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Current status of automation of the SLR-systems at the Geodetic Observatory Wettzell

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Abstract. *The Geodetic Observatory Wettzell operates two laser ranging systems: the newer Satellite Observing System Wettzell (SOSW) and the Wettzell Laser Ranging System (WLRS), which was installed in the early 1990th. Both systems are controlled by one operator to run both systems with the existing staff. To decrease the number of duties of an operator, keeping both systems tracking in parallel while optimizing the data production, a new project was started to resume the implementation of system automation again. The automation should be increased in several phases, while the final goal is a completely autonomous system. The design consists of three pillars: the (Laser) Safety System, the System Monitoring, and the System Scheduling and Control. All three run independently. The Safety System implements all safety, interlock, and emergency features. The System Monitoring collects and presents system status parameters. Finally, the System Scheduling and Control plans and operates the autonomous observations. It interacts with individual control software using the middleware "idl2rpc.pl" to command the hardware.*

Introduction

The Wettzell observatory operates two laser ranging systems: the Wettzell Laser Ranging System (WLRS) and the Satellite Observing System Wettzell (SOSW). Both are fully operative. This increases the possible number of observations of satellites and supports special research tasks or missions on the one hand. On the other hand, it requires a suitable operation mode to run both telescopes with the existing staff.

Automation is here a key feature. But laser ranging systems have to deal much more with critical circumstances. Human safety is an essential aspect, because the laser is not eye-safe over a long distance along its path to its target. Safety systems must protect humans independently on ground and even in airplanes in the air.

Another aspect is that current systems always require human interactions based on individual experiences. To support autonomous activities, much more parameters must be collected, evaluated and used. Metrics allow the conversion of qualitative experiences of individual operators to quantitative counts generally used by an autonomous system to make decisions for the next steps. The foundation is an efficient system monitoring.

Finally, the heart of autonomous laser ranging is scheduling and controlling. Scheduling is the selection of future targets and settings according to a currently given situation. The controller of the laser ranging system just follows this schedule and commands subordinated hardware. Collected system parameters are used as feedback for internal state machines deriving the next direction on possible paths through predefined state charts.

Thus, automation can be split into three pillars of work packages: the safety system, the system monitoring, and the observation scheduling and control (see fig. 1). The new automation project at the Wettzell observatory uses this idea to implement a suitable operation mode for its laser ranging systems.

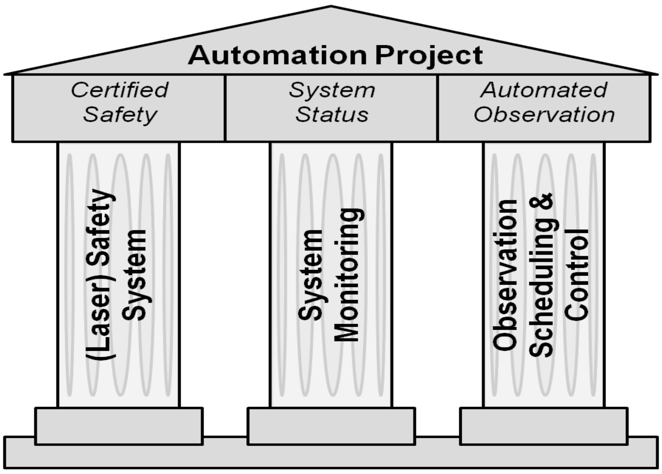

Figure 1. The three pillars of the Wettzell automation project.

Safety System

The first pillar of the design focuses on human and system safety. Human safety is the protection of people from risks of injury or bodily harm with fatal consequences, like death. Humans must be protected from moving or rotating components, from electrical dangers, or in cases of laser ranging systems from contact with destructive laser beams. System safety is the protection of the machine itself from destructive, cost-intensive influences, provoked by its operations, faulty operations, or external issues, like weather conditions.

Especially human safety for laser ranging systems is a serious aspect because used laser beams of laser class 4 are not eye-safe over long distances. The path of the laser is locally not limited and passes the free atmosphere on the way to its target and back. Thus, human safety has two aspects in this context:

- in-air safety to protect people from harmful laser contact in airplanes, balloons, or under parachutes or paragliders,
- on-ground safety to protect operators working with the laser system on ground or visitors getting in contact with reflections close to the sending equipment and around the observatory

While most of the risks on ground can be avoided or reduced with technical measures like containments, or protection systems, or with organizational procedures, personal protective equipment or at least special trainings, in-air safety is the most difficult aspect. It is one of the causes, why automation of laser ranging systems lacks behind technical possibilities used in other fields.

