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EAO-BASED NEAR AND FAR SPACE SCIENCE AND TECHNOLOGY RESEARCH CENTER

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Abstract

The purpose of this work is to propose innovative research and technical solutions to create a scientific, educational, observational and promotional world-class center for the study of near and far space. The center will be established on the basis of the Engelhardt astronomical observatory (EAO) infrastructure in Kazan Federal University (KFU) using available resources of the observatory, departments of astronomy, radio physics, radio astronomy, radio electronics. The main center's elements are described; their selection satisfies three conditions: 1) independence from climate change (for example, lack of a sufficient number of clear nights); 2) high level of technical solutions related to the center's instrumental baseline; 3) rapid adaptation to new scientific and technological realities. Special attention is paid in the work to the issues of the main specifications of the equipment and educational programs. The following devices are described: Mini-Mega TORTORA optical celestial sphere monitoring system with subsecond temporal resolution; radio telescope with a mirror of 13 m in diameter for very long baseline radio interferometry (VLBI); complex of optical telescopes with a lens diameter of at least 0.6 m, CCD photometer and adaptive optics assembly; Sazhen TM quantum-optical system for laser scanning of satellites; Planetarium's digital systems and 3D-Visualization Center.

Keywords: Science and Technology Center; Instrumentation: miscellaneous, photometers, polarimeters; Techniques: high temporal resolution, telescopes, digital planetarium

1. Introduction

Scientific and technical solutions described in this article are aimed at development and introduction of innovative technologies in the area of space communications, navigation, meteorology, study of natural resources, monitoring of anthropogenic processes, mapping, development of education, familiarizing of young people with the modern scientific cognition methodology, popularization of scientific knowledge. With the launch of the first artificial Earth satellite, the modern space research is made using the latest astronomical and geodetic technologies. Space navigation, meteorite safety of space flights, tracking of spacecraft in orbits, satellite planetary geodesy are based on advanced space and ground-based observations and celestial sphere scanning technologies. In order to remain among the leaders in space research, the development of high-tech ground stations, astronomical and geodetic observation locations is needed.

The EAO-based educational activities are implemented in the field of training and retraining of specialists, educational, educational and industrial, scientific training of students and post-graduate students in the following areas of training: astronomy; geodesy and remote sensing; radio physics.

The main professional educational component is the practice baseline in the field of astronomy, land and space geodesy, topography, radio physics and radio astronomy.

To implement certain scientific programs the following departments are involved:

– space astronomy and geodesy;

– applied astrophysics;

– radio astronomy.

It should also be noted that in 2010 the Metrological polygon was built, which Roscosmos (Russian Space Agency) uses for navigational equipment testing according to observations of the GLONASS satellite constellation, in the territory of the EAO within creation of the Interregional Center for Applied Navigation Technologies and Services and Polygon of Satellite Navigation Technologies and Services Processing.

2. Near and Far Space Science and Technology Research Centre

Figure 1. Conceptual plan of the Near and Far Space Research Center

The conceptual plan of the Near and Far Space Research Center is given in Figure 1. Creation of a scientific and technical equipment complex of the Near and Far Space Research Center involves design and installation, in addition to the existing KFU-based observational basis, of interrelated most accurate high-tech instruments:

1) Mini-MegaTORTORA optical celestial sphere monitoring system with subsecond temporal resolution. The complex has been already successfully operated;

2) Radio telescope with a mirror of 13 m in diameter for very long baseline radio interferometry (VLBI);

3) Complex of optical telescopes with a lens diameter of at least 0.6 m, CCD photometer and adaptive optics assembly;

4) Sazhen TM quantum-optical system for laser scanning of satellites, including GLONASS constellation to determine its elements.

Figure 2. Mini-Mega TORTORA optical celestial sphere monitoring system

The Mini-Mega TORTORA optical celestial sphere monitoring system is designed to detect and investigate rapid processes of unknown space and time location in the far and near cosmic space (Figure 2). Optical wide-angle scanning of the celestial sphere [1] is performed with high temporal resolution in the automatic mode. During a scanning, the main task on discovery of new non-stationary objects of various nature is solved, and the known objects are studied. In order to carry out such continuous observations, a robotic multichannel (nine separate lenses) optical system was created with a time resolution of 0.1 s and celestial sphere field covering nine hundred square degrees. Such complex summarizes information about all transient and stationary in time and space optical sources that are present on the celestial hemisphere (20 000 sq. deg.) with a luminosity of up to 17.5 magnitude. It should be noted that on the basis of the considered wide-angle scanning system (through hardware and software integration and modernization of the wide-field meniscus telescope AST-452 and a set of optical telescopes with aperture of at least 0.6 m) a single set of monitoring and online analysis of observed events was set up; its is equipped with the appropriate situational IT-center.

