Lunar Program Status and Lunar Science Research Activities in Korea

NASA SSERVI
EXPLORATION SCIENCE FORUM 2015
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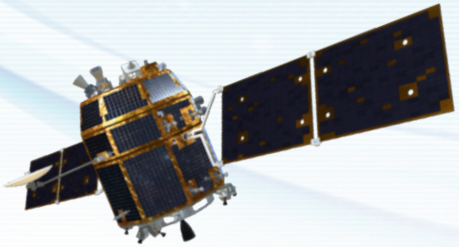
Korean Lunar Program Overview & Status



Why Lunar Exploration in Korea?

KARI

- **Enhancement & Economic Revival**
  - National Brand Image
  - Symbol of Opening Era of Deep Space Exploration
- **Investigation for the future**
  - Future Lunar Resource
  - Lunar Science
- **Achievement**
  - Technology Development
  - Space Market Survival
  - Science and Knowledge of the Moon
- **Contribution**
  - Inventing New Technology Driven Business
  - Fusion of Science and Technology

Lunar Exploration

National Policy Agenda #13/140

Feasibility Study (2014)

- 79.3% of the respondent of the poll are positive about necessity of the lunar exploration in Korea

National Space Development Plan

Presidential Agenda

To realize the vision of becoming one of space leading countries by developing indigenous space technologies

1 Acquire domestic space launch capability to su pport independent space development

1. KSLV-II
2. MEO and GEO LV
3. Space Launch Center

2 Independently develop satellites to meet natio nal demand for satellites

1. LEO satellites
2. MEO and GEO satellites

3 Establish a satellite utilization system to impro ve the quality of life of the people

1. Demand based satellite information se rvices
2. National satellite information utilizatio n system

4 Implement space exploration activities to prep are for future opportunities in space

1. Robotic Lunar Exploration
2. Deep Space Exploration
3. Space Science Research
4. Space Situational Awareness

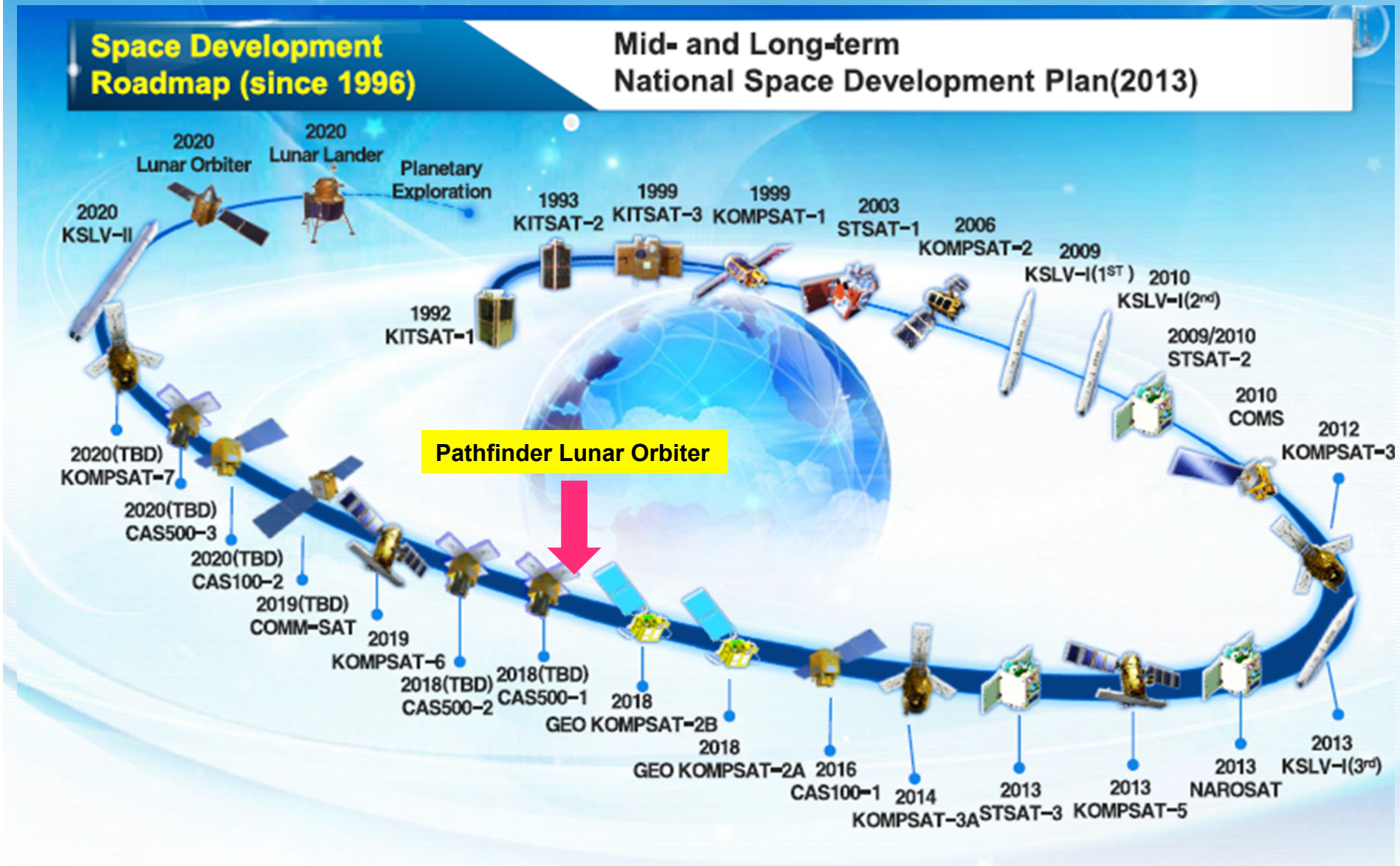
5 Strengthen the space industry to support susta inable space development

1. Increase role and competitiveness of the industry
2. Increase exports by combining the capabilities of th ndustry, university, and research institutes
3. Promote the convergence of space technology

6 Expand the basis to promote and advance spac e development activities

1. Strengthen core space technology and deve lop future fundamental technology
2. Train manpower and increase space aware ness
3. Strengthen intentional cooperation

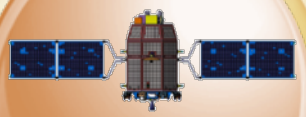
National Space Development Plan



Korean Lunar Program Overview

1st Phase: Domestic led/ International Collaboration

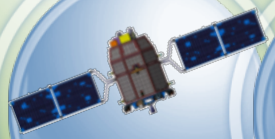
- Technology demonstration for interplanetary exploration
- International cooperation
- Establishing deep-space antenna



Pathfinder Lunar Orbiter (KPLO)

2nd Phase: Domestic development

- Domestic development
- Korean Launch vehicle



Lunar Orbiter

Lunar Lander

Deep Space Ground Station

- Deep-space antenna
- Science/Imaging data processing
- TM & TC Operation

Payload [1st Phase]

- Lunar science payloads
- International payload
- Space internet

Preliminary Study

- Rover ground test model
- Key technologies for lunar landing
- Energy source for the lander mission
- Preliminary design for upper stage of launch vehicle

Payload [2nd Phase]

- Space internet
- Energy source
- Mineral resources
- Topography
- Space environment

LV Upper stage

- Trans-lunar injection
- 550kg to trans-lunar orbit

1st Phase Korean Lunar Exploration Program

Program Overview (1st Phase)

Goal	Pathfinder Orbiter for Technology Demonstration & Science
Plan	2015 ~ 2018
Budget	~170M USD (197.8 B KRW)
Mission Req	Lunar Polar Orbit 100km Launch Mass : 550kg Mission Lifetime : 1yr
Launch	2018

