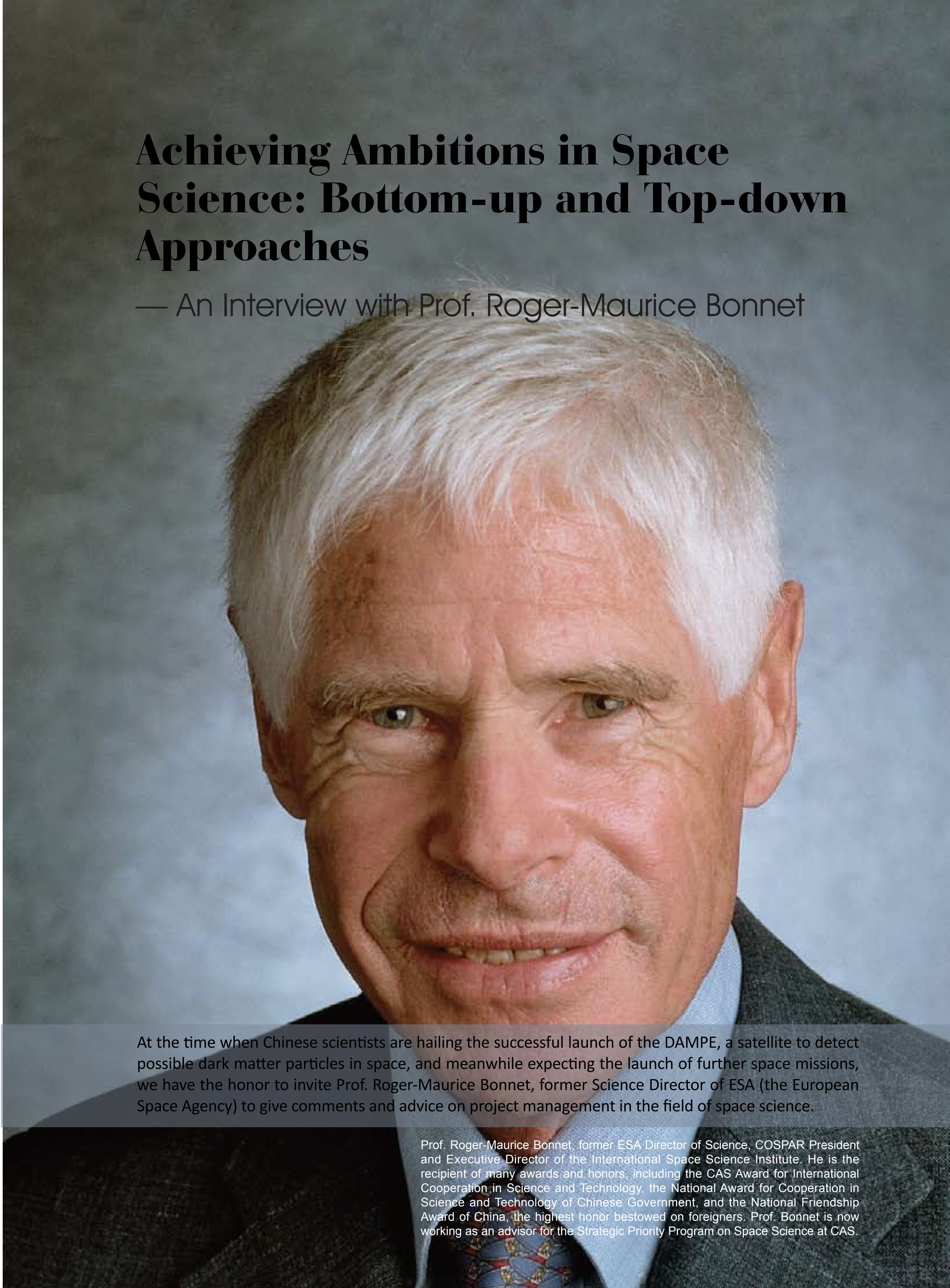
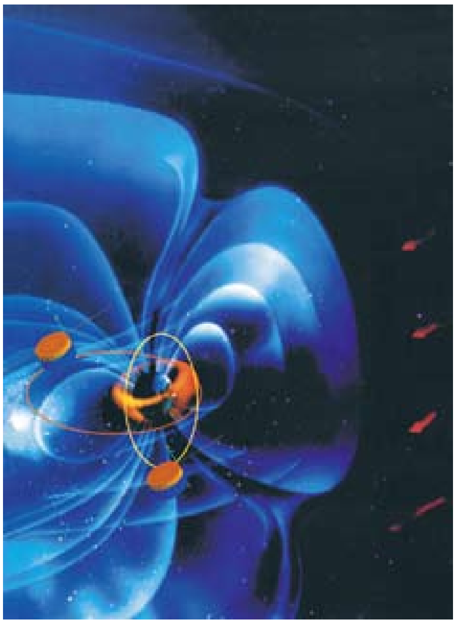
Achieving Ambitions in Space Science: Bottom-up and Top-down Approaches

— An Interview with Prof. Roger-Maurice Bonnet



At the time when Chinese scientists are hailing the successful launch of the DAMPE, a satellite to detect possible dark matter particles in space, and meanwhile expecting the launch of further space missions, we have the honor to invite Prof. Roger-Maurice Bonnet, former Science Director of ESA (the European Space Agency) to give comments and advice on project management in the field of space science.

