One-Stop-Lab CENAGIS: from calibration of surveying devices and application testing to large-scale geodata computation

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SUMMARY

As a part of the CENAGIS project (Centre for Spatial and Satellite Analyses) conducted at the Warsaw University of Technology, several unique, interconnected laboratories have been designed to enable testing, calibration, and accuracy assessment of various surveying devices and sensors (e.g., cameras, laser scanning systems, rangefinders, GNSS receivers) as well as testing of positioning systems (outdoor/indoor) and navigation applications. In particular, the laboratories enable the testing of Mobile Mapping System solutions. Additionally, laboratories are connected to the Center's geo-cyber infrastructure (cloud solution), which allows for efficient big data processing and computations, especially with artificial intelligence methods.
The laboratories are equipped with the calibration test fields located inside and outside the centre building, namely a photogrammetric calibration field for evaluation of mobile and static laser scanners, a calibration field for UAVs, a 250-meter base for testing rangefinders, and a test field for indoor positioning systems (using Wi-Fi, BLE beacons, UWB technologies). Thanks to this innovative application, it is possible to evaluate the tested devices comprehensively.
The laboratories offer, among others, an industrial laser interferometer (Laser Tracer) for high-precision 3D measurements (API), enabling real-time point positioning with an accuracy of 10 mm + 5 mm/m and tracking objects in motion with a measurement frequency of 1000 points per second, Bosch-Rexroth Linear Rail Systems for the linear and non-linear motion of objects on the measurement base at 5 m/s, the test field for the calibration of optical measurement sensors according to VDI/VDE standards and a top-class satellite simulator/generator Spirent (GNSS 9000). Another important component are VR/AR devices that commonly applied in the navigation application testing lab, namely, Microsoft HoloLens, HTC Vive Pro Eye, and Vuzix M400.
The main idea of the CENAGIS was to create a place where surveyors and developers of various geodetic measurement systems could carry out comprehensive research and development work as possible in one place - from instrument inspection to application testing to advanced data processing using two computer clusters (MERCATOR and ROMER). Thus, this solution can be described as One-Stop-Lab, mainly for geodetic R&D teams. This paper presents the idea of a One-Stop-Lab CENAGIS centre and describes selected features of the research infrastructure and potential applications.

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1. INTRODUCTION

The idea of a one-stop shop is known, applied, and proven in many fields. Therefore, at the Warsaw University of Technology (WUT), research has been conducted, and the concept of building this type of solution has been developed, but in an unusual way, i.e. as a connection of several scientific laboratories for testing some types of modern systems and applications related to the acquisition and use of geospatial data.

In recent years, we have seen highly intense development of various types of Mobile Mapping Systems (MMS) to acquire and use geospatial data. The essential components of these systems are positioning devices, laser scanners, cameras, and computational computer systems for processing and sharing geodata.

The number of different applications is growing, and mobile mapping is widely used in autonomous systems (e.g., driverless cars, photogrammetric UAV missions) and many navigation applications. The MMS is also treated as a method of mobile space inventory and control of various phenomena. An example of new applications is the automatic identification of paid parking spots in city centres. Another application of the MMS is the development of technologies for the building's interior mapping to analyse the construction process and create applications that support the movement of people, especially for emergency services or people with disabilities, continues.

Due to that fact, it needs research on emerging system prototypes, quality assessment of new applications and sensors, comparison of solutions, and searches for new, more optimal systems. However, there is a lack of laboratories in which it is possible to carry out the most complex and sophisticated tests in this area. The solution to such demand was planning and realising the One-Stop-Lab CENAGIS at Warsaw University of Technology, which contains laboratories with novel procedures to validate sensors and technologies. Most of the laboratories are unique in Poland, while their combination probably constitutes an original solution in the international context.

2. SCOPE OF LABORATORY ACTIVITIES

In order to meet the baseline assumptions of the One-Stop-Lab CENAGIS services, it was decided to propose the following laboratories: (1) Terrestrial Laser Scanning and Photogrammetric Calibration Laboratory with UAV test fields; (2) The surveying reference outdoor baseline for research and calibration of measurement instruments; (3) The Navigation Application Testing Laboratory with indoor navigation/localisation test fields and (4) The GNSS Receiver Calibration Laboratory.

