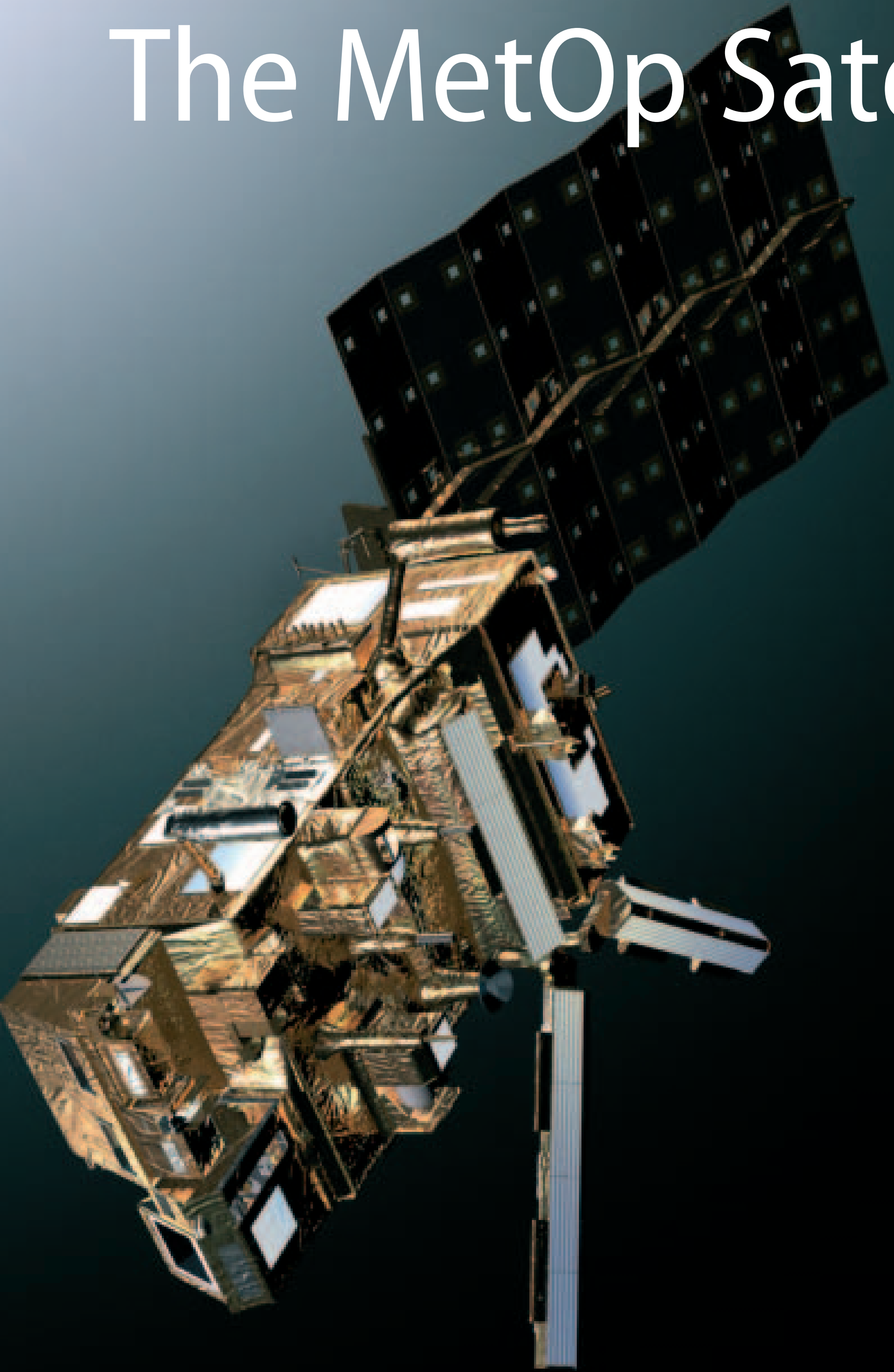
The MetOp Satellite



Weather Information from Polar Orbit

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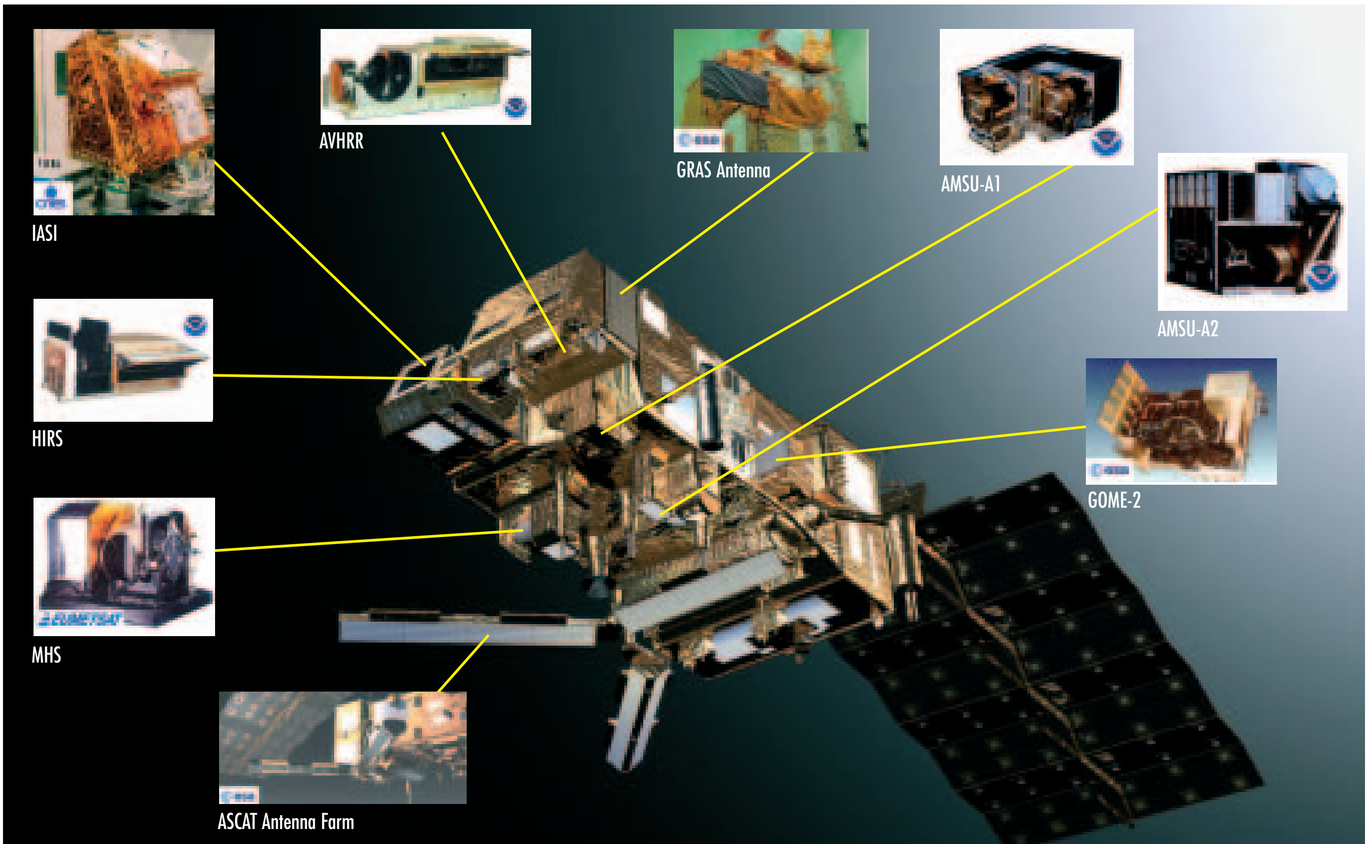
MetOp-A is Europe's first polar-orbiting satellite dedicated to operational meteorology. With its array of advanced instruments, it will provide data of unprecedented accuracy and resolution on temperature and humidity, wind speed and direction over the ocean, and ozone and other trace gases, making a huge contribution to global weather forecasting and climate monitoring. In addition, MetOp-A will observe land and ocean surfaces and its search-and-rescue service will help ships and aircraft in distress.

Introduction

MetOp-A is Europe's first satellite dedicated to operational meteorology from polar orbit. It will balance the long-standing service provided by the US since the first Tiros satellite in 1960. The US has provided the data from this evolving series free of charge to the world's meteorological community. As early as 1967, Europe looked at contributing to this effort, but selected the geostationary satellite mission as the higher priority. This led to the development of the Meteosat series, which has been remarkably successful since 1977.



The MetOp Payload

The three satellites carry identical payloads except that HIRS and S&R are not aboard MetOp-3.

