# Cloud Ice Water Sub-millimetre Imaging Radiometer

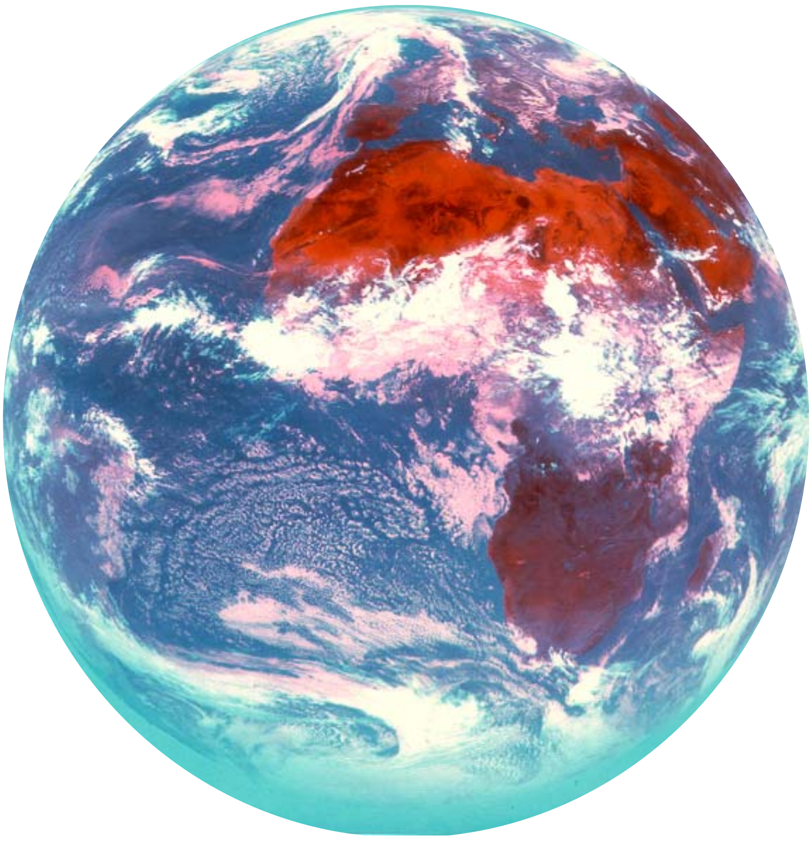
# CIWSIR

**Submitted**
**in Response to the Second Call for Proposals for Earth Explorer Opportunity Missions**

**by**

**Klaus Künzi**

**September 2001**



## A. Introduction

Cirrus clouds play an essential role in the energy budget of the atmosphere. They are at high altitudes, absorb longwave radiation from below and, as they are cold, emit little infrared radiation; this greenhouse effect results in general in a warming of the earth-atmosphere-system. On the other hand, cirrus clouds reflect direct solar short wave radiation, hence cool the surface. The net effect is crucial for the atmosphere, but will depend highly on the cloud's horizontal extent, vertical position, and ice particle size distribution, which all influence the cloud's optical thickness. Thus, the special properties of cirrus clouds have a strong impact on radiative exchanges. Furthermore, cirrus clouds affect the energy budget by release of latent heat during depositional growth of ice particles, and ice particles, if large enough, sediment through the atmosphere and may enhance precipitation generation in lower clouds by the seeder-feeder mechanism.

The importance of clouds in weather and climate processes has been recognized through a number of observational and modeling studies (see e.g., Liou, 1992 [1]) and is especially emphazised in the third IPCC-Report [2]. However, the knowledge of characteristic properties of cirrus clouds with respect to climatological purposes and numerical models for the atmosphere is still insufficient. For example, the mean cirrus cover over the U.S. varies from 20 to 70 % according to various authors and sensors (Wylie, 1998[3]). Prerequisite for a climatology of cirrus cloud properties including their long term changes are global observations with high spatial and temporal resolution, at least of the vertically integrated ice mass concentration and characterisitic size and shape. This requires radiation measurements from satellites within appropriate frequency ranges.

