World Wide Student Laboratory: Global Educational Infrastructure for Remote Experimentation

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Abstract

The World Wide Student Laboratory, WWSL, is an innovative advance in the delivery of science and engineering education over the Internet. The WWSL allows students anywhere in the world to control advanced experiments in remote locations and to have access to equipment that would otherwise be unavailable. Using the WWSL, students perform experiments with real experimental setups and, under the guidance of their professor, teacher, or instructor, collect real data for analysis. The WWSL can serve traditional universities, colleges and high schools, as well as distance education institutions. With the WWSL's new approach, educational institutions will be able to afford better facilities for the education they provide, access the best lab facilities in other institutions, and substantially broaden the number of lab study items in their curriculum. Using the WWSL Internet portal, students will access the individual laboratory setups by means of "web centers" arranged by topic – Topical Group Web Centers. The WWSL also brings greater economic efficiency to existing university laboratories by eliminating instrumental downtime and creating a revenue source to offset purchase and maintenance costs, while improving the educational experience.

Keywords: *Remote experimentation, Remote access laboratory, Advanced laboratory*.

1. Introduction

The World Wide Student Laboratory, or the WWSL, is an Internet-based scalable education infrastructure that enables students, under the guidance of their educator, to have remote access to, and carry out, educational experiments in modern laboratories at leading universities and research centers. Access is available twenty-four hours a day, seven days a week, regardless of the student's location. The WWSL can serve traditional universities, colleges, and high schools, as well as distance education institutions. Using this new concept, educational institutions will be able to afford better facilities for the education they provide, have access to the best lab facilities at other institutions, and broaden the number of laboratory study

subjects in their curriculum. This approach will improve the quality of the laboratory experience and substantially reduce the cost of the educational laboratory, which is the most difficult and expensive segment of engineering and science education [1-6]. It is important to emphasize that WWSL is a real laboratory -- not simulation -- where actual experiments (with all real-world "noisy" effects) can be performed. The WWSL does not offer courses, but rather enables many universities, colleges, and schools, which have limited equipment budgets, to offer laboratory studies lacking in their curriculum.

Introductory laboratories are intended to introduce students to basic lab practice and hands-on research experience, and are best taught in the traditional way – sitting at a lab bench. However, in typical in-residence labs students often do not have the opportunity to explore deeply a number of important sections of laboratory courses. Not all educational institutions can support a wide spectrum of laboratory setups because of their high price, maintenance cost, lack of necessary space, etc. Sometimes laboratory classes are too short to obtain persuasive research results for the given process or phenomenon. In many cases, the laboratory instruction and student research projects do not reflect the current level of professional experimental research. While this is not always necessary (as in the case of "classic" experiments), it is important to be able to provide access to truly state-of-the-art experimentation. Using traditional lab models students often do not have the opportunity to study a particular process or phenomenon due to security or Health and Safety Regulations.

Advanced laboratories, as compared to our definition of introductory laboratories, are science educational labs designed to explore laws of nature or processes for students who have already learned basic lab technique in previous introductory work. WWSL is focusing on the advanced labs for students from high school to graduate University levels. These labs typically require some of the following conditions [1, 3, 7]:

- Specialized, expensive equipment
- Special environments for their fulfillment
- Considerable preliminary theoretical or practical preparation
- Lengthy time to complete
- Repeated change of experimental environments

WWSL will provide these environments. Through the WWSL Internet infrastructure, students are able to meet the requirements for advanced labs in many scientific and engineering subject areas. The WWSL will enrich the personal research experience of each student and help lab studies more closely resemble top-level scientific research. The economic benefit of the WWSL approach is based on a considerable increase of the efficiency of existing lab facilities in universities. The possible business models of WWSL operation will be discussed elsewhere.

The concept of WWSL has been introduced in mid 90s. [1, 8]. Third generation of WWSL Internet infrastructure and new WWSL-ready lab setups are under development now [8-10].

2. WWSL Internet Infrastructure

The Internet infrastructure of WWSL is presented in Figure 1. Using the Internet portal operated by DiscoverLab Corporation, students will access the individual laboratory setups by means of "web centers" arranged by topic – Topical Group Web Centers (Topical Centers).

Each Topical Center is connected to the sites of experimental setups at participating universities and research labs. Using this approach, students can be presented with lab work of different levels of difficulty, and with labs that use various methods to obtain results. In addition, students can conduct simultaneous experiments with several setups, located in different places with differing experimental environments, and compare results. The use of high-quality streaming media feedback will provide "telepresence" [11] for participating students. Instructors can customize for their students the task and methods of lab studies.