AVHRR Advanced Very High Resolution Radiometer: a 6-channel visible/infrared imager with a pixel size of 1 km square at nadir. Its data are used, inter alia, to identify clouds, generate cloud parameters, measure sea-surface temperature and derive vegetation conditions. AVHRR has been the primary low-orbit imager for meteorology for more than 20 years, and also flies on NOAA's satellites.

HIRS High-resolution Infra-Red Radiation Sounder: a 19-channel infrared sounder measures atmospheric temperature and humidity profiles, with one visible channel for cloud identification. Pixel diameter is about 10 km at nadir. HIRS is also flying on NOAA's satellites.

AMSU-A Advanced Microwave Sounding Unit: a 15-channel 23–90 GHz microwave sounder to produce atmospheric temperature profiles. It consists of two separate sounders (AMSU-A1 and AMSU-A2) to cover the frequency range. Microwave measurements have the significant advantage of being much less affected by the presence of clouds than infrared soundings. The AMSU-A pixel diameter is 48 km. The instrument is also flying on NOAA's satellites.

MHS Microwave Humidity Sounder: a 5-channel, nadir-viewing 90–190 GHz microwave sounder provides atmospheric humidity profiles. It is a technological advance on the previous-generation AMSU-B on the NOAA-K/L/M satellite series. Nadir pixel size is about 15 km. It is also carried by the NOAA-N and N′ satellites.

