Who is backing Odin and why?

cnes TEKES CSA ASC

SNSB (Swedish National Space Board), together with the corresponding authorities in Finland, France and Canada, are backing the Odin venture.

There is considerable public interest in the present and future state of the ozone hole, i.e. the breakdown of ozone in the part of the atmosphere called the stratosphere. People want to know if the hole is going to grow or shrink during the coming century. And now is an important point in time to take readings to understand the basics behind ozone breakdown, for example how breakdown is affected by high chlorine contents in the atmosphere. Canada, Finland and Sweden occupy pretty much the same latitudes and it is therefore natural that their atmospheric scientists are interested in what is happening to the protective ozone layer at the poles. Additionally, France is conducting her own research in this area at Esrange in Kiruna, Sweden, among other places.

It is very difficult to carry out a satellite project on one's own. So it is natural that small and medium-sized countries co-operate with each other. The form of international co-operation worked out for Odin has made it possible for the countries to pose their own questions and develop their own particular interests in space research. It is very important to acquire one's own knowledge and participate in capability build-up within research and industry. Only then is it possible to determine which direction of development is best for each country in the future. On this, the scientific workers from all the Odin countries are agreed.

Odin is well suited to the scientific programs conducted by ESA (the European Space Agency) and NASA. Experience gained from Odin will also be useful in the considerably larger projects usually run by ESA and NASA. Another good reason why researchers from several countries wanted to participate in the Odin project is its high level of versatility. Other larger satellites with more instruments and a larger contingency of scientists provide less opportunities for the individual scientist to influence instrument designs and observation programs.

Research groups and institutions

Finland
Finnish Meteorological Institute
Radio Laboratory, Helsinki University of Technology
Arctic Research Centre, Sodankylä

France
Laboratorie de Physique de l'ENS, Paris
Service d'Aeronomie du CNRS/Institut Pierre Simon Laplace
Observatoire de Bordeaux, CNRS/INSU, Floriac
Laboratorie d'Astronomie Spatiale, Marseille
Observatorie de Paris-Meudon
CESR, Toulouse

Canada
Inst. of Space and Atmospheric Studies, University of Saskatchewan
Dept. of Earth and Atmospheric Science, York University
Department of Physics, University of Toronto
Dept. of Physics and Astronomy, University of Waterloo
Dept. of Physics and Astronomy, University of Calgary
Dept. of Astronomy and Physics, St Mary's University, Halifax
Dept. of Physics and Astronomy, McMaster University, Hamilton

Sweden
Onsala Rymdobservatorium
Mikrovågselektronik, Chalmers
Radio- och rymdvetenskap, Chalmers
Meteorologiska Institutionen, Stockholms Universitet
Stockholms Observatorium, Stockholms Universitet
Astronomiska Observatoriet, Uppsala Universitet

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Swedish National Space Board

SNSB is a central governmental agency under the Ministry of Industry, Employment and Communication. SNSB is responsible for national and international space efforts, primarily research and development.

