The New Korean SLR System and its Automatic Operation

October 5, 2017

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Outline

1. Current Status of Korean SLR Station
2. Introduction to New SLR System
3. Sensors for Automated Operation
4. Operation Software for Automated Operation
Two Korean SLR Stations

- Seoul (Korean Capital)
- Daejeon (KASI HQ)
- Geochang Station
- Sejong Station

Sejong SLR Station (Aug 2015)

Geochang SLR Station (Nov 2017)
Sejong Core Station

- Composition
  - VLBI + GNSS + SLR

- VLBI and GNSS: NGII
  - Operated since March 2012
  - National Geographic Information Institute

- SLR: KASI
  - Operated since August 2015

- Radio Interference (VLBI, Radar)
  - Physical block by the building

**SLR**
- 40cm Rx and 10cm Tx telescope
- 5kHz repetition rate
- 2.5mJ/pulse and 50ps pulse width
- Aircraft detection using a radar

**VLBI**
- 22m Cassegrain antenna
- Rx frequency: 2, 8, 22 and 43GHz
- Pointing accuracy: 47.2 arcsec
- Hydrogen maser atomic clock
Characteristics of Geochang SLR System

- **Status and Plan**
  - Started from Jan. 2014 and now under the SAT (Site Acceptance Test)
  - Test operation for 3 months (Nov. 2017 ~ Jan. 2018)

- **Tracking Capability**
  - Capable of tracking satellites between 300km and 36,000km altitude
    - LEO, MEO and GEO satellites
  - Daytime and nighttime tracking
  - 60Hz laser ranging for satellites
    and 10Hz laser ranging for space debris
  - Satellite imaging using adaptive optics
    - Correction rate: > 30Hz
    - Deformable mirror: 97 channel

- **Ranging Accuracy Requirements**
  - Lageos: <10mm (SS), <3mm (NP)
  - Ground Calibration: <5mm (SS)

- **Operational Functions**
  - Fully automatic remote operation
  - Automatic ranging based on schedule and aircraft detection (radar and IR camera)
Layout of Optical Tables

- SLR/AO Lab
- AO Table
- DLT Lab
- Laser Beam
- Optical Beam
- Telescope pier

※ DLT : Debris Laser Tracking
System Configuration for SLR, AO and DLT

Using one OTA, tracking mount and operation system

**SLR/AO/DLT Lab**

- C7 Rotation Mirror in Pier

**AO Lab**

**DLT Lab**

- Laser, Tx/Rx Optics, Timing system

**SLR Lab**

- Laser, Tx/Rx Optics, Timing system

**Operation & Electric Room**

**Weather Station**

**Aircraft Detection Radar**
• T/R disk
  – T/R disk provides optical switch (transmit/receive)
  – Disk has mirror coating for receive with two coating holes for transmit
  – Coating holes are synchronized to laser fire so that pulses are transmitted

• Laser
  – Pulse energy: 15 mJ
  – Pulse width: 10 ps
  – Beam diameter: 10 mm

• Receiving box
  – Spatial & spectral filter
  – C-SPAD, CCD camera

• Beam Expander
  – Two beam expanders: x3.2, x7
Telescope & Dome

• Optical telescope
  – Clear aperture: 1000 mm (M1), 250 mm (M2)
  – Material: Clearceram Z-HS (M1), Zerodur (M2)
  – M1 reflectivity: 96%

• Focus mechanism
  – Automated focus mechanism with 10um accuracy
  – Two temp. sensors on truss maintain focus depending on temp.

• Tracking mount
  – Slew rate: 30 deg/s (Az), 20 deg/s (El)
  – Acceleration: 10 deg/s² (Az), 5 deg/s² (El)
  – Slew range: ±335 deg (Az), -5~185 deg (El)
  – Pointing and tracking accuracy: < 1 arcsec
  – Arc motor torque (continuous/peak): 976/3900 Nm

• Dome
  – Type: ash dome
  – Diameter: 8 meter
  – Slew rate & acceleration: 15 deg/s & 8 deg/s²
  – 4 windows to decrease the air turbulence for adaptive optics
Sensors for Weather Monitoring

METS Sensor
- Ambient temp.
- Sky temp.
- Dew point
- Wind direction
- Wind speed

Fullsky Camera
- Temperature
- Humidity
- Pressure
- Raining
- Visibility
- Wind direction
- Wind speed

Rain Sensor (for dome close)
- Temperature
- Humidity
- Pressure
- Raining
- Visibility
- Dew point
- Wind direction
- Wind speed

Cloud Sensor
- Ambient temp.
- Sky temp.
- Dew point
- Wind speed
- Humidity
- Moisture
- Brightness

Observatory Server
The laser fire is prohibited by the dual system, aircraft detection radar and IR camera in order to increase system reliability. The laser fire is paused when one of them detects an airplane.
Architecture of Operation Software
System Architecture for Automatic Process

Automatic Task Control
- Checking H/W status
- Setting HW configuration
- Checking safety interlocks
- Logging events and errors
- Tracking schedule
- Star calibration

Automatic Tracking
- Aircraft detection, weather
- Sun avoidance
- Return rate calculations
- Control of ranging window widths and offsets
- Satellite searching and signal acquisition

Automatic Processing
- Flattening signals
- Removing noise (Poisson, polynomial and amplitude filters)
- Generating residuals
- Generating CRD files (NP and Full-rate data)

Automatic Communication
- Downloading CPF files from ILRS data center
- Downloading TLE files from Space-Track
- Uploading CRD files on ILRS data center
- Data archive

Software Applications

Hardware and Infrastructure
General Observation for Automated Operation

System becomes ready

- All servers/clients are running
- Tracking schedule is ready

Weather state

- Rain, wind, humidity, dew point, cloud

Device state

- Laser chiller, Q switch
- Gimbal, radar, IR camera
- Coude camera, dome
- Delay generator, event timer
- Others

Emergency check

- Sun avoidance
- Rain from the dome server
- UPS capacity < 50%

Device setup

- Set the laser power level
- Set the C7 rotation mirror to be positioned
- Set the radar to slave/transmit mode
- Switch on aircraft detection IR camera
- Home the ND wheel
- Switch on laser

Operation STOP

Open dome

Open mirror cover

Operation START
Exception Situation for Automated Operation

Device are operating

Good

Weather check

Bad

Close mirror cover
Close dome

Park position (Telescope/dome)

Receive weather info

Good

Monitor emergency & Significant error

Bad

Close mirror cover
Close dome

Observation stop

Waiting for engineer

Start applicable devices

Open dome
Open mirror cover

Observation

Yes

Interlock laser

Waiting

Aircraft detection
Mirror cover closed
C7 rotator not in position
Telescope not tracking
Dome misaligned

Monitor Interlock condition

No

Move telescope

Waiting

Close mirror cover
Close dome

Yes

Observation stop

Waiting

Close dome

Monitor Sun avoidance

No

Open dome
Open mirror cover

Observation stop

Waiting

Close dome

System shutdown

UPS capacity < 50%

Resume Operation

Observer stop

UPS

Monitor

Good

Bad

Start applicable devices

Waiting for engineer
감사합니다

Gam-sa-ham-ni-da!