A Status Report on KASI Prediction Center (KAS)

Y.-R, Kim, E. Park, and H.-C. Lim

Space Science Division, Korea Astronomy and Space Science Institute, 776, Daedeok-Daero, Yuseong-Gu, Daejeon, 305-348, South Korea

yrockkim@kasi.re.kr

Abstract

The Korea Astronomy and Space Science Institute (KASI) has been providing a supplementary Consolidated Prediction Format (CPF) for Science and Technology Satellite (STSAT)-2C as one of ILRS prediction centers since April 7, 2014. The abbreviation in CPFs by KASI is KAS. As satellite laser ranging (SLR) observations can be used for orbit determination (OD) for STSAT-2C, an attempt to make enhanced CPFs from SLR-based OD was accomplished. In this study, we report an operation status and prediction procedure on KASI prediction center. For verification of CPFs generation strategy, test periods are prepared first and their results are investigated. Next, regular periods are started with CPFs generation if new SLR observations are available. The details of satellite orbit predictions procedure are described and the history of KAS CPFs for STSAT-2C generation is summarized. We will prepare better strategy for quality assessment of KAS CPFs and continuously try to generate confirmed CPFs for more SLR tracking for STSAT-2C.

Introduction

The Korea Astronomy and Space Science Institute (KASI) has been providing a supplementary orbit predictions for the Science and Technology Satellite (STSAT)-2C as one of ILRS prediction centers since April 7, 2014. The satellite orbit predictions are delivered in the form of the Consolidated Prediction Format (CPF). The STSAT-2C is the first Korean satellite equipped with the laser retro-reflector array for satellite laser ranging (SLR) [1]. The abbreviation in CPF files by KASI is KAS. The main provider of CPFs for STSAT-2C is the Korea Advanced Institute of Science and Technology (KAIST, KAI). The KAI prediction center consistently provides CPFs for STSAT-2C. However, KAI CPFs based on two line element (TLE) have limits in ensuring accuracy. The only source for orbit determination (OD) for STSAT-2C is SLR observations, and therefore an attempt to make enhanced CPFs from SLR-based OD was accomplished [2] and KASI started to operate KAS prediction center. In this study, an operation status and prediction procedure on KASI prediction center are reported.

Orbit Determination and Prediction System

For OD and prediction, workstation with Intel Xeon E5645@2.40GHz (64bit Linux OS) and NASA/GSFC GEODYN II software [3] are used. Detail models and setting of system are presented in Table 1.

Table 1. The models and parameters of orbit determination.

Model/Parameter	Description
Reference Frame	
Reference system	Inertial reference system
Precession/nutation	IAU2000
Polar motion	C04 IERS
Station coordinates	SLRF2008 [4]
Numerical Integration	Cowell's method
Step size	30 s
Arc length	Variable (depend on normal point acquisition condition)
Dynamic Model	
Earth geo-potential	GGM-2C (200 by 200) [5]
Planetary ephemeris	JPL DE-403 [6]
Earth tide	IERS convention 2003 [7]
Ocean tide	GOT00.2 [8]
Dynamic polar motion	Applied
Relativistic effect	Applied
Atmospheric density	MSIS-86 [9]
Solar radiation	Box-wing macro
Earth Albedo pressure	Applied
Empirical acceleration	Radial, along and cross-track
Measurement Model	
Observations	15s SLR normal points (EDC data center)
Tropospheric delay	Mendes and Pavlis [10,11]
Center of offset of the LRA	-203.54, -167.67, 928.05 (mm, X, Y, Z)
Estimation Parameters	Position and velocity of satellite

The OD and prediction strategy of KAS prediction center consists of 3 steps. The first step is initial orbit acquisition. The information of initial state can be obtained from KAI CPFs or previous determined orbits. Next, iterative initial orbit adjustment is performed for better O-C residuals of OD. After that, OD results can be adjusted by iterative OD tuning process. If final OD results have good precision (post-fit residuals < 1 cm), new KAS CPF for STSAT-2C is generated. Overall process of OD and KAS CPFs generation is described in Fig. 1.

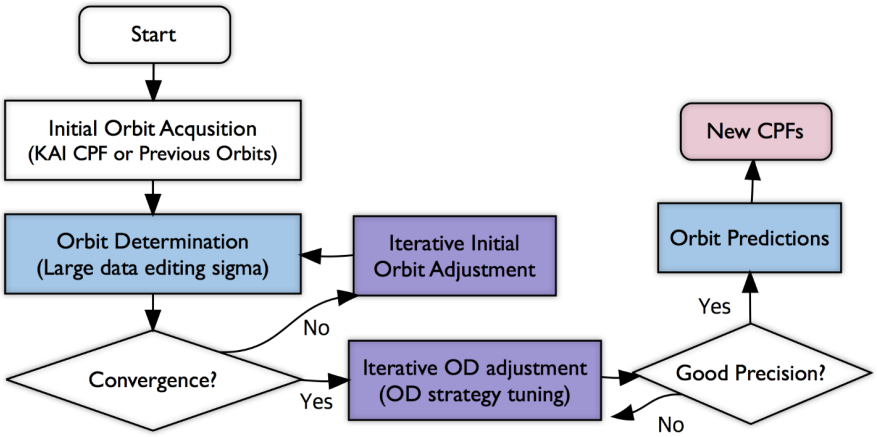

Figure 1. The flowchart of OD and KAS CPF generation.