Features

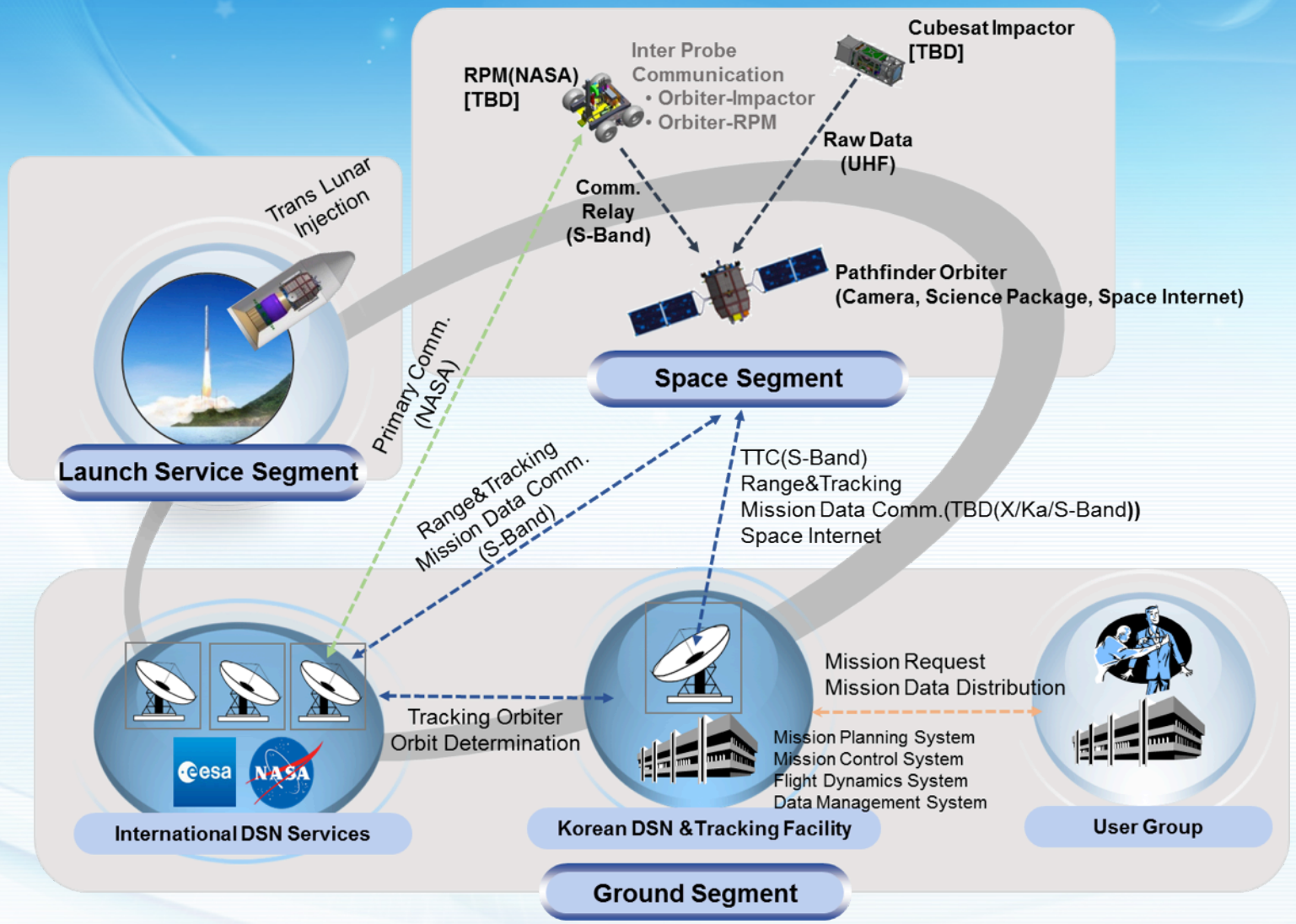
- System and Bus development
- Building DSN Ground-station
- Domestic science instruments and International collaboration instruments
- Space internet demonstration
- Pre-study Lunar landing mission technology

KPLO Mission Objective

- Develop indigenous lunar exploration technologies
- Build Korean DSN Ground Station
- Investigate Lunar Resources & Environments
- Realize new space-based technology by demonstrating space-internet & smartphone operation in moon territory
- Planned Activities in FY2015

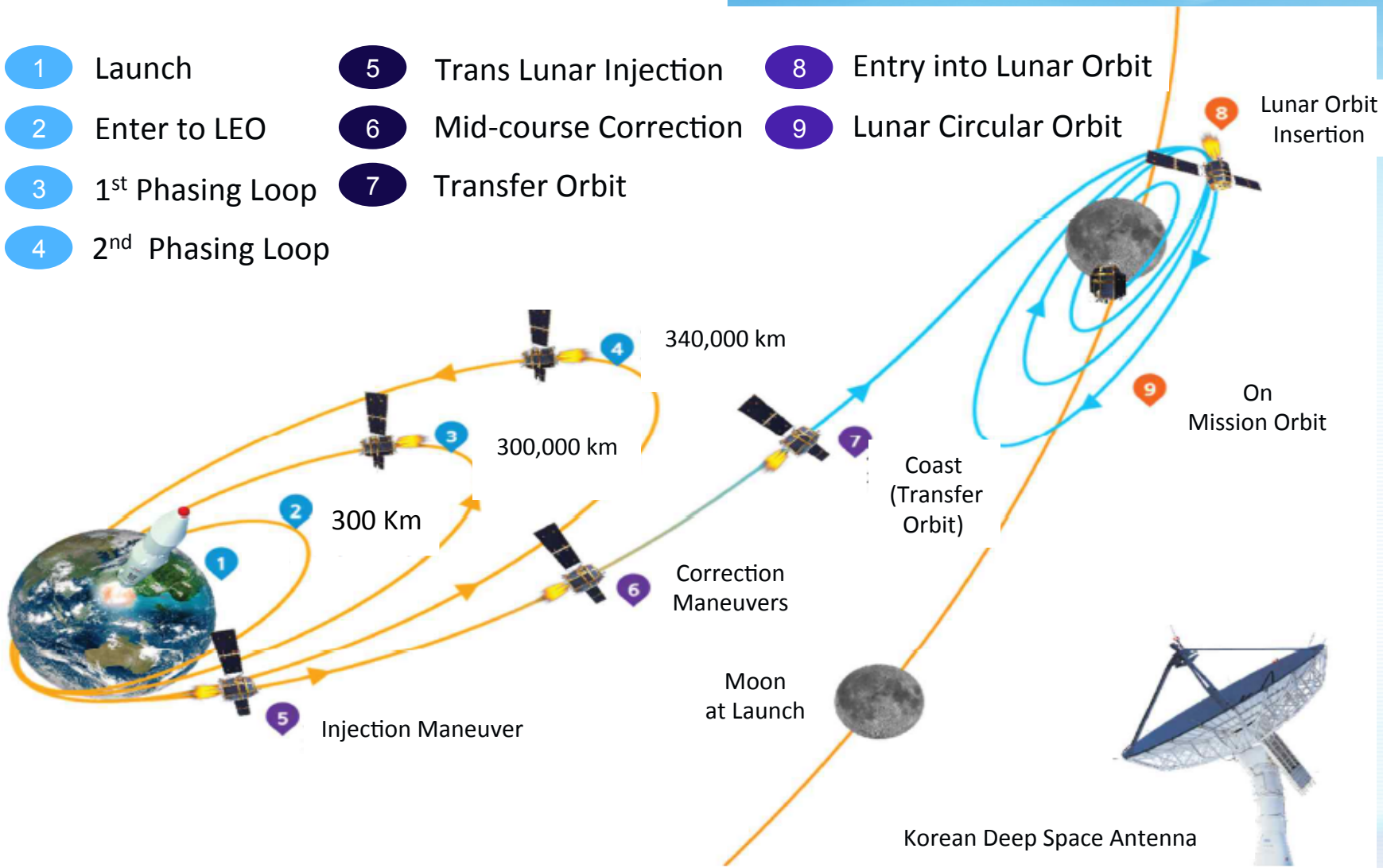
- KPLO MDR & Conceptual Study
- KPLO Science Definition Study
- Korean DSN Site Selection
- NASA-KARI MOU Preparation

