
- Dock-sat -> multiple un-docking and re-docking CubeSat demonstrator
- SUN IoT Sat -> Cubesat with IoT payload to support sustainable IoT sensing in Africa i.e. Agriculture, Water etc

Ryu Funase

Associate Professor
Univ. of Tokyo & JAXA
Japan

Self-introduction: Small satellite missions I have been involved in

The First Interplanetary Full-scale Micro-Satellite

PROCYON (2014)

Size & Weight

55cm, 65kg

Developer

Univ. of Tokyo + JAXA

Development time

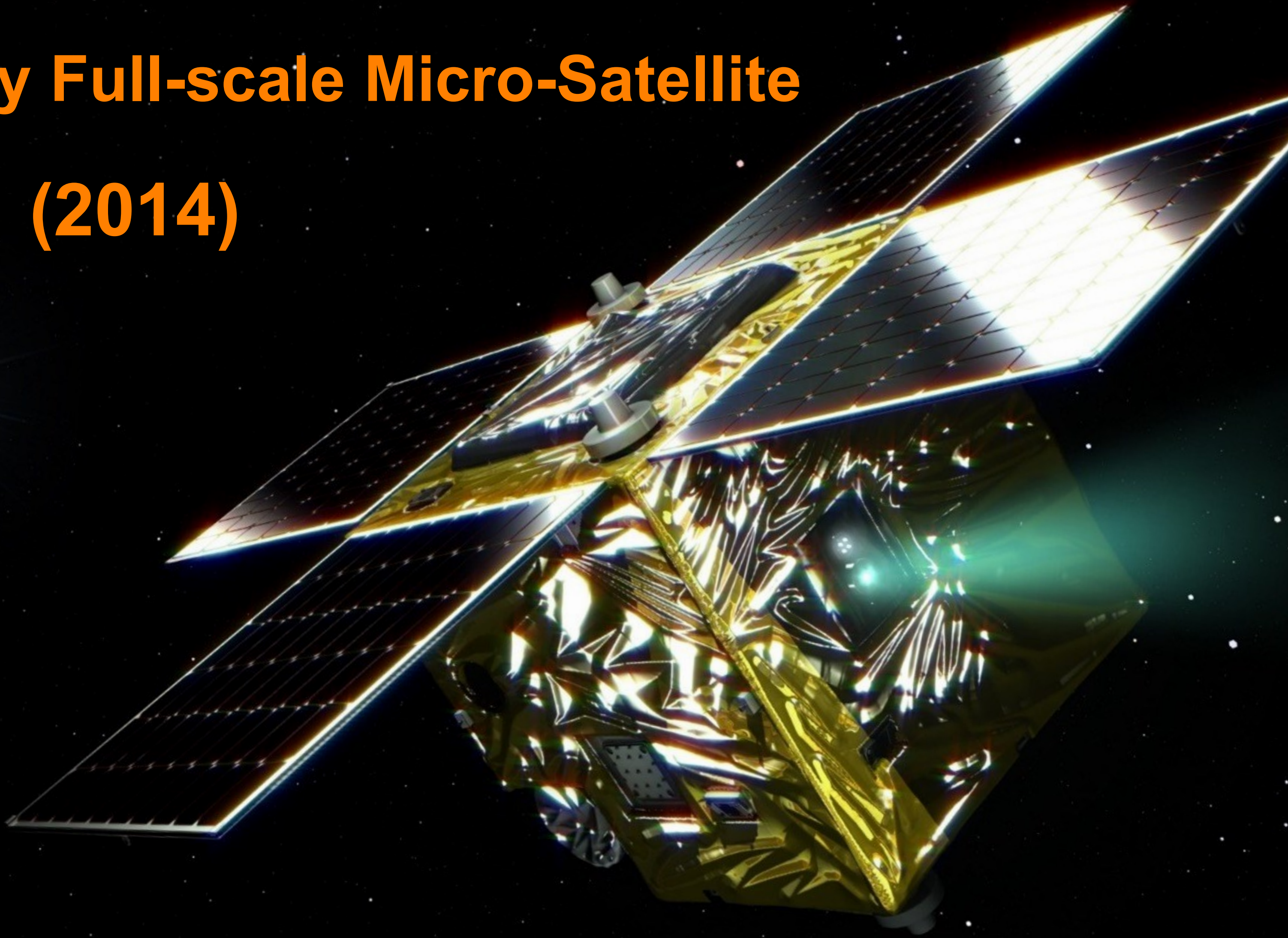
14 months

Development budget

< 5 M$

Launch date

Dec. 04, 2014 (with Hayabusa2)

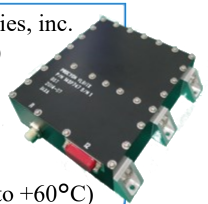


A lot of novel technology demonstrations by PROCYON

S/C size: 55cm
S/C mass: 65kg

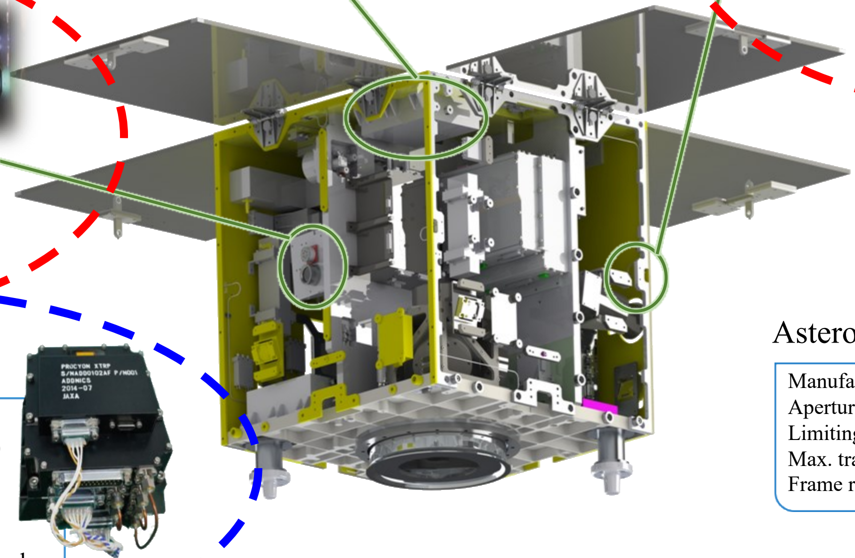
DDOR Tone Generator

Manufacturer: Digital Signal Technologies, inc.
Max. output power: +9 dBm (each tone)
Max. tone width: 86 MHz
Max. sweep width: 7.9 MHz
Sweep time: 2 to 40 min
Alan variance: < 1×10^{-1} (1-100 s),
< 1×10^{-9} (1000 s) (-20 to +60°C)



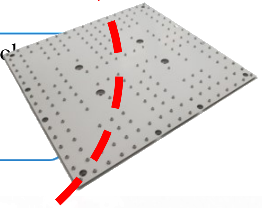
Ion Thruster

Manufacturer: The University of Tokyo
Thrust: 300 μN
Specific impulse: 1000 s
Propellant: Xenon



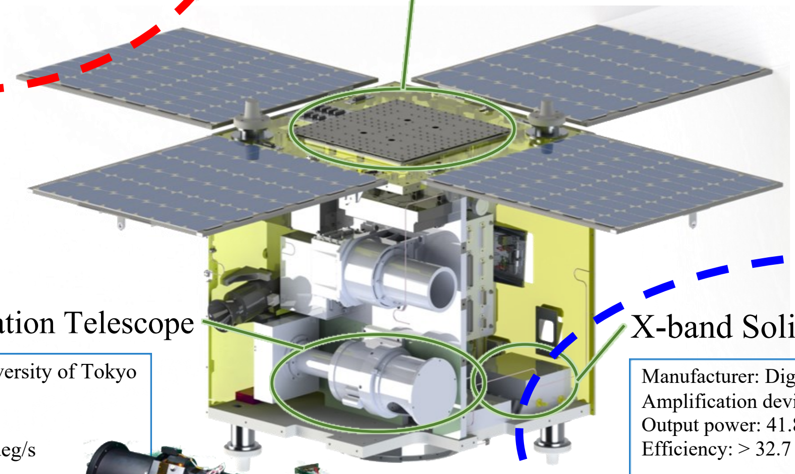
Thrusters (RCS)