Operation Status

The operation of KAS prediction center has two stages: test period for effective strategy and regular period for stable operation. The SLR tracking for STSAT-2C are very few and sparse distribution. For example, for KOMPSAT-5, which is another Korean LEO satellite, one month had 152 passes (3,526 NPs), and however, for STSAT-2C, the only 204 passes (2,215 NPs) during one year were uploaded to EDC data center. Therefore, daily orbit predictions (CPFs) were generated by OD with most recent SLR data for performance check during from 7 to 22 April, 2014. This verification was carried out by OD results a few days later. As a result, only SLR-based CPFs from OD with new SLR observations have meaningful accuracy. As the CPFs based on OD results of previous day have bad accuracy, it is not good strategy that orbit predictions without new SLR observations. In this period, Yarragadee station demonstrated that KAS CPFs using SLR observation have smaller bias than KAI CPFs. Then, regular period was started from 28 April, 2014 to now. Only if new SLR tracking are added, OD and CPFs generation are tried. For CPFs performance verification, SLR tracking trials by ILRS stations using KAS CPFs and SLR residual check using both KAI and KAS CPFs are conducted.

Test KAS Operation	Regular KAS Operation
20140407 ~ 0422 Daily CPFs generation CPFs performance check	20140428 ~ now CPFs with new SLR observations only CPFs performance check

Figure 2. The stage of KAS operation.

Prediction Procedure

The process for CPFs generation for STSAT-2C has two steps. The first stage is OD for STSAT-2C using SLR observations. Because the condition for OD for STSAT-2C is very poor, short/sparse measurements and inaccurate initial orbit information, the successful estimation is a lot of hard work. If the number of SLR normal points (NP) is small (under 6), the OD for STSAT-2C cannot be performed. For reliable OD results, it is recommended that more than 10 NPs are used. The information of initial orbit can be obtained from KAI CPFs or previous determined orbits. Second step is to predict orbits from OD results. After OD, predicted orbits (4 days) can be transformed to geocentric true body fixed reference frame, which is a default frame of CPFs. Finally, generated SLR-based CPFs can be compared to KAI CPFs for consistency verification and uploaded to CDDIS data center. Figure 1 shows the flowchart of KAS CPFs for STSAT2C generation.

Status of KAS CPFs Generation

A total of 35 KAS CPFs for STSAT-2C were uploaded to CDDIS data center up to October, 2014. The history of uploaded KAS predictions is presented in Table 2. Figure 4 shows the details of SLR observations for STSAT-2C and KAS CPFs follow-up. Green color means the day which obtains SLR observations. The obtained orbit prediction period by KAS CPFs is described by pink color. Table 3 and Fig. 5 show the statistics of KAS CPFs follow-up via SLR observations. As KAS prediction has 4 days orbits, the number of coverage days of KAS CPFs is more than those of SLR observations.

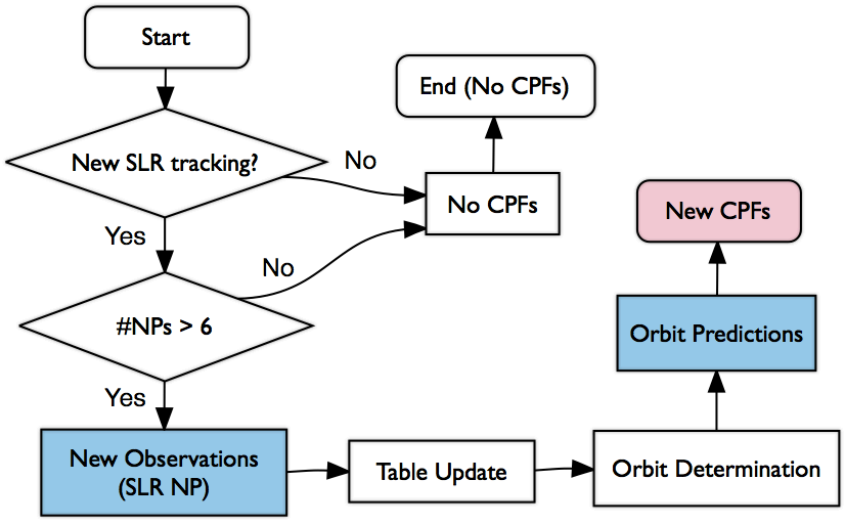

Figure 3. The flowchart of KAS CPFs Generation.