Topical Centers will make available the necessary educational materials, such as software tools for experimental data analysis and modelling, lectures and articles, reference materials and more. To ensure a

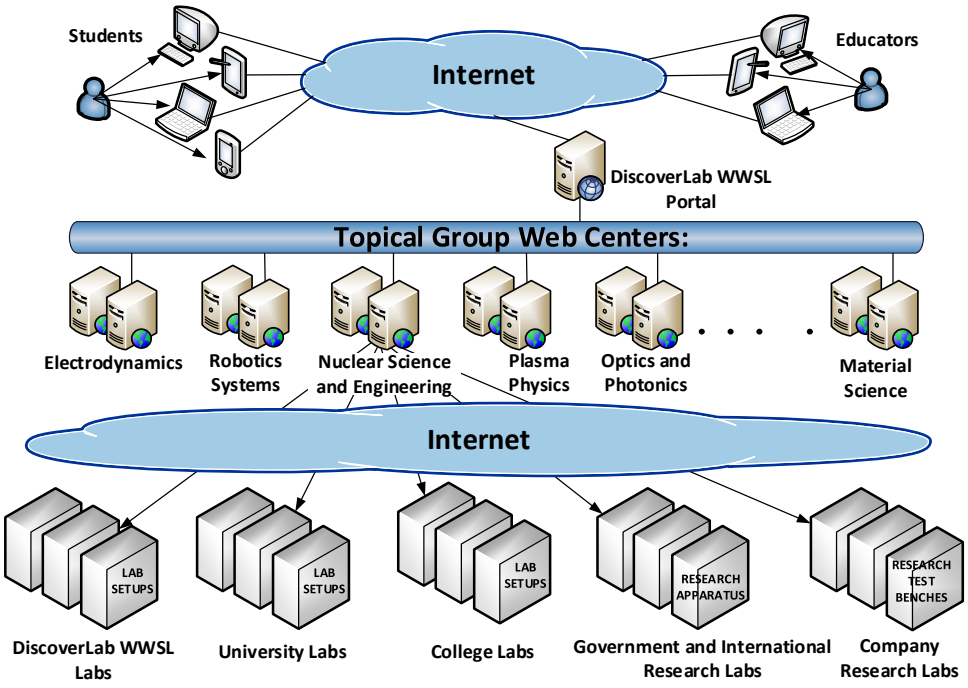

Figure 1. The WWSL infrastructure.

high-quality educational standard, a recognized expert in a field will be invited to review the content of Topical Centers.

The Topical Group Web Servers and Lab Setups use REST architecture of network communications [12]. The key strengths of this architecture are performance, scalability, simplicity of interfaces, portability, and reliability. The REST architecture of the client–server interface simplifies their implementation, improves performance tuning, and boosts the scalability of server components. This architecture allows various proxies, gateways, and firewalls to be introduced at any time without changing the interfaces between components. This greatly improves security and/or accessibility of the overall system and its components.

JSON data format [13] has been chosen to be used in communication between different parts of the WWSL system. JSON is a lightweight, flexible and scalable format used to store information in an organized, easy-to-access manner. In a nutshell, it gives us a human-readable collection of data that we can access in a really logical way without unnecessary format overhead (XML). This format has a native support in all modern languages (C#, PHP, Java, JavaScript). This allows various parts of the system to be developed on different platforms (Windows/Unix/etc.) with different frameworks (ASP.NET, JSP, PHP, etc.) and still communicate with each other without any limitations.
The typical architecture of network communications between Topical Server and Lab Setup is presenting in Figure 2.

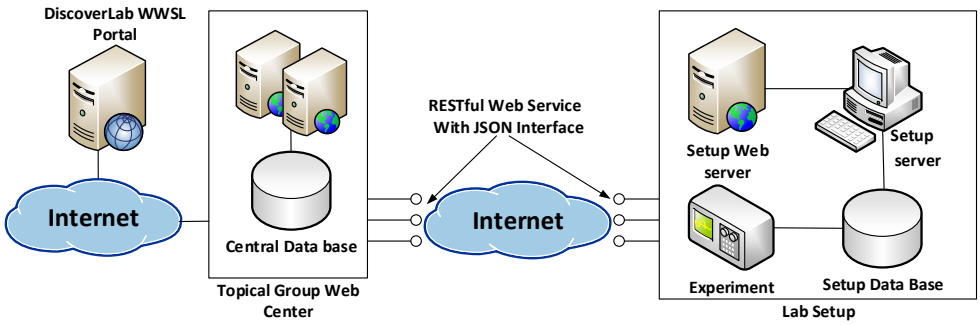

Figure 2. Network communication between Topical Center and Lab Setup based on RESTful architecture and JSON data format.

3. WWSL Subsystems

The WWSL infrastructure consists of several subsystems deployed at WWSL Portal, Topical Group Servers, and at Lab Setup Servers. The subsystems located at WWSL Portal are:

- User registration;
- Authentication;
- Usage statistics.

