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Report on the zero-gravity instrument project

I. Introduction

1. The Human Space Technology Initiative was launched in 2010 within the framework of the United Nations Programme on Space Applications. The role of the initiative 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 education and research and to benefit from space applications. Those activities are built on three pillars: (a) promoting international cooperation in human spaceflight and activities related to space exploration; (b) creating awareness among countries of the benefits of utilizing human space technology and its applications; and (c) building capacity in microgravity science education and research (see ST/SPACE/62/Rev.2).

2. In 2011, during the United Nations/Malaysia expert meeting on human space technology, 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. A recommendation was made that dedicated capacity-building programmes be established through the initiative, including through the provision of educational materials and the distribution of scientific instruments (see A/AC.105/1017).

3. During the United Nations/China workshop on human space technology in 2013, a recommendation was made for further expanding the role of the initiative in promoting education and outreach activities by providing educational materials and expert and astronaut forums to assist professionals and inspire students, academia and the general public regarding human space exploration (see A/AC.105/1050).

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4. In response to those recommendations, the following scientific activities were initiated through the initiative: the zero-gravity instrument project in 2012 and the drop tower experiment series in 2013.

5. Those activities are conducted in accordance with the multi-annual workplan of the initiative that was developed in consultation with representatives of Member States and worldwide experts (see A/AC.105/2013/CRP.16).

6. The activities of the zero-gravity instrument project for the period 2013-2014 were reported at the fifty-first session of the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space (see A/AC.105/C.1/2014/CRP.20).

7. The present document provides a report on the status of the project for the period 2013-2015.

II. Zero-gravity instrument project

A. Project outline

8. The zero-gravity instrument project was initiated in 2012 as part of the capacity-building activities of the Human Space Technology Initiative, in which a fixed number of microgravity-simulating instruments, called clinostats, were distributed to selected schools and institutions worldwide.

9. The major objectives of the project are to provide unique opportunities for students and researchers to investigate the influence of simulated microgravity on diverse samples and to inspire them to undertake further study in the field of space science and technology. In addition, the project is aimed at creating data sets of plant species from all over the world with their gravity responses, which will contribute to the design of future space experiments and to the advancement of microgravity research.

10. Participation in the project is primarily targeted at people from developing countries and countries with economies in transition. Heads of research groups, university professors with a scientific orientation and 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 clinostats.

11. Within the limited availability of clinostats, research teams from spacefaring countries are also welcome to take part in the project. It is intended that a global educational and scientific network be created through exchanging and sharing experience and experimental results among participants from different geographical regions.

12. Three cycles of the project have been scheduled, with a duration of three years each, starting from the announcement of opportunity to the submission of the final activity report. The first cycle has been completed and the second and third cycles are ongoing. During each cycle, institutions use the clinostats to conduct experiments on the projects proposed.

13. In order to increase the scientific value of the project, evaluate applications and select suitable institutions for participation in it, the Science Advisory Group of the Human Space Technology Initiative was established. The group currently comprises seven renowned academic experts in microgravity life science, who joined it voluntarily.

14. The Office for Outer Space Affairs 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 on how 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 members of the Science Advisory Group.

15. The implementation of the zero-gravity instrument project relies on contributions in cash and in kind from Member States, including China and Japan, and voluntary scientific contributions from the following institutes: the Biomedical Science Support Center, German Aerospace Center; the Dutch Experiment Support Center, Academic Centre for Dentistry at the Free University, Amsterdam; Laboratory of Plant Physiology, Division of Biology and Geosciences, Osaka City University, Japan; Laboratory of Space and Adaptation Biology, Tohoku University, Japan; the National Microgravity Laboratory, Chinese Academy of Science; and the State Key Laboratory of Space Medicine Fundamentals and Application, China Astronaut Research and Training Center.

B. Scientific background

1. Principles of a clinostat

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 plants, fungi and other small organisms. The quality of the simulation is determined by the size of the test system selected.

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). Those methods are suitable for fast-responding systems. In order to study the long-term effect 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 it. Since 1998, the International Space Station has been in space, providing living and working accommodations for up to six astronauts at a time. The space station offers laboratory conditions for systematic studies in microgravity.

