United Nations

A/AC.105/1017

General Assembly

Distr.: General
16 March 2012

Original: English

Committee on the Peaceful Uses of Outer Space
Fifty-fifth session
Vienna, 6-15 June 2012

Report on the United Nations/Malaysia Expert Meeting on Human Space Technology

(Putrajaya, Malaysia, 14-18 November 2011)

I. Introduction

1. The United Nations/Malaysia Expert Meeting on Human Space Technology was held in Putrajaya, Malaysia, from 14 to 18 November 2011. The Meeting was part of the Human Space Technology Initiative, a new initiative carried out under the framework of the United Nations Programme on Space Applications (see www.oosa.unvienna.org/oosa/en/SAP/hsti/index.html).

2. The first meeting of its kind, the Expert Meeting focused on facilitating discussion of the benefits of human space technology, capacity-building and microgravity research and on identifying potential opportunities for developing countries to cooperate in human space technology activities and to take part in space science research. Based on the results of the meeting, the content of the Initiative and its workplan can be adapted to fit the requirements observed at and the recommendations emanating from the discussions.

3. The Meeting was organized by the Office for Outer Space Affairs of the Secretariat, as part of the activities of the United Nations Programme on Space Applications in 2011, and hosted by the Institute of Space Science of the Universiti Kebangsaan Malaysia, in cooperation with the Astronautic Technology Sdn Bhd, the National Space Agency of Malaysia and the Universiti Malaysia Pahang. The Meeting was co-organized by the partner agencies of the International Space Station, namely the Canadian Space Agency (CSA), the European Space Agency (ESA), the Japan Aerospace Exploration Agency (JAXA), the National Aeronautics and Space Administration (NASA) of the United States of America and the Russian Federal Space Agency (Roscosmos).

4. The present report describes the background, objectives and programme of the Meeting, provides a summary of the thematic sessions and contains the observations and recommendations made by the participants. The report has been prepared pursuant to General Assembly resolution 65/97.

A. Background and objectives

5. From the beginning, outer space has caught the imagination of humanity. With technological development, travelling into space finally became a reality. On 12 April 1961, Yuri Gagarin became the first human being to venture into space, opening up a new era of human activity which was no longer limited to the surface or atmosphere of the Earth. Within a decade, the first human beings set foot on the surface of the Moon. After the end of the Apollo programme of NASA, human space activity focused on the low-Earth orbit and on research. Several temporary space laboratories were operated by the Union of Soviet Socialist Republics (USSR) and the United States. In the 1980s, USSR launched the Mir space station and operated it for more than a decade. With the end of the cold war, a new opportunity for cooperation emerged, culminating in the combined effort of the five space agencies CSA, ESA, JAXA, NASA and Roscosmos (representing 15 countries: Belgium, Canada, Denmark, France, Germany, Italy, Japan, the Netherlands, Norway, the Russian Federation, Spain, Sweden, Switzerland, the United Kingdom of Great Britain and Northern Ireland and the United States) to develop, launch and operate the International Space Station (ISS) since 1998. During the past five decades, about 500 humans have lived and worked in space.

6. The Third United Nations Conference on the Peaceful Uses of Outer Space (UNISPACE III), held in Vienna from 19 to 30 July 1999, recognized that large human space exploration missions exceeded the capacity of a single country and that cooperation should be privileged in that area. ISS was cited as an example of that new paradigm made possible by the end of the cold war.[1] UNISPACE III recommended the development of future space science programmes, in particular through international cooperation, and the encouragement of access to ISS from countries that had never participated in that endeavour. It also advocated the worldwide dissemination of information about research activities aboard ISS.[2]

7. In 2010, the Human Space Technology Initiative was launched in the framework of the United Nations Programme on Space Applications, for the purpose of raising awareness of the benefits of human space technology, promoting international cooperation in activities related to human space flight and space exploration and supporting capacity-building in microgravity research and education.

8. As part of the Initiative, the Office for Outer Space Affairs organized, in cooperation with the five ISS partner agencies, an outreach seminar on ISS in Vienna on 8 February 2011. At the seminar, the status of educational and research activities aboard ISS was presented and information provided on opportunities for

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[1] *Report of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space, Vienna, 19-30 July 1999* (United Nations publication, Sales No. E.00.I.3), chap. II, para. 388.

