Technology R&D Programme Support to Future ESA Science Missions

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ESA's Directorate of Scientific Programmes has recently introduced a novel approach aimed at reducing the costs and minimising the risks associated with the procurement and implementation of its missions. This approach hinges on two complementary elements: technology preparedness and new management practices. The first aims at reducing the risk of unavailability of key technologies during the actual project development phases and thus avoiding substantial delays and cost increases. The second focuses on the need to lower overall mission-management costs.

ESA Bulletin No. 95 (August 1998) reported on the new management practices, and so this article focuses on the technology-preparedness aspect. It provides an overview of the objectives, the main challenges, the programmatic aspects and the current status of the recently approved Science Technology R&D Programme that ESA is pursuing to support its future missions.

The ESA Science Technology R&D Programme

The strategic need to achieve technology preparedness can be considered from two different points of view, which in turn imply two different but complementary objectives. On the one hand, technology preparedness can be seen as a 'means', aimed at consolidating the 'realism' of the ESA Science Programme. The first main objective is thus:

"To develop the necessary technologies on time and within budget, by reaching a readiness level equivalent to an elegant breadboard or an electrical model, tested in the relevant environment before the beginning of Phase-B, with the aim of minimising schedule delay and cost increases, at a late stage in the programme".

On the other hand, technology preparedness can be considered as the 'scope' itself of the Technology R&D Programme. The second main objective is therefore:

"To maintain and expand European technological knowhow, by setting up a coherent and ambitious R&D Programme, in order to increase the competitiveness and the technological independence of Europe from to the other world players in the space sector".

The future ESA science missions and their technology challenges

On 13 September 2000, the Science Programme Committee (SPC) was presented with the results of the studies carried out during the previous three years, which defined the mission concepts and identified the technology needs for the four 'Cornerstones' of the ESA Science Programme:
- BepiColombo: a planetary mission to Mercury
- GAIA: an astrometric mission to unveil the origin and evolution of our Galaxy
- DARWIN: an interferometric mission for the detection and spectroscopic characterisation of terrestrial exoplanets
- LISA: a fundamental-physics mission for the detection of low-frequency gravitational waves.

The bulk of the Science Technology R&D Programme is completed by development activities related to two other missions:
- SMART-2: a Small Mission for Advanced Research in Technology, a precursor of DARWIN and LISA, which will flight-test some of their key enabling technologies
- XEUS: an X-ray imaging and spectroscopy mission, to establish the evolution of the early Universe.

Finally, at a lower level, resources have been made available also for technology developments within the framework of the NGST (Next-Generation Space Telescope) mission, and for long-term activities not yet related to a specific mission.

The BepiColombo mission
BepiColombo is a mission to Mercury, the innermost planet of our Solar System, aimed at characterising its internal structure, its surface features and composition, its magnetic field and planetary environment. It consists of three scientific elements, namely two orbiters and a lander.

The first orbital element, the Mercury Magnetospheric Orbiter (MMO), provided by ISAS (Japan), is a small spinning spacecraft, which will be placed in an elliptical orbit (400 km by 12 000 km) around Mercury. It will be equipped with a range of field and plasma experiments to allow analysis of the magnetospheric physics of the planet. The Mercury Planetary Orbiter (MPO), a three-axis-stabilised spacecraft, is the second orbital element and will be placed in an elliptic polar orbit (400 km by 1500 km). It will carry a range of remote-sensing instruments to study Mercury's surface and interior. The Mercury Surface Element (MSE) is the lander element, which will analyse the planet's chemical and surface properties for a period of at least 7 days. Transfer to Mercury is achieved using a combination of planetary swing-bys, solar electric and chemical propulsion.

BepiColombo's launch is currently foreseen for summer 2009. More information about the mission and its scientific objectives can be found at:
http://sci.esa.int/home/bepicolombo/index.cfm

Two main drivers have dictated BepiColombo's pecific technology domains:
- the harsh thermal and radiation environments to which the model payloads will be subjected
- the need for miniaturisation and mass reduction due to the high Delta-V.

As far as the first driver is concerned, the main technological domains encompass:
- thermal-control technologies, including insulation materials, thermal coatings, heat pipes, optical solar reflectors, dichroic elements, and louvers; solar-array technologies, encompassing development at cell, module and array level, and testing under high temperatures and high light-insolation conditions
- antenna system technologies: reflector materials; RF components like wave-guides, feeds, rotary joints; two-axis steering and de-spin mechanisms.

The second driver requires that significant technology development, for mass and power saving, has to be carried out in areas such as: landing systems (to alleviate the shock at touchdown); avionics systems and vision-based descent and landing navigation systems; high-energy-density batteries; cameras and robots for in-situ geochemical and geophysical measurements.