Figure 3. Radio antenna complex

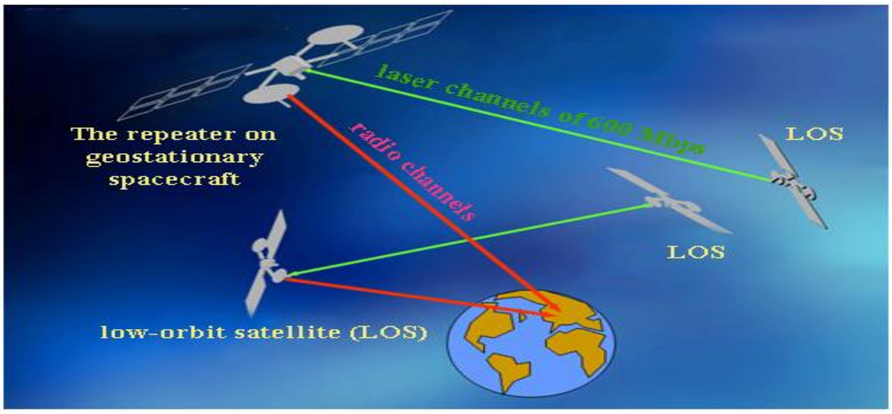

Figure 4. Intersatellite data transmission systems based on laser technology with speed of up to 600 Mbit/s and operational range from 1 to 6 thous. km (LOS-LOS line) from 30 to 46 thous. km (LOS-RGS line)

The main purposes of installation of the radio telescope with a diameter of 13 m (Figure 3) operating up to Ku-band (14 GHz) are: fundamental coordinate and time support; construction and maintenance of the International Celestial Reference System (ICRF), its realization in the form of lists of coordinates of extragalactic radio sources; building of ground coordinate systems (ITRF and versions of PZ.90 systems), their realization in the form of lists of coordinates and velocities of the reference stations; determining the orientation parameters of the Earth's coordinate system relative to the celestial coordinate system and Earth rotation parameters (Figure 4); construction of dynamic reference systems, their realization in the form of ephemerides of the Solar System bodies and spacecrafts; definition of the Earth's gravitational field settings [2]; construction of a national coordinated time scale UTC (SU), its maintenance in the set limits in relation to the scale of the Coordinated Universal Time (UTC) [3]. As a part of the fundamental astrophysical research, the aim is to study the Galaxy (molecular lines, X-ray and gamma-ray sources, microquasars) and active galactic nuclei [4-6]. The ground support of spacecrafts, single-mirror and VLBI network operation, including in the national Russian and international networks (ALMA) will be implemented. Concerning educational problems, the antenna installation will allow to raise the study of fundamental and applied geodesy, astrophysics, microwave technology, cryogenic engineering, digital signal processing to a higher level.

An optical telescope with the main mirror's diameter of 60 cm is a modern optical and mechanical electronic complex, equipped with adaptive optics unit necessary for the image quality correction at the max. frequency of 100 Hz. The main purpose of installing an optical telescope with aperture of at least 0.6 m is solving a wide range of tasks: detection of different new and investigation the known (stationary and non-stationary) objects in the near and far space; implementation of object observation programs that require high angular resolution (using adaptive optics), fiber spectrographic equipment, CCD-based photometers of UBVRI bands and other standards; atmospheric research; development and testing of various types of equipment included in the system's observational complex using adaptive optics during observations under different astroclimatic (man-made) conditions. The complex should provide studying any rapid phenomena in the near and far cosmic space when applying both the current observational programs and detection signals for observed objects by spacecrafts or other monitoring systems.

SAZHEN-TM system is an important element of the monitoring system. The quanto-optical system will become the necessary support of the VLBI antenna accuracy. Currently, the complex of "antenna and laser rangefinder" becomes a daily practice of the satellite monitoring.

3.Systems Of Astronomical Process Visualization

The created Science and Technology Center will be the world's first complex that combines the existing astronomical observatory and modern Planetarium. Such an approach would complement the Planetarium's work with real observations using existing telescopes, celestial bodies and astronomical phenomena (planets, stars, galaxies and nebulae, asteroids and comets, meteor showers, solar and lunar eclipses, satellites, etc.) [7- 9], thereby ensuring the visitor's "immersion" in a professional environment of the Universe cognition.