[2] Ibid., paras. 389, 390, 401 and 402.

cooperation and utilization. Participants from ISS partner organizations and non-ISS partner countries were present during the seminar, at which it was concluded that the Initiative could be a meaningful mechanism for raising awareness about the potential of ISS and the research activities aboard the Station (A/AC.105/2011/CRP.13).

9. The Meeting pursued the following objectives:

(a) To review the status of human space activities, including activities concerning space station programmes, and space-based and ground-based microgravity research;

(b) To provide an overview of national and multinational space programmes, including programmes for capacity-building and educational programmes;

(c) To discuss how the Human Space Technology Initiative should be employed to meet the respective needs of Member States with regard to human space technology, capacity-building and microgravity research.

B. Attendance and financial support

10. Each participant in the Meeting was selected on the basis of work experience in a field related to the overall theme of the Meeting, including microgravity research, involvement in the operation of ISS or the planning and implementation of national, regional or international space programmes. The participation of specialists at the decision-making level from both national and international entities was particularly encouraged.

11. The Meeting was attended by 125 professionals from governmental institutions, universities and other academic entities, as well as the private sector, in the following 23 countries: Azerbaijan, Canada, China, Czech Republic, Democratic Republic of the Congo, Germany, Ghana, India, Indonesia, Japan, Jordan, Kenya, Malaysia, Maldives, Nepal, Netherlands, Nigeria, Pakistan, Republic of Korea, Russian Federation, Turkey, United States and Viet Nam.

12. Funds allocated by the United Nations and the co-sponsors were used to defray the cost of air travel, daily subsistence allowance and accommodation for 20 participants. The local host provided conference facilities, secretariat and technical support and transportation from and to the airport and organized a number of social events for all participants.

C. Programme

13. The programme of the Meeting was developed by the Office for Outer Space Affairs in cooperation with the programme committee. The programme committee included representatives of the five ISS partner agencies, two representatives of the National Space Agency of Malaysia and staff members of the Office for Outer Space Affairs. The local organizing committee also contributed significantly to the successful organization of the Meeting.

14. The programme consisted of one keynote speech, a session dedicated to the commemoration of the fiftieth anniversary of human space flight, nine technical

presentation sessions and six working group sessions. Chairs and rapporteurs were assigned to each session and provided their comments and notes as input for the preparation of the present report. The detailed programme and the documentation relating to the presentations made at the Meeting are available on the website of the Office for Outer Space Affairs (www.oosa.unvienna.org/oosa/en/SAP/hsti/expert-meeting-2011.html).

15. Following the welcoming remarks by representatives of the host organization and the Office for Outer Space Affairs, a keynote address, on the experience of Malaysia in conducting microgravity experiments, was delivered by the Director General of the National Space Agency of Malaysia. Representatives from four of the five ISS partner space agencies and a representative of the China Manned Space Engineering Office delivered speeches on the commemoration of the fiftieth anniversary of human space flight. A representative of the Office for Outer Space Affairs gave a presentation introducing the Human Space Technology Initiative.

16. The nine technical presentation sessions were divided into four categories: ISS programmes; microgravity science; education, outreach and capacity-building; and national, regional and international space programmes. These were complemented by six sessions of three working groups: microgravity science; education, outreach and capacity-building; and the Human Space Technology Initiative. The working group sessions were the principal occasions for discussion to provide observations and recommendations related to human space technology. In a final joint working group session, the observations and recommendations were reviewed by all participants. The Meeting concluded with a wrap-up session during which the participants endorsed the recommendations.

17. During the Meeting, poster sessions were organized, providing an opportunity for participants to exhibit posters on a topic related to the themes of the Meeting. During two of the sessions, demonstrations were given of two types of hardware for microgravity-related research: a random positioning machine, and a commercially available rack system for accommodating small experiments to be conducted on ISS.

18. A public forum of astronauts took place in the National Planetarium of Malaysia on 17 November, in conjunction with the Meeting. The outreach event, organized jointly by the National Space Agency of Malaysia and the Institute of Space Science of the Universiti Kebangsaan Malaysia for local secondary school students, as well as the general public, featured talks by four astronauts from China, Malaysia, the Republic of Korea and the Office for Outer Space Affairs.