Manufacturer: The University of To
Thrust: 22 mN
Specific impulse: 24.5 s
Propellant: Xenon



High Gain Antenna

Manufacturer: Antenna Giken Co., Ltd.
Tx gain: 25.5 dBi
Rx gain: 24.7 dBi
3dB beam width: ±4 deg



X-band Transponder

Manufacturer: Addnics corp.
Max. output power: +17 dBm (tunable)
Receiving level: -150 to -50 dBm
Coherent ratio: 749/880
Modulation: PCM/PSK/PM,
two-way Range & two-way Doppler,
DDOR ($\pm0.5F_0$, $\pm2F_0$)

Asteroid Observation Telescope

Manufacturer: The University of Tokyo
Aperture: 40 mm
Limiting magnitude: 12
Max. tracking rate: 55 deg/s
Frame rate: 30 fps

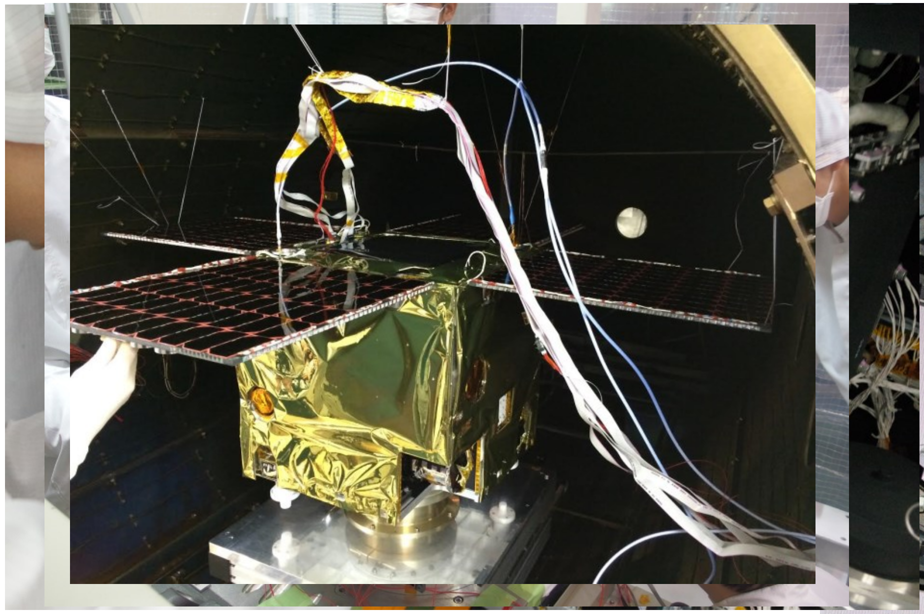
X-band Solid State Power Amplifier

Manufacturer: Digital Signal Technologies, inc.
Amplification device: GaN HEMT
Output power: 41.85 ± 0.15 dBm
Efficiency: > 32.7 % (Max. 35.1 %) (-20 to +60°C)

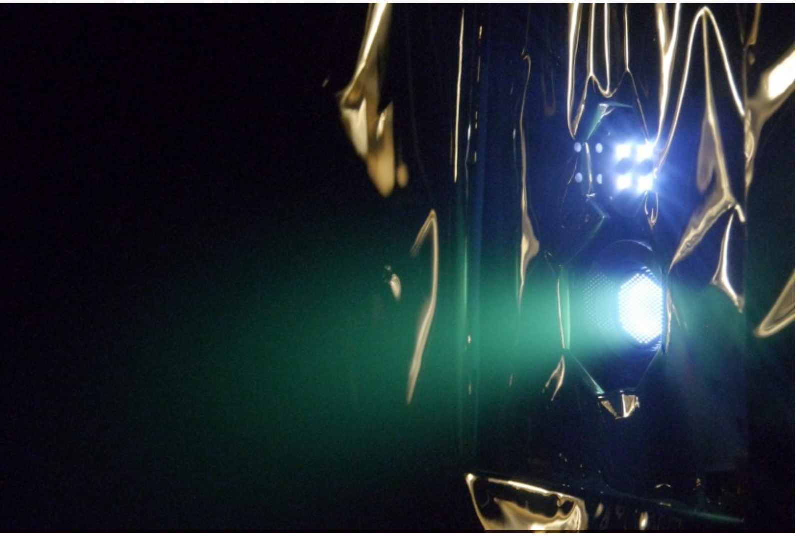
RF Output > 15W
Efficiency > 32.7%

Deep space X-band SSPA
with world's highest efficiency

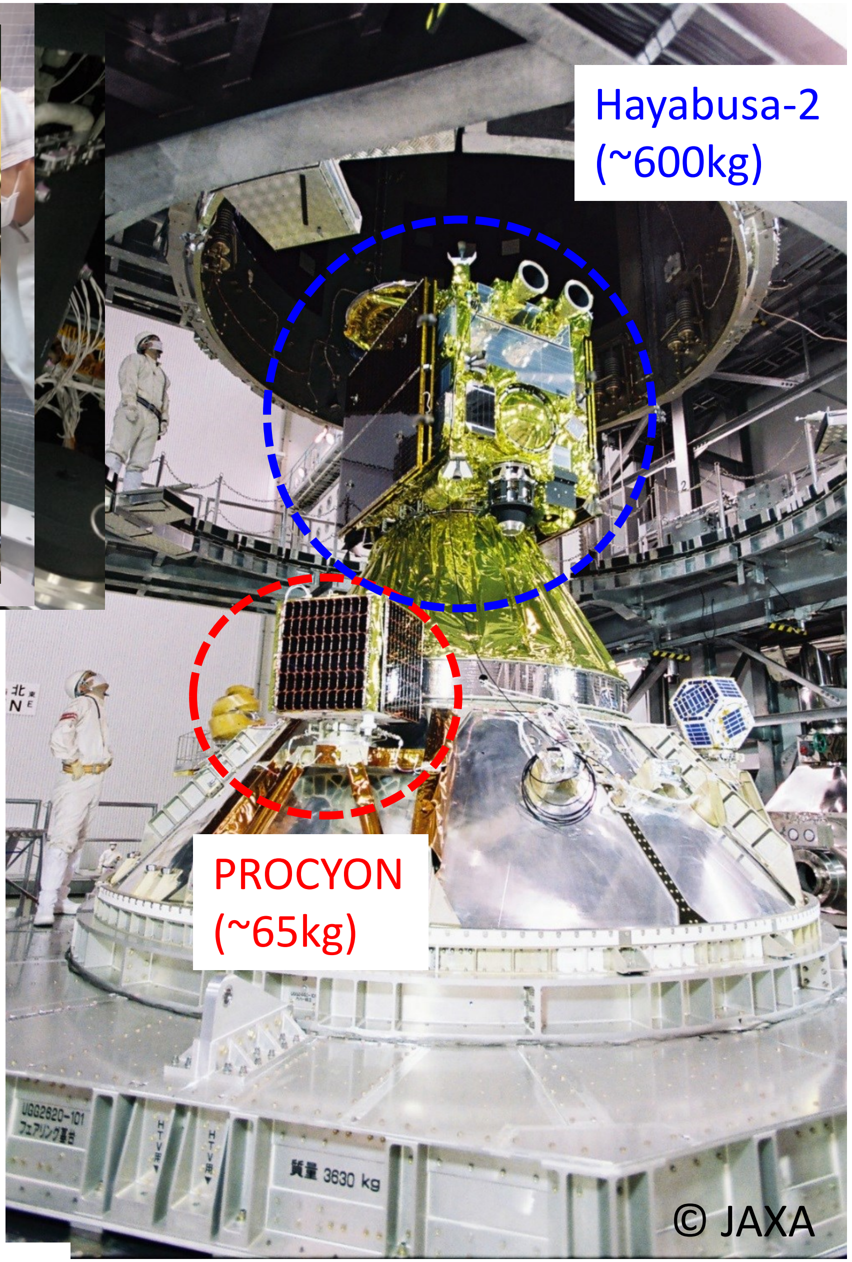
PRYCYON proved the possibility of deep space exploration by small satellite

