OPTICAL SYSTEMS

High precision focused on planetary exploration

Knowing whether you are going to need an umbrella or seeing your house in a maze of streets on a gigantic map of the world are acts that have become part of our daily lives. **Complex optical systems that can zoom in on the Earth** from the heavens have made this possible.

Pointing towards outer space, optical systems are fundamental in the achievement of complicated scientific missions that unravel the mysteries of far-off galaxies, or in providing crucial information on the origin of the Universe. They are systems that reach places the human eye cannot, and amplify the view from our planet to incredible levels. In national or international programs, sponsored by transnational institutions such as the European Space Agency (ESA) or the European Southern Observatory (ESO), optical systems have become a key sector in civil and military technology. Spain, with SENER at the head, is beginning to stand out in the world scenario by virtue of its excellence in these projects.

Below: view of the rich star formation region NGC 3603 and its massive compact central star cluster, an image taken by the Hubble telescope.

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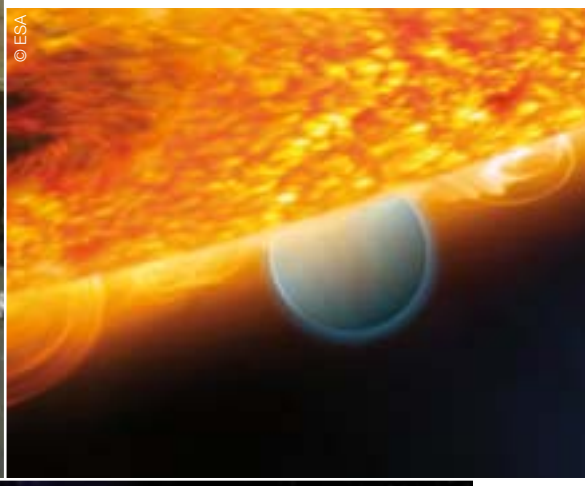
The 1980s, the beginnings

The field of optical systems is one of the most promising areas at SENER, and in recent years has witnessed a major development, particularly in flight equipment for space applications. But SENER's involvement in this field began with an important program carried out for the Spanish Ministry of Defense: the creation of a laser-guided missile, called the SBGL, which the company developed and successfully tested at the beginning of the 80s. The SBGL had a quadrant seeker whose effectiveness was demonstrated in real flying conditions. Its technology was much more advanced than that of other missiles of the time, such as the famous GBU-15.

In the 90s, SENER began to work on digital image processing, always in highly innovative fields such as image fusion or super-resolution. Equally noteworthy is the development of an image acquisition system in the visible and thermal spectra for combustion chambers in micro-gravity conditions for the ESA, as well as the LINZE project, which included the supply of an airborne camera on board an inspection helicopter for automatically recording the state of high-voltage lines in the visible and infrared ranges.

During this period, SENER also participated in different optical instruments for space applications as a supplier of precision mechanisms. It made the filter wheels and the refocusing mechanism of the FOC (Faint Objects Camera) that operated on board the famous Hubble telescope between

