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Status of Zero-Gravity Instrument Project (ZGIP) and Drop Tower Experiment Series (DropTES)

Human Space Technology Initiative (HSTI)

I. Introduction

1. The Human Space Technology Initiative (HSTI) was launched in 2010 within the framework of the United Nations Programme on Space Applications. The role of HSTI 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.[1]

2. In 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 as well as enhanced cooperation in sharing various opportunities for using space and ground research facilities. A recommendation was made to urge HSTI to establish dedicated capacity-building programmes, including through the provision of educational materials and the distribution of instruments (A/AC.105/1017).

* A/AC.105/C.1/L.341.

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

3. In the United Nations/China Workshop on Human Space Technology in 2013, a recommendation was made that HSTI should promote education and outreach activities by providing educational materials as well as expert and astronaut forums to assist professionals and to inspire students, academia and the general public about human space exploration (A/AC.105/1050).

4. In response to these recommendations, HSTI started science activities called the Zero-Gravity Instrument Project (ZGIP) in 2012 and the Drop Tower Experiment Series (DropTES) in 2013.

5. These activities are conducted in accordance with the HSTI multi-annual work plan developed in consultation with representatives from Member States and experts from all around the world (A/AC.105/2013/CRP.16).

6. The activities of ZGIP in 2013-2014 were reported in the fifty-first session of the Scientific and Technical Subcommittee (STSC) of the Committee on the Peaceful Uses of Outer Space (COPUOS) (A/AC.105/C.1/2014/CRP.20).

7. This document reports on the overview and status of ZGIP and DropTES of HSTI in 2013-2014.

II. Zero-Gravity Instrument Project (ZGIP)

A. Project outline

8. 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, are distributed to selected schools and institutions worldwide. ZGIP is being implemented by the Space Applications Section of the Office for Outer Space Affairs.

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

10. The Project expects participation from people 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, research teams from spacefaring countries are 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 from 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. Each successful applicant receives one (1) unit of the clinostat. The experiment phase lasts for approximately two years. During this period, institutions use the clinostats to conduct experiments on the proposed projects. The selected applicants are 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 on the Project's webpage at www.unoosa.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 the "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 also available online on the Project's web page.

15. The implementation of ZGIP relies on in-cash and in-kind contributions from Member States. Those contributions include a total of approximately US$ 140,000 from Japan and US$ 30,000 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, 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); and the State Key Laboratory of Space Medical Fundamentation and Application, Astronaut Research and Training Center of China (ACC), China.

B. Scientific background

16. 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.

17. 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 that 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.[2]

18. 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.[3] A three-dimensional (3-D) clinostat has two rotational axes which are perpendicular to each other.[4] A rotation on a clinostat is often called "clinorotation".

19. 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. A simulated microgravity condition can be achieved in which particles have no relative movement by adjusting the speed of the clinorotation.

C. Project implementation

1st cycle of ZGIP (2013-2015)

20. The Announcement of Opportunity of the first cycle was released on 1 February 2013. 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 six proposals were for both purposes — research and educational activities. A list of the participating institutions is in Annex I.

21. Participating institutions are required to submit their annual reports on their educational and research activities using the clinostats. HSTI is now collecting and consolidating the first annual reports and is going to conduct scientific reviews on them with HSTI-SAG.

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

[3] 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.

[4] 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.

2nd cycle of ZGIP (2014-2016)

22. The second cycle of ZGIP began with the Announcement of Opportunity released on 1 January 2014. In the second cycle, out of 18 valid applications, 13 schools and institutions from the following 12 nations were selected to join the Project: Belarus, Brazil, China, Democratic People's Republic of Korea, Honduras, India, Nepal, Nigeria, Pakistan, Peru, Spain and United States of America. Proposals from three selected applicants were for educational purposes, another seven were for research purposes, and the remaining three proposals were for both purposes — research and educational activities. A list of the participating institutions is included in Annex II.

23. The distribution of clinostats to each selected institution was completed, and the experiments of each selected institution have started. The first annual reports for the ZGIP second cycle are expected to be submitted by the end of December 2015.

3rd cycle of ZGIP (2015-2017) and beyond

24. The announcement of the third-cycle of ZGIP was released on 1 January 2015 with a deadline of 30 April 2015. This application period will be followed by a three-month evaluation of the submitted proposals. The Office is planning to distribute up to 15 units of clinostat in the fourth quarter of 2015. Further information is available online on the ZGIP web page.

25. HSTI is planning to compile the annual reports for the first and second cycles and publish the first results of ZGIP. The participating institutions are also expected to play an important role in disseminating the results obtained thorough ZGIP in order to get more people interested in space science and space exploration-related activities.

26. In order to continue with the extension of the Project to its fourth cycles and beyond, the support of Member States is crucial. The Office would like to reiterate its gratitude to the countries and institutions that have provided in-cash and in-kind contributions and is looking for further donor countries and research institutes that are interested in providing in-cash and in-kind contributions and/or scientific and educational support for ZGIP. Those interested donor countries and institutes are welcome to contact the Office for Outer Space Affairs.

