Early CAL/VAL process for an optical tracking system by Korea

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ABSTRACT

An optical satellite tracking system has been developed and deployed by Korea Astronomy and Space Science Institute since 2010. The objectives of the system consist of acquiring ephemerides of domestic low Earth orbit satellites, monitoring domestic geosynchronous Earth orbit satellites and investigating the behavior of space debris. This system employs in-house software for image processing and operating system. Most of mount, observatory enclosure and control system was designed and manufactured domestically. A commercial 4k CCD camera was adopted for the back-end image sensor. And the broken satellite streak is generated by a chopper system in front of the CCD camera. The first observatory was built in Mongolia in September 2014. For the early calibration and validation phase, astrometric data of several bright low Earth orbit satellites has been collected from two observation sites in 2014. The preliminary results show the performance of system is close to the design specification.

1. INTRODUCTION

Korea Astronomy and Space Science Institute (KASI) has developed an optical satellite tracking system (OWL-NET) since December 2010. The detailed history and design are presented in [1]. All five optical observatories will be ready for the test operation phase. Three OWL-NET observatories including a test-bed in Daejeon, Korea are currently completed and in the test phase. Due to the many technical and environmental difficulties, the calibration and validation (CAL/VAL) schedule has been delayed and started on late July 2015. For CAL/VAL process, we need to download all the raw image files from the observatories. It has a fair amount of difficulties and pushed the schedule further back. The metric data from the OWL-NET system has been checked step by step after selection process for the effective points on each exposure by manually. Several corrections for timing issues, geometry of the image and reduction program have been investigated. In this paper, we introduce the current status of OWL-NET construction, some issues regarding the operation of OWL-NET system and an example of our pre CAL/VAL results of a LEO satellite orbit determination and its corrections.

2. CURRENT STATUS OF OWL-NET

KASI has successfully deployed one test-bed in Daejeon, Korea and two observatories in Mongolia and Morocco as you can see in Fig. 1. However, due to the remote location of the observatories and the local harsh weather, the completions of the observatories had been severely delayed. To perform an effective orbit determination of a satellite we need to acquire an adequate amount of points in certain time. After completion of the test-bed, we have used it to test most equipment and to verify the operation worthiness of systems. With the completion of the observatory in Mongolia, CCD camera and chopper system were tested for the photometric capability and the metric data reduction. And dedicated metric data of selected LEO satellites for CAL/VAL has been acquired only recently.

To complete OWL-NET, KASI need to build three observatories more. Fortunately, Wise Observatory in Israel and University of Arizona agreed to host an OWL-NET observatory each as shown in Fig. 2. KASI is still looking for the fifth site for an OWL-NET observatory.

Fig. 1. (Clockwise from upper left) OWL test-bed in Daejeon, Korea, first OWL-NET observatory in Songino, Mongolia, second observatory in Oukaimeden, Morocco.

Most of OWL-NET team member is occupied by completing the remaining parts of a jigsaw puzzle of OWL-NET. However, a full test operation has been performed since the night of the first light at OWL-NET observatory in Mongolia. With this on-going test operation, we have found many issues and minor faults of the system.

Fig. 2. Locations of OWL-NET observatories in September 2015, One test-bed in Daejeon, Korea, first OWL-NET observatory in Songino, Mongolia, Second one in Oukaimeden, Morocco, third one is under construction in Mizpe Ramon, Israel and fourth site will have foundation work soon in Mt. Lemmon, Arizona.

3. CALIBRATION/VALIDATION PROCESS FOR OWL-NET

We have found various glitches on the hardware and the software of OWL-NET since its first operation. Some of this problem affects the performance of the final observation products. The original plan of CAL/VAL consists of finding time synchronization off-sets at each observatory and geometric compensation parameters. With newly found issues, we need to find every confirmed parameter from the beginning and to check it again with a few reference orbits.

