Preliminary Study on Transportation Concept for Future Lunar Exploration

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Abstract
This paper describes the launch architecture concept studied for near term and future lunar exploration programs both manned and unmanned, following the SELENE project. Near term launch architecture concept, which assumes to be applied to unmanned mission, such as lunar sample return, are based on H-IIA/H-IIB launchers. And for future missions, such as manned explorations, two types of launch architecture are studied in terms of magnitude of the total system architectures which impacts the development cost.

月探査に向けた輸送構想に関する初期検討

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摘要
月周回衛星 SELENE に続く月探査計画として，無人探査機による月面への着陸，月サンプルリターン，及び有人での月探査までを視野に入れたときの，輸送構想の初期検討結果について述べる。無人探査機については，近い将来の実現性を考慮して，H-IIA，H-IIB ファミリーによる月探査機の打上能力について示す。また，有人での月探査については，その全体規模，モジュール構成案と 2 種の打ち上げ方式の得失について示す。

Abbreviations

CM: Command Module
EDS: Earth Departure Stage
ESAS: Exploration Systems Architecture Study
LEO: Low Earth Orbit
LLO: Low Lunar Orbit
LM: Lunar Module
LMa: Lunar Module -Ascent Stage
LMd: Lunar Module -Descent Stage
LOI: Lunar-Orbit Insertion
SM: Service Module
TEI: Trans-Earth Injection
TEO: Trans-Earth Orbit
TLI: Trans-Lunar Injection
TLO: Trans-Lunar Orbit

1. Introduction

In January 2004, George W Bush, the president of the United States, disclosed a new space exploration plan called “Bush vision”, which includes “return to the moon” policy. Following the Bush vision, a lot of countries such as China, India and Russia brought out their lunar exploration plan. In Japan, JAXA also made its vision, which aims to send Japanese astronauts to the moon. As the first step, the lunar orbiting explorer “Kaguya ” was sent to the lunar orbit in autumn, 2007.

MHI has been studying transportation architecture for future lunar exploration in order to clarify its goal and roadmap, which will stimulate discussion about the exploration and promote launching program following Kaguya. This paper states (1) transportation architecture to send astronauts to the moon in the early phase, and (2) transportation options for unmanned lunar exploration, as a precursor of manned lunar exploration.

2. Manned Lunar Transportation

2.1 Mission Model

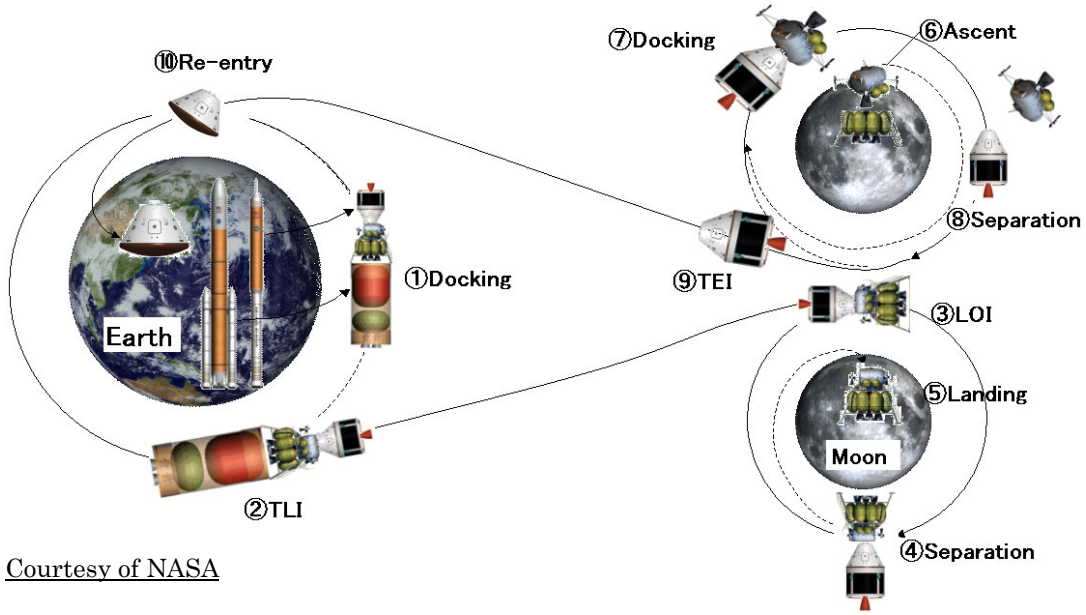
The following mission model, for our study, is set by reference to the NASA ESAS report [1], RSC Energia’s lunar transportation concept [2] and Apollo.

