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Manned Lunar Launching Mode and the Requirement for Heavy Launch Vehicle

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Some manned lunar missions and the launching mode are introduced, the feature of manned lunar launching mode is summarized. Several flight modes are presented, including Earth Orbit Rendezvous and Lunar Orbit Rendezvous and so on. Based on this, the requirements of launch vehicle system are analyzed. In the end, a proposal is given, which is for manned lunar launching mode's choice and accelerating the development of the heavy launch vehicle.

I. INTRODUCTION

The moon is the nearest and only natural satellite of the earth, where is rich in natural resources, and the human outpost of exploring the mysteries of the universe, the optimal station of transferring and expanding the living space into deep space. Meanwhile it has great value in economic, technology and military. With the development of space technology, human footstep for exploring and landing on the moon has never stopped, which tide has appeared twice in lunar exploration and manned lunar. Along with developing of human space activities, the exploration aim is becoming further and further, but the moon always is the first aim. Research and analyse manned lunar flight mode, put forward requirement for the launch vehicle system, has an important promotable effect and practical significance for manned lunar mission.

II. MANNED LUNAR LANDING MISSION AND FLIGHT MODE FEATURE

II.1 The Manned Lunar Missions in the Past

So far, there are three manned lunar landing projects have been implemented. They are the Apollo Project, American Constellation Program, and former USSR N1/L3 Project.

II.1.1 The Apollo Program

Apollo program was approved in May 1961, and ended in December 1972, conducted a total of seven times manned lunar landing flight. In addition to the Apollo13, the remaining six flights are successful. Apollo program use the Lunar Orbit Rendezvous (LOR) mode, that is directly transport the mooncraft to the earth-moon transfer orbit (LTO) by rocket firstly, then, carry out a rendezvous and docking in lunar orbit (LLO). The total weight of the spacecraft is about 50t.

The main process is as follows:

I) The rocket put the mooncraft into lunar trajectories. II) Spacecraft decelerate into the LLO spacecraft. III) The lunar module transport astronauts to landed on the lunar surface, and spacecraft body waiting in LLO at the same time. IV) Astronauts completed lunar missions are took back to LLO where the spacecraft is waiting by the lunar module, return to the spacecraft. V) The spacecraft returned to earth after abandoned the lunar module. VI) After entering in low earth orbit (LEO), the command module carrying astronauts separate from service module, reentering, falling on the sea.

For the implementation of Apollo program, NASA developed a three stages liquid rocket — Saturn 5 heavy launch vehicle, whose LTO capacity is about 50t, and LEO capacity is about 120t.

II.1.2 The N1-L3 Program

In the United States began implementing the Apollo moon landing project, the Soviet Union began a program of manned lunar landing demonstration, and put forward its own manned lunar landing program, N1-L3 program.

N1-L3 program also uses LOR mode, by launching a N-1 rocket and Lunar orbit docking once. The rocket launches spacecraft and L3 combination into LLO. Firstly, the rocket carries the L3 combination spacecraft to the Low Lunar Orbit (LLO). Secondly, the moon-landing vehicle which is one part of the combination leaves and land on the lunar surface. Thirdly, the moon-landing vehicle returns and dock with the lunar vehicle which is another part of the combination. Finally, the reentry capsule carries astronauts back to earth.

This program use N-1 heavy launch vehicle. The N-1 is a five stages liquid rocket, LEO capacity is about 100t. Since N-1 rocket launched failure several times, N1-L3 program did not succeed, canceled in February 1976.

II.I.III The Constellation Plan

NASA started Constellation Plan in 2005, and intended to launch astronauts separated from cargo with twice docking at LEO and LLO. However, it was finally canceled owing to the shortage of funds and delay of schedule.

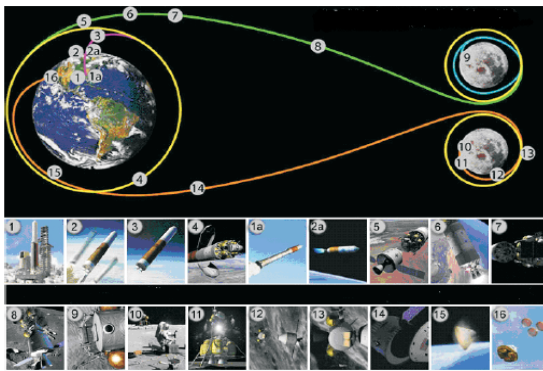


Fig. 1: Constellation moon mission process

According to the plan of Constellation Plan, the Ares I rocket was designed to launch the Orion spacecraft, whose LEO capacity is 25.4t; Ares V rocket, bundled with huge boosters, was used to launch the combination of the lunar Lander and EDS into Earth-Moon transfer orbit.