European and German law defines strict regulations for systems operated in a similar context. In this sense, laser ranging systems are machines. Their construction and use must follow the EC Machinery Directive [EU2006]. Developers and operating companies of such machines must use EC-conform equipment or must declare the conformity to this machinery directive, if they want legal certainty. In principle, this is the identification and avoidance of risks involving the degree of harm when failing, the exposure time, the occurrence probability, and the possibilities of avoidance.

Because human safety has so many critical scenarios and requires a detailed knowledge of technical and legal requirements, all primary components for the (laser) safety system are from certified companies. A primary radar coating the laser beam is used as such a primary in-air protection system. It might be replaced by a LIDAR-system in the future. Secondary components support these primary systems and follow a specific development and change management at the Wettzell observatory. The Wettzell system uses real-time data from the air traffic control DFS in combination with live data from the Automatic Dependent Surveillance-Broadcast (ADS-B) sent by each air carrier. The position information smoothed by a Kalman filter is used to automatically identify protection zones around the airplanes. The whole system is supported by an optical camera system with image processing software which is also used to cross-verify the other systems [Leidig2016].

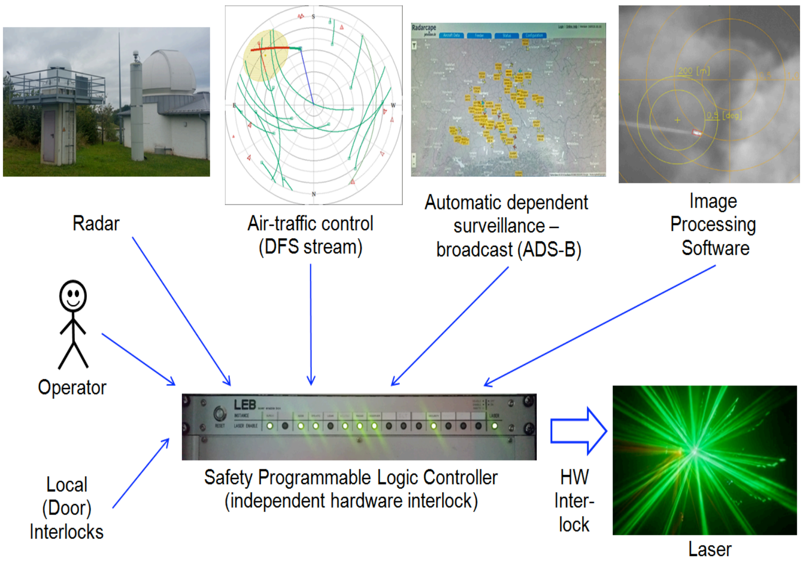

Figure 2. A schematic sketch of the primary and secondary in-air and on-ground safety interlocks.

Together with the ground-based safety systems, like door interlocks or emergency buttons, all safety systems mainly are hardware systems producing hardware interlock signals (see fig. 2). The signals can be processed with storage-programmable logic controllers certified for safety tasks or with elementary electronics controlling an electro-mechanic shutter. A single positive detection of an interlock is enough to interrupt the sending of the laser. The complete collaboration of all systems is currently in the evaluation and conformity check for the required CE-conformity, commissioned to a specialized, external company.

Having a successfully working, modern, technically stable, tested, and legally compliant safety system is the foundation for a safe system, which independently protects operators and people in its circle of influence. It is a must for automated tasks.

System Monitoring

Another essential requirement for automation is to always know all system-relevant parameters. This is guaranteed by a sophisticated monitoring system, like the Wettzell System Monitoring suite (SysMon) (see [Neidhardt2016]). It consists of data suppliers, data collectors and central analyzing and presentation tools.