We currently are checking following items;

- Specifications of timing devices and data handling server
- Time synchronization level of each hardware and software
- Geometric reduction of image algorithms
- Time-coordinate registration procedures

Also, we are performing following processes to evaluate any improvements or differences.

- orbit determination with various combination of corrections and bias estimations
- comparing the results with TLE
- comparing Precise Reference orbits from SLR measurements with OWL-NET orbits with options
- comparing the results from EKF and Batch filter

4. ISSUES

Beside many project management related problems, we have experienced many operational issues. The system at the two OWL-NET observatories has been struck by the frequent power outages on the sites, suffered from slow internet speed and unstable connection. Also the weather plays major role on many malfunctions, especially lightning. We have lost several components by lightning even after we have tried many countermeasures.

In a raw image (as shown in Fig. 3) processing stage, OWL-NET performs following job in sequence.

- detecting streaks
- detecting stars
- identifying stars from a star catalogue
- finding coordinates
- matching time information

And we can easily define time related processes as possible culprits.

- TC/DT server time synch off-set
- chopper action delay
- time information recording delay
- chopper/satellite position on CCD geometry off-set
- skipped streak mismatching

We could not quantize any numbers from each possible candidate of time synchronization off-set yet. However, we are looking into it now.

5. ORBIT DETERMINATION RESULTS WITH CORRECTIONS

To get the basic information for the CAL/VAL process, we have selected various satellites with certain categories. Also some bright and faint satellites were chosen to check the photometric characteristics of the CCD camera and the chopper system. Cryosat-2 has been tracked to compare the observed orbit arc, precise orbit from SLR observation, and the orbit determination results. Most Korean LEO satellites including decommissioned one has been tracked to verify the design requirements.

In this study, we selected one decommissioned satellite, the Kompsat-1 to get orbit determination results with several different corrections. The Kompsat-1 is the first medium size remote sensing satellite in Korea, launched on Dec 21, 1998 and de-commissioned on Jan 6, 2008. Its mass and dimension are 469 kg and 1.34 m × 2. 35 m, respectively. When a solar panel is fully deployed, the length reaches 6.9 m. The characteristics of the orbit has currently 694 km × 729 km and 98.28° inclination.

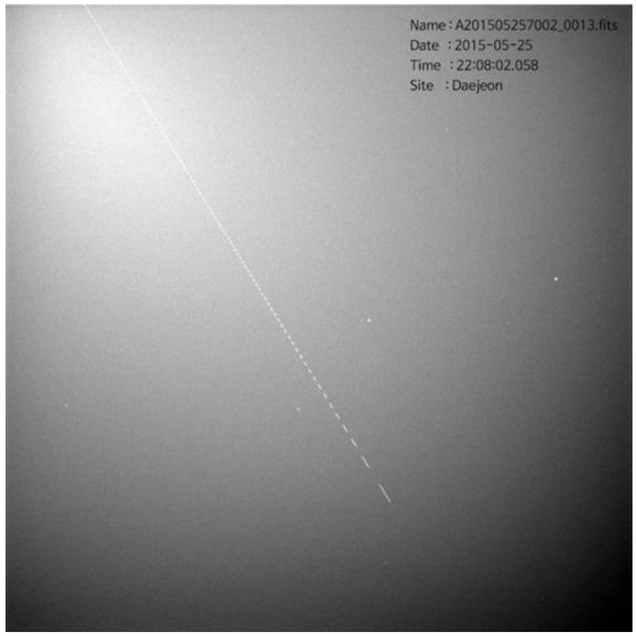

Fig. 3. Raw image of the Kompsat-1 by OWL-NET on May 25, 2015 in Mongolia observatory

We had obtained the observation data of Kompsat-1 as shown in Table 1. The numbers of observation data point of each pass satisfy the minimum requirements of orbit determination process not in normal operation mode.

Table 1. Observation data statistics of Kompsat-1 used in this study.

