Session 2
Improving current station performance

Poster Presentations

ILRS Technical Workshop 2019
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System Survey

Question

What do we mean if we talk about

- Automated station?
- Highly automated stations?
- Stations with high automation level?
- Autonomous station?

Problem

- More precise definition would allow
  - Comparison of different stations and system designs
  - Discussion of goals for the update or upgrade of existing stations
  - Discussion with institutes interested in new stations (and automation)
  - Discussion and negotiations with national regulation authorities with respect to in-sky laser safety

- Basic problem
  - Many tasks are in general only loosely coupled
  - Automation is done task by task
  - Maturity, stability and robustness of an automated procedure/task or sub-task can vary largely between stations
  - Stations have different priorities for the order tasks are automated
  - Must reflect the variety of solutions within the existing ILRS network

Classification system

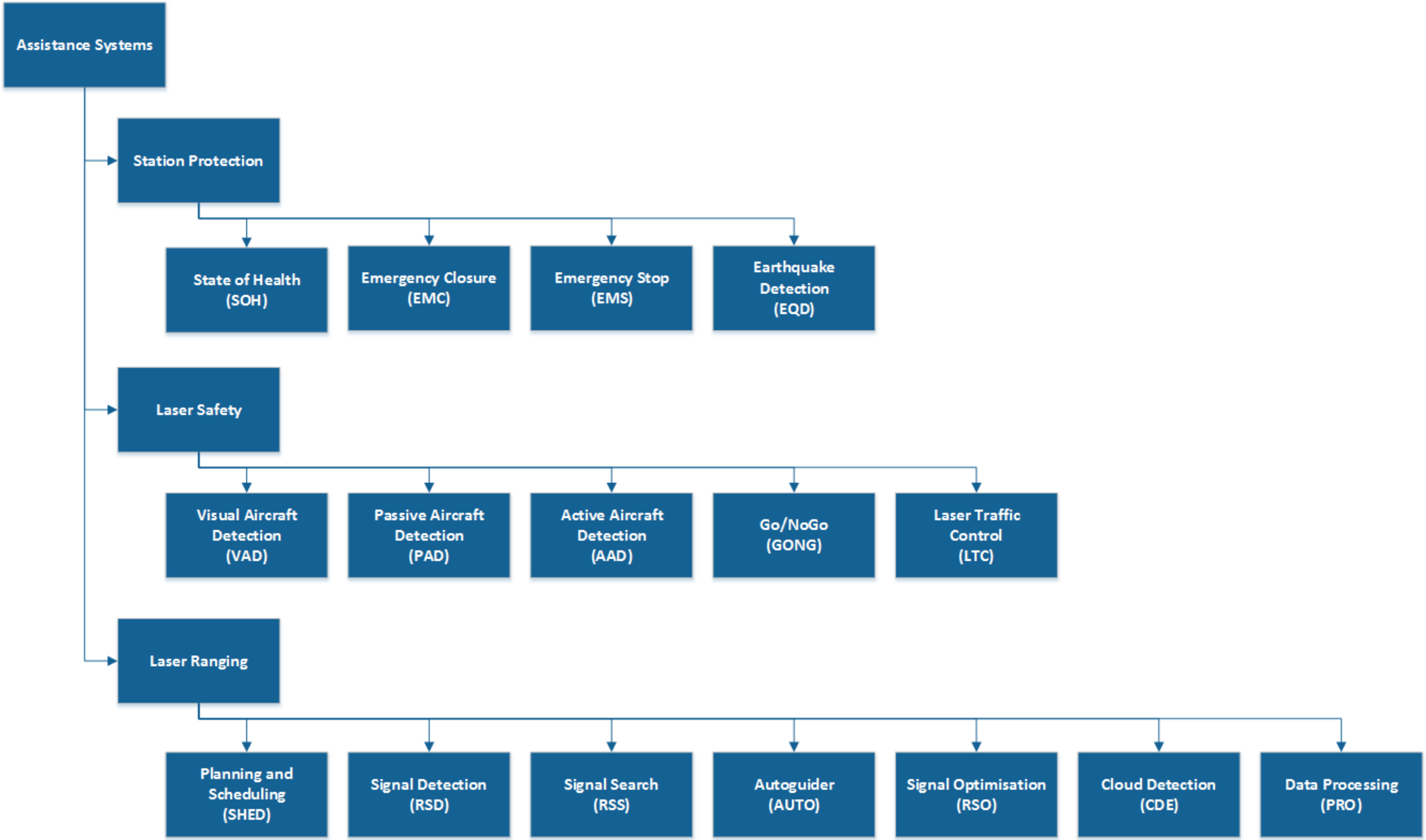
- Classification system for self-driving cars
  - Published in 2014 by SAE International as J3016, *Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems*
  - Adapted by several countries
  - Level of required intervention and attentiveness by an driver
  - Six different levels
  - Assistance systems like ABS, ESP, Lane Assist each with different levels of maturity e.g. provides only warnings, visual guidance or full automation