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 or one-axis clinostat has a single rotational axis which runs perpendicular to the direction of the gravity vector.[1]

[1] See Wolfgang Briegleb, "Some qualitative and quantitative aspects of the fast-rotating clinostat as a research tool", *ASGSB Bulletin*, vol. 5, No. 2 (October 1992); R. R. Dedolph and

A three-dimensional clinostat has two rotational axes which are perpendicular to each other.[2] A rotation on a clinostat is often called "clinorotation".

19. The first factor to be considered is the speed of rotation of the clinostat. Under a 1-g condition, particles fall and become sediment. Under a free-fall condition, there is no sedimentation, and particles homogeneously distribute. On Earth, that situation can be achieved by rotating a vertically positioned object. In those conditions, particles will fall along the gravity vector but also will be forced into circular paths because of the clinorotation. The faster the system rotates, the more the radii of the circles decrease. However, if the rotation speed is too high, particles will disperse owing to centrifugal force. At an ideal rotation speed, particle movement due to sedimentation and centrifugal force is kept within the limits of Brownian motion.

20. The second factor to be considered is centrifugal force, which is in proportion to the distance between the sample and the axis of rotation and the rotational speed squared. If the rotational speed is too high, then the centrifugal force acting on the samples will force them to move outward.

21. The third factor to be considered is the horizontal placement of the rotational axis of the clinostat. The rotational axis of the clinostat must be placed horizontally as accurately as possible. An error of 0.5 degrees can create an axial acceleration of the order of 10^2 g.

2. Gravitational biology

22. The main objective of gravitational biology is the identification and understanding of the effect of gravity on organisms. That includes the identification of the underlying mechanisms and of the role of gravity, not only in individual development but also during evolution in general.

23. Gravitational biology as a discipline started in the nineteenth century, when Thomas Knight, Charles Darwin, Julius Sachs and Wilhelm Pfeffer investigated the influence of gravity on plants. They had already demonstrated the role of the root cap in downward growing plants. Knight, Sachs and Pfeffer constructed machines (centrifuges and simple clinostats) in order to change the influence of gravity and to study its impact on the growth of plants. Today, various experimental platforms, on the ground and in space, have been developed to study the influence of altered gravity. Consequently, knowledge of the impact of gravity/microgravity has increased greatly. Key research findings in gravitational biology cover all levels in biology ranging from isolated proteins, single cells and tissues to complex organisms.

24. Gravity-sensing mechanisms evolved early. Free-moving organisms, even unicellular ones, use gravity for their orientation, such as for their swimming

M. H. Dipert, "The physical basis of gravity stimulus nullification by clinostat rotation", *Plant Physiology*, vol. 47, No. 6 (1971); and D. Klaus, "Clinostats and bioreactors", *Gravitational and Space Biology Bulletin*, vol. 14, No. 2 (2001).

[2] See Takayuki Hoson and others, "Evaluation of the three-dimensional clinostat as a simulator of weightlessness", *Planta*, vol. 203, No. 1, supplement, (1997); and Jack J.W.A. van Loon, "Some history and use of the random positioning machine, RPM, in gravity-related research", *Advances in Space Research*, vol. 39, No. 7 (July 2007).

direction, a behaviour called gravitaxis. In addition, the growth and orientation response of sessile organisms is called gravitropism.[3] The direction with respect to the gravity vector is defined as positive (in parallel to gravity) and negative (against the direction of the gravity vector).

25. Gravity is the stimulus which the plant uses to grow its roots toward the gravity vector (down), anchoring the plant in the ground, and to grow the shoot in the opposite direction of the gravity vector (up), out of the soil in the direction of the sun. To understand "up" and "down" is mandatory for the survival of plants on Earth.[4] That is also indispensable for all life on Earth because photosynthesis is needed for food and oxygen production.

26. The impact of gravity on the orientation and growth of plants can be observed in a fascinating and easily detectable manner by growing plants. Considerable progress in the basic knowledge of plant gravity sensing and its final response in the form of gravitropism has been achieved.[5] Experiments performed in microgravity have greatly contributed to the understanding of how plants sense the direction of gravity and respond to it. However, the complete signal transduction process is not yet understood in detail.