II. Summary of technical sessions

A. International Space Station programmes

19. The purpose of the thematic session on ISS programmes was to provide an overview of activities on board and related to ISS, delivered by representatives of the ISS partner space agencies. ISS was the result of the combined efforts of 15 nations and an example of a successful and fruitful multinational long-term

partnership. Some examples of cooperation involving partners outside the circle of ISS partner countries were also provided during the session.

20. It was noted that ISS had been assembled over a period of 10 years, requiring about 30 missions. It was about 110 metres long and 74 metres wide and weighed about 360 tons. It orbited the Earth at an altitude of nearly 400 km, with an average velocity of about 7.8 km per second, and was supplied by an international fleet of space launch systems. Crew transport capabilities were currently limited to the Russian Soyuz launch system, but that would be complemented in the near future by capsules developed by the private sector.

21. It was also noted that a comparatively small space agency could participate in large space programmes such as ISS by seeking ways of cooperating with larger organizations. It was essential for such a small organization to carefully select the domains of technological excellence that could be brought into such a partnership. The Canadian robotic arm Special Purpose Dexterous Manipulator (Dextre) had been a vital part in the assembly and operation activities of ISS and was cited as such an example. It had enabled CSA to contribute to the ISS programme, in exchange for which CSA had been granted access to research facilities aboard ISS. There were other examples of collaborative scientific and educational activities between ISS partner organizations and non-ISS partner organizations, such as the Japanese Experiment Module (Kibo) utilized by Asian countries through the Asia-Pacific Regional Space Agency Forum.

22. ISS had both internal and external experiment modules available to researchers. Its particular environment could be used as a research platform for a variety of research fields, such as life science, biology and biotechnology, physical and material science, human research, and Earth and space science. It could also be used for educational activities and for demonstrating the viability of certain technologies such as robotic refuelling in space or multibody manoeuvring in orbit. It was equally suitable for observation activities and making use of the full electromagnetic bandwidth available in space. Its long operational schedule enabled long-term activities such as the monitoring of space weather or long-duration exposure experiments. It was highlighted that the human presence on ISS made it possible to gradually upgrade equipment and research facilities, as well as execute necessary repair work. Life and work under the conditions on ISS were considered as being of interest to researchers.

23. A few drawbacks with respect to research and operations involving ISS were identified, such as those linked to the particular conditions under which ISS operated. Further drawbacks mentioned included difficult conditions for thermal stabilization, a wide range of vibration, the potential incompatibility of the atmosphere on ISS with requirements for a pure vacuum and a certain level of electromagnetic interference encountered on ISS.

B. Microgravity science

24. The session on microgravity science provided an opportunity for scientists to present their latest research results obtained by using microgravity conditions. The session focused on microgravity research and on life science. Some presentations

provided information on microgravity research facilities such as drop towers, clinostats and small racks for use on ISS.

25. It was observed that current questions in fundamental physics were strongly linked to gravity. Scientists had attempted to remove the incompatibilities between the theories of general relativity and quantum mechanics by developing the quantum gravity theory. The removal of gravity pull as a factor by conducting research in space was regarded as a means of providing answers to such questions. It was further remarked that fundamental physics would eventually lead to future applications but that such applications should not be measured by criteria such as return of investment.

26. Similarly, microgravity conditions were considered beneficial for research, with potential direct application on Earth, e.g. protein or enzyme crystallization. The development of new proteins or enzymes was found to require a profound understanding of their structure. It was highlighted that, under microgravity conditions, a finer and higher resolution in the crystal structure could be obtained. It was emphasized that, in order to understand the effect of gravity, it was essential that parallel experiments be conducted in space and on the ground.

27. Research on body cells or microorganisms such as bacteria was a major focus during the session on microgravity science. Gravity, or the absence of it, was found to have a significant impact on the functions and behaviour of cells. It was noted that an understanding of the mechanisms involved was important to understanding certain diseases and possibly developing a cure for them.

28. The utilization of ground-based facilities that could provide short-term microgravity conditions, such as drop towers or devices that simulated microgravity conditions (e.g. clinostats or random positioning machines), was named as an alternative to more costly in-flight experiments. It was stressed, however, that the results thus obtained should be verified by space-based experiments whenever possible. During the session, it was emphasized that, in order to understand the effect of gravity, it was useful to consider the use of hypergravity. Centrifuges were considered to be capable of presenting a suitable facility for exploring the other end of the gravity scale.

