# Some results of GEO space debris observations and orbit determination under experimental operation

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**Abstract**

The Bisei Spaceguard Center (BSGC) is an optical observation facility for Near Earth Objects (NEO) and space debris with 50cm and 25cm telescopes. It is developed by the Japan Space Forum, and operated by the Japan Spaceguard Association from February 2000. At present, NASDA requests BSGC to observe space debris and has evaluated orbits obtained by a debris orbit determination system using observational data at BSGC. This paper shows some results of orbit determination, the debris identification program and ideas for future observations.

## 1. Overview of BSGC and NASDA's debris orbit determination system

BSGC, an optical observation facility, is set at Bisei city, Okayama, Japan. BSGC has a slide roof with 50cm and 25cm telescopes and a dome for the 1m telescope and a control room. Fig.1 and Table 1 show an outline view of BSGC and FOV of telescopes. The 1m telescope has a particularly wide field of view. The 50cm telescope can track LEO (Low earth orbit) objects because it has 5 deg/sec tracking speed. The 1m telescope is being installed and will be operational in summer 2001. Additionally the telescope control system (tracking system) and the image data processing system are not completed yet. Currently, BSGC is in the test phase.

Fig. 1. BSGC outline view

Table.1 FOV of telescopes

| Telescope | FOV |
|---|---|
| 25cm | 1.3deg*1.3deg |
| 50cm | 2.0deg*2.0deg |
| 1m | 3.0deg*3.0deg |

NASDA requests observation of satellites and space debris to BSGC because study of debris environment and check of Japanese satellites, and has evaluated orbital determination accuracy. Fig.2 shows the flow of debris observation. NASDA carries out orbit determination at Tsukuba city, Ibaraki, by a debris orbit determination system. Predicted data (azimuth & elevation) for target objects are also made at Tsukuba and sent to BSGC, where the target objects are observed. From the observation data BSGC calculates positions of objects (epoch, right ascension and celestial declination) with an image data processing system and sends them to Tsukuba.

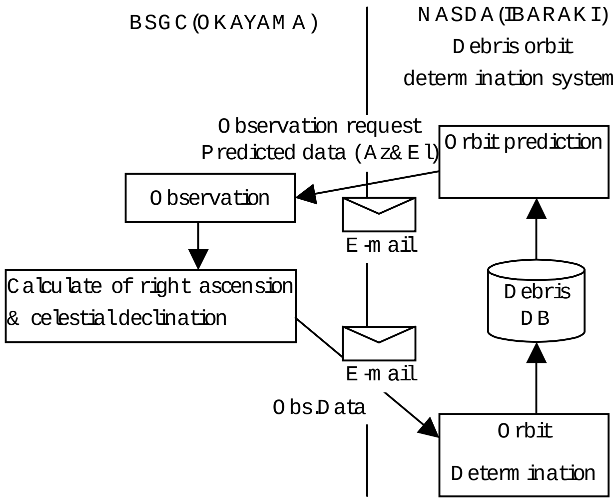


Fig. 2. Flow of debris observation

The current main operations at BSGC are as follows

a) Observation of Japanese GEO satellites
b) Identification of unknown objects
c) Observation and orbit determination for LEO objects

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Table.2 Comparison between orbit determinations results for GMS-5 by BSGC and by JMA and O-C of Az and El