Prof. Roger-Maurice Bonnet, former ESA Director of Science, COSPAR President and Executive Director of the International Space Science Institute. He is the recipient of many awards and honors, including the CAS Award for International Cooperation in Science and Technology, the National Award for Cooperation in Science and Technology of Chinese Government, and the National Friendship Award of China, the highest honor bestowed on foreigners. Prof. Bonnet is now working as an advisor for the Strategic Priority Program on Space Science at CAS.



Initiated by the CAS Center for Space Science and Applied Research (CSSAR), the predecessor of today's National Center of Space Science, CAS, and jointly run by the China National Space Administration and the European Space Agency (ESA), the Geospace Double Star Exploration Program (Double Star Project) marked the first space mission of China aimed at science exploration. Its twin probes, one launched in late December 2003 and the other in 2004, form a 3D system together with the "Cluster II" system of ESA to monitor the magnetic field around the Earth. In so doing it provides data to help understand the mechanism of disastrous geospace weather during solar activities and interplanetary disturbance.

"Ambitious Program"

"It is also very original in the sense that only 10 years after the launch of the Double Star Mission, you are addressing fields of science like quantum physics and dark matter physics, which are extremely challenging in terms of technology and science goals."

BCAS: You know we are developing four satellites, one for dark matter detection, namely the DAMPE, which is to be launched by the end of this year, and three others, including the one for hard X-ray modulation, the one for quantum science experiments, and the one called *Shijian*-10 (SJ-10) for microgravity and space life science research. Would you give us some comments on the four satellites?

Bonnet: Yes, with pleasure! I think this is a very ambitious program. Certainly it is not big as compared with other space programs in the world as to what concerns the number of missions, but the quality of the program is high. It is also very original in the sense that only 10 years after the launch of the Double Star Mission, you are addressing fields of science like quantum physics and dark matter physics, which are extremely challenging in terms of technology and science goals. These missions are addressing science of Nobel-Prize level. That's my opinion.

The X-ray mission you mentioned is also entering this category, to some extent in a difficult environment: many missions have been launched or are ready to be launched in the world in the field of high-energy astronomy where competition is very severe. However, the scientists involved here in China are first class, well known in the world, and their missions will provide new data and contribute to a large international effort in high-energy astrophysics.

I am not especially familiar with the mission SJ-10, but I understand that what China intends to do in microgravity is also quite unique. This big satellite that will stay some two weeks in orbit to study physical and biological phenomena in a reduced gravity environment is very impressive.

The diversity of these four missions is broad and quite unique, addressing fundamental physics problems: the detection of new particles like the hypothetical dark matter particles, and the study of the entanglement of photons.

BCAS: Thank you for your nice words. Is there any project in the world similar to the one for dark matter particle detection?

Bonnet: Yes, there is a dark matter detection experiment on the International Space Station being prepared, which by the way also involves Chinese scientists working in the USA, but the DAMPE mission, to be launched at the end of this year, rests on new instrumentation: it has a very high position accuracy and a very high sensitivity. Compared with other missions, DAMPE is by far the most original.

The mission to study whether quantum entanglement is really surviving over large distance separation, the largest ever thanks to space, is also very challenging and of Nobel-Prize level.

Major Gaps: Bottom-up and Top-down

"Only them (scientists) are best placed to know what is necessary to do to advance science. They know what problems must be solved and what programs need to be pursued."

BCAS: You are now working as an advisor for the Strategic Priority Program on Space Science at CAS. From your view, where do you think the major gap lies in between China and other space powers in space science?

Bonnet: Well, to be frank and honest, I cannot hide that there are several gaps between Chinese space science and that of the West. There certainly exists a very high potential in China of high-level scientists and engineers, some of whom have been trained in Europe and in the USA, two places often considered as the heaven of space science. The approach developed after more than 50 years of space research in the Western world has proven its efficiency in leading to major advances and discoveries that could also be used by the Chinese scientific community as well. That community has to learn, but the scientists have all the qualities to do it fast and well.