C. Project implementation

First cycle of the zero-gravity instrument project (2013-2015)

27. 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 all over the world had been received. After a careful review by the Science Advisory Group and the programme experts of the Office for Outer Space Affairs, 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. The proposals of seven of the selected applicants were for educational purposes, another six were for research purposes and the remaining six proposals were for both educational and research activities. A list of the participating institutions is contained in annex I.

Second cycle of the zero-gravity instrument project (2014-2016)

28. The second cycle of the project 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 countries 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 educational

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[3] See Rujin Chen, Elizabeth Rosen and Patrick H. Masson, "Gravitropism in higher plants", *Plant Physiology*, vol. 120, No. 2 (June 1999).

[4] See Ellison B. Blancaflor and Patrick H. Masson, "Plant gravitropism: unravelling the ups and downs of a complex process", *Plant Physiology*, vol. 133, No. 4 (December 2003).

[5] Fred D. Sack, "Plastids and gravitropic sensing", *Planta*, vol. 203, No. 1, supplement, (August 1997).

and research activities. A list of the participating institutions is contained in annex II.

Third cycle of the zero-gravity instrument project (2015-2017)

29. The announcement of the third cycle of the project was released on 1 January 2015 with a deadline of 30 April 2015, and 42 institutions worldwide applied. The three-month evaluation process was carried out by experts from the Human Space Technology Initiative and members of the Science Advisory Group, followed by the selection of 13 project proposals from the following eight countries: Algeria, Brazil, Chile, Ethiopia, France, Nigeria, Pakistan and Republic of Korea. A list of the participating institutions is contained in annex III.

30. The Human Space Technology Initiative team, in collaboration with the Science Advisory Group, compiled annual reports for the first and second cycles in order to publish the first results of the project. The participating institutions are playing an important role in disseminating the results obtained through the project, in order to boost interest in space science and activities related to space exploration and initiate further educational and scientific activities within the project.

III. Scientific investigations and educational activities

A. Effects of simulated microgravity on plant growth

31. The Universidad Técnica Federico Santa Maria in Chile studied the effects of gravity on the germination and early growth of the following five plants: *Solanum lycopersicum* (tomato), *Lactuca sativa* (lettuce), *Capsicum annuum* (chilli pepper), *Raphanus sativus* (radish) and *Spinacia oleracea* (spinach).

32. The Soil and Water Resources Center in the Ministry of Science and Technology of Iraq examined the hypothesis that plants exposed to microgravity have weaker growth properties with *Oryza sativa* (jasmine rice and rice variety Anber 33), *Triticum aestivum* (wheat), *Hordeum vulgare* (barley), *Panicum americanum* (millet) and *Pisum sativum* (pea). They observed that the 1-g control groups showed a better growth rate of the roots than the clinorotated groups and that there was a significant difference in the amount of amino acids between the two groups.

33. The Technical University of Kenya studied the morphological, histological and histochemical changes in various tissues in *Phaseolus aconitifolius* (moth bean). They found that the growth of the roots was much faster under simulated microgravity than under 1-g and that the growing direction of the roots was random under simulated microgravity.

34. The National Space Agency of Malaysia conducted plant growth experiments using a clinostat with green beans and two kinds of rice (MR219 and 269) to confirm the experimental methods before conducting similar experiments with students from two schools in Kuala Lumpur. Sekolah Mehehgah Kebangsaan Convent Bukit Nanas studied the effects of microgravity on green beans and *Oryza sativa* (rice) and Sekolah Menengah Sains Alam Shah studied the effects of microgravity on corn and green beans.

35. Staff of the Malaysian Agricultural Research and Development Institute also investigated the effects of clinorotation on the germination and seedling morphology with *Oryza sativa* var. MR269 (Asian rice), *Capsicum annuum* var. MC11 (chilli pepper), *Cucumis sativus* var. MTi (cucumber), *Carica papaya* var. Eksotika (papaya) and *Vigna angularis* (adzuki bean). They observed that slow clinorotation showed more positive effects on seedling germination than fast clinorotation.

36. The Federal University Lafia in Nigeria studied the effect of gravity on the following plants native to West Africa: black and white *Amaranthus* spp. (spinach), *Digitaria* spp. (acha) and *Sesamum indicum* (sesame). They confirmed that all the plants showed a decreased angle of curvature of the roots, which indicates a positive response to simulated microgravity.