A total of thirty-three activities, involving an overall investment of more than 25 MEuros, have been identified for the BepiColombo Technology Programme, to be developed in the 2001–2003 time frame in line with the start of the programme's main design phase (Phase-B).

Figure 1 illustrates some of main features related to BepiColombo technology development.

The GAIA mission
GAIA's primary scientific goal is to clarify the origin and evolution of our Galaxy. The mission will provide unprecedented positional and radial velocity measurements with outstanding accuracy (10 µarcsec at 15 mag and 5 km/s at 18 mag, respectively). Such demanding requirements are necessary in order to make a stereoscopic and cinematic census of about one billion stars in our Galaxy, which represent about 1% of the galactic stellar population.

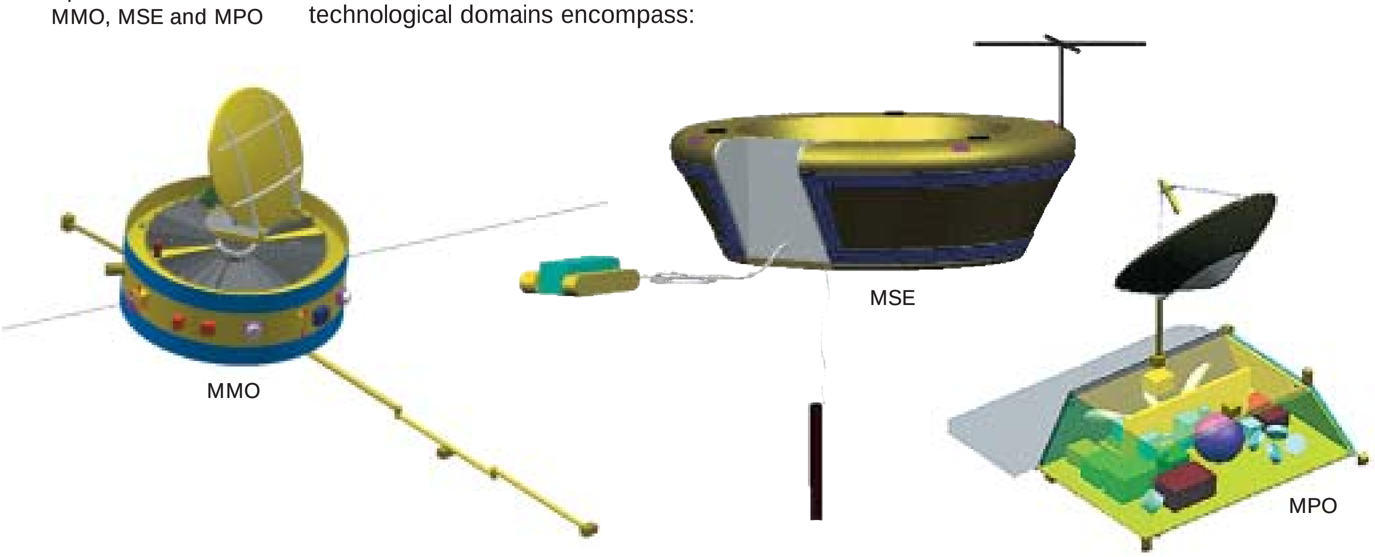

Figure 1. The scientific elements of the BepiColombo mission: MMO, MSE and MPO

Combined with astrophysical information for each star, provided by the onboard multicolour photometry, these data will have the precision and depth necessary to address key questions associated with the formation of the stars in the Milky Way and the distribution of so-called 'dark matter' in our Galaxy.

The three-axis-stabilised spacecraft will use its onboard propulsion system to reach its final orbit, around the L2 Lagrangian point of the Sun – Earth system, after about 200 days of cruise. For 5 years, the 1700 kg spacecraft will scan the heavens at a rate of 2 arcmin/sec, and will deliver an equivalent science data rate of about 1 Mbps, corresponding to an impressive overall data volume of several Terabytes (10^{12} bytes).

At its October 2000 meeting, ESA's Science Programme Committee recommended a launch date for GAIA of no later than 2012. More information about the mission and its scientific objectives can be found at:
http://sci.esa.int/home/qaia/index.cfm

Three demanding design features drive the requirements of the GAIA payload:
- a complex and compact optical design, which features two identical three-mirror telescopes, plus two astrometric instruments and a third three-mirror spectrophotometer (Fig. 2)
- an array with a very large number of CCDs (~250) in each of the three focal planes, with associated video lines (>300), which in turn implies demanding onboard real-time data-handling requirements
- an opto-mechanical bench with extreme thermal-stability requirements (30 µK over 3 hours) comprising a large octagonal structure (4 m in diameter) equipped with a large mirror made of the same material (Fig. 2).