Two elements are realized as systems of astronomical process visualization in EAO KFU: Planetarium and 3D-Visualization Center for Astronomical Processes.

Figure 5. Fixed-star projecting machine for the Planetarium.

The main Planetarium's instrument is Megastar II A opto-mechanical projector (star machine) produced by Japanese company Ohira Tech Ltd; it is installed in the center of the Star hall, and it can project onto the Planetarium dome the stars of magnitude up to 6.5, with more than 40 of the brightest stars having a colour corresponding to their spectral class, and they can be displayed separately from other stars (Figure5) as well. Images of celestial objects are created using metal plates, which have the smallest holes of different diameter (in accordance with brightness of the stars). Next to the main "star sphere" there are special projectors to show the motion of the Sun, Moon and five planets visible to the naked eye. Other visualized models [10] may also be created.

The Planetarium provides "moving" in space and time. If desired, it is possible, for example, to appear in the distant past to understand how ancient people have seen the sky, or how the shape of constellations will be changed in the future. One can "fly over", literally for some seconds, to another continent, for example, to Australia and observe the starry sky the way Australians do. It is possible to see how the sky moves during a day not only in a particular town, but also on the equator and in the poles.

Nowadays, due to the rapid development of digital technologies planetariums began to install digital playback systems. Currently, when displaying images and video programs on the KFU Planetarium screen, 4096 × 3112 (4K) resolution is used. Gradually, with advancement of technology, the digital playback systems will overtake, on the quality of starry sky image, the features of an opto-mechanical planetarium, although the latter can work steadily for decades, whereas operation of digital systems depends on the computer hardware features. A digital planetarium uses specialized software. Uniview Digital Versatile Universe Emulator produced by the Swedish company SCISS is installed in the KFU Planetarium. Images that are projected onto the dome are modelled in real time based on the NASA server and other astronomical system data, and these data are updated on a daily basis. Unlike a classical planetarium, a digital emulator helps observe the starry sky from any point of the Universe, display the Sun position in the Milky Way and see the location of our Galaxy relative to other galaxies. It is possible not only to arrange a tour of the Solar System planets, but also to go, for example, inside the Saturn ring. In addition to the projection equipment, to ensure the effective Planetarium's operation a full-dome screen is crucial. In the KFU Planetarium, all images are projected onto the dome of 15 m in diameter, which is produced by the U.S. company Spitz Inc. and inclined to the horizon at 10 degrees. The screen surface is coated with overlapping sheets of thin perforated aluminium, which is important to reduce the dome's weight and sound transmission. The screen is immersive and allows viewers to be plunge into an action. The KFU Planetarium building features a modern astronomical telescope, which is located in the tower of 4.5 m in diameter, which roof slides apart. The telescope's support has four pipes, which can perform different functions. The main element is a 50-cm astrograph designed to observe deep sky objects. On the telescope there is also a planetary refractor, which will allow to study the surface of the Solar System's large planets. Two more tubes are designed for the Sun observation. The telescope is equipped with professional radiation receivers, which help with observations of various astronomical objects. In future, the telescope will be used for practical training of astronomy students. It should be noted that the telescope's dome hemisphere can be opened fully; there is an automatic meteorological station near the dome, and if sensors detect that its starts raining, the dome is closed automatically. Images from the telescope can be both translated on a large monitor located in the Planetarium vestibule and represented as a full-dome projection. The visualization center for astronomical processes is intended for modelling 3D-images of space objects. The projection itself is carried out in a passive mode, which allows the use of inexpensive glasses for 3D-content viewing. At the same time, a simple process of modelling is performed using standard programs. The 3D-visualization enables, for example, to receive volumetric models of the Moon and planet surface and to analyze them from different angles of the line of sight, as well as to model the processes occurring in celestial bodies.

4. Conclusions

In this work, the following conclusions can be drawn:

1) The main scientific and technical components of the created Near and Far Space Research Center are considered

2) The instrumental baseline of the land and space geodesy, topography, radio physics and radio astronomy was modelled

3) Coordination system project for activities of all scientific and technical departments was developed as a part of a single Near and Far Space Research Center

4) The results of the work have a high degree of novelty and practical value; they can be used during scientific and technical works and educational activities.

5. Summary

The created EAO KFU-based Science and Technology Center is designed to solve various problems related to the near and far space study, modern selenodesy [11, 12], navigation coordinate and time support [13], creation of digital models of celestial bodies [14]. All components of the complex are modern innovations and together represent a unique system for scientific and educational activities.

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