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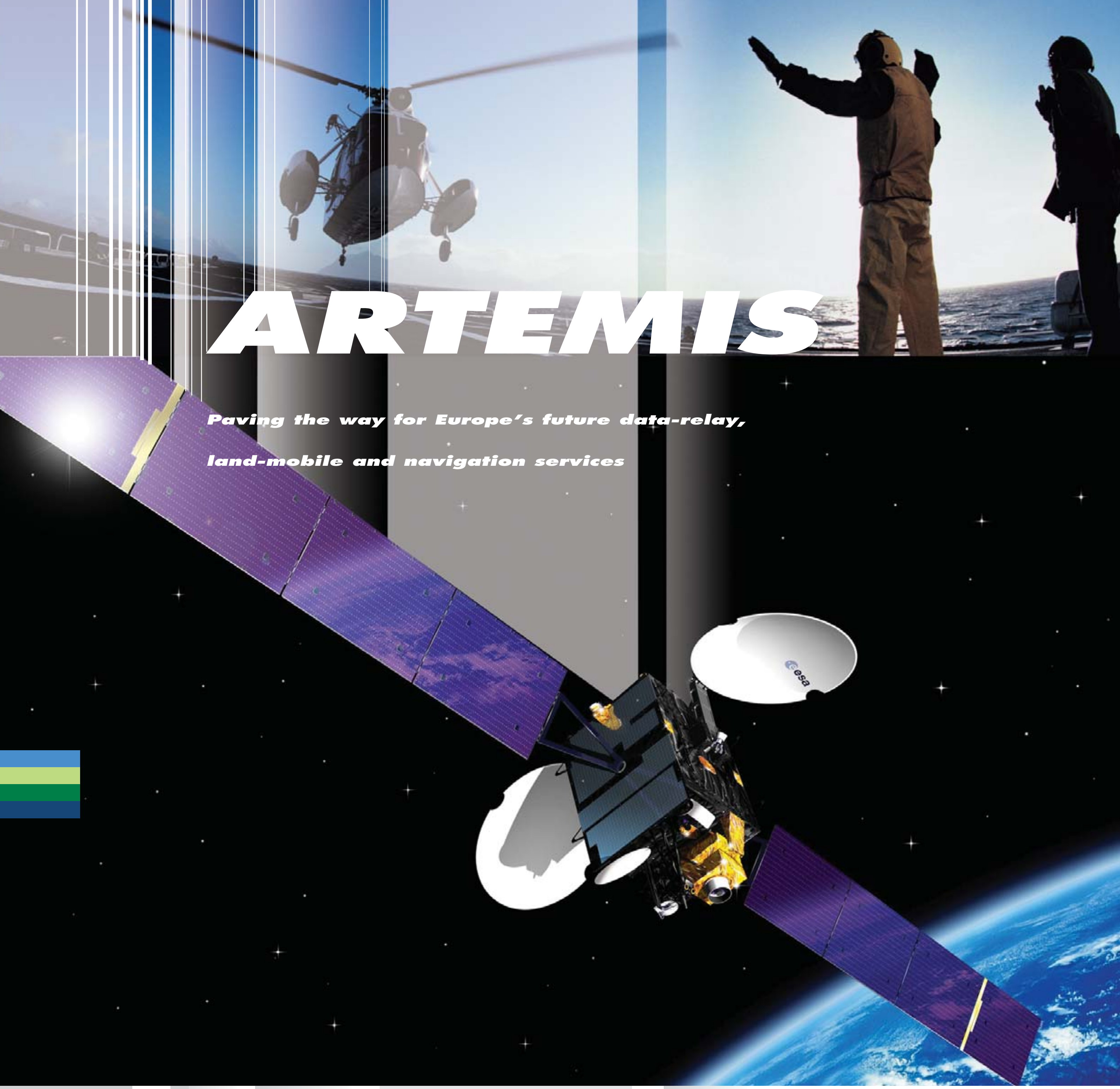
ARTEMIS

PAVING THE WAY FOR EUROPE'S FUTURE DATA-RELAY LAND-MOBILE AND NAVIGATION SERVICES



ARTEMIS

Paving the way for Europe's future data-relay, land-mobile and navigation services

Technological breakthroughs, a World premiere in space, European engineers rising to meet the meet the challenge of a launch malfunction – these are the Artemis achievements. Artemis is ESA's latest telecommunications satellite. It is the most advanced communications satellite yet produced by the Agency, being designed both to test and develop new areas of mobile communication, and to initiate a European data-relay system involving satellite-to-satellite communication. It is ESA's contribution to advancing the use of satellite communication systems for land transport, air and sea navigation, and is acting as a new inter-orbit link between satellites in low Earth orbit and the ground.