II.I.IV The SLS Lunar Exploration

Along with Constellation Plan being cancelled and rockets of Mars Series terminated, The USA proposed the plan of Space Launch System(SLS) for future, and lunar exploration is one of its main objectives.

Earth-Moon Platform (EMLP) was used as route-point, space transfer level and astronauts station in the lunar exploration. Lunar landing aircraft could complete flight

mission repeatedly between moon and lagrange-point after it fueling on the EMLP. Varies launch mission including multipurpose manned spacecraft, orbital transfer stages, supplements and propellant with LEO capacity at 130t.

II.II The Feature of Manned Lunar Launching Mode

(I) Combined transport of people and goods, directly flying to the moon is the simplest model of manned lunar mission

Early manned lunar landing program most took the method of cargo and passenger mixed transporting, directly flying to the moon or rendezvous and docking as few times as possible. This is the concise manner for manned lunar landing, but with the highest demands of rocket capacity. It is also the most time-saving way in the context of the United States and the Soviet Union carrying out competition in landing on the moon.

(II) Passenger and cargo separated transit, rendezvous and docking represent the future trend of manned lunar landing

Different from early manned lunar program, most recent programs use passenger and cargo separated transit, launch independently and docking. This is determined by the different periods of political demand and technology base. This kind of mode can reduce the heavy launch vehicle design difficulty because of the high reliability requirements of manned, and improve the manned security and implementation flexibility. On the other hand, separating passenger and cargo transit make the rocket development can use as reference mature technologies and products, thereby improving engineering reliability and reducing the risk of task. It is an important development direction of manned lunar in the future.

(III) Heavy launch vehicle is an inevitable choice for the development of manned lunar mission

The mode transport people and goods together and flying to moon directly needs the rocket have 50t capability for LTO at least. The method separate transport and docking requires the LEO capabilities 100t at least, and needs the launch vehicles carry the combination into LTO. With the deepening of space exploration, and the growing demand for payload weight, heavy or super heavy capacity of launch vehicle is particularly necessary.

III. SEVERAL LAUNCHING MODE OF THE MANNED LUNAR MISSION

III.I Lunar Mission Mode Based on Earth-Moon Lagrange-point

The components to build the Earth-Moon Lagrange point platform, as a transfer-stage and base station astronauts, is launched by heavy launch vehicle. When the platform is built, manned spacecraft, lunar lander, supplies, and propellant etc. are transported, assembled

and supplied in orbit, transferred into the lunar orbit transfer orbit. The lunar lander is re-fueled/refilled the fuel in the Earth-Moon Lagrange Point Platform, execute missions between the platform and the moon surface repeatedly.

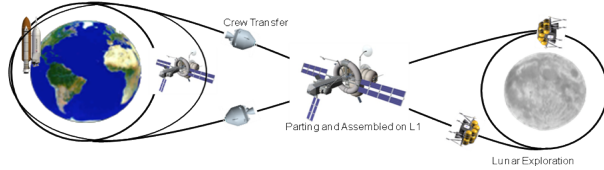


Fig. II: The mode based on Earth-Moon Lagrange-point

III.II 1-launch Lunar Orbit Rendezvous Lunar Mission Mode

A manned heavy launch vehicle transport lunar lander and manned spacecraft assembly into the LTO, lunar lander completes earth-moon transfer midway corrections and brakes in recent months.