III. Drop Tower Experiment Series (DropTES)

A. Fellowship outline

27. The Drop Tower Experiment Series (DropTES) is a fellowship programme launched in 2013 as the second capacity-building activity of HSTI. Students can learn and study microgravity science by performing experiments at the Bremen Drop Tower in Germany. DropTES has been implemented in close cooperation with the Centre of Applied Space Technology and Microgravity (ZARM) and the German Aerospace Center (DLR). The Bremen Drop Tower is a ground-based microgravity laboratory with a height of 146 meters and can enable short-duration weightlessness for various scientific fields such as fundamental physics, fluid dynamics, planetary formation, astrophysics, biology and material sciences.

28. The primary objective of DropTES is to provide students from non-spacefaring countries with the opportunity to conduct their own microgravity experiments at the Bremen Drop Tower. Each experiment consists of four drops or catapult launches within a one-week period. The entire programme is also aimed at contributing to the promotion of space education and research in microgravity.

29. DropTES expects participation from one research team from a non-spacefaring country and each team can have up to four bachelor, master and/or PhD students, who must be endorsed by an academic supervisor. Although the nationalities and institutions of the participating students may differ, the supervisor must belong to the same institution as at least one of the students and is expected to endorse the entire application and development process of the team and bear responsibility for the execution of the experiment.

30. The participating team will be selected by the Selection Board which consists of members from the Office for Outer Space Affairs, ZARM and DLR. The selection criteria include the following: (i) the scientific and/or technological value of the proposed experiment, (ii) the involvement of the proposed experiment in the students' syllabuses, (iii) the relevance of microgravity in the proposed experiment, and (iv) the relevance of the drop tower utilization in the proposed experiment. The entire selection process will be performed in a single step.

31. After being selected, the participating team will start preparation work for about six months in close cooperation with ZARM. Such preparation work includes, inter alia, the submission and collaborative finalization of experiment progress reports and a critical design review. In the experimental phase, the participating team is given one week of experiment integration on-site at the Bremen Drop Tower followed by one-week drop tower experiments. Upon completion of the experiments, the selected team is required to submit the final experiment report.

32. As a fellowship programme, in addition to the provision of the opportunity to conduct microgravity experiments for students and researchers from non-spacefaring countries, DropTES places importance on enhancing the ability as well as the expertise in relevant fields of the experiments through interaction with ZARM before, during, and after the experiments. In this regard, experts from ZARM will support the entire programme. Moreover, if the participating team desires, scientific mentors will be appointed to support the successful implementation together with the ZARM experts and to help the team with the pursuit of specific matters. Furthermore, feedback from ZARM will be given in the final report submitted by the participating team with the purpose of enabling the team to cultivate and extend their capability after the experiment is finished.

B. Fellowship implementation

1st cycle of DropTES (2014-2015)

33. The Announcement of Opportunity for the first cycle was released on 1 November 2013. By the deadline of 30 April 2014, five valid applications from around the world were received. Out of the five applications, the Selection Board selected a student team from the German Jordanian University, Jordan, to be awarded the fellowship. The title of the proposed experiment is "Stabilizing the

Electrodynamic Tether by Using Tilger". The main objective of the experiment is to investigate the stability of tether dynamics for satellites with electromagnetic tether systems using a tilger, a mass damper.

34. Many satellites are equipped with thruster rockets for station-keeping and attitude control in orbit. However, the thruster rockets gradually run out of fuel, and refuelling is very difficult in space. If a long electromagnetic wire is attached to a satellite, it can create an electromagnetic force from its motion through the Earth's magnetic field. This force will be able to accelerate or decelerate the satellite and may be used for station-keeping of the satellite. However, it has not been used practically. The primary reason is that the electromagnetic tether oscillates and the libration amplitude increases naturally. In the end, the whole system becomes unstable.

35. The primary focus of the experiment using the drop tower was how to control the libration amplitude under a simulated space environment, in particular, a microgravity environment. The hypothesis of the team was that the libration amplitude could be controlled by introducing a mechanism of tuned mass damper called "Tilger" which would reduce the libration motion by removing the kinetic energy from the oscillating system.

36. The experiment was conducted at the Bremen Drop Tower for two weeks from 17 to 28 November 2014. The period is composed of on-site preparation from 17 to 24 November and actual once-a-day drops from 25 to 28 November. The student team obtained the desired results by changing the experimental conditions for each drop. The team is now analysing the results in detail back in Jordan with support from ZARM. A brief report of the experiments is attached in Annex III. The Selection Board expects the submission of the final report which is due on 31 March 2015.

2nd cycle of DropTES (2015-2016)

37. The announcement of the second-cycle of DropTES was released on 1 October 2014 with the deadline of 31 March 2015. The application period will be followed by a two-month evaluation of the submitted proposals.

38. DropTES is expected to extend to the third cycle. After the third cycle, the Office for Outer Space Affairs, DLR, and ZARM will review whether DropTES should be extended further, taking into account the results achieved in the previous cycles as well as the availability of budget and human resources.

IV. Conclusions

39. HSTI is implementing two capacity-building activities — the Zero-Gravity Instrument Project (ZGIP) and the Drop Tower Experiment Series (DropTES).