-Number of crew: 3 (2 for lunar surface)
-Mission time: 21days,
  -7days: at LEO for Rendezvous and docking (considering 6-launch scheme, see Figure 2)
  -7days: at lunar surface
  -7days: at Earth-Lunar transfer orbit, go and back total
-Cargo mass: 1000kg

2.2 Transportation Options for Tradeoff

Two options are selected. One is "2-launch scheme" which is as almost same as ESAS. The other is "6-launch scheme" which is modified the RSC Energia's concept.

The 2-launch scheme uses one huge unmanned cargo launcher and one relatively small manned launcher. Figure 1 depicts the mission profile of the 2-launch scheme. In this scheme, a manned module and a cargo module rendezvous at LEO, and an Earth Departure Stage (EDS) performs TLI burn. When it arrives at the moon, a Lunar Module (LM) performs LOI burn. Astronauts transfer from a Command Module (CM) to the LM, and then the LM undocked and performs a descent to the lunar surface. After 7 days on the lunar surface, a Lunar Module Ascent Stage (LMa) lifts off from lunar surface, and the LMa and the CM combined with a Service Module (SM) rendezvous and dock at LLO. Astronauts transfer to CM, and SM performs TEI burn. The only CM comes back to the Earth while SM is disposed just before reentry.



Courtesy of NASA

Figure 1　mission profile — 2-launch scheme

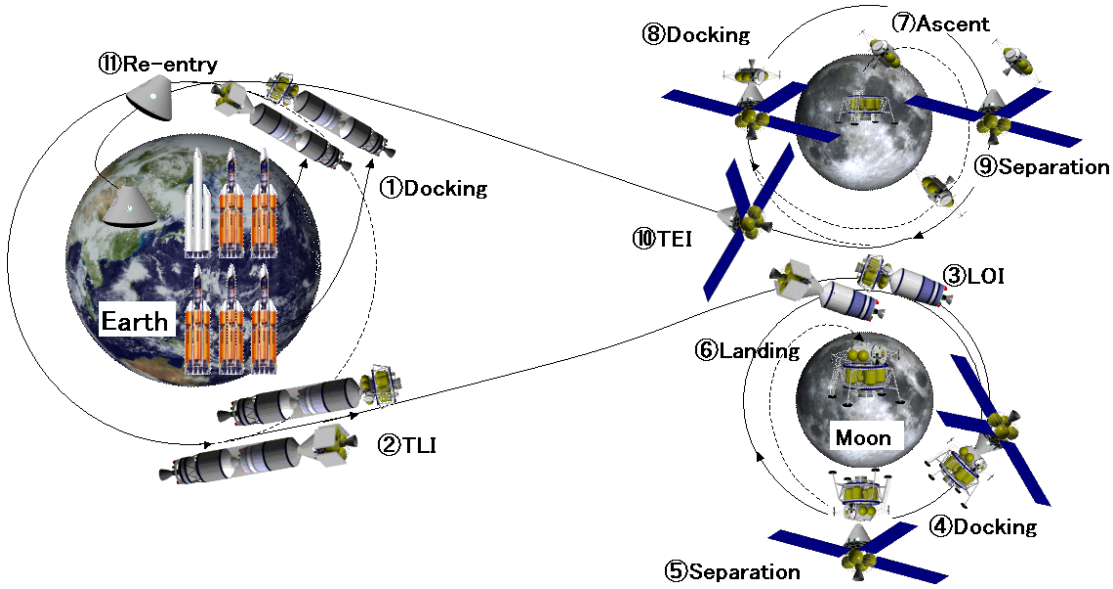


Figure 2　mission profile — 6-launch scheme

On the other hand, the 6-launch scheme uses some medium launchers compared to the huge launcher required for the 2-launch scheme. Figure 2 shows the mission profile of the 6-launch scheme. In this scheme, 1 manned module and 5 unmanned modules rendezvous and dock at LEO, and 2 transportation complexes are assembled as shown in Figure 3. These complexes depart to the moon

separately and then rendezvous at LLO.