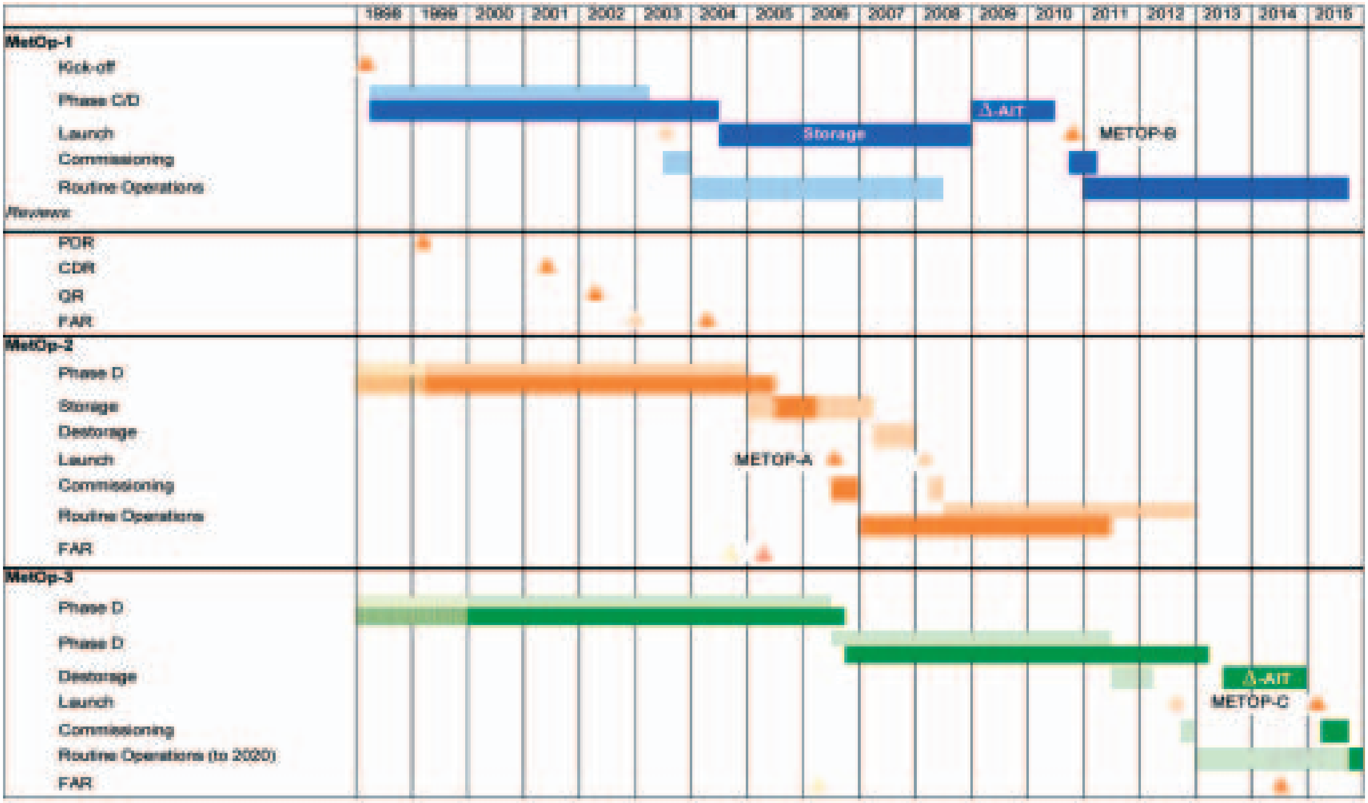
HIRS, AMSU-A and MHS together constitute the **ATOVS** Advanced TIROS Operational Vertical Sounder suite, which provide the operational sounding data from low orbit for today's numerical weather prediction models. The AVHRR imager supports this sounding mission for cloud detection. In addition to these operational sounding and imaging instruments, MetOp carries the new-generation **IASI** Infrared Atmospheric Sounding Interferometer, a nadir-viewing Michelson interferometer operating at 3.6–15.5 micron.

GOME-2 Global Ozone Monitoring Experiment: an improved version of the GOME instrument on ERS-2. It monitors the ozone concentration and the components involved in ozone chemistry in the atmosphere. It measures the backscattered ultraviolet-visible sunlight in four bands between 240 nm and 790 nm, at a spectral resolution of 0.25–0.5 nm. It also monitors the concentrations of trace gases such as bromine oxide, nitrogen dioxide and sulphur dioxide.

ASCAT Advanced SCATterometer: a C-band (5.3 GHz) dual-swath (2 x 550 km) radar providing ocean wind speed and direction. It is an augmented version of the radar on ERS-1/2, with a 25 x 25 km grid resolution. In addition, high-resolution wind information can be generated over a 12.5 x 12.5 km grid. ASCAT can measure sea-ice type and boundaries. Land surface applications are an emerging area and will provide global soil moisture data for numerical weather prediction.

The **GRAS** Global navigation satellite system Receiver for Atmospheric Sounding uses signals from the GPS constellation of satellites slicing through the atmosphere to produce atmospheric temperature and humidity profiles, complementing the data from the nadir-viewing scanning sounding instruments.

Other payloads include: the **SEM** Space Environment Monitor, which measures the charged particle environment; the **A-DCS** Advanced Data Collection System, which collects data from various meteorological and other platforms; and a **S&R** Search & Rescue package for locating distress beacons.



Comparison of the schedule planned in 1998 (lighter colours) with the achieved schedule (solid colours). CDR: Critical Design Review. FAR: Flight Acceptance Review. PDR: Preliminary Design Review. QR: Qualification Review

In 1992 plans were formulated to extend Europe's contribution by using using satellites in polar orbit. ESA's MetOp-1 programme was approved in 1998, followed shortly after by approval of the Eumetsat Polar System (EPS). Eumetsat – the European Organisation for the Exploitation of Meteorological Satellite – is charged with operating the system once the satellites are developed and launched by ESA. The joint system is the basis for an improved being offered to the world's meteorological organisations. It also satisfies specific needs of the European and US meteorological services.