29. A private company provided information on a commercially available opportunity to transport small-sized experiments on ISS. It was noted that this kind of opportunity might be particularly suitable for students, including postgraduate students, owing to the low requirements in terms of budget and the comparably short preparation time of about one year.

30. A representative from the Office for Outer Space Affairs gave a presentation on the objectives, activities and current workplan of the science activities of the Human Space Technology Initiative. The zero-gravity instrument distribution project and the education project were highlighted; both were described as destined for use in capacity-building under the Initiative. Small instruments such as clinostats or desktop drop tubes were presented as possible candidates for distribution.

C. Education, outreach and capacity-building

31. The session on education, outreach and capacity-building focused on the challenges and programmes in the field of education and capacity-building. A tendency to lose interest in science and technology had been observed among the younger generation in many countries, including in current spacefaring nations. That tendency was identified as a challenge for education and training. It was recognized that capacity-building was a vital step on the path to indigenous space technology programmes. It was highlighted that governmental policies and decisions were pivotal in promoting education and research in many domains, in particular in space science and technology.

32. It was observed that, in order to implement a space science and space technology programme, a critical mass of expertise was vital. It was also observed that local industry with indigenous capabilities and capacities was necessary to sustain human capital development. The importance of focusing on some areas in space science and on international collaboration in capacity-building for countries with scarce resources was emphasized. The establishment of local facilities for training and education was identified as a means of preventing brain drain and ensuring the acquisition of local expertise and capabilities. Additionally, it was regarded as a necessity to provide space science and technology instruction at all levels of education, from primary school to the university level.

33. The importance of informing the public in developing countries of the benefits of space science and technology in the face of existing problems such as hunger, disease and poverty was emphasized. It was also emphasized that, owing to a lack of information, data obtained by national satellites was too often underused.

34. It was found that, among teachers and educators, awareness of the space context and the possibilities of using it for subjects such as mathematics, science and technology was important and should be increased. Space-related educational projects were presented as a means of capturing and increasing the interest of students in science and technology. Such projects were also considered particularly suitable for creating awareness among students about the importance of working together.

35. It was noted that, owing to the long-term operation of ISS, a considerable number of students could be reached by educational projects that utilized ISS. Projects such as “Seeds in Space” and “Amateur Radio on the International Space Station” were cited as examples. Over 400,000 students had studied golden orb spiders living on ISS. Additionally, astronauts often supported educational activities, for example, by giving talks in schools or carrying out educational demonstrations.

36. Participants were introduced to activities carried out by the United Nations Educational, Scientific and Cultural Organization (UNESCO) as part of its science education and space activities, in particular its current network of universities and the Associated Schools Project Network. It was noted that one potential area of collaboration would be to make use of the existing university network of UNESCO in order to encourage the use of ISS as an educational means, targeting undergraduate and graduate students, teachers and researchers. One purpose given for such collaboration was to highlight the peaceful use of space, as well as

scientific and technological research cooperation, for the well-being of humankind through the use of ISS.

D. National, regional and international space programmes

37. The session on national, regional and international space programmes was designed to provide an opportunity for participants to exchange information on present and future space programmes and national, regional and international cooperation. It was stressed that international cooperation was an important factor in the implementation of a national space programme. Space science and technology were frequently mentioned as a means of enhancing the socio-economic situation in a country.

38. The current status of national space programmes was found to vary widely among countries. Some countries were found to have achieved considerable progress in the development and implementation of their space programmes, while others had yet to create an organization dedicated to developing and implementing a national space strategy. Others had sent or were planning to send astronauts into space.

39. A considerable portion of the presentations delivered during the session provided an overview of national programmes linked to the development and launch of indigenous satellites dedicated mostly to remote sensing or telecommunication. It had been found useful to cooperate with other entities during the initial phase in order to build indigenous capacities. It was emphasized that many follow-up projects saw either a significant increase in the participation of the country concerned in the development of a satellite or the development of a satellite entirely locally.

40. An overview was given of China's manned space programme, including its three-step approach to a permanent space station. The success achieved thus far in China's first space rendezvous and docking flight mission marked a major step towards the operation of Chinese space laboratories; a future space station was also showcased.

41. The session also highlighted the examples of successful astronaut programmes from Malaysia and the Republic of Korea and the related beneficial effects on socio-economic development.

