
Orbital transportation system featuring a Lunar Expeditionary Complex to be assembled in low Earth orbit by using heavy-lift launch vehicles

© A.D. Bychkov^{1,2}, V.M. Filin¹

¹ S.P. Korolev Rocket and Space Public Corporation Energia,
Korolyov, Moscow Region, 141070, Russia

² Bauman Moscow State Technical University, Moscow, 105005, Russia

The article presents a design-stage ballistics analysis of an orbital transportation system featuring a Lunar Expeditionary Complex to be assembled in low Earth orbit. The Lunar Expeditionary Complex includes a manned transportation vehicle, a reusable lunar lander, a space tug running on oxygen and kerosene, and an integrated upper stage booster system using oxygen and hydrogen, equipped with extra oxygen tanks. We consider a method of long-term liquid oxygen storage making use of a cryogenic gas liquefier. Since there is no need to store liquid hydrogen for a prolonged period of time, a passive liquid hydrogen storage system may be set up. The mission profile should require five unmanned launches of the Angara A5V vehicle and one manned launch of either Angara A5P or Soyuz 5 systems. The interval between launches would be approximately a month. There is no loss of previously launched elements even in the case of a postponed launch or if losing any other element of the Expeditionary Complex. It is possible to gradually transition to employing super heavy-lift launch vehicles.

Keywords: the Moon, manned lunar program, Lunar Expeditionary Complex, manned transportation vehicle, promising manned transportation system, Angara launch system, Soyuz 5 launch system

REFERENCES

- [1] Legostaev V.P., Lopota V.A., ed. *Luna — shag k tekhnologiyam osvoeniya Solnechnoy sistemy* [The Moon as a step towards exploring the Solar System]. Korolyov, S.P. Korolev Rocket and Space Public Corporation Energia Publ., 2011, 584 p.
- [2] Bychkov A.D., Ivashkin V.V. *Kosmonavtika i raketostroenie — Cosmonautics and Rocket Engineering*, 2014, no. 1, pp. 68–76.
- [3] Lupyak D.S., Radugin I.S. *Izvestiya RAN. Ser. Energetika — Proceedings of the Russian Academy of Sciences. Power Engineering Journal*, 2017, no. 4, pp. 116–128.
- [4] Koptev Yu.N., Kuznetsov Yu.V. *Voenno-promyshlenny kurer — Military Industrial Courier*, 2015, no. 32 (598), pp. 8–9.
- [5] Medvedev A.A. *Izvestiya*, 2016, no. 167 (29659), September 9, pp. 1–2.
- [6] Smolentsev A.A., Sokolov B.A., Tumanin E.N. *Kosmicheskaya tekhnika i tekhnologii — Space Engineering and Technology*, 2013, no. 3, pp. 46–56.
- [7] Tumanin E.N. *Dlitelnoe khranenie zhidkikh kriogennykh komponentov topliva v kosmicheskikh usloviyah* [Long-term liquid cryogenic fuel component storage in the conditions of space]. *Raketno-kosmicheskaya tekhnika. Trudy. Seriya XII* [Aerospace technology. Proc. Series 12]. Korolev, PAO RSC Energia Publ., 2000, no. 1–2, pp. 63–76.
- [8] Lipin M.V., Gromov A.V. *Sovremennoe sostoyanie razrabotki i perspektivy razvitiya MKS Split Stirling dlya okhlazhdemykh FPU* [State-of-the-art developments and prospects of split-pair Stirling microcryogenic systems for

cooled photodetectors]. *Doklad na XXI Mezhdunarodnoy nauchno-tehnicheskoy konferentsii po fotoelektronike i priboram nochnogo videniya*, 25–28 maya 2010 g., Moskva [Proc. of the 21st International scientific and engineering conference on photoelectronics and night vision devices, May 25–28, 2010, Moscow]. Available at: http://www.cryontk.ru/media/files/doklad_orion_2010.pdf (accessed May 26, 2017).

- [9] Lipin M.V., Gromov A.V. Rezul'taty razrabotki miniatyurnykh mikrokriogenykh sistem dlya okhlazhdaemykh FPU [Results of developing miniature microcryogenic systems for cooled photodetectors]. *Doklad na XXIV Mezhdunarodnoy nauchno-tehnicheskoy konferentsii po fotoelektronike i priboram nochnogo videniya*, 24–27 maya 2016 g., Moskva, AO NPO Orion [Proc. of the 24th International scientific and engineering conference on photoelectronics and night vision devices, May 24–27, 2016, Moscow, Orion Research and Production Association JSC]. Available at: http://www.cryontk.ru/media/files/2016_orion.pdf (accessed May 26, 2017).
- [10] Zagarola M.V., McCormick J.A. *Cryogenics*, 2006, vol. 46, Feb–Mar, pp. 169–175.

Bychkov A.D., post-graduate student, Department of Dynamics and Flight Control of Rockets and Spacecraft, Bauman Moscow State Technical University. Engineer, S.P. Korolev Rocket and Space Public Corporation Energia. Author of 4 scientific publications and 9 conference reports in the field of spacecraft motion ballistics and dynamics simulation, space tug and transportation system design, transformable orbital space station module design. e-mail: abychkov@ro.ru

Filin V.M., Dr. Sc. (Eng.), Professor, Leading Research Scientist, S.P. Korolev Rocket and Space Public Corporation Energia. Full member of the Russian Academy of Cosmonautics and International Informatisation Academy, Honoured Designer of the Russian Federation. Author of 12 printed works, over 120 scientific and technological publications in journals, digests, conference proceedings, and a large number of popular science publications dealing with matters of rocket science and design of large aerospace complexes. e-mail: vyacheslav.filin@rsce.ru