BR-267
April 2007

REPORT BY THE 2006 SCIENCE PROGRAMME REVIEW TEAM TO THE ESA COUNCIL

Members of the Science Programme Review Team

Dr Reinder van Duinen (Chairman of the Review Team)
Former President of the European Science Foundation (ESF) and former Vice-Chairman of Fokker
The Netherlands

Mr Álvaro Azcárraga
Former Managing Director of Aerospace, SENER
Spain

Mr Jean-Jacques Dechezelles
Former Director, Science Meteorology and Environment, Alcatel
France

Prof. Thérèse Encrenaz
Director of Research at the Centre National de Recherche Scientifique Laboratoire d'Etudes Spatiales et d'Instrumentation, Observatoire de Meudon, Paris
France

Prof. Kerstin Fredga
Former Director General of the Swedish National Space Board (SNSB)
Sweden

Mr Kurt J. Gluitz
Former Vice President and Managing Director Science and Earth Observation Division of DASA/Dornier Satelliten Systeme GmbH
Germany

Prof. Michael Grewing
Former Director of the Institut de Radio Astronomie Milimétrique (IRAM)
Germany

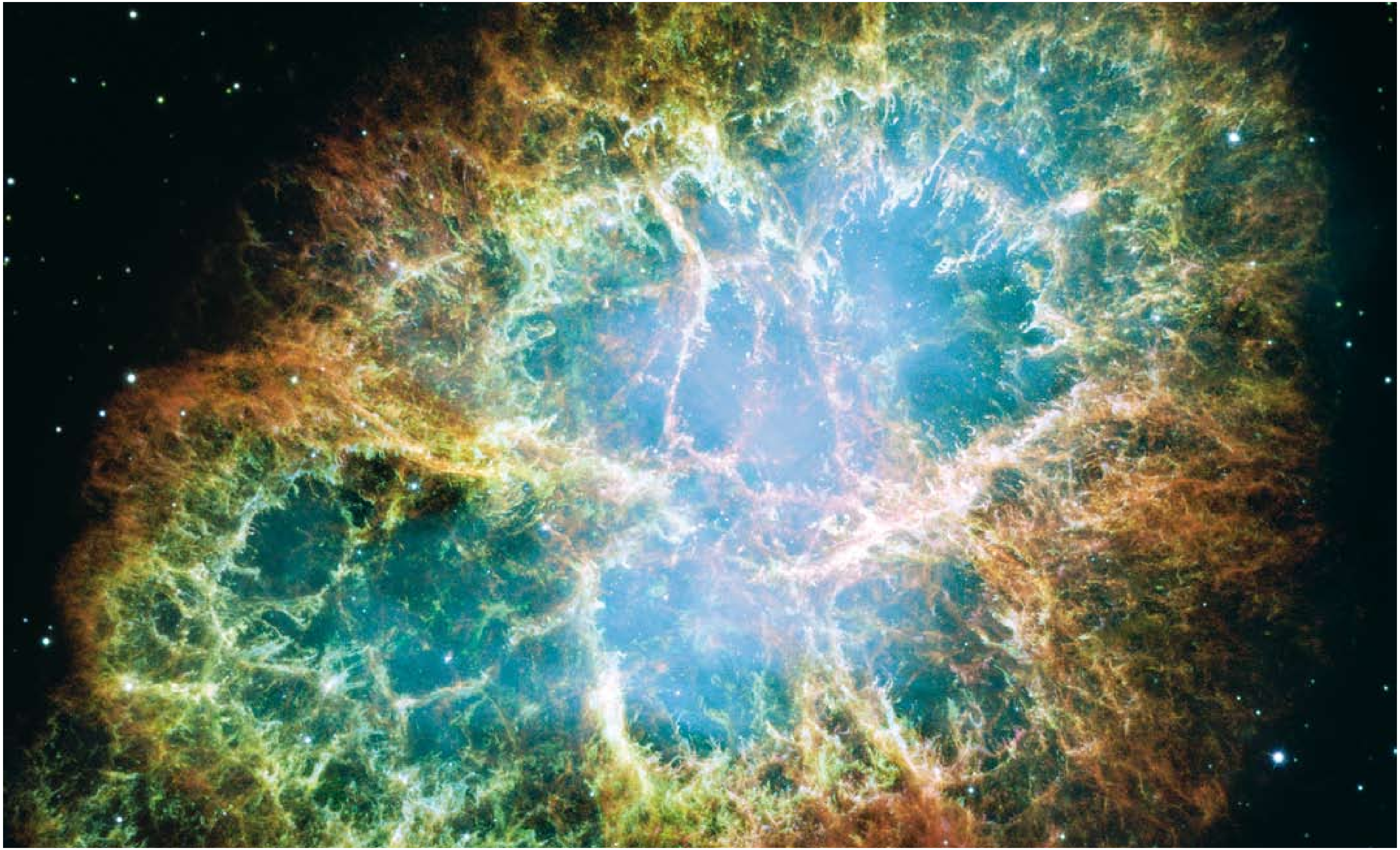
Prof. Luciano Maiani
Department of Physics, University of Rome "La Sapienza" and former Director General of CERN
Italy

Prof. Sir Martin Sweeting
Group Chief Executive of Surrey Satellite Technology Ltd. (SSTL)
United Kingdom

Observer:
Dr G. Debouzy, CNES (France), Chair of the Science Programme Committee

Executive Secretary:
Leo Hennessy, ESA Headquarters
France

Contents



This image of the Crab Nebula (M1), a six-light-year-wide expanding remnant of a star's supernova explosion, was assembled from 24 individual exposures taken by the Wide Field and Planetary Camera 2 on board the NASA/ESA Hubble Space Telescope in 1999 and 2000.

1

INTRODUCTION AND EXECUTIVE SUMMARY

1.1 History

(i) Nowadays space science helps us to understand the evolution of the Universe and the Solar System including Earth. Space science in Europe has initially been the main driver for the development of space technologies, which were later the basis for many applications serving a wide range of societal needs. It provides tools and insights, which are of direct interest to mankind.

(ii) ESA's contribution to space science has been outstanding. Without question, its efficiency and efficacy are on a par with national space science programmes in Europe and elsewhere. Nevertheless, the present level of funding, close to 400 million€ per year through mandatory contributions by Member States, is now some 20% below the average level at the inception of Space Science in the ESRO days (1964–75), and also some 20% lower than the level of the mid-nineties. The 'low-hanging' fruit in space science has now largely been harvested and the Science Programme enters the implementation of the Cosmic Vision Plan. It has, thus, been considered necessary to re-assess the planning and decision-making processes, as well as the management and governance of the Science Programme. Accordingly, based on a decision by Council in February 2006, the 2006 Science Programme Review Team (SPRT) was set up and mandated to carry out the review.

The Main Issue

Based upon a detailed review and analysis of the current situation, the SPRT is convinced that the Science Programme is seriously over-committed. Assuming a continuation of the present level of resources, including a yearly increase as agreed at the Berlin Council of Ministers, no launch of a mission not yet covered by present commitments will be possible before 2020. This would imply that proposers of missions for the new Cosmic Vision 2015–25 Plan will have to wait for some 20 years before they see scientific data. This is considered to be unacceptable. The SPRT recommends that ESA returns to the perspective of a first launch by 2015. This requires that at least 200 million€ is taken out of the present suite of commitments, but also that measures are put in place, concerning the decision-making process and the management of the programme, to avoid similar problems emerging in the future.

1.2 Cosmic Vision

(i) The community is anticipating the first call for mission proposals, after an extensive elaboration of new ideas and concepts for future science missions, which resulted in the Cosmic Vision Plan. The SPRT considers that the launch of such a call is urgently needed, in order to maintain the momentum and the support and vitality of the space science community. However, the call must also be realistic, such that expectations to start a new programme, with launches commencing around the announced date of 2015, can actually be met.

(ii) Having considered the financial position of the programme in detail, the SPRT recommends that the launching of a call has to be conditional upon the removal, as a minimum, of 200 million€ from the present suite of commitments. While this is a tough decision to take, such a drastic measure is considered imperative to prevent piling delays on delays, which is presently the only way to compensate for the cost-increases of missions currently under development, within the constraints dictated by the financial resources. However, over and above the 200 million€ minimum cut, other measures are needed to prevent a similar situation from re-occurring.

1.3 Mission Mix and International Collaboration

(i) For planning purposes, the SPRT notes that missions in the so-called L(arge)-class are possible at a level of ~400 million€ for external costs (i.e. for spacecraft development + launch procurement) and M(edium)-class missions at some 200 million€. Under the assumption of maintaining the present level of financial resources, and assuming that the external purchasing power remains at ~50% of the Level of Resources, ESA can afford to launch two L-class missions and up to five M-class missions in a ten-year time frame, or three L-class missions and three M-class missions. In addition, in all cases, some S-Class missions at a cost level of some 75 million€ are affordable. This perspective reduces the launch frequency below the ideal level of one launch opportunity per year on average. By pooling the resources of ESA with those in the national programmes of Member States and internationally, one might hope that this ideal level could still be achievable for space scientists in Europe. Equally, in the case of international collaboration on one or more missions, the number of missions or the ambition level may of course increase, which could lead to a scientifically more attractive programme.

(ii) Meanwhile, the tendency is towards ever more complex missions (also in the Cosmic Vision Plan) and one of the present missions under development in the Science Programme is currently estimated to pass the 'magic' limit of 1 billion€. This implies that, more than ever, international collaboration is needed to meet the requirements of space science in this century. The SPRT recommends that an appropriate system of consultation and planning be set up to achieve a more effective coordination and harmonisation with national agencies in Europe and with others, such as NASA, RSA, CNSA and JAXA.

(iii) Under the present circumstances, the practice of approving a block of missions to serve a wide range of interests in a 'balanced' programme, is no longer affordable. Rather, missions will have to compete until, at decision time, a solid assessment of costs and risk has been achieved. These assessments should be transparent and independent and the SPC should be fully apprised of the results of these assessments to allow informed decisions to be made.

1.4 Managing the Programme

(i) The main cause of cost increases in missions under development has been the delay, resulting from a longer-than-anticipated development of some mission-critical technology; this delay, in turn, causes costs to increase, as teams have to be kept on standby and spacecraft integration and test costs increase, mostly due to extra efforts to reduce the launch delay as much as possible. Better cost control is only possible if and when technology and other risks are contained more effectively and measures to achieve this have been put in place. The SPRT proposes the creation of a new mechanism to achieve intra-European and intra-agency collaboration and coordination for the development of future mission-critical spacecraft and payload technology. The use of technology roadmaps is recommended to pool resources across Europe and to apply these effectively to meet the challenges of new missions, be it in traditional space science, in Exploration or Earth observation. Roadmaps can also be used to plan and to track the development of new technology, either inside the Agency or outside, as has been demonstrated successfully in other sectors (e.g. microelectronics).

(ii) Technology readiness can, to a considerable extent, be quantified. The SPRT recommends that such a quantitative system be put in place, with clear decision points, as regards the required level of readiness, before commitment to full development, be it at the spacecraft or at payload instrument level. We recommend that whenever assessments of proposals are made, independent peers should judge the technology readiness and status, relative to the roadmaps; their report should be available to the SPC. In addition, an external 'tracking committee' should advise the Executive during the development phases.

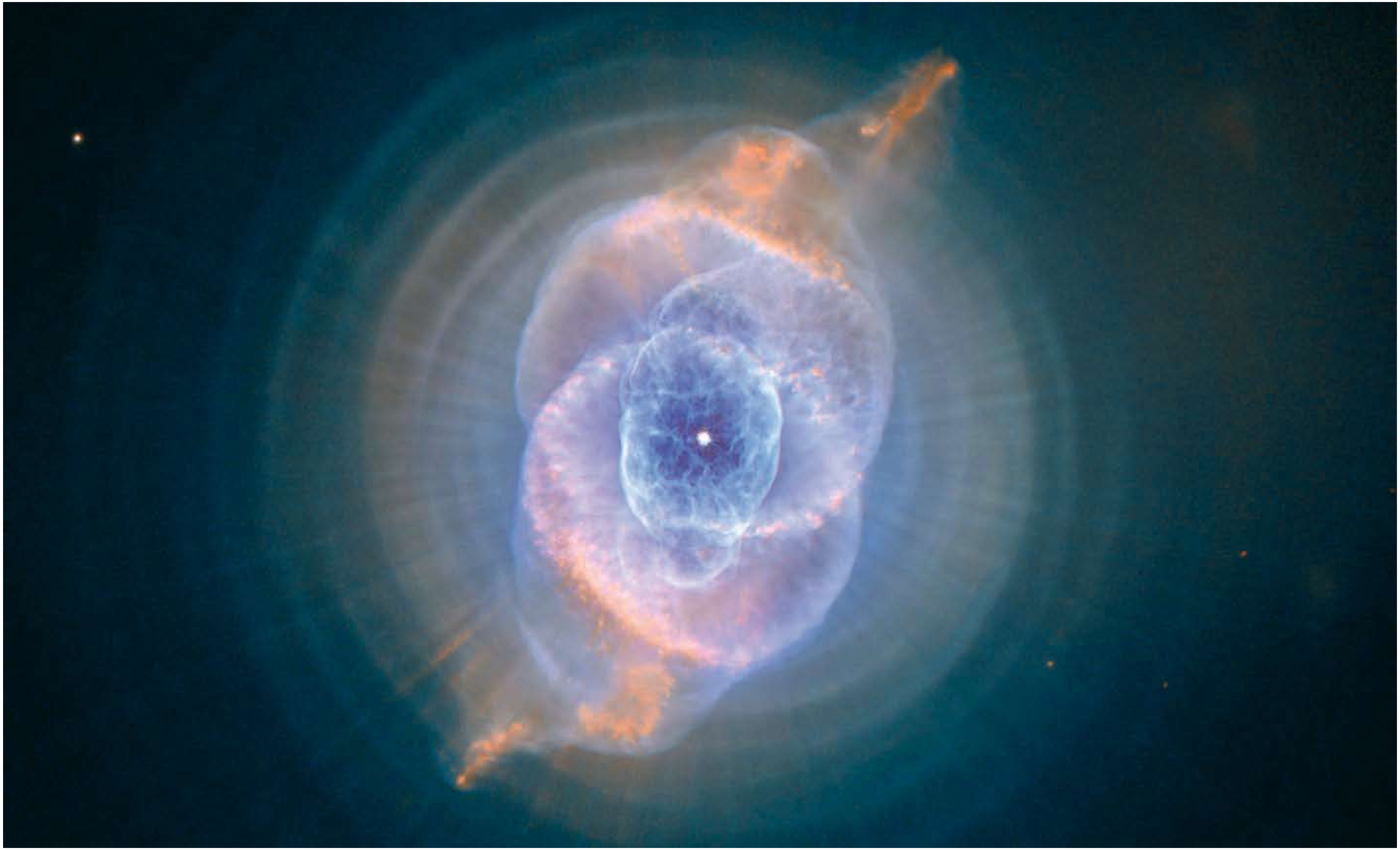
(iii) Risk management is well established in the ESA Science Programme. However, whenever such risks have consumed the available contingency margins, the standing practice is to increase the Cost at Completion. This then results in stretching the schedule, with the effect that new mission opportunities are pushed ever further into the future.