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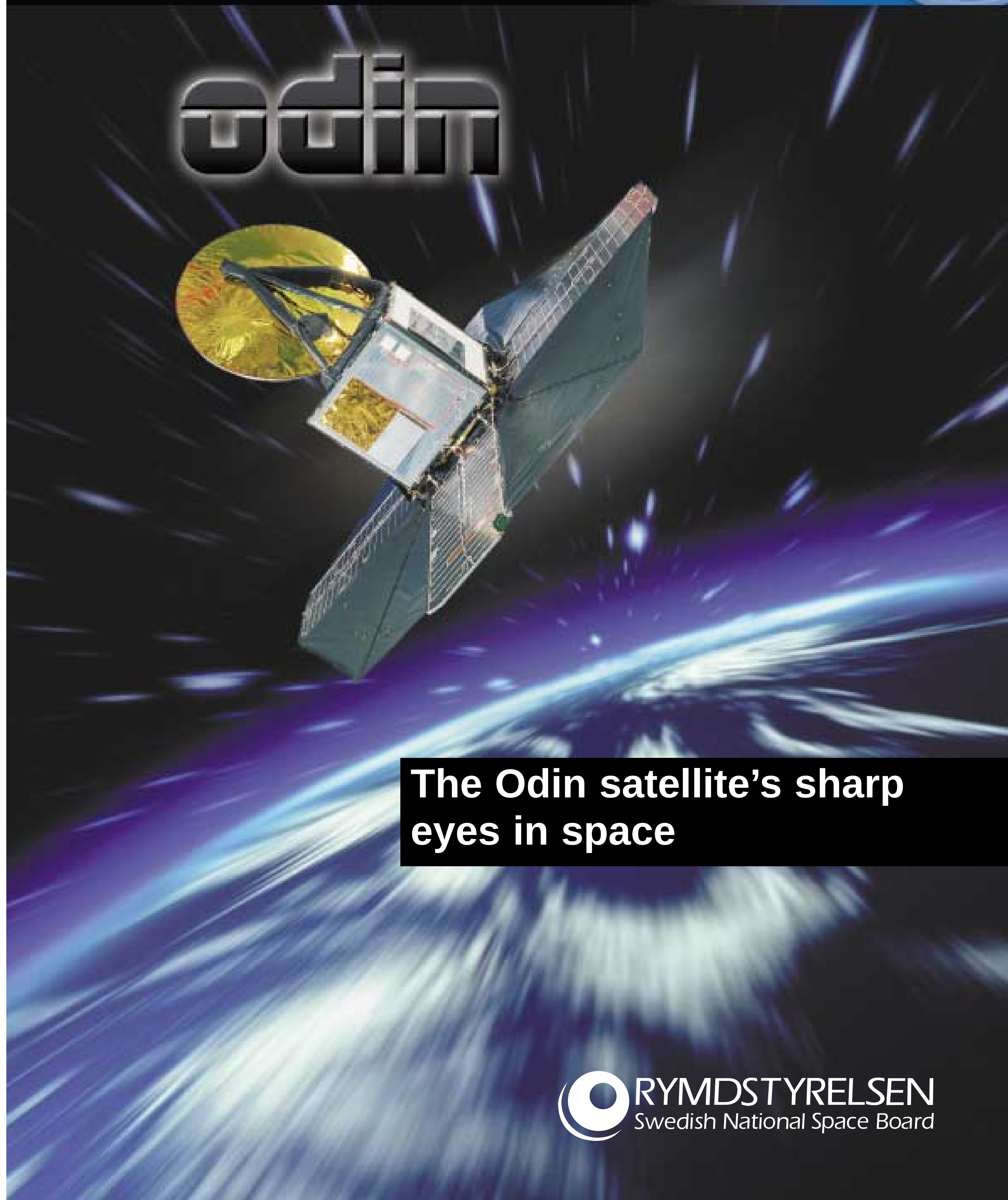


The Odin satellite's sharp eyes in space

RYMDSTYRELSEN
Swedish National Space Board

The Odin satellite's sharp eyes in space

The Odin satellite is the sixth member of Sweden's family of small, high-tech, scientific satellites. In a manner of speaking, Odin is an all-seeing being, like its namesake in Nordic mythology, as it can focus its instruments on both outer space and our own planet.

The Odin satellite has two missions: to study the earth's atmosphere and to investigate outer space. Its measuring instruments will help scientists to identify different molecules and answer questions about the prevalence of various substances in the areas Odin is to study.

When the Odin project was still in its initial stages, atmospheric researchers discovered that they could use the same instruments to take readings of the earth's atmosphere as astronomers use to study space. Both categories of scientists – aeronomers and astronomers – started working together and co-operation on Odin began. In the Odin project, the aeronomers are mostly interested in water, chlorine monoxide and ozone. The astronomers are mainly interested in water molecules and oxygen molecules (O2) in space.

Orion Nebula Mosaic. Credit: IRAS Project, IPAC

Odin is also important to the aerospace industries of the countries participating in the project. The aerospace industry, for instance, has been commissioned to design and develop entirely new space technology to meet the requirements of the scientists involved.

Odin in mythology

The Odin satellite is named after the god Odin – ruler of the Old Norse deities. The name is well chosen, since Odin was an all-knowing god. By sacrificing himself he gained secret knowledge about runes and other things, and by throwing one of his eyes in Mimer the Giant's well, he acquired all of Miner's knowledge. Odin also received reports on world events from both of his informers, the ravens Hugin and Munin.

Source: The Swedish National Encyclopaedia. Illustration: © Peter Madsen.

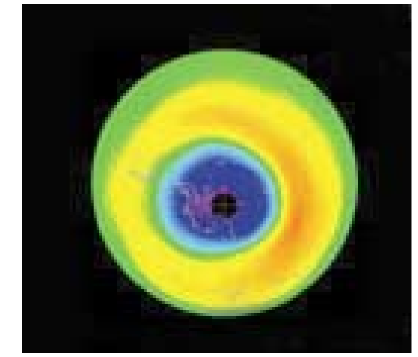
Odin seeks answers to basic questions

Odin is a satellite for basic research. Humankind needs more knowledge to understand complex relationships, as has been the case throughout history. And Odin will gather very special knowledge – both from space and from our atmosphere.

Odin will be studying the atmosphere, particularly in regard to the formation and deterioration of ozone and how this affects the ozone hole. With more knowledge, we get closer to the answers to important questions like how pollution affects the atmosphere.

The satellite will also be spreading new light over the chemical processes that control the chain of events involved in the formation of new stars. Odin will also be studying comets which are by-products of new star formation, and can give new clues as to how our own solar system came into being.

Odin at EMC-test. Credit: Saab Ericsson Space.



