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Research Article

Educational NASA Project: Artificial Intelligence and Cybersecurity at a Mobile Lunar Base

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ABSTRACT:

The article presents research and numerical experiments related to the participation of authors and students from Nikola Vaptsarov Naval Academy in the NASA International Program: Simulation Exploration Experience (SEE) 2020 for the creation of computer simulations of federations on the moon. A Mobile Lunar Base has been designed, in which the following processes are controlled with Artificial Intelligence: movement of three lunar platforms; control of the biosphere used to produce and purify air, water and food; control of a space airport for transfer of employees, passengers and tourists; control of security systems and a cybersecurity module.

The following simulation and programming tools are used: Specially licensed software from NASA; 3D modeling with SketchUP, Blender and AutoCAD; Java programming. The authors analyze the dangers in the Mobile Lunar Base; the possible methods, ways and means for protection, prevention and dealing with each of the analyzed threats. He article concludes with a summary on the security of the systems for provision of cyber and space security of the Mobile Lunar Base.

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Introduction

The development of science and technology has allowed faster and more diverse assimilation of the near space. In recent years, preparations have begun to return to the Moon to stay. There is a growing demand for qualified scientists and engineers to design, create and develop space technologies. The study of the Moon and the creation of lunar bases will be realized mainly with the help of robots and systems that have elements of Artificial Intelligence and are provided with a high level of cybersecurity. Moon colonization programs are developed and prioritized by all space agencies. All lunar programs focus on the study and use of the lunar surface and the construction of lunar bases. The innovation and relevance of the programs for colonization of the Moon are the main motivating factor for the team of students and teachers from the Naval Academy, who have been participating for the third year in NASA's Simulation Exploration Experience (SEE) International Program for Computer Simulations of Moon Federates.

1. The SEE Program and the Participation of the Naval Academy

The scientific development is realized within the educational program Simulation Exploration Experience (SEE) of NASA.[25] The Simulation Exploration Experience (SEE) joins students, industry, professional associations, and faculty together for 10 years now for an annual modelling and simulation (M&S) challenge in space industry. The main part of the work in SEE is an active process of training students in the use of computer programs, platforms and opportunities to achieve specific targets on specific objects of the solar system. The final phase of each one-year program is a conference, during which individual teams of scientists, faculty and students demonstrate the "Live and remote" deployment of their models in the Atkin Basin, located on the opposite side of the moon. The Naval Academy has been participating in the SEE educational program since 2018, and in 2018 and 2019 it was the only representative in the conference from Eastern Europe.[1, 2, 23] Due to Covid-2019, this year for the first time the Final Conference is being held virtually.[24] On 27th April 2020, thirty professors and students from different countries presented simulations of their space 3D models. They used free licensed software from NASA in the Distributed Observer Network (DON). The process of modelling and simulating is practiced in the preparation of each space mission.

This year the Naval Academy Team is composed of 20 students, divided into four groups depending on the tasks to be performed, their interests and skills. The task of the first group, called “researchers,” is to generate ideas for the development of individual modules - federates based on reliable and verified scientific information.[5-7, 10, 13-20] The second group - graphic designers design images according to the ideas. The third group of students creates 3D models of graphic projects. The fourth and most important is the group of programmers. This group has to program the location and movement of the federations in the NASA simulation environment. The task of each team is initially to create their own baseball card, in which to summarize the ideas for the project, which will later be implemented.

The idea of the Naval Academy team is to create a Mobile Lunar Base, in which the processes and objects are managed by Artificial Intelligence, offering solutions to ensure their cybersecurity.