The first essential step in the formulation of an ambitious program is what I would call the "bottom-up approach" whereby the scientists are the originators of the ideas of the proposals. Only them are best placed to know what is necessary to do to advance science. They know what problems must be solved and what programs need to be pursued. Their work, their discoveries some day in the future, may well lead to broad applications. Fundamental research always precedes applications even though the scientists do not know ahead of time what these might be. For example, laser research started as pure research trying to understand the behavior of atoms and how they emit and absorb light. But now everyone on Earth knows what lasers do in an immense number of domains without asking the question whether it was worth spending the research money that helped discovering the laser phenomenon.

Returning back to dark matter, we don't know what it is, but some day you, we, may well discover a new unknown particle that might have many applications. We don't know! Scientists are working at the bottom of the discovery process, which can be compared with a high tower with many steps eventually leading to major discoveries and applications. On the top of the tower lie the deciders, the politicians and the money raisers who are there to define the frame inside which the scientists can create their science and develop their ideas.

In the United States, and also in Europe, the top-down approach is generally accepted as the best method for implementing first class space science missions. Space science is big science. It covers the sciences of the Universe, as well as fundamental physics, Earth and climate sciences. It also includes sciences of matter and microgravity and life sciences.

Moments: Prof. Bonnet and Rosetta Mission

A very concerned and anxious Prof. Roger-Maurice Bonnet – here with Dr. B. Feuerbacher of the German Space Agency (DLR) – appearing in front of the TV on November 12, 2012 at the ESA Space Operation Center in Darmstadt (Germany) a few minutes before the separation of the Philae lander of the Rosetta Mission to land on the nucleus of Comet 67P.

Prof. Roger-Maurice Bonnet – here with J-C. Worms of the European Science Foundation – appearing in front of the TV on November 12, 2012 at the ESA Space Operation Center in Darmstadt (Germany) a few minutes before the separation of the Philae lander from the Rosetta Orbiter to land on the nucleus of Comet 67P.

Roger-Maurice Bonnet surounded by the press and TV on November 12, 2012 at the ESA Space Operation Center in Darmstadt (Germany) after the confirmation that the Philae lander of the Rosetta Mission was on its way to landing on the nucleus of Comet 67P.

It's a broad field. Some experiments can be done using modest and small rockets or balloons; some may require large telescopes of several meters in diameter that imply big technology developments to implement. There exist a big variety of missions: small, medium, big and extra-big. One may wish to launch a probe around the planet Mars or land on its surface, orbit around a satellite of Jupiter, like Europa or also land on it. Ten years ago, ESA using the NASA big Cassini mission landed the Huygens probe on Titan, the biggest moon of Saturn. However this was still a small and relatively cheap mission, though with Huygens ESA accomplished the most distant landing ever made by humanity. Big missions usually require more than five years to develop, while smaller ones can be done more rapidly. The Double Star Mission of intermediate size was developed in less than three years, even though it took several years before the project was eventually approved. Future more complex missions may take a longer time before their technology has matured, and before all the experiments are ready to fly. Working in an international cooperation framework may add a few more months or years to the development time. International cooperation adds a lot of value to space missions, but it often requests more time because of the many actors involved.

A five-year plan as established presently in China, is a first and major step but that is neither optimum nor sufficient for the future. At the European Space Agency (ESA), the Horizon 2000 plan established for 20 years was defined in 1984, and approved by the governance of ESA in 1985. I am not saying that China should adopt immediately such an approach, but five years is definitely too short. A five-year program might be acceptable for just the development of approved projects, but is not long enough when long-term research in technology in particular is necessary to prepare for high-level competitive missions. Indeed, space science must be competitive: one cannot re-do what has been done before, except for studies requiring repetition of the same measurements over long times like in climate science for example. In other cases, being competitive means developing the most advanced instrumentation based on the most advanced technologies, prepared ahead of time. You also need long-term funding commitments ensuring that missions will not be abandoned in the midst of their developments because of lack of resources. So, five years seems to me to be too short if you include all the elements of the mission.

Another essential aspect of a high-level effort in space science is that the scientific results must be published in the scientific literature and also explained to the public. It is fine to have missions successfully put into orbit, but what is mandatory is to break new barriers in our knowledge of nature and its phenomena. In the United States, the National Aeronautics and Space Administration (NASA) is in charge of not only developing the missions and their supporting technologies, of launching the mission, but also, most importantly, of supporting the scientific community for analyzing and publishing their research in the best scientific journals. I insist that it is essential. If the scientific community in China wants to be in a leading position, the scientists must have the insurance that their data will be analyzed and that they have the human and material means to do that.

BCAS: Do you think we need to make more efforts to analyze the data from the lunar probe?

Bonnet: Without any doubt, China has accomplished a great prowess and has acquired unique and spectacular scientific results with the *Chang'e* 3 on the Moon and also on the Earth but, to my knowledge, very little of these scientific discoveries have been published in international scientific journals. This is regrettable! Certainly, more efforts should be made.

