Report of Long-stay Researcher (Form 2)

(Formulated in September 2008)

NAOJ's long-stay researchers must submit a report on the results achieved during the research period. Fill in this form, and submit it to NAOJ Research Support Section within two weeks after the end of the research period. This report will be published on the website of the research exchange committee even before the articles on the research results are published. Therefore, it is not necessary to describe the details of the research contents. When publishing the research results in academic journals, etc., mention that effect in the acknowledgement.

Institution Moscow Aviation Institute

Name Mikhail Barkin

Acceptance Name: Hideo Hanada

Period of stay From 10-17-2012 to 11-17-2012

I. Summarize your activities as a long-stay researcher during your stay in NAOJ.

In the research period, studies of forced physical libration of the Moon by the gravitational attraction of the Earth and the Sun were carried out. Writing a program in MAPLE to calculate amplitudes and periods of first-order perturbation in the rotation of the Moon in Andoyer variables and Poincare variables, and making tabulation and ordering librations to classical variables P_1, P_2 and τ are details of the work.

I also attended at 118th Meeting of the Geodetic Society of Japan, Sendai, Japan, (29 October – 2 November 2012, Sendai) and two special seminars at the Astronomical Observatory (19 October and 15 November, Mizusawa).

The obtained scientific results will be submitted to scientific journals (Solar System, Astronomical and Astrophysical Transactions and others.

II. Summarize the results you obtained as a long-stay researcher this time.

The bases of all calculations are formulas in the analytic theory of lunar rotation with liquid ellipsoidal core and elastic mantle. A precise presentation of spherical harmonics in spherical coordinates of the Moon in the form of Poisson series played an important role in carrying out investigations. Programs have been developed to

identify and explore the effects of (contributions) of the liquid core and elastic mantle in the physical libration of the moon. It was shown that these effects are small (about 5-15 mas), but significant for the high-precision theory suitable for the study of the Moon's rotation with telescope set up on the surface of the Moon (Japanese project ILOM).

- The first step was to construct a table for the perturbations of the Andoyer variables and compared with the results of the new theory and similar tables derived as early as 1989 (Y. Barkin). Full agreement of the results was the confirmation of validity of the developed programs and analytical formulas of developed theory.

- During the reporting period, table of librations of the Moon in classical variables P_1 , P_2 and τ were built. These tables have been constructed for the solid model of the Moon, for the model of the Moon with a solid mantle and the ellipsoidal liquid core and for the general two-layer model of the Moon with a liquid core and elastic mantle. By comparing the models, the effects caused by the elastic properties of the Moon, as well as effects caused by the liquid core were determined.

- The constructed new tables of libration for classical variables P_1 , P_2 and τ are compared with similar tables constructed by Eckhardt (1981), Migus (1980), Moons (1982), Petrova (1996), as well as with modern empirical theory by Rambaux and Williams (2011) based on 40 years of laser observations of the Moon. Along the way, all the theories are also compared with each other by their common and specific features.

- The amplitude and periods of variations projected on the angular velocity of rotation of the Moon in the principal central axes of inertia of the Moon were identified. The new features in the theory of the rotation of the Moon - the variation of the length of the lunar day (LOD)- have been determined. These features are unique in the existing theories of the Moon's rotation. But they represent an important interest for diverse studies of lunar rotation in modern projects, including the project ILOM.

III. Any comments on this system

Staying for one month in the Astronomical Observatory of Mizusawa gave me a lot of experience. This is a very good place to work and obtain new scientific results. Also in observatory works many very good researchers, which helps in any cases and give many advices. I am very grateful to everyone for their help in the work, especially prof. Hideo Hanada, without him my visit and work in the project would have been impossible.