Current Status and Future Prospects on JAXA's Lunar Exploration

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Personal Background Related to Lunar Exploration

- 1991-93@NASDA, System concept study on robotic Lunar & planetary missions
- 1997-2000@NASDA, Joined SELENE project team (project management, satellite bus – mission instrument IF, mission operation & analysis center)
- 2009-present@JAXA/JSPEC, Mission/system concept study on human Lunar & planetary exploration

JAXA's standpoint for Lunar exploration

- Japan's Space Basic Plan (June 2009)

  Policy, System & Program Plan,

  Exploration (Solar System, Moon)

- JAXA's Space Exploration Vision

  Solar System Exploration, and

  Lunar Exploration

  (**The Space Basic Plan dose not cover the details.)**

The Space Exploration at JAXA is performed in both Robotic and Human Exploration.

JSPEC (JAXA Space Exploration Center) was built for Solar System Exploration as well as the Mission Design Stage of the Human Lunar Exploration.

Space Basic Plan –Human Space Activities -

Themes/Objectives/Goals:

- Leading top scientific and accumulation of human intellectual assets,
- Advanced technology for future industrial power and human resources development,
- Securement of national benefits and improvement of international presence through enhanced diplomatic power as an advanced country
- Dream, confidence and pride for the Japanese people

Target **ISS, Moon**

For Coming 5 years

- **For ISS "Kibo"**
  - Space environment utilization related to people's life
  - International cooperation with Asian countries to use "Kibo"
  - Commercial use
  - New technology development
- **For Moon :**
  - Examination of the moon exploration with robotic technologies in perspective of human space activities.

→ Governmental Study Group for Lunar Exploration

Governmental Study Group for Lunar Exploration

Context and process

- Space basic plan calls for a comprehensive study for Japan's lunar exploration
  - To clarify the exploration objectives and roadmap for technology development
  - To consider robotic lunar exploration for science and utilization, foreseeing manned lunar exploration afterward.
  - To seek for international cooperation
- Study group was organized under the Minister of state for Space Policy and completed in July 2010. (Results shown in following pages)

  Members: Reps.from industry, jurist, academy, astronaut, sociologist, etc
- A report was published and also referred from the policy authorized by Strategic Headquarters for Space Policy.
- Still need budget requests for the proposed activities in the report in the yearly budgetary cycle.
- The report is now being translated into English. (will be released in the end of November.)

Report by Governmental Study Group for Lunar Exploration

1. Robotic Exploration

Proposed Approaches :

- 2015 : First lunar landing and short-term investigation
- 2020 : Assembly of the scientific exploration base, long-term investigation and sample return
- Demonstrate leadership in the international collaboration

Images of robotic exploration in 2015

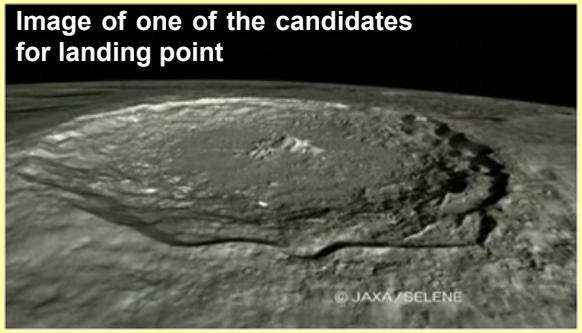


Image of one of the candidates for landing point


Image of soft landing

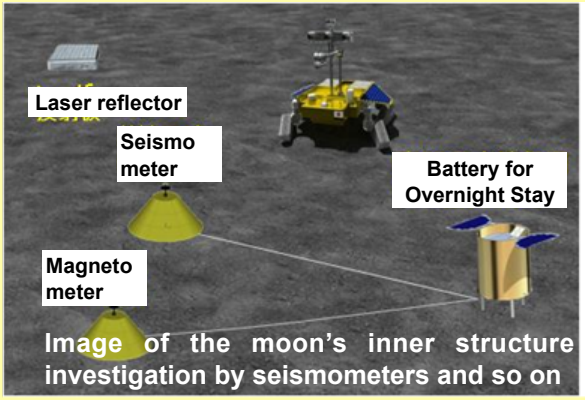


Image of the moon's inner structure investigation by seismometers and so on

Images of robotic exploration in 2020

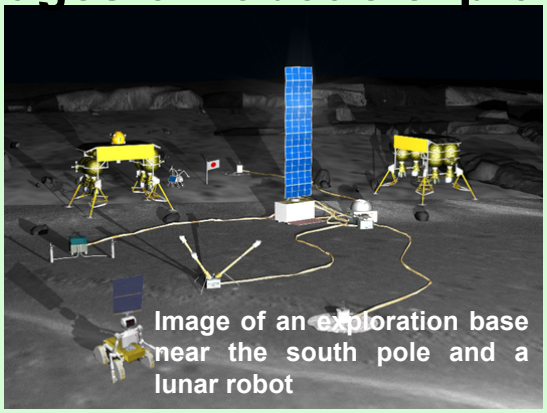


Image of an exploration base near the south pole and a lunar robot

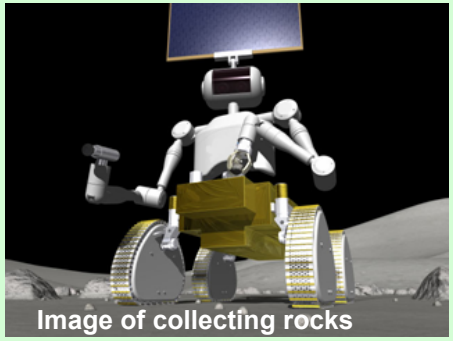


Image of collecting rocks

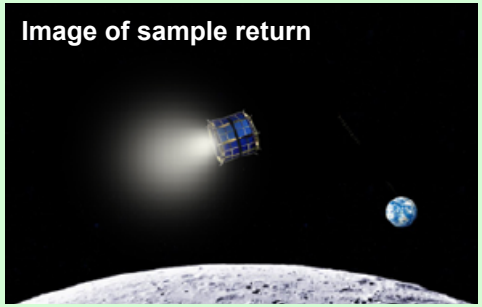


Image of sample return

2. Human Space Activity

Proposed Approaches :