Aimed at Space Science

"China is a great country, and it shows strong desire to be leading in many areas but it is missing something, which would make it a respected partner among other great nations and that is space science research."

BCAS: So do you think there is any gap between China and powers in space science in terms of long-term planning? Have we given due attention to bottom-up innovations?

Bonnet: I feel that the implementation of the bottom-up approach in the selection of missions and instrumentation, as far as I can judge, is improving rapidly in China. What did not exist a few years ago seems to have been implemented by the Academy and the scientific administration here in China. It does seem to be more systematic and the situation is clearly improving.

China is a great country, and it shows strong desire to be leading in many areas but it is missing something, which would make it a respected partner among other great nations and that is space science research. Space research does not exist yet in China at the level it should be for such a great nation. The only mission that has been launched so far is the Double Star Mission. Hopefully, the DAMPE launched on December 17 will offer a second opportunity to prove Chinese excellence in space science and the next year will see three more missions in orbit. So the Chinese space science program is definitely growing in number of missions and in ambition. But that number is still far from big, far from what it should be. China is just starting, and apparently at a high pace and there are good hopes that very soon the Country will be in a leading position in several domains of space science. So I am optimistic for the future, but I hold this optimism with caution, as some principles should be in place to make the future ambitious program first-class. You've gained a lot of experience with the Double Star Mission and can rest on that to take a leap. It is impossible to be a leader in the world while not being a leader also in space science.

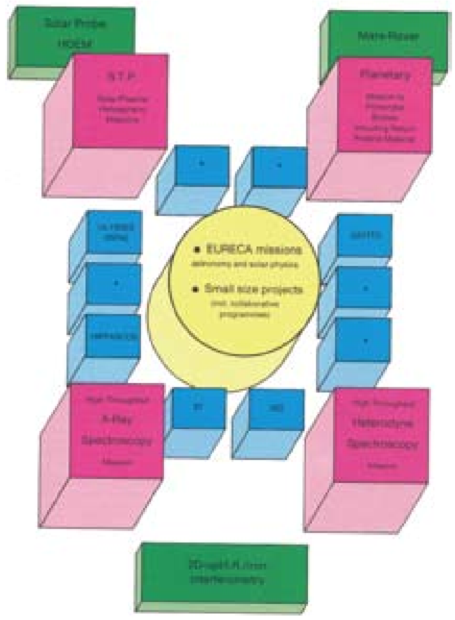
BCAS: We are talking about bottom-up and top-down planning in space science. Is there any procedure in NASA, ESA or other space science agencies to make sure innovations rising from the bottom can reach the top to get due support and fully considered by the administration?

Bonnet: The bottom-up approach leading to innovation requires a series of intermediate steps before it reaches the political and financial deciders. As far as the first scientific selection is concerned, the scientific community is organized and governed by its own rules, which have proven their validity and efficiency. Among the rules what we call the "peer-review system" ensures that the best choice of scientific topics is made. The following fate of a proposed mission is also determined through a filtering process by a series of specialized committees able to judge its scientific and technical qualities. The closer you get to the final political decision, the more financial considerations enter the review process. At some stage you might meet the situation where the deciders consider the mission too ambitious, too expensive and not affordable. The scientists are then sent back to the drawing board and must, if they wish to proceed, re-define or re-scope the mission. This is a period when more imagination and innovation is entering the process leading to maintaining the scientific objectives of the mission with the use of new technologies. I personally used this method for all the missions of the Horizon 2000 program at ESA and it worked remarkably well: all Horizon 2000 missions launched have been developed within a fixed cost, on schedule and all produced world-wide first class science.

NASA also implements the approach I described with a big difference however in that they do not follow the "design-to-cost" I have used at ESA. The Japanese space science organization, ISAS, also follows the design-to-cost method. To my knowledge, China has not had a chance to implement the approach for the very reason that the space science program is just starting now. But feeling financial responsibility by the scientists increases their impact and might assist the deciders in better appreciating their seriousness.

On the other hand, what organization does not exist in China is a space agency. You need a space agency to balance the political/financial limits and the scientific requirement. NASA is an example of that.

Design-to-Cost Approach at ESA



ESA's Horizon 2000, a 20-year program as established in June 1984 and eventually adopted by the ESA Council at Ministerial level in January 1985. It identifies four main Cornerstones (showed in the big red boxes) and a mix of medium to small missions in blue and yellow boxes. At that time the cost for ESA of the four large missions was fixed at about €400 millions and that for medium and small size missions at €200 and €100 million respectively, forcing ESA to adopt a "design-to-cost" approach for their development.

"... it worked remarkably well: all Horizon 2000 missions launched have been developed within a fixed cost, on schedule and all produced world-wide first class science," Prof. Bonnet, who supervised the compilation of the program, introduces.