Ozon hole over the Antartica as measured by GOME. Credit: DLR

Knowledge leading to smaller ozone holes

Odin will be measuring, for example, how water vapour, chlorine compounds, ozone and other substances distribute themselves in the atmosphere. This will provide aeronomers – atmospheric scientists – with new knowledge about things like ozone breakdown near the poles and about the mysterious night luminous clouds that can sometimes be seen in the summer at northern latitudes.

The satellite will examine the effect of atmospheric chlorine pollution on the thinning of the ozone layer. This will help scientists to see if the reduced use of CFC's will alleviate the situation.

Odin will study the interaction of the chemical substances involved in the breakdown of ozone. The measurements will be made during a period in time when chlorine content in the stratosphere is expected to stop rising. Chlorine is one of the substances that causes ozone to break down, so there are hopes that the breakdown of ozone will also decline and that the ozone layer's protection against ultraviolet radiation will be restored.

Readings from Odin will provide a three-dimensional map of the atmosphere showing the substances the satellite is designed to measure. With the aid of advanced methods of analysis, the map will show the distribution of these substances throughout the entire atmosphere.

Building up a map image of the atmosphere's chemistry can be described in two steps. The first step is to translate signals received by the satellite into physical data like substance concentrations and temperatures. The second step is to create an image showing how the substances are distributed through the atmosphere every time the measuring sequence is run. This will provide a good foundation for understanding the dynamic processes that are continually at work in our atmosphere.

Noctilucent Clouds. Credit: Pekka Parviainen, University of Turku, Finland.

Clouds that glow at night

Sometimes in northern latitudes clouds that glow at night can be seen. They are known as night luminous or noctilucent clouds. Odin is going to study the apparent relationship of noctilucent clouds with carbon dioxide in the atmosphere.

The season for noctilucent clouds in the northern latitudes spans from summer solstice to mid-August. They can be distinguished from ordinary clouds, as ordinary clouds appear black whereas night luminous clouds – as the name implies – glow in the dark.

There are indications that noctilucent clouds are becoming more common. The observations available today have not been confirmed and Odin's aeronomers now want to lay the groundwork for further observations.

One good reason for mapping the prevalence of noctilucent clouds is that this could have a connection with the amount of carbon dioxide present in the atmosphere. When the carbon dioxide content rises, the atmosphere gets warmer closer to earth and colder higher up. The increasing formation of noctilucent clouds could therefore be a visible sign of an ongoing climate change.

Where new worlds are created

We humans cannot help but wonder how we came into being. Almost everyone, at one time or other, asks himself "why do I exist?". But the chain of events that brings about life has to start with the formation of a sun – a star. This is one of many good reasons why Odin's astronomers want to find out how stars are formed.

Odin is an important tool for astronomers who study how stars come into being. The satellite's sensitive instruments can detect the signals scientists use to determine which molecules reside in the extremely thin clouds of gas in space that give birth to new stars - so called interstellar clouds. First and foremost, Odin will show how concentrations of water vapour and oxygen vary in the clouds and how these substances influence the clouds' tendency to form new stars.

It mustn't be too hot when a star is about to be born – at least not in the beginning. When a gas cloud starts to contract under its own weight, it is important that the temperatures inside the cloud do not increase because the resulting internal pressure will hold back the forces of gravity that pull the cloud together. Understanding how the gas is cooled is therefore very important to understanding how a star comes into being. Odin will study water molecules and oxygen molecules (O_2) as scientists have good reason to believe that these substances effectively radiate away heat energy, cooling their surroundings.

If cooling is sufficiently effective, the gas cloud will be able to contract into what is known as gravitational collapse which, in due course, will lead to the formation of one or more stars. During this collapse, an enormous increase in gas density takes place. In the final phase of the collapse, temperature and density in the core become so great that a nuclear reaction starts, providing the star with energy for a very long period of time.

A Mosaic of Orion's Great Nebula.
Credit: C. O'Dell and S. Wong (Rice U.), NASA.