2. Mobile Lunar Base, Processes and Objects Controlled by Artificial Intelligence

Lunar bases can be stationary (positioned in a crater or in selected regions of the Moon) and mobile (whose main areas can be moved along the lunar surface). For the most part, current space projects focus on stationary lunar bases. NASA began work on the design of lunar bases in 2003, offering active involvement of robots in their construction.[19, 20] A project of a stationary lunar base, developed by the authors of the article and students from the Naval Academy, has been presented in the International Program for Computer Simulations of Federates on the Other Side of the Moon, organized by a Consortium of Universities, IT Business Organizations and NASA in 2018.[1, 2] We offer the use of Artificial Intelligence in the operation of the entire complex of systems that control a Mobile Lunar Base. A Mobile Lunar Base would be much more productive, innovative and efficient. For the first time in the SEE program, the Naval Academy team offers a project and computer simulation of a Mobile Lunar Base.

The management, maintenance and operation of a Mobile Lunar Base based on Artificial Intelligence will contribute greatly to the quality, efficiency and security (technical and human) of all objects and systems. Human participation in the work of a Mobile Lunar Base will be purposefully and harmoniously combined with the use of automatic spacecraft and robotics based on systems and elements of Artificial Intelligence. Robotic systems will be used as much as possible during lunar research in order to reduce the risks of harm to human health. Of paramount importance to the functioning of a Mobile Lunar Base is the provision of security and protection provided by Artificial Intelligence.

The first task of the “Brain of the Mobile Lunar Base” - Artificial Intelligence will be the choice of location of the Mobile Lunar Base - spaceport, energy center and biosphere.

The Mobile Lunar Base (Figure 1.) will consist of three main mobile platforms and three stationary sites. The fixed objects - the core of the Mobile Lunar Base are the spaceport, the biosphere and the energy module. The spaceport provides opportunity for the arrival and departure of people - professionals, scientists, staff and tourists. The biosphere aims to provide air, food and water to the people. The energy module is a small nuclear reactor that has the task of providing energy to all objects and systems of the Mobile Lunar Base. The Mobile Lunar Base is a system of three mobile platforms, resembling trains (Figure 1) that can move independently or connected to each other. Each of them has a specific task that determines the movement - horizontally, vertically or combined.

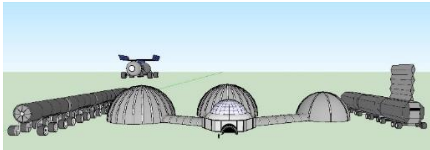

Figure 1: 3D visualization of the mobile platforms, developed by the team of 3D designers of the Naval Academy.

The first platform will solve research tasks related to the study of the lunar surface; it will carry out a detailed lunar topography. With the help of solar telescopes, optical, infrared and radio telescopes it will study solar and cosmic radiation and will make observations of astronomical objects. This platform will be equipped with additional mobile devices – type of lunar drones and will be able to move horizontally and vertically.

The second platform will aim to do biochemical research and experiments with material from the lunar surface – lunar regolith. This platform will only move horizontally. It will collect samples. It will maintain the operation of a stationary lunar factory for processing lunar regolith to produce He3 - the fuel for the nuclear reactor, and to supply other lunar and terrestrial reactors. The second platform will conduct research on water in craters on or below the lunar surface. This platform will do research on lunar earthquakes.

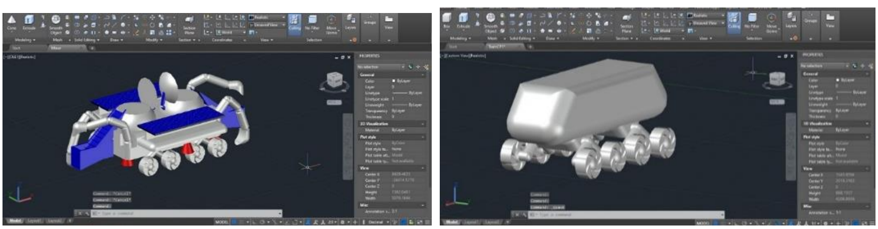

Figure 2: 3D visualization of moving objects in the development environment, realized by the team of the Naval Academy.

The third platform will provide an opportunity for tourists and astronauts to explore interesting objects on the lunar surface. This platform will be able to move horizontally and vertically. It will be equipped with modules for vertical travel.