Detour to Scientific Ambitions

To compromise the ambitions of achieving science excellence with economic limitations, ESA has set an upper limit to the budget for every mission under its own management responsibility. Scientists might have to redefine or re-scope the concept of their proposals to find affordable solutions to their ambitions, and this might extend the time needed for design and development.

It took scientists 10 years to redefine the Rosetta Mission, which was first proposed as an ambitious concept, though incompatible with the assigned cost limit, aimed at bringing comet samples back to Earth for analysis, into the successful in situ comet exploration that hit headlines last year. The re-designed mission included a lander, called Philae (above), and an orbiter (middle).

(Bottom) Spectacular image captured at 17:35 GMT on 12 August, 2015 by the Rosetta Navigation Camera, when the comet was arriving at its shortest distance to the Sun, called perihelion, showing powerful outbursts of water vapor jets emitted by the Comet 67P.

BCAS: But we do have a space agency called the China National Space Administration (CNSA).

Bonnet: Yes, but it seems that CNSA is different from the three examples I just quoted (ESA, NASA and ISAS/JAXA). To me, what is missing here to implement the space science program of China is a space agency that would have the proper structure to evaluate, review the proposals and manage the programs from the very beginning of mission proposal to the end through all the steps of implementation: industrial development, launch, operations in orbit and scientific exploitation. If China wants to be a world leader, it also needs to be a leader in space science; and from that perspective the establishment of the proper administrative and scientific structure is necessary!

Enhanced Long-term Planning Needed

"I already mentioned the 'bottom-up' approach but I would also insist that the elaboration of a long-term plan extending over more than the five-year one is also essential."

BCAS: What are the main differences between China and ESA concerning the procedures applied to pre-study, selection and endorsement for space science projects? What are your specific suggestions to China?

Bonnet: Let's note that ESA is a very different organization from all other organizations in the world, because it is an international organization where several countries agree to work together in the framework of an international convention and a budget contribution from all the states involved. In Europe several organizations similar to ESA have been created: the CERN in Geneva for particle physics and the European Southern Observatory (ESO) in Chile for the development and exploitation of very large telescopes. NASA often claims that it is international but even though it cooperates broadly with other countries in the world, their organization, budget and programs are decided by the US Government.

There are however a large number of methods and principles that are followed both in ESA and NASA, which can be used as a model for any other organization and might be useful for China to follow. I already mentioned the "bottom-up" approach but I would also insist that the elaboration of a long-term plan extending over more than the five-year one is also essential. In both the American and the European examples, the National Academy or its equivalent establish every ten years surveys of the progress in space science that help assessing the evolution of knowledge from the results obtained, and define the broad goals or the topics for the future programs from which the scientific community might propose specific missions and projects, identify the crucial technologies and start negotiating with potential international partners. So, if I have to offer any advice to China, that would be to establish a long-term plan on space science covering more than five years, maybe 10 or more and review it regularly (there 5 years is a good figure), but make it both ambitious, of international standards and at the same time realistic so that it offers an appeal to the political authorities that will eventually provide the financial support it requires. I insist that the practice to set a cap on each individual mission's budget is a good way to force scientists to find the best and the cheapest solutions to achieve their ambitions. It can be an efficient factor of innovation. I cannot insist enough on the essential role of international cooperation, which is absolutely a must for space science. I think China understands that very well.

"... I think in particular for the large missions sticking to the present approach might force China to develop only modest and small missions."

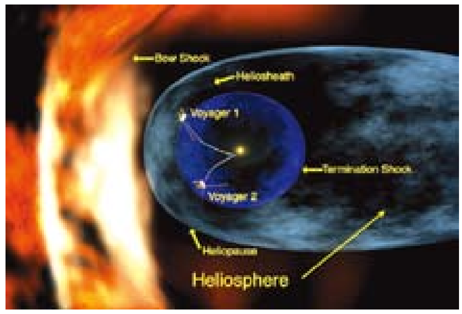
BCAS: You have talked about the time limit on projects in the field of space science. As the case in China, for the projects in the field of space science during the Twelfth Five-Year Plan, the project teams are required to start up their missions at the beginning of the Five-Year period, and finish the whole development and launch the satellites by the end of the period. These seem quite different from other countries' approaches. What suggestions would you like to give us in this scenario?

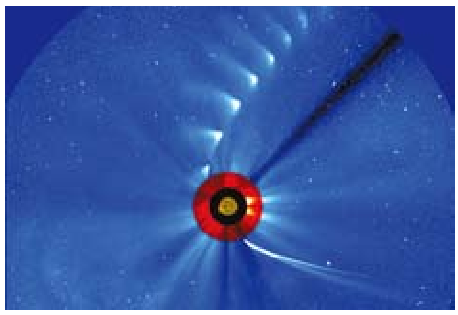
Bonnet: To be very frank, I think in particular for the large missions sticking to the present approach might force China to develop only modest and small missions. In case of high-class international missions, accomplishing everything from first ideas through to the development, launch and in-orbit operation of the satellite, only in five years, is impossible. If you are thinking about a long-term program involving a large share of international cooperation, the schedule is not only dependent upon your own schedule but also on that of the international partners.