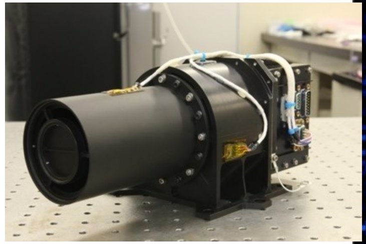


(during integration/testing)



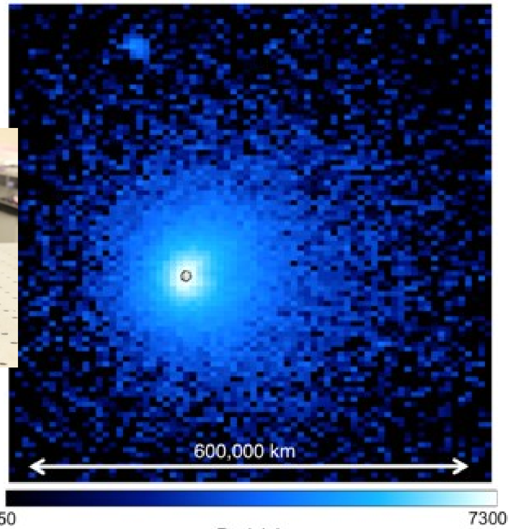
(ion thruster test in a vacuum chamber)



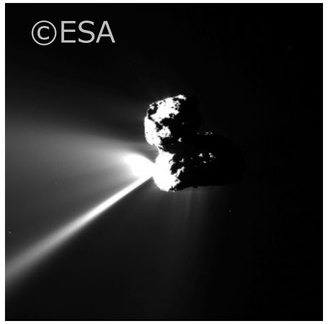


LAICA
(Hydrogen imager)

Earth's hydrogen corona

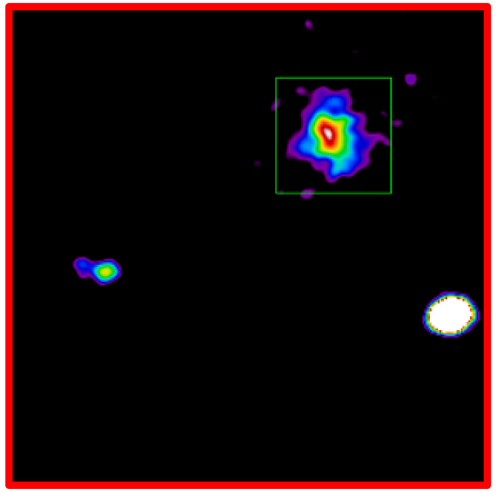


Kameda et al., 2017 GRL



Comet 67P/Churyumov−Gerasimenko

Hydrogen around 67P



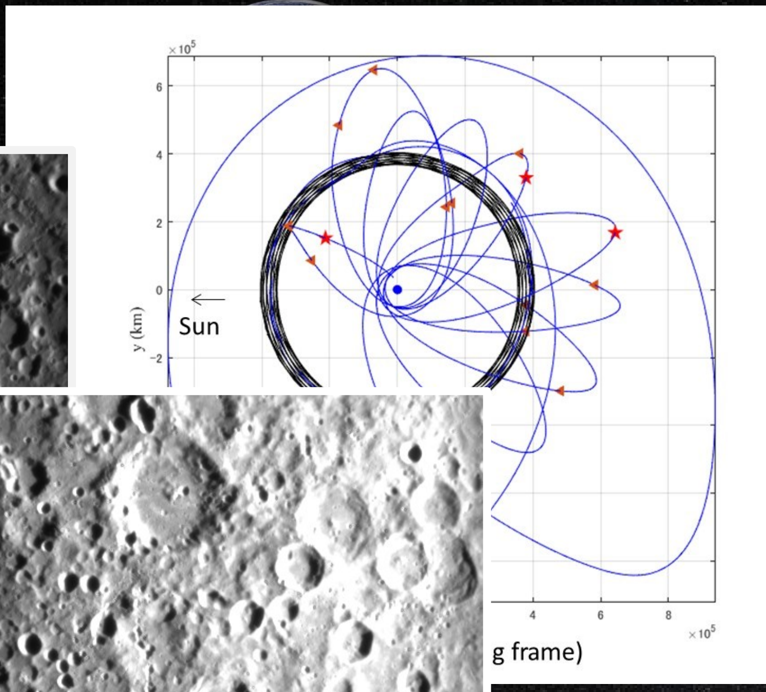
Shinnaka et al., 2017 AJ

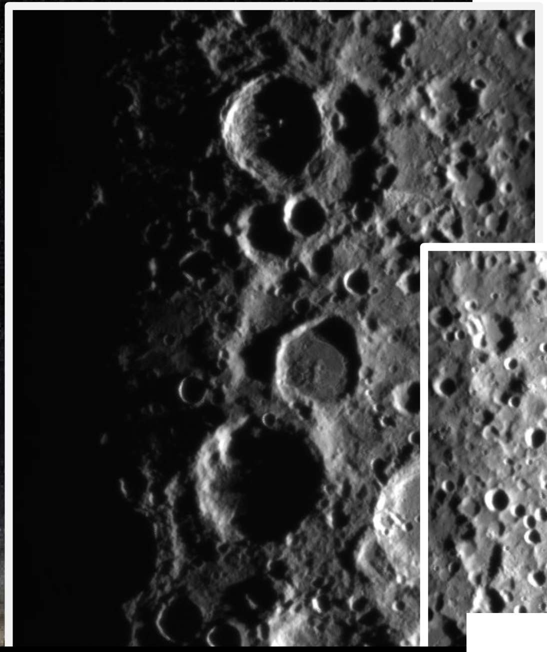
EQUULEUS on SLS Artemis-1

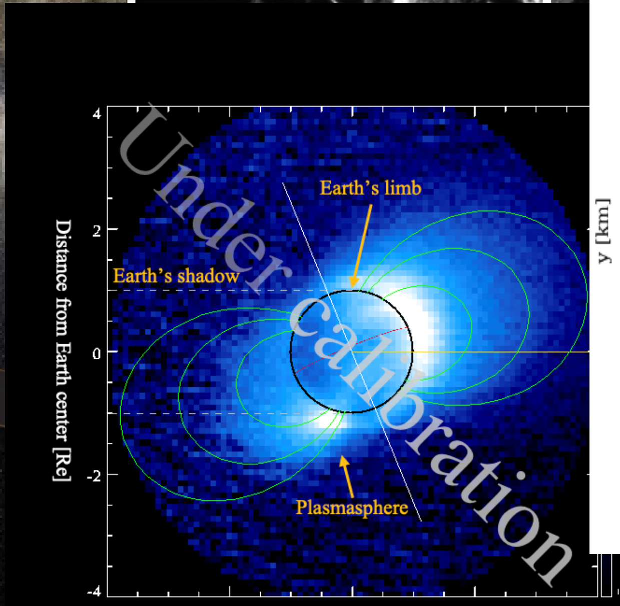
(EQUULEUS = EQUilibriUm Lunar-Earth point 6U Spacecraft)

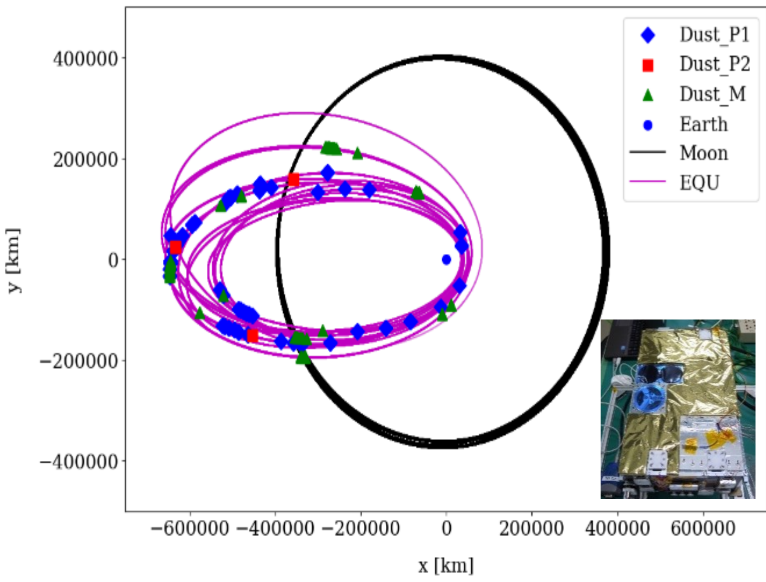
Achieved its full success!!