42. Telemedicine was identified as a notable example of an Earthbound application of space-related technology that had been found to have a direct and beneficial impact on socio-economic development. Telemedicine and remote sensing in general were presented as being able to play an important role in developing strategies for sustainable resource management and providing access to health care, particularly in remote areas and large geographical regions. In that context, it was noted that access to health care and health-related expenses were unevenly distributed in a world in which 90 per cent of such expenses were in high-income countries, representing about 16 per cent of the world population.

III. Summary of working group sessions

43. From the second day until the final day, working group sessions were organized on the following themes: microgravity science; education, outreach and capacity-building; and the Human Space Technology Initiative. The purpose of the sessions was to allow participants to provide remarks and observations relative to those themes, with the final objective being to develop shared recommendations to the Initiative and to Governments and institutions. For each theme, three working group sessions were organized in which the potential recommendations related to the theme, based on observations and findings of the participants, were first identified and then refined. Those recommendations were then presented to all participants and merged into one set of recommendations in the joint working group session on the last day of the Meeting.

A. Microgravity science

44. Approaches, means, challenges and recommendations on how to facilitate microgravity science research were subjects of discussion in the working group on microgravity science. Space-based and ground-based research was identified as complementary to conducting microgravity research. The principal approaches to facilitating microgravity research were discussed with respect to infrastructure, capacity-building, international cooperation and industrial opportunities.

45. On-orbit space facilities such as ISS could provide an ideal microgravity environment for research and experiments to better understand fundamental scientific questions and to provide solutions for problems on Earth in the fields of physics, fluid science, material science, life science and engineering science. Additionally, such space facilities were regarded as suitable platforms for developing and verifying technologies for long-duration space exploration.

46. Microgravity simulators (such as clinostats), drop tubes, drop towers and parabolic flights, among others, were named as examples of ground-based microgravity research facilities whose utilization should be encouraged. It was stressed that countries should be encouraged to establish national microgravity centres, which could significantly contribute to infrastructure and capacity-building in microgravity science. A solid ground-based research programme using microgravity and hypergravity facilities was considered essential to the facilitation of space flight experimentation.

47. The importance of international cooperation in microgravity research was emphasized. Non-spacefaring countries were encouraged to seek cooperation with spacefaring countries through individual scientific collaboration, multinational institutional agreements and the establishment of national or regional expert centres. Such initiatives could promote capacity-building for independent national science and technology programmes. Countries were also encouraged to explore commercial opportunities in their efforts to build capacity in human space technology.

48. It was important for the Office for Outer Space Affairs to provide non-spacefaring countries with informational material to train and create awareness among scientists and the general public of the possibilities and benefits of human space flight and space technology programmes and to establish ground-based

research programmes and international cooperation opportunities in microgravity research and its applications.

B. Education, outreach and capacity-building

49. The working group on education, outreach and capacity-building was mandated to provide observations and to give recommendations related to education, outreach and capacity-building.

50. Space education was commonly viewed as a tool for capturing and cultivating interest and expanding the imagination. It was noted that combining mathematics, science and engineering was essential to space education. The interdisciplinary character of engineering education was highlighted. Practical training, project-based training and, in particular, cross-border projects and specific courses on microgravity were cited as means of achieving educational goals such as increasing skills, knowledge and interest with respect to space science and improving teamwork skills and abilities to work and network in a multinational environment.

51. A gap between space education at a young age and at the university level was identified by participants. The importance of securing continual space education throughout all levels of education was emphasized. Further, it was considered necessary to initiate space education already during early childhood. It was also desirable to increase outreach activities and hands-on experiences for students.

52. Creating and maintaining public awareness of space science were identified as challenges by the participants. It was desirable for knowledge about space science to be extended to the public. In that context, it was important for space education projects to employ language that could be easily understood by the targeted audience. Simplicity was suggested as a factor to enhance space education for the public.

53. Particular focus was directed at the necessity of training the trainers. The participants noted that the number of trainers and the available competences, resources and facilities presented a challenge. The creation of an award to motivate the development of ideas for innovative space science presentations was proposed.

C. Human Space Technology Initiative

54. The working group on the Human Space Technology Initiative began with a presentation by a representative from the Office for Outer Space Affairs, who provided background information and an overview of the Initiative and its objectives, which were to provide a forum for exchange of information between ISS partner countries and non-partner countries, to inform member States about microgravity research opportunities on ISS and other facilities and to support Member States in increasing their competence level with respect to microgravity research.