KPLO System Configuration



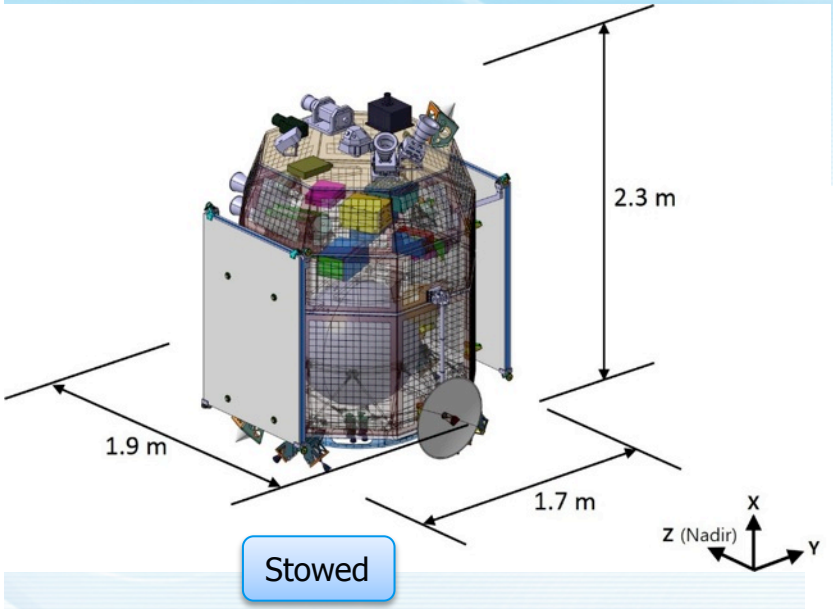
KPLO Mission Trajectory

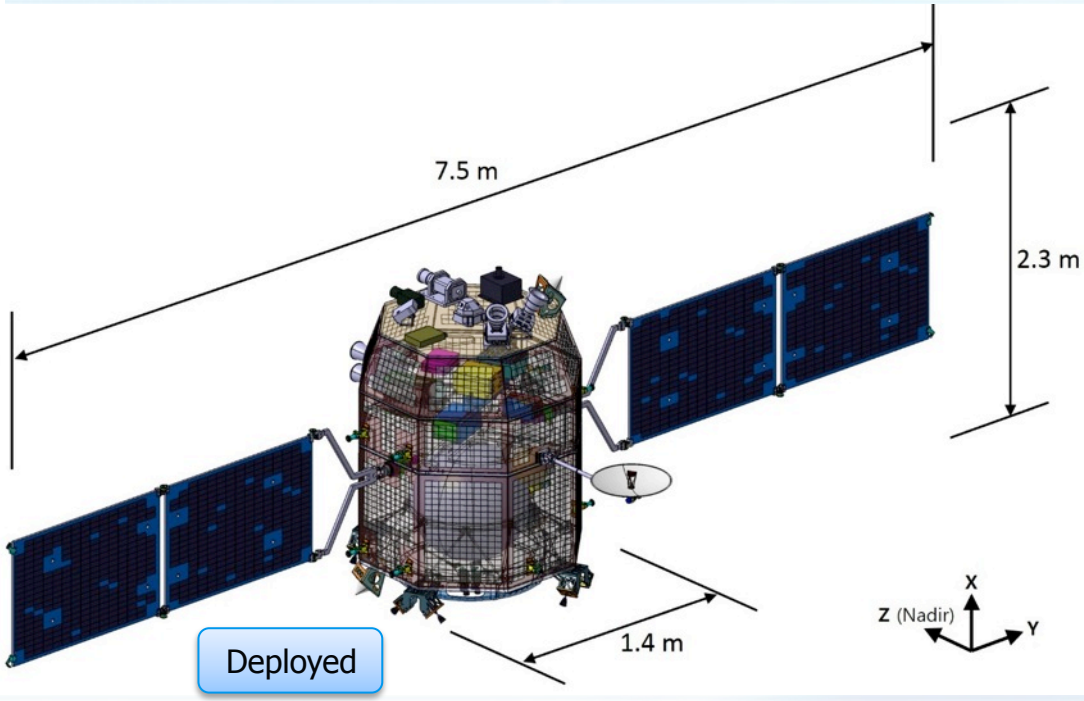
1 Launch
2 Enter to LEO
3 1st Phasing Loop
4 2nd Phasing Loop
5 Trans Lunar Injection
6 Mid-course Correction
7 Transfer Orbit
8 Entry into Lunar Orbit
9 Lunar Circular Orbit



