Annual Report 2014

About ISECG

ISECG was established in response to the "The Global Exploration Strategy: The Framework for Coordination" (GES) developed by 14 space agencies[1] and released in May 2007. This GES Framework Document articulated a shared vision of coordinated human and robotic space exploration focused on solar system destinations where humans may one day live and work.

The purpose of ISECG is to provide a forum to discuss interests, objectives and plans in space exploration and to support promotion of interest and engagement in space exploration activities throughout society. The work of ISECG results in documents, papers, findings and recommendations that are critical in informing individual agency decision-making. In 2014, ISECG remained focused on working collectively towards the further development and implementation of the GES to facilitate collaborations.

Since September 2014, the Chairmanship of ISECG is held by ESA (European Space Agency).

INTERNATIONAL SPACE EXPLORATION COORDINATION GROUP

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1 Introduction

The 2014 Annual Report of the International Space Exploration Coordination Group (ISECG) provides an overview of ISECG activities, products and accomplishments in that year. It also highlights the national exploration activities of many of the ISECG participating agencies in 2014.

2 Executive Summary

Activities in 2014 mainly focused on: works towards the third issue of the Global Exploration Roadmap (GER); initial activities for developing a Science White Paper; and on preparations for a dedicated exchange amongst member agencies about delivering and communicating benefits from space exploration. ISECG webnews were published about every two months on its website www.globalspaceexploration.org. Additionally, the GER work was informed through a broad dialogue with exploration stakeholder communities about global exploration planning initiated by several ISECG participating agencies.

The analysis of science drivers for exploration destinations and of science opportunities in the GER mission scenario have been considered interesting by the science communities. They have confirmed their willingness to support the development of an ISECG Science White Paper that will focus on the enhancement of science by human/robotic partnerships in exploration.

The establishment of an inter-agency exchange on ´Communicating and Delivering Benefits from Space Exploration´ was prepared. Its objective is to provide a platform for member agencies for sharing best practices and lessons learned in three areas of interest: Technology Transfer, Health & Medicine, and Resource Management (e.g. life support systems).

In 2014, ISECG continued to serving as the international forum where agencies share their objectives and plans for human and robotic space exploration. ISECG products and activities continued to contribute to individual agency decision-making processes, enabling an internationally coordinated approach to space exploration.

3 ISECG at a Glance: Background and Scope

In May 2007, 14 space agencies[1] jointly released "The Global Exploration Strategy: The Framework for Coordination". It describes a shared vision of coordinated human and robotic space exploration focused on solar system destinations where humans may one day live and work.

The GES identifies a common set of **exploration themes and benefits**:

- New knowledge in science and technology
- A sustained presence – extending human frontiers
- Economic expansion
- A global partnership
- Inspiration and education

One of the many Framework Document findings was the need to facilitate information exchange among individual agencies regarding their interests, plans and activities in space exploration.
Therefore, the GES called for a voluntary, non-binding coordination mechanism among interested space agencies. This call led to the establishment of the **International Space Exploration Coordination Group (ISECG)** by the participating agencies. The Terms of Reference (ToR) for ISECG were formally adopted at the first meeting of the group in November 2007.

ISECG serves as the forum where space agencies work together on means of strengthening individual exploration programmes, facilitating collaborations and advancing the GES through the coordination of participating agencies' mutual efforts in space exploration. ISECG also supports promoting interest and engagement in space exploration activities throughout society.

The **scope of ISECG** is broad and strategic. Its activities are based on the following **principles**:

- Open and inclusive
  - ISECG receives inputs from all interested agencies that invest in and perform space exploration activities
  - ISECG provides for consultations among all agencies with a vested interest in space exploration
- Flexible and evolutionary
  - Existing consultation and coordination mechanisms are taken into account
- Effective
  - ISECG workshops and products provide value to individual participating agencies
- Of mutual interest
  - ISECG activities benefit all participants and respect national prerogatives
  - ISECG activities allow for optional participation based on the level of interest

ISECG participants focus on developing non-binding products - findings, recommendations and other outputs as necessary – based on consensus.

[1] In alphabetical order: ASI (Italy), CNES (France), CNSA (China), CSA (Canada), CSIRO (Australia), DLR (Germany), ESA (European Space Agency), ISRO (India), JAXA (Japan), KARI (Republic of Korea), NASA (United States of America), SSAU (Ukraine), Roscosmos (Russia), UKSA (United Kingdom). "Space Agencies" refers to government organizations responsible for space activities.

4 Activities

4.1 Overview

ISECG products are developed by working groups partly supported by dedicated teams that are initiated as required to work on special subjects. The activities of ISECG working groups are based on respective annual workplans. The work is guided by regular plenary meetings and monthly plenary ISECG teleconferences. The degree of participation in ISECG working groups varies by agency and by product. As ISECG work is based on consensus among the members, all products developed at the working group level need approval by the ISECG plenary.

ISECG members participating in the production of specific ISECG products (referred to as "participating agencies" of that product) demonstrate the flexible and evolutionary nature of ISECG to serve as a forum for interested agencies to advance a variety of initiatives of interest to their respective programmes and plans. Overall, ISECG continues to focus on the development of products that are both effective and of mutual interest to address the needs of the participating agencies. The work is performed through a periodically updated workplan as required by the evolving needs of the participating agencies and the status of the products.

ISECG and supporting working groups are supported by a permanent secretariat, provided by ESA. In addition, the ISECG secretariat provides generic information about ISECG and its products, hosts and manages the ISECG website and supports space agencies that request ISECG membership.

4.2 Activities and Events on ISECG Level

The annual ISECG meetings at Senior Agency Management (SAM) level took place on September 30, 2014 in Toronto, Canada. Those meetings ensure timely and effective alignment between strategic considerations of ISECG members and ISECG activities, and are being used by senior agency managers to provide guidance for future work. Following the meeting, the following press release was issued:

"Hand-over of ISECG chairmanship
On 30 September 2014, during the ISECG meeting at Senior Agency Management level, the Canadian Space Agency (CSA) handed over the ISECG Chairmanship to the European Space Agency (ESA).
ESA noted the importance of ISECG for agencies´ strategic planning and emphasised two key points:

- It is essential for the space exploration community to continue to converge on the path forward from the International Space Station´s foundation with support on the governmental/political level.
- It is important for ISECG to continue to prepare for cooperation and to aid agencies in identifying concrete cooperation opportunities, and to foster global engagement in space exploration.

The Senior Agency Managers took note of the progress and the way forward for the road-mapping process as well as some of the key elements for the global science engagement presented at the meeting, such as the interaction with the scientific communities. Hereby, the focus will be on science drivers for exploration destinations and science opportunities in the ISECG Global Exploration Roadmap (GER) mission scenario.
Notable achievements during the CSA chairmanship of ISECG included: an update of the GER; publication of the "Benefits Stemming from Space Exploration" document and CSA representation

of the work of the ISECG agencies at the International Space Exploration Forum on ministerial level in January 2014."

In order to increase the visibility of ISECG products and to feed the dialogue with exploration stakeholder communities, ISECG representatives presented papers and contributed to panel discussions at the *International Space Exploration Conference* held at ISU in Strasbourg, France; the *Symposium on International Space Exploration 2014* in Tokyo, Japan; and at the *65th International Astronautical Congress 2014* in Toronto, Canada.

In January 2014, the International Space Exploration Forum (ISEF) was held in Washington, DC. It provided a platform for political representatives from around the globe to further advance the exploration and utilisation of space and to highlight their direct benefit to humankind. The ISEF supported the work of ISECG in developing a strategic roadmap for human space exploration documented in the GER. The Forum welcomed an expansion of efforts to increase synergies between human and robotic missions to maximize the unique contribution made by each and their collective contribution to common goals. It also recognized the value of the stepwise approach to exploration, enabling nations to demonstrate advanced space exploration capabilities through cooperative international missions which allow individual national priorities to be met while achieving shared long-term goals. The Forum also encouraged broadened participation in ISECG from additional space agencies.

4.3 Activities on Working Group Level

3.3.1 Exploration Roadmap Working Group (ERWG)

The Exploration Roadmap Working Group (ERWG) work in 2014 continued the collaborative agency human spaceflight roadmapping work. Work centered around the mission scenario, including further work on of each of the three mission themes based on planned and conceptual capabilities.
ERWG findings include:

- Near-term human missions in the lunar vicinity and the lunar surface are extremely useful to prepare for future human missions to deep space and Mars. They represent the opportunity for interested agencies to advance capabilities in a way that is consistent with their objectives and long term interests. Space agencies participating in the ISS Program have begun to study how available ISS capabilities can be evolved and transitioned to support beyond LEO missions.

- Conceptual missions, such as human-assisted robotic lunar surface operations and human-assisted sample return, could provide a good opportunity to foster integration between human and robotic missions. They show promise for mitigating development risk for a future human lunar surface architecture and enhancing the return on investment to both the science and human exploration communities in general. Agencies are working to elaborate a design reference mission concept which can enable humans in the lunar vicinity to retrieve and return samples which have been robotically retrieved and delivered to the human-tended infrastructure.

- Human missions to the lunar surface will be enabled by the provision of a lunar lander and surface systems necessary to support chosen objectives. Agencies began to evaluate possible lunar surface missions in order to inform future agency lunar lander studies.

