Press Release

German Comet Dust Analyzer to launch on Rosetta

SCHWETZINGEN, 24 February 2004: When on the morning of 26 February 2004 the large comet probe Rosetta is launched on an Ariane 5, it will carry yet another major space experiment built in the small German town of Schwetzingen. COSIMA, the Cometary Secondary Ion Mass Analyzer, has been developed by the von Hoerner & Sulger GmbH, under the scientific leadership of Dr. Jochen Kissel of the Max Planck Institute for Aeronomy in Katlenburg-Lindau. Several national and international institutes have contributed hard- and software to the complex instrument for which vH&S was the main contractor. The project was financed by the German science ministry and the respective ministries of the other countries involved.

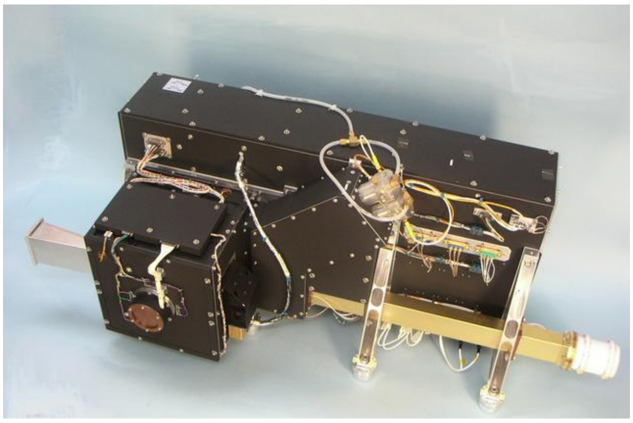

Figure 1: The COSIMA Instrument.

The Rosetta Mission

The Rosetta mission by the European Space Agency ESA is an important milestone in the exploration of our solar system – and the most ambitious venture in comet exploration by far. Its destination is comet Churyumov-Gerasimenko which will be reached in 2014. Rosetta consists of an orbiter – that will accompany the comet for several years on its journey towards the Sun – and a lander, recently christened Philae, that will touch down on the comet's nucleus. The orbiter carries eleven scientific instruments, among them COSIMA, and will at first map the nucleus with its instruments. Soon afterwards Philae, carrying another ten instruments, will be sent to the surface where it will investigate its structure in great detail. Data are being sent to the Earth via the orbiter. Von Hoerner & Sulger has also contributed to Philae by building the central electronics of the SESAME experiment.

COSIMA will already be the 6th comet dust analyzer built by vH&S that has been sent into space in the last two decades: The Schwetzingen-based company can claim complete dominance of this field of space science in the world. Three predecessors of COSIMA, called PUMA 1 and 2 and PIA, passed close to Halley's comet in 1986. The PUMAs were part of the payload of the Soviet VeGa spacecraft, PIA travelled on ESA's Giotto. Modified versions of these instruments were launched on two NASA comet probes in 1999 and 2002 under the name CIDA, and just on January 2 this year, the Stardust spacecraft reached comet Wild 2 (see the detailled vH&S Press Release from 29 December 2003). Several dozen dust particles were analyzed by its CIDA experiment, and the results from the Halley flybys on their typical composition could already be confirmed and expanded upon. COSIMA is building on the Halley experience, but the instrument is much more sophisticated. And, once more, it is the only one on the Rosetta orbiter that can analyze the chemical composition of Churyumov-Gerasimenko's dust in situ.

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1 Why Study Comets?

Comets can be seen as the last semi-primordial material from the youth of our solar system. They formed $4^{1}/_{2}$ billion years ago, together with the Sun and the planets, but at such distances from the Sun that the original building blocks are still thought to reside inside their nuclei in a rather pristine shape. And cometary dust provides ready access to this fascinating reservoir. Comets spend most of their lives far from the Sun, billions of kilometers away, beyond the orbits of the major planets. There, comets are not more than oddly-shaped clumps of refractory material and frozen gases, and these so-called nuclei (nucleus in singular) are so small that most of them cannot be imaged with the best telescopes. But when a comet approaches the Sun, dramatic changes happen: The nucleus heats up, the frozen volatiles enter the gas phase directly without thawing (a process known as sublimation), and the venting gas – predominantly carbon monoxide and water vapor – drag dust particles along with them. A glowing cloud forms around the nucleus, tens of thousands of kilometers in diameter, much larger than the nucleus itself.

