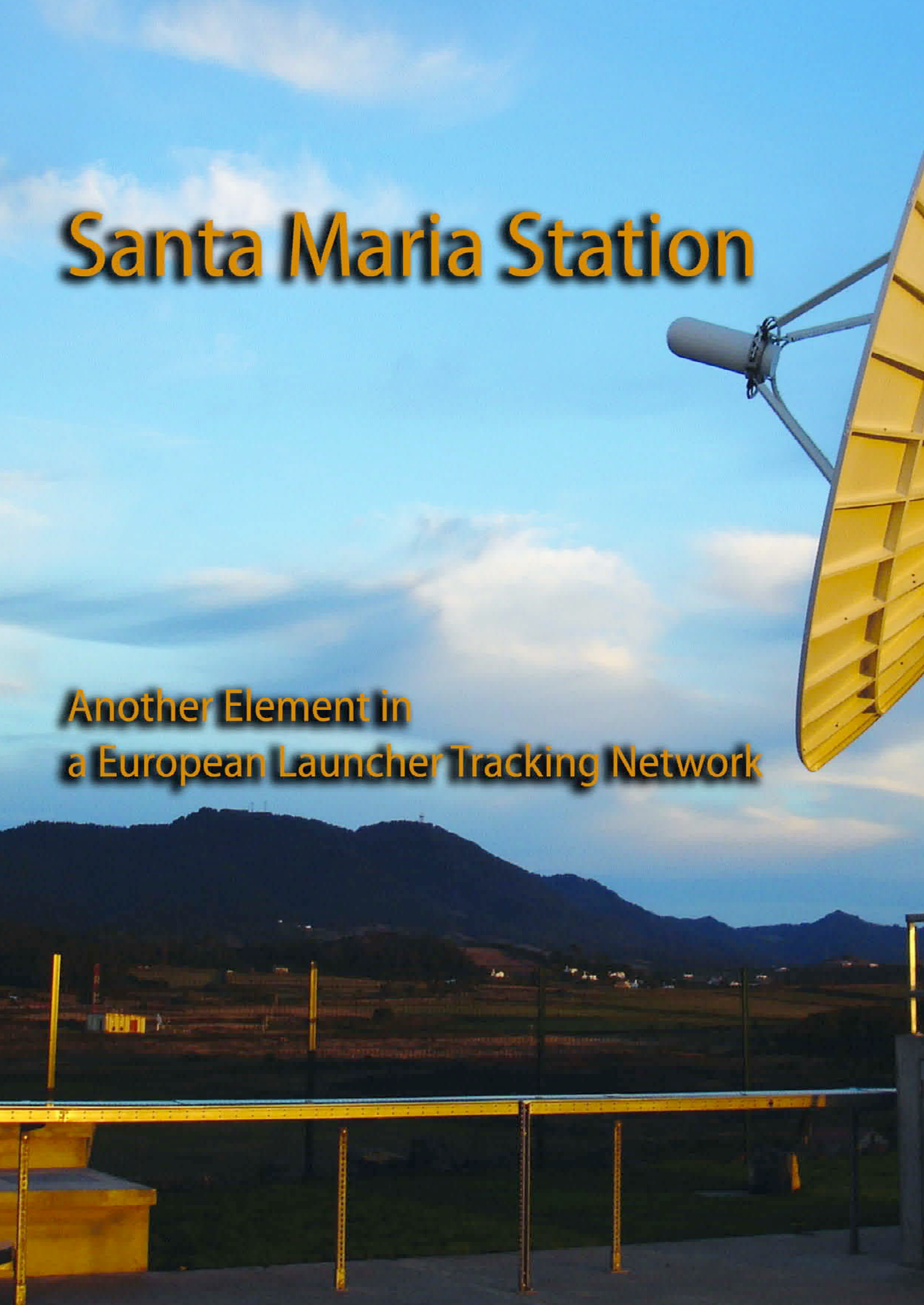
Santa Maria Station

Another Element in a European Launcher Tracking Network



The antenna and view of the Montes das Flores area from the Santa Maria station

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The Santa Maria station, also known as 'Montes das Flores' (Hill of Flowers), is located on the Portuguese island of Santa Maria, in the Azores. Santa Maria is one of ESA's first tracking stations with launcher tracking capability, used to receive real-time telemetry from launches from ESA's Spaceport in Kourou, French Guiana.

