esa bulletin

number 99 - september 1999

European Space Agency
Agence spatiale européenne

european space agency

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(c) by co-ordinating the European space programme and national programmes, and by integrating the latter progressively and as completely as possible into the European space programme, in particular as regards the development of applications satellites;
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agence spatiale européenne

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Editorial/Circulation Office
ESA Publications Division
ESTEC, PO Box 299, Noordwijk
2200 AG The Netherlands
Tel.: (31) 71.5653400

Editors
Bruce Battrick
Duc Guyenne
Dorothea Danesy

Layout
Carel Haakman

Graphics
Willem Versteeg

Montage
Paul Berkhout

Advertising
Brigitte Kaldeich

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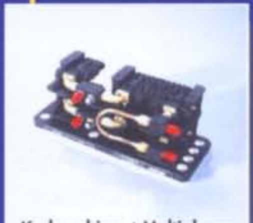
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ISO's Astronomical Harvest Continues*

M.F. Kessler, A. Heske, L. Metcalfe, T. Prusti & A. Salama
ISO Data Centre, Astrophysics Division, Space Science Department,
ESA Directorate for Scientific Programmes, Villafranca, Spain

Last autumn, nearly 400 astronomers gathered in Paris for a week-long discussion and review of ISO results, as presented in some 300 papers. This article presents a handful of ISO's many results, selected - mainly from the Proceedings (ESA SP-427) of the Paris meeting - both to show the breadth of the scientific fields being impacted by ISO and to complement results that have previously appeared in the 'In Brief' pages of the Bulletin. ISO has delivered a wealth of new results, spanning long-awaited confirmations of models to unexpected surprises and from our own Solar System out to the most distant extragalactic sources.

Introduction

During its 29-month operational lifetime in orbit, ESA's Infrared Space Observatory (ISO) provided astronomers with a facility of unprecedented sensitivity, wavelength coverage and spectral resolution for exploring the sky at infrared wavelengths. It carried four scientific instruments: two spectrometers each with a medium and a high spectral resolution mode, a camera, and an imaging photo-polarimeter. ISO made nearly 30 000 individual scientific observations of all types of astronomical objects and the data have been re-processed homogeneously and are now available to the entire astronomical community via the World Wide Web.

Solar System

Deuterium-to-hydrogen (D/H) ratio

The abundance of deuterium - the heavy isotope of hydrogen - in the giant planets and in comets is one of the keys to understanding how they formed. Our Solar System is believed to have formed out of a protosolar nebula composed of gas and grains. In Jupiter and Saturn, the lighter elements of the gas such as hydrogen (H) and deuterium (D) constitute the bulk of the planets' mass, with only a small fraction (3% for Jupiter, 10% for Saturn) being made of an icy/rocky core of solid material. It is therefore likely that the deuterium abundances in these two planets represent those of the gaseous part of the protosolar nebula. On the other hand, Uranus and Neptune may have been enriched in deuterium by the mixing of their atmospheres with comparatively much larger cores (more than 50% of their mass) containing deuterium-rich icy grains. Therefore, measuring the D/H ratios in the giant planets and using interior models provides important information on the early history of our Solar System.

ISO provided a coherent and direct determination of the D/H ratio in the four giant planets through the first detections of HD rotational lines (Fig. 1). The results are in agreement with the value obtained by the Galileo probe for Jupiter and are compatible with independent measurements of the protosolar value. On Uranus and Neptune, the D/H ratio is consistent with the current understanding of planetary evolution. The inferred D/H ratio for their icy cores is three times less than that found on comets, implying a different time and/or location for their formation.

Planetary atmosphere composition and structure

ISO observations have enhanced our knowledge of the composition and turbulence of the atmospheres of the giant planets. New hydrocarbons have been detected (CH_3CCH, C_4H_2, C_6H_6 on Saturn; CH_3 on Saturn and Neptune). These components of the planet's stratosphere are produced by photochemistry of methane through complex reaction schemes. Different species have different vertical distributions, so that their relative abundances allow reconstruction of the strength of the vertical transport as a function of altitude. ISO data also show evidence for ammonia clouds on Jupiter, best understood in terms of a two-cloud model, with 10-micron-sized particles in the upper cloud.

Water in planets and comets

A surprise obtained with ISO was the first detection of external water in the stratospheres of all of the giant planets and Titan (Fig. 2). Water is expected to be present deep in their atmospheres, because during their formation they incorporated oxygen, for which H_2O is the main carrier. This water, however, condenses out in the troposphere, as the temperature

* Additional information on ISO, including results galleries and how to retrieve data, can be found by following links from the ISO Home Page (www.iso.vilspa.esa.es); news items are also posted at www.sci.esa.int. Previous ESA Bulletin articles have addressed the data archive (Arviset & Prusti, No. 98, June 1999); the ISO operations (Kessler, Clavel & Faelker, No. 95, August 1998); early ISO results (Kessler, No. 86, May 1996); and pre-launch descriptions of the overall mission (No. 84, November 1995).

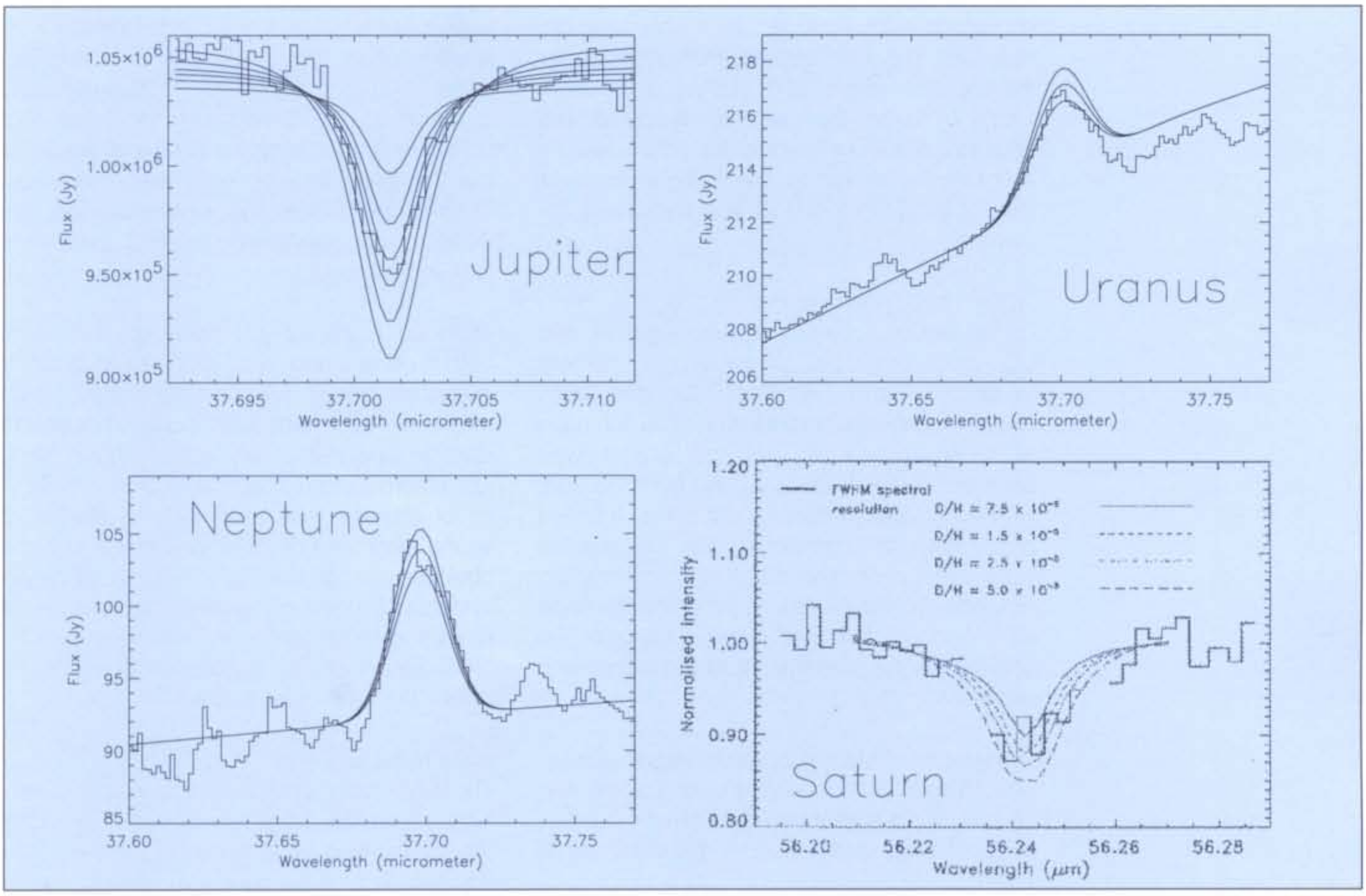


Figure 1. The first detections of HD rotational lines in the four giant planets: HD R(1) detected by LWS/FP in Saturn, HD R(2) detected by SWS/FP in Jupiter and SWS/grating in Uranus and Neptune (after Lellouch, ESA SP-427)

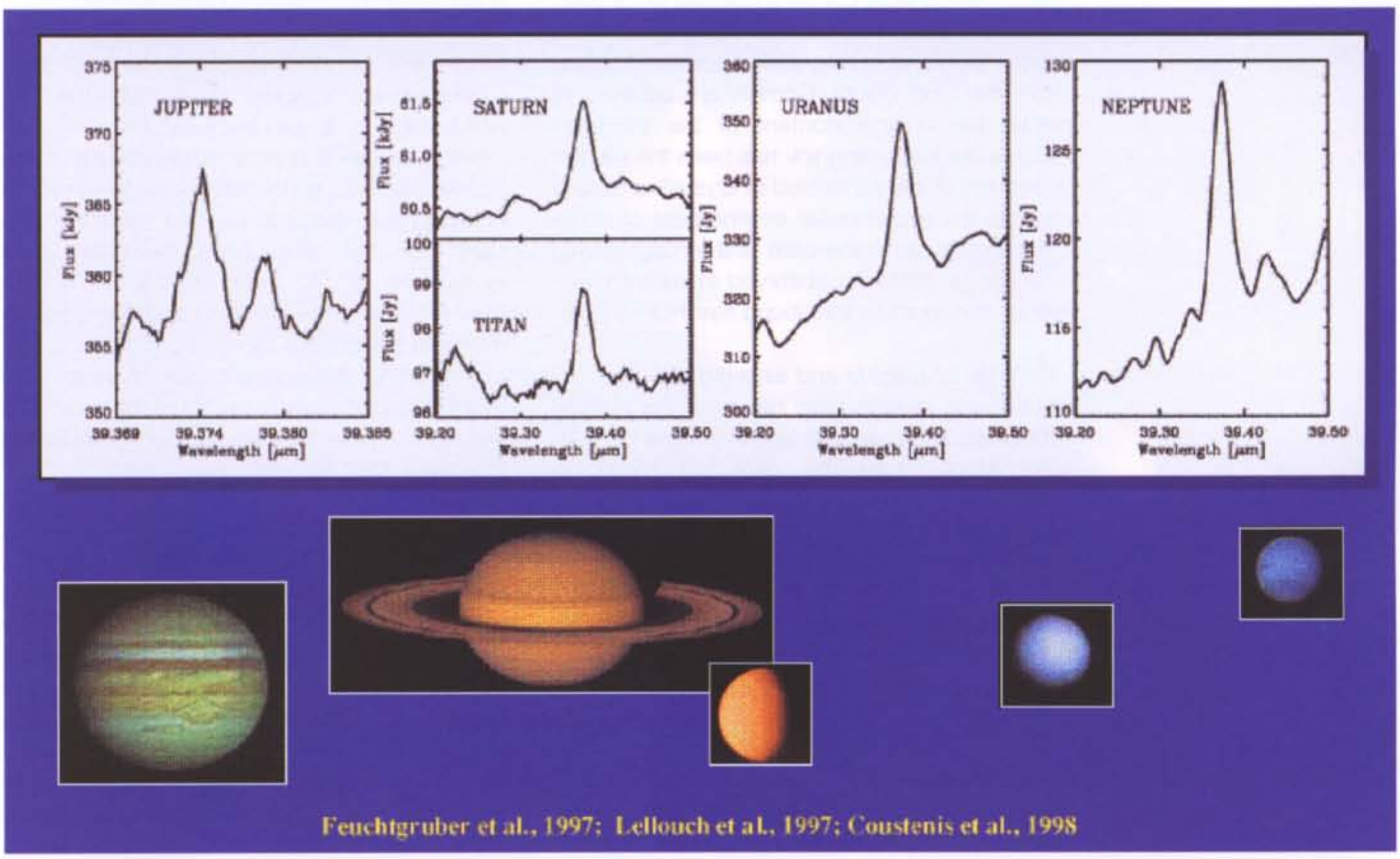


Figure 2. Detections of water lines on all four giant planets and Titan (after Feuchtgruber et al., ESA SP-427)

decreases with altitude. The water vapour detected by ISO comes from the upper tropospheric layers and implies a constant supply of oxygen from an external source. The inferred water input fluxes for the Jovian planets and Titan are similar, thus implying a dominant role for interplanetary dust and comets as the carriers.

Water has been found to be the main constituent of cometary activity, together with CO and CO_2, as observed in comets P/Hartley 2 and Hale-Bopp. On the latter, ISO saw changing production rates for each of those individually, as the comet was approaching the Sun. At 2.9 AU from the Sun, water-ice was detected, and the inferred production rate is consistent with the gaseous water production rate at the same heliocentric distance. This shows that such grains could be an important source of water sublimation, in addition to the nucleus, at such heliocentric distances.

ISO spectra of Mars show an incredibly rich set of water lines. From these, the vertical distribution of water vapour has been determined; the data are consistent with a cloud-forming altitude of 10 km.

Dust

A remarkable result has been the discovery that the cometary dust contains crystalline silicates, both in short-period comets (coming from the Kuiper belt) and in long-period comets (coming from the Oort cloud). Comets are believed to retain the original content of the pre-solar nebula. An interesting link has been the parallel discovery of the same kind of crystalline silicate dust in the circumstellar environment of some young stars, as in the case of the magnesium-rich olivine (fosterite) observed in comet Hale-Bopp and towards the young star HD 100546.

Surfaces of planets and asteroids

ISO is also revealing the nature of the surface of planets and asteroids, as in the case of Pluto and Mars, from the detected rotational modulation of their thermal spectrum. Spectral signatures of SO_2 ice will be used to reconstruct physical parameters of Io's surface. ISO data also suggest the presence of oxides on some asteroids, such as Hygiea and Polyxo, indicative of aqueous alterations on their surfaces early in the history of the Solar System.

Star formation

Star formation is one of the fundamental astrophysical processes and it impacts many very different research areas. Its consequences are seen at almost all astronomical distance scales. Many galaxies get their brightness from star formation. The spectacular Orion nebula - some 1500 light years away - in the winter sky is visible to us due to star formation. Our planetary system is based on the remnants of the formation process of a star - the Sun. Despite its far-reaching consequences, the details of the star-forming process are still not fully understood.

There are many ways to study star formation, both in general and with ISO. One can examine interstellar clouds, full of gas and dust, which will condense to form stars. It is also possible to study in great detail the youngest known stars, just emerging from their dusty birth clouds. A lot of attention has been paid to studies of young stars with disks around them, with the obvious aim of seeing a link to planetary systems. Instead of trying to summarise all studies in these areas, we will focus here on ISO's impact on our knowledge of a quantity called 'the initial mass function'.

Initial mass function

The initial mass function is, in principle, a very simple quantity. It just tells us how many stars are born and with which masses. The importance of knowing the masses is due to the fact that a star's entire future history depends on its mass at birth, i.e. on the amount of material gathered during its very short accretion phase. One mass-dependent factor is the lifetime of a star. High-mass stars have very short lives. They convert their hydrogen very quickly to heavier elements, which are then spread back into the interstellar medium when the star ends its life as a supernova. It is worth noting that this process provided the elements needed for life on the Earth. On the other hand, low-mass stars evolve very slowly. Their lifetimes are longer than the age of the Universe and therefore the matter in these stars can be considered as lost to any further chemical evolution. If we are able to tell how many low-mass stars are born, then we can estimate the amount of mass locked in these very faint objects.

Observations with ISO are needed to address the question of the number of low-mass stars being born, for several reasons. A newly born low-mass star is much brighter than its older companion of the same mass. At the extreme, this statement is true for brown dwarfs, which are objects below the stellar mass limit. This age-dependence of brightness means that these faint objects are best found when they are young. The requirement of observing stars when they are young forces the observer to look at star-forming regions. This brings problems because the interstellar clouds,

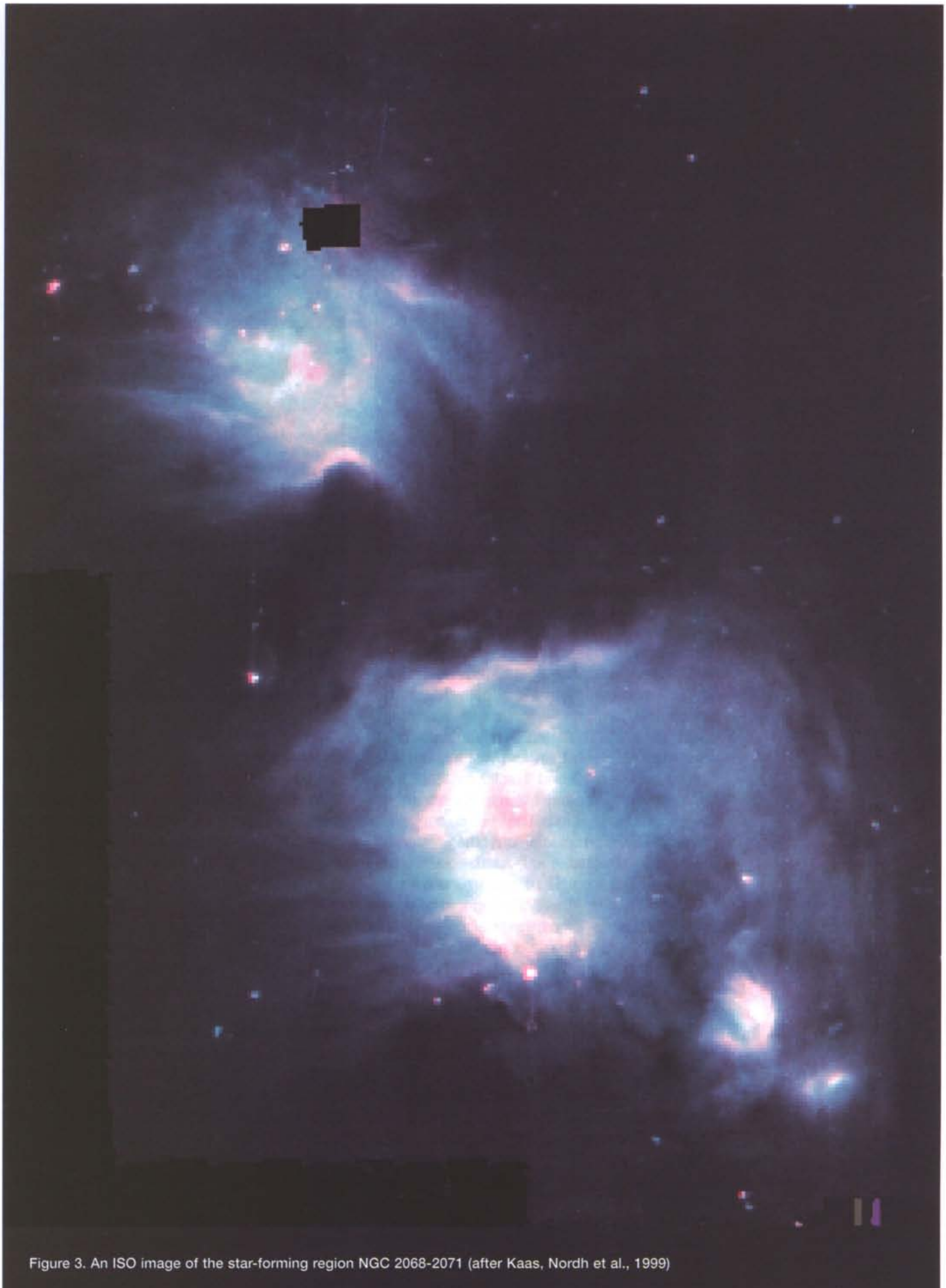
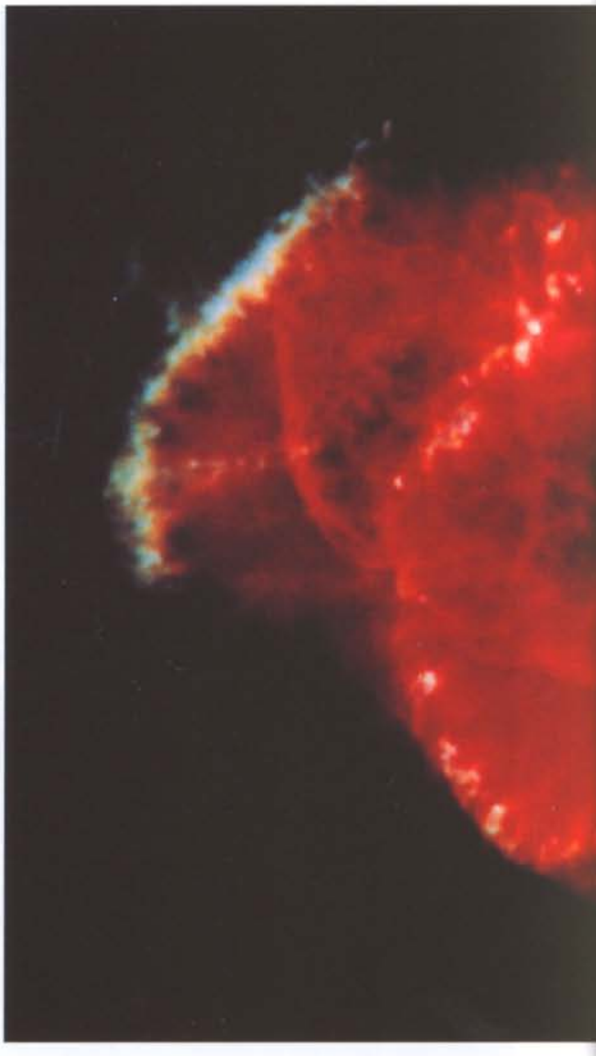


Figure 3. An ISO image of the star-forming region NGC 2068-2071 (after Kaas, Nordh et al., 1999)



A Hubble Space Telescope image of the 'Cat's Eye Nebula' (NGC 6543), one of the most complex and eye-catching planetary nebulae ever seen. It is estimated to be 1000 years old and is a visual 'fossil record' of the late evolution of a dying star

Courtesy of J.P. Harrington & K.J. Borkowski (Univ. of Maryland) and NASA

where stars are born, contain huge quantities of dust, which very effectively block visual light. The remedy is to change the observations from optical to infrared wavelengths. Many star-forming regions had already been studied in the infrared prior to ISO, either with ground-based near-infrared telescopes or with the Infrared Astronomical Satellite (IRAS). However, the key to ISO's success has been the provision of high sensitivity at mid-infrared wavelengths.

The route from observation through data reduction and analysis to initial mass function is long and complex, but also astronomically exciting. Many interesting results have been found. For the star-forming region in the constellation of Serpens, the ISO data reveal a surface density for newly-born stars above 400 per square parsec. To put this number in context, note that the closest star to us is at 1.3 parsec. In the Chameleon star-forming region, the ISO results indicate that there are young stars with big dust disks around them, but at the next step there are stars without any dust disk at all. The intermediate cases are practically absent. This result suggests a very rapid change in the disk. Maybe the dust coagulates at this early stage into planet seeds which are, unfortunately, currently undetectable.

At the end of the data reduction and interpretation, we arrive at the initial mass function. The data indicate that the mass spectrum starts to flatten between 1 and 0.1 solar masses. If we take as a comparison the interval between 10 and 1 solar masses, then there are many more 1 solar mass stars than 10 solar mass stars. The trend continues towards lower masses, but the flattening means that the ratio is less for 0.1 solar mass stars when compared to 1 solar mass objects. The significance of this flattening is that when changing the view from number of stars per mass interval to total mass per mass interval, we are observing a drop: there is no evidence of large quantities of 'hidden' mass in the very lowest mass stars.

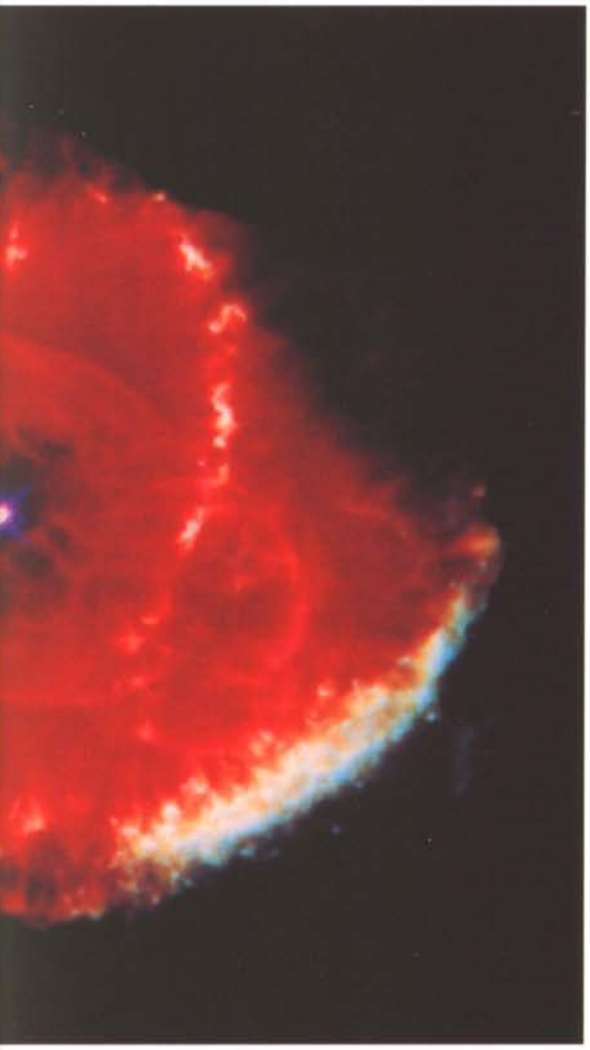
The current state of the art in data reduction indicates that the number of stars in the lowest mass bins continues to rise, but in the similar shallow manner as in the 1 to 0.1 mass interval. On the other hand, studies of brown dwarfs suggest that the number of objects is decreasing towards smaller masses. The challenge of the future ISO work is to examine whether a consistent picture can emerge and whether further flattening and eventual bending down of the initial mass function can be confirmed when entering the brown-dwarf mass domain.

Evolved stars

Oxygen- and carbon-rich stars

Stars are dense gaseous spheres which, for most of their lives, fuse hydrogen to form helium in their interior. For intermediate-mass stars, once their hydrogen supply is exhausted, their interior collapses, heats up and finally ignites fusion of helium to heavier elements. One consequence of this ignition is the expansion of the outer layers of the star - the star becomes very large and cool, a red giant or supergiant. However, this stage also does not last forever. Once the giant star has nearly exhausted its helium supply, the core finally collapses and the star becomes a white dwarf, surrounded by the swept-up circumstellar envelope, a planetary nebula, one of the most beautiful types of object in the sky (e.g. NGC 6543).

Another consequence of the expansion is that the star starts to lose material from its outermost layers, and slowly builds up a 'circumstellar envelope'. These circumstellar envelopes contain various constituents: warm gas, simple and complex molecules, ices and dust grains. Depending on the evolutionary state of the star, its composition may be richer



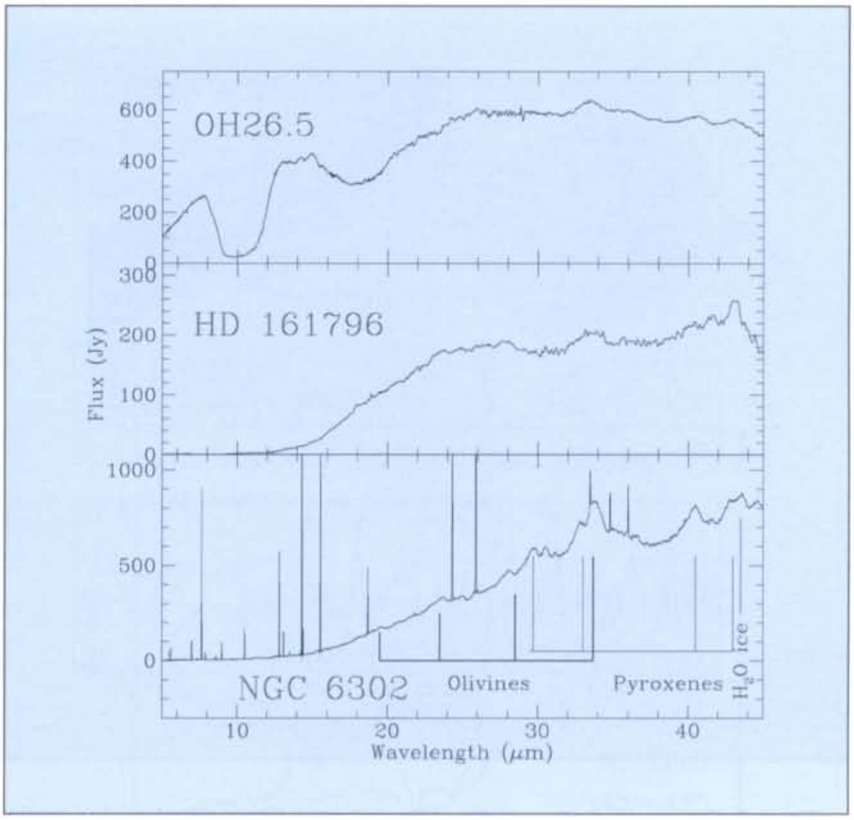


Figure 4. Crystalline silicates in ISO spectra of oxygen-rich evolved stars: OH 26.5, a star with heavy mass loss; HD161796, a star in transition to a planetary nebula; and NGC 6302, a bipolar planetary nebula. The strong narrow peaks in NGC 6302 are fine-structure lines from the ionised gas (after Waters et al., ESA SP-427)

in oxygen or richer in carbon, giving rise to either oxygen-rich or carbon-rich signatures in the infrared spectrum. At least, prior to ISO, that was the popular thinking about chemical evolution.

ISO observations of a variety of evolved stars have revealed, however, that the co-existence of oxygen-rich and carbon-rich circumstellar material is much more common than was previously believed.

One of the surprises of the ISO results has been the detection of crystalline silicates (such as olivines, pyroxenes and fosterites) in red giants and planetary nebulae. As discussed earlier, ISO has also found such materials in the Solar System and around young stars. These spectral signatures, only detectable at infrared wavelengths, get stronger with increasing evolutionary state, and were detected to be strongest in planetary nebulae (Fig. 4). It is still an open question whether these solid-state silicates reside in a circumstellar disc, thus being indicators for such a disc, or whether they are formed in the outflow of the expanding circumstellar envelope.

The mammoth wavelength coverage and resolution of the ISO spectrometers is proving crucial in accurately modelling the chemical composition and temperature regime of the lower layers of the circumstellar envelope. As an example, Figure 5 shows the richness of the lines detectable in the spectrum of the brightest carbon-rich evolved star CW Leo (also known as IRC+10216).

OH masers and megamasers

A large number of red giant and supergiant stars exhibit prominent hydroxyl (OH) maser lines at radio wavelengths. For more than a decade, radio astronomers have also been studying intense OH emission - dubbed 'OH megamasers' - from infrared luminous galaxies. It was a long-standing suggestion that the inversion mechanism for this maser emission was radiative pumping. The pumping cycle consists essentially of the OH radical absorbing stellar light in the mid-infrared and a subsequent cascading to lower energy levels - seen as emission lines - resulting in an overpopulation of the levels from which the maser arises. Before ISO, however, this model could not be confirmed, since the absorption and emission lines involved in the pumping cycle are not observable from the ground.

ISO spectra of a prominent evolved star IRC+10420, an extreme supergiant with strong OH maser emission, and of Arp220, the prototypical ultra-luminous infrared galaxy, have revealed all the lines relevant for the pumping

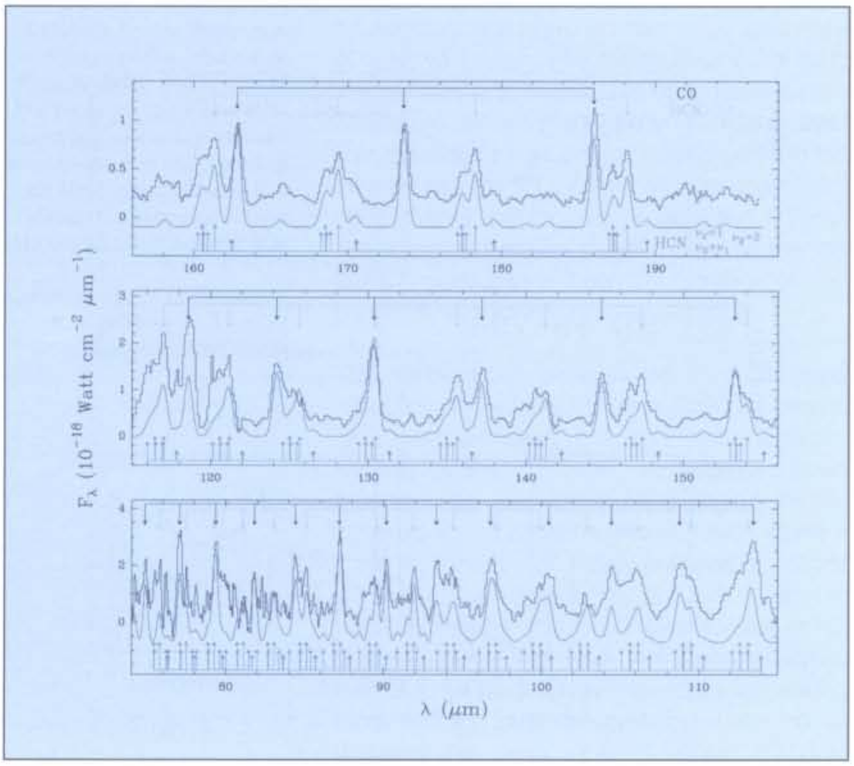


Figure 5. ISO spectrum of the carbon-rich evolved star IRC+10216 (CW Leo), with a wealth of emission lines from highly excited CO and from HCN (from Cernicharo et al., 1996), in Waters et al., ESA SP-427)

cycle. This provides direct proof of the model and confirms that we now understand the processes at work.

Beyond our galaxy

Beyond our own galaxy, apart from the few nearest galaxies, we enter a regime in which observation and its interpretation become intimately entangled with the evolution and history of the Universe as a whole.

Light arriving from objects at intergalactic and cosmological distances takes millions to billions of years to reach us. The objects from which it originates are diverse, including giant old elliptical galaxies, dusty spiral galaxies exhibiting various degrees of star formation, galaxies in violent collision - obscured by dust and massively star-forming. At the extremes of energy production are found the enormously powerful Active Galactic Nuclei (AGNs). These are believed to be powered by enormous black holes at their centres, consuming gas and dust, entire stars and stellar systems.

All of these objects are seen by us at various stages of their 'life-cycles', literally scattered through time by the many different 'light-travel times' which separate them from us. The aim of much of modern cosmology is to understand how the Universe has developed from its formation (the Big Bang), through the formation of the first stars and galaxies, through the aggregation of galaxies into the diverse forms seen in the observational record, and on to the emergence of the structures (like our own Milky Way galaxy) found in our 'locality' today.

Prior to the launch of ISO, certain fundamental questions concerning the relationships among the different types of galaxies seen, remained open or poorly resolved. For example, of the most luminous galaxies - the Ultra-Luminous Infra-Red Galaxies (ULIRGs) which emit as much energy as a million million Suns - what fraction of their number is dominated by active nuclei powered by massive black holes (Active Galactic Nuclei, AGNs), and what fraction derive their energy from huge star-formation events? What happens in detail when galaxies collide? At which epoch or epochs in the history of the Universe did stars form in greatest abundance? How much of the history of star formation is obscured from our view in visible and ultraviolet observations by intervening dust? ISO has been able to advance the study of these important questions very significantly.

Ultra-luminous infrared galaxies

Pre-ISO models for the evolution of ULIRGs envisaged their formation in the collision and merging of galaxies, triggering a starburst, which then faded giving way to a black-hole-powered AGN fed by interstellar material falling inwards to the central black hole. ULIRGS should therefore progress through degrees of interaction and end up as fully merged systems with AGNs. Pre-ISO observations produced no clear conclusions as to the energy source in ULIRGs, optical and radio observations giving conflicting impressions of AGN and starburst activity, respectively.

Indeed, while both mechanisms are present to some degree, ISO spectroscopy in the mid- and far-infrared has provided a powerful technique for discriminating starburst and AGN energy sources. Because of its ability to make observations through dust layers opaque to visible and ultraviolet light, ISO has been able to study the normally obscured inner, energetic regions of ULIRGs.

A crucial factor discriminating between AGN activity and star-formation activity is the 'hardness' and 'intensity' of the ultraviolet radiation field. The hardness refers to the energy of the individual photons, while the intensity refers to their abundance. ISO could measure the energetics of the ultraviolet photons by studying their ability to ionise the gas in the target galaxies. A high ratio of, for example, energetic highly-ionised oxygen (OIV) species relative to low-energy ionised neon (Ne II) species signifies a hard radiation field. At the same time, the intensity of the ultraviolet radiation could be measured by determining its ability to destroy the layers of organic compounds that form on dust grains in the interstellar medium of target galaxies.

The earlier infrared survey mission IRAS showed that mid-infrared spectral features, normally attributed to carbon-rich molecules accumulated on small dust grains, were common throughout the galaxy and in other galaxies. ISO has confirmed the ubiquity of these substances - usually referred to as Polycyclic Aromatic Hydrocarbons (PAHs) or for the more cautious as the Unidentified Infrared Bands. These substances, however, are believed to be destroyed, and their spectral signatures consequently erased, in regions with intense ultraviolet radiation fields. At the same time, the dust grains that carry the PAHs are heated by the ultraviolet and emit stronger thermal continuum radiation.

It follows that a search with ISO's various spectrometers allows both the O IV/Ne II line ratio (ultraviolet hardness) and the presence or absence of PAHs relative to hot-dust emission (ultraviolet intensity), to be explored for a range of targets. It was found that high values of the line ratio ('hard' photons) coupled with low ratios of the PAH features to dust emission (lots of photons), correlate well with AGN energy sources, while low values of the line ratio ('soft' photons) and higher values of PAH signature (fewer photons) correlate with starbursts.

By comparing the properties of a sample of ULIRGs with the above criterion, it has been established that most ULIRGs derive the bulk of their energy from enormous bursts of star formation, while only a fraction, and mainly the most luminous ones, are powered by massive black holes in AGNs. Also, there is no evidence for the model-predicted trend of moving from starburst power to AGN power with the progression of the galaxy merger. In fact, no simple evolutionary trend from starburst to AGN mechanisms is seen in ISO observations of ULIRGs, but the discrimination of the two mechanisms has become possible.

Galaxies in collision

A number of results with ISO have revealed fascinating and hitherto unseen details of galactic interactions. One example is the case of the merging pair of galaxies called the Antennae (NGC 4038/4039) - so-called because of the diffuse tails of material (dust, gas and stars) seen in optical images and cast off from the galaxies through their gravitational tidal interaction. In the Antennae, spectroscopic imaging with ISO's camera revealed that by far the brightest source in the infrared is neither of the merging galaxies' nuclei, but instead a region at the location of 'collision' of the two systems. Completely hidden by dust in visible light, it is revealed as a strong star-forming event in ISO's infrared images.

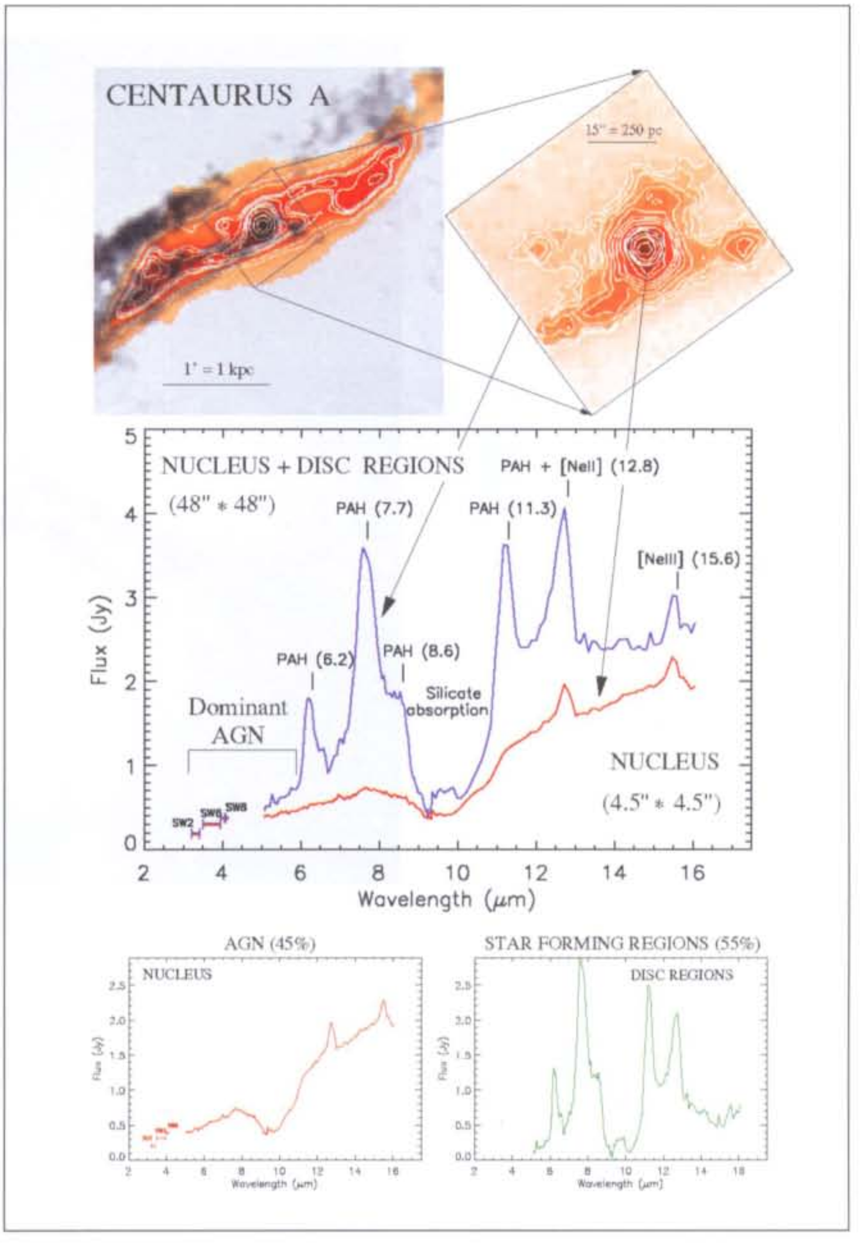


Figure 6. Centaurus A. Upper left panel: Distribution of dust in the inner region observed at 7 microns (contours) with optical dark lanes superimposed. Upper right panel: Map at 8 microns of the nuclear region in spectro-imaging mode where we observe the nucleus as well as a part of the disc structure. Middle panel: The lower curve represents the mid-IR spectrum covering the nuclear region, whereas the upper curve shows the spectrum integrated over a larger region including both disc structures and the nucleus. Bottom panel: The AGN spectrum (left) represents 45% of the energy between 5 and 16 microns and is highly dominant at short wavelengths between 3 and 6 microns. The emission associated with star-formation regions (right) is not detected with the three narrow-band filters at 3-4 microns. The absence of PAH bands is clearly observed in a region of 50 pc in radius containing the AGN, whereas PAH bands dominate the emission outside the nucleus. In addition, the high [Ne III]/[Ne II] ratio detected in the AGN reveals the presence of a hard radiation field (after Laurent et al., ESA SP-427)

Another beautiful example of the detailed events within a galaxy merger is found in the spectroscopic imaging of the giant elliptical galaxy Centaurus A. This galaxy contains the closest Active Galactic Nucleus (AGN) to Earth. The camera data, shown in Figure 7, reveal the presence of a spiral galaxy, captured in a merger, and now residing inside the giant-elliptical galaxy. These data raise the question

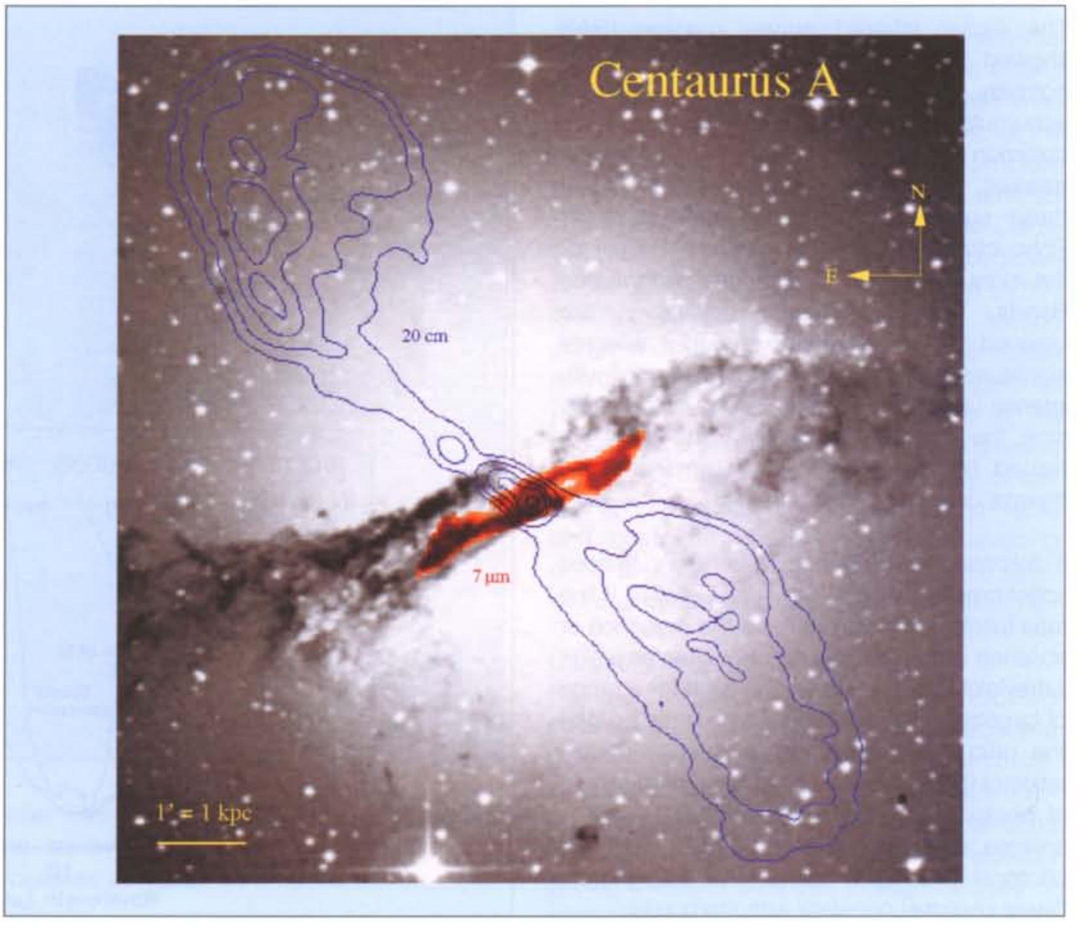


Figure 7. ISO image of Centaurus A (red) superposed on an optical image. Also shown are the radio-continuum (50 cm) contours (from Mirabel et al. (1998), in Vigroux et al., ESA SP-427)

as to whether giant radio galaxies like Centaurus A are composed of a barred spiral inside an elliptical, where the bar serves to funnel gas towards the central AGN black hole - a picture which resonates with the discussion of the nature of ultra-luminous infrared galaxies above.