In numerical weather prediction models and climate simulation models the effect of cloud microphysical processes and of radiative processes are treated by sophisticated parameterizations (e.g., Doms and Schättler, 1999 [4], for the German mesoscale weather forecast model, or Roeckner et al., 1996 [5], for the ECHAM climate model). However, especially the parameterized treatment of microphysics related to the ice phase is subject to many problems. Recent sensitivity studies, like the one by Wilson (2000) [6] using the UK MetOffice forecast model, find that zonally averaged water and ice concentrations vary considerably depending on the chosen parameterization. To evaluate such results, again measurements of cloud properties continuous in space and time are urgently needed.

Although satellite measurements with visible and infrared techniques can be used to detect the presence of cirrus clouds and to determine the cloud top altitude (from the cloud top temperature), as well as optical depth, they are not suited to determine cloud internal properties as the ones mentioned above, because most clouds will be opaque in this frequency range. On the other hand, the sub-millimeter wave spectral range offers a number of advantages, as has first been pointed out by Evans [7].

In this frequency range, the brightness temperature depression measured by the sensor will be proportional to the total mass of ice in an upper tropospheric column of air. Although the constant of proportionality for a given frequency will depend on characteristic particle size and shape, measurements at different frequencies can be used to eliminate this ambiguity to a large extent. This thechnique is used by the proposed CIWSIR sensor. Primary data products will be upper tropospheric columns of ice mass concentration, characteristic size of the ice particles, and an estimate of the predominant shape. Nearly daily global coverage will be possible by using a polar orbiting platform. These data products are some of the most basic, and therefore most urgently needed, cirrus parameters, and they are not measurable with comparable coverage in time and space by any other method.

---

[1] Liou, K.N., 1992: Radiation and Cloud Processes in the Atmosphere. Oxford University Press, Oxford, 487pp.
[2] IPCC, 2001: Technical Summary. A report accepted by Working Group I of the IPPC, but not approved in detail. 83pp.
[3] Wylie, D., 1998: Cirrus and Weather: A satellite perspective. OSA Meeting, pp.66-68, Baltimore, U.S.A., 6-8, Oct. 1998
[3] IPCC, 2001: Technical Summary. A report accepted by Working Group I of the IPPC, but not approved in detail. 83pp.
[4] Doms, G. and U. Schättler, 1999: The nonhydrostatic Limited-Area Model LM (Lokal-Modell) of DWD. Part I> Scientific Documentation. DWD, GB Forschung und Entwicklung.
[5] Roeckner, E., et al., 1996: The atmospheric general circulation model ECHAM-4: Model description and simulation of present-day climate. MPIfM, Report 218.
[6] Wilson, D., The impact of a physically based microphysical scheme on the climate simulation of the Meteorological Office Unified Model. Q.J.R.Meteor.Soc., 126, 1281-1300.
[7] Evans, K.F, A.H. Evans, I.G. Nolt, and B.T. Marshall, 1999 - The prospect for remote sensing of cirrus clouds with a submillimeter-wave spectrometer - *J. Appl. Meteorol.,* v.38, pp.514-525

## B. Mission Characteristics

**Sub-mm sensors for cirrus clouds:** Recently, sub-millimetre radiometric measurements from satellites or aircraft in the frequency range of 300-1000 GHz (i.e., wavelength: 1.0-0.3 mm) have been proposed to investigate cirrus clouds (Evans and Stephens 1995a[8], b[9]; Evans et al. 1998[10], 1999[11], Künzi et al. 2000[12]). Since water vapour absorption is strong within this band, the lower atmosphere is in most cases opaque, therefore the surface and low clouds do not contribute to the up-welling radiation. In this frequency range, the interaction between the cirrus clouds and the radiation is by scattering, so emission and therefore cloud temperature are not important. The situation can be sketched as that of a layer of cloud ice lying on top of a radiation source. Hence, the effect of the cloud is to reduce the brightness temperature compared to the clear sky case. It can be shown that, except for very strong cirrus clouds, the RT occurs in the linear regime, i.e., the brightness temperature depression is proportional to the integrated ice water content (IWC). The linearity of the RT has the advantage that radiation averages correspond to the radiation of an average atmospheric state, i.e., problems related to beam-filling in the presence of non-linearities, which are significant for optical and IR techniques, are unimportant.