Introduction

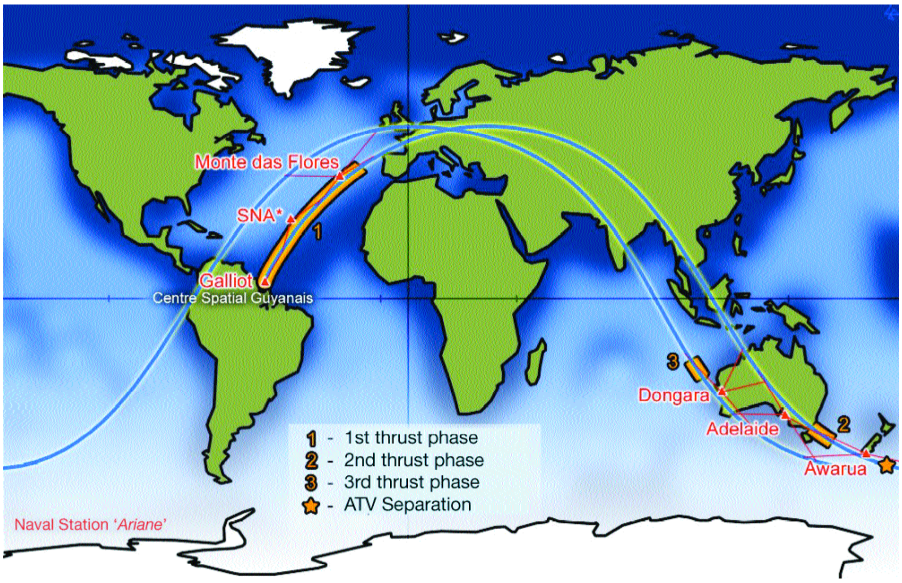
During any Ariane launch, the reception of vehicle data via telemetry is essential for several reasons, for example to provide information for the launch vehicle specialists and the customers and, of course, flight safety. Overall, more than 1500 parameters are measured from the launch vehicle and recorded throughout the flight.

All these data are received through a specific network of ground stations, historically called 'the Ariane network'. This is composed of several facilities, fully or partially dedicated to launch vehicle telemetry reception, and developed by the ESA Ariane programmes and operated by the French space agency CNES/Guiana Space Centre (CSG). The Ariane network is tailored for the most common Ariane trajectory (the geostationary transfer orbit, GTO), therefore its stations are based near the equatorial plane: Galliot station (Kourou), Natal (Brazil), Ascension Island in the South Atlantic Ocean (UK), Libreville (Gabon) and Malindi (Kenya).

For some specific missions, with trajectories other than GTO, additional facilities must be set up. For long ballistic or steady-state flight phases, it is possible to use on-board data recorders to cover the reception 'holes' between one ground station and the next. However, for some key phases, for example engine start/shut-off and stages or payload separations, real-time data reception is mandatory. This means that specific receiving facilities must be positioned in the right geographical locations.