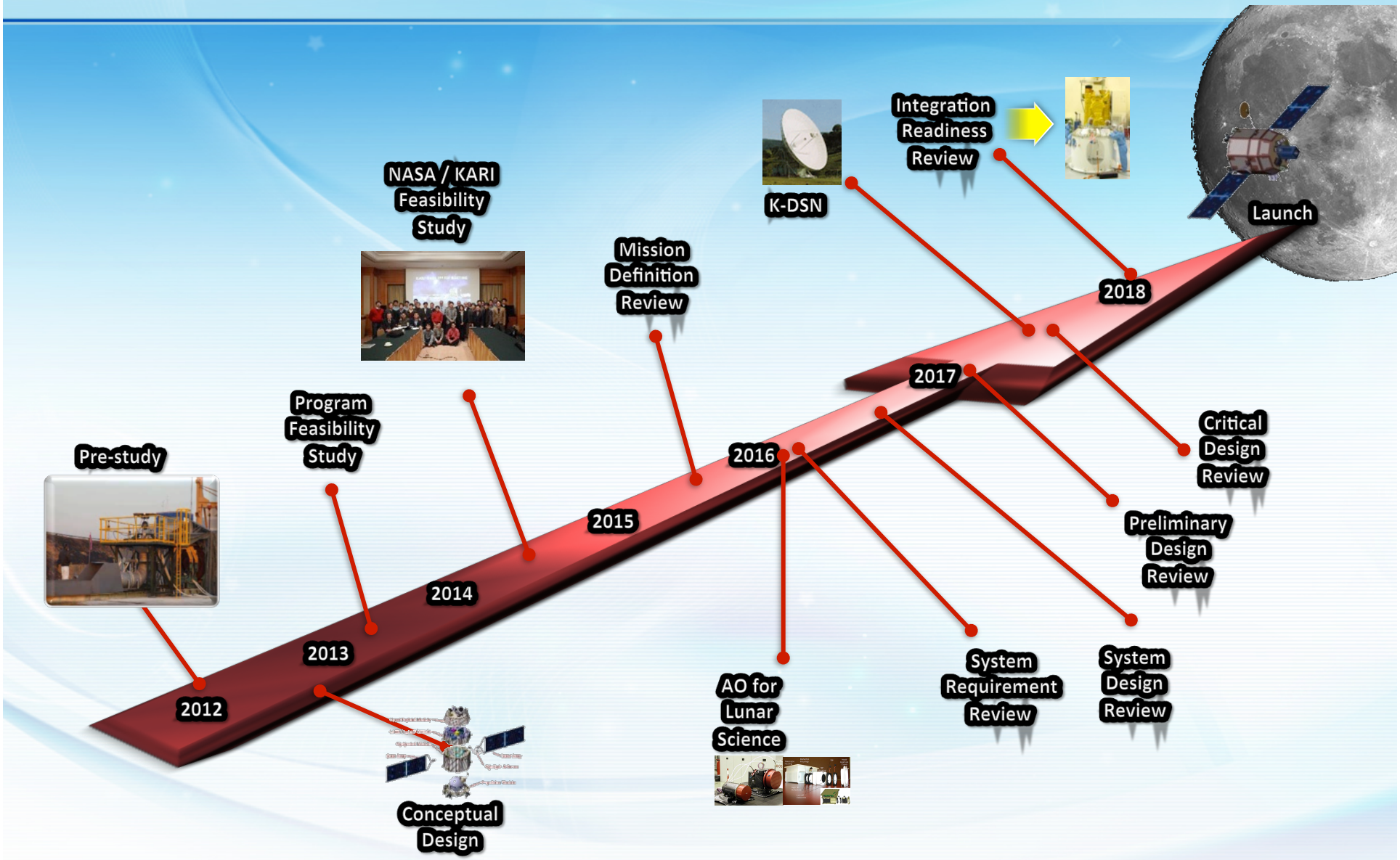
KPLO Bus Design

- Deployable solar arrays
- Deployable High-gain Antenna with two-axis tracking capability





KPLO Milestone



KPLO Project Status

Program Approval & Budget

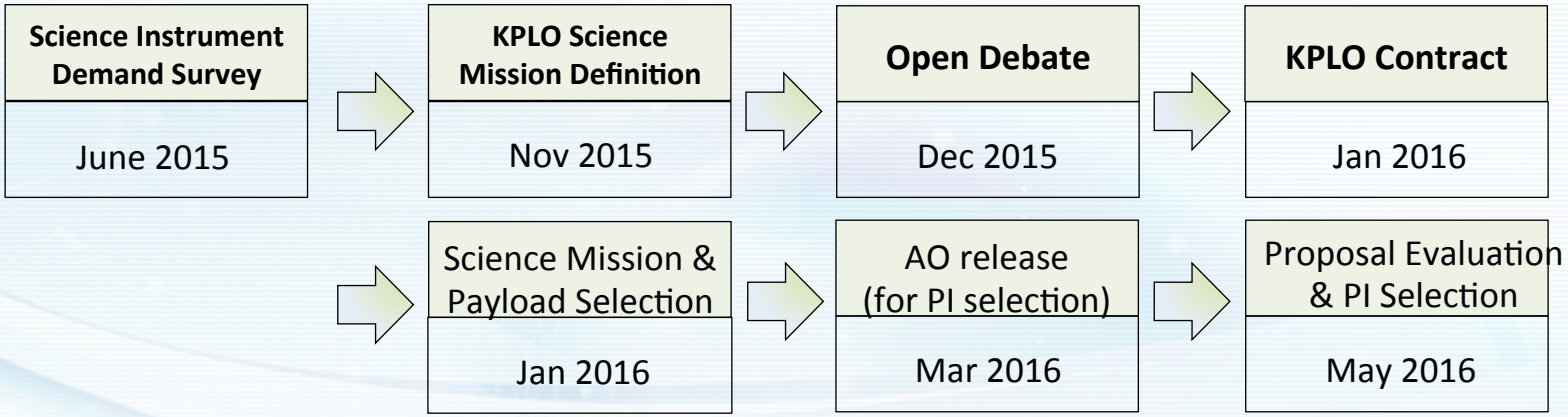
- Official Architectural & Planning Study (Jan-May 2013)
- Technical Feasibility Evaluation Process (Jun-Sep 2013) → Passed
- Preliminary Feasibility Evaluation Process (Dec 2013 – Sep 2014) → Passed
- Pathfinder Program Plan Approval (Dec 2014) → Passed
- FY2015 budget final submitted by National Assembly (Dec 2014) → Not Included
- Re-apply, Governmental budget process (Mar-Sep 2015)
- Final FY2016 budget approval by National Assembly (Dec 2015) → To be Included
- Program Execution (Jan 2016 – Dec 2018)

International Collaboration

- NASA invited KARI to NLSI/SSERVI as associate partnership (Dec 2012)
- KARI submitted SSERVI proposal (May 2014) & Agreement Signup (Aug 2015)
- KARI-NASA Robotic Lunar Feasibility Study Agreement (July 2014) & Study Report (A pr 2015)
- TAA Agreement between KARI and NASA JPL (Apr 2015)
- KARI-NASA LOI (May 2015) & MOU(TBD 2015)

KPLO AO Status

- **BACKGROUND**
  - Korean Lunar Exploration Planning Study (.Jan-Aug '13)
  - Korean Lunar Science Mission Study ('14) → Draft (Not Official)
  - No Specific Science Definition Study dedicated to KPLO
- **KPLO AO Status**
  - Lunar Science Instruments Demand Survey (Jun '15) → 19 proposals collected
  - AO will be coming soon right after FY2016 budget approval



* All schedules are tentative

KPLO's Payloads

- Plan: 2 domestic science payloads and 2 NASA developed payloads + technological demonstration instruments

Instrument	Korea developed payload	NASA-related payload
Science	Imaging Camera	CubeSat (TBD)
	• mid-high resolution camera	• local lunar magnetic field
	Science payload through domestic AO (TBD)	Science payload through NASA AO (TBD)
	• Lunar Science	• Lunar Science
Technology Demonstration	Space Internet	Communication Relay
	• Develop new DTN protocol • Connect spacecraft, rover & lander	• Provide RF communication & remove interference

Science payloads for KPLO

Scientific Mission of The Korean Pathfinder Lunar Orbiter

- Environment of the Moon
- Lunar Resource & Topo graphy

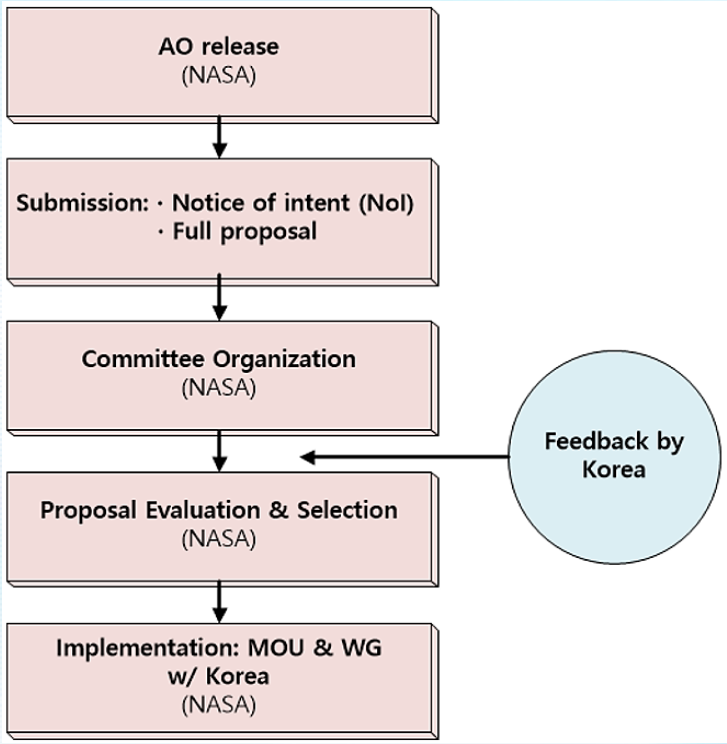
Science Mi ssion paylo ads for KP LO

Korea Domestic	Optical Imaging System (TBD)	Science mission and Payload selection Committee (TBD)
	Scientific Instrument (TBD)	Science mission and Payload selection Committee (TBD)
International Collaboration	Scientific Instrument	AO (NASA HQ)
	Cubesat Impactor	NASA ARC