(iv) To provide stability for the overall Science Programme, the costs must be better controlled and margins should be commensurate with the risks ESA and instrument providers have to take to implement challenging and scientifically rewarding missions. The SPRT therefore recommends that a contingency of 5% of the overall Level of Resources be budgeted at the Programme level at the start of a ten-year planning period. At mission level, the contingency should be negotiated and the outcome must appropriately reflect the risks, but one should not exclude margins of up to 20% of the total external procurement value, excluding the launcher and launch services.

(v) Consumption of contingencies must always be approved by the higher echelon and be proposed only when all other measures, including descoping, have been exhausted. Missions under development should be capped at 120% of the cost originally approved by the SPC (including project-level contingencies, but excluding programme-level contingencies). Once a new CAC estimate exceeds the 120% level, the development is automatically frozen until a means is demonstrated, and approved by the SPC, by which to return the CAC to within the (120%) envelope. If this cannot be achieved by a descoping, acceptable to the SSAC, or by other means, then there should be a specific decision taken by the SPC to cancel the mission.

(vi) In the course of time, several new demands have been made on the Science Programme, all of them reasonable in their own right. Some are the result of the success of the Programme, others because the Programme has taken on new responsibilities. Taken together, these have led to a reduction in the external purchasing power of the SP from 75% of the Level of Resources in 1995 to some 50% in 2005. Examples of these include participation in nationally-led missions, new communities/activities entering the Programme, mission operations extensions, maintaining data-centres and virtual observatories, etc. The SPRT recommends that the Executive and the SPC critically examine such demands, not only with regard to the initial investment, but also regarding the recurring costs to the programme, decide on priorities and agree on a budget envelope for specific categories. The evolution of non-spacecraft development and launch ('operations and support') costs, including sub-contracting of tasks by ESA centres, should be strictly controlled to avoid an even deeper erosion of purchasing power in the future. A plan should be developed and agreed to cap complementary costs to the SP (excluding payload technology development support and CTP) at a level of, maximally, 160 million€ per year on average, or below 40% of the Level of Resources. Elements of the plan should include a critical evaluation and assessment of the performance and costs of the various centres and support activities under the ESA umbrella.

(vii) The SP management should use the introduction of the new financial rules as an opportunity to redirect the effort to the delivery of missions on schedule and within cost, rather than the year-on-year tracking of spending that is currently practised.



This image of the 'Cat's Eye Nebula' (NGC 6543) was taken with Hubble's Advanced Camera for Surveys (ACS) in 2004 and reveals the full beauty of a bull's-eye pattern of eleven or more concentric rings, or shells, around the Cat's Eye.

2

THE SPRT REVIEW PROCESS

(i) The review of the Science Programme was conceived as a project. As a first step, the Chair agreed with the Science Programme Directorate that a so-called 'self-evaluation' should be undertaken as a means for gathering and presenting information that would be useful to both the review team and the Agency itself. From the very start of the Review Team's activities, it was clear that the issuing of a Call for Proposals for the implementation of Cosmic Vision could impact upon or be affected by the analysis and the recommendations coming from the SPRT; in the first meeting of the SPRT it was, therefore, decided to request that this Call be postponed, until such time as the SPRT would be in a position to develop recommendations concerning the fit-for-purpose of the Call in relation to the development of the Science Programme. The Call was postponed, as requested.

(ii) The first phase of the review project was designed to give the SPRT **maximum exposure to the status of the Science Programme**. This was achieved through a series of presentations by the Science Directorate and other ESA staff, among them being a detailed presentation of the results of the self-evaluation. This phase was concluded by the adoption of a problem statement and context description. The second phase consisted of conducting various specific and **detailed analyses**. For this the team used the methodology of logic trees to arrive at a set of 8 major issues, which were felt to be the main drivers (Appendix III). Sets of two issues were assigned to one of four breakout groups (sub-sets of the SPRT) for detailed analysis, which was carried out through a variety of methods: interviews with ESA staff, desk research, report studies, etc. (see Appendix IV for an overview of interactions). The results of these activities were presented to and discussed by the full Team and formally adopted. The third step, following directly from the detailed analyses, was to develop the so-called **'solution**

hypotheses'. These were discussed firstly in the breakout teams and, subsequently, the results were reviewed by the full Team. These activities led to the writing of the main 'story line' and a summary of recommendations, which were the basis for a first draft report that was discussed by the SPRT in its December meeting. This draft report was further developed during December and early January and approved by the SPRT in January. The report was submitted for comments to the SPC and to the ESA Director General. These comments have not led to substantial changes to the final report which was subsequently submitted to Council.

(iii) The aim of making **'actionable recommendations'** was adopted, with the implication that an effort would be made by the Team to interact with the Executive and with the SPC as much as possible, without losing its independence. The purpose was to ensure, insofar as reasonably possible, that the recommendations made would be accepted, adopted and executed. The implementation of this meant that representatives of the Science Directorate, as well as the Chair of the SPC, participated in the plenary meetings of the SPRT, except when it was considered necessary to have 'closed sessions'. In pursuing this general approach, discussions with ESA staff were oriented towards both understanding the issues and involving them in the analysis and the development and exploration of the solution hypotheses. Furthermore, the SPRT was invited to attend an informal meeting with the SPC in September in Villafranca and, in November, presented an interim report to a formal meeting of the SPC. Similarly, the chair of the SPRT had meetings with the Director General and the Director of Science and the Chair and Vice-Chair of the SPC to inform them about the development of the activities of the SPRT. The Draft Report, incorporating the recommendations, was made available to the Executive and the SPC in December to assist the preparation of their respective comments.

(iv) These interactions have proven to be extremely valuable for the work of the SPRT and, it is hoped, to the parallel activities of the Executive and SPC and we wish to express our appreciation for the support given to the Review by all those concerned.

3

A BRIEF HISTORY OF THE SCIENCE PROGRAMME

3.1 History (drawn from *30 years of ESA Achievements*, ESA BR-250)

(i) The Science Programme, one of the Agency's mandatory activities in which all Member States participate, has its origins in the European Space Research Organisation (ESRO), whose seven successful scientific satellites paved the way for ESA's remarkable series of pioneering missions, which have placed Europe at the vanguard of many scientific disciplines. ESA's Science Programme, together with European national programmes and instrument development, has pushed the technology, by consistently focusing on missions with ambitious scientific goals and strong innovative content. Over the years, it has been the driving force behind many other ESA activities to the extent that much of the advanced technology used today stems from the Scientific Programme.

(ii) An important milestone in the history of ESA's Science Programme came in 1985, with the approval of the long-term 'Horizon 2000' programme of scientific research in space. Executing Horizon 2000 required a special financial effort from the Member States, amounting to a progressive budgetary increase of 5% per year from 1985 to a steady plateau in 1994 of about 470 million€, in 2004 terms (about 490 million€ in 2006 e.c). Horizon 2000 encompassed the missions already approved (Hubble Space Telescope, Ulysses, Hipparcos and ISO) and added four Cornerstone missions, plus Medium-size ('M') missions, selected competitively. Preparatory work began in 1993 on the follow-up 'Horizon 2000 Plus' programme, to cover new missions for 2007–16, including three new Cornerstones.

(iii) The ESA Ministerial Council in September 1995 approved the long-term programme, but imposed a 3% annual reduction in purchasing power on the Scientific Programme. When the Cluster satellites were lost, as a result of the Ariane-501 launch failure in June 1996 and it was decided to rebuild them, the Science Programme had to be revised. The Cornerstones were maintained, but the medium M-missions were replaced by smaller missions in order to regain programme flexibility. These were 'F' (Flexible) missions with purely scientific goals, and 'SMART' (Small Missions for Advanced Research in Technology), which were to provide in-orbit proof of technologies, particularly for Cornerstones, and, as a secondary goal, carry a specific scientific payload.

(iv) In October 2000, the Science Programme Committee (SPC) approved a package of missions for 2008–13. Following the Ministerial Council of November 2001, where there was no increase in real terms in the level of resources allocated to Science, ESA undertook a complete reassessment of the Science Programme in close collaboration with the science community. The resulting proposal was approved by the SPC on 23 May 2002 when, not only were the missions that had been approved in October maintained, but the Eddington mission was also added. The planning then consisted of:

Astrophysics
Group 1: XMM-Newton, Integral
Group 2: Herschel, Planck, Eddington
Group 3: Gaia

Solar System
Group 1: Rosetta, Mars Express
Group 2: SMART-1, BepiColombo, Solar Orbiter

Fundamental Physics
STEP (Satellite Test of the Equivalence Principle, cancelled by NASA in 2002)
SMART-2 (became LISA Pathfinder), LISA (joint mission with NASA)

In addition, the Agency was committed to cooperation with NASA on JWST.

The above **'production groups'** are more than scientific groupings. Missions within each share technologies and engineering teams wherever possible. For example, Herschel, Planck and Eddington were to use not only the same bus, but also the same engineering team. BepiColombo and Solar Orbiter were teamed, and international collaboration sought. The philosophy saw Venus Express added in November 2002 to re-use the Mars Express bus, expertise and most of the instruments. The high ambitions, combined with the slow decline in funding, meant there was little flexibility left to cope with adverse events. A major blow was dealt when the failure of the new Ariane-5 design, in December 2002, grounded the whole fleet and forced major delays on Rosetta (13 months) and SMART-1 (6 months), costing about 100 million€. Faced with this and other financial demands, the SPC on 6 November 2003 was forced for the first time ever to cancel a mission. Accordingly, the Eddington mission and, in addition, the Mercury lander of BepiColombo were cancelled.

3.2 The ESA Science Programme's Achievements

The successes of the ESA Science Programme can be seen from the following list of past, current and planned science missions:

- *Cos-B* (1975): ESA's first satellite mapped the little-explored gamma-ray sky.
- *Geos* (1977/78): two satellites studied the particles, fields and plasma of Earth's magnetosphere.
- *ISEE-2* (1977): worked in tandem with NASA's ISEE-1, in studying Earth's magnetosphere.
- *IUE* (1978): the International Ultraviolet Explorer was the world's longest serving and most prolific astronomy satellite, returning UV spectra on celestial objects ranging from comets to quasars until 1996. It was a trilateral project involving NASA, ESA and the UK.
- *Exosat* (1983): studied the X-ray emissions and their variations over time of most classes of astronomical objects in 1780 observing sessions.
- *Giotto* (1985): first close flyby of a comet (Comet Halley, in March 1986), followed by a bonus encounter with Comet Grigg-Skjellerup in July 1992.
- *Hipparcos* (1989): produced the most accurate positional survey of more than 100 000 stars, fundamentally affecting every branch of astronomy. Lead taken by Europe and now followed up by ESA with Gaia.
- *Hubble Space Telescope* (1990): 15% ESA contribution, including the Faint Object Camera. Still operational.
- *Ulysses* (1990): investigation of fields and particles of the inner heliosphere at all solar latitudes. First mission ever flown over the solar poles. Still operational.
- *ISO* (1995): infrared astronomical observatory which provided crucial data on the 'cold Universe', including star formation and the interstellar medium.
- *SOHO* (1995): studying the Sun's interior, as well as the corona and its expansion into the solar wind. First Horizon Cornerstone. Still operational.
- *Huygens* (1997): the ESA-built probe designed to descend through the atmosphere of Saturn's moon Titan. Landed successfully in January 2005.
- *XMM-Newton* (1999): the X-ray Multi-Mirror mission is the

most sensitive X-ray astronomy satellite yet, finding millions of new objects. Still operational.

- *Cluster-2* (2000): to investigate plasma processes in Earth's magnetosphere, using four satellites in order to separate time and spatial variations in the plasma. This was a replacement of the four Cluster satellites lost in the first Ariane launch in 1996. Still operational.
- *Integral* (2002): the International Gamma-Ray Astrophysics Laboratory is observing gamma-ray sources within our Galaxy and beyond, including exploding stars, black holes, gamma-ray bursts and pulsars. Still operational.
- *SMART-1* (2003): First European lunar orbiter to demonstrate methods and key technologies including primary propulsion by a solar electric thruster. The planned impact on the Moon occurred on 3 September 2006.
- *Mars Express* (2003): first European Mars orbiter and lander. The orbiter sent back spectacular high-resolution stereo images, in full colour, with a resolution of 2-3 metres. The aim was to have global coverage in the search for water and life. The orbiter is still operational.
- *Rosetta* (2004): first comet orbiter and lander on its way to rendezvous with Comet 67P/Churyumov-Gerasimenko in 2014; Rosetta will orbit the nucleus for 2 years of intensive studies, releasing a lander.
- *Venus Express* (2005): re-use of Mars Express bus and instruments. The scientific objectives include global observations of the Venusian atmosphere and of the surface characteristics. Still operational.
- *Planck* (2008): the mission to map the structure of the Cosmic Microwave Background, in unprecedented detail. Launch in tandem with Herschel.
- *Herschel* (2008): using one of the least explored windows on the Universe, it will observe the births of stars and galaxies throughout the history of the Universe. Launch in tandem with Planck.
- *LISA Pathfinder* (2009): to demonstrate key technologies for LISA.
- *JWST* (2014): 15% contribution to NASA's infrared observatory for probing back to the time of the very first stars.
- *Gaia* (2011): building on Hipparcos to create a high-precision 3-D map of 1000 million stars in our Galaxy and beyond.
- *BepiColombo* (2013): two Mercury orbiters, arriving in 2017, in collaboration with Japan.
- *Solar Orbiter* (2015): SOHO successor to study the Sun to within 45 solar radii.
- *LISA* (2015): three satellites in formation to detect gravitational waves for the first time, in collaboration with NASA.

By any standards, the ESA Science Programme has demonstrated its outstanding performance, as also reflected in the accompanying statements.