The 13 MEuro investment spread over the fifteen development activities identified for the GAIA Technology Programme reflects these technological challenges and includes the development and manufacture of:

- a large (1.7 m x 0.7 m), lightweight, silicon-carbide mirror
- a large mosaic of CCD arrays (700 mm x 600 mm), needed for the three Focal-Plane Assembly instruments
- a metrology system for the measurement and active control, down to few picometres accuracy, of the relative positioning of the two telescopes
- high-speed, low-power data-handling electronics and related software for data readout (several Mbps), thresholding, compression and storage (300 Gbit), before safe transmission to the ground at about 3 Mbps.

Other GAIA technology development activities include the qualification of a reaction-control system based on Field-Emission Electric Propulsion (FEEP) technology for spacecraft attitude control during observations, and the development of a representative prototype of the large Deployable Solar Array/Sun Shield assembly (9 m in diameter).

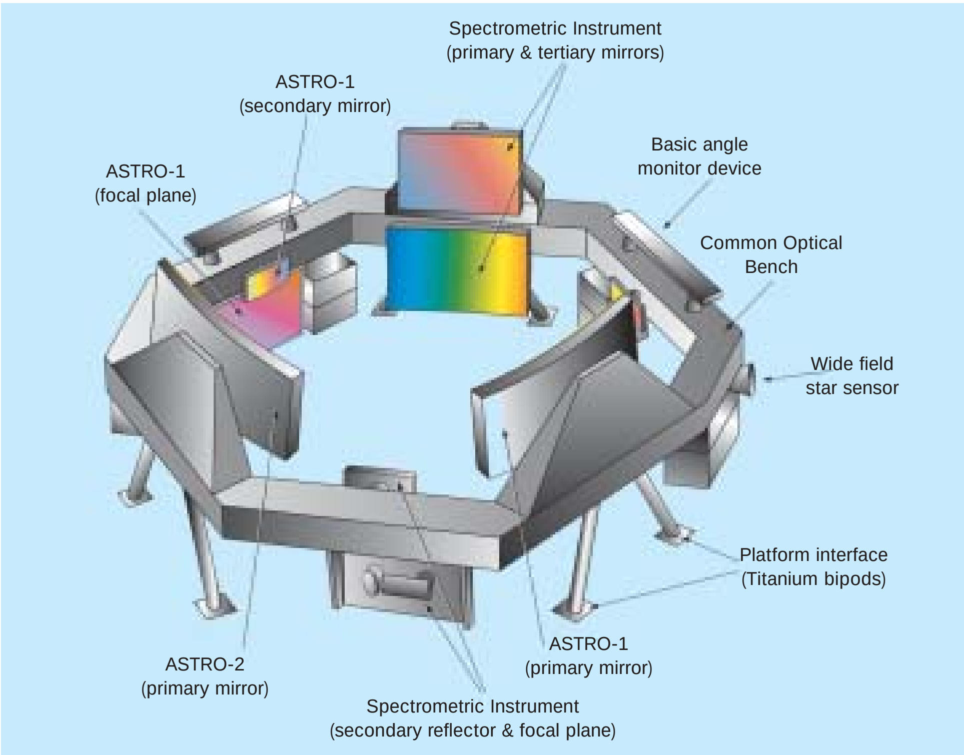

Figure 2. The GAIA three-mirror spectrometer

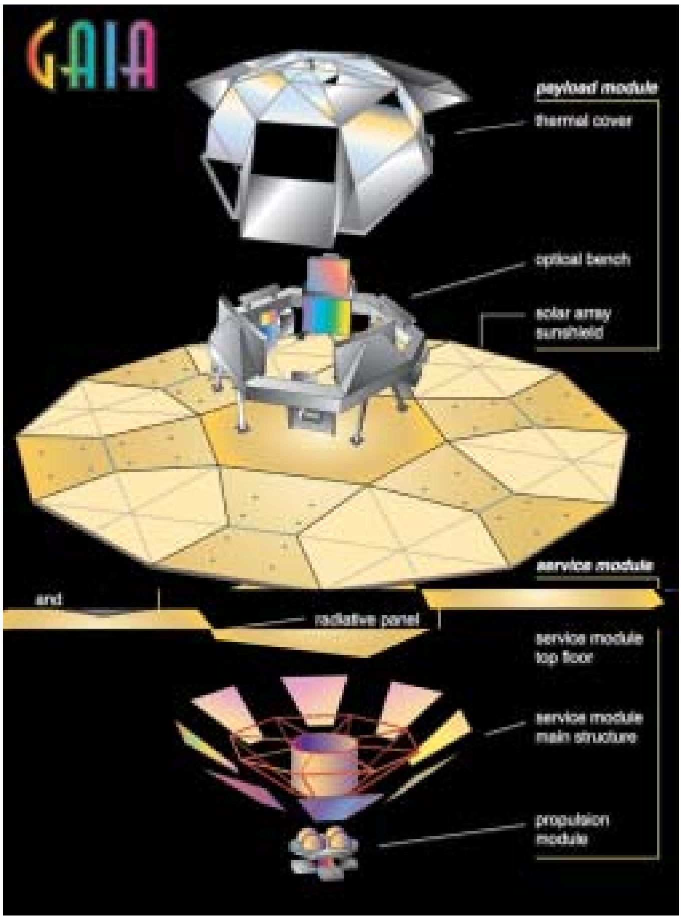

Figure 3. Exploded view of the GAIA satellite

Figure 3 is an exploded view of the GAIA satellite, with some of the main features related to GAIA technology development indicated.

The DARWIN mission
DARWIN (Detection and Analysis of Remote Worlds by Interferometric Nulling) is a multiple-spacecraft mission to perform nulling interferometry in the medium- and far-infrared wavelength bands, with the prime objective of detecting and spectroscopically characterising terrestrial exoplanets. It consists of six free-flying spacecraft in a hexagonal configuration, each equipped with a 1.5 m-diameter telescope that collects the incoming photons and transmits them to a seventh beam-combining spacecraft. The latter, positioned at the centre of the satellite formation, is equipped with optical benches for both the nulling interferometry and imaging functions. An eighth spacecraft is dedicated to overall management of the constellation, data handling and communication to and from the Earth and the other seven spacecraft (Fig. 4).

A dedicated Ariane-5 launch, together with a suitable chemical or electric-propulsion stage for cruise and orbit insertion, will place DARWIN at the L2 Lagrangian point of the Sun-Earth system.

Figure 4. The Darwin multiple-spacecraft mission

Formation flying will be achieved by a combination of GPS techniques, high-precision laser metrology, and accurate low-thrust electric propulsion, keeping the optical path differences between spacecraft below 20 nm. On-axis star light will be cancelled by using suitable phase-shifting techniques, while planetary light collected by the different telescopes will have a phase difference proportional to the off-axis angle of the planet and will thus not be nulled.