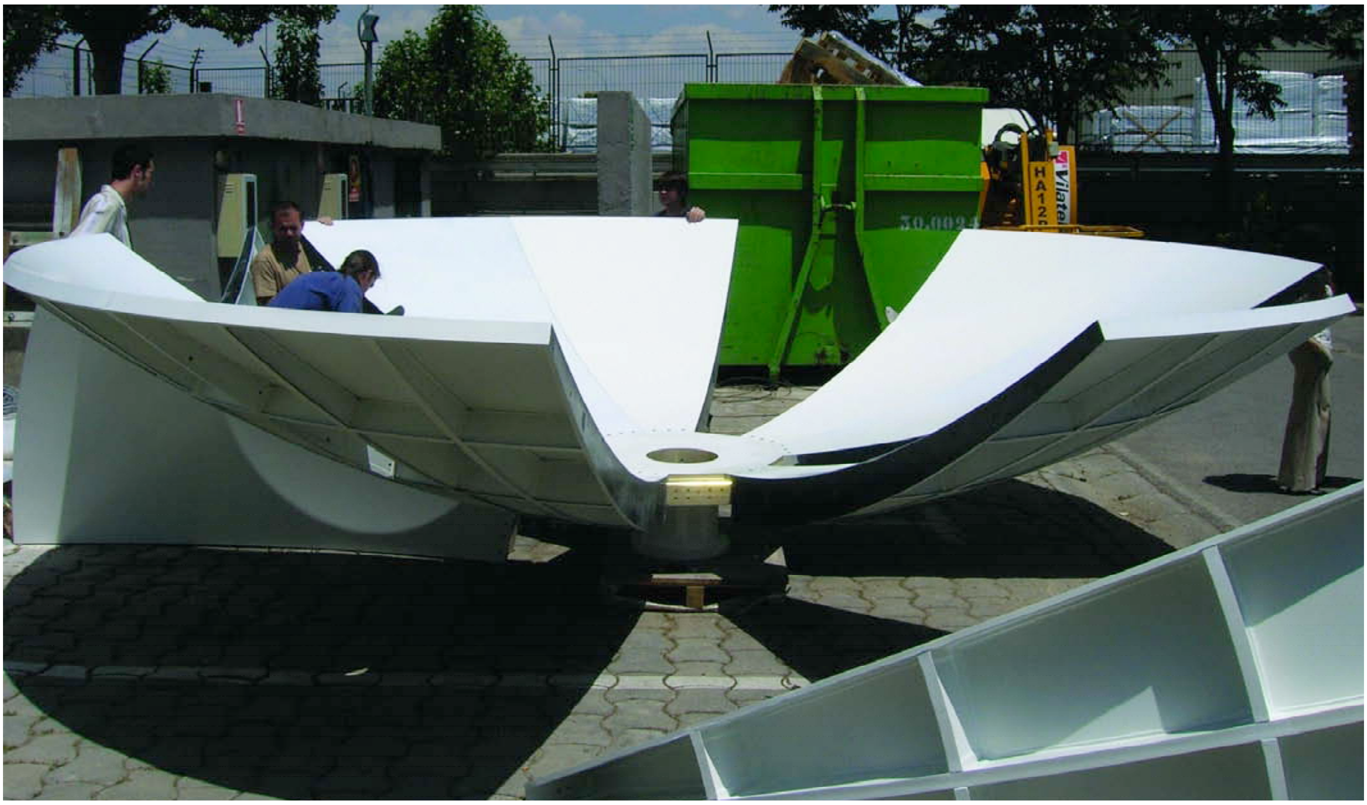
One of these 'exotic' missions is the launch of ESA's Automated Transfer Vehicle (ATV), such as the flight of *Jules Verne* that took place in March this year. This type of launch needed an inclined trajectory (about 50 degrees). From the very first Ariane/ATV mission analyses several years ago, it seemed evident that after the loss of signal from the Kourou station, the existing Ariane equatorial network was of no use and that a specific network had to be set up.

In the same period, Portugal joined ESA as a Member State, and this opened the discussions to investigate the possibility for setting up a telemetry reception site in the Azores islands, for inclined trajectories such as the ATV ones. The first site surveys were made jointly by ESA and CNES experts in 2003. The Santa Maria Island, the southernmost of the archipelago, turned out to be the best location, even if from a logistical point of view this solution was less easy than the main island of



ATV trajectory and ground station coverage

The site for the new ground station in 2006, with concrete platform, access road, power supply and lightning protection



The antenna dish under construction at Indra Espacio in Spain

São Miguel. Thanks to a very fruitful cooperation between ESA, CNES and local authorities (the regional government of the Azores and the Town Hall of Vila do Porto), some possible sites were identified on the island. One of these, in the 'Monte das Flores' area, 5 km from Vila do Porto, was selected.