The art of detecting molecules in space

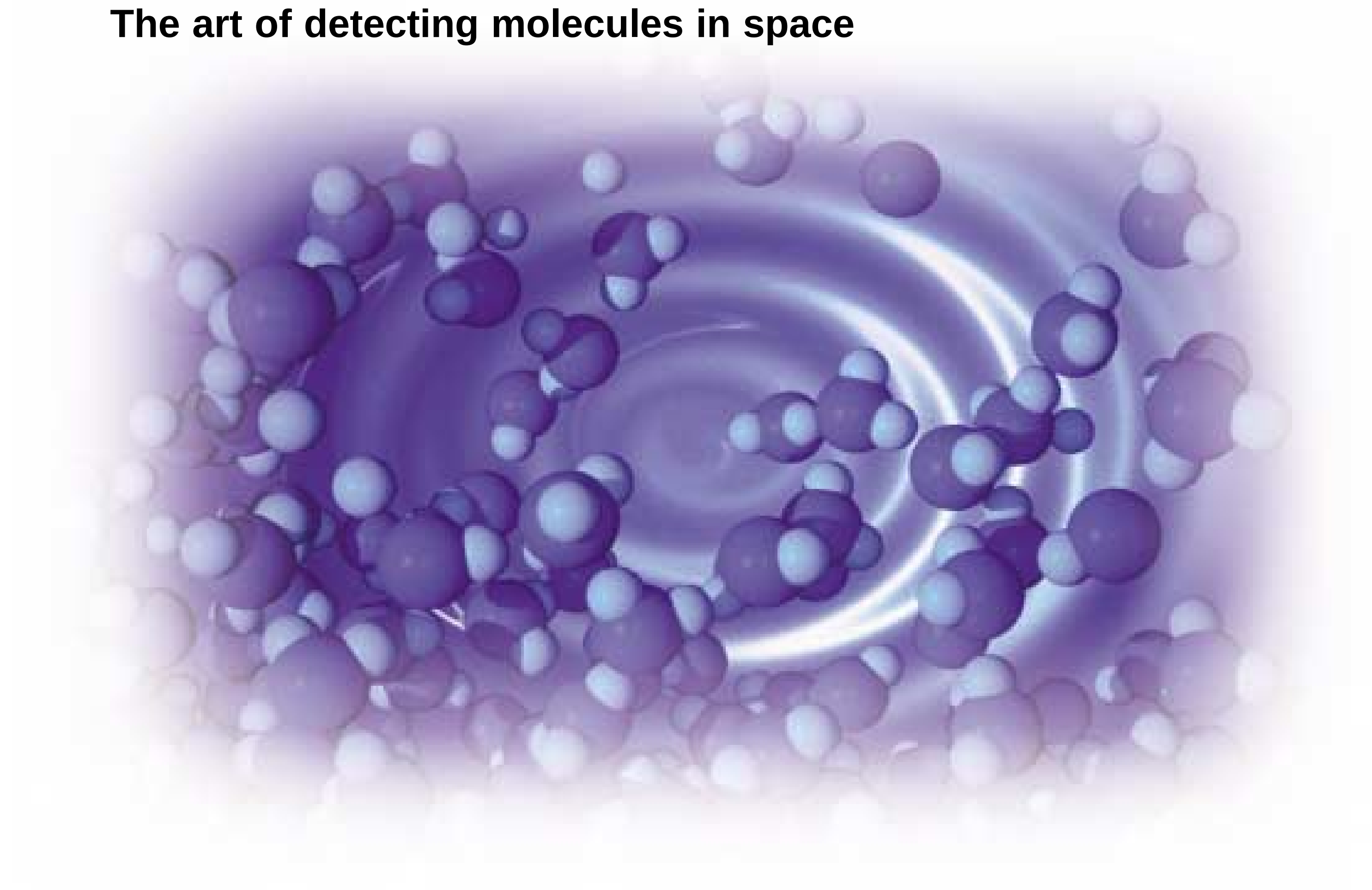


Photo: Jacob Halaska/Pressens Bild.

Sensitivity, versatility and placement outside the atmosphere are essential prerequisites for Odin's ability to see what is happening in the outer reaches of space where stars are formed. The satellite's sensitive radio telescope measures the unique emissions of individual molecules which scientists then use to figure out how new solar systems come into being.

The radiation that the measuring instruments on Odin will monitor is electromagnetic emissions from atoms and molecules. These signals are emitted at fixed wavelengths that are called spectral lines. The lines are unique for each type of molecule, and can consequently be used to identify molecules at very great distances.

The molecules in cold interstellar clouds (a few to some tens of degrees above absolute zero, –273°C) mainly emit wavelengths in the radio and infrared bands. The tool our radio astronomers use to detect atoms and molecules in space is a radio telescope equipped with a sensitive radio receiver unit. This instrument can detect radio waves that are shorter than a millimetre in length, such as emissions from oxygen and water in interstellar clouds.

Odin's strength is that its telescope is outside the earth's atmosphere, which means the atmosphere does not disturb the weak signals from the oxygen and water molecules in the interstellar clouds.

A second advantage with Odin is that its measuring instruments are versatile and can be used in many different ways. The radio telescope has five receivers, four of them can operate simultaneously and be set at different wavelengths. Scientists will make use of this to scan all the wavelengths they can from interesting objects, such as the molecular cloud in the direction of the Orion constellation. Odin's receiver unit will be about five times more sensitive than that of NASA's latest radio telescope in space on the SWAS satellite.

Antennas and co-operation – advances generated by Odin

Odin is not just providing advances in the form of knowledge about space and the atmosphere. Direct results of the project are the newly developed technologies used in the satellite and the new international network of researchers and companies that has been built up around Odin.

Odin in Svobodny. Credit: Swedish Space Corporation.