- There are many stakeholders interested in learning more about lunar polar volatiles, and in particular water ice. Several planned and conceptual robotic missions are targeting the lunar polar region. As such, there is an opportunity for ISECG to promote coordination and collaboration related to acquiring desired knowledge. Agencies have formed a team to assess specific tasks designed to promote the desired coordination

Several participating agencies conducted stakeholder consultation events based upon the updated GER, released in August 2013. Globally, the updated GER is seen as an excellent international roadmap and very helpful in guiding work and investments of individual agencies leading to sustained human missions beyond LEO.

Future Work

Agencies will continue the human space exploration road-mapping work. Key objectives for the forward work are to advance the definition of the near-term mission scenario in the 2020 to 2030 time period and to integrate additional agencies in the discussion on the international vision on the next steps in implementing the common human exploration strategy. A decision to update the GER for a second time is expected to be taken by Senior Agency Managers in late 2015.

3.3.2 International Architecture Working Group (IAWG)

In 2014, the International Architecture Working Group (IAWG) advanced concepts associated with the overall mission scenario identified in version 2 of the Global Exploration Roadmap (GER). The three mission themes,

(1) exploration of a near-earth asteroid,
(2) extended duration crew missions in the lunar vicinity and
(3) humans to the lunar surface

were all considered.

The focus of the IAWG for 2014 was on developing the third mission theme and identifying activities and opportunities which will feed forward to human missions to Mars.

IAWG findings:

- The transportation architecture that is designed to place humans on the lunar surface in the late 2020's should be compatible with the evolvable deep space habitat (eDSH) identified for delivery in the early 2020's. Where applicable, key architectural drivers which might influence the eDSH should be identified.

- Through a process of soliciting and combining agency inputs, the following key driving requirements and constraints to be considered in conceptualizing a human lunar lander include (1) staging location, (2) number of crew members to the surface, (3) existing or planned launch vehicle capabilities, (4) main lander propellant type, (5) reusability and (6) surface landing location.

- In addition to the driving attributes of a human lunar lander design, the key driving requirements for the surface strategy were established as: (1) payload quantity delivered to the surface (2) duration of surface stay(s), (3) pre-deployment of assets and timing, (4) Mars forward objectives and (5) science objectives.

- To better define the available trade space for humans to the lunar surface, it was necessary for the IAWG define and analyse the assumptions for various options. Multiple agencies participated in this process and successfully modelled potential lunar lander configurations. An agreed to set of common ground rules and assumptions for many parameters was established to be used by interested agencies for informing agency lunar lander studies.

- To support the work of the IAWG, all participating ISECG agencies were asked to identify priorities and strategic considerations related to lunar surface exploration. This information has been integrated and will influence IAWG work in 2015.

IAWG Future Work

In 2015, IAWG agencies will continue to collaborate on assessing the mission themes, primarily focused on refining the humans to the lunar surface strategy to help inform the definition of the GER mission scenario and mission themes. The goal is to coalesce on a lunar surface reference architecture which will be elaborated in the next version of the GER.

3.3.3 Science Working Group (SWG)

The Science Working Group (SWG) was created in November 2013 to promote the scientific accomplishments in present and future exploration activities as articulated in the GER. SWG started meeting in March 2014. Most of the work has been done through monthly teleconferences, augmented by two face-to-face meetings in July 2014 (Japan) and October 2014 (France).

As a promising element and product for the coordinated interaction, the development of a Science White Paper has been proposed and decided. This White Paper shall be jointly developed by the science communities and the SWG and will discuss the science drivers for exploration destinations and the science opportunities in the GER mission scenario. Most of the SWG work in 2014 was related to the initial steps leading eventually to the publication of such a Science White Paper in 2016, provisionally called: 'Science Enhanced by the Human/Robotic Partnership in Exploration'. A draft Table of Contents has been established by the SWG at the ISECG Workshop in Strasbourg (October 2014). The process for the development of the paper has been drafted. The writing of the document will start in early 2015. The process will be facilitated by NASA's Solar System Exploration Research Virtual Institute (SSERVI).

Initial discussions with international scientists, e.g. at a dedicated SSERVI event on the ISECG GER and at the COSPAR meeting 2014, have confirmed the interest and willingness of the science communities to support the White Paper development. First links have been established between the SWG and international scientific groups through the participating agencies.

3.3.4 Strategic Communications Working Group (SCWG)

In 2014, the SCWG continued supporting ISECG and its members in all aspects of internal and external communication.

The following webnews were published in 2014 via the ISECG website www.globalspaceexploration.org:

January	*International Government Representatives and Heads of Agencies meet to discuss Space Exploration*
February	*Stakeholder Engagement Opportunities: Seeking Community Ideas for Addressing Exploration Challenges and Opportunities* (NASA Community Workshop on the Global Exploration Roadmap, April, USA)
March	*Strengthening the interaction between space science and exploration communities*
May	*Stakeholder Engagement Opportunities: Seeking Community Ideas for Addressing Exploration Challenges and Opportunities* (Symposium on International Space Exploration 2014, July, Japan)
October	*Hand-over of ISECG chairmanship*
November	*Stakeholder Engagement Opportunities: Community Ideas for Addressing Exploration Challenges and Opportunities* (ISU International Space Exploration Conference, October, France)
	Historic Step in Exploration: First Landing on a Comet
December	*Hayabusa2: Space voyage to an asteroid*
	NASA's Orion Crew Module Successfully Completes Flight Test

Furthermore, the establishment of a SCWG Tiger Team on ´Communicating and Delivering Benefits from Space Exploration´ was prepared. The objective has been to provide a platform for member agencies for sharing best practices and lessons learned on delivering/realising and communicating benefits. Member agencies decided to focus on the exchange in three areas of interest: Technology Transfer, Health & Medicine, and Resource Management (e.g. life support systems). The activity has been planned to run until the end of 2015. Five agencies decided to engage in the activity and to involve respective experts.

Various occasions throughout 2014 – e.g. international conferences, symposia, workshops, meetings – have been utilised to further increase visibility of ISECG and to inform about its work and products.

3.3.5 Technology Working Group (TWG)

The Technology Working Group (TWG), previously referred to as the Technology Assessment Team (TAT) and established as a stand-alone WG in Jan. 2014, is tasked with the compilation and assessment of individual technology development interests and priorities of the participating agencies. The goal is to facilitate leveraging investments in technology development efforts of individual ISECG agencies supporting implementation of exploration missions like those depicted in the Global Exploration Roadmap (GER).

Over the course of the last year, the TWG has held regular teleconferences, met at two major ISECG workshops hosted in Tokyo (July 2014) and Strasbourg (Oct 2014).

The TWG continues to focus on further improvements of the GER Technology Development Map (GTDM) contents and analysis tools, while further disseminating this repository of applicable technology development information amongst each participating agencies. The GTDM categorizes technology development inputs of participating agencies by technology areas and maps them to the elements and capabilities identified in the GER mission scenario. The GTDM data set has been updated to more accurately reflect the GER architecture (released in August 2013) with both elements and destinations mapping information. As the number of ISECG agencies participating in the activity increase, the GTDM will broaden in technical content, analysis scope, and collaboration potential.

The TWG continues to look for coordination and collaboration opportunities in technology development efforts of participating ISECG space agencies to prepare roles for future exploration missions. In that regard, gap analysis, technology development milestones, and identification of partnership/coordination opportunities will be forward work focus for 2015 for the TWG.

Annex I

Space Exploration Highlights of ISECG Member Agencies

(in alphabetical order of their acronyms)

Agenzia Spaziale Italiana (ASI), Italy

Introduction

The year 2014 has been characterized, by the continuation of the programmes approved during the ESA Ministerial Council held in 2012 (C/M12), mainly the ExoMars Programme with its two robotic missions to Mars foreseen in 2016 and 2018, for which Italy confirms its leadership, and the participation to the Exploitation of the International Space Station ISS, through the Intergovernmental Agreement, IGA, and the PMM, Permanent Multipurpose Module, MoU between NASA and ASI. The MPCV Service Module programme, approved as the European barter element to NASA during ESA C/M12, is another initiative with a major Italian contribution.

It is worthwhile to mention here the landing of Philae on the surface of Comet 67P/Churyumov-Gerasimenko as part of ESA Rosetta mission, which saw major contributions by ASI.

Past significant events and missions

Hereafter are reported the significant events related to exploration during the past year:

- The activities within the Permanent Multipurpose Module (PMM), derived from the MPLM FM1 Leonardo, developed by ASI (through Thales Alenia Space) for NASA, and docked in 2011 to the ISS, are on-going as planned.

- The ESA Astronaut of Italian nationality, Samantha Cristoforetti, has just started her long term mission to ISS (November 2014 – May 2015, ISS Increment 42/43). Her mission, named Futura, will be complemented by ten ASI experiments, covering various disciplines.

- Together with European partners, the activities on ExoMars Programme (Italian Prime Contractorship) are on-going.

- Continuation of the activities on DREAMS, the Italian experiment on board the ExoMars 2016 EDM, Entry, Descent and Landing Demonstrator Module. DREAMS has positively passed all the Project Reviews so far and is respecting the schedule for the integration on board.

- Continuation of the operations, data acquisition and analysis of the Italian instruments on-board Mars Express (MARSIS and PFS) and NASA MRO mission (SHARAD).