Ground Station Build-up

When the ESOC involvement started, the site for the new ground station was already selected, and the infrastructure was prepared to temporarily host a portable containerised station. It consisted of a concrete platform, lightning protection, an access road and connection to the public power supply.

In July 2006, ESA awarded a contract to Carlo Gavazzi Space SpA to develop the new ground station in Santa Maria. The telemetry-receiving system (called the TM kit) had already been developed by the company and was in use at different equatorial ground stations to track Ariane-5 launchers. The new development called for an equipment shelter to house the new installation, and a new antenna system to receive the Ariane-5 telemetry. Indra Espacio S.A. was selected as supplier of the antenna. In addition the contract included the remotely controlled calibration tower equipment.

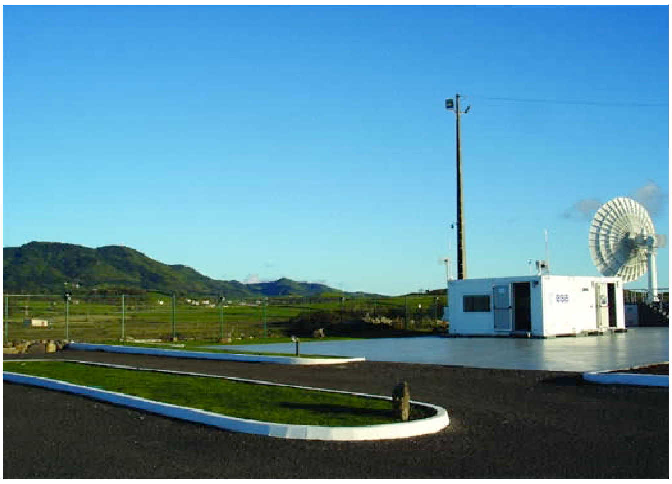
One key design parameter for the antenna is to autotrack an S-band telemetry signal with a received flux between –109 and –75 dBm/m^2, and to receive the Ariane-5 telemetry at a data rate of 1 Mb/s. For this a 5.5 m parabolic reflector made of carbon fibre sectors was selected with a newly developed prime focus feed.

Normally, satellites transmit on one frequency and the autotrack systems are also designed for one frequency. The Ariane-5 telemetry is transmitted simultaneously on two different frequencies from two antennas mounted on opposite sides of the spinning rocket. In this way at least one of the frequencies will be seen from the ground station.

This required the development of an 'autotrack' system that automatically selects the best signal to steer the antenna during the pass. Autotrack is the capability of an antenna to autonomously follow a target once acquired. This capability is crucial for launcher tracking, because the pointing predictions may not be as accurate as for satellites in well-known orbits.

As an extra option, an X-band feed with a dichroic reflector could be added to have the possibility to use the antenna to receive Earth observation satellite data in X-band. The antenna uses an X-Y mount to avoid problems when following targets at high elevation near zenith. There are still two points that the antenna cannot easily cover, but they are located at the horizon in a direction where the rocket is not expected to appear.

The design also had to consider the possible interference from nearby UMTS transmitters that had been found in radio frequency interference measurements



Views (left) inside the power generator plant, and (right) the completed station

made at Santa Maria. The UMTS frequency was outside the nominal Ariane-5 frequency band, but close enough to cause disturbance if not using input filters for the required attenuation of the UMTS signals (UMTS, or Universal Mobile Telecommunications Service, is a mobile computer and cell phone network standard).