The platforms and devices (Fig. 2) will be equipped with Artificial Intelligence control systems. This will allow tasks to be performed in the event of a delay or lack of command from the Stationary Command Center on the base and from Earth.

All platforms-trains, devices and systems will be controlled by Artificial Intelligence. It will analyze the environment and take actions that increase the possibility of achieving predetermined goals.

Tasks that will be solved by the Artificial Intelligence:

1. Selection of a suitable location for the main and permanent position of the Mobile Lunar Base. Information will be collected for the creation of a database for detailed relief and composition of the lunar surface, a group of site requirements will be created, the location of the spaceport, the nuclear reactor, the biosphere and the command center will be chosen.
2. The so-called intelligent agents will control all bio-chemical systems of the Biosphere for the creation and purification of air and water, for growing food and preparing it for consumption. Any information received will be evaluated according to the accumulated data with subsequent assessment of reliability. This is necessary to ensure the most efficient operation of life support systems in the Biosphere.
3. Control of the energy module through the systems for operation of the micro-nuclear reactor.
4. Collection, accumulation and analysis of the obtained data from the mineral resources from the lunar regolith, the observational data from the optical, infrared, radio and optical telescopes.
5. Management of the programs for movement of the platforms-trains and of the flying and moving separate objects.
6. Control of the space airport concerning the transfer of employees, passengers and tourists;
7. Control of security systems and cybersecurity module.
8. Evaluation of received technical and scientific information according to the already collected with subsequent evaluation of reliability.

Any information obtained will be determined with a confidence level of T- (0 <T <100) [%] (T is determined according to related non-identical information).

Conventional Artificial Intelligence will be used in the management and operations of the Mobile Lunar Base. The method of the Expert Systems will be applied to solve the different tasks. These will be programs that work according to certain rules, process a large amount of information and as a result make decisions based on it.

Computational Artificial Intelligence will also play an important role in researching tasks. Systems operating on the following basic methods will be applied:

- Neural network: A system with excellent recognition capabilities given the insufficient knowledge of natural lunar objects, the study of space objects (space hazards) and human potential (specialists and tourists, excluding terrorists).
- Fuzzy system: methods of reasoning in conditions of uncertainty, which is still poor knowledge of the Moon.
- Approved training: Automatic learning methods, characterized by their ability to function without the need for exemplary solutions to a problem,

are required given the unknown dangers and problems that may arise on the Moon.

The control of a Mobile Lunar Base, processes and objects with Artificial Intelligence is possible with the software provided in SEE and NASA, for space simulations using the Java programming language.

3. Computer simulation of a Mobile Lunar Base

The students, who are programmers have to study and install the new software, that is not part of the curriculum materials at the Naval Academy. The basic software platforms of the NASA project are:

- SISO - Simulation Interoperability Standards Organization, supporting the HLA standard (IEEE 1516).[9, 22]
- RTI - Run Time Infrastructure, thanks to which the various simulations are connected. Includes Pitch and MaKprovide RTI software for SEE teams. Our team uses Pitch; Pitch Runtime Infrastructure pRTI ™ [21] enables the programmers to exchange data and synchronize events between simulations;
- SEE HLA Starter Kit which contains samples with source code to design HLA federations;
- Java developed framework (SEE-SKF);
- DON (Distributed Observer Network) - NASA's 3D simulation environment, which receives data from the DON federation HLA2MPC. It simulates the movement of the federations developed by the project participants.[4]

The students have to install SEE Virtual Private Network (VPN) and several software products in order to program the federations - HLA Evolved Starter Kit, develop Federation Object Models (FOM), mastering the services of the Run-Time Infrastructure (RTI), Eclipse IDE for programming in JAVA; Distributed Observer Network (DON). The students also have to write programs in Java and use XML.

After the baseball card project, the students created 3D models of objects describing the Mobile Lunar Base. These objects are - the spaceport, the biosphere, the energy module and the mobile platforms. These objects are created in SketchUp, Autocad and Blender.