Having reached its final orbital position on 31 January 2003, Artemis soon began delivering its planned data-relay, land-mobile and navigation services. In particular, its L-band land mobile payload is being used to complement and augment the European Mobile System, its data-relay payloads are being prepared to provide operational services to Envisat and SPOT-4, and its navigation payload will form an operational element of the European Geostationary Navigation Overlay Service (EGNOS).

Mission Impossible ?

"Mission impossible, mission accomplished..... and I am the first to be happy about the recovery of Artemis since we can say that Artemis is my baby, having worked on this project for many years before joining ESA. Artemis is a great success for the European Space Agency since we have demonstrated our ability both to develop new technologies effectively and also our capabilities to recover a mission that many believed to be lost."

Claudio Mastracci, Director of Applications, ESA

Artemis was launched on Ariane flight 142 on 12 July 2001. Due to a malfunction in the launcher's upper stage, Artemis was injected into an abnormally low transfer orbit. For any conventional communications satellite, this would have resulted in loss of the mission. Thanks, however, to the combination of advanced technologies that Artemis has on board, and the innovative recovery procedures devised by the spacecraft control team, the satellite could still be slowly and carefully coaxed, over a period of 18 months, into its intended operating position in geostationary orbit (GEO).

When it was realised that the launch failure had left Artemis in an elliptical orbit much lower than intended, a team of ESA and industry specialists immediately set to work to rescue the satellite. The shortfall in the satellite's injection velocity was such that the mass of chemical propellant carried by Artemis was insufficient to reach GEO and still provide a useful station-keeping function. It was therefore decided to use some of the chemical propellant to reach an intermediate parking orbit 5000 km below GEO, and then employ the satellite's novel experimental ion-propulsion system, together with an innovative attitude-control strategy, to make the transfer to GEO.

Two ion thrusters on the south face of Artemis (above)
One of the RITA ion-propulsion thrusters (below)

In all, about 20% of the original spacecraft control software would have to be modified in order to accomplish the new mission scenario. Thanks, however, to the re-programmable onboard control concept, these modifications could be made by uplinking 'software patches' to the satellite. These software patches amounted to a total of 15 000 words, making it the largest reprogramming of flight software ever attempted for a telecommunications satellite.

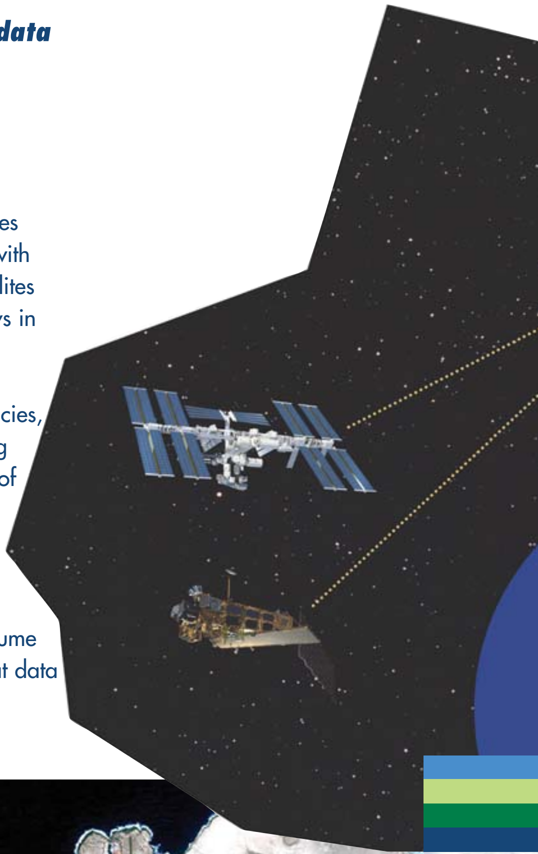
While this software reprogramming was in progress, with the satellite in a temporary parking orbit, Artemis logged another World first, with the establishment on 30 November 2001 of the first-ever optical link between orbiting satellites. It allowed France's national Earth-observation satellite, SPOT-4, to transmit its first image via the SILEX payload on Artemis, which then forwarded it to the Spot Image Processing Centre in Toulouse (F).

Beaming Data through Space

"For the Envisat Earth observation mission, bringing Artemis online to relay Earth imagery and scientific measurements means that more data can be acquired and downloaded and the process of delivering Earth-observation data to end users will be much faster. This is very good news."

José Achache, Director of Earth Observation, ESA

Until the arrival of Artemis, Earth-observation missions and other low-Earth-orbiting (LEO) satellites have had to send their data to ground while in sight of an earth station. Since the contact times with such stations is usually only a few minutes per orbit, data has had to be stored onboard the satellites and several earth stations have had to be used. This leads to a need for complex planning, delays in delivering and processing data, and costly satellite operations.