Furthermore, considering technological developments and preparative work before final approval of the missions, five years might not be long enough to achieve the best performances. If the five years mentioned covers only industrial development and testing before launch, that might be possible assuming however that the scientific instrumentation does not face drastic difficulties. Including scientific exploitation in these five years is just unrealistic. Let's also consider the case of long-distance planetary exploration for which it might take more than 5 years to reach the target (it took 10 years for the ESA Rosetta Mission to reach the Comet 67P and 31 years for the original idea of the mission to develop and mature to get ready for launch). Large space observatories may well last more that 5 years in orbit. Hence the 5-years scenario followed by China should define more accurately what phases of a space program it does include.

"I would say that ambitious missions require 'out-of-the-art' new technologies and long time to develop, sometimes leading to dead-ends and sometimes not fitting to available financial resources."

Long Journeys of Space Exploration





(Above) The satellites Voyager 1 and 2, launched in 1977 by NASA to explore the external planets of the Solar System, have since been operating normally for 40 years. The Voyager 1 came back into the spotlight when it was announced that it might have broken the limits of the Heliosphere, the "physical edge" of the Solar System. Carrying greetings to possible extraterrestrial civilizations in 55 human languages, it is currently the only manmade object travelling through the Milky Way.

(Middle) Schematic illustration of that part of the Solar System where the pressure of the solar wind is larger than the interstellar pressure, also called the Heliosphere. The two Voyager spacecraft are identified, referring to their relative positions in mid 2012.

(Bottom) SOHO, a joint effort of ESA and NASA to observe the activity of the Sun, was defined in 1983 and launched in 1985. Due to the uniqueness of the mission, ESA and NASA decided to pay for its maintenance and operation until more performing mission fills the gap. The picture was taken by the LASCO 3 instrument that creates an artificial eclipse of the Sun's bright disk, which corresponds to the yellow circle at the center of the image. It shows a series of successive images taken at the time when Comet ISON passed at the distance of 1.2 million km from the Sun and was broken in several fragments after that.

BCAS: Do you think it possible to divide an ambitious project into smaller ones and achieve the goal in phases?

Bonnet: I am not assuming that! Small missions have values of their own, but you cannot slice a program into small missions unless you limit your ambitions to a modest-class program, which is not what I understand China is considering. It is not impossible to slice a big telescope into smaller pieces, but at a very high cost. However, some long-term programs like the landing and building bases on the moon might be sliced into several steps depending upon what are the objectives of a lunar exploration program. Certainly, a long-term program can be composed of a mix of small, medium and big missions: that was the case of ESA's Horizon 2000 program mentioned here several times.

BCAS: And it might take a very long time to maintain the project once it is launched, right?

Bonnet: Yes! For example, the NASA Voyager Mission to explore the external planets of our Solar System does offer an excellent example in that respect. The technologies used to build the twin space probes of the mission date back to the 1970s. They are completely obsolete with respect to modern standards but perform nominally 40 years after launch. It is the only mission that explores our Milky Way. It ought to pursue that extraordinary and unique journey until its sources of energy decide to stop. The ESA/NASA SOHO mission to observe the activity of the Sun was defined in 1983 and launched in 1985. It is still in operation today, because it carries unique instrumentation that no other satellite possesses. Every two years NASA and ESA join hands to decide whether to continue paying for the operations and the salaries of the scientists and the engineers as well. That has been the case until now and may continue until a new more performing mission would fill the gap and replace SOHO with better instruments.

BCAS: Now we know that generally five to 15 years is needed for ESA's space science projects to proceed from concept study, official endorsement, to the launching phase, while for some major programs it may even take longer. What do you think the major reason is? Why does ESA allow such a long time for the R&D?

Bonnet: There are many reasons. One of them is that it takes the scientists some time to agree on the best way to implement their ideas. I can mention again the Rosetta Mission for which it took the scientists 10 years to refine the concept and transform what was at the beginning a mission to bring samples of comets and asteroids back to Earth into a re-defined one-doing *in situ* analysis of a Comet with a lander and an orbiter. One of the main reasons was that the Comet sample-and-return idea was found to be too expensive. In that particular case, the design-to-cost approach mentioned above forced the re-design of the mission with the result of a delay of several years, but that delay did not result in a budget over run. On the contrary, in a project big money is spent during the development phase, it is wiser to spend more time refining the mission and make it possible, than running full speed in the development of a concept that would be abandoned at a later stage.