Figure 2: The comet 67P/Churyumov-Gerasimenko (`http://www.tls-tautenburg.de`).

The technical term for this cloud is coma: It consists of the released gases (that are excited to emit their own light by the radiation from the Sun) and the dust (which simply reflects the sunlight). A comet's apparition can grow particularly spectacular when a tail grows from the coma which can reach a length of several million kilometers. The solar wind – a continuous fast stream of charged particles from the Sun – is dragging the gas particles with it, which have been ionized by the solar ultraviolet radiation, while solar radiation pressure is pushing the dust particles out of the coma.

1.1 The Story of Comet Dust

We must not think of comet dust as the dirt found underneath some furniture. The particles are generally much smaller and rather resemble the toner in xerox machines or laser printers, even matching their deep black color. Most dust particles encountered in 1986 by several spacecraft in the vicinity of Halley's comet had masses of only 10^{-12} to 10^{-14} grams. Their composition was measured back then by three pioneering instruments built by vH&S, PUMA-1 and -2 and PIA, with PUMA-1 delivering the best data. A key insight was that the atoms making up Halley's dust were on the average 30 % carbon and 50 % oxygen (with carbon making up 20 % of the dust mass). Individual grains could differ a lot, though, and 30 % of them consisted of particularly light atoms such as carbon, hydrogen, oxygen and nitrogen.

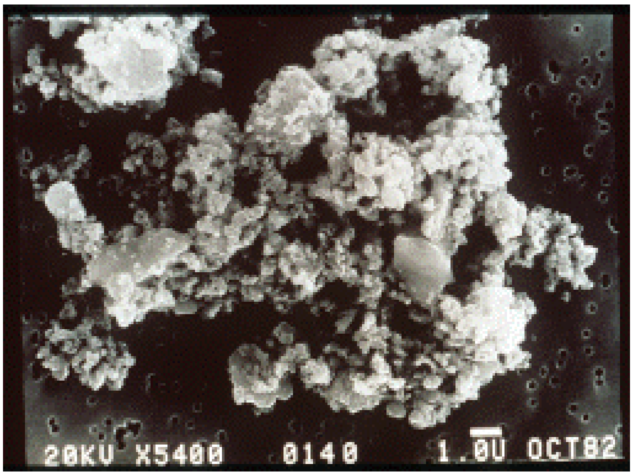

Figure 3: Interstellar dust "Brownlee-Particle" (Source: JPL).

This completely unexpected type was soon christened CHON particle (from the first letters of the chemical signs): Having CH, they are organic substances, a term that does not necessarily imply a connection to biology, though. Another 35 % of Halley's dust was a mix of CHON and silicates, and the remaining 35 % were pure silicates, i. e. consisted only of heavier chemical elements, although somewhat enriched in oxygen. The enormous carbon content in Halley's dust was in marked difference to all known meteorites as well as the interplanetary dust particles planes are catching in Earth's upper atmosphere: The exceptional standing of comets in the solar system was confirmed by this discovery. Their solid components were different and more complex but also more primitive than meteorites.

Instead, the material bore more resemblance to the interstellar dust thought to make up the solar nebula from which the solar system formed $4^1/_2$ billion years ago by dramatic collapse. It is not clear, though, what percentage of the dust of Halley – or any comet – is genuine interstellar dust and what are particles that formed only later, in the solar nebula. It is evident even to the naked eye that space between the stars is full of dust: It silhouettes against the bright band of the summer Milky Way. This dust can be studied with a variety of astrophysical methods, and it is thought to play a major role in the formation of stars, planets and comets – in our own solar system as well as in others.

