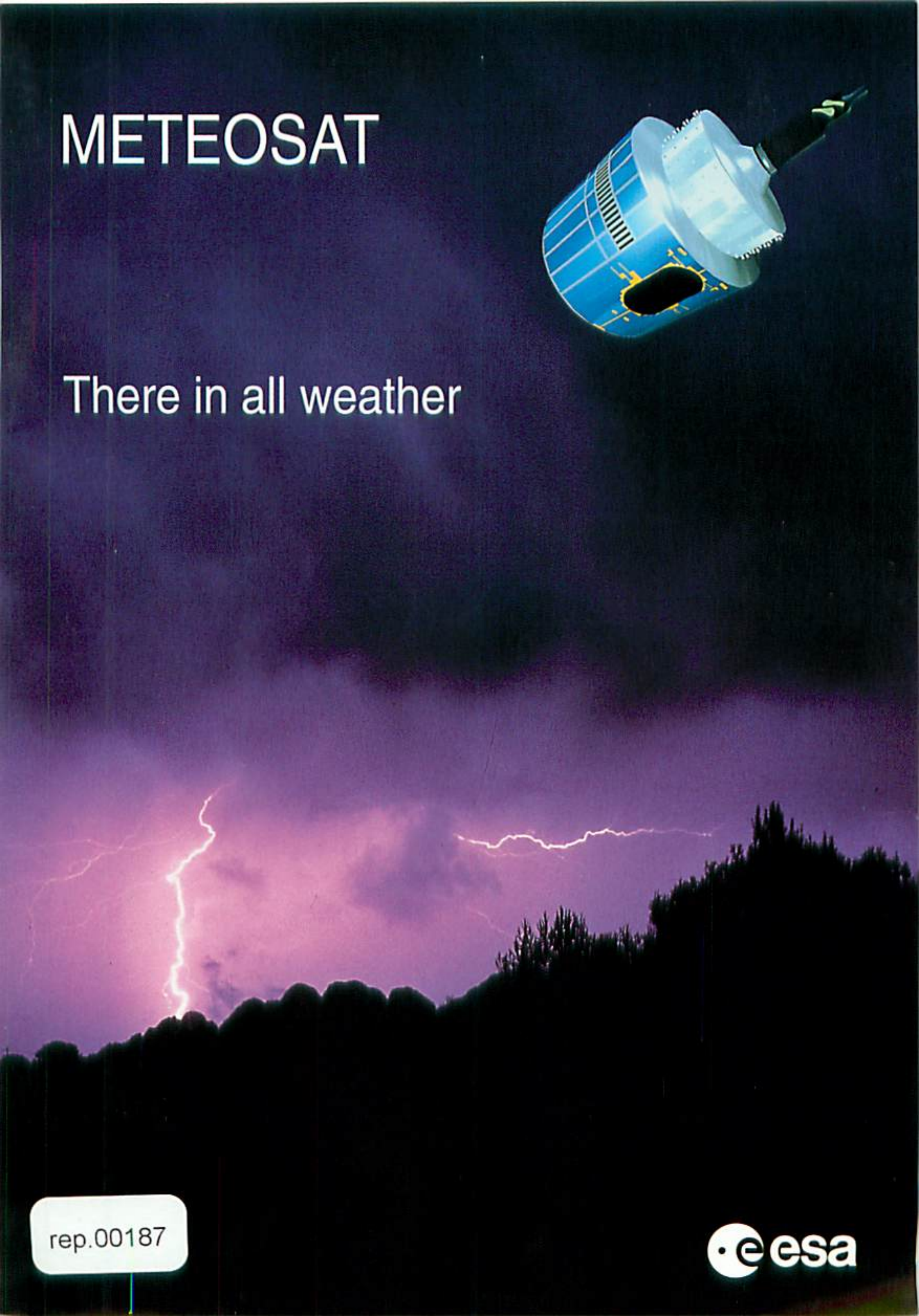
METEOSAT

There in all weather



METEOSAT

THERE IN ALL WEATHER

"One must wait until the evening to see how splendid the day has been."

Sophocles

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Clouds With A Silver Lining

As the European Space Agency (ESA) and EUMETSAT prepare to launch the sixth Meteosat weather satellite, recent independent economic studies have shown that every cloud seems to have a silver lining. The economic benefits of improved weather forecasting are worth hundreds of millions of Pounds Sterling in Europe alone.

Meteosat's images of the weather are an everyday feature of European television, but most of us are not aware of how dependent we all are upon accurate weather forecasting. Power stations run more efficiently because accurate weather forecasts allow the forward demand for electricity to be assessed with greater precision. Construction companies plan their scheduling around weather forecasts so that their workers are not left standing idly around building sites in bad weather. For the same reasons roads are quickly cleared of snow and ice, reducing accidents, insurance claims and saving lives. Long distance air traffic routes are now optimised just before take-off, as fresh Meteosat data comes in every 30 minutes.

In terms of saved resources alone Meteosat's contribution to weather forecasting is calculated at approximately £90m a year - more than twice what ESA spends on manufacturing and operating the satellites themselves!

The first satellite in the series, Meteosat-1, was launched in 1977, followed by four others in 1981, 1988, 1989 and 1991. All operate from a position over the equator at 0 degrees longitude providing weather information over Europe, Africa and the Middle East. However in 1991, Meteosat-3 was shifted westwards over the Americas. From its new position, it supplies data over the Americas to NOAA, the US weather service, which has only one operational weather satellite left in geostationary orbit. Meteosat-3 plays a key role during the hurricane season, providing early warning and real-time monitoring of these destructive weather anomalies.

All Meteosat satellites consist of four stacked cylinders. The main body is covered with solar cells. Most subsystems, including the radiometer which generates the images, are also located in the cylinder. The radiometer is a telescope which has three detectors in its focal plane to measure the radiance of the Earth and its cloud cover in the visible, thermal infrared and water-vapour spectral bands.

Raw images are transmitted from the satellite to a ground station near Darmstadt, Germany. It is here, at the ESA Operations Centre, that these images are processed and meteorological products derived and distributed via a telecommunications payload onboard Meteosat to a network of over 2000 receiving stations all over the world.

Forecasters value Meteosat's capability to deliver global weather information in real-time. Placed in geostationary orbit, at 36000 km above the Equator, it ensures a continuous flow of data - one set of images every thirty minutes, available day and night, 365 days a year.

The Meteosat satellites are financed by EUMETSAT, an inter-governmental organisation founded in 1986. Its primary role is to establish, maintain and exploit European systems of operational meteorological satellites. The prime users of Meteosat data are the meteorological offices of EUMETSAT Member States. ESA is currently responsible for developing and launching the satellites, and operates them on behalf of EUMETSAT. Aérospatiale of France leads an industrial consortium of European companies that manufacture the spacecraft.

Meteosat-6 will help to ensure the continuity of meteorological data from Space. Following its launch in late 1993 and comprehensive in-orbit testing, ESA is confident that it will be able to hand over yet another European weather satellite in top condition to EUMETSAT.