Then, with the help of specialized software Pitch Runtime Infrastructure (pRTI ™) and SEE HLA Starter Kit,[5, 8] students program the simulation of time, transformation of coordinates, publication events and subscription on mobile platforms called federates. The behavior of federates is developed in Java. Students can use Pitch in local host or on NASA's server via a browser via a VPN connection (SEE Virtual Private Network (VPN) [11]) with a NASA-provided IP address and port for VPN connection. Only the federations of Naval Academy are visible on the local computer, and when connecting to the NASA server, the federations of all participating teams are displayed. The federates SpaceShip, Excavator1, Master Excavator and Excavator 9, created from the Naval Academy team in the Pitch environment on the NASA server in SEE'2019 are presented in Figure 3.

The window of Pitch Control Center is also view below the window of Pitch Web View on the figure.

Figure 3: The Naval Academy federates in PITCH on NASA server, SEE 2019.

The students can upload their 3D models in .obj format in the simulation environment Distributed Observer Network (DON) required from NASA. The simulation of the movement of the objects and interactions between the federates of the teams involved in the NASA project is also possible in DON.

The process of involving the federations in DON demands that they are described in XML code in the configuration file used by HLA2DON.[4]

For the first time in SEE 2019 we have used Artificial Intelligence in computer simulations in order to determine the optimal path of a lunar excavator from a found target to a stationary lunar base. This is an important and significant innovation in the development of computer simulations, which we are upgrading in 2020. The final simulation of the Naval Academy team at SEE 2019 in DON is presented on the Figure 4.

Figure 4: Final of the Naval Academy team computer simulation at SEE 2019 in DON together with the other participating teams.

4. Analysis of Space Hazards – Means of Warning and Protection

The hazards in the Mobile Lunar Base may be divided into two main categories: space hazards and terrorist attacks.

To prevent dangerous situations, we will have at our disposal a comprehensive system for protection against terrorist attacks, which will be managed by Artificial Intelligence.

It is necessary to build servers with improved design of input-output architecture, memory, data storage and network technologies. Computer systems allow a flexible approach to designing configurations suitable for a wide range of tasks - from standard applications to critical operations, real-time data analysis and Artificial Intelligence.

4.1. Space hazards

Danger of Powerful Solar Storms

To protect ourselves from powerful solar storms, we will have a system of two solar telescopes positioned on the research platform.

Danger of Collision with an Asteroid, Comet or Meteorite

A collision with asteroids, comets and meteorites will destroy the Mobile Lunar Base or mobile modules. Several telescopes will be used to detect small and large asteroids and comets near Earth. Another possibility is to fire rockets at objects and thus change their trajectories. Artificial intelligence will play a big role in this protection in the security system.

Danger of Collision with Space Junk

Space junk is the most dangerous and collision with the smallest particles will cause major problems. Optical and radio telescopes that can detect space junk will be used on the research platform. Artificial Intelligence will provide safety and security for the platforms and the base.

Danger of Cosmic Radiation and Protection

Cosmic radiation can kill human cells, but the human body has the function of repairing them immediately. Small particles are the most dangerous because once they enter the human body, they instantly begin to destroy all types of cells and the body cannot repair them.

4.2. Cyber Attacks: Cyber and Real Attacks

Modern systems used in NASA developments are diverse. In order to work accurately, they must have reliable and secure communication. NASA is the number one goal of many hackers and hacking organizations. The services and opportunities provided by specialists provide a prerequisite for many vulnerabilities. Hackers initially test public services, such as websites and servers with open ports. For example, one of the most common attacks that are implemented is SQL Injection in order to compromise databases and delete them later.[3] Another attack is Distributed Denial-of-Service (DDoS), which sends multiple network packets that cause servers to overload and stop working. In order to be able to protect the used IT services on the servers, it is necessary to have an input /output network with a hardware Firewall, which filters the input /output data and thus prevents DDoS attacks. In addition to protecting web-based portals, we will use a specialized Web Application Firewall that filters input sent to web platforms, which will drastically limit and drastically reduce XSS and SQL Injection attacks.[12]

The Dangers of Cyberattacks:

- Hacking of research programs to steal scientific information, information from lunar regolith research, helium-3 sites and lunar seismography;
- Hacking systems which control the platforms, telescopes and lunar drones;
- Hacking of systems in spaceport, nuclear reactor and biosphere.
- A real attack is for the theft of resources from the biosphere and materials from lunar research.