- Comparison to SLR
  - Operator driven
  - Complex system
  - Interaction with environment
  - Safety aspects
  - Assistance systems like signal hold, gate center, emergency dome closure …

Levels of automation

Level	Name	Definition	Task Execution	Fallback
Operator monitors the system				
0	No Automation	Full time command & control by human operator for all task, system may provide visual or acoustic warnings	Operator	Operator
1	Operator Assistance ("hands on")	Operator and system share control. Some sub-tasks like signal search or aircraft avoidance are performed by assistance systems. The operator must be ready to retake full control at any time.	Operator & System	Operator
2	Partial Automation ("hands off")	The system is capable to perform the complete tasks required for tracking a satellite from start to finish on its own using a combination of assistance systems. The operator is still required to actively monitor the system and to intervene if the system fails to response properly.	System & Operator	Operator
System monitors itself				
3	Conditional Automation ("eyes off")	The system is capable to operate on its own for several hours under specific conditions like for example periods with clear sky during night. The operator doesn't need to monitor the system permanently but must intervene within a certain time frame if the system requires attention.	System	Operator
4	Full Automation ("mind off")	The system controls all aspects of the station.	System	System

Assistance systems



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An SLR Receiver to discriminate single- from multiphoton events

S. Häusler, J. J. Eckl, J. Kölbl[1]

In Satellite Laser Ranging the distance to satellites is determined by laser pulse time-of-flight measurements. To minimize systematic errors in the measurements usually time-correlated single photon counting is applied. This method provides a high dynamic range as long as the signal is kept at the single photon level. Higher signal levels introduce systematic errors. Assuming a Poisson distributed signal, which is valid for a coherent light source such as a laser, the single photon level can be reached at a detection rate of below 10 percent. In Satellite Laser Ranging, however, laser pulses are sent through the turbulent atmosphere. This leads to speckle formation at the satellite and at the ground side. Speckle causes the photon statistics to change to that of thermal light. Therefore it is not ensured to stay at the single photon level during Satellite Laser Ranging measurements at a detection rate up to 10 percent. To investigate the effects caused by the turbulent atmosphere on the photon statistics in more detail we build a photon number sensitive receiver. The receiver allows to discriminate single- from multi-photon events. We want to give an overview of the technical details of this receiver.

[1]*TH Deggendorf, Germany*

Upgrade Hardware & Software Golosiiv Station 1824

M. Medvedsky[1], D. Sovgut[2]

Over the past two years, software and hardware have been updated at the 1824 Golosiiv-Kyiv station. The A033 event timer has been installed. The time gate generator has been designed, assembled and implemented. The weather service has been manufactured and installed, and the calibration process has been automated.

Software was developed for the aforementioned equipment, and software for downloading ephemerides was upgraded.

The station management system uses 5 PCs connected to the LAN. All PCs run under Windows.

[1]*Main astronomical observatory of NAS of Ukraine, Kyiv, Ukraine*

[2]*University of Illinois Urbana-Champaign, Urbana-Champaign, USA*

Raspberry Pi based laser beam profiler

T. Mourlon[1], J. del Pino[2], K. Salmins[2], J. Kaulins[2]

In order to carry out the sporadic control of the SLR laser beam profile, we developed a low-cost beam profiler solution using a single board computer (Raspberry Pi) with the associated software written in Python.

We present information about the hardware, the software and some examples of experimental results.

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[2]Institute of Astronomy, University of Latvia, Riga, Latvia

Processing of Satellite Laser Ranging data to GNSS satellites at IGiG WUELS

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Satellite Laser Ranging (SLR) is a precise geodetic technique that provides range measurements to artificial satellites equipped with laser retroreflectors. The International Laser Ranging Service (ILRS) unites and coordinates all laser stations and their activities in terms of tracking satellites. Due to the fact that almost all the Global Navigation Satellite System (GNSS) satellites are equipped with the laser retroreflector arrays, SLR measurements are performed with cm-accuracy. As a result, the SLR technique can be used for the validation of GNSS-derived products as well as for the independent GNSS orbit determination.

SLR serves as an independent validation technique for the GNSS-derived orbits due to the fact that SLR uses optical wavelengths in contrast to GNSS which is based on the microwave observations. Since March 2017, a new Associated Analysis Center (AAC) of the ILRS has been established at the Wroclaw University of Environmental and Life Science (WUELS) who runs an online platform GOVUS for the SLR validation of microwave-based orbit products. The web-service GOVUS allows the users to perform fast and advanced online analyses on the stored SLR validation results which are calculated automatically.