DARWIN is scheduled for launch in the 2014 time frame.

More information about the mission and its scientific objectives can be found at:
http://sci.esa.int/home/darwin/index.cfm

Such a complex satellite configuration, combined with the demanding scientific requirements, has imposed the need to initiate an ambitious technology programme. Over the next three years breadboard developments will take place in several areas:

– Radio-frequency (RF) ranging and goniometry systems, together with laser metrology and an interferometric fringe tracker, are needed to acquire and maintain the six-telescope constellation geometry and to point it precisely towards the selected target. The actual geometry of the constellation will have to be measured with linear and angular accuracies of a few nanometres and a few microarc-seconds, respectively.

- Field-Emission Electric Propulsion (FEEP) systems, with their ability to provide extremely low, accurate thrusts (10^{-6} Newton), will be developed to counteract the tiny forces disturbing the constellation geometry.
- Medium- and far-infrared detectors ($\lambda = 6$ – 25 micron) technology and related front-end electronics need significant development in order to provide the required low dark current and good quantum efficiency at temperatures compatible with standard passive cooling techniques.
- As an alternative solution, vibration-free, low-power (10 mW) coolers need to be developed for the focal-plane detectors.
- Optical components and assemblies mounted on the beam-combining satellite and including achromatic phase shifters for nulling interferometry; integrated optics for combining in single monolithic devices functions like beam-splitting, front-end filtering, beam combining; fibre-optics for wave-front filtering, operating in single mode over the infrared spectral range ($\lambda = 1$–20 micron); dichroic components; optical delay lines; and high-stability optical benches.

Although DARWIN is not due to be launched before 2014, substantial development and verification of key technological issues needs to be carried out via precursor experiments. For this reason, in collaboration with the European Southern Observatory (ESO), ESA will develop a nulling-interferometer breadboard, equipped with a suitable optical target simulator for its validation. The breadboard will be integrated into the Very Large Telescope Interferometer. This nulling-interferometer precursor will be operational in 2005 and will characterise the DARWIN targets with respect to exo-zodiacal light.

In parallel, the SMART-2 mission, to be launched in 2006, will provide in-orbit demonstrations of other key technological challenges.

More than twenty activities have been identified for the DARWIN Technology Programme, for an investment of some 12 MEuro.