"ESA is the lead agency in Europe for space research programme definition, technology and system development and in-orbit operations. (..) It has striven for efficiency and competitiveness within the limits of a global budget for space research that is only one-sixth of the US equivalent. Major successful space research missions under European leadership have placed the European science community and industry at the forefront and created a strong position from which to negotiate co-operative projects with international partners."
{Source: **European Commission White Paper, Space: a new European frontier for an expanding Union – an action plan for implementing the European Space Policy**}

"High-quality space research is a well-recognised asset of Europe's space programmes, and ESA's role is crucial to maintain this leadership. ESA has an excellent track record in space research and can be regarded as a successful self-organisation of that research sector. ESF believes that an issue to be taken up in the forthcoming White Paper on a European Space Policy relates to ESA which, in its current mission, fulfils a complex and onerous role in the domains of basic and applied space research and the provision of facilities at the European level. That is, it acts and operates at the same ►

time as a funding agency for research, a funding agency for large research facilities, a facility operator and a coordinator and manager of research with responsibilities including peer review and evaluation."
{Source: European Science Foundation – ESF Statement on the Green Paper on European space policy, July 2003}

"The Science Programme of ESA is a successful programme. Over the last twenty years, its missions have gained leadership or co-leadership in most space science research areas. Referring to 2004-2005 alone, the Science Programme has achieved an unprecedented harvest of scientific results through 16 spacecraft currently in operation (the last addition being Venus Express, successfully launched on 9/11/2005), culminating with the successful landing of the Huygens probe on Titan in January 2005 which had the strongest impact on public attention. Success, reliability and focus on the needs of the users, have created a strong European identity within the space science community of about 3000 space scientists, which recognises the Science Programme of ESA as its own programme. In Europe, the ESA Science Programme has become the reference for all national programmes. Outside of Europe it is sought after as a reliable partner and lends itself naturally to international collaboration. It is also the programme that can have the strongest public impact (Mars Express, SMART-1, Huygens)."
{Source: ESA/C(2005)157 – The Case for a Strong ESA Scientific Programme}

3.3 Funding Evolution and Main Events

(i) The present level of funding is some 20% below the average level at the inception of Space Science in the ESRO days (1964–75), and also some 20% lower than the level of the mid-nineties. The ESA Council meetings at Ministerial level are decisive for the implementation of the agreed programme, since it is at this level that the Level of Resources is established.

The following graphic presents this situation:

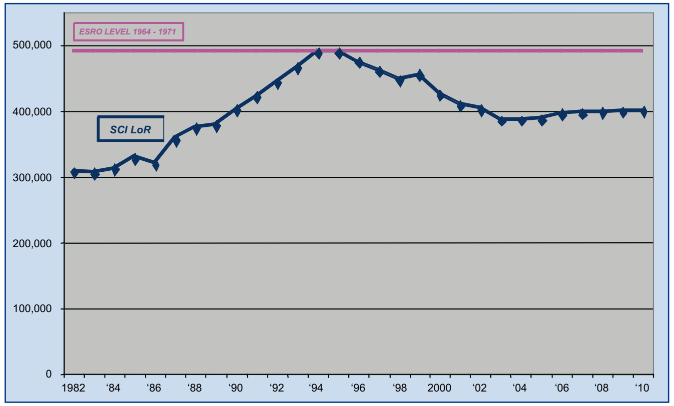


Figure 1. Evolution of the Level of Resources of the Scientific Programme in kEuro, 2006 economic conditions

(ii) Major decision points in the history of the Science Programme:

- 1984: the drafting of a long-term planning framework by the first Survey Committee: Horizon 2000
- 1985: Council at Ministerial Level (Rome): endorsement of Horizon 2000 and start of an increase in Level of Resources for 10 years
- 1989: set-up of SPRT (Pinkau), leading to a temporary adjustment of the charging policy
- 1994: birth of Horizon 2000 Plus Long-Term Plan to cover 2006–16 science missions
- 1995: Council at Ministerial Level (Toulouse): turning point in the evolution of the Science Programme, starting a continuous decline in the funding of the programme
- 1996: adoption by the Council of the Reform of Budget Structure and Charging Policy; Science Programme loses the 'Pinkau effect'

- 1997: Horizons 2000 and Capodimonte : start of a series of re-assessments of the programme, trying to cope with the continuous reduction of the purchasing power by systematically increasing the risk level, both at project and programme level
- October 2000: selection of the 'package of missions', thereby reducing long-term flexibility in the programme
- 2002: Andenes: the last stage in the process started in 1997, introduction of families of missions in order to re-introduce the lost flexibility in the programme; birth of Cosmic Vision Long-Term Plan to cover 2015–25 science missions
- 2003: reconstruction of the programme following the grounding of Ariane-5, deleting Eddington to ensure affordability of the programme
- 2005: introduction of 'best financial predictions', the end of the aggressive risk taking; Council at Ministerial Level (Berlin) – Increase in Level of Resources (escalation of 2.5% per year) that stabilises the Level of Resources economic power around an annual 400 million€ budget at 2005 e.c.

3.4 Cosmic Vision

(i) Cosmic Vision is a living programme, having to adapt to the available funding at the same time as responding to the expectations of the scientific community. The challenge for the SPC is to maximise the outcome of Cosmic Vision across disciplines, retaining high scientific value, within affordable limits.

(ii) ESA issued a call for themes in Spring 2004. 4 major themes were condensed from the 151 proposals. These are:

- What are the conditions for planet formation and the emergence of life?
- How does the Solar System work?
- What are the fundamental physical laws of the Universe?
- How did the Universe originate and what is it made of?

(iii) The Agency then focused on developing mission scenarios and technology requirements to satisfy these themes, within the envisaged timescale. Following endorsement by the SPC in May 2005, the 'Cosmic Vision 2015–25' document was produced, setting out the targets for European space science for that decade.

3.5 Towards the Future

(i) The Science Programme has considerably matured since its inception, as has space technology more generally. Originally, both spacecraft and payload technologies were, by definition, all new. Nowadays, especially in the spacecraft or support module, one can rely on several space technologies that are fully matured and space proven. With the maturity in space technologies comes the possibility to tackle new and exciting problems in science, which would have been completely out of reach even in the recent past. The missions indicated in the Cosmic Vision Plan, for example, present very considerable challenges for some elements of the spacecraft as well as to the instrument packages that are needed to meet the scientific objectives of the missions. However, at the same time, the financial resources available to the Science Programme impose constraints both on the number of missions that can be afforded and on the costs of individual missions.

(ii) In a way, the 'low-hanging fruit' in space science has now largely been harvested. Nonetheless, it should not be excluded that new possibilities for advancing research may emerge, e.g. through miniaturisation or through integration of functionalities that were hitherto implemented in different 'boxes', which could lead to new approaches and mission concepts. Most likely, however, the next phase will see challenging missions that carry considerable technology risk and therefore, also, risks in costs. Some signs of such a trend are already apparent in missions presently under development. It is clear, therefore, that this next phase of the Science Programme requires a different approach to decision-making and management. The Executive has recently made several proposals along these lines and improvements are already being introduced. This is very encouraging. Nevertheless, a review of the Science Programme focussing on these aspects seems timely and justified.

ESA's Herschel telescope will carry the largest primary mirror ever launched in space. In this image, the mirror is being coated with a thin layer of aluminium, which is the working surface of the telescope, in the vacuum chamber at Calar Alto Observatory, Spain.

4

IMPLEMENTING COSMIC VISION

4.1 The Call for New Mission Proposals

(i) In the past few years, the science community has been very much involved with ESA in developing a vision on the way forward for space science. This coordinated effort resulted in the Cosmic Vision Plan, which outlines the aspirations for space science in the period 2015–25, The community has been anticipating the first Call for Mission Proposals since early 2006. The SPRT considers that the launch of such a Call is urgently needed to maintain the momentum and the support and vitality of the space science community. Notwithstanding this, however, the Call must also be realistic, such that expectations can actually be met to start a new programme, with launches commencing around the announced date of 2015.

(ii) The Level of Resources is insufficient to fulfil the existing commitments, as well as the new missions selected by the SPC. In addition, the Science Programme has suffered a number of unforeseen and external expenses and delays. Furthermore, the success of the Programme has led to an increase in expenditure for mission operations and mission extensions. Although spending is controlled by a phased payment system, the cumulated commitments of the present Programme represent an overall financial burden that consumes the available resources for 10 years ahead, i.e. to 2015, assuming a Level of Resources from 2010 to 2015 comparable to the one adopted by the Ministerial Council in Berlin 2005 (see Fig. 2). As demonstrated in ESA/C(2006)141, rev.1 (Table 5.1) the financial position of the Science Programme shows a cumulative negative balance of 58 million€ out to 2014, only reaching a 74 million€ positive balance in 2015. Clearly then, the Programme is now in a state of 'over-heating' and has no capacity to commit to Cosmic Vision candidate missions within a reasonable timeframe, without removing something from the full plate of already considered and selected missions.

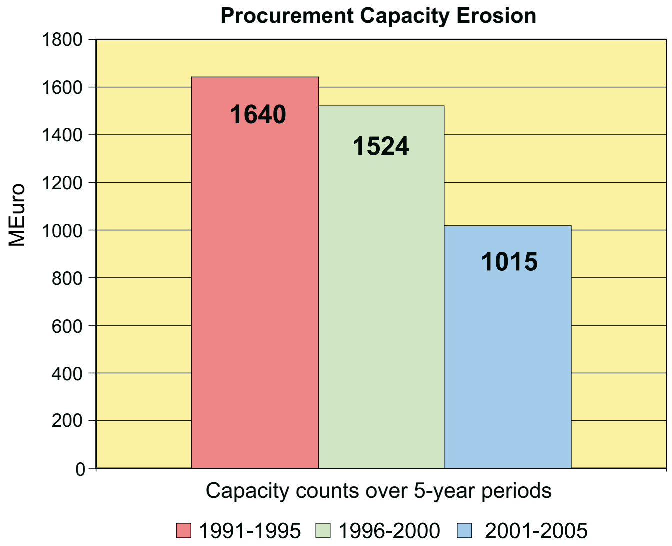


Figure 2. Erosion of procurement capacity

(iii) The Science Programme planning management operates with an 'overplanning mode', whereby there is about a 6 to 9 months time shift in payments with respect to planned financial engagements, in the yearly budget. This results in a rolling bow wave, above the annual Level of Resources in the planning profile. The manageability of the overplanning has been proven over years, and it works provided that the financial over-commitment never exceeds 150 million€. This limit has now been reached with the on-going missions operations and the implementation phases of projects such as Herschel Planck (arriving to completion in 2008), Gaia (started mid 2006) and BepiColombo (started at the end of 2006). Any additional financial engagement coming on top of these already mentioned projects would immediately provoke a financial crisis which would require either a loan, to compensate for the insufficient resources — with all the associated consequences — or the cancellation of some of the ongoing developments.

(iv) An analysis of the Science Programme planning leads to a clear conclusion with respect to the short-term choices to be made: either (a) a cut of 200 million€, as a minimum, is made in present planning of selected 'post-BepiColombo' missions, or (b) no new mission will be in orbit before 2020, a shift away from the original 'Cosmic Vision' planning of starting in year 2015.

The SPRT recommends, having considered the financial position of the Programme in detail, that before launching a Call for Mission Proposals, 200 million€, as a minimum, be taken out of the present suite of commitments.

(v) While this is a difficult decision to take, such a drastic measure is considered imperative to stop the practice of piling delays upon delays, which is presently the only way to compensate for the cost-increases of missions currently under development, and to accommodate future commitments, given the constraints imposed by the available financial resources. Over and above the proposed 200 million€ minimum cut, however, other measures are needed to prevent a similar situation re-occurring in the future.

The four following planning diagrams demonstrate the present situation (see Fig. 3a and Fig. 3b) and what may be anticipated in the future (Fig. 3c and Fig. 3d) if no cut is made. Figures 3a + 3c present the familiar 'waterfall diagrams' that are frequently displayed in ESA documents. Figures 3b and 3d show the financial profile (positive number), the corresponding potential deficit (negative number), the Level of Resources (the black dotted line) and the manageable limit (the red line at –150 million€) of over-commitment.

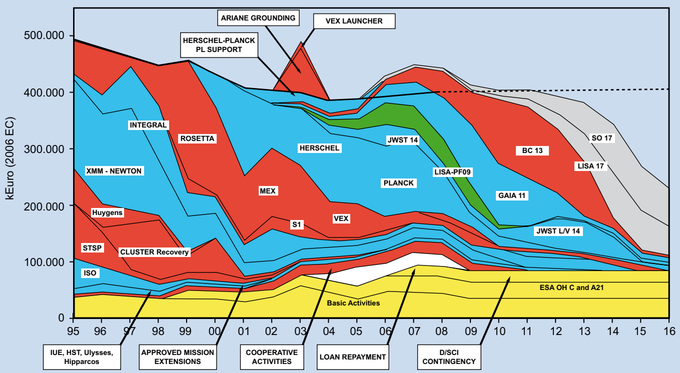


Fig. 3a
Financial planning diagram 1996-2016, showing current 'overplanning'

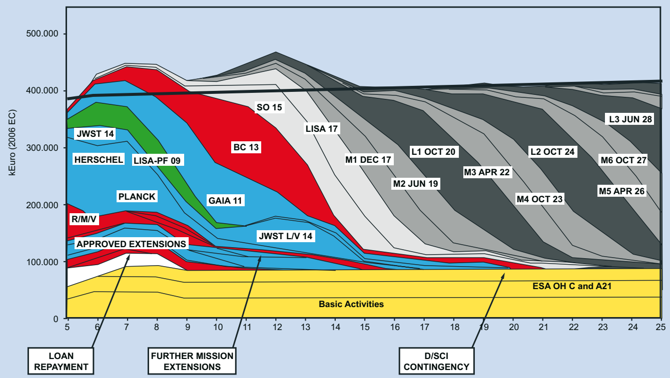


Fig. 3c
Tentative planning diagram 2006–25

Figure 3. Present/simulated financial profiles of the Science Programme

(vi) Based on this extrapolation, not only is the implication that, for another decade and a half, there will be no possibilities to respond to new scientific challenges, beyond those covered by the present suite of missions, either under development or presently flying, but an even more severe problem could arise for the development and training of a new generation of space scientists. Those scientists with an interest in working on the data of the missions they originally put forward in the Call for Ideas, will no doubt make proposals for Cosmic Vision missions. However, in the present scenario, they will be faced with a time delay of some 20 years between seeding the mission proposal and harvesting any science returns. Considering this to be unacceptable, the SPRT believes that the Executive should make a strong effort to maintain the first launch of a Cosmic Vision mission, at or close to 2015, as originally foreseen.

(vii) The SPRT presented its analysis of the situation and the required conditions for issuing a Call in September the Executive has responded to this, initially by amending the documents for the Call and, in parallel, by conducting an internal review to identify how to achieve the financial reduction called for by the SPRT.