Together with a local server room (the cluster ROMER), the laboratories are located in the building of WUT in Józefosław near Warsaw and are connected with the CENAGIS Cloud Computing Platform located in the main server room (the cluster MERCATOR) of WUT through the optical fibre. The outdoor linear measurement base is connected to the building's power supply and computer network. To the Terrestrial Laser Scanning and Photogrammetric Calibration Laboratory, it is possible to enter by a vehicle with a mounted an MMS system undergoing tests or calibration.

The building in Józefosław serves as a basic one-stop shop and, at the same time, has the character of a Living Lab. In one place, it is possible to check and test systems and applications, work in the computer lab, organise small conferences and seminars, and provide accommodation. It is also possible to relax in a green recreational area covering several hectares.

Another advantage of the One-Stop-Lab CENAGIS is the possibility of remotely accessing some laboratories and performing selected tests from any location via the Internet. The elements integrating the laboratories from the technical side are mainly:

1) Top-of-the-line satellite signal simulator/generator (GSS9000 Series GNSS Simulator - Spirent), which can be used both to check the quality of GNSS receivers forming part of the tested MMS systems as well as stand-alone receivers and at the same time acts as a simulator in the process of testing navigation applications,

2) Industrial laser tracker (Laser Tracer) for highly accurate 3D measurements (made by API) used both for precise calibration of measurement fields as well as for independent tests of other measurement systems (including reference measurements),

3) IT Cloud Platform with the necessary software,

4) Remote Work Monitoring System.

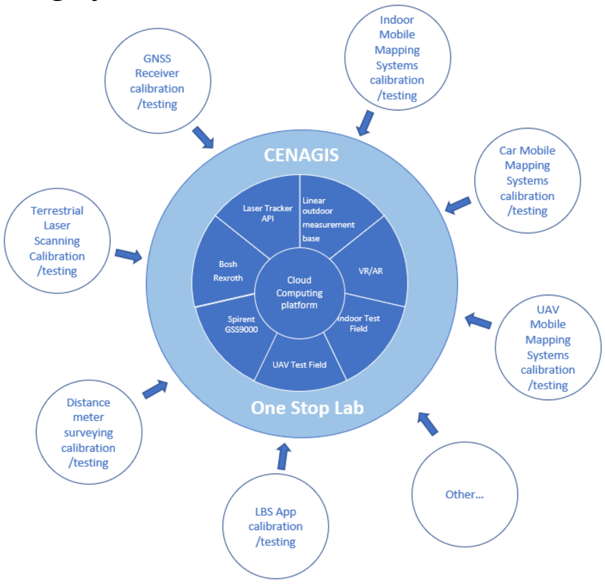


Figure 1. Multiple functions, multiple test devices available - one point of access for user-researchers.

The advantage of One-Stop-Lab CENAGIS is the possibility of overall calibration and evaluation of measurement systems, for example, the user can perform a multi-faceted test that can be conducted in the lab could be the testing of a seamless navigation application. The testing team or manufacturer in one place can check:

- the quality of the GNSS receiver used in the system under test,
- the quality of the indoor positioning system using Wi-Fi, BLE beacons, or RFID technology,
- the quality of the cameras,
- the quality of the laser scanner,
- the quality of indoor routing algorithms (using an accurate 3D BIM/GIS model of the building),
- the quality of outdoor routing algorithms (using available data on the CENAGIS Cloud Computing Platform.

Other examples might be tests and assessments of mobile scanning backpacks, photogrammetric platforms mounted on the cars' roofs, UAV platforms, GNSS receivers, range finders, and laser scanners. This broad spectrum of research can be performed in one place in a comprehensive manner (Fig. 1).

Further technical details of the selected laboratory equipment and the scope of the proposed tests in these laboratories are presented below.

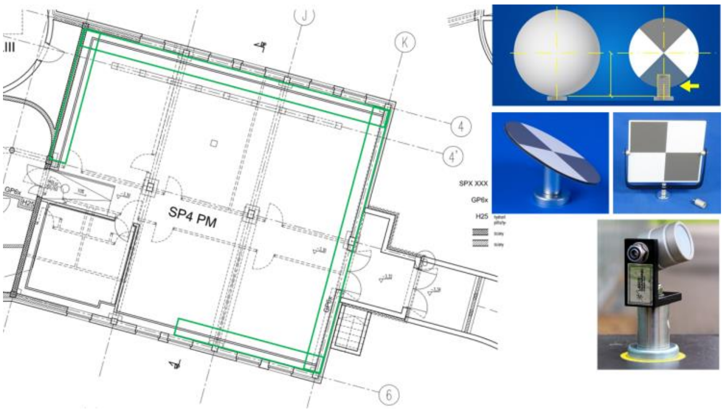
2.1. **Terrestrial Laser Scanning and Photogrammetric Calibration Laboratory**