A scientific satellite is a tool for finding answers to scientists' questions, while the development of advanced instruments gives the space industry new technological challenges. The Odin project has been characterised by innovation and co-operation between scientists and companies within various fields and from several countries. Together, they have generated new business opportunities, technical development and greater exchange of knowledge between the participating countries.

Odin is an advanced satellite for which large portions of the technologies involved represent completely new developments. Examples of these are new antennas, transistors, data handling methodology, measuring instruments and a new control system.

Odin's radio antenna has, in fact, the most precise reflecting surface in the world for its particular application. An entirely new tool has been developed to produce dish antennas with such an accurate surface. And the same technology has already been used again to make a large antenna for Sirius – a new European telecommunications satellite.

The Odin project has built up and reinforced co-operation between French, Canadian, Finnish and Swedish scientists and space industries. It has also brought about new interdisciplinary contacts between two different areas of research – aeronomy and astronomy. Space operations are almost always conducted as international programs. So Odin is also an important bridge to future international co-operation among both industries and scientists.

The Swedish Space Corporation is the prime contractor and is responsible for development and project management around Odin.

Contractors

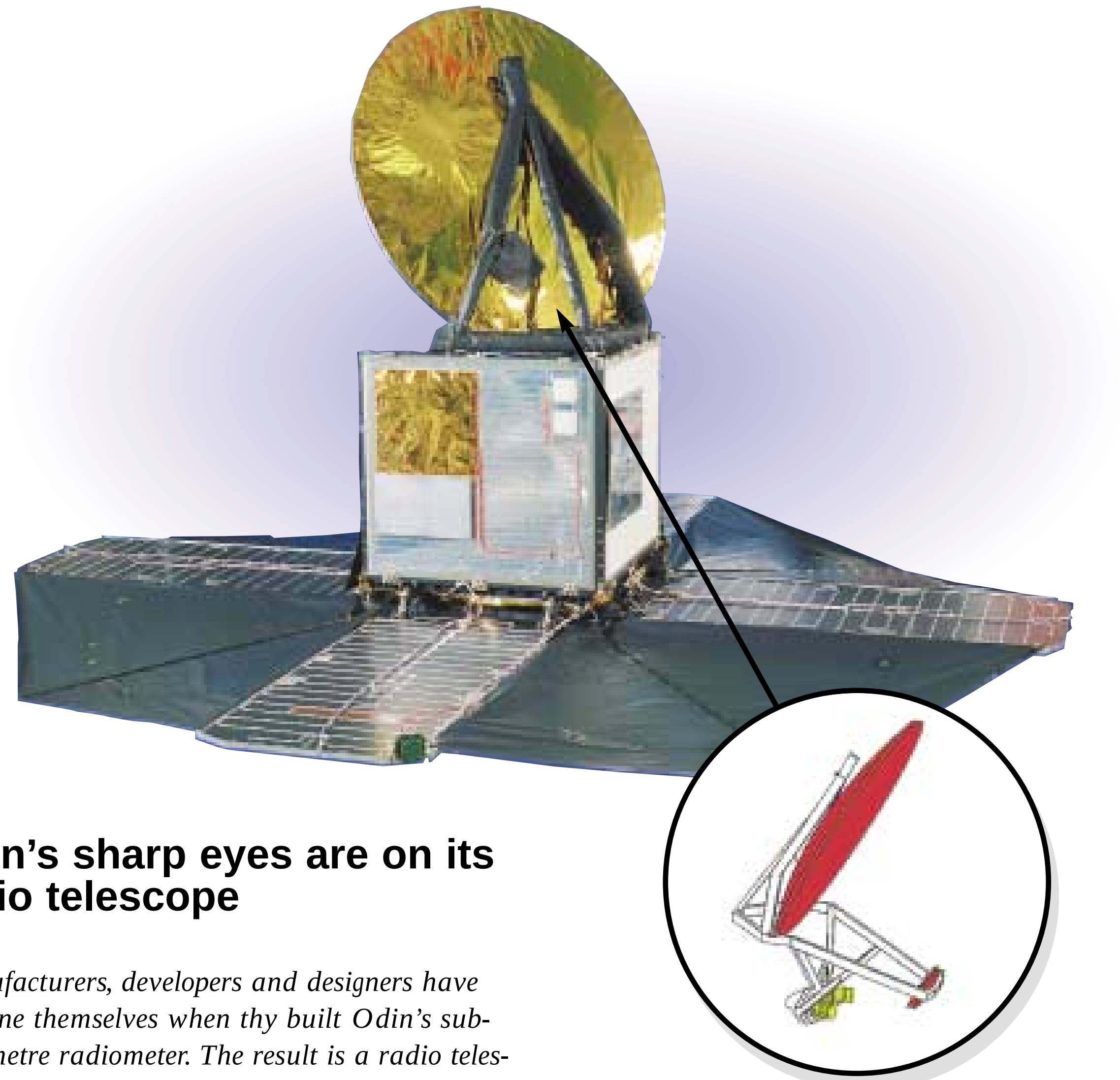
Finland
Ylinen Ltd
CCC Systems Oy

France
Interspace
Sagem
Sodern

Canada
Routes Inc.