4.2 Mission Mix

(i) The SPRT developed a tentative model for 10 years of planning, which captures our recommendations for several spending categories in Table 1. In addition, for planning purposes, the SPRT adopts the hypothesis that missions in the so-called L(arge)-class can be achieved at a level of ~400 million€ for external costs (i.e. for spacecraft

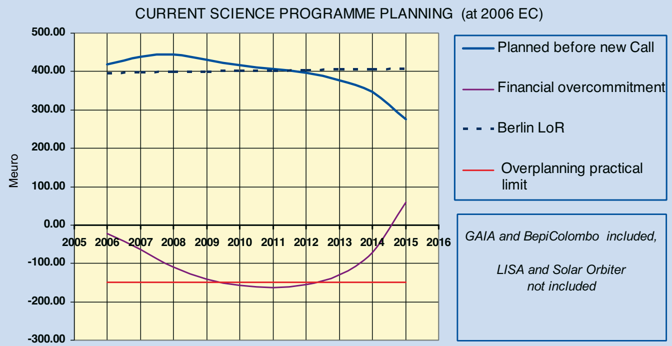


Fig. 3b
Financial planning showing the deficit reaching the 150 million€ limit (same data as 3a)

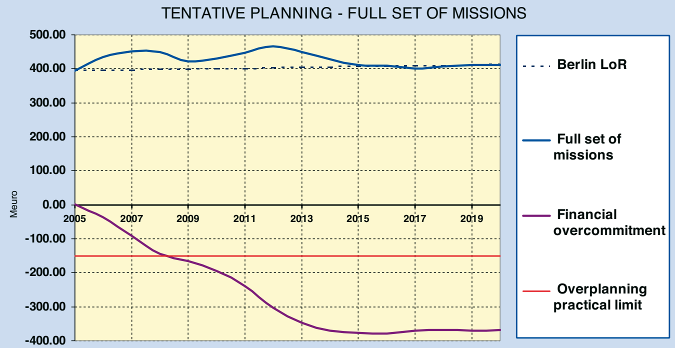


Fig. 3d
Financial planning showing deficit (same data as 3c) way beyond the 150 million€ level

development + launch procurement), while M(edium)-class missions could be achieved at a level of ~200 million€.

	MEuro
Level of Resources for 10 years	**4 000**
Programme-level contingency (5%)	200
ESA SP operations	
Assessment-type activity	
Advanced studies	60
CTP	100
Payload technology development support	100
Implementation-type activity (*)	
Contributions to nationally-led missions	100
Project Management & Technical Support	250
Missions' Operations MOC+SOC	550
Mission-level contingencies	240
Overhead Charges	300
Procurement Potential (S/C+L/V)	**2100**
5M + 2L Scenario *(basic cost) (**)*	1800
3M + 3L Scenario *(basic cost)(**)*	1800
Margin for extra development (***)	300
NOTES	
bare costs : S/C : Medium =150, Large = 250;	
L/V : Medium = 50, Large = 150	
(*) Subsidies for P/L development not considered	
(**) S/C bare cost excludes every payload item	
(***) Smaller opportunity missions or payload items procured from Industry	

Table 1. Tentative model 10-year planning Cosmic Vision period, 2006 e.c.

The table assumes expenses for a number of identified items for the Cosmic Vision period 2015–25, and gives an indication of what options for a mission-mix might be affordable under these assumptions.

(ii) Assuming that the present Level of Resources will be maintained, and that the external purchasing power will remain at ~50% of the Level of Resources, the SPRT believes that ESA can afford to launch two L-class mission and up to five M-class missions, or three L-class missions and three M-class missions in a ten-year time frame. In addition, in all cases, some S-class missions at a cost level of some 75 million€ are affordable.

(iii) Especially in the case of a larger number of L-class missions, this perspective would reduce the launch frequency below what has been considered in the past as the ideal average (see Fig. 4) of one launch opportunity per year. However, by pooling the resources of ESA and those of the national programmes of Member States and international partners, a prospect would exist for retaining that average, which would clearly be advantageous for space scientists in Europe. Equally, in the case of international collaboration on one or more missions, the number of missions or the ambition level may of course increase, which could lead to a scientifically more attractive programme.

(iv) Over the years, the tendency has developed to have ever more complex missions. The Cosmic Vision Plan contains ideas for missions estimated to exceed the previously unthought of limit of 1 billion€.

The SPRT recommends that the Science Programme re-opens the option to have small missions in the planning.

(v) The SPRT recognises that small missions (S-class <75 million€) provide important opportunities for:

- validation of technology or proto-instruments to de-risk L/M-class missions;
- more frequent and responsive opportunities for a wider (indeed different) science community to participate in the Science Programme through small-scale but high-class science missions (e.g. SWARM);
- practical, hands-on training of young scientists (in both ESA and Member States' institutions) to provide valuable experience prior to taking responsibility for L/M-class instruments/missions;
- addressing the geographical return especially for small member countries.

The SPRT is concerned that pressures on budget, due to overheating, have almost eliminated the S-class missions.

4.3 Payload Development

(i) The ESA Science Programme, together with European national programmes and nationally funded instrument development, has been an outstanding success, leading to more missions in operation than ever before and delivering excellent science. Payloads, traditionally developed in nationally funded institutes and laboratories in Member States, are, in many cases highly innovative and world class, as a result of long-term technology development in specific fields (optics, detectors, special signal processing electronics, etc). In various cases, these are developed with the involvement of ESA's technical departments at ESTEC. However, with the increases in payload complexity come additional demands and requirements on the payload providers. These additional demands are, on the one hand, in the domain of payload technology development, where demand is driven by the ever-advancing needs for accuracy, resolution, etc., sometimes in addition to challenging operating conditions, such as instruments operating at temperatures near absolute zero. On the other hand, additional burdens come from the growth in international consortia of payload providers necessary to provide the payload, which consists of a 'package' of instruments all working together and integrated in a unit, e.g. a focal plane unit on a telescope. This collaboration requires management of an international team of many suppliers (up to 24 institutions, in the case of a Planck instrument package) working towards a very complex end-product, which requires skills not naturally available in the 'academic' laboratories.

(ii) Both the technology and the collaboration challenges have recently proven to be difficult to manage and have contributed to cost increases for some missions presently under development, both on the instrument side and in the overall mission development. In some instances, the Science Programme has found itself forced to support instrument development financially and otherwise, to solve a technological or management problem. This choice led to a 'moral hazard' in that the Executive was, in effect, obliged to violate the ground rule that instruments are provided at zero cost to the Agency, which has contributed to the erosion of the financial position of the Science Programme.

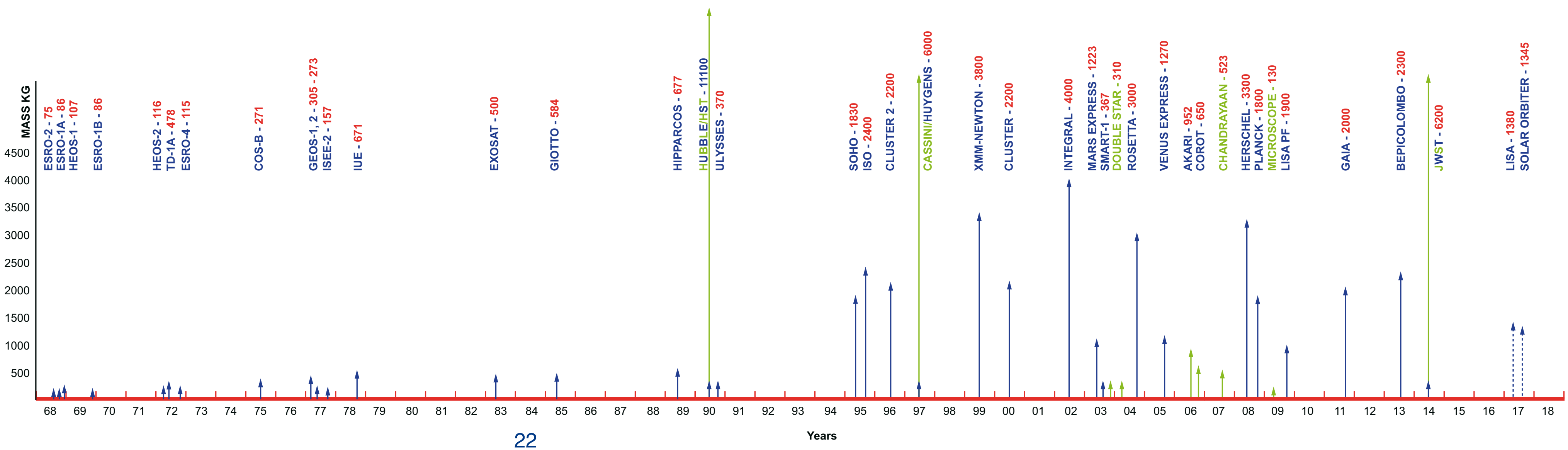
(iii) The SPRT considers that, despite these difficulties, the traditional baseline of delivery of instruments to ESA by the Member States must be maintained, except in cases where the mission concept dictates that the payload is an integral part of the spacecraft (Hipparcos, Gaia). However, the situation as described above does require that ESA's control over instrument development be strengthened, both in the very early stages of exploratory payload technology development and in the actual payload development stage. The former may require that in the future ESA selectively supports critical payload technology development by national institutes and laboratories, on a strictly competitive basis. In the latter case, the SPRT notes, with satisfaction, that efforts are underway to have formal contractual relationships between ESA and the potential instrument providers and their funding organisations. This would help to avoid a situation where national funding organisations cannot – for whatever reason – cover their share in the (sometimes considerably increasing) costs of instrument development and, thus, avoid the call on ESA for additional funds.

Observation:
The SPRT encourages these steps towards a more formalised contractual relationship, as a necessary element of improved control over payload development; we suggest, however, that, in addition, other measures are required to better assist and control the development process and to provide visibility and transparency, so that indications of potential problems and options for solutions emerge early and can be tackled in time.

(iv) Also, critical technology development must be pulled forward in time, so that the technology development status of payloads can be critically assessed at the time of decision-making concerning the specific mission. The SPC must be informed regularly about the status of advanced technology development, as is presently the case for missions under development. We recommend that a Phase-B study of the payload, or the equivalent thereof, must be concluded before a mission can be approved by the SPC and that the experiences gained in ESA and by the institutes

Figure 4. Overview of ESRO and ESA launches since 1968 with an outlook until 2018.
In blue: names of ESA missions.
In green: names of missions in which ESA collaborates or participates.
The length of the arrows is indicative of the dry satellite mass (numeric value in red)

Satellites ESA and Cooperation with other Countries – Weights



throughout the study phase are transferred seamlessly to the ESA project team after mission approval. Selection of payload providers must include an assessment of their ability to 'deliver'. It is important that, during integration and testing of the spacecraft, the competences and skills of the instrument providers are used to the maximum extent, as well as that the experiences and familiarity developed during the test and integration phase in industry be available during initial in-orbit checkout.

The SPRT recommends that a 'Phase-B type' study of the payload be concluded before a mission is approved by the SPC and that payload suppliers are assessed to ensure their ability to deliver.

(v) Instruments or instrument packages are delivered to industry for integration and testing of the spacecraft, as customer-furnished equipment. This arrangement provides for contractual clarity and should be maintained, although ESA must make every effort to prevent delays and cost claims as a result of inadequate interface management.

4.4 International Collaboration

The increasing demands both on payloads and on spacecraft performance together with limits on available funding, implies that now, more than ever, multinational collaboration is needed in order to satisfy the aspirations of space scientists in this century. With this end in mind, the SPRT recommends that an appropriate system of consultation and planning be set up to achieve a more effective harmonisation with national agencies in Europe and with other, non-European entities, such as NASA, JAXA, RSA and CNSA. The SPRT is aware that this might require a substantial effort, but we consider the urgency to take the planning and execution of space science missions to an international level to be very high, especially in view of the fact that the times of relatively 'easy' missions are behind us and that the dynamics of international collaboration have changed, with the addition of China and India to the space-faring nations.

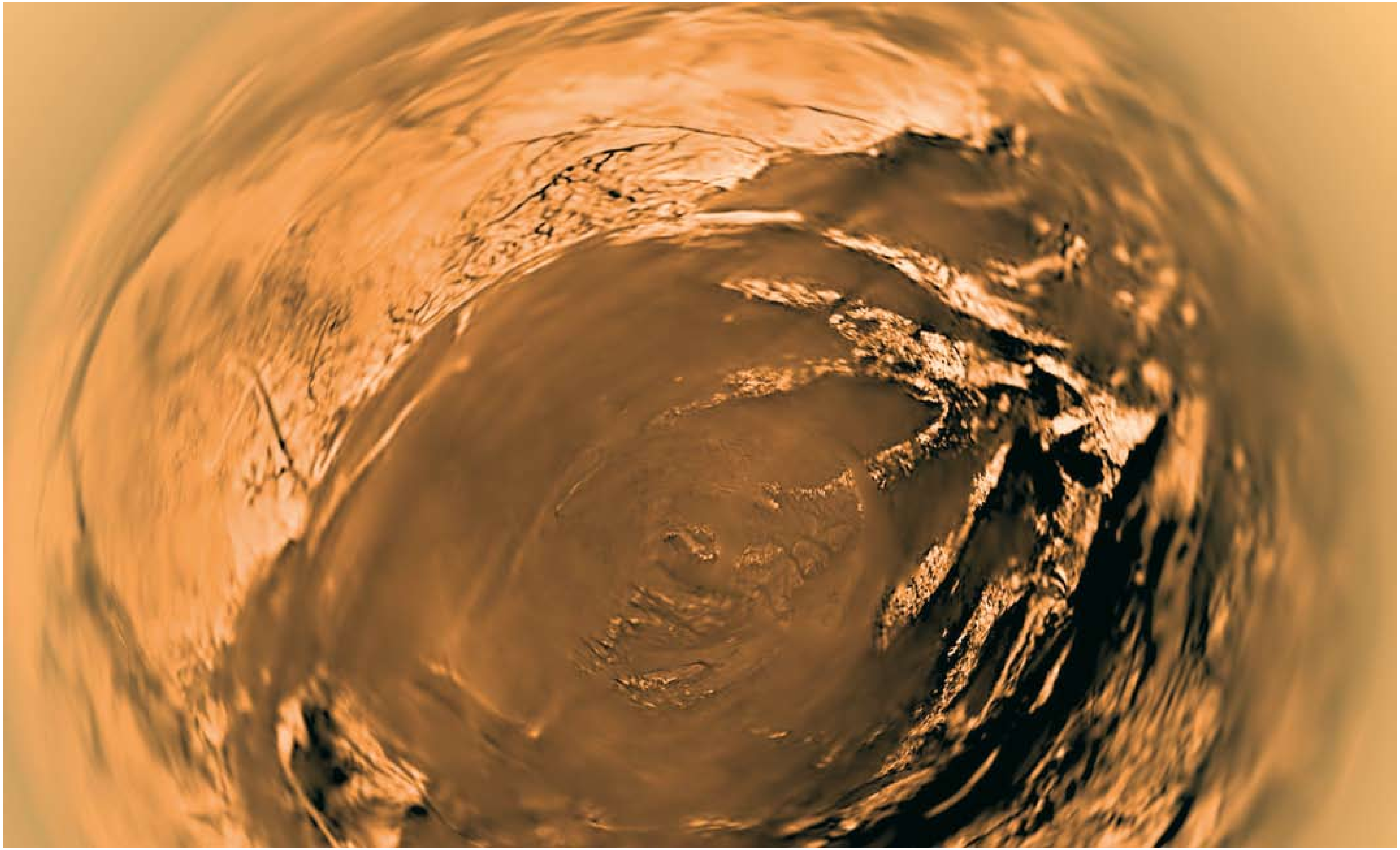
The SPRT recommends the establishment of a consultation and planning system with national and international counterparts

4.5 Block Decisions

With the publication of the Cosmic Vision Plan 2015–25, the SSAC has outlined the main fields of research on which future ESA science projects should focus. However, given the fact that many more missions would be required than can possibly be realised by ESA during that time-frame under the current budget constraints, only a small fraction of the exciting scientific themes outlined in the document can actually be tackled.