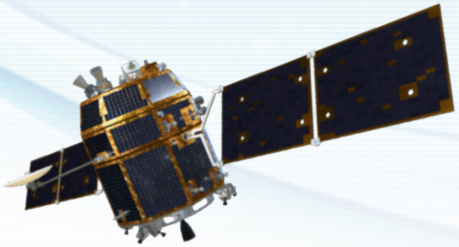
International collaboration – AO plan

- **Limited to NASA as a partner**
- **Technical requirements and constraints**
  - Total mass of a payload (<15 kg)
  - Power provided: 28 Volts
  - Continuous power allowed (20W, TBD)
  - Continuous data rate (10 kbps, TBD)

Parameters (Unit)	Pathfinder
Expected Launch	2018
Mission Lifetime	1 yr
Mass Budget (kg)	< 550 (wet mass)
Propellant	Mono
Stabilization type	3-axis
Mission Orbit	Polar Orbit (TBD)
Altitude (km)	50 or 100 (TBD)
Inclination (deg)	90
Communication	Remote command & telemetry: S-band Data link: X- or Ka-band



Lunar Science Research Activities



Research Activities Overview

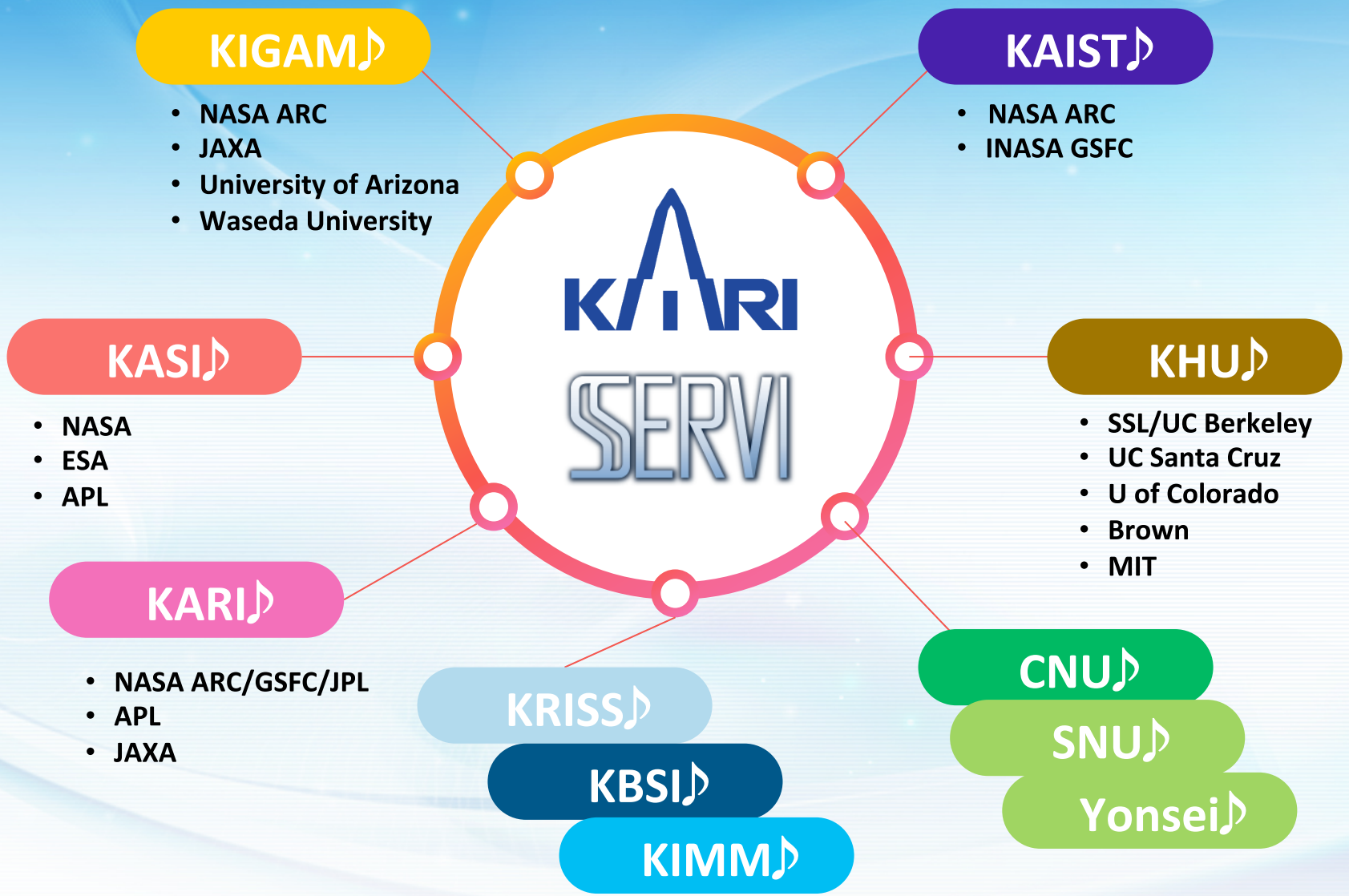
RESEARCH

- **BUDGET STATUS for LUNAR SCIENCE**
  - 5 National Labs & more than 2 universities started with ~4M USD at the beginning of FY2015
  - ~2M USD/yr fund for prelim lunar science instruments added as of July
  - ~15M USD will be assigned for KPLO science payloads
- **RESEARCH STATUS**
  - Mostly in Pre-Phase A or preliminary stage focusing on instruments
  - KIGAM, KHU show outstanding and matured outcome

PLANNING & NETWORKING

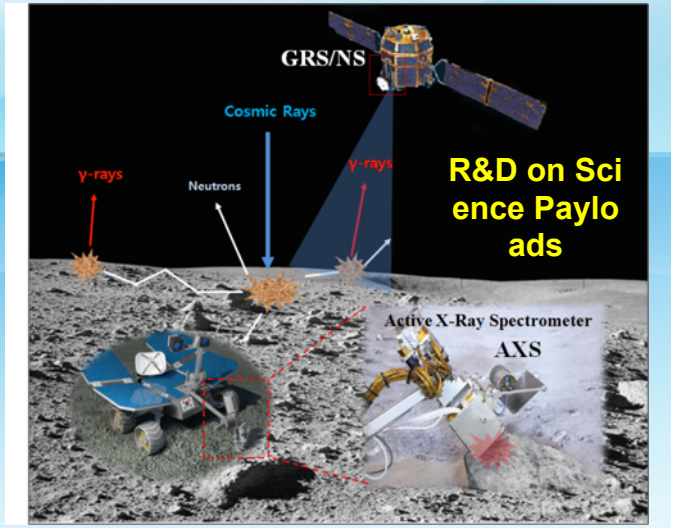
- **ADMINISTRATIVE ACTIIVITIES**
  - Korean Lunar Mission Roadmap Planning
  - KPLO Scientific Demand Survey
  - KPLO Science Definition Study
  - Policy & Funding Making Support
- **PUBLIC OUTREACH**
  - Annual Korean Lunar Symposium
  - Public Debate in National Assembly
- **International Relation**
  - KARI-SSERVI Agreement
  - Collaborative Research Promotion

