



This report, drawn up by CNES with input from the French scientific community for the 40th COSPAR meeting, summarizes two years (2012-2013) of scientific space research in France. It includes both an overview of current research programs in Universe sciences, Earth and environment sciences, condensed-matter physics and life sciences in space, and also a small selection of noteworthy scientific results obtained over this period.

First of all, I would like to point out that CNES, the French space agency, was assigned the task by the French government of organizing national research in space sciences. It has no research laboratories of its own but works jointly with the French scientific community, public research laboratories and organizations, by providing them with technical and financial support.

There are two sides of the French space program: (i) participation in programs run by the European Space Agency (ESA) – with CNES managing the French contribution to ESA – and (ii) programs that are carried out outside of this framework, most of them through bilateral or multilateral partnerships. Participation in ESA and non-ESA programs is planned with complementarity in mind.

In the field of Universe sciences, ESA's *Cosmic Vision* program is at the heart of the French space program. French laboratories, supported by CNES, supply more than a quarter of the scientific instruments of the program's mission, whereas France's contribution to *Cosmic Vision* – based on the French GDP, should only represent 15.5% of the contributions.

Among the most noticeable events of the past two years, I would like to mention the publication in April 2013 of the first cosmological results of PLANCK, the end in 2013 of HERSCHEL's operations aiming to study the cold Universe, and the launch in December 2013 of the GAIA mission, where CNES is playing an important role for the ground segment. Medium-sized missions M1 (SOLAR ORBITER) and M2 (EUCLID, dark energy) were definitely adopted in October 2011 and June 2012 respectively. In May 2012, the first large-sized mission L1 (JUICE), was selected to study Jupiter's icy moons. And in November 2013, scientific themes for the future missions L2 ("the hot and energetic Universe") and L3 ("the gravitational Universe") were selected. Besides the *Cosmic Vision* program, I would like to emphasize the importance of international cooperation, especially with the US in the field of robotic exploration on Mars, with MSL, MAVEN and INSIGHT.

The cooperation between France and China for the SVOM mission (gamma-ray bursts monitoring) will restart after the decision of our partners to use a Chinese platform and to launch the satellite from China.

I would also like to stress the importance of small opportunities with high return on investment, such as the participation to the Japanese mission HAYABUSA 2, with a French contribution to the lander MASCOT.

CNES has also played an important role in the emergence of new scientific themes, such as fundamental physics with the atomic clock PHARAO, which will be installed in the International Space Station (ISS) in 2015, and the MICROSCOPE microsatellite, which aims to test the principle of equivalence and will be launched in 2016. Besides, the development of the TARANIS microsatellite, studying transient luminous events above storms, is continuing and it will be launched in 2015. Last but not least, I'll mention the end of the operations of the PICARD satellite, aiming to measure solar irradiance.

In the field of condensed-matter physics and life sciences in space, priority is given to the use of orbital infrastructures. The instrument DECLIC, in cooperation with NASA, is still being used on board the ISS, with a new flight of its DSI and HTI inserts. The development of CARDIOSPACE, a cardiovascular monitoring instrument, is about to be completed. It will be carried on board TIANGONG 2. The CNES space center in Toulouse also carried out flight control, docking and deorbiting operations for the ATV3 "Edoardo Amaldi" in 2012 and ATV4 "Albert Einstein" in 2013 after they were launched by Ariane 5 from the Kourou space center in French Guiana.

Robotic and human exploration of the Solar System, which will be an important theme for the coming decades, must be planned as an international enterprise, through equitable cooperation between partners, without any country taking an exclusive interest or more than a fair share, with each participant being allowed to contribute according to their capabilities, strengths and preferences. The European Space Agency (ESA) currently bears the greatest burden in terms of Europe's contribution to exploration. However, if exploration is to be opened up to international cooperation, then a shared political vision is necessary. CNES has actively participated in the work of the International Space Exploration Coordination Group (ISECG), a working group gathering 14 space agencies and created to draw up global strategy concerning exploration – the second iteration of the Global Exploration Roadmap was released in August 2013. CNES also contributed to organizing the second International Forum on Space Exploration, which was held in January 2014 in Washington.

In the sciences of Earth and the environment, a large proportion of scientific activities are bound up with major social issues that require the global, consistent and long-term vision made possible by space observation. Space can make an essential contribution to key challenges such as environment monitoring and protection, adaptation to climate change and management of natural resources. Such observations are of benefit to much more than just fundamental science, because it is vital for our survival on Earth that we improve our knowledge of how the planet works. We are now acquiring a vision of it as a holistic system, where all components interact in a complex manner, with the effects of human activity playing an increasingly important role in these mechanisms.