An essential component of the SysMon ([Ettl2010]) is the local data nodes, which collect data and make them available. Data collected are used for system operations, diagnostics, science, and analysis. Each sensor node contains a data storage system using the Data Base Management Systems (DBMS) PostgreSQL. It holds the short-term and current data sets. Monitoring data are kept for a few months to be presented using suitable plots. These are generated with ZABBIX running a web service [Zabbix2017]. ZABBIX is an open-source monitoring system which offers all capabilities to present and interact with monitoring data. A parallel file system server completes a hybrid storage design. The file system contains historic and long-term data.

SysMon offers a general application interface to interact with all software components, data bases, presentation layers, and data selectors. The sensor node uses this interface to collect monitoring data from hardware connected. Each of these counts can be configured with a configuration file. It is used by the SysMon program “sysmon_senderc” to register counts or monitoring items, to feed in according monitoring values, and to manage the items. Calling "sysmon_senderc -R test.conf" uses the definitions in the configuration file “test.conf” to register relevant details of a sensor, like sensor identification number, sensor name, unit, manufacturer, limits, alert levels, and so on. The registration creates the database tables, prepares the file directories and produces a template file, which can be imported to ZABBIX creating graphs, triggers, and data injectors for the defined items.

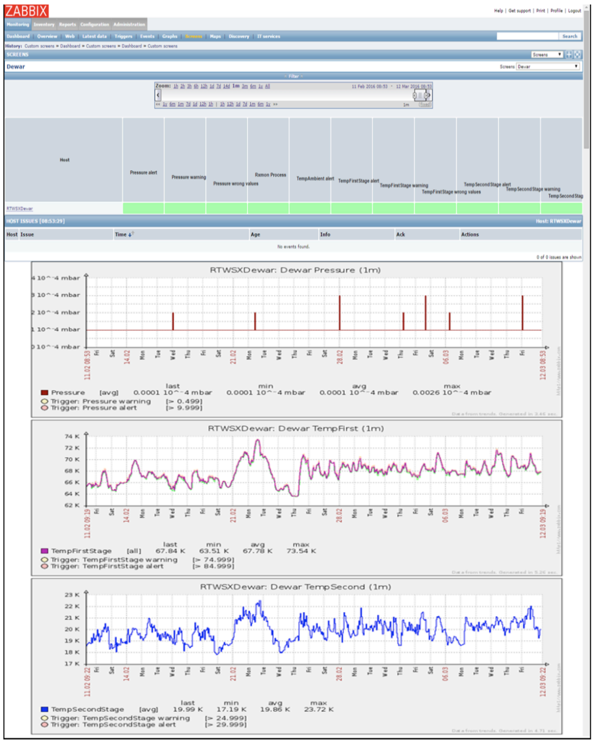

Figure 3. The web page showing monitoring data of the cryo-system in the Wettzell 20m radio telescope

"sysmon_senderc" is also used to inject single counts or tables of counts from individual sensors to the data storage of the sensor node. Single values can be injected by entering them as program arguments ("sysmon_senderc -s test.conf TestID1 200.0 1", where "TestID1" is the sensor identification, "200.0" is the value and "1" is an additional trigger for alert levels). Tables of values can be read from a file and injected in one step ("sysmon_senderc -f test.conf datafile.txt", where "datafile.txt" contains a table of sensor inputs with the same structure like the program arguments).

After importing the template file to ZABBIX, data can be directly presented via a web browser using a web server on the sensor node (see Fig. 3). ZABBIX is a sophisticated monitoring tool, so that zooming into the timeline of data plots, extended sensor maps, alert pages, or individual plots are possible.

Even if the Wettzell SysMon suite is specially designed for the Wettzell observatory, it is interoperable to all other monitoring systems. SysMon data injectors can be programs, scripts, or other code snippets. They can take data from hardware sensors or even from other monitoring systems. Either the application interface or the program “sysmon_senderc” can be used to integrate such interoperability.

The nodes are combined to hierarchy levels, so that values from nodes on lower levels propagate their data to higher levels. This enables a centralization of the monitoring to get an overview about a complete observatory. Having such centralized archives and reporting systems, a central failure and error management becomes possible. First experiences at the Wettzell observatory are made to send text messages to mobile phones or to call regular phones with automated text-to-speech functionalities.