- ✓ Demonstration of the efficient and precise trajectory control techniques within the Earth-Moon region by a nano-spacecraft
  → Enables deep space exploration by small satellites using lunar gateway in the future
- ✓ Orbital maneuver using a water-based propulsion system beyond LEO (world's first!)
- ✓ Capture of the entire image of the Earth's plasmasphere
- ✓ Dust detection in the cis-lunar space

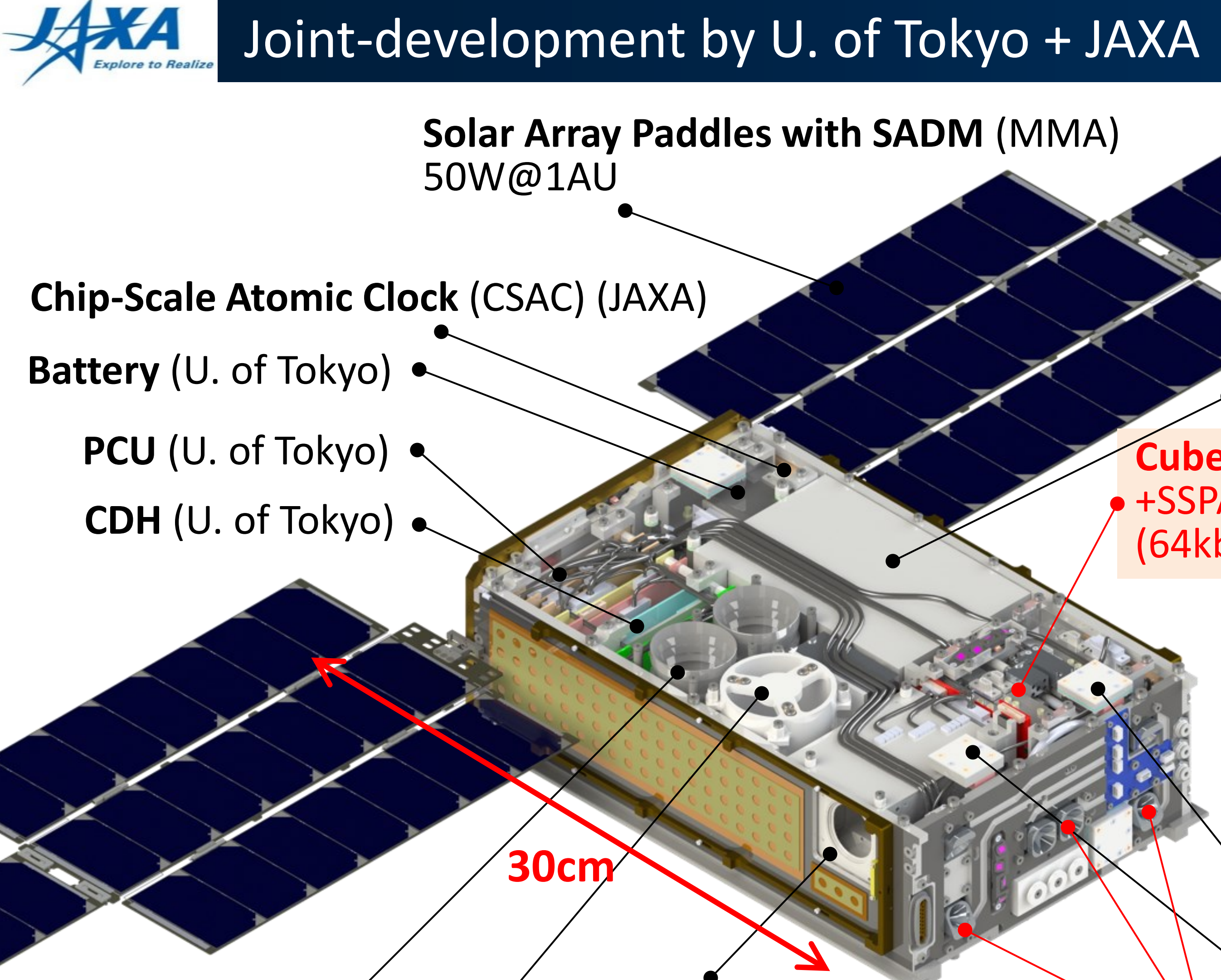






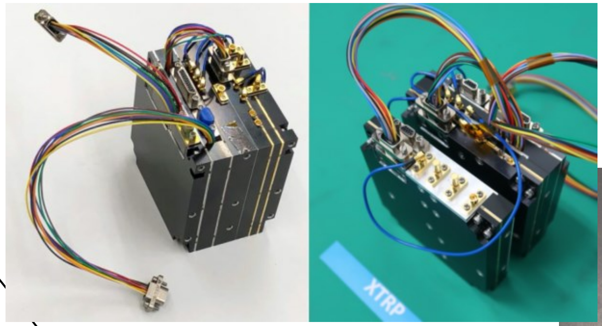


Joint-development by U. of Tokyo + JAXA



S/C size: 6U
S/C mass: 10.5kg

CubeSat Deep-space Transponder
+SSPA (JAXA)
(64kbps@1.5M km with MGA)



X-Band LGA x5 (JAXA)

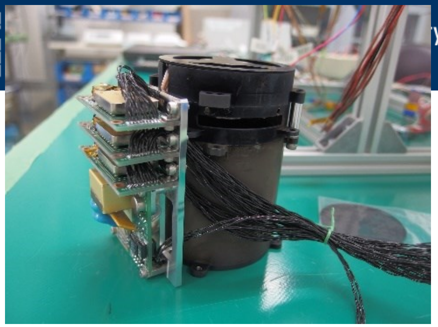
X-Band MGA (JAXA)

Attitude control unit
(IMU, STT, SS, RW) (BCT)
(<0.02deg pointing accuracy)

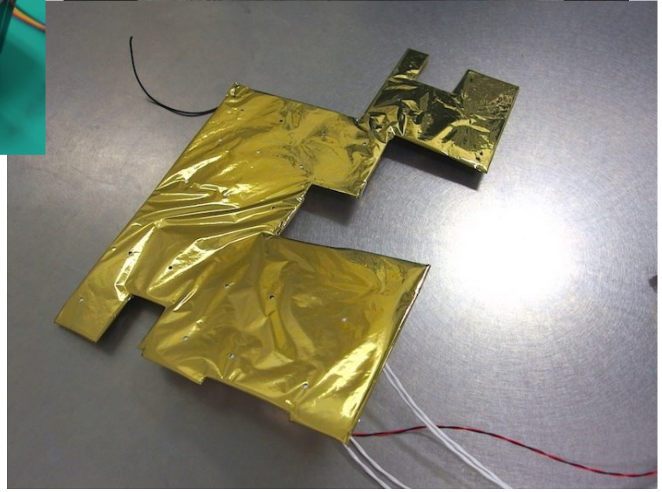
PHOENIX (plasmasphere obs.) (U. of Tokyo)

DELPHINUS (lunar impact flashes obs.) (Nihon Univ.)