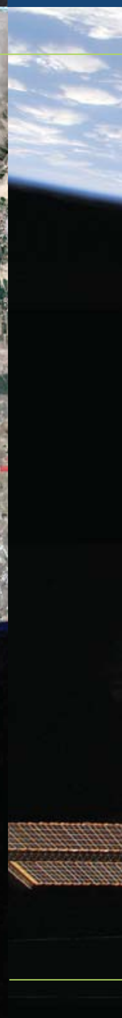
Now, thanks to the data-relay links provided by Artemis at Ka-band, S-band and optical frequencies, greater visibility is provided and large volumes of data can be delivered directly to the processing centre or control centre, avoiding bottlenecks and delays, and reducing operating costs. The use of Artemis also reduces the data-collection workload at the earth stations, and ultimately helps reduce the overall costs.

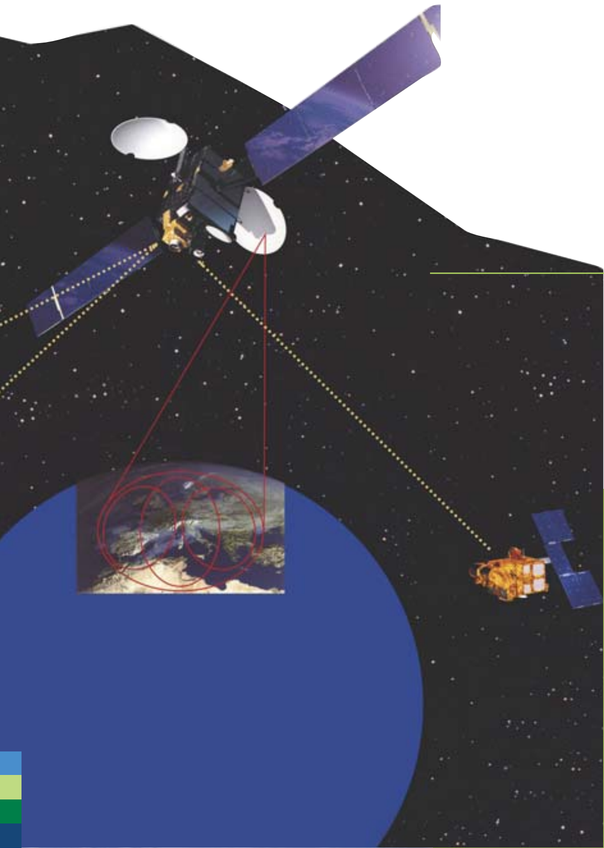
Earth-observation users need to accumulate extensive in-orbit experience with this form of data transmission to optimise their control and operations philosophies, to cope with the increased volume and immediacy of the data, and to exploit the flexibility in planning the acquisition of images that data relay brings.

The first SPOT-4 image transmitted via the SILEX optical link to Artemis

Since April 2003, Artemis has been routinely providing high-data-rate links to France's SPOT-4 and ESA's Envisat missions. Both the optical and Ka-band links are providing very-high-quality image transmission. SPOT-4 has been using one link session per day to transmit its data via Artemis to the Spot Image Processing Centre in Toulouse. Envisat is using 8 links per day on two channels for its ASAR and MERIS instrument image data, which Artemis transmits directly to the Envisat Processing Centre at ESRIN in Frascati, Italy. Before the introduction of the data-relay service, there could be a delay of up to 7-8 days when data had to be to retrieved and processed at the remote Envisat earth stations.

During the first 10 months of Artemis operations, the total link connect time reached 440 hours (1370 links) for Envisat and 60 hours (300 links) for SPOT-4. It is expected that the link usages of both users will increase as the commercial potential of the system is realised.





The most dramatic potential of space-based data relay is in assisting emergency services when there is an environmental disaster, such as a volcanic eruption or a major forest fire, by transmitting real-time imagery. The first such emergency support was given on 7 August 2003, when Artemis supported an Envisat Earth Watch data-acquisition campaign in response to a request from the Portuguese Civil Protection Authority for help in fighting major forest fires northeast of Lisbon.