- Research and development of basic technologies for human transportation system by around 2020
  - Safety enhancement rocket engine
  - Emergent escape technology
  - Human rated re-entry technology
  - Environment Control and Life Support technology
  - etc.
- Efficient technology development leveraging other space activities such as
  - Robotic lunar exploration
  - H-IIA/B launch operation
  - ISS utilization and operation for technology demonstration
- International cooperation is mandatory for human space exploration

JAXA's Lunar Exploration Roadmap

06	07	08	09	10	11	12	13	14	15				20				25				30
H18	H19	H20	H21	H22	H23	H24	H25	H26	H27				H32				H37				H42

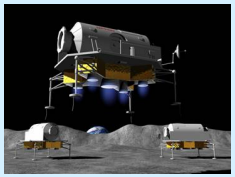
▲Kaguya　　SELENE-2　　SELENE-X

■Robotic

Kaguya (SELENE)
Orbiter

SELENE-2
Lander

SELENE-X
Advanced Lander
Robotic Outpost



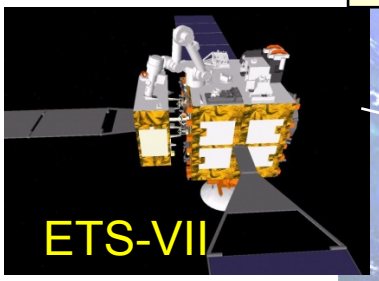
International Human Lunar Exploration Activity

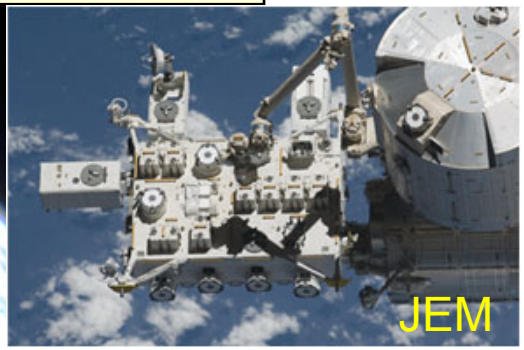
■Human

J. Astronaut

Among International Crews

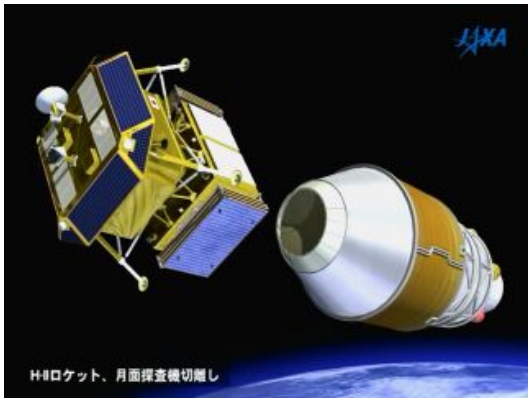
Human-related Technology through ISS, HTV etc.

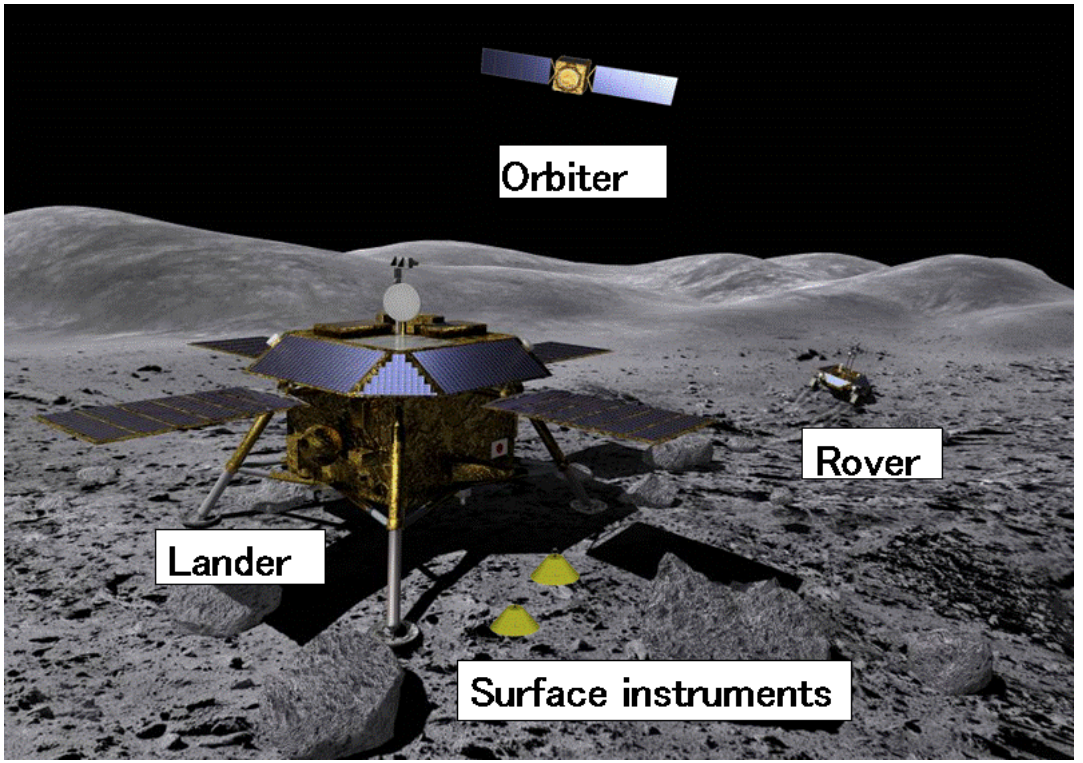




Example of SELENE-2 configuration

Item	Specification (TBD)
Mass	Orbiter: 500 kg (Dry) Lander: 1,000 kg (Dry) Rover: 100 kg
Mission Duration	Two weeks for lander and rover A few month for geophysical observation
Launcher	H-IIA Rocket
Launch date	2015 or 2016 (TBD)
Landing area	TBD (near side, middle latitude)