Water resistojet thrusters
(DVx2, RCSx4) (U. of Tokyo)
(Isp >70s, Delta-V >70m/s)



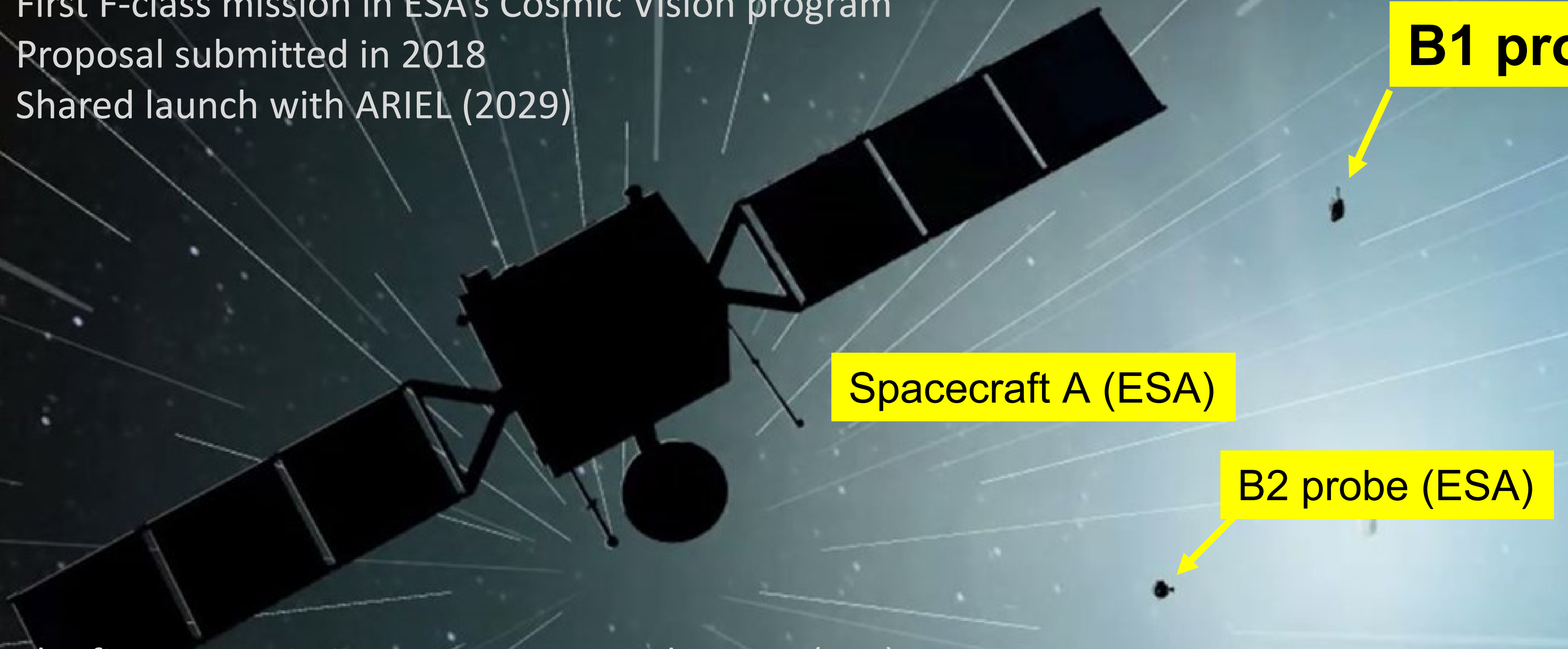
Earth's plasmasphere observation telescope

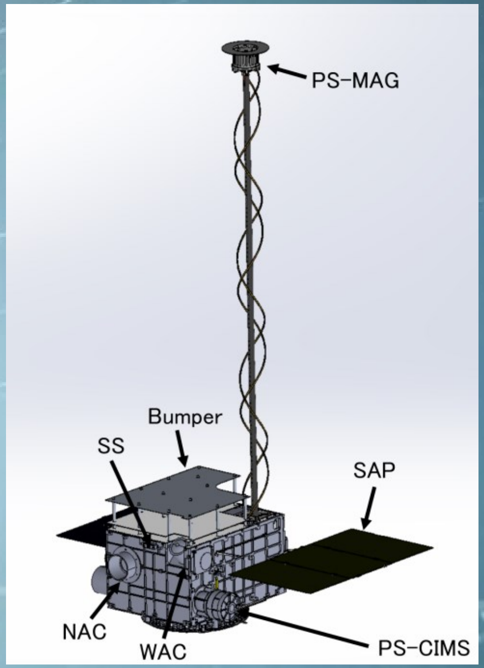


Dust detector in a thermal insulator (MLI)

Comet Interceptor (ESA-JAXA joint mission)

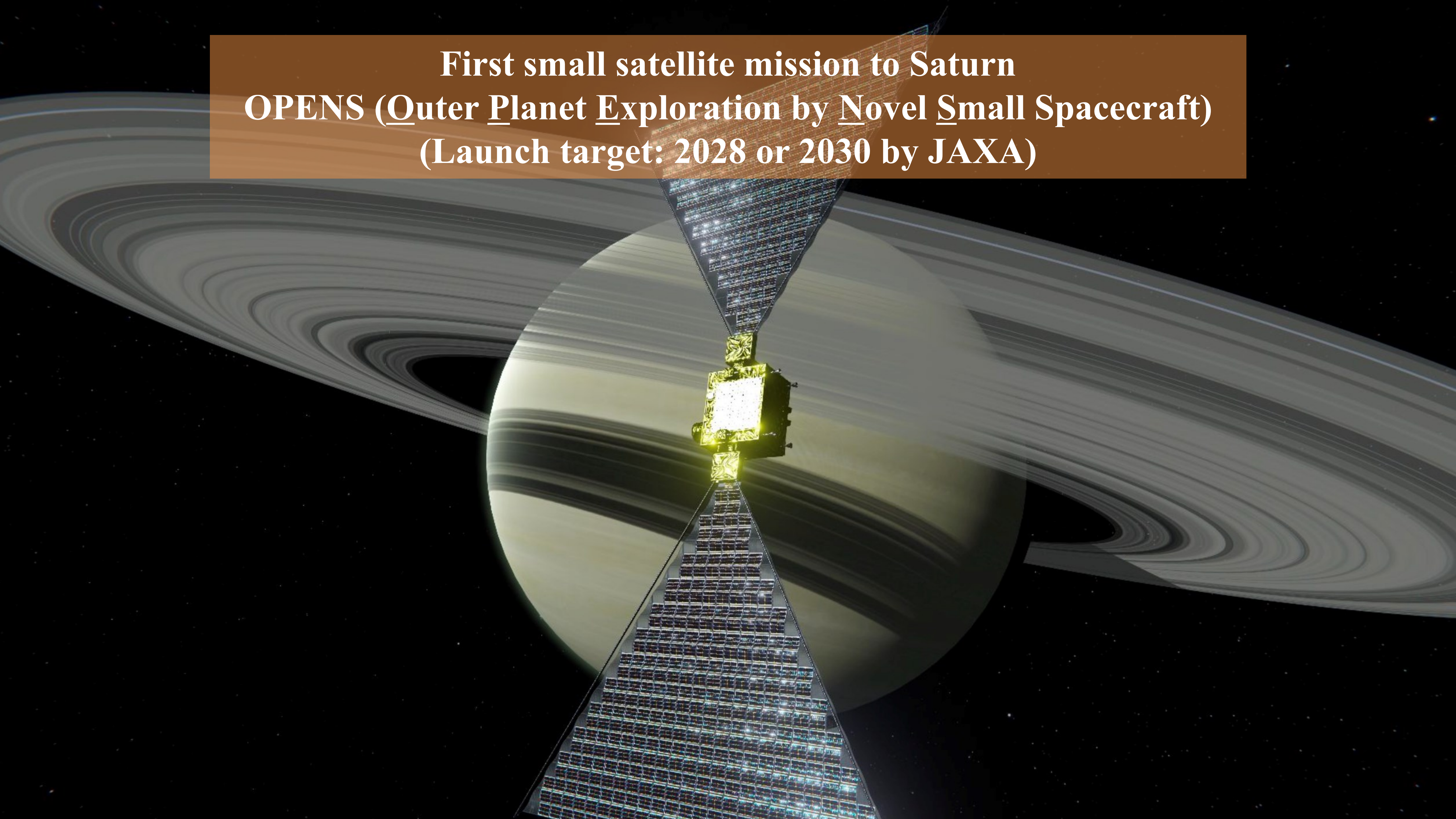
- First F-class mission in ESA's Cosmic Vision program
- Proposal submitted in 2018
- Shared launch with ARIEL (2029)





- The first-ever mission to a Long-Period Comet (LPC)
- Flexible mission duration, 6 years max
- Mission is a fast flyby (<70km/s), 72 hrs
- Main Spacecraft + two Small probes
  - one of them contributed by JAXA
- Joint development by JAXA + ArkEdge Space Inc.