The dangers and protection of a Mobile Lunar Base are summarized in the block diagram of Figure 5. The stages that the attack protection algorithm goes through are:

- Analysis: Periodic analysis of the current state of computer-based systems for error checking and review of log-files for authorized and unauthorized access;
- Data hack: Based on the above analysis, it is concluded whether the operating systems have been compromised. If it is found that the system has not been hacked, the algorithm returns to the “Analysis” stage. In case of network compromise: a new security rule is added to the hardware Firewall to prevent future cyberattack;
- Hacking of control systems: After adding the Firewall security rule, all available computer-powered systems are checked for compromise, and if this event occurs, Secure Connection protection is enabled, which encrypts all communication and tries to limit unauthorized attempts. to send information from Mobile Lunar Base systems to the Internet. After performing Secure Connection, the algorithm checks the input / output data again in the “Analysis” stage.

Conclusion

The proposed development, made from the team of teachers and students of Nikola Vaptsarov Naval Academy at Mobile Lunar Base considers, analyzes and offers innovative, non-standard, but working solutions to an important problem. The computer programs provided by NASA and the opportunity for continuous communication and exchange of ideas contributed greatly to the successful development of the project. The models of the mobile platforms developed by the students and the overall vision of a future Mobile Lunar Base

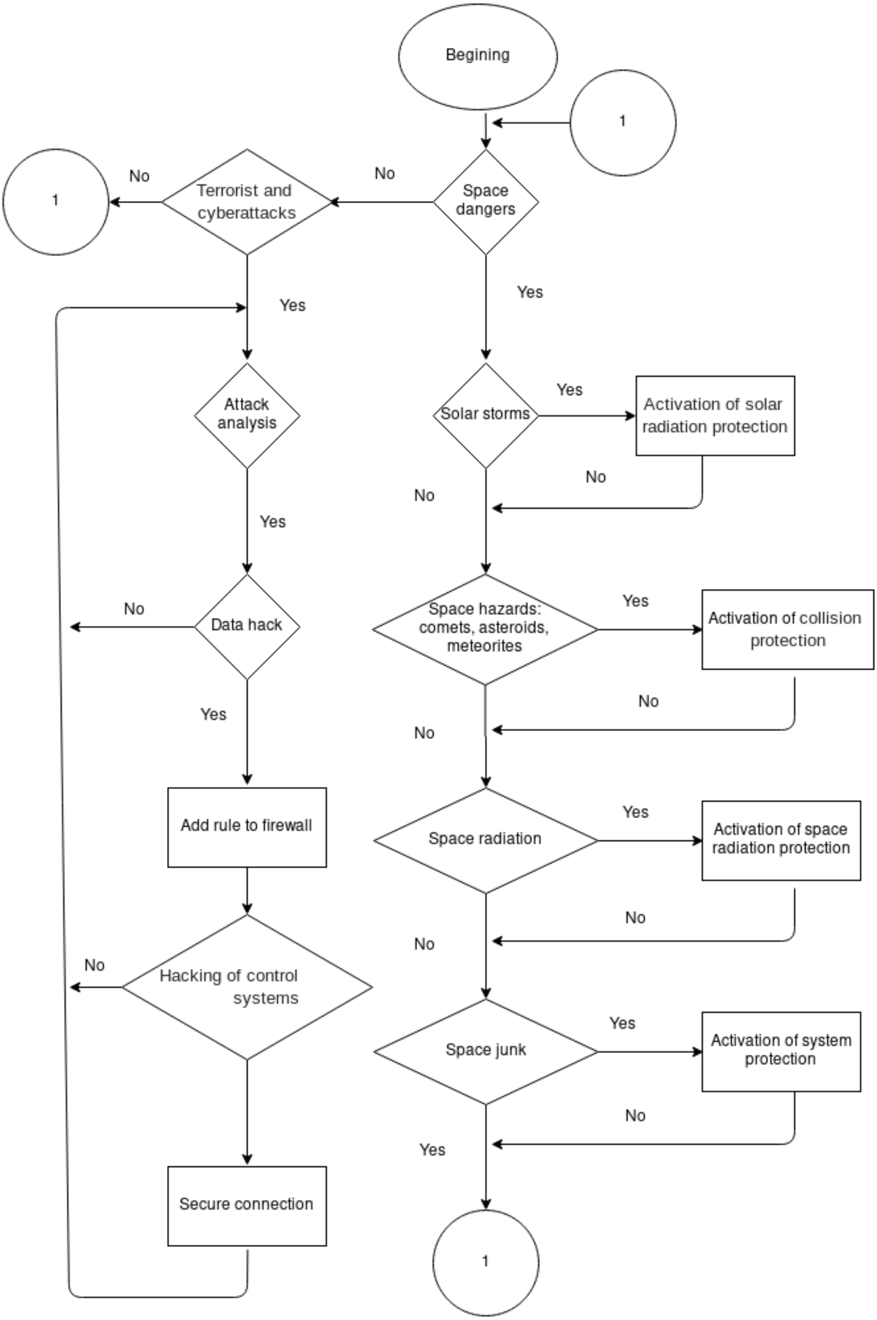

Figure 5: Block diagram for hazards and protection of a Mobile Lunar Base.