Apart from the independent validation tool, SLR solely may serve for the determination of the GNSS satellite orbits. We calculated the boundary conditions for the precise Galileo orbit determination using at least 60 SLR observations provided by 10 homogenously distributed SLR stations within 5 days. Based on solely SLR data we obtained Galileo orbits with the accuracy at the level of 4 cm.

The SLR constitutes a valuable tool for both the accuracy assessment as well as an independent orbit product provider. Based on the two techniques, SLR and GNSS microwave, it is possible to provide the combination of two types of observations whose preliminary results will be shown in this contribution.

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San Fernando laser station updates and new improvements

M. Sánchez[1], M. Catalan[1], M. Larrán[1], F. della Prugna[1, 2], Á. Vera[1],
J. Marín[1], J. Relinque[1]

The laser station of the Royal Observatory of the Spanish Navy has been working on artificial satellite tracking since early 1980s. Nowadays, these observations serve a dual purpose. First, our tracking data on active artificial satellites contribute to the International Laser Ranging Service (ILRS) in order to improve the definition of their orbits, and to define the International Terrestrial Reference Frame (ITRF). Besides, this activity is complemented by space debris tracking.

Regarding the second mission, the number of non-collaborative objects has increased rapidly, particularly in LEO where the probability of collision can reach an alarming level in next few years because of the gradually increases of the number of space debris generated compared to the number of objects extracted because of atmospheric friction. This situation poses a risk for manned and unmanned space missions, with devastating consequences in some cases.

In order to participate in this demanding type of activity it has led to severe modifications and technical developments at the station in order to obtain echoes on this type of objects, some of them with low reflectivity, moving at speeds of several kilometers per second and distances of thousands of kilometers.

These modifications has led to the incorporation of a new laser almost 100 times more powerful than the previous one, to develop an air safety system, or to include new optical and electronic components that improves the signal-to-noise ratio.

Besides that, a new laser bench is nowadays operative. This new laser (30 ps pulse width) transmits 50 mJ per pulses, and it is in charge of the 'leitmotiv' that justifies the appearance of this technique at ROA, that is tracking active collaborative satellites. In this poster we will show the sate-of-the-art of San Fernando station, and we will provide details regarding all these improvements and last figures on echoes and trackings.

[1]*Royal Observatory of the Spanish Navy*

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The performance of 1m Aperture SLR Telescope in Wuhan JiuFeng SLR station

J. Zhang[1]

The first SLR ranging data was obtained on September 29, 2018 at WUHAN JFNG SLR station, and the 1m Aperture SLR system can range all SLR satellites listed on ILRS website now. The pointing accuracy of the telescope is less than 2 arc second after correction with pointing model, and the tracking accuracy of servo controlling system is less than 0.3 arc second (RMS value of O-C). The accuracy of single target calibration is less than 8mm, and the single ranging accuracy of Lageos satellite is less than 12mm. The normal point data and full rate data are uploaded to EUROLAS Data Center (EDC) from July 3, 2019, and more than 500 passes has been uploaded until now.

[1]*Institute of Geodesy and Geophysics, CAS*

Continuous Sky Clarity monitoring at Riga and Metsähovi: January 2018 - June 2019

J. del Pino[1], A. Raja-Halli[2], K. Salmins[1], J. Naranen[2]

Following the preliminary test presented at the ILRS Technical workshop in Riga, October 2017, we started the permanent sky clarity -cloud cover level- monitoring at both the SLR stations Riga and Metsähovi.

Both stations are separated by 364 km., about 50% of the chord is over the Baltic Sea. The purpose is not only to identify and quantify the seasonal cloud cover trends in both stations, but also to evaluate the simultaneous cloud cover conditions and how it will influence on the realization of future joint observations, particularly of space debris.

We present the results of the first 18 months of systematic data (>95% of the possible data for individual stations and >91% of the possible simultaneous data), discuss the trends and present recommendations.