Table 2. The history of uploaded KAS CPFs.

#	File name (.kas)	#	File name (.kas)	#	File name (.kas)
1	stsat2c_cpf_140404_5941	13	stsat2c_cpf_140418_6081	25	stsat2c_cpf_140622_6731
2	stsat2c_cpf_140407_5971	14	stsat2c_cpf_140419_6091	26	stsat2c_cpf_140712_6931
3	stsat2c_cpf_140408_5981	15	stsat2c_cpf_140420_6101	27	stsat2c_cpf_140714_6951
4	stsat2c_cpf_140409_5991	16	stsat2c_cpf_140421_6111	28	stsat2c_cpf_140716_6971
5	stsat2c_cpf_140410_6001	17	stsat2c_cpf_140422_6121	29	stsat2c_cpf_140905_7481
6	stsat2c_cpf_140411_6011	18	stsat2c_cpf_140428_6181	30	stsat2c_cpf_140910_7531
7	stsat2c_cpf_140412_6021	19	stsat2c_cpf_140506_6261	31	stsat2c_cpf_140912_7551
8	stsat2c_cpf_140413_6031	20	stsat2c_cpf_140507_6271	32	stsat2c_cpf_140929_7721
9	stsat2c_cpf_140414_6041	21	stsat2c_cpf_140508_6281	33	stsat2c_cpf_140930_7731
10	stsat2c_cpf_140415_6051	22	stsat2c_cpf_140517_6371	34	stsat2c_cpf_141001_7741
11	stsat2c_cpf_140416_6061	23	stsat2c_cpf_140521_6411	35	stsat2c_cpf_141002_7751
12	stsat2c_cpf_140417_6071	24	stsat2c_cpf_140529_6491		

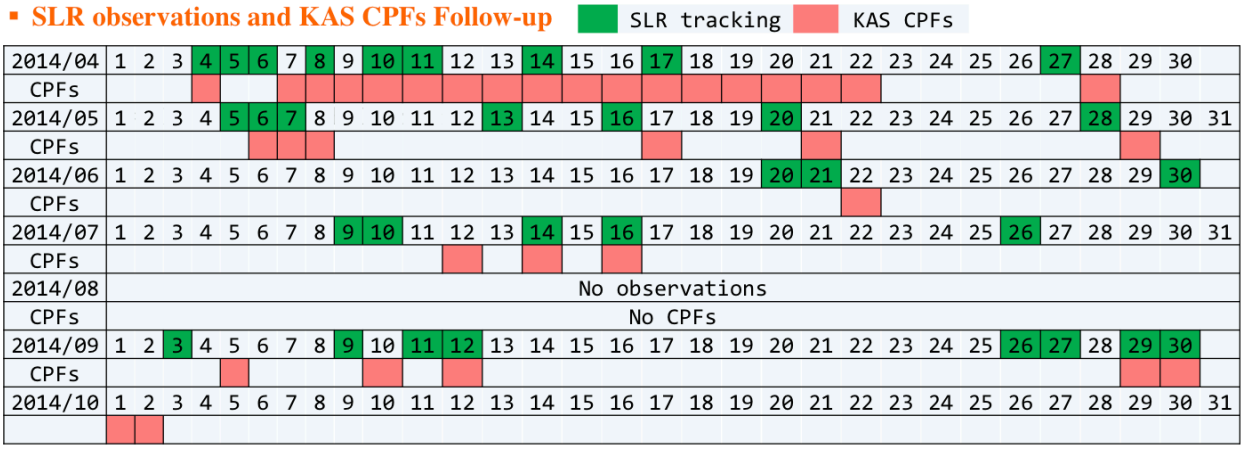

Figure 4. Detail history of KAS CPFs follow-up.

Table 3. SLR observations and KAS CPFs follow-up.

Month	CPFs/SLR NPs (days)
2014/04	18/9
2014/05	6/7
2014/06	1/3
2014/07	3/5
2014/08	-
2014/09	5/8
2014/10	2/2

