The FMI Contribution to the Rosetta Mission

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The Finnish contributions to the European Space Agency's Rosetta mission are significant. Researchers at the Finnish Meteorological Institute (FMI), the largest individual space research group in Finland, play an important role in several instruments on board, and an industrial company has built the structure of the entire spacecraft. FMI's contributions are collected under one umbrella project called CARL, after Carl Wirtanen, the astronomer who found the original target comet for the mission. The FMI scientists have contributed to the COSIMA and RPC instruments on the orbiter and the instrument package PP/SESAME built into the feet of the lander. In addition some parts of the lander's computer system have been built at FMI.

***Dr. Johan Silén**, since 1986 employed at the Finnish Meteorological Institute working with space science related development work. Presently active in work on the COSIMA instrument of ESA's Rosetta project andanalysing data from the CIDA instrument on NASA:s Stardust spacecraft.*

***Dr. Walter Schmidt,** since 1988 employed at the Finnish Meteorological Institute and working as head of our Space Technology group. Technical manager of our contributions to SOHO, Mars Express, SMART-1 and to six different instruments on Rosetta; Principle Investigator for the Rosetta Lander's Permittivity Probe.*

The mission, a long duration project, is a nice example of international cooperation. The scarce funding has forced groups from many countries to join forces, working in a variety of consortia. The COSIMA instrument, Cometary Secondary Ion Mass Analyzer, is a sophisticated mass spectrometer capable of collecting dust grains hoovering around the comet and then processing, imaging and analysing them with high mass resolution. The instrument's primary investigator is Dr. Jochen Kissel from Germany. Contributions are provided by two research groups from France, one group in Austria and the Finnish group.

The Rosetta Plasma Consortium instrument (RPC) is a traditional plasma diagnostics device measuring the properties of the ambient plasma. Five different sensors are used, contributed by Finland, France, Germany, Sweden and the UK: a Langmuir Probe (LAP), an Ion and Electron Sensor (IES), an Ion Composition Analyzer (ICA), a Fluxgate Magnetometer (MAG) and a Mutual Impedance Probe (MIP). This setup should provide a good view on the detailed properties of the cometary plasma environment. The ICA and LAP sensors are provided by Sweden and significant parts of the data processing electronics were contributed by FMI. Additionally MIP has got its ground support equipment as a contribution from FMI.

The cometary lander Philae is essentially a simplified miniature spacecraft carrying nine instruments. The lander is from the Rosetta project point of view regarded as a single instrument. The instrumentation on board attempts to find out details about the cometary surface morphology, composition and which processes that are in operation.

One of the lander instruments, the Permittivity Probe (PP), from FMI is attempting to measure the water ice contents in the cometary surface layer using a quadrupole measurement principle with the legs of the lander and two additional movable detector bodies as sensor elements.

The contribution to the COSIMA instrument is the entire flight software development and testing. The PP instrument is a PI instrument where the main responsibility is at the FMI. The entire concept is provided as is the hardware and the software. For RPC the complete control electronics for two of the sensors has been developed and manufactured. In addition the lander solid state memory has been developed and built at FMI.

This artist's impression shows the Rosetta lander, Philae, anchored to the comet's surface, it will work for a minimum mission target of 65 hours, but its operations may continue for many months. An antenna transmits data from the surface to earth via the orbiter. The lander carries nine experiments, with a total mass of about 21 kilograms. It also carries a drilling system to take samples of subsurface material.
Illustration. ESA

The COSIMA Instrument

The goal of the scientific investigation of the new target comet Churiumov-Gerasimenko is to find out as many details as possible about its physical and chemical properties. It is extremely interesting to find out what the surface of the comet is like and what the composition and structure of dust grains is, lifted from the surface by the sublimating ice vapour pressure. It is thought that possibly complex polymerized organic molecules could be found, and they might play a significant role in the formation of life. The COSIMA instrument is designed to find out something about this.

The instrument consists of a target manipulator unit, a robotic arm moving target substrates between a storage and the different action areas. The target can be exposed to the dusty cometary environment, it can be chemically processed by heating. The substrate is photographed by a CCD-camera automatically identifying grains and telling the main computer where the grains are located and how large they are. Using this information, the scientists can set up a session of automatic analysis tasks to be performed by the Secondary Ion Mass Spectrometer (SIMS). This device makes an ion beam of Indium ions, chops the beam into narrow 50 µm thick 2 ns long pulses and steers the pulses onto the selected dust grain. The individual Indium ions knock off some ionized atoms and molecules from the grain surface. These released ions are accelerated into an ion detector. The flight time through the device is an accurate measure of the mass of the released ion from the dust grain.

The device is able to provide two-dimensional maps of the distribution of elements on the surface of a big, say 100 µm dustgrain. Because of the relatively high mass resolution (m/dm ~ 2500), it will be possible to investigate some isotopic properties of the dustforming elements. This is a powerful tool presently used only in laboratory to find out about the cosmic origin of the elements and the formation of the solar system.

A demanding laboratory program will be initiated to operate a flight spare instrument model to be used remotely to collect data on real interplanetary dust particles, micro meteorites and some dust grains from the NASA Stardust mission.

The Rosetta Plasma Consortium RPC

The five sensors are designed to monitor a wide energy range of charged and neutral particles and weak electrical and magnetic fields. The double-magnetometer measures the magnetic field in the interaction region between the solar wind plasma and the comet. The Mutual Impedance Probe is a quadruple arrangement mounted on a 1m long boom for measuring plasma electron density, temperature and flow velocity in the comet's coma in a similar way as PP is measuring the permittivity on the comet surface. The dual Langmuir probes studies plasma ion density, temperature, and flow velocity of ions and neutral gas.