represent a kind of contribution to the international process of preparation for future working bases on the Moon. The developed algorithm, the analysis of the possible space dangers and cyberattacks, and the proposed protection solutions are of utmost importance for the smooth and safe operation of each habitable lunar base. By working on the project, together with a large international university student team and NASA scientists, students gain new knowledge and skills to work with new professional software. For three years the team of students and professors from the Naval Academy developed computer simulations of lunar federations, which are original, practical and applicable in a future project on a real lunar base.

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Reference

1. Evgeni Andreev, Mariya Nikolova, Veselka Radeva, and Georgi Bochev, "Creating Moon Port and Spaceship Simulations in a Virtual Environment," *Proceedings of the 44th International Conference on Applications of Mathematics in Engineering and Economics AIP Conference Proceedings* 2048, no. 1, 2018, pp. 020028-1–020028-8, https://doi.org/10.1063/1.5082046.
2. Evgeni Andreev, Veselka Radeva, and Mariya Nikolova, "Innovative Biomonitoring Systems in The Aerospace Industry,“ *CEMA'19 conference, Sofia*, 2019, pp. 17-21, http://suggestor.step.scopus.com/progressTracker.
3. Justin Clarke, *SQL Injection Attacks and Defense* (USA: Syngress, 2012).
4. M. Conroy, "Design and Development with Very Distributed Teams," 2018, http://it.naval-acad.bg/wp-content/uploads/2018/07/DON-MPC-GitHub-Presentation.pptx.
5. Dave Dietzler, "Making it on the Moon: Bootstrapping Lunar Industry,“ The *NSS Space Settlement Journal* 1 (September 2016), https://space.nss.org/wp-content/uploads/NSS-JOURNAL-Bootstrapping-Lunar-Industry-2016.pdf.
6. Douglas Isbell and David Morse, "Latest lunar prospector findings indicate larger amounts of polar water ice," LRC Publications, 2005.
7. Sarah Dunkin and David Heather, *New views of the Moon* (Physics Web, 2005).
8. Alberto Falcone, Alfredo Garro, S.J.E. Taylor, A. Anagnostou, N.R. Chaudhry, and O. Salah, "Experiences in simplifying distributed simulation: The HLA development kit framework," *Journal of Simulation* 11 (2017): 208-227, http://doi.org/10.1057/s41273-016-0039-4.

