

## The New Korean SLR System and Its Automatic Operation

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**Abstract.** *Korea Astronomy and Space Science Institute (KASI) has been operating the Sejong station as the member of International Laser Ranging Service (ILRS) tracking network as well as the core station of Global Geodetic Observing System (GGOS) since 2015. Additionally, KASI has established a new Satellite Laser Ranging (SLR) station on the Mt. Gamak called Geochang station for the contribution of ILRS tracking network and support of Korean space missions. The Geochang system has the common Coude optical path using 100 telescope, which is capable of taking satellite images using adaptive optics and laser ranging. The operation software was developed based on the client-server architecture in order to distribute the processing tasks which enables the automatic process more easily. For more secure automatic operation, weather monitoring and aircraft detection are conducted by the dual system.*

### Introduction

Satellite Laser Ranging (SLR) is the most accurate ranging technique for satellites and space debris using an ultra-shot pulse laser, which has provided crucial technologies for many space applications. KASI has been operating the Sejong station with mm level accuracy for the researches of space geodesy, geophysics and precise orbit determination. The Sejong station has been the member of ILRS tracking network as well as the core station of GGOS since 2015. The Sejong core station consists of Very Long Baseline Interferometry (VLBI), Global Navigation Satellite System (GNSS) and SLR system. The SLR system has the separate optical path using 40cm Rx telescope and 10cm Tx telescope, and its repetition rate is 5kHz to research the satellite spin dynamics. On the other hand, the VLBI system has a 22m Cassegrain antenna, a hydrogen maser atomic clock and a four-channel receiver using 2, 8, 22 and 43 GHz frequencies.



Figure 1. Geochang SLR station on Mt. Gamak

Currently, KASI has established a new SLR station on the Mt. Gamak called Geochang station for the contribution of ILRS tracking network and support of Korean space missions. The Geochang system has the common Coude optical path using 100 telescope, which is designed to be a fully automatic remote operation. It is capable of laser ranging to satellites in the range between 300 km and 36,000 km including GEO satellites. Especially, it is able to take satellite images brighter than 10 magnitude using Adaptive Optics (AO) to support Korean space missions and will have the function of laser ranging to the space debris in the near future called Debris Laser Tracking (DLT) because it provides ranging data as well as angle data of azimuth and elevation.

### Technical Aspects of Geochang SLR System

The Geochang system consists of SLR, AO and DLT. The rotation mirror in the telescope pier changes the optical beam path to the direction of SLR, AO and DLT system. As shown in Figure 2, Optical Tube Assembly (OTA), tracking mount, operation system, weather station and aircraft detection radar are common to realize the SLR, AO and DLT system but laser, Tx/Rx optics and timing system are separate for SLR and DLT system, which are located inside the clean booth.

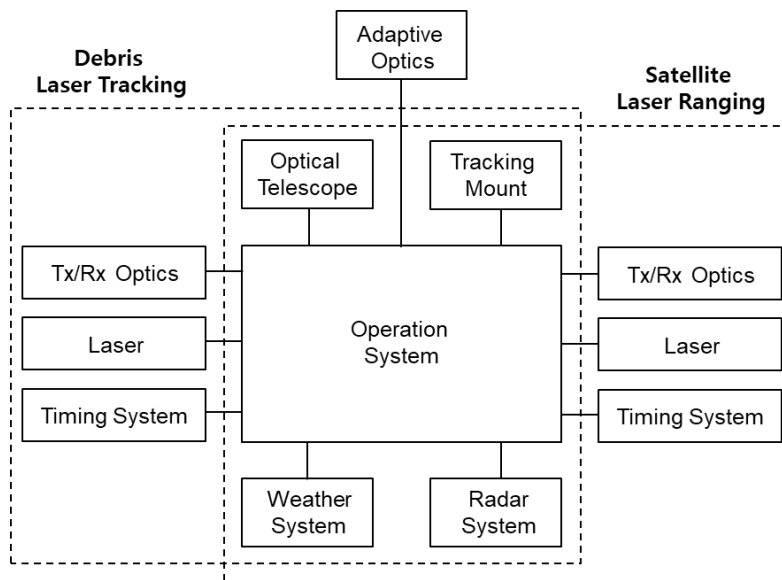


Figure 2. Configuration of Geochang system

The laser system consists of four modules; mode-locked laser oscillator, regenerative amplifier, power amplifier and second harmonic generation. The laser has 15 mJ of pulse energy and 9 ps of pulse width. The laser beam size is expanded 21 times by two beam expanders in the transmitting optics and 3 times in the telescope. The Geochang SLR system has common coude optical path. So the T/R disk provides the optical switch for transmitting and receiving beam, which has two coating holes for transmitting laser. These holes are synchronized to laser fire so that pulses are transmitted. The clear apertures are 100 and 25 cm for the primary mirror and secondary mirror, respectively. The material of primary mirror is the Clearceram Z-HS which has lower thermal expansion than Zerodur material. The telescope focus is controlled