The Terrestrial Laser Scanning and Photogrammetric Calibration Laboratory laboratory include test fields that are relatively complementary and can be used to calibrate single sensors and measuring systems (through the analysis of geometric and radiometric relationships). The spatial test field consists of two main modules, allowing for calibration of active measurement sensors (terrestrial close- and medium-range laser scanners) and passive measurement sensors (cameras with different optical resolution and matrix sizes).
An important feature of the laboratory is the shutter door (2.55 m by 2.30 m dimensions), which allows the entry of mobile systems mounted on cars or other platforms and can be accessed by vehicles for measurement purposes. The laboratory is equipped with a specialised air filtration system (meeting ISO 5 standards) to eliminate dust and an air conditioning system to maintain a constant temperature (a gradient of not more than 1-degree Celcius). The illuminance level complies with the EN 12464-1 guideline, and the average illuminance is 750lx with a function to set 4 colour temperature values.

2.1.1. Calibration field for active measurement systems

The calibration and validation of active measurement systems, such as Terrestrial Laser Scanning (TLS), are fundamental tasks for high measurement accuracy and reliability (Medić et al., 2019). The calibration test fields presented in the literature are commonly based on the quasi-random distribution of a high number of targets, and they rely on sufficient redundancy (Medić et al., 2019). It is assumed that reference features may be cylinders (Chan et al., 2015), planes (Bae and Lichti, 2007), paraboloids (Holst et al., 2018), or specialised targets, either intensity-based black and white planar targets (Chow et al., 2011), monochrome planar targets (Li et al., 2018) or spherical targets (Neitzel, 2006).

The proposed calibration test field for active measurement systems assessment is a reconfigurable field that allows the placement of signs (specialised signs) and measurement points at 80 locations on walls, pillars, and columns to complement the "permanently placed points." (Fig. 2a). The free placement of signs and the use of precision measurement prisms (Fig. 2b) used in pulse laser scanner measurements laser scanners and black - white checkerboards and spheres (used in pulse and phase scanners), significantly extends the functionality of the field and allows to meet the requirements of the most demanding users.
Using a reconfigurable approach, it will be possible to place the points differently to calibrate active measuring systems measuring in different ranges. The selection of the measurement points will be based on the assumptions of reliability assessment (Luhmann et al., 2013), which allows, among others, for the selection of the minimum number of points while meeting the condition of the best possible geometric distribution of points taking into account multiple positions of the tested sensor/sensors.



(a) (b)

Figure 2. Illustration of the spatial test field used to calibrate active measurement systems. (a) The green colour indicates the walls on which the points of the reconfigured test field are placed, and (b) Example marks are used for calibration of active measurement systems pulse and phase (LSE, 2021).

2.1.2. A rectilinear guideway with a carriage that allows tested objects to move

The main task of this infrastructure is testing the accuracy of range measurement determinations and measurement systems in motion.
The range measurement system is a critical component of many measurement techniques (such as TLSs or total stations) and provides the link to the SI unit of length, the meter. Evaluating the ranging errors is an important step toward establishing the metrological traceability of TLS measurements. However, the range measurement system of a TLS may be based on time-of-flight or phase-shift technology (Muralikrishnan, 2021). The proposed methodology is based on two approaches for assessing the accuracy of distance measurements:
(a) The zero error determination (the constant error in the range) is typically evaluated by comparing the distance measured between two targets on opposite sides of the measured range system.

(b) Relatively error determination allows for analysing the range effect in the function of the measurement distance and a relative relationship in the range functions.
(c) Evaluation of the distance measurement accuracy is also possible by continuous measurement of points in motion.

The combination of the zero error and the relative range errors provide a general view of the ranging errors expected of a TLS. The errors obtained from these tests are valid for the targets employed and in the environmental conditions at the time of testing.

To calibrate the distance measurement in the terrestrial scanners, a base (for close-range distances - inside the building) is used on the solution of a rectilinear guide with a cart that allows the movement of objects(Fig. 3). Additionally, a 250 m linear measurement base is used for long-distance testing near the laboratory's building. Due to the use of reference measuring points mounted on a trolley on the linear guide, any feature reference such as spheres, black and white checkers, precision reflectors or reference points dedicated to a particular measuring system can be mounted.