- On 12 November 2014, the Philae lander touched down on the surface of Comet 67P/Churyumov-Gerasimenko as part of ESA Rosetta mission. This is the first time a man-made device has landed on a comet and collected data directly from the surface. The Philae lander is provided by a European cooperation among DLR, ASI and CNES. ASI is responsible for four of the twenty one instruments on board Rosetta and the Philae lander:
  - VIRTIS - Visual and InfraRed Thermal Imaging Spectrometer
  - GIADA - Grain Impact Analyser and Dust Accumulator

- WAC - Wide Angle Camera
- SD2 - Sample, Drill and Distribution system

- During the last ESA Ministerial Council held in 2014 (C/M14) Italy confirmed its engagement to support the extension of the ESA ISS Exploitation and to fund the 2015-2017 period.

Upcoming events

Italy foresees to confirm its continued support to Exploration activities. Attendance and active participation to the major events like IAF, COSPAR, etc... is confirmed.

The 2015 will be characterized by:

- a relevant involvement of Italy in the exploitation of the ISS, thus confirming its relevant role in this endeavour, whose importance is growing as a testbed to prepare future exploration beyond LEO.

- The execution of the aforementioned ASI experiments in the frame of the Futura mission, which will engage an important part of ASI ISS resources during the first half of 2015.

- Continuation of the activities, nationally and within ESA, in preparation for the ExoMars 2016 and 2018 missions. The ESA-Roscosmos cooperation is confirmed and consolidated.

- An ASI Announcement of Opportunity on Space Exploration Technologies is foreseen. The AO will be focused on Closed Loop Environmental Support Systems, Habitable Modules and Protection Systems from Radiation.

Conclusion

Italy is still strongly involved in Exploration. Currently the major objectives are the Mars Robotic Exploration (mainly ExoMars) and the utilisation of ISS. At the same time, Italy is also aiming at enhancing the Italian expertise in exploration related fields like robotics systems, pressurized modules and the relevant life support systems, aiming to acquire new technologies for the future space exploration.

Centre National d'Etudes Spatiales (CNES), France

CNES has participated at the International Space Exploration Forum meeting in January 2014 in Washington DC. Furthermore, CNES has continued to be an active member of ISECG. In particular, CNES has taken the co-chairmanship of the ISECG's Science Working Group and has been the key organizer of the ISECG Workshop held at the International Space University (ISU) in Strasbourg in October 2014. A successful international conference on exploration (co-organized by CNES and managed by ASTECH) also took place at ISU just after the workshop.

For France, recent significant exploration-related activities are:

Robotic exploration

- Contribution to NASA Mars missions (CURIOSITY, MAVEN, INSIGHT, MARS-2020)
- Contribution to landers: PHILAE on a comet (within the ESA ROSETTA mission), MASCOT on an asteroid (within the JAXA HAYABUSA-2 mission)
- Participation to EXOMARS (ESA/ROSCOSMOS mission)

Human spaceflight

- ISS exploitation and utilisation:
  - ATV Control Center at CNES
  - French participation to the relevant ESA programs
  - CADMOS: French part of the ISS scientific ground segment (USOC from ESA)
- Family of cardiovascular monitoring instruments (CARDIOLAB with DLR, CARDIOMED with ROSCOSMOS, CARDIOSPACE with China)
- Preparation of a CNES/ESA bedrest campaign in 2016 (at the MEDES Space Clinic, a CNES subsidiary)
- Parabolic flights (zero or reduced gravity), in particular for astronaut training

China National Space Administration (CNSA), China

1. CNSA continue to operate the instruments on the CE-3 mission. The mis-function of Yutu rover is courses be electric protection mechanism and it is still responsive to TT&C commend;

2. CNSA conducted the T-1 reentry test for CE-5mission. The sample return capsule was launched directly into lunar orbit and returned to Earth surface safely. This paved the way for future lunar sample return mission.

3. CNSA started Mars exploration project evaluation process and calling for its scientific Objective. Mars mission of CNSA shall include orbiter, lander and rover with one single mission.

4. CNSA continue to develop Long March launch vehicle by conducting successful cryogenic core engine test fire. Long March 5 is planned to be launched in 2016 with 25 Tons of LEO launching capacity.

Canadian Space Agency (CSA), Canada

Summary

Canada's Space Policy Framework has identified the exploration of space as an area of action for the Government of Canada. Investments in space exploration fulfill the needs for knowledge gain, inspiration and economic growth of Canadian citizen and companies alike. Space exploration missions enable unique science investigations leading to discoveries about the Universe, solar system and humans´ ability to live in space. They allow for demonstration of leading-edge technologies and capabilities resulting in new products and services for Canadians. Space exploration missions transform science into knowledge, and in turn, knowledge into innovation and economic growth.

CSA Structure

Under a Director General, the CSA's Space Exploration branch is organized in directorates that are responsible for the following program areas:

- Space Exploration Operations & Infrastructure
- Astronauts, Life Sciences and Space Medicine
- Space Exploration Development

Space Exploration Operations & Infrastructure

2014 on the International Space Station (ISS) marked a year of continued and heavy logistics re-supply and dexterous activity for the Mobile Servicing System (MSS). The CSA's Canadarm2 was used regularly to capture and berth resupply vehicles, including three Space-X Dragon and two Orbital Cygnus spacecraft.

Canadam2 and the Mobile Base have long been established as a core service on the ISS, supporting visiting vehicles, cargo operations and supporting US spacewalks. These important assets, specifically the Latching End-Effectors at each end of Canadarm2 used to grapple and manipulate payloads and to serve as a base for the large symmetrical arm, are now showing signs of wear-and-tear. The Canadian engineering support team has worked closely and successfully with NASA, who will be performing an on-orbit lubrication of some of the end-effector mechanisms.

Use of Dextre, Canada's two-armed and more agile robot, was significant and important in 2014. Subsequent demonstrations of on-orbit satellite servicing techniques were successfully carried out with the second phase of the joint CSA-NASA Robotic Refueling Mission (RRM). Dextre was used on all three Space-X missions to retrieve multiple payloads, as many as three each flight, from Dragons' "trunk" and deploy them on the ISS. Dextre is now also being used in support of experiment payloads for science, deploying micro-satellites. And, very significant to Canadian robotics capabilities, Dextre was used to retrieve an MSS Camera from the Japanese Airlock on the ISS, and replace a failed unit on the Canadarm2, effectively repairing itself on-orbit—another significant first in space robotics. As always, these dexterous operations are controlled from the ground, demonstrating capability and freeing up ISS crew-time for science.

Astronauts, Life Sciences and Space Medicine

Canada's two active astronauts, Dr. David Saint-Jacques and LCol Jeremy Hansen are pursuing their pre-assignment training activities and have been assigned collateral duties at NASA's Johnson Space Center within the CAPCOM, Visiting Vehicles, ISS Operations and Medical branches. They completed MSS robotics training at the CSA in the spring 2014, as well as the ensuing Robotics Specialist Skills training at JSC. Both are ready for assignment to ISS missions and are medically certified for ISS duties.

The mandate of the CSA's Space Health and Life Sciences group is to identify, characterize and mitigate risks to humans during extended space travel. The CSA currently has three ongoing activities on the ISS to support this objective:

1. VASCULAR examines the effects of long-duration exposure to weightlessness on the structure and function of the cardiovascular system. The final on-orbit subject session has been successfully completed.

2. BPReg is a cardiovascular experiment that aims to validate techniques for monitoring cardiovascular health. Three of the eight planned on-orbit sessions have been completed.

3. Radi-N2, a collaborative study with Russia characterizing the ISS neutron radiation environment, will continue on the ISS through.

Four new payloads in Life Sciences are being targeted for Increment 45/46. These studies will shed light on the risks of human spaceflight and the potential for novel countermeasures. They will focus on cardiovascular (Vascular-Echo), psychosocial (At Home in Space), musculo-skeletal (T-Bone) and metabolic effects (MARROW) of spaceflight on humans.

The CSA participated in the 2014 International Life Sciences Research Announcement (organized by the International Space Life Sciences Working Group), where additional Canadian life sciences payloads for the ISS will be identified.

Life Sciences Research Systems Early Studies assessing the status of five technology areas have been completed. The result of these studies has guided CSA's next instrument development in support of Space Health and Life Sciences objectives for the ISS.

A successful national Space Health and Aging Research (SHARE) workshop in 2012 identified several overlapping issues between aging and changes seen in humans in space. These changes include cardiovascular and balance dysfunction, bone and muscle loss, disturbed sleep, severe isolation and depressed immune response. The CSA continues to work on a collaborative agreement with the Canadian Institutes of Health Research-Institute of Aging (CIHR-IA) to support joint activities on Earth and in space to address SHARE. In the past year, we have engaged international partners through bilateral videoconferences with space and aging colleagues in Europe, the United Kingdom, France and the United States. In addition WE-SHARE (**W**orld **E**xplores **S**pace **H**ealth and **A**ging **R**esearch) an informal special interest group has been formed within the Gerontological Association of America to work with this large organization with links internationally to reach out to the greater community of academia, industry and government.

Space Exploration Development

Planetary Exploration

Canada's main planetary science goals are to understand the origin and evolution of the solar system, to investigate habitability and to detect life elsewhere in the solar system. The CSA's focus in planetary exploration is the exploration of Mars, the Moon and cislunar space.