Other ISO observations of interacting galaxy systems include observations of ring-shaped galaxies, which result when a small galaxy passes through the centre of a larger one causing a star-forming density wave to propagate outwards through the target galaxy (Fig. 8). In one particularly difficult observation, ISO imaged a very distant (redshift = 1) ring galaxy through a foreground cluster of galaxies whose gravity bent the light from the background object and magnified its image and brightness. Gravitational-lensing theory allowed the intrinsic visual form of the ring galaxy to be reconstructed and correlated with the ISO measurements, leading to the recognition of an interaction-generated starburst in the ring. Further, based upon the ISO mid-infrared fluxes, it was inferred that the nucleus of this particular very distant ring galaxy harbours an AGN.

In general, as in the case of the ULIRG study described earlier, ISO observations show that interacting galaxies are not always associated with active nuclei (well-fed central black holes). Indeed, interactions are observed whose infrared properties place them comfortably into the ranges of star formation occupied by more typical 'normal' galaxies.

Epochs of star formation

Apart from the detailed studies of the properties of galaxies and galaxy types, ISO has been used to perform a number of deep surveys in the mid- and far-infrared using the camera and photometer. Collectively, these surveys have led to the recognition of major global star-forming events in the Universe, previously undetected due to dust obscuration. These account, in the emission of discrete sources, for much of what was previously attributable only as a mysterious diffuse infrared background. A significant population of infrared bright, and presumably star-forming, galaxies has been found in camera surveys at redshifts between 0.6 and 1, and the fall-off beyond a redshift of 1 may be partly due to important mid-infrared spectroscopic features (Polycyclic Aromatic Hydrocarbons, PAHs) being red-shifted out of the range of the camera filters for redshifts larger than 1.4. However, for the higher redshifts, the far-infrared capability of the photometer takes over in 175-micron survey work. The latter has extended ISO's detection of global star-formation out to red-shifts beyond 2. ISO's resolving of much of the

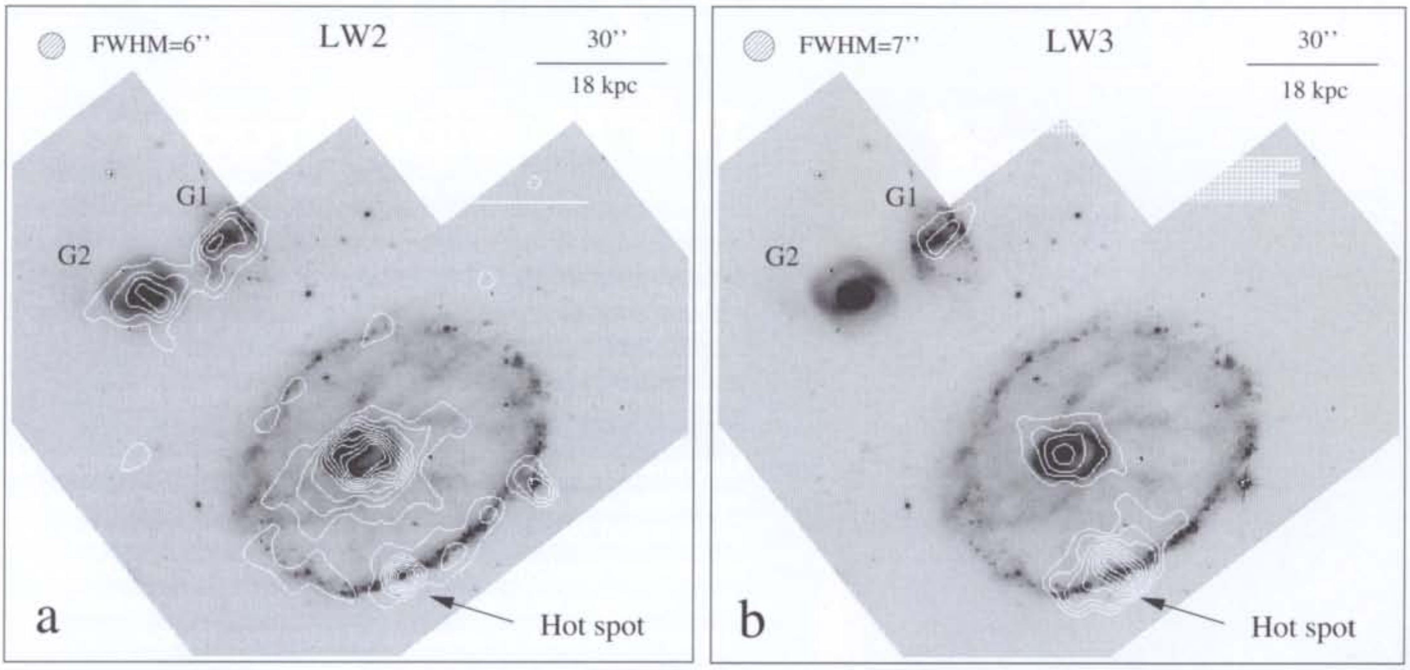


Figure 8. The Cartwheel Galaxy: ISO images at wavelengths of 7 microns (left panel) and 15 microns (right panel) overlaid on an HST image (after Charmandaris et al., ESA SP-427)

universal infrared background into discrete sources is a major cosmological result, helping us to recognise when and where the stars formed, and strongly emphasising the caution needed when interpreting star-formation rates from optical or ultraviolet measurements alone – which cannot see through obscuring dust to recognise the events seen by ISO. Its implications will trigger follow-up work for some time to come.

Conclusion

Across the full range of astronomical objects and spanning the history of the Universe, ISO's sensitivity, broad wavelength coverage and diverse instrument complement have permitted it to study crucial physical processes related to planet, star and galaxy formation and evolution. It has revealed hidden events of major importance and given clear views into the details of key evolutionary processes, previously completely unobtainable. The broad spectral coverage and instrumental diversity of ISO have allowed physical mechanisms to be constrained simultaneously in several energy ranges and on several spatial scales. The capacity of ISO's results to draw unifying threads through diverse areas of astrophysics can be glimpsed in the examples discussed above.

Major themes and puzzles of modern astrophysics and cosmology, including Solar System studies, the star-formation process, stellar evolution, the energy sources of ultra-luminous galaxies, the relative importance of star formation versus active galactic nuclei driven by black holes, the properties of colliding and interacting galaxies, and the global history of star formation, have been addressed by ISO and are being drawn together.

The ISO data have been only partly exploited so far, but already the emergence of vital new perspectives on fundamental puzzles has become evident. With the availability of its entire data set to the world-wide astronomical community, the harvest of new and exciting results from ISO will continue for some time yet.

Acknowledgements

The results described above are the work of a large number of astronomers, who for reasons of readability have not been individually credited throughout the article. Details of their work, and full references, can be found in *'The Universe as Seen by ISO'*, ESA SP-427, March 1999, edited by P. Cox and M.F. Kessler. As starting points for each of the sections of this article, the reader is referred to the following papers in those Proceedings: *Solar System*, review by E. Lellouch and references therein, J. Crovisier et al., H. Feuchtgruber et al., and many of the Poster Papers; *Initial Mass Function*, review by T. Prusti and references therein, review by G. Olofsson et al. and references therein; *Evolved Stars*, review by L. Waters and references therein, J. Cernicharo et al., conference summaries by M. Harwit and R. Genzel; *Extragalactic*, reviews by A. Moorwood and by G. Helou, conference summary by R. Genzel, and many of the poster papers, including Charmandaris et al., Dole et al., Elbaz et al., Laurent et al., Metcalfe et al., Rigopoulou et al. and Vigroux et al.

The authors thank the world-wide astronomical community for their enthusiastic use of ISO data, without which this article would not have been possible.

The Hipparcos and Tycho Catalogues

The Mission Products

The principal parts of the Hipparcos Catalogue are provided in both printed and machine-readable form. Tycho Catalogue results are provided in machine-readable form only. The printed volumes include a description of the Hipparcos and Tycho Catalogues and associated annexes, a description of the satellite operational phase, a description of the corresponding data analysis tasks, and the final data.

Machine-readable versions of the catalogues are provided in two forms: the definitive mission products are released as a set of ASCII files on a series of CD-ROMs, which contain all of the printed catalogue information as well as some additional data. Auxiliary files containing results from intermediate stages of the data processing, of relevance for the more-specialised user, are also included.

A distinct single CD-ROM product, Celestia 2000, contains the principal astrometric and photometric data, in compressed form, along with specific interrogation software developed for specific platforms.

The Hipparcos Mission

The Hipparcos space astrometry mission was accepted within the European Space Agency's scientific programme in 1980. The Hipparcos satellite was designed and constructed under ESA responsibility by a European industrial consortium led by Matra Marconi Space (France) and Alenia Spazio (Italy), and launched by Ariane-4 on 8 August 1989. High-quality scientific data were acquired between November 1989 and March 1993. The scientific aspects of the mission were undertaken by nationally-funded scientific institutes. All of the scientific goals motivating the mission's adoption in 1980 were surpassed, in terms of astrometric accuracy, photometry, and numbers of stars.

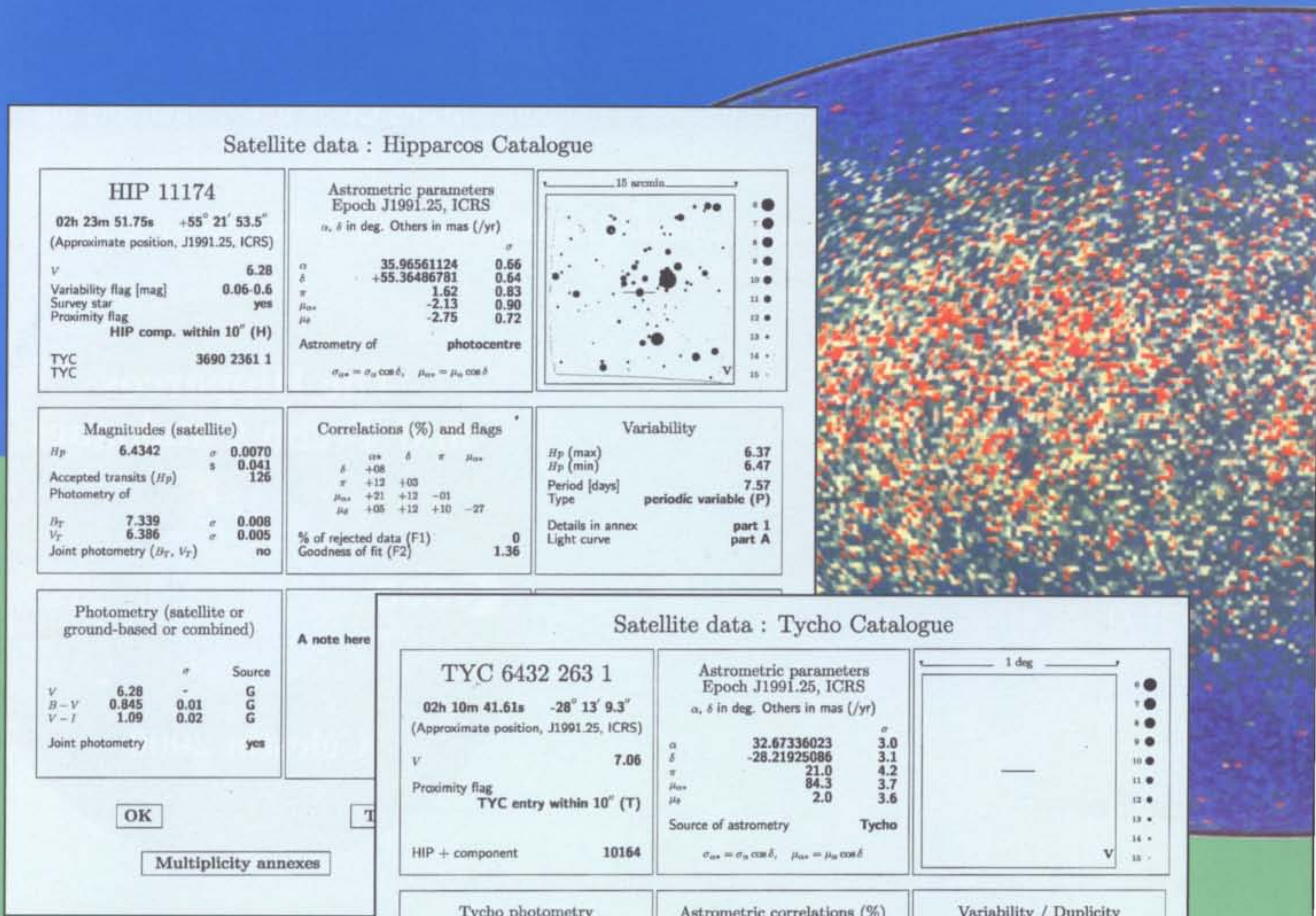
The global data analysis tasks, proceeding from nearly 1000 Gbit of satellite data to the final catalogues, were undertaken by three scientific consortia: the NDAC and FAST Consortia, together responsible for the production of the Hipparcos Catalogue; and the Tycho Consortium, responsible for the production of the Tycho Catalogue. A fourth scientific consortium, the INCA Consortium, was responsible for the construction of the Hipparcos observing programme. The production of the Hipparcos and Tycho Catalogues marks the formal end of the involvement in the mission by ESA and the four scientific consortia.

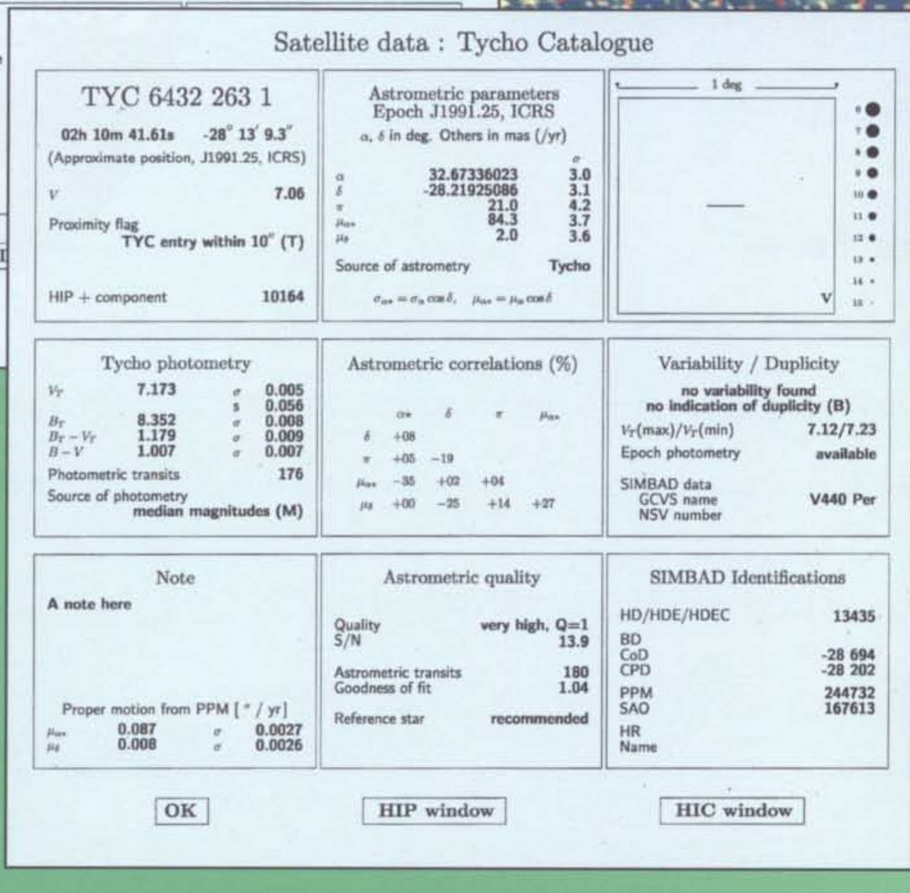
The Hipparcos and Tycho Catalogues

The final products of the European Space Agency's Hipparcos mission are two major stellar catalogues, the Hipparcos Catalogue and the Tycho Catalogue.

Each catalogue includes a large quantity of very high quality astrometric and photometric data. The astrometric data in the Hipparcos Catalogue is of unprecedented accuracy: positions at the catalogue epoch (J1991.25), annual proper motions, and trigonometric parallaxes, have a median accuracy of approximately 1 milliarcsec. The Hipparcos Catalogue includes annexes featuring variability and double/multiple star data for many thousands of stars discovered or measured by the satellite. The Hipparcos and Tycho Catalogues will remain the definitive astrometric stellar catalogues for many years.

Celestia 2000





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Celestia 2000 is a CD-ROM package containing the Hipparcos and Tycho catalogues, plus related annexes, in compressed binary format, along with dedicated software permitting interrogation, sample construction and information display.

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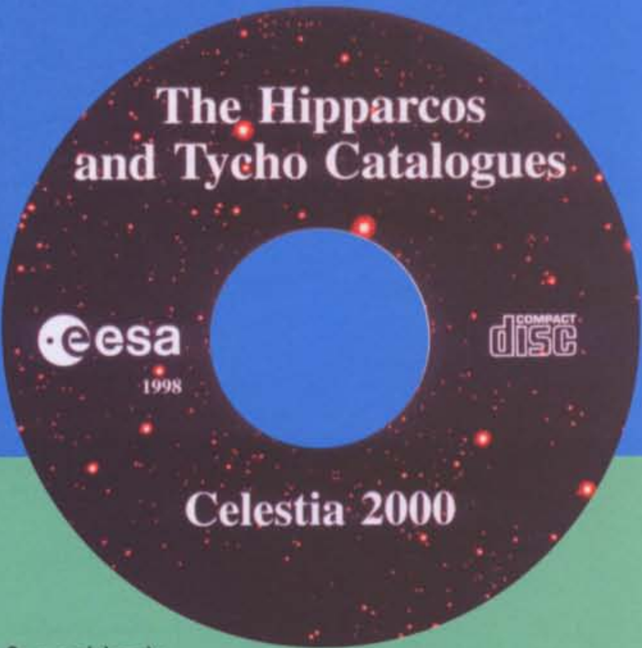

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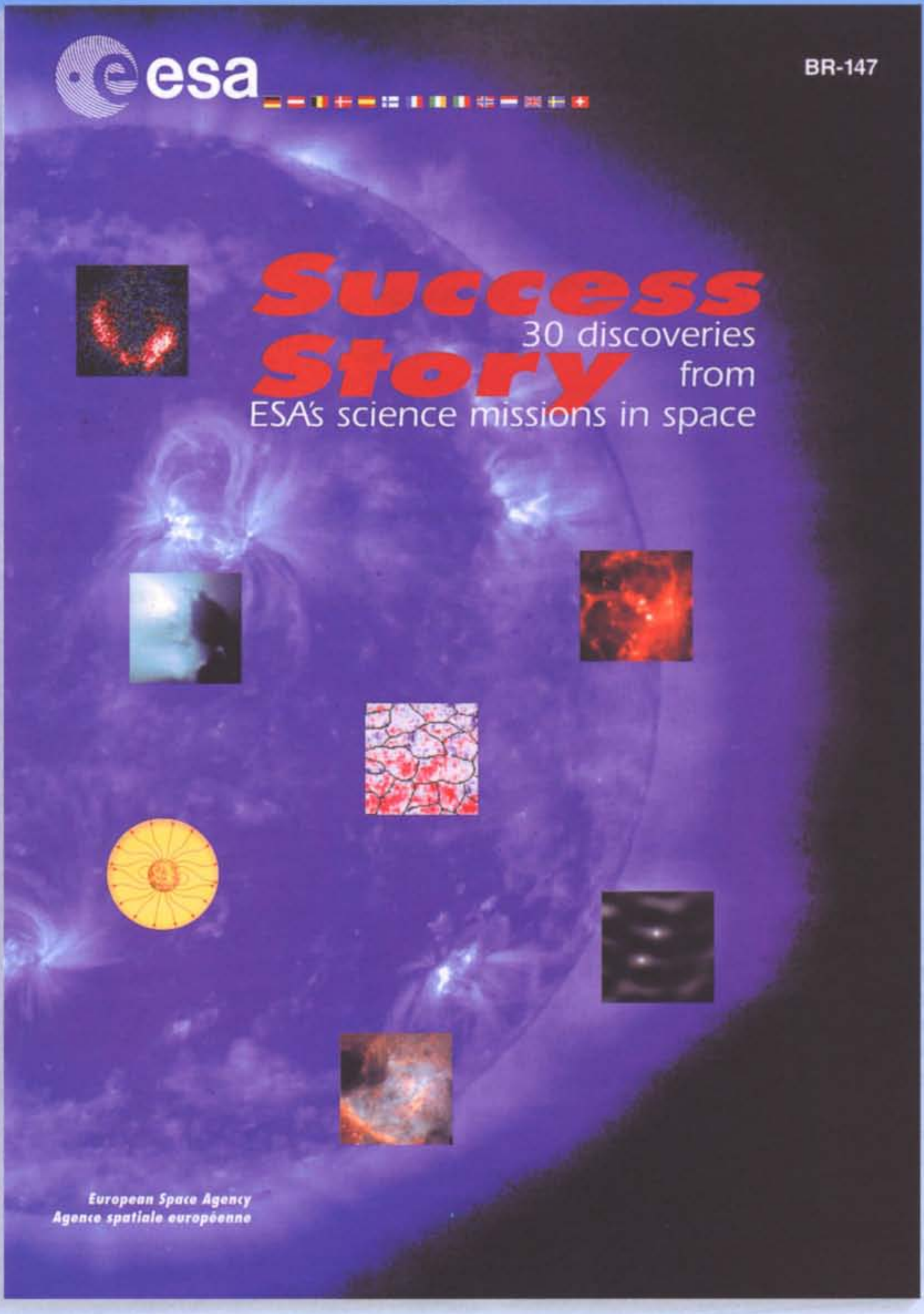

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The Harsh-Environment Initiative – Meeting the Challenge of Space-Technology Transfer

P. Kumar
Director of Space Systems and Applications, C-CORE, Memorial University of Newfoundland, St. John's, Canada

P. Brisson & G. Weinwurm
Technology Transfer Programme, ESA Directorate for Industrial Matters and Technology Programmes, ESTEC, Noordwijk, The Netherlands

J. Clark
Principal Consultant, C-CORE, St. John's, Canada

ESA's Harsh Environments Initiative (HEI) is a programme aimed at transferring space technologies to terrestrial operations in harsh environments. C-CORE is the prime contractor to ESA for implementing the programme, and the Canadian Space Agency is a programme sponsor.

C-CORE's approach to meeting this challenge is to seek out operational priorities in the oil & gas and mining sectors and to develop and implement test-bed projects that apply selected space technologies to demonstrate improved operating efficiencies, lowered risks and enhanced safety. These projects typically involve one or more partners from industries in Canada and Europe, and additional sources of funding that exceed the ESA contribution.

Commercialisation of the space technologies is a key objective. Accordingly, C-CORE and its partners have developed selection criteria that have ensured that only projects with high potential for commercialisation and quick technology transfer (involving the exchange of funds between the space-technology supplier and the end-user) would go ahead.

Introduction

ESA awarded the Harsh Environments Initiative (HEI) contract to C-CORE in August 1997 following an open bidding process in Canada. Supported by the Canadian Space Agency (CSA) also, C-CORE undertook 'The Application of Space Technologies to Operations in Harsh Terrestrial and Marine Environments'. Phase-1 of the Initiative ended in February 1999 and was followed by a seamless transition into Phase-2, which ends on 14 January 2000. The focus of the programme is to transfer space technologies for industrial application in the oil & gas and mining sectors.

The key issues relating to oil & gas and mining operations were identified through specialist workshops as well as one-on-one meetings with potential industry users. New technologies that could enable the targeted sectors to enhance operations in harsh environments, to develop capabilities for more automated operations and provide the ability to operate year round, were determined. Oil & gas and mining development in remote regions such as the Arctic require safe, reliable and efficient operations. Likewise, offshore oil & gas development, particularly in areas invaded by sea ice or icebergs, requires subsea systems that integrate such technologies as robotics and artificial intelligence. Remote operation of subsea systems was identified by the offshore industry as an R&D priority as the need to protect its workers from having to enter high-risk environments becomes ever more critical.

The first 18 months (Phase-1) of the Harsh Environments Initiative brought a number of notable achievements:

- Three operations nodes were established in Canada:
  - Host Node (C-CORE)
  - Oil & Gas Operations Node (C-CORE)
  - Mining Operations Node (Mining Innovation, Rehabilitation and Applied Research Corporation (MIRARCo), Laurentian University, Sudbury, Ontario).
- The European Network was initiated through the Norwegian Geotechnical Institute (NGI) in Oslo.
- An International Advisory Board was established with members from ESA, CSA,

the Spacelink Group, the Province of Newfoundland and Labrador, Small and Medium-sized Enterprises (SMEs), the oil & gas and mining sectors, and Government research agencies.
- Eight demonstration projects were initiated, each with its own partnerships and strategic alliances. Space technologies were introduced into existing projects being undertaken within the oil & gas and mining sectors. The projects were evaluated against five criteria and were approved by the International Advisory Board. They were:

Oil & Gas Node
- *The Consortium for Offshore Aviation Research (COAR)*: This project focussed on the issues associated with operating helicopters on the Grand Banks, with particular emphasis on final approaches to helidecks in low-visibility conditions.
- *Radome Icing*: Microwave communications towers in Labrador develop very large accretions of rime ice, which can disrupt communications. The objective of this project was to evaluate advanced ice-phobic materials able to reduce these ice accretions.
- *Monitoring of Ground Motion using Interferometric Synthetic Aperture Radar from Space*: The objective of this project was to measure ground movements of unstable slopes in which pipelines had been installed so as to be able to take action to relieve stresses before they caused pipeline failures.
- *A Feasibility Study for the Detection of Shallow Gas Hazards in Deepwater Seabeds*: As oil & gas exploration moves into ever deeper waters, the hazard posed by gas hydrates increases. This study was undertaken to develop systems that can identify such gas pockets at depths of more than 3000 m.

Mining Node
- *Sensori-Motor Augmented Reality for Tele-robotics (SMART):* The main objective of this project was to develop systems that would enable the entire mining process to be automated.
- *Geosensing:* To efficiently identify and exploit ore bodies underground, it is essential to be able to determine what lies ahead of the drills. This project focused on developing sensors for 'geo-probing' or 'looking ahead' in mining operations.
- *Micro-Seismic Pressure Monitoring*: The focus of this project was to monitor the underground environment in order to delineate ore bodies or reservoirs over a period of time.
- *Evaluation of ESA Simulation Tools*: To model the end-to-end mining process, complex simulation techniques are required. The evaluation of ESA-developed simulation software and tools was therefore the focus of this project.

A total of 14 European and 33 Canadian industries – from both the space and non-space sectors – had some involvement in these 8 projects, either as potential suppliers of space technologies or as partners. The space technologies evaluated in the various projects included advanced materials, sensors and sensor systems, robotics hardware and software, vision systems, communications and simulation software and tools. The majority of these technologies came from European industries. Ten technologies were incorporated into the demonstration projects.

One of the key thrusts during Phase-1 was to get end-user commitment at an early stage so as to ensure continuous support – either in cash or in kind – for the demonstration projects. ESA had set a number of targets for this funding leverage (0.58 in cash and 0.83 in cash+kind) and all were exceeded (1.12 in cash and 1.82 in cash+kind).

The technology-transfer process

The HEI is continuing to focus its efforts on the oil & gas and mining sectors, where many operations are being conducted in extremely harsh environments. These two Operations Nodes seek either existing projects for which priorities were set, or accelerate those projects that were prioritised at a series of specialist Workshops held in Canada and Europe. The Workshops included Offshore Aviation Research; Mining Operations; Oil & Gas Operations; Deep-Water Operations, Arctic Development and Underground Tunnelling; and the Application of Advanced Space Technologies to Improving Efficiencies in the Petroleum and Mining Industries.

The selection criteria developed ensured that only those projects that meet all of the following requirements were presented to the International Advisory Board for approval:
- *Relevance:* There must be potential major benefits to the project from adapting, or adopting, space-developed technologies, or through developing new technologies that might have applications in space.
- *Support:* The project must have a receptor industry as an end-user, or a partnership of industries as end-users.
- *Timing:* The project must be capable of being substantially demonstrated during the programme activities.

- *Leverage:* The project must have significant potential to lever industrial funding greater than, or equal to, the ESA seed funding.
- *Commercialisation:* The project must have commercial potential and the partners to undertake commercialisation.

The challenges of space-technology transfer
The C-CORE Technology Transfer Model is illustrated in Figure 1. All of the HEI demonstration projects are industry-driven. The key to a successful transfer is to involve industry at an early stage in the demonstration project's development. This will ensure that future commercialisation opportunities can be facilitated.

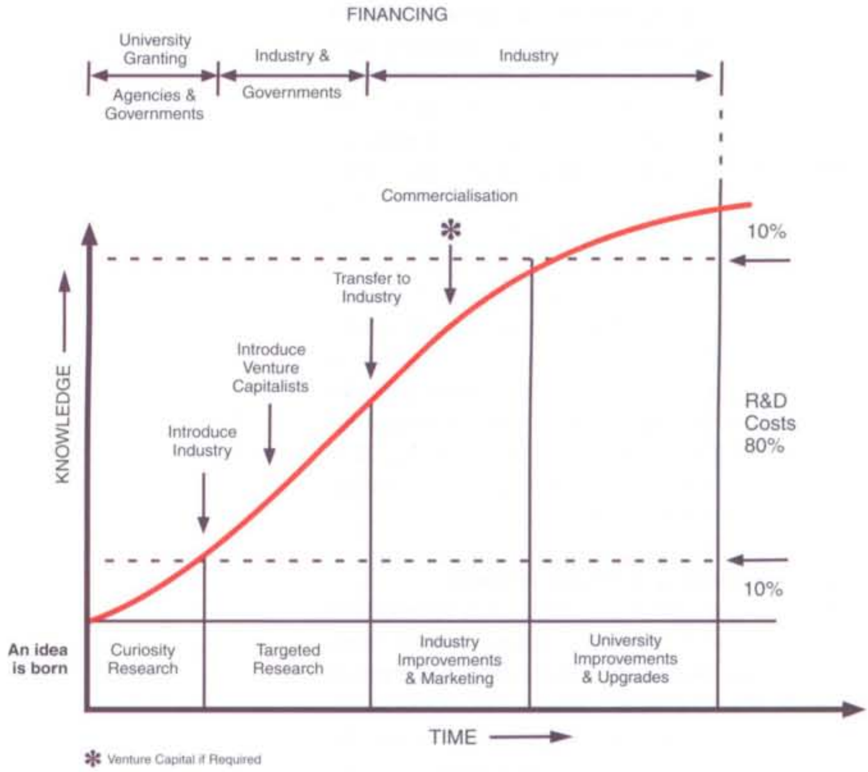


Figure 1. The C-CORE Technology Transfer Model

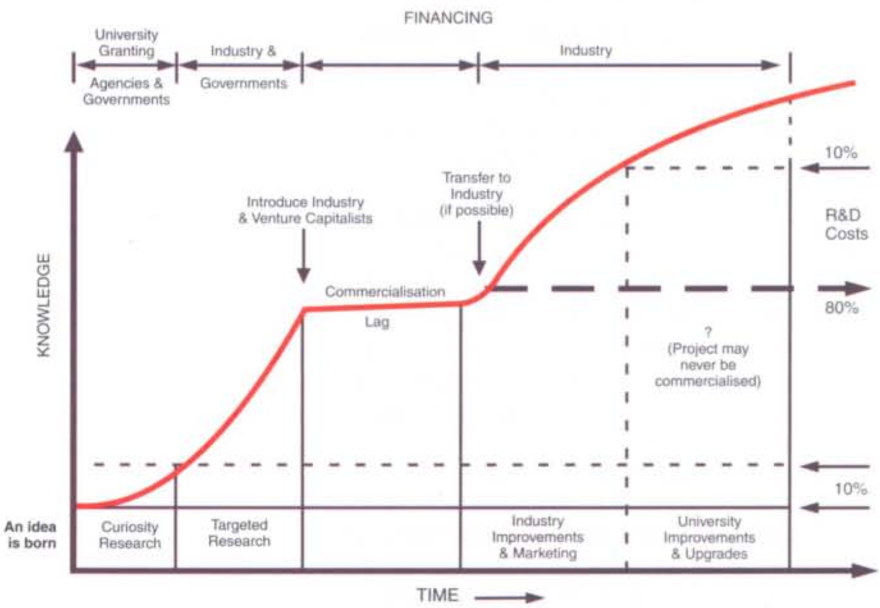


Figure 2. The negative effect of late industry involvement

The consequences of late industry involvement can be seen in Figure 2, where a 'commercialisation lag' may delay effective adoption of the technology, or may even result in the project never being commercialised. This is a result of waiting too long to include industry in the project or to seek venture capital where it is needed. The latter should happen very early in the project, as shown in Figure 1, well before the technology is expected to be developed to the point where it can be commercialised.

Based upon the above philosophy for technology transfer, C-CORE established a Commercialisation Committee for Phase-2, to focus specifically on early commercialisation. This Committee requires that the project managers:

- demonstrate a commercial need for the technology
- provide a preliminary assessment of potential market size
- identify the potential to generate new products and services
- describe how space technologies will be integrated
- indicate the involvement of end-users and commercialisers
- furnish a plan for the demonstration of products and services
- focus specifically on the potential mechanisms for commercialisation, and
- assess the impact of the transfer (economic, visibility etc.).

Case studies

Sensori-Motor Augmented Reality for Tele-robotics (SMART)
In mining, large and slow-moving mechanical units such as shovels, drilling rigs, rock breakers, load/haul/dump vehicles, etc. operate under hazardous conditions and at speeds that directly affect the operation's productivity. The tasks to be performed – drilling, scaling, bolting, fragmenting, scooping, etc. – involve complex mechanical interactions with the environment, and require operator skills based upon extensive experience and intuitive knowledge. These skills cannot be modelled easily, precluding at this stage the possibility of full automation. Tele-operation of this equipment can, however, be adopted as an interim technology.

Conventional tele-operation maintains a direct link between the operator and the equipment, which has three major disadvantages:

- the slow motion and the complex machine/environment interactions require continual operator/equipment dialogues, which demand the operator's attention for most of the task; such tasks are typically very tedious, resulting in a reduced attention span
- the task is prone to collisions and control errors, with potentially detrimental consequences to the equipment, the environment or the task itself; and
- transmission delays to and from the operator's site adversely affect efficiency, stability and safety.

The SMART program seeks to alleviate these problems by developing an alternative method of operator/equipment interaction that decouples task specification and task execution. This requires two primary technological advances:

- interactive 3D sensing: minimising the volume and frequency of sensory-data transmitted to the operator and supplementing it with real-time, synthesised information upon request; and
- enhanced sensory-motor interaction: mediating between task specification and task execution using a virtual representation of the equipment in the task representation perceived by the operator.

Both of these areas address the disadvantages associated with the transmission delays, and create a form of operator/equipment interaction that reduces the operator's involvement during the lengthy execution phase. They will also offer the option of simulating the task prior to its execution, considerably reducing risk. Overall, the development will lead to more efficient, safer, and realistic alternatives to present-day operating methods.

Project description

The work during the period from February 1999 to January 2000 will consist of in-depth analysis and adaptation of three technologies:

- a head-mounted stereo display system (CASA-Space Division)
- a force-feedback joystick (Matra Marconi Space)
- robot-control software (collaboration with Space Applications Service, Belgium)

which were identified during Phase-1 following an evaluation of 21 space technologies. Adaptations may include hardware modifications and will necessitate substantial software development in order to integrate and test the technologies with the rest of the SMART development, in close consultation with the manufacturers.

The integration of the head-mounted technology in SMART will consist of developing a graphical computation system that could support the real-time overlay of graphics on the head-mounted stereo display system. We will be using a system of two synchronised PC's with enhanced graphical capabilities, each responsible for presenting one of the views in the display system. This requires software and hardware developments for synchronisation and graphical overlaying at video rates. The system developed will not be limited to the SMART application and can easily be extended to similar immersive virtual-reality applications.

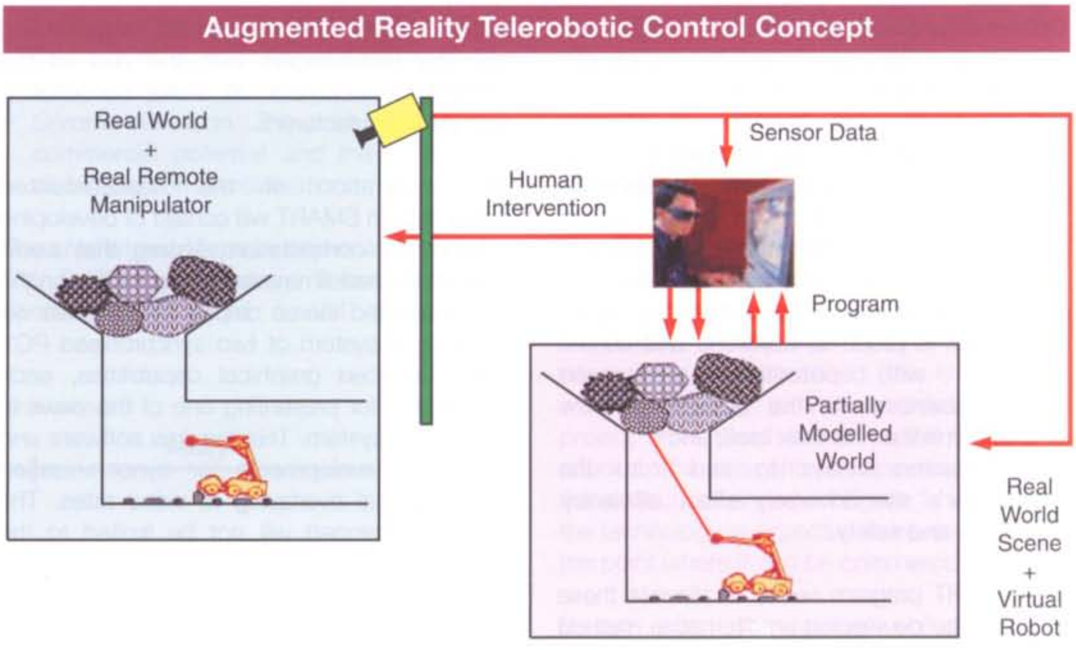
The integration of the force-feedback system in SMART will involve developing software for providing force feedback in tele-operated mining operations such as surface drilling or block caving. The feedback should enhance the augmented reality environment created in SMART, and so enable more precise tele-operation of equipment and facilitate improved safety features, preventing the operator from making potentially dangerous movements. The integration software should incorporate additional graphical information, which should be displayed in the enhanced perception environment for further reinforcement of the force-feedback information. The software should also be constructed in a way that allows its easy adaptation to other applications.

The integration of the SAS robot control software (FAMOUS) with SMART will involve developing a link with the discrete-event tool under development in SMART, which will be enhanced to include control-signal generation, system-performance monitoring and facilities for the supervision of human intervention. This tool will include the modelling of both the human operator and the mining operations as discrete-event dynamic systems, including a provision for controlling the interactions between the human operator, mining vehicles and the partially-modelled mine environment. A second, related activity will be the development of a graphical user interface that will provide an appropriate task-specification tool for mine-vehicle operators, with the ability to translate this graphical representation of the task(s) into both FAMOUS scripts and SMART DES representations.

Transfer of FAMOUS into the SMART project

FAMOUS (Flexible Automation Monitoring and Operation User Station) is space-robotics

Figure 3. The application of FAMOUS to SMART



software developed by Space Systems Services (SAS, Belgium), under contract to ESA. C-CORE has undertaken work to adapt FAMOUS for use in the tele-operation of mining equipment utilising the SMART concept illustrated in Figure 3.

The plan for transferring FAMOUS to mining applications involves:

- establishing the requirements, specifications and architecture for the FAMOUS/SMART control station
- prototyping a selection of FAMOUS/SMART components
- proof-of-concept demonstrations to ensure that the functional-capability targets can be achieved
- demonstrations to potential customers in the mining sector
- completion of the FAMOUS/SMART control station
- determination of pricing policy and the preparation of marketing material, and
- customer development for worldwide exploitation.

Figure 4. NewTel's microwave tower at Monkey Hill, Labrador

The use of advanced ice-phobic materials for anti-icing

NewTel Communications microwave communication towers and antennas located in Labrador develop very large build-ups of rime ice during wintertime. These ice accretions frequently result in the loss of communications or, worse still, can cause extensive physical damage to the towers and antennas.

Likewise, Cougar Helicopters Inc., who provide helicopter transportation services to and from the Hibernia Platform on the Grand Banks, frequently encounter in-flight icing conditions. Although their helicopters are the only ones in North America cleared to fly in known icing conditions, the penalty of having to install electrical anti-icing equipment is a reduced payload capability and lowered aircraft performance. Any means of eliminating this heavy equipment through the use of lightweight ice-phobic materials will lead to more efficient operation.

Project descriptions

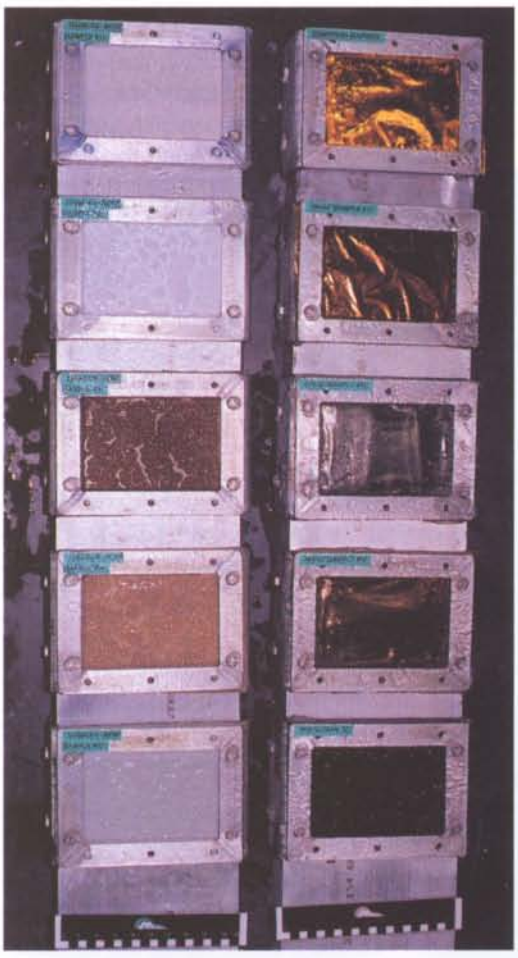
The objective of these projects is to evaluate the effectiveness of state-of-the-art ice-phobic materials, developed initially for space applications, for anti-icing applications in the telecommunications and aviation sectors.

High buildups of rime ice on the NewTel microwave towers can cause loss of communications. The worst sites are located at Sand Hill near Cartwright, and at Monkey Hill near Makkovik, where ice thicknesses of more than 1.5 m have been measured. Figure 4 shows the ice accumulation on the tower at Monkey Hill in January 1998.

NewTel has upgraded its facilities to operate at 6 GHz, rather than the current 900 MHz, and this increased frequency is of concern since the decreased wavelength is likely to result in increased sensitivity to ice accumulation.

C-CORE is currently designing and installing a mechanical system to prevent radome ice accumulation, and also installed a new test panel at Monkey Hill in May 1999 to further evaluate the ice-phobic properties of various advanced materials. Figure 5 shows snow/ice accretions produced in the laboratory on some of the material samples obtained from Daimler-Benz and RST Systemtechnik (Germany), Diavac (UK) and Cametoid Ltd. (Canada). These samples are listed in Table 1.