Topical Group Server will typically have the following subsystems:

- Planning, scheduling and remaining;
- Preliminary knowledge control;
- Data archiving;
- Support of data analysis and modelling tools;
- Educator information;
- Student activity monitoring;
- Student communications.

The subsystems located at lab setup server are:

- Remote control of lab setup;
- Flow control of experimental data;
- Streaming audio and video;
- Test and calibration of lab setup.

Additionally, all servers and WWSL Portal will have security subsystems. The specifications and details of WWSL subsystems, as well as student and educator interfaces will be described elsewhere [10].

4. WWSL Lab setups and apparatus

At the beginning of WWSL project, Cosmic ray lab setups were selected for the pilot development [1, 14]. Currently there is third generation of setups for Cosmic ray studies deployed, Figures 3 and 4. Using such systems students are able to conduct the following research project:

- Study of composition of Cosmic ray at Earth level
- Angle distribution of Cosmic ray

- Cosmic ray muon lifetime
- Charge particles energy losses and Landau fluctuation in radiation detectors

Cosmic ray setups are part of the "Nuclear Science and Engineering" Topical Center. We continue to use Cosmic ray setups as a test platform for improvement of WWSL Internet infrastructure and methodology [14].

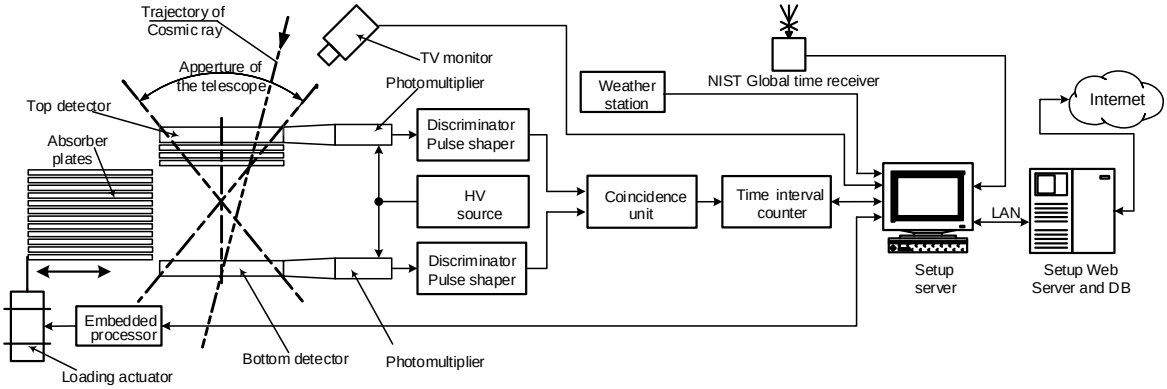

Figure 3. Principal layout of typical lab setup for study composition of Cosmic rays developed by DiscoverLab Corporation. Similar system was built at Bauman Moscow State Technical University.

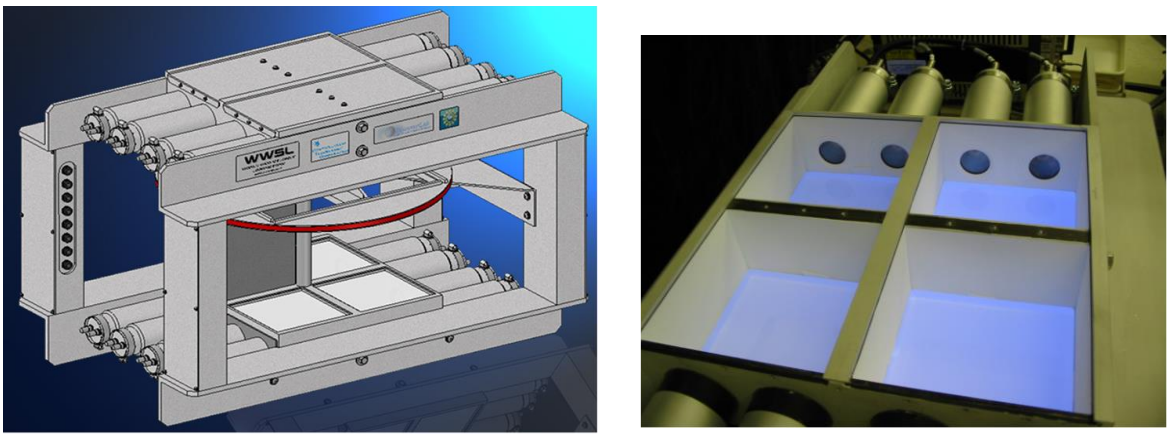

Figure 4. Lab setup for study of properties of Cosmic ray developed in DiscoverLab Corporation. Left: View of four-channel wide aperture Cosmic ray telescope. Right: View of detector section (protection lid was removed).