In 2014, the CSA continued to support the Canadian Alpha Particle X-ray Spectrometer (APXS) investigation on NASA's Mars Science Laboratory mission, which landed in August 2012. APXS provides data on the chemical composition of Martian rocks and soils. The instrument has played an important role in the mission to date as a decision-making tool for scooping and drilling activities and in the selection of samples for analysis by MSL laboratory instruments.

The development of the CSA's OSIRIS-REx Laser Altimeter (OLA) investigation for NASA's OSIRIS-REx New Frontiers mission continued in 2014 for the spacecraft's launch, scheduled for 2016. The instrument has heritage from the CSA's lidar on the Phoenix Mars Lander's meteorological station. In return for Canada's contribution, a portion of returned sample will be curated in Canada. OSIRIS-REx marks Canada's first involvement in a sample-return mission.

In 2014, the CSA issued several concept studies to assess potential contributions to future international missions

Astronomy

Since 2013, the CSA has supported the integration of the Fine Guidance Sensor (FGS) and Near-Infrared Imager and Slitless Spectrograph (NIRISS) instruments to the Integrated Science Instruments Module (ISIM) and of the first two cryogenic vacuum test campaigns of the ISIM of NASA's James Webb Space Telescope, slated for launch in 2018.

Canada contributed to ESA's Herschel and Planck missions and CSA continues to support post-operations since early 2013 for data reduction that continues to yield excellent science results.

Since its launch in 2003, Canada's micro-satellite space telescope, the Microvariability and Oscillation of STars (MOST), has made valuable contributions to the field of stellar astronomy and exo-planets. As of September 2014, MOST operations are no longer supported by CSA; however, the satellite's extensive data archives will allow further science investigations. Based on similar micro-satellite technology, our Near-Earth Object Surveillance Satellite (NEOSSat) was launched in February 2013 and is undergoing commissioning. Scanning the sky near the Sun, NEOSSat will search for new near-Earth asteroids.

The CSA is developing a laser metrology system for JAXA's next large X-ray observatory ASTRO-H, slated for launch in 2015.

The CSA is contributing read-out electronics for the detectors of the UV Imaging Telescope (UVIT) on board ISRO's ASTROSAT space observatory (delivered to India in 2010) and is continuing to support testing of the detectors during the AI&T phase.

The CSA has also supported the development of BRight Target Explorer (BRITE), a constellation of 6 nanosatellites in collaboration with Austria and Poland to perform photometry of the brighter stars from

orbit. Two Canadian BRITE nanosatellites were launched in June 2014; one was inserted into orbit and is now operational, while the other apparently did not separate from the launch vehicle.

Advanced Exploration Technology Development

The CSA's Exploration Core Program funds advanced exploration technology development. The program activities cover the full spectrum required to develop and validate science, technology and operational solutions in support of future exploration missions. The first step is to conduct concept studies and data analyses to flesh out mission concepts and to carry out state-of-the-art reviews. Next, prototypes are developed to advance the technology and scientific readiness of selected concepts. Finally, field deployments, analogue missions, laboratory experiments or clinical tests are conducted to test the ideas developed in the concept studies and obtain operational experience. The goal of the program is to ensure Canada's readiness to participate in future human and robotic exploration missions.

In 2014, the CSA completed two concept studies related to asteroid initiatives. It has also awarded a total of four contracts to perform concept studies: two contracts related to lunar polar rover night-survival technologies; one contract related to space astronomy for the WFIRST mission; and one contract for a compact active sensor technology. Science definition studies investigating Lunar Surface Gravity Geophysics and an Ultraviolet Raman Spectrometer for the Identification of Organic Carbon on Mars were also put into place.

The CSA also continued to focus on the utilization of the prototypes developed using accelerated funding from Canada's Economic Action Plan in analogue missions and the enhancement of Technology Readiness Level (TRL) for potential future space missions. In 2014, four analogue deployment activities were completed with these prototypes to assess Mars Sample Return (MSR) technologies and science related activities, three of which were held at the CSA's analogue terrain: the CSA hosted the NSERC Canadian Field Robotics Network annual field trials; a team from the International Space University Summer Program used a CSA rover as part of a science activity; and students in NSERC's CREATE Program conducted a two-week simulation activity emulating a MSR science mission. A fourth deployment was also held at a sand quarry near the CSA's headquarters in Quebec. In preparation for future deployments that will be performed with increased autonomous capabilities, two contracts were awarded to further advance guidance, navigation and control software on two rovers.

In addition to these activities, prototypes are being developed to increase the TRL as far as TRL-5 to TRL-6 for some selected applications, including a Rendezvous Navigation Lidar System for Earth orbit maneuvers, a rover Lidar Navigation and Imaging System to enhance future Mars/Lunar rover missions, a drill for lunar ISRU applications and a new generation of compliant wheels. A rover-compatible TRL-4 Laser-induced Breakdown Spectroscopy instrument is being finalized and the CSA is investigating a Direct-to-Earth Communication system prototype to enable continuous tele-operation of a lunar rover from Earth to be delivered by spring 2015. Finally, two new contracts related to rover development were awarded, namely the Lunar Rover Platform & Drivetrain Prototype (LRPDP) focusing on the development of a lunar TRL-6 drive train assembly and a TRL 4+ chassis and the Small Planetary Rover Platform (SPRP), a 90kg targeted TRL-4 planetary rover prototype that will complete the spectrum of CSA's rover prototypes.

In the area of advanced technologies for crew medical systems, the CSA developed a wearable physiological monitoring system (Astroskin), a robotics task-based Performance Readiness Evaluation Tool (PRET), and a medical ultrasound remote control interface. The Astroskin system underwent field testing as part of an Antarctic expedition and all three technologies are undergoing laboratory testing

and validation. A concept for an integrated Advanced Crew Medical System for exploration-class missions has also been developed.

Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Germany

Summary

The space exploration activities in Germany in 2014 have been dominated by three major highlights connected to human and robotic space missions: ESA astronaut of German nationality Alexander Gerst spent six months on the International Space Station, with the ESA expedition supported by a strong national research and outreach programme. For the first time ever, the Philae lander, built and operated by a European consortium led by DLR, has successfully landed on the comet 67P/Churyumov-Gerasimenko and investigated the surface in-situ. The asteroid surface package MASCOT has been integrated and launched successfully on JAXA's Hayabusa-2 sample return mission, promising further insights into the surface properties of small bodies in our solar system.

The following sections will provide some more detail on these highlights as well as selected other German exploration events and activities, while DLR continues to develop and implement the German Space Programme, based on the National Space Strategy published in 2010. DLR together with German research institutions and industry remain strongly involved in the ISS, ExoMars and lunar preparatory activities at ESA level, while complementing this with excellent scientific instrumentation, robotics contributions and data analysis in the National Programme and in cooperation for international exploration missions.

Human Spaceflight Activities

The German human spaceflight activities clearly focus on the exploitation of the International Space Station (ISS). On 28 May 2014, the German ESA astronaut Alexander Gerst launched from Baikonur to the station and safely returned on 10 November 2014. Throughout his "Blue Dot" mission, Gerst worked for six months on the ISS and conducted more than 100 German, European and international experiments. The German contributions to his activities included e.g. experiments on the interaction of magnets with the Earth's magnetic field on the station and on functional textiles for physical exercise. As but one example of exploration related research on the ISS, the experiment BIOMEX, led by DLR, investigates the understanding of potential life on Mars. 12 experiment chambers hosting simple organisms in Mars simulants, Martian atmosphere and with varying radiation protection will remain at the exterior of the ISS for 1.5 years, before being returned to Earth for careful analysis.

As a highlight during Gerst's mission and recognizing more than 15 years of peaceful international cooperation in space, the Westfalian Peace Prize 2014 was awarded to the crews of the ISS on 25 October 2014. This renown German award highlights individuals and groups that have advanced and demonstrated peaceful international cooperation.

Alexander Gerst was the eleventh German in space. For the first time, he was directly returned to the European Astronaut Center and DLR's life sciences facility :envihab in Cologne after his landing, where all the post-flight medical analysis will be completed

Preparing future exploration within the ISS partnership, German industry leads the development of the European service module for the US Orion crew vehicle (MPCV-ESM). The mockup of the MPCV with the ESM was a highlight of the Berlin Air Show in May 2014, prominently recognized by the German state

secretary and aerospace coordinator, Brigitte Zypries, as well as the heads of ESA, NASA and DLR. The development contract for the first flight unit between ESA and Airbus Defence & Space was finally signed on 17 November in Berlin.

Robotic Exploration Activities

Science-driven robotic exploration activities are another German contribution to global exploration efforts.

The ESA science mission Rosetta has dominated media and public attention in Europe and worldwide throughout 2014, having arrived at the comet 67P/Churyumov-Gerasimenko in August. DLR has contributed several payloads to this exciting mission, including the lead of the European consortium for the Philae lander. After the awakening of the Rosetta spacecraft in January, Philae was reactivated by the lander control centre at DLR Cologne in March. With careful landing site characterisation and selection from orbit, it had to wait until 12 November until descending for the first ever landing of a man-made robotic element on a comet core. During its successful approach and landing, Philae has recorded scientific data of the surface for more than 60 hours that is now being analysed in every detail by the international science teams. The landing was showcased prominently at several live events throughout Germany as well as by thousands of followers on the internet, highlighting the interest of the public in exciting exploration missions and investigations.