Another example is the NASA James Web Space Telescope (JWST), successor to the very successful 2.4m Hubble Telescope that is still in operation today. The first concept of JWST was proposed in the mid 1990s and conceived as a joint venture between ESA and NASA, to be developed within a budget limit that was set to be less than 1.0 billion dollars for a launch in 2007! NASA did not apply the design-to-cost philosophy and it took more than 10 years to re-define and re-scope the telescope with however a much larger cost. It is now scheduled to be launched in 2018 with a delay of ten years. I would therefore say that ambitious missions require "out-of-the-art" new technologies and long time to develop, sometimes leading to dead-ends and sometimes not fitting to available financial resources, which may require a very long process of lobbying and discussions.

New Organization of Space Science Program

"Such an agency might offer better chances to secure the long-term commitment needed for China to embark on an ambitious space science program of the highest international level."

BCAS: In your opinion, what types of procedures are to adopt for such major programs in China, going through phases from pre-study, selection to endorsement, before entering the launching phase?

Bonnet: China should establish a new structure, a new organization of its space science program, in a way similar to that of a space agency, if not a genuine space agency. Such an agency might offer better chances to secure the long-term commitment needed for China to embark on an ambitious space science program of the highest international level. The existence of such an agency would ensure continuity and long-term support for undertaking ambitious projects from initiation to exploitation.

BCAS: What do you think would be the main difference between such an agency and the current structure we have in China?

Bonnet: I think you need an organization that is committed to space science research, including engineering also, but an organization funded by the government to do essentially science, to do projects and that would be responsible through all the steps of a mission: from selection through development, launch, in-orbit operations and scientific exploitation. The responsibility for some of these steps might be delegated to other entities but the coordination and control of the proper implementation of these steps should be placed under the responsibility of a single entity.

In China, as far as I can judge, there exist a large number of excellent engineers, a large number of excellent scientists but they are not necessarily belonging to the same organization. They give me the impression of a set of musicians composed of excellent brass and string instruments trying to play a symphony but in separate orchestra directed by different conductors. Such an organization would not produce the best music! Similarly, the organization of space science in China would deserve better coordination and leadership from a single entity in order to create the best space science program.

BCAS: As far as we know, the budget for China's space science projects does not cover the costs for the ground science center, the in-orbit operations and the science research after the launching. Is it the case at European Space Agency? Does its budget cover such costs?

Bonnet: ESA's budget does not cover such costs either. However the situation at ESA is very peculiar and different from all other space agencies in the world. So, it is not a good reference for comparison. ESA covers the development of all elements in a mission, which strictly speaking does not include the scientific payload. That peculiarity results from the principle adopted at the creation of ESA that the Agency should not create its own science. In other words, scientific work should be placed under the responsibility of scientific institutes in each member state that would then also be responsible for financially supporting their scientists once their experiment has been selected by ESA, including scientific data analysis. In other words, ESA provides all common services: launcher, ground-based facilities, tracking network and in-orbit satellite operations but all what refers to science and instrumentation is the responsibility of the member states to which the selected scientists belong. There is also some money available in the European Commission (organically not connected to ESA) accessible through competitive selection in responses to announcements of opportunities released by the commission.

Let me give you an illustration of the drawbacks of ESA's approach. In 1985 ESA launched a satellite called Giotto to fly by comet Halley in March 1986, and for the first time in space exploration humanity was able to approach a comet nucleus at a short distance (600km). That was a historical first and more than one billion of people on Earth were watching their TV screens to discover the mysterious nucleus that was spitting spectacular jets of dust and gas since its discovery many centuries before. On board the spacecraft was a scientific camera placed under the responsibility of a German scientist. That scientist was very concerned that some of his

Re-definition of JWST at NASA

Shown is a schematic design of NASA's James Web Space Telescope (JWST), future successor to the Hubble Telescope. The first concept of this large telescope was proposed in the mid 1990s as a joint venture between ESA and NASA within a maximum budget of 1.0 billion dollars. It took the scientists more than 10 years to re-define and re-scope the telescope and to fit it in a realistic but much larger budget based on more affordable and adequate technologies. It is now scheduled to launch in 2018.

"Dubious Image" of Halley Comet

(Top) For the first time human beings were able to approach a Comet, in this case Comet Halley, and captured the image of its nucleus from a record short distance of 660km.

(Bottom) In the early hours of March 14, 1986 at the control room of the ESA Space Operation Center (ESOC) in Darmstadt, Germany, triumphant Giotto Project Manager, Dr. David Dale, holds the TV BBC microphone to Dr. Uwe Keller, Principal Investigator of the Giotto Imaging Camera. The well-anticipated images, however, were masked with a special coding invented by Dr. Keller (here showing the coded image to the worldwide TV audiences of more than 1.8 billion people). The coded and fuzzy appearance of the comet raised the anger and irritation of then UK Prime Minister Mrs. Margaret Thatcher, who publicly expressed her strong disappointment in view of these cryptically coded pictures.