The LISA mission

Predicted already at the beginning of last century by Einstein’s Theory of General Relativity, gravitational waves have so far eluded actual detection. The Laser Interferometry Space Antenna, or LISA, is the first ESA Cornerstone mission in ‘Fundamental Physics’. It has the daunting objective of detecting tiny changes in relative distance due to the passage of gravitational waves.

To do this, three spacecraft will be positioned at the vertices of an equilateral triangle, with sides about 5 million km long (Fig. 5). Each spacecraft will contain two ‘proof-masses’, which will be kept in a ‘free-fall’ environment shielded from all forces except gravity. The mutual position of each proof-mass with respect to its ‘companion’ in the other spacecraft 5 million km away is continuously measured by means of a sophisticated optical system. The configuration forms a giant Michelson-type interferometer with three arms, in which the proof masses are effectively adjustable elements. The passage of gravitational waves will move the proof-masses by a fraction of an Angstrom (10^{-10} m), changing the length of the optical path of one arm of the interferometer with respect to the others.

The LISA mission is planned as a joint venture with NASA, with a launch in 2010. More information about the mission and its scientific objectives can be found at:

http://sci.esa.int/home/lisa/index.cfm

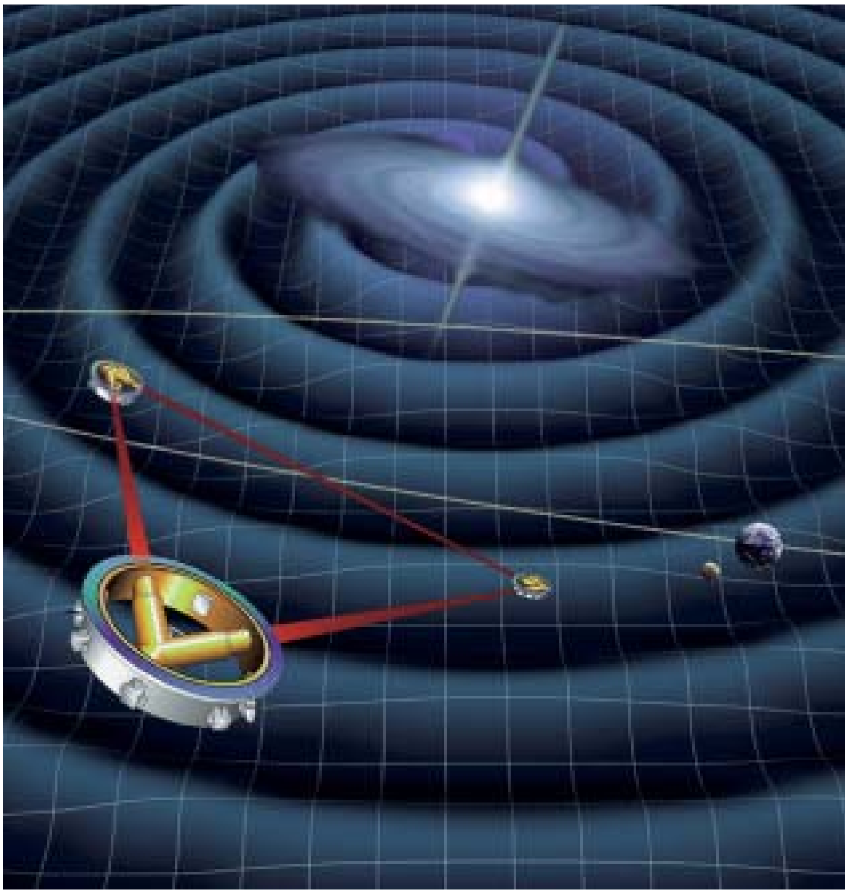

Figure 5. LISA: Laser Interferometer Space Antenna

LISA's scientific objectives make it one of the most complex ESA Cornerstone missions. Like DARWIN, it requires both a considerable technology development plan and the verification of key technologies by means of a precursor mission, namely SMART-2. The technology needs stem mainly from the necessity to distinguish between relative displacements between the two proof masses induced by gravitational waves and those induced by spurious forces.

LISA is heavily reliant on the development of a series of technologies that include:

– Inertial acceleration sensors, based on capacitive displacement measurement of the proof masses with respect to the spacecraft, for which the spectral amplitude of the inertial acceleration should be measured and kept below 3×10^{-15} m sec^2 Hz$^{-1/2}$.
– A Field-Emission Electric Propulsion (FEEP) system capable of providing thrusting at micro-Newton levels (10^{-6} N). Such a system, commanded in a feedback loop by the inertial acceleration sensor, is baselined for the precise control and positioning, with nanometer accuracy, of the LISA spacecraft with respect to the proof masses. In this way, the masses can be kept isolated from spurious forces and in a 'free-fall' condition.
– Thrust-measurement instruments with 1×10^{-9} N accuracy for the characterisation of the above FEEP system.
– A high-power, high-stability Nd:YAG laser.
– Pointing systems for two separate lasers 5 million kilometres apart with nano-radian angular accuracy.
– Laser interferometry between the proof masses using heterodyne techniques and a slowly varying phase difference between the two laser beams. Critical elements in such a subsystem include high-sensitivity photodiodes, ultra-stable oscillators, etc.