In addition, the electromagnetic transmissivities of these materials will shortly be measured at



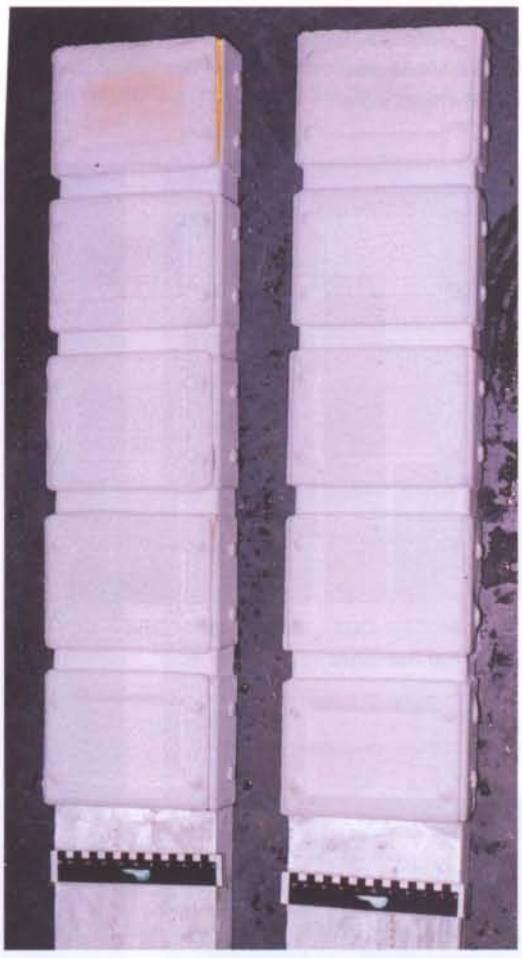


Figure 5. Advanced materials with ice-phobic properties subjected to ice (left and below) and snow (right) accretions in the laboratory

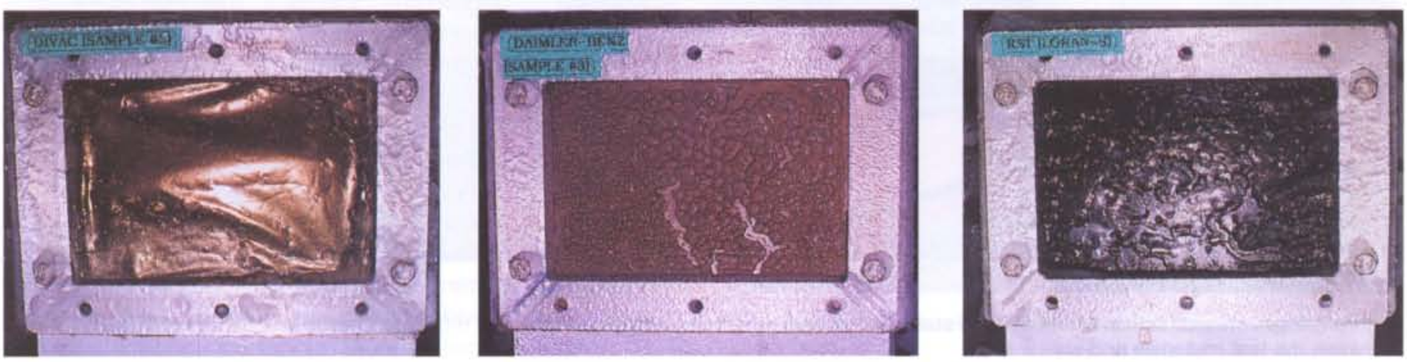


Table 1. List of samples obtained to date

Company	Material Type	Comments
Cametoid Ltd. (Canada)	Kapton-coated aluminium	Flexible
Raumfahrt Systemtechnik GmbH (Germany)	Loran-S	Rigid
Daimler-Benz (Germany)	PTFE-coated glass fabric	Flexible
	PTFE-coated PTFE fabric	Flexible
	TFM-coated glass fabric	Flexible
	TFM-coated aramide fabric	Flexible
	Fluor-elastomer-coated glass	Rigid
Diavac ACM Ltd. (UK)	DLC coated Mylar film:	All samples flexible
	5 min at 200 V one side	
	20 min at 200 V one side	
	5 min 300 V one side	
	10 min 300 V one side	
	5 min 300 V both sides	

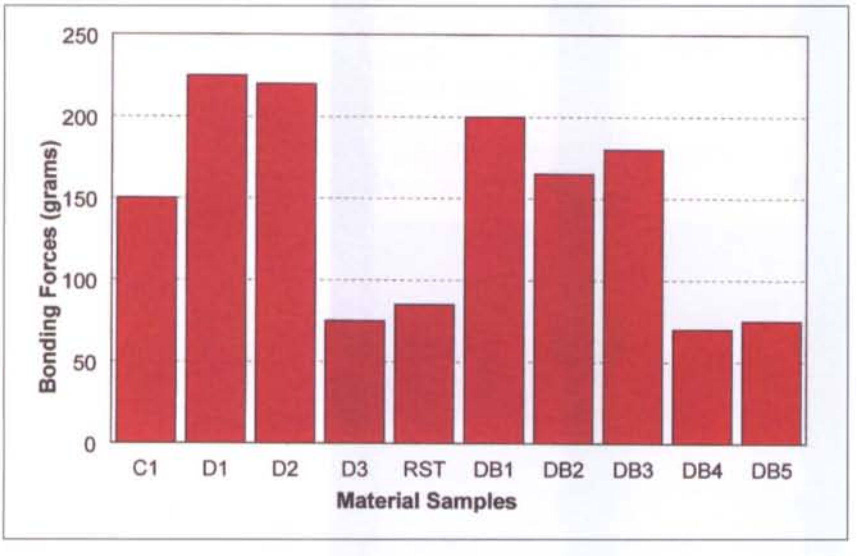


Figure 6. Ice-phobic properties of the sample materials

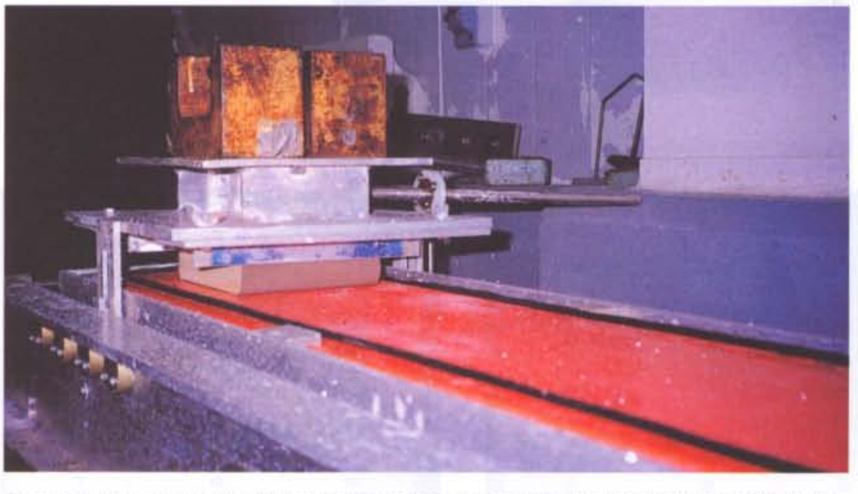


Figure 7. Experimental set-up for measuring static and dynamic friction coefficients between the test materials and ice

frequencies ranging from 900 MHz to 6 GHz. The propagation of microwave signals through ice of various thicknesses has already been characterised over this range of frequencies.

The ice-phobic properties of these materials, measured through a simple scratch test, are indicated in Figure 6.

Laboratory tests to determine both the static and dynamic coefficients of friction between ice and the test materials were also undertaken by C-CORE at the National Research Council of Canada's Institute for Marine Dynamics. The experimental set-up is shown in Figure 7, and the friction coefficients measured are reported in Figure 8.

Figure 9 shows the test site with the panel (next to the person standing) covered in rime ice built up over a six-week period. Access to this remote site is by helicopter only and, as such, visits are made on an opportunistic basis. Figure 10 shows the test panel cleared of the rime ice that had built up around the edges of the test frame and then completely covered the test samples. The clear areas on the samples indicate lack of adhesion of the ice to their surfaces.

The materials being tested for ice-phobic properties at the Labrador site were also mounted at strategic points on Cougar Helicopter Inc.'s Super Pumas (Fig. 11) to evaluate their potential for in-flight icing. Trips to and from the Hibernia Platform from St. John's, Newfoundland involve low-level flying (typically at 1500 m) and the probability of encountering icing conditions, particularly during the winter months, is high. The electrical anti-icing (or de-icing) system currently installed on the helicopters results in a 6 knot reduction in cruising speed and a 115 kg reduction in payload. When all flights are operating at their payload and range limits, any means of eliminating these drawbacks is welcome. It is recognised that the introduction of new materials onto the aircraft structures will require approval from the relevant certification authorities (Transport Canada for Canadian operations) and that this may take time. Nevertheless, enhancing the performance of the aircraft will be an ongoing task.

The technology-transfer process

Unlike the transfer of software, or a specific technology, the use of advanced materials in new terrestrial applications is a joint endeavour between the supplier and the end-user. In the current applications, C-CORE became the R&D provider to industry. Testing of the advanced materials under operational conditions, through the demonstration projects initiated by C-CORE under the HEI, proved to be of significant commercial value to the suppliers. Furthermore, the use of these materials in non-traditional sectors opened up new market opportunities for the suppliers. Two types of technology transfers were undertaken:

- a straightforward purchase of sample materials from the suppliers for testing purposes, and
- the negotiation of a cooperative agreement between C-CORE and the suppliers, whereby C-CORE conducted the materials testing under operational conditions and in the laboratory and provided the results to the suppliers. As C-CORE opened up new market opportunities for the suppliers, both C-CORE and ESA (through its investment in the development of the advanced materials in the first place) stand to recover royalties.

In the former case, if the suppliers seek to increase their market opportunities resulting

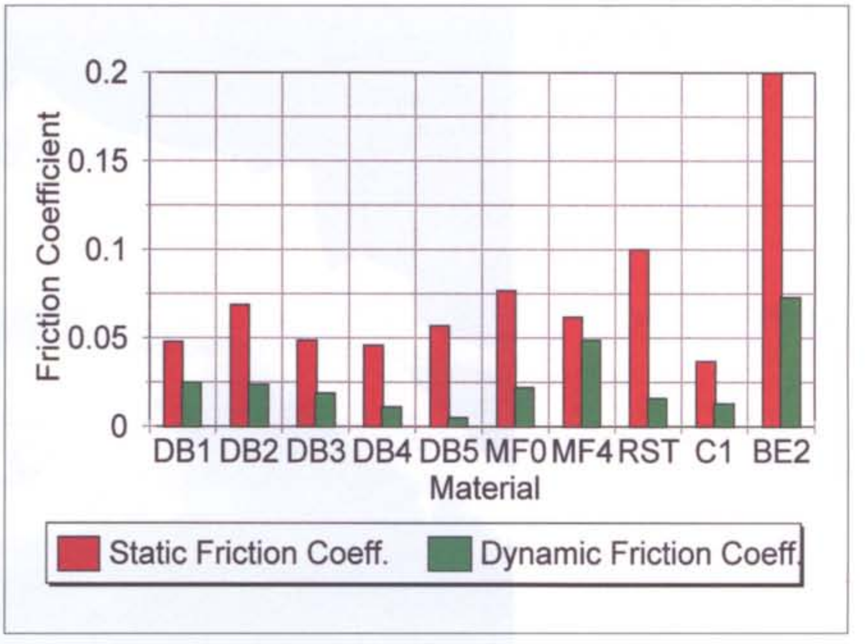


Figure 8. Static and dynamic coefficients of friction between the test materials and ice. DB1-5, MF0-4, etc. are codes for the various test samples

Figure 9. The Monkey Hill test site showing the rime-ice-encrusted test panel (left)

Figure 10. The test panels partially cleared of rime ice (right)

Figure 11. A Super Puma operating under typical weather conditions on the Grand Banks

from the demonstration projects, then C-CORE will enter into a 'commercialisation agreement' whereby royalties from sales flow to both ESA and C-CORE. Since the testing of the materials was not conducted under a true partnership agreement (test samples were purchased from the supplier rather than being provided free of charge), the foreground technology (foreground intellectual property) would rest with C-CORE and its partners in the demonstration projects, and the royalties flowing back to C-CORE would be set at a higher level than those under a true partnership.

In the latter case, the foreground technology (foreground intellectual property) would belong to all partners, since each would be contributing to the project. In effect, C-CORE would be acting as the manager of an R&D consortium conducting materials research for the industry suppliers and the end-users. However, any out-of-pocket expenses incurred by C-CORE would need to be covered by the industrial partners.

As with the FAMOUS/SMART project described earlier, the partners would seek wider markets worldwide in order to fully commercialise the results.

In addition to the aviation sector, the power and communications utilities are very interested in applying ice-phobic materials to their transmission and communication towers. The disastrous ice-storm of January 1998 in Ontario and Quebec has highlighted the need for such advanced ice-phobic materials. Likewise, drilling ships, oil rigs and fishing fleets operating in regions prone to spray icing can also benefit considerably from using materials more resistant to ice build-up. The enhancement in operational safety is significant.

Conclusion

Phase-1 of the Harsh Environments Initiative (HEI) resulted in the activation of eight projects in the oil & gas and mining sectors. The main objective is to improve terrestrial operations in these sectors by improving both efficiency and cost-effectiveness, without incurring any reduction in safety or unacceptable environmental consequences. A technology-transfer model that was developed by C-CORE more than a decade ago has been adopted to provide a smooth flow of technologies developed for space to terrestrial applications.

Automation has a very high priority with mining companies and several space technologies are being explored to assist in meeting the goal of full mine automation within the next few years. Offshore aviation is a major issue for oil & gas development in cold oceans. Means for improving efficiency and safety are being researched, one aspect being the use of ice-phobic materials to improve flying operations in icing conditions. The materials tested to date have shown a wide variation in their ability to shed ice. The work also has relevance for power-transmission and communications towers and for shipping operations in northern waters.

Co-funded Contracts: The New Approach in Support of European Space Competitiveness

S. Benetti
Contracts Department, ESA Directorate for Industrial Matters and Technology Programmes, ESTEC, Noordwijk, The Netherlands

C. Elia
Project Services Department, ESA Directorate for Technical and Operational Support, ESTEC, Noordwijk, The Netherlands

The Resolution on the Agency's Industrial Policy adopted by the ESA Council at Ministerial Level in Paris in 1997 marked a clear step towards action to improve the competitiveness of European Industry in the worldwide space market. In particular, Ministers decided that the technologies developed within the Agency's programmes should be used more extensively to stimulate Europe's industrial competitiveness in commercial markets. A transitional period of three years (1997-1999) was established in which to define specific measures to achieve these objectives and to test them. This article is based on the experience of the authors in the processing of more than 100 industrial proposals in the framework of the ESA Technology Research Programme (TRP).

The co-funding approach in technology procurement

The fundamental principle of the new procurement approach described here is to support the development of those technologies/products needed to improve European Industry's competitiveness. In practice, while ESA still defines the strategic areas to which public investments should be directed, Industry is widening its traditional role by taking the lead in the product definition, specification and implementation aspects. This represents a major change in the traditional customer/contractor relationship between ESA and Industry and, as a consequence, they now share the financial burden of the project development effort (so-called 'co-funding').

The implementation of such a novel approach requires changes in several elements of the procurement process, namely the Invitation to Tender (ITT), the evaluation process, and the inclusion of a business plan, and there are also the contractual issues.

Table 1

Fully ESA-funded approach	Co-funded approach
Agency's full financial coverage	50% maximum Agency contribution to the total contract price
Agency's technical requirements	Industry's technical requirements (justified by commercial interest)
Agency's detailed definition of the Statement of Work (SOM) and programme of work	Agency's Top-Level Statement of Work (SOW). Programme of work defined by Industry
Standard ESA contract conditions	Contract conditions tailored to guarantee Industry's Intellectual Property Rights (IPR)

The Invitation to Tender

In order to ensure a proper selection process, a modified ITT approach has been developed. A quick comparison between the traditional ITT and the co-funded one is provided in Table 1.

In addition, in a co-funded ITT there is a need to obtain access to information on the commercial potential of the technology/product to be developed by Industry in order to assess the commercial credibility of the industrial proposal. A 'Business Plan' is therefore requested as an essential element of the offer. Consequently, in the evaluation process there is specific action and criteria to assess the quality and credibility of that Business Plan.

The need to protect sensitive commercial information contained in the Business Plan has led to the implementation of a stricter confidentiality procedure within ESA (i.e. secure document warehousing, restricted document access controlled by security guards, etc.). In particular, the Business Plan is requested to be delivered in one copy only, and it is kept at ESA's premises only for the time needed to conduct the proposal evaluation. It is returned to the bidder immediately the evaluation process is completed. In the case of contract award, the contractor selected is obliged to keep the Business Plan, duly countersigned by ESA, at its premises and at the disposal of ESA Contracts representatives.

The Business Plan

A major novelty brought by the new co-funded approach is the introduction of the Business Plan into the evaluation process. Companies who want to develop or improve their products for the market place must have an in-depth knowledge of that market. They must assess their ability to tap part of that market successfully at the right time, with the right product offering. Data and ideas have to be collected and organised in a structured manner, ways of acquiring the necessary funding for the project have to be found, and marketing and sales actions have to be planned. All of this should be found in a good Business Plan.

The Business Plan is a tool that the Company utilises as a blueprint in order to progress from the project idea to a successful (in a commercial sense) product or service. The companies themselves are not the only users of the Plan. Where there is a need to access external financial resources, the Business Plan is a pre-requisite for the venture. A thorough analysis of the Business Plan can provide potential investors with the necessary confidence that the venture has a good chance of being profitable and therefore represents a good investment opportunity. There are many different forms of Business Plan that go through different levels of the business process giving details depending on the project time horizon, the level of competition, and the specific industry.

The Agency is already dealing with Business Plans in the framework of the ARTES telecommunications programme, where the Business Plan is an integral part of the overall proposal-evaluation process. In the Technology Research Programme (TRP), where the project time-scales are usually longer, the emphasis is more on the strategic, longer-term prospects for the proposed product/technology; as a consequence, the estimates and evaluations to be found in the Business Plan cannot be quantitatively very precise. Qualitative considerations and trends become more important in such cases.

The main elements of a TRP Business Plan requested in a co-funded Invitation to Tender are:

- The Technical Description of the Product/Service
- The Market Analysis
- The Competitive Analysis
  - Competitors and their Products
  - Strengths, Weaknesses, Opportunities, Threats (SWOT) Analysis
- The Company's Marketing Strategy
- The Financial Planning and Risk Analysis.

The main concepts and most commonly used terminology in these elements, which we ourselves used in the industrial proposal evaluation process, are discussed here to give an idea of the rationale for the information that one can expect to see in a sound Business Plan. We will not distinguish between products and goods or services, which we will simply term the 'product', and we will refer to the company that originates the Business Plan as 'the Company'.

Description of the product

This part of the proposal presents the characteristics of the proposed product in detail. It must be noted that this description is substantially different from the one given in the technical proposal. While the latter provides a detailed description of the technical features of the proposed product, here the Company talks about user benefits and services. It describes how the product's technical features translate into user benefits. For example, a producer of electric engines would describe the technical characteristics (efficiency thrust, impulse, dimensions, etc.) in the technical proposal; in the Business Plan, he will describe the possible applications of that engine: where it could be fitted on board standard platforms, provide sufficient thrust to avoid use of other engines, and/or save propellant mass, etc.

In the same way, a producer of disposable contact lenses will describe in the technical proposal, the production process, the clarity, and the resistance to folding of a new contact lens. In the Business Plan he will rather describe its improved compatibility with the human eye, its greater durability, and the easier cleaning process for the user.

Market analysis

The second step in the synthesis of the Business Plan is the so-called 'Market Analysis'. There are a number of ways of conducting this exercise. Market analysis can be performed through interviews with potential customers (primary data), utilising previous market analysis for similar products and or markets, utilising macro-economic indicators such as Gross Domestic Product (GDP), spending power, etc. (secondary data). The effectiveness of each methodology depends on the specific case.

All of these methods have a common objective: 'to estimate the size of the (potential) need for the product', which means making an evaluation on how many people are willing to pay to satisfy such need and therefore to buy the product. At this level, we do not yet talk about pricing, but assume that the product will be fairly priced. The extent of the market analysis very much depends upon the specific product, the actual status of the market's development, and the competitive scenario. If, for instance, we are in the market-introduction phase for a product that is relatively new, the market-analysis effort will concentrate on interviews and focus groups. If instead the market is a mature one (similar products have already been introduced and we are now at the second or third product generation, customers know the product, its competition and prices), the market analysis can be done through deskwork: data mining, database consultation, etc.

It must be stressed that, as for many other elements of the Business Plan, it is very important for the evaluator to have a good knowledge of the market. The output of this activity is a quantitative evaluation of the so-called 'Available Market'.

Competitive analysis
This section of the Business Plan deals with the analysis of other companies that offer, or are about to offer, the same or a similar product. In particular, it evaluates which portion of the 'Available Market' they serve (market share). Also here, depending on the state of evolution of the specific market, we see different scenarios that require different analysis tools. In a mature market, the competition scenario is rather stable and well-known; established-competitor performances are also known. The analysis is then much easier than in a new, undeveloped market where it is not clear how many competitors will appear, what the market dynamics will be, and how the buyers will behave, etc. (e.g. Iridium's mobile system).

The marketing strategy of the Company is very important. It makes a big difference whether the Company is trying to enter a (new) market, or whether it wants to increase its market penetration, or whether it merely wants to defend its existing market share against a new entrant.

The market share of each competitor is not the only important element of the competitive analysis. To get a complete picture of the competitiveness scenario, it is necessary to perform a 'Strengths, Weaknesses, Opportunities and Threats' (SWOT) analysis. This is a systematic and powerful tool for assessing the major strengths and weaknesses of each competitor. Examples are intellectual property rights (Strength), low market-entry barriers (Threat), access to unlimited resources (Strength), new regulations (Opportunity/ Threat), etc. The SWOT analysis gives the Business Plan evaluator a complete report on the forces and dynamics of that particular segment of industry, and also provides valuable inputs for the strategic marketing plan where the Company will have to fight the competition. The SWOT helps the Company to identify current market opportunities or temporary competitor weaknesses, which may be used to improve its strategic position.

Finally, the competitive analysis should provide a quantitative estimation of the so-called 'Addressable Market', which is defined as the portion of the Available Market that is targetable by the company (addressable market minus the shared market that is, or is going to be, taken by competitors).

Marketing strategy
The marketing strategy is a top-level description of *how* the Company intends to capture (part of) the Addressable Market. It is a list of actions that derives directly from the market and competitive analysis and goes into the planning of how to interface with the market. These planning exercises generate a 'Marketing Plan'.

Once again, in practice we do not have a universal marketing plan structure, but in most cases the marketing activity contains the following three elements: Market Segmentation, Market Targeting and Market Positioning.

In the market segmentation, the Company 'segments' the total addressable market. This segmentation permits one to identify and isolate a group of potential customers who share some of the same requirements; in other words, they can be considered somewhat 'homogeneous'. Typical examples of segmentation variables for consumer markets would be: geographical area, religion, age, family size, gender, life style, language, spending power, buying behaviour, etc.

The second step is evaluation of the attractiveness of each market segment. The process of selecting the most attractive segments is called 'Market Targeting'. Note that the selected segment may not necessarily be the most profitable. The targeting strategy can then be: single-segment concentration (one product for one market segment), product specialisation (one product for more than one market segment), market specialisation (a set of products for a single market segment), etc.

The last step is the 'Market Positioning', which determines how the company will attract customers in the target segment. Typical examples are cost leadership (selling at lower prices than competitors, e.g. K-Mart), product differentiation, quality (e.g. Hewlett-Packard).

Financial planning and risk analysis
The financial planning deals with the acquisition and utilisation of financial resources. The financial plan contains details about the investment needed to acquire the assets and capabilities to produce and sell the Product. As the risk associated with Technology and Research projects is normally high, it is generally more difficult to acquire financial resources for the project. The level of investment required for the project must therefore be very carefully evaluated. In many projects, there is the possibility to dilute the investment requirement over some period of time, thereby facilitating the acquisition of financial assets.

Investment is one of the most important elements, but not the only one. Fixed and variable costs (for development, production, marketing, sales, etc.) also need to be evaluated together with the projected sales and associated revenues. The financial tools that are usually used are the so-called 'Financial Statements' such as Cash Flow, Profit and Loss (P/L) Accounts, and Balance Sheet. To complete the picture, a set of 'Financial Indicators' is normally given, which are derived from the financial data to provide a measure of the project's profitability. The most commonly used indicators are NPV (Net Present Value), IRR (Internal Rate of Return), Payback Period (also called the break-even point), and Profitability Index. Without going into the technical details, such indicators provide a measure of how and when the money invested will be returned in the Company (in the form of profit), and how much extra money will be generated. Such indicators represent a useful tool for quickly comparing different investment opportunities or projects and selecting the most profitable.

Risk analysis is very often an integral part of the financial plan. Projects can have a high risk profile, meaning that the business involves quite a number of uncertainties and unknowns. For instance, there may be project cost overruns due to product-development difficulties, or lower than expected sales or revenues. There may be new competitors entering the market that were unknown at the time when the decision to invest was taken. New (cheaper) substitute products may appear on the market. The list can be very long!

All 'Risk Elements' should be analysed in detail in terms of their probability of occurrence and impact on the proposed product's profitability and, finally, possible recovery actions. Risk analysis and countermeasures have, in turn, a direct impact on the 'nominal' financial statements, which are then modified to include these uncertainties. Very useful in this domain is the 'scenario analysis' in which adverse conditions are simulated to estimate their impact on the financial indicators and therefore on overall project profitability. These simulations are also called 'sensitivity analyses'. Often, risk analysts use the so-called 'worst-case analysis', which is easier to compute. All variables in the financial statements are replaced with worst-case values and the worst-case financial indicators are evaluated.

More sophisticated risk-analysis methods are being used more often in business today, the 'What-if analysis' being one of them. This analysis provides a better simulation of reality, and even foresees a first level of counter action in response to worse-than-expected market behaviour. For instance, if the projected sales are lower than expected, the marketing expenses will be increased and the investment requirement contracted, since less production power is required. The combined effect on the financial indicators is then computed.

Clearly, each method has its own particular advantages and limitations. There is no universal tool for performing risk analysis. However, the combined use of some of them can provide the necessary confidence for internal and external investors to decide whether or not to fund the project.

Contractual issues in a co-funded contract
The 'General Clauses and Conditions' applicable for all ESA contracts are based on the principle that the full development costs are paid by for the Agency. Under this assumption, the Contractor is the owner of any information and invention produced under an ESA contract, but the Agency, and its Member States/Participating States:

- Retains the rights in licensing all patents and copyrights, obtained by the Contractor as a result of the contract, in the field of space research and technology and their space application.
- Has full dissemination rights over the contract results.

In the case of co-funded contracts, neither of these fundamental principles is directly applicable. A full Agency licensing or dissemination right would in fact allow potential competitors to have access to sensitive technical information and data. This would void the Contractor's competitive advantage in the market place. Full protection of contract results and limited Agency licensing rights have been introduced into the co-funded contracts to protect Industry's competitive position.

Special clauses have been introduced to protect and safeguard the correct use of the Agency's funding:

- The Agency has the right to make a financial audit to verify, at contract or phase completion, the actual funding contribution by Industry in the contract.
- The technology/product developed under co-funded contract shall be available at fair and reasonable conditions to all potential customers residing in the Agency's Member States or Participating States.
- There shall be regular reviews of the Business Plan's validity during the contract's execution.

Other clauses like penalty application, royalties, guarantees, cancellation of the contract and right of reproduction, have also been adapted to take into account the industrial financial participation in the development.

Conclusions

The introduction of the co-funded TRP contract approach is proving very challenging not only for its novelty, but also the varied nature of the problems associated with responding successfully to the new industrial policy requirements. Given the many things that we feel we have learned through this hands-on exercise, in concluding we would like to highlight just a few key issues:

1. In contrast to the traditional engineering approach, Business Plan evaluation is a multidisciplinary task led by a business analyst supported by a team of technical/legal experts. It is the interrelation between the commercial objectives and the technical choices that determines, in most cases, the value and the credibility of the business proposition. For instance, when evaluating a Business Plan for the development and production of advanced solar cells, the technical experts are fundamental to providing a judgement on the suitability and fair pricing of the proposed production facilities. No critical business decision can be taken without considering the technical implications, and vice-versa. The multidisciplinary team should also include legal expertise, as in many cases the IPRs, licensing, import restrictions, exclusivity issues, etc. can have a tremendous impact on the business case's success.

2. Despite the Agency's strict application of security procedures to protect Business Plan information, Companies with proven track records of commercial success have generally been very reluctant to release commercially sensitive information in writing. This is understandable considering that such information is often of huge strategic value to the company. Lack of such information is, however, a 'show-stopper' for the evaluation process, which in turn could put the overall philosophy of the co-funded approach into question.
It was therefore decided to try to overcome this impasse by inviting the Bidders to a presentation to the Agency's Tender Evaluation Board (TEB). A set of questions identifying the missing information was sent to the Bidders with the request to provide answers during the presentation. The companies felt more comfortable with this approach and were then more willing to release sensitive information to ESA. All material presented was configured, countersigned by both parties and left in the custody to the Bidder, with the agreement that such material would, as already foreseen within our procedure, be made available on request to ESA Contracts representatives. In this way, the TEB was able to gain access to all of the critical information needed to complete the evaluation, whilst at the same time the Bidders were certain that there would be no physical dissemination of sensitive information. This solution has therefore proven to be extremely successful and has allowed a thorough and fair evaluation of the various proposals. The effort involved in the TEB is, however, substantially higher than in a traditional evaluation process.

The co-funding approach, like similar initiatives being undertaken within the Agency, is an attempt to provide a first response to the new demands from Member States for more efficient utilisation of public resources, while at the same time supporting European Space Industry in the face of ever-increasing worldwide competition. The new approach is already being applied and we are pleased to confirm that the first results look very good. They indeed appear to confirm the validity of co-funded contracts as a sound and worthwhile approach to supporting European competitiveness in the global space market.

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Concurrent Engineering Applied to Space Mission Assessment and Design

M. Bandecchi & B. Melton
Mission Control Systems Division, ESA Directorate for Technical and Operational Support, ESTEC, Noordwijk, The Netherlands

F. Ongaro
General Studies Programme, ESA Directorate for Strategy, Paris

ESA performs pre-Phase-A assessment studies as part of the definition of future space missions. To evaluate the benefits of the 'concurrent engineering' approach to these studies, an experimental design facility was created in ESTEC and used to perform an assessment of the Italian Space Agency's CESAR (Central European Satellite for Advance Research) mission. This article describes the approach adopted and the experience gained during the study, and draws preliminary conclusions on this new approach to space-mission assessment and design.

Introduction

Within the framework of its General Studies Programme (GSP), ESA performs a number of pre-Phase-A assessment studies each year. The purpose of these studies is to assess the feasibility of a new space mission from the technical, programmatic and economic points of view. This is normally achieved by producing a preliminary conceptual design of the mission and space system. The resulting study report is used as an input to the industrial Phase-A design studies.

Pre-Phase-A studies are normally performed in-house at ESTEC, by technical-support specialists using a classical approach, in which each specialist prepares a subsystem design relatively independently from the others, using stand-alone tools. Design iterations at system level take place in meetings at intervals of a few weeks. This method, which is still the one most frequently used, has obvious advantages, such as the flexibility in the use of manpower resources and the fact that it is a well-tried and routine process. On the other hand, it has drawbacks in that it favours a certain 'segregation' in the subsystem preliminary design, reducing the opportunity to find interdisciplinary solutions and to create system awareness in the specialists. Furthermore, the time required for performing studies using the classical approach (6–9 months) may be incompatible with today's drive towards a shorter time-span from mission concept to spacecraft flight (e.g. the SMART and Flexi missions).

An alternative to the classical approach is offered by 'concurrent engineering', which provides a more performant design method by taking full advantage of modern information technology. There are many definitions of the meaning of this term, but the following one best describes the thinking behind the experiment described in this article:

'Concurrent engineering is a systematic approach to integrated product development that emphasises the response to customer expectations. It embodies team values of co-operation, trust and sharing in such a manner that decision making is by consensus, involving all perspectives in parallel, from the beginning of the product life-cycle.'

The concept is not new; in fact, it is already practised in many industrial sectors throughout the product development cycle. There are also examples in the space domain, such as the well-known NASA/JPL Project Design Center, used for conceptual mission design. In ESA, the method has been studied and even already partially applied in two mission-assessment studies (Euromoon and Venus Sample Return). These examples were not concerned with the suitability of the method itself, being focussed more on the actual mission under definition rather than a re-usable infrastructure.

The objectives of the current experiment were to:
- create an experimental mission design environment (hereafter referred to as the Concurrent Design Facility, or CDF) in which the conceptual design of space missions could be addressed in a more effective way

- apply the practice of concurrent engineering to a number of test cases to identify the potential of such an approach in the various phases of space-mission development
- gather the information needed to evaluate the resources required to create a permanent facility available to all programmes.

A first case study was provided by the CESAR mission assessment, performed from January to March 1999, which ESA had undertaken jointly with the Italian Space Agency (ASI), on behalf of the Central European Initiative (CEI).

The approach

The means to create the facility on an experimental basis was simply to organise the existing tools and human resources already employed for space-mission assessment studies in a more effective (i.e. concurrent) way.

The concurrent-engineering approach is based on five key elements:
- a process
- a multidisciplinary team
- an integrated design model
- a facility, and
- a software infrastructure.

The process

The conceptual model of the design process is shown in Figure 1, which highlights the fact that a space system has many interdependencies between components. This implies that the definition and evolution of each component has an impact on other components and that any change will propagate through the system. The early assessment of the impact of changes is essential to ensure that the design process converges on an optimised solution. The concurrent-engineering approach is intended to provide the means to achieve this.

The process starts with a few meetings involving a restricted number of specialists (customer, team leader, system engineer) to refine and formalise the mission requirements, to define the constraints, to establish design drivers, and to estimate the resources needed to achieve the study objectives.

The design process is conducted in a number of sessions in which all specialists must participate. It is an iterative process that addresses all aspects of the system design in a quick and complete fashion. The simultaneous participation of all of the specialists reduces

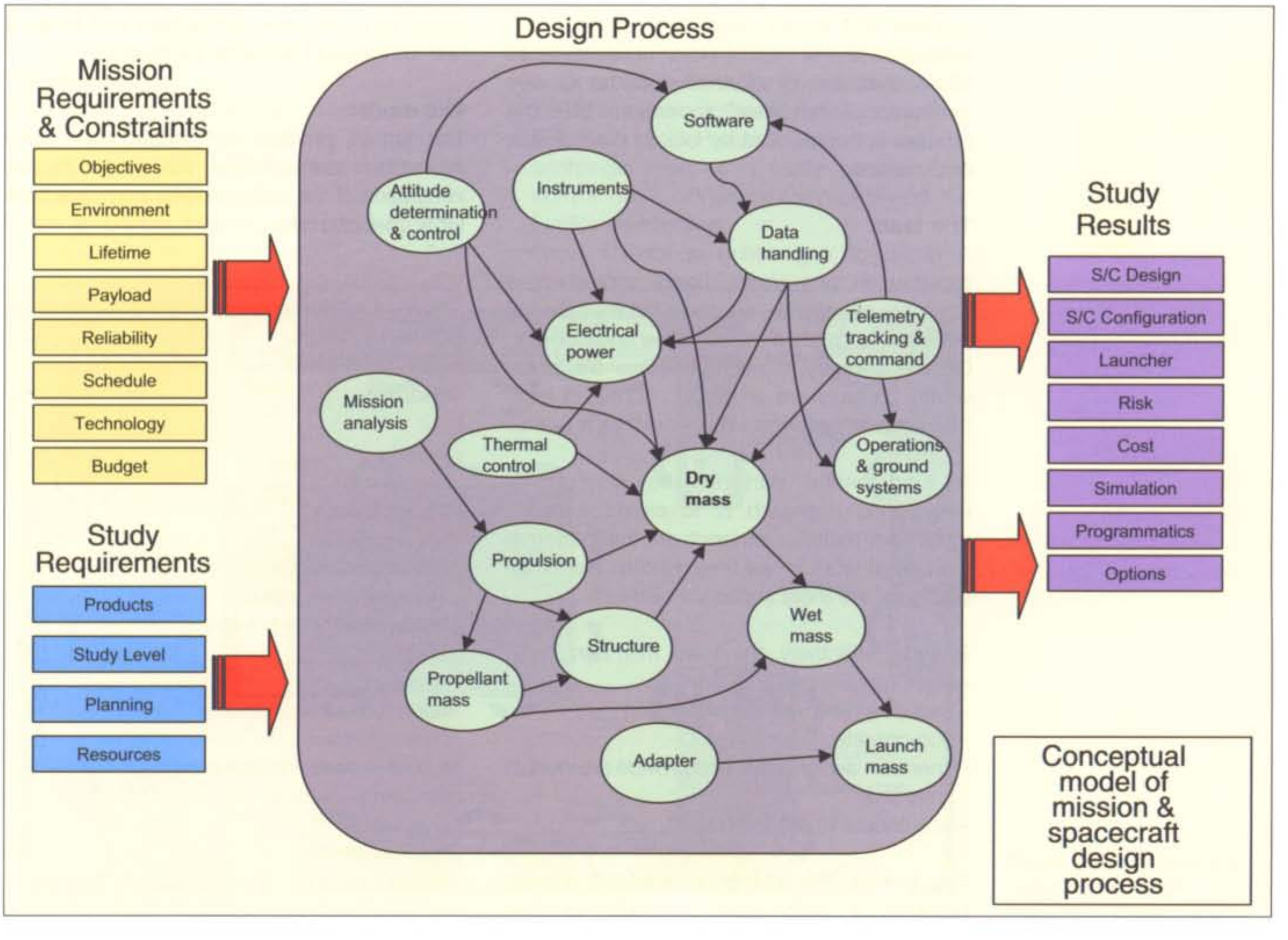


Figure 1. Conceptual model of the mission and spacecraft design process

the risk of incorrect or conflicting design assumptions, as each major decision is debated and agreed collectively. In this way the design progresses in parallel and allows those disciplines that were traditionally involved at a later stage of the process the opportunity to participate from the beginning, to correct trends that might later invalidate the design.

The customer is invited to participate in all sessions along with other specialists of his/her choice (e.g. study scientist, project controller), so that they can contribute to the formulation of the study assumptions, answer questions from the team, and follow the evolution of the design. This includes the possibility to discuss and correct in real time any orientation of the design not in line with their expectations.

The first design session starts with the customer presenting the mission requirements and constraints to the team. In subsequent sessions, each specialist presents the proposed option or solutions for his/her domain, highlighting/discussing the implications for the other domains. Out of this debate, a baseline is retained and the related values recorded in a shared database.

One key factor is the ability to conduct a process that is not dependent on the path followed. At any step, it must be possible to take advantage of alternative paths or use 'professional estimates' to ensure that the process is not blocked by lack of data or lack of decisions.

The team
A group of engineering specialists working together in one room, using sophisticated tools, are all essential elements but they are not sufficient to create a collaborative environment. On the contrary, it might become the place where conflicts are amplified. Above all else, the group of specialists must work as a team.

A fundamental part of the concurrent-engineering approach is to create a highly motivated, multidisciplinary team that performs the design work in real time. Human resources are by far the most important element!

To work effectively, the team members must accept to:
- adopt a new method of working
- co-operate
- perform design work and provide answers in real-time
- contribute to the team spirit.

This is more difficult than it might first appear, because it puts more pressure on the engineers, who are required to participate in every session and to:
- prepare the designs of their subsystems using the facility's computerised tools
- follow the main-stream presentation/discussion to identify possible influences of other domains on their own domain
- be ready at all times to answer questions relating to their domain
- adapt the model of their subsystem to changes in the mission baseline
- record design drivers, assumptions and notes, which will form the basis for the preparation of the final report.

The technical disciplines selected for the CESAR study are listed in Table 1.

For each discipline, a 'position' is created within the facility and assigned to an expert in that particular technical domain. Each position is equipped with the necessary tools for design modelling, calculations and data exchange (as described below).

The choice of disciplines involved depends on the level of detail required and on the specialisation of the available expertise. On the other hand, the number of disciplines has to be limited, especially in the first experimental study, to avoid extended debate and to allow fast turn-around of design iterations.

The model
The design process is 'model-driven' using information derived from the collection and integration of the tools used by each specialist for his/her domain.

Table 1. The technical disciplines in the ESTEC CDF

POSITION
Systems
Instruments
Mission Analysis
Propulsion
Attitude and Orbit Control
Structures/Configuration
Mechanisms/Pyrotechnics
Thermal
Power
Command and Data Handling
Communications
Ground Systems and Operations
Simulation
Cost Analysis
Risk Assessment
Programmatics

Why a model? A parametric-model-based approach allows generic models of various mission/technological scenarios to be characterised for the study being performed. A parametric approach supports fast modification and analysis of new scenarios, which is essential for the real-time process. It acts as a means to establish and fix the ground rules of the design and to formalise the responsibility boundaries of each domain. Once a specific model is established, it is used to refine the design and to introduce further levels of detail.

A first activity in the modelling process is to acquire or establish the model suited to the mission scenario before it can be parameterised to perform the iterative design process. Each model consists of an input, output, calculation and results area. The input and output areas are used to exchange parameters with the rest of the system (i.e. other internal and external tools and models). The calculation area contains equations and specification data for different technologies in order to perform the actual modelling process. The results area contains a summary of the numeric results of the specific design to be used for presentation during the design process and as part of the report at the end of the study.

The facility

The team of specialists meets in the Concurrent Design Facility (CDF) to conduct design sessions. The accommodation comprises a design room, as illustrated in Figure 2, plus a meeting room and project-support office space. The equipment and layout of the CDF is designed to facilitate the design process, the interaction, the co-operation and the involvement of the specialists. In particular, the disciplines with the most frequent interaction or other affinities (e.g. data/model sharing) are located close to each other. The central table is dedicated to the customer, support specialists and consultants.

In front, large projection screens can show the display of each workstation, so that the specialists can present design options or proposals and highlight any implications imposed on, or by, other domains. Video-conferencing equipment is installed to allow team members to participate in sessions from remote sites.

The software infrastructure

An infrastructure to implement the Concurrent Design Facility outlined above requires:
- tools for the generation of the model
- integration of the domain models with a means to propagate data between models in real time
- a means to incorporate domain-specific tools for modelling and/or complex calculations
- a documentation-support system
- a storage and archiving capability.

The infrastructure must allow its users to:
- work remotely from the Facility both within ESTEC and in other centres especially ESOC and ESA Headquarters
- exchange information easily between the normal office working environment and the Facility environment.

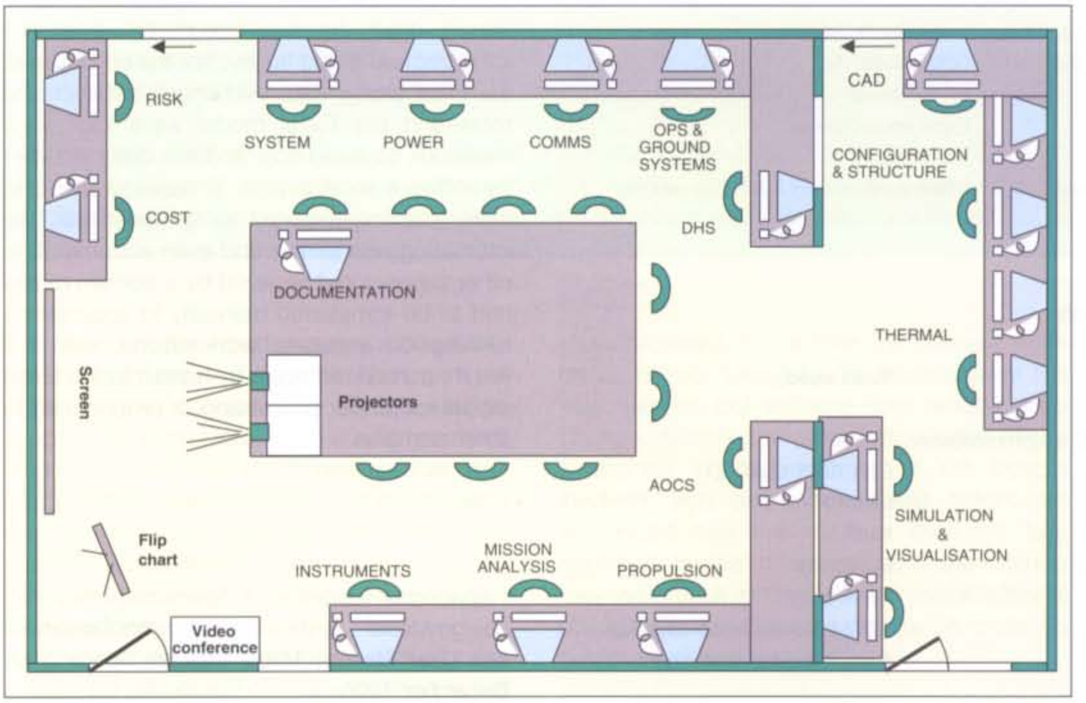


Figure 2. Constitution and layout of the ESTEC Concurrent Design Facility

In creating such an infrastructure to support the concurrent-design process, a number of important issues had to be considered.

Due to the experimental nature of the exercise, it was decided to use existing equipment and tools to build up the facility. The architecture of the system required workstations for the development of the project model and a supporting documentation system. The solution adopted was to base the infrastructure on the products already available either within the office-automation domain or within the technical domain of the participating engineers. As a result, no additional licences were required for the major software products to be employed. Low-power personal computers (75 to 133 MHz) were used to host the office-automation products.

Only two months were available to prepare a working system, leaving no time for the training of users. Use of existing tools with which the staff were already familiar was the only solution to this problem.

Table 2 identifies the general tools chosen as basic infrastructure items used by all team members, while Table 3 identifies the domain-specific tools used by the domain experts.

Although driven by the constraints identified above, the choice of tools has, in fact, proven to be satisfactory when looking to the future. Using tools that are already part of the Agency's infrastructure brings many benefits.

Table 2. General tools

Function	Tools Used
Documentation storage & archiving	Lotus Notes database
Electronic communication within the team	Lotus Notes mail
Storage area for all data files	NT file server
System modelling	Excel spreadsheets
Project documentation	MS-Word
Remote audio/visual communication	Video conferencing & MS-Netmeeting

Table 3. Domain-specific tools

Domain	Tools used
Structural design, configuration & accommodation	CATIA
Thermal	ESATAN & ESARAD
AOCS	Matrix X
Mission analysis	IMAT
Mission simulation & visualisation	EUROSIM
Programmatics	MS-Project
Cost modelling and estimation	ECOM cost/technical database & small-satellite cost model

For the system model, the choice of Microsoft Excel® spreadsheets was driven not only by its availability and the existing skills of the team, but by the fact that relevant work had already been performed under an ESA contract* in 1996. A fundamental decision was taken to split the system model into components that mirrored the domains of expertise of the team members, allowing work to be performed on the modelling independently and in parallel and without the reliance on a single modelling expert. This raised the need for a mechanism to exchange relevant data between domains in a controlled manner. This was solved by preparing a shared workbook to integrate the data to be exchanged, with macros to handle the propagation of new data in a controlled way.

Figure 3 shows the architecture of the model.

A significant output of any pre-Phase-A study is the Study Report. The use of Microsoft Word® allowed each engineer to prepare their section of the report as a sub-document that was then incorporated into the master document, prepared in accordance with the ESA standard document template.

The use of Lotus Notes® as the mail and document repository tool gave ESA-wide access to the project information, providing (subject to access control) a facility to browse, access or contribute to the study documentation.

The domain-specific tools brought by each expert had to be integrated into the infrastructure of the facility. For the purposes of the initial study, data exchanges between the tools and the Excel model were kept to a minimum, to avoid cost and the delay incurred by software development. In cases where tools were also implemented as spreadsheets, the interfacing was simple and even automated. In other cases, input received by a domain model had to be transferred manually to applications running on separate workstations, with the results transferred again by hand into the Excel model for further processing or propagation to other domains.

* *Spacecraft Modelling: A Spacecraft Integrated Design Model* - System Requirements Document and User Manual, Matra Marconi Space (UK), December 1996.