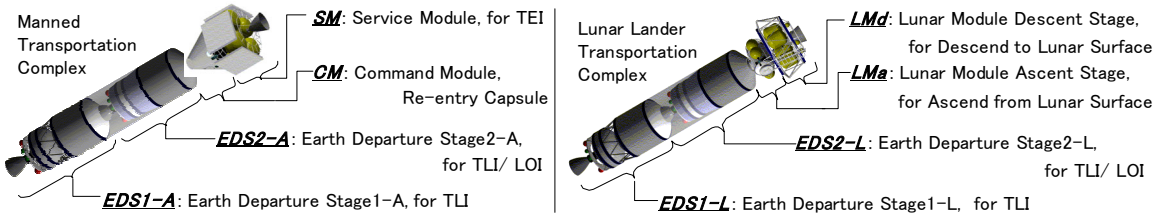


Figure 3　module description for 6-launch scheme

2.3 Comparison

In order to compare two schemes, we estimate masses of each modules and required rocket launch capability of each launch scheme considering the mission model and required delta-V. The result is shown in Figure 4. The 2-launch scheme needs only 2 rendezvous-dockings, but requires huge launcher of about 200 tons launch capability for LEO. So the 2-launch scheme fits for one country that has technologies and budget to construct and operate such a huge launcher. On the other hand, the 6-launch scheme needs 6 rendezvous docking, but required launch capability is about 25 tons for LEO.

For Japan, though it's difficult to develop a new huge launcher with 200 tons launch capability considering our budget size, we could develop a launcher with about 25 tons launch capability with heritage of H-IIA/B launch vehicle family. In addition, considering international cooperation approach, the 6-launch scheme is preferable. For example, cooperative countries of the international cooperation for lunar exploration could share crews, development and launch of the necessary modules, depending on their technologies and strategies.