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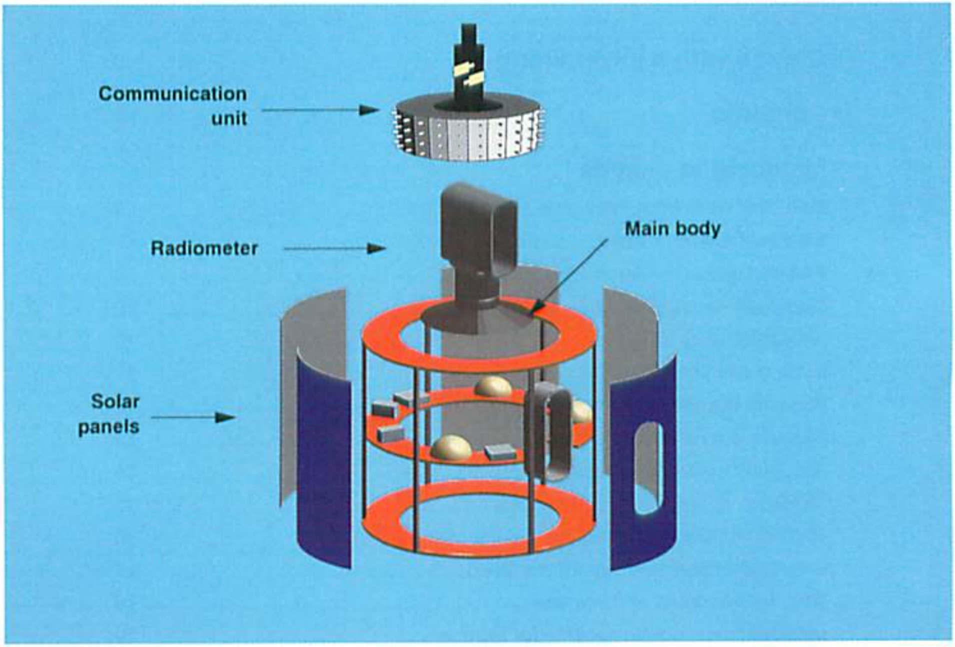
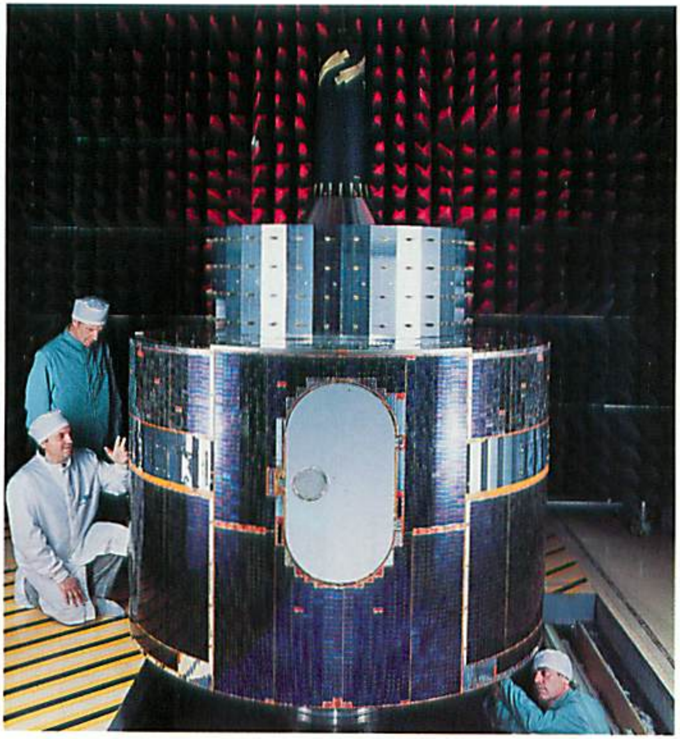


The Meteosat satellites are composed of a main cylindrical body to which six solar panels and a telecommunications payload (top) are attached. The radiometer, which generates the images, is located inside the cylinder together with most of the electrical systems and spherical tanks filled with propellant for the thrusters to perform attitude manoeuvres.

The radiometer is a telescope with a focal length of 3.65 metres and electronic detectors in its focal plane to measure the Earth's radiance in three spectral bands: 0.5-0.9μm (visible band), 5.7-7.1μm (infrared water vapour absorption band) and 10.5-12.5μm (thermal infrared window band). The spatial resolution of the radiometer is 5km in the infrared and 2.5km in the visible band.

The telecommunications payload is equipped with power amplifiers and antennas to receive processed Earth images and other meteorological data via the Odenwald ground station, and to transmit them to over 2000 user receiving stations throughout the world.

Illustration: ESA



Meteosat barely resembles a "typical" satellite, reflecting the fact that its principal mission differs from that of most other satellites in geostationary orbit which are mainly concerned with telecommunications services. The main feature of Meteosat is a big cylinder containing a special telescope - the radiometer. This cylinder's shining dark blue cover consists of solar cells, and the two smaller cylinders stacked on top of it carry a telecommunications system and special antennas.

Unlike most other satellites, Meteosat spins in orbit (at 100 rev/min) to stabilise its attitude. At the same time, the spin motion enables the radiometer, which before launch is covered by a white protective lid, to scan the Earth from East to West in consecutive lines. As these lines build up from the South to the North Pole, a fresh image showing a full Earth disc with up to 5 000 lines is made every 30 minutes.

All the Meteosat satellites have been manufactured by Aérospatiale of France, at whose test facilities this photo was taken in April 1993.

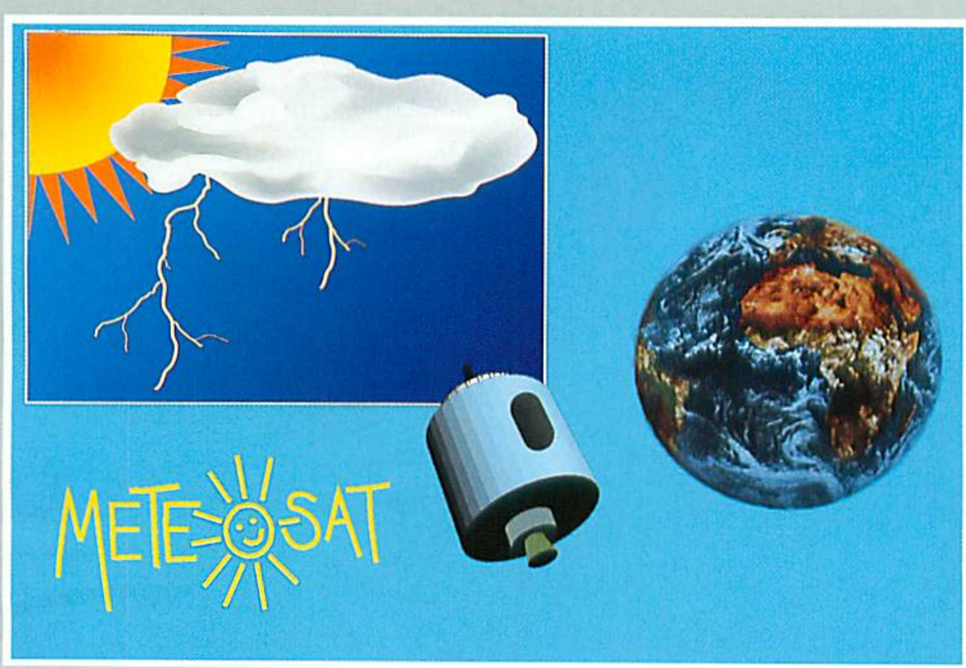
Photo: ESA/David Parker

French Guiana, 1 March 1991: Liftoff!

This photo shows Meteosat-5 being launched by Ariane from CSG, Europe's spaceport in French Guiana, on the evening of 1 March 1991. Ariane and Meteosat are undoubtedly the two best known offspring of the European Space Agency. As both have left the experimental or pre-operational stages, ESA has handed them over for exploitation to specialised space operators: Arianespace for the production and marketing of the European launcher, and EUMETSAT for establishing, maintaining and exploiting operational weather satellites.