(a) (b)

Figure 3. (a) The linear base for distance calibration (photo taken during the construction of the laboratory). (b) List of modules for control and programming of the measurement system for specific specialised applications.

The use of a linear measurement base also allows for testing measurement systems in motion, taking into account the speed of movement, changes in acceleration values, the introduction of controlled vibrations, and in combination with the Laser Tracker API - tracking and linear measurement of the object position with an accuracy of 0.5 μm/m. Different programming languages and environments make it possible to configure and adapt the solution to specific customer applications.

2.1.3. Precision test field for calibrating optical measuring sensors according to VDI/VDE standards

The verification procedure of the measuring accuracy of scanner 3D, according to recommendations of the German PTB (German National Institute of Metrology) with VDI/VDE 2634 norm (Ostrowska et al., 2012). According to these standards, the following errors are analysed:
(1) probing error - optical head system error describes the characteristic error in 3D optical measurement systems based on scanning surfaces in a small measurement range. In order to

determine this error, it is necessary to acquire the point cloud of the reference sphere face, calculate the sphere diameter by the method of least squares and determine the difference between the measured value and the nominal value. The reference is a sphere made of ceramic, steel or suitably light-scattering material. It is assumed that a minimum of 5 measurement clouds of one sphere from different positions are necessary. According to VDI/VDE guidelines, the spheres should be positioned at different distances and levels from the measuring system. The operations are performed separately for ten different ball positions according to the proposed verification procedure. The accuracy criteria according to the VDI/VDE procedure of the optical head error are met when all diameter determination errors do not exceed 1/5 of the diameter of the ball standard, and the measurement uncertainty is considered to be the largest diameter determination error.

(2) sphere-spacing error is used to verify the capability of the distance measuring system. According to the VDI/VDE definition, the length determination error is the difference between the measured value and the calibrated value between the spheres forming the test section. As with the spheres used to determine the sampling error, the spheres used in the distance measuring standard should be made of ceramic, steel or another material that diffuses light adequately. The uncertainty of measurement, similar to the sampling error test, should be known and should not exceed 1/5 of the length of the standard.

(3) flatness measurement error is the range of distances of the measured points from a plane fitted by the least squares adjustment method. To determine flatness, reference standards are used in the form of cuboids made of steel, ceramic, aluminium or other material with low reflectivity. It is assumed that the width shall not be less than 50 mm and the length less than 0.5*L0 (L0 - the diagonal of the cube describing the measurement range). It is assumed that the flatness error should not be greater than 1/5 of the measured characteristic. In order to determine the flatness error (within the CENAGIS equipment verification procedure), the flatness reference shape is measured in at least six settings: parallel to the XY plane, at three distances, in line with the diagonals of the bases of the cuboid delimiting the measurement space and along the diagonal of the cuboid delimiting the measurement space.

The test VDI/VDE calibration field is located in the separated room, which has an independent air circulation and air conditioning system and simulates different atmospheric conditions. According to VDI/VDE standards, the spatial test field allows the verification of measuring systems based on a maximum measuring area of 1.5 x 1.5 x 1 m. Additionally, since the test field is mounted on a precision column tripod allows the test field to be positioned freely in the main laboratory room.

Terrestrial Laser Scanners acquire not only three-dimensional geometric information of the scanned objects but also the intensity data of returned laser pulse. Recent studies show a great potential for the application of the intensity TLS data in many applications, namely cultural heritage (Kashani et al., 2015), identifications of rock and soil layers (Burton et al., 2011), structural health monitoring (Olsen et al., 2010), glacier and snow distribution (López-Moreno et al., 2017; Schwalbe et al., 2008) and more.

Recorded intensity is based on a measure of the electronic signal strength obtained by converting and amplifying the backscattered optical power of the emitted signal. Intensity measurement is, first and foremost, a means of controlling the quality of range information. Indeed, the scanner detector is originally not designed for intensity measurement but rather to optimise the range determination (Sanchiz-Viel et al., 2021). Laser scanner intensity is a function of the power of the received backscattered signal, which in turn depends on the laser scanner system, atmospheric effects, distance and incidence angle, and target-surface physical characteristics (Bolkas, 2019).