Throughout the year 2014, DLR has also supported the final integration and test of the MASCOT asteroid surface package on JAXA's Hayabusa-2 asteroid sample return mission. Hayabusa-2 together with MASCOT launched successfully from Japan on 3 December 2014. Upon arrival at the asteroid 1999JU3/Bennu in 2018, MASCOT will be separated from the Hayabusa-2 spacecraft and descend to the asteroid surface to allow in-situ investigations with several instruments to characterise the surface properties and composition.

On a European level, ESA's ExoMars programme continues its development and preparation towards the two missions launching in 2016 and 2018. In February 2014, German industry handed-over the flight hardware of the core module of the Trace Gas Orbiter (TGO) for further integration and testing prior to launch. OHB has developed this major German contribution to the 2016 mission, incorporating the main and secondary structures, the propulsion system and the thermal control elements. Furthermore, DLR has completed the integration of a sensor package for temperature and thermal flux measurements during Mars entry with support from CNES. The package has been provided for integration on the Schiaparelli Entry, Descent and Landing Demonstrator Module that will accompany TGO on its 2016 mission to Mars.

Preparatory Activities

DLR together with German industry, academia and research institutions continues to prepare its capabilities and technologies for future space exploration beyond low Earth orbit.

Highlighting one example of these preparatory activities, the DLR scientist Lucie Poulet participated to the Mars simulation HI-SEAS, conducted by NASA and the University of Hawaii from March to July 2014. Poulet used the isolation in the Mars habitat for investigations about greenhouse design and lighting influences on plant growth. This is but one element of several German preparatory activities that address habitat technology such as life support, regenerative systems and crew health and performance for long duration spaceflight.

Other Relevant Space Events

From 20-25 May 2014, the bi-annual International Air Show was held in Berlin. Space activities in Germany and Europe were highlighted in the Space Pavilion as well as at the booths of the German Ministry of Economics and Energy, DLR and industry for more than 220000 visitors and experts. During the fair, DLR and ESA also renewed an agreement for collabotion on space robotics.

European Space Agency (ESA)

Outcome of ESA Council meeting at ministerial level (C/M14)

At the C/M14 in Luxembourg on 2 December, Ministers of ESA Member States adopted a "Resolution on Europe's access to space" agreeing to the further development of a family of new launchers (Ariane 6 and Vega C) and a "Resolution on ESA evolution", covering the vision for ESA until 2030.

Ministers also adopted a "Resolution on Europe's space exploration strategy" reaffirming the objectives for space exploration and the relevant destinations (Low Earth Orbit, the Moon and Mars).

Member States committed funding for the ISS Exploitation Programme up to 2017, which includes funding for the completion of the Multi-Purpose Crew Vehicle-European Service Module (MPCV-ESM) development activities and initial funding for the development of lunar exploration products. Additional funding has also been secured for the ExoMars Programme and the Mars Robotic Exploration Preparation Programme (MREP) period 2 (2013-2017). This means that the three destinations for space exploration identified by ESA in its Space Exploration Strategy are all addressed through ESA programmes.

The Resolutions adopted at the C/M14 can be downloaded from:
http://esamultimedia.esa.int/docs/corporate/Final_resolutions_1_2_3_from_CM_2014_Releasable_to_the_public.pdf

International Space Station (ISS) / LEO

The fifth and last Automated Transfer Vehicle (ATV-5) "Georges Lemaître" was launched successfully from Kourou on 29 July. The docking went perfectly with mm accuracy on 12 August. ATV-5 delivered a record 6,602 kg of freight, including dry cargo, water, propellants and gases. The Laser InfraRed Imaging Sensors operated successfully during fly-under and docking, and recorded the expected data. The ATV-5 has performed four reboosts and two debris avoidance manoeuvres for the ISS. Undocking and re-entry are scheduled for February 2015.

The Expedition 40/41 crew of ESA astronaut Alexander Gerst, NASA astronaut Reid Wiseman and Roscosmos commander Maxim Suraev returned to Earth on 10 November in the same Soyuz TMA-13M spacecraft that flew them to the ISS on 28 May. Alexander conducted over 50 experiments during his six-month "Blue Dot" mission. He also performed a spacewalk to maintain and improve the Space Station, installed ESA's Electro-Magnetic Levitator and supported the docking of ATV-5.

The Soyuz TMA-15M spacecraft carrying the Expedition 42/43 crew of ESA astronaut Samantha Cristoforetti, NASA astronaut Terry Virts and Roscosmos Soyuz commander Anton Shkaplerov launched successfully from the Baikonur cosmodrome in Kazakhstan on 23 November. Samantha will conduct science and technology research as well as outreach activities during her almost six-month "Futura" mission on board the ISS.

Roscosmos has confirmed their commitment to launching the Multipurpose Laboratory Module together with the European Robotic Arm. The anticipated launch date is March 2017.

ESA utilisation of the ISS continues with a large number of experimental activities successfully performed. Most of the human research and biological experiments are of scientific significance for human exploration preparation as they elaborate on the adverse effects of space on the human well-being and performance during long-duration missions.

With regard to post-ISS LEO exploitation, a bilateral meeting was held with the management team of the Chinese Space Utilisation Centre in order to elaborate joint experiments on board the ISS and the Chinese Space Station respectively.

Lunar Exploration

The Science & Challenges of Lunar Sample Return Workshop took place at ESTEC on 18-19 February. This was an opportunity for the worldwide lunar science community to come together and present its current work in this field. The outcomes and recommendations are available at:
http://esamultimedia.esa.int/docs/hso/Workshop_Outcomes_and_Recommendations_v18.pdf

The ESA approach for "Destination Moon" has been further elaborated, with the goal of providing access to the lunar surface to the European stakeholders. ESA is now focused on developing core exploration products for precursor robotic missions: PILOT for landing, PROSPECT for investigating resources and SPECTRUM for communicating. A first flight opportunity has been identified on the Luna missions of Roscosmos and related preparatory activities have been on-going in European institutes and industry. Such an incremental participation of ESA could pave the way for a more important contribution in a joint Lunar Polar Sample Return mission, for which a mission and system assessment study is planned in 2015.

The contract between ESA and Airbus D&S for the Phase C/D Development of the MPCV-ESM, which will enable human missions to the Moon's vicinity, was signed on 17 November in Berlin. An agreement was reached with NASA for the ESM delivery date of 29 January 2017.

Mars Exploration

The ESA-Roscosmos ExoMars Programme consists of two missions to be launched in 2016 and 2018, respectively. The 2016 ExoMars mission is on track for a launch in January 2016. For the 2018 mission, ESA and Roscosmos are following a plan that should lead to a successful System Preliminary Design Review close-out by 5 May 2015, still enabling a launch in 2018. An important step in the mission's scientific definition has been the first ExoMars 2018 Landing Site Selection Workshop (held on 26-28 March in ESAC), where the eight proposals received in response to the call for Landing Site proposals, issued in December 2013, were discussed. The ExoMars 2018 Landing Site Selection Working Group issued their first report in September, recommending the further study of four out of the eight proposed candidate Landing Sites.

In the context of the MREP Programme, a number of candidate missions have been identified and studied for post-ExoMars launch opportunities to Mars in 2024. Among these, a Phobos sample return (PhSR) mission is one of the most promising candidates. A joint ESA-Roscosmos PhSR CDF study was successfully performed in 2014, and in 2015 an industrial A/B1 study will start on PhSR. In parallel, several technologies have been developed which are relevant to these candidate missions, and at the same time prepare for a future potential European participation to Mars Sample Return (MSR).

Rosetta

Following the wake-up of Rosetta from its hibernation on 19 January, Rosetta arrived at its target Comet 67P/Churyumov–Gerasimenko on 6 August 2014. The arrival marked an important milestone for the ESA Science Programme, this being the first time that a spacecraft has followed and studied from close quarters a low-gravity body such as a comet. The successful landing of Rosetta's Philae module on the comet on 12 November marked another global first for the Agency, and despite the unplanned series of three touchdowns, all of Philae's instruments (ROLIS, COSAC, Ptolemy, SD2 and CONSERT) could be operated and the science data returned before it went into hibernation.

Indian Space Research Organisation (ISRO), India

The year 2014 has witnessed momentous achievement of the Indian Space programme by placing the Mars Orbiter spacecraft in the Martian orbit.

Mars Exploration

Mars Orbiter Spacecraft was launched onboard PSLV-C25 on November 05, 2013 from Satish Dhawan Space Centre, Sriharikota. After Earth-bound Orbit raising manoeuvres, the Trans Mars Injection manoeuvre was successfully conducted on December 01, 2013 to set the course of the spacecraft towards Planet Mars through a Sun-centric trajectory. Enroute to Mars, three Trajectory Correction Maneuvers were carried out on December 11, 2013, June 11, 2014 and September 22, 2014 to achieve the precise path towards Mars Orbit. The spacecraft traversed 666 million kilometres of inter planetary space to reach close to Mars.

The most crucial manoeuvre of Mars Orbit Insertion (MOI) was successfully carried out on September 24, 2014, with which the Mars Orbiter Spacecraft successfully entered into an elliptical orbit around planet Mars.

With the successful Mars orbit Insertion of the Mars Orbiter spacecraft, India became the fourth space agency to successfully send a spacecraft to Mars orbit and first nation in the world to do so in its first attempt.