First small satellite mission to Saturn
OPENS (Outer Planet Exploration by Novel Small Spacecraft)
(Launch target: 2028 or 2030 by JAXA)



Ertan Umit

Payload system engineer
ispace, inc.
Luxembourg

Mohammed Khalil Ibrahim

Senior Lecturer

EGYPT-JAPAN University of Science and Technology

Egypt

Egypt-Japan University of Science and Technology
الجامعة المصرية اليابانية للعلوم و التكنولوجيا
エジプト日本科学技術大学

How can African universities to join the mission of Lunar and beyond?

Interactive Panel Discussion

Mohammed Khalil Ibrahim, Ph.D.

Professor and Chairman, Aerospace Engineering Department (ASE)

School of Innovative Design Engineering (IDE)

EGYPT-JAPAN University of Science and Technology

Email: mohammed.khalil@ejust.edu.eg

Member of the Board of Director of Egyptian Space Agency

Former Deputy CEO of the Egyptian Space Agency

Agenda

- Self-Introduction
- About Egypt-Japan University of Science and technology (E-JUST)
- Current activities about deep space missions.
- Challenges & opportunities of university deep space missions.
- Advice to deep space pioneers in African universities
- Closing

Self-Introduction

Education

- B.Sc. Cairo University, Egypt, 1991
- M.Sc. Cairo University, Egypt, 1996
- Ph.D. Nagoya University, Japan, 2002

Academic Experience

Cairo University, Zewail City of S&T, EGYPT-JAPAN University of S&T, AUC (Egypt), **KFUPM (KSA)**, UIR (Morocco), Nagoya University, Nihon University (Japan),

Industrial Experience

Volvo, Mitsubishi Heavy Industries, TransTechno-Egypt, The Steel Network Inc., Egyptian Space Agency.

My Background in Space Engineering

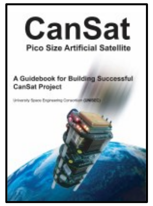
CLTP-1

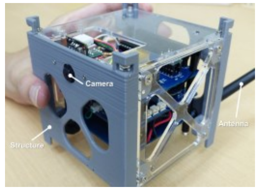
Steering Committee

UNISEC GLOBAL
University Space Engineering Consortium

CLTP Instructor

自 主 創 造
日本大学
NIHON UNIVERSITY

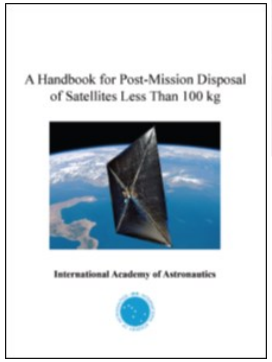


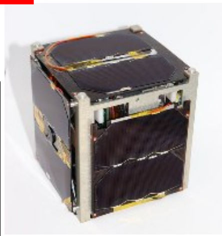


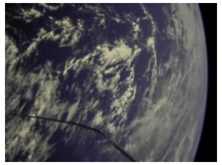
iCanSat & HEPTA-Sat

2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017

2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024



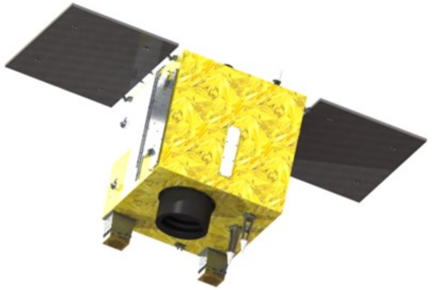




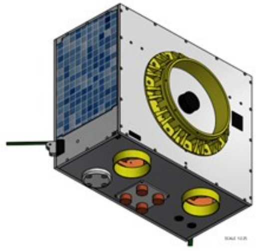
NEXUS, 1U

EgSA
وكالة الفضاء المصرية
Egyptian Space Agency

Space Technology Portal, EgSA-CanSat, SpaceKeys



MisrSat-2



NExSat-1

National Role in Space Science and Remote Sensing

- Member of BOD, Egyptian Space Agency (2019 – Present)
- Member of National Council of Space and Remote Sensing (2020 – Present)
- Founder and Chairman of Aerospace Engineering Department, E-JUST University of Science and Technology (2023 – Present)
- Founder of Space System Technology Laboratory @ Cairo University

About EGYPT-JAPAN University of Science and Technology

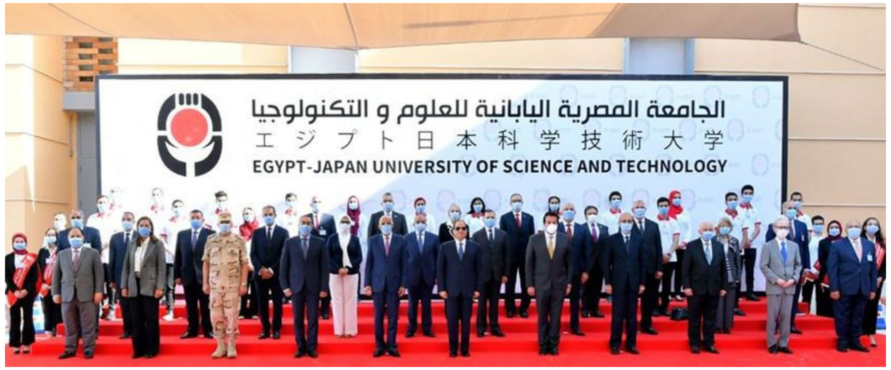
الجامعة المصرية اليابانية للعلوم و التكنولوجيا
エ ジ プ ト 日 本 科 学 技 術 大 学
EGYPT-JAPAN UNIVERSITY OF SCIENCE AND TECHNOLOGY

- **Established in 2010, as a JICA project between the Egyptian government and Japanese government.**
- **In 2010, M.Sc. And Ph.D. Programs were launched in**
  - School of Electronics, Communications and Computer Engineering (ECCE)
  - School of Energy Resources, Environmental, Chemical and Petrochemical Engineering (EECE)
  - School of Innovative Design Engineering (IDE)
  - Institute of Basic and Applied Science (BAS)
- **In 2017, undergraduate programs were launched in the above schools in addition to**
  - Faculty of International Business and Humanities (FIBH)
  - Computer Science and Information Technology Programs
  - Sustainable Architecture Program
  - Pharm D Program
  - Art and Design Program

About EGYPT-JAPAN University of Science and Technology

الجامعة المصرية اليابانية للعلوم و التكنولوجيا
エジプト日本科学技術大学
EGYPT-JAPAN UNIVERSITY OF SCIENCE AND TECHNOLOGY

- In 2023, **Aerospace Engineering Department** was launched within the School of Innovative Design Engineering (IDE).
- Currently the number of Undergraduate students is around **5000** students.
- M.Sc. and Ph.D. students is around **450** students with around 30% African Students sponsored by JICA and Egyptian MOHE.
- In 2024, E-JUST is ranked the **top research university** among all Egyptian Universities according to Times Higher Education (THE) World University Rankings.
- Additionally, E-JUST is ranked **#19** globally for SDG#7 (Affordable and Clean Energy), **#21** for SDG#6 (Clean Water and Sanitation), and **#38** for SDG#13 (Climate Action)
- Overall, E-JUST is ranked among the top **401-600** universities globally.
- Recently, E-JUST has been shortlisted by the Times Higher Education Arab World 2024 Awards Committee as one of the leading Arab universities in supporting entrepreneurship



THE WORLD UNIVERSITY RANKINGS 2024

Space Imperatives

- **A global perspective**
  - The ultimate high ground
  - High Speed Earth Coverage (5-8 km/s)
  - Communication, Broadcasting, GPS, Meteorological, Earth Observation, Disaster Monitoring
- **A clear view of the heavens**
  - Unobscured by the atmosphere
  - Space Telescope, Various spectral observation,
- **A free-fall environment**
  - Enabling us to develop advanced material impossible to make on Earth.
  - Life science experiment.
- **Abundant resources**
  - Such as solar energy and extraterrestrial materials
- **A unique challenge as final frontier**
  - Planet, Small bodies, Particles, Fields, etc.
  - Permanent Human existence

Current activities about deep space missions

- **International Luner Research Station ILRS**
  - Egyptian Space Agency, Cairo University and BeniSuief University signed LOI with DSEL.
  - Egyptian Space Agency will develop lunar Imager (Luna Cam) to be on-board a Lunar orbiting spacecraft.
  - E-JUST is studying to join the ILRS.