The complete LISA Technology Development Programme is made up by more than fifteen activities to be developed in the next four years, at a cost of 11 MEuro.

The SMART-2 mission

The Small Missions for Advanced Research in Technology are tasked with testing key technologies for future ESA Science Cornerstone missions. While SMART-1 has been conceived for demonstrating the feasibility of electric propulsion for deep-space propulsion, preparing the way for missions like BepiColombo, SMART-2 will pave the way for DARWIN and LISA.

As a mission involving two spacecraft flying in formation, SMART-2 will demonstrate LISA technology in three areas: inertial sensor performance, spacecraft position control, and laser interferometry between proof masses (Fig. 6). SMART-2 will also demonstrate DARWIN technology in terms of the formation-flying performance of two spacecraft capable of sustaining nulling interferometry. It is envisaged that coarse metrology (based on RF ranging and goniometry) and intermediate metrology (based on a laser metrology system), capable of positioning the spacecraft with micron accuracy, will be demonstrated, together with the related FEEP actuators and guidance, navigation and control system.

More information about the SMART-2 mission and its scientific objectives is available at:
http://sci.esa.int/home/smart-2/index.cfm

The XEUS mission

The X-ray Evolving Universe Spectroscopy (XEUS) mission will be the powerful successor

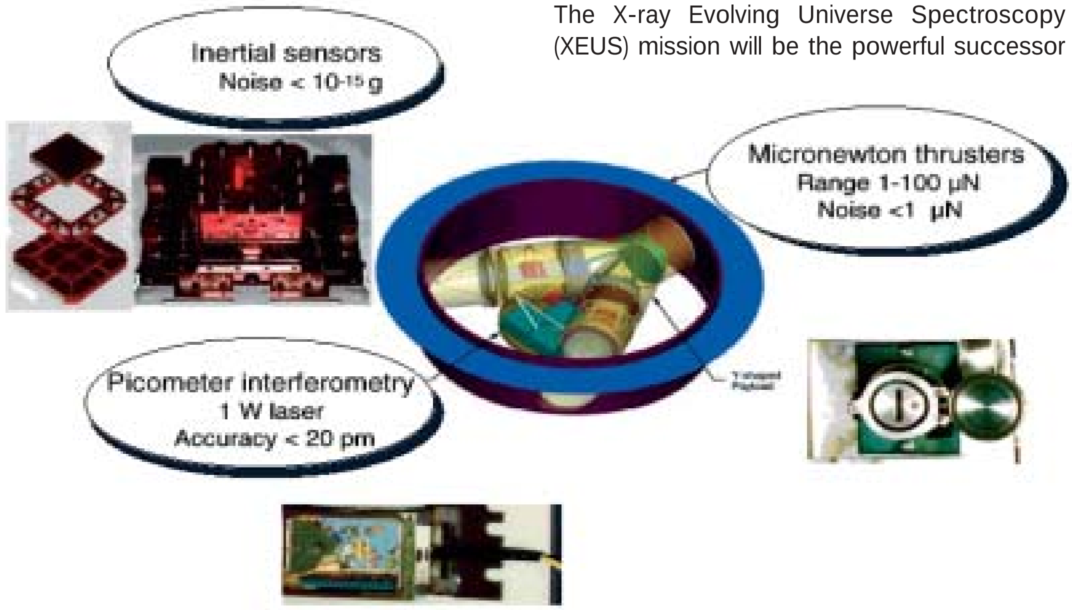

Figure 6. SMART-2 key technologies

Figure 7. XEUS: the X-ray Evolving Universe Spectroscopy mission

to the European and American X-ray observatories XMM-Newton and Chandra. The formation and evolution of the Universe is at the heart of the XEUS science case. Supermassive black holes, which emit most of their energy in the X-ray band, seem to have played an important role in the formation and present structure of our Universe. They can probably only be detected in the electromagnetic band in which XEUS operates because of their high contrasts with respect to other objects and their low absorption by the intergalactic medium.