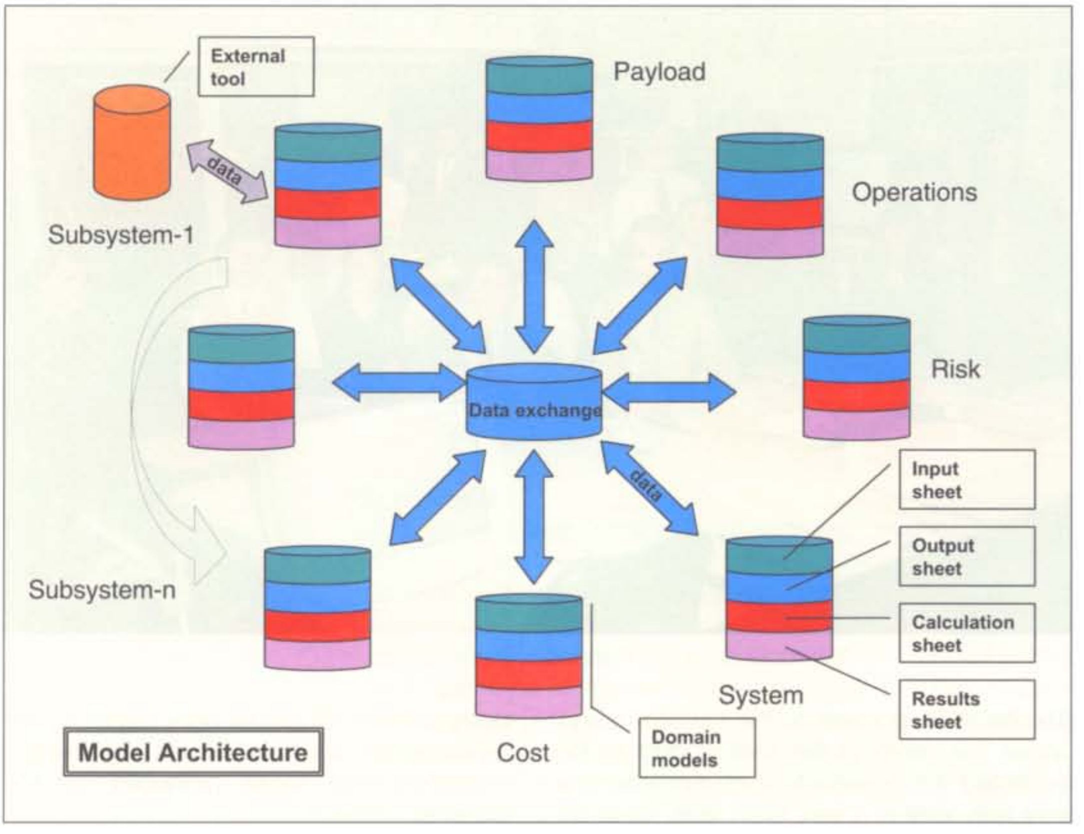


Figure 3. Architecture of the software model

Each domain workbook is comprised, as a minimum, of an input, output, model and results worksheet. In practice, multiple sheets are used for the modelling to give clarity to the major parts of the model and to ease display of the model during design sessions. The input and output sheets implement the data exchange with other domains as well as external tools. Figure 3 shows the conceptual architecture.

During a design session, discussion will lead to the necessity to perform an update to the model to reflect decisions or test hypotheses (e.g. to demonstrate the impact of changing the type of solar cells). Key parameters controlling the selection of the technology would be updated in the appropriate domain model. This will result in a new set of output parameters that must initially be restricted to the generating domain and not propagated to the rest of the system. If a decision is taken to propagate the data, then the locally held values are saved in the domain output sheet. The next step is to update the shared data area by propagating the domain output sheet. At this stage, the data is available to other domains should they decide to use it (i.e. other domain models are not triggered). The last step is to trigger the affected domains to read the new input data and to execute the model.

This process must be repeated until the impact of the change has been propagated to the point where iterations no longer have a significant effect. Clearly, the possibility for several, if not endless, iterations arises since two or more domains may be affected by each other's output!

This aspect of the infrastructure is a candidate for improvement in the longer term and will enhance the concurrency of the design process. An example of such an improvement would be the export of geometrical 3-D spacecraft-configuration data to the simulation system, which uses geometric models for the spacecraft visualisation.

Conclusions

As often happen, the adaptation of a process to take full advantage of a new method is not straightforward. For a time the process goes on as before, taking partial advantage of the new method, but suffering from resistance to change. Adopting a new method often needs a change in the mentality of the people involved, and only when these actors are convinced can the method itself be fully exploited. Furthermore, the use of the method may well result in the need for organisational changes external to the facility, in order to obtain maximum benefit.

Figure 4. The study team, gathered in the ESTEC Concurrent Design Facility

The iterative approach to the mission design allows the depth of the final product to be controlled. It is possible to study a mission at a very high level in a very short time, or to go to detailed design over a longer period. Furthermore, capturing the design in a model allows breaks in the programme of work for reflection, without the loss of information during the inactive period.

The experiment has shown the benefits of centralising system-engineering tools as part of an integrated facility. This approach can give focus to developments that in the past have been mostly independent. The approach also lends itself to activities other than pre-Phase-A mission assessments. The same principles could be applied to individual module/sub-system/instrument design and extended to cover other phases of the mission development life-cycle, in line with the goals of concurrent engineering in general. Use of the facility to support training, reviewing and proposal evaluation could also be investigated.

The case study has indicated that a conceptual design could be performed in a much shorter time and at a lower cost than with traditional methods. Clearly, further resources would be needed to implement a permanent facility, with fully trained users and populated databases, before such gains can be fully exploited.

The success of the first study output was confirmed by a thorough review conducted by an ESA Board using the procedures normally followed in the Agency, but taking advantage of the model and the facility, for both presentation and explanation of the chosen design. The study results were judged by the review team to be more detailed and internally consistent that those produced via the classical approach.

The CESAR study alone is, of course, not sufficient for a complete validation of the method. More studies, preferably in different mission domains, should allow a better assessment of the consequences of adopting the method in general, plus identification of the advantages and disadvantages of the approach. A second study is now in progress in the ESTEC CDF for an ESA solar-orbiting science mission, and others are currently being proposed.

Finally, a decision to set up a permanent facility should be addressed, once sufficient experience with the method has been obtained.

Acknowledgements

The authors wish to thank:

- the team of specialists who enthusiastically supported the first study
- the participants from the Italian Space Agency (ASI) for their support and fruitful co-operation.

Fruitful discussions with and inputs from the Aerospace Corporation's Concept Design Center and NASA/JPL's Team X are also gratefully acknowledged.

No Exchange of Funds – The ESA Barter Agreements for the International Space Station

R. Veldhuyzen & E. Grifoni
ESA Directorate of Manned Spaceflight and Microgravity,
ESTEC, Noordwijk, The Netherlands

In the course of the past three years, ESA has engaged in a series of barter agreements with parties outside the Agency within the framework of the International Space Station (ISS) Programme. These agreements formalise exchanges of goods and/or services between the participating parties without a corresponding financial transaction, i.e. without an exchange of funds. This article discusses the rationale for establishing such arrangements, their main elements and their key benefits.

The rationale

The following barter agreements have been concluded so far:

- Arrangement between the European Space Agency and the Russian Space Agency concerning Cooperation in the Development and Operations of the Service Module Data Management System (DMS) for the Russian Segment of the International Space Station (ISS), and of the Space Vehicle Docking System - signed in March 1996.
- Memorandum of Understanding between the European Space Agency and the United States National Aeronautics and Space Administration Enabling Early Utilisation Opportunities of the International Space Station - signed in March 1997.
- Arrangement between the European Space Agency and the Italian Space Agency on the Exploitation of Common Features of the Pressurised Modules Developed by the Parties - signed in April 1997.
- Barter Contract for the ESA Provision of a Super Guppy Transport (SGT) in Exchange for NASA Provision of Shuttle Services - signed in August 1997.
- Arrangement between ESA and NASA regarding Shuttle Launch of Columbus Orbital Facility and its Offset by ESA Provision of Goods and Services - signed in October 1997.
- Memorandum of Understanding between NASDA of Japan and the European Space Agency on Hardware Exchange for Utilisation of the International Space Station - signed in November 1997.
- Arrangement between the National Aeronautics and Space Administration of the United States of America and the European Space Agency concerning ESA's Provision of Cupola 1 and 2 in Exchange for NASA's Provision of Shuttle Launch and Return Services for Five External European Payloads (signature cycle in progress).

The element common to all of the barter agreements implemented so far is that goods and/or services are exchanged by the parties involved without a corresponding financial transaction. For ESA, this approach is especially interesting in those cases where it avoids the need to make cash payments to non-Member States, and instead permits that money to be invested with European industry. In addition, the barter agreements have made it possible for ESA to fix the costs associated with early utilisation of the ISS by European users prior to the start of the operations with ESA's Columbus Laboratory (ESA/NASA Early Utilisation MOU), as well as the costs for launch and transportation services provided by NASA (COF Launch Barter, Super Guppy and Cupola Barters), thereby avoiding any risk of later price escalations.

The main benefits of these barter arrangements for Europe can be summarised as follows:

- No transfer of funds to non-Member States.
- Increase in work for European industry.
- Reduction of technical and financial risks.
- Contribution to standardisation and commonality throughout the ISS Programme.
- Strengthening of the ISS cooperation and partnership.

For a barter arrangement to be successful, it must be beneficial to both partners. It can therefore be assumed that our ISS partners will also benefit through, for example, risk reduction, development-cost reductions (or even complete avoidance thereof) and other technical or cost advantages.

Figure 1. The International Space Station

The agreements

ESA/RSA DMS-R MOU

With this agreement, ESA committed itself to providing Russia with the Data Management System (DMS-R: on-board avionics as well as the necessary ground-support system) for the Russian Service Module (RSM). Russia, for its part, agreed to provide ESA with two flight sets of the active part of the Docking System to be installed on ESA's Automated Transfer Vehicle (ATV), as well as spares and ground equipment. Although this agreement is more of a political and strategic nature (supporting the development of technology for peaceful purposes in the Russian Federation), its financial and technical benefits for Europe should not be underestimated:

- The cost developing Docking Systems for the ATV would have been considerably higher than the cost for the DMS-R, which is the recurring cost of the data management system for the Columbus module and ATV, with RSM-specific adaptations.

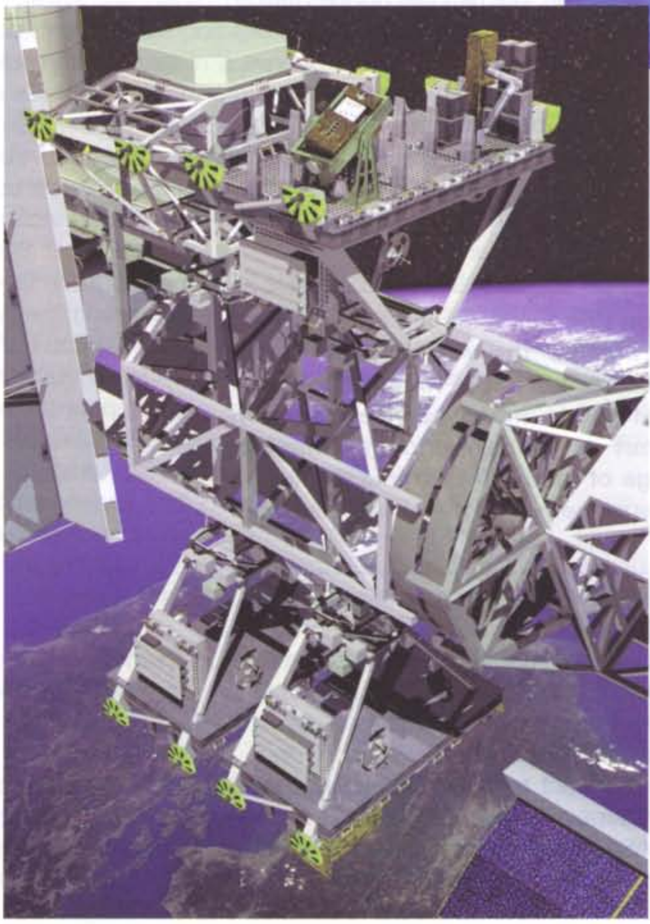


Figure 2. In return for providing the Data Management System for Russia's Zvezda Service Module, ESA received the Docking System for its Automated Transfer Vehicle (ESA / D. Ducros)

- The alternative of buying the Docking Ports directly from Russia presented a high risk of price uncertainty (significantly increased by the volatile political situation in Russia since 1996).

ESA/NASA Early Utilisation MOU

The primary objective of this barter was to ensure that the European User Community would gain early utilisation access to the Space Station, prior to the Columbus Laboratory's availability in orbit. Through this agreement, ESA has obtained access to three external payload sites – located on the ISS Truss – for three years, and to the equivalent of 1.5 equipment racks for 1 year; two flight opportunities for ESA astronauts are also guaranteed. In exchange, ESA has developed 'Laboratory Support Equipment' for NASA – the Microgravity Science Glovebox (MSG), the Minus Eighty Degree Freezer (MELFI) and the Hexapod – and implemented adaptations to the Columbus Mission Data Base (MDB) to be used as part of NASA's ISS Ground Segment.

Beyond the primary objective of this arrangement, this barter has proved to have several other particularly interesting features:

- The open-ended cost associated with the early usage of the internal and external NASA facilities on the ISS has been fixed at a level considered both affordable and fair.
- An investment in European technology development has been implemented (rather than spending European tax payers' money in the USA).

- Investments already made (i.e. the MDB) have been fully exploited to the overall benefit of the Space Station Programme, standardising on a unique (European) ground database system (and opening the door to further standardisation and possible licensing, e.g. to NASDA in 1998).

ESA/ASI ECLSS for MPLM MOU
Through this arrangement, ASI is providing ESA with the Primary Structure of the Columbus module (derived from the ASI-developed Multi-Purpose Logistics Module, or MPLM), whilst ESA is providing ASI with the Environmental Control and Life Support System (ECLSS) for the MPLM (an adaptation of the ECLSS for the Columbus module). This arrangement has ensured:
- optimisation of industrial development within Europe, with the associated cost benefits (ECLSS manufacturing at recurrent cost plus adaptations, versus full development of a primary structure for the Columbus module)
- stronger commonality and standardisation within the ISS Programme.

ESA/NASA Super Guppy Barter
This specific barter originated from a NASA request for ESA to support their negotiations with Airbus Industrie for the acquisition of a Super Guppy aircraft for ferrying large critical ISS elements between different NASA centres. It resulted in the provision by NASA to ESA of standard Shuttle services for ESA internal payloads, up to a total of 450 kg, in the period until end-2001 (starting with STS-95, launched in October 1998). ESA, in turn, made all the necessary arrangements with Airbus Industrie, including the payment of an ESA-negotiated price, for the transfer to NASA of a Super Guppy Transporter and associated equipment, spares and services.

This arrangement:
- avoids cash payments to the USA for Shuttle transportation services, via the spending of a fixed amount in Europe
- allows the European User Community to continue basic and applied microgravity research through to the year 2001, despite ISS delays and the shortage of utilisation resources during the first years of ISS assembly.

Figure 3. As part of the ESA/NASA Early Utilisation MOU, the Agency has access to three payload sites on the Truss (ESA / D. Ducros)

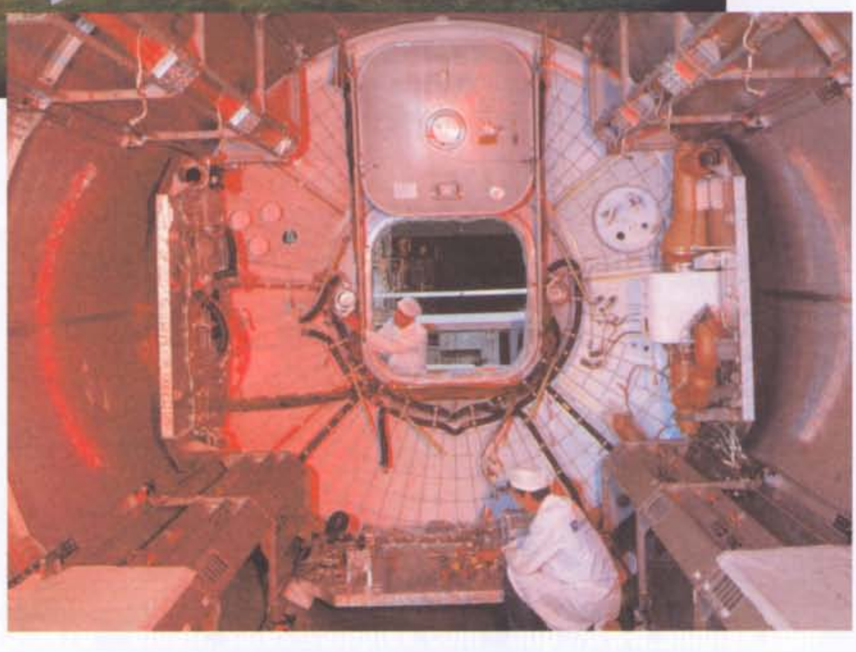


Figure 4. An arrangement with ASI has seen ESA provide the environmental control and life support system for Italy's MPLM, in exchange for the primary structure of the Columbus module (Alenia Aerospazio & ESA / D. Ducros)

ESA/NASA COF Launch Barter
Through this arrangement, NASA will launch the Columbus module and its initial payload on the Shuttle for ESA, as compensation for the latter's provision to NASA of fully integrated Node-2 and -3 ISS Modules, Cryogenic Freezer and Crew Refrigerator/Freezer equipment for ISS, spares and sustaining engineering for the Laboratory Support Equipment items provided by ESA to NASA under the Early Utilisation MOU, and hardware/support for software development and integration in the NASA ground software test and integration facilities for ISS.

The key benefits of this arrangement for Europe are:
- the procurement at fixed conditions – avoiding the risk of price uncertainties and cash payments to NASA – of the launch of the Columbus laboratory
- the creation of additional industrial work for Europe in high-technology domains.

Figure 5. ESA is providing the Station with two Cupolas and, in a separate agreement with NASA in part return for launching Columbus aboard the Space Shuttle, Node-3, seen here in the centre of the illustration. The Crew Rescue Vehicle, at left, may become part of a later arrangement between ESA and NASA (ESA / D. Ducros)

ESA/NASDA MOU on Hardware Exchange
Within the framework of this MOU, NASDA is providing ESA with 12 International Standard Payload Rack (ISPR) flight units for use on the ISS. ESA, for its part, is providing NASDA with one MELFI Freezer identical to those developed by ESA for NASA in the context of the Early Utilisation MOU.

The main benefits for Europe of this barter are:
- a financial investment in Europe instead of the USA (it was previously planned to purchase the ISPRs from the NASA ISS ISPR supplier) or Japan
- a competitive, fixed procurement as compared to the estimated procurement cost for 12 ISPRs in the USA
- full exploitation of the investments made in Europe for the development of MELFI for NASA.

ESA/NASA Cupola Barter
The main elements of this barter are:
- provision by NASA to ESA of Shuttle transportation services for five external European payloads, and allocation to ESA of 68 kg of additional launch mass on the Columbus laboratory launch
- delivery by ESA to NASA of the Cupola-1 and -2 ISS elements, with associated spares and sustaining engineering; ESA will also enhance the Columbus module payload support in the areas of thermal control and Ethernet connectivity.

The main benefits of this arrangement are:
- procurement at fixed conditions of the transportation services for five ESA external payloads
- avoidance of cash payments in the USA (and price uncertainties) for Shuttle transportation services.

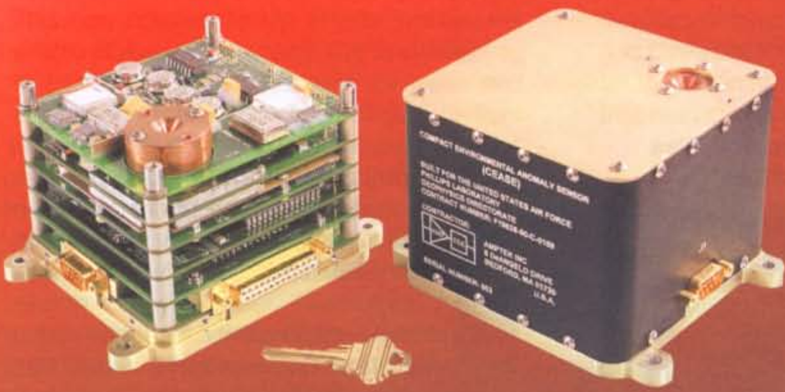
Conclusions
The rationale for the implementation of the barters, as illustrated in the previous paragraphs, varies from case to case and involves a range of programmatic considerations. The financial significance of the barters implemented so far should not be underestimated. Price uncertainties and/or lack of pricing policies, changing political and economic conditions, and schedule shifts are all risk factors that have been taken into account when considering the merits of each of these barters, and in fact supported the finalisation of most of them by favouring a firm commitment today versus the uncertain future pricing conditions of tomorrow.

The implementation of the barter agreements just described has made it possible to allocate additional, technologically challenging work to European industry worth more than 300 MEuro. As far as the total benefit associated with the barters concluded so far is concerned, a final balance taking into account all of the various parameters will only be possible once these projects have actually been completed. Nevertheless, one can already say today that the introduction of the barter arrangements has helped a lot in reducing costs for the partners, has helped to streamline the development efforts and to increase the spirit of partnership in this global programme and, above all, is a very practical means of implementing cooperation on the basis of no exchange of funds.

Space Radiation Alarm

"CEASE"

COMPACT ENVIRONMENTAL ANOMALY SENSOR



FEATURES:

- Compact: 10 x 10 x 8.1 cm^3, 1 kg
- Low Power: 1.5 W
- Flexible I/O: Supports 1553B and RS422
- Full GSE and operational software
- On-board determination of hazardous conditions

CEASE is a compact, radiation hard, low power, space "weather" hazard sensor developed to monitor the local radiation environment and to provide autonomous real-time warnings of:

- Total Radiation Dose
- Radiation Dose Rate
- Surface Charging
- Deep Dielectric Charging
- Single Event Effects
- Solar Cell Damage.

CEASE detailed radiation data is used to pinpoint causes of spacecraft anomalies, and to forecast hazardous conditions before they affect the mission. The spacecraft, in turn, can re-prioritize its operations, inhibit any anomaly sensitive tasks such as attitude control adjustments, or initiate other prudent actions as indicated by the **CEASE** warning flags. Device degradation mechanisms and radiation tolerance of components can also be monitored.

The US Department of Defense has selected **CEASE** for several missions, including:

- **TSX-5**
- **STRV-1C**
- **SBIRS LADS**

and the **DSP** operational spacecraft.

Amptek has a long and distinguished track record in the manufacture of space instrumentation. Mission examples include: DMSP, TIROS, CRRES, NEAR and APEX.

Current off-the-shelf Amptek sensors measure spacecraft charging, thermal and suprathermal, and high energy particles. In addition, Amptek provided the X-ray Detector on the Mars PATHFINDER Mission.

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ESRIN – Its Development and Role

R. Franciosi
ESRIN Site Management Services Department, ESA Directorate of Administration, ESRIN, Frascati, Italy

Created in 1965 as the European Space Research Institute, ESRIN has succeeded over the last 30 years in maintaining its own unique identity, despite the constant growth of and changes in its primary activities. Situated in the picturesque surroundings of the Castelli Romani, southeast of Rome, ESRIN has evolved, particularly over the last ten years, into a truly multidisciplinary centre. Although ESRIN's main role is still firmly linked to the Earth Observation Programme, especially since the launches of the ERS-1 and ERS-2 satellites and with management responsibility for the new Envisat ground segment, the Italian establishment is also in charge of the Agency's corporate informatics applications and associated infrastructures. ESA's new Vega small-launcher project has also chosen ESRIN as its base.

The Establishment's main activities

The Earth-observation activities

The ESA Member States have shown a sustained commitment to bringing the development of innovative European Earth-observation technologies and satellites to full fruition via an accompanying long-term programme of operations and exploitation. This has involved hundreds of scientific groups, institutional entities and commercial service companies world wide, for more than a decade. This firm programmatic commitment has acted both as a stimulus and as a determining factor in the evolution of the ESRIN site.

From the inception of the Earthnet Programme in the seventies, and the ERS programmes starting in 1985, ESRIN has become the focal point for the exploitation of all ESA Earth-observation satellites. The Establishment has become a regular venue of activity for all major European and Canadian industries involved in the development and exploitation of Earth-observation systems.

The ESRIN site is today widely appreciated as an easily accessible, modern and attractive technical centre, capable also of accommodating many international workshops, meetings and symposia throughout the year. It is familiar to earth scientists and industrialists coming from both advanced and developing countries all over the World. Hence the successful entry into operation of the ERS-1 satellite in 1991 and of ERS-2 in 1995 proved to be major milestones in the evolution not only of the Agency's Earth-observation programmes, but also of ESRIN.

More recently, responsibility for implementing the Payload Data Segment of the new Envisat remote-sensing platform, and for subsequent exploitation of the Envisat mission itself, was entrusted to the Directorate of Applications team at ESRIN. This in turn necessitated the

installation of further major new facilities dedicated to Envisat exploitation on the site. Perhaps the most striking of these is a 10 m Ku-band receiving antenna, which will acquire real-time data transmissions from the polar-orbiting Envisat satellite, as they are relayed back to ESRIN via the Artemis data-relay satellite, itself located in a fixed geostationary position over the equator.

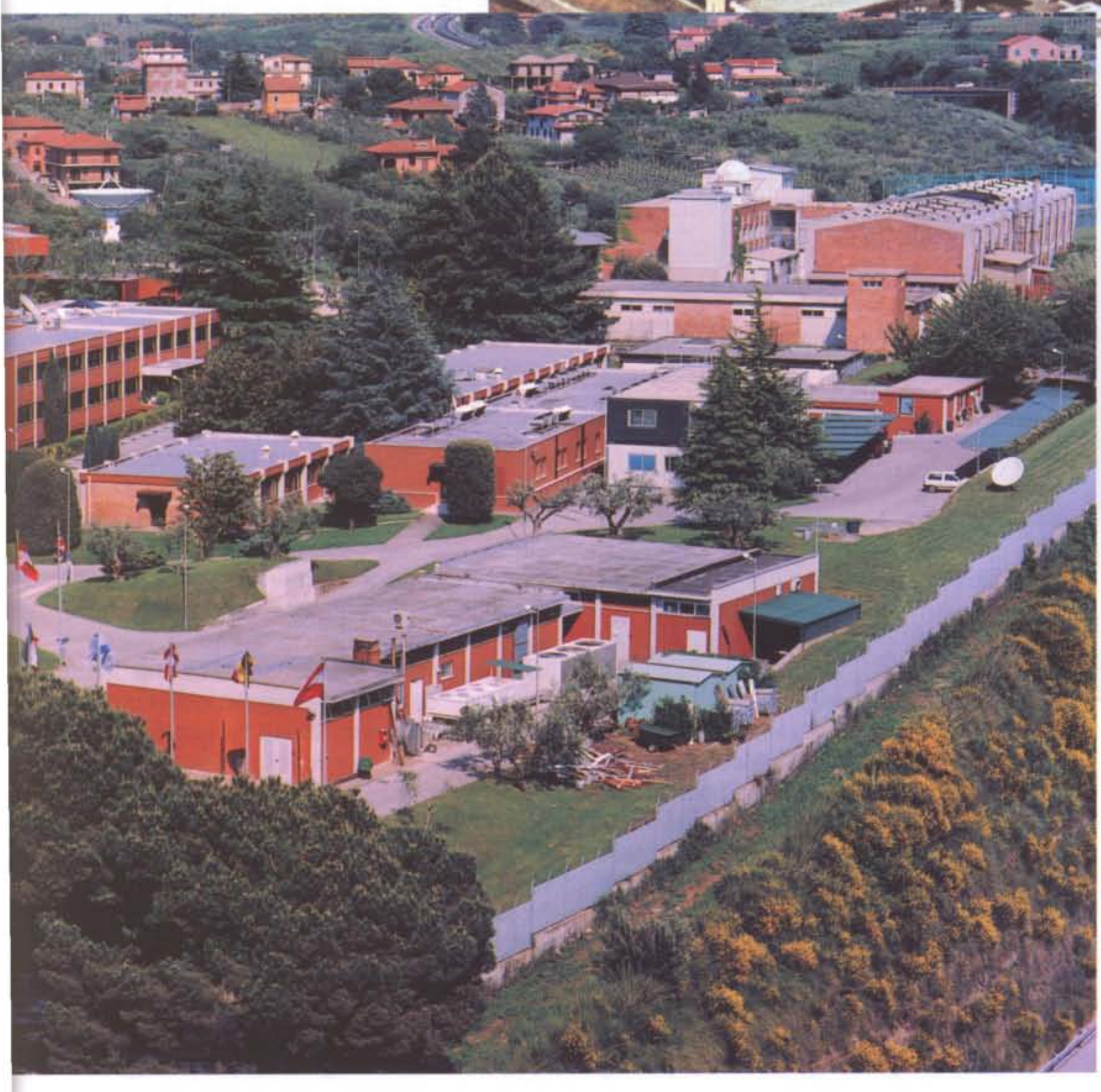
This new addition to the ESRIN facilities will enable ESA to respond promptly and efficiently to the ever-increasing demand for faster and easier access to Earth-observation data from anywhere in the World. Such data will be rapidly acquired, transmitted to ESRIN, processed there in near-real-time, and the resulting data products sent via high-speed telecommunications links directly to the end-user. This service will be of enormous benefit to users and decision-makers when prompt, up-to-date geospatial information is needed from inaccessible areas struck by natural disasters, anywhere on the planet.

The informatics activities

The Informatics Department at ESRIN became part of the Agency's Directorate of Administration in 1997. Managed from Frascati, but with a presence at all of the main ESA Establishments, the Department has been created to provide to the whole Agency with all of the informatics services that it needs for its daily operation, including:

- development and operation of corporate and Directorate-specific information systems for the automation of the various processes that management of the Agency requires

Aerial view of ESRIN in the 1970's



Aerial view of ESRIN in 1999

- provision of the infrastructure required to support the various systems (e.g. servers, local- and wide-area networks)
- planning, engineering, support and operation of the corporate data communications infrastructure
- provision of personal computers and other office-automation tools to some 2500 users located throughout the Agency.

The Department currently consists of about 63 staff, deployed mainly in ESRIN, but with a significant presence, designed to provide close contact with all the users, in the other main ESA Establishments.

The main entrance at ESRIN

The grouping of all of the activities pertaining to general-purpose data processing in the Agency within a single Department has allowed considerable standardisation of the often diverse components involved. Among the systems developed and deployed by the Department are the new ESA financial system (AWARDS) and several specialised Lotus Notes applications available to all ESA users. The unification of this task under a single Department has also allowed significant progress in the rationalisation of the ESA informatics infrastructure:

- All of the old mainframe computers have been replaced by a network of servers.
- All of the data-communication networks (with the exception of those supporting spacecraft control) have been consolidated in ESACOM, the name given to the unified network that satisfies the general-purpose data networking requirements of the Agency. The Wide Area Network is now supplied by a major network provider through a single outsourcing contract.
- A number of related services previously supplied through separate contracts have been consolidated under a single, ESA-wide contract for the provision of informatics services. The new contract assigns to the contractor full responsibility for all of the tasks involved in operating and supporting the Agency's Common Information Technology Infrastructure, including
  - provision to end users of network, desktop-computer, office-automation, application and help-desk support
  - ensuring the existence of all management services required for the smooth running of the end-user services
  - reporting regularly to the Informatics Department to provide continuous visibility of the level of services provided.
- Personal computers for office automation have been standardised, and most users have now received a standard desktop computer and a standard software suite. This has greatly reduced the number of problems encountered due to incompatible software products experienced by the users, and at the same time has reduced the cost of maintenance and support.
- The Lotus Notes infrastructure has been rationalised and extended, and means have been put in place by which users who normally work with desktops other than PC's can make use of Lotus Notes and the applications based on it.

All of these developments have required the continuous adaptation over the years of the site infrastructure and services to the new structure and to the new technologies being applied. Space has had to be found, for instance, to house the ESA-wide Informatics Help Desk, and various upgrades to the site's electrical installations have been undertaken in order to ensure the smooth running of this and of all of the other informatics-related developments.

The Vega activities

ESRIN has also recently become the home for the Project Team charged with the management of the Vega small-launcher Programme. This results from a decision taken by the ESA Council in June 1998, when the Step-1 of the Vega development programme was approved and the associated management scheme endorsed. The latter includes the setting up of an Integrated

Programme Team (IPT) which, in addition to ESA staff, will include personnel from the Italian Space Agency (ASI) and from the French National Space Agency (CNES).

The Vega launcher, qualification of which is planned by the end of 2002, will offer Europe the opportunity to extend its launching capability to the lower end of the payload launch-mass range, namely:

- 800 kg into a 1200 km Sun-synchronous orbit
- 1000 kg into a 700 km circular polar orbit

although it can also service a wide range of other mission possibilities for, for example, scientific satellites.

Vega would eventually be launched from ESA's launch base in Kourou, French Guiana, where the dedicated ground infrastructure for the new small launcher is in an advanced stage of definition, making maximum use of available synergy with the existing Ariane launch facilities there.

Similarly, the choice of ESRIN as the location for the Vega launcher-development activities is logistically very rational given that the industrial prime contractor, the Vegaspazio company newly established by Fiat-Avio and Aerospatiale, is based in Colleferro, just a few kilometres south of Frascati.

The presence of the Vega team at ESRIN constitutes another addition to the site's reservoir of novel and highly-respected competences.

An integrated approach to development

The expansion on the ESRIN site has closely mirrored the evolution in the Establishment's activities and responsibilities, striving always to ensure the highest possible quality in the developments undertaken and the facilities and infrastructure provided, at reasonable cost.

From the mid-1980s, with the explosion in Earth-observation activities, ESRIN began to shake off its somewhat parochial image and gradually acquired the role of a fully-fledged - albeit small - ESA Establishment. Restructuring took place everywhere: the computer building was re-furbished, the newly created ISD Division (1988) was accommodated in a totally remodelled building, the main entrance hall was transformed, the archives relocated and offices created in their place, the canteen was doubled in size, the main building was extended, and a new conference room and a much-needed training room added.

In the 1990s, the Establishment has undergone a further metamorphosis, following the launches of ERS-1 and ERS-2, together with its being allocated the management of the Envisat Ground Segment, giving ESRIN a clear new role. ESRIN's customer base was thereby greatly expanded to include the very extensive remote-sensing user community, in addition to its long-established customer base on the informatics side.

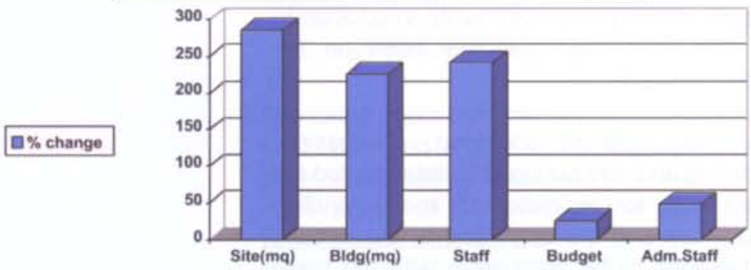
The new role of acquiring, processing, archiving and distributing ERS data created the need both for sophisticated image-handling equipment and the upgrading of the existing installations to be compatible with the latest ESA standards. The launch at the beginning of the next millennium of a new generation of remote-sensing satellites, of which Envisat will be the first, will mean even greater challenges for ESRIN Site Services.

The new Envisat antenna at ESRIN

In the last few years, ESRIN has almost doubled in size: in 1994, the buildings covered 9000 m^2, while today they cover 18 000 m^2. Building activities in recent years have included enlargement of the canteen (1993), a new office building and new main entrance (1994), a new power plant (1996), a new technical building (1997) for the Envisat ground-segment activities, provision of a new parking lot, and enlargement of the gate house (1998). All of the computer rooms have been moved and

THE EVOLUTION OF THE ESRIN SITE 1990 - 1998

Site mq	28000	80000
Bldg. mq	8000	18000
Staff	170	410
Budget	4200	5200
Adm.Staff	25	37



The evolution of the ESRIN site, from 1988 to 1998

rationalised in order to optmise the use of space and to create synergy between them.

The main driver behind all of this work was not simply to build more offices for people to work in, but rather to create a functionally-integrated and architecturally-pleasing working environment which would give the Establishment an atmosphere of efficiency and harmony. A special effort has been made to blend the new buildings in with the existing environment, in order to promote communication and synergy between the various activities on the site, and to bring the standards of a number of services up to the highest European level.

Along with this physical expansion of the site, both the personnel and support services have had to be increased accordingly. The number of personnel on site has more than doubled, to approximately 450 today, one third of whom are ESA staff and two-thirds are contractors. The relatively high percentage of young staff has undoubtedly contributed to the enthusiastic and lively atmosphere at ESRIN.

The growth of activities at ESRIN has also meant a significant increase in visitors, meetings and conferences, bringing new requirements for support and more complex services, as well as greater exposure of the Establishment to the outside world.

Conclusion

The main challenge for the site-management services at ESRIN over the past ten years has been the need to foster a unified corporate image on a site that has not always been blessed with a clear role and mission. This has involved rethinking both the physical infrastructure, where an architectural and design uniformity has been sought, and the service management approach, which has been directed towards providing a more cohesive link between the activities and the staff.

One of the keys to success has undoubtedly been the particular attention paid over the years to careful planning in order to get the most out of the investments made, despite the Establishment's sometimes uncertain future. The relatively small size of the site has allowed a personalised approach, still maintaining 'an Italian touch', and enough flexibility to make staff and visitors feel at home and properly cared for. This, combined with the surrounding environment has contributed to making ESRIN a very lively and pleasant place to work. esa

Le Service d'Information et de Documentation de l'ESA (ESA IDS) – Un Outil d'Entreprise pour l'Agence

J.-J. Régnier
Chef du Centre d'Information et de Documentation Technique*,
ESA Direction associée pour les systèmes d'information,
ESTEC, Noordwijk, Pays-Bas

Le Service d'information et de documentation technique de l'ESA (ESA IDS) est un système reposant sur l'Intranet destiné à la diffusion de l'information relative à l'Agence et à la conservation de documents de référence. Le personnel de l'ESA peut non seulement utiliser ce service interne pour rechercher l'information et la documentation nécessaires pour son travail quotidien, mais également pour se tenir au courant de tout ce qui touche à l'Agence et à son environnement.**

Introduction

Avec l'évolution des techniques de communication, l'accroissement du nombre des sources d'informations et le besoin de plus en plus important d'obtenir rapidement des informations pertinentes, l'Agence spatiale européenne se devait de disposer d'un outil de documentation et d'information interne efficace.

Mise en place en 1995 par le Centre d'Information et de Documentation Technique (TIDC*) de l'ESA, la première partie de ce service comprenait essentiellement une base documentaire composée des références bibliographiques et de quelques documents électroniques, qui composaient le fonds documentaire du Centre de Documentation et de la Bibliothèque technique de l'ESTEC. Ce service était déjà basé sur l'utilisation des outils de type Internet et devenait l'un des premiers éléments de l'Intranet de l'ESA.

Rapidement complété par des informations relatives au fonctionnement et à la vie de l'Agence, ce service, à la demande du Groupe de Transformation mis en place par la Direction générale, a élargi son domaine d'intérêt de manière à couvrir tous les aspects de communication interne à l'entreprise. C'est ainsi qu'a été défini en 1996, la mission du Service d'Information et de Documentation de l'ESA (ESA IDS**), dont la mise en œuvre et la maintenance ont été confiées à TIDC.

C'est sur la base de cette nouvelle définition de mission et à l'aide d'un progiciel de gestion d'Intranet que TIDC a construit en 1997 la structure du Service d'Information est de Documentation de l'ESA.

Qu'est-ce que ESA IDS?

ESA IDS est le service d'information et de documentation en ligne de l'Agence. Il est accessible depuis tous les postes de travail reliés au réseau interne ESAnet et par le biais d'un navigateur Web classique.

Son objectif est de fournir au personnel travaillant à l'ESA l'ensemble des éléments d'information nécessaires non seulement à leurs activités professionnelles, mais aussi à leur vie dans l'entreprise. Ce service permet de retrouver des documents techniques et scientifiques sur le sujet recherché, ainsi que les instructions administratives et des informations sur le fonctionnement et la vie de l'Agence. Il offre aussi la possibilité d'être informé de manière factuelle sur les décisions, les nouvelles orientations politiques ou stratégiques de l'Agence et sur le déroulement des activités spatiales ou des évolutions technologiques en général. C'est en outre une porte d'accès à des services externes (sites Web ou bases de données) et il sert d'interface pour des recherches documentaires approfondies.

L'une des missions de TIDC étant de maintenir la mémoire technique et scientifique de l'ESA, ESA IDS joue aussi le rôle de 'base des connaissances' dans laquelle le client/utilisateur peut naviguer autour d'un concept et retrouver les informations et les documents qui y sont relatifs.

* TIDC: Technical Information and Documentation Centre
** ESA IDS: ESA Information and Documentation Service

Organisation du service d'information et de documentation en ligne

Concept et structure

ESA IDS est organisé, d'une part, par rapport aux principales fonctions de l'Agence:
- Direction générale et Communication interne
- Programmes et support techniques
- Affaires industrielles et technologies
- Ressources Humaines
- Procédures internes et services généraux
- Relations publiques
- Documentation

et d'autre part, autour des notions Documentation/Information/Forum.

Figure 1. Page d'accès à ESA IDS

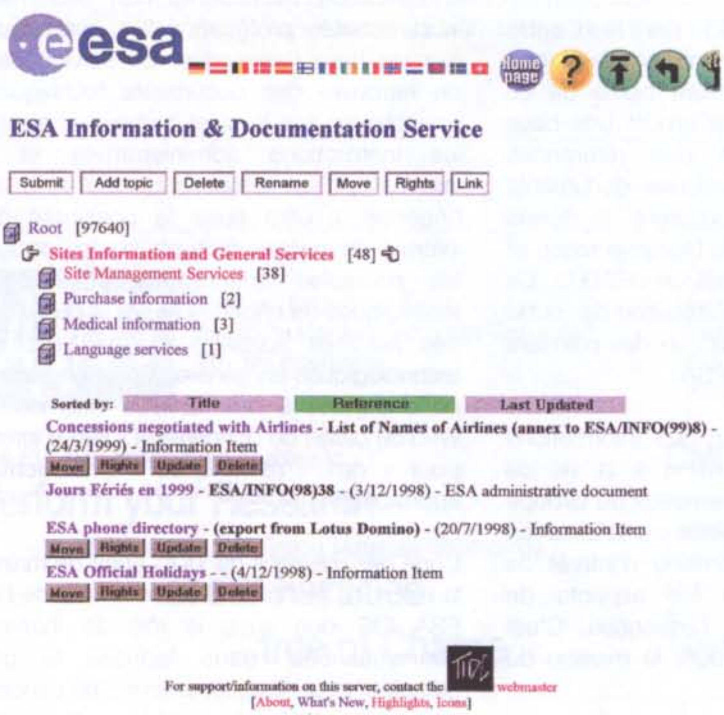


Figure 2. Exemple de dossier (arborescence)

La partie *Documentation* regroupe l'ensemble des documents de référence utilisés ou produits par l'Agence. Ceci correspond aux documents relatifs aux activités scientifiques et techniques, enregistrés sous forme d'une fiche signalétique avec dans certains cas le texte intégral associé, aux documents officiels et administratifs internes sous forme électronique, aux publications et aux documents sources ou références bibliographiques des ouvrages conservés dans les bibliothèques des établissements.

La partie *Information* est composée des documents d'application propres au fonctionnement de l'entreprise (procédures, manuels, ...), des notes d'information (communications internes, ressources humaines, services des sites, association du personnel, ...), des nouvelles sur les activités de l'Agence.

La notion de *Forum* représente une zone d'échange où les différents acteurs de l'entreprise peuvent déposer des informations sous forme de messages avec ou sans documents associés en fonction de thèmes prédéfinis et variés, allant de la 'perception de l'ESA dans la presse' ou que les 'évolutions technologiques des lanceurs réutilisables'.

Dans les trois cas, un certain nombre d'informations réorientent le client/utilisateur vers des sites Web ou des sources documentaires externes. Le principe de base retenu pour ESA IDS est une approche conceptuelle de type 'base des connaissances' qui permet au client/utilisateur, à partir d'un premier résultat (liste de documents ou dossier), de naviguer vers des documents ou des pages d'informations en rapport avec le sujet de la recherche initiale.

Utilisation du service

ESA IDS contenant des informations non publiques, son accès est contrôlé; ce n'est qu'après s'être authentifié que le client/utilisateur peut accéder aux documents en ligne.

Pour trouver les éléments dont il a besoin, le client/utilisateur dispose de deux moyens:
- l'outil de recherche multi-critères
- la navigation dans les dossiers thématiques.

Ces deux approches sont complétées par des services en ligne qui permettent de demander la copie des documents retenus (s'il ne sont pas en texte intégral) ou de commander, auprès de TIDC, ceux qui ne sont pas disponibles dans ESA IDS. Il est aussi possible de s'abonner à des fora (les nouveaux messages seront alors automatiquement envoyés dans la boîte aux lettres électronique du client/utilisateur) ou de recevoir régulièrement les résultats de recherches systématiques préalablement enregistrées (veilles documentaires ou profils stratégiques).

Maintenance de ESA IDS

Le service ESA IDS est géré par la section Information de TIDC qui en assure l'exploitation – fonctionnement et assistance aux utilisateurs – et surtout la mise à jour pour le compte des clients/fournisseurs (communication interne, ressources humaines, services des sites, services techniques ou projets, centre de documentation, ...).

Les mises à jour sont transmises à TIDC selon des procédures standardisées. Les différents documents sont réalisés à partir de modèles prédéfinis, de manière à optimiser les tâches – délais réduits et ressources minimisées – et à assurer le contrôle de la qualité.

Sur le plan pratique, les documents en texte intégral sont en format PDF (Adobe Acrobat), associés à une fiche signalétique et les pages d'information sont en format HTML.

L'ensemble des données de la base ESA IDS est chargé dans un système de gestion d'Intranet qui est un progiciel permettant à TIDC de gérer à la fois ses sites Web internes et la base documentaire de l'ESA, ainsi que l'administration globale du système avec un outil unique dont l'interface client (utilisateur et fournisseur) ne nécessite qu'un navigateur Web classique et Acrobat Reader.

En tant que responsable du service ESA IDS, TIDC s'enquiert régulièrement auprès de ses clients/fournisseurs de la qualité et de la pertinence de leurs informations, veillant en particulier à leurs tenues à jour, garantissant de ce fait aux clients/utilisateurs des informations les plus fiables possible.

ESA IDS en chiffres

ESA IDS, c'est en moyenne, chaque mois, plus de 11000 consultations de documents (hors forum), une activité Web du serveur de 130 000 hits, 4000 recherches et 150 demandes de documents en ligne.