Measuring the reflectivity of a laser beam is a difficult process to parameterise because of the various variables accompanying this process. The test has to consider the decrease of the reflection of the laser beam with distance (intensity decreases according to Lambert's law). Another aspect is the variable reflection angle of the laser beams for the scanned surface, which also affects the recorded intensity.

The One-Stop-Lab CENAGIS laboratory is designed for testing the effect of intensity on terrestrial laser scanner measurements, and it is possible to:

- testing the effect of intensity on distance measurement accuracy. Using a colour checker with an X-Rite colourimeter and the linear guide with the trolley combined with the LaserTracker from API, it is possible to establish functional dependencies between distance accuracy and measured colour.
- to determine the intensity correction functional model, taking into account the near-distance effect, incidence angle and range effect (Fang et al., 2015).

2.1.4. Field for calibration of instruments and passive measurement sensors

The camera calibration determines the geometric parameters of the image formation process (Hartley and Zisserman, 2003). This is a crucial step in many computer vision, photogrammetric and geodesy engineering applications, especially when high accuracy metric information about the scene is required. During the camera calibration process, the interior or orientation (also known as an intrinsic; calibrated focal length, principal point, radial and tangential distortion parameters and or skew of axis) and exterior orientation parameters (extrinsic, rotation and translation). Both intrinsic and extrinsic parameters are estimated by linear or non-linear methods using known points in the real world and their projections in the image plane (Trucco and Verri, 1998).

The calibration field in the research and teaching centre of Warsaw University of Technology in Józefosław allows for geometric calibration of various optical sensors. Currently, non-metric cameras, characterised by the lack of constancy of the so-called internal orientation elements, i.e. parameters describing the camera geometry, are widely used in various branches of the economy. Depending on the measurement set used (lens and camera), the parameters are variable and are not determined by the manufacturer. Therefore, to obtain reliable metric products (e.g. orthoimages or 3D models), it is necessary to perform calibration under laboratory conditions. The use of non-metric cameras is becoming standard in many fields, including the inventory and protection of cultural heritage, industrial measurements, or other specialised measurements. The widespread use of non-metric cameras and ensuring adequate quality and accuracy of reproducing the shapes of surveyed objects make it necessary to use an appropriate calibration field to develop appropriate standards for generating specific metric products.

The test field for calibrating the cameras from a close- and medium-range distance is a 3D field, approximately 2.0 x 2.5 m in size, side ratio of 1:1.4, consisting of 250 symmetrically spaced points located on two main walls and 60 on the rest of the wall. Those points are in the form the black and withe circles, black and white crosses and ArUco markers.

The research and development field for calibrating passive measurement systems and testing image matching algorithms consists of two 75-inch 4K resolution monitors that can display designed textures and characters of various sizes and shapes. Additionally, a high-resolution 4K projector with interchangeable lenses is mounted, which is used to densify the "traditional field" (signs placed on the walls) with any texture, image or additional measurement marks.

2.2. Navigation Application Testing Laboratory with indoor navigation/localisation test fields

The concept of the lab is primarily based on the creation of navigation application simulators and a testbed for application verification. VR and AR technology was chosen as the primary technology to achieve this goal.
The growing popularity of Virtual Reality systems increases the number of scientific broadcasts in which they are used. Since its appearance, VR has been used in spatial data science (Çöltekin et al., 2020). The Navigation Application Testing Lab is designed for interdisciplinary research at the intersection of cartography and UX (User Experience) issues. The importance of such research has been presented by, among others (Roth, 2015) and (Cybulski and Horbiński, 2020). Using VR hardware, innovative concepts for cartographic visualisations can be explored. VR devices allow test subjects to get a "sense of immersion in virtual reality" effect. In such a solution, it is possible to create various simulations and, as a result, to evaluate the user's behaviour in various scenarios, which are challenging to realise in reality, e.g. in crises (Lochhead and Hedley, 2018). This reduces the cost of such studies and thus extends their scope. Eye-tracking using research has long been used in cartography (Liu et al., 2017; Majaranta et al., 2019). Using this technique, tracking the user's reaction to certain stimuli, it will be possible to test the perception of designed cartographic visualisations, e.g. the impact of the use of variable LOD (Level Of Detail) on the reception of information about the modelled space. Research on the quality of cartographic messages of designed navigation applications will allow adjusting their parameters to the expectations and capabilities of individual users. VR devices and the VR simulations could be a tool and a subject of research, e.g. identifying and testing physiological issues (Guna et al., 2019) or perception issues (Ping et al., 2020).
Two VR Omni-directional VR treadmills, Kat Walk Mini and Kat Walk C (Fig. 4) allow for 360 degrees of human motion, creating infinite movement area in VR on minimum physical space in reality. To observe the virtual world, there are two VR headsets: HTC Vive Pro Eye with 2880 x 1660 resolution and eye-tracking functionality, and Pimax 8K Plus with 3840 x 2160 resolution and a vast field of view (200 degrees).