Sweden
Swedish Space Corporation AB, prime contractor
Saab Ericsson Space AB
ACR Electronics AB
Omnisys Instruments AB
SaabTech Electronics AB, formerly Celsius Tech Electronics AB
Kilda Antenna Consulting AB
Avantel AB

Credit: Saab Ericsson Space AB.



Odin’s sharp eyes are on its radio telescope

Manufacturers, developers and designers have outdone themselves when thy built Odin’s sub-millimetre radiometer. The result is a radio telescope that can be pointed at both the atmosphere and outer space, which is more sensitive than any other previous radio telescope in space.

This radio telescope with its receivers is the main instrument of the Odin scientific satellite. It is specially designed to receive radio emissions in the sub-millimetre range. This means that the instrument can detect radio waves that are less than a millimetre long, such as emissions from oxygen and water in interstellar clouds in the deep reaches of the universe.

The radio telescope and its receivers, together, are called SMR (Sub-Millimetre Radiometer. Two dish-like antennas pick up the emissions – a main antenna that picks up emissions from space and directs them towards a smaller sub-antenna which guides the signals into the radiometer. The signals are directed towards the receivers, and are divided up and filtered optically. The optics consist of a combination of mirrors, slots and grids.

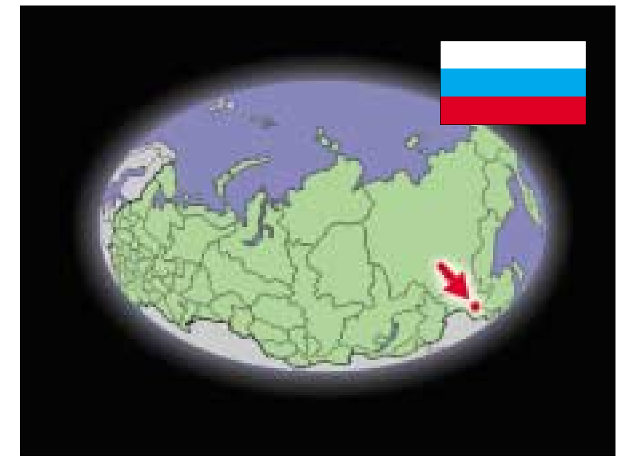
Since astronomers and aeronomers research different things, they also make different requirements on Odin’s telescope. Astronomers want to have as sensitive an instrument as possible in order to detect the weak radio emissions from molecules far out in space. Aeronomers, on the other hand, want to have an as well-defined field of view as possible. By developing a new shape and new production techniques, it has been possible to satisfy both astronomers and aeronomers.

Additional eyes help the aeronomers

A combined optical spectrograph and infrared imager, named OSIRIS, will provide the aeronomers with additional information about important gases in the Earth's atmosphere. OSIRIS will also complement the radiometer measurements by being able to measure the light scattered by atmospheric aerosols.

Odin in figures

Project start:	*1994*
Cost:	*USD 45 million*
Finance:	*Swedish National Space Board, CNES (France), CSA (Canada), TEKES (Finland), Knut and Alice Wallenberg Foundation (Sweden)*
Weight:	*250 kg, of which scientific instruments account for 80 kg*
Height:	*2 metres*
Width at launch:	*1.1 metres with retracted solar panels*
Width in space:	*3.8 metres with deployed solar panels*
Power from solar panels:	*340 W*
Pointing accuracy:	*+15 seconds of arc in a fixed position for up to 60 minutes, +1.2 minutes of arc during Earth limb scanning*
Data link:	*> 720 kbit/s to Esrange*
Memory:	*> 100 Mbyte solid state memory*
Launch:	*scheduled for 20 February 2001 from Svobodny, Siberia*
Launcher:	*Start 1 (converted SS-25)*
Orbit:	*Circular polar orbit, 600 km altitude*
Life expectancy:	*2 years*
Radiometer	
Frequency range:	*486 – 580 GHz and 119 GHz*
Frequency resolution:	*150 kHz – 1 MHz*
OSIRIS	
Wavelength range:	*280 – 800 nm; spectral resolving power: 900*
IR channel:	*three spectral bands centred at 1.263, 1.273, 1.530 µm*



Launch

Odin will begin its journey into space from Svobodny, Siberia in Russia.
The satellite will be launched using a converted missile originally intended for nuclear warheads.
The trip from the ground into an orbit 600 km above the earth will take 16 minutes.

The launcher, START-1, Credit: Swedish Space Corporation.