Interstellar dust originates in the vicinity of old or dying stars: Molecules can form in the extended and comparatively cool atmospheres of these stars, and they can aggregate into larger particles floating about in space even when the stars are long gone. Dust grains formed this way have been isolated in primitive meteorites, and their chemical make-up even gave clues about the types of stars they had formed around. But these particles have suffered severely before they were included in the meteorites, and they are no longer good examples for typical interstellar dust. It is likely, for example, that interplanetary dust particles acquire a thick shell of frozen gases – which is then modified when they approach a star. The hard ultraviolet radiation leads to the formation of complex organic molecules, which are incorporated into comet nuclei.

And so, finally, biology may enter the picture after all: The insights from the Halley missions and especially the three vH&S dust experiments have actually made it more likely that comets played some role in the origin of life on Earth. The data clearly exclude that complete bacteria are travelling through space in comet nuclei, but the chemical compounds found in Halley's dust would be quite reactive, especially in warm water. And cometary dust with its fluffy structure would constitute an almost ideal delivery vehicle for these compounds to the young Earth, keeping them together until pre-biotic chemical reactions would commence. This scenario is pure speculation at this point, but the insights gained in the years after the Halley visits have quickly led to the longing for a much more systematic study of cometary dust. Rosetta's COSIMA experiment is the answer.

2 The History of the COSIMA Experiment

The development of the COSIMA experiment began in 1992 with a phase A initial study by ESA for the planned Rosetta mission. Dr. Kissel, then at the MPI for Nuclear Physics in Heidelberg, was asked to submit for study a concept for a dust spectrometer. At that time vH&S had a fully developed spectrometer experiment, COMA, that was to fly on the NASA mission CRAF – which had been cancelled in 1991, unfortunately. ESA chose Rosetta as the winner among several candidate missions in 1993 and defined it as one of the cornerstone missions in the Horizon 2000 program. To reduce the cost for Germany for the development of the experiment, Dr. Kissel in June of 1994 visited several scientific institutes in Germany and abroad, collected externally financed contributions to the instrument, and submitted the COSIMA proposal to ESA. VH&S was contracted to build the instrument in 1998, and the final flight model was delivered in July 2002.

When Rosetta reaches comet Churyumov-Gerasimenko, it will still be far from the Sun (670 million kilometers): The spacecraft will accompany the comet on its journey inwards. The surface of its nucleus will heat up, gases and ice and dust particles will be released and a coma will form. This is the time when COSIMA will collect and analyze dust particles, one after the other. The dust particles stick to the porous surfaces of tiny metal substrates, so called targets, which are exposed to space. Inside the instrument the dust particles collected on the targets will first be located by a microscope camera – then the targets will be analyzed about their chemical composition with a sophisticated mass spectrometer. The measured mass spectra are then downlinked to Earth as raw data where they will be analyzed.

3 How COSIMA works, in More Detail

Please refer to the following functional overview:

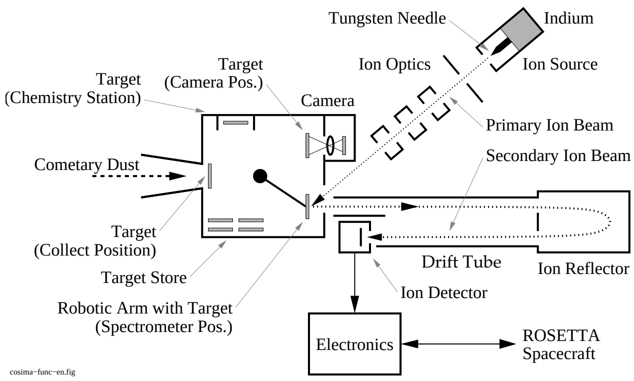

Figure 4: COSIMA functional overview. This schematics shows the major subunits of COSIMA, the various analysis positions, and the trajectories of primary and secondary ions.