In this false-colour Envisat image of Portugal, acquired through Artemis by ESRIN on 7 August 2003, the burnt areas appear as very dark patches, to the northeast of Lisbon

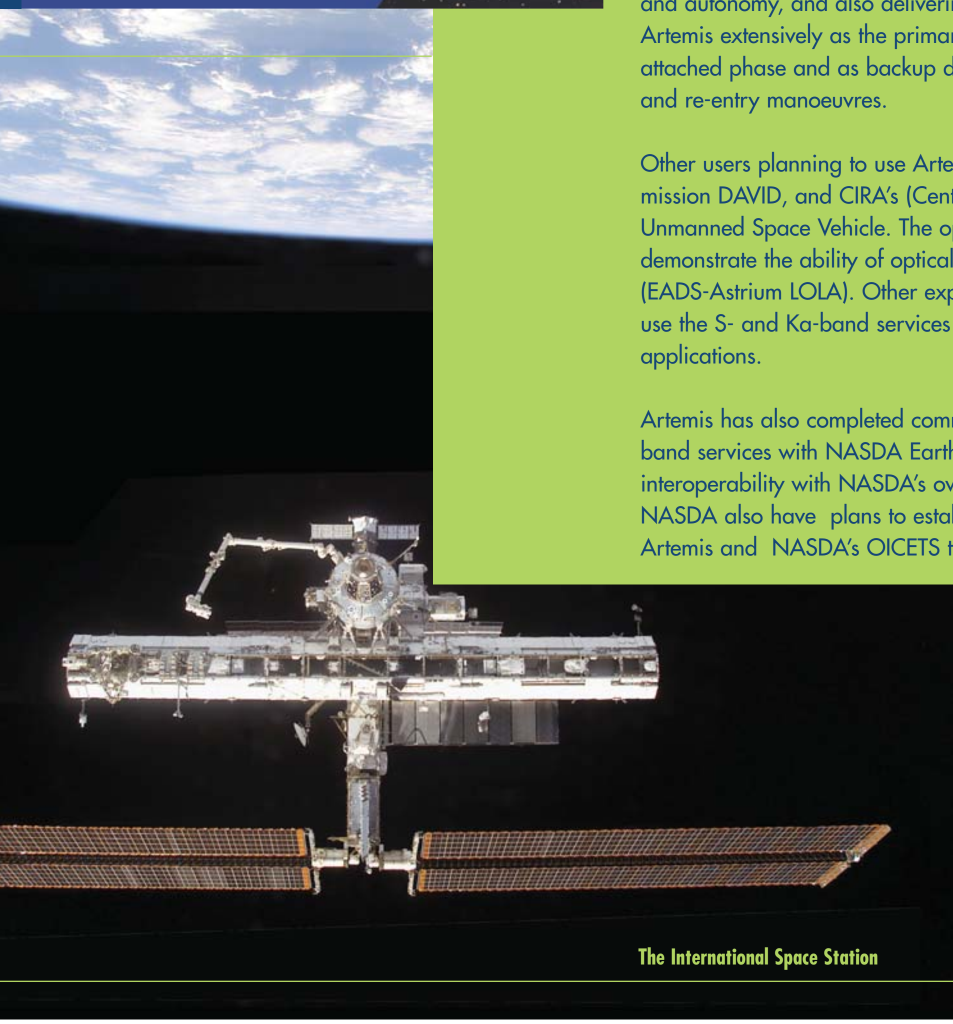
Under its Artemis programme, ESA has also supported the development of an optical ground station at Tenerife, in the Canary Islands (E). In its first few months of operation, this station has made some 100 links with Artemis, conducting atmospheric attenuation and characterisation experiments for furthering science applications.