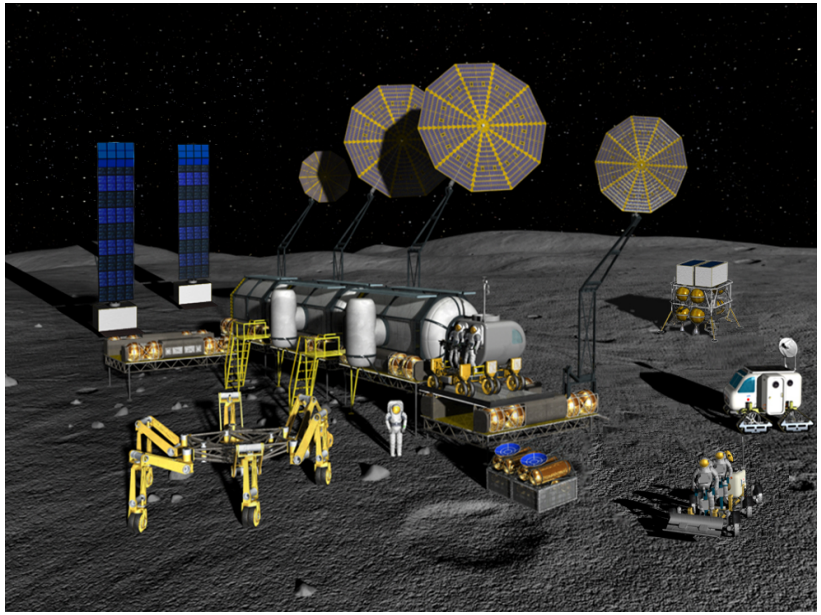




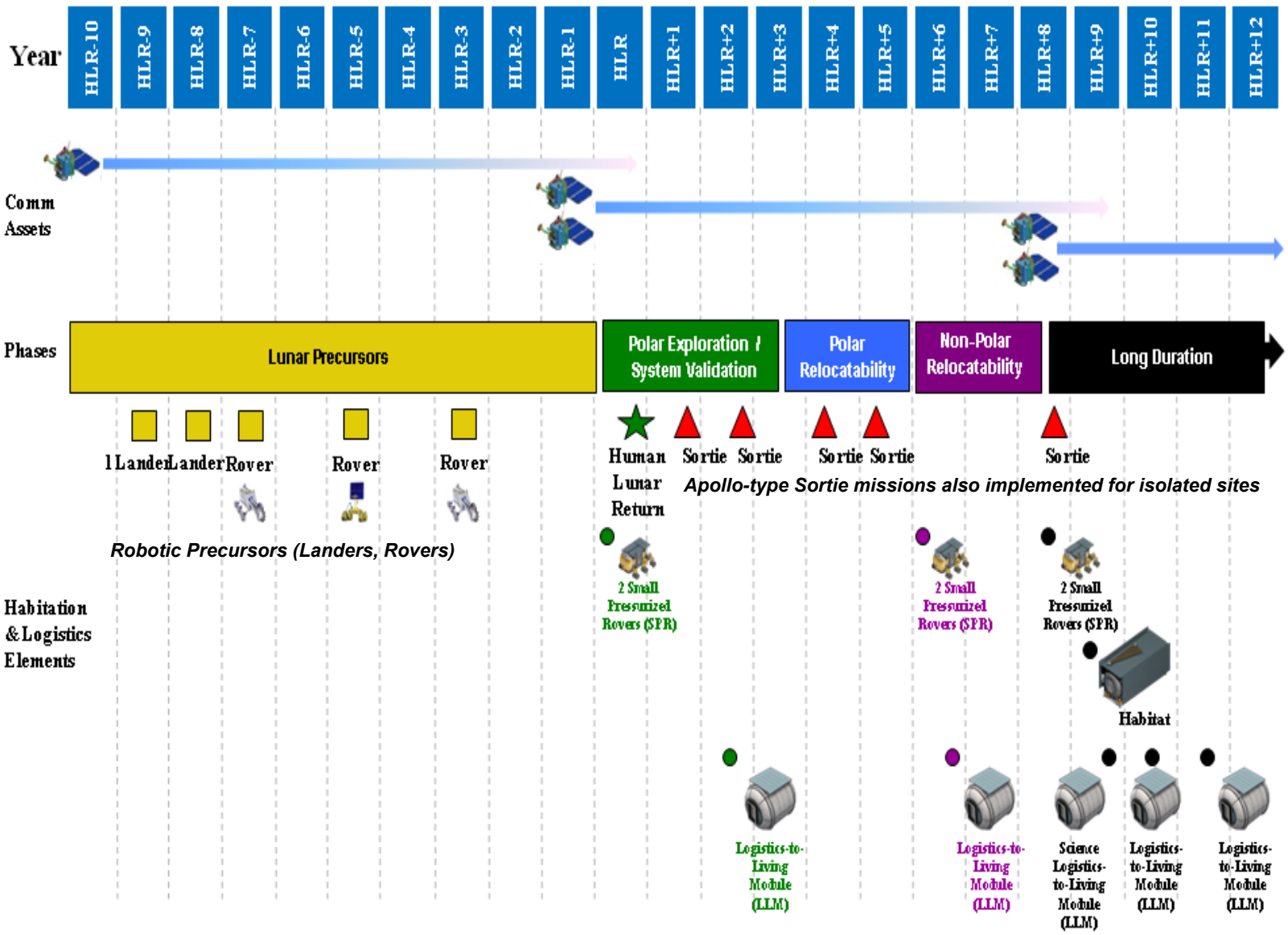
Human Lunar Exploration by International Collaboration beyond 2020

International Space Exploration Coordination Group (ISECG), collaboration framework among global space agencies, studied the conceptual plan for the International Human Lunar Exploration.