The mission is primarily a technological mission, which enabled ISRO to achieve critical mission operations with enhanced autonomy function and stringent capabilities of propulsion and other spacecraft systems. It carried five scientific payloads to study the Martian surface features, morphology, mineralogy and Martian atmosphere. The images and data from all the payloads are received and are of good quality. They are being uploaded on the ISRO websites at regular intervals.

Lunar Exploration

Chandrayaan-2, the follow on mission to Chandrayaan-1 has indigenous Orbiter, Lander and Rover configuration. This mission will be primarily technological to prove ISRO's capability to soft-land on the Moon and to deploy and control the movement of the Rover on the lunar surface. This mission will have a suite of payloads on the orbiter, lander and rover.

Atmospheric Re-entry experiment

GSLV-Mk III is the next generation launch vehicle of ISRO capable of launching 4 ton class of satellites to Geosynchronous Transfer Orbit (GTO). The vehicle's first experimental sub-orbital flight was conducted on December 18, 2014. The payload for this flight was the Crew module Atmospheric Re-entry Experiment (CARE) to study the re-entry characteristics of the experiment. CARE re-entered the Earth's atmosphere from 126 km, survived the re-entry phase, landed near its scheduled landing spot in the Andaman Sea with the help of parachutes and was successfully recovered.

International Co-operation

With the successful MOM mission, an ISRO-NASA Mars Working Group (INMWG) has been formed to explore possibilities of enhancing the cooperation between the two agencies in Mars Exploration.

Japan Aerospace Exploration Agency (JAXA), Japan

Asteroid Explorer HAYABUSA2

JAXA successfully launched the asteroid explorer "Hayabusa2" on December 3, 2014 with an expected arrival at the target asteroid in 2018 and an expected return to the earth with the sample in 2020.

Learning from the experience gained in the original HAYABUSA, the asteroid explorer HAYABUSA2 will facilitate and secure two-way exploration to astral bodies within the solar system.

HAYABUSA2 faces challenges in new fields of science. Like the original HAYABUSA, it will be a sample-return mission to bring back substances from asteroids of a different kind. The Itokawa asteroid that the original HAYABUSA explored was an S-type asteroid consisting of rocky substances, but the asteroid called 1999JU3 to which HAYABUSA2 is destined is a C-type that is thought to contain much more organic matter and water.

The organic matter constituting the Earth's oceans and life is assumed to have been present in the interstellar gas that formed the solar system some 4.6 billion years ago. The mission assigned to HAYABUSA2 is to examine the water and organic matter that were present when the solar system was created.

HAYABUSA2's destination asteroid 1999JU3 is, like the Itokawa asteroid, on an orbit that comes close to the Earth's orbit and is roughly globular in shape with a diameter of about 900 meters.

The substances on the surface of the asteroid may have been degraded by solar rays and other factors, so HAYABUSA2 will also try to collect subsurface substances by exposing and gathering them with the collision device in an attempt to obtain substances with the least possible degradation.

Robotic Lunar Landing Missions

For future human Moon and Mars exploration, the development and demonstration of the required technologies are essential. JAXA thinks about lunar exploration as the test bed of those technologies and also obtaining scientific knowledge of Moon. JAXA has been working on the lunar landing explorer SELENE-2, as the lunar explorer program succeeding the KAGUYA (SELENE) expedition.

SELENE-2 will land on Moon and use a robotic rover to investigate surrounding area, demonstrating accurate safe landing technologies and surface mobility. For long duration observation on lunar surface, night survival technologies are also developed. SELENE-2 will help to solve the mystery of the origin and revolution of Moon and Earth system. It will also contribute to know detailed lunar surface environment such as radiation, temperature, regolith dust, soil mechanics, and prospective lunar resources.

Following SELENE-2, Moon sample and return mission SELENE-3 is planned. Lunar sample from South Pole Aitken Basin, etc will step ahead lunar science.

ISS (KIBO)

Japanese Astronaut, Koichi Wakata has returned to the ground on May 14th , 2014, completing his 3rd stay on ISS. During the stay, he became the first Asian Commander of the ISS for about 3 months during the 39th expedition period. Also, he conducted several medical researches about biological effects on astronauts due to the long zero gravity flight and radiation environment in space toward the future human space exploration.

H-X rocket and Orbit Transfer Vehicle

The purpose of H-X are to ensure sustainable access to space of Japan and to be competitive in the market of commercial satellite in 2020's. JAXA has started concept design (phase A) of new launch system H-X since the beginning of this fiscal year.

In addition, JAXA continued to advance the R&D activities of orbital transfer vehicles to contribute to the space exploration. These include both cryogenic propulsion and electric propulsion, based on the experiences of H2A launch vehicle and Hayabusa explore, respectively.

Investigation of human lunar vicinities missions

Prior to the human Mars mission, the mission to the lunar vicinities including Lagrangian point and lunar surface exploration are potential candidates for near-term human exploration. The mission objectives, system architecture and conceptual system requirement are begun to investigate. The research activities are continuing to pursue the required technologies to realize the human Lagrangian mission and the human lunar landing mission.

Symposium on International Space Exploration 2014

On July 31, 2014 JAXA hosted the Symposium on International Space Exploration 2014 in Japan. Experts in space exploration from around the world provided the latest status of international space exploration and exchanged their views with the audience. Panel discussions on the GER with experts from the broader community (such as policy, science and diplomacy experts) were also organized.

Korea Aerospace Research Institute (KARI), Republic of Korea

In 2014, KARI consistently conducted the development of an indigenous launch vehicle (KSLV-II), studies on the applications and commercialization of satellite technology, and the development of core technologies in aeronautics. Based on this effort and accumulated technologies, KARI will actively promote international cooperation with other space agencies.

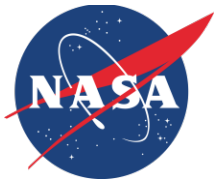
With respect to the Korean launch vehicle, KARI continues to make effort to develop the launch vehicle system (KSLV-II). The construction of the propulsion system test facility for performance verification of liquid engines was completed in September 2014 and the PDR for the launch vehicle and engine system was performed in December 2014.

With respect to the lunar exploration mission in Korea, the review of preliminary feasibility study for the lunar exploration project was successfully completed and passed in September 2014. KARI is also expanding its international partnerships in relation to the lunar exploration mission.

Towards ISS utilization, KARI has been working with JAXA to implement a joint space experiment (cell culturing experiment) onboard the ISS JEM. KARI has completed the engineering model (EM) development of semi-automated bioreactor at the end of 2014. For KARI-JAXA joint space experiment on ISS JEM, KARI will develop the flight model (FM) of semi-automated bioreactor in 2015. And Korean Microgravity Society (KMS) and KARI have organized and held successfully the 10th Asian Microgravity Symposium 2014 (AMS 2014) in Seoul, Oct. 28 ~ 31, 2014, supporting by other Asian Space Agencies. AMS2014 is the major international (Asian area) scientific forum for researchers in microgravity sciences utilizing the space environment, in particular microgravity.

With respect to satellite programs, Korea is operating 6 satellites (COMS, KOMPSAT-2, 3, 5, STSAT-3, and the Naro Science Satellite) upon which a satellite information application plan was established in May 2014. The KOMPSAT-3A, KOMPSAT-6, and GEO-KOMPSAT satellites were under development in 2014 with the launch of KOMPSAT-3A planned for 2015.

KARI held the 5th international space training program in June 2014 and the 32nd board meeting of the international charter on space and major disasters in October 2014. KARI continues to make effort to expand its space programs further in space exploration and strives to become an important player and partner in future global space exploration activities.



National Aeronautics and Space Administration (NASA), USA

In 2014, NASA took significant steps on the agency's journey to Mars -- testing new space transportation systems, cutting-edge technologies and making scientific discoveries while studying our changing Earth and the infinite universe as the agency made progress on the next generation of air travel.

Journey to Mars

NASA achieved a major milestone in December on its journey to Mars as the agency's Orion spacecraft completed its first voyage to space during a four-and-a-half-hour flight test. Orion is part of NASA's plan to develop new technologies and capabilities to send astronauts farther than ever before The SLS rocket, the most powerful ever built, moved from the concept phase to the development phase in 2014. Also this year, all major tools were installed at NASA's Michoud Assembly Facility in New Orleans where the rocket will be constructed.

NASA's human spaceflight effort took a giant leap forward in September when the agency announced U.S. astronauts once again will travel to and from the International Space Station (ISS) from the United States on American spacecraft under groundbreaking contracts worked by NASA's Commercial Crew Program. The agency selected Boeing and SpaceX to transport U.S. crews to and from the space station using their CST-100 and Crew Dragon spacecraft, respectively.

For 40 years, increasingly advanced robotic explorers have studied the conditions on Mars. This has dramatically increased our scientific knowledge about the planet, as well as helped pave the way for astronauts on the journey to Mars. In July, NASA announced its Mars Rover 2020, which is based on the successful Curiosity rover. Mars 2020 will carry instruments to conduct unprecedented science and exploration technology investigations on the Red Planet, including help with data for a human mission to Mars.