This setback prompted ESA to re-consider the separation of financial responsibility between the Agency and its member states. It has also convinced ESA to fund and install a navigation camera on board the Rosetta mission, which actually provided all the photos released through out all critical phases of its journey, of which an example could be found in page 216 .

competitors would use the pictures of the comet and interpret them before he could do so himself. These pictures were HIS data; they belonged to him, his country paid for them. Consequently he tried to mask the pictures by coding them in different colors adapted to the different degrees of luminosity of the nucleus. By that process he offered the TV gazers of the world just a fuzzy and very poorly exciting picture of the nucleus. That attitude unfortunately had some unpleasant consequences. Everyone watching that historical encounter was expecting spectacular results from the fly by. Instead, they got nothing else than some kind of colorful humps. Some high level chiefs of government expressed strong doubts as to whether it was worth spending their national money for getting such fuzzy cryptically coded images. A few years later when we had to design the Rosetta mission, we were confronted to the same scientist who proposed another high-resolution camera, but this time I decided that ESA should build its own camera. At the end, Rosetta has two cameras: one scientific camera under the responsibility of the German scientist and one – so-called navigation camera – placed under ESA's own and unique control, which in effect has produced the pictures that were continuously released during all critical phases of the mission. I must admit that this is not necessarily optimum and the separation of responsibilities between ESA and the scientists in member states ought to be re-discussed. I just used that example to illustrate the problem, which fortunately does not affect other agencies such as NASA in particular, which controls and finances the scientific payload and has the authority to impose its policies to the scientists.

BCAS: What about the ground-based science center?

Bonnet: It is the same! Outside of ESA! In principle, ESA does not support the scientific data centers, nor do ESA pay for the data analysis. But there may be some exceptions.

BCAS: To my knowledge, if a big project is conducted through international cooperation, all participant countries attending the project can share the data from it by principle. If so, why could this have happened?

Bonnet: In that case, the commonly accepted procedure granting exclusivity to the scientists for a given period of time can be developed as a common facility but not necessarily funded by ESA. That is for example the case of the Cluster data center in England use by all the investigators of the Cluster mission that the UK government is paying for. The same applies for the Integral Science Data Center installed near Geneva in Switzerland that is accessible by all the users of this big gamma ray astronomical space observatory but has been paid by the Swiss government.

International Cooperation a Must

"I don't see any space science mission today, and that also includes Chinese missions, that do not rest on international cooperation."

Prof. Roger-Maurice Bonnet describing in 1983 to then UK Prime Minister Mrs. Margaret Thatcher at the occasion of her visit to the ESA Space Research and Technology Center in Holland, the details of the ESA/NASA Out-of-Ecliptic Ulysses mission.

BCAS: So we are talking about international cooperation. Do you think it particularly important for projects in space science?

Bonnet: Yes. Today, you cannot do space science without international collaboration. It is as simple as that!

BCAS: Why?

Bonnet: For several reasons! First, space science projects are becoming more expensive. Except in rare cases, no single laboratory or institute can develop such sophisticated and expensive experiments by itself. Second, you don't necessarily find all the required scientific competence in the same institute for the development of the payload or the exploitation of the results. You might want to develop an instrument, but you do not have the necessary technology in your country. However you know another country that has the technology. So you can invite this country to join you and contribute making the mission possible. I don't see any space science mission today, and that also includes Chinese missions, that do not rest on international cooperation.

BCAS: What kind of collaboration mode would be the best from your view? Would you give some advice to China?

Bonnet: I think you are doing quite well already in this respect. You have here with the National Space Science Center (NSSC) of CAS a first-class international space science institute. The NSSC has also recently hosted the extension of the International Space Science Institute (ISSI) of Bern (Switzerland) (ISSI-BJ) where scientists from some 53 countries do cooperate in exploiting science from space science missions be they European, American, Russian, Japanese or coming from other countries. Even though the new ISSI-BJ institute has just been recently created, it already attracts the broad world international space science community. There, scientists from all around the world get together and work in the framework of forums of discussion, workshops, working groups and scientific teams where they address and solve new scientific problems or define the science of future missions be they Chinese or non-Chinese. These scientists come to Beijing because they are attracted by the ambitions of the Chinese space program. Here at NSSC and ISSI-BJ, China appears as a central pole for international cooperation in space science. Therefore my advice would be to expand the role of ISSI-BJ and keep addressing state-of–the-art scientific issues, exploiting in a broad international context the wealthy Chinese space science program. Today, NSSC offers a nucleus from which to constitute the space science element of a future Chinese space agency.