By adopting phased development approach, human missions starting from one to a few weeks stay to, eventually, a few months stay will be possible.



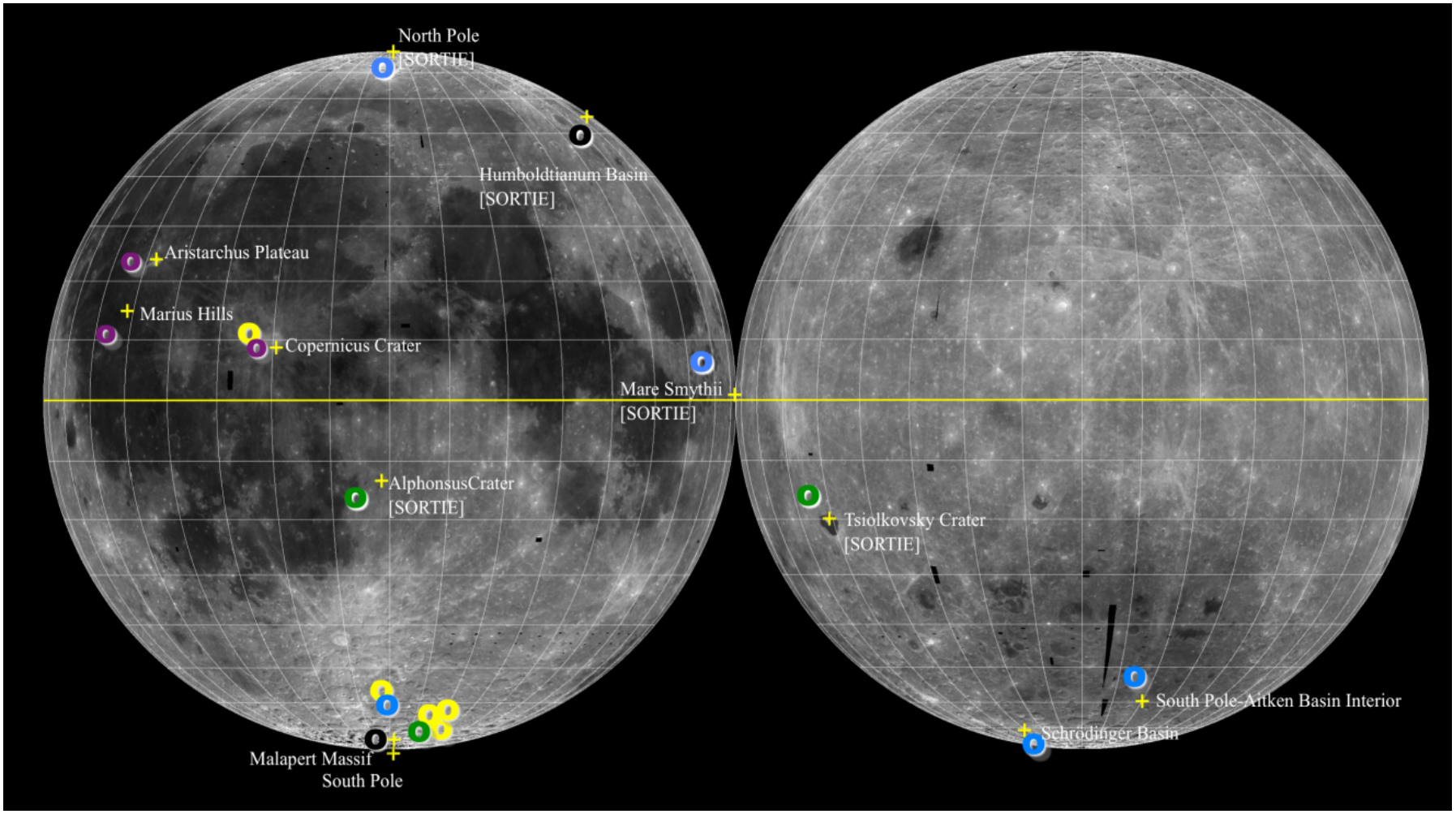
Reference Architecture Concept and Approach



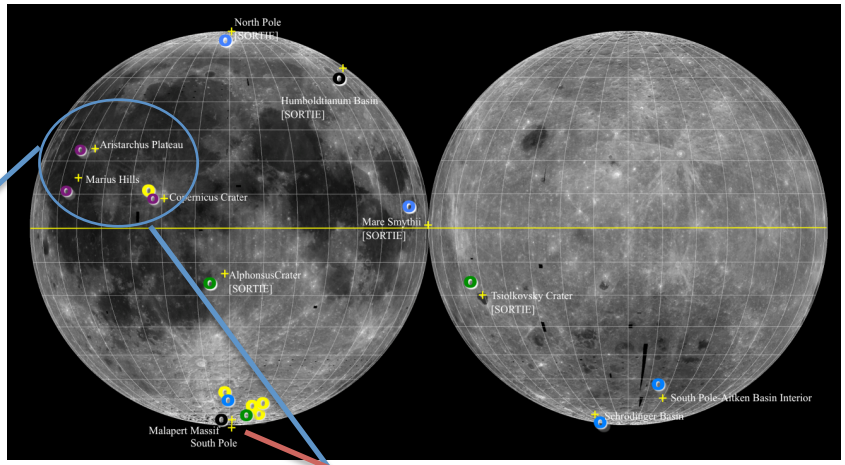
Candidate Landing Sites for Human Lunar Missions