Future Users of Artemis

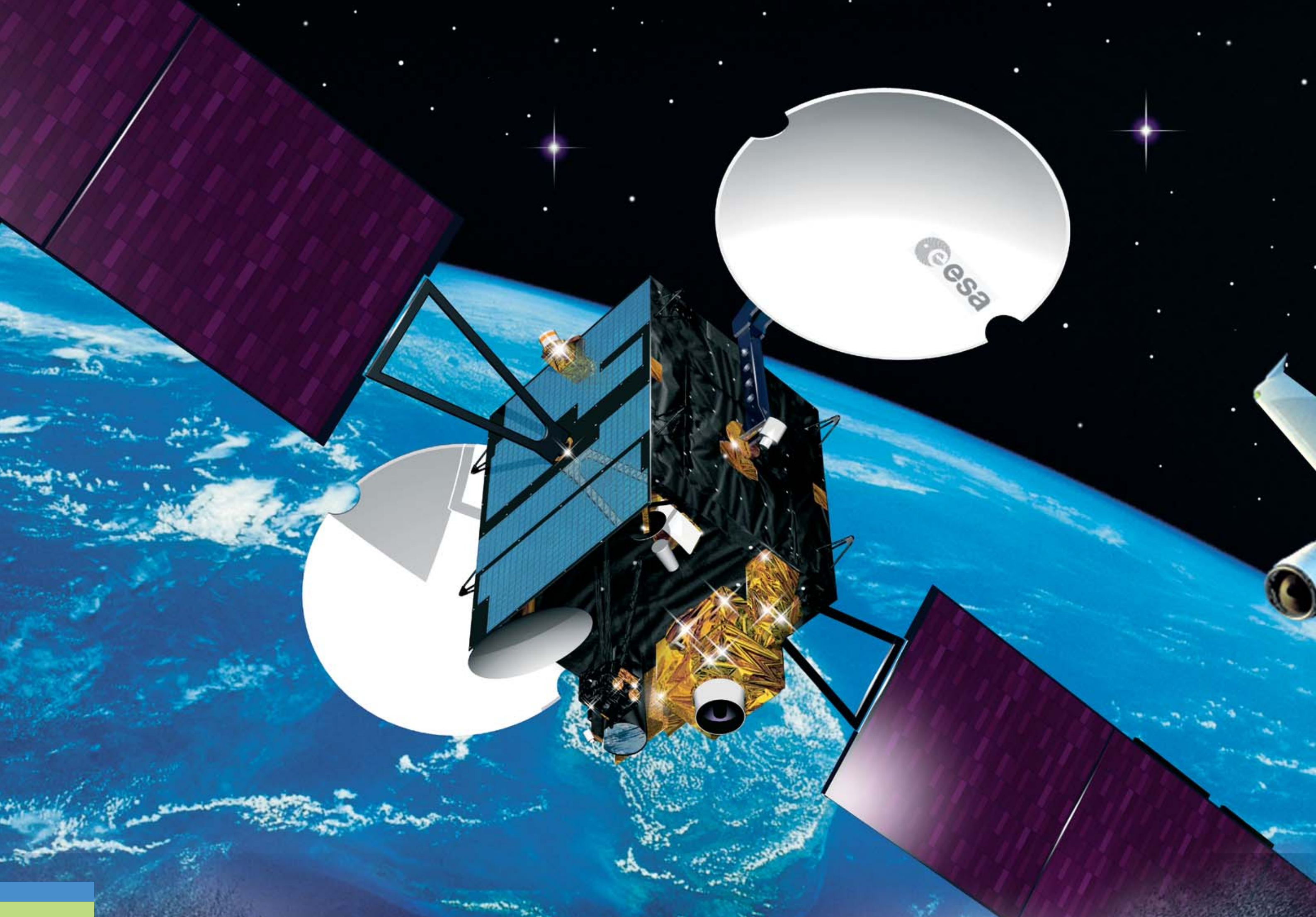
It is planned that in the future Artemis will also support the major institutional users of the International Space Station (ISS). The Automated Transfer Vehicle (ATV) and the Columbus Orbital Facility (COF) will also be able to use Artemis to complement existing capacity for communicating with the ISS, resulting in greater reliability, flexibility and autonomy, and also delivering potential cost savings. ATV will use Artemis extensively as the primary data-relay element during the attached phase and as backup during the critical docking, separation and re-entry manoeuvres.

Other users planning to use Artemis are the Italian national scientific mission DAVID, and CIRA's (Centro Italiano Ricerche Aerospaziali) Unmanned Space Vehicle. The optical link will also be used to demonstrate the ability of optical terminals to transmit from aircraft (EADS-Astrium LOLA). Other experiments under discussion that would use the S- and Ka-band services include wideband multimedia applications.

Artemis has also completed commissioning tests for S-band and Ka-band services with NASDA Earth-observation satellites, demonstrating interoperability with NASDA's own data-relay satellite DRTS. ESA and NASDA also have plans to establish an in-orbit optical link between Artemis and NASDA's OICETS test satellite.



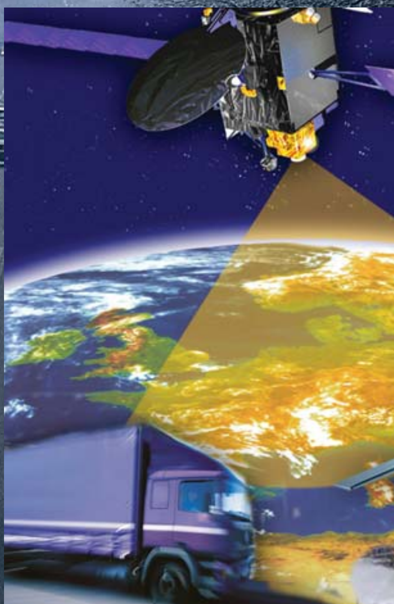
The International Space Station



Affordable Communications on the Move

ESA has been very active in promoting land-mobile services in Europe. Many market and mission studies have been conducted and concluded that, despite the growth of cellular telephones, there is an important niche market for a European satellite system providing for mobile voice and data services. Fishing vessels, trucking companies and government agencies require secure and reliable possibilities for integrated services such as telephone, fax, e-mail, position reporting and messaging. As a result, the European Mobile System (EMS) was conceived and it was promoted in conjunction with ASI and Telespazio using an EMS payload on the Italsat-F2 satellite.