XEUS is characterised by a large, free-flying, grazing-incidence mirror assembly of some 20–30 m^2 collecting area at 2 keV, with an angular resolution of about 2–5 arcsec and a spectroscopic resolution of about 2 eV. The X-rays collected by the mirror assembly are focussed 50 m or more away onto a separate free-flying detector assembly, equipped with novel semiconductors and superconductor detectors. Both assemblies will be flying in formation in a low Earth orbit (Fig. 7).

When completed, the XEUS facility will be some 250 times more sensitive than the XMM-Newton telescope. It will be constructed in stages, using the International Space Station (ISS) as a base. Launch of the first stage is planned around 2012. For more information about the mission and its scientific objectives, visit:

http://sci.esa.int/home/xeus/index.cfm.

The highest priority for the XEUS Technology Programme are the X-ray optics, based on open-surface Wolter-I mirror elements integrated into units called ‘petals’. The mirror technology development has benefitted from the extensive investment already made by ESA in the X-ray optics for the XMM-Newton mission, allowing European industry to acquire a world-leading position in this field of technology.

However, further developments are required to meet the XEUS mirror requirements in terms of new mirror geometry and methods for their support, lower mass, higher spatial resolution (< 2 arcsec), and cost-effective production.

The potential instrument detectors include semiconductor wide-field imagers, narrow-field cryogenic superconductors and bolometric spectrometers, will also require substantial research and development. Proper cooling of the detector arrays to cryogenic temperatures (50 mK), with adiabatic demagnetisation techniques and the development of low-noise, large-bandwidth front-end electronics, based on a Superconducting Quantum Interference Device (SQUID), will also need to be developed.

At the spacecraft level, the major technology developments will focus on compatibility with the International Space Station (ISS) and the formation-flying of the two spacecraft, including the solar-electric-propulsion elements.

The complete XEUS Technology Development Programme is made up of thirteen activities to be developed over the next four years. The total investment plan corresponds to about 11 MEuro.

The preparation and harmonisation of the R&D programme

The Future Project Studies and Technology Office, in co-ordination with the other ESA Directorates, has set up a complete, coherent and realistic R&D Programme, following a three-step plan. The first step focussed on an assessment of the technology requirements for each future mission. During this phase, the study managers, together with the study scientists from ESA Space Science Department (SSD), critically reviewed and selected the technology activities proposed by the industrial contractors, who were responsible for the preliminary system designs for the different future missions. In a second phase, with the support of the Industrial Matters and Technology Programmes Directorate, the selected activities were harmonised by identifying overlaps and synergies with the other ESA Technology Programmes. The third step concentrated on the more detailed definition of the various technology activities. Together with the staff of the Technical and Operational Support Directorate, considerable effort was devoted to the clear identification of the objectives for each technology activity. In-depth definition of the technical requirements, detailed assessment of the duration of each activity and a critical review of allocated budgets were at the centre of this exercise.

The plan that has emerged for Science is thus an integrated element of the ESA-wide Technology Plan.

This co-ordinated effort has led to the establishment of a complete set of Technology Schedules for each future mission, and and of a detailed Technology Work Plan covering the 2000–2004 time frame. The latter was submitted to and unanimously approved by ESA's Industrial Policy Committee (IPC) in December 2000. Both the technology schedules and the Work Plan can be accessed via the ESA Science web site :
http://sci.esa.int

At the same time, the evolution in the procurement approach for the future missions foresees the selection of two Prime Contractors for each mission-definition phase. Both Primes will be closely associated, via ESA, to the development of the technology activities. They will support ESA in the analysis and assessment of their progress, and will inject relevant requirements and constraints stemming from mission-level design. This approach should lead to the development of the technology activities being fully in line with the assumptions at spacecraft system level, and if successfully developed, to their endorsement. Last but not least, it should allow the Primes provide a more reliable bidding price, because of their increased knowledge of, and confidence in, these key mission-enabling technologies.

Financial envelope

The ESA Science Technology Work Plan for the years 2000-2004 comprises more than 110 technology development activities, with a total budget of more than 80 MEuro. It builds upon activities identified and funded by the various ESA Technology Programmes, which can be summarised as follows:

- Activities carried forward from the previous plans, funded by the Technology Research Programme (TRP) and the General Support Technology Programme (GSTP) budgets.
- Activities currently identified in the 2000-2002 TRP plan.
- Activities identified and funded in the Science Core Technology Programme (CTP).
- Activities identified as 'mission preparatory'.

These technology activities, funded from different budgets, generally have different goals in term of technology maturity or readiness. The feasibility demonstrations and breadboarding are usually funded from the Technological Research Programme budget. The Science Core Technology budget will mainly be used to reach a higher technology maturity level (electrical model), while the Mission Preparatory Activities will address the adaptation of mature technologies to specific mission requirements.