37. The African Regional Centre for Space Science and Technology Education in Nigeria conducted educational activities with 10 public schools in Osun State by organizing introductory workshops, laboratory sessions, poster presentations and evaluation sessions. The students studied the effects of gravity on black-eyed peas, cowpeas, guinea corn, maize, millet, okra, rice and wheat.

38. The National Agricultural Research Centre in Pakistan studied the effects of gravity on three different types of rice: IR6, super basmati and Nipponbare and observed that the roots under clinorotation grew in random directions.

39. The Pakistan Space and Upper Atmosphere Research Commission examined gravitropism on the roots of white and pink radishes and peas. They also investigated gravitropism on the shoots of marigolds and phototropism on the shoots of *Conocarpus* spp.

40. The Geo-Informatics and Space Technology Development Agency in Thailand studied the effects of gravity on the growth of the roots of mung beans. They also used the clinostat as a teaching tool to teach microgravity science to students.

41. Hanoi University in Viet Nam studied the growth of green beans from germination to sprouting. They planted the seeds in the soil after they were clinorotated. They found that the 1-g control group sprouted much faster that the clinorotated samples.

42. The Tay Nguyen Institute for Scientific Research in Viet Nam investigated the germination, early growth and development of *Hibiscus sagittifolius* under simulated microgravity. They found that the germination ratio and shoot multiplication were better with the clinorotated samples than with the seeds of the 1-g control.

43. The Institute of Physiology of the National Academy of Sciences of Belarus studied the effects of microgravity on three plant seeds: *Pisum sativum* (pea), *Oryza sativa* (rice) and *Lepidum sativum* (cress) and found that all three plants grew well under simulated microgravity.

44. The National Autonomous University of Honduras investigated the effects of gravity on plant growth by conducting morphological observations and microscopic examinations. They used the following seeds: *Phaseolus vulgaris* (common bean); *Phaseolus acutifolius* (tepary bean); *Phaseolus lunatus* (lima bean); *Vigna unguiculata* (cowpea); and *Sorghum bicolour* (sorghum). They found that *Phaseolus*

vulgaris under simulated microgravity showed noticeable variations in its cell structure compared with that of the 1-g control.

45. The Maharaja Sayalirao University of Baroda in India studied the effects of gravity on the root growth of *Cicer arietinum* (chickpea) and *Sorghum bicolour* (sorghum), as well as on the shoot regeneration of *Solanum nigrum* (black nightshade). They observed that the mean curvature of the roots was reoriented and reduced after the plants were placed under simulated microgravity.

46. The Smt. Kasturbai Walchand College in India studied the effect of simulated microgravity on the germination of *Phaseolus aureus* (mung bean), *Lens culinaris* (lentil) and *Vigna aconitifolia* (mat bean).

47. The Nuclear Institute for Food and Agriculture in Pakistan studied the effects of gravity on the germination of *Cicer arietinum* (chickpea), *Vigna mungo* (mungo bean), *Raphanus sativus* (radish) and *Helianthus annuus* (sunflower). They are also planning to investigate the transmission of black point disease from seed to seedling under simulated microgravity.

48. The Centro de Investigaciones Biológicas in Spain conducted educational activities to show the effects of gravity on seedling growth of *Brassica rapa* by comparing the experimental results on the ground with those of the seedling growth-2 experiment carried out on board the International Space Station.

B. Effects of simulated microgravity on cellular activities

49. Beihang University in China investigated the effects of simulated microgravity on the antioxidant enzyme system of *Triticum aestivum* (wheat) seedlings in order to understand the impact of microgravity on one of the core grain crops, which are important elements of the bioregenerative system for long-duration space flights. They observed that peroxidase, superoxide dismutase and catalase, which are important enzymes associated with plant resistance, were significantly higher in the clinorotated samples than those in the 1-g control.