Figure 4. Selected items of equipment in the Navigation Applications Research Laboratory

The Navigation Application Testing Lab has a Vuzix M4000 device for research on Augmented Reality applications. This headset will test head-mounted AR devices' usability for navigation applications. The set has an 854 x 480 resolution transparent display placed in front of an eye. It could open a new path to studying the effectiveness of the message conveyed by the small HUD display in navigation applications. Previous research has focused on automotive displays (Schwarz and Fastenmeier, 2017).

Another device is a Microsoft HoloLens 2. Its most important feature is the ability to precisely combine virtual reality with real-world imagery. A rich set of sensors allows the device to accurately determine its position in space in real-time mode. Having a display with 1440 x 936 resolution and 40 degrees field of view, HoloLens 2 is considered the best augmented reality headset on the market in 2022. Since its release in 2019, a platform is also a research tool in cartography and related sciences (Lovreglio and Kinateder, 2020). The possibility of presenting virtual objects against the background of reality should be interesting for people involved in urban planning or engineers managing land development networks (Stylianidis et al., 2020). Potential research could focus on the effective implementation of a field demonstration of planned development or a methodology for visualising subsurface infrastructure facilities for maintenance support.

Research on navigation applications can also be done on a testbed where virtual world visualisations are displayed on a large curved screen with laser projectors. It could be used, among other things, to study the perception of in-car navigation applications under different conditions, such as under the glare of external lighting.

The Location System Test Lab is a testbed for the accuracy verification of positioning systems in indoor navigation applications. It was designed to be able to test systems using various sensors and having different characteristics. The testbed consists of three independent positioning systems with devices installed to ensure wide coverage inside the building of the Warsaw University of Technology Observatory in Józefosław.

Based on a Wi-Fi signal, the first positioning system covers the entire building. The system supports the development and verification of Wi-Fi positioning systems utilising popular methods for position determination – path loss modelling, radio fingerprinting and multilateration based on round trip time of arrival. Depending on the chosen method, the system achieves a typical positioning accuracy of a few meters. The system integrates networks of two different types of devices. The first group consists of 34 Ruckus H5500 Wi-Fi routers. They are supplemented with 18 Compulab fitlet2 routers to provide a dense network on all building floors. The second group of routers supports the RTT (Round Trip Time) protocol and can be used to test positioning algorithms based on multilateration. An important feature of the system is the ability to be controlled programmatically. It allows not only easy maintenance but also to simulate specific conditions of Wi-Fi router set-up or to conduct research on the impact of the number of visible routers on positioning accuracy.

The second system, which covers the entire building, uses a Bluetooth signal. The system is built with 70 standard BLE (Bluetooth Low Energy) beacons. Similar to Wi-Fi positioning, BLE positioning uses radio fingerprinting less frequently than other methods such as path loss modelling or proximity sensing, which achieve similar positioning accuracy with relatively easier maintenance.

The third system uses UWB (Ultra-Wideband) technology. The laboratory has three sets available. Each consists of five Sewio Vista Omni units. These kits are portable and could be installed in selected rooms. This allows the configuration of the test field to be adapted to specific scenarios. The system makes it possible to determine the position inside the building with an accuracy of several cm. Being the most precise solution, the system is intended to be a reference for other tested solutions.

2.3. GNSS Receiver Calibration Laboratory

The main objective of the laboratory is to study and test multisystem GNSS satellite receivers for positioning quality and reliability.

This research includes an analysis of:

- measurement equipment, i.e., satellite receivers and antennas using a GNSS signal generator and calibration base;
- measurement errors of GNSS observations, such as atmospheric delays, measurement noise, hardware delays;
- signal acquisition algorithms and precise positioning.

The essential equipment in the laboratory is a GNSS signal simulator (Spirent series GSS9000) (Fig. 5). Besides, multisystem and multifrequency GNSS receivers, reference stations, and control bases are available.