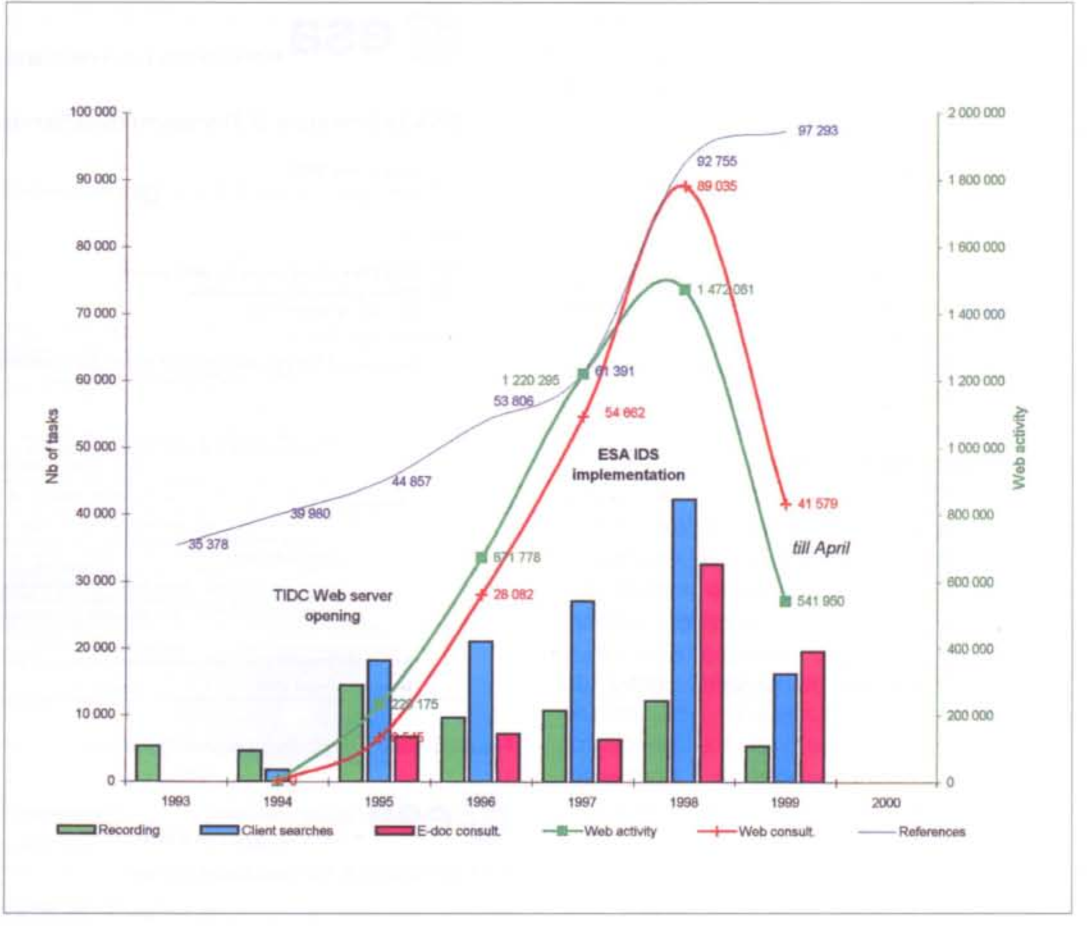
Sur le plan de la maintenance, cela représente

Figure 3. Exemple de fiche signalétique

Figure 4. Menu principal

Figure 5. Organisation du travail

Figure 6. Courbes d'activités



environ 340 heures d'activité mensuelle, réparties sur quatre personnes qui sont en charge de:
- l'administration et l'exploitation du serveur
- du support aux utilisateurs
- de la mise à jour de la 'base de connaissances' – données, liens, structure – entre 50 et 80 ajouts ou modifications par jour
- de la création des nouveaux sites Web.

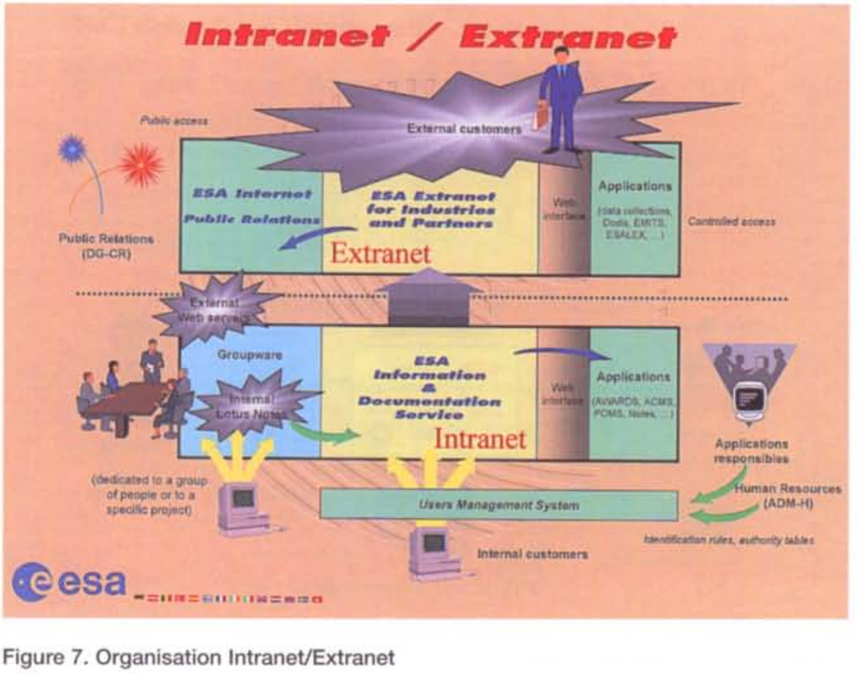


Figure 7. Organisation Intranet/Extranet

Actuellement le service ESA IDS contient 97 500 références et plus de 6500 documents en texte intégral, à la disposition de prés de 2000 clients/utilisateurs répartis dans tous les sites de l'Agence au travers de l'Europe.

Conclusion

Après un an et demi de fonctionnement opérationnel et près de 200 000 consultations en ligne, le service ESA IDS a prouvé qu'il était bien le noyau de la 'base des connaissances' de l'Agence et un outil d'intégration puissant pour l'entreprise. Il fournit au client/utilisateur un moyen simple pour accéder non seulement à l'ensemble des informations de référence de l'ESA mais aussi à des données contenues dans les sites externes au travers du réseau Internet, et de ce fait, il permet de mettre en relation un ensemble de documents concourant à répondre à ses recherches.

Le plan d'actions actuel est de poursuivre la consolidation et l'enrichissement de la 'base des connaissances' avec l'intégration de nouvelles informations et le maillage des documents (hyper-liens), puis d'ouvrir une partie du service aux partenaires extérieurs de l'ESA par le biais d'un site Extranet. esa

The New ImageDB Server – Direct Access to Selected ERS SAR Data Products

S. D'Elia
Earth Remote Sensing Exploitation Division, ESA Directorate of Application Programmes, ESRIN, Frascati, Italy

G. Araco
Web Bridges, Rome, Italy

To support the prevention, management, analysis or mitigation of natural hazards, users need rapid access to the latest remote-sensing data for the area concerned. ESA's internal Earth Watching project has also shown the strategic value of access to historical data for 'change detection' in such critical situations. A novel system has therefore been set-up at ESRIN, for both internal and external use, to support activities requiring the fast availability of archived remotely sensed data. The new ImageDB server provides instantaneous on-line access both to specific collections of quick-looks and full images.

The project was started at the end of 1998, in cooperation with the company Web Bridges (I) for the server design and development. The implementation proceeded in steps, with releases of intermediate functions as soon as available. The first release was opened on-line in May 1999, providing access, through DESCW*-supported inventory searches and quick-look downloads, to 100 geocoded (GEC) products over the major European rivers, generated from data acquired by ERS-2 during the period July–September 1998.

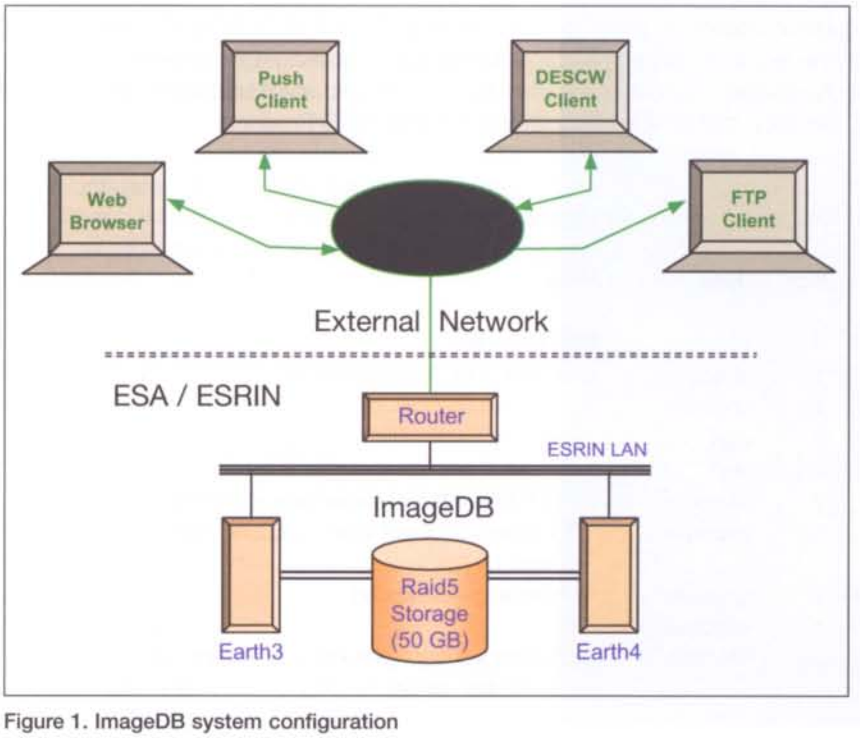


Figure 1. ImageDB system configuration

What is the ImageDB?

The ImageDB acronym identifies a server at ESRIN, which provides direct access to remote-sensing products, and in particular to those generated from the data acquired by ESA's ERS-1 and ERS-2 satellites. It has been implemented (Fig. 1) in the Windows NT environment (Release 4.0 Enterprise Edition) and resides on two clustered, dual Pentium-II 450 MHz machines (one for operational use and the other for maintenance). The two machines, known as Earth-3 and Earth-4, are connected to a storage subsystem providing 50 Gbyte of mass storage with built in redundancy, where the products (ERS GECs), quick-looks (for ERS and Landsat) and thumbnails (ERS only) reside.

The ImageDB application is replicated on both machines, although one of the installations is used primarily for internal/development purposes. The software configuration also includes the Internet Information Server 3.0, provided by Microsoft with Windows NT 4.0, in order to allow HTTP and FTP access to the ImageDB data. As indicated in Figure 1, the external access methods also include DESCW* and push clients.

ImageDB is built to host products, as well as related quick-looks, thumbnails and inventory information. All data can be freely accessed, but products can only be downloaded by entering an ESRIN-provided user name and

* DESCW is a PC software tool that allows one to perform multi-mission inventory searches on the major ESA-supported remote-sensing missions – ERS-1, ERS-2, JERS, Landsat and Envisat – by displaying the satellites' coverage over the Earth map (see ESA Bulletin No. 97, March 1999 issue, for a description, or contact the Help Desk).

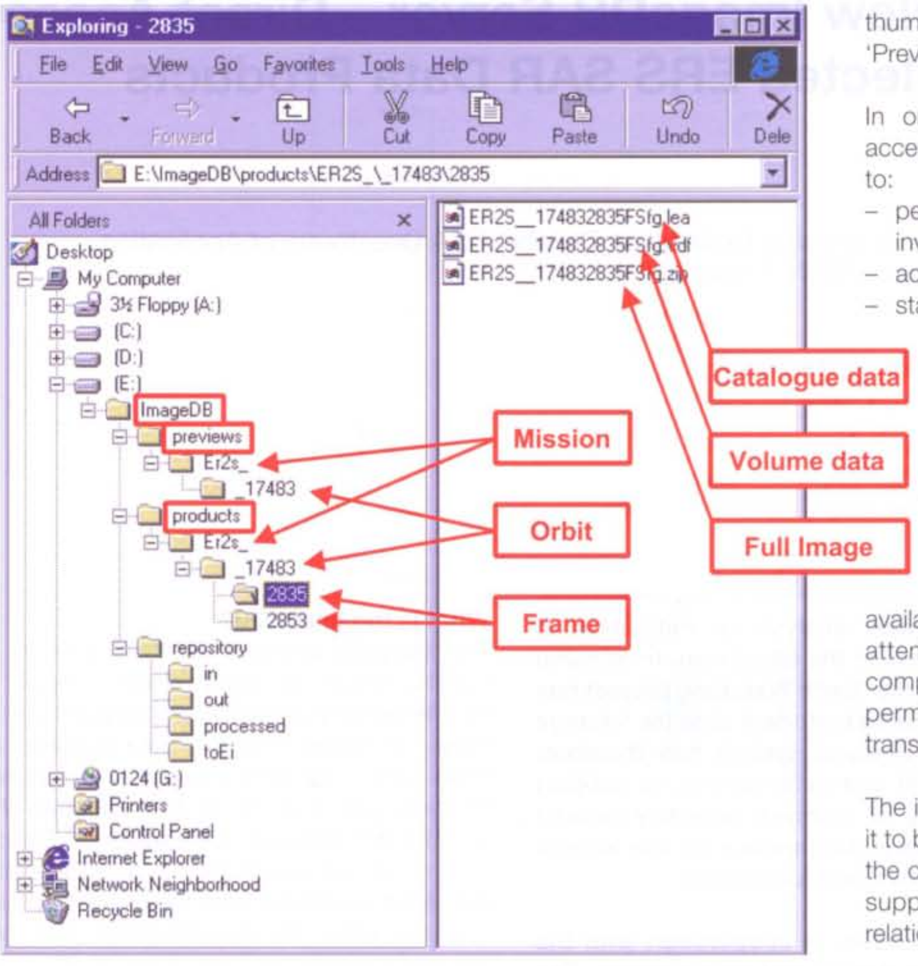


Figure 2. ImageDB directory structure

thumbnails can be accessed starting from the 'Previews' directory.

In order to provide the most user-friendly access, DESCW has been upgraded in order to:
- permit the search and filtering of specific inventory collections
- access the quick-looks on-line
- start the product's downloading.

Potential users should apply to the ESRIN HelpDesk (see address below) or to one of the commercial distributors in order to obtain the access conditions and a password. Data downloads are registered and invoiced, as appropriate. Dedicated processing and functions have been included to make this service available also via a network. In particular, special attention has been paid to reducing and compressing the images, as well as to permitting the on-line selection and transmission of user-defined image sub-sets.

The inherent flexibility of the system also allows it to be used for additional applications, such as the creation of specific collections of images to support training, promotion, and public-relations activities.

password, since there might be a cost associated with them.

The system is organised around a simple directory structure (Fig. 2), which gives the user easy access to the data being sought. Basically, it is necessary to know the mission, orbit, frame and acquisition station in order to reach the *.zip file* of the product, stored with this standard compression under the 'Products' directory. Similarly, quick-looks and

What does it contain?

Products, quick-looks, thumbnails and inventory data can all be stored in the ImageDB. Thanks to its flexible naming convention (Table 1) and the use of a central indexing table, it permits one to store and handle different types of images, and even to create 'collections' of images.

In addition to some collections intended for internal use, the ImageDB currently hosts two major collections: the Landsat-5 Quick-Looks and the ERS GEC Products.

Table 1. ImageDB naming convention for data and products

Field	Size	Type	Value
Mission identifier	3	character	ER1, ER2, LN5
Sensor identifier	1	character	S for SAR, T for Thematic Mapper
Mode identifier	1	character	"_"
Orbit	6	digit	
Frame	4	digit	
Station identifier	2	character	FS for Fucino, MS for Maspalomas, KS for Kiruna
Image type	1	character	Quick-looks: q = Quick-look, l = ILU, b = IBP Products: f = Full
Representation mode	1	character	n= Normal, g = Geocoded
Separator	1	character	"."
Extension	3	character	zip (full images), jpg (quick-looks), gif (thumb-nails), lea (leader file), vdf (volume data), cat (catalogue data)

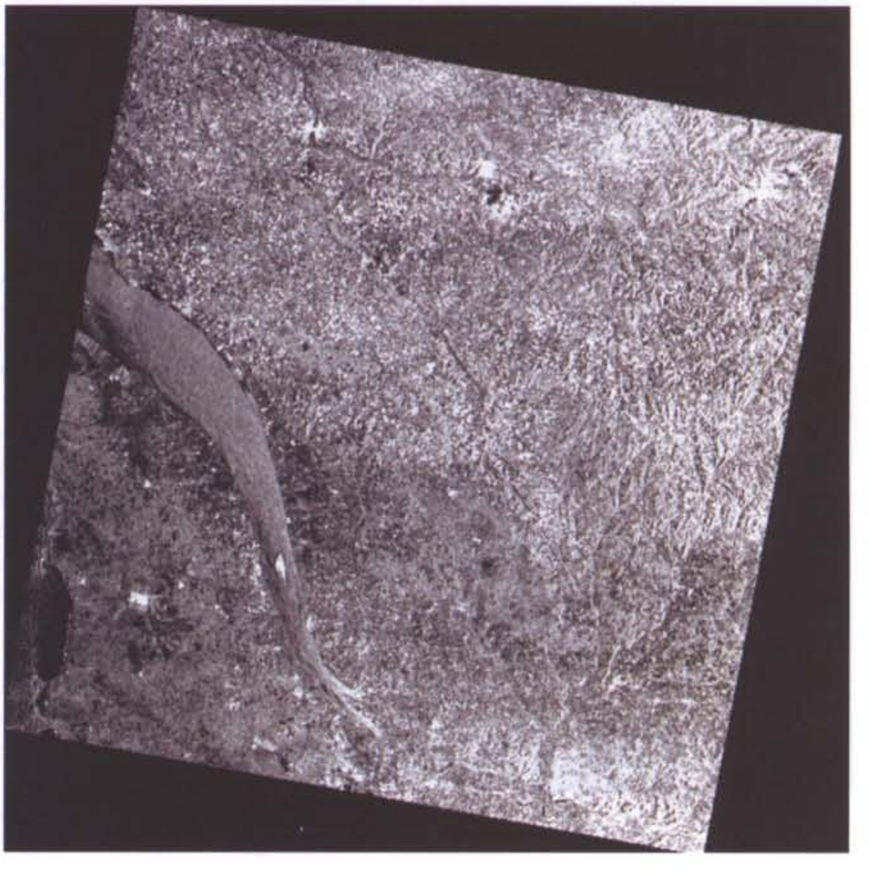
Landsat-5 Quick-Looks
Full Landsat-5 quick-look strips, covering the entire acquisitions of one station, are received at the ImageDB server, where they are split into frames, according to the standard Landsat World Reference System. These output frames, covering an area of about 180 km x 170 km, contain about 500 x 480 pixels. During the splitting, the data are processed and compressed in such a way as to provide the best compromise between image quality and file size. Bands 7, 5 and 2 are used for best cloud detection and provide an artificially coloured image. A histogram stretching is then applied, acting on contrast and luminosity, improving the readability of the images at northern latitudes. The result is compressed in jpg format, with minor losses (Fig. 3).

The Landsat quick-looks are available for the recent past and can be directly downloaded using DESCW, by searching the relevant items in the dedicated inventory collection and clicking with the mouse on the status column of the item in the Scene List.

Figure 3. Example of a Landsat-5 quick-look

ERS GEC Products
For ERS-2, a special collection of GEC products, each covering an area of 100 km x 100 km, is made available. The GEC products are originally generated positioning each pixel on its location on the Earth, using the transverse Mercator projection, without additional correction related to target height. In order to reduce storage needs and transmission times, the GEC products are stored in the ImageDB with a 2 x 2 block averaging, bringing the geometric resolution to 25 m. The product is also compressed using the standard Zip compression tool (Fig. 4). This processing allows the original image of about 160 Mbyte to stored in less than 25 Mbyte.

Figure 4. Example of a GEC product



The related quick-looks are stored as 600 x 600 pixel images in jpg format, whilst the thumbnails, which have a resolution of about 1 km, are stored in gif format with a transparent background.

With the current coverage (Fig. 5), the images are progressively covering the whole of Europe, with most of the data acquired during the period July – September 1998 (for as homogeneous as possible coverage during the dry season). The quick-looks and the products can be searched and downloaded through DESCW.

Data loading

The Landsat-5 quick-look loading activity is almost entirely offline and automatic: periodically, each incoming Landsat jpeg quick-

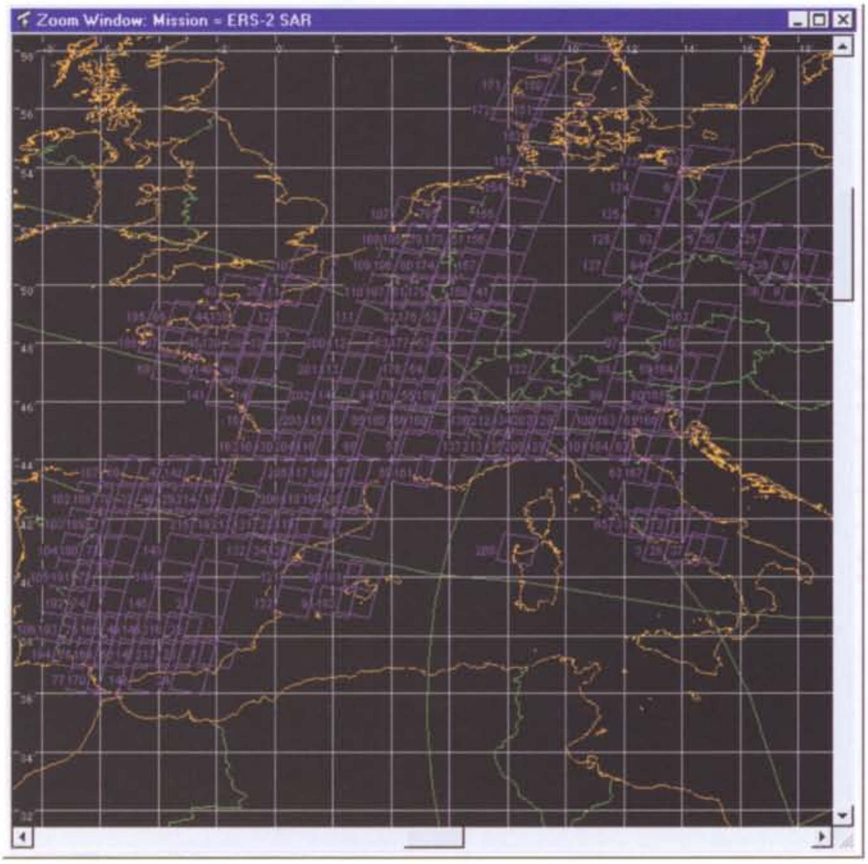


Figure 5. Coverage of GEC products

look strip (the full pass of data acquired by one station) is cut into a set of frame-sized jpeg's and gif's and a *catalogue* file generated for each frame. The files (three for each frame) are then moved into the RAID storage and the ImageDB index table is updated. The only interactive activity is the log-watching to be performed by the operator to detect any ingestion errors.

The loading process for GECs is more sophisticated and is divided into two phases: pre-loading and processing. During the *pre-loading* phase, three or four GEC products are copied from the CD-ROM into an internal temporary storage. During the *ingestion phase,* all of the pre-loaded images are processed concurrently, resulting in a set of six files for each product:

- a sub-sampled GEC image, with unchanged radiometric resolution (still 16 bits per pixel), stored as a .zip file of about 22 Mbyte (subsampling is performed by applying a 2 x 2 block averaging to the original image)
- a header file (with .lea extension), containing geographic and radiometric information about the product, updated in terms of the parameters that have been changed by image subsampling

Table 2. Index table layout

Field	Description
Mission ID	Identifies the mission (satellite) associated with the image
Sensor ID	Identifies the sensor from whose data the image was generated
Mode ID	Identifies the special mode (if any) in which the sensor was at data acquisition time
Mission Orbit Number	The absolute orbit number at data acquisition time
Frame Number	The frame number at data acquisition time, according to the World Reference System (WRS) defined for this mission and sensor
Station ID	Identifies the station that acquired the data
Image Class	Separates the entries in this Index Table into major classes like no product entry (no product associated), quick-look entry, full product entry, etc.
Image Type	Represents the type of the image (e.g. interferometric image, full product, quick-look, etc.)
Representation Mode	Describes the representation mode of the image (e.g. normal, geocoded, etc.)
Track Number	Cyclic track number (as defined by the WRS) during data take
Archive Location	Indicates the location where the data is archived
Pass Type	Can be ascending or descending
Acquisition Start	The date and time when the data acquisition started
Acquisition Stop	The date and time when the data acquisition ended
Centre Co-ordinates	Latitude and longitude of the scene centre
Four Corners Co-ordinates	Latitude and longitude of the four image corners (NW, NE, SE, SW)
Missing Data Percent	The percentage of missing data during image acquisition
Cloud Coverage	The cloud coverage relative to the four image quadrants (NW, NE, SE, SW)
Keywords	A set of keywords associated with the image that can be used during a search session by the user
Related Documents	Documents or hyperlinks to documents (Texts or Articles) related to the image

- a volume descriptor file, which is an unchanged copy of the one on the source CD-ROM
- a 600 x 600 pixel jpeg-compressed quick-look
- a gif thumbnail with a spatial resolution of about 1 km per pixel
- a catalogue file (with .cat extension) filled in with the available inventory data, including image co-ordinates.

After ingestion is completed, the temporary storage area is cleaned up and the result files are moved into the storage subsystem according to a specific directory structure organised by mission, sensor, mode, orbit and frame number of the processed images. The average duration of the ingestion process for three GEC products loaded concurrently is about 10 min per product, consisting of a fixed pre-loading time of about 1.5 min for each product, plus 25 min for the parallel processing of the three GEC images.

Ingestion is then completed by inserting the inventory information on the loaded images into the internal index table, the layout and field descriptions of which are shown in Table 2. The various fields of this table are filled in according to the mission (e.g. cloud-cover information is available for optical sensors only).

The loading process is guided via a Graphical User Interface. This GUI offers not only a set of tools for easily performing the loading into the ImageDB archive of the ERS GECs, but also a way of checking out the logs produced during the ingestion phases of both ERS GECs and Landsat quick-looks. Another feature of the operator interface is the possibility to start the generation of the DESCW collection inventory files. It allows the operator to specify the parameters necessary to generate and send via FTP these files, which contain the inventory data related to a subset of the ImageDB archived entries.

The user interface

DESCW

The simplest way to retrieve and download the ERS-2 quick-looks and the GEC images available in the ImageDB is through DESCW. A prerequisite is the provision to DESCW of personal user information, through the dialogue window opened by selecting the 'User Info' option of the 'Define' menu.

The weekly updates to the DESCW inventory files include one ERS-2-specific collection designated GEC_Prod.cll, which lists all of the ERS-2 GEC products stored on the ImageDB server. From the DESCW Mission window, for ERS-2, it is possible to select this collection and perform a normal search on it (most of the products are currently from the period July - September 1998). From the result of the search, listed in the Scene List window, by clicking with the mouse on the status column of the relevant frame and selecting when requested the source station and the quick-look location (the 'ImageDB' remote server), the quick-look is automatically transferred and displayed on the screen.

The compressed GEC products can also be obtained by following the above procedure, but then selecting 'Full Image Download' in the dialogue window used to define the image location ('ImageDB'). The system then asks for the User Name and Password, which must have been requested beforehand from the ESRIN ERS Help Desk or one of the ESA distributors. If the user is recognised, the FTP transfer of the GEC product (about 22 Mbyte) starts as a separate process, the progress of which is indicated in real time.

Direct FTP download

When the full identifier of the required image is known, it is also possible to directly log onto the ImageDB server (earth3.esrin.esa.it), look

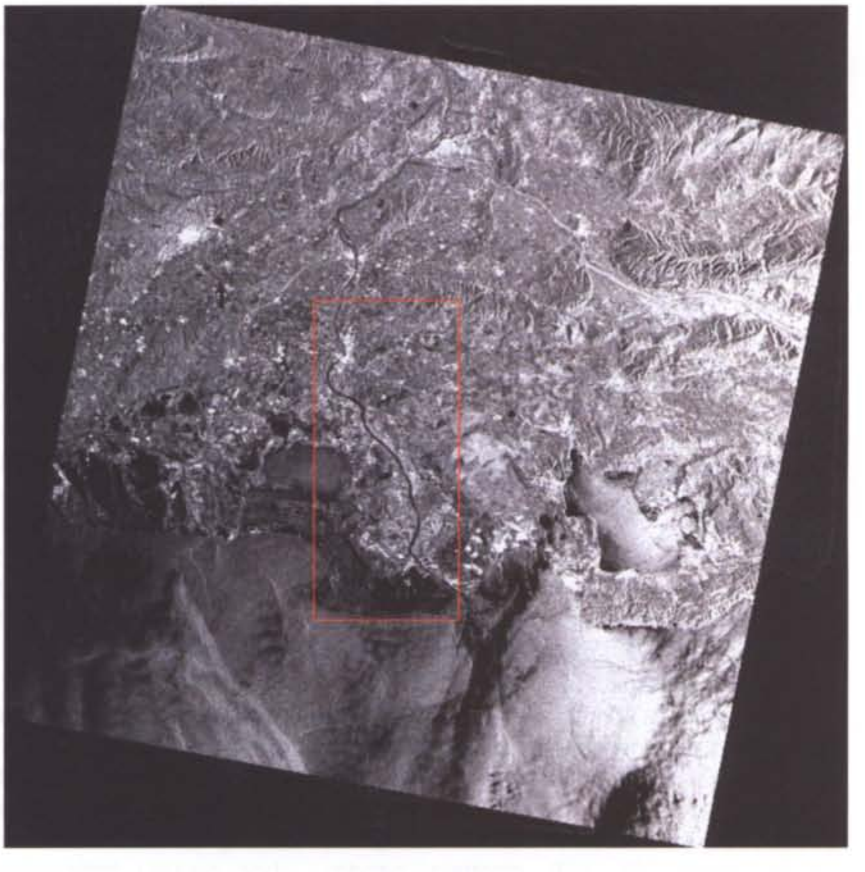


Figure 6. Example of image-subset selection

freely at the quick-looks, and download the full image after having provided the correct user name and password.

Image subset
It will be possible soon to identify from DESCW the relevant subset of the image just by drawing a rectangle on the screen over the related quick-look, in order to receive only this image subset. This will allow the number of bytes to be transmitted over the network, and therefore the transmission time, to be considerably reduced.

It will be possible at the same time to specify other parameters for the image subset, such as radiometric resolution (8 or 16 bits), spatial resolution (as a multiple of 25 m), desired format and delivery method. For the latter in particular, the user can select among FTP.get, FTP.put and possibly BackWeb. When FTP is selected, the system provides the image sub-set into a user-reserved directory for a maximum specified period of time. It FTP.get was selected, the system also starts the transmission towards the user equipment. In the case of BackWeb, transmission occurs through this nonintrusive push technology, with the advantages of using at best the available bandwidth (without impacting on other ongoing user transactions), of ensuring correct data transfer even after hardware switch-off/on, and of permitting unattended transfer over a long time period (e.g. during the night) over a limited-capacity network like the Internet.

Future expansions
The following enhancements are planned:

- extend the set of GEC products stored in the ImageDB also to sites outside Europe
- repeat periodically (e.g. annually) the European coverage of the GEC products
- store in the database and handle through DESCW the keywords, documents or links associated with the images
- create specific subsets of images, text, documents and hyperlinks for loading onto CD-ROMs
- handle multi-temporal and mosaicked images
- implement a web-browser interface.

Access through DESCW
The DESCW software and related inventory files (updated weekly) are available off-line (see 'Support' below) or on-line at the ESA/ESRIN server, from where they can be downloaded for free installation and updating. Downloading can occur through:

– **FTP access**

Address	earthnet.esrin.esa.it
Username	anonymous
Password	(please enter your e-mail address)
Directory	/FTP/software/descw

– **World Wide Web access**

http://earthnet.esrin.esa.it

Please follow 'Software Gallery' and then 'Software to Obtain Satellite Earth Coverage'

– **BackWeb**

BackWeb is a client-server application that permits one to send data via the Internet from a server to all clients who have subscribed to a specific 'channel'. It applies data-push technology using idle on-line time and check-point/restart (after a break, the transmission resumes from the point of interruption, even if the break is due to switching-off of the computer). The BackWeb software is free of charge and can be downloaded for a specific platform from the address:

http://www.backweb.com

Once the BackWeb client is installed, it is necessary only to subscribe to the DESCW channel from the location:

http://earth1.esrin.esa.it/backweb

Support
Requests for support with ImageDB-related activities can be submitted to:

ERS Help Desk
ESA/ESRIN
Via Galileo Galilei
I-00044 Frascati
Italy

Tel: +39-06-94180777
Fax: +39-06-94180272
E-mail: eohelp@mail.esrin.esa.it

Testing Space Robotics on the Japanese ETS-VII Satellite

G. Visentin & F. Didot
Mechanical Engineering Department, ESA Directorate of Technical and Operational Support, ESTEC, Noordwijk, The Netherlands

In April 1998, the first collaboration between ESA and NASDA on space robotics culminated in a very successful demonstration on the Japanese Engineering Test Satellite (ETS) VII. From an ESA control station at NASDA's Tsukuba Space Centre in Japan, a team of ESA and industry staff commanded the satellite's robot arm through a series of a advanced manoeuvres in a demonstration that will contribute to future applications of space robotics. The data collected will allow us to quantify the exact performance and reliability achievable with such modes of control. Apart from its technical success, this joint experiment was also a very positive experience at the personal level due to the excellent spirit of professional dedication and co-operation between the Japanese and European teams.

Introduction

ETS-VII (Engineering Test Satellite VII) is a NASDA programme designed to test key rendezvous, docking and robotics technologies in space. The Japanese space agency has built, launched and operates this test satellite, equipped with a robotic manipulator and a small subsatellite, to carry out such experiments. In response to a NASDA call for co-operation, ESA proposed two experiments to be conducted on-board ETS-VII. The ESA proposal was accepted with the understanding that NASDA and ESA would jointly co-operate in the development and operation of the two experiments.

Following the initial contacts, the International Relations offices of the two agencies worked together to establish a Memorandum of Understanding (MOU) that would govern the co-operation. Belgium expressed its willingness to fund the activities involved in implementing the experiments, under the ESA Technology Demonstration Programme (TDP) and General Support Technology Programme (GSTP).

After an open competitive tender, the Vision Interactive Autonomy Bi-Lateral Experiment on ETS-VII (VIABLE) contract for experiment implementation was awarded to a consortium led by TRASYS Space, with the VISICS group of the Katholieke Universiteit Leuven and Space Application Services.

The ESA rationale for the co-operation

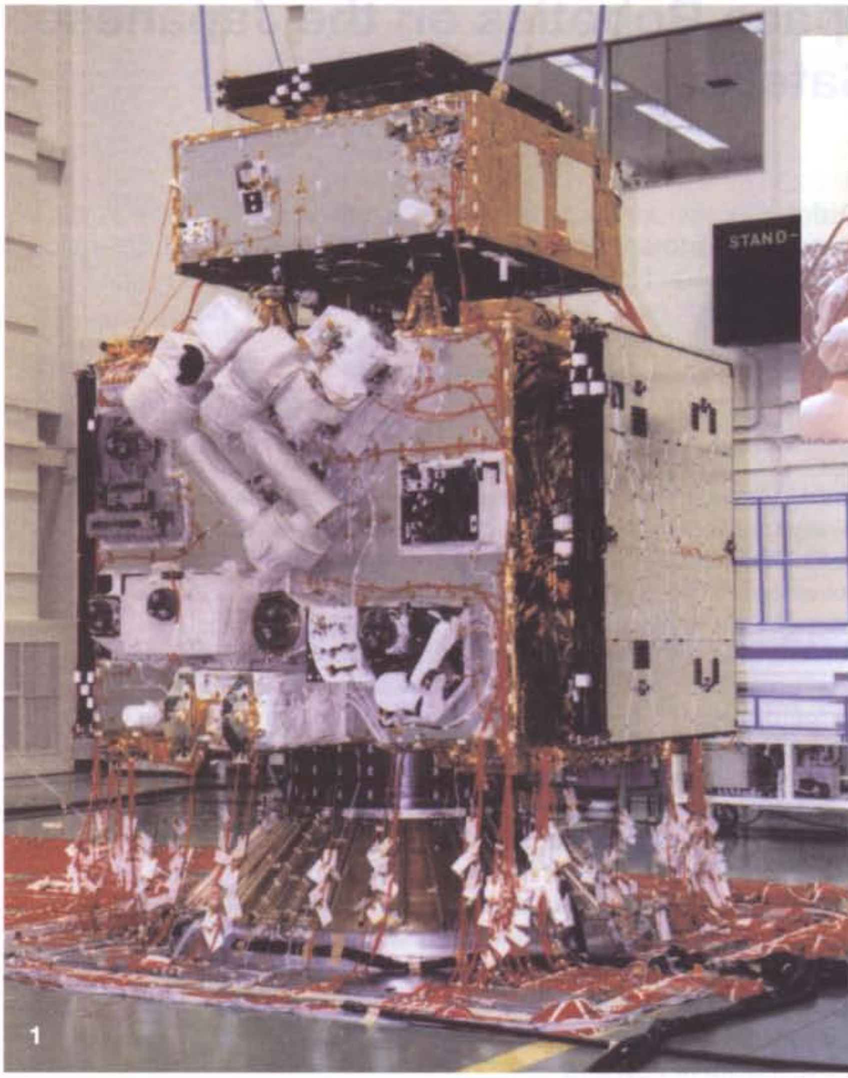
There are several reasons why the ESA Technical and Operational Support Directorate has pursued co-operation within the ETS-VII project. Firstly, earlier ESA research and development (R&D) activities have developed several space-robotics technologies to a high level of maturity. Their feasibility has been proven mainly through ground-based demonstrations. However, in-flight demonstrations are essential for full acceptance of these technologies, but are difficult to organise because they are expensive and not readily covered by R&D funding. Consequently, when the ETS-VII project opened its doors to international cooperation, it presented a unique flight-demonstration opportunity.

Secondly, ETS-VII features the first, and so far the only, satellite-mounted robot arm to be remotely controlled from the ground. This unique characteristic was particularly interesting for demonstrating technologies relevant to satellite servicing which ESA had been studying for some time.

Thirdly, there was strong interest in developing co-operation with NASDA on space-robotics issues. There is an increasing need for international co-operation at all levels in space projects, and NASDA with ETS-VII and its JEM robotic system is promoting itself as an authoritative partner for space-robotics activities. It was therefore important for ESA to establish first contacts with such a key player.

The ETS-VII system

ETS-VII (Fig. 1) consists of two satellites: the 'chaser' and the 'target'. During rendezvous-and-docking (RVD) experiments, the chaser releases the target and drifts away to distances of up to 9 km. Subsequently, a rendezvous manoeuvre brings the chaser back close to the target and a docking between the two is performed. The chaser is also equipped with a robotic platform (Fig. 2), which allows assessment of the following technologies:



already been finalised, the experiments could only be implemented as additions to the ground segment. Therefore they consisted of specific software which would run on the so-called 'ESA Terminal' to be connected to the ETS-VII robotics ground-control segment.

Figure 1. The ETS-VII satellite system undergoing vibration testing at NASDA's Tsukuba Space Centre (TKSC)

Figure 2. The robotics platform during final integration at TKSC

- teleoperation in the presence of time-delayed and limited-capacity telecommunication
- coordinated control of satellite and robot arm
- in-orbit satellite servicing.

The MOU allowed ESA to carry out the experiments using two elements of the robotics platform: the external robot arm and task board.

The ETS-VII space and ground segments are linked via the NASA TDRS data-relay satellites. Figure 3 provides an overview of the communications chain. This communication set-up allows one to extend the radio visibility of the satellite system, enabling operation windows of up to 45 min duration.

The ESA experiments

The two experiments proposed by ESA aimed, within the limitations imposed by the already settled satellite configuration, to assess the efficacy of two technologies developed under ESA R&D activities: the Interactive Autonomy robotic control mode, and computer-vision-assisted robotic control. Given that the configuration of the ETS-VII flight segment had already been finalised, the experiments could only be implemented as additions to the ground segment. Therefore they consisted of specific software which would run on the so-called 'ESA Terminal' to be connected to the ETS-VII robotics ground-control segment.

The Interactive Autonomy Experiment

In the Interactive Autonomy (IA) robotic control mode, robot operations are analysed and broken down into a modular and hierarchical set of activities and related parameters. This breakdown has the effect that robot operations become programmed sequences of:
- autonomous robot manipulations, and
- robot-user interactions

in a way that optimises flexibility and efficiency. Such a mode has many advantages. Pre-programming and verification via simulation guarantee enhanced safety during the execution of robotic tasks. More predictable performance and better reliability are achieved. There is lower demand on operator skills and a reduced workload, allowing the robot to be operated by non-robotics specialists.

Interaction with the user happens basically on two occasions:
- when the user wants to change the autonomous robot operations
- when a divergence or an anomaly occurs between the expected manipulation results and the actual results.

In both cases, the interaction is limited to the selection of activities, and related parameters, that the robot has to execute autonomously. The activities and parameters that can be selected are limited to those that are meaningful and safe for the current robot and robot-environment configuration.

The Vision Based Robot Control (VBRC) Experiment

Computer vision to enhance robotic control is the subject of many research projects all over the World and particularly in Europe, where knowledge on this technology is quite strong. The technology, using cameras as enhanced means of perception and with the help of sophisticated software, allows the robotic working environment to be assessed exactly, without a-priori knowledge. The technology can therefore be used to boost autonomy in robotic operations, as well as to increase the performances of human-operated robot systems. The VIABLE experiment foresaw experiment sequences to prove the validity of this technology.

Through the VIABLE activities, the technology developed and first validated on the ground has been demonstrated successfully in a space environment under real illumination conditions.

The challenges of ETS-VII

The main technical challenges that the experiment developers had to face were linked to the fact that ETS-VII had not originally been conceived to support the ESA experiments. Because NASDA had set up a ground segment capable of hosting guest experimenters (Fig. 3), the main limitations stemmed from the flight segment.

For the IA experiment, the functionality offered by the basic NASDA ETS-VII robot controller did not allow great autonomy. Due to its main utilisation as a tele-operated system, it could only execute simple, low-level trajectory commands. To enhance autonomy, an Autonomous Executive able to understand high-level commands was introduced by ESA, to serve as a front-end to the ETS-VII robot operation facility.

On the VBRC side, the problems resided in the generation and transmission of video pictures from the flight segment. The two wrist-mounted cameras used by the experiment were designed to provide visual feedback to human operators. The cameras had not been built or calibrated specifically for computer-vision purposes. Moreover, the video signal was transmitted using JPEG compression, which preserves the appearance of the pictures, but introduces artefacts that disturb computer-vision algorithms. The vision algorithms had to be re-engineered by ESA to cope with these unusual working conditions.

The development of the experiments

The time available for the development of the experiments was rather short. In fact, the industrial development contract could not be started until the MOU had been finalised and signed by the Directors of both Agencies. Due to the lengthy finalisation process, the real

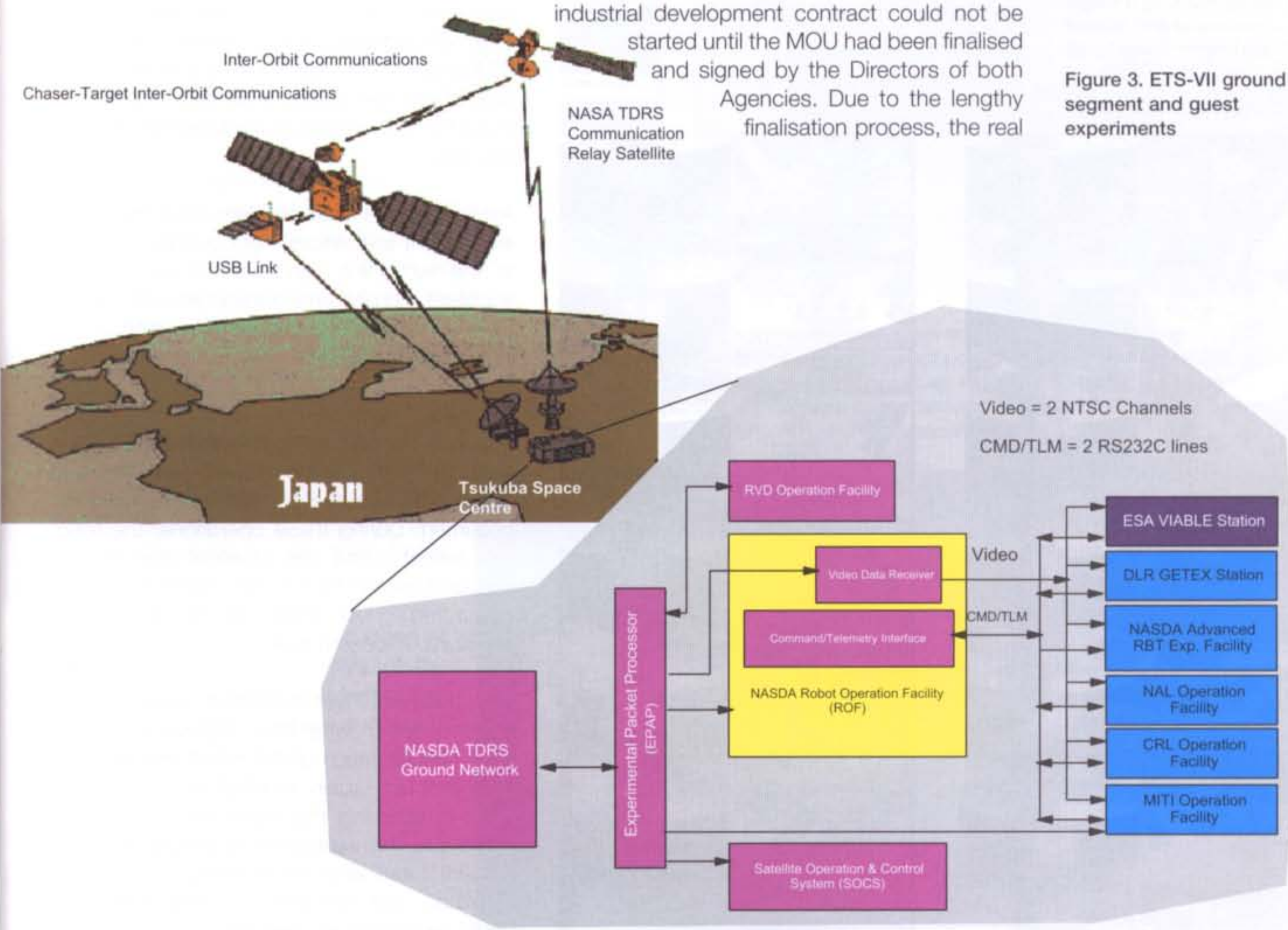


Figure 3. ETS-VII ground segment and guest experiments

effort could not start before April 1998, even though the mission was fixed for April 1999.

However, the developers were not starting from scratch in that the 'ESA Terminal' could be based on the 'FAMOUS' system. This is an ESA technology development that provides a general-purpose, project-independent software framework, designed to actively support a ground-based operator in the preparation and execution of space-based robotic experiments. The framework had to be instantiated (by the addition of dedicated software or the configuration of existing software) to support the VIABLE experiments. Moreover, a large part of the computer-vision experiment could be based on the 'TargetJR' system. This is a large integrated Image Understanding (IU) environment, designed both as a computer-vision research tool and as a platform for building end-user IU applications.

Mission time

After about one year of development work, it was time for the mission. NASDA had reserved the use of the ETS-VII ground segment for ESA for two weeks starting on 29 April. The first week was devoted to the rehearsal of the experiments on the ETS-VII ground simulator, the second to the in-flight experiment execution itself.

Figure 4. Video sequence from an IA experiment (top-to-bottom and left-to-right). In a single picture, the left image shows a robot-hand camera view, and the right image a robot-base camera view. The robot tool slides over a sinusoidal profile under strict force control. This classical robotics test is representative of many robotic operations, such as rubbing a surface. In IA, the complete operation was initiated by invoking a single command and related parameter (force level)

The European team consisted of two ESA and three industry staff members. The first week of experiment rehearsal was very satisfactory. The 'ESA Terminal' had already been installed in the ETS-VII ground operations network a few weeks earlier, at the time of an electrical interface compatibility test. However, the rehearsal was the first occasion on which full interaction between the Terminal and the ETS-VII ground segment could be tested. Remarkably, only very minor problems were identified and these were easily corrected.