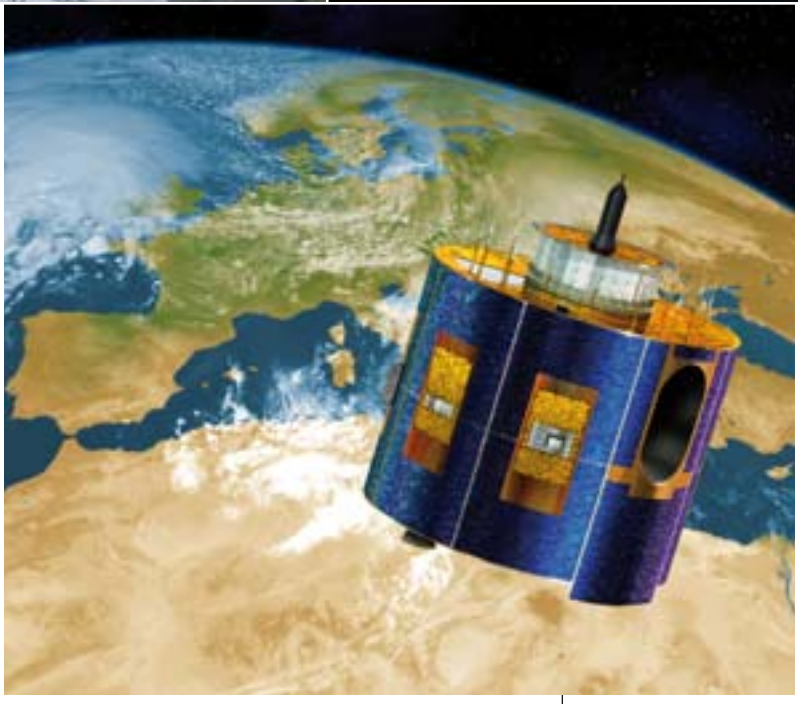


1990 and 2002. The refocusing mechanism makes it possible to correct the pointing of this camera with outstanding precision, enabling it to acquire images in the visible and ultraviolet spectra and to count individually the received light particles (photons). It recorded the first direct image of a star other than the Sun, the star Betelgeuse, also known as Alpha Orionis.

Consolidation in Space

These first contracts afforded SENER visibility in the field of optics for space applications, in which Spain lacked a specialized industry. Halfway through the 90s, the country began to study a national system for observation of the Earth that would permit the acquisition of images with applications in cartography, territorial planning, the management of natural resources and civil defense. These feasibility studies eventually took form as the National Territorial Planning Program, which included the SEOSAT/INGENIO satellite, and SENER was chosen as the company to supply the satellite's main payload, a high resolution camera with panchromatic and multispectral channels. As the projects progressed, SENER's optical instrumentation area gradually received new contracts.

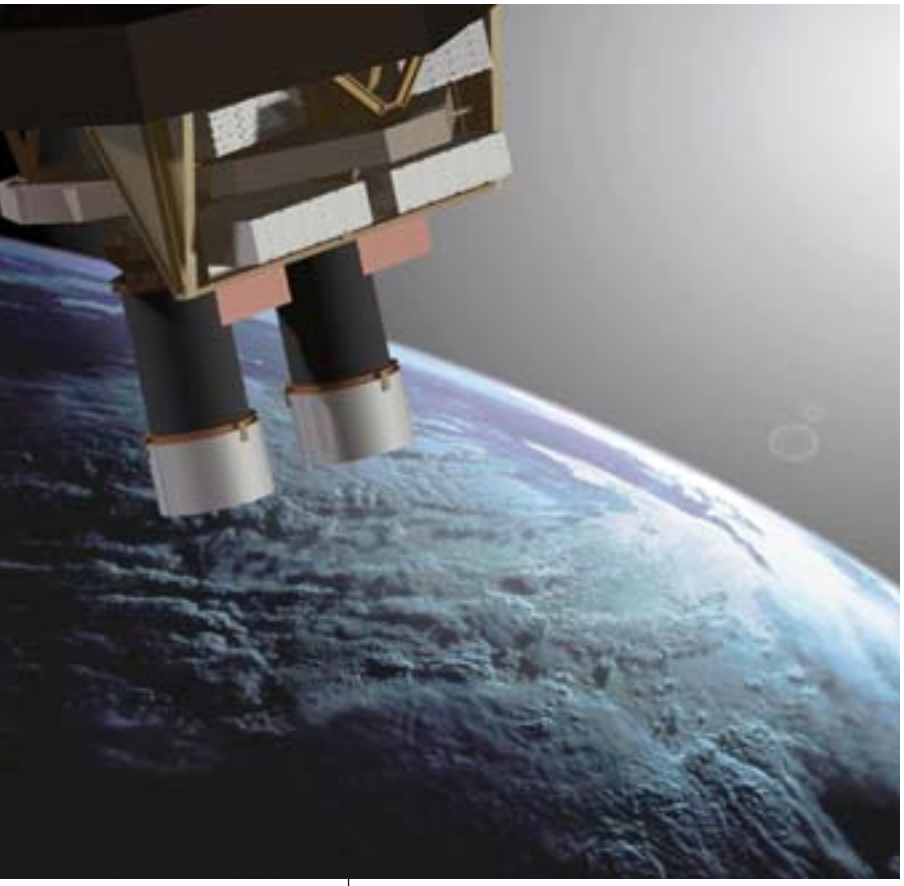
The Gaia satellite, an ESA program for composing the greatest map of our galaxy ever known through two powerful telescopes, will also carry SENER equipment. The company recently delivered the flight model of the refocusing mechanism of the secondary mirror (called M2M), an outstanding piece of equipment that renders it possible to adjust these mirrors with enormous precision (5 degrees of freedom and movement resolutions of tens of nanometers). And in Meteosat Third Generation (MTG), the ESA satellite which provides meteorological information on Africa and Europe, SENER has manufactured a first prototype of the scanning mechanism of the Flexible Combined Imager (FCI), whose precision of movement is counted in tenths of seconds of arc. The FCI camera can obtain images with higher radiometric resolution and greater precision in time and space of atmospheric conditions, cloudiness, humidity and fire, information which will help to provide more exact weather forecasts and to implement more efficient emergency action in the event of natural disasters, for example.



