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United Nations Programme on Space Applications

Zero-Gravity Instrument Project (ZGIP)

Human Space Technology Initiative (HSTI)

I. Introduction

1. The United Nations Programme on Space Applications was launched as a result of discussions at the first United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE), held in Vienna in 1968.[1] The Programme is implemented by the United Nations Office for Outer Space Affairs and provides support to capacity-building in space technology and its applications to all Member States of the United Nations, regardless of their level of economic development.[2]

2. The initial focus of the Programme was on the applications of space technology, such as in satellite communications, Earth observations and positioning and navigation services. In the 1990s space science-related activities were added to the Programme through the Basic Space Science Initiative (BSSI), followed by the launch of the Basic Space Technology Initiative (BSTI) in 2009 as a response to the interest in a growing number of Member States to build capacity in space technology development.

* A/AC.105/C.1/L.332.

[1] United Nations, General Assembly, Official Records Twenty-Third Session, Agenda item 24, Report of the Committee on the Peaceful Uses of Outer Space, Annex II "Documentation on the United Nations Conference on the Exploration and Peaceful Uses of Outer Space", New York 1968.

[2] United Nations Office for Outer Space Affairs, "United Nations Programme on Space Applications", United Nations, ST/SPACE/52/Rev.1, September 2012.

3. In 2010, the Human Space Technology Initiative (HSTI) was further added within the framework of the Programme, aimed at involving more countries in activities related to human space flight and space exploration and at increasing the benefits from the outcome of such activities through international cooperation, to make space exploration a truly international effort. BSSI, BSTI and HSTI represent new cornerstones of the Programme on Space Applications.

4. The role of HSTI in those efforts is to provide a platform to exchange information, foster collaboration between spacefaring and non-spacefaring countries, and encourage emerging and developing countries to take part in space research and to benefit from space applications. HSTI activities are built on three pillars: (a) promoting international cooperation in human spaceflight and space exploration-related activities; (b) creating awareness among countries of the benefits of utilizing human space technology and its applications; and (c) building capacity in microgravity education and research.[3]

5. Under pillar (c) building capacity in microgravity education and research, HSTI is carrying out its primary science activity called the Zero-Gravity Instrument Project (ZGIP).

6. This document reports on the overview and status of ZGIP. It should be read in connection with the document titled the Human Space Technology Initiative — Activities in 2011-2013 and plans for 2014 and beyond (A/AC.105/2013/CRP.16) which describes the mission, underlying objectives and activities of HSTI.

II. Zero-Gravity Instrument Project (ZGIP)

A. Project Outline

7. The “Zero-Gravity Instrument Project” (ZGIP) was initiated in 2012 as part of HSTI capacity-building activities, in which a fixed number of microgravity-simulating instruments, called Clinostats, have been distributed to selected schools and institutions worldwide. ZGIP is implemented by the Space Applications Section of the Office for Outer Space Affairs.

8. The Project was established in response to the recommendation at the first HSTI international meeting, the United Nations/Malaysia Expert Meeting on Human Space Technology in 2011. Participants in the working group on education, outreach and capacity-building addressed the need to develop capacity through training and education and enhanced cooperation in sharing various opportunities for using space and ground research facilities. The conclusions and recommendations of the Expert Meeting are contained in the Report on the United Nations/Malaysia Expert Meeting on Human Space Technology (A/AC.105/1017).

9. The major objectives of the project are to provide unique opportunities for students and researchers to observe natural phenomena of samples under simulated microgravity conditions on the ground, and to inspire them to undertake further study in the field of space science and technology. The project is also aimed at

[3] United Nations Office for Outer Space Affairs, “Human Space Technology Initiative”, United Nations, ST/SPACE/62/Rev.1, November 2013.

creating datasets of plant species with their gravity response, which would contribute to design future space experiments, and to the advancement of microgravity research.

10. The project expects participation from nationals of developing countries or countries with economies in transition. Heads of research groups, university professors with scientific orientation, or science teachers are the expected profiles of the applicants. Moreover, applicants are required to act as leaders of the proposed activities under the Project in their institutions, and are expected to provide their ideas on how they plan to utilize the distributed clinostat.

11. Within the limited availability of clinostats, participation of research teams from spacefaring countries is also welcome to take part in this project. The project is intended to create a global scientific and educational network by sharing experiences and experimental results in different geographic regions.

