

# Monitoring the lunar capture of Chang'E-1 satellite by real-time reduction of the instantaneous state vectors

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**Abstract.** Based on our independently developed data processing software, the real-time reduction of the instantaneous state vectors of satellite during the maneuver stage near to perilune is analyzed via experimental observations. Results show that it is a quick and practical method to monitor the orbit evolution and the lunar capture of Chang'E-1 satellite.

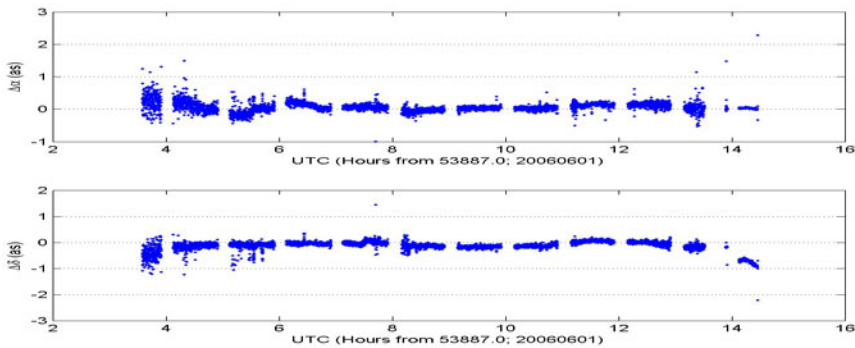
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## 1. Introduction

As designed in the Chinese lunar exploration project Chang'E-1 (CE-1), the tracking data of satellite consist of range and Doppler measurements from the Chinese United S-Band (USB) network as well as the delay and delay rate from the Chinese VLBI network (CVN). USB tracking stations are Qingdao, Kashi and survey vessels. VLBI antennas are at Shanghai, Urumqi, Beijing and Kunming. We are assigned to process the tracking observations of CE-1 satellite in a real-time way and we have independently developed the data reduction software, which provides the instantaneous state vectors (ISVs) including the three dimensional position and velocity. The software real-timely reads in tracking observations with corrections of clock, instruments and propagation, automatically identifies the central gravitational body within the Earth-Moon system, as well as takes into consideration of the perturbations of non-spherical figure, N-body gravitation, light pressure, atmospheric drag, tidal effects and so on. The satellite ISVs are sequentially reduced with a 5s sampling interval.

From the ISVs it is easy to get the corresponding orbit elements and to predict the satellite ephemeris by orbit integration [1-3]. The ISVs at a specified epoch could be reduced whenever the independent observations related to the wave-front of signal at this epoch are sufficient, that is, enough delay and range observations for the three dimensional position and enough delay rate and Doppler for the velocity. This reduction is geometrically performed rather than applying dynamical constraints on the observations belonging to different wave-fronts at different epochs, and so the length of tracking arc is not a crucial prerequisite. It could be used to monitor the quality of tracking data and to identify the evolution of satellite orbit, which satisfies the needs of efficiency and speediness in the view of the implementation of projects. Comparatively, precise orbit determination requires an enough tracking arc in length and is mainly applied in scientific studies with great precision requirement as in the post analysis stage rather than real-timely.



**Figure 1.** Comparison between the real-time reduced ISVs with the reconstructed ephemeris of a satellite

## 2. Experimental data verification

Since March of 2005 several tracking experiments of Chinese domestic and abroad satellites have been organized by the orbit monitoring system of CE-1 project and large amount of data have been accumulated. As an example, Figure 1 shows the comparison of the real-time reduced ISVs with the reconstructed ephemeris of Smart-1, a lunar satellite of the European Space Agency. Here reconstructed means that the orbit is post-stage determined and is high in precision. After some outliers are removed the standard deviation of the difference is about 0.1arcsec in both directions of right ascension and declination, which demonstrates that the ISVs are reliable and with sufficient precision for the identification of the lunar capture of CE-1 satellite.

On November 5 of 2007, CE-1 satellite was successfully captured by the Moon. During that period the real-time reduced ISVs by our software very well followed the evolution of the satellite orbit with a delay behind the clock about five minutes, which demonstrated the feasibility of the proposed method and software in this report.

## 3. Concluding remarks

The real-time reduction of the ISVs of CE-1 satellite is proposed in order to monitor and identify the orbit evolution during the maneuver stage nearby the perilune. In comparison with the precise and short-arc orbit determinations, the sequential ISVs reduction does not set any prerequisites on the length of tracking arc, does not require a precise modelling of various forces exerting on the satellite. This reduction could be real-time performed and be applied to monitor the quality of tracking data and to identify the orbit evolution of satellite, which is suitable to project needs of great efficiency and speediness.

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