The addition of any mission to the suite of already selected and approved missions and eventual cost increases of missions presently under development would clearly reduce the Cosmic Vision implementation, in the 2015–25 period, below the theoretical tentative scenarios sketched in paragraph 4.2. (see Figs. 3b, 3d). While the Cosmic Vision document reflects the wide range of interests expressed by the European scientific community, the affordability of only a small subset of the proposed missions implies that a 'balanced' programme cannot be achieved in that period.

This makes it even more important that missions are selected only after they have been kept in competition with each other until, at the time of taking the decisions, there is a solid assessment of costs and risks. These assessments should be both transparent and independent, and the SPC should be fully apprised of the results, in order that informed decisions can be taken.



This part of a distorted fish-eye projection shows features on Titan's surface from 5 kilometres altitude, using images taken by the Descent Imager/Spectral Radiometer (DISR) on board ESA's Huygens probe, during descent on 14 January 2005.

5

DECISION-MAKING AND MANAGING THE SCIENCE PROGRAMME

5.1 Cost Increases

(i) The SPRT has identified three main causes of cost increases in missions under development:

- delays, resulting from a longer-than-anticipated development of certain mission-critical technology. The costs have increased because teams had to be kept on standby and spacecraft integration and test costs increased, mostly due to the extra efforts required to compensate for and reduce, insofar as possible, the consequences of the launch delay;
- shortage or delays in payload funding by National Agencies or Institutes;
- in the present procedure, decisions on missions by the SPC are taken at a stage when the CaC of the mission is not yet consolidated, due to the absence of a study of the mission, with a realistic payload and the assumptions concerning technologies, which may not be at the appropriate level of readiness.

In addition to the effect on the relevant mission, such cost increases have also severely impacted future missions, as these too had to be delayed as a consequence of financial constraints.

(ii) In the opinion of the SPRT, the new financial rules presently under development in the Agency should, in addition, be used as a means of focusing the efforts of the Science Programme management on the delivery of missions under development **on schedule and within the approved cost-at-completion**, instead of the current emphasis on meeting the year-on-year spending limits.

Observation:
The erosion of the available resources by costs associated with operations and support costs and extra additional demands on the Science Programme have reduced the safety margin of the Programme itself as well as the possibility of advancing new projects.

(iii) We acknowledge that several initiatives are in preparation or have already been introduced by the Executive, among them the concept of developing competing mission proposals more fully before they are brought forward for the approval of the SPC (see SPC 2006/17). However, better cost control is only possible if and when technological and other risks are identified in a timely manner and contained more effectively, and appropriate measures to achieve this have been put in place.

Observation:
There is no doubt that the stability of the Science Programme would be much improved were decisions to be based upon solid cost estimates and if the strict adherence to year-on-year spending limits could be avoided.

5.2 Technology Readiness

Technology readiness can to a considerable extent be quantified. The following is a standard classification model of NASA, commonly used by industry:

TRL1 - Basic principles observed and reported
TRL2 - Technology concept and/or application formulated
TRL3 - Analytical and experimental critical function and/or characteristic proof-of-concept

TRL4 - Component and/or breadboard validation in laboratory environment
TRL5 - Component and/or breadboard validation in relevant environment
TRL6 - System/subsystem model or prototype demonstration in a relevant environment (ground or space)
TRL7 - System prototype demonstration in a space environment
TRL8 - Actual system completed and 'flight qualified' through test and demonstration (ground or space)
TRL9 - Actual system 'flight proven' through successful mission operations

Note : Space R&T projects are usually funded to cover levels 2 to 5, with the application/mission project taking care of levels 6 to 8 and 9. The progression from level 4 to level 5 is often difficult. Some scientific research laboratories are logically dedicated to exploring and creating levels 1 and 2, the most advanced steps, related to very challenging scientific space missions.

Technology versus Project Application	**Feasibility demonstration**	**Pre-development**	**Pre-qualification**
Innovative / Prospective Technology	**TRL 1-2**		
Go-ahead for Project Assessment	**TRL 3**	**TRL 4**	**TRL 5**
Go-ahead for Project Implementation	**TRL 1-2-3**	**TRL 4**	**TRL 5**

Prospective only	**Regular starting level**	**Limited risk level**	**Full risk level**

Figure 5. Proposal for a Technology Readiness Level grid

The SPRT recommends that this, or a similar quantitative system be put in place, with clear decision points for the different levels of readiness, before any commitment is made to full development, be it at the spacecraft or at payload instrument level.

5.3 Core Technology Programme

As stated earlier, requirements for technology development are driven, on the one hand, by the demands of the scientific community, while, on the other hand, new options for space research are coming within reach, due to technology developed for other purposes (e.g. infrared detector arrays for defence). This dynamic requires an active exchange across disciplines, which should be tracked by technology roadmaps, as described earlier. However, an active programme to adapt the existing technologies or to develop new ones is needed to seed these ventures.

An additional reason for an active technology development programme for scientific spacecraft is that nowadays some of these critical technologies fall under ITA regulations. Therefore, not only the specific application of the technology, but the place where the spacecraft using it is to be launched, comes under detailed scrutiny from US authorities. Mandatory authorisation from the State Department, and sometimes by the US Congress, can be required. Such authorisation, even in the most favourable situations, is subject to aleatory considerations and takes a long time. This can become a major hurdle in the schedule of any programme. The present lack of precise guidelines to evaluate what is subject to ITAR can, on occasion, become a significant obstacle to progress.

The SPRT recommends that the Science Programme maintains the Core Technology Programme at the level of 100 million€ over a ten-year period with a transparent decision-process on resource allocation, to leverage activities within Europe and elsewhere.

The SPRT recommends the use of technology roadmaps to focus resources across Europe and to apply these effectively to meet the challenges of new missions, be it in traditional Space Science, in Exploration or Earth Observation. Roadmaps can also be used to plan and to track the development of new technology, either inside the Agency or outside, as has been demonstrated successfully in other sectors (e.g. microelectronics).

5.4 Cooperation

The SPRT proposes the creation of a new mechanism to facilitate intra-European and intra-agency collaboration and co-ordination for the development of future mission-critical spacecraft and payload technology. We are encouraged by the recent creation of the advisory committee for science policy, HISPAC, which will advise the Director General on science policy, cutting across the various programmes under ESA's auspices and with the European Union and ESA Member States, including technology development. The SPRT recommends that HISPAC be charged with advising the Director General on the implementation of the new mechanism mentioned above.

5.5 Peer Reviews

The SPRT recommends that, whenever assessments of proposals are made, independent peers should assess the technology readiness and status. These peer-review reports should be available to the SPC. In addition, an external 'Tracking Committee' should advise the Executive during the development phases.

While it may be difficult to find truly 'independent' peers, the Executive should, nevertheless, make every effort to avoid even the slightest suggestion of any conflicts of interest. By involving not only scientists in academia in such ad-hoc review teams, but also scientists and engineers from industry and research establishments, and by involving non-European scientists in addition, such reviews may help to reveal weaknesses at an early stage. This would provide the possibility to take appropriate measures, on a timely basis, rather than discovering problems in advanced stages of mission development. This is not to say that all future problems and risks can be avoided by having such mechanisms in place, but these ideas can, to a great extent, introduce a counterbalance to any possible influence of special-interest groups that want a particular mission to go ahead 'at any cost'.

5.6 Timing of Mission-selection and Adoption by SPC

(i) The present practice is that a mission is selected by the SPC after an assessment phase, where cost is assessed on the basis of a 'strawman payload'. The procedure weights potential scientific merit, however, at the expense of making the selection when the cost and the readiness of the involved technologies are imprecisely known.

(ii) Risk management is well established in the ESA Science Programme, with an excellent monitoring system and process in place. Nonetheless, it would appear that the standing practice, whenever the risks have consumed the available contingency margins, is to simply increase the cost estimates currently in use. Depending on the timing of the adoption of the formal CaC by the SPC, this leads to an increase over the estimates valid at the time of selection of a mission, or to a formal adjustment of the CaC. In any case, this then results in further stretching the schedule, with the effect that new mission opportunities are pushed ever further into the future.

The SPRT recommends that competition be maintained between at least two candidate missions until a study with realistic payloads be made and the CaC of the missions is better established.

The SPRT recommends that a quantitative monitoring system of the project's evolution in cost and schedule must be in place, such as the well-known Earned Value Management in use at NASA, DoE and CERN, to enable Management to take early countermeasures.

5.7 Contingency in the Science Programme

ESA's policy with regards to the levels of contingency margins in missions has changed over time, under the pressure of various cost increases. There has never, so far, been a policy on contingency margins formally codified in rules or established practices.

In effect, contingency exists at four different levels:

Programme Contingency
When planning Horizon 2000 Plus, in 1996, a Programme Contingency was considered, at the level of 5% per year, starting from 2001. This concept was suppressed in 1997. A Programme Contingency of 5% per year is now, once more, being considered, starting in 2008.

Mission Contingency
The mission-level contingency margin is 5% of the Cost at Completion (CaC) minus launch-vehicle purchase. It is introduced at the start of the implementation phase and reported to SPC at CaC approval. Any cost increases are taken from this contingency until it is consumed, at which time the practice, so far, has been to define and present an increased CaC for approval by the SPC.

Project Level
The project-level contingency margin is introduced in variable proportions, based upon the estimated risk, at the level of the best financial predictions.

Contract Level
This contingency margin is introduced in the form of a 'management reserve', as part of the committing price of the Prime Contractor.

To re-introduce the necessary stability into the overall Science Programme, costs must be better controlled and contingency-margins have to be made commensurate with the risks ESA and instrument providers have to take in their respective roles.

The SPRT recommends that a contingency of 5% of the overall Level of Resources be maintained at the Programme level at the start of a ten year period. At mission level, the contingency-level should be determined on the basis of negotiation, the outcome reflecting the risks in an appropriate way.

Margins of up to 20% of the total external procurement value, may be needed and should not, therefore, be excluded.

Planning in the future must be based on cost estimates made, a priori, by properly informed people. The stability of the Programme will require that no single mission should be supported, whatever the cost, at the expense of other missions within the overall Programme. In a situation where the Level of Resources is at a constant level, protecting the overall stability of the Programme also means that scientific choices have to be made.

Consumption of mission or Programme contingencies must always be approved by the higher echelon and be proposed only when all other measures, including descoping, have been exhausted.

Missions under development should, excluding matters extraneous to the Science Programme such as, for example, a launch failure, be capped at 120% of the cost originally approved by the SPC (including project-level contingencies, but excluding programme-level contingencies). The implication is that approval of missions must be based on reliable cost estimates and that cost evolution during development is tracked and reported regularly, to allow corrective action to be taken early on.

This proposal may be difficult to implement in the environment of a multi-country membership organisation with different interests. Nevertheless, the SPRT feels that strong measures are needed. The incentive to obtain solid cost estimates will already improve when mission proposals are more fully developed and kept in competition until decision time, as is now under active consideration. However, this in itself is not seen to be sufficient, as the present culture would seem to be to propose only success-oriented schedules and estimates.

It should be stressed that the SPRT has proposed that other measures are needed, concerning technology development and risk assessment, better management of contingencies and risks and a more effective tracking of progress during the development of missions. The proposal for some form of 'drop-dead' limit, therefore, is not a stand-alone proposal and should be considered in the context of all the other measures that are already being introduced and those that are now being proposed. While the SPRT appreciates the difficulties entailed in the actual implementation, we consider that such an option should be part of the suite of control instruments available to the Agency.

The SPRT recommends that once a CaC estimate exceeds the 120% level, the development will be automatically frozen until an independent assessment validates the ways and means by which to return the CaC to within the (120%) envelope. If the external assessment fails to achieve this, the decision should then be taken by the SPC to cancel the mission.

Observation:
The phrase "More science with less money" has been used, more often than not, to imply that instruments should cost less. However, this is often no more than wishful thinking that can lead, and indeed has led, to serious problems for the Science Programme.

A similarly well-used concept, "Time is contingency" has sometimes been applied, instead of having a real contingency. However, such a practice of delaying one mission after the other has led to a time scale for new missions which is very discouraging to future generations of scientists.

The decision to approve a programme should be based on the most advanced cost estimate possible (therefore the decision should not come too early), which includes an appropriate, realistic contingency margin.

5.8 Extra Demands on the Programme

(i) In the course of recent years, a number of new demands have been made on the Science Programme, each of them reasonable in its own right. Some are the result of the success of the Programme, others because the Programme has taken on new responsibilities. Taken together, however, these have contributed to an erosion of the external purchasing power of the Science Programme, from a level of 75% of the Level of Resources in 1995 to 50% in 2005 (see Fig. 6 below).

Examples of these new demands include participation in nationally-led missions, new communities/activities entering the Programme, mission-operations extensions and maintaining data-centres.