3.1 The Dust Collector Unit

The dust collector unit holds a supply of 24 targets. A miniaturized robot arm moves a target either to the outside for collecting dust or into one of several analysis positions where the collected dust is investigated. The targets are made of several very pure metals, their surfaces prepared for dust catching, and were mounted into COSIMA under extreme cleanroom conditions at the vH&S facility. It is to be avoided at all cost that dust carried along from Earth is mistaken for comet dust! Just before collecting in space begins, COSIMA checks all targets for possible contamination and cleans them with an ion beam (see below).

3.2 The Camera

When a target has collected enough dust, the robot arm swings it in front of the lens of a digital microscope camera. Several light emitting diodes illuminate the target surface at a slant angle, so that the dust particles make themselves known thanks to their long shadows. The camera calculates the position of each particle on the target during the procedure.

3.3 The Chemistry Station

In another analysis position the target can be heated. Here it is investigated how the dust particles change under heating.

3.4 The Mass Spectrometer

The most important analysis position belongs to the mass spectrometer component of COSIMA. Here the target is being fired at with bursts from an ion source, lasting only nanoseconds. When this primary ion bean hits a dust particle it sputters off secondary ions. These are accelerated by electrical fields, move a certain distance in a drift tube, are being turned around by electrical fields in a reflector and move through the drift tube a second time. This doubling of the flight distance reduces the physical size of COSIMA and increases the mass resolution at the same time. The secondary ion beam is eventually caught by a highly sensitive ion detector. In the beginning all ions receive the same energy: Heavier ions will move more slowly than lighter ones, which hit the detector first.

The signal at the detector as a function of time thus yields directly the mass spectrum of the dust particle. Therefore such a system is called a time of flight mass spectrometer, and since COSIMA works with secondary ions, it is a ToF-SIMS or time of flight secondary ion mass spectrometer. This measurement principle has a high resolution, is conceptionally simple, highly reliable and thus ideally suited for automatic measurements without personnel: perfect for use in spaceflight. The spectrometer can determine element masses from 1 to 4000 atomic mass units (AMU), with a relative mass resolution of 3000 (at 13 AMU). The company von Hoerner & Sulger has accumulated experience with this type of spectrometer over many years, thanks to PUMA, PIA and CIDA.

3.5 The Indium Sources of the Mass Spectrometer

COSIMA uses two liquid metal emitters, filled with the element Indium, as ion sources. This metal has a low melting point and can be liquefied easily with a little heater element. The liquid indium creeps along a tungsten needle to its point. There an electrical field draws off indium ions, so that a thin indium beam is formed which is collimated by ion optics and cut into short pulses. Eventually the ion beam hits the target with the comet dust to be studied. A second indium source with separate ion optics is used to clean the target surfaces by sputtering – and it also serves as a redundant source in case the main source should fail.

3.6 COSIMA's Electronics

To make all these things happen, COSIMA contains a large number of electronics components, distributed on 32 tighly packed printed circuit boards. Many precision high-voltage generators ensure that the ions stay exactly on their predefined trajectories and find their way to the ion detector. The flight times are measured with nanosecond precision by high-speed electronics. A fast signal processor runs and controls all functions and establishes the data connection to the spacecraft. The whole COSIMA instrument nonetheless uses less than 20 Watts of power in routine mode; it receives just one voltage (28 V) from the spacecraft and generates all voltages needed internally by itself. The complete COSIMA experiment weighs a little less than 20 kg.

3.7 Reliability Aspects during the Construction of COSIMA

In the development of such a complex system reliability and robustness under the extreme conditions of space is the key. There are enormous changes in temperature, depending on the distance from the Sun, and there is high energy radiation everywhere in space. Components cannot be cooled by fans – like in a PC on Earth – because there is no atmosphere. Another critical aspect of all Rosetta experiments is that the all-important activity phase will not come until ten years after launch. Thus all systems must use particulary reliable and long-living components. The company vH&S has spent particular effort in building this instrument and selecting its components. Some of the components have been tested explicitly by vH&S with the help of ESTEC for their radiation hardness. There is even a small radiation detector flying in COSIMA to record the space radiation hitting the experiment, an experiment within the experiment in a way.