The notable improvements required from MetOp include:

- new instruments (ASCAT, IASI, GOME-2, GRAS) in addition to the existing suite on the NOAA satellites of the US National Oceanic & Atmospheric Administration (AVHRR, HIRS, AMSU-A1/A2, SEM);
- a low-rate digital direct broadcast VHF service to replace the analogue Automatic Picture Transmission system, employing data-compression to ensure high-quality images;
- continuous onboard recording of the global dataset to be dumped every orbit at a high-latitude ground station, with the ground system providing the global processed data within 2.25 hr of the measurements being made;
- high pointing accuracy and orbital stability to ensure that data can be geo-located without reference to ground-control points in imagery;
- selective encryption to meet the commercial and data-denial needs of Eumetsat and the US Government, respectively.

Programme

The ESA MetOp-1 Programme is an optional programme of the Agency, subscribed to by 12 member states (Austria, Belgium, Denmark, Finland, France, Germany, The Netherlands, Norway, Spain, Sweden, Switzerland, United Kingdom) and covering the design and development of the first satellite as the space segment for EPS. The EPS Programme is funding the building of two recurrent satellites, the launch of all three satellites, and the design and construction of a ground segment to operate the satellites and process, archive and distribute the data collected. EPS is designed for a total operational lifetime of 14 years. The EPS Programme is also making a financial and material contribution to the ESA MetOp-1 Programme, providing 36% of the € 746 million cost (current conditions).

Accordingly, the ESA/Eumetsat Single Space Segment Team was established to manage MetOp development via a joint contract with the industrial Prime Contractor (EADS-Astrium, Toulouse, F). While this arrangement inevitably led to increased bureaucracy, and could have resulted in significant organisational frustration and friction, most potentially contentious issues in practice were addressed positively thanks to the constructive attitudes of the teams in ESA and Eumetsat.

Challenges

MetOp carries 13 instruments provided cooperatively by Eumetsat, ESA, NOAA and CNES. They vary from the largely recurrent units (AVHRR, HIRS, AMSU-A1/A2) developed within the US Polar Orbiting Environmental Satellite (POES) Programme to wholly new instruments developed specifically for MetOp (IASI, ASCAT, GRAS). The accommodation of such a diverse payload, each with its very specific requirements and constraints, proved to be a major challenge. Coordinating and synchronising the delivery of the instruments for three satellites and an Engineering Model required significant effort and flexibility. From the start, the development schedule for two major European instruments (IASI and GOME-2) lagged significantly behind MetOp's timeline. MetOp development, which kicked off in early 1998, baselined launch-readiness of the first satellite in mid-2003. Late availability of instruments, coupled with later development problems in the ground segment, pushed the first launch to mid-2006. Then three attempts 17–19 July were scrubbed and the Soyuz launcher was returned to its factory for refurbishment.

Despite this, the financial impact caused by this major delay have been contained within reasonable bounds thanks to a complex restructuring. This allowed primary qualification of the design, including vibration, thermal vacuum and electromagnetic compatibility tests, to be achieved in mid-2004 using a payload module comprising a mixture of Engineering Model and flight-standard instruments. The MetOp-1 satellite was then placed in long-term storage and will be completed with its full flight payload for launch as MetOp-B around 2009–2010.

Meanwhile, the MetOp-2 integration and test schedule matched the availability of the first flight instruments. MetOp-2's assembly, integration and verification was completed in mid-2005 and the satellite was placed in short-term storage, awaiting call-up for the first launch in 2006 as MetOp-A. That gap was a consequence of delays accrued in the complex Eumetsat ground system.

Finally, the core modules of MetOp-3 (Service Module, Payload Module and Solar Array) have also been completed and put into long-term storage, but without the full set of instruments. The missing instruments will be delivered over the next 2-3 years and added before the call-up for launch, as MetOp-C, around 2014–2015. The satellite's own integration has also been deferred until this time.

MetOp-1 and MetOp-3 are stored as separate modules in enclosures purged with nitrogen. The Payload Modules and critical elements of the Service Modules are reactivated annually to assure longevity of important equipment.

MetOp Main Features

Orbit: Sun-synchronous, near-circular, 817 km altitude at ascending node; repeat cycle 29 days (412 orbits); local solar time 09:30 (descending node)

Mission life: 5 years

Launcher: Soyuz ST-Fregat (also compatible with Ariane-5)

Size: 6.2m (high) by 3.4 x 3.4 m cross-section in launch configuration; 17.6 x 6.5 x 5.2 m with solar array and antennas. deployed

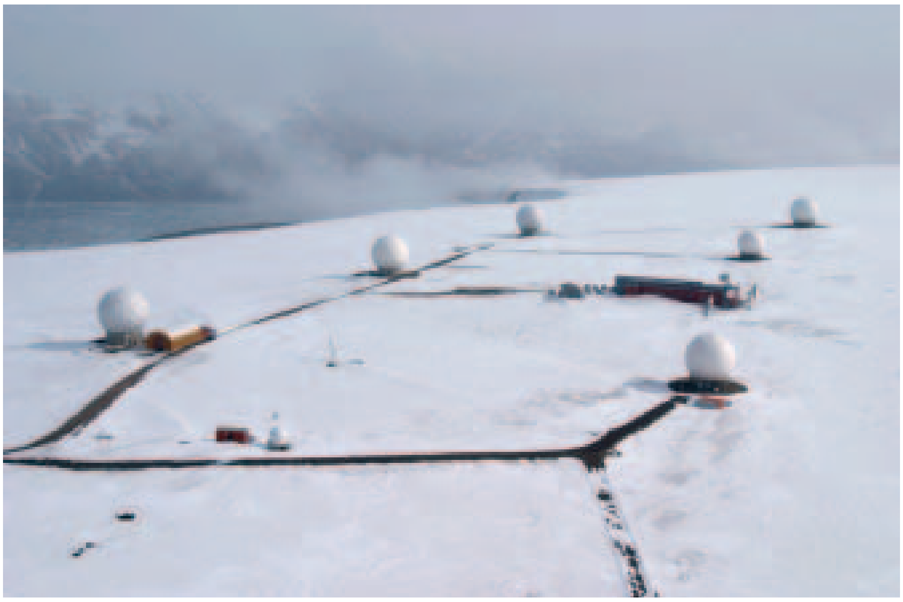
Launch mass: 4093 kg, including 316 kg hydrazine in 4 tanks