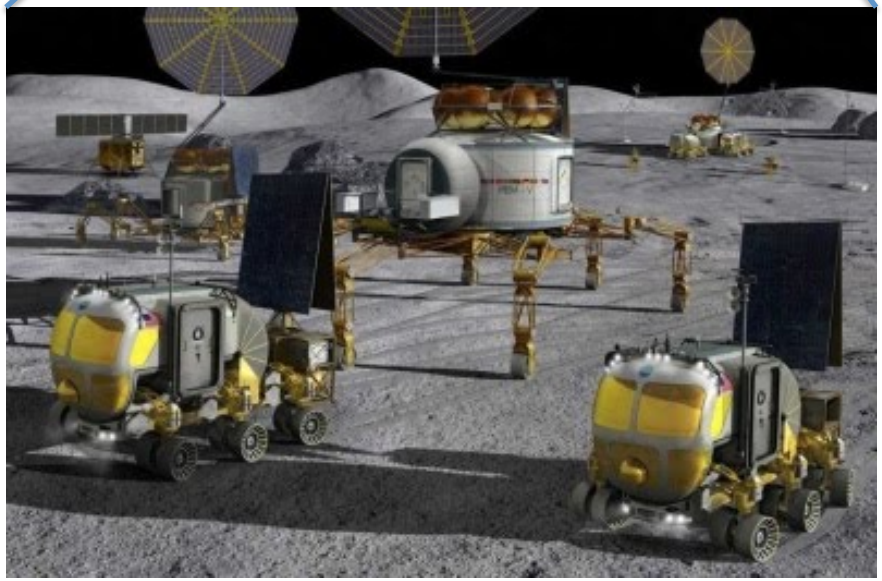
Near-side

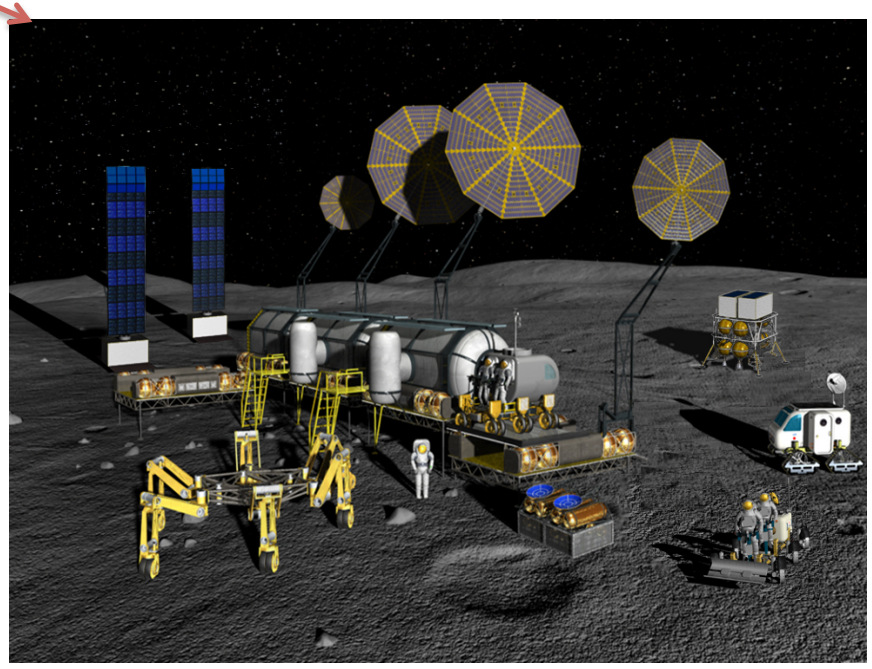
Far-side



Apollo sites shown for reference only.







Concept for Relocatability

Concept for Long Duration Habitat at Lunar Polar Site

Possible JAXA Contribution for the Lunar Exploration Architecture (1/2)

Pressurized Rover

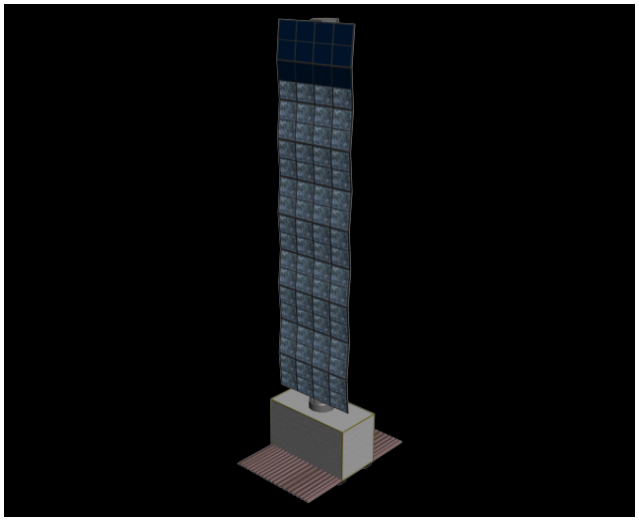
- Lunar surface transportation / exploration system with pressurized cabin
- One week operation & stay is possible for two crews with normal suits inside.
- A few hundred km traverse distance at one time
- Space Suits are available for outside operation.
- Electrical power charges on lunar surface for multiple use

Cargo Lander

- Automated cargo transportation system from the Earth to lunar surface for logistics support, such as
  - Rovers
  - Electric Power System
  - Consumables (Oxygen, water, food, etc.)
- Sample return vehicle as a payload is considered
- Approx. 1.5 ton payload mass to the lunar surface is possible by a Japanese H-IIB launch vehicle.

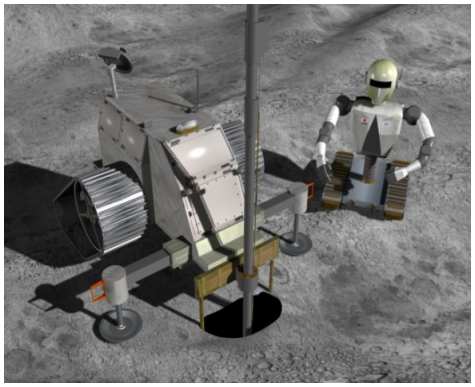
Possible JAXA Contribution for the Lunar Exploration Architecture (2/2)