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Accuracy of Single Measurements in a Laser Location

Ignatenko I.Yu.[1], Tryapitsyn V.N.[2], Ignatenko Yu.V.[2], Tryapitsyna V.V.[3], Tryapitsyna E.V.[3]

In this paper, the determination of the accuracy of single measurements in a laser location of a satellite is considered. Various accuracy estimates for measurement and calibration are investigated. The influence of systemic and geometric errors caused by existing optical schemes of measuring systems and the design of satellite and reflective elements on them is studied. The time diagram of events at a laser location is considered. The geometrical, temporal and instrumental errors, as well as the electronic, geometrical and optical time delays arising during the laser location of existing satellites are investigated. The application of a new optical scheme for laser-location measurements and internal calibration is considered. The displacement of the calibration angle to the point of intersection of the optical axes of the telescope is considered. Error estimates are given for various types of satellites and their orbits. The most suitable reflector designs for satellites for improving the accuracy of single measurements are proposed. The question of the feasibility of developing new reflectors and their placement on the moon and Earth orbit is being studied. A mode of organizing measurements is proposed to increase their accuracy. We consider the joint work of laser location stations SLR 1874, the old and new laser stations in Mendeleevo to control the results and find the difference in the course of two time and frequency standards. We consider a method for comparing two nearby stations of a laser station in Mendeleevo, designed to determine the quality of measuring devices and their accuracy. The question of the applicability of this methodology to other nearby measuring installations is being investigated.

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[2]Crimean Astrophysical Observatory, p. Katsiveli, Republic of Crimea, Russia

[3]Saint-Petersburg State University, St. Petersburg, Russia

An array of compact cheap CCRs for high-elliptical navigation spacecraft

A. Sokolov, V. Murashkin, V. Vasiliev, A. Akentiev

This paper covers the results of the calculation and modeling of the CCR array for high-elliptical spacecraft orbiting at middle altitudes of about 36 000 km. The analysis shows that the CCR optimal aperture lies within the range of 12 mm, while the CCR mass is 2.3 g, and the manufacturing accuracy of dihedral angles is low, approximately 1-2 ang.sec. The corresponding FFDP broadening is not critical provided, that the velocity aberration angle is 4 ang.sec. Modern laser stations (like "Tochka") allow to get a suitable response signal from the array located at the altitude, with the cross section of 200 million sq.m. To achieve the given cross section it is enough to use the array with 2,000 CCRs and the mass of the construction of no greater than 6 kg.

All Sky Camera Concept

E. Günther[1], S. Bauer[2]

To optimize manual and autonomous tracking operation under various sky conditions, it is necessary to monitor these conditions. Available commercial off-the-shelf all-sky cameras are often optimized for night time usage which makes daytime use difficult or even requires a second camera optimized for day time.

Having a single all-sky camera provides economic benefits and a simplified design. For cloud detection at day time a color camera is extremely beneficial, but such cameras often cause problems at night, due to high image noise.

We present a concept for an all-sky camera build from a commercial off-the-shelf analogue color camera with a night mode. The camera is placed within an aluminum housing equipped with heaters to remove dew and raindrops from the copula and to keep the camera in the operational temperature range. In order to process the sensor data, a microcontroller within the housing is used. Furthermore, an adaptive camera image stacking algorithm is implemented to address the high image noise in night mode.

[1]DiGOS Potsdam GmbH

[2]Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum GFZ

Mount model of 1.2m telescope at Kunming station

R. Li[1]

Mount model is important for a telescope, especially in autonomous application. The 1.2m telescope at Kunming station is an Alt-Az mount telescope, with coude optics path and a bind night track sub-system. Using a sCMOS mounted in the end of coude optics path, in which the field of view is rotating, we achieved the pointing accuracy about 1 arc second. The mount model consists of fundamental terms (like encoder offset, collimation, tube flexure, etc), and spheric harmonic terms determined by residual analysis.

[1]*Yunnan Observatories, Chinese Academy of Sciences*

Status of the NASA SGSLR Subsystem Development

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The NASA Space Geodesy Satellite Laser Ranging (SGSLR) system continues to be developed and built at the Goddard Space Flight Center in Greenbelt, MD, USA. During 2019, significant progress has been made on each of the SGSLR subsystems and several are undergoing subsystem level testing. The system software, which is integrated with the tested Time and Frequency subsystem and components of the Meteorological Subsystem, is currently under development in the SGSLR Software Laboratory facility at the Goddard Geophysical Astronomical Observatory (GGAO). Construction of the SGSLR GGAO shelter began in March and the installation of the Observatory dome was completed in May. While the SGSLR telescope build is ongoing, the Gimbal and telescope mass simulator were installed in the shelter in September for more intensive testing. The Laser is undergoing characterization testing, while the Laser Safety and Optical Bench Subsystems are being built. The Receiver Subsystem, which enables system automation and is essential to meeting the ITRF requirement, continues to be developed and is currently in high level subsystem testing and data analysis. This poster will show the status of the development each of the SGSLR subsystems.

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[2] NASA Goddard Spaceflight Center, Greenbelt, MD USA

[3] Hexagon US Federal (Sigma Space Corporation), Greenbelt, MD USA