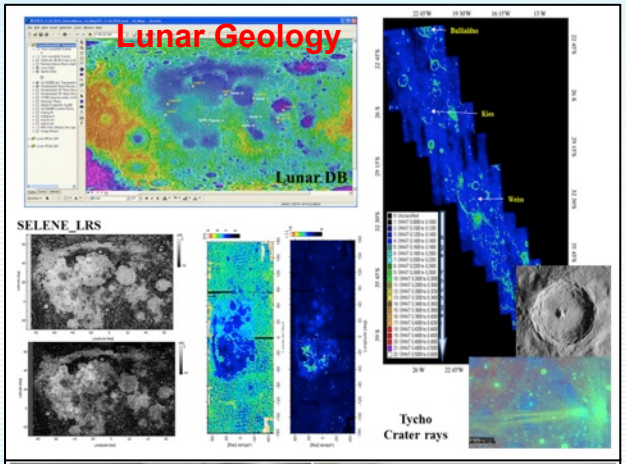
Korean Lunar Science Network



Research Activities at KIGAM

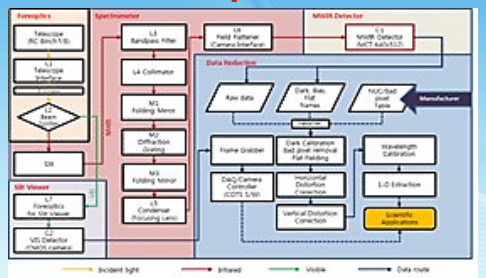
- **Development of Nuclear Science Payloads**
  - Gamma-Ray Spectrometer, Neutron Spectrometer EM model for future lunar orbiter (recently funded by NRF)
  - Active X-ray spectrometer (internal fund)
- **Planetary Geology Department (major research)**
  - Lunar geology and crustal evolution history from Lunar analogue rocks and meteorites and lunar image and spectroscopic data
  - All meteorite found in Korea except Antarctic meteorites to be evaluated and registered at KIGAM (Established in 2015)
- **Planetary Research Facilities**
  - TIMS, SEM/EDX, XRF, ICP-MS, GRS/NS instruments
- **Educational Activities in Planetary Exploration**
  - Secondary Level (teachers, students)
  - Tertiary Level (graduate, planetary science major)





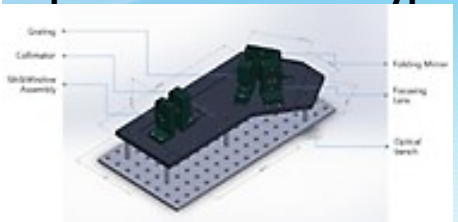
Research Activities at KARI

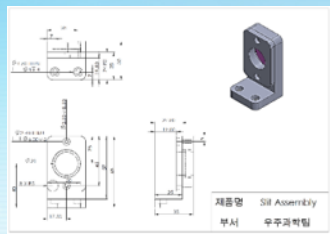
Mid-Infrared Spectrometer

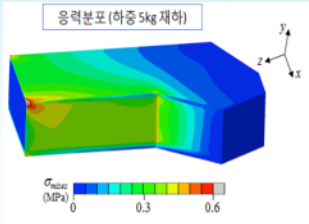


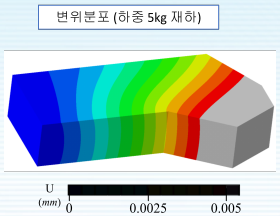
Modified Czerny-Turner

Spectrometer components and mounts, Optical bench Prototype design and production

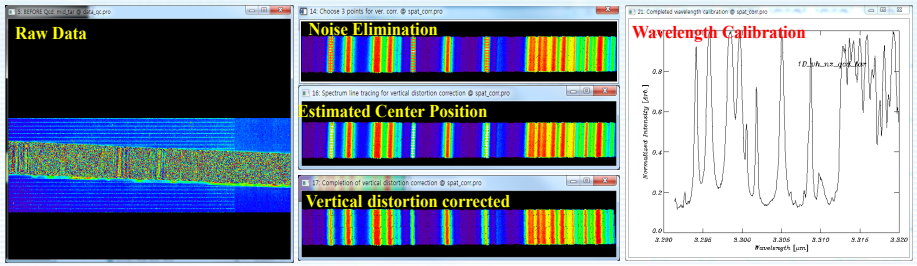




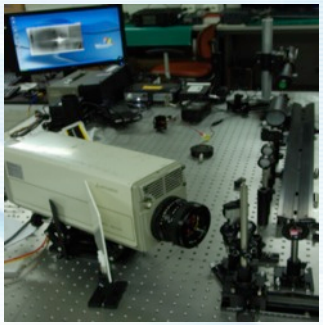


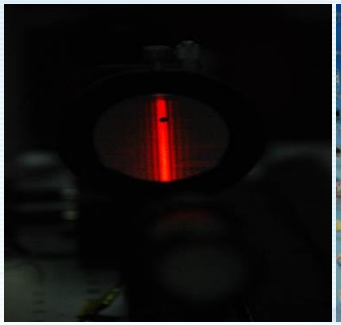


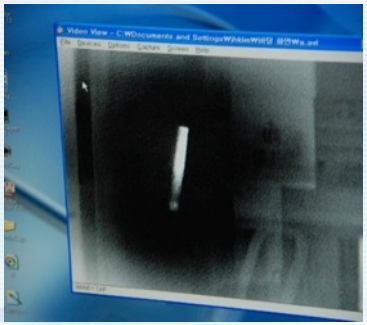
Mid-Infrared spectrometer Prototype design and thermal anal.



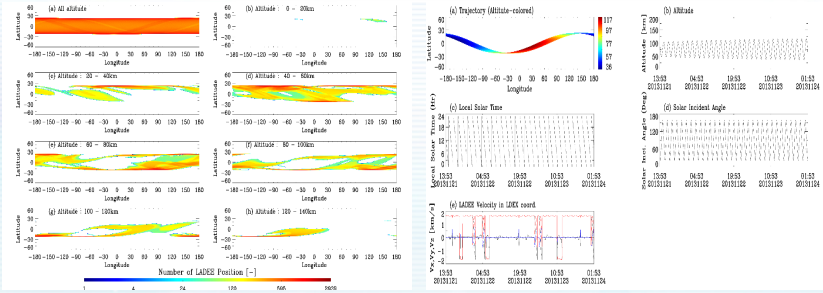
Prototype development and Data analysis tool