NASA's newest member of its fleet of robotic Red Planet explorers, the Mars Atmosphere and Volatile Evolution (MAVEN), spacecraft successfully entered Mars' orbit Sept. 21, where it is beginning its study of the planet's upper atmosphere. That extensive fleet of science assets, particularly those orbiting and roving Mars, were able to image and study a once-in-a-lifetime comet flyby of Mars in October.

The agency's Curiosity rover continued this year to help refine our understanding of Mars. In December, NASA announced Curiosity has measured a tenfold spike in methane, an organic chemical, in the atmosphere around it and detected other organic molecules in a rock-powder sample collected by the robotic laboratory's drill. Curiosity's findings from analyzing samples of atmosphere and rock powder do not reveal whether Mars has ever harbored living microbes, but the findings do shed light on a chemically active modern Mars and on favorable conditions for life on ancient Mars. Observations by Curiosity also indicate Mount Sharp near the rover's landing site was built by sediments deposited in a large lake bed over tens of millions of years.

NASA continues to advance the journey to Mars through progress on the Asteroid Redirect Mission (ARM), which will test a number of new capabilities needed for future human expeditions to deep space, including to Mars. This includes advanced Solar Electric Propulsion -- an efficient way to move heavy cargo using solar power, which could help pre-position cargo for future human missions to the Red

Planet. As part of ARM, a robotic spacecraft will rendezvous with a near-Earth asteroid and redirect an asteroid mass to a stable orbit around the moon. Astronauts will explore the asteroid mass in the 2020's, helping test modern spaceflight capabilities like advanced spacesuits and sample handling techniques. The agency has identified asteroids that could be good candidates for the ARM mission. Efforts to identify good candidates for the mission are also helping augment NASA's existing work to survey near-Earth objects and identify those that could threaten Earth. In addition to the spaceflight capabilities , the mission will also present a new opportunity for planetary defense demonstrations, to help mitigate asteroid risks in the future.

NASA's Asteroid Grand Challenge is an effort to reach beyond traditional boundaries and encourage partnerships and collaboration with a variety of organizations to find all asteroid threats to human population and know what to do about them. The challenge had success in 2014 engaging the public through a variety of new partnerships, such as ECAST, SpaceGAMBIT and the Asteroid Data Hunter contest.

International Space Station

NASA's journey to Mars begins in low earth orbit aboard the ISS. The agency is using the space station to conduct cutting-edge research and technology development and to increase our knowledge about what it takes to live and work for long periods of time in space. 2014 marked 14 years of continuous human presence on the orbiting laboratory. Recognizing the long-term benefits of the space station, the Obama Administration in January announced it intends to extend operations on the ISS until at least 2024.

Scientific accomplishments on ISS continue to increase, as does the quantity of data returned from automated research instruments, and astronaut crew time dedicated to research. During fiscal year 2014, ISS hosted 368 experiments including an estimated 64 in biology and biotechnology, 91 in Earth and space science, 50 educational activities, 36 in human research, 43 in physical science, and 84 in technology.

Research into human health and performance continues onboard the ISS to understand and mitigate long duration and radiation effects on crew members such as bone loss, vision impairment and muscle degradation as well as physical performance in micro-g. NASA also made significant progress in preparing for the 1-year crew expedition to understand the full effects of space travel on humans beyond the current 6-month exposures.

NASA has also made progress in testing and demonstrating the systems and technologies needed for missions beyond LEO, such as launch preparations for the NASA docking system that will be utilized on ISS and for deep space missions, upgrades to the environmental support systems to increase the reliability, development activities continue for common rendezvous and proximity operations sensors demonstrations, and next generation crew waste systems.

NASA biological and physical sciences implemented a new research approach called "open science" – a way to maximize return on investment in ISS research by greatly increasing the number of investigations and development of translational applications, which will enhance the current traditional approach to NASA Research Announcements (NRAs). The Open Science approach entails providing access to NASA obtained data for analysis of both human exploration and commercial applications.

The first rodent investigation was delivered to the ISS in September 2014. These investigations enable researchers to observe spaceflight-induced changes to tissues and cells, muscles and bones, cardiovascular and reproductive systems, and even behavior. This research helps quantify human health

risks and the countermeasures needed for exploration of space and provides a platform for research into new drugs and causes of disease for application here on Earth.

NASA launched the RapidScat instrument to ISS for a two year mission to measure ocean surface wind speed and direction. As an autonomous externally-mounted payload to the Columbus laboratory, this instrument will help improve weather forecasts, including hurricane monitoring, and understanding of how ocean-atmosphere interactions influence Earth's climate. ISS-RapidScat will help fill the data gap created when another satellite stopped collecting ocean wind data in late 2009.

CASIS is making strong progress on its mission to engage non-traditional users and enable a new era for space investigations capable of improving life on Earth. Payloads include innovative research from both solicited and unsolicited channels. CASIS established several new partnerships including the United Nations, the Broad Institute, the MassChallenge Institute, and National Geographic among others to support a variety of applications, including water and forest management, humanitarian relief, disaster prevention and recovery.

Installation and activation of Vegetable Production System ("Veggie") – the largest plant growth system to date for use in space – was completed in 2014. This facility is key to studying how plants grow in space, to determine whether humans can successfully grow food in microgravity during long-duration missions. This research may also lead to innovations that allow people on Earth to grow more food using less land, and to regenerate lost forest areas more quickly. The first crop grown in the Veggie system was lettuce; it was harvested by astronauts and returned to Earth for analysis of microbial content.

Technology

Technology drives exploration, and it is a significant part of NASA's endeavors, including the journey to Mars. In June, the agency used a rocket-powered, saucer-shaped vehicle called the Low Density Supersonic Decelerator to test technologies needed for landing large payloads on the surface of Mars. The agency continued its successful small spacecraft technology demonstrations in 2014 with the in-space test of Phonesat 2.5. The small smartphone-controlled spacecraft hitched a ride into orbit on SpaceX's cargo launch to the ISS in April.

Progress was made this year for the 2016 launch of NASA's Green Propellant Infusion Mission. The small satellite is designed to test a high-performance, non-toxic, "green" fuel in orbit as a potential replacement for highly toxic hydrazine and complex bi-propellant systems currently in use. This summer, NASA completed a complex series of tests on one of the largest composite cryogenic fuel tanks ever manufactured, bringing the aerospace industry much closer to designing, building, and utilizing lightweight, composite tanks.

The agency also created a one-stop online shop for all the current opportunities available to the public to contribute to solving tough problems related to NASA's mission through challenges, prize competitions, and crowdsourcing activities. One such opportunity, the Cube Quest Challenge, was announced in November and is NASA's first in-space competition that offers the agency's largest-ever prize purse. Competitors have a chance at a share of $5 million in prize money and an opportunity to participate in space exploration and technology development, to include a chance at flying their very own small satellite, known as a CubeSat, to the moon and beyond as secondary payload on the first integrated flight of NASA's Orion spacecraft and Space Launch System rocket.

Earth, Solar System and Beyond

For the first time in more than a decade, five NASA Earth Science missions (including 2 payloads to ISS) were launched into space within a one year period. Together with NASA's existing fleet of satellites, airborne missions, and researchers, these new missions will help answer some of the critical challenges facing our planet today and in the future: climate change, sea level rise, freshwater resources, and extreme weather events.

Looking out into space on our journey of discovery, a number of new findings were announced in 2014. In November, NASA announced a rocket experiment found that the universe is brighter than scientists originally thought. NASA's Kepler mission announced in February the discovery of 715 new planets outside our solar system. These newly-verified worlds, known as exoplanets, orbit 305 stars, revealing multiple-planet systems much like our own solar system. Two months later, astronomers using Kepler announced they have discovered the first Earth-size planet orbiting a star in the "habitable zone" -- the range of distance from a star where liquid water might pool on the surface of an orbiting planet.

One of the biggest mysteries in astronomy, how stars blow up in supernova explosions, finally started to be unraveled in February with the help of NASA's Nuclear Spectroscopic Telescope Array (NuSTAR). The high-energy X-ray observatory has created the first map of radioactive material in a supernova remnant. The results, from a remnant named Cassiopeia A (Cas A), reveal how shock waves likely rip massive dying stars apart.

NASA’s Van Allen Probes mission, which is studying the mysteries of Earth’s radiation belts, celebrated its two year anniversary on Aug. 30. The twin probes, shortly after launch in 2012, discovered a third radiation belt around Earth when only two had previously been detected. In October, NASA announced its Interface Region Imaging Spectrograph (IRIS) spacecraft provided scientists with five new findings into how the sun’s atmosphere, or corona, is heated far hotter than its surface, what causes the sun’s constant outflow of particles called the solar wind, and what mechanisms accelerate particles that power solar flares. Scientists using NASA's Interstellar Boundary Explorer (IBEX) announced in February that data from the spacecraft has showed a magnetic field that is nearly perpendicular to the motion of our solar system through the galaxy. In addition to shedding light on our cosmic neighborhood, the results offer an explanation for a decades-old mystery on why we measure more incoming high-energy cosmic rays on one side of the sun than on the other. In December, after a voyage of nearly nine years and three billion miles -- the farthest any space mission has ever traveled to reach its primary target -- NASA’s New Horizons spacecraft came out of hibernation for its long-awaited 2015 encounter with the Pluto system.