12. One cycle of the Project is scheduled for three years, starting from the announcement of opportunity to the submission of the final activity report. Currently, two cycles have been scheduled, distributing up to 20 clinostats per cycle. Each successful applicant receives one (1) unit of the clinostat. The experiment phase lasts for approximately two years. During this period, institutions will use the clinostats to conduct experiments on the proposed projects. The selected applicant will be required to provide annual reports to the Office for Outer Space Affairs on the activities with the clinostat. The details of the project, including the Terms of Participation, are available online in the web page of the project at www.oosa.unvienna.org/oosa/en/SAP/hsti/zgip.html.

13. In order to select suitable institutions to receive clinostats and increase the scientific value of the project, the HSTI Science Advisory Group (HSTI-SAG) was established. The HSTI-SAG is currently comprised of seven renowned academic experts in microgravity life science who have joined the Group voluntarily.

14. The Office developed a "Teacher's Guide to Plant Experiments in Microgravity" (ST/SPACE/63) which is intended to provide step-by-step instructions to teachers and students to perform experiments on plant growth using the clinostats in a school laboratory. Work on the development of the Teacher's Guide began in 2012 with the support of the HSTI-SAG members. The electronic version of the Guide is available online in the ZGIP website that could be reached at www.oosa.unvienna.org/oosa/en/SAP/hsti/zgip.html.

15. The implementation of ZGIP relies on in-cash and in-kind contributions from Member States. Those contributions include a total of approximately US$ 100,000 from Japan and US$ 20,000 from China, as well as voluntary scientific contributions from the following institutes: the Biomedical Science Support Center, Institute of Aerospace Medicine, German Aerospace Center (DLR), Germany; the Dutch Experiment Support Center (DESC), ACTA-Free University and University of Amsterdam, the Netherlands; Laboratory of Plant Physiology, Department of Biology and Geosciences, Osaka City University, Japan; Laboratory of Space and Adaptation Biology, Tohoku University, Japan; National Microgravity Laboratory (NML), Chinese Academy of Science (CAS), China; and the State Key Laboratory of Space Medical Fundamentation and Application, Astronaut Research and Training Center of China (ACC).

16. The Project is conducted in accordance with the HSTI multi-annual workplan developed in consultation with representatives from Member States and experts from all around the world. The Project is reviewed annually and updated with the purpose to incorporate the feedback received from participants and lessons-learned through the project activities.

B. Scientific background

17. The one-axis clinostat provided by the Office for Outer Space Affairs is a tool that is used to study the impact of altered gravity conditions on organisms such as plants, fungi and other small organisms. The quality of the simulation is determined by the size of the selected test system.

18. Short-term microgravity can be provided in drop towers or drop shafts (for 2-10 seconds), balloons (30-60 seconds), parabolic flights of aircraft (20-25 seconds) or sounding rockets (up to 15 minutes). These methods are suitable fast-responding systems. In order to study the long-term effects of microgravity, however, satellites or human-tended space laboratories have to be used. The development of space stations fulfilled the dream of a long-term stay by humans in space. The Russian MIR space station orbited at a height of 300-400 km above the Earth, and more than 100 astronauts and cosmonauts had the opportunity to visit the space station. Since 1998, the International Space Station (ISS) has been in space, providing living and working accommodations for up to six astronauts at a time. The ISS offers laboratory conditions for systematic studies in microgravity.[4]

19. Although experiments in real microgravity in space are rare and expensive, similar experiments can be conducted on the ground.[5] Scientists have developed various kinds of ground-based facilities and equipment to achieve the condition of functional weightlessness. For example, astronauts are trained underwater, since buoyancy can compensate for gravity and create simulated microgravity conditions in a pool. A clinostat is an experimental device that can equalize the gravity vector around one or two rotational axes, if it is for a slow-reacting phenomenon. Research under simulated microgravity conditions must, however, be verified by research under real microgravity conditions.

20. Various kinds of clinostats have been developed, differing in the number of rotational axes, in addition to the modes of operation with respect to the speed and direction of the rotation. A two-dimensional (2-D), or one-axis, clinostat has a single rotational axis, which runs perpendicular to the direction of the gravity vector.[6]

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[4] United States of America, National Aeronautics and Space Administration, *Reference Guide to the International Space Station* (Washington, D.C., 2010).

[5] R. Herranz and others, "Ground-based facilities for simulation of microgravity: organism-specific recommendations for their use, and recommended terminology", Astrobiology, vol. 13, No. 1 (2013), pp. 1-17.