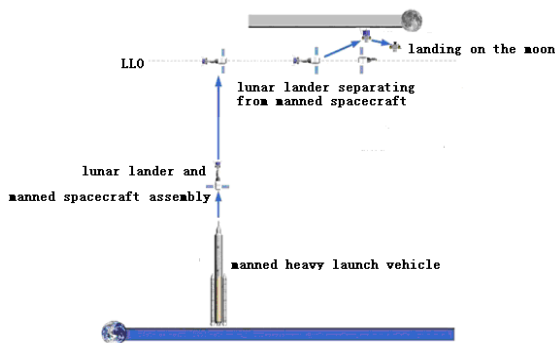


Fig. III: 1-launch LOR lunar mission mode

III.III 2-launch Earth Orbit Rendezvous Lunar Mission Mode

The lunar lander transported by a heavy launch vehicle rendezvous with the manned spacecraft transported by a manned launch vehicle at LEO and assembles. The upper stage of the vehicle transport lunar lander into the LTO, lunar lander completes earth-moon transfer midway corrections and brakes in recent months.

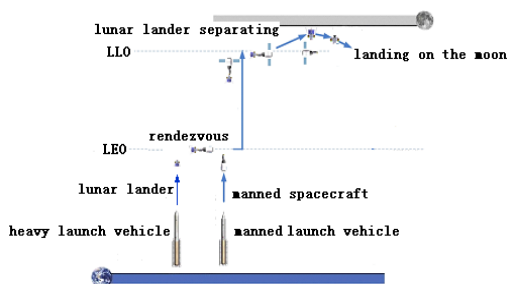


Fig. IV: 2-launch EOR lunar mission mode

III.IV 3-launch Earth Orbit Rendezvous Lunar Mission Mode

A heavy launch vehicle lunar lander and propulsion vehicle assembly into LEO, rendezvous with another propulsion vehicle transported by another heavy launch vehicle, and then rendezvous with the manned spacecraft carried by manned launch vehicle. Propulsion vehicles speed up and drive the combination into LTO, lunar lander completes earth-moon transfer midway corrections and brakes in recent months.

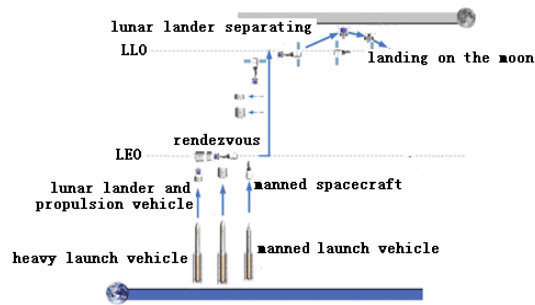


Fig. V: 3-launch EOR lunar mission mode

III.V 4-launch Earth Orbit Rendezvous Lunar Mission Mode

Three heavy launch vehicles launch lunar lander and propulsion vehicle assembly and other two propulsion vehicles into LEO respectively, rendezvous twice, and then rendezvous with the manned spacecraft carried by manned launch vehicle to form the lunar aircraft combination. Propulsion vehicles speed up and transport the combination into LTO, lunar lander completes earth-moon transfer midway corrections and brakes in recent months.

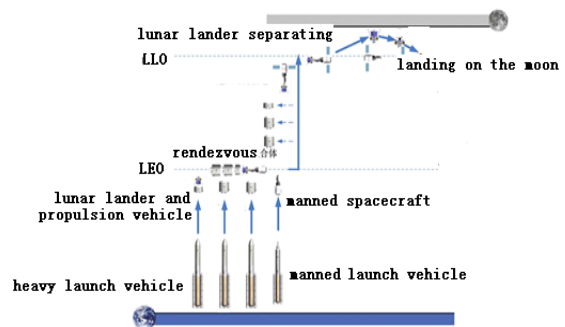


Fig. VI: 4-launch EOR lunar mission mode

III.VI 2-launch Low Lunar Orbit Rendezvous Lunar Mission Mode

A heavy launch vehicle transport lunar lander into LTO while a manned launch vehicle transport manned spacecraft into LTO, lunar lander and manned spacecraft complete earth-moon transfer midway corrections and brake in recent months respectively, and then they rendezvous at LLO form to a lunar aircraft.