55. A presentation was delivered by a representative from NASA on behalf of all ISS partner agencies, introducing a mechanism which had been developed by the ISS partnership in 2002: the Non-Partner Participation policy. The policy governed how non-ISS partners could participate in ISS; the process was that a non-partner

should first form a team with one of the five ISS partners (CSA, ESA, JAXA, NASA and Roscosmos) and the ISS partnership would then review the bilateral cooperation for approval. Non-partners were encouraged to review and contact one of the ISS partners with their research and education collaboration ideas.

56. On behalf of all the ISS partners, the representative from NASA also introduced the ongoing “ISS benefits for humanity” missions and proposed a partnership activity between ISS and the Initiative to facilitate cooperation in extending the benefits of ISS research and education to the world. It was noted that ISS partners had identified three areas in which activities on ISS could benefit all of humanity: education; earth observation and disaster response; and human health. Scientific cooperation, global extension of research applications and the motivation of students worldwide with respect to science, technology and mathematics were cited as examples of how all of humanity could benefit from ISS. A short presentation was given on the proposed concept of how the ISS partnership, the Initiative and other United Nations entities could cooperate in order to extend the benefits of ISS globally. Within that concept, the Initiative would take the role of liaising between the ISS partners and other United Nations agencies such as UNESCO, the World Meteorological Organization, the United Nations Environment Programme and the World Health Organization.

57. The participants of the Meeting were then invited to bring forward any observations and comments related to the Initiative. The participants regarded space-related activities as a means of fostering national pride, reflecting national comprehensive strength, satisfying human curiosity, preparing humans for long-distance space travel and living in space, conducting scientific research, promoting excellence in engineering, developing new technologies, utilizing space to generate new industrial processes and utilizing space technology for sustainable development.

58. It was emphasized that ISS was beneficial to humanity in many ways, such as by increasing mutual understanding through collaboration, presenting outreach and educational activities, improving the quality of life on Earth as a result of spin-offs, providing a platform for life science and offering the potential of economic benefits.

59. The representative of the China Manned Space Engineering Office expressed a willingness to cooperate with the Office for Outer Space Affairs in achieving the goals of the Initiative. It was suggested that a suitable framework should be established for cooperation between the two sides. Three offers would be provided under that framework: flight experiment opportunities on board Chinese space laboratories and the future space station for scientists from around the world; an international astronaut programme, including astronaut selection, training and flight opportunities; and the launch of supporting projects to provide China’s human space technologies, facilities and human resources to developing countries, with the aim of promoting capacity-building activities in human space technology and its applications.

60. The working group was organized so as to allow participants to express their expectations with respect to the Initiative. Ideas and suggestions expressed during the discussions included the provision of the following: support for capacity-building through training and education for ground-based research; opportunities for space activities; support for establishing national strategies for the development of

space activities; the facilitation of cooperation, including promotion of the creation of groups with shared interests; awareness-raising with respect to the benefits of space, particularly among Governments and decision makers; and information on human space technologies and their applications.

IV. Observations and recommendations

61. The last day of the Meeting was dedicated to finalizing the observations and recommendations of participants. The findings of each working group were first presented by the Chair for the participants to share and review. Then, at the wrap-up session, the final recommendations were presented for the participants to review and endorse.

62. During the discussion, a lack of awareness of space science and technology, their related benefits, the accessibility of space and opportunities for research was found to exist, particularly among Governments and policymakers but also among potential users and the public.

63. It was observed that ISS was an incubator for future improvements in the quality of life. It was also considered a first step towards the colonization of space and the development of habitats for overpopulated regions. Some benefits were identified: education, Earth observation, life science and economic benefits. ISS offered a unique environment that was well-suited to research.

64. A lack of access to experiment results obtained on board ISS was identified by participants. There was also a lack of knowledge about the availability of such data. It was observed that information was needed about alternatives to space stations.

65. It was emphasized that there was a lack of capacity in space-related areas. It was noted that there was a need to develop capacity through training and education and to provide instruments for microgravity simulation. There was also a need for policy, strategy and governance development, through practical support for using space research equipment and facilities as well as through outreach activities.

66. A desire for more cooperation between developing countries and ISS partners was communicated. Such cooperation should extend from individuals to organizations. Institutional cooperation was suggested to facilitate microgravity research. International cooperation in science should be established between countries with long experience in microgravity science and countries that were newcomers in the field. It was emphasized that international cooperation would be needed to access flight opportunities.