Attitude control: 3-axis stabilised by reaction wheels; orbit manoeuvres by hydrazine thrusters; pointing knowledge 0.07° X-axis, 0.11° Y-axis, 0.15° Z-axis

Data-handling: science data acquired as CCSDS packets (the standard set by the Consultative Committee for Space Data Systems); science data formatting and multiplexing, encryption for selected instruments; instrument and housekeeping data storage in solid-state recorder (24 Gbit end-of-life)

Communications: omnidirectional S-band coverage (uplink 2 kbit/s, downlink 4 kbit/s); instrument global data stream downlinked via X-band (70 Mbit/s); realtime broadcasting of instrument data with HRPT at 3.5 Mbit/s via L-band for all instruments, and LRPT 72 kbit/s

The Svalbard station in the far north of Norway provides contact with MetOp on every orbit



System Overview

EPS is devoted to operational meteorology and climate monitoring. It consists of the MetOp satellites, the core ground segment of satellite command, control and health monitoring, instrument data processing and dissemination, data archiving and retrieval facilities in Eumetsat's central site in Darmstadt (D), and a control and data acquisition station in Svalbard (N). Svalbard's northerly position (78°N) inside the Arctic Circle gives it the unique advantage of being within range of MetOp on all 14 orbits each day.

Satellite

The satellite and its payload embody a great deal of heritage from Spot, ERS and Envisat, leading to significant cost savings in development and paving the way to efficient exploitation of the data. Further, most of the instruments are either fully recurrent units or have operational precursors. The sole exception is GRAS, and even this is the operational follow-on to an in-orbit experiment.

The satellite is modular, consisting of two largely independent modules, the Payload Module (PLM) and the Service Module (SVM), and a deployable Solar Array.

The PLM houses the instruments and their support systems. Instrument sensors and antennas are mounted on the external panels, while most of the electronics are housed internally.

The SVM is derived from the Envisat and Spot-5 service modules. It consists of a box-like structure interfacing with the launch vehicle and the PLM. Subsystems provide standard support such as attitude and orbit control, electrical power (solar array) and data management, including telemetry generation and telecommand processing.

The Payload Module

Accommodating a large set of instruments was a major design driver for the overall satellite and the PLM configuration, with many constraints originating from the instruments' fields of view, antenna patterns and thermal radiators. The PLM also houses all of the avionics to ensure:

- power regulation for the US instruments (they need a 28 V regulated power bus not available from the SVM);
- power distribution: each unit or instrument is powered through a switchable and protected line, provided by specific PLM units;
- command and control: a dedicated data bus, based on the European On-Board Data Handling Standard is used. The PLM computer receives commands from the SVM and interfaces with the European instruments' control units, the MHS adaptation unit and the NOAA interface unit for the US instruments;
- handling of scientific data via acquisition, formatting, encryption and transmission to ground of packetised data through the regional broadcast links: High-Rate Picture Transmission (HRPT), which contains all the science data, and the limited subset of Low-Rate Picture Transmission. Additionally, following storage in the solid state recorder, the global data-set is transmitted to ground through an X-band link.

MetOp and its Soyuz launch vehicle

The Service Module

The SVM provides all the standard service functions, including:

- attitude and orbit control, to maintain accurate Earth-pointing for the various operational modes, and to perform orbit acquisition and maintenance;
- propulsion, for orbit and dedicated manoeuvres, and propellant storage;
- power generation, through the solar array, storage, conditioning and overall distribution;
- distribution of commands from the ground and onboard, and collection of housekeeping telemetry data for transmission to ground through the S-band link;
- central software for telemetry generation, telecommand processing and various application functions, such as thermal control, onboard surveillance and automatic command sequencing.

Changes and Problems

Large and complex satellites usually encounter changes to the requirements and technical and programmatic difficulties along the way. MetOp was no exception in its 8 years of development.

Launcher

The programme began on the basis of a dual launch on Ariane-5, but the lack of available co-passengers compatible with MetOp's very specific orbit meant that an alternative had to be sought. Eventually, following a competitive process run by Eumetsat, the Starsem Soyuz-ST was selected. This required no modifications to the MetOp design, as the Soyuz interfaces were fully consistent with the Ariane standard, and the launch environment (particularly mechanical) was generally equivalent to, or more benign than, Ariane-5.

Checking the radio emissions of MetOp in the anechoic chamber in Intespace. The satellite's complex payload and many antennas made it difficult to avoid interference

However, some additional system analyses were necessary. The compatibility of the propulsion system and MetOp's structural fatigue life with the horizontal encapsulation, launcher integration and ground transportation imposed by Soyuz had to be assessed. Analysis of the random vibration levels generated by Soyuz (not required for Ariane) was carried out, and an analysis (primarily thermal) of the extended period required for MetOp injection into the baseline orbit (some 70 minutes after lift-off, versus 20 minutes for Ariane) was necessary.