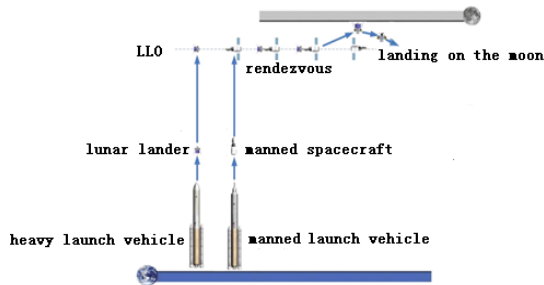


Fig. VII: 2-launch LOR lunar mission mode

III.VII 3-launch Earth Orbit Rendezvous + Low Lunar Orbit Rendezvous Mode

A heavy launch vehicle transport lunar lander into LTO, and the lunar lander completes earth-moon transfer midway corrections and brake in recent months. Then, a heavy launch vehicle and a manned launch vehicle transport a propulsion vehicle and manned spacecraft into LEO respectively and rendezvous, the upper stage of the vehicle completes earth-moon transfer, the propulsion vehicle brake in recent months. And then they rendezvous at LLO form to a lunar aircraft.

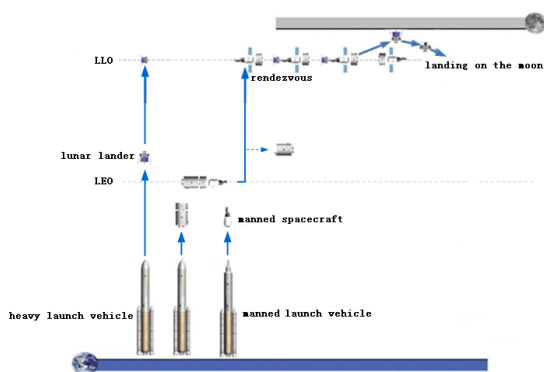


Fig. VIII: 3-launch EOR+LOR lunar mission mode

IV. THE REQUIREMENT FOR LAUNCH VEHICLE SYSTEM

Based on abundant investigation and research, suppose manned spacecraft 20t initially. In this case, the several lunar flight patterns were analyzed and the initially the demand on the transport system is proposed.

Launching Mode	Requirement for Launch
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	Vehicle Capability (amount)
Bases on Earth-Moon	~40t to Earth-Moon
Lagrange-point	Lagrange-point(4)
1-launch LOR	~ LTO 60t (1)
2-launch EOR	~ LTO 50t (1) ~ LEO 20t (1)
3-launch EOR	~ LEO 80t (2) ~ LEO 20t (1)
4-launch EOR	~ LEO 50t (3) ~ LEO 20t (1)
2-launch LOR	~ LTO 40t (1) ~ LTO 30t (1)
3-launch EOR+LOR	~ LTO 40t (2) ~ LEO 20t (1)

Table I: The requirement for launch vehicle system

(I) In these modes, the direct flight mode is combined transport of persons and goods, others are passenger and cargo separated transit.

(II) The direct flight mode is simple, could avoid the risk of multiple rendezvous and docking and has higher reliability. But the persons and goods result are combined transported in this mode, the security of the astronauts is relatively low, and requires manned heavy launch vehicle. The vehicle will cause technical difficulty and high-risk for development and manufacturing, meanwhile it need the high thrust engines that require high reliability and long development cycle.

(III) If apply passenger and cargo separated transit mode, the security of the astronauts is relatively high and the requirement for the vehicle's development and manufacturing will be reduced. But multiple docking also brings lower reliability.

(IV) If does not set constraints on the economic and schedule, the the heavy launch vehicle can be developed and manufactured according to reliability standard of manned rocket. Then the combined transport mode has advantage compared with the separated transport because of higher security standards.

(V) From the economic perspective, if need to repeatedly perform a manned lunar landing mission, to carry out the construction of a lunar base and so on, it is suitable to use the flight mode base on EMLP, while for a once-mission, the other modes are more economical.

V. CONCLUSION

This article describes the past manned lunar landing mission, the main program and the corresponding flight mode, summed up the flight mode feature of the manned lunar missions. Proposed several manned lunar landing flight mode, analyzes the various mode's requirements on the launch vehicle system. Obtain the following conclusions.

(I) If does not set constraints on the economic and schedule, the direct flight mode is the best choice, and

corresponding it need to develop manned heavy launch vehicle with high reliability.

(II) If considering the economy factors and the time limit, the passenger and cargo separated transport mode with rendezvous and docking is appropriate, and it need to develop heavy launch vehicle for cargo.

(III) It is suitable to use the flight mode base on EMLP when a repeatedly perform a manned lunar landing mission is needed.

(IV) In practice, the selection of manned lunar flight mode need to integrated all aspects of constraints and weighed via further analysis and appraisal, and then determined.