The Work Plan is long-term oriented. Reviews and updates in support of newly approved scientific missions, potential candidates for future missions or specific projects' needs, are foreseen at periodic intervals. The objective is to ensure a constant level of resources to allow a consistent technology development effort in the years ahead. Although the current approach foresees linking technological research activities to specific missions, in order to provide a framework in terms of schedule and end-product, many technologies will have much wider ramifications and relevance. This is particularly true for technologies that will be developed within the framework of the LISA, DARWIN and XEUS missions.

Management tools

One of the key requirements when working on projects involving many organisations and

individuals is the need for easy on-line access to and dissemination of accurate, up-to-date information. In this regard, a special Information System has been created for the Science R&D programme in order to gather and rapidly distribute all of the information related to the 113 activities, which involve more than 100 people in various ESA Directorates at ESTEC. This Information System includes:
- a Technology Development Activities Database
- a Technology Document Management System.

From an initial Microsoft Access application, the Development Activities Database has rapidly evolved into a web-based Oracle database, now known as the Science Technology Information System (STIS), which all of the parties involved can easily access. The system allows the user to browse through the information for each activity, ranging from the technology objectives to technical notes, reports and requirements documents, from costs to programmatic assumptions and schedules, from the list of people involved to its current status. It can be used both as an archive to find the details concerning specific activities, and as a reporting tool for system-level analysis and assessments.

The Technology Document Management System (DMS), developed within the ESA Scientific Programmes Department, complements the Database. Its main functions include:
- Registration: recording all information regarding a document, and maintaining version control.
- Archiving: safe and controlled storage of electronic document files.
- Search: location of documents through registration attributes.
- Retrieval: on-line availability of electronic document files.
- Distribution: electronic distribution of documents.
- External Collection: integration of documents sourced externally (files, e-mails, faxes).

Figure 8 shows the DMS screen layout with available search functions.

Present status, prospects and conclusions

Since December 2000, when the Science R&D Technology Plan was approved by the Industrial Policy Committee, the Future Projects and Technology Office has initiated an intense plan of action. In close co-ordination with Directorate of Technical and Operational Support, Space Science Department, and Directorate of Industrial Matters and Technology Programmes staff, considerable effort has been focussed on trying to speed-up the preparation, review and final issue of the technical and contractual documentation needed for the timely award of the industrial contracts.

In the meantime, the System Definition Phase for BepiColombo has started in May 2001, with the two Primes already engaged in the assessment of the technology activities. The System Definition Phase for SMART-2 has just started, in September.

It is still premature to judge, on the basis of the present results, whether the Science R&D Programme will achieve the overall objectives outlined at the beginning of this article. However, the results obtained so far allow us to maintain a confident outlook for the successful implementation of this huge and challenging programme.

Acknowledgements

The Future Projects and Technology Office wishes to acknowledge the substantial efforts of the many colleagues in ESTEC, working in D/TOS, D/IMT and SSD, who have contributed greatly to the creation of this Technology Programme and hopefully to its successful implementation.

Figure 8. The Technology Document Management System (DMS)

The ESA Scienceâ€™s Voyage 2050 missions promise insights into the big existential questions of our era: the prevalence of life in the Universe; the nature of space and time; and the intertwined nature of matter, energy and gravity. It is likely that innovations in the acquisition, handling and processing of vast data sets will drive these themes to scientific maturity in the next decades.Â This white paper is a modest attempt to support ESA Science improve its engagement with society. It focuses on issues and topics to improve ESA Scienceâ€™s Education and Public Engagement activities. It does not dwell on the topics that ESA already excels at; hence this White Paper provides a critical review of what should and could be improved. ESA is responsible for R&D of space projects. On completion of qualification, they are handed to outside entities for production and exploitation. Most of these entities emanated from ESA.Â Science operations include the interface with scientific users, mission planning, payload operations and data acquisition, processing, distribution and archiving. The scientific archives for the majority of ESAâ€™s science missions are kept here ESA so thatUNCLASSIFIED - For rOfeficsiael Uaserchers have a single â€˜entry pointâ€™ for accessing the wealth of scientific data. ESA | 11/01/2017 | Slide 38. Science missions in development and operation.Â Logic of technology programmes; prepare ESA missions. ESA technology roadmaps: Describe future ESA needs in technology development. The future ESA science missions and their technology challenges On 13 September 2000, the Science Programme Committee (SPC) was presented with the results of the studies carried out during the previous three years, which dened the mission concepts and identied the technology needs for the four â€˜Cornerstonesâ€™ of the ESA Science Programme: â€“ BepiColombo: a planetary mission to Mercury â€“ GAIA: an astrometric mission to.Â technologies to support future esa science missions. Combined with astrophysical information for each star, provided by the