The experiment execution

The schedule for the execution of the ESA experiments foresaw three days of operations with four 45-minute operating windows per day. The following text has been extracted from the mission logbook:

Day one, 6 April

Ten minutes before the first window, NASDA reported that they could not contact the satellite. Analysis showed that it was a TDRS problem, and this was confirmed by NASA. Unfortunately, the previous day (after the ETS-VII initialisation) NASA had performed an update to the TDRS ground software, and a newly introduced bug prevented TDRS operation during the first and second windows. This necessitated a major rescheduling of the ESA experiments, with the new schedule being even more demanding than the original one, featuring five experiment windows over the next two days.

Aside from this initial problem, all of the VBRC experiment sequences that could be executed in the remaining windows on day 1 were successful in performing measurements on the ETS-VII robotic equipment and testing the vision algorithms.

Day two, 7 April

This was the second day of operation and, as all experiments were dealing with contact operations, had the highest risk of problems occurring. During these operations, the robot tool would come into physical contact with various items on the satellite, calling for careful commanding in order to avoid exerting excessive forces on them.

Regrettably, our first experiment sequence was aborted due to what later analysis showed to be a miscalibration of the robot joint sensors. This problem again resulted in some major work in adapting the experiment sequences. Thanks to the experience and support of the ETS-VII team and the flexibility of the 'ESA Terminal', the remaining contact operations could be performed flawlessly.

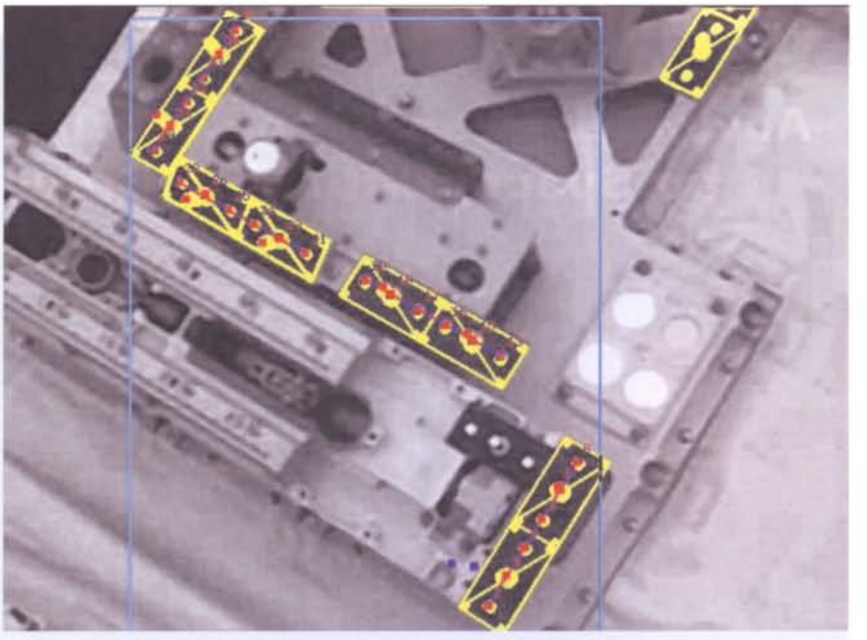


Figure 5. The computer-vision algorithms provide the robot controller with an exact perception of the working environment. Here the position of some task-board markers is identified and computer-generated clues are superimposed on the camera picture. In VBRC, this feature enables the robot to find out autonomously where the subjects of its manipulation are located

Day three, 8 April
After an early start, with the window briefing at 03:00AM, the day looked promising. Based on the experiences of the previous days, all indications were that the ESA Terminal was performing well. In the event, all experiment sequences worked correctly and no real problems were experienced. On the contrary, some sequences went faster than expected, so that it was even possible to run additional sequences during the last window.

The experiment results
Final evaluation of the mission data is still in progress at the time of writing, but some general conclusions can already be drawn. The IA robot mode of operation has been applied successfully during a real robotics mission and its benefits demonstrated (Fig. 4). The difficulties encountered even served to offer an additional positive validation of the performance of IA. This conclusion has great importance for the robotics applications on the International Space Station, which will make use of various forms of IA (ERA, the Technology Exposure Facility).

The VBRC experiment demonstrated the computer-vision support to autonomous robot control (Fig. 5) as well as to human tele-operation (Fig. 6) in a real mission scenario. Additional capabilities that will be useful for robot operations with non-cooperative objects have also been successfully demonstrated (Fig. 7).

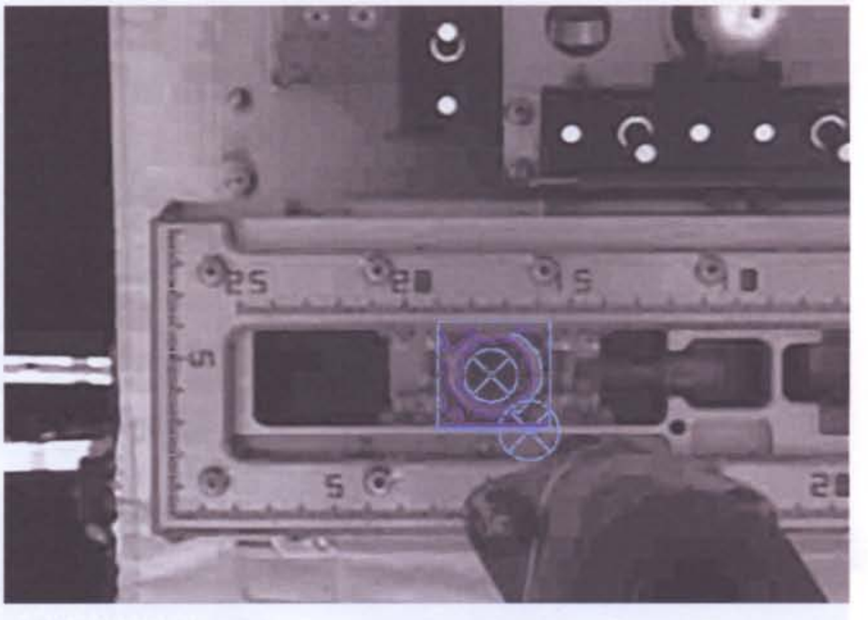


Figure 6. The hole in the task-board slider is identified by the computer vision (dark blue) and the current and updated impact points of the peg are presented to the robot operator with visual clues (light blue). Here, the computer vision is providing the robot operator with additional information that helps in performing the peg-into-hole operation more quickly and more accurately.

Acknowledgements
The authors wish to thank all members of the VIABLE team - Dr. D.Galardini, Mr E. Maesen, Dr. K. Kapellos and Mr M. Vergauwen - for their highly professional work and for their support during the mission. Many thanks are also due to Dr. M. Oda, Mr N. Inaba at NASDA and all the members of the ETS-VII team for the time and effort that they devoted to this highly successful co-operative endeavour. esa

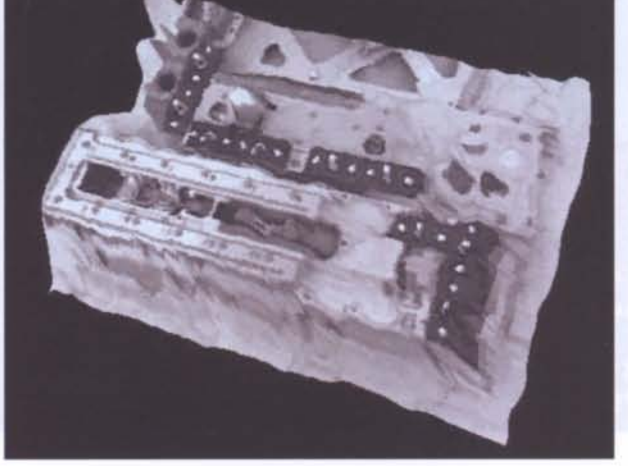
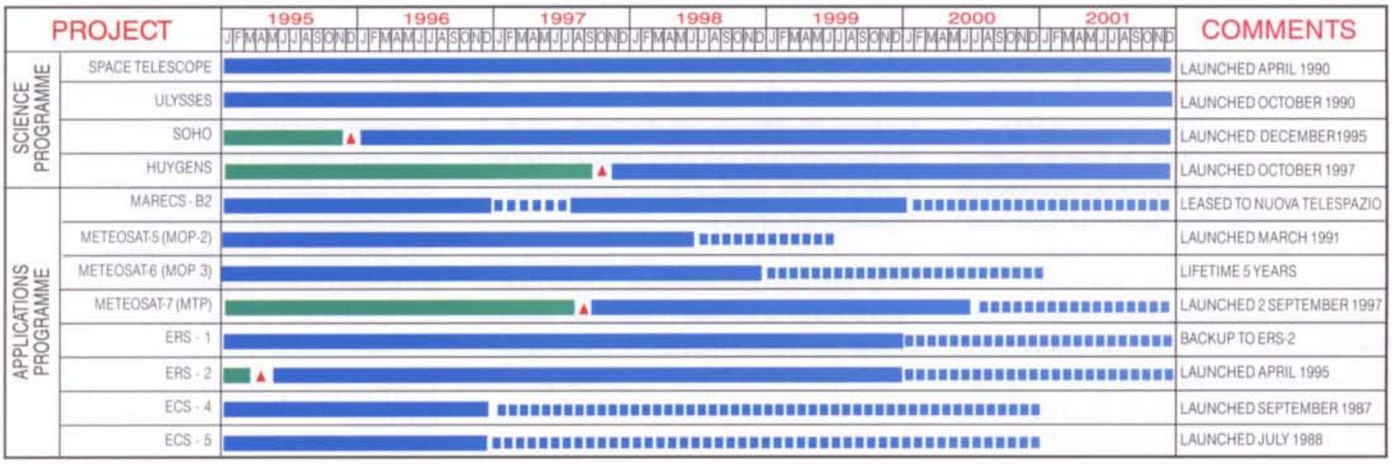


Figure 7. By processing a sequence of images taken from the robot-hand camera, the geometry of the slider element of the task-board can be reconstructed. This VRBC feature enables robots to operate successfully in a previously unknown working environment

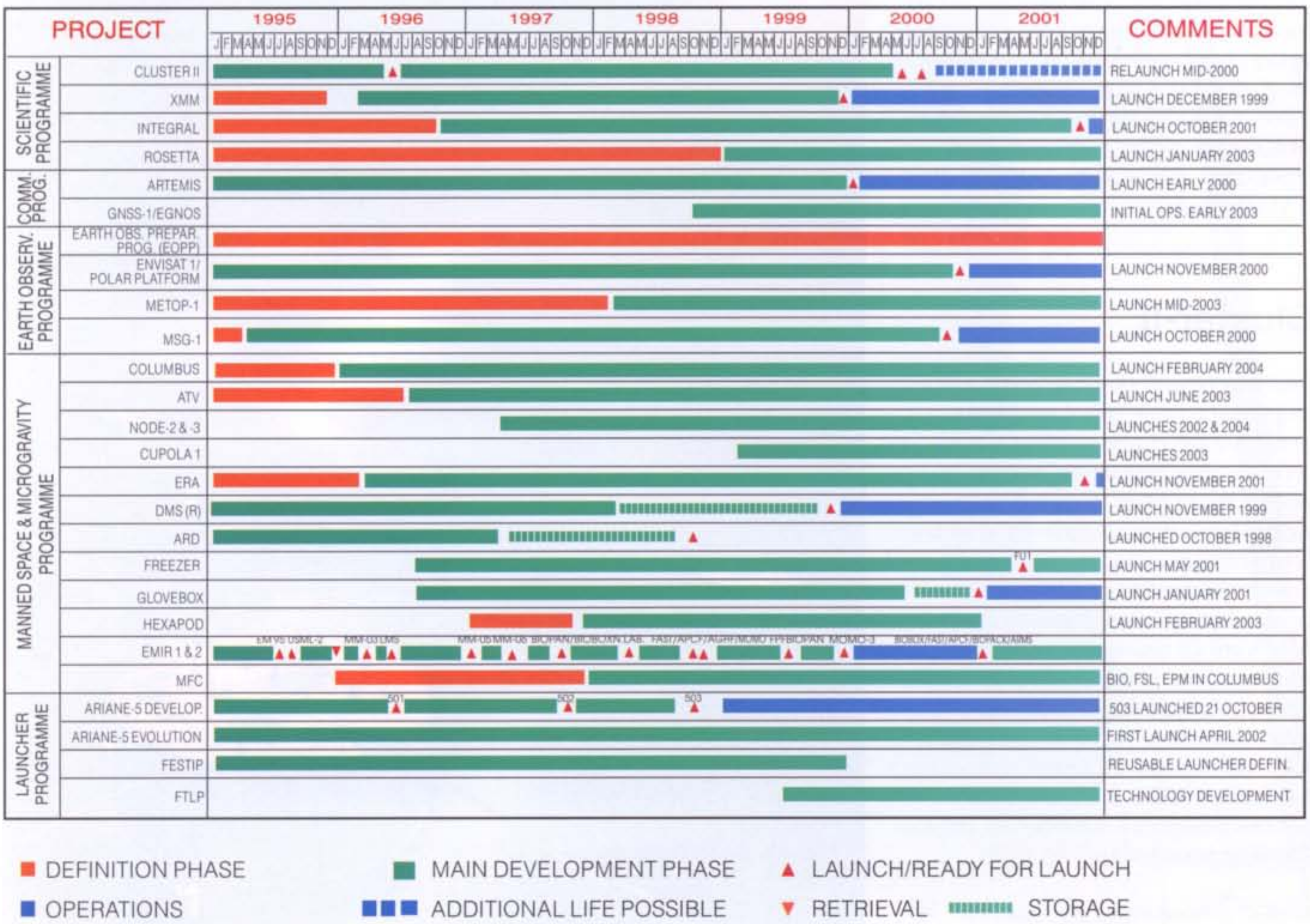
Programmes under Development and Operations
Programmes en cours de réalisation et d'exploitation

(status end June 1999)

In Orbit / En orbite



Under Development / En cours de réalisation



ERS

Le système ERS a célébré ses huit années de service ininterrompu depuis le lancement d'ERS-1 en juillet 1991. Les performances du satellite ERS-2 et de son secteur sol restent inchangées en termes de qualité des données et de disponibilité. ERS-1 est maintenu en hibernation comme satellite de secours.

De nouveaux algorithmes de contrôle d'attitude et de correction d'orbite sont en cours d'élaboration : la conception détaillée et l'architecture du logiciel sont terminées. Cette amélioration renforcera le système satellitaire en cas de défaillances multiples des gyroscopes en fin de vie et facilitera la poursuite des opérations, l'objectif étant d'aller jusqu'à la phase de mise en service d'Envisat. Le financement de la prolongation de l'exploitation d'ERS a été obtenu dans le cadre du programme EOEP mais à un niveau représentant une réduction annuelle de 30% par rapport au programme actuel.

Une campagne spéciale a été menée en mai avec l'altimètre radar d'ERS-2 pour mesurer des échos radar parasites sur un choix de cibles terrestres ; cette simulation servira pour l'étalonnage de l'instrument RA-2 d'Envisat. En juin, l'altimètre radar d'ERS-1 a été réactivé pour prendre des mesures combinées avec l'instrument d'ERS-2 au-dessus de bouées GPS dans la Méditerranée.

Cluster-II

Tous les éléments du projet continuent à progresser comme prévu, en vue du lancement des quatre satellites à la mi-2000 par deux Soyouz. Le premier modèle de vol (FM6), qui a subi avec succès la totalité du programme d'essais, est maintenant entreposé. Certaines expériences sont en cours de révision et de réétalonnage avant d'être réintégrées pour le vol. Le deuxième modèle de vol (FM7) a subi la moitié de son programme d'essais d'ambiance, qui s'achèvera début septembre. Le troisième satellite (FM8) est en cours d'intégration et sera transporté à l'IABG, à Munich (D), en octobre. Les travaux sur le dernier satellite, Phénix, doivent reprendre en août.

L'ESOC a mené à bien les essais de validation système des deux premiers satellites, effectuant de Darmstadt la commande et le contrôle des satellites qui se trouvaient chez Dornier à Friedrichshafen (D). Les autres activités de préparation du secteur sol se déroulent comme prévu.

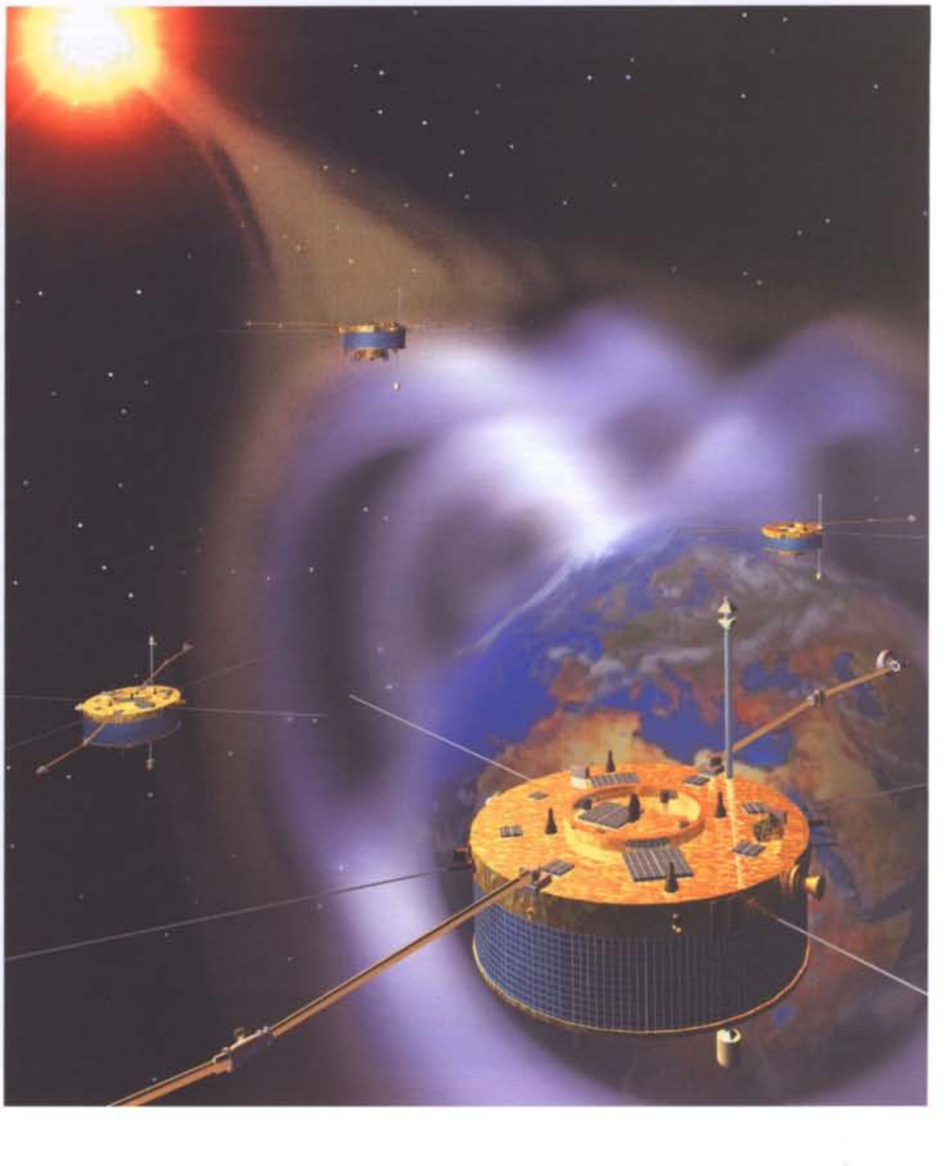
La revue de mise en œuvre du système de données scientifiques et du centre commun d'opérations scientifiques de Cluster a été menée à bien, donnant le feu vert au démarrage des essais système avant la fin de l'année. Le système de gestion des données, qui a été spécialement développé pour Cluster-II, vient d'être testé et aucun problème sérieux n'est apparu.

Le programme de qualification au sol du nouvel étage supérieur Frégate du lanceur Soyouz est presque terminé. Les essais mécaniques sont finis et les derniers essais électriques sur le modèle de qualification s'achèveront d'ici fin août. Le premier vol de qualification de Soyouz/Frégate est prévu en janvier 2000.

XMM

La campagne d'essais d'ambiance du satellite a été menée à bien. L'essai acoustique a été réalisé début juillet dans la grande chambre européenne d'essais acoustiques (LEAF) et tous les systèmes fonctionnent normalement.

Les préparatifs des divers essais fonctionnels sont en cours, ceux-ci devant se dérouler sur la base des procédures de vol rédigées pour exploiter le satellite en orbite. Pendant le deuxième essai de validation système, l'ESOC assurera toutes les opérations de contrôle/commande du satellite à partir de Darmstadt. Cet essai fera partie de la formation des opérateurs.



Artist's impression of the four Cluster-II spacecraft

Vue conceptuelle de la flottille des quatre satellites Cluster-II

ERS

The ERS system is celebrating eight years of continuous service since the launch of ERS-1 in July 1991. The performance of the ERS-2 satellite and ground segment is unchanged in terms of data quality and availability. ERS-1 remains in hibernation as the back-up satellite.

The development of new attitude and orbit control algorithms has reached the stage of completion of the software architectural and detailed design. This enhancement will give the satellite system additional robustness for dealing with potential multiple end-of-life failures of gyroscopes and will facilitate continued operations with the goal of overlapping with the Envisat commissioning phase. The financing of this extension of ERS operations has been secured within the framework of the EOEP programme, albeit at a level representing a 30% annual reduction compared with the present programme.

A special campaign in May with the ERS-2 Radar Altimeter provided measurements of unwanted radar echoes over selected land targets - an artefact that needed to be quantified for future calibration of the Envisat RA-2 instrument. In June, the ERS-1 Radar Altimeter was reactivated to support combined measurements with the ERS-2 instrument over GPS buoys in the Mediterranean.

Cluster-II

All of the project elements are still progressing according to plan, aiming for the launch of the four spacecraft in mid-2000 by two Soyuz rockets. The first flight model (FM6) has successfully completed its full test programme and is now in storage. Some experiments are undergoing refurbishment and recalibration before their re-integration for flight. The second flight model (FM7) is half way through its environmental test programme, which will be completed in early September. The third flight spacecraft (FM8) is presently being integrated and will be transported to IABG in Munich (D) in October. Work on the last spacecraft, which was 'Phoenix', is due to recommence in August.

ESOC has successfully performed system-validation tests on the first two spacecraft, commanding the spacecraft at Dornier's premises in Friedrichshafen (D) from Darmstadt. The rest of the ground-segment preparation is going according to plan.

The Cluster Science Data System and Joint Science Operations Centre have successfully undergone an Implementation Review, which gave the 'green light' to start system testing later this year. The data-management system, which has been newly developed for Cluster-II, has recently been tested and no major problems were identified.

The ground qualification programme for the new Frégat upper stage for the Soyuz launch vehicle is nearing completion. The mechanical tests have been finalised and the remaining electrical qualification-model testing will be completed by the end of August. The first qualification flight of the Soyuz/Frégat is planned to take place in January 2000.

The XMM spacecraft undergoing acoustic testing at ESTEC (NL)
Le satellite XMM aux essais acoustiques à l'ESTEC (NL)

XMM

The spacecraft has successfully completed the environmental test campaign. The acoustic test in the Large European Acoustic Facility (LEAF) was conducted in early July and all systems are performing nominally.

Preparations are now being made for the various functional tests, which are run using the flight procedures written to operate the satellite once it is in orbit. During the second system validation test, ESOC will take over full control of the satellite and remotely operate it from Darmstadt. This test will be used for operator training.

By 13 September, the spacecraft will be aboard a vessel sailing from Rotterdam (NL) on its way to the launch site, the European space port in Kourou, French Guiana.

The mission-control system is already operational and the staff are commencing

Le satellite embarquera d'ici le 13 septembre à bord d'un navire qui le mènera de Rotterdam (NL) à Kourou (Guyane), le port spatial de l'Europe, d'où il sera lancé.

Le système de contrôle mission est déjà opérationnel et le personnel a démarré la formation des utilisateurs. Le simulateur du satellite est utilisé pour valider les procédures de contrôle en orbite. Logica (GB) a fourni les premiers éléments du système de contrôle des opérations scientifiques et s'est chargé des modifications nécessaires pour s'adapter aux derniers changements concernant les expériences ; l'ESOC réalise les essais. Les travaux d'intégration de la station sol devraient s'achever à temps pour la date de livraison, prévue en août. Tous les éléments sont conformes au calendrier en vue de la revue d'aptitude du secteur sol qui aura lieu en octobre.

Parallèlement, les premières propositions d'observation avec XMM ont été reçues via le système de télésoumission. Ce système a traité sans défaillance un volume important de propositions, reflétant l'intérêt considérable suscité par la mission. L'évaluation de ces propositions est en cours.

Les trois miroirs sont installés à bord du satellite, l'une des tâches essentielles étant maintenant de veiller à leur propreté pendant la phase d'essais, dans la mesure où leurs performances optiques en dépendent directement.

Les essais d'ambiance de toutes les expériences ont été menés à bien. Le responsable de recherche chargé de la caméra EPIC s'est montré préoccupé par une fuite interne dans la caméra MOS-2. Une enquête et des activités de remise en état sont en cours pour s'assurer qu'il n'y aura pas d'incidence sur la date de lancement prévue pour XMM (voir ci-après).

Le programme des préparatifs de lancement et du lancement lui-même a été mis au point définitivement avec Arianespace en mai. La dernière série d'analyses détaillées est en cours pour confirmer les paramètres actuels de lancement et de l'orbite.

Le calendrier du projet reste le même, sauf en ce qui concerne la date de lancement qui a récemment été avancée, passant du 21 janvier 2000 au 15 décembre 1999. Cette modification a pu être possible grâce à l'augmentation des performances d'Ariane-5 et parce que l'aptitude au lancement du satellite a été démontrée en temps voulu.

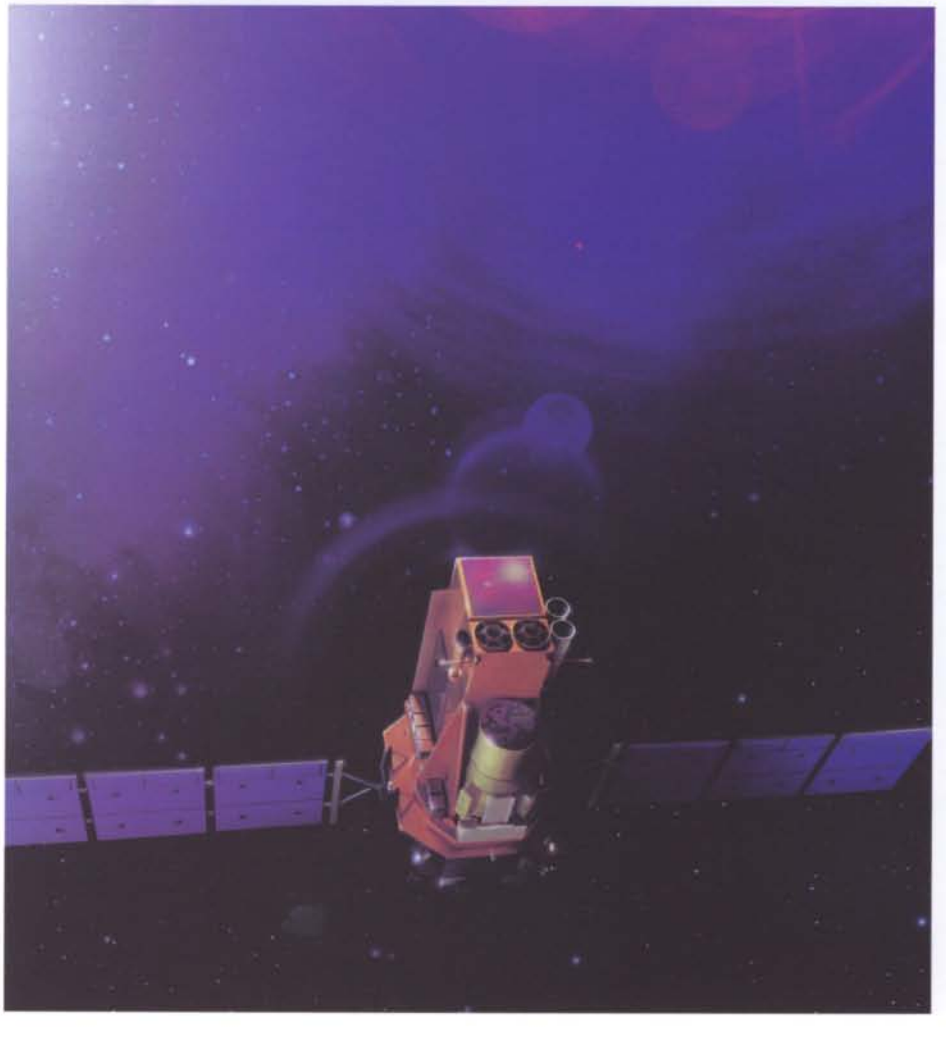
Intégral

Le programme du modèle d'identification (EM) du satellite a considérablement progressé au cours du dernier trimestre. Une première série d'essais avait été réalisée précédemment avec une partie des instruments, certains étant simulés. Toutes les équipes des responsables de recherche ont maintenant livré au maître d'œuvre, Alenia (I), un EM complet de chaque instrument. Fin juin, les essais fonctionnels système complets avaient été menés à bien. Les essais de compatibilité électromagnétique par conduction et par rayonnement sont prévus début août, ce qui mettra un terme à la campagne d'essais de l'EM.

Le programme du modèle de vol (FM) s'est poursuivi. La structure du module de servitude, sur laquelle le système de pilotage par réaction est intégré, a été livrée à Alenia et est prête pour l'installation des divers boîtiers électroniques. Le planning des FM des instruments a été revu en profondeur et la date de référence pour le lancement est maintenant fixée au 25 octobre 2001.

Le secteur sol progresse comme prévu. L'essai de validation système entre le satellite et le secteur sol a été revu afin de réduire au minimum les activités au niveau satellite à la fin du programme.

L'Arrangement relatif au lancement d'Integral par Proton n'est pas encore entré en vigueur dans sa totalité car la procédure d'approbation progresse lentement. Le contrat relatif aux adaptations à apporter à Intégral en vue du lancement par Proton a toutefois bien progressé. Toutes les questions



Artist's impression of the Integral spacecraft in orbit

Le satellite Intégral en orbite (vue conceptuelle) user training. The spacecraft simulator is being used to validate orbit-control procedures. The first deliveries of the science operations control system, including the necessary modifications to accommodate the latest changes to the experiments, have been made by Logica (UK) and are being tested by ESOC. The ground-station integration work is expected to be completed in time for the planned hand-over date in August. All elements are on schedule for the Ground-Segment Readiness Review, which will take place in October.

In the meantime, the first batch of observation proposals for the XMM mission has been received via the remote proposal-submission system. The system handled the significant volume of proposals received flawlessly, the sheer volume showing the strong interest in the mission. Evaluation of the proposals submitted is currently in progress.

All three flight mirrors are installed on the spacecraft and one of the major tasks during the test phase is to maintain the cleanliness of the mirrors, which directly affects their optical performance.

All experiments have successfully passed their environmental tests. A concern raised by the Principal Investigator for the EPIC camera is related to an internal leak in the MOS-2 camera. Investigations and recovery activities are under way to ensure that this has no impact on the planned XMM launch date (see below).

The plan for launch preparations and for the launch phase itself was finalised with Arianespace in May. The last round of detailed analyses is presently being performed to confirm the current launch and orbit parameters.

The project schedule is unchanged except for the launch date, which has recently been brought forward from 21 January 2000 to 15 December 1999. This change was made possible by the increased performance of the Ariane-5 vehicle and the timely readiness of the spacecraft for launch.

Integral

The satellite engineering-model (EM) programme progressed significantly during the last quarter. A first round of tests had been conducted in the previous period with partial or simulated instruments. In this phase, Alenia (I), the Prime Contractor, received from each Principal Investigator team a full EM instrument. By end of June, the complete system functional testing of the satellite had been successfully performed. Conducted and radiated electromagnetic-compatibility tests, planned up to early August, will complete the EM test campaign.

The flight-model (FM) programme continued. The Service Module structure with the reaction control system integrated was received at Alenia, ready for the installation of the various electronic boxes. A thorough review of FM instrument planning has been performed and a launch date of 25 October 2001 has now been baselined.

The ground segment has progressed according to plan. The system validation test between the spacecraft and the ground segment was revised to minimise the activities on the spacecraft at the end of the programme.

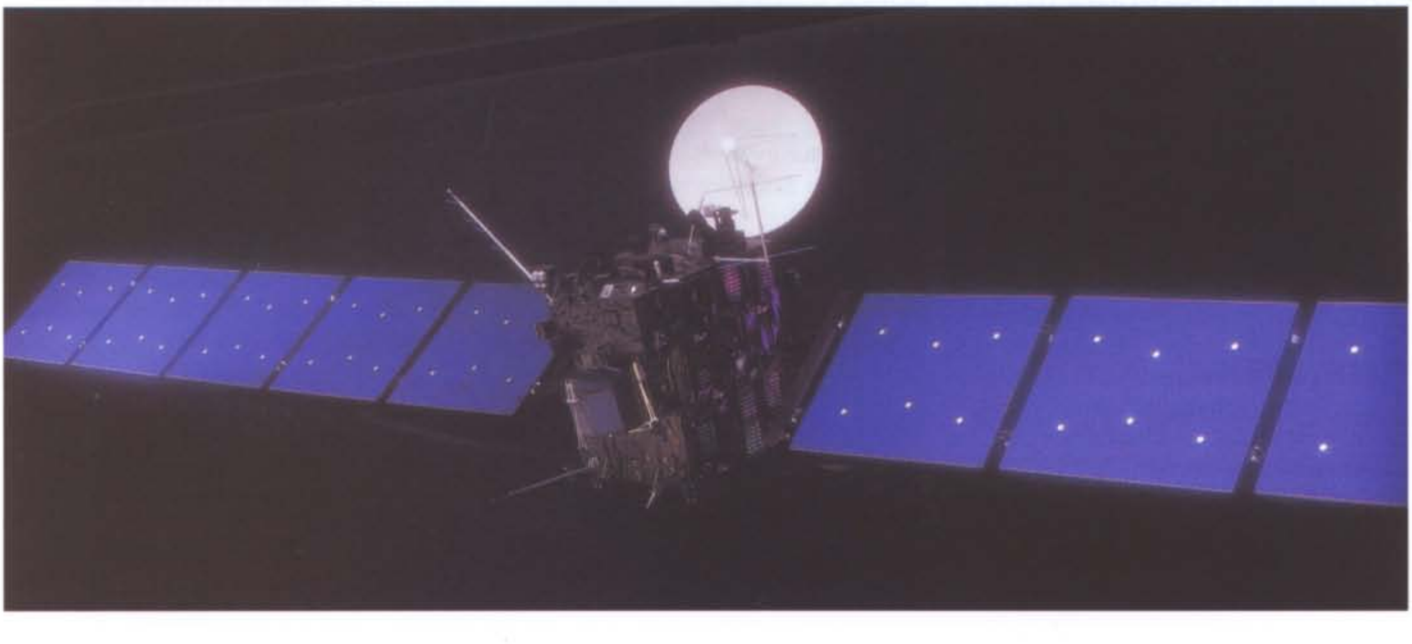
The overall Arrangement for the launch of Integral on a Proton vehicle has still not entered into force, as the approval cycle is progressing only slowly. As far as the contract for the Integral-specific adaptations to the Proton launcher is concerned, however, significant progress has been made. All open contractual and technical items have been closed out and the work can proceed just as soon as the Arrangement enters into force.

Rosetta

The consolidation of the spacecraft structural and thermal model (STM) programme has been the focus of activities in recent months. The spacecraft's main structure has been assembled and successfully passed the static load test in mid-June. Delivery of the structure is planned for early August, allowing for a formal start to be made with the STM programme at spacecraft level. The manufacturing of the instrument STM models is also complete, and delivery will take place in a staggered manner from mid-June to end-July.

Artist's impression of the Rosetta spacecraft

Vue conceptuelle du satellite Rosetta



contractuelles et techniques ont été réglées et les travaux pourront démarrer dès l'entrée en vigueur de l'Arrangement.

Rosetta

Les activités se sont concentrées ces derniers mois sur le programme de consolidation du modèle structurel et thermique (STM) de la sonde. La structure principale de la sonde a été assemblée et a subi avec succès les essais de charge statique à la mi-juin. La structure devrait être livrée début août, ce qui permettrait de lancer officiellement le programme du STM au niveau satellite. La fabrication des STM des instruments est également terminée et la livraison s'échelonnera de la mi-juin à fin juillet.

Le STM de l'atterrisseur de Rosetta a subi début mai des essais d'ambiance approfondis à l'IABG (D). En raison des très fortes sollicitations, il a fallu renforcer localement le dispositif d'atterrissage. L'atterrisseur a subi avec succès les essais acoustiques et l'essai thermique sous vide. Le premier essai de séparation s'est également bien passé. Le STM de l'atterrisseur devrait être livré à la mi-août.

Au niveau du satellite, les revues préliminaires de conception sont en cours au niveau équipements et devraient être terminées fin juillet. Il a été jugé approprié d'y associer l'équipe industrielle de Mars Express afin de veiller à la compatibilité conceptuelle des éléments communs entre Rosetta et Mars Express.

Les activités du groupe de travail chargé de l'analyse de la mission sont terminées et un 'modèle d'identification' portant sur les propriétés de la surface du noyau de la comète a été adopté. Ce modèle a été approuvé par les scientifiques associés à Rosetta et servira de référence pour la vérification de la conception de la sonde et de l'atterrisseur.

Artémis

La campagne d'essais d'ambiance du satellite Artémis s'est terminée à l'ESTEC (NL), la dernière étape, à savoir la mise en fonctionnement du satellite dans le vide et sur toute la gamme de température, s'étant bien déroulée. La dernière main est mise à la campagne d'essais et une série d'essais détaillés est réalisée pour s'assurer que les performances restent conformes aux spécifications après l'exécution des essais mécaniques et thermiques.

La construction des installations sol qui seront utilisées pour exploiter et tester Artémis après le lancement est bientôt terminée ; la revue de projet visant à évaluer l'aptitude des installations de Fucino (I) à l'exploitation d'Artémis est notamment en cours.

EOEP

Stratégie et programmes futurs
Le Conseil, réuni en mai au niveau des ministres, a décidé d'engager la première tranche du programme-enveloppe d'observation de la Terre (EOEP). Ce programme réunit des missions d'exploration de la Terre de circonstance et de base ainsi que diverses activités sous le titre 'Développement et Exploitation'. La composante Développement et Exploitation doit couvrir des activités telles que la poursuite de missions de satellites (au départ ERS), le prédéveloppement d'instruments afin d'éliminer les risques, des études de définition de missions de surveillance de la Terre ainsi que l'exploitation des données et le développement de marchés. Elle fournira également une partie du financement d'Earthnet.

La première tranche couvre les engagements des trois premières années. Bien que le programme souffre d'un déficit de financement d'environ 25%, il offre suffisamment de souplesse pour atteindre facilement les objectifs initiaux.

Missions futures
La première sélection des missions d'exploration de la Terre de circonstance est terminée. La première mission, CRYOSAT, fera l'objet d'une étude de phase A/B avant que la décision définitive de mise en œuvre ne soit prise. Pour la deuxième mission, SMOS, une phase A approfondie sera réalisée. La troisième, ACE, sera gardée en réserve, prête à démarrer en cas de problème avec les autres missions.

Les études de phase A des quatre missions d'exploration de la Terre candidates comme missions de base sont presque terminées. Deux missions seront retenues à la fin de l'année en vue de leur mise en œuvre au titre du programme-enveloppe.

Envisat/Plate-forme polaire

Système Envisat
Les activités système se concentrent actuellement sur deux domaines : veiller à ce que toutes les vérifications système soient terminées avant le lancement, y compris la vérification d'ensemble du secteur sol (GSOV), et mettre sur pied les équipes d'étalonnage et de validation qui apporteront leur soutien à l'ESA lors de la mise en service du satellite.

Activités liées au satellite
Les activités relatives au modèle d'identification du satellite se sont achevées à la mi-avril ; les objectifs de qualification électrique et fonctionnelle sont parfaitement atteints et l'aptitude de l'infrastructure AIT (assemblage, intégration, essais) pour le modèle de vol est démontrée.

L'intégration du modèle de vol (FM) du module de charge utile d'Envisat, instruments compris, a progressé. Tous les instruments ou ensembles d'instruments du FM ont été livrés ces derniers mois et ont pu être intégrés. Le FM complet du module de charge utile a été préparé pour subir les essais de bilan thermique et thermique sous vide (TB/TV). Le modèle réalisé est proche de la configuration de vol finale (l'instrument MERIS et les ensembles optiques SCIAMACHY et MIPAS ont été temporairement remplacés par des modèles qui ne sont pas aux normes de vol). Cette configuration a servi pour certains essais fonctionnels au niveau système (essais système intégrés).

Début juin, le FM du module de charge utile ainsi qu'un ensemble important d'équipements électriques et mécaniques de soutien au sol (EGSE et MGSE) ont été envoyés à l'ESTEC en vue des essais TB/TV dans le grand simulateur spatial (LSS). Le FM du module de servitude sera envoyé ensuite. Une grande partie de l'équipe MMS a été transférée de Bristol (GB) à l'ESTEC pour les activités AIT.

The STM model of the Rosetta Lander has been subjected in early May to extensive environmental tests at IABG (D). Due to excessively high loads, a local reinforcement of the landing gear had to be implemented. The Lander successfully passed the acoustic and the thermal-vacuum tests. The first separation test has also been successfully performed. Delivery of the Lander STM model is foreseen for mid-August.

On the spacecraft side, Preliminary Design Reviews are in progress at unit level and are expected to be completed by end-July. Participation by the Mars Express industrial team has been deemed appropriate to ensure a compatible design for the Rosetta/Mars Express common items.

The work of the Mission Analysis Working Group has been completed and an 'engineering' model for the surface properties of the comet nucleus has been agreed. This model has been endorsed by the Rosetta scientific community and will be used as a reference for the verification of the spacecraft and Lander design.

Artemis

The Artemis satellite has completed its environmental test campaign at ESTEC (NL), the final event of which was the successful operation of the satellite in vacuum and over the full temperature range. The test campaign is now being finalised with a detailed series of tests to ensure that performances have remained within specification after exposure to the mechanical and thermal test environments.

Construction of the ground facilities to be used to operate and test Artemis after launch is now nearing completion, and in particular the Project Review to assess the readiness of the facilities at Fucino (I) to operate Artemis is under way.

EOEP

Strategy and future programmes

The Council, meeting at Ministerial Level in May, agreed to proceed with the first slice of the Earth Observation Envelope Programme (EOEP). This Programme brings together the Earth Explorer Opportunity and Core missions and various activities under the heading of 'Development and Exploitation'. The development and exploitation element is designed to cover activities such as continuity of satellite missions (initially ERS), instrument pre-development for risk retirement, Earth Watch definition studies and data exploitation/market development. It will also provide partial funding for Earthnet.

The first slice covers commitments for the first three years. Although approximately 25% under-funded, the nature of the programme provides sufficient flexibility for the initial objectives to be largely achieved.

Future missions

The first round of selection for the Earth Explorer Opportunity Missions has been completed. The first mission, CRYOSAT, will be the subject of a Phase-A/B study before final implementation decision; the second, SMOS, will go into extended Phase-A; and the third, ACE, will be maintained in 'hot-standby' in case of problems with the first two.

The Phase-A studies of the four candidate Earth Explorer Core Missions are nearing completion. These will be narrowed down to two missions at the end of the year for implementation within the Envelope Programme.

Envisat/Polar Platform

Envisat system

The system activities are currently focussing on two areas: ensuring completeness of the system verifications before launch, including Ground Segment Overall Verification (GSOV), and setting up the calibration/validation teams that will support ESA in the in-orbit commissioning of the satellite.

Satellite activities

Mid-April marked the completion of the Satellite Engineering Model Programme, which completely fulfilled its electrical and functional qualification objectives, as well as proving the readiness of the AIT infrastructure for the flight model.

The integration of the Envisat Payload Module flight model (FM) with its instruments has progressed. All of the FM instruments or instrument assemblies were delivered in the recent months and have now been integrated successfully. The complete FM Payload Module has been readied for the forthcoming thermal-balance/thermal-vacuum (TB/TV) testing.

Arrival of the Envisat flight-model payload module at ESTEC (NL) for testing

Arrivée du module de charge utile d'Envisat à l'ESTEC pour les essais

Cette équipe restera à Noordwijk jusqu'à l'envoi du satellite à Kourou pour le lancement.

La revue de qualification du satellite Envisat (ESQR) s'est bien déroulée en mai/juin.

Charge utile d'Envisat

Les activités de vérification du modèle de vol de l'instrument optique MIPAS ayant bien progressé, la livraison est maintenant prévue fin août.

Les caméras du modèle de vol de MERIS, qui souffraient d'un problème d'étanchéité à la lumière, ont été réparées et seront bientôt réintégrées dans l'instrument pour la fin des essais de recette.

L'antenne ASAR a subi avec succès l'ensemble des essais d'ambiance. Il ne reste plus que deux étapes à franchir avant de livrer l'instrument, à savoir les essais de mise en forme du faisceau pour vérifier le diagramme de rayonnement de l'antenne et les essais intégrés de l'instrument ASAR.

L'ensemble optique SCIAMACHY n'a pas encore été livré en raison d'un problème de lumière parasite dans l'ultraviolet. Un programme de réparation a été mis au point et la livraison de l'instrument est reportée à début 2000.