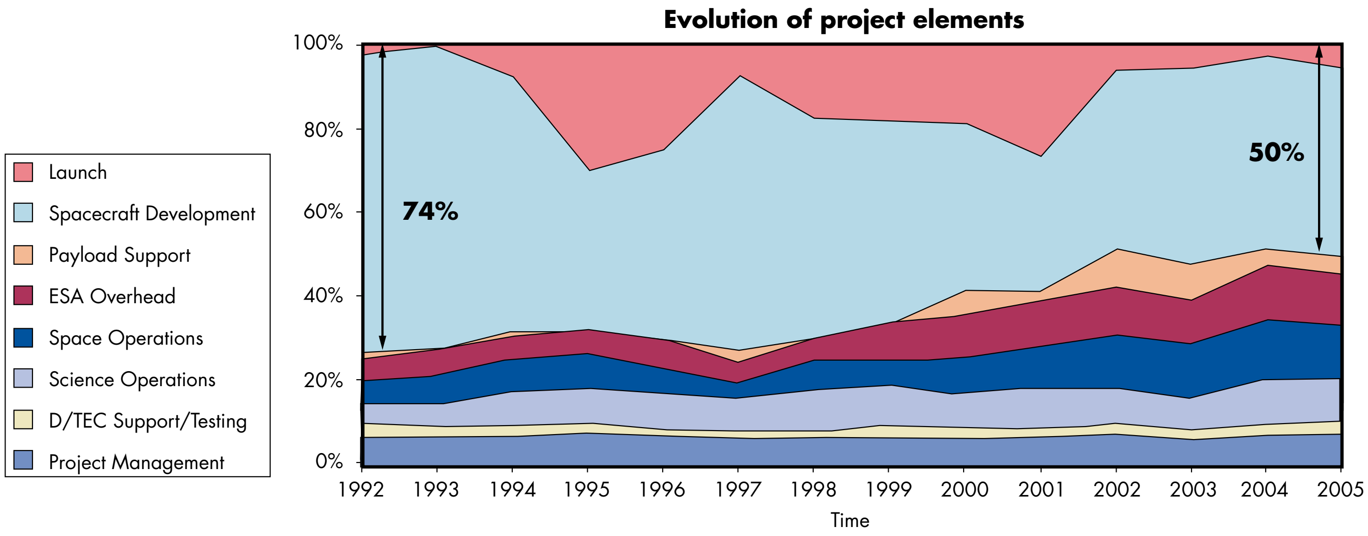


Figure 6. Evolution of project elements

We would also mention that, as a consequence of an exceptional event, the Science Programme faced the need to take a loan of 100 million€, which is currently being reimbursed, until 2008.

The SPRT recommends that, in addition to the proposed 200 million€ reduction, a commitment should be agreed to cap the operations and support costs and overhead charges at a level of, maximally, 160 million€ per year on average, or below 40% of the Level of Resources (excluding payload technology development support and CTP). Furthermore, a critical evaluation and assessment, with benchmarking, of the structure, the performance and the costs of the various centres and support activities under the ESA umbrella, must be undertaken and the results reported to the SPC.

(ii) Operations and Support Costs: The evolution of non-spacecraft development and launch costs, or 'operations and support' costs, which include sub-contracting of tasks by ESA centres, should be strictly controlled to avoid an even deeper erosion of purchasing power in the future.

(iii) Overhead Charges : The question of the charging mechanism and its unequal application to the Science Programme was one of the issues focused upon by the previous SPRT. The present SPRT has little to say on the matter as its investigations point to two unavoidable facts: (a) services and facilities that a Programme uses have to be paid for, and (b) transparency in the application of the policy is being improved. The evolution of the situation, since the Pinkau Report, may help to put the situation in perspective.

The SPRT recommends the implementation, as soon as possible, of the proposed new Financial Management System {Ref ESA/AF(2006)154}, utilising, insofar as possible, the proposal coming from the Inter-Directorate Reform (D/REF) project on the General Budget Structure {Ref ESA/C(2006)136}. This new approach is considered by the SPRT to have potential benefits to the Science Programme, in terms of structure, transparency and equity.

- In 1989, the SPRT (Pinkau) Report recommended to impose recharges on the basis of the programme budget instead of the level of manpower involved.
- In 1992, recharges were reduced from 25% to 12% to preserve the purchasing power of the Science Programme,

but the reduction that had been recommended (1/3 of GH C – Tech. infrastructure) was not granted.

- In 1996, the General Budget Charging Structure was updated and approved.
- In 1998–99, the New Charging Structure came into force, the previously-granted reduction was cancelled and the recharge rate to the Science Programme was re-established at 25%.
- In the period 2000–05, there were no major changes to the system and the recharge rate to the Science Programme has remained at an average of 25%.
- The General Budget recharge rates for Admin. Support, Site Services & Common IT Infrastructure and for Technical Infrastructure are applied to the Science Programme at a level of 20%, which is similar to other programmes.
- Technical and Operations support charges are, however, substantially higher for the Science Programme, given that the support services are directly related to the number of satellites under design and development and those operated in orbit during planned and extended missions.

(iv) Financial contributions to Payload Developments by Scientific Institutes: the challenging nature of the developments of some payloads has led to a situation in which the financial capabilities of the institutes in charge of the payloads themselves were exceeded. Faced with that situation and in the interests of saving the mission, the Executive decided to provide a financial contribution, on an exceptional basis.

Observation:
The SPRT considers that measures of this kind should remain exceptional and encourages the Executive to implement procedures that will provide for regular monitoring and discussions with the Institutes and Agencies involved, so as to facilitate the timely provision, by the national funding organisations, of the necessary funding.

(v) Extensions of Mission Operations: Arguably, mission-operations extensions are the most cost-effective way to obtain scientific results. Nevertheless, the total cost of these mission extensions amounts to some 60 million€ per year (until 2009). The SPRT believes that this points to the need for a more in-depth and Programme-level consideration being given to such proposals, before making the decisions on extending missions.

(vi) Beyond that, as already referred to above, such decisions must always be made in the wider context of the potential impact on the overall Science Programme. In addition, the SPRT considers that, in the case of any further extensions, the SPC and the Executive should explore more creative/less orthodox approaches to mission operations. These could involve, for example, a compromise on the number of operator shifts, the involvement of young scientists rather than professional operators, shifting some tasks to outside institutions, etc.

(vii) The SPRT further recommends that the Executive and the SPC critically examine demands for support by the ESA Science Programme which are not in the core of ESA's mission, not only with regard to the initial investment, but also with regard to the recurring costs to the programme, to decide on priorities and to agree a budget envelope for specific categories of activity.

The SPRT recommends that as a rule and if and when applicable, one period of extension of mission operations, beyond the nominal life of a mission, is included in the CaC, when the SPC decides on a mission. It further recommends that extra demands on the Programme be critically examined by the Executive and the SPC.

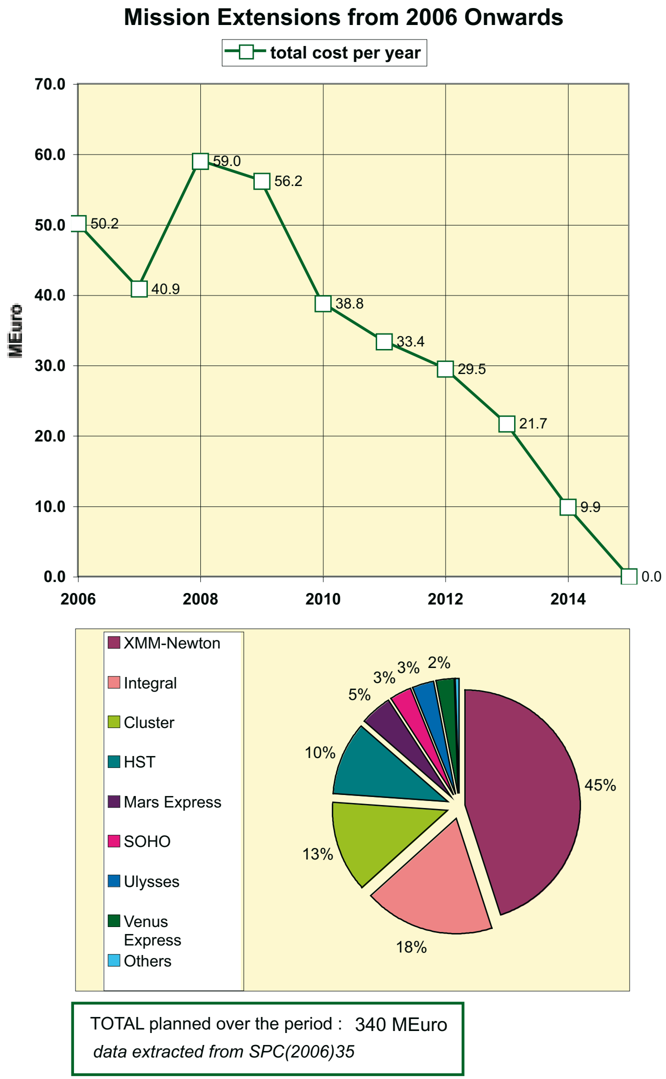
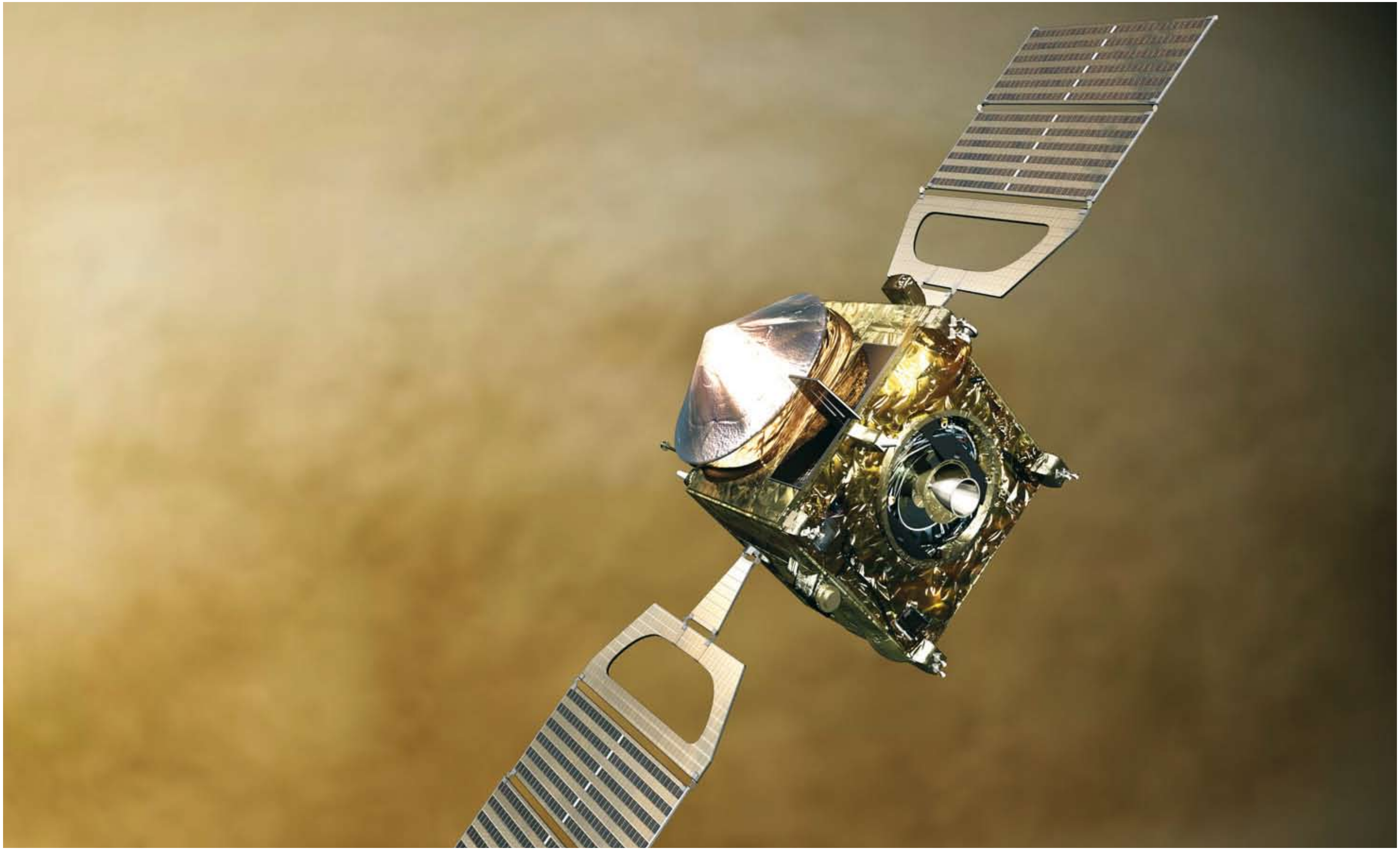


Figure 7. Mission extensions from year 2006 onwards



This artist's impression of ESA's Venus Express, launched in November 2005, shows the spacecraft in orbit around Earth' mysterious sister planet. Venus Express is an outstanding example of ESA's practice of coupling missions.

6

INDUSTRY INVOLVEMENT

During its analysis, the SPRT did not identify any major issues concerning the Science Programme that relate explicitly to industry. However, there are several issues where industry involvement may contribute to improvement-related actions.

6.1 Follow-up of Payload Instrument Development and Assessment of Risks

(i) The issue concerning payload development and associated risks has been thoroughly analysed. In this, the role of ESA management is considered crucial, with a recommendation to strengthen this role, to the extent necessary, in many respects, e.g. assessment of design and technology maturity, management of interfaces, space qualification and testing.

(ii) A regular complaint from industry relates to late delivery of valid interface data from instruments. Equally, scientific instrument designers also have a need for proper instrument interfaces, which reflect valid spacecraft design constraints. An effective system of coordination, managed by ESA, is therefore essential. Similarly, any system testing involving payload instrument performance would require a similar co-ordination of respective responsibilities. The involvement of industry in payload development has increased as a result of technology constraints and the associated manufacturing capabilities. For example, in the case of observatory-type missions, the interfaces between industrial deliveries and scientific-institute deliveries have been moved up and are now elevated to the level of the focal-plane assembly, thus creating a closer relationship and complementary contributions to meeting the scientific mission requirements. Similarly, since onboard data processing is generally taking care of both the spacecraft and the scientific instruments, it is obvious that the ESA Project Team has to closely follow the development, at the technical level, and must establish the pace of overall design freezing and payload interface configuration management.

The SPRT recommends that ESA retains the management of payload development, interface control, testing and, later on, mission operations. At the request of ESA, industry can provide valuable and efficient contributions to the instrument development programme by offering dedicated engineering expertise, during the various project phases. It would be beneficial to invite the participation of Industry experts in critical and/or formal reviews related to the payload development cycle.