50. Tarbiat Modares University in the Islamic Republic of Iran also investigated the effects of microgravity on some Iranian plants by measuring the activities of antioxidant enzymes. They used the following plants: *Peganum harmala*, *Anthemis mazandaranica*, *Artemisia khorassanica*, *Salsola crassa*, *Malva sylvestris* and *Suaeda fruticosa*. They found significant reduction of superoxide dismutase activity in *Peganum harmala*, significant increased superoxide dismutase in *Malva sylvestris* and no significant superoxide dismutase activities in *Salsola crassa* and *Suaeda fruticosa* in the clinorotated samples compared to those in the 1-g control.

51. The Soil and Water Resources Center in the Ministry of Science and Technology in Iraq investigated the effects of gravity on the growth of roots and the plant amino acids of corn, *Pisum sativum* (pea), *Panicum americanum* (pearl millet), jasmine rice and rice variety Anber 33. They found that the clinorotated samples showed significantly different characteristics of amino acids compared to those of the 1-g control.

52. Chongqing University in China investigated the effects of simulated microgravity on the migration of bone marrow-derived mesenchymal stem cells

which have been widely regarded as potential candidates for tissue repair and regeneration because of their high self-renewal capacity, migration ability and pluripotency. Bone marrow-derived mesenchymal stem cells are an important progenitor, as well as supporting cells that have the intrinsic ability to self-renew and differentiate into multiple types of cells, and can act as a major source for osteoblasts. The investigation found that simulated microgravity inhibited the migration of such cells, which may contribute to bone loss induced by microgravity.

C. Effects of simulated microgravity on microorganisms

53. The University of São Paulo studied the effects of simulated microgravity on the longevity of yeast cells by conducting chronological ageing experiments in which the amount of time a cell can stay in a quiescent state without losing its viability was measured. They found that the clinorotated samples showed a decrease in both mean and maximum life span compared to those in the 1-g control.

54. The Smt. Kasturbai Walchand College in India studied the effects of simulated microgravity on *Bacillus firmus* and six actinobacterial cultures isolated from Lonar Lake, which is the world's oldest meteoric crater, located in Maharashtra State in India. They found that simulated microgravity showed significant effects on the activities of *Bacillus firmus* and actinobacteria.

55. The Federal University of Technology, Akure, in Nigeria investigated the effects of microgravity on the antibiotic resistance pattern of *Staphylococcus aureus*, which was isolated from human skin. *Staphylococcus aureus* is an opportunistic pathogen, which is often carried asymptomatically on the human body and is commonly found in the soil, water and air. They found that the clinorotated condition greatly increased the resistance of *Staphylococcus aureus*.

IV. Conclusions

56. The Office for Outer Space Affairs has been conducting the zero-gravity instrument project to provide unique opportunities for students and researchers to investigate the influence of simulated microgravity on diverse samples and to inspire them to undertake further study in the fields of space science and technology.

57. The first cycle of the project was initiated in 2013 and the second and third cycles are currently ongoing. In total, 45 institutions from around the world have been selected to participate in the project. The institutions selected are conducting various life science experiments, utilizing clinostats which can provide simulated microgravity conditions.

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

institutes which are interested are welcome to contact the Office for Outer Space Affairs.

Annex I

Institutions participating in the first cycle of the zero-gravity instrument project

			Purpose		
	Receiving institution	*Location*	*Education*	*Research*	*Country*
1	Academia de Ciencias Aeronáuticas	Av. Santa Maria 6400, Vitacura, Santiago	–	X	Chile
2	Laboratory of Environmental Biology and Life Support Technology, Beihang University	No. 37, Xueyuan Road, Haidian District, Beijing	X	X	China
3	School of Life Sciences, Northwestern Polytechnical University	127 Youyi Xilu, Xi'an, Shaanxi Province	X	–	China
4	Ecuadorian Space Institute	Calle Seniergues E4-676 y General Telmo Paz y Miño, Edf. del Instituto Geografico Militar, Quito	–	X	Ecuador
5	TEMA Senior High School	Community Two, Tema, Greater Accra	X	–	Ghana
6	Iranian Space Research Centre	15th Alley, Mahestan Blvd., Shahrak-e Gharb, Tehran	–	X	Iran (Islamic Republic of)
7	Soil and Water Center, Agriculture Directorate Ministry of Science and Technology	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 (ANGKASA)	National Planetarium, Lot 53, Jalan Perdana, 50480 Kuala Lumpur	X	–	Malaysia
10	Malaysian Agricultural Research and Development Institute	Persiaran MARDI-UPM, 43400 Serdang, Selangor	X	X	Malaysia
11	Federal University Lafia	PMB 146, Lafia, Nasarawa State	X	X	Nigeria
12	African Regional Centre for Space Science and Technology Education in English (ARCSSTE-E)	PMB 019, Obafemi Awolowo University Campus, Ile-Ife, Osun State	X	–	Nigeria
13	National Agricultural Research Center	Park Road, Islamabad	–	X	Pakistan
14	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	Hub River Road, near Murshid Hospital, Karachi	X	–	Pakistan
16	Geo-Informatics and Space Technology Development Agency	THEOS Control Ground Station, 88, M.9, Thungsukhla, 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	No. 1 Dai Co Viet Street, Hai Ba Trung District, Hanoi	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 the zero-gravity instrument project