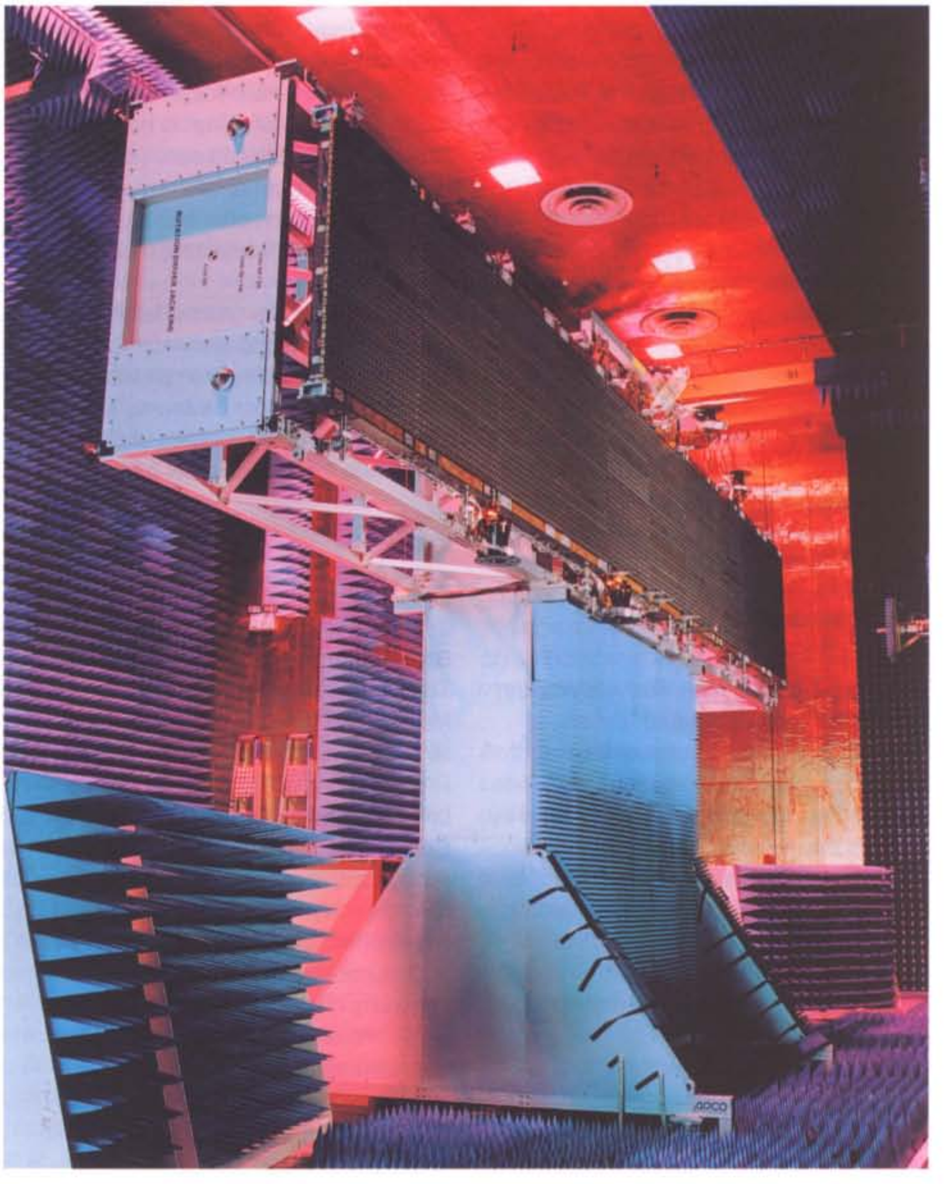
Secteur sol d'Envisat

La revue de mise en œuvre du secteur sol des opérations en vol (FOS) a été menée à bien. L'intégration des sous-systèmes FOS se poursuit au centre de contrôle (ESOC) et à la principale station de contrôle (Kiruna/Salmijärvi).

La version VI du système sol de gestion des données de charge utile (PDS) a été réceptionnée et l'installation de l'équipement PDS sur les deux sites de l'ESRIN et de Kiruna/Salmijärvi est presque terminée. La recette sur site de la version V2 du PDS est prévue en novembre 1999.

Météosat de seconde génération (MSG)

L'intégration et les essais du modèle d'identification du satellite ont repris début juin, après la livraison de l'instrument optique SEVIRI au site d'intégration. L'essai thermique sous vide réalisé au niveau instrument sur SEVIRI a confirmé le respect de tous les impératifs de fonctionnement de base.



The Envisat ASAR antenna flight model deployed for beam-forming testing
(photo Matra Marconi Space)

Déploiement du modèle de vol de l'antenne ASAR d'Envisat pour essai de mise en forme du faisceau

Le modèle de vol du satellite MSG-1 est prêt à recevoir l'instrument SEVIRI ainsi que les sous-systèmes de communication de la mission qui doivent être livrés en juillet.

Le lancement de MSG-1 reste fixé à octobre 2000. Le calendrier de MSG-2 et MSG-3 est respecté, la date de lancement de MSG-2 étant fixée à 2002 tandis que la date de stockage de MSG-3 a été avancée à 2003.

L'analyse des essais de résistance aux chocs induits par Ariane-5 a montré que MSG n'est pas qualifié pour cet environnement. On étudie maintenant si les chocs induits par Ariane-5 peuvent être réduits de façon à les porter au niveau des chocs induits à la séparation par Ariane-4 ou s'il convient de lancer au moins MSG-1 sur Ariane-4, lanceur pour lequel le satellite est qualifié.

Métop

L'approbation de l'ensemble du programme a été obtenue, les derniers États membres d'Eumetsat ayant levé leurs votes 'ad referendum', ce qui a permis l'entrée en vigueur du programme relatif au système polaire d'Eumetsat. L'ESA et Eumetsat mettent la dernière main aux détails de leur coopération en vue de la signature de l'Accord de

The build standard is close to the final flight configuration (the MERIS instrument and the SCIAMACHY and MIPAS optical assemblies have been temporarily replaced by non-flight-standard models). A number of system-level functional tests (Integrated System Tests) have been successfully performed in this configuration.

At the beginning of June, the FM Payload Module, accompanied by an impressive array of Electrical and Mechanical Ground-Support Equipment (EGSE and MGSE), was shipped to ESTEC for the forthcoming TB/TV test in the Large Space Simulator (LSS). Shipment of the FM Service Module will follow. A large part of the MMS team has been moved from Bristol (UK) to ESTEC to perform the AIT activities. This team will stay in Noordwijk until the spacecraft is shipped to Kourou for launch.

The Envisat Satellite Qualification Review (ESQR) was successfully performed in May/June.

Envisat payload

The verification activities on the MIPAS Instrument Optical (MIO) flight-model assembly have progressed well, leading to its delivery currently being planned for end-August.

The MERIS flight-model cameras, which were suffering from a light-tightness problem, have been repaired and will soon be re-integrated on the instrument for finalisation of the instrument acceptance testing.

The ASAR antenna has successfully completed environmental testing; the two remaining steps before instrument delivery are the beam-forming tests, to verify the antenna pattern, and the ASAR instrument integrated tests.

The SCIAMACHY Optical Assembly has not yet been delivered due to a stray-light problem in the ultraviolet. A repair programme has been defined, which will delay the instrument's delivery until the beginning of 2000.

Envisat ground segment

The Implementation Review for the Flight Operations Segment (FOS) has been successfully concluded. Integration of the FOS subsystems is in progress at the Control Centre, ESOC, and the primary control station, Kiruna/Salmijarvi.

The Payload Data Segment (PDS) Version-V1 has been accepted, and the installation of PDS equipment at the two sites of ESRIN and Kiruna/Salmijarvi is nearing completion. The on-site acceptance of PDS Version-V2 is planned for November 1999.

Meteosat Second Generation

The engineering-model (EM) satellite resumed integration and testing at the beginning of June, when the SEVIRI optical instrument was delivered to the integration site. SEVIRI instrument-level testing in thermal vacuum confirmed that all basic performance requirements have been met.

The MSG-1 flight-model (FM) satellite is still waiting for the SEVIRI instrument and the mission communication subsystems to be delivered in July.

The predicted launch of the MSG-1 spacecraft remains on schedule for October 2000. MSG-2 and MSG-3 also remain on schedule, with a predicted launch date of 2002 and an anticipated storage date in 2003, respectively.

The evaluation of Ariane-5-specific shock test results has shown that MSG is not qualified for that environment. It is now being investigated whether the Ariane-5 shock environment can be improved to be equivalent to the Ariane-4 separation-shock environment, or whether MSG-1, at least, has to be launched on an Ariane-4, for which it is qualified.

Metop

The approval of the overall programme has now been completed, with the remaining Eumetsat Member States lifting their 'ad-referendum' votes and allowing the full entry into force of the Eumetsat Polar System Programme. ESA and Eumetsat are currently finalising the details of their cooperation to permit the signature of the Cooperation Agreement itself, the last legal act associated with the EPS/Metop Programme.

As far as industrial activities are concerned, the period from March to June has been characterised by a series of Preliminary Design Reviews (PDRs) at module and instrument level, culminating in the System PDR in May and June. This has entailed a major effort from both industry and the customer and has been successfully completed, with a number of recommendations having been formulated by the Review Boards.

Several major reviews have already been completed: the Service Module Hardware Design Review, the ASCAT and Payload Module PDR, the GOME PDR and finally the Satellite/System PDR. During the course of these reviews, many hundreds of items have been raised by the review teams and these have all been resolved, either directly or by establishing action plans.

Manufacture of the first flight-hardware elements has started with the structural model of the Payload Module, which will later be refurbished for use as the flight structure for Metop-2. This is being manufactured at the same time as the engineering-model (EM) structure. In parallel, many of the engineering-model avionics units are nearing completion, ready to begin testing prior to delivery, which is expected in the autumn. Delivery of the first instruments from the United States will also take place in the autumn, for use on the EM Payload Module.

International Space Station

European Participation in the ISS Exploitation Programme

At the Ministerial Council in Brussels on 11 and 12 May the Participating States endorsed the European participation in the ISS Exploitation Programme. They approved the Initial Phase (year 2000 to year 2004), allocating funding for 'Early Activities' to be committed in years 2000 and 2001, and provisional funding for 'Second Step' activities to be committed in the years 2002 to 2004. By mid-2001 they will examine the contribution scheme for the financing of the variable costs of the ISS exploitation and decide on the second step of the initial phase.

The Participating States also agreed in Brussels to carry out an Additional Programme Slice for the co-operation with NASA on the ISS Crew Return Vehicle.

coopération lui-même, dernier acte juridique à accomplir dans le cadre du programme EPS/METOP.

Sur le plan des activités industrielles, la période allant de mars à juin a été marquée par une série de revues préliminaires de conception (PDR) au niveau modules et instruments, aboutissant à la PDR au niveau système en mai et juin. L'industrie et le client ont fourni un travail considérable, couronné de succès, et les commissions de revue ont formulé un certain nombre de recommandations.

Plusieurs revues importantes sont terminées : revue de conception du matériel du module de service, PDR d'ASCAT et du module de charge utile, PDR de GOME et enfin PDR du satellite au niveau système. Plusieurs centaines de points ont été soulevés par les équipes de revue et tous ont été résolus, soit directement, soit par la mise en place de plans d'action.

La fabrication des premiers matériels de vol a démarré, notamment celle du modèle structurel du module de charge utile, qui sera remis en état ultérieurement afin de servir de structure de vol pour METOP-2. La structure du modèle d'identification est fabriquée parallèlement. De nombreuses unités d'avionique du modèle d'identification seront bientôt terminées et prêtes pour les essais précédant la livraison, qui devraient avoir lieu à l'automne. Les premiers instruments provenant des États-Unis seront également livrés cet automne en vue de leur utilisation dans le modèle d'identification du module de charge utile.

The MPLM under construction at Alenia Spazio, Turin (I)

Le MPLM en construction chez Alenia Spazio à Turin (I)

Station spatiale internationale

Participation de l'Europe au programme d'exploitation de l'ISS

A la session du Conseil tenue au niveau ministériel les 11 et 12 mai, les États participants ont entériné la participation de l'Europe au programme d'exploitation de l'ISS. Ils ont approuvé la phase initiale (2000-2004), allouant des crédits aux 'activités préliminaires' à engager en 2000 et 2001 ainsi qu'un financement provisoire pour les activités de la 'deuxième étape', à engager en 2002-2004. Ils examineront d'ici la mi-2001 le système de contribution aux coûts variables d'exploitation de l'ISS et prendront une décision sur la deuxième étape de la phase initiale.

Les États participants sont également convenus à Bruxelles de réaliser une tranche additionnelle du programme, portant sur la coopération avec la NASA au développement du véhicule de retour de l'équipage (CRV) de l'ISS.

Séquence d'assemblage de l'ISS

La Commission de contrôle de la Station spatiale (SSCB), réunie au JSC de la NASA le 9 juin, a approuvé la révision E de la séquence d'assemblage. Cette révision prévoit le lancement du module de service en novembre 1999 et couvre tous les vols d'assemblage jusqu'au lancement du dernier élément (module d'habitation américain), en novembre 2004. Il s'agit de la première mise à jour officielle de la séquence d'assemblage depuis la révision D, établie comme base de référence en mai 1998 par la SSCB.

Laboratoire Columbus

L'assemblage du modèle d'essais électriques (ETM) est terminé, les équipements électriques de soutien sol (EGSE) y ont été reliés et la phase d'essais système a débuté. La séquence d'essais de l'ETM a été modifiée et la revue critique de conception (CDR) au niveau système est maintenant prévue l'été prochain.

Les problèmes survenus avec la masse du laboratoire sont totalement résolus et les modifications correspondantes de la

ISS Overall Assembly Sequence

The Space Station Control Board (SSCB) met at NASA/JSC on 9 June and approved Revision E of the ISS Assembly Sequence. This revision assumes a Service Module launch in November 1999 and covers all assembly flights through the Last Element Launch (US Hab Module) in November 2004. Revision E is the first formal updating of the overall Assembly Sequence since Revision D was baselined by the SSCB in May 1998.

Columbus laboratory

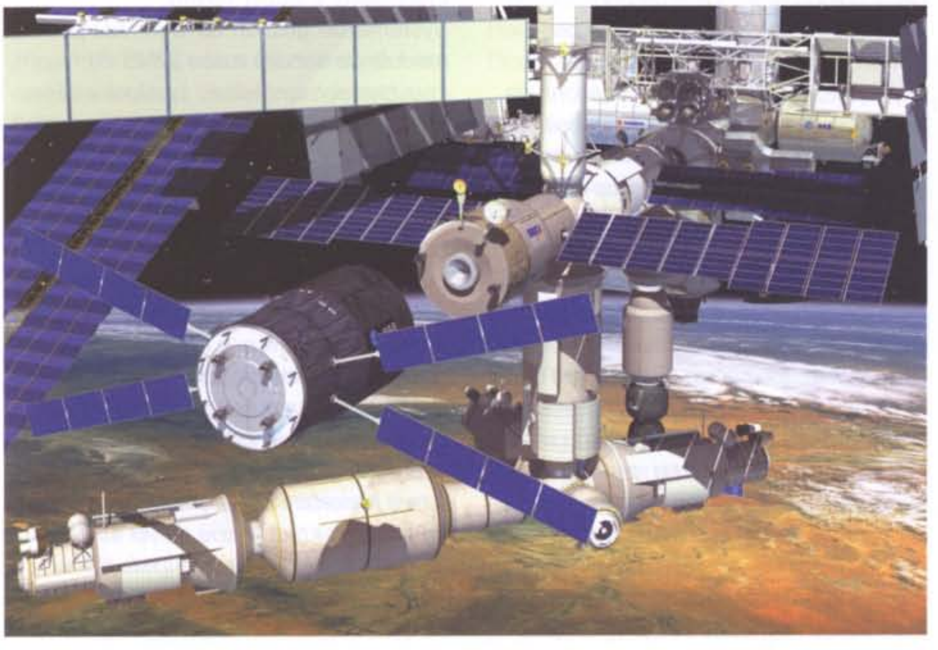
The Electrical Test Model (ETM) assembly has been completed, the Electrical Ground Support Equipment (EGSE) has been connected to it, and the system test phase has been initiated. Changes have been made to the ETM test sequencing and the system Critical Design Review (CDR) will now take place next summer.

Earlier problems with the laboratory mass properties have now been completely resolved and the associated design changes incorporated. The eventual delivery date to the launch site has slipped a few weeks. The launch is scheduled for early 2004.

Columbus launch barter

Nodes-2 and -3

Node-2 development is progressing nominally. Node-3, however, is still in a state of flux, with further changes to the baseline requirements being made by NASA.



The ATV approaching the ISS (D. Ducros)

L'ATV à l'approche de la Station spatiale internationale

Software Deliveries/ DMS-R items / Associated Sustaining Engineering for NASA

These barter activities are virtually complete.

Crew Refrigerator/Freezer Racks

The Phase-B0 study/breadboarding has been started, but the new NASA inputs, in particular the requirements for a small refrigerator/freezer for the early operational phase of the ISS, have not yet been received.

Cryogenic Freezer Racks

Due to the large number of technical changes that have been introduced, a new feasibility phase must be performed which will result in a slippage in the delivery of the first flight unit.

Cupola

All subcontracts have been finalised and signed. However, the possibility that the second Cupola will not be required is under investigation and discussions with NASA will need to be held in the near future to determine how to proceed.

Automated Transfer Vehicle (ATV)

The concept of ATV safety with respect to the Space Station, including implementation of a closed-loop Collision Avoidance Manoeuvre (CAM) and a dedicated Safety Unit, has been agreed in principle with the NASA Safety Panel.

An initial small contract, allowing proper follow-up of the Ariane-5 to ATV adaptation activities, has been awarded in anticipation of the 'Launch Service Agreement', which has still to be negotiated.

X-38/CRV and Applied Re-entry Technology (ART)

A number of design reviews have taken place successfully during the reporting period for specific ESA elements of the X-38 V-201 spacecraft. The second drop test with vehicle 132 is scheduled for 8th July 1999.

Atmospheric Re-entry Demonstrator (ARD)

The ARD capsule has been exhibited to the public several times, in particular during the Le Bourget Airshow, and has triggered wide interest. The ARD flight-data exploitation contract is expected to be signed in September.

Ground-segment development and operations preparation

During April, agreement was reached with ASI on the outstanding issues related to the distribution and location of Operations Support functions and the roles and responsibilities of ASI/ALTEC and Italian industry were summarised in a protocol which was signed by both parties.

Procurement Proposals for the implementation of Columbus and ATV Control Centres were approved in May and the preparation of the corresponding Requests for Quotation is being adapted to the revised Columbus launch date and the expected availability of the ATV vehicle.

Utilisation

Promotion

Two major Announcements of Opportunity have been issued in Life Sciences and Physical Sciences including Microgravity Applications. More than 200 proposals were received and industry is associated with about 60 of them. External peers have evaluated them and recommendations have been reported. Following the peer evaluation, a detailed assessment of resource requirements (facilities, astronaut time, etc.) and funding will be performed. The results of this analysis and the financial requirements, including support to the research teams, will form the basis for discussions with delegates and representatives of national agencies for the programmatic implementation and eventually for concerted support to the high-priority proposals and Microgravity Application Promotion (MAP) programmes.

Preparation

The detailed accommodation work for the Early Utilisation external payload *conception ont été intégrées. La date envisageable pour la livraison au site de lancement a été repoussée de quelques semaines. Le lancement est prévu début 2004.*

Compensation du lancement de Columbus

Éléments de jonction 2 et 3

La réalisation de l'élément de jonction 2 progresse normalement. En revanche, l'élément de jonction 3 n'est pas définitif puisque la NASA continue à modifier les impératifs de référence.

Livraisons de logiciels et d'éléments du DMS-R - Soutien technique associé fourni à la NASA

Ces activités menées dans le cadre de l'accord de compensation sont pratiquement terminées.

Bâtis réfrigérateurs/congélateurs de l'équipage

La phase B0 d'étude et de montage table a débuté mais les nouvelles données de la NASA, notamment les impératifs relatifs à un petit réfrigérateur/congélateur pour le début de la phase opérationnelle de l'ISS, n'ont pas encore été reçues.

Bâtis congélateurs cryogéniques

Un grand nombre de modifications techniques ayant été apportées, une nouvelle phase d'évaluation de la faisabilité doit être menée, ce qui décalera la livraison du premier modèle de vol.

Coupoles

Tous les contrats de sous-traitance ont été établis et signés. Toutefois, la deuxième coupole ne sera peut-être pas nécessaire ; cette question est à l'étude et des discussions avec la NASA seront tenues rapidement afin de déterminer la marche à suivre.

Véhicule de transfert automatique (ATV)

La conception de l'ATV sur le plan de la sécurité pour la Station spatiale, y compris la mise en place d'une manœuvre d'évitement des collisions (CAM) en circuit fermé et d'une Unité Sécurité spécialisée, a été convenue dans son principe avec le Comité Sécurité de la NASA.

Un petit contrat initial permettant un suivi adéquat des activités d'adaptation d'Ariane-5 à l'ATV a été attribué dans l'attente de la conclusion de 'l'Accord sur les services de lancement' qui reste à négocier.

X-38/CRV et application des technologies de rentrée (ART)

Les revues de conception de certains éléments du X-38/V201 réalisés par l'ESA ont été menées à bien pendant la période de référence. Un nouvel essai de largage est prévu le 8 juillet 1999 avec le V-132.

Démonstrateur de rentrée atmosphérique (ARD)

La capsule ARD a été plusieurs fois présentée au public, notamment au Salon du Bourget, suscitant un vif intérêt. Le contrat d'exploitation des données de vol de l'ARD devrait être signé en septembre.

Réalisation du secteur sol et préparation de l'exploitation

Un accord a été obtenu en avril avec l'ASI sur les questions en suspens relatives à la répartition des activités et aux lieux d'installation des fonctions de soutien des opérations ; les rôles et responsabilités de l'ASI/ALTEC et de l'industrie italienne sont résumés dans un protocole signé par les deux parties.

Les propositions d'approvisionnement relatives à la mise en place des centres de contrôle de Columbus et de l'ATV ont été approuvées en mai et la préparation des demandes de prix correspondantes est adaptée pour tenir compte de la révision de la date de lancement de Columbus et de la date de disponibilité prévue de l'ATV.

Utilisation

Promotion

Deux grands avis d'offre de participation ont été diffusés dans le domaine des sciences de la vie et des sciences physiques, y compris les applications de la microgravité. Plus de 200 propositions ont été reçues, dont 60 élaborées en association avec l'industrie. Des experts externes les ont évaluées et leurs recommandations ont été transmises. A la suite de cette évaluation, une analyse détaillée des besoins en ressources (installations, temps de travail des astronautes, etc.) et du financement sera réalisée. Les résultats de cette analyse et les besoins financiers, y compris le soutien des équipes de recherche, serviront de support aux discussions avec les délégations et les représentants des agences nationales relatives à la mise en œuvre programmatique et éventuellement à un soutien concerté des propositions hautement prioritaires et des programmes de promotion des applications de la microgravité (MAP).

Préparation

Les travaux détaillés d'installation des charges utiles externes qui seront exploitées dans le cadre de l'utilisation initiale, à savoir les cinq lots d'adaptateurs dénommés ACES, EXPORT, SOLAR, ETEF et FOCUS, se sont poursuivis. La Commission européenne de l'utilisation a demandé à l'ESA de désigner les trois premiers lots qui pourraient voler en février et mai 2003.

Réalisation des matériels

Les activités de phase C/D relatives aux quatre adaptateurs de palettes Express (ACES, ETEF, EXPORT et SOLAR) devraient démarrer après les vacances d'été ; la phase de développement des équipements complémentaires des charges utiles standard (SPOE) s'achève, les équipements matériels et logiciels ayant été livrés.

Activités des astronautes

Thomas Reiter a rejoint le Centre des Astronautes européens (EAC) où il a entamé un cours de remise à niveau tandis que Pedro Duque est temporairement détaché à l'ESTEC pour aider l'équipe de développement. Des recrutements dans les domaines médical et biomédical ont eu lieu pour renforcer l'infrastructure médicale de l'EAC et un médecin d'équipage de l'EAC a été homologué pour la première fois médecin d'équipage à bord de l'ISS.

Livraisons à court terme

Système de gestion de données pour le module de service russe (DMS-R)

Lors des derniers essais système réalisés chez RKK-Energia, on a constaté que le système d'alimentation du module de service génère des pics de perturbation à l'entrée des lignes d'alimentation du DMS-R lorsque certains sous-systèmes du module de service sont actifs, ce qui déclenche le mode veille du DMS-R. Une enquête a montré que le système d'alimentation du module de service n'est pas conforme aux spécifications figurant dans le document de contrôle des interfaces (ICD) approuvé. Pour éviter tout retard important du calendrier du module de service et tout risque en vol au niveau du DMS-R, l'ESA a convenu de placer des filtres du côté DMS-R de l'interface, ce qui a été fait.

complement – consisting of five Adapter groupings ACES, EXPORT, SOLAR, ETEF and FOCUS – has continued. The European Utilisation Board had requested that ESA nominate the first three groupings that should fly in February and May 2003.

Hardware development
The Phase-C/D activities for the four Express Pallet Adapters (ACES, ETEF, EXPORT and SOLAR) should start after the summer holiday period, and the development phase for the Standard Payload Outfitting Equipment (SPOE) is drawing to a close with deliveries of hardware and software now being made.

Astronaut activities
T. Reiter has rejoined the European Astronaut Centre (EAC) and started a refresher-training course and P. Duque has been temporarily detached to ESTEC to support the development team. The medical infrastructure at EAC has been reinforced by recruitment in the medical and biomedical areas and a first EAC flight surgeon has been certified as an ISS Flight Surgeon.

Early deliveries
Data Management System for the Russian Service Module (DMS-R)
During final system testing at RSC-Energia, it was found that the Service Module power system generates large spikes on the DMS-R input power lines when certain Service Module subsystems are activated, causing DMS-R to switch into a standby mode. Investigations confirmed that the Service Module power system does not meet the approved ICD specification. In order to avoid severe impacts on the Service Module schedule and to safeguard DMS-R from potential in-flight problems, ESA agreed to incorporate filters on the DMS-R side of the interface and this has now been done.

MPLM ECLSS Environmental Control and Life Support Subsystem
Technical close-out is in progress.

ERA European Robotic Arm
The ERA Critical Design Review (CDR) was held during June. It produced acceptable results, but some additional work must be done to demonstrate the robustness of the ERA control system. Closure of the CDR is now expected in October. Flight hardware is in the process of delivery and ERA's launch on the Russian Science Power Platform is now scheduled for November 2001.

Laboratory Support Equipment
The cooling performance issue for the -80°C Freezer (MELFI), raised by NASA, has been resolved, thereby allowing the formal closure of the MELFI CDR to be planned for July 1999. Delivery of the first MELFI flight unit is delayed until the end of 2000, but this is compatible with the current launch date. The ground unit of the Material Science Glovebox (MSG) is undergoing final checks prior to its delivery to NASA. The Hexapod Preliminary Design Review (PDR) was successfully completed in May.

Microgravity

At the Ministerial Council in May, an extension of the EMIR-2 Programme was approved. However, only approximately 50% of the requested budget was approved, making adaptation of the proposed programme elements necessary. A revised proposal should be available for approval by the relevant Programme Board in November.

EMIR-1 and EMIR-2
A re-flight in December 1999 of MOMO (Morphological Transition and Model Substances) was recently agreed and the APCF (Advanced Protein Crystallisation Facility), Biobox, and FAST (Facility for Adsorption and Surface Tension) facilities are currently being refurbished for their next flight, together with ARMS (Advanced Respiratory Monitoring System) and Biopack, in January 2001.

The second APCF unit will be the first ESA microgravity payload that will fly on the ISS, being due to be uploaded in November 2000.

The ESA Microgravity Programme is contributing three facilities to NASA's Human Research Facility on board the ISS. The Handgrip Dynamometer/Pinch force Dynamometer System (HGD/PFD) is being prepared for hand-over to NASA this summer, the Muscle Atrophy Research and Exercise System (MARES) has just passed its Preliminary Design Review (PDR) and the PDR for the Percutaneous Electrical Muscle Stimulator (PEMS) started in June.

The retrievable Russian Capsule Foton-12 is scheduled for launch in September carrying the ESA facilities FluidPac, Biopan and four autonomous experiments including Stone.

The development phase for the Protein Crystallisation Diagnostics Facility (PCDF) started in June.

The PDR of the Modular Cultivation System (MCS) is scheduled for August.

The 26th ESA Parabolic Flight Campaign, which was the third ESA campaign using the Airbus A300, took place at the beginning of June, performing experiments with an emphasis on Life Sciences. A Parabolic Flight Symposium was organised at the Paris Air Show.

The sounding rocket Maser 8 flew successfully in May and two Texus flights, 37 and 38, are scheduled for launch in November.

Microgravity Facilities for Columbus (MFC)
The engineering model for Biolab is under manufacture, and the system Critical Design Review (CDR) is expected to take place in early-2000. The Invitation to Tender (ITT) for Phase-B/C/D of the Experiment Preparation Unit (EPU) was released in June.

The system Preliminary Design Review (PDR) for the Fluid Science Laboratory (FSL) was successfully completed in April. The assessment of the introduction of the Microgravity Vibration Isolation System (MVIS) developed by the Canadian Space Agency (CSA) is planned to be completed by September. A parabolic-flight campaign using MVIS in an FSL configuration was successfully conducted by CSA in June to support the ongoing assessment.

The system PDR for the Materials Science Laboratory (MSL) in the US Lab was successfully completed in June.

The Phase-B/C/D contract for the European Physiology Modules (EPM) was awarded in May. Discussions with NASA concerning the EPM's co-location with the Human Research Facility (HRF), as well as the harmonisation of the respective science equipment items, have been hampered.

Sous-système de régulation d'ambiance et de soutien-vie (ECLSS) du MPLM
Les activités techniques s'achèvent.

Bras télémanipulateur européen (ERA)
La revue critique de conception (CDR) de l'ERA a eu lieu en juin. Ses résultats sont acceptables mais des travaux supplémentaires sont nécessaires pour démontrer la solidité du système de commande de l'ERA. La clôture de la CDR devrait maintenant se faire en octobre. Le matériel de vol est en cours de livraison et le lancement de l'ERA installé sur la plate-forme russe science et énergie est actuellement prévu en novembre 2001.

Équipement de soutien de laboratoire
La question soulevée par la NASA au sujet du niveau de refroidissement du congélateur de laboratoire à -80°C pour l'ISS (MELFI) ayant été résolue, la clôture officielle de la CDR du MELFI devait avoir lieu en juillet 1999. La livraison du premier modèle de vol du MELFI est reportée à fin 2000 mais reste compatible avec la date de lancement actuelle. Les dernières vérifications de la version sol de la boîte à gants pour la recherche en microgravité (MSG) sont en cours avant sa livraison à la NASA. La revue préliminaire de conception (PDR) de l'hexapode a été menée à bien en mai.

Microgravité

Une extension du programme EMIR-2 a été approuvée à la session du Conseil tenue au niveau ministériel en mai. Toutefois, seul 50% du budget requis ayant été approuvé, il a fallu adapter les éléments de programme proposés. Une proposition révisée devrait être prête pour approbation par le Conseil directeur du programme en novembre.

EMIR-1 et EMIR-2
Il a récemment été convenu du réemport de MOMO (Études de transition morphologique sur des substances modèles) en décembre 1999 ; l'APCF (installation de cristallisation des protéines de pointe), le Biobox et FAST (installation d'études de l'adsorption et de la tension de surface) sont en cours de remise en état en vue de leur prochain vol en janvier 2001, avec ARMS (système de surveillance respiratoire de pointe) et le Biopack.

La deuxième APCF, qui sera la première charge utile de recherche en microgravité de l'ESA à bord de l'ISS, doit être lancée en novembre 2000.

Le programme de recherche en microgravité de l'ESA fournit trois équipements destinés à l'installation de recherche sur l'Homme de la NASA à bord de l'ISS : le dynamomètre à poignée et à pince (HGD/PFD), qui est préparé en vue de son transfert à la NASA cet été ; le système d'exercice et de recherche en atrophie musculaire (MARES), dont la revue préliminaire de conception (PDR) vient de s'achever ; le stimulateur musculaire électrique percutané (PEMS), dont la PDR a commencé en juin.

La capsule récupérable russe Foton-12 doit être lancée en septembre, avec à son bord le Fluidpac et le Biopan de l'ESA ainsi que quatre expériences autonomes parmi lesquelles Stone.

La phase de développement de l'installation de diagnostic pour la cristallisation des protéines (PCDF) a débuté en juin.

La PDR du système de culture modulaire (MCS) est prévue en août.

La 26ème campagne de vols paraboliques de l'ESA, la troisième de l'ESA à utiliser l'Airbus A-300, a eu lieu début juin. Les expériences portaient plus particulièrement sur les sciences de la vie. Un symposium sur les vols paraboliques a été organisé au Salon du Bourget.

La fusée-sonde Maser-8 a été lancée avec succès en mai et deux vols de Texus, les vols 37 et 38, sont prévus pour novembre.

Installations de recherche en microgravité pour Columbus (MFC)
Le modèle d'identification du Biolab est en cours de fabrication et la revue critique de conception (CDR) au niveau système devrait avoir lieu début 2000. L'appel d'offres relatif à la phase B/C/D de l'unité de préparation des expériences (EPU) a été diffusé en juin.

La revue préliminaire de conception (PDR) au niveau système du laboratoire de science des fluides (FSL) a été menée à bien en avril. Il est prévu de finir d'ici septembre l'évaluation de l'impact du système d'isolation contre les vibrations en microgravité (MVIS) conçu par l'Agence spatiale canadienne (ASC). En soutien de l'évaluation en cours, l'ASC a réalisé en juin avec succès une campagne de vols paraboliques au cours de laquelle le MVIS a été utilisé avec le FSL.

La PDR système du laboratoire de sciences des matériaux (MSL) destiné au laboratoire américain s'est achevée avec succès en juin.

Le contrat de phase B/C/D relatif aux modules de physiologie européens (EPM) a été attribué en mai. Les discussions avec la NASA sur la co-implantation de l'EPM et de l'installation de recherche sur l'Homme (HRF) et sur l'harmonisation des équipements scientifiques respectifs n'ont pas progressé comme prévu.

esa

In Brief

Erasmus User Centre Inaugurated at ESTEC

An important part of Europe's contribution to the International Space Station (ISS) was inaugurated at the Agency's ESTEC site on 28 June. The Erasmus User Centre (EUC) was officially opened by Mrs Monique de Vries, the Dutch State-Secretary of Transport, Public Works and Water Management, supported by ESA's Director General Mr Antonio Rodotà, Director of Technical and Operational Support Mr David Dale, and Director of Manned Spaceflight and Microgravity Mr Jörg Feustel-Büechl.

EUC is primarily a resource centre for those interested in conducting research aboard the International Space Station's European elements. Scientists, engineers and businesses can learn about the orbital facilities and how to access them, and discuss with ESA experts the procedure for developing experiments. First-time and potential users from the non-space sector – as well as those from the 'traditional' space-research community – can familiarise themselves with Space Station hardware, in particular with the full-size, functional model of ESA's Columbus laboratory. Interactive 3D virtual-reality simulations enable them to explore the entire Station, inside and out. A comprehensive electronic library provides information on completed and planned experiments, and gives access to a Space Station database.

Mr Rodotà commented that Mrs de Vries was responsible in her ministerial capacity for roads and waterway, adding that, *"We in ESA are also opening new roads. We open them to increase our scientific knowledge, to improve the capabilities and quality of our products, and to create new business opportunities for our economy.*

The Netherlands occupy a prominent place in the European space ventures. This is the place where the ESA management team is based which is responsible for the development of the European elements of the International Space Station and for the utilisation of the Station by Europe. Therefore, we thought that Noordwijk would be an excellent place to install the Erasmus User Centre [to] bring the utilisation potential of the Station closer to its users and ... explain to the public at large the utilisation and, last, but not least, the utility of the International Space Station."

State-Secretary de Vries noted that, *"With the Space Station we are building a unique research centre for important tests that we cannot conduct on Earth. Such a beautiful research facility should be put to good use. This is why I am happy to open*

Mr Antonio Rodotà: "... the Erasmus User Centre ... will bring the utilisation potential of the Station closer to its users."

State-Secretary Monique de Vries: "Of course, I truly hope that scientists from all over Europe will find their way to this Centre."

this user information centre today. Scientists who want to conduct experiments in the Space Station can obtain all the information they need right here. What's more, they can prepare their experiments here.

Just as with the premiere of the latest Star Wars film, all available [Space Station] room has already been booked for the first period. Yet I should like to appeal to all companies, laboratories and scientific institutes to determine how they can best use these facilities. Excellent projects can always find the capacity they need.

... perhaps you've seen the film Apollo 13 ... so you probably also remember the famous call, 'Houston, we have a problem.' I am positive that we will hear totally different signals here in the years to come. How about, 'Noordwijk, we've got some great result'"

The Dutch Government contributed significantly to the cost of creating the Erasmus User Centre, supported by the Gemeente (Council) of Noordwijk.

The International Space Station is now becoming a reality – two modules are already in orbit, a third is set to join them in November and the first astronauts are scheduled to go aboard in March 2000. The first experiments will begin in the second half of 2000 and exploitation will continue throughout the life of the Space Station, until at least 2013. It is expected that several hundred experiments per year will be carried out in Europe's Columbus laboratory alone.

Mr Jörg Feustel-Büechl: "Let me thank again all those who have contributed to making this Centre a reality."

Mr Feustel-Büechl outlined the centre's four main purposes. Firstly, the team of engineers and documentalists will show potential users what the Space Station offers. There is direct contact with the managers responsible for facility development and utilisation. Not only that, he said, *"It will be equally important to attract new users who today are not yet well aware of the Station and who do not know where to ask for information and advice."*

Secondly, the EUC will provide access through its multimedia library to recorded Station data and to related experiment information within ESA's own databases and those of our international partners.

Thirdly, the centre will be used to operate experiment facilities such as the European Drawer Rack in the Columbus laboratory. This makes the EUC, in Space Station terminology, a Facility Responsible Centre (FRC).

Fourthly, it will enable the public and media to share in the Space Station as it becomes the communications hub between the European public and the working astronauts. It offers narrowcasting techniques (visioconferencing and Internet visiophone) and a television and multimedia studio (satellite transmission of video images and Internet streaming).

Broadcasters will be able to conduct interviews with ESA specialists from the television studio or broadcast live via satellite. In addition, ESA will offer broadcasters a daily menu of satellite news items, including interviews down-the-line and archive material of relevance to the day. Ariane launches from Kourou and launches of Space Station hardware from Cape Canaveral and Baikonur and inflight events with crews will be broadcast live via the centre.

Mrs Monique de Vries (centre) with, from left, Mr Jean-Claude Degavre (EUC project manager), Mr Jörg Feustel-Büechl, Mr H. Tankink (Dutch Ministry of Economic Affairs), Mr David Dale, Mr T.B. Sweers (Deputy Mayor of Noordwijk), Mr Antonio Rodotà and Ms Pola Wickham, who painted the fresco in this pre-show area.

Mrs de Vries cuts the ribbon to begin the unveiling of the full-scale Columbus training model.

Mrs de Vries discusses the finer points of Space Station design with Lieke Jitte and Joost de Bont, who took part in the EUC inauguration as winners of a space-drawing competition in a Dutch Primary School.

Introducing three of ESA's astronauts following the Columbus unveiling. From left: Ulf Merbold, André Kuipers and Pedro Duque.

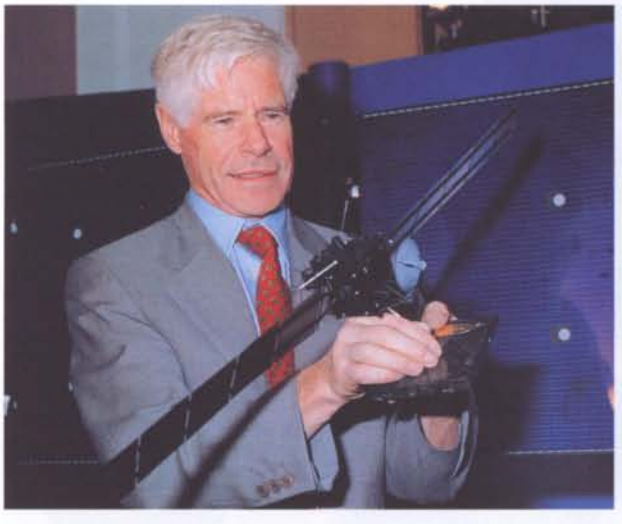
Mr. C. Heemskerk (right) of Fokker Space describes the man-machine interface for the European Robotic Arm to Mrs de Vries and Mr Feustel-Büechl.

Rosetta – ESA's New Comet Chaser Unveiled

In 1986, the European Space Agency's Giotto spacecraft made history by providing mankind's first close-up views of a comet nucleus. Now, 13 years after this remarkable encounter with Halley's Comet, ESA is preparing its Rosetta spacecraft for an even more ambitious robotic space mission to Comet Wirtanen. At a press event held on Thursday 1 July at the Royal Society in London, ESA's Director of Science, Dr. Roger Bonnet, presented this next mission in ESA's ambitious comet exploration programme and unveiled a quarter-sized model of the Rosetta Orbiter and Lander. The full-size spacecraft is 32 m across, almost 90% of this span being accounted for by the giant solar panels needed to power the spacecraft in the darkest depths of the Solar System. The Orbiter will 'chase' Comet Wirtanen for two years and millions of kilometres through space, sending back valuable data and ensuring that Europe retains its lead in cometary science. The Lander will attach itself to the comet's surface and will analyse samples of this lump of frozen ice and dust as it travels through space at over 130 000 km per hour.

Comets – among the oldest and least altered objects in the Solar System – are regarded as the building blocks from which the planets formed. Virtually unchanged after 4.6 billion years in the deep freeze of the outer Solar System, they still contain ices and dust from the original solar nebula. They also contain complex organic compounds that some scientists believe may have been the origin for life on Earth. Therefore, just as the re-discovery of the Rosetta Stone, 200 years ago, enabled the mysteries of ancient Egyptian hieroglyphics to be unravelled, so the Rosetta mission will help scientists learn even more about the birth and evolution of the planets and about the origin of life.

The timing of this 1 July event was chosen to coincide with the London meeting of the Rosetta Science Working Team, and the second Earth flyby of the Giotto spacecraft (no longer operational), 13 years after its original encounter with Comet Halley. Also, the opening of the British Museum's 'Cracking Codes' Exhibition, for which the Rosetta Stone is the centrepiece, was set to take place just a few days later.



Dr. Roger Bonnet, ESA's Director of Scientific Programmes, holding a 1:15 model of the Rosetta spacecraft

The Press Conference. From left to right: Peter Evans, Journalist and Press Conference Moderator; Alan Fitzsimmons, Queens University of Belfast; Gerhard Schwehm, Rosetta Project Scientist; Bruno Gardini, Rosetta Project Manager; Roger Bonnet, ESA Director of Scientific Programmes, with the 1:4 scale model of Rosetta in the background

The Rosetta Mission

Rosetta is the third Cornerstone mission in ESA's 'Horizon 2000' Long-Term Scientific Programme. It will be launched by an Ariane-5 from Kourou, in French Guiana, in January 2003.

In order to gain sufficient speed to reach the distant comet Wirtanen, Rosetta will require gravity assists from the Earth (twice) and Mars. After swinging around Mars in May 2005, the spacecraft will return to Earth's vicinity in October 2005 and October 2007 before heading away from the Sun to rendezvous with Comet Wirtanen.

As it bounces around the Solar System, Rosetta will also make two excursions into the main asteroid belt, where it will obtain the first close-up images and information on two contrasting objects, 4979 Otawara and 140 Siwa. Scientists believe Otawara is less than 20 km across, whereas Siwa is probably 110 km in diameter, and therefore much larger than any asteroid so far visited by any spacecraft. Rosetta will fly within 1000 km of Otawara in July 2006, before making a similar rendezvous with Siwa two years later.

The most difficult phase of the mission will be the final rendezvous with the fast-moving comet. The main rendezvous manoeuvre is foreseen for 27 November 2011, close approach is set for 20 May 2012, and orbit insertion around the nucleus should occur on 28 May 2012. Thus, after a 5.3 billion km space odyssey, Rosetta will make its first contact with Comet Wirtanen about 675 million km from the Sun. At this distance, the sunlight will be 20 times weaker than on Earth, and the comet's nucleus will be frozen and inactive.

Once the navigation team are able to determine the comet's exact location from images returned by the spacecraft camera, a series of braking manoeuvres will allow Rosetta to match its speed and direction with those of its target. After about seven months of edging closer, Rosetta will eventually close to within 2 km of Comet Wirtanen's frozen nucleus. From this close orbit above the tiny nucleus, Rosetta will be able to send back the most detailed images and information ever obtained from a comet. When a suitable landing site has been chosen, about a month after global mapping starts, the Orbiter will release the 100 kg Lander. Touchdown on the comet's surface must be quite slow – less than one metre per second – to allow for the almost negligible gravitational pull of the tiny nucleus. To ensure that the Lander does not bounce and disappear into space, an anchoring harpoon will be fired into the surface on impact.

By this time, the warmth of the Sun will probably have begun to vapourise parts of the nucleus, initiating some form of surface outgassing. For a period of about a month, data from the Lander's eight experiments will be relayed to Earth via the Orbiter, providing unique information on the nature and composition of the nucleus. Samples for chemical analysis will be taken of the organic crust and ices to a depth of at least 20 cm. Other instruments will measure such characteristics as near-surface strength, density, texture, porosity and thermal properties.

Meanwhile, as Comet Wirtanen approaches the Sun, the Orbiter will fly alongside it, mapping its surface and studying changes in its activity. As its icy nucleus sublimates, 12 experiments on the Orbiter will map its surface and study the dust and gas particles it ejects. For the first time, scientists will be able to monitor at close quarters the dramatic changes that take place as a comet plunges sunwards at 46 000 km/h.

By mission's end in July 2013, Rosetta will have spent almost two years chasing the comet for millions of kilometres through space. It will also have returned a treasure trove of data, allowing us to learn a great deal more about how the planets formed and where we all came from.

Dr. Gerhard Schwehm, Rosetta Project Scientist, presenting the mission's scientific goals to the assembled audience

Members of the Rosetta Science Working Team and ESA and Industry Project Teams

Cassini-Huygens Swings by Earth

On 18 August, the NASA/ESA Cassini-Huygens spacecraft bade goodbye to Earth as it completed a highly accurate pass of our planet and swung away towards its encounter with Saturn. The Earth flyby, at 3:28 UT, gave the space probe a 5.5 km per second boost in speed, propelling it towards the ringed planet, more than 1 billion kilometres away.

Engineers at ESA's European Space Operations Centre (ESOC) in Darmstadt, Germany, and NASA's Jet Propulsion Laboratory, in Pasadena, California, confirmed that the spacecraft passed within about 1171 km of Earth, as planned, over the South Pacific.

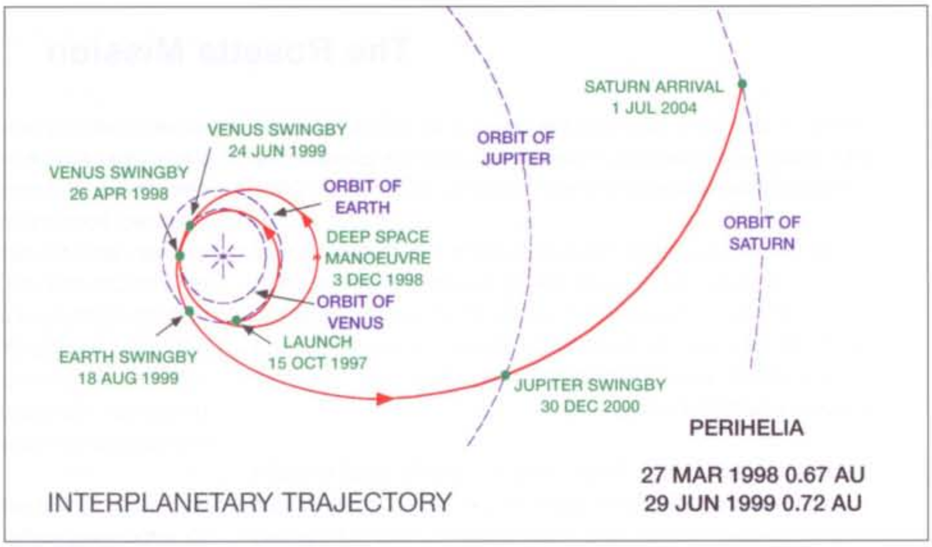
"Everything worked just perfectly and we're very happy" said Jean-Pierre Lebreton, ESA Project Scientist for Huygens. *"Now we're looking forward to an exciting mission of discovery inside the atmosphere and on the surface of Titan, Saturn's largest moon."*

The spacecraft remains in excellent condition as it continues its seven-year flight to Saturn. During the Earth flyby, nine of the twelve scientific instruments on Cassini were turned on to gather data on the Earth/Moon system. The Huygens Probe and its six scientific instruments remained dormant during the Earth flyby. The next bi-annual in-flight Probe checkout activities will take place in mid-September.