ESA has equipped the CSG, Europe's spaceport in Kourou, French Guiana, with modern launch facilities. All the Meteosat spacecraft, apart from the first, have been launched from the CSG, whose location, just five degrees north of the Equator, is particularly suitable for launching satellites into geostationary orbit.

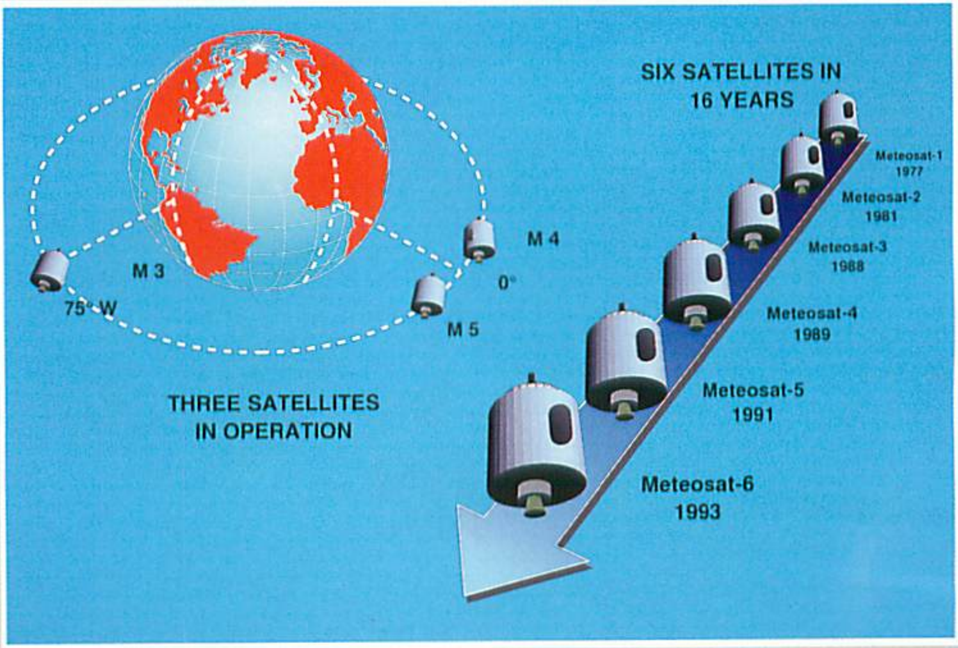
Photo: ESA/CNES/CSG



Data from Earth observation satellites have become indispensable for numerous researchers, public services and operations around the world. Only satellites have the global overview it takes to deliver a continuous flow of measurements needed for a fuller understanding of the Earth's weather and climate. ESA's contribution to this worldwide effort began with the Meteosat spacecraft, and is continuing with the environmental ERS satellites, the first of which was launched in 1991.

Meteosat has a threefold mission: first, its radiometer constructs accurate images of the Earth in three spectral bands at 30-min intervals; second, Meteosat collects environmental and meteorological data from nearly 1000 measuring stations on ships, planes or buoys and transmits them to a central facility; and, third, Meteosat transmits processed images and meteorological data directly to several thousand user stations in more than 130 countries.

Illustration: ESA

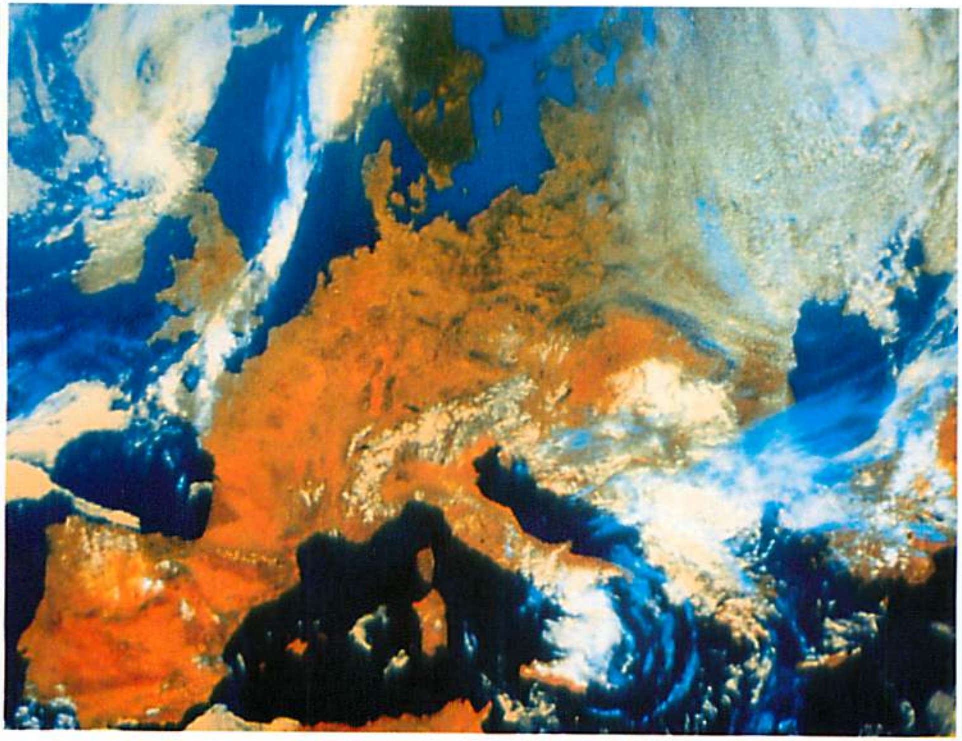


When ten European States decided in the early 1960s to pool their resources in joint space projects, they initially concentrated on scientific missions. But it soon became apparent that Space offered many opportunities, most notably for Earth observation and telecommunications. Thus ESA launched a first weather satellite, Meteosat-1, in November 1977, followed by Meteosat-2 in June 1981.

As these satellites fulfilled their mission to the complete satisfaction of meteorologists and scientists, a specialised organisation, EUMETSAT, was set up in 1986 by 16 European states to establish, maintain and exploit operational meteorological satellite systems.

The first and the second Meteosats have been switched off after many years of successful operations. ESA is currently running Meteosat-3, -4 and -5 on behalf of EUMETSAT and continues to supervise the manufacture of new satellites. Meteosat-6 is already waiting to be launched by Ariane in late 1993. As to the future, a seventh Meteosat satellite is now under construction and is to be launched by Ariane, this time under a EUMETSAT contract, in 1995/96.

Illustration: ESA

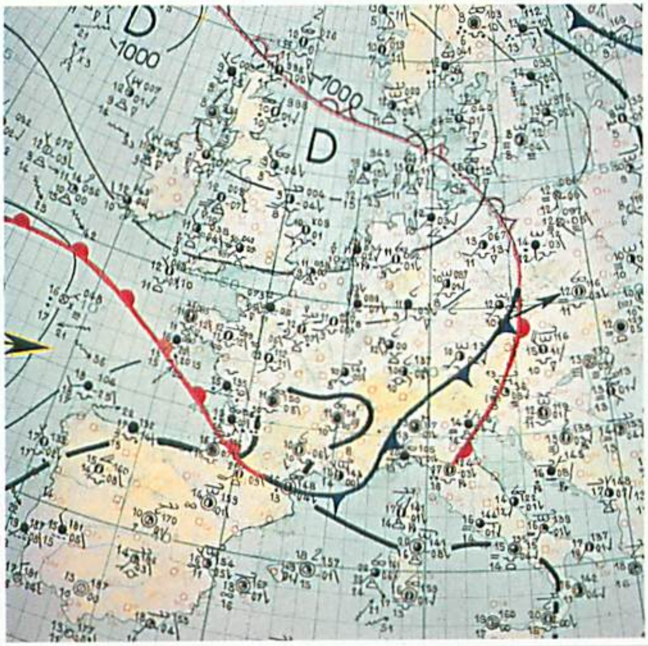


Meteosat's images of the Earth are an everyday feature of European television. In many countries, national meteorological offices provide television networks with animated sequences of Meteosat images specially processed to give a picture of the weather that is as "realistic" as possible. These computer animations are usually artificially coloured, and some may even unfold the distorted view of Europe which the satellite provides from its position above the Equator into a cartographic projection.