Figure 5. GNSS signal simulator (Spirent series GSS9000) (source: WUT-left and Spirent - right)

With the available hardware, it is possible to generate full spectrum GNSS signals (GPS, Galileo, GLONASS, BeiDou, SBAS, QZSS, IRNSS) with high accuracy: 0.3 mm RMS for code observations and less than 0.005 Rad RMS for phase observations, and 0 mm inter-channel delay uncertainty.
The device allows, among others, to test encrypted GNS signals (Galileo PRS, GPS M-code), test cyber-attacks (jamming, spoofing) and test vehicles with the highest traffic dynamics (relative velocity 120,000 m/s 7, relative acceleration 192,600 m/s^2 8, relative jerk 890,400 m/s^3, angular rates (at 1.5 m lever arm) >15π rad/s).
The generator can also generate signals for tested applications in Navigation Application Testing Laboratory.

2.4.CENAGIS Cloud Computing Platform

Most of the measurement and test equipment described above is connected to the CENAGIS Cloud Computing Platform. It is an advanced IT infrastructure (cyber-infrastructure). The Platform integrates labs and equipment and, at the same time, allows for the processing of big geo-data sets and implementation of geospatial analyses (such as spatial big data with data mining functionality) and satellite computations. The CENAGIS Platform is based on MERCATOR and ROMER's two computer clusters. The CENAGIS Platform can operate independently as a Geospatial and Satellite Analysis Center and a platform to support the laboratories described above. A unique solution includes the possibility to configure virtual machines according to users' demands, ensuring the required computational power, GIS software, disk space, and, first, the configured access to relevant spatial data files.
The modern technologies applied in CENAGIS will allow remote access to the unique datasets and analytical software for the wide range of scientists and innovative technology companies cooperating with them.
The repository (database) contains almost all geospatial data available in Poland for research and education and a part of commercial datasets.
The basic technical and hardware parameters are as follows:

- Big Data component: (30 compute nodes - a total of 1800 vCPUs, 11 TB of RAM and 60 NVIDIA Tesla T4 GPU cards)
- Virtualisation component (33 compute nodes located in two locations, MERCATOR and ROMER - a total of 1700 vCPUs, 10 TB of RAM and 3 NVIDIA Tesla V100 and A100 GPU cards),
- Storage component (3 PB of disk space).

The CENAGIS Platform provides access to a range of commercial and open-source software used in advanced spatial analysis (Tab. 1)

Table 1

Virtual Labs Subsystem	Big data Subsystem
Hexagon (Geomedia, Erdas Imagine/Apollo, M. App. Enterprise, WebMap), ArcGIS, FME, QGIS, PostGIS, GeoServer, Dephos (Limon), other Computer operating system: Windows, Linux Hypervisor: KVM + CloudStack	GeoMesa, RasterFrames, Dephos, Accumulo (baza NoSQL), Jupyter Notebook, self-created programming libraries other Computer operating system: Linux Big data management technologies: HDFS, Mesos, Spark, others.

3. SUMMARY

The laboratories are intended for the activities of both scientists and entrepreneurs, with particular emphasis on R&D departments. The Center for Scientific Geospatial and Satellite Analyses has also begun cooperation with the Central Office of Measures.
In the following years, it is planned to expand the capabilities of the laboratories. Among other things, a preliminary project for the construction of a field for testing geoinformation components for autonomous vehicles in motion (outside the building) has been developed, an expansion of the UAV field is planned, and the installation of one or two simulators for driving a car or flying an aircraft. It is also planned to create an outdoor infrastructure for simulating selected structures and terrain forms measured with typical surveying instruments. The construction of a small swimming pool for testing the performance of geodetic instruments on measuring devices operating in immersion is also considered.
All these elements constitute a coherent concept of a modern complex of related laboratories realising the idea of One-Stop-Lab, which can provide comprehensive R&D services to both teams of scientists and modern companies, especially start-ups.
All presented concepts have been developed within the framework of statutory research at the Faculty of Geodesy and Cartography, Warsaw University of Technology.
The first phase of the CENAGIS implementation has been co-financed by the European Fund for Regional Development within the Priority Axis I "Utilisation of research-and-development activities in the economy," Activity 1.1. "Research-and-development activities of research units" of the Regional Operational Programme of the Mazovia Voivodship for the period 2014-2022.

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