6.2 Procurement Practice and Development Methodology

For some years, regular workshops have been set up between ESA and industry. As an example of the outcome of such workshops, improvements have been made to the procurement processes and to development methodology. The SPRT encourages the continuation of such exchanges as a means to review the evolution in technology and complexity of hardware, especially software systems, for inclusion in the life cycle of projects.

The SPRT, noting that in the space industry, extensive experience with the methodologies of determining technology readiness level exists, recommends that, insofar as the ethics of competition are not compromised, Industry experts should participate, with ESA specialists and others, in the comprehensive assessment of the technology readiness level of mission-critical technologies, before a mission is adopted.

6.3 Costs, Contingencies and Contractual Terms

(i) The SPRT has observed that, in the past, the go-ahead given to some ambitious missions was premature, given the situation with regard to technology readiness and overall preparation, resulting in delays and/or cost-overruns on some missions. Both industry and the scientific community are implicated in this, in that there were, on occasion, potential weaknesses in industry performance and associated cost overruns later and, in the case of the scientific community, weaknesses in its ability to readily engage in complex payload developments, resulting in delivery delays. Additionally, the cost assessments and project contingencies, as provided by industry, did not properly reflect the complexity of the development of the mission as a whole.

(ii) It is clear that the competitiveness of the space industry has progressed significantly and that the Science Programme has benefited from the growth of the spacecraft market. This is particularly relevant when equipment developed for scientific projects has a commonality with what is used in other applications. However, this benefit may be offset by the trend for future scientific missions to have more ambitious scientific objectives and, consequently, more demanding technical requirements. These more complex missions will need higher investments in specific technology programmes and will require longer development times, with the potential that precursor missions may be needed as an intermediate step. Consequently, in general one should not expect that system activities, and the related manpower costs at industry level, will decrease in all science projects. The comparison of system-engineering activities between scientific and application satellites will not always be relevant as a practical tool to obtain a baseline reference.

(iii) The evolution from 'cost plus' to 'firm price' and 'cost sharing' contracts has moved part of the risks under the responsibility of industry. The standard Class-A/Class-B process for engineering changes establishes the borderline between the ESA and industry liabilities. The industrial Prime Contractor, with a standard spacecraft contract share of some 25%, is generally selected with a number of key co-contractors at the end of the competitive process. The Prime Contractor takes on not only the spacecraft design and development risk but, in addition, all procurement risks on the spacecraft elements that will be contracted (about 50% of the total contract) later during the implementation phase (B2 or early C/D). The finalisation of these subcontracts by the Prime, which is under the supervision of the ESA Project Team, gives ESA some flexibility to set the geographical return close to the planned target percentages. Taking all of this into account, the Prime Contractor is compensated, following ESA practice, by the provision of a reserve fund in the overall price commitment.

The SPRT recommends that the reserve fund in the industrial contract should be agreed on the basis of the complexity of technical and managerial interfaces and the related industrial structure, taking account of geographical-return requirements.

Observation

The industrial structure in a science project has to respond to conflicting requirements :

- *On one hand, the innovative technical complexity of science projects calls for demonstrated expertise of Prime and main co-contractors.*
- *Being covered by mandatory contributions, the Science Programme is given a high value by the so-called 'smaller'*

Member States' industries, sometimes bringing a requirement for special measures;

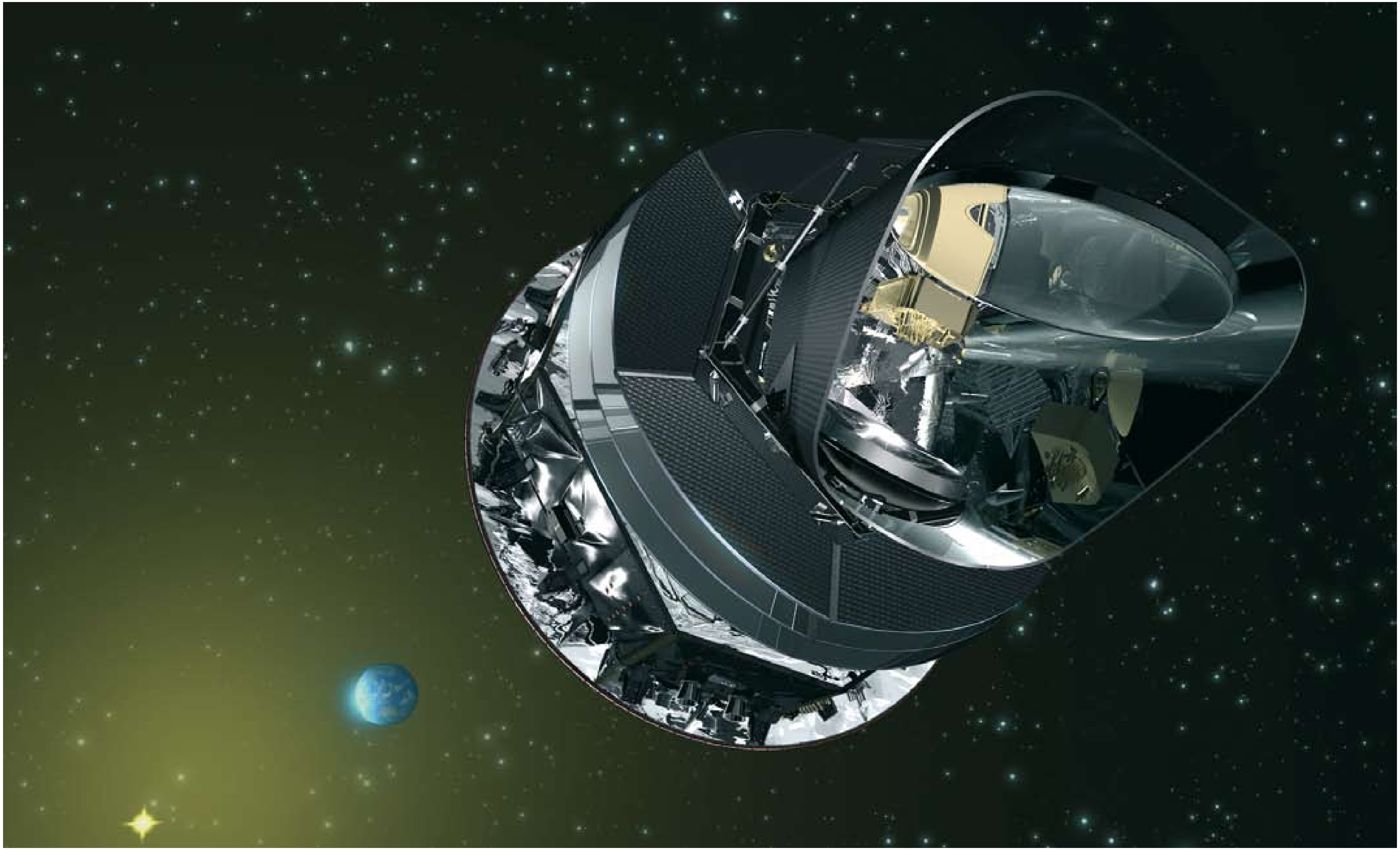
- *On the other hand, new Member States legitimately wish to get their national industry engaged in space activities through the mandatory Science Programme.*

These two factors have obvious influences on Industry quotations of risks and contingencies. One may also notice in recent science projects that the number of subcontractors has dramatically increased, from a previous average of 30 to about 100 or more low-tier subcontractors, therefore sometimes calling for a heavier deployment of managerial tasks.

6.4 Coupled Missions and Related Potential Cost Savings

Industry has, with ESA approval, advocated the practice of coupling some science missions, with the purpose of getting an economy of scale through demonstrated commonality in spacecraft platform development. Examples are XMM-Newton coupled with Integral, Venus Express closely derived from Mars Express, and Herschel coupled with Planck in a single project implementation. Although difficult to accurately quantify, this has resulted in significant savings in those cases. The most obvious advantages of this approach are the creation of an up-to-date generation of equipment and the reduction in the preparation of in-flight operations, due to the similarities of mission profiles and spacecraft remote-control procedures. Such an approach is especially valid when the time scale of the coupled developments is not too long – say 2 to 3 years maximum.

The SPRT recommends that, in spite of the urgency to implement the Cosmic Vision Plan, some consideration should also be given to coupled missions. This could have the effect of conciliating the available resources with the aspirations of the scientific communities, taking into account the various constraints of technology challenges and the long-term planning objectives.



ESA's Planck is Europe's first mission to study the relic radiation from the Big Bang. It will be launched with ESA's Herschel spacecraft, then it will separate and start its cruise to L2, the second Lagrangian point in space.

7

BACK TO THE FUTURE AND ACKNOWLEDGEMENTS

The SPRT has analysed the various issues that are involved in the governance and management of the ESA Science Programme. As in other walks of life, when circumstances change and organisations mature, occasionally revisiting past procedures and habits is a healthy exercise, especially when the tasks become more demanding, as is the case here. Naturally the emphasis in our analysis had to be directed to causes and consequences of decisions in the past, which is why our recommendations deal with improvements and adaptations in the Science Programme that the SPRT considers **necessary** to maintain a healthy and fruitful programme in the future.

However, the question may be asked whether these recommendations are **sufficient** to ensure a successful future for the Science Programme. Here, we have to be cautious. Presently some major developments, of and surrounding the Agency, are under consideration, especially concerning the future role of the EU and the position of ESA in relation to the Union. Obviously, at this stage we were unable to test our analyses and recommendations against this, still very uncertain future; nevertheless, depending on the outcome of the ongoing process, the consequences for the Science Programme may be quite considerable. As the decisions concerning the 'fusion' of ESA with the EU are still pending and will be for some time, we strongly recommend the implementation of our recommendations – fully and with urgency. This will help to put the Science Programme on a solid footing as soon as possible and assist its position in the discussions around the division of tasks. It seems quite unlikely that anything we have recommended would be invalidated by the developments as sketched. However, one may expect that additional measures will be needed if and when the relations with the EU will ultimately change.

During the development of our work we have been impressed with the achievements of the Science Programme and with the dedication and energy devoted by ESA staff implementing the missions of the Science Programme. Yet, we feel that the review concerning the tasks under ESA control (technical services, operations, project management, advanced technology development) that we have recommended should be used to critically analyse the adequacy of the present **processes and structures**, in view of the new demands put on the Agency, including the need to expand its involvement in international collaboration. Indications as to where attention is needed can be found in the main text of the report; however, closer scrutiny may reveal other areas that need management attention.

A major point we have identified concerns the transparency of decision-making and the avoidance of conflicts of interest. This is especially important now that the Programme can no longer afford to make block decisions, with a number of missions 'approved' simultaneously. In view of the relative scarcity of missions in the future, owing to the increased complexity required by the scientific community, without a commensurate increase in funding, the competition will be more intense and the consequences of a particular mission proposal not being selected potentially more severe. While, on the one hand, this must imply that the selection process is beyond criticism, on the other hand, the strategic role of ESA in mission planning and technology development will need enhancement. For that reason the tie-ins with the science community must be intensified. Clearly these two conflicting demands must be carefully balanced, which is why we recommend that the Agency develops strict procedures and involves 'outsiders' in reviews and assessments. The SPC as a delegate body must always be seen to take the 'high ground' by ensuring that the proposals that are being selected will return the most science for the investment. At the same time, the SPC must provide overview and guidance, devoid from particular national interests. To stimulate this attitude, it is important that trust is maintained between the Executive and its staff on the one hand, and the SPC on the other. We propose that the SPC involves itself more fully with those decisions that it must make, but at the same time refrains from micromanaging the programme. We recommend that an assessment of a proper and effective division of roles between the Executive and the SPC is undertaken; in the meantime, we suggest that a mechanism for the preparation of the SPC for important decisions be put in place, perhaps along the lines of ad-hoc working groups of SPC delegates and, where appropriate seconded by outside experts, for interactions with the Executive and staff, concerning various aspects (i.e. planning, cost, technology readiness, payload provisioning) of the proposal under consideration.

Industrial involvement in the Science Programme is key, as industry must deliver the spacecraft and launchers. The present tradition in the Science Programme separates industry from the science community, with ESA acting as the go-between. The SPRT believes that this practise has its merits, but at the same time may give rise to sub-optimal solutions. We therefore recommend that a mechanism be developed whereby, during the initial thinking about mission concepts and functional allocations in systems design, Industry is involved more fully without compromising the ethics. This early involvement of industry in concept trade-offs and system design may result in new approaches and trade-offs between instrument complexity and spacecraft hardware and between spacecraft design and operational costs and, therefore, in more science for the investment, than would otherwise be possible. It would also introduce fresh ideas at a stage where they can still be adopted.

The work of the SPRT will hopefully contribute to a brilliant future for one of ESA's great successes: the Science Programme. We are encouraged by the active interactions with ESA's staff and their participation both in the analytical work that we have undertaken, and in the development of solutions and recommendations. However, we should stress that the outcome of the work is the responsibility of the SPRT alone.

We are encouraged by the fact that this report is to be accompanied by comments and reactions from both the SPC and the Executive. Equally, it is notable that, even before the Review was completed, changes proposed by the SPRT were being seriously considered and, in some cases, are already being implemented. Nonetheless, the full value of having an SPRT will only be shown by the manner in which its recommendations are handled in the medium-/longer-term. In our view, this will best be facilitated by the establishment of a structured follow-up process, whereby Council will be informed, on a regular basis, as to progress towards the implementation of, and the outcomes associated with implementing the SPRT recommendations.

We thank all those who have in one way or another contributed to our work! Special thanks goes to the Executive Secretary of the SPRT, Mr Leo Hennessy, without whom this Report would not have been possible.

8

ACRONYMS

CaC	–	Cost at Completion
CNSA	–	China National Space Agency
CTP	–	Core Technology Programme
D/LAU	–	ESA Directorate of Launchers
D/OPS	–	ESA Directorate of Operations
D/REF	–	ESA Directorate of Reforms
D/RES	–	ESA Directorate of Resources
D/SCI	–	ESA Directorate of Science
D/TEC	–	ESA Technical Directorate
ESAC	–	European Space Astronomy Centre
ESF	–	European Science Foundation
ESOC	–	European Space Operations Centre
ESRO	–	European Space Research Organisation
ESTEC	–	European Space Research and Technology Centre
HISPAC	–	High-level Space Policy Advisory Committee
ITAR	–	International Traffic in Arms Regulations
JAXA	–	Japan Aerospace Exploration Agency
L/V	–	Launch Vehicle
LoR	–	Level of Resources
MOC	–	Mission Operations Centre
NASA	–	National Aeronautical and Space Administration (USA)
RSA	–	Russian Space Agency
S/C	–	Spacecraft
SOC	–	Science Operations Centre
SP	–	Science Programme
SPC	–	Science Programme Committee
SPRT	–	Science Programme Review Team
SSAC	–	Space Science Advisory Committee
TRP	–	Technology Research Programme
TRL	–	Technology Readiness Level

Built for ESA by the European aerospace industry, Hipparcos operated in space from 1989 to 1993. The spacecraft mapped stars and recorded their brightness, enabling a set of the most accurate star data catalogues to be published by ESA in 1997. Hipparcos confirmed Einstein's prediction of the effect of gravity on star light, and discovered that the Milky Way is changing shape.