| The data period (Number of data) | Initial epoch (UTC) | Difference between orbit determinations for GMS-5 by BSGC and by JMA | | The O-C RMS Az & El | |
|---|---|---|---|---|---|
| | | Delta R (km) | Delta a (km) | Az (deg) | El (deg) |
| 02/10 12:02:00-19:00:02 ( 8)<br>02/11 13:10:23-19:47:35 ( 7)<br>02/12 12:31:28-20:01:04 ( 7) | 02/15 00:00:00 | 1.4132 | 0.0017 | 1.817031D-03 | 3.836884D-04 |
| 02/28 12:21:05-18:55:35 ( 7)<br>02/29 12:16:36-20:42:01 ( 7)<br>03/01 10:46:16-10:46:16 ( 1)<br>03/02 10:23:54-18:23:19 ( 6) | 03/01 00:00:00 | 1.8509 | -0.0261 | 2.430707D-03 | 6.668194D-04 |
| 03/06 13:00:00-20:00:00 ( 8) | 03/09 00:00:00 | 2.3561 | -7.2082 | 2.456768D-03 | 4.672118D-04 |
| 03/08 10:29:59-13:58:43 (37)<br>03/09 11:01:29-20:09:15 ( 5) | 03/09 00:00:00 | 2.5174 | -0.0399 | 2.439764D-03 | 5.056879D-04 |
| 03/12 10:05:21-19:32:47 ( 8)<br>03/13 13:15:42-19:30:19 ( 3) | 03/09 00:00:00 | 2.5470 | -0.0828 | 2.000243D-03 | 8.814533D-04 |
| 03/20 10:36:12-11:18:43 ( 6)<br>03/22 10:11:40-20:02:58 ( 7) | 03/17 00:00:00 | 3.3725 | -0.0427 | 2.321248D-03 | 8.386419D-04 |
| 03/30 10:38:09-16:34:33 (32)<br>03/31 18:39:02-18:47:30 ( 6)<br>04/01 10:43:32-12:59:28 ( 6) | 03/29 00:00:00 | 2.4358 | -0.0272 | 3.307380D-03 | 7.708629D-04 |
| 04/06 11:03:08-13:01:16 ( 2)<br>04/07 10:57:04-13:59:53 (13)<br>04/08 11:08:09-16:01:13 ( 8) | 04/06 00:00:00 | 2.3853 | -0.0788 | 2.376230D-03 | 4.957767D-04 |
| 04/10 15:08:53-18:42:46 ( 9)<br>04/11 13:23:40-17:34:33 (15) | 04/06 00:00:00 | 2.9756 | -0.0657 | 3.006124D-03 | 5.637943D-04 |
| 04/23 11:08:19-15:29:51 (21)<br>04/24 11:03:50-16:37:24 (18) | 04/20 00:00:00 | 1.1110 | -0.0886 | 2.117207D-03 | 3.551144D-04 |

To item a): at present we cannot carry out a lot of observations because the observation system and the image data processing are not yet automated perfectly. We regularly observe few Japanese satellites at BSGC and determine their orbits using the observation data by the orbit determination system. To item b): when a target object is observed, other objects are sometimes found and are registered as unknown objects. NASDA can identify them and check whether they have already been registered in the TLE database by a debris identification program. To the last item c): using an observation system with a wide lens and CCD, LEO objects are experimentally tracked at BSGC. NASDA determines their orbit using optical observation data.

In the next chapter, we will explain these items in detail.

**2. The accuracy of orbit determination**

We can determine the orbits of satellites and debris when observation data are available. The accuracy of orbit determination depends on the quality of observation data, the data quantity, the orbital estimation model and so on. We investigated the accuracy of the orbit determination using the optical observation data obtained by BSGC. GMS-5 is the geosynchronous meteorological satellite No.5 of JMA (Japan Meteorological Agency). JMA has determined the orbit of GMS-5 by S-band ranging. We have compared the orbits determined from optical observation data obtained by BSGC and from S-band ranging data obtained by JMA and evaluated the accuracy of the orbit determination by NASDA.

Table 2 shows the results of the comparison. "The data period" of Table 2 is the period of the observation data that we used to determine orbits. The "number of data" denotes the number of observation data. "Initial epoch" shows the epoch of the orbits determined by JMA. We shifted the epoch of the orbit determined by NASDA to "initial epoch" and compared NASDA's orbit with that of JMA. The differences of the position “Delta R” and of the semi-major axis “Delta a” are shown in Table 2.

The quantities "O-C RMS Az & El" denote the difference between the observation direction (azimuth & elevation) of orbit calculated by orbit determination system and observation data. The root mean square (RMS) values are listed.

In Table 2, we can see that differences of position are within 2.5km and differences of semi-major axis are within 80m in case of orbital determination using three days observation data. Also we can see the difference of semi-major axis is over 7km in case of orbital determination using data of one day.

Generally, "O-C RMS Az and El" are large values. But we expect that these values will be small if the adjustment of telescope is fixed. However, we confirmed that the accuracy of orbit determination by S-band ranging data and by BSGC's optical observation data are almost the same, and we also confirmed that it is possible to continuously observe objects determined using observation data during 2 days.