9. Alfredo Garro and Alberto Falcone, "An introduction to the SEE HLA Starter Kit," *Spring Simulation Multi-Conference (SpringSim'16)*, 2016.

10. Al Globus and Joe Strout, "Orbital Space Settlement Radiation Shielding," *NSS Space Settlement Journal* 2 (April 2017), https://space.nss.org/wp-content/uploads/NSS-JOURNAL-Orbital-Space-Settlement-Radiation-Shielding.pdf.

11. Simon Gorecki, Grégory Zacharewicz, and Nicolas Perry, "Using High Level Architecture in the SEE Project for industrial context," In: Borangiu T., Trentesaux D., Thomas A., Cardin O. (eds) *Service Orientation in Holonic and Multi-Agent Manufacturing*, Studies in Computational Intelligence, vol 762 (Springer, Cham, 2018). https://doi.org/10.1007/978-3-319-73751-5_21.

12. Rajneesh Gupta, *Hands-On Cybersecurity with Blockchain: Implement DDoS protection, PKI-based identity, 2FA, and DNS security using Blockchain* (Packt, 2018).

13. Milena Lefterova, "Verification and Validation Strategy for Precisely Drag Estimation of ERCOFTAC Test Body," *Proceedings "Black Sea'2010," Varna,* 2010, pp. 150-156.

14. Milena Lefterova, *Mathematical models of ship maneuverability* (University publishing house, Technical University of Varna, 2020).

15. Milen Sotirov and Yuliyan Tsonev, ", "Implementation of Gamification in the University Classrooms," *Conference proceedings of seventh national conference "E-learning in higher education," Sofia*, 2018, pp. 232-236.

16. Jordan Sivkov, "Information system for collection, processing and presentation of data from sensor nodes," *Proceeding of 16th Conference on Electrical Machines, Drives and Power Systems, ELMA 2019, Varna,* 2019, pp. 290-293, DOI: 10.1109/ELMA.2019.8771493.

17. Mark Wieczorek, Bradley Jolliff, Amir Khan, Matthew Pritchard, Benjamin Weiss, James Williams, Lon Hood, Kevin Righter, Clive Neal, Charles Shearer, Stewart McCallum, Stephanie Tompkins, Ray Hawke, Chris Peterson, Jeffrey Gillis, and Ben Bussey, "The constitution and structure of the lunar interior," *Reviews in Mineralogy and Geochemistry* 60, no. 1 (2006): 221–364.

18. Yuliyan Tsonev and Milen Sotirov, "Gamification in Education as a Way for Improving Student Knowledge and Productivity," S*cientific proceedings of The 11th International Scientific Conference "Digital Economy and Blockchain Technologies," Varna,* 2018, pp. 445-452.

19. Marc Cohen, "Mobile Lunar and Planetary Bases," *Space 2003 Conference, San Diego, CA, Sept. 23-25, 2003*, https://www.researchgate.net/publication/228851327_Mobile_Lunar_Base_Concepts, 2003.

20. Marc Cohen, "Mobile Lunar Base Concepts," *AIP Conference Proceedings 699, 2004,* http://www.astrotecture.com/Space_Architecture_files/AIP-CP-699-Cohen.pdf.

21. Pitch pRTI™, 2020, http://www2.pitch.se/pRTI1516e/Releases/v5.3.2.1/MxdozAZrF/install.asp.

22. The HLA tutorial, 2020, http://www.pitchtechnologies.com/hlatutorial.

23. SEE 2018 - Sofia, Bulgaria May 8-10, 2018, https://www.youtube.com/watch?v=3N8dO2G4E8s, 2018.

24. SEE 2020, Final Event Video, https://www.youtube.com/watch?v=O7asaD9iUeI&t=7209s.
25. SEE Web site, https://www.exploresim.com/about.

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