Pass number	Number of shot	Number of data	Date and Time (UTC)
1	8	752	2014. 11. 02 22:16:01.034 ~ 22:20:03.945
2	9	791	2014. 11. 05 20:37:47.867 ~ 20:41:50.507
3	8	412	2014. 11. 05 22:15:08.628 ~ 22:18:41.783
4	7	378	2014. 11. 06 21:11:04.368 ~ 21:14:06.488

To make a reference to compare the estimated orbits, we first performed an orbit determination without any correction. The comparison of this estimated orbit with 12 epochs of TLE is represented as in Fig. 4. With this reference orbit, we have tried various combinations of corrections for orbit determination. However, we didn't have better results that this reference orbit yet. Thus, we are going to re-check the procedure we went through.

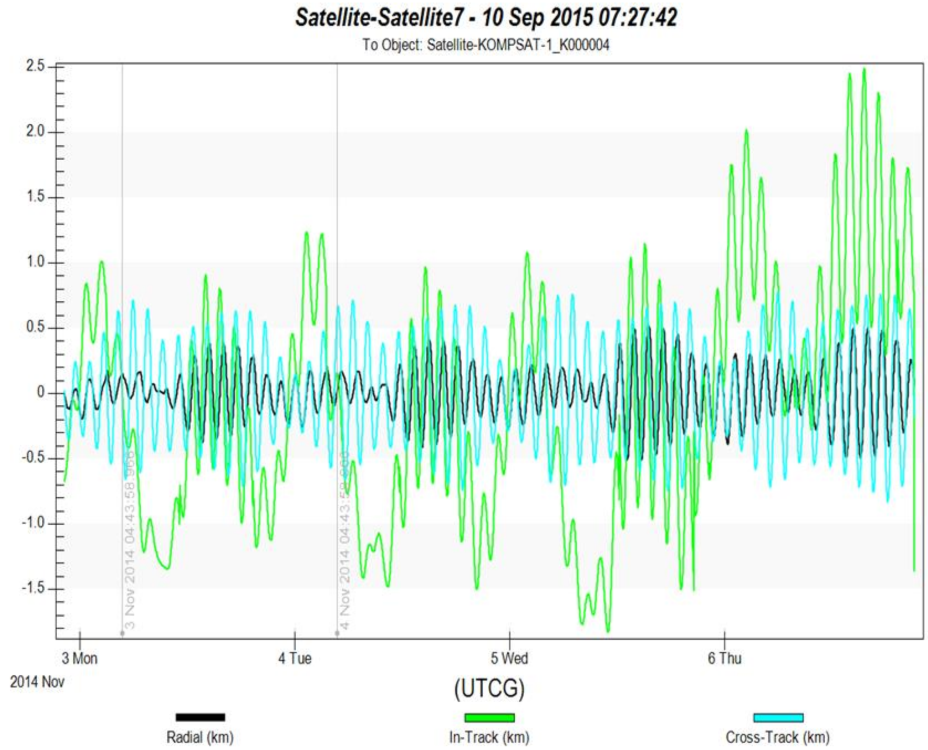

Fig. 4. RIC difference between 12 TLE epoch and estimated orbit with raw observation data of KOMPSAT-1 from OWL-NET Mongolia observatory in November 2014

6. SUMMARY

Even several design review processes of OWL-NET had been performed to overcome many issues before the CAL/VAL phase, we still have unresolved issues in operation and data production. The preliminary results of the orbit determinations of several LEO satellites show that most of orbit determination requirement can be fairy achievable. Though, the applications of time mis-matching, diurnal and annual aberration, light travel time, and hardware time synchronization off-set do not improve the final orbit products. First, several hardware and software time synchronization processes of the OWL-NET system will be re-checked. Second, more LEO satellite orbit we have tracked will be investigated. Third, we will compare the precise orbits of a laser retro reflector equipped LEO satellite with ours.

7. REFERENCES

1. Park, J.-H. et al, Proto-Type Development of Optical Wide-field Patrol Network and Test Observation, *AMOS Conference Proceedings*, 2014.