67. It was pointed out that the utilization of ground-based research facilities, such as clinostats, drop towers, parabolic flights and centrifuges, could facilitate microgravity research and was essential as a preparatory step towards flight experiments. It was recommended that commercial flight opportunities should be evaluated. It was emphasized that hypergravity and its effects should be explored, and a large human centrifuge was proposed as a ground-based tool to conduct hypergravity experiments with the purpose of studying the effects of gravity on the human body. Developing software to simulate the physiology of the human body and providing informational material to scientists and the public were cited as potential activities for ground-based microgravity research.

68. Space education was identified as a tool for capturing and cultivating interest in science and sparking imagination among students, but such education should be presented in a more attractive way and in a language adapted to the target group. It was emphasized that space education should be part of mainstream education and should be offered to students at all levels of the educational system, from a young age to the university level.

69. A solid education in basic disciplines such as mathematics, engineering and science was perceived as essential to paving the way for space education. It was emphasized that educators played an essential role in implementing a plan for space education. The number of trainers, their competences, available facilities and available resources were identified as challenges. The necessity of sufficient training of educators was stressed. The desire was expressed for access to space education for the public and for cross-border education projects with the purpose of allowing students in different countries to gain competence in building networks with others and acquiring international experience.

70. Based on those observations, the following 10 recommendations were formulated and endorsed by the participants:

(a) The Human Space Technology Initiative should take action to create awareness among stakeholders, including decision makers in the public and private sectors, researchers and students, of the social and economic potential of space science and technologies and to initiate outreach activities;

(b) The Initiative should identify and inform Member States about space-related research opportunities and organize meetings in which invited experts can provide information to interested parties;

(c) The Initiative should establish capacity-building programmes, including through the provision of educational material, instrument distribution and/or access, national or regional expert centres, training of trainers, exchange programmes and competition and motivation programmes;

(d) The Initiative should serve as a catalyst for international collaboration by promoting the formation of common interest groups, conducting regular surveys of countries concerning their space competence profiles, developing a set of guidelines for collaboration, promoting multinational institutional agreements and creating regional expert centres;

(e) The Initiative should promote the exchange of knowledge and the sharing of data by raising awareness, promoting user-friendly mechanisms for data access and providing knowledge about self-supporting habitats for application, including for energy efficiency on Earth;

(f) Governments, institutions and individuals are encouraged to use space-based platforms for research in the following areas: psychology and social interaction in a multicultural, confined and isolated environment; vaccine development; nutritional, agricultural and food security; human physiology and aging; space technology for future exploration; and the space environment;

(g) Governments, institutions and individuals are encouraged to explore ground-based research for gravity-related science, preparing space-based experiments and making use of microgravity simulators (such as clinostats), microgravity instruments (such as parabolic flights, drop tubes and drop towers), hypergravity instruments (such as centrifuges) and software models;

(h) Governments, institutions and individuals are encouraged to explore the opportunities for commercial alternatives for educational and research activities in space, such as sub-orbital flights and long-duration experiments;

(i) Governments and institutions are encouraged to use space education as a tool for inspiring and motivating people and sustaining interest in science and technology;

(j) Governments are encouraged to incorporate space education into the curricula of schools (in different subjects such as mathematics, physics, biology, chemistry and social science) and universities.

V. Conclusions

71. The United Nations/Malaysia Expert Meeting on Human Space Technology was held with the intention of disseminating information about on-board activities of ISS; different national, regional, and international space programmes; and microgravity research and education. It was also aimed at defining potential activities of the Human Space Technology Initiative, in particular with regard to capacity-building in the areas of microgravity research and education.

72. Intensive discussions on the potential benefits of human space technology, ways to promote human space technology and its utilization and how to facilitate access to space-related research opportunities and provide space education were carried out during the working group sessions. The recommendations to the Initiative, as well as to Governments, institutions and individuals, were formulated and endorsed by the participants during the Meeting. The results of the Meeting will serve as a point of departure for supporting the development of the Initiative.

73. During the past 50 years of human space exploration, human space technology has become an essential technology for the advancement of civilization. The Initiative is aimed at sharing human space technology in all parts of the world and at bringing countries together in that endeavour in human space exploration, thus creating new opportunities for international cooperation.