Visible and mid-infrared, laser

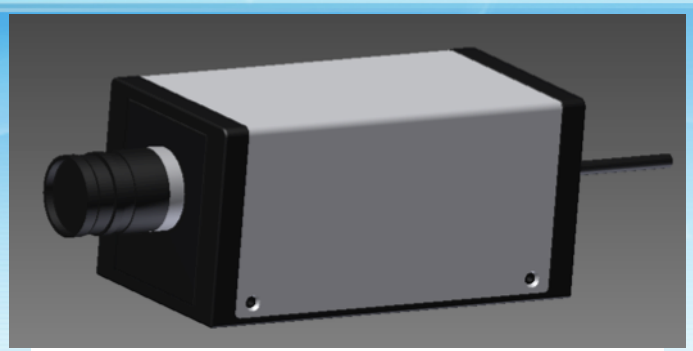


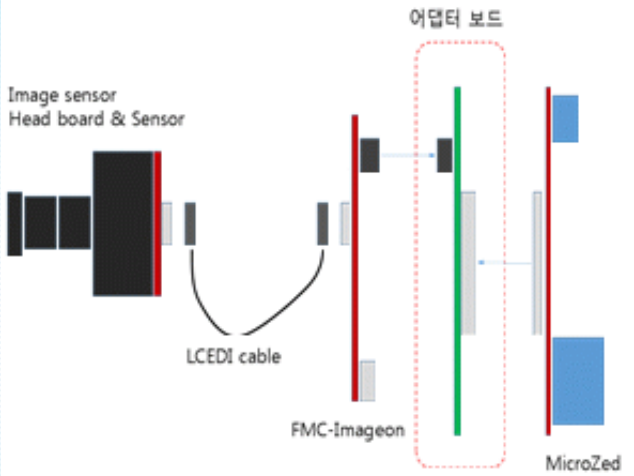
LADEE data for space science research (LADEE position and solar angle analysis)

Research Activities at KASI

- **Ongoing Science Research Topics**
  - Solar system bombardment History
  - Lunar surface properties
  - Mineralogy / Water
  - Plasma environment in cis-lunar space

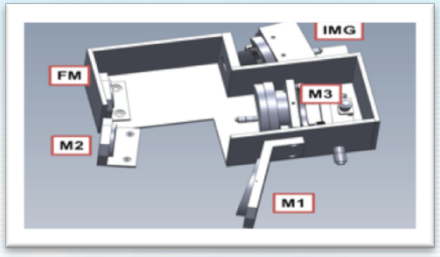
- **Development of Science Instrument Prototypes**
  - Wide-angle camera for Polarimetry and lunar impact monit oring
  - Narrow angle camera
  - Space Environment Package (ESA, SST, LRM)



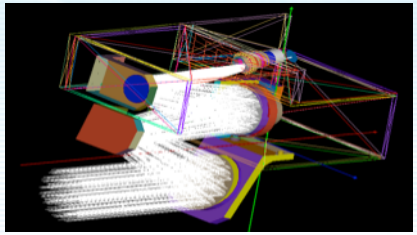


Research Activities at KBSI

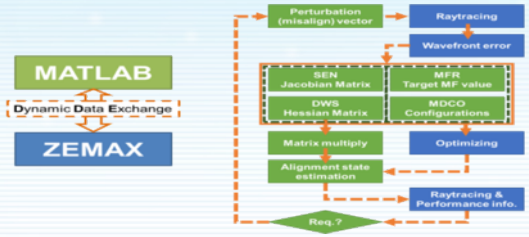
- **Development of a light weight Infrared Spectrometer**
  - Space environment and infrared/thermal Imager
  - Active X-ray spectrometer (internal fund) High resolution imager (GSD : 10 m@100 km, volume: 0.3x0.3x0.4 m, WFE < 1/15λ)



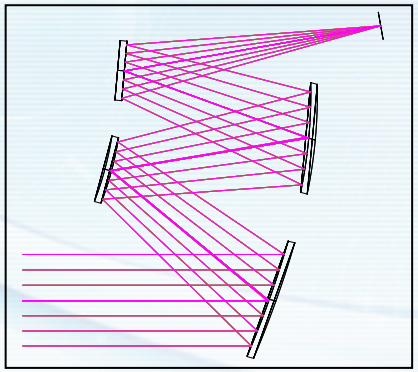
TMA Opto-Mecahnism Design



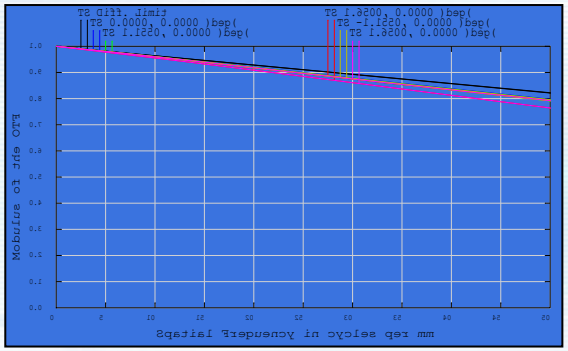
Stray-light analysis



DDE-based Alignment Algorithm



F/5.0 TMA Optics Design



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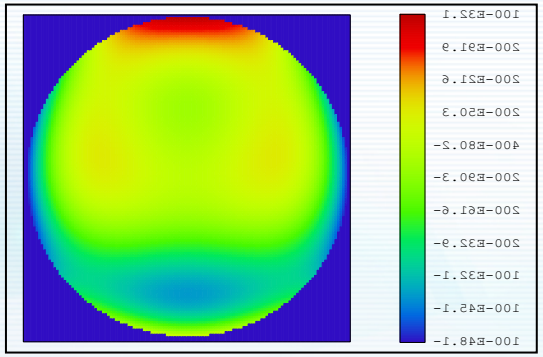
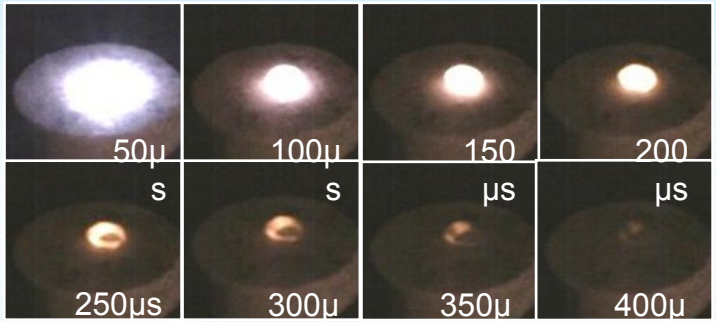
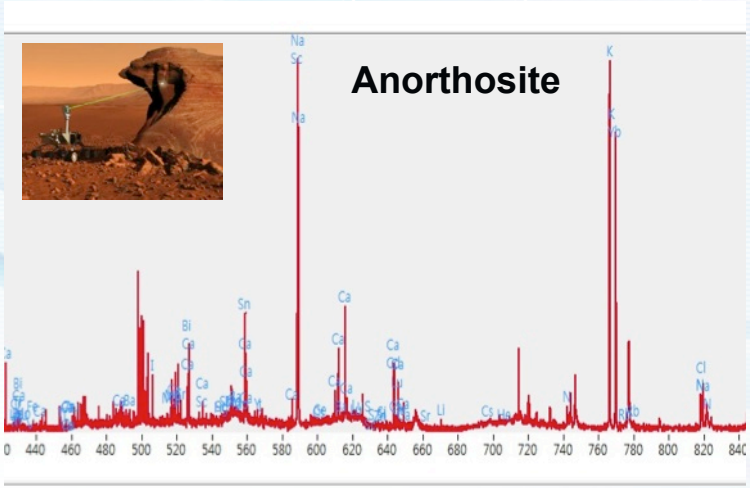