Other example of WWSL-ready lab system is Distance Robotic Learning which was developed at Bauman State Technical University [8, 9], Figure 5. This system provides an environment for carrying out complex study on real sophisticated robotics equipment and can serve, for example, as a core for building astronauts training device, and for the preparation of robotic operation in Space. This lab system is a part of "Robotic System" Topical Center.

University of Liverpool in cooperation with Vertilon and DiscoverLab Corporations is developing apparatus for remote experimentation with Silicon Photomultipliers, SiPMs [15]. SiPM is a novel generation of avalanche photodetectors and widely used now for medical imaging (Positron Emission Tomography), high-

energy physics and astrophysics applications. After development is completed, this apparatus will be core component of Photonics section of "Optics and Photonics" Topical Group.

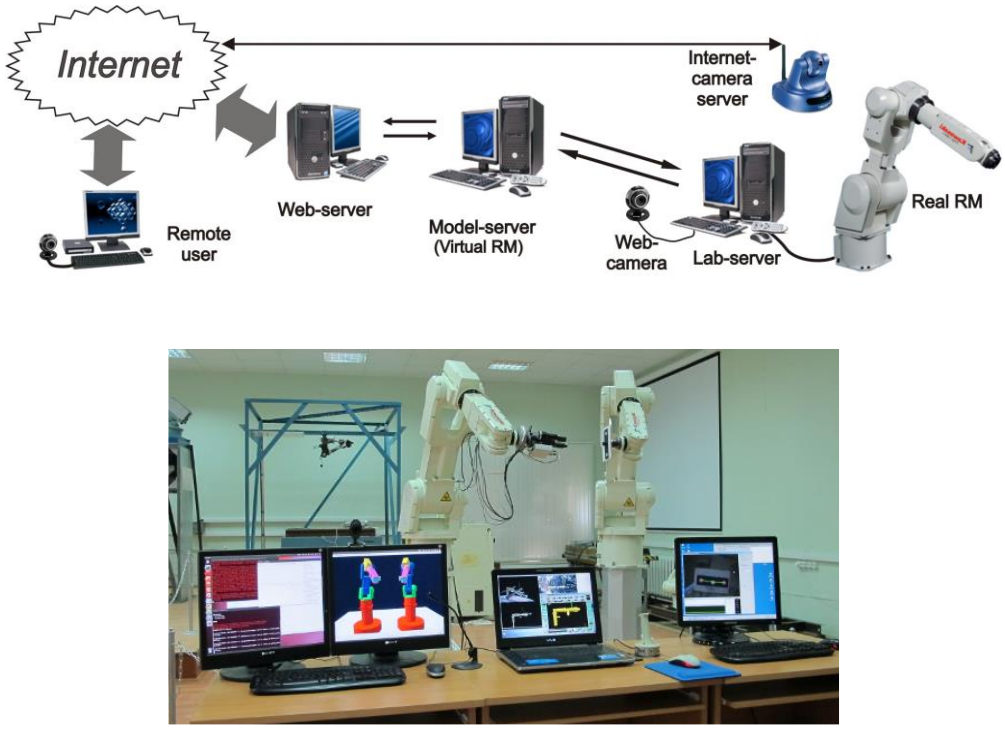

Figure 5. Robotic laboratory at Bauman State Technical University, Moscow.
Top: Architecture of Internet lab for study of the dynamics of remote robotic manipulator. Bottom: Robotic manipulators during on-line lab session.

Several other projects is considering for integration into the WWSL Infrastructure. Among them are:

- Neutron Spectrometer at MIT Nuclear Reactor Laboratory. Can provide online versions of three classic experiments executed in the reactor containment building [16];
- Low-energy Ultra-fast Electron Diffraction Apparatus developed by University of California, Los Angeles and RadiaBeam Technologies [17]. Time resolved measurement of atomic motion is one of the frontiers of modern science, and advancements in this area will greatly improve students' understanding of the basic processes in materials science, chemistry and biology;
- System for isotopes detection and identification by means of Xenon Gamma-ray detector. This remote access lab setup was developed at the National Research Nuclear University "MEPhI, Moscow. The detector setup provides a high-resolution gamma-ray spectroscopy and is very useful for remote experimentation.

5. Conclusion

This paper outlines the development status of the Internet infrastructure for advanced remote educational experimentation, World Wide Student Laboratory, in its third generation. It also describes the innovative concept of the Topical Group Web Centers and our progress in development of some advanced WWSL-

ready experimental apparatuses. Open source REST architecture of network communications and platform independent JSON data format allow having scalable infrastructure without any commercial software applications and tools. Future work will concentrate on integration of several new advanced labs into the WWSL infrastructure.

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