The mass spectrometer ICA resolves the 3-D velocity distribution of cometary and solar wind ions with mass resolution high enough to record protons, helium, oxygen, molecular ions and heavy ion clusters. The Ion and Electron Sensor measures the energy distribution of electrons and ions in the vicinity of the spacecraft.

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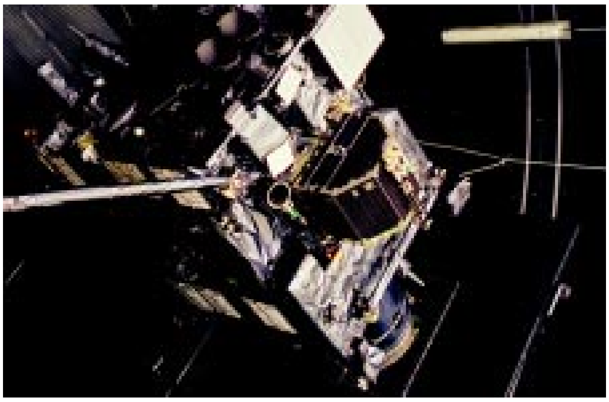
The Permittivity Probe (PP) as part of the SESAME package on the lander

This lightweight, low power instrument on the lander (180g, 400mW) measures the complex permitivity of the comet's surface material and its variation with illumination and the distance from the Sun. This is an indicator for the water ice contents and its temperature down to a depth of about 2 meters and describes the water evaporation processes on the comet surface.

The instrument digitally generates alternating currents of different frequencies between 10 Hz and 10 kHz with adjustable Voltage amplitudes up to +/-10V. This current is capacitively injected into the comet's surface between two electrodes about 2m apart. Two additional electrodes with built-in amplifiers pick up the induced potential changes in the comet's surface. From the size of the induced potential variation, the injected current and the measured phase shift between them one can calculate the permitivity as a function of the used frequency. Water contents and temperature define the details of this function. Using capacitive coupling makes this measurement independent of the details of contact between electrode and surface. As electrodes any area in contact with the comet surface can be used. Insulated wire meshes imbedded into the lander's feet serve as 2 receiving and 1 transmitting electrode. The other transmitter is attached to the bottom of the X-ray spectrometer (APX) and as geometrical alternative to the thermal sensor MUPUS, a 50cm long rod to be hammered into the comet's surface material providing information about temperature gradients and thermal conductivity.



Rosetta flight spacecraft with tha lander Philae, preparing for the interneal vacum test which simulates the deep space environment, in the Large Space Simulator at ESTEC in February 2002.
Photo: ESA

Additionally the 2 receivers can be used alone already during descent, but also on the surface, to measure plasma waves caused by interaction between solar wind and ejected surface material.

PP works together with a seismic device also built into the feet (CASSE), which analysis artificialy or naturally excited sound waves through the comet surface in a similar way oil exploration is done on earth. The 3rd instrument of SESAME is a 3-dimensional Dust Impact Monitor (DIM), which uses piecoelectrical surfaces to monitor the speed, size, amount and direction of dust particles in the vicinity of the lander. The cube-like detector is mounted at a top edge of the lander. ■

Swedish contribution to the Rosetta scientific camera

The cometary research group at Uppsala Astronomical Observatory is mainly involved in the scientific imaging on board the Rosetta spacecraft, whose name is OSIRIS. The name stands for Optical, Spectroscopic and Infrared Remote Imaging System, and dates back to the early days when an infrared channel was planned. That facility, however, had to be cancelled at an early stage, as the model payload had to be trimmed. The OSIRIS pictures will hence be limited to the optical and near ultraviolet spectral regions.

This is a very advanced camera system with two principal components: the narrow angle camera NAC and the wide-angle camera WAC. The leadership of the teamm and all co-ordination work is stationed at the Max-Planck Institute für Aeronomie at Lindau, Germany. The optical designs and the construction work for the two cameras have been done at the Laboratoire d'Astronomie Spatiale in Marseille, France, and the University of Padova, Italy, respectively. Both cameras use rotating dual filter wheels whose construction was performed in Spain, while the procurement of the filters was the responsibility of the Swedish group. Spectrogon AB at Täby (a northern ssuburb of Stockholm) delivered these interference filters, as they had earlier done with the filters for the ISOCAM camera on ISO, the ESA Infrared Space Observatory.

Imaging will be performed in a wavelength interval from about 250 nm to close to 1 micron, and the bandpasses have been matched for mineralogical characterisation of the nuclear surface and the mapping of gas emissions and dust structures in the innermost coma of the comet. Of course, OSIRIS will also provide great help in identifying the optimal landing site for the Rosetta lander. NAC is mainly responsible for the nucleus, and with the aid of a refocusing lens it is planned to take images with resolution down to a few centimetres! WAC will be able to image the whole nucleus but will in fact concentrate on its closest surroundings with the aid of narrow band filters centred on strong emissions by important cometary molecules.

Interpreting these images will require a very advanced set of models for all physical phenomena at the nuclear surface, where the gas and dust feeding the coma emanate. This is a speciality of the Uppsala group, whose involvement in OSIRIS thus has a very strong emphasis on theoretical interpretation. For instance, Björn Davidsson, a young scientistt with a PhD from Uppsala 200 devoted to cometary gas production, is now working at ESTEC, Noordwijk, in close collaboration both with the Uppsala group and the Rosetta project team.