DSEL
DEEP SPACE EXPLORATION LAB
深空探测实验室

- **Capstone project(s)**
  - Conceptual Design of Mars Lander Mission: A Digital Twin Technology
  - Conceptual Design of Lunar Lander Mission: A Digital Twin Technology


CONCEPTUAL DESIGN OF MARS LANDER SIMULATION (DIGITAL TWIN)
By:
Ahmed Medhat Salama
Mohamed Essam Ahmed
Ahmed Mohamed Abdulhafe
Nada Abdelgaber Abdellah
Ahmed Mohamed Hassan
Rana Said Fahmy
Ahmed Mohamed Ibrahim
Seif Eldeen Ahmed Mostafa
Mario Magdy Besher Hakim
Samah Amer El-Said
Mohamed Aboelanwar Mohamed
Tag Eldeen Abdellaah
Under the Supervision of:
Prof. Osama M. Shalabiea
Prof. Muhammed Khalil
Dr. Ahmed Aboulftouh
1

Thank you for your kind attention
Any questions are welcome

Mohammed Khalil Ibrahim, Ph.D.

Professor and Chairman, Aerospace Engineering Department (ASE)

School of Innovative Design Engineering (IDE)

EGYPT-JAPAN University of Science and Technology

Email: mohammed.khalil@ejust.edu.eg

Member of the Board of Director of Egyptian Space Agency

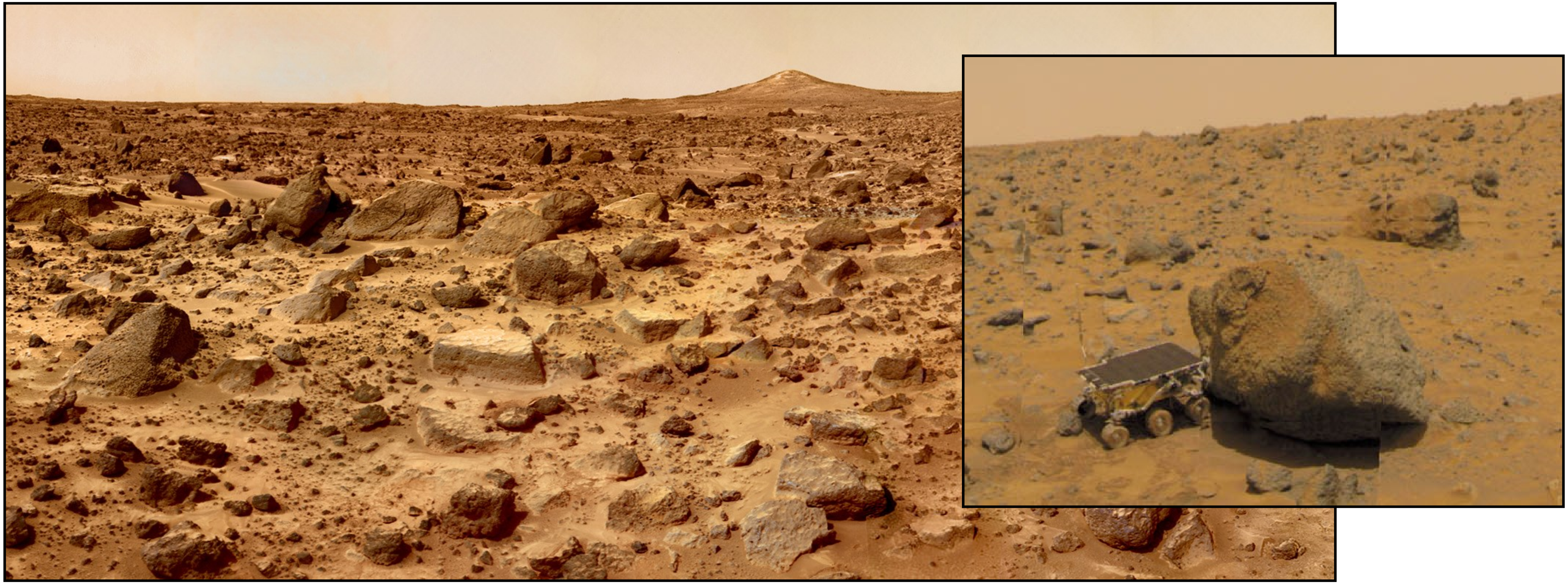
Former Deputy CEO of the Egyptian Space Agency

Panel 2:
Challenges & opportunities of university deep space missions

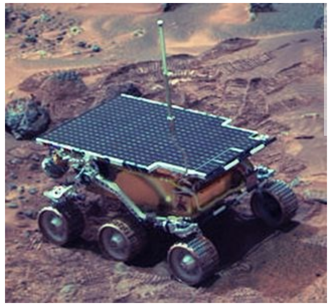
2. Challenges & opportunities of university deep space missions

- Why did panellists decide to develop their own deep space mission? Why did they decide to do space projects in their universities / institutions?
  - Space is COOL!
  - Space projects draws some of the best students
  - Space based problems are challenging!
  - Space technology pushes the boundaries of technology and science
- What have been some of the memorable challenges and opportunities, during this process?
  - Creating space level systems with very limited resources
  - Convincing general public and stakeholders that satellite technology and development is important for SA
  - Radiation is NOT THAT dangerous! Well it is but we can safely work with it.
  - Procuring sustainable funding for space system research

Why deep space missions?



From Mars Pathfinder/Sojourner to my own deep space missions

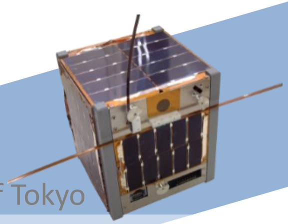


Mars Pathfinder /Sojourner (1998)

1) 2000~2007: Small sat missions @ U. of Tokyo

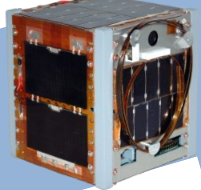
© Univ. of Tokyo

CanSat (2002)



© Univ. of Tokyo

XI-IV (2003): 1kg
World's first CubeSat



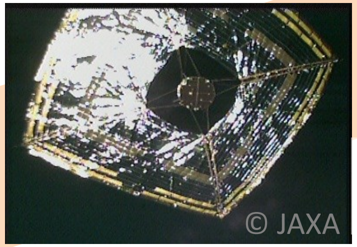
© Univ. of Tokyo

XI-V (2005): 1kg
Tech Demo.

2) 2007~2012: (Not so small) deep space missions @ JAXA

© Akihiro Ikeshita

Hayabusa (2007-2010): 510kg
Asteroid sample return



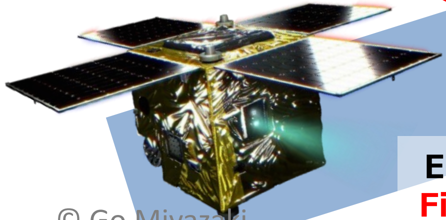
© JAXA

IKAROS (2007-2010): 315kg
World's first interplanetary solar sail

© Akihiro Ikeshita

Hayabusa2 (2009-2012): 600kg
Asteroid sample return

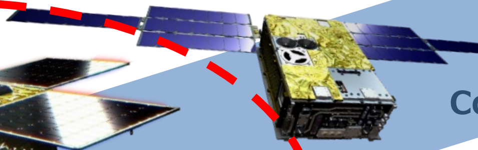
3) 2012~2023+ Deep space × small sat @ U. Tokyo+JAXA



© Go Miyazaki

PROCYON(2014): 65kg
World's first deep space micro-sat

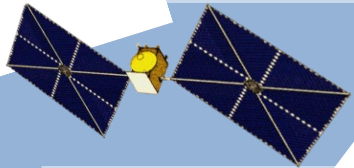
My first deep space mission initiated/led by myself