To obtain this weather image of Europe, nearly identical special processing techniques were applied by the Centre for Space Meteorology of the French meteorological office. They produced a weather image of Europe much resembling a colour photo taken from Space.

The Meteosat Second Generation satellites, the first of which will be launched in 2000, will exhibit more spectral channels at higher resolution. Such enhanced data are being provided at the request of the meteorologists, but the public will also benefit from ever more realistic weather forecasts.

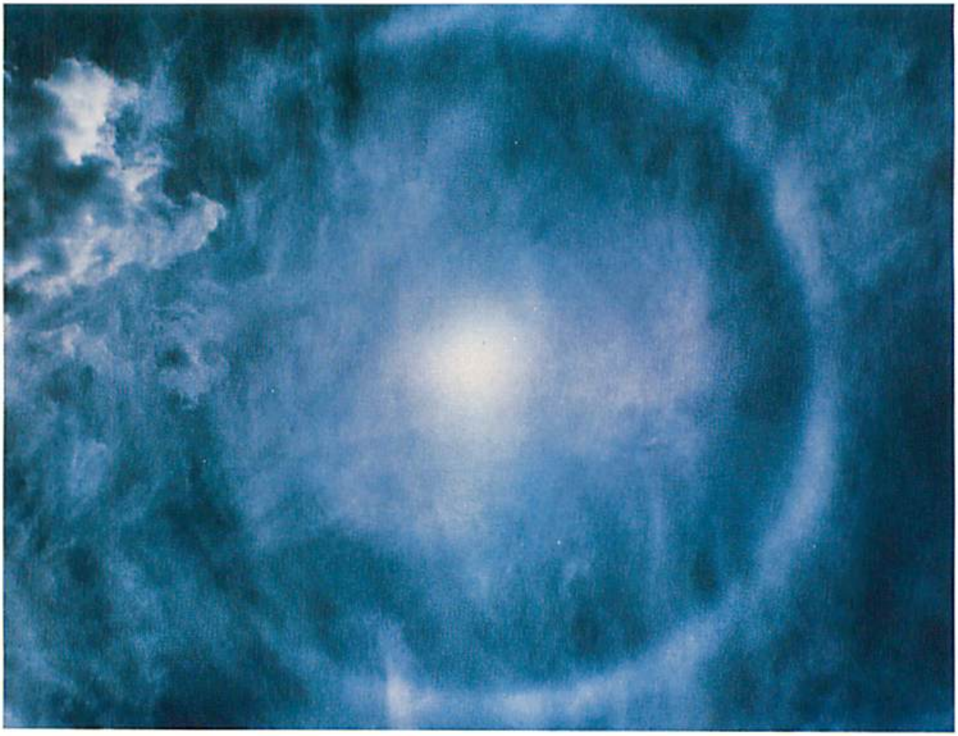
Photo: Meteo France



Weather can be described by many parameters: temperature, humidity, wind speed and direction, and above all barometric pressure. These and other data are measured twice a day by thousands of radiosondes released into the upper atmosphere by means of helium-filled balloons. This information is complemented by data from meteorological stations and satellites in polar and geostationary orbit.

Barometric maps, which show lines of equal air pressure, and thus weather systems, have been used for decades by forecasters to assess the weather situation. This barometric weather map was prepared 25 years ago, in 1968, by the French weather service. In addition to showing isobaric lines and cold and warm fronts, the map indicates weather parameters measured by the main meteorological stations and by ships on the open sea.

Photo: Meteo France

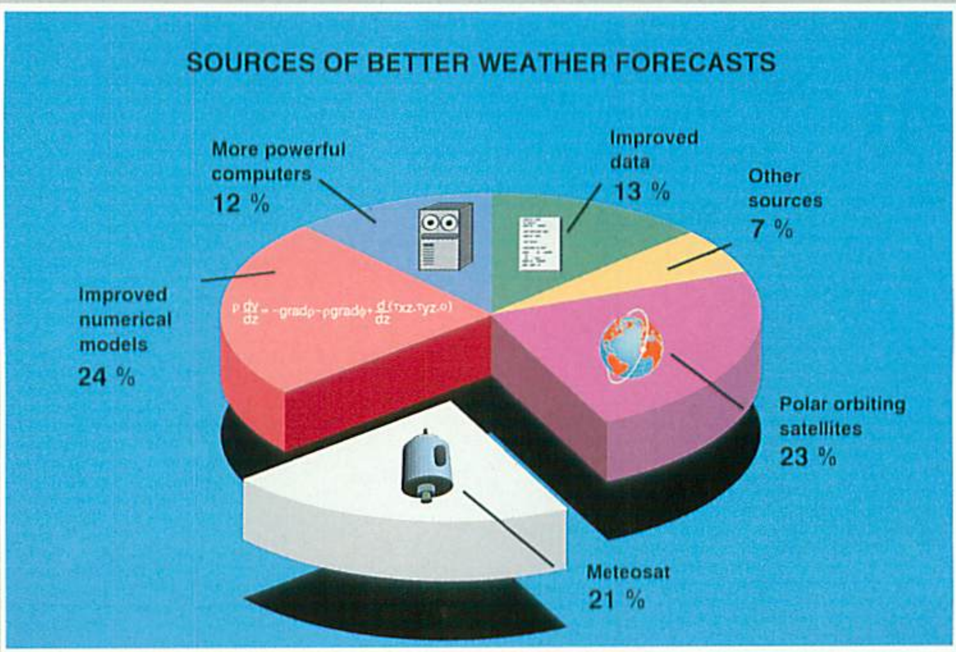


Clouds can tell us a lot about the weather and its development. The grey, threatening wall of cumulonimbus clouds announcing a thunderstorm, for example, differs a lot from fleecy fine-weather clouds, which meteorologists call cumuli. Clouds are also the major feature of Meteosat images in the visible and thermal infrared spectral bands, and just as the observation of clouds from the ground can tell the expert alot about the weather, meteorologists extract a vast range of information from cloud image data provided by Meteosat.

By measuring cloud movements as recorded in consecutive images, wind speed at altitude is determined; the intensity of the signal in the thermal infrared channel indicates cloud-top temperatures; and analysis of cloud structure often helps to identify underlying weather phenomena like hurricanes, thunderstorms or blizzards.

This photo shows cirrostratus clouds exhibiting a ring-shaped halo structure.

Photo: Meteo France



Two technologies largely account for today's better weather forecasts: powerful computers, and satellites. This illustration shows their relative importance for improvements of six-hour forecasts: better numerical weather models are considered to have made the biggest impact, but it would be impossible to run them without ever more powerful computers. Polar-orbiting satellites and the geostationary Meteosat spacecraft take much of the rest of the credit. Finally, better quality of data gathered on the ground is also of some importance.