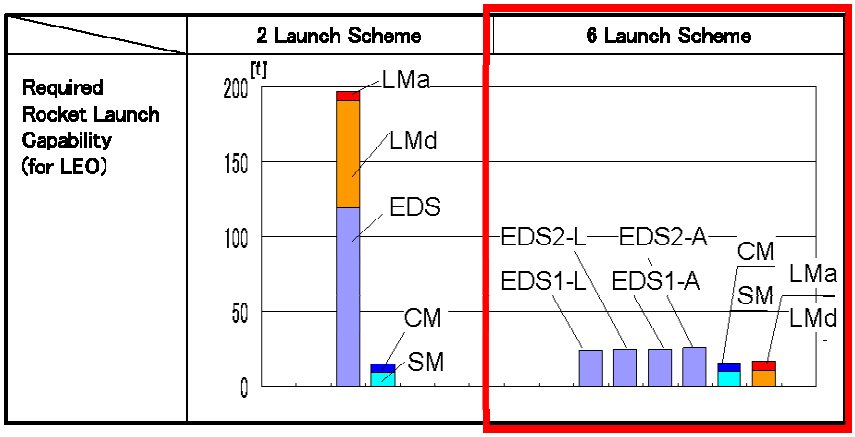


Figure 4　Comparison of 2-launch scheme and 6-launch scheme

3. Unmanned Lunar Transportation

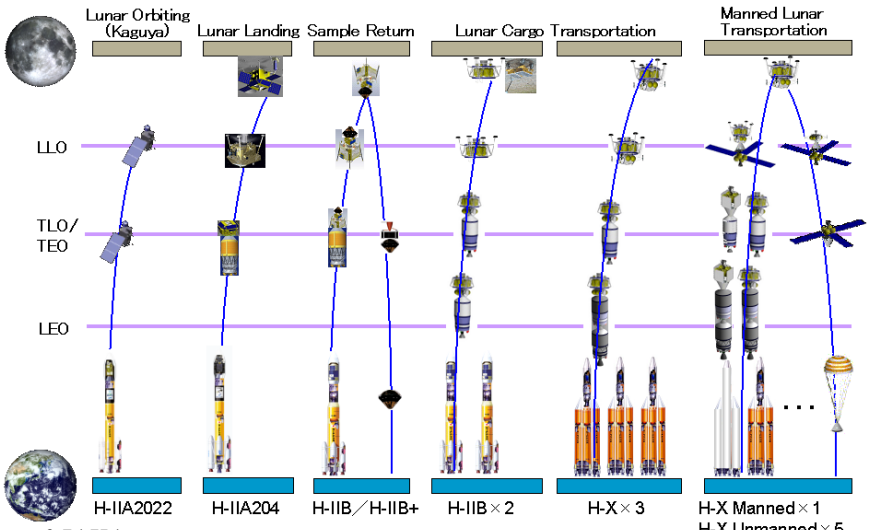
3.1 Mission Candidates

Candidates of unmanned mission before manned mission is as follows.

-Lunar orbiting exploration (such as Kaguya)
-Lunar surface exploration
-Lunar sample return
-Lunar cargo transportation

3.2 Transportation Scheme and Transport Capability

We studied transportation plan and transportation capability for each mission. In this study, we selected candidate launchers from current H-IIA/B family and future H-IIB+ or H-X launcher that has 25ton launch capability, required for manned lunar mission (see Figure 4). Figure 5 shows the launcher plan and Figure 6 shows each transportation capabilities. As shown in these figures, we can chose wide variety of launcher and fleet corresponding to mission requirements.



Courtesy of JAXA

Figure 5　Launcher and fleet plan for unmanned lunar exploration

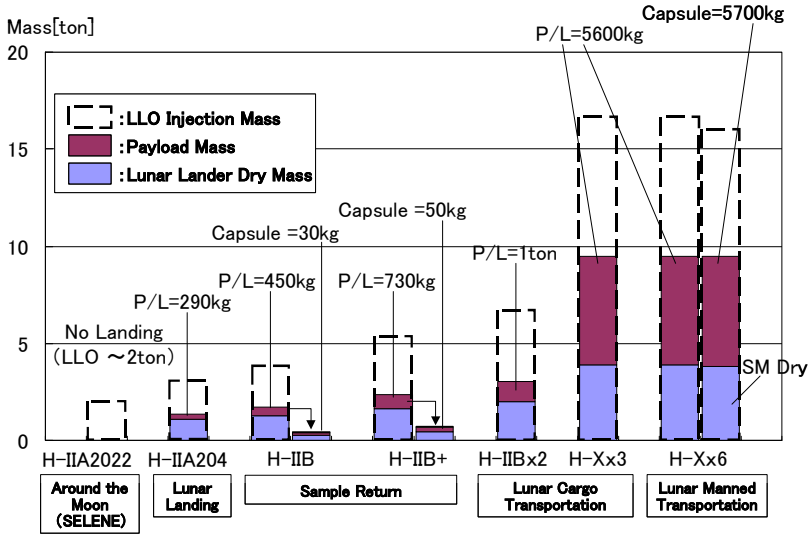


Figure 6　variety of launch capability

4. Conclusion

For manned lunar exploration, we studied two types of launch scheme. The 6-launch scheme is preferable for Japan, considering launcher size and international cooperation approach. The 6-launch scheme requires a new heavy launcher carrying 25 tons class payload into LEO which launcher can be developed with heritage of H-IIA/B family. Major issues for our further study are 6-launch timing and LEO rendezvous (including backup planning), propellant management for long coast, emergency escape and abort scenario.

For unmanned lunar exploration, we showed variety of launch capability of H-IIA/B family, future H-IIB+ (20 tons class), H-X (25 tons class), and combination of them corresponding to unmanned lunar exploration candidates. We will study and brush up our concept for manned and unmanned missions in order to make future lunar explorations a reality.

Reference

[1] "NASA's Exploration Systems Architecture Study: Final Report", NASA-TM-2005-214062, November 2005

[2] "Concept of Russian Manned Space Navigation Development", http://www.energia.ru/eng/news/news-2006/public_07-01.html, RSC ENERGIA Web Site