40. In ZGIP, 19 qualified schools and research institutions were selected to take part in the first cycle and 13 in the second cycle. The Announcement of Opportunity for the third cycle was released in January 2015.

41. In DropTES, the student team from the German Jordanian University, Jordan, conducted its own experiment at the Bremen Drop Tower in November 2014 in

the first cycle. The Announcement of Opportunity for the second cycle was released in October 2014.

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

Annex I

Institutions participating 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

Annex II

Institutions participating in the second cycle of ZGIP

		Purpose		
Receiving Institution	*Location*	*Education*	*Research*	*Country*
1. Institute of Physiology, National Academy of Sciences of Belarus	28 Akademicheskaya Street, Minsk 220072	–	X	Belarus
2. University of São Paulo/School of Arts, Sciences and Humanities	Av. Arlindo Béttio, 1000 – Ermelino Matarazzo – São Paulo – SP	–	X	Brazil
3. College of Bioengineering, Chongqing University	College of Bioengineering, Chongqing University No. 174, Shapingba Street, Shapingba District, Chongqing	–	X	China
4. Laboratory of Plant Tissue Culture No. 1, Institute of Plant Tissue Culture, Branch Academy of Biotechnology, State Academy of Sciences	Institute of Plant Tissue Culture, Branch Academy of Biotechnology, State Academy of Sciences, DPR Korea Munsu 3 dong, Taedongang District, Pyongyang	–	X	Democratic People's Republic of Korea
5. National Autonomous University of Honduras	Ciudad Universitaria, Tegucigalpa	–	X	Honduras
6. The Maharaja Sayajirao University of Baroda	Department of Botany, Faculty of Science, The Maharaja Sayajirao University of Baroda, Vadodara-390002, Gujarat	X	X	India
7. Smt.Kasturbai Walchand College, Shivaji University, Kolhapur	Timber Area, Wood house Road, Rajnemi Campus, Sangli	X	X	India
8. Tribhuvan University	Central dept. of physics, T.U., Kirtipur	–	X	Nepal
9. The Federal University of Technology Akure	Department of Microbiology, Federal University of Technology, PMB 704, Akure	X	–	Nigeria
10. Nuclear Institute for Food and Agriculture	G TRoad, Peshawar	–	X	Pakistan
11. National Commission for Aerospace Research and Development	Luis Felipe Villaran 1069, San Isidro, Lima 27	X	–	Peru
12. Centro de Investigaciones Biológicas	Ramiro de Maeztu 9, E-28040 Madrid	X	X	Spain
13. McPherson College	1600 East Euclid Street, McPherson, KS	X	–	United States of America

Annex III

Experiment summary of the first cycle of DropTES

1. A student team from the German Jordanian University, Jordan, was awarded a fellowship in the DropTES 1st cycle with the theme of “Stabilizing the Electrodynamic Tether by Using Tilger”.

2. The dynamics of electromagnetic tethers have been studied for de-orbiting, orbital boosting, and station-keeping of satellites. When a conductive tether moves through the Earth’s magnetic field, the motional electromotive force generates an electric current through the tether, and the interaction between the current and the Earth’s magnetic field generates a Lorentz force. However, the electromagnetic tether system has been found to be inherently unstable by itself. The main objective of the fellowship proposal is to investigate the stability of tether dynamics for satellites with electromagnetic tether systems using a tilger, a mass damper.

3. The preparation work began with drafting the work plan using the ZARM Drop Tower User Manual in close cooperation with ZARM. Following the work plan, the team manufactured the experimental model instruments and conducted preparatory ground work at their university. The team transported their instruments to the Bremen Drop Tower and started on-site preparation on 17 November 2014.

4. The first drop experiment was conducted on 25 November 2015. The preparation of the drop capsule to make it ready for testing took approximately two hours. The experiment was observed by a set of high-speed cameras. The results of the first drop were surprising and unexpected. The simple pendulum moved without any interaction with the Tilger system. This led the team to conclude that a feedback mechanism must be installed between the simple pendulum and the Tilger system. Two rubber bands were installed in such a manner that when the simple pendulum moved the rubber bands, they would activate the Tilger system. A series of preparatory experiments were conducted using the rubber bands to find the optimum masses and spring constants that would give the pendulum system maximum damping.

5. The second drop experiment confirmed that the system in microgravity behaved similar to its behaviour on the ground, as expected. It means that the Tilger system can be used in outer space if the proper feedback mechanism is installed. The team wanted to examine a different setup in which one rubber band was attached to the pendulum mass and fixed to the lower platform of the capsule in order to see whether this arrangement would lead to a similar result as the two-rubber-band setup.

6. The third drop experiment was carried out, but it did not give the expected results. In the fourth drop experiment, the team wanted to confirm that the second drop results were genuine and to see that the damping of the system would be induced by the Tilger system but not by the rubber bands. So the fourth drop was carried out and indeed the pendulum behaved similarly to its behaviour on the ground with much less damping. These results confirmed that the interaction between the simple pendulum and the Tilger system will lead to damping of the simple pendulum and that it could be used for damping of tethers in satellites.