This quantitative result was obtained by a study performed by meteorologist Dr John Thornes of Birmingham University. His survey covered the seven largest European meteorological offices and reflects assessments by dozens of professionals actually making weather forecasts day by day. It is of course difficult to quantify forecasting improvements since it is difficult to "measure" the weather. But there are clear indicators, like the error rate in forecasts, which show that there have been improvements over the past ten years. The same is true of extreme weather situations, warnings of which can now be issued earlier.

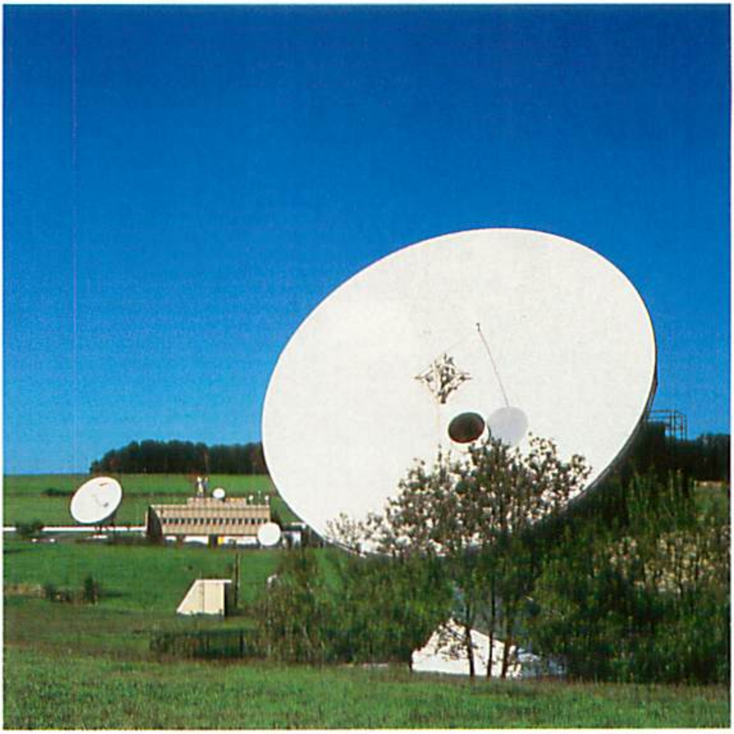
Illustration: ESA

The Meteosat mission control centre is manned 24 hours a day. Although a powerful computer has been programmed to carry out routine data processing for spacecraft control and image correction, the presence of highly qualified engineers, technicians and meteorologists is indispensable to ensure smooth running of the Meteosat system.

The room shown in this photo houses the consoles used to oversee operations and performance of the satellites. The Meteosat-3 ground station at Wallops in the United States is remote-controlled from here. Located next to the mission control centre is the meteorological centre, where shift meteorologists oversee the extraction of meteorological products and perform quality control.

ESA's Space Operations Centre ESOC, which is responsible for the running of more than 10 spacecraft, is located in Darmstadt, Germany, 25 km south of Frankfurt.

Photo: ESA

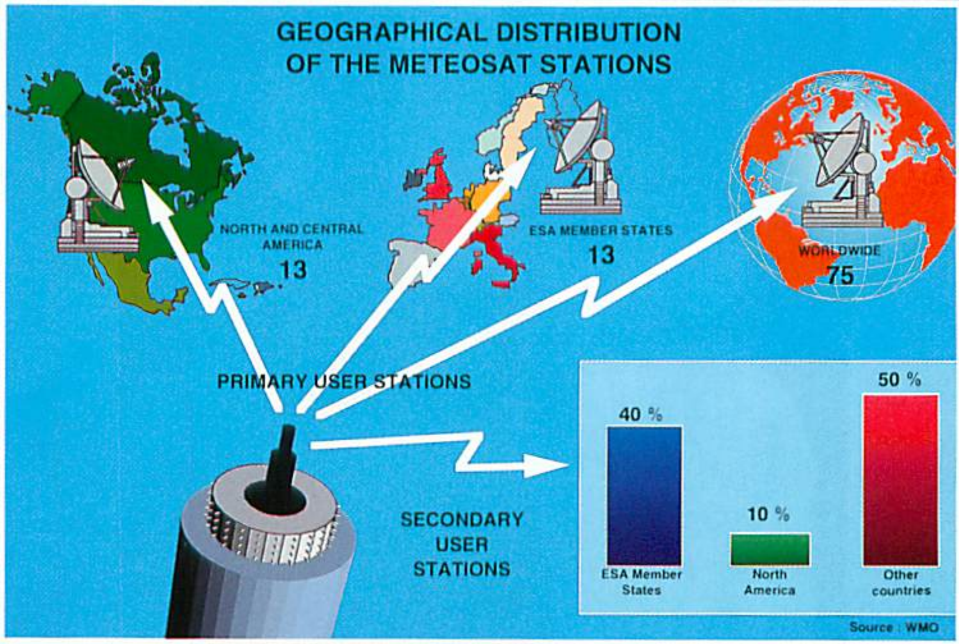


The 13.5 metre diameter antenna in the foreground and the 15 metre antenna in the background are located near Michelstadt in Germany. They ensure an uninterrupted link between Meteosat and its mission control room at ESA's Space Operations Centre in Darmstadt, Germany.

The 15 metre antenna receives raw images from the satellite; these are transmitted to Darmstadt via ground telecommunications links, where they are processed and meteorological products extracted. The images and data products are in turn transmitted via the Odenwald ground station to Meteosat for dissemination to over 2000 user stations throughout the world. The antenna in the foreground, 13.5 metres in diameter, serves for the stand-by satellites in orbit.

Michelstadt, whose old town is famous for its half-timbered houses, is located some 50 km south of Frankfurt in the scenic Odenwald forest.

Photo: ESA



Hundreds of millions of people in Europe, Africa, Asia and the Americas benefit from Meteosat data. The biggest users of these data are connected to one of about 75 primary user stations worldwide which have been registered at the World Meteorological Organisation (WMO) in Geneva. These users are mainly meteorological offices which receive high-resolution Meteosat data in digital format.

Many of the several thousand smaller, secondary user stations are located in the ESA and Eumetsat Member States. But African countries also value Meteosat weather data, as their capabilities for collecting meteorological information are often limited. Since 1991, when Meteosat-3 was positioned over the Americas at the request of NOAA, the US weather service, to replace a failed American weather satellite, the number of Meteosat users in the United States has been increasing. Many NOAA-GOES user stations are in fact also receiving Meteosat-3 data.

Finally, a European consumer electronics company is now selling an affordable receiving station which only needs to be connected to a standard TV set.