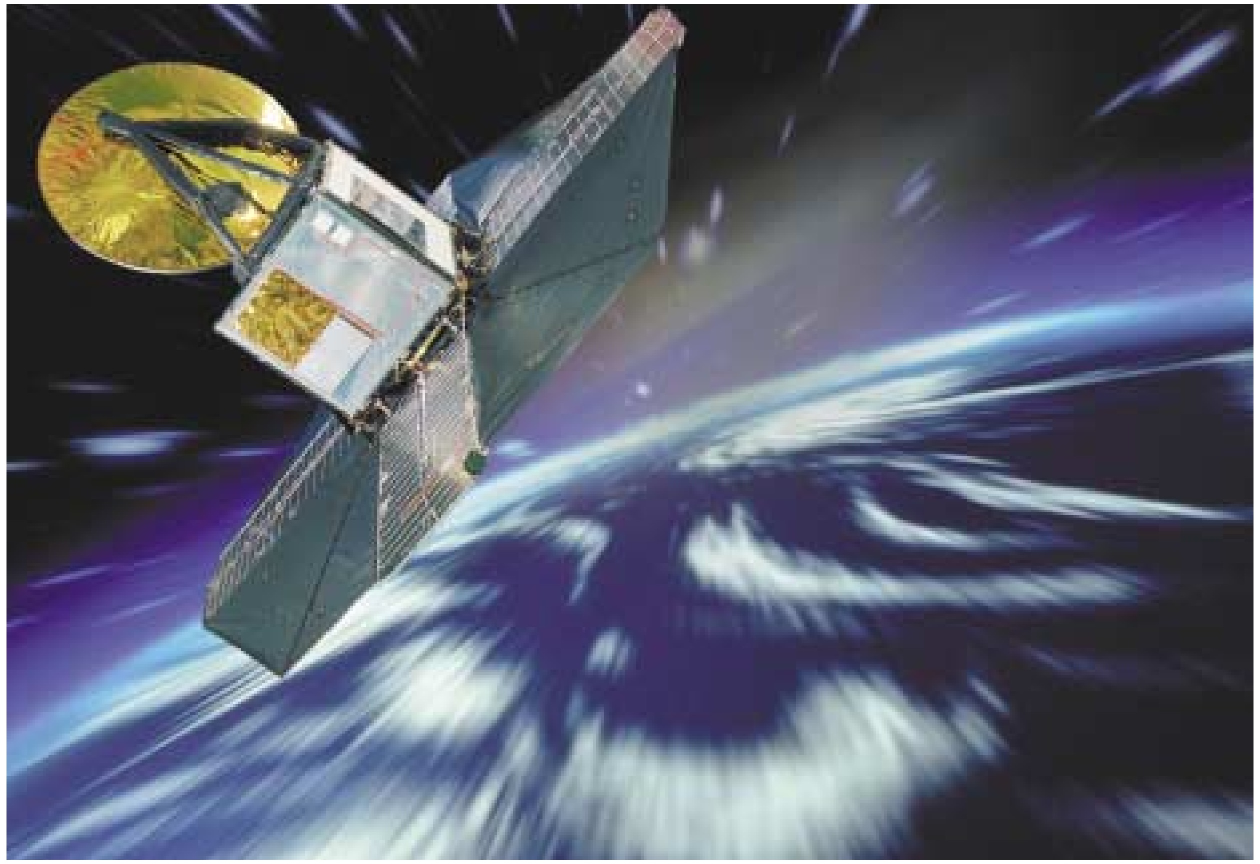


Photo: Bill Frymire/Pressens Bild and Swedish Space Corporation.

A sharpshooter among satellites

Odin can aim its measuring instruments very accurately and move with great precision. Regardless of whether or not readings are taken from outer space or the atmosphere, the satellite sets its position by the stars with the aid of an advanced, newly-developed Attitude Control System (ACS).

Since Odin's radio telescope is firmly fixed to the satellite itself, the whole satellite has to move to point its instruments, either towards outer space or towards the earth's atmosphere. A very advanced pointing system (Attitude Control System, ACS) makes it possible to set desired directions with very high accuracy. Odin's ACS can aim the satellite's instruments at an area as small as a bottle cap at a distance of 350 metres.

The ACS primarily uses star sensors and the gyroscope to determine what direction the satellite is pointed in. A special computer has been developed to handle the calculations and guidance commands of the ACS.

When the satellite is to turn in a particular direction to take its readings from outer space or from the earth, signals are sent to gyro-flywheels and electromagnetic coils that bring the satellite to the predetermined attitude.

To enable astronomers to measure emissions from remote objects in space, the satellite has to be fixed onto carefully selected points in space, usually for a very long time. At the same time, movements to other measuring points must go as quickly as possible so as not to lose valuable observation time.