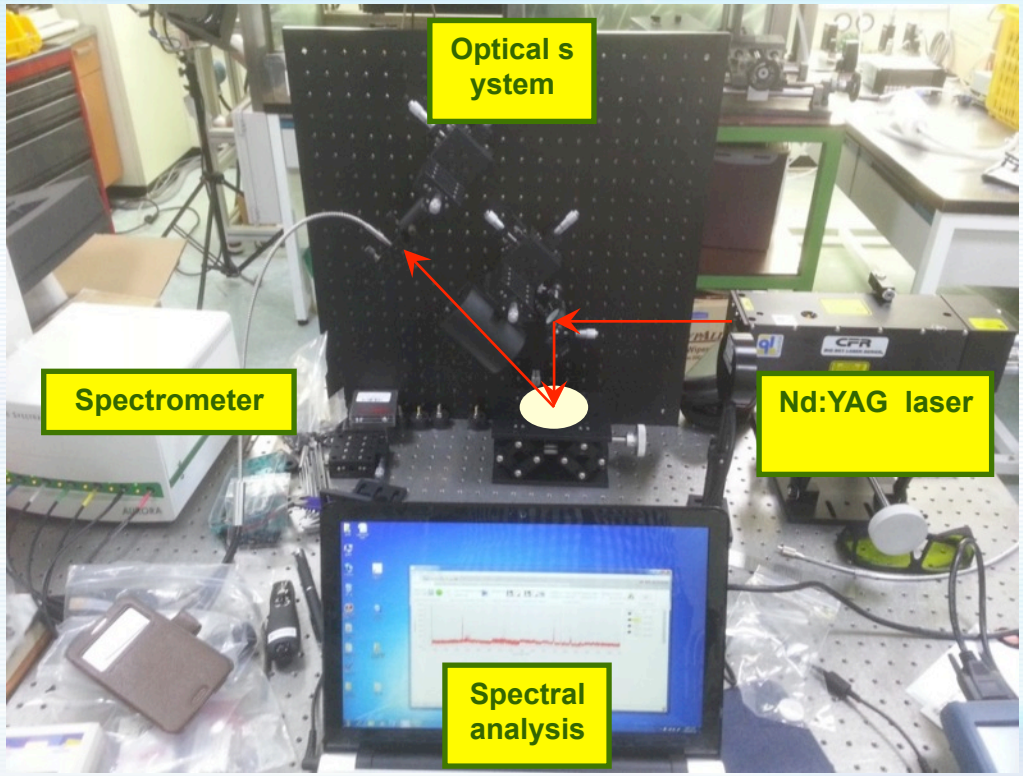
WFE Perfomance : < 1/15λ

Research Activities at KIMM

- **LIBS (Laser Induced Breakdown Spectrometer)**
  - Lunar analog rock analysis (Sn 1000 ppm)
  - Using a high speed camera, laser induced plasma production and data analysis





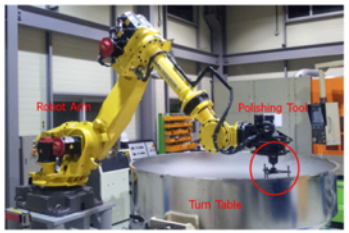


LIBS system at KIMM

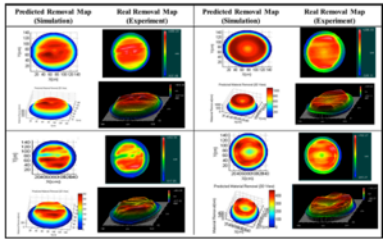
Research Activities at KRISS

High resolution camera/imager & LIDAR (light detection and ranging)

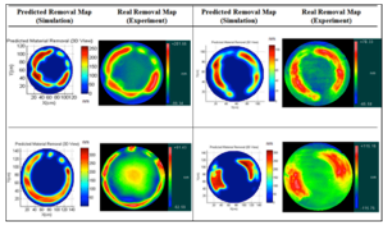
Large mirror development



Robot-arm based machine

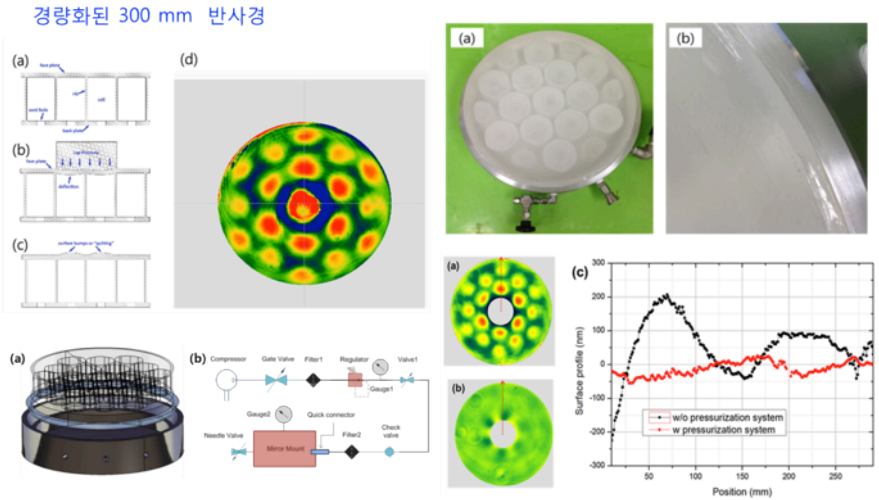


CNC type machine

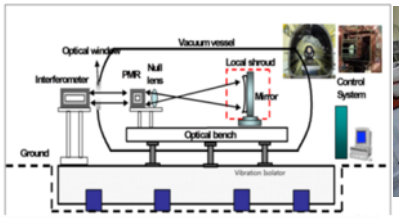


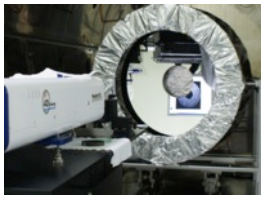
Polishing algorithm

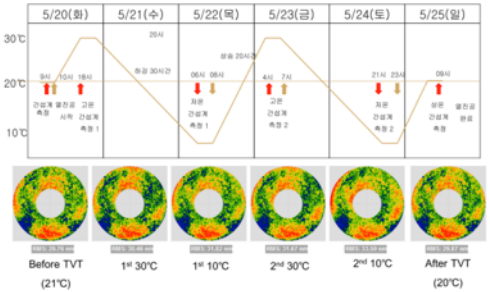
Super light, large reflecting telescope, 300 mm



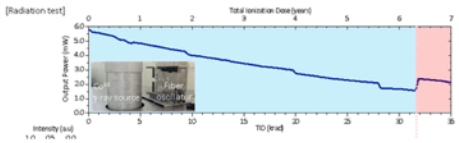
Camera/ 1 m DI reflecting telescope (space Envir. Test)

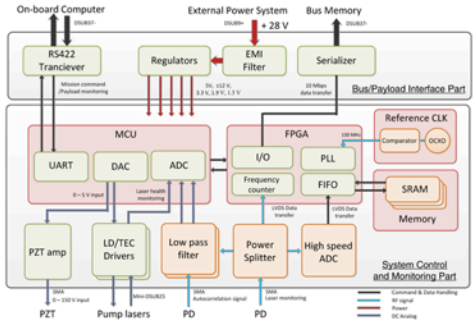






(LIDAR) Fiber cabled laser





Summary & Suggestions

- **Korean Lunar Program**

  - Pre-Phase A study for KPLO is ongoing with preparation for MDR in Oct 2015.
  - The KARI-NASA Robotic Lunar Feasibility Study Report submitted & LOI signed
  - The AO for science payloads will be released in early 2016.
  - Originally NASA assigned payloads for KPLO can be funded by KPLO budget through N ASA/SSERVI partnership and its affiliate member's collaboration
  - Korea is seeking for the chance to participate Resource Prospector and/or Moonrise missions by making additional convergence research funding from government. (not only drill but also science payloads, lander/rover subsystems

- **Lunar & Planetary Science**

  - Continue collaboration on the FINESSE project
  - Exchange scholars and attending training course at NASA
  - Joint products (map and educational materials)
  - Joint workshop with the SSERVI and the Korean Planetary Science community

Fly to the Moon