3.8 Company Profile of vH&S

The company von Hoerner & Sulger is a privately owned small business (SME status), located in Schwetzingen and founded in 1971 by Mrs. Dr. Hanna von Hoerner. Apart from special projects for medical technology and industrial applications, the speciality of the company is instrument development for space missions. With about 20 employees, vH&S has already developed and built more than 15 space instruments as the main contractor. Add to that numerous experiments flown on sounding rockets and scientific studies for space systems.

Current projects of vH&S include the development of UV radiation detectors for the University of Bonn that will fly on the NASA mission TWINS, the development of a digital real-time video system for robotic applications (ROKVISS) on the International Space Station and a technology study for ESA of a minirover to explore the Martian surface. Already in orbit for some time are vH&S developments for the astronomy satellite SWAS and the solar observer SOHO. Today von Hoerner & Sulger is an integral part of Germany's activities in space science.

3.9 Address and Contact at vH&S

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4 Images for Download

The original images with high resolution can be downloaded from the vH&S homepage through the given links.

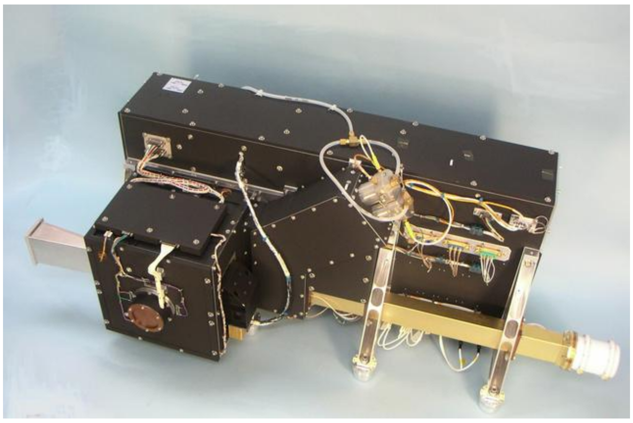

Figure 5: COSIMA Flight Model, photo 1.

`http://www.vh-s.de/projects/cosima/press/cosima-fm-a.jpg`

Figure 6: COSIMA Flight Model, photo 2.

`http://www.vh-s.de/projects/cosima/press/cosima-xm-a.jpg`

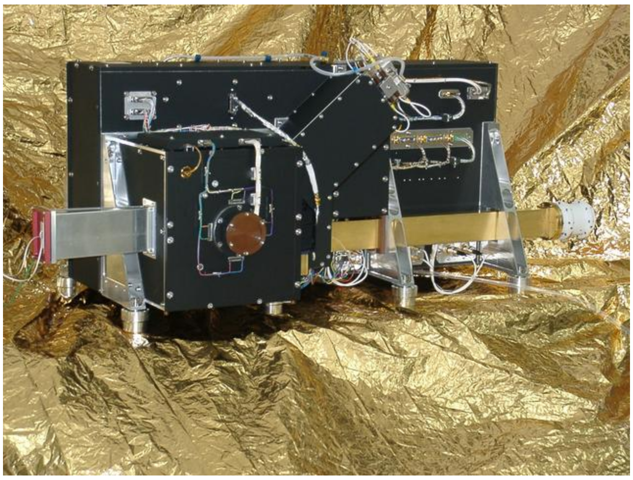

Figure 7: COSIMA Flight Model, photo 3.