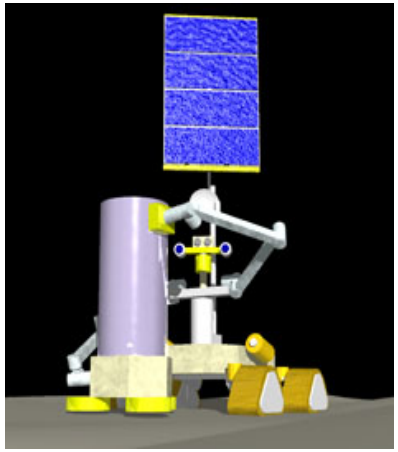
Electric Power System



- Lunar surface electric power system with the Regenerate Fuel Cell and the Solar Battery Cell
- Solar cells generate power under sunlit condition to provide necessary power for other systems
- A part of power generated by solar cells is used for the Oxygen & Hydrogen regeneration by electrolyzing water.
- Fuel Cell uses the Oxygen and Hydrogen to produce power and water under lunar night condition

Robotic Support System





- Robotic systems for supporting surface operations with surface transportation systems and intelligent robotic arms
- Various kind of tasks such as construction, drilling, and support works for astronauts will be possible by fully automated operation or teleoperation.

Backup

Government study group for Lunar Exploration

- Under the Minister of state for Space Policy in 2009.
- The study group for
  - Study of the lunar probe using robots, foreseeing human exploration afterward.
  - Completed the report for lunar exploration strategy in July, 2010.

<u>Rationales</u>
-Develop space technologies for Solar system exploration
-Promote Japan's top-level lunar science
-Establish Japan's presence in the international community for lunar exploration and utilization

<u>Near-term targets by 2020</u>
-Assemble a scientific exploration base by robots on the South Pole area in 2020
-Acquire continuous lunar interior data for more than 1 year
-Explore surrounding area for a few months by robotic mobile system
-Return lunar samples to the Earth that are totally new to humans
-Develop key technologies for space explorations and acquire key scientific data for the lunar origin and evolution

From the Report for Lunar Exploration Strategy

Japanese Rationales for Lunar Exploration

1. Develop space technologies for Solar system exploration

   - Stepwise approach: Moon is the nearest celestial body with partial gravity and so is the best target for technology development of, such as, landing and return.

2. Promote Japan's top-level lunar science

   - Based on excellent scientific results from SELENE, Japan's position in lunar science should be continuously promoted.

3. Establish Japan's presence in the international community for lunar exploration and utilization

   - Japan should lead the related international community to the Moon by its continuous lunar activities and leading to make collaborative international guidelines on lunar development & utilization.

From the Report for Lunar Exploration Strategy

Goals for Japan's Robotic Lunar Exploration

Goals by 2020:

- Establish scientific exploration base on Lunar South Pole area on 2020 by robotic construction for the first time in the world
- Acquire continuous lunar interior data for more than 1 year
- Explore surrounding area for a few months by robotic mobile system
- Return lunar samples to the Earth that are totally new to humans
- Develop key technologies for space explorations and acquire key scientific data for the lunar origin and evolution, eventually

Goals beyond 2020:

Based on the scientific and technical achievements, goals for more advanced robotic exploration and human exploration beyond 2020 will be considered.

Developed technologies will also be used for the future explorations of the Solar System.

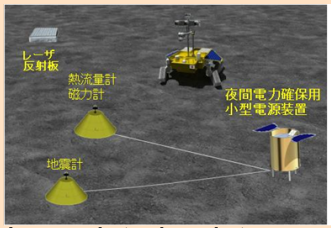
Concept for 2015 Robotic Lunar Exploration
- Lunar Near-side -

Technology development:
-Unmanned autonomous soft landing with approx. 100m accuracy
-Lunar night survival demonstration by using solar cell and Li-ion battery
-Robotic rover exploration on celestial body with gravity

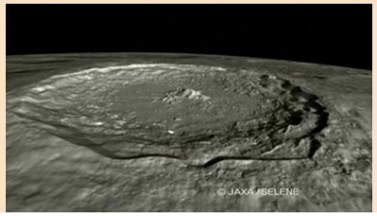
Science:
-Precise determination of lunar crust depth and lunar interior density, etc.

Others:
-HD video transmission from the lunar surface to the Earth

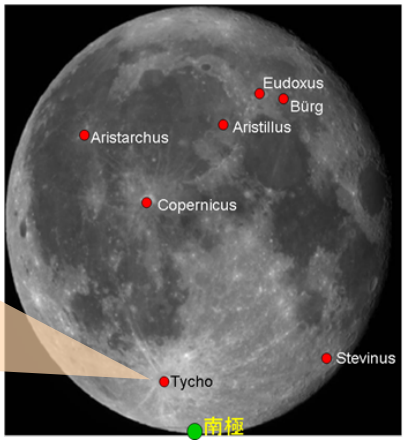
Autonomous soft landing



Lunar interior data acquisition by seismometer, etc.



Candidate landing site for 2015 (e.g. Tycho crater)



- Candidate landing sites for 2015 (large-scale craters)
- Candidate landing site for 2020 (Lunar South Pole)

Concept for 2020 Robotic Lunar Exploration
- Lunar South Pole Area -

Technology development:

-Robotic exploration base construction and explorations of surrounding area for a few months and with more than 100km traverse

-Long-duration (more than 1 year) power supply by using solar cell, Li-ion battery and reproductive fuel cell

-Sample return from a celestial body with gravity

Science:

-Precise determination of lunar interior density distribution and core size, and verification of the origin

-More accurate history of lunar evolution by in-situ analysis and sample return of various lunar rocks created different time and/or from lunar mantle

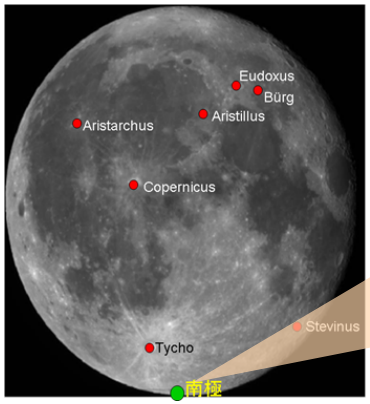
Utilization:

-Evaluation of lunar resource utilization by analyzing lunar rock composition, etc.