In May 2007, the equipment shelters with the Ariane-5 telemetry kit and the calibration tower equipment were installed at Santa Maria. At the same time the antenna system was assembled and partly tested at the factory in Madrid. Performance tests in the factory were limited since there was no access to a calibration tower and there was a lot of domestic radio interference in the urban area.

In August 2007, the antenna was shipped to Santa Maria for installation and continued testing and commissioning. From October, the station was used for training and preparation by the operations team, in parallel with the final engineering verifications and then the final autotrack tests with an aircraft in January 2008.

Infrastructure

Since the plan changed to host the station permanently, the infrastructure needed to be adapted. From the Azores Regional Government, a power plant was supplied, providing fully autonomous electrical power to the station by means of diesel generators and Uninterruptible Power Supplies. The design process was in close collaboration with ESA. Furthermore, a site security system, a fence and a telecom system was installed to adequately support the permanent installation.

Inauguration of the complete ground station took place in January 2008, integrating the station into the ESA Tracking Network.

Validation

The majority of the validation tests was done the same as for satellite ground stations. Some of the requirements, however, made extra tests necessary, mainly the tracking and the end-to-end data flow tests. End-to-end data flow tests with the

The Portuguese Minister of Science, Technology and Higher Education, Prof. José Mariano Gago (left) shakes hands with Gaele Winters, ESA's Director of Operations and Infrastructure, with Carlos Cézar, President of the Autonomous Region of the Azores, and José Contente (right), Regional Secretary for Housing and Infrastructure at the formal inauguration of Santa Maria station, 17 January 2008

customer took place between the ground station and CSG directly. These tests comprised all aspects of data exchange: extracted launcher telemetry, orbital predictions as well as telemetry recording.

Autotrack test campaign using an aircraft
The launcher, as seen from the ground station, appears to have a much higher angular velocity than a satellite. This is mainly because the launcher is much closer when over Santa Maria, around 200 km compared to roughly 800 km for a satellite in a low-Earth orbit.

Obviously testing of the autotrack function was highly desirable, both for the ESOC team as well as for CNES/CSG, but this was not possible using satellites as is normally done for tracking stations. The solution was to downscale the geometry by a factor of about 100 and to replace the target with an aircraft carrying representative transmitters.

The equipment was installed in a 10-seat twin-propeller aircraft, with one antenna in the front window and one in the back, both radiating to the lefthand side on the two different frequencies. For flight regulations, both antennas had to be mounted inside, but the two different locations made it possible to see at least one antenna from the station. This was also a good test case for the frequency diversity function.

The pilots flew exactly along a path, defined by GPS coordinates, at a given speed, simulating both passes of the rocket over the ground station. The test was performed successfully in January 2008, and the results confirmed the theoretical analysis and local measurements already performed earlier. With this, the antenna was fully validated and technically in a state to support the launch.

Seen after the ATV launch, the full Santa Maria team including support (top, from left): Paulo Rocha, Ricardo Conde, Ricardo Mourao, Diego Rodriguez, Maite Arza, Herve Tailame, Boris Smeds, Aage Riise, (front) Robert Launer, Gerhard Billig

Operational Preparation

The operations performed for launcher tracking are somewhat different than those for satellite tracking, but the preparations for satellite support at ESOC formed a solid baseline for this new type of support. The operations team, composed of the maintenance and operations contractor consortium Edisoft/Segma/Global EDA and ESOC engineers, underwent an intense training session by CNES at CSG in 2007, to understand the specifics and the elements of operation during a launch support.

Operational qualification
The Santa Maria ground station was part of the Ariane-5 launcher tracking network for the ATV *Jules Verne* launch. Operational qualification of that whole network was performed in January 2008. The Santa Maria station took part in this, when all the elements occurring during a normal launch countdown and the launch support were exercised. In addition to this, station-dedicated operational and performance tests were performed, as also done for satellite launch supports. This mainly covered contingency situations, which the team had to respond to, also under time

pressure. By mid-February, all preparations were finalised and the station was ready for launch.