### 3. Debris identification program

At present, in the test phase, we mainly observe few Japanese satellites. Sometimes also other objects are found in the field of view and are registered as unknown objects. However, at that time, we cannot know what the objects are. If the unknown objects are new satellites, rockets or new breakup objects, it is important to track the objects. Thereupon we need to compare the unknown objects with known ones and to identify those objects.

Thus, NASDA developed a debris identification program to identify those unidentified objects. This program compares positions obtained from the Two Line Elements (TLE) offered by Goddard Space Flight Center (GSFC) to those of observation data for unknown objects, and finds data for some objects.

Fig. 3 shows the flow of the identification program. First, when BSGC finds unknown objects in the field of view, their positions (epoch, right ascension and celestial declination) are calculated and registered. Next, NASDA receives TLE from GSFC and calculates their directions from BSGC. At last, the debris identification program compares differences of position between the unknown objects and TLEs at each epoch, and determines a TLE object whose position is closest from unknown object's position, to an identified object. The result of an identification is shown in Fig. 4, where the horizontal axis is azimuth and the vertical axis is elevation. Observation date is 11th August 2000. X00469 is the number of the unknown object given by BSGC and its positions every moment are plotted as triangle.

Also positions of an object (the international designation number is 1992-017A), are plotted as quadrangle. This object is the Russian satellite GORIZONT 25. With the small differences of 0.02° in azimuth and 0.01° in elevation, we can identify X00467 as GORIZONT 25.

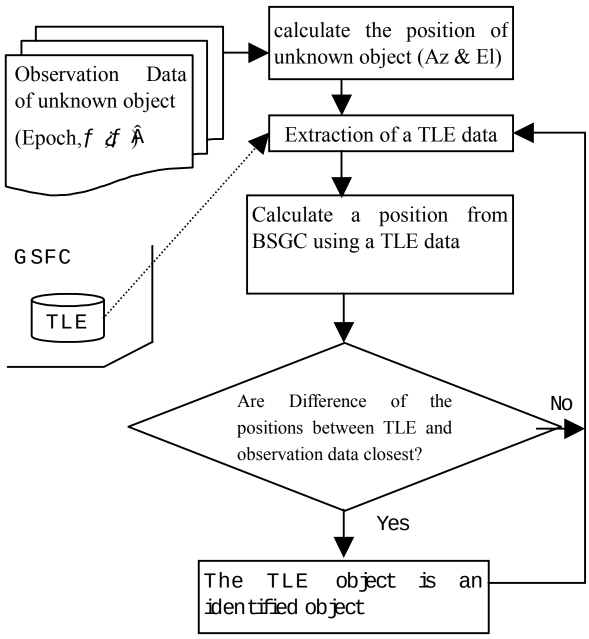


Figure 3. Flow chart for the identification program

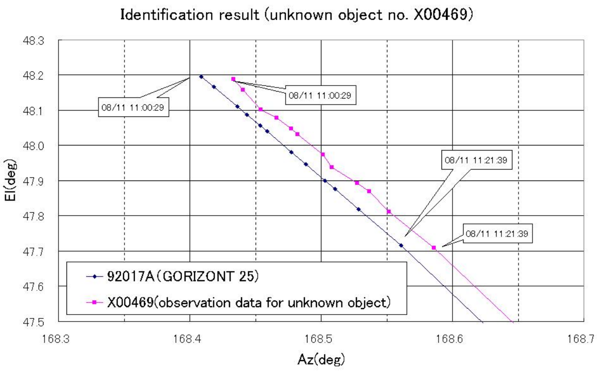


Fig. 4. An identification result

This program can also find unsafe objects quickly. When BSGC observed GMS-5 at 140° east longitude, two objects on the same longitude were found by the identification program. They were GORIZONT 25, a Russian satellite and BEIDOU1, a Chinese satellite.

Fig. 5 shows the longitude history of GMS-5, GORIZONT 25 and BEIDOU1. GMS-5's longitude history is a blue line. GORIZONT 25's is a red line. BEIDOU1's is a green line. Cross points are points where objects reach minimum relative distance. In Fig. 5 we can see that there are nine or ten close approaches during four months.

Source data for Fig. 5 are TLEs. But NASDA can analyze the possibility of collision using observation data obtained by BSGC. We calculated that the objects reach a minimum distance of about five kilometers at the cross points.