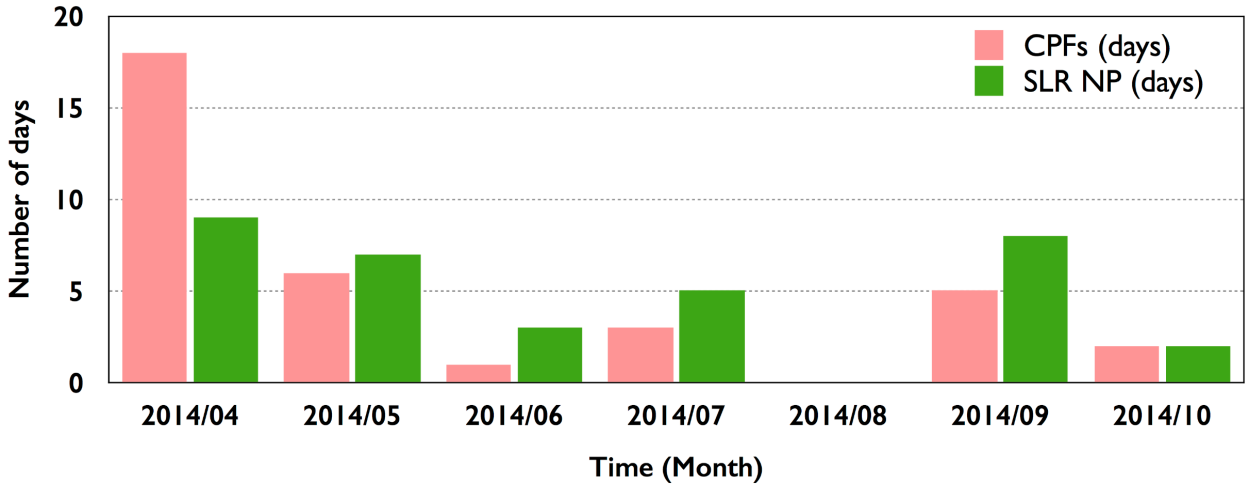

Figure 5. Number of KAS CPFs follow-up via SLR observations.

Conclusions and Future Works

The KASI prediction centers (KAS) provides supplementary CPFs for STSAT-2C using SLR observations. The proper strategy was selected by test period. If SLR tracking is accomplished, KAS CPFs for STSAT-2C can be generated. The unsolved issue is to verify the practical accuracy of KAS CPFs. Now, the only way to assess KAS CPFs accuracy is to attempt to track STSAT-2C using KAS CPFs, however it is not easy work because satisfying all condition such as CPFs, SLR NPs, day time and weather at the same time is very hard. We will prepare better strategy for quality assessment of KAS CPFs and continuously try to generate confirmed CPFs for more SLR tracking for STSAT-2C.

Acknowledgements

The authors deeply appreciate the STSAT-2C mission operation and SLR support of the Satellite Technology Center (SaTReC) at the Korea Advanced Institute of Science and Technology (KAIST). The authors also gratefully acknowledge all ILRS stations for trying to track STSAT-2C using KAS CPFs. The authors especially thank the Yarragadee station in Australia for tracking and providing the bias information of the CPFs used in this work.

References

[1] Kang, K.-I., Lim, C.-W., Shin, H.-J., et al., 2014. Operation results of STSAT-2C satellite. 2014 KSAS Spring Conference, Wonju, Republic of Korea, 17-18 April 2014, 902–905.

[2] Kim, Y.-R., Park, E., Lim, H.-C., 2013. Orbit determination and analysis for STSAT-2C. 18th International Workshop on Laser Ranging, Fujiyoshida, Japan, 11-15 November 2013, 13-0208.

[3] Pavlis, D.E., Luo, S., Dahiroc, P., et al., 1998. GEODYN II System Description. Hughes STX Contractor Report.

[4] Altamimi, Z., Collilieux, X., Métivier, L., 2011. ITRF2008: an improved solution of the international terrestrial reference frame. J. Geod. 85 (8), 457–473.

[5] Tapley, B., Ries, J., Bettadpur, S., et al., 2005. GGM02 - an improved Earth gravity field model from GRACE. J. Geod. 79 (8), 467–478.

[6] Standish, E.M., Newhall, X.X., Williams, J.G., et al., 1995. JPL Planetary and Lunar Ephemerides, DE403/LE403. JPL IOM 31410-127.

[7] McCarthy, D.D., Petit, G., 2004. IERS conventions (2003). IERS Technical Note No. 32.

[8] Ray, R.D, 1999. A Global Ocean Tide Model from TOPEX/POSEIDON Altimetry: GOT99.2. NASA Goddard Space Flight Center technical memorandum. NASA/TM-1999-209478.

[9] Hedin, A.E., 1991. Extension of the MSIS thermosphere model into the middle and lower atmosphere. J. Geophys. Res. 96 (A2), 1159–1172.

[10] Mendes, V.B., Prates, G., Pavlis, E.C., et al., 2002. Improved mapping functions for atmospheric refraction correction in SLR. Geophys. Res. Lett. 29 (10), 53-1–53-4.

[11] Mendes, V.B., Pavlis, E.C, 2004. High-accuracy zenith delay prediction at optical wavelengths. Geophys. Res. Lett. 31 (1), L14602.