

The system of Ephemeris Research in Astronomy ERA, Ephemeris of Planets and the Moon EPM: current status and future plans

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Abstract. This paper presents the current status of work on the new version of the EPM2026 solar system ephemerides and plans for modernizing the astronomical ephemeris calculation system ERA. The main differences between the EPM2021 and EPM2026 ephemerides are outlined, including the set of adjusted dynamic model parameters and the database of radio, optical, and light-ranging observations used. A programming language for the planned ERA system update is selected, and a plan for automating this work is outlined.

Introduction

In December 1985, the first experimental versions of the ERA system (Ephemeris Research in Astronomy) and the object-oriented SLON language were presented on the BESM-6 computer [1, 2]. The first versions of the ERA (ERA-5) system and the SLON language, which were ready for use in practical scientific work, appeared only 10 years later [3]. In 2015, the ERA system was redesigned [4]. During the redesign, the source code was rewritten from Pascal to Racket (for running programs written in the SLON language, data management, and much of the computing) and C (libraries for computing).

EPM ephemeris (Ephemeris of Planets and Moon) has been produced for more than 20 years and contains information about the position of the planets of the Solar system, the Sun, the Moon, five asteroids (Ceres, Pallas, Vesta, Iris, Bamberga) and five TNO (Pluto, Eris, Makemake, Haumea, Sedna). As well as TT-TDB and Euler angles for lunar physical libration. The ERA system and the database of observations of Solar system bodies are used to create

EPM ephemerides. To date, several versions of EPM ephemerides have been released: EPM2004, EPM2008, EPM2011/m, EPM2015, EPM2017 and EPM2021. The EPM ephemerides cover a time interval of more than 400 years (1787-2214).

Current status of EPM ephemerides

In recent years, a number of works have been published on the development of the ERA system and the construction of new versions of EPM ephemerides [5, 6]. Based on these works and the latest version of the ERA system, the next version of the EPM ephemeris, EPM2026, is planned to be released this year.

Some time ago, due to the geopolitical situation, we had limited access to high-precision and most informative radio observations of spacecraft for building ephemeris of planets. For this reason, the main addition to the measurement database was the re-processed observations of planets and satellites made at the Pulkovo Observatory from 1930 to 2018 [7]. To reduce the correlations of the specified parameters, the EPM2026 ephemeris model will be assigned to the reference Julian date 2453371.5, instead of the date 2446000.5 used in the EPM2021 ephemeris.

Access to the Lunar Laser Ranging (LLR) observations remains available for the time being. To compile the lunar section of the ephemeris, we processed new LLR measurements up to 2025. In addition, the first LLR observations of the NGLR-1 retroreflector, obtained by the Apache Point Observatory Lunar Laser-ranging Operation (APOLLO) and Wettzell stations, have been analysed. One of the results of the analysis was the refinement of the coordinates of the NGLR-1 retroreflector, which are in good agreement with the results obtained by our Chinese colleagues [8], calculated using the American and French ephemerides DE440 and INPOP21a, respectively. The rates of change in the coordinates of LLR stations were also added to the list of parameters to be refined, which has improved the representation of LLR observations in the EPM ephemerides.

Modernization of the ERA system

When developing the latest, eighth, version of the ERA system, a number of decisions were taken which, under our circumstances, prevent this software product from being developed to its full potential and, as a result, hinder further scientific research. In addition to the difficulties involved in maintaining the source code written in Racket without the involvement of qualified programmers, a whole range of further problems arose. First and foremost, these include the relatively slow execution speed of calculations using Racket compared with the more widely used programming languages C/C++ and Fortran, as well as the removal of support for 80-bit variables in newer versions of Racket, which is critical when performing high-precision astronomical calculations. Consequently, when work began on modernising the ERA system, a choice had to be made: either to continue using

one of the latest versions of Racket that supported 80-bit variables, with the associated risks, or to switch to other programming languages that would support the required computational precision in their current versions for the foreseeable future. Taking into account the experience gained and the length of time the ERA system and other software products in the field of ephemeris astronomy have been in use, as well as the testing carried out, the programming languages C/C++ and Fortran were selected [9].

Currently, work has begun on porting the main computing modules of the ERA system to the C/C++ programming language. As well as maintaining the required accuracy of ephemeris calculations, the use of this language will significantly reduce computation time and lay the groundwork for improving their accuracy. There are plans to speed up the porting of computational modules from Racket to C/C++ by using AI. It is also envisaged that AI will be used to create a suite of unit tests, which should reduce risks and accelerate the forthcoming modernisation of the ERA system.

Conclusion

By the end of 2026, a new version of the EPM ephemeris, EPM2026, is being prepared for release based on an updated database of optical and lunar laser ranging observations of Solar System bodies, as well as an expanded set of dynamic model parameters. For the planned ERA system update, the C/C++ programming language has been selected, and a plan has been outlined to automate the conversion of the system's main computing modules from Racket to C/C++.

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