The Use of Laser Altimetry in the Orbit Determination of Chang'E-1. Chang Shengqi[1,2], Huang Yong[1], Li Peijia[1] and Hu Xiaogong[1]. [1] Shanghai Astronomical Observatory, Chinese Academy of Sciences (80 Nandan Rd, Shanghai 200030, China. E-mail: changsq@shao.ac.cn) [2] University of Chinese Academy of Sciences

Introduction: The application of satellite laser altimetry measurement in planetary spacecraft precision orbit determination (POD) and planetary gravity field recovery has been implemented in Mars Global Surveyor (MGS), Lunar Reconnaissance Orbiter (LRO) and Selenological and Engineering Explorer (SELENE), and shows improvements both on POD and gravity field solution. Accurate altimetric measurements can improve the quality of the orbit reconstruction with altimetry data in the form of crossovers. Altimetry from the Chang'E-1 (CE-1) laser altimeter (LAM) has been analyzed in this work.

At first, the combined use of altimetry and Earth-based range measurements has been examined in a simulation study. The differences between crossover constraint in the form of height discrepancies and in the form of minimum distance are mainly discussed. And then, the same method is applied into analysis of altimetry from LAM. It is shown that including laser altimeter data improves the orbit precision. The result will be helpful to recomputed Chang'E-1 ephemeris to improve Chang'E-1 topography model.

Method: Crossover is the point where the ground tracks of two different orbits intersect, the same topography should be measured. Shum et al. give a detailed description of the use of crossovers in orbit determination and gravity field estimation for the case of radar (large footprints) altimetry over deep oceans [1]. Crossover constraint equation in the form of height discrepancies is given as:

$$O-C=[alt(t_i)-alt(t_j)]-[h(t_i)-h(t_j)] \qquad (1)$$

$alt(t_i)$ and $h(t_i)$ is altimetry measurement and altitude of the satellite at t_i, respectively. This form of crossover constraint equation has been applied in the POD of oceanic satellites, such as Jason-1 [2].

In the POD of MGS, LRO and SELENE, crossover equations have been formulated in the terms of the minimum distance between two curves that have been traced out by the altimeter on the planet surface:

$$O-C=\Delta d(t_i,t_j)=\left|\vec{x}'_b(t_i)-\vec{x}'_b(t_j)\right| \qquad (2)$$

$$\vec{x}'_b(t_i)=\vec{x}_b(t_i)-atl(t_i)\bullet\frac{\vec{x}_b(t_i)}{\left|\vec{x}_b(t_i)\right|} \qquad (3)$$

$\vec{x}_b(t_i)$ is the position vector of the satellite in the body-fixed coordinate. This form of crossover equation enables sensitivity to directions other than the radial one [3] [4] [5].

We apply both forms of crossover equations into the POD of CE-1 to compare the differences.

Results: During Chang'E-1 the first nominal mission phase, the satellite laser altimetry provided continuous measurements for about two months and a half, from Nov 26, 2007 to Feb 7, 2008.

The sub arc length is about 48 hours, with 2-4 hour overlaps. In order to achieve a reasonably full coverage of crossovers, processing needs to be done with a span of at least 1 month of time.(see in *Fig.1*)

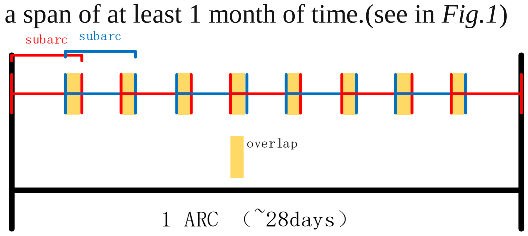
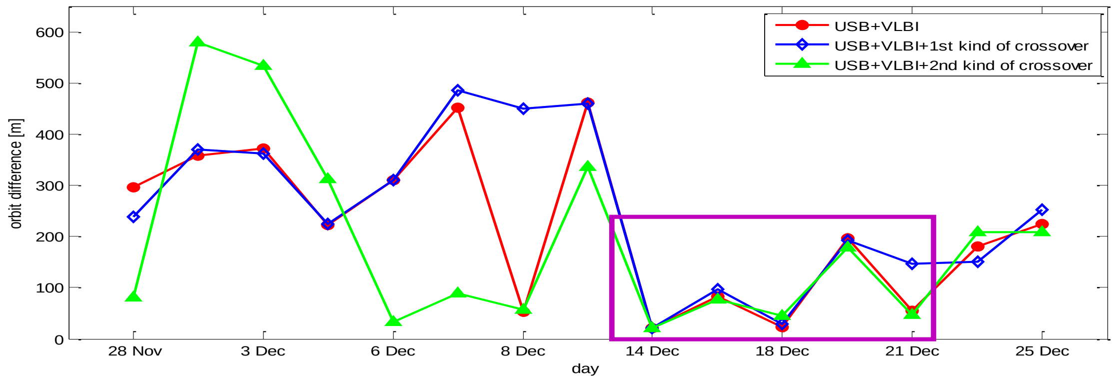