[6] W. Briegleb, "Some qualitative and quantitative aspects of the fast-rotating clinostat as a research tool", *ASGSB Bulletin*, vol. 5, No. 2 (1992), pp. 23-30; R. R. Dedolph and M. H. Dipert, "The physical basis of gravity stimulus nullification by clinostat rotation", *Plant Physiology*, vol. 47, No. 6 (1971), pp. 756-764; and D. Klaus, "Clinostats and bioreactors", *Gravitational and Space Biology Bulletin*, vol. 14, No. 2 (2001), pp. 55-64.

A three-dimensional (3-D) clinostat has two rotational axes, which are perpendicular to each other.[7] A rotation on a clinostat is often called "clinorotation".

21. Under a 1 g condition, particles fall and become sediment with liquid media. Under a free-fall condition, there is no sedimentation, and particles homogeneously distribute. On Earth, this situation can be achieved by rotating a vertically positioned object. Under this condition, particles will fall along the gravity vector but also will be forced into circular paths because of the clinorotation. The simulated microgravity condition can be achieved in which particles have no relative movements by adjusting the speed of clinorotation.

22. For the Zero-Gravity Instrument Project, a one-axis clinostat is used. This could provide a rotational speed in a range of 0 to 20 revolutions per minute (rpm) for educational purposes and 0 to 90 rpm for research purposes.[8] When using a clinostat, the speed of rotation, the diameter and time sensitivity of the sample, and the horizontal placement of the clinostat are essential parameters to determine the effectiveness of the microgravity simulation.

23. In the aforementioned Teacher's Guide to Plant Experiments in Microgravity, a model experiment using cress seedlings and cress roots is introduced. This experiment demonstrates the function of and methods for using the clinostat. In addition, a great deal of information is available on the Internet and in scientific literature about the impact of gravity and microgravity on other biological systems, ranging from bacteria and cells to small organisms. This may serve as a foundation for further experiments with a clinostat.

III. Project Implementation

A. 1st cycle of the Project (2013-2015)

24. The Announcement of Opportunity of the first cycle was released on 1 February 2013. It was disseminated through all Permanent Missions to the United Nations in Vienna and various networks including the Learning Managers Network of the United Nations Development Programme, as well as academic entities including the International Academy of Astronautics.

25. By the deadline of 30 May 2013, 28 valid applications from around the world were received. After a careful review made by HSTI-SAG and the programme experts of the Office for Outer Space Affairs, a total of 19 schools and institutions from the following 12 countries were selected to take part in the project: Chile, China, Ecuador, Ghana, Iran (Islamic Republic of), Iraq, Kenya, Malaysia, Nigeria, Pakistan, Thailand, and Viet Nam. Proposals of seven selected applicants were for educational purposes. Another six were for research purposes, and the remaining

[7] T. Hoson and others, "Evaluation of the three-dimensional clinostat as a simulator of weightlessness", *Planta*, vol. 203, No. 1 (1997), pp. S187-S197; and J. J. van Loon, "Some history and use of the Random Positioning Machine, RPM, in gravity related research", *Advances in Space Research*, vol. 39, No. 7 (2007), pp. 1161-1165.

[8] United Nations Office for Outer Space Affairs, "Teacher's Guide to Plant Experiments in Microgravity", United Nations, ST/SPACE/63/, August 2013, pp.12.

six proposals were for both purposes, research and educational activities. A list of the participating institutions is included in Annex I.

26. The distribution of clinostats initiated in September 2013. As of January 2014, each selected institution is at the initial phase to perform their own experimental work.

27. Technical and scientific assistance with support of HSTI-SAG members is provided to the participating groups upon request via tele/Internet communication.

28. Each participating institution is required to submit their annual activity report to the Office for Outer Space Affairs after the completion of the first-year activity by the end of 2014.

B. Plan for the 2nd cycle (2014-2016) and beyond

29. The announcement of the second-cycle of ZGIP was released on 1 January 2014 with a deadline of 30 April 2014. This phase will be followed by a three-month evaluation of the submitted proposals. The Office is planning to distribute up to 20 units of clinostat in the third quarter of 2014. Further information is available online in the ZGIP webpage.

30. Moreover, the Office is planning to compile activity reports for both the first and second cycles, which will be submitted by each participating school and institution. These reports will be published with the purpose of sharing detailed experiences and experimental results which will contribute to build a global network of the Project.