Launch campaign

The launch campaign started 10 days before launch. Now the tests again comprised the whole station network and were mainly focused on the smooth work-together of all the involved entities. This culminated with the Repetition Generale, which was a simulation of the full launch countdown and launch chronology.

Launch countdown and launch support

As the support to Ariane-5 for ATV takes longer than for a normal mission (1.5 orbits), also the countdown phase is longer. The station team was required to be on post 10 hours before lift-off. All the preparations and tests went nominally; everything was 'green' for the launch. Lift-off took place at 05:03 CET in the night of 9 March 2008. Twelve minutes later, the Santa Maria station received the signal of the rocket and telemetry provision to CSG started. The whole pass went smoothly. The rocket could even be seen visually during its thrust phase.

All the other stations also received the signal flawlessly and the separation of ATV finally took place over New Zealand. Half an orbit later, the rocket was again tracked by Santa Maria. Again, the new station and its team worked perfectly. The mission ended successfully after the deorbit burn, again monitored over New Zealand.

Outlook

The Santa Maria station is being upgraded with X-band (8 GHz band) receive capability to allow reception of Earth observation satellite payload data. For this, a dichroic sub-reflector will be put in front of the S-band feed, only reflecting the X-band signals into the X-band feed located on the main reflector. The station will support the MARISS and CLEANSEANET initiatives when it is not required for launcher tracking.

ESA tracking stations

The ESA tracking stations network - ESTRACK - is a worldwide system of ground stations providing links between satellites in orbit and ESA's European Space Operations Centre in Germany. The core ESTRACK network comprises 13 terminals sited at nine stations in six countries.

The essential task of all ESA tracking stations is to communicate with our missions, up-linking commands and down-linking scientific data and spacecraft status information. ESTRACK stations also gather radiometric data to help mission controllers know the location, trajectory and velocity of their spacecraft.

ESTRACK stations provide additional services, including searching for and acquiring newly launched spacecraft, autotracking, frequency and timing control using atomic clocks and gathering atmospheric and weather data. Some stations are also equipped with GPS receivers connected to our GPS Tracking and Data Analysis Facility at ESOC, enabling highly precise orbit and geophysical calculations.

Each ESTRACK station hosts one or more terminals, each of which comprises an antenna and its associated signal processing equipment. Stations can support multiple missions and ESTRACK also shares resources with other agencies and satellite operators.

ESTRACK Core Network

Kourou (French Guiana), Maspalomas, Villafranca and Cebreros (Spain), Redu (Belgium), Santa Maria (Portugal), Kiruna (Sweden) and Perth and New Norcia (Australia). The ESA Perth ground station, located in Western Australia, is being upgraded to receive launcher telemetry.

Maspalomas

Villafranca

Perth

Kiruna

ESA Deep Space Network

ESTRACK's new 35 m stations at New Norcia (Deep Space Antenna 1, DSA 1) and Cebreros (DSA 2) form the European Deep Space Network.

The new stations provide the improved range, radio technology and data rates required by current and next-generation exploratory missions such as Mars Express, Venus Express, Rosetta and BepiColombo.

Cebreros

ESTRACK Augmented Network

The ESTRACK system also includes terminals operated by external organisations on ESA's behalf:

1. MAL-1 in Malindi (Kenya)
2. SG-3 in Svalbard (Norway)
3. AGO-1 in Santiago (Chile)

Additional stations are used in some cases, including Alaska, Dongara and Weilheim (used most recently for Cluster).

Svalbard

CNES/CSG Ariane network

In order to cover the entire length of an Ariane's trajectory when launched from Kourou, CNES/CSG uses a network of downrange stations whose antennas relay signals to CSG as the launch progresses.

The network consists of the following stations: Galliot (Kourou), Natal (Brazil) Ascension Island (UK), Libreville (Gabon) and Malindi (Kenya), and now Santa Maria in the Azores.

Natal, Brazil