Having completed its cruise among the inner planets, Cassini-Huygens' future now lies in the cold, dark realms of the outer planets. It will pass by Jupiter on 30 December 2000 and the giant planet's gravity will bend the spacecraft's trajectory and put it on course for its arrival in orbit around Saturn on 1 July 2004. In November 2004, the Huygens Probe will be separated from Cassini to parachute through Titan's atmosphere and onto its surface.

More information about the Huygens mission can be found at:

http://sci.esa.int/huygens/



More Discoveries from SOHO

SOHO Shows Us the Far Side of the Sun! A truly astounding discovery about our Sun was unveiled by a European team of scientists headed by Jean-Loup Bertaux, of the CNRS Service d'Aéronomie in France, when he reported to the SOHO-8 Workshop in Paris (22 to 25 June). They have found a way of studying the hidden far side of the Sun, allowing us, among other things, to predict the imminent appearance of solar storms originating out of our view behind the Sun.

Bertaux presented a compelling video sequence based on images captured by the ESA/NASA Solar Heliospheric Observatory (SOHO) using one of its instruments called SWAN (Solar Wind ANisotropies). It shows how projections of sunspots on the far side of the Sun rotate through the sky in time with the Sun's own rotation, ultimately emerging on the eastern (left-hand) side of its visible surface. This intriguing discovery could be used to predict the solar storms that periodically threaten the Earth.

"Strong ultraviolet emissions from active regions at the back of the Sun behave like the beams of a lighthouse sweeping over the sea", explained Bertaux, who is Principal Investigator for SWAN. *"The 'beams' rotate through the sky with the Sun,"* taking approximately 28 days to complete one cycle, *"and allow us to monitor activity on the far side of the Sun without observing it directly. This method could be used in future studies on space weather, which is capable of disrupting orbiting satellites and Earth-based electronics"*.

"SOHO has allowed us to study the Sun extensively, from its interior to the space surrounding it. It is fascinating to think that now we can detect what's coming at us from the other side of the Sun", says Martin Huber, Head of ESA's Space Science Department.

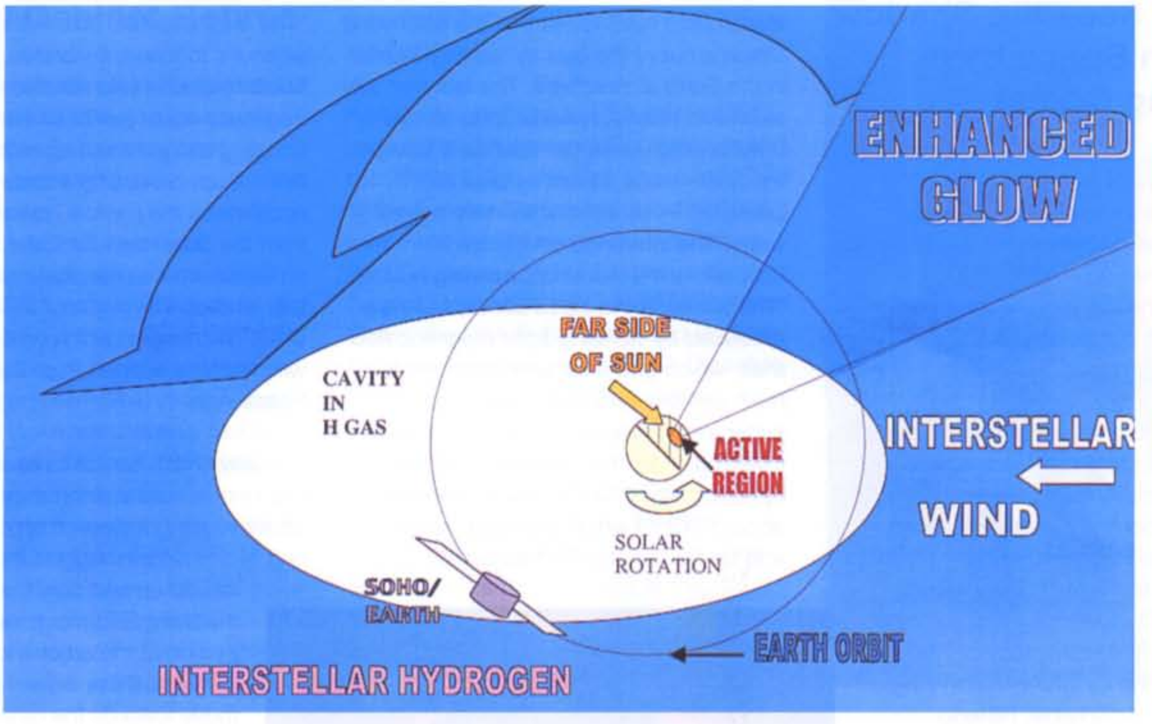
Figure 1. The observational geometry. The Sun illuminates (in Lyman alpha) the hydrogen atoms of interstellar origin in the Solar System. An active region on the Sun's surface which emits more Lyman-alpha radiation will illuminate the hydrogen atoms within its view even more. This increased illumination (a few percent) can be detected by SOHO's SWAN instrument, even if the active region is on the far side of the Sun. The hydrogen cloud in the Solar System acts as a screen onto which the rotating beam from the active region is projected.

Figure 2. Comparison of SWAN normalised images of the two hemispheres of the sky, and an image of the solar disc taken by SOHO's EIT instrument, both on 30 July 1996. The left hemisphere is that surrounding the Sun (fiducial white circle in centre), and is therefore illuminated by the far side of the Sun. The right hemisphere is the anti-solar hemisphere, seen from the Earth and illuminated by the Sun as seen by EIT.

There is a conspicuously bright active spot on the EIT image, and a corresponding wide brighter area in the right-hand SWAN image.

Figure 3. Same data as in Figure 2, but acquired 10 days earlier, on 20 July 1996. There was no bright spot in the EIT image, and no corresponding brighter area in the right-hand SWAN image. In the SWAN image on the left, however, corresponding to the area of the sky illuminated by the far side of the Sun, there is indeed a wide brighter area. It therefore already reveals the presence of the bright spot on the far side of the Sun which only came into our and EIT's view several days later.

1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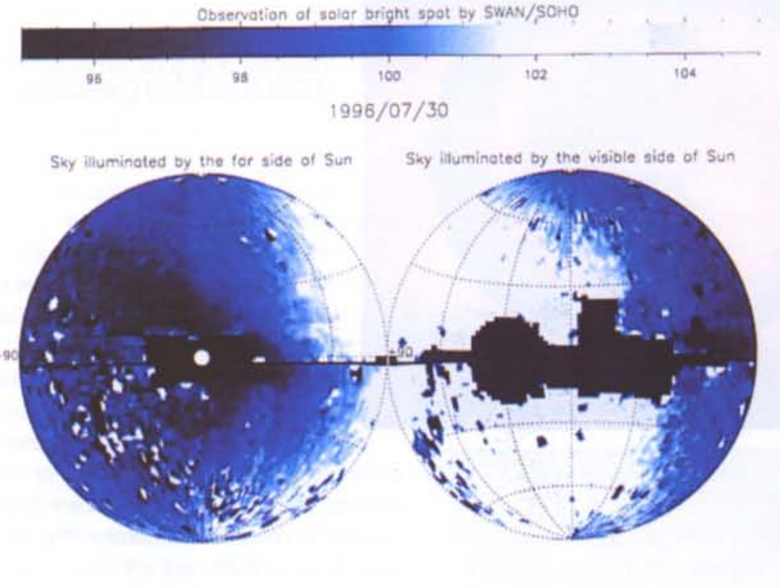
Observation of solar bright spot by SWAN/SOHO
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Sky illuminated by the far side of Sun
Sky illuminated by the visible side of Sun
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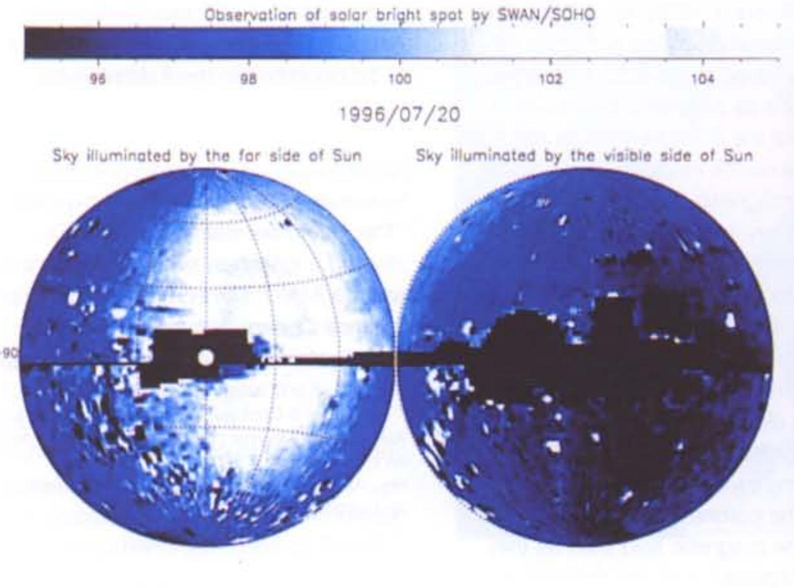
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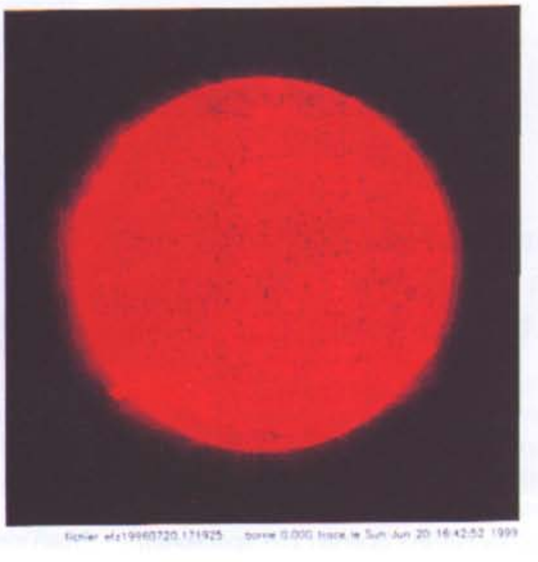
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SOHO Sees the Shadow Cast in Space by a Passing Comet

SOHO's SWAN (short for Solar Wind ANisotropies) instrument was designed to create an ultraviolet map of the entire sky. It has chalked up another first by recording the biggest shadow ever observed in our Solar System: the shadow of a passing comet.

Although most of the hydrogen atoms in the Solar System blow in from interstellar space, comets are surrounded by large hydrogen clouds of their own. When Comet Hale-Bopp blazed past the Sun in 1997, sporting a tail 100 million km long, SOHO was on duty in orbit to observe it. Scientists studying the data recorded by SWAN have now detected a remarkable, hitherto unknown feature: the comet cast a shadow more than 150 million km long on the sky behind it.

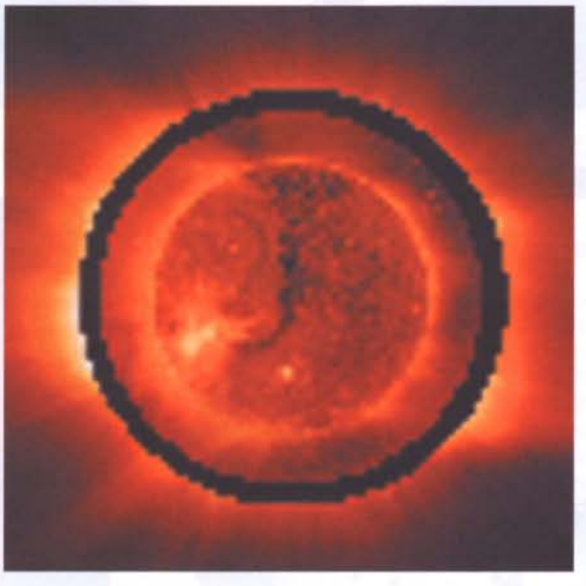
"This allows us to calculate directly the amount of hydrogen and water released by the comet, namely about 300 tonnes per second," says Jean Loup Bertaux.

Roger Bonnet, Director of ESA's Scientific Programme, expressed his appreciation for the SOHO results: *"After many years, SOHO is still at work and fully operational. As in the case of the comet's shadow, it keeps making discoveries and amazing observations."*

Says Bernhard Fleck, SOHO Project Scientist for ESA: *"The nice thing about this discovery is that with SOHO we're not just confined to studying the Sun. Here we are contributing to a different and intriguing field. We are learning more about comets and their physics."*

Solar Wind Surfs Waves in the Sun's Atmosphere!

Solar scientists believe they may have solved yet another long-standing enigma about the Sun. Working on data first gathered from the ESA's Solar and Heliospheric Observatory (SOHO) and then by NASA's Spartan 201 spacecraft, researchers have found that the solar wind streams out of the Sun by 'surfing' waves in the Sun's atmosphere. The fact that this electrified plasma speeds up to almost 3 million kilometres per hour as it leaves the Sun – twice as fast as originally predicted – has been known for several years. The interpretation of how it happens is the real and surprising novelty: *"The waves in the Sun's atmosphere are produced by vibrating solar magnetic field lines, which give solar wind particles a push just like an ocean wave gives a surfer a ride"*, says Dr John Kohl, Principal Investigator for the Ultraviolet Coronal Spectrometer (UVCS) – the instrument aboard SOHO which gathered the data – and for the Spartan 201 mission.



The outermost solar atmosphere, or corona, is only seen from Earth during a total eclipse of the Sun, when it appears as a shimmering, white veil surrounding the black lunar disc. The corona is an extremely tenuous, electrically charged gas, known as plasma, which flows throughout the Solar System as the solar wind. The waves are formed by rapidly vibrating magnetic fields in the coronal plasma. They are called magneto-hydrodynamic (MHD) waves and are believed to accelerate the solar wind.

The solar wind is made up of electrons and ions, electrically charged atoms that have lost electrons. The electric charge of the solar-wind particles forces them to travel along invisible lines of magnetic force in the corona. The particles spiral around the magnetic field lines as they rush into space.

"The magnetic field acts like a violin string: when it's touched, it vibrates. When the Sun's magnetic field vibrates with a frequency equal to that of the particle spiralling around the magnetic field, it heats it up, producing a force that accelerates the particle upward and away from the Sun," says Dr. Ester Antonucci, an astronomer at the observatory of Turin, Italy, and co-investigator for SOHO's UVCS instrument, which was developed with financial support from the Italian Space Agency (ASI).

In a way, this is similar to what happens if two people hold a string at opposite ends after threading it through an object like a ring. If one person wiggles the string rapidly up and down, waves form in the string and move towards the person at the other end. The ring will 'surf' these waves and also move towards the other person.

"Even with this major discovery, there are questions left to answer. The observations have made it abundantly clear that heavy particles like oxygen 'surf' on the waves, and there is also mounting evidence that waves are responsible for accelerating the hydrogen atoms, the most common constituent of the solar wind. Future observations are needed to establish this fact. Many other kinds of particles, such as helium (second most common), have never been observed in the accelerating part of the corona, and new observations are also needed to refine our understanding of how the waves interact with the solar wind as a whole," says Dr. Steven Cranmer of the Harvard-Smithsonian Center for Astrophysics, lead author of the research to be published in the Astrophysical Journal*.

Nevertheless, SOHO has again been able to reveal another of the Sun's mysteries: *"This is another triumph for SOHO, stealing a long-held secret from our Sun"*, says Dr Martin Huber, Head of ESA Space Science Department and a co-investigator for UVCS.

* Article by S.Cranmer, G.B. Field and J.L. Kohl in Astrophysical Journal (Vol. 518, p. 937-947) available on the web at: http://www.journals.uchicago.edu/ApJ/journal/issues/ApJ/v518n2/39802/sc0.html

Head of Cabinet Retires

Karl-Egon Reuter retired as ESA's Head of Cabinet at the end of July, after having been involved in European space activities for almost 30 years.

A graduate of Aachen Technical University, Karl Reuter joined the ESRO Forecast and Programmes Division in Paris in 1969, from the Nuclear Research Centre KFA Jülich in Germany, where he had been Head of the Project Planning and External Contracts Section. Following the formation of ESA, in 1976 he was appointed Head of the General Planning Department, a post he held until 1980.

From 1981 to 1985, he returned to Germany where, as a DFVLR staff member, he served as Project Control Manager for the Franco-German Direct Broadcast Satellite Project TV-SAT/TDF-1, in Munich.

Karl Reuter returned to ESA in late 1985 as Head of the Agency's Coordination and Monitoring Office. He was appointed Head of the Director General's Cabinet in 1988, with responsibility for the Secretariats of the ESA Council, Administrative and Finance Committee (AFC) and Management Board, the ESA Publications and Public Relations Divisions and the ESA Offices in Brussels, Moscow and Washington.

Karl Reuter was also the initiator, in 1990, of the ESA History Project, which was hosted for the first five years by the European University Institute in Florence and is now being continued at the University of Bologna

ESA Signs the European Physiology Modules Contract

The contract for the development and delivery of ESA's European Physiology Modules (EPM) facility for the International Space Station was signed on 26 May 1999, at ESTEC in Noordwijk (NL), by Mr J. Feustel-Büechl, ESA's Director of Manned Spaceflight and Microgravity and Prof. M. Fuchs, for the EPM Prime Contractor, OHB GmbH.

EPM is a multi-user physiology laboratory developed under ESA's Microgravity Facilities for Columbus (MFC) Programme. It consists of several Science Modules which will allow studies to be conducted in space in the areas of cardiovascular, musculo-skeletal, neuro-sensory and regulatory physiology.

It is planned to launch EPM on board the Columbus laboratory, where it will initially contain the following Science Modules:

- Bone Analysis Module (BAM)
- Multi-Electrode EEG Mapping Module
- Biomedical Analysis Sample Drawer
- Cardiolab Module (provided by CNES/DLR, to investigate the cardiovascular system)
- ELITE-S2 Module (provided by ASI, to investigate motion in space)
- Physiological Pressure and Skin Blood-Flow Instruments (provided by DAMEC).

The EPM facility is designed so that the Science Modules can be exchanged in orbit, allowing in-orbit facility upgrades to be made to perform research in other fields of physiology. As a part of the ESA-NASA co-operation, and in order to optimise utilisation and minimise hardware duplication, EPM will be co-located with the NASA Human Research Facilities 1 and 2. This co-location will allow experiments to be conducted through the combined use of equipment items contained in the ESA and NASA racks.

The industrial consortium, led by OHB GmbH, which is a Small/Medium-sized Enterprise (SME), includes the following subcontractors: EREMS (F), Carlo Gavazzi (I), Innovision (DK), Verhaert (B) and CIR (CH). This is the first contract that has been awarded by ESA to OHB as Prime Contractor. This step underlines the increasing role that SMEs will play in the technology innovation process in Europe, in line with European Union and ESA strategy.

Prof. Fuchs (left) and Mr J. Feustel-Büechl

European Space Initiative to Support Disaster Management

Natural disasters such as floods, earthquakes, volcanic eruptions, forest fires or tropical storms and man-made disasters such as oil-spills continuously strike our planet, causing tremendous human suffering and severe damage to property. Data from Earth-observation satellites such as ERS-1 and ERS-2 operated by ESA, and Spot-1, 2 and 4 operated by CNES (in the framework of cooperation with Belgium and Sweden) can provide the authorities responsible for disaster management with reliable information to complement conventional ground-based and airborne systems.

Over the last few years, many initiatives have been undertaken by space agencies in conjunction with civil protection authorities to demonstrate the usefulness of space techniques for improving our management of natural and man-induced catastrophes. On 21 July, in the context of the UNISPACE-III Conference in Vienna, ESA's Director General, Antonio Rodotà, and the Director General of CNES, Gérard Brachet, announced plans to create a Space System Operators' Charter to promote efficient support to disaster management.

In the event of a disaster, Charter signatories will undertake to support organisations involved in disaster assistance and rescue by making available Earth-observation assets, including satellites, instrumentation, ground facilities and archive image data resources. These will be provided, on request, to civil protection authorities in the signatories' countries. In particular, ESA and CNES specifically agree to jointly allocate their satellite resources to the observation of geographical areas affected by a disaster, with a view to rapidly providing the authorities with the relevant data.

This Charter will be open to all space agencies and satellite operators around the World. esa

Eyes in Space Monitor Floods in Bangladesh

Since 11 July when river levels rose dramatically due to heavy monsoon rains and several embankments gave way, Bangladesh has once again been battling against floods, affecting half a million people and one tenth of the nation's territory. To assist local authorities in coping with this natural disaster, a local receiving and processing station is ready to provide near-real-time flood information derived from data transmitted by radar imaging systems on board ESA's ERS Earth-observing satellites.

This low-cost station, dubbed RAPIDS (Real-time Acquisition and Processing Integrated Data System), funded by British and Dutch national co-operation programmes, covers the Ganges and the Brahmaputra-Jamuna flood plain. Installed at Dhaka by the Dutch national aerospace research institute NLR, Synoptics (NL), BURS (UK) and NRI (UK), the station is operated by Bangladeshi experts, working with the Bangladesh Water Resources Planning Organisation.

These operations have been made possible by an ESA-funded project, covering six months of ERS data acquisition, processing and associated training activities, under the ESA Data User Programme, one of the Agency's optional programmes, funded by Belgium, Switzerland and the Netherlands. This project is a practical demonstration of Europe's commitment to putting space technology to effective use on behalf of the developing countries most severely affected by major catastrophes. Bangladesh was hit last year by the worst flooding this century, which killed over 1200 people and caused economic losses of more than two billion Euros.

The Synthetic Aperture Radar (SAR) imager on board ERS-1 and ERS-2 is particularly well suited to monitoring floods over large areas since it penetrates clouds and operates day and night. The accompanying archive images cover a 100x100 km^2 area, where the Ganges (left) and Brahmaputra or Jamuna (top) rivers converge in Bangladesh (right).

These images are an example of one of the techniques used in flood mapping. The first is a multi-date, false-colour image derived from three black and white SAR images taken before and during the flood. The colours in image 2 distinguish between the flooded (blue) and the non-flooded (brown) areas, with the normal riverbeds in black, following analysis and interpretation of the multi-date image. This information is then matched against a digital elevation model to derive water levels and estimate the duration of the flooding.

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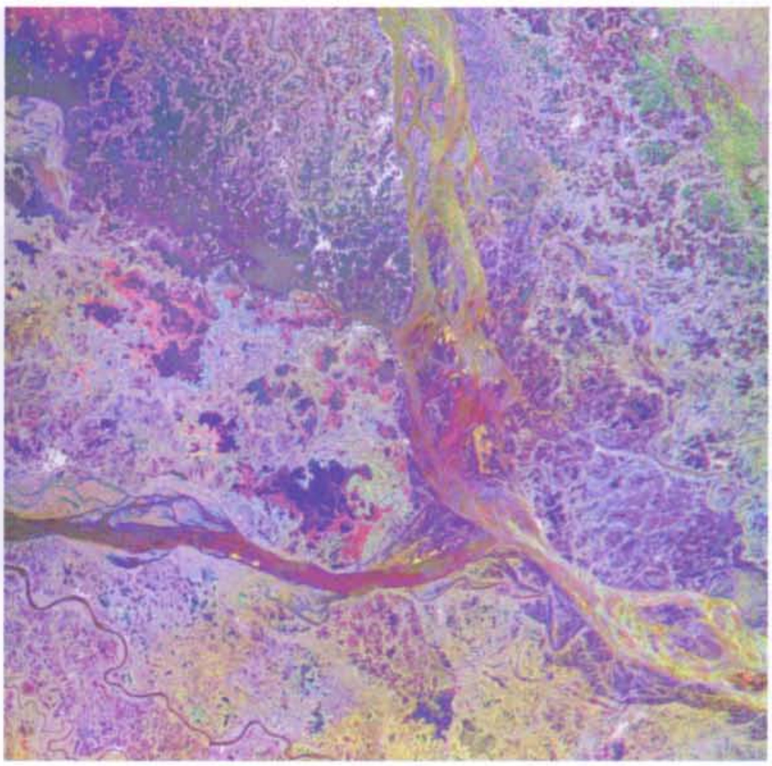

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Over the long term, the radar image archive on Bangladesh in the monsoon season will facilitate mapping of hazards in areas where the population fishes and farms (growing rice in particular), when the flood plain is subject to unusual flooding or droughts. The radar archive also serves to identify river migration and coastal processes due to the yearly monsoon and flooding.

ESA's ERS-1 and ERS-2 Earth-observing satellites, launched in 1991 and 1995, respectively, have been collecting a wealth of valuable information on the Earth's land surface, oceans, sea ice, polar caps and atmosphere. Europe's future contribution to addressing worldwide environmental problems comes in the shape of Envisat. This sophisticated satellite, to be launched in 2000 by an Ariane-5, will provide users with even more refined and specialised remote-sensing data with which to chart and document changes in our environment, and will supply reliable information for better management of natural or man-made disasters.

For further information, please contact:

Ms F. Morgia, ESA/ESRIN Public Relations, Tel. + 39 06 9418 0950 esa

European Students Explore Possible Mars Mission

Seventy-two students from the Agency's Member States attended this year's Alpbach Summer School from 3 to 12 August, in the small mountain village of Alpbach in the Austrian Tyrol. The annual Alpbach Summer School is co-organised by the Austrian Space Agency, the Austrian Federal Ministry of Science and Transport, and ESA with support from its 14 Member States.

This year, the students were set the task of defining a future Mars Exploration Mission. Some twenty-five European experts were on hand to provide them with an overview of all aspects of the Red Planet, including the chemical and mineralogical composition of its surface, its geophysics and its geochemistry. A review of past, present and future exploration of Mars was also presented. ESA's Director of Science, Dr. Roger Bonnet, opened this year's gathering with a lecture on "Mars Exploration: For What Purpose? How?"

Having studied a variety of possible missions to Mars, the students proposed the use of an airship, or 'Zeppelin', as a highly versatile vehicle for exploring the Red Planet. Space scientists have so far traditionally concentrated their efforts on rovers, balloons or planes, i.e. systems that are bound to the surface, are free-flying but not steerable, or are too fast for detailed local investigations. The novel idea of using a Zeppelin provides for three-dimensional steering and a choice between sojourning at an interesting spot, and travelling for surveying the landscape or to visit another location. A Zepplin would be especially useful for studying the so-called 'Mars dichotomy', a seven-kilometre-high wall that gives access for the study of many geological layers which could otherwise only be studied by deep Martian drilling.

"The students of this Summer School demonstrated with their studies that we can look forward to a future generation of European space scientists with excellent skills and creativity", said Prof. Hans Balsiger, Chairman of ESA's Science Programme Committee, when he summarised the results of the two weeks' work by the 72 students.

Additional information on this and other Alpbach Summer Schools can be obtained from:

Ms Michaela Gitsch
Austrian Space Agency
Garnisongasse
A-1090 Wien

Tel. 43+1+403 81 77/12
Fax 43+1+405 82 28
E-mail: mgitsch@asaspace.at esa

Some of the Alpbach students at work

Black Sun: ESA's Eclipse99 Activities

The total solar eclipse of 11 August 1999 was a unique opportunity to share our enthusiasm for space with the public. Scientists and technicians from ESA's Space Science Department prepared a range of activities culminating with dedicated eclipse events in Europe as part of the Eclipse99 campaign. The experience and emotions proved to be overwhelming, even for those who suffered cloudy skies. More than 300 million Europeans became eclipse viewers as the shadow swept across the southwest of England, northern France, Belgium, Luxembourg, Germany, Austria, Hungary, Romania and Turkey.

ESA's multi-site campaign along the path of totality provided a longer sequence of coronal observations plus video images transmitted for live internet distribution. The core SSD science experiments built on previous eclipse campaigns to study coronal temperature and density structure and dynamics, and to search for cool material in the very hot corona. These eclipse results are now being analysed in conjunction with Soho data.

ESA concentrated its activities in Noyon, France, where some 8000 amateur astronomers and general public at the official eclipse viewing site included 380 staff from ESA ESTEC and Paris, plus 40 000 people in the city of Noyon itself. This was a major public relations event for ESA and the solar-viewing Soho satellite. Soho images and results were shown and described for the public and radio listeners by Eclipse99 coordinator Bernard Foing and M. Laurent, vice-president of Societé Astronomique de France. Live interviews were given to national radio stations such as France-Inter, France Info and even Washington, DC. More than 30 interviews were given by the Agency's multinational staff. Although the cloud cover thickened before totality, the darkness still provided a unique experience and the partial eclipse was visible later.

In Thionville, France, ESA's small eclipse imaging team found good weather conditions and took eclipse pictures that were used by the BBC's online site. At Chateau de Malbrouk, near Metz, Roger Bonnet, ESA's Director of Science, appeared on French TV several times over two days, but the sky was cloudy at totality.

The whole week leading up to the eclipse saw daily press conferences in the France 3 TV auditorium at Strasbourg, where Soho videos, CD-ROMs and the latest images were presented by Bernard Foing and the Soho Deputy Project Scientist Pål Brekke. *"The eclipse day started with morning rain, then clouds. Just before*

Noyon

Alan Denton was proud of his home-made viewer.

Eclipse99 coordinator Bernard Foing maintained a flow of information at the site.

Photos: Anneke v.d. Geest, ESA Photographer

Spreading the ESA word at Noyon.

eclipse totality, the sky just opened up", Dr Brekke says. *"It was blue and it was dark and people were just stunned."* A beautiful eclipse video sequence was obtained.

Soho Project Scientist Bernhard Fleck was in Stuttgart, where the Science Fair attracted 500 000 participants. It was, however, raining on the day of eclipse. Detlef Koschny and Joe Zender had better luck in Munich, where there was a clear sky at totality and great eclipse video images were obtained and relayed to ESTEC.

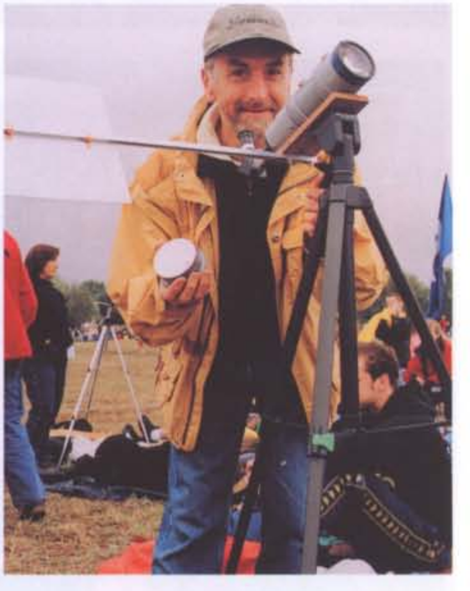
In Burgenland, Austria, a team from the Space Generation Forum that last met at the UNISPACE III conference in Vienna had organised a trip led by ESTEC Young Graduate Trainees Norbert Frischauf and Gudrun Weinwurm to the central totality line near Oberwart, where they watched the shadow approaching from the west and experienced the longest period of totality of all the ESA member states (2 min 21.5 s).

At the International Youth Astronomy Camp in Vep, near Szombathely, Hungary, more than 150 students had been enjoying lectures and experimental activities since the beginning of August. Salvatore Orlando and his local collaborators installed the SSD eclipse science experiments previously used in total eclipses in Chile in 1994 and Guadeloupe in 1998. There was rain and clouds during the morning until first contact, but clear sky at totality. Excellent video images were obtained, routed to the BBC for their web broadcast.

In Bucharest, Romania, the superb blue sky allowed Bernard Zufferey (ESA Prodex) to obtain video eclipse images. In Turin, Italy, Eclipse99 committee member Ester Antonucci reported that 6000 people turned up and that the eclipse live on TV took 41% of the national audience, with a peak of 6 million people.

At ESTEC, a public event was organised at Noordwijk Space Expo for more than 1600 people. SSD solar scientist William Chaplin and eclipse veteran Thierry Beaufort gave presentations about the Sun, Soho and eclipses. Working from ESTEC, Frans Moser and Thierry Beaufort coordinated the installation of the cameras and simultaneous data acquisition and transmission system from ESTEC for the six different sites. The captured images were relayed directly for the BBC's live web site.

Selected images from the eclipse sites can be found on and downloaded from http://sci.esa.int/eclipse99/index.html



Ulysses Project Scientist Richard Marsden took a different view of the Sun this time.

Willem Smit and daughter Fiona brought their own eclipse, just in case.

The view towards Noyon during totality. Inset: the partial phase was visible after totality

Noordwijk

Although the Netherlands was outside the path of totality, Noordwijk Space Expo drew a large audience.

Trevor Sanderson, of the ESA Space Science Department, decided to fly on the morning of the eclipse from Rotterdam in a light aircraft with the ESTEC Flying Club down to Le Tréport, a small private airfield on the Normandy coast, on the northern edge of totality.

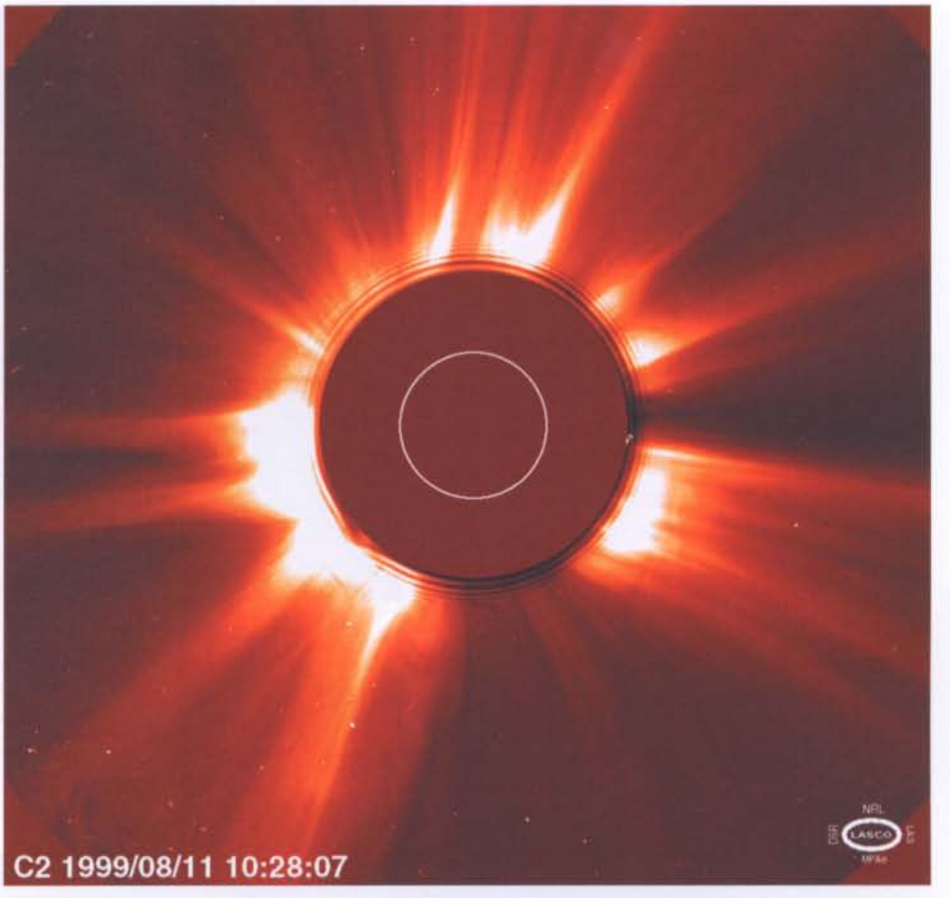
"We were lucky in choosing Le Tréport because, by the time we landed at 9am, visibility was 90 km as a result of a high-pressure area pushing into France. Thanks to clear skies, the temperature dropped dramatically in the hour before totality, so much so that most of us had to put on pullovers or jackets to keep warm. In the few seconds before totality, the excitement grew. The Sun's crescent was now very thin, and already it was possible to see some of the planets. Then the Diamond Ring appeared for a few seconds, and suddenly totality was upon us.

Looking into the viewfinder of my camera, with its 500 mm lens, the sight was overwhelming. Baily's Beads were visible,

extending almost all the way around the Moon's disc, sparkling all the time. Now it was also possible to look through my binoculars, where the eclipse looked truly fantastic. I was enthralled by the red chromospheric light in the beads. No photograph can really do this justice.

Then, someone shouted 'Don't look any more!', as the Diamond Ring reappeared and a brilliant shaft of light emerged, and it was all over. Only 1 1/2 minutes, gone in a flash. Slowly, the crescent filled out and the temperature rose again. Unbelievable. Incredible.

Afterwards, we learned that we were part of the privileged small fraction of the population of Western Europe who had seen the whole of the eclipse under not only blue skies, but such exceptionally clear blue skies. Not far to the south, it was still raining for the eclipse, and inland, in the rest of France, it was generally overcast."



Baily's Beads were captured by Hubert Degroote positioned at St-Martin-aux-Buneaux, Normandy, in a 1/1000 s exposure on 100 ISO film using a 1000 mm lens. The beads are created by sunlight flickering through mountain ranges on the Moon's limb.

Trevor Sanderson used an exposure of 0.5 s with a 500 mm lens and 200 ISO film to reveal the extent and structure of the corona as seen from Le Tréport, France. The coronal features can be compared with those recorded at the same time by the LASCO coronagraph aboard Soho (courtesy of Simon Plunkett, US Naval Research Laboratory, Washington DC).

This sequence of images was returned by the Meteosat-6 weather satellite from its position at 9°W in geostationary orbit. Instead of covering the full Earth disc at 30-minute intervals, as Meteosat does in its normal operating mode, a large part of the northern hemisphere was scanned every 10 minutes. This provided a more frequent observation sequence as the Moon's shadow moved across the Earth's surface. The images were rectified to 0° longitude and enhanced to emphasise the shadow. The first frame (right) shows the eclipse-free Earth at 10:10 CET. The heavy cloud cover that spoiled the view for many along the path of totality is evident. The next frame, at 12:10, shows the eclipse approaching Europe across the Atlantic. The final three frames are of 12:30, 12:50 and 13:10 CET. (©1999 EUMETSAT)

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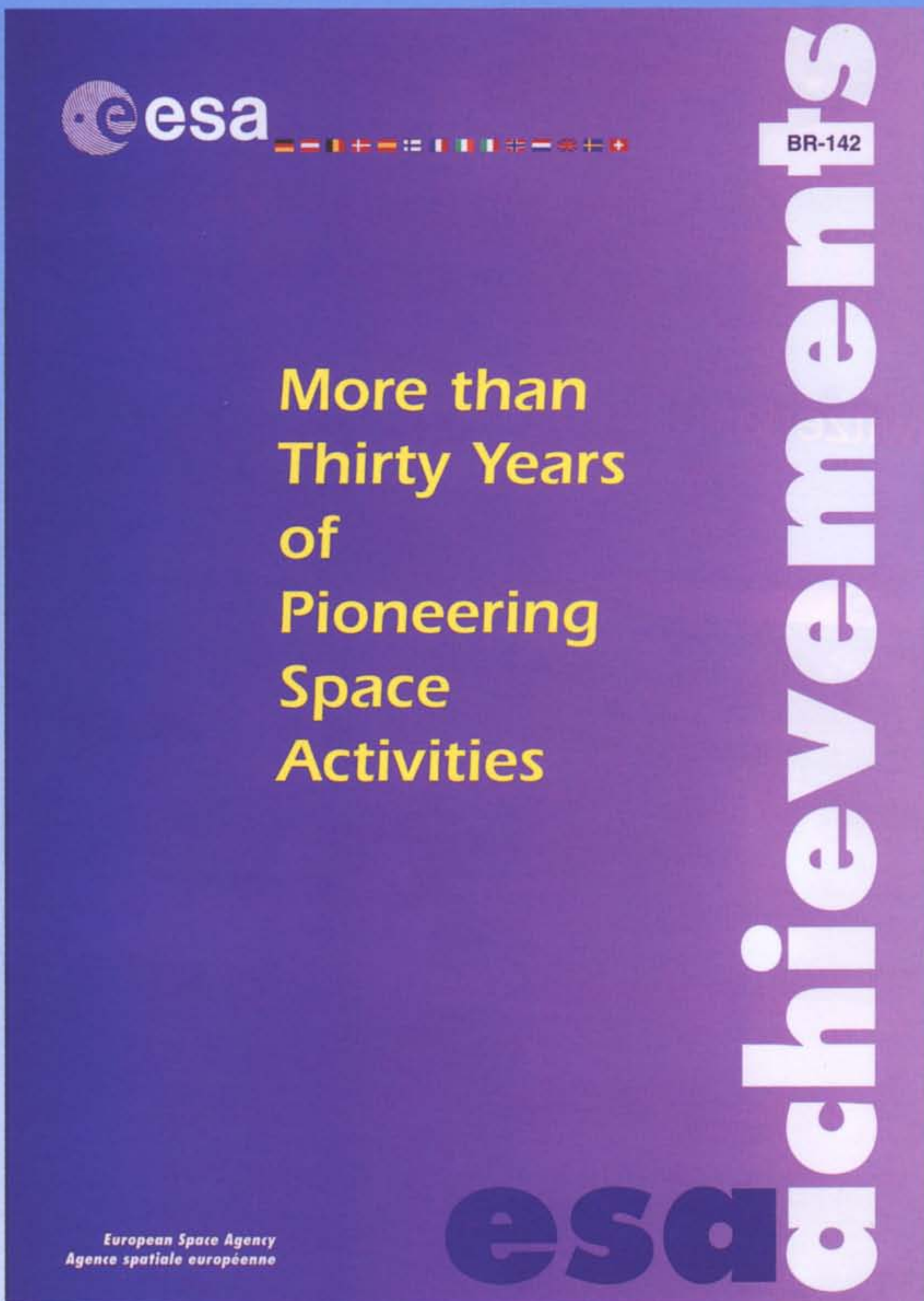

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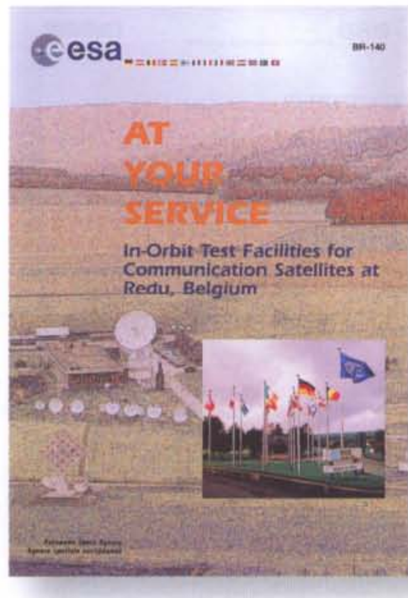

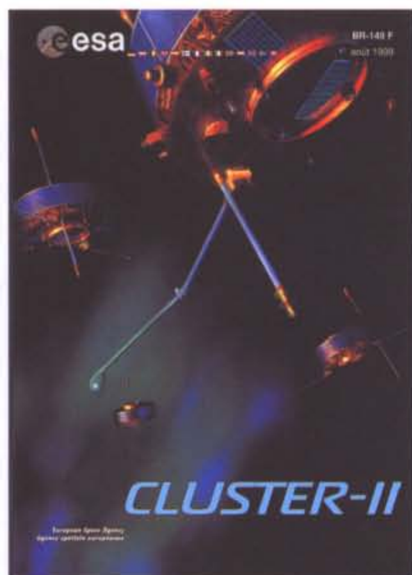

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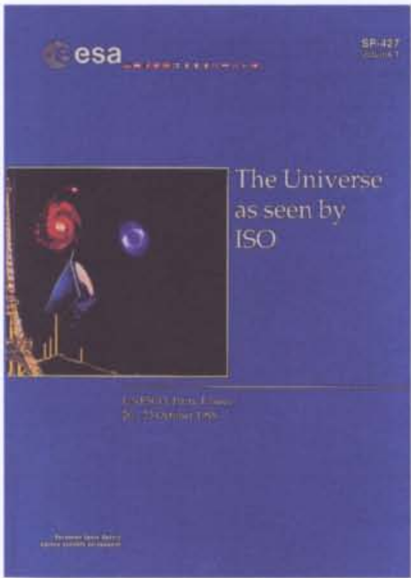

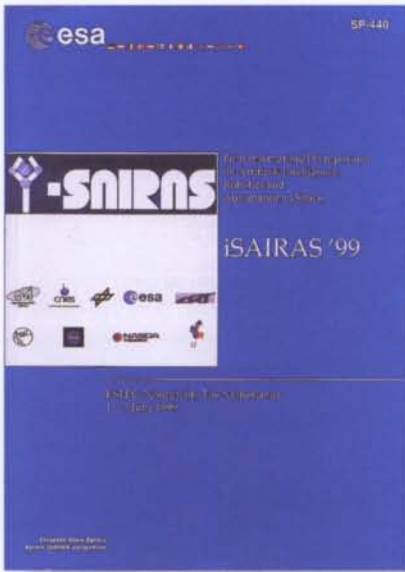

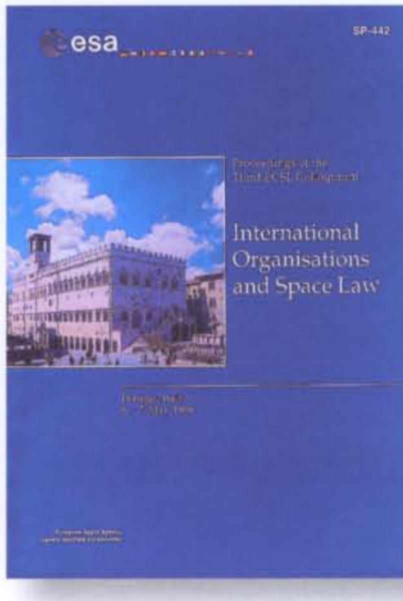

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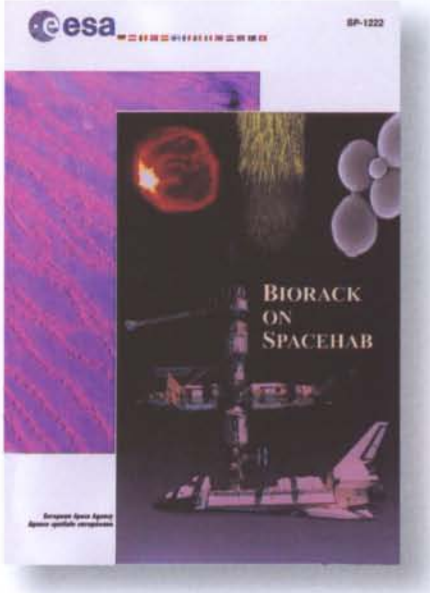

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