			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	–	X	Brazil
3	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, Academy of Biotechnology, State Academy of Sciences	Munsu 3 dong, Taedongang District, Pyongyang	–	X	Democratic People's Republic of Korea
5	National Autonomous University of Honduras	Ciudad Universitaria, Blvd. Suyapa, Tegucigalpa	–	X	Honduras
6	Department of Botany, Faculty of Science, Maharaja Sayajirao University of Baroda	Pratapgunj, Vadodara 390002, Gujarat	X	X	India
7	Smt. Kasturbai Walchand College, Shivaji University, Kolhapur	Rajnemi Campus, Timber Area, Sangli, Maharashtra	X	X	India
8	Central Department of Physics, Tribhuvan University	Kirtipur, Kathmandu	–	X	Nepal
9	Department of Microbiology, Federal University of Technology Akure	PMB 704, Akure, Ondo State	X	–	Nigeria
10	Nuclear Institute for Food and Agriculture	G T Road, 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	Calle Ramiro de Maeztu 9, E-28040 Madrid	X	X	Spain
13	McPherson College	1600 East Euclid Street, McPherson, KS 67460	X	–	United States of America

Annex III

Institutions participating in the third cycle of the zero-gravity instrument project

	Receiving institution	Location	Purpose: Education	Purpose: Research	Country
1	Scientific and Technical Research Centre for Arid Areas (CRSTRA)	Centre de recherche scientifique et technique sur les régions arides, Biskra, Algérie	–	X	Algeria
2	Pontifical Catholic University of Rio Grande do Sul	Avenida Ipiranga, 6681, Porto Alegre, RS	–	X	Brazil
3	Instituto Federal de Educação Ciência e Tecnologia do Ceará	Av. 13 de Maio, 2081-Fortaleza, CE	–	X	Brazil
4	Aspen Oncológica LTDA	Rua Ramiro Barcelos 2350, 7° andar sala 733 Porto Alegre, RS	–	X	Brazil
5	Departmento de Biologia Celular e Genética, Centro de Biociencias, Universidade Federal do Rio Grande do Norte	Campus Universitário, Lagoa Nova, Natal, RN	X	X	Brazil
6	Federal Institute of Education, Science and Technology of Piauí	Avenida Pedro Marques de Medeiros, s/n. Bairro Pantanal. Picos, PI	–	X	Brazil
7	RTR Co. (a CNPq-accredited research laboratory)	Estrada RS-T 101, Km 157, Mostardas, RS	–	X	Brazil
8	Calebu School	Kilometro 7 Calebu Interior, Contulmo	X	–	Chile
9	Department of Physics, College of Natural Sciences, Jimma University	P.O. Box 378, Jimma	–	X	Ethiopia
10	National Space Research and Development Agency (NASRDA)	Obasanjo Space Centre, Opposite Pyakasa Junction, Airport Road, PMB 437, Garki, Abuja	X	X	Nigeria
11	International Space University	1 rue Jean-Dominique Cassini, Parc d'innovation, 67400 Illkirch-Graffenstaden		X	France
12	Plant Biochemistry and Molecular Biology Group, Department of Biosciences, COMSATS Institute of Information Technology	Bioscience Block, Chak Shehzad Campus, Park Road, Islamabad	X	X	Pakistan
13	Yonsei University	50 Yonsei-ro, Seodaemun-gu, Seoul	–	X	Republic of Korea