A present loaded with projects

Nowadays, SENER is the main contractor in optical instrumentation for scientific applications, particularly in the field of astronomy and astrophysics, both in image-formation systems and spectroscopy. In this field, the company is participating in the World Space Observatory – Ultraviolet (WSO-UV) project, a huge orbiting telescope whose scientific interest is comparable to the Hubble telescope's UV channels. SENER is the supplier of the ISSIS instrument (Imaging and Slitless Spectroscopy Instrument for Surveys), comprised of two high-

Above, on the left: **Meteosat Third Generation's testing mechanism in SENER facilities.**
Above, on the right: **an artist's impression of the Jupiter-size extrasolar planet, HD 189733b, one of the investigation lines of the astronomers using the Hubble telescope.**
Below: **artistic view of the Meteosat Second Generation.**



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Above: artistic view of the Spanish satellite for Earth observation SEOSAT/INGENIO. *Below:* SEOSAT/INGENIO's optical instrument configuration developed by SENER.

sensitivity cameras capable of taking images in the far ultraviolet. The company is also performing a feasibility study for the thermal infrared radiation camera of the EUSO project (Extreme Universe Space Observatory) that will be installed in the Japanese experimental module of the International Space Station (ISS). This camera will be used to detect high-energy particles in space. Other astronomy projects in which SENER is involved are the E-ELT (European Extremely Large Telescope) being developed by the CSE, for which SENER has designed the HARMONI (High Resolution Monolithic Optical/Near Infrared) instrument, a spectrograph of the near infrared, or the SOL2 feasibility study for permitting the communication of spacecrafts in deep space through laser-based optical links.

Of the ESA's planetary exploration missions, SENER is participating in the ExoMars mission exploring Mars. Specifically, the company is designing (among other projects) a spectrometer for the scientific payload of one of the rover vehicles that will be sent to the red planet to analyze samples of minerals and rocks from Mars. The Raman spectrometer will obtain information about the samples' structure and molecular composition. With its sights set on Mars, the company is participating in the development of the SOLID (Signs of Life Detector) instrument to discover signs of life on the planet by means of biological marker fluorescence detected by an optical system in field samples submitted to chemical processes.

The activity of the optical systems group in space projects has also been reinforced with the recent incorporation of the NTE-SENER company, which specializes in precision mechatronics for astronomy. Excellent examples are the filter wheels for the OSIRIS multi-object spectrograph of the Canaries Great Telescope (GTC) and above all the alignment mechanism of the secondary mirror for this same telescope. At the same time, SENER's experience in military applications leaves the way open for new projects in this field.

Be they for scientific or military use, in land-based or space applications, the development of optical systems calls for non-stop investment in technological innovation. SENER, faithful to its culture and driven by the pursuit of excellence, continues to work to improve both the integration and validation of complex optical systems as well as video electronics design capacity, a fundamental area for controlling the features delivered by an optical system. The goal is to become a leading company on the national scene and, in the medium term, a relevant actor in Europe within the complex, high-technology field of optical-systems development.

SEOSAT/INGENIO, THE KEY PROGRAM. SENER has been selected to supply the main payload of the Spanish SEOSAT/INGENIO satellite, comprised of a high-resolution optical instrument in panchromatic and multi-spectral bands for cartography and remote detection applications. In this project, SENER has carried out the complete systems engineering and complete opto-mechanical design of the instruments, coordinating, in turn, the work of the consortium, comprised of THALES España (in charge of the electronic module) and INTA (in charge of straylight studies and AIV of the instrument).

The main payload is comprised of two identical cameras, with a resolution of 2.5 m in the panchromatic channel and 10 m in each one of the four multi-spectral bands (R, G, B, NIR). Each camera covers a scanning width of 30 km, providing the 60 km required by the instrument, and is based on an optical design of the Korsch type, with a focal lens of 3.6 m and an aperture of 254 mm. The optical system, comprised of three on-axis conical mirrors, can provide images in the required spectral ranges, fulfilling very demanding conditions in terms of image quality (MTF) and signal-to-noise ratio.