In reality, however, the major effort resulting from this shift was in the additional preparation and planning required for the launch campaign in Baikonur, ensuring the compatibility of the cosmodrome facilities with MetOp's final integration, test and encapsulation, and preparing the logistics. MetOp-A and its support equipment for the launch campaign filled three Antonov-124 heavy-lift cargo planes!

MetOp's mission requirements call for use of the new-generation Soyuz-ST with a Fregat upper stage. Soyuz modifications include a new fairing (similar to an Ariane-4 fairing), mechanical adaptation and strengthening of Fregat, and a new digital avionics system for a more flexible launch trajectory and sufficient stability margins to cope with the aerodynamics of the new fairing. Specifically for MetOp, the thrust is offset from the longitudinal axis for both stage-3 and Fregat to cater for the large offset of MetOp's centre of mass.

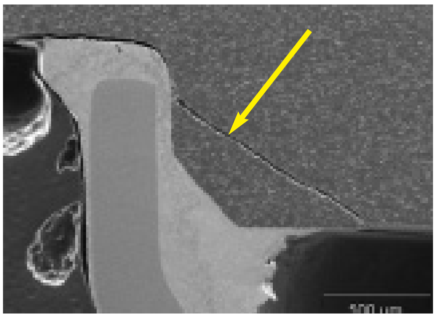
All of these launcher modifications were subjected to a rigorous qualification campaign from late 2004 to May 2006.

Electromagnetic and RF interference

Avoiding electromagnetic and radio-frequency (RF) interference between the instruments and avionics was one of the greatest design and verification challenges. Two main concerns were evident from early on in the programme. The first was the necessary common electrical grounding all elements despite their different design heritages. The second was the coexistence of powerful radio transmitters on one side and extremely sensitive receivers in a large frequency band (100 MHz up to 200 GHz) on the other.

The radio-compatibility campaign was particularly demanding because of the second point, with the high number of transmitters/receivers and the multi-purpose antennas. This required early testing with a full-size satellite mock-up to determine how they were coupling and, in some cases, to assist in finalising the antenna design.

MHS and GOME were modified after it was discovered that their emissions were being picked up by the Combined Receive Antenna owing to the extreme sensitivity of the Search & Rescue receiver. Later tests on MetOp-1 showed the need for additional local GOME shielding and improvement in the electrical harness shielding of the SVM Sun and Earth sensors. The testing also confirmed the need for an electro-



Brazing the cell connectors in MetOp-type batteries sometimes created cracks (arrowed)

magnetic enclosure to reduce the emissions from the interface harness between the PLM and SVM. The modifications were verified on MetOp-2, with additional 'sniff' checks made at Baikonur to confirm the shielding on the final flight configuration.

Batteries

Leaks in cells of MetOp-type nickel-cadmium batteries have been seen a few times on Envisat, Spot/Helios and ATV. They finally appeared on MetOp, but affected only the 'integration batteries' used on the ground. The cause was found to be cracks in the ceramic material isolating the cell connectors, from thermal/mechanical stress during brazing to the battery cover.

Investigations to isolate the problems and to develop and qualify improvements were exhaustive – taking more than 3 years. They were ultimately successful, with no further leaks occurring in the flight batteries delivered for MetOp.

Thruster control valves

During the MetOp-A SVM thermal tests, a leak of pressurising gas from a propellant flow-control valve was found at low temperature. A similar event occurred later on the MetOp-C SVM. It was puzzling, because these valves have a long and successful history in space, having been used on Eureca, XMM-Newton and Integral without problems. The cause was found to be a combination of thermal contraction and creepage of the valve's elastomeric seal.

As a result, all the valves on all MetOp models were leak-tested at low temperature on a special rig. On MetOp-A, valves leaking above 4°C (the lowest qualification temperature, and the freezing point of hydrazine) were replaced with leak-tight valves.

A test representing the MetOp storage time and the mission duration was performed on two leaking valves to monitor any change over time. Although it showed that the temperature at which leaks started increased with time, it confirmed there would not be a problem under realistic conditions: with the hydrazine pressurised at 22 bar, both valves remained leak-tight even at abnormally low temperatures of around +5°C. The operating conditions in flight are always warmer than 11°C in safe mode and 25°C during normal operations.

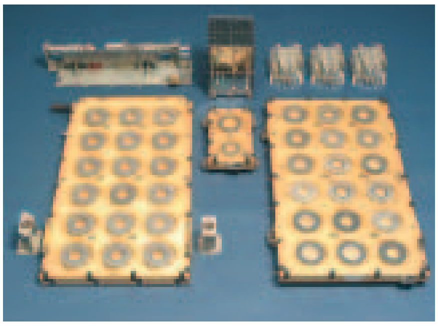
It was also demonstrated that MetOp is rather insensitive to leaks. Early detection, isolating a leaking branch and even disabling the entire thruster system are at the disposal of the operator (procedures are detailed in the flight operations manual) without major impact on the mission.

GRAS ground processing prototype

The GRAS ground processing prototype (GPP) was developed to validate the performance of the GRAS instrument and its level-1b algorithms. It was a demanding task becasue the error sources are numerous, depending on the instrument and external sources such as the GPS navigation satellite constellation, the atmosphere and ionosphere. A detailed error budget was compiled by the instrument supplier, and had to be confirmed using the GPP.

To demonstrate this budget, a complete simulator environment was developed to simulate the signals generated by the full GPS satellite constellation. All the errors can be added one by one, or all together and with variable magnitude.