Probe from the HAYABUSA 2 mission © JAXA



MASCOT lander set down by the HAYABUSA 2 probe on the Near-Earth asteroid 1999JU3 © JAXA

In this context, the scientific community has defined two main themes for research:

- to understand, experiment and model the processes governing physical, chemical and biological functions taking place in the surface envelopes of planet Earth: biosphere, lithosphere, ocean and atmosphere, a natural interconnected system where matter, energy and living creatures interact;
- to understand, observe, model and mitigate the way these systems respond at every level (global, regional and local) to past and present human pressure on these envelopes and on the working of the great biogeochemical cycles, by identifying their characteristic duration, and the manner in which ecosystems and societies adapt to these changes.

In this specific field of sciences of the Earth and the environment, international cooperation has a primordial position. Noteworthy recent events include:

- with Germany: a cooperation agreement between CNES and DLR on the development of the MERLIN microsatellite, aiming to measure atmospheric methane;
- with the USA: an agreement on the study of the SWOT mission, for continental and oceanographic hydrography, which follows a successful cooperation on oceanographic satellites, such as TOPEX/POSEIDON and its successor JASON;
- with China: the CFOSAT oceanography project that will carry the French SWIM instrument, aiming to measure wave height;
- with India: the exploitation of the MEGHA-TROPIQUES satellite launched in October 2011 with three French instruments on board (MARFEQ, SAPHIR and SCARAB) and the launch in February 2013 of the SARAL mission, carrying the French altimeter ALTIKA as well as copies of the DORIS and ARGOS-3 instruments.

Whenever possible, we should also use the civil-defense duality of space systems, as the optical imaging system PLEIADES, whose two satellites were launched in December 2011 and December 2012.

I will also mention CNES participation in ESA's *Earth Explorer* scientific missions and the selection of BIOMASS as the future EE7 mission of the European program. A notable difference compared to Universe sciences is that the instruments are generally not provided by laboratories.

Operational missions, such as EUMETSAT's weather satellites and the future SENTINEL satellites of the European program Copernicus (formerly known as GMES), are providing scientists with key data. EUMETSAT's second polar satellite METOP-B, carrying on board a copy of the infrared sounder IASI and an instrument ARGOS-3, was launched in September 2012. Late 2012, at ESA's ministerial Council in Naples, it was decided to develop the future generation of European weather polar satellites, METOP-SG, which will be launched during the next decade. At the beginning of 2013, CNES and EUMETSAT reached an agreement on the IASI-NG project, a new generation of infrared atmospheric sounder, which is to be carried by METOP-SG satellites.

A few pre-project studies are under way, among which I would like to mention MICROCARB (measurement of atmospheric carbon dioxide), MISTIGRI (measurement of surface temperatures), OCAPI (phytoplankton monitoring from a geostationary orbit) and R&T activities, notably on the various uses of lidar.

The space segment needs to be completed with processing and archiving systems to allow users an easy access to the data obtained, for use in both research and service applications, and to allow past data to be reprocessed. The creation of thematic units associating CNES and the user community are part of this need. I can mention for instance the new unit THEIA dedicated to continental surfaces. A think-tank led by CNES and CNRS-INSU advised to organize thematic units in Earth Observation in four new units: Continental Surfaces (THEIA), Solid Earth, Ocean and Atmosphere (created from the merger of two existing units: ICARE, for clouds and aerosols, and ETHER, in atmospheric chemistry).

CNES also organizes campaigns involving the launch of balloons for science missions, mainly for environmental and climate studies. The new monitoring and protection system NOSYCA was selected in 2013. An agreement was reached in 2012 with Canada for a cooperative partnership. Besides, the possibility to launch CNES balloons at medium latitudes from a Canadian base in Timmins was validated in 2013.

The recommendations resulting from the Scientific Prospective Seminars organized by CNES every five years serve as a roadmap to draw up a scientific program. During the period 2012-2013, we pursued the implementation of the recommendations from the seminar held in Biarritz (France) in March 2009. Throughout 2013, we organized the seminar held in La Rochelle (France) in March 2014, through an intensive dialogue between CNES and the scientific community. The coming years will therefore see the implementation of the conclusions drawn at the La Rochelle seminar.

Richard Bonneville

Deputy Director, Directorate for Strategy, Programs and International Relations