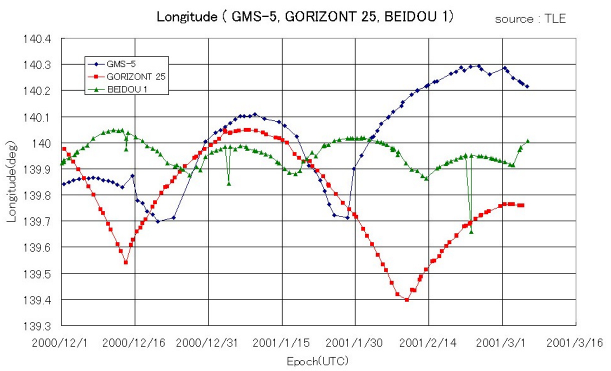


Fig. 5. Longitude history of GMS-5, GORIZONT25 and BEIDOU1

**4. Observation and Orbit Determination for LEO objects**

BSGC has also observed LEO objects by a simple observation system with a wide lens and CCD. The 50cm telescope is not used because its tracking system is not completed yet. NASDA determines the orbits of Mir and other deorbit objects using observation data obtained by the observation system and has evaluated the orbits. The determination error between TLE and these orbits is within 30km in the position. When the tracking system for the 50cm telescope is fixed, we will carry out observations of LEO objects substantially.

**5. Ideas of BSGC for future observations**

In the test phase, observation targets are limited to few Japanese satellites. In the near future, we will survey in GEO region when the 1m telescope is completed and the observation system is automated perfectly. There are some problems such as schedule and operation of the survey, although we can have a grip of orbit information of several hundred objects.

Furthermore, collaboration observation with Kamisaibara SpaceGuard Center (KSGC), a radar site which will be set up in 2003, has been planned. KSGC can observe LEO object with active phased array antenna and can detect cross section and so on. On the other hand BSGC can calculate the reflected light grade for objects and angle accuracy. So if BSGC and KSGC carry out observation collaboratively, we can determine orbits of target objects and analyze the objects using optical unique data obtained from BSGC and unique data of radar obtained from KSGC.

At present, the feasibility of collaboration observation is studied. Overview of collaboration observation are shown in Fig. 6.

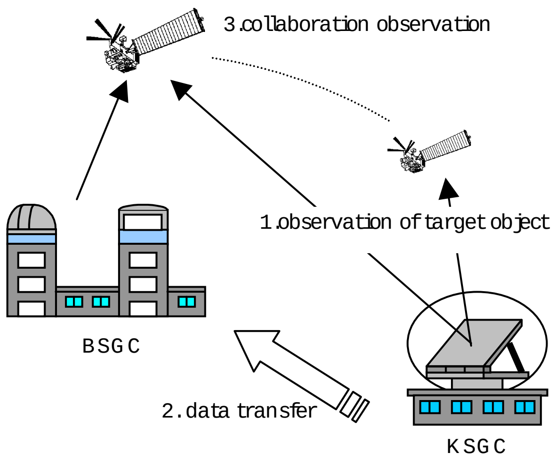


Fig. 6. Overview of collaboration observation

**6. Conclusion**

BSGC is an optical observation facility for space debris and NEO with 1m, 50cm and 25cm telescopes and operated from February 2000. NASDA requests BSGC to observe few Japanese satellites and space debris, and has evaluated orbits obtained by a debris orbit determination system.

The accuracy of orbit determination using observational data during three days at BSGC is within 2.5km in the position and 80m in the semi-major axis. Unknown objects are identified with the identification program. This program is used with found new objects and unsafe objects. With this program, we know that there is the possibility of collision between GMS-5 and GORIZONT 25. Furthermore, we will plan collaboration observation, tracking of LEO objects and surveying in GEO region.

**7. References**


1. Syuzo Isobe and Kazuaki Nonaka, Status Report of the Bisei Spaceguard Center, 18th Inter-Agency Space Debris Coordination Meeting, Colorado Springs, 2000.
2. Syuzo Isobe, Nariyasu Hashimoto, Kazuaki Nonaka, Mikio Sawabe, Takao Yokota and Masaya Kameyama, Experimental operation results of GEO space debris observation and orbit determination, 44th Space Science and Technology Conference, Japan.