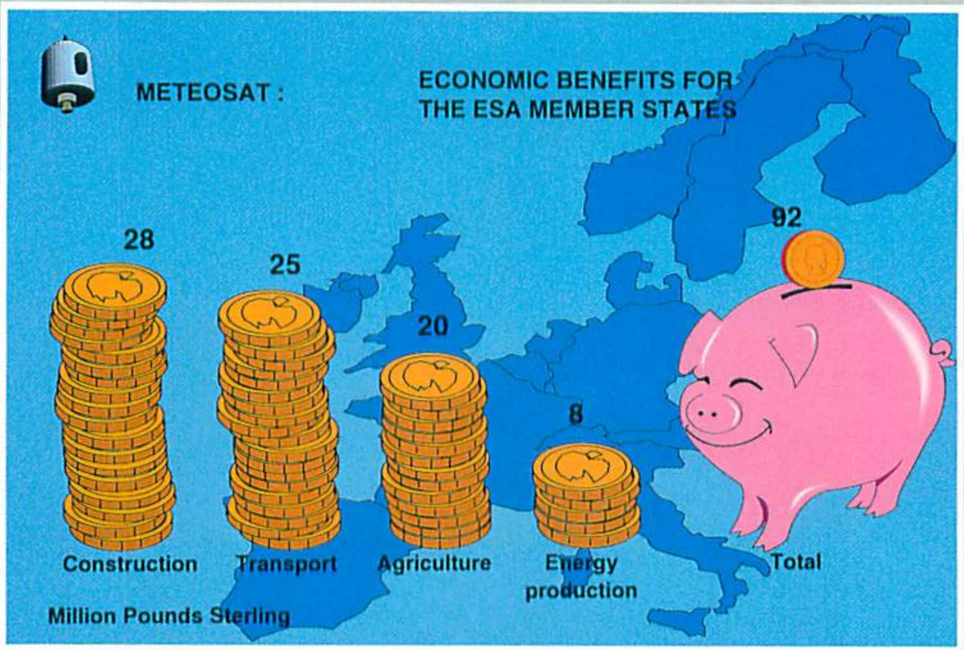
Illustration: ESA

Manufacturing the Meteosat satellites, operating them in orbit, maintaining the ground installations, feeding Meteosat data into the weather forecasting services - all these activities provide highly qualified jobs for about 1000 Europeans. These jobs are an additional asset of the operational Meteosat programme, over and above the benefits to European companies and taxpayers of improved weather forecasts.

The ESA teams which manage the construction of the spacecraft and their operations are drawn from many European nations, as are the staff of EUMETSAT and the dozens of companies involved in manufacture of the satellites, led by a team of Aérospatiale engineers working at Cannes, France.

This photo shows ESA and Aérospatiale staff inspecting the solar cells of Meteosat-6. Cannes, where the photo was taken at Aérospatiale's test facilities, is mostly known for its annual film festival, but it is also the home of one of Europe's biggest "satellite factories".

Photo: ESA/David Parker



This illustration summarises the economic benefits derived from the Meteosat system by all the ESA Member States, which amount to £92m a year, with four economic sectors enjoying the most significant benefits: transport, construction, agriculture and energy production.

The figures are part of the final result of a comprehensive study conducted by Bramshill Consultancy of Basingstoke, England, who combined a detailed case study covering the value of weather forecasts to the United Kingdom (cf. page 23) with a survey on the improvements in weather forecasts attributable to Meteosat (cf. page 13), and established a comprehensive database of climatic and economic data on all ESA Member States. Starting with the UK economic benefits of weather forecasts, Bramshill Consultancy applied a matrix method to calculate, sector by sector and country by country, the economic benefits for the whole of Europe that result from the provision of improved weather forecasts due to Meteosat.

Illustration: ESA

A long haul aircraft is landing at Frankfurt airport. Before taking off for the return flight, it will be refuelled and the exact flight route will be determined. Thanks to accurate weather information, the amount of fuel to be loaded can be better calculated, taking head- or tailwinds into account. Choosing a flight route that circumvents storms and strong headwinds reduces fuel consumption while ensuring maximum safety and comfort for passengers.

Meteosat imagery is playing an important role in the production of dedicated forecasts for aviation. Some European meteorological offices are now distributing such forecasts via telecommunications satellites directly to airlines and airports. On the user side, a small parabolic dish and a PC are sufficient to run the system. The economic benefits of Meteosat's part in such services for the air transport sector total £6m a year in the ESA Member States.

Photo: FAG Foto

In a large European country like Great Britain or France, a change of temperature of just one degree Celsius in winter can correspond to a variation in electricity demand of 1000 MW. This is why electricity and gas suppliers are leading users of weather forecasts. Their requirements are for short-term forecasts, to help bring energy production in line with demand, and medium-term forecasts (covering months and seasons) to optimise such operations as filling of reservoirs, planning of maintenance work and cooling water supply.

It has been estimated that today's power generation capacity would have to be increased by 2 to 3% if there were no weather forecasts at all. Meteosat contributes £8m annually to forecast-related savings realised by the energy industry.

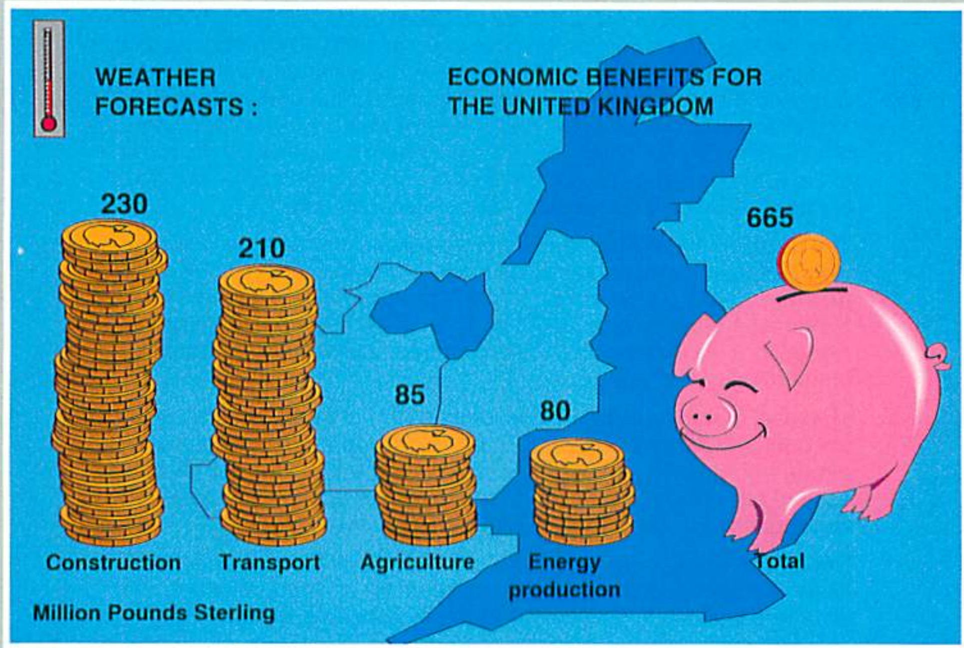
The photo shows the Roselend reservoir in the French Alps, which supplies a hydroelectric power station. The insert shows an operator working at the Electricité de France meteorological service in Chatou, near Paris.

Photo: Photothèque EdF/Brigaud

During bad weather, the safety of land traffic depends to a large extent on the state of roads. A difference of only a few degrees Celsius can turn rain into snow, completely blocking traffic and requiring the deployment of snowploughs. Road patrols in most European countries now rely heavily on weather forecasts when issuing their road reports and planning the use of their servicing equipment. Thanks to weather forecasts, roads can be cleared of snow and ice promptly, and traffic can be reduced by early warnings.

It is of course helpful if salt and de-icing chemicals are used efficiently, limiting environmental damage. However, the major benefit of Meteosat in the land transport sector lies in a reduced risk of accidents. This has a direct impact on premiums charged by insurance companies, which usually bear the financial consequences of damage to cars, absence from work due to injury or loss of life. Altogether, the economic benefits of Meteosat in the ESA Member States in the land transport sector are put at £18m a year.

Photo: Mercedes-Benz



This illustration summarises the benefits of weather forecasts in general, not just of Meteosat, to the economy of the United Kingdom. There are four sectors which together make up nearly 90% of the total figure of £665m per year: transport, construction, agriculture and energy production.