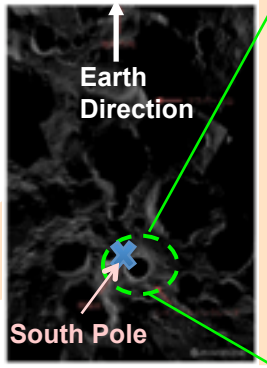
Others:

-Periodic HD video transmission from the lunar surface to the Earth

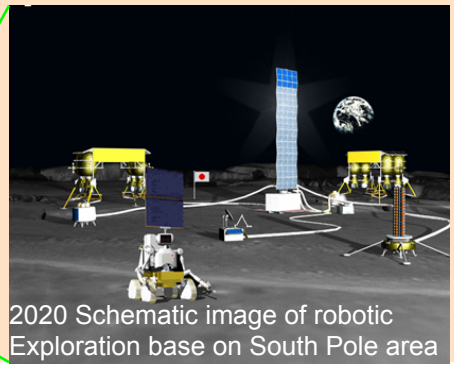
-Consideration of announcement of opportunity for lunar surface experiments by offering resources

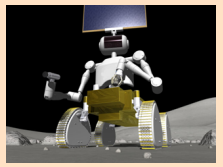


- Candidate landing site for 2020 (Lunar South Pole)

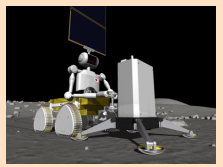


Candidate landing site for 2020 (Lunar South Pole area)





Sampling lunar rocks



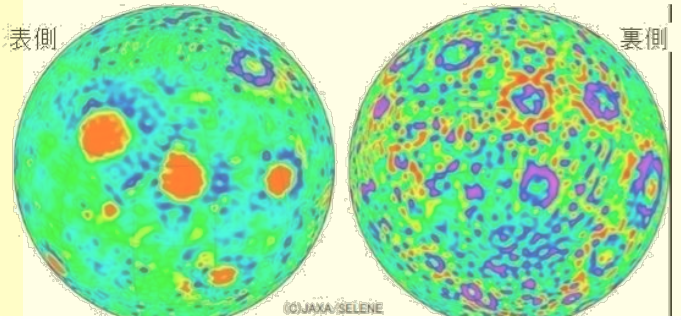
Mission equipment setting

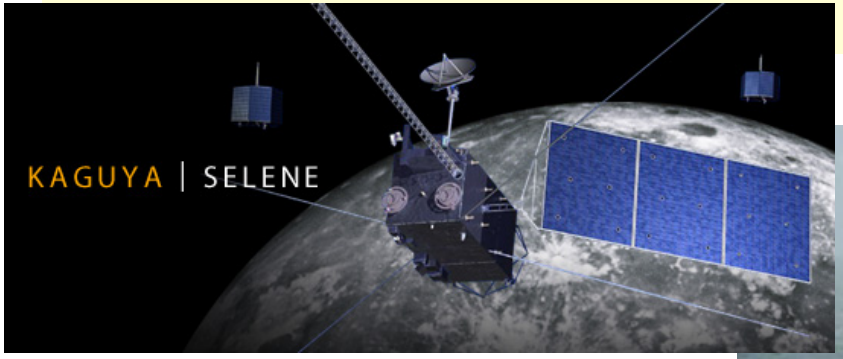
Lunar Orbiter KAGUYA（SELENE）

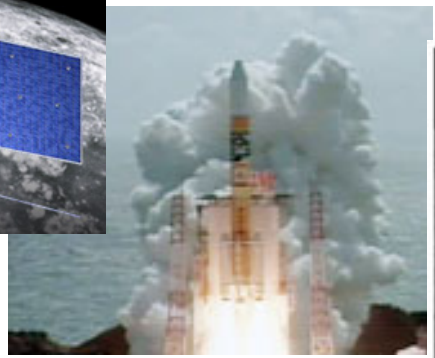
Kaguya (14th Sept., 2007 ---11th June, 2009)

- Largest Lunar Orbiter after Apollo
- Missions :
  - Origin & Evolution :
    - ✧ Global Map of Lunar topography, gravity, soil, material, magnetics, sub-surface structure
  - Lunar orbiter :
    - ✧ Guidance & navigation, thermal control, and so on
  - Data for future lunar lander