© Univ. of Tokyo

EQUULEUS(2022): 11kg
First CubeSat to explore lunar Lagrange point

Comet Interceptor (2029): 35kg
First mission to explore long-period comet

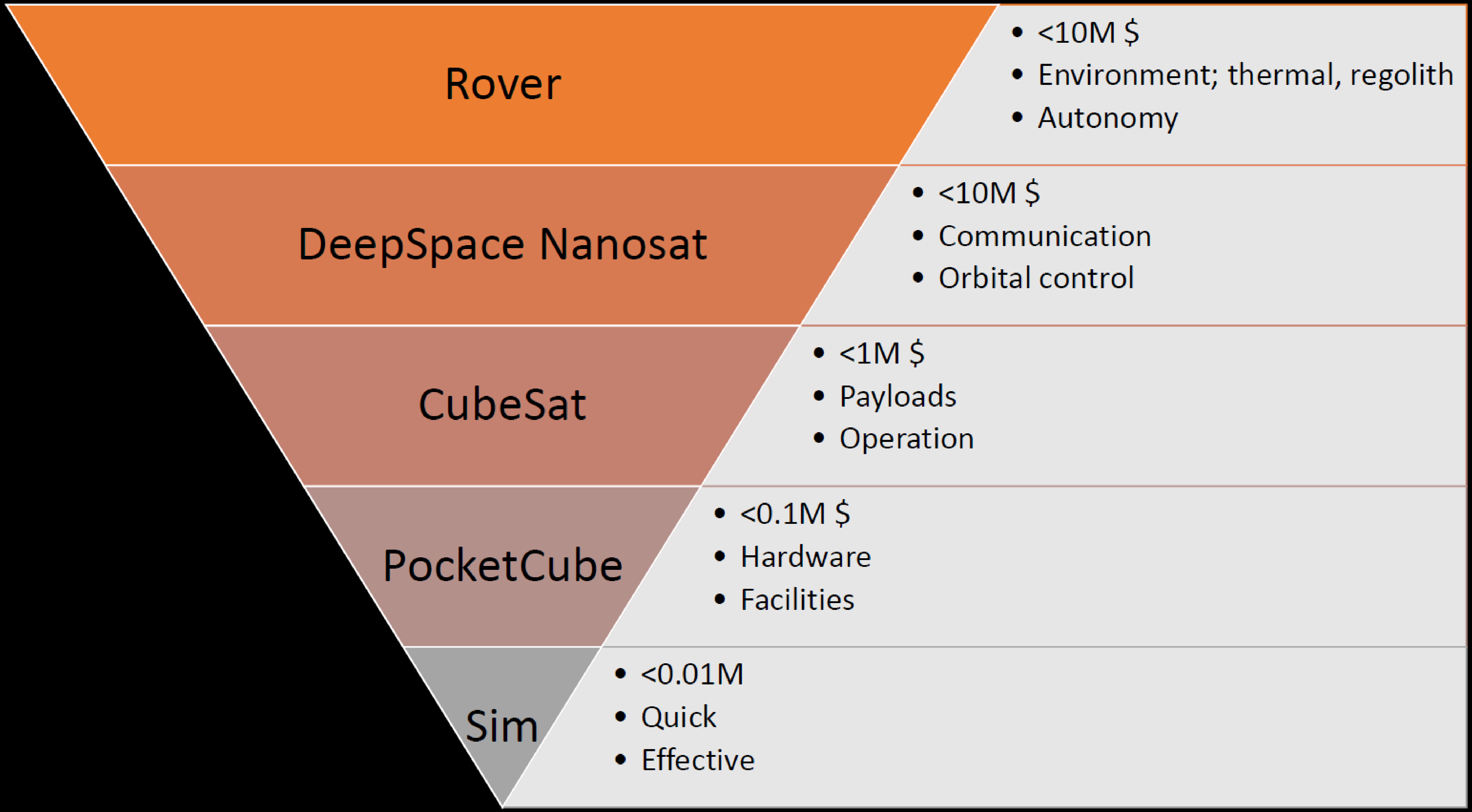


OPENS (202x): ~150kg
First small satellite mission to Saturn

Memorable challenges and opportunities

- First starting point: Mars Pathfinder/Sojourner (1998)
  → CubeSat (2001-2007), Hayabusa (2007-2010), IKAROS (2007-2010), Hayabusa2 (2010-2012) …
- The experience gained in all these missions formed the basis for the realization of my first deep space mission (led by myself), PROCYON (2014)
  - Our laboratory's extensive experience in LEO missions and my experience in doing deep space missions together with JAXA colleagues may have led to expectations for the successful joint development of an ultra-small deep space probe (?)

- **Opportunities always come suddenly!**
  - The rideshare interplanetary launch opportunity with Hayabusa-2 was announced <u>only 1.5 years before the launch</u>!
  - Although it was expected (and did happen!) that such a short development period would involve tremendous difficulties, the bold decision to raise the hand resulted in the success of PROCYON and the subsequent trend of ultra-small spacecraft in Japan.
  - An "expert" advised me that committing to such a risky mission would damage my career!
  - Finally, thanks to the cooperation of many organizations, the development of the spacecraft was completed in time and full success was achieved in on-orbit operations.


Rover
<10M $
Environment; thermal, regolith
Autonomy
DeepSpace Nanosat
<10M $
Communication
Orbital control
CubeSat
<1M $
Payloads
Operation
PocketCube
<0.1M $
Hardware
Facilities
Sim
<0.01M
Quick
Effective

Challenges & opportunities of university deep space missions

- **Challenges**
  - Lack of space engineering related experimental laboratories.
  - Lack of fund allocated for deep space mission.
  - Multidisciplinary field.
  - Modeling/Simulation validations.

- **Opportunities**
  - Master the relevant simulation tools in the field (Ansys STK, Fluent, MATLAB, ..etc)
  - Embedded software represent about 30% of the spacecraft based on the cost.
    - On-board software development based on the simulation.
  - Tackle Multidisciplinary problem.
    - Mars Atmospheric Models for entry CFD simulation
  - Increase awareness about the benefit of deep space mission spin-off technologies.

Panel 2: Challenges & opportunities of university deep space missions

Is deep space more exciting than Earth orbit? If so, how?

What can be done in deep space, that can't be done in Earth orbit?

What are some specific challenges for deep space, from a university perspective?

Do you have any memorable anecdotes to share?

Panel 3:
Advice to deep space pioneers in African universities

3. Advice to deep space pioneers in African universities

- Advice to students: what are the available frameworks to develop or join a deep space mission?
  - Use UNISEC network and team up with institutions/universities that are already involved with or have access to deep space missions and programs – even just to observe will be valuable!
- Advice to professors: how to develop a deep space exploration program in their institution?
  - Need to get their institutions/governments/industry buy-in even if just in a small capacity at first
  - Training and capacity development first – research second
  - Build it and they will come?

Advice to deep space pioneers in African universities

- **Student**
  - Award Driven Deep Space Project(s)
    - Graduation Projects
    - Deep Space Competition (MIC, AIAA)
  - Basic Knowledge about essential simulation tools (ANSYS STK, Fluent, MATLAB, ..etc)
- **Professor**
  - Team formation and task assignment
  - Motivation of low performing students
  - Reporting Frequency
  - Beneficiary institution (space agency, research centers, ..etc)

Panel 3: Advice to deep space pioneers in African universities

ADVICE FOR STUDENTS

How can I get involved in a deep space mission?

What do I need to learn before joining?

ADVICE FOR EDUCATORS, DECISION-MAKERS

How to develop a deep space exploration program in my university?

How to gather the required resources, e.g., funds, equipment, team members?

How to set up an international collaboration?

How can African universities join the mission of Lunar and beyond?

Interactive Panel Discussion

Q&A with audience

Image credits: ispace, inc.

Closing

"Imagine you are starting your journey into the space field in an African university.
What advice would you give to yourself?"

Closing

- Start NOW with deep space mission design and analysis (Design Competition, Graduation Project)
- Don't worry about the lack of experimental facilities or mission realization at this moment, there are lots of problems that should be solved before coming to experimentation and realization.
- Capitalize on the strength of the university (software, CFD simulations, …etc).
- Do more one iteration (2 or more) for the same project, knowledge is an accumulation process of learning.
- Periodical reporting is crucial.

How can African universities join the mission of Lunar and beyond?

Interactive Panel Discussion

Thank you for joining!

Image credits: ispace, inc.