HUMAN AND ROBOTIC MISSIONS COMBINATION IN THE CONCEPT OF RUSSIAN LUNAR EXPLORATION PROGRAM. M. I. Danilova[1] and Dr. Eng. Sc. G. F. Karabadzhak[2], TSNIImash, Pionerskaya St. 4, Korolev, Moscow region, 141070, Russia ([1]danilovami@tsniimash.ru, [2] gfk@tsniimash.ru).

Introduction: According to the strategic documents for space activities of Russian Federation, the main direction of human space missions after 2025 is the Moon. Some elements of Russian lunar program are planned in the actual space program for 2016-2025, for instance robotic spacecraft, crew and launch vehicles. Other elements are currently being in their initial stages of development. Robotic spacecraft is an essential part of the lunar program. It enables lunar exploration and prepare us for human missions through key technologies testing. On the other hand, development of a full-scale lunar base will be impossible with only either robotic spacecraft, or human missions spacecraft.

The Roadmap of Lunar Exploration: The concept of Russian lunar exploration program includes four major phases [1], that are based on the balance between human and robotic missions.

The first phase is preparative and is based mainly on the first robotic spacecrafts, that will investigate the most promising lunar landing sites and test a number of technolohies. During this phase development of Russian space transportation system for human and cargo delivery will be developed and critical technologies will be tested.

In the second phase the initial lunar communication and navigation systems will be deployed. The first manned lunar flybyhuman circumlunar mission will be launched. The technology of automatic lunar regolith return to Earth will be tested.

The third phase is a human lunar base development in its minimal configuration and infrastructure development for resources manufacturing, scientific and experimental complexes development, development of basic conditions for the purposes of manned lunar base.

The fourth phase is a lunar base enlargement and closed-loop life-support system enhancement, that will function with the use of lunar resources; propellant components production and its usage in Russian space transportation system; oxygen, water, metals, constructional materials recovery from lunar resources.

This roadmap is presenting a wide range of opportunities for moon exploration by virtue of robotic and human spacecraft combination.

Planned Robotic Missions: Nowdays a number of lunar robotic missions are preparing for the first and second phases of the Moon exploration [2].

Luna-25. It is a robotic spacecraft for a complex research in the circumpolar lunar region. The soft-landing technology is expected to be tested.

Luna-26. This orbiter is supposed for remote exploration of lunar surface, for support of communication with Luna 25 and Luna 27 landers, and for support of communication in between Earth and future lunar base.

Luna-27. The projectIt provides testing of technology of highly-precise and safe landing in difficult lunar geological conditions of circumpolar region. It provides a scientific hardware complex, including lunar manipulating complex for soil sampling and investigation.

Luna-28. The main project goal is to deliver lunar soil sample with undisturbed structure on Earth for further investigation in ground research centers. Also there is an option to dock its take-off stage to the Gateway platform for on-station samples research.

The possibilities of carrying out the following missions of delivering a heavy lunar rover to the lunar surface and construction of a radio telescope on the Moon are also being considered.

Planned Human Missions: The second phase of the lunar program, which is preparatory to the crew landing, includes manned flights to cis-lunar space. This mission will be possible upon the readiness of a transport system consisting of a manned transport ship and a super-heavy class launcher.

The third phase of the lunar program enables human missions to the lunar surface. During these first short-term missions crews will conduct research on the most interesting lunar landing sites, and a program of scientific experiments will be established. Using the possibilities of special robotic means crews will remotely prepare lunar infrastructure for long-term missions. Equipment installation and switching-on operations that cannot be performed in automatic mode will be scheduled in manned mission programs.

A visit to the lunar base by the crew can be quite rare - to perform the most responsible operations with complex equipment and to conduct a program of full-scale scientific program on the Moon.

Key Technologies Development: The roadmap of lunar exploration involves the key technologies development. The task of key technology areas specification now is being solved by the International Space Exploration Coordination Group (ISECG), in which Russia also participates. The status of this work is documented in ISECG's Global Exploration Roadmap (GER) [3]. According to this investigation we can place emphasis on the next key technology areas and its subareas that are critical for the Moon exploration: propulsion systems, space power generation and storage, robotics,

communications and navigation, landing systems, life and health support systems, in-situ resources utilization.

The Possibilities of International Partnerships: The many years of human and robotic space exploration show that the most sustainable and cost effective way to explore space is to establish partnerships. Based on ISS experience, the future Lunar Orbital Platform, Gateway, is now under discussion. As per Russian lunar exploration strategy the lunar orbital platform is not the core element but it enables the opportunity to expand the program of scientific experiments, exchange technologies and reduce risks by making systems redundant.

Collaborative design of payload for lunar robotic spacecraft also brings powerful capabilities for international partnership. HERACLES mission, which goals are very similar to russian "Luna" robotic missions, is an example for such a collaboration.

References:

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