automatically with 10  $\mu\text{m}$  accuracy using two temperature sensors on the truss. The tracking mount moves very fast with the slew rate of 30 degree/sec for azimuth and 15 degree/sec for elevation and acceleration of 10 degree/sec<sup>2</sup> for azimuth and 5 degree/sec<sup>2</sup> for elevation because the arc motors are used. The dome has 8 meter of diameter, 5 tons of weight and 15 degree/sec of slew rate. Even though the dome is heavy, it is synchronized with the telescope movement using 4 direct drive motors, even in the case of LEO space debris tracking. It has 4 windows to decrease the air turbulence inside the dome for adaptive optics. Table 1 shows the specification comparisons between Sejong and Geochang SLR system.

Table 1. Comparisons between Sejong and Geochang SLR system

Item	Parameter	Sejong	Geochang
Telescope	Optical path	Bistatic	Common Coude
	Rx and Tx telescope	40/10 cm	100 cm
	Transmit beam divergence	5 ~ 200 arcsec	
	Max slew rate	20 deg/sec (Az) 10 deg/sec (El)	30 deg/sec (Az) 15 deg/sec (El)
	Tracking & Pointing accuracy	< 5 arcsec	1 arcsec
Detector	Type	C-SPAD	C-SPAD
	Quantum efficiency	20%	20 %-
Laser	Wavelength	532 nm	532 nm
	Pulse energy or Power	7.5 mJ @5 kHz	15 mJ@60 Hz
	Pulse width	50 ps	9 ps
	Repetition rate of Operation	2 kHz	60 Hz
	Beam diameter @ Tx telescope	7.5 cm	90 cm
Etc	Timing system	Event timer	Event Timer
	Aircraft detection type	Radar	Radar

### Automatic Operation

The Geochang SLR system has 4 kinds of sensors to monitor weather; METS sensor, full-sky camera, rain sensor and cloud sensor. The METS sensor gathers weather information such as temperature, humidity, pressure, raining, visibility, dew point, wind direction and wind speed. The full-sky camera provides the sky image to the observatory server by processing raw data in the full-sky image server, which help the operators to see the sky conditions only in the manual mode. An additional rain sensor is installed beside the dome only for the dome emergency close when it detects raining. The observatory server can also close the dome automatically when the METS sensor detects raining. The cloud sensor provides the ambient temperature, sky temperature, dew point, wind speed, humidity, moisture and sky brightness to the observatory server. This information from the cloud sensor is used for automatic operation including the decision of starting or stopping SLR operation. But the main purpose of the cloud sensor is to provide cloud coverage information for automatic operation by monitoring the sky temperature.

The Geochang SLR system has 2 sensors for aircraft detection; aircraft detection radar and aircraft detection IR camera. The radar has a directional antenna, whose direction is always

synchronized with telescope direction. If the radar detects aircraft or it is not synchronized with telescope direction, the radar controller sends the interlock signal to the laser interlock controller to make the laser firing paused. On the other hand, the aircraft detection server receives the sky IR images from the IR camera via aircraft camera server and then processes the IR images to determine whether the aircraft is on the field of view of IR camera or not. When the aircraft detection server detects aircraft, it also sends an interlock command to the laser interlock server. The laser fire is paused in the laser oscillator when one of two aircraft detection systems detects an aircraft. This dual system will increase system reliability even though they often recognize heavy cloud as aircraft.

The operation software was developed based on the client-server architecture in order to distribute the processing tasks. As shown in the figure 3, there are many servers which are connected through the communication network.