Since March 2003, EMS coverage has been provided by Artemis over Western and Eastern Europe, the Mediterranean and North Africa, and the Middle East. The service is particularly suitable for areas without a well-developed traditional infrastructure, and the market has been boosted in recent years by the changing political landscape of Europe and the continued instability in the Middle East.



The L-band Land-Mobile (LLM) payload on Artemis is highly reconfigurable. Spot beams allow communications traffic to be directed straight to the area of interest, and facilitate operation with smaller, lower power mobile terminals. Many recognised mobile service operators, including Telespazio, Inmarsat and Eutelsat, have shown a keen interest in leasing LLM capacity to extend or complement their existing services, or to provide a back-up to their current systems.

The LLM payload has also been used for the demonstration of a number of advanced mobile systems presently under development by ESA.

Navigating the World

"Artemis will allow EGNOS to increase its full-service coverage area, will improve both EGNOS navigation service continuity and availability, and will enlarge the interoperability and service-expansion possibilities of the EGNOS system."

Javier Ventura-Traveset, EGNOS Principal System Engineer, ESA

Europe is bringing advanced satellite navigation to the civilian population with Galileo, a European global satellite navigation system that is set to transform our land and sea transportation and revolutionise air-traffic control worldwide. The United States and Russia have been operating their own navigation satellite systems for many years. Their GPS and Glonass systems allow moving or fixed objects in the air, on land or at sea to determine their positions with high accuracy. But until now, it is the military that has been the greatest beneficiary of such technology, with civilian use of these systems restricted in scope and accuracy.

The first steppingstone in Europe's ambitious programme is the European Geostationary Navigation Overlay System, or EGNOS, a joint programme involving ESA, Eurocontrol and the European Commission. The first orbital element for EGNOS built by ESA is the navigation payload onboard Artemis. This payload, which will be integrated into the overall EGNOS system by the end of 2003, will broadcast navigation signals from the EGNOS Master Control Centre (MCC). Test transmissions from the navigation earth station at Scanzano in Italy have already started, and a second station at Torrejon in Spain will come soon.

The EGNOS concept

Driving Technological Breakthroughs

"Artemis's attitude and orbit control system (AOCS) equipment is operating well and the performance of the newly developed AOCS software has been excellent, running without any failure since the first upload to the satellite's onboard computer. The new mode used being used earth-pointing is providing perfect attitude accuracy in the highly inclined geostationary orbit phase and during station-keeping manoeuvres."

Michael Surauer, Attitude Control System Designer, Astrium

ESA began developing telecommunication satellites in the late 1960's and launched its first Orbital Test Satellite (OTS) in 1978. It paved the way for the ECS and Marecs series of communications satellites operated by Eutelsat and Inmarsat. ESA's Olympus satellite, launched in 1989, further developed and consolidated the design for Europe's future communication satellites.

Without research and development today, there will be no commercial market tomorrow. It is not sufficient to develop space equipment on the ground. The demanding process of acceptance testing and integration prior to launch, launch itself and survival in the harsh environment of space are essential steps in the qualification of new technologies.

The SILEX optical data-relay link between Artemis and SPOT-4

Although Artemis owes its heritage to previous European telecommunication satellites, it contains many innovative technological elements that are new for European industry. Only comprehensive verification in space can confirm their long-term performances. Nearly 70% of the onboard equipment that Artemis carries has been designed specifically for it. Many of these items are already finding application in other commercial satellite programmes.

Among the most innovative of Artemis's technologies are:

- the SILEX optical data-relay payload (together with its partner terminal on SPOT-4, which was also funded by the Artemis Programme)
- the ion-propulsion system
- the Integrated Control and Data Handling system.

All of these new developments, which are described in greater detail in the accompanying panels, are proving exceptionally successful, showing that Artemis is fulfilling its technology-demonstration role admirably. The accumulation of further in-orbit experience over a longer period is therefore now an important goal for continuing Artemis operations.

The ENVISAT Data-Relay Earth terminal at ESRIN, Italy.

Laser Beams for Inter-satellite Communication

"The Artemis optical data link used by SPOT-4 has considerably expanded the 'Toulouse visibility circle', ... making our satellite accessible for real-time data transmissions to Toulouse when flying over an area ranging from India to South America. This has dramatically increased our ability to capture imagery throughout this area, process it and deliver it in near-real-time, which is needed more and more for such applications as responding to natural disasters, crop monitoring, etc."

Philippe Delclaux, Manager, Spot Image

Optical space communication systems can deliver high data rates, but yet have low masses and low power consumptions. The development of the SILEX payload has addressed all of the problems likely to be encountered in the building of future optical terminals, in terms of pointing accuracy, thermal and structural stability, optical surface characteristics and handling, point-ahead steering and many more.