○Magnetic Anomaly in Near Side and Far Side







Launcher H-IIA 13

From the Report for Lunar Exploration Strategy

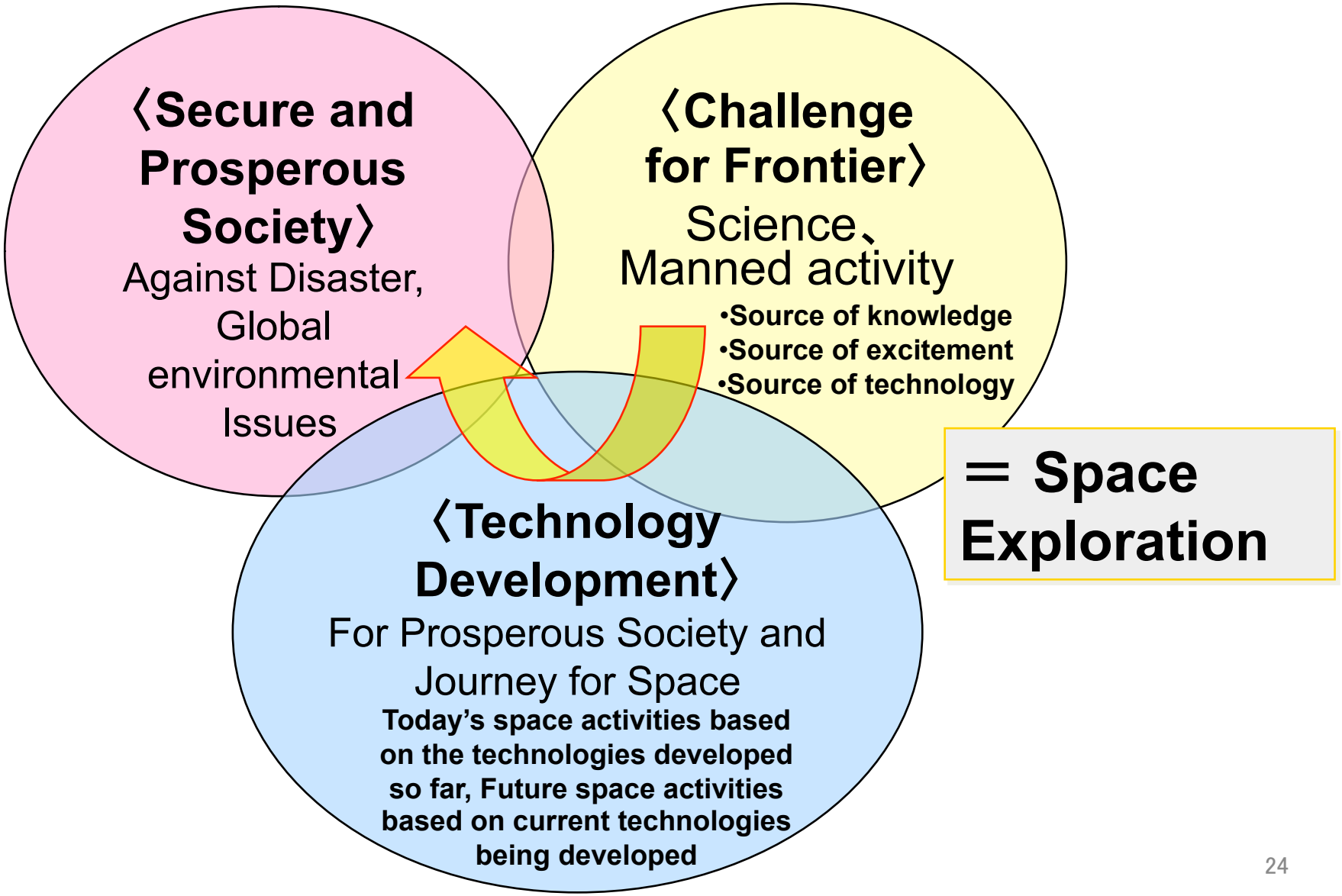
Lunar Exploration after 2020

- **Expansion of Lunar Exploration with**
  - Advanced robotic exploration
  - Human exploration

⇒ Technological base for various solar system exploration

- **Requirements for advanced robotic capability**
  - Adaptability and flexibility for various exploration tasks
  - Moving over the un-leveling natural ground
  - Self restoration without human assist
  - Intelligence for autonomous work planning

What is Space Exploration?



Principle & Objectives for Space Exploration JAXA thinks

Principle for Space Exploration

Achieve lofty themes such as expansion of human activities and contribute to evolution of civilization.

(1) Strategic & Political Objectives:

- To contribute and sustain to the nation's economy and industry growth to commensurate with its position in science & technology,
- To expand human activities as a stepping stone to Mars and beyond,
- To foster human resources of next generation for science and technologies in future.
- To contribute and formulate international collaboration and framework,

(2) Objectives from Technology and Innovation Point of View:

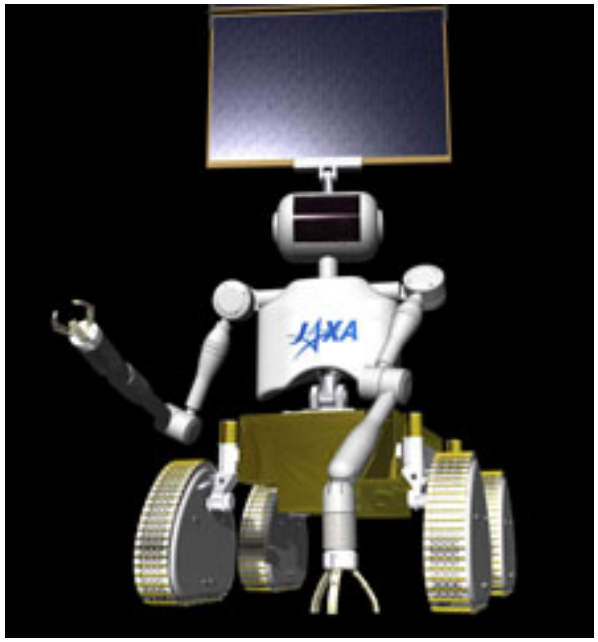
- To develop fundamental systems skills such as landing, return, mobility, etc enabling autonomous and perfectly controllable missions.
- Through the challenges, to induce technological innovation and to promote spin-offs so as to bring welfare and evolution to society.

(3) Objectives from Science and knowledge point of view:

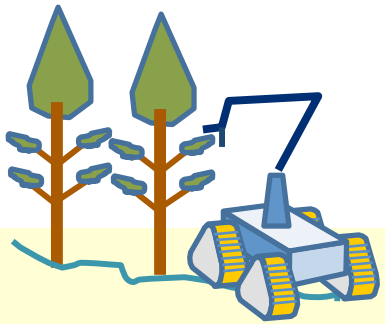
- To lead the top science, and to obtain new knowledge, and to contribute for the creation of new culture,
- To investigate the environment for full scale manned exploration to the moon and beyond.

Technological Innovation and Spin-offs in Future

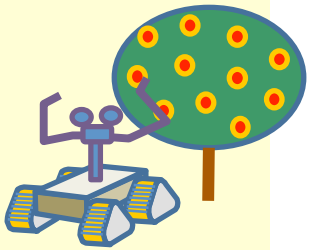
For Example



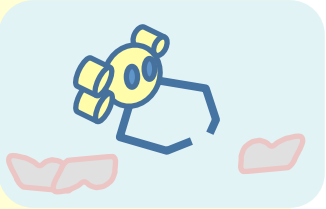
Advanced Lunar Robot



- Field Robot



- Agricultural robot
- Forestry robot



- Marine Robot
- Intelligent Transportation Systems