In view of the accuracy needed for GRAS, which is much greater than for a standard GPS receiver, the verification of all the simulator modules and their interfacing was a meticulous task that took more time than expected. It included extensive testing with various datasets from the real instrument. The results of this complex test programme have been used for correcting and fine-tuning the level-1b data-processing algorithms for the instrument.



Gold-plating the GRAS antennas solved the corrosion problem

GRAS ASIC

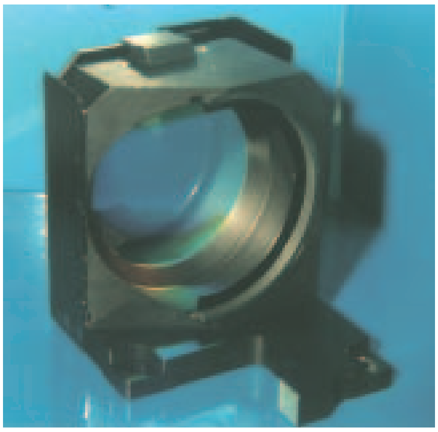
The GRAS receiver is built around an Application-Specific Integrated Circuit (ASIC) known as 'AGGA-2' which performs most of the digital processing of the GPS signals. This was developed for another space application, but was finally qualified within the MetOp programme. A significant number of problems were discovered during the process, which led to the ASIC's redesign as the AGGA-2A. The redesign and requalification took considerable time, and risked MetOp's schedule. Extra efforts in industry, coupled with workarounds for the satellite integration, avoided this.

GRAS antenna metallisation

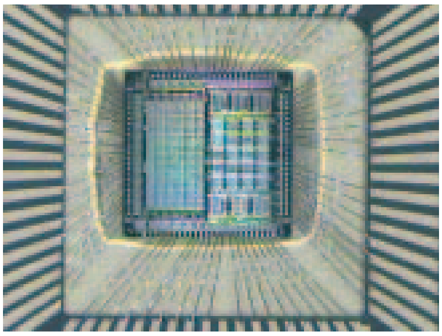
The three GRAS antennas (one for navigation and two for occultation measurements) initially had carbon-fibre structures finished with a layer of aluminium. It transpired that the combination can lead to corrosion – and MetOp's antennas shed flakes of corroded aluminium. Instead, gold-plated antennas were qualified and remanufactured.

GOME-2 improvements

Once in orbit, GOME-2 must be



GOME's diffraction gratings had to be recoated to prevent absorption of moisture



ASCAT's switching front-end ASIC

precisely calibrated by 'observing' a set of three light sources: a hollow cathode lamp for spectral calibration, a tungsten lamp for the broadband, and the Sun via a diffuser. On GOME-1 this diffuser was an electrically-grounded aluminium surface. Even though this type of diffuser adds only very small spectral features to the incoming light (less than a fraction of 1%), it still distorts GOME's results. Instead, a 'quasi-volume diffuser', which contributes only a tenth of the aluminium's effects, was identified. Following lengthy qualification, the original aluminium diffusers were replaced by the new models in all of the GOME-2 models.

GOME gratings

During calibration of GOME-2, the optical efficiencies of channels 1 and 2 were found to be lower than expected. It was soon established that the efficiencies of their diffraction gratings had degraded. After deep analysis by the supplier, the cause was identified as the porosity and resultant moisture absorption of the coating, which affected, at the sub-micron level, the geometry of the gratings. A slightly modified coating process was developed to produce stable coatings.

The deficient gratings were stripped and recoated, and GOME's calibration was successfully repeated. In parallel, the long-term stability of grating samples is being carefully monitored.

ASCAT switching front-end ASIC

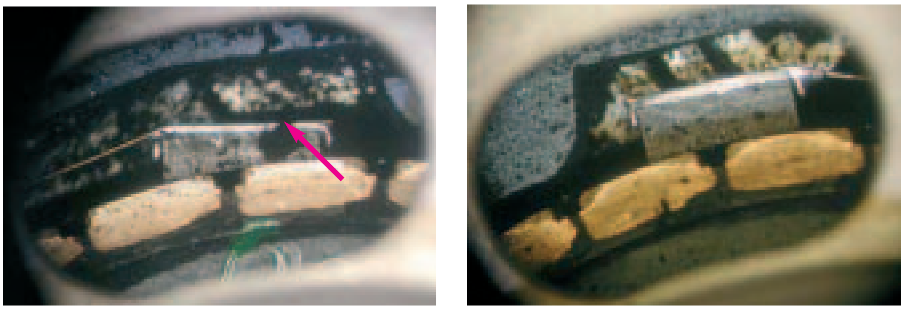
This ASIC for the ASCAT scatterometer includes both analogue and digital circuits that turned out to involve non-standard (and now obsolete) technology. Their production proved to be very time-consuming, and then, in addition to the delays caused by late delivery of the components, two major issues were found during development. First, the technology was found to be highly susceptible to electrostatic discharges, which destroyed many parts during assembly. Improvements in the ASIC's design (causing further delays) and in the soldering process did not completely remove the risk. However, sufficient numbers could be produced, and the discharge threat was not a problem once the components were assembled in the units. Dedicated life tests on all the switching front-end units confirmed their flightworthiness.

The second issue was that radiation tests showed the parts were highly susceptible to proton and heavy ions, causing a high rate of bit-flips. If this happened in flight, ASCAT would be unavailable while it was reset. The problem was solved by reprogramming the switching logic, so that the antenna switches were systematically reset at the start of each switching cycle.

ASCAT antenna deployment motors

Excessive wear of the motor brushes was found during life testing of the ASCAT antenna deployment motor. The motors were tested in air, vacuum and under simulated orbital conditions. Following an unsuccessful search for a better brush material, it was decided instead to replace the brushes close to flight.