SILEX represents the first application in space of an optical communication system. With minimum design changes, and by using the more powerful diodes and other components now becoming available, new small optical terminals can be produced which would be very competitive for future space data-relay systems as they are perceived today. Policy changes in the USA regarding the need for a high-bandwidth communications infrastructure have also focussed on the application of optical data-relay systems. It is therefore doubly important that European industry does not lose its lead in this area.

An extensive in-orbit technology-evaluation test programme is currently in progress with SILEX. It will measure such important system characteristics as far-field patterns, performance of optical paths, laser diodes and CCD's, as well as the micro-vibration environment, knowledge of which is vital for the development of tomorrow's terminals. A similar cooperative test programme is planned with NASDA's OICETS mission around 2005. The SILEX technology and experimentation programme will also be extended to include an experiment (LOLA) in 2006 between a new optical terminal on an aircraft and Artemis.

SILEX is also capable of pointing at a neighbouring satellite in geostationary orbit, and such an inter-satellite link demonstration mission could also be contemplated during the limetime of Artemis.

Ion Propulsion to the Rescue

"The use of ion propulsion on the Artemis satellite was the first significant step in Europe to demonstrate the readiness of a technology that is needed for the next steps of utilisation and exploration of the Solar System and even beyond. Only the very high specific impulse of ion propulsion will allow commercial satellites to use more than 50% of their launch mass for payload, to put meaningful scientific payloads into orbit around distant planets like Mercury or the outer planets beyond the asteroid belt, and enable humans to remain in space for long periods of time and ultimately fly to our neighbouring planet Mars."

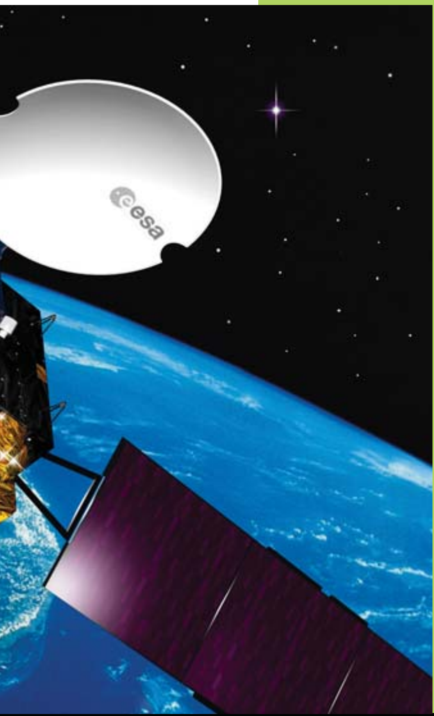
Rainer Killinger, Head of Electric Propulsion, EADS

Ion engines use ionised xenon gas for propulsion, rather than the chemicals found in conventional satellite propulsion systems. These novel engines offer a high exhaust velocity for much less propellant consumption than conventional chemical systems – providing tremendous mass advantages – and are therefore being baselined for many future communication satellites and deep-space missions.

Ion propulsion has been under development in Europe for more than a decade, and Artemis carries two prototype European ion-thruster systems, in a functionally redundant configuration. Originally planned to be used only for demonstrating north-south station-keeping in geostationary orbit, some 40 kg of xenon would have done the work of 400 kg of chemical propellant. The Artemis recovery operation turned out to be the first and totally unforeseen demonstration of their wider capabilities in orbit!

Many planned space missions that are only feasible when using ion propulsion have eagerly been awaiting the results of the original Artemis station-keeping demonstration. During the critical 18-month mission-recovery process, however, the ion-propulsion system operated for the equivalent of 4 years of geostationary lifetime and accumulated some 6000 hours of in-orbit operation. The Artemis experience therefore represents a major demonstration of the capabilities of ion-propulsion technology.

Further operation of the system in-orbit is important in order to answer any questions that remain concerning the future design and operation of ion engines, not only for the lifetime qualification in orbit of the engines themselves, but also for such system-related aspects such as their interaction with the attitude control system, and possible contamination or radio-frequency interference. Regular test campaigns to exercise Artemis's ion-propulsion system are therefore planned.



Re-programming the Satellite

"The Artemis programme has been a fundamental milestone in demonstrating both Telespazio's capabilities in the satellite-control domain and the Fucino Space Centre's ability to cope with highly demanding operational tasks."

Francesco D'Amore, Head of Fucino Space Centre, Telespazio SpA

The Artemis programme has also supported the development of the first combined data-handling and attitude-control system – the two most critical design areas of any satellite – relying on software running on a common onboard processor. Having already benefited from the Artemis development effort, similar systems are now in orbit on many operational platforms.