The figures were obtained in a study conducted by Professor Peter Stubbs, Director of the School of Economic Studies at Manchester University. A survey of the UK's biggest companies in all relevant economic sectors helped him to establish a database on how weather forecasts enable businesses to make better use of their resources or to increase company turnover. If there were no weather forecasts at all, British companies would have to spend about £600m more per year to keep their output constant, and they would in addition lose about £60m of "weather dependent" turnover.

These figures were calculated for the year 1990. Those for 1993 should be slightly higher as the dependence of operations on weather conditions tends to increase.

Image: ESA

Europe's First Application Satellite

Ever since the Television and Infrared Observation Satellite (TIROS-1) sent back its first cloud formation images in 1960, Earth observation satellites have provided a unique view of the weather on our planet. Suggested by the United Nations, a complete network of meteorological satellites has been set up to improve weather forecasting capabilities. Since the end of the 1970s, this system has provided coverage of the Earth by means of four satellites in polar orbit and five - including Meteosat, Europe's contribution - in geostationary orbit.

The decision of the European meteorological community to enter the field of space meteorology dates back to the early 1970s. The legal arrangements between eight ESA Member States to develop Meteosat-1 were made in 1972, and they were followed by a protocol signed in 1978 that enabled ESA to operate this satellite for Europe's meteorological services.

Meteosat-1 was launched in November 1977. Placed in geostationary orbit at 0 degrees longitude, it provided a permanent field of view over most of Europe, the whole of Africa, the Middle East and the eastern half of South America - in total over 100 countries. Meteosat-2 was launched in June 1981 to replace Meteosat-1.

During the eight years until 1985, ESA's initial Meteosat system fulfilled its mission to the complete satisfaction of meteorologists and scientists working in climatology and atmospheric physics.

However, ESA's satellite programmes focus on exploring new space applications. Financing and running the operational systems that result from ESA experimental programmes has to be done by specialised operators, and for this reason, an intergovernmental European conference in 1981 sought ways of financing an operational Meteosat programme. A dedicated organisation, EUMETSAT, the convention on which came into force on 19 June 1986, was set up for this purpose. ESA's responsibilities within the Meteosat Operational Programme include the construction and launch of the satellites and their orbital operations, on behalf of EUMETSAT which owns and finances the operational spacecraft.

Meteosat-3, built from spare parts left over from the initial programme, was launched on 15 June 1988. The first operational satellite, Meteosat-4, was launched on 6 March 1989 and the second, Meteosat-5, on 1 March 1991. It is to be followed by yet another spacecraft, Meteosat-6, in late 1993.

More Than Just One Satellite

The two major components of the Meteosat system are two or more satellites in orbit and the ground segment.

The operational Meteosat satellites are located at 0 degrees longitude at 36000 km above the equator. Only one spacecraft, the primary satellite, is active, while the reserve satellite(s) are located nearby in standby mode. However, in exceptional cases the spacecraft can be moved above any point over the equator. In 1991 it was possible, for example, to shift one of three Meteosat satellites in orbit (Meteosat-3) westwards over the Americas. From its new position, it supplies data to NOAA, the US weather service, which had only one satellite left in geostationary orbit.

All Meteosat satellites are composed of a main cylindrical body, on top of which a drum-shaped section and two cylinders are stacked concentrically. They are 2.1 metres in diameter and 3.195 metres long, and weigh 320 kg in orbit including 39 kg of consumable propellant used for orbital manoeuvres. The satellite spins at 100 rev/min around its main axis, which is aligned parallel to the Earth's north-south axis.

The principal payload of the satellite is a multispectral radiometer. This instrument provides the basic data of the Meteosat system, which are images of the full Earth disk in three spectral bands: 0.5-0.9μm (visible band), 5.7-7.1μm (infrared water vapour absorption band) and 10.5-12.5μm (thermal infrared window band). The infrared and water vapour images are composed of 2500 lines of 2500 picture elements each, while the visible image has 5000 lines of 5000 picture elements, giving spatial resolutions of 5 km and 2.5 km, respectively.

"I have no doubt that satellites will continue to contribute, and increasingly, to the accuracy and the economic use of weather forecasts"

Prof Peter Stubbs,
Director of the School of Economic Studies,
University of Manchester

A set of three Earth images is generated every 30 minutes. The onboard communications system transmits these raw images from the satellite to a ground station in Germany, whence they are relayed to the nearby ESA Operations Centre (ESOC). From there the spacecraft and its payload are controlled, the images processed and meteorological products derived.

Meteosat is equipped with power amplifiers and antennas which allow processed Earth images and other meteorological information (weather charts, and images from other meteorological satellites) to be transmitted from ESOC via the satellite to the user reception stations.

Finally, Meteosat has a total of 66 telecommunications channels to receive environmental data from automatic or semi-automatic Data Collection Platforms, relaying them to Darmstadt.

Darmstadt/Germany: The Brains of the Meteosat System

The Meteosat ground segment can be split into two parts: the Meteosat Ground Facilities needed to carry out the missions, and over 2000 user stations of different types.

The Meteosat Ground Facilities consist of five elements, the first three of which are located at ESOC, the fourth at Michelstadt, 40 km from ESOC in the Odenwald, and the fifth at Wallops on the east coast of the United States.

The Meteosat Operations Control Centre at ESOC oversees the performance and operations of the satellites and ensures that the missions are performed correctly; the Meteosat Ground Computer Systems carries out data processing for spacecraft control and image correction and oversees the data collection and distribution missions; the Meteorological Information Extraction Centre supplies meteorological information such as wind fields, sea surface temperature charts, cloud system analyses etc. from the processed images.

The Data Acquisition, Telecommand and Tracking Station near Michelstadt, with its impressive 15 and 13.5 metre antennas,acquires from the satellite raw images, housekeeping data and messages from the Data Collection Platforms. It transmits to the satellite telecommands and meteorological data or images for dissemination to the user stations.

There are two different types of user station: Primary Data User Stations, which receive high-resolution Earth images in digital format, are mainly located at the European meteorological offices or at sites of important meteorological data users. Secondary User Stations, which are conceptually simpler and thus cheaper, and which receive images, data and charts in an analog format, are now widely used throughout Europe as well as in Africa and the parts of Asia that are within Meteosat's field of view. A consumer electronics company is even offering a secondary station for use in conjunction with a TV set.

The nearly 1000 Data Collection Platforms take measurements of the local environment and transmit the data to the satellite. They can be installed in extremely varied locations on the ground, on buoys, ships or aircraft. Meteorological Data Distribution Stations receive weather charts and bulletins from the satellite in digital format.

The Meteosat mission is completed by an archive of all images, image-related data and meteorological products. Users can request retrieval of individual images from this archive and receive them as digital data on magnetic tape or on photographic film. Recently, a collection of 2300 images at 460 lines resolution (one image per day over the period 1986 - 1991, plus the catalogue of the full archive) has been made available in digital format on a single CD-ROM.

For the orbital control of Meteosat-3 at its temporary position over the Americas, where it is out of sight of the Odenwald ground station in Germany, a dedicated ground station has been set up on the US east coast at Wallops, Virginia. This station is connected via telecommunications links with the Meteosat facilities in Darmstadt in order to receive and transmit images, telemetry data and telecommands. The raw images from Meteosat-3 are actually processed at ESOC and digital high-resolution images transmitted back to the US weather service, NOAA, for use in conjunction with daily weather forecasts for the United States. Meteosat-3 plays an important role during the annual hurricane season, as it is able to observe in real time the creation and movement of tropical storms that have their origins in the eastern Atlantic. As a consequence, loss of life was minimised during two natural disasters that hit the US recently - Hurricane Andrew on 14 August 1992 and the blizzard of 12/13 March 1993 - thanks to timely warnings issued on the basis of Meteosat imagery.