http://www.vh-s.de/projects/cosima/press/cosima-xm-b.jpg

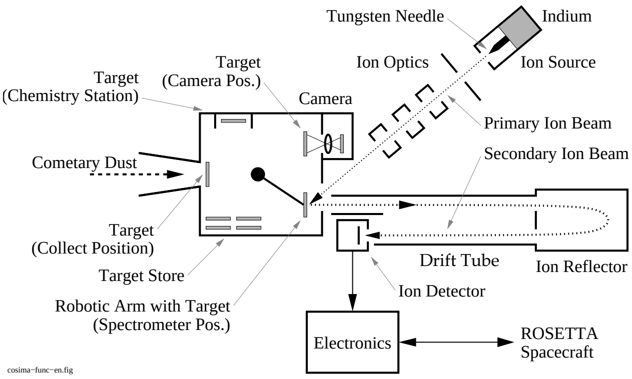

Figure 8: COSIMA functional overview.

http://www.vh-s.de/projects/cosima/press/cosima-func-en.pdf

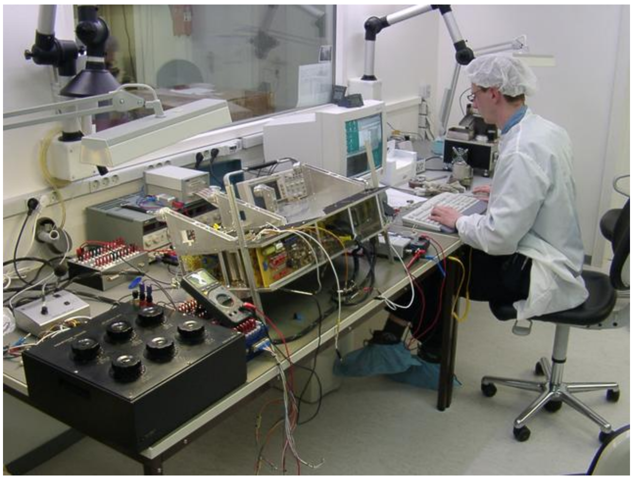

Figure 9: View into the vH&S cleanroom, during instrument calibration phase. The COSIMA electronics box is seen in the image center. On the right side: Dipl.-Ing. Andreas Koch (vH&S) at the test system.

http://www.vh-s.de/projects/cosima/press/xm-020228.jpg

5 Further Informations via Internet

Homepage of the Rosetta Mission
http://rosetta.esa.int

Homepage of vH&S
http://www.vh-s.de

COSIMA project page at vH&S
http://www.vh-s.de/projects/cosima/cosima.html

CIDA project page at vH&S
http://www.vh-s.de/projects/cida-stardust/cida.html

CIDA Press Release from 29 Dec. 2003
http://www.vh-s.de/projects/cida-stardust/press/cida-031229-en.html

Homepage of the MPAe, Katlenburg-Lindau
http://www.linmpi.mpg.de

Homepage of the MPE, Garching
http://www.mpe.mpg.de

Informations about COSIMA at the FMI
http://www.geo.fmi.fi/PLANETS/Cosima.html

Homepage of Arianespace
http://www.arianespace.com

Homepage of ESA
http://www.esa.int

6 Abbreviations

CHON	Carbon-Hydrogen-Oxygen-Nitrogen
CIDA	Cometary and Interstellar Dust Analyzer
COSIMA	COmetary Secondary Ion Mass Analyzer
CRAF	Comet Rendezvous & Asteroid Flyby
ESA	European Space Agency
FMI	Finnish Meteorological Institute
MPAe	Max-Planck-Institut for Aeronomy
MPE	Max-Planck-Institut for Extraterrestrial Physics
NASA	National Aeronautics & Space Administration
JPL	Jet Propulsion Lab
PIA	Particulate Impact Analyzer
SIMS	Secondary Ion Mass Spectrometer
TOF	Time-Of-Flight (Mass spectrometer principle)
vH&S	von Hoerner & Sulger GmbH

7 URL of this Press Release

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http://www.vh-s.de/projects/cosima/press/cosima-040224-en.pdf
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