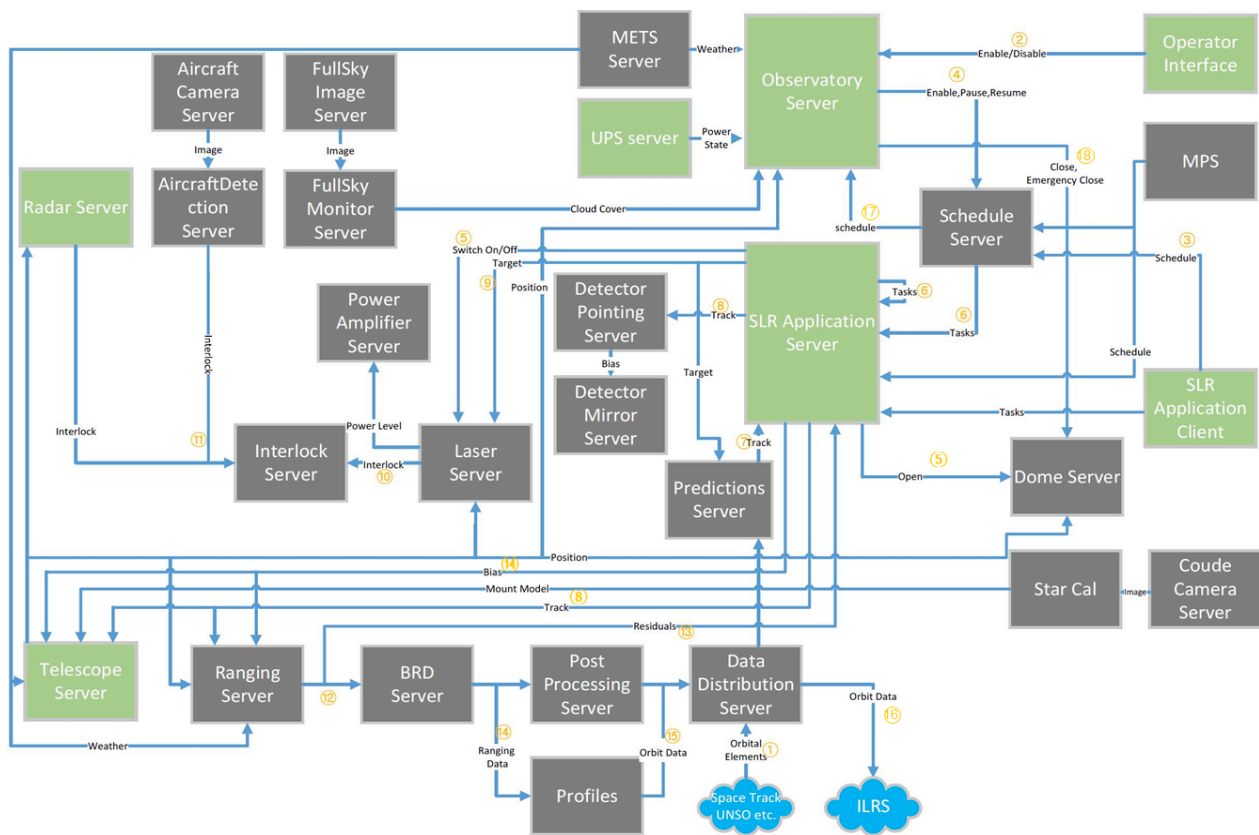


Figure 3. Architecture of operation software

The automatic process can be divided into 4 major procedures; automatic task control, automatic tracking, automatic processing and automatic communication. The groundwork or preparing work is done in the automatic task control, in which many works are done; checking the H/W status, setting the H/W configuration, checking the safety interlocks, logging events and errors, making the tracking schedule and star calibration. The automatic tracking process makes range measurements by monitoring aircraft detection, weather and sun avoidance. The ranging window width and offset are controlled automatically. Additionally, automatic satellite searching and signal acquisition algorithm are implemented. The CRD files are generated in the automatic

processing step using three noise filters such as Poisson, polynomial and amplitude filter. In the automatic communication process, CPF and Two Line Element (TLE) files are downloaded and CDD files are uploaded on the ILRS data center automatically. TLE data are used for DLR and AO, which are downloaded from the Space-Track.

If all servers and clients are running and the tracking schedule is ready, the automatic system monitors weather status and then checks the all device state. The elements of weather criteria are raining, wind speed, humidity, dew point and cloud coverage. If there is no emergency case such as sun avoidance, raining from the dome server and UPS capacity less than 50%, the automatic system goes into the device setup step such as laser power, C7 rotation direction and radar mode. If there is no error in the step of device setup, finally dome shutter and primary mirror cover are opened and then observation starts.