Making Weather Forecasts from Meteosat Images

Although Meteosat images are received at several thousand sites, their primary users are the meteorological services of the Eumetsat Member States and of many other countries in the world. Meteosat data play a pivotal role in weather forecasting, and have contributed significantly to improvements in this area over the past 10 years.

Thirty years ago, weather forecasts were limited to about 24 hours ahead and to areas a few hundred kilometres across. Meteorologists used barometric charts and other measurements to make an "educated guess" based upon linear approximations, knowledge of atmospheric processes and experience. Only with the advent of powerful computers in the early 1970s was it possible to extend forecasting to 72 or more hours ahead and to large geographical areas.

"Today we're on the verge of an average weather forecast of about 80% accuracy."

Mr John Thornes,
Meteorologist,
University of Birmingham

Today, in numerical weather prediction models, meteorologists have wrapped a finely spaced three-dimensional grid over the Earth's surface and its atmosphere. Over 100000 daily measurements taken at 21000 sites are the basis for numerical forecasts making use of the world's most powerful computers. But these forecasts still require "fine-tuning" by meteorologists, a task for which data from satellites such as Meteosat are needed as they provide a real-time image of the weather systems, in particular the position of weather fronts. Without such fine-tuning, the accuracy of short- and medium-range forecasts would be significantly below the present standard.

Computer-generated weather forecasts are usually provided at 12-hour intervals, but the capability of Meteosat to follow the actual development of the weather in real time helps forecasters to make very precise short-term and regional forecasts. For example, the movement of a weather front bringing rain or the development of thunderstorm clouds over a specific region can be forecast with reasonable certainty for a few hours ahead. A recent survey of meteorological services confirmed this: forecasters estimate that 21% of the improvements in six-hour forecasts over the past 10 years have been achieved thanks to Meteosat imagery.

As accurate and timely weather forecasting becomes ever more important, specialised forecasting services are emerging that make extensive use of the Meteosat system.

The Economic Benefits of Meteosat

There are many examples of production businesses or services that benefit from the Meteosat system. Although it is difficult to calculate their exact cash value, an independent group of meteorologists, economists and consultants has recently made a comprehensive study of these benefits, covering all relevant economic sectors and all ESA Member States.

The study's objective was to give answers to the following questions: what improvements have been made in weather forecasting over the last decade and how much has Meteosat contributed to these? What is the cash value of weather forecasts in general, and of the Meteosat contribution in particular? On the basis of a large survey carried out in the United Kingdom, complemented by the establishment of a comprehensive database of economic and climate data covering all ESA Member States, the group was able to paint a detailed picture of how every single ESA Member State profits from the Meteosat system.

Not surprisingly, the majority of the benefits arises from economies of resources (90%). However, in certain areas the group also observed increases in sales or production thanks to better weather forecasts (10%). These Meteosat-induced benefits total an annual £92m - more than twice what ESA is currently spending on Meteosat manufacturing and operations each year.

It is equally interesting to compare the average annual ESA spending on the 10-year Meteosat Operational Programme with the annual benefits: here the ratio is £34m average annual expenditure to £92m in annual benefits, corresponding to a return factor of more than 2.5 for the ESA Member States' economies alone. As Meteosat imagery is used in many developing countries and by the US weather service, the figure for the benefits on a global scale must be considerably higher.

There are four areas of economic activity that benefit more than others from weather forecasts and Meteosat:

Construction: bad weather has a direct impact on many types of civil construction work. Moreover, certain critical operations such as pouring concrete require fair weather conditions over a guaranteed period of time. By using weather forecasts to plan the use of resources more carefully and to schedule critical operations, construction companies can substantially reduce their costs. The cash value of Meteosat's contribution to weather forecasting amounts to £28m a year on the companies' balance sheets.

Transport: All types of transport - land, air and maritime - are obviously in some way dependent on the weather. Timely knowledge of impending bad weather enables roads to be cleared of ice and snow, reducing accidents and loss of life while minimising environmental damage caused by salt and de-icing chemicals. Long distance routes for aircraft and ships are now adjusted in real-time as weather fronts develop. In Europe, where aircraft must stay within narrow air corridors, knowledge of wind speed and direction allows efficient fuelling. North Sea helicopters and supply vessels can optimise their scheduling to avoid the worst weather conditions and reduce the risk of aborted missions. The cash value of Meteosat's contribution in the transport sector amounts to £25m a year, reflecting reduced insurance claims and fuel bills.

Agriculture: fields have to be sprayed regularly with pesticides and herbicides during the growing season. These are costly operations, the success of which can be jeopardised by rainfall washing chemical products from the plants. The cash value of Meteosat's benefit to farmers amounts to £20m a year, not including reduced contamination of ground water because less chemical products are washed off the plants.

Energy production: weather forecasts play an important role for gas and electricity companies in establishing forward demand. As the pressure in gas pipelines has to be increased in anticipation of increasing demand, precise assessments minimise the need to liquify and store unused gas. Power stations update their forward planning at half-hourly intervals taking into account weather forecasts. Experts estimate that today's power generation capacity would have to be increased by 2 to 3% if there were no weather forecasts. The cash value of Meteosat's contribution is worth £8m in reduced provision of capacity by energy utilities.

Finally, there is a benefit in Meteosat for everyone which is not measurable : the "value" of public weather forecasts in television, radio and newspapers. Today this service allows everybody to plan his life a little bit more carefully: ski-ing, sailing, walking, cycling, climbing, outdoor games, domestic gardeners and decorators, holidaymakers ... indeed everybody who decides what clothes to wear uses weather forecasts! Although it is basically provided free of charge, a survey showed that Europeans would be willing to pay on average an annual £18 each for it - a striking demonstration of the cash value of public services.

"Over the last few years we've paid something like $60b in catastrophic losses. So it's very interesting to us to know what is happening to weather out there."

R.J.R. Keeling,
underwriter at Harvey Bowring & Others - Lloyd's

Ambition and Continuity

The Meteosat programme was started over 20 years ago. Although the six spacecraft that will have been launched by the end of 1993 allow services to the meteorological community to be continued until well beyond 1995, ESA and EUMETSAT are already preparing for the future of Europe's weather satellites.

The last spacecraft in the initial Meteosat-series will be Meteosat-7, to be launched in 1995/96. It will be followed, in 2000, by MSG-1, the first Meteosat-Second-Generation satellite, which will provide more frequent images at higher resolution, will employ more spectral channels and exhibit increased telecommunications capabilities.

By that date, ESA will also launch its first meteorological satellite into a polar orbit, METOP-1, complementing the measurements provided by the US NOAA series.

As from the end of 1995, EUMETSAT will gradually take over from ESA responsibility for running the Meteosat satellites, thanks to a new operations centre and a network of ground facilities. Following a financial contribution to MSG-1 and METOP-1, it is intended that EUMETSAT will completely fund and operate subsequent MSG and Metop satellites.

When the European Space Agency was set up in 1975, it was the political will of its founders that ESA's research and development programmes should lead to a strong, independent European space sector and to tangible economic benefits. A look at the results of the Meteosat programme justifies this political choice: Aérospatiale of France, which has built all the Meteosat satellites, was able to acquire a position among the world leaders in the space sector thanks to this programme. And the success of EUMETSAT, like that of Arianespace and Eutelsat, is a direct result of an R&D programme, started by ESA in the early 1970s to serve a specific user community.

Today, it is the shared aim of ESA and EUMETSAT to continue this success story well into the next century.

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