Over-worn brush on ASCAT's antenna deployment motor (left, arrowed). Normal wear on a bedded-in brush (right)



Conclusion

MetOp is one of the most complex satellites ever developed in Europe. It provides both continuity and major advances in observational data for meteorologists and Earth scientists.

Despite significant delays in the deliveries of key instruments, and many challenges along the way, the first MetOp was launched from Baikonur in July in time to meet Europe's commitment to the Initial Joint Polar System of meteorological satellites with NOAA. This is thanks in no small part to the close cooperation between ESA, Eumetsat, CNES, NOAA and NASA, founded on the excellence of the ESA industry teams led by EADS-Astrium for MetOp and Galileo-Avionica for GOME-2.

Detailed information on MetOp and its mission can be found at www.esa.int/metop and in the new brochure "MetOp: Monitoring the Weather from Polar Orbit" (BR-261, available from ESA Publications)

FAR to Launch: A Long Journey

MetOp-A completed its Flight Acceptance Review (FAR) at EADS-Astrium in Toulouse in July 2005. The go-ahead to prepare for launch in early summer 2006 was then given. At the same time, remaining open items had to be taken care of, including retrofitting some instruments, swapping some avionic units and completing the investigations of anomalies.

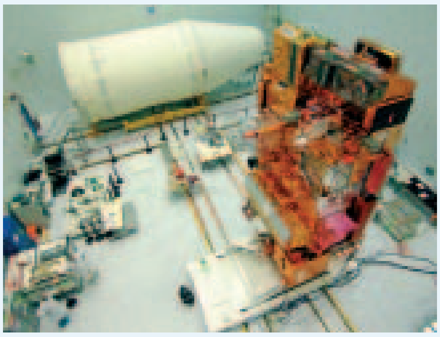
Soyuz has seen more than 1700 launches so far, with a reliability exceeding 95%. It is the workhorse of the Russian space programme and a key element for operating the International Space Station. Starsem has used it for 16 successful commercial launches. Starsem is a European-Russian partnership created in 1996 by the key players involved in the production and operation of Soyuz (EADS Space, Arianespace, Roskosmos, TsSKB-Progress).

Baikonur is the world's largest space centre, spread over thousands of square kilometres among the barren steppes of Kazakhstan. Built in the mid-1950s as a strategic test site, it dispatched hundreds of launchers and missiles each year at its peak from around 65 pads.

Organising the MetOp launch campaign was a complex task. Three fully loaded Antonov-124 cargo flights were needed to transport all the flight and ground hardware from Toulouse to Baikonur. Its size meant that MetOp's Service Module, Payload Module and Solar Array had to be transported separately, and then reassembled and tested. A large quantity of electrical ground support equipment was transported and installed at Baikonur, occupying some 500 m^2 of the Payload Processing Facility and the Upper Composite Processing Facility (UCPF) in the MIK 112 building, to perform the final checks on the satellite and its instruments.

MetOp-A arrives at Baikonur

The solar array is attached to MetOp during final reassembly at Baikonur



The flight-ready MetOp awaits encapsulation in its Soyuz fairing

Permission to ship was finally granted in March 2006, at the end of the satellite preparation activities in Europe and after the Launch and Operations Readiness Review confirmed the ground segment was ready. On 10 April the first of the Antonovs was on its way to Baikonur, followed by the main flight elements on 17 April and the final cargo with the Solar Array on 20 April.

The launch campaign team, representing the main participants in developing the satellite (ESA, Eumetsat, Astrium, DutchSpace) and instruments (NASA, CNES, ITT, Northrop-Grumman, Galileo Avionica), worked in Baikonur for 3.5 months. Averaging 55 people, this is the largest team involved so far in a Starsem launch campaign.

After arrival in Baikonur, 9 weeks were required for the satellite's final assembly and checkout, achieved by mid-June. During this time, unplanned last-minute replacements of two US instruments (AMSU-A1 and -A2) were made. They were urgently shipped from the US following the discovery of problems affecting the MetOp-A instruments.

The satellite was fuelled in the second half of June and finally, at the beginning of July, MetOp-A was declared ready to meet its Soyuz upper stage in the UCPF cleanroom. Reflecting the team's hard work in preparation over the previous months, MetOp, the Soyuz adapter, the Fregat upper stage and the intermediate bay were stacked flawlessly in sequence.

On 8 July the team had the last chance to wish good luck to MetOp before it was slowly slid into the large fairing during the horizontal encapsulation. Following a 6-hour train transfer, the fairing composite reached MIK40, where the upper composite was mated with its Soyuz.

A final short train ride brought the vehicle to Pad 31 on 14 July where, after the last countdown rehearsal, the launch was targeted for 22:28:10 local time (16:28:10 UT) on 17 July. But faulty software checking the inertial platform's alignment stopped the countdown 1 h 36 min before launch. On 18 July, the automated checkout routines proved unable to deal with the partially-fuelled launcher configuration, which had resulted from investigations into the previous abort. This led to an abort 3 h 10 min before launch. On 19 July, it was within 185 sec when the ground system again stopped the clock, this time due to an operator error. Unfortunately, this meant that the Soyuz exceeded the maximum time it can be kept on the ground after fuelling, so it had to be returned to the factory for refurbishment. Meanwhile, the upper composite was demated and arrived back in in MIK 112 on 22 July, where the fairing was removed. Everything is being kept ready awaiting the decision on a new launch date.