31. In order to continue with the extension of the Project to its third and fourth cycles, the support of Member States is crucial. The Office is looking for donor countries and research institutes that are interested in providing in-cash/in-kind contributions and/or scientific and educational support to ZGIP. Those interested donor countries/institutes are invited to contact the Office for Outer Space Affairs.

32. The Office, through HSTI activities, also continues to provide useful information services to the research and education community on relevant topics, such as microgravity experiments, which is available online in the HSTI web pages at www.oosa.unvienna.org/oosa/en/SAP/hsti/index.html.

IV. Conclusions

33. HSTI initiated its capacity-building activities by introducing the Zero-Gravity Instrument Project (ZGIP) as an educational and research project. Under this Project, 19 qualified schools and research institutions have been selected to take part in the first cycle of the project which will be completed by 2015.

34. Member States and their research institutions and educational bodies are invited to be part of the different HSTI activities. The Office for Outer Space Affairs welcomes support, comments and suggestions on the implementation of the Project, as well as expressions of interest for cooperation on activities related to capacity-building in human space technology and microgravity research.

Annex I

Institutions participate in the first cycle of ZGIP

	Receiving Institution	Location	Purpose Education	Research	Country
1.	Academia de Ciencias Aeronáuticas	Av. Santa Maria 6400, Vitacura 766 0255, Santiago	–	X	Chile
2.	Laboratory of Environment Biology and Life Support Technology, Beihang University	No. 37, Xueyuan Road, Haidian District, Beijing	X	X	China
3.	School of Life Science, Northwestern Polytechnical University	127 Youyi Xilu, Xi'an, Shaanxi Province	X	–	China
4.	Ecuadorian Space Institute	Instituto Espacial Ecuatoriano, Seniergues E4-676 y General Telmo Paz y Miño Edf. Del Instituto Geografico Militar (IGM), 2do - 4to PISO	–	X	Ecuador
5.	TEMA Senior High School	TEMA Secondary School , Community Two, Tema, Greater Accra	X	–	Ghana
6.	Iranian Space Research Centre	15th Alley, Mahestan Blvd., Shahrake-Gharb, Tehran	–	X	Iran
7.	Soil and Water Center, Agriculture Directory, Ministry of Science and Technology	Ministry of Science and Technology, Iraq, Baghdad	X	X	Iraq
8.	Technical University of Kenya, Faculty of Applied Sciences and Technology	P.O. Box 52428, 00200 Nairobi	–	X	Kenya
9.	National Space Agency (Agency Angkasa Negara)	National Planetarium, Lot 53, Jalan Perdana, 50480 Kuala Lumpur	X	–	Malaysia
10.	Malaysian Agricultural Research and Development Institute	MARDI Headquarters, Persiaran MARDI-UPM, 43400 Serdang, Selangor Daru Ehsan Malaysia	X	X	Malaysia
11.	Federal University Lafia	P.M.B 146, Lafia, Nasarawa State	X	X	Nigeria
12.	African Regional Centre for Space Science & Technology Education in English (ARCSSTE-E)	PMB 019, Obafemi Awolowo University Post Office, Ile-Ife, Osum State	X	–	Nigeria
13.	National Agricultural Research Center	National Agricultural Research Center, PARC, Park Road, Islamabad	–	X	Pakistan
14.	Institute of Molecular Biology and Biotechnology	Institute of Molecular Biology and Biotechnology, Bahauddin Zakariya University, Multan 60800	–	X	Pakistan
15.	Space and Upper Atmosphere Research Commission of Pakistan Institute of Technical Training	SUPARCO Institute of Technical Training, SETC, Hub River Road, near Murshid Hospital, Karachi	X	–	Pakistan

	Receiving Institution	*Location*	*Purpose* *Education*	*Research*	*Country*
16.	Geo-Informatics and Space Technology Development Agency	THEOS Control Ground Station, 88, M.9, Thungsukhla, Sriracha, Chonburi 20230	X	X	Thailand
17.	Lamthabphachanukhrao School	111 Lamthap, Krabi, 181120	X	–	Thailand
18.	School of Environmental Science and Technology, Hanoi University of Science and Technology	302- C10, Ha Noi University of Science and Technology, No 1 Dai Co Viet Street, Hai Ba Trung District, Ha Noi	X	–	Viet Nam
19.	Department of Molecular Biology and Plant Breeding, Tay Nguyen Institute for Scientific Research	116 Xo Viet Nghe Tinh, Ward 7, Dalat city, Lam Dong province	X	X	Viet Nam