However, the Artemis system remains unique in having the freedom to exploit the re-programming capability to such a great extent. In fact, the new attitude-control strategy developed for the satellite's recovery has been retained as the best option for normal-mode operation in an inclined orbit. Moreover, an extension of this mode has been devised for station-keeping operations, which could be of great value for future telecommunications missions, as it provides for smooth attitude control during station-keeping without mode transitions, and with minimal operator involvement. This test-bed in orbit is therefore a critical asset that enables ESA to evaluate and improve the performance of its technology for application in future platform designs.

Mission Accomplished? – It's not over yet !

"Continuous operation of the satellite for the expected lifetime will provide additional confidence in the design and the technologies used, with important benefits for telecommunications in the years to come."

Antonio Pullara, Programme Manager, Alenia Spazio SpA

Not only has Artemis already clocked up a number of unique firsts in space during its recovery process – first optical inter-orbit satellite link, first major reprogramming of a telecommunications satellite in orbit, first transfer to geostationary orbit using ion propulsion, and survival of the longest ever operational drift orbit – but it is providing the much-needed promotional opportunity and stimulus for Europe's future data-relay services.

Artemis is also accomplishing its other main aim of improving the competitiveness of European industry. Technological breakthroughs and advanced in-orbit technologies are influencing many areas in the commercial world. Artemis is not only addressing the specific needs of European industry and operating agencies in this respect, but it is also expanding their capabilities and competitiveness in World markets.

In short, Artemis is heavily supporting Europe's autonomy in exploiting and using outer space. It is also promoting the interests of European industry and supporting major institutional efforts such as Earth Watch and EGNOS. Artemis's contribution to EGNOS is an essential element of that system's operation over the next several years.

Artemis is now working exactly as originally planned and, thanks to the role of its ion engines in the satellite's rescue, there is sufficient chemical propellant onboard for another 10 years of ground-breaking operations, both to prove the longevity of the newly developed European technologies onboard and to meet Europe's growing need for time-critical data for environmental monitoring and disaster mitigation.

Industrial Participation (at launch)

System	Alenia Spazio (Italy)
CDS	" "
Thermal Control	" "
Structure	Casa (Spain)
Power Subsystem	Fiar (Italy)
Solar Array	Fokker (Netherlands)
Solar Array Drive Assembly	Astrium (United Kingdom)
Batteries	Saft (France)
Unified Propulsion System	Fiat Avio (Italy)
Ion Propulsion RITA	Astrium (Germany)
Ion Propulsion EITA	Astrium (United Kingdom)
LLM Payload	Alenia Spazio (Italy)
SKDR Payload	" "
IAPS/IOL Antenna	" "

Forward Repeater	Alcatel Espace (France)
Return Repeater	Bosch Telecom (Germany)
TT&C	Alenia Spazio (Italy)
OPALE (SILEX)	Astrium (France)
System MGSE	ORS (Austria)
System EGSE	Laben (Italy)
Parts Procurement	Top-Rel (Italy)
Ground Segment & Operations	ALTEL (Alenia Telespazio, Italy)
	INDRA (Spain)
RYMSA (Spain),	Laben (Italy)
	Vega (UK)
	GMV (Spain)

Artemis Overview

Satellite Characteristics

Mass at launch	**3100 kg**
Power consumption	**2.5 kW**
Height	**4.8 m**
Length (solar array tip-to-tip)	**25 m**
Width (with antennas deployed)	**8.0 m**
Launch	**2001**
Lifetime	**10 yr**
Orbital position	**21.5°E**

Mobile payload

Coverage	**Europe, North Africa & Middle East (one European beam and three spot beams)**
Frequency bands	**1.5 GHz (L-band) to/from mobiles 12/14 GHz (Ku-band) to/from fixed earth stations**
Voice channels	**up to 662 bi-directional**
Mobile terminal antenna	**20 cm by 40 cm**

Data-relay payload

Coverage	**Approx. 65% of orbits up to 1000 km altitude**
Feeder/downlink coverage	**Western Europe**
Inter-orbit link (S-band 2GHz)	**Up to 1 Mbps in the forward direction (i.e. Artemis to low-altitude spacecraft) Up to 3 Mbps in the return direction (i.e. low-altitude spacecraft to Artemis)**
Ka-band (23/26 GHz)	**10 Mbps in the forward direction - 3 x 150 Mbps in the return direction**
Optical (800 nm)	**2 Mbps in the forward direction - 50 Mbps in the return direction**

Navigation payload

Coverage	**global (specifically Europe)**
Mass	**25 kg**
Power	**110 W**
Antenna	**L-band to user: 45 cm diam. horn antenna**
Frequency bands	**Downlink 1.575 GHz (L-band, L1 GPS) & 12.748 GHz (Ku-band) Uplink 13.875 GHz (Ku-band)**

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