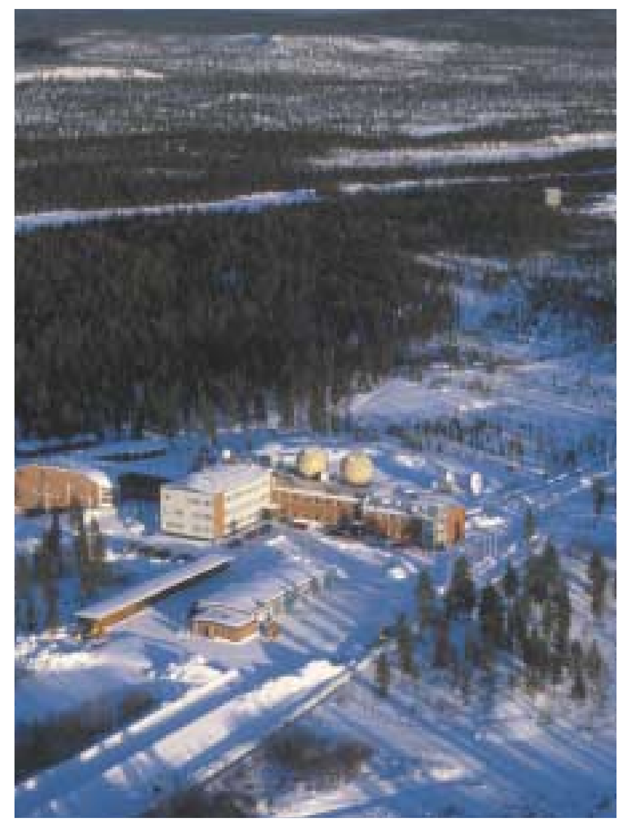
When aeronomers are to take measurements, they point the instruments towards the edge of the earth. They either study the atmosphere at a fixed altitude above the surface of the earth or they can also let Odin scan the atmosphere from about 7 km to 120 km up, about 40 times per orbit. The direction of the satellite must be continuously changed; either to compensate for the satellites movements in its orbit or to carry out the atmosphere scanning movement.

Gather, pass on, and so on…

During its career as a scientific satellite, Odin will be gathering enormous amounts of data. But Odin's memory capacity is limited so it will be transmitting its data to earth 11 times a day.

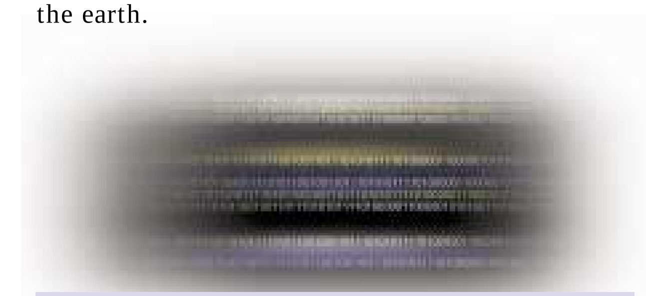
Odin will be carrying out its mission for at least two years, if everything goes as planned. During this entire period, the satellite has to be self-sufficient when it comes to power supply. Most of the time this does not present a problem as the sun provides ample energy via solar cells on the sides of the satellite. But the satellite also needs power when it is on the night side of earth, so Odin is equipped with rechargeable batteries as well.

The satellite's computer sends the data it has gathered once every orbit. This can only be done for somewhere between three and thirteen minutes per orbit, just when the satellite passes over Esrange at Kiruna, Sweden. This short transmission time has necessitated the development of a very fast transmission technique. Odin's computer sends data to Esrange at a speed of 720 kilobits a second, which is equivalent to more than ten times the speed of a modem.



Esrange in Kiruna, Sweden. Credit: Swedish Space Corporation.

But information does not just go from Odin to the ground. The satellite is, understandably, not self-sufficient when it comes to getting instructions. During its short space of time over Esrange, Odin receives commands on measurements, settings and attitude changes for its continued journey around the earth.



Figuring on Odin's data

Data from Odin's readings have to be processed before scientists can use them. The processing makes the data interpretable for scientific analyses.

Basic processing of measurement data is based on algorithms and methods which are developed by research groups in all the participating countries.

The Onsala Space Observatory/Chalmers is responsible for the preliminary processing of data from the radiometer. For astronomers, this first processing of data by Onsala/Chalmers is sufficient for making the information useful for their purposes. But aeronomers have to go a step further. Their data is further processed by the Meteorology Department at the University of Stockholm. Subsequent to this, various research groups can work on analysis of the data.

The corresponding processing of data from OSIRIS, the satellite's optical spectrometer, is done at Saskatoon/Canada (Institute of Space and Atmospheric Studies) and at Sodankylä/Finland (Arctic Research Centre).

The readings from Odin will also be compared with other readings from the atmosphere to ensure its accuracy before scientists attempt to make any conclusions. A few examples of comparative measurements are those of balloon experiments which are to measure the atmosphere's content of various molecules and a rocket experiment which is to measure water content. Odin's data will also be compared with data from the environmental satellite Envist which is to be launched into orbit in the summer of 2001.