Concept for a new minimal SLR system

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The need for new SLR stations

ILRS stations (from: ILRS website)

Passes tracked per continent (Pearlman 2017)
More to come...

- More navigation satellites
- More Earth observation satellites
- Space Traffic Monitoring
- ...

### Satellite Information

<table>
<thead>
<tr>
<th>Satellite Name</th>
<th>Sponsor</th>
<th>Exp. Life Time</th>
<th>Purpose</th>
<th>Launch Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Astrocast</td>
<td>ETH Zurich and Astrocalt SA</td>
<td>1-2 yrs</td>
<td>Positioning information, precise orbit determination</td>
<td>November 15 to November 21, 2018</td>
</tr>
<tr>
<td>COSMIC-2</td>
<td>UCAR</td>
<td>5 yrs</td>
<td>Atmospheric research, validation of GNSS orbits</td>
<td>NET June 13, 2018</td>
</tr>
<tr>
<td>HY-2B</td>
<td>CNES, CNSA</td>
<td></td>
<td>Earth observation</td>
<td>October 25, 2015</td>
</tr>
<tr>
<td>ICESat-2</td>
<td>NASA</td>
<td></td>
<td>Ice-sheet elevation change, sea-ice focesed, and vegetation canopy hight</td>
<td>September 15, 2016</td>
</tr>
<tr>
<td>Lightsat-2</td>
<td>The Planetary Society</td>
<td>30 days</td>
<td>Orbit determination</td>
<td>NET June 13, 2018</td>
</tr>
<tr>
<td>NISAR</td>
<td>NASA/JPL, ISRO</td>
<td>3 yrs</td>
<td>Earth observation</td>
<td>2020</td>
</tr>
<tr>
<td>PN-1B, 1C, 1D</td>
<td>Beijing Aerospace Control Center</td>
<td>1 yr</td>
<td>Precise orbit determination</td>
<td>Sep-2015</td>
</tr>
<tr>
<td>RANGE</td>
<td>Georgia Institute of Technology</td>
<td>1 yr</td>
<td>Positioning information, precise orbit determination</td>
<td>Jul/Aug 2018</td>
</tr>
</tbody>
</table>

### Future Satellites

<table>
<thead>
<tr>
<th>Future Satellites with Retroreflectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS-III  (m=977)</td>
</tr>
<tr>
<td>GRASP</td>
</tr>
<tr>
<td>HY-2C</td>
</tr>
<tr>
<td>HY-2D</td>
</tr>
<tr>
<td>IRS-PS (CARTOSAT-1)</td>
</tr>
<tr>
<td>Sentinel-6</td>
</tr>
<tr>
<td>SWOT</td>
</tr>
</tbody>
</table>

### Number of SLR missions (Data: ILRS website)
Minimal SLR - Design goals

• Minimal…
  • Small
  • Inexpensive
  • Few components (COTS where possible)
  • Modular
  • Easy to maintain
  • Eye-safe?

• …yet powerful
  • From LEO up to GNSS orbits
  • 1 cm NP accuracy
  • Day and night ranging
  • Automated operation

Make it as simple as possible – but not simpler
A unified minimal SLR system – open source

• Together…
  • Share efforts in development
  • Share experiences in operation
  • Share software and hardware designs

• …and alone
  • Funded and built by individual agency
  • Operated locally
  • Enhancements / modifications encouraged

Arduino Uno R3
(From: Wikimedia / user “Clic17”)

SatNOGS

White Rabbit time-synchronisation
(Image from: Sevensolutions)

Linux
OOOS: Orbital Objects Observation Software

- Supports full SLR operation
- Modular hardware layer

Released as open source (GPL v3)

See also: spacedebris.dlr.de/0OOS_software
Uhlandshöhe SLR station

- Location: Historic observatory in Stuttgart, Germany
- First returns 2016
- ILRS Engineering station since 2017

- Specs:
  - 100 kHz repetition rate
  - 50 µJ pulse energy
  - 42 cm receiver telescope
  - 10 cm transmitter
  - Fibre coupling
  - Ranging at 1064 nm
100 kHz laser ranging

• Why?
  • Low pulse energy (50 µJ)
  • Long pulses (~10 ns)

• How?
  • Burst mode pulse collision avoidance
  • Fast event timer
  • Multithreading

• Results?
  • Ranging up to GNSS targets
  • NP scatter ~ 1 cm

See also: D. Hampf et al: Satellite Laser Ranging at 100 kHz repetition rate (submitted to CEAS space journal)
100 kHz laser ranging: Results
100 kHz laser ranging: Results

- Swarm B: NP Dur. 5 s, Points per NP 20k – 40k
- Explorer 27: NP Dur. 15 s, Points per NP 100k
- Larets: NP Dur. 30 s, Points per NP > 100k
- Lageos: NP Dur. 120 s, Points per NP 10k – 20k
- GNSS: NP Dur. 300 s, Points per NP 1k-2k
miniSLR

- Complete SLR system “in-a-box”
- Transportable
- Fully automated
- Sealed and air-conditioned
- Easy maintenance

<table>
<thead>
<tr>
<th></th>
<th>UFO</th>
<th>miniSLR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy</strong></td>
<td>50</td>
<td>200</td>
</tr>
<tr>
<td><strong>Divergence</strong></td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td><strong>Aperture</strong></td>
<td>42</td>
<td>20</td>
</tr>
<tr>
<td><strong>Photons / Puls</strong></td>
<td>0.02</td>
<td>0.08</td>
</tr>
<tr>
<td><strong>Rep-Rate</strong></td>
<td>100</td>
<td>30</td>
</tr>
<tr>
<td><strong>Return-Rate</strong></td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Link budget Lageos @ 7000km
Summary

• New technology opens up interesting new possibilities for SLR (fibre coupling, 100 kHz, …)
• Open source software and hardware foster cooperation
• Let's build a minimal SLR station!

We invite for collaboration!