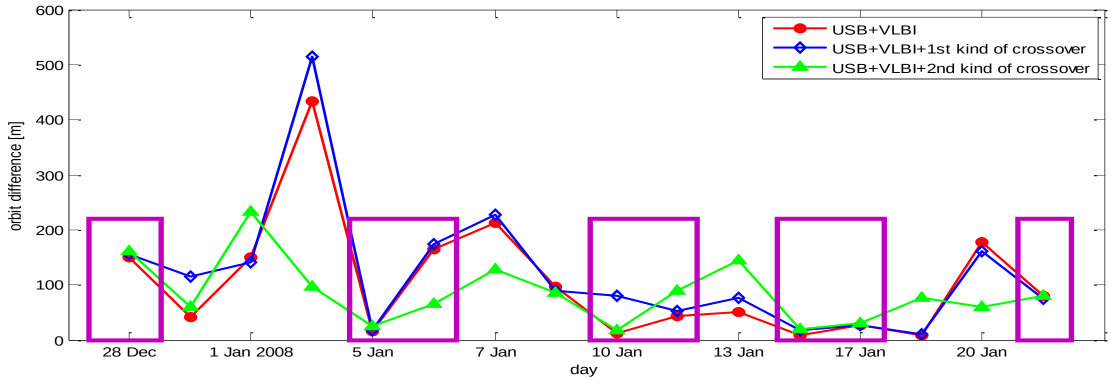
***Fig.1** Diagram of arc distribution in a batch*

Orbit precision is quantified by orbit differences computed from overlaps. Compare to the result from Earth-based tracking data only, adding crossovers in the form of minimum distance improve the orbit consistency significantly. Crossovers tie separate arcs of the satellite together and this helps especially when one of the orbits is not well-determined from the tracking data alone so that the orbit error is more homogeneous. However, addition of crossovers in the form of height discrepancy doesn't make any contribution (see in *Fig. 2* and *Tab. 1*).

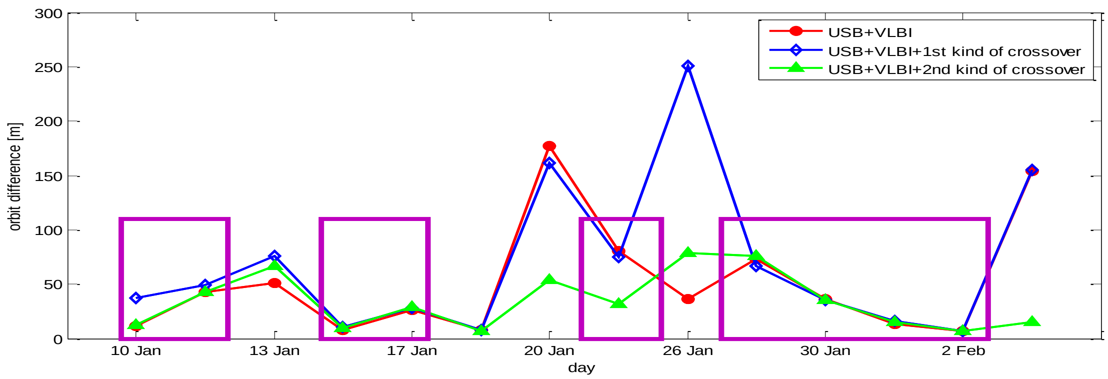
References: [1] Shum C. K. et al. (1990) *J . Astronaut. Sci., 38*, 355-368. [2] Luthcke S. B. et al. (2003) *Marine Geodesy, 26*, 399-421. [3] Rowlands D. D. et al. (2008) *J Geod, 83*, 709-721. [4] Neumann G. A. et al. (2001) *J. Geophys. Res., 106*, 23753-23768. [5]Goossens S. et al. (2001) *J. Geod., 85*, 487-504. [6]Yan J. et al. (2010) *Advances in Space Research, 46*,50-57.



(a) Arc 1



(b) Arc 2



(c) Arc 3

Fig.2 *RMS of total orbit overlap differences for CE-1* （tracking data include ranging measurement and VLBI measurement in purple rectangle. Otherwise, only ranging measurement is including.）

Tab.1 *RMS of orbit overlap differences for CE-1 separated per direction in the local satellite orbit frame*

Arc	Data Combination	Orbit Differences [m]			
		Radial	Along	Cross	Total
1	USB+VLBI	8.43	178.65	117.25	220.39
	USB+VLBI+1st XO	24.50	205.26	124.85	252.88
	USB+VLBI+2nd XO	8.15	159.24	83.74	186.81
2	USB+VLBI	11.64	70.83	50.82	104.41
	USB+VLBI+1st XO	14.72	86.06	52.81	120.93
	USB+VLBI+2nd XO	9.59	63.13	42.53	85.95
3	USB+VLBI	5.91	31.53	31.11	51.95
	USB+VLBI+1st XO	9.68	49.87	30.58	69.77
	USB+VLBI+2nd XO	7.27	28.15	12.00	34.23