A mini-PC with Voyage-Linux is used to run the open-source software "Asterisk", which can be used to automatically make phone calls. Trigger alert represent critical limits and send text messages to the mini-PC. The text messages are converted to audio files, and phone calls are provoked to contact the responsible operator. He can then use remote access methods to check the observing system [Neidhardt2016].

Observation Scheduling and Control

The third pillar of the Wettzell automation project is the observation scheduling and control (see fig. 4). Scheduling is the planning of next or future observations, defining according main tasks. Control is the commanding of the hardware following the schedule and dealing with feedback and information from the hardware. Currently, the controller is under implementation and first tests were made. The scheduler is in the planning phase.

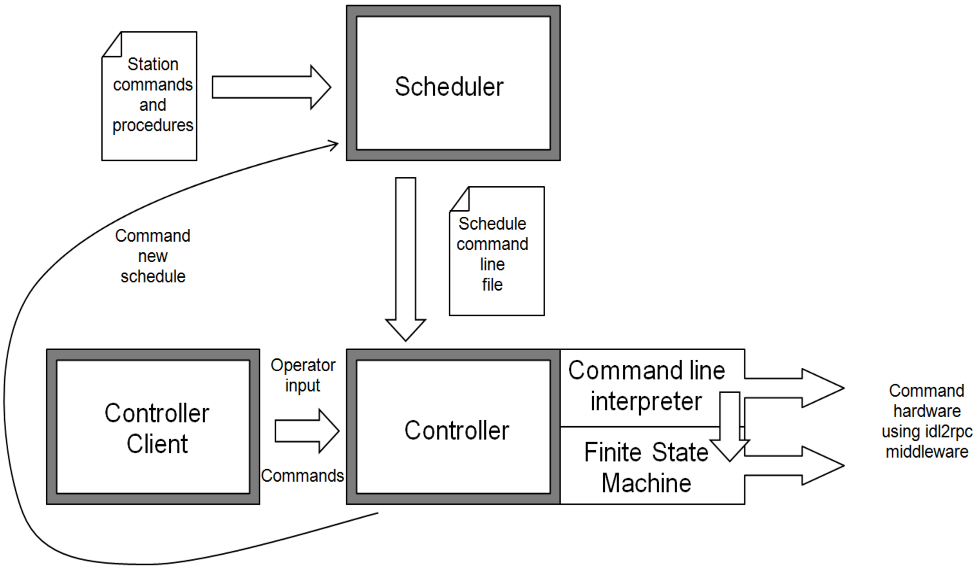

Figure 4. Scheme of the scheduling and controlling of SLR observations.

The scheduler uses predefined station commands and procedures for the main tasks and a suitable planning evaluation metrics. The metrics defines parameters to quantize priorities for the selection of a new satellite observation. Rise, transit, and set times, single priorities, number of required returns, safety parameters, cloud coverage, meteorology, interleaving times, sky coverage, and so on might be parameters, which can be introduced. The result of a scheduling run is a text file with a sequence of instructions used to control the hardware. The file is sent to the controller. Scheduling runs can be started regularly to generate static a-priory plans for the next time period. The control is interrupted after each of these time slices to continue with the new orders. More dynamics can be created if the controller uses an end criterion which defines the values finishing a current observation. The controller triggers the scheduler to produce a new schedule for the next a-priory period. Most flexibility can be reached if the controller uses several end and interleaving criteria to trigger a scheduler run in real-time according to the given observation situation identified by combinations of limits of metrics counts. This enables a dynamic, real-time observation.

The controller follows the instructions line-by-line. Instructions can trigger synchronous or asynchronous activities of connected hardware and just propagate to the hardware, where they are processed. They can also command controller tasks or set parameters for the control loop, so that the controller processes them. Finally, they start combined functionalities of hardware and control activities, which follow a predefined state machine in the controller to do an observation or a calibration. The hardware and the controller use a standardized middleware “idl2rpc.pl” for their communication, which was designed at the Wettzell observatory to simplify the communication tasks. Interactions with the operator follow the same technique. The operator enters commands which are then processed by the controller like commands from the schedule file.

Conclusion and outlook

First integration test are promising. The advantage of this approach is that it is similar to the work flow of VLBI observations, so that one schedule file might be used to command VLBI and SLR telescopes for common, co-location observations in the future.

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