APPENDICES

Appendix I

ESA/C/CLXXXVII/Res. 1 (Final)

Resolution on the Establishment of a Science Programme Review Team

(adopted on 15 March 2006)

The Council,

HAVING REGARD to Article V.1 (a) (ii) of the Convention;

HAVING REGARD to the Resolution on the Level of Resources for the Agency's Mandatory Activities 2006-2010, adopted on 6 December 2005 by the Council Meeting at Ministerial Level in Berlin (ESA/C-M/CLXXXV/Res. 2 (Final));

HAVING REGARD to the Agency's Scientific Programme, and in particular the Science Long-Term Plan for the period 2015-2025 (hereinafter referred to as the "Cosmic Vision Plan");

HAVING REGARD to the report of the Science Programme Review Team established on 15 December 1988 (ESA/C(90)16);

I. DECIDES to establish an independent review team, called the Science Programme Review Team, to review the management of the Scientific Programme, in the light of the present level of resources and without putting into question the scientific content, with the objective to:

(i) Evaluate the overall structure of the Scientific Programme, considering large missions, medium missions and small projects, taking into account the present cost estimates.

(ii) Identify potential improvements in the management of the Scientific Programme to achieve direct savings and ensure cost effectiveness in the use of the programme resources, including the Agency's facilities, compatible with the present level of resources.

(iii) Point out the implications of the findings under (i) and (ii) for the Scientific Programme and the long-term viability of its implementation.

(iv) Consider ways in which Member States can support the Scientific Programme, including intra-European cooperation and coordination.

II. INVITES the chairperson of the Review Team to report regularly to the Director General and to deliver the conclusions within a year;

III. REQUESTS that the Agency's Science Programme Committee (SPC) be consulted by the Review Team and that the final consolidated report, including the assessment of the Director General and an executive summary, is presented to the Council;

IV. APPROVES the attached terms of reference and list of the members of the Review Team, proposed by the Director General, in consultation with the Chairperson of SPC and attached hereto.

Terms of Reference of the Science Programme Review Team

1. In achieving the objectives defined by the Council, the Review Team shall consider:

   1.1. The management procedures and related risks:

   1.1.1. within the Agency with regard to:
   (i) mission evaluation, selection and valorisation;
   (ii) payload selection;
   (iii) procurement practices and constraints;
   (iii) determination of staffing levels;
   (iv) the impact of the corporate re-charge on the Scientific Programme.

   1.1.2. in connection with Industry with regard to:
   (i) procurement practices and constraints;
   (ii) level and quality of manpower resources;
   (iii) reporting and reviews;
   (iv) product and quality assurance.

   1.1.3. in relation to Member States, their national institutions and scientific groups:
   (i) payload selection;
   (ii) payload provision;
   (iii) interface requirements.

   1.2. The updated estimates of the cost of the elements of the Scientific Programme, including approved projects, basic activities, contingency margins and Agency-level overheads, and take due account of the ongoing reform of the financial management of the Agency.

   1.3. The synergies of the Scientific Programme with other programmes of the Agency (in particular in the field of space exploration, Earth observation and ISS utilisation), Member States' programmes, other European programmes, including the use of large infrastructures available in Europe, and international cooperative ventures.

   1.4. The international cooperation with respect to:
   1.4.1. the level of risk regarding the provision of payloads and implementation of missions;
   1.4.2. the impact of export regulations.

   1.5. The Agency's cooperation with the European Union with a view to exploiting the potential for improvements vis-à-vis the Scientific Programme.

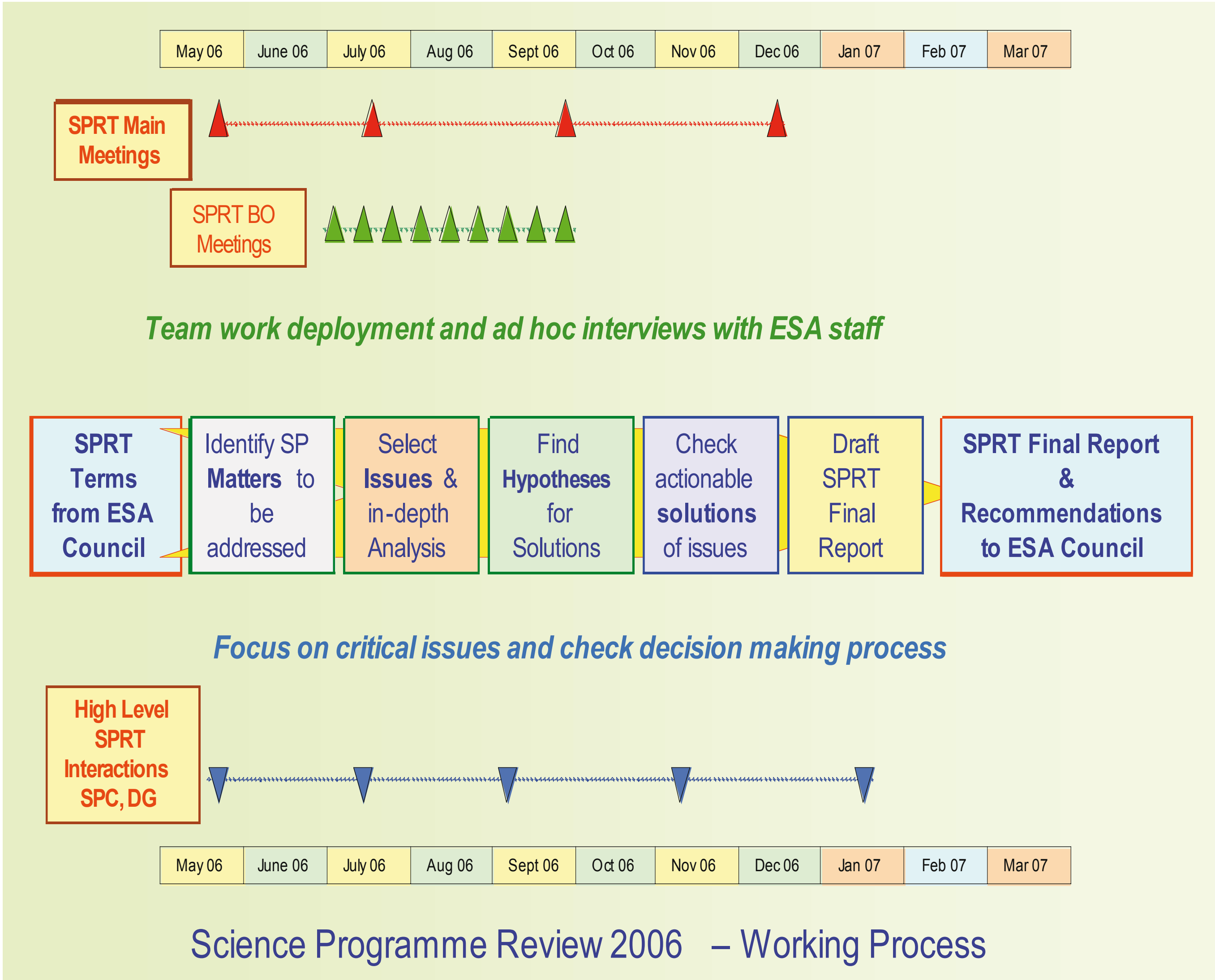
2. Working methods

Except if otherwise decided, the Chairperson and Secretary of the Agency's Science Programme Committee shall attend meetings of the Review Team.

The Review Team may interview members of the ESA staff or any other external experts as needed.

The SPRT Working-Process

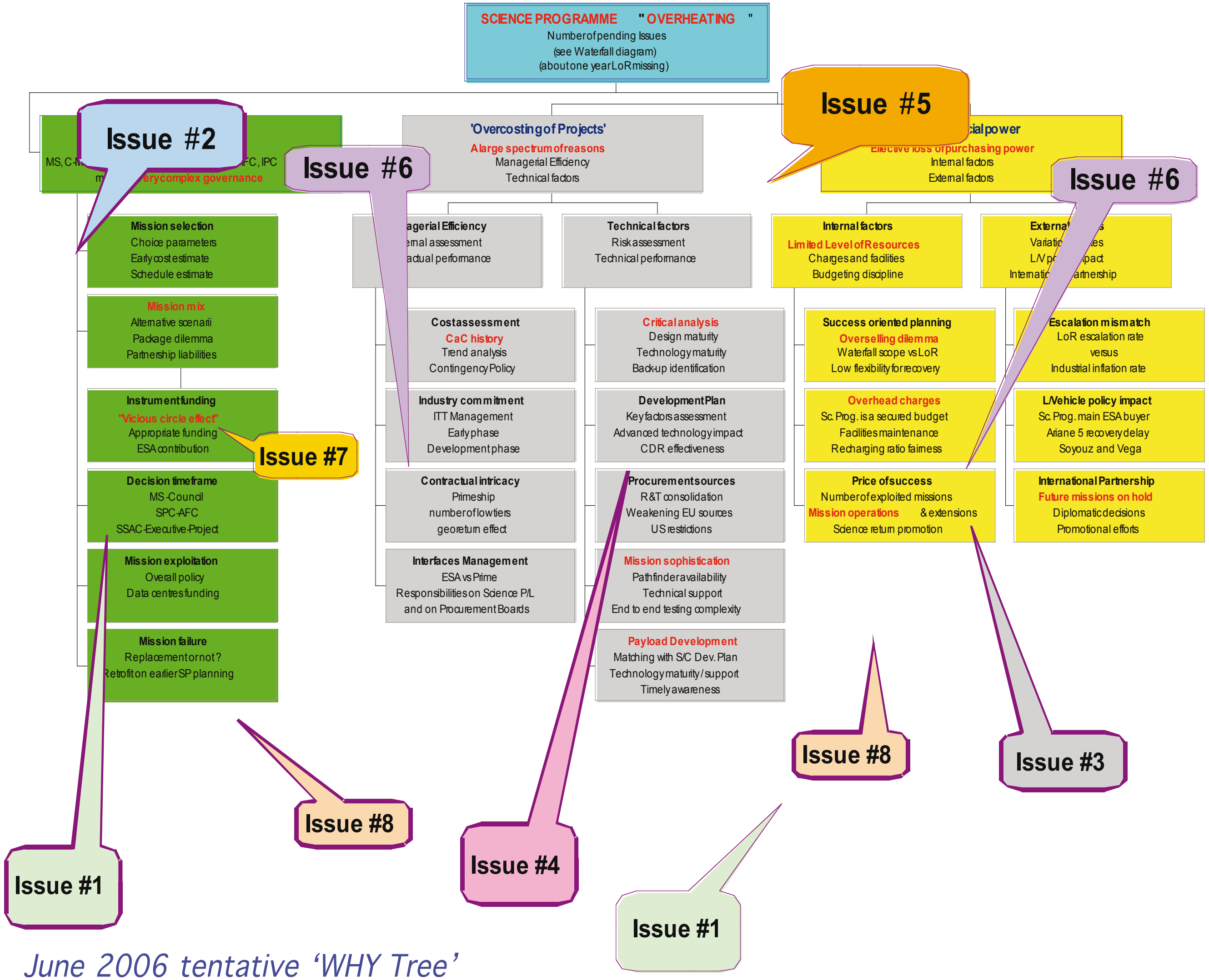
Appendix II



1

Appendix H

Main Issues for Initial Review



June 2006 tentative 'WHY Tree'

Appendix IV

Interactions between the SPC and the Executive

Meetings

Director General	2 November 2006, 17 January 2007
Director of Science	18 & 19 May, 2 November, 7 November

Science Directorate

B Bastijns	}	
J Clavel	}	
J van Casteren	}	
M Coradini	}	
L Hennessy	}	
M Kessler	}	
A Linsen	}	
J Louet	}	VARIOUS DATES
D Martin	}	
H Olthof	}	
T Passvogel	}	
A Peacock	}	
M Perryman	}	
S Volonte	}	

Legal Service

M Ferrazzani	ESTEC, June; Paris, November
M Torrado	ESTEC, June; Paris, November

Finance Department

M Brady	Paris, September
F Petitjean	Paris, September
G Kreiner	ESTEC, September
D Parpex	Paris, September

Procurement Department

E Morel	Paris, November

Directorate of Operations

M Warhaut	ESOC, August; Paris, September
H Nye	ESOC, August
J-J Gujer	ESOC, August
V Gomez	VILSPA, September

Inter-Directorate Reform of Corporate & Risk Management

M Tabbert	ESOC, August

Directorate of Technical and Quality Management

M Courtois	ESTEC, July

Directorate of Launchers

A Fabrizi	Paris, September

Directorate of Human Spaceflight and Microgravity

D Sacotte	ESTEC, September

Other Meetings

SPC Chair	8 March, 18 & 19 May, 26 & 27 June, 7 September, 28 & 29 September, 7 November, 17 January 2007
SPC Vice-Chair	21 August
SPC	7 September, 7 November
R Pellinen	3 November
SSAC	Chairman G Bignami (telecon), C Turon and T de Zeeuw

Endorsement by ESA Council

Council congratulated everybody involved in the Report, in particular the Members of the SPRT and the Science Programme Committee (SPC), on the excellent report and forward-looking response.

The Director of Science and the Director General confirmed that the Executive would implement all of the Recommendations. The Director General considers that the Report has relevance not only for the Science Programme, but also in other areas of ESA in the context of the ongoing reform process. The Executive will come back with one or two interim reports on progress in all of the axes that are outlined in the Report and with an action plan before the end of 2007.

BR-267, April 2007

Prepared by:	The Executive Secretary at the Science Programme Review Team (SPRT)
Published by:	ESA Publications Division ESTEC, PO Box 299 2200 AG Noordwijk The Netherlands
Editor:	Bruce Battrick
Layout:	Jules Perel
Copyright:	© 2007 ESA
ISSN:	0250-1589
ISBN:	92-9221-003-3
Price:	10€
	Printed in the Netherlands