STEM Education Collaboration

NASA’s Office of Education continued to leverage opportunities in 2014 with other federal agencies, industry partners and academia to provide unique and compelling agency content as a catalyst for increasing STEM literacy throughout the United States. This year, NASA and Honeywell celebrated a decade of successful STEM collaboration with a west coast city tour of the award-winning science education program FMA LIVE! Forces in Motion. The tour marked an important milestone in the 10-year collaboration: reaching 1,000 schools and more than 400,000 students and teachers.

Russian Federal Space Agency (Roscosmos), Russia

In 2014 Federal Space Agency (Roscosmos) has been implementing the document called “Milestones of state policy of the Russian Federation in the area of space activities for the period till 2030”. This document states national interests, main principles and tasks of space exploration policy. Particular attention is being paid to international cooperation in space exploration. In accordance with this document the following activities in the field of space are being performed:

- development of new generation space cargo vehicle
- development of new launch vehicle for the purposes of lunar and Mars exploration
- development of unmanned spacecrafts for deep space exploration and new generation space robotics.

Roscosmos has continued the development of infrastructure for manned space exploration in low Earth orbit (LEO). Roscosmos utilization of ISS continues not only with a large number of experimental activities, but also with testing advanced technologies for Moon exploration (robotics, life support system, medical researches) onboard ISS.

This year Roscosmos has been working with ESA to implement joint experiments program and with JAXA on the “Crystallizer” experiment. Moreover, joint experiments with NASA were being discussed during 2014. Thus, ISS today is the world’s largest platform for research experiments of scientists from different countries.

In 2014 Russia has performed four launches of manned space vehicle “Soyuz TMA” and 4 launches of freighter “Progress M” that provided rotation of ISS crews and delivered the cargo. 12 ISS crew members and 10 000 kilos of cargo were delivered to ISS and 12 ISS crew members were brought back to the Earth.

To expand the possibilities for carrying out the science program on Russian segment of ISS Russia is developing three new modules for the station that will provide more space for installing scientific equipment, additional power supply and will enable to conduct the research in the promising areas including equipment and technologies testing for future space exploration programs.

In accordance with the Federal Space Program the Russian Federation is working on development of unmanned serviceable technological spacecraft. This spacecraft will be serviced while temporarily docked with ISS.

2014 became the year of enhancing cooperation between Russia and China. In September the 6th meeting of joint Russian-Chinese Committee on human spaceflight was held which provided a great opportunity for Russian and Chinese experts to discuss their proposals on further ways of cooperation.

The main target of Russian human spaceflights is the Moon. Full scale Moon exploration will involve several steps - at first robotic missions, then human assisted robotic missions. First launches of

unmanned spacecrafts are planned to start after 2018. That will become feasible with utilizing unmanned landing stations Luna-Glob and Luna-Resurs. After 2020 lunar exploration will be performed by carrying out joint missions of manned space vehicles and automated stations. The projects to develop space infrastructure for lunar exploration will involve reusable unmanned serviceable landing stations, lunar orbital station and lunar base.

State Space Agency of Ukraine (SSAU), Ukraine

Activities

Today Ukraine is open for participation in the global space projects. Based on the provisions of the Association Agreement between Ukraine, on the one hand, and the European Union, the European Atomic Energy Community and its Member States, on the other hand, finally signed in Brussels on June 27, 2014, Ukraine seek to maintain a constant dialogue jointly with the EU and extend cooperation in space activities (Articles 7 and 371-373), in particular, through the European Space Agency (ESA).

In this context, on February 14, 2014 the validity period of the Agreement between the Government of Ukraine and the European Space Agency on cooperation in the peaceful use of outer space has been extended till February 24, 2019.

In October 2014 the first discussions at the expert level between the State Space Agency of Ukraine and ESA were held at the ESA headquarters regarding the future format of cooperation in the field of space exploration.

The SSAU participated in the IAA Space Exploration Conference and the Heads of Space Agencies Summit held during January 9-10, 2014 in Washington D.C. (USA).

The 4th International Conference Space Technologies: Present and Future was held in Dnipropetrovsk (Ukraine) on May 16-19, 2014.

Delegation of the SSAU participated in the third open consultations on the draft International Code of Conduct for Outer Space Activities (Luxembourg, Grand Duchy of Luxembourg) on May 26-30, 2014.

Delegation of the SSAU took part in the 65th International Astronautical Congress in Toronto (Canada) within September 29 - October 3, 2014.

The International aerospace salon Aviasvit-XXI has been held during September 24-27, 2014 in Kyiv (Ukraine). The Aerospace Salon hosted the International Aerospace Forum “Ukraine’s Aerospace Industry: Vital to Economic Modernization”, organized by the American Chamber of Commerce in Ukraine and the State Space Agency of Ukraine under support of Dnipropetrovsk Regional Council.

The Regional meeting of the International Academy of Astronautics (IAA) in cooperation with the National Academy of Sciences of Ukraine (NASU) and the SSAU was held in Kyiv on November 6, 2014.

Research

On September 8-12, 2014 the Institute of Electron Physics, National Academy of Sciences of Ukraine in Uzhgorod hosted the 14th Ukrainian Conference on Space Research, devoted to a topic of wide range of space research, space biology, medicine, science of microgravity, astrophysical and cosmological studies, materials and technologies for space research and others. The exhibition of space engineering prototypes, scientific and technical publications on space subjects has been held in the framework of the conference. The conference ended with a round table "Problems of modern space activities in Ukraine and space research perspectives".

Education

On November 5-7, 2014 the National Youth Aerospace Education Center of Ukraine (NYAECU) held the 9th Annual Scientific Readings «Dnipro orbit». This event was attended by scientists and specialists of enterprises and organizations of the aerospace industry, lecturers and scientists of leading higher educational institutions of Ukraine. More than 40 papers on various topics related to the humanitarian aspects of rocket and space technology were presented during the readings.

International projects

Cyclone-4: Ukrainian enterprises kept working in the framework of the Cyclone-4 project in cooperation with Brazilian partners throughout the year. The construction of facilities and ground-based infrastructure, manufacture and ground tests of launch vehicle structures continued.

Sea Launch: May 27, 2014. The Zenit-3SL LV has been successfully launched from the floating platform "Odyssey" with the European EutelSat-3B spacecraft onboard.

Dnipro: June 19, and November 6, 2014. The Dnepr LV has been successfully launched from the Yasniy Launch Base (Orenburg region, Russia). During the first launch, the payload of 22 satellites from 17 countries has been successfully injected into orbit (including Ukrainian PolilTAN nano-satellite).
During the second launch the Japanese ASNARO ERS satellite and 4 microsatellites have been placed on their orbits.
Dnipro launch vehicle is based on the SS-18 ICBM.

Force Majeure

The SSAU has temporarily lost some of the ground space infrastructure, in particular, Ukrainian RT-70 radio-telescope (Yevpatoriya, Crimea) with the unique parameters of the antenna and a dish diameter of 70 meters. This has caused the termination of a number of space researches in the field of radio astronomy.

UK Space Agency (UKSA), United Kingdom

The UK continues to support cutting edge science and technology and to develop capabilities for robotic and human space exploration. The UK Space Agency leads the growth of the UK space sector, coordinating these activities and working closely with national and international partners.

UK scientists and engineers played an important role in the successful ESA mission Rosetta, whose Philae lander in November made the first ever landing on a comet. The Ptolemy instrument on Philae was led by the Open University in collaboration with RAL Space. This instrument performed in situ analysis of the composition of the ices and organic material on the comet. UK scientists were also involved in ten of the other Rosetta instruments.

The UK continues to strongly support the ESA Mars Robotic Exploration Preparatory programme and committed further funding to this programme in December 2014. The UK also remains an active member of the ExoMars programme, committing additional funds to the programme and, following negotiations at the ESA Council of Ministers, taking on leadership of the rover module, to be launched in 2018. The UK is also contributing to the NASA InSight mission to Mars, with Imperial College London leading a team which will provide the micro-seismometers.

A robotics and autonomy facility is being established at the new ESA centre in Harwell, Oxfordshire: the European Centre for Space Applications and Telecommunications (ECSAT). This facility will use simulation models combined with field trials to validate autonomous systems for planetary surfaces.

A field trial in the Atacama desert in September 2014, as part of the CHAMELEON project, tested new autonomous systems which adapt dynamically to changing terrain and environments. This technology, led by researchers at the University of Oxford and SCISYS, will improve safety, reliability and efficiency of rovers on future missions exploring planetary surfaces.

Human space exploration activity is increasing in the UK. At the ESA Council of Ministers in December 2014, the UK formally committed to the ISS for an extended period, continuing UK involvement in the programme for the next six years. This is the first time the UK has made an ongoing contribution to this project and marks a positive development in national policy. A draft National Strategy for Space Environments and Human Spaceflight was published in August 2014; following public consultation this document will be published in early 2015 and will set the direction and overarching strategy for UK endeavours in these fields.

Complementing these activities, national funding was confirmed for education activities associated with the mission of ESA astronaut Tim Peake, who will become the first British astronaut to visit the ISS in 2015. This will harness the public fascination with spaceflight to deliver a comprehensive programme of science, technology, engineering and maths (STEM) education, in both formal and informal settings. An independent study was also commissioned in 2014, in partnership with the Economic and Social Research Council, to assess the social effects of human spaceflight programmes and, specifically, to answer the question: How does human spaceflight affect perception and uptake of STEM subjects?


ISECG
International Space Exploration
Coordination Group