The automatic system should monitor many exception situations during automatic tracking; weather, emergency, device significant error, interlock condition, sun avoidance and UPS. In case of bad weather and sun avoidance, the primary mirror cover and dome shutter are closed, and then the system waits until weather is good and sun avoidance is clear. In the case of emergency and device significant error, mirror cover and dome shutter are also closed, and then observation is stopped. The interlock conditions come from the aircraft detection, mirror cover status, C7 rotator position, telescope status and dome misalignment. If the system detects any interlock condition, the laser fire is prohibited until all interlock condition are clear. Figure 4 shows the various exception situations and its procedures.

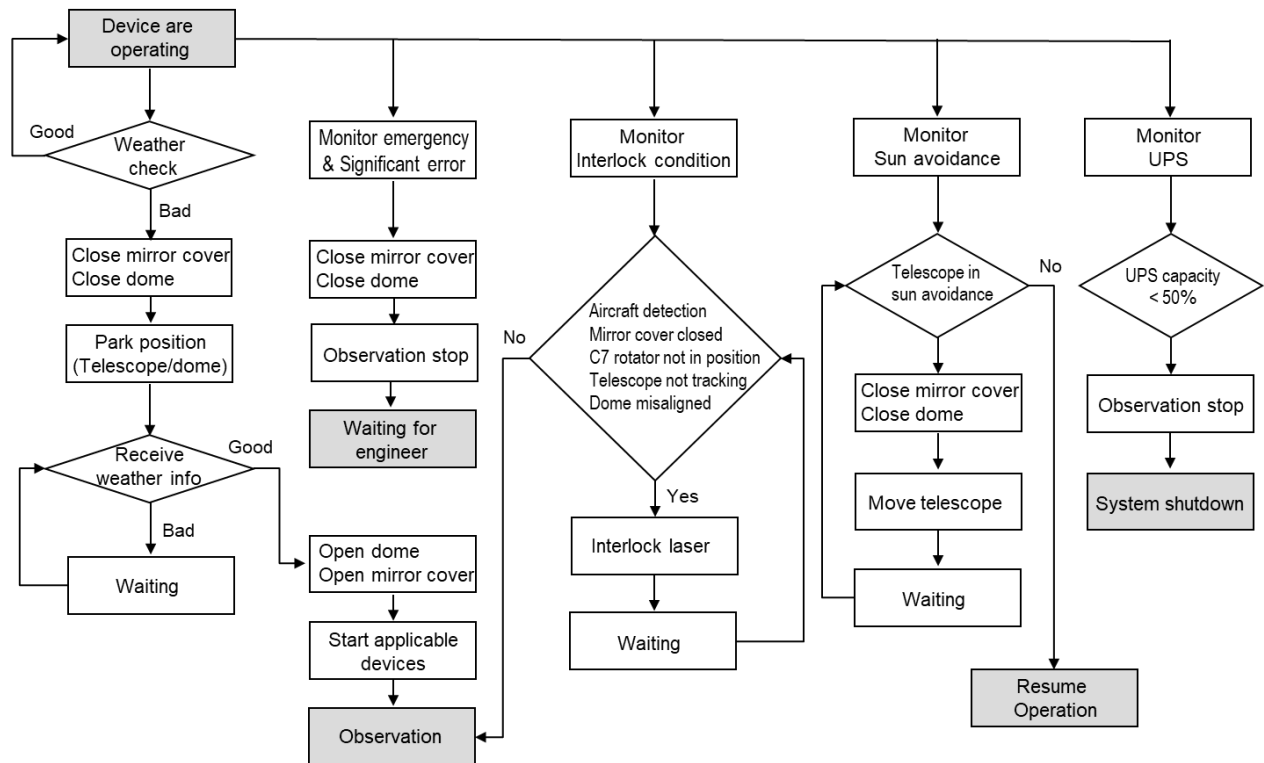


Figure 4. Exception situation for automatic operation

## **Summary**

KASI has established a new SLR station called Geochang station for the contribution of ILRS tracking network and support of Korean space missions. The Geochang system is capable of taking satellite images using adaptive optics as well as laser ranging, which is designed to be a fully automatic remote operation. The operation software was developed based on the client-server architecture which enables the automatic process more easily. For more secure automatic operation, weather monitoring and aircraft detection are conducted by the dual system. It is expected that the Geochang station plays an important role in Korean space missions as well as ILRS tracking network.

## **References**

Lim, H., Park, J., Kim, D., Seong, K., Ka, N., Laser Tracking Analysis of Space Debris using SOLT System at Mt. Gamak, J. of The Korean Society for Aeronautical and Space Sciences, Vol. 43, No. 9, pp. 830-837, 2015