As stated above, the monochromatic brightness temperature depression due to the presence of cirrus for a down-looking radiometer is closely related to the total mass of ice in the observation path. The mean size of the ice crystals can be estimated using the ratio of brightness temperature depressions measured at two frequencies. Simulations performed for horizontally oriented non-spherical particles at two orthogonal polarisations (vertical and horizontal) further demonstrate that the depolarisation effects might be useful in determining the ice particle shape, although the fact that realistic cirrus clouds contain a mixture of ice crystals with different shapes and sizes may limit the applicability of this technique. A sub-millimetre radiometer dedicated to the investigation of cirrus clouds should have multiple channels in order to cover a wide range of total columnar ice and particle sizes and it should include a lower frequency channel for determining the atmospheric background emission.

**Frequency selection:** In determining the sub-millimetre channels needed for cirrus detection it is necessary to fine-tune the channel frequencies. This includes (1) the matching of the temperature weighting functions of all sub-mm channels and (2) avoiding ozone resonances. Here, 'matching' means all channels sense the same layer in the atmosphere, i.e., they measure the same brightness temperature for a cirrus free situation. The result of quantitative weighting function matching for the US standard atmosphere at the selected frequencies is demonstrated in figure B.1. The three sub-millimetre channels are located in flat window regions between strong water vapour lines, and have been optimised to avoid ozone lines (see figure B.2).

Above 200 GHz only airborne sensors have been flown so far, e.g., the airborne NASA Millimetre-wave Imaging Radiometer (MIR) is equipped with a 220 GHz channel since 1992 (Racette et al. 1996[13]). The primary use of this channel was initially the retrieval of water vapour in the lower troposphere. However, it was soon found also to be very useful in detecting ice particles in clouds (Gasiewski 1992; Liu and Curry 1996, 1998[14]; Wang et al. 1997[15], 1998[16]). Moreover, the work per-

---

[8] Evans, K.F. and G.L. Stephens, 1995a - Microwave radiative transfer through clouds composed of realistically shaped ice crystals. Part I: single scattering properties - *J. Atmos. Sci.*, v.52, pp.2041-2057

[9] Evans, K.F. and G.L. Stephens, 1995b - Microwave radiative transfer through clouds composed of realistically shaped ice crystals. Part II: remote sensing of ice clouds - *J. Atmos. Sci.,* v.52, pp.2058-2072

[10] Evans, K.F, S.J. Walter, A.J. Heymsfield, and M.N. Deeter, 1998 - Modeling of submillimetre passive remote sensing of cirrus clouds - *J. Appl. Meteorol.,* v.37, pp.184-205

[11] Evans, K.F, A.H. Evans, I.G. Nolt, and B.T. Marshall, 1999 - The prospect for remote sensing of cirrus clouds with a submillimeter-wave spectrometer - *J. Appl. Meteorol.,* v.38, pp.514-525

[12] Kunzi , K, G. Heygster, and J. Miao, 2000 - Appendix-7: Ice cloud and background water vapour by sub-millimetre and very high frequency microwave radiometry - *CLOUDS-A Cloud and Radiation Monitoring Satellite: Final Report to EU*

[13] Racette, P., R.F. Adler, J.R. Wang, A.J. Gasiewski, D.M. Jackson, and D.S. Zacharias, 1996 - An airborne millimeter-wave imaging radiometer for cloud, precipitation, and atmospheric water vapour studies - *J. Atmos. Oceanic Technol.,* v.13, 610-619

[14] Liu, G. and J.A. Curry, 1998 - Remote sensing of ice water characteristics in tropical clouds using aircraft microwave measurements - *J. Appl. Meteorol.,* v.37, pp337-355

[15] Wang, J., J. Zhan, P. Racette, 1997 - Storm-associated microwave radiometric signatures in the frequency range of 90-200 GHz - *J. Atmosph. Ocean. Technol.*, v.14, pp.13-31

[16] Wang, J., J. Zhan, and P. Racette, 1998 - Multiple aircraft microwave observations of storms over the western Pacific Ocean - *Radio Sci.,* v.33, pp.351-368

formed by Gasiewski (1992) and Liu and Curry (1998) showed that the 220 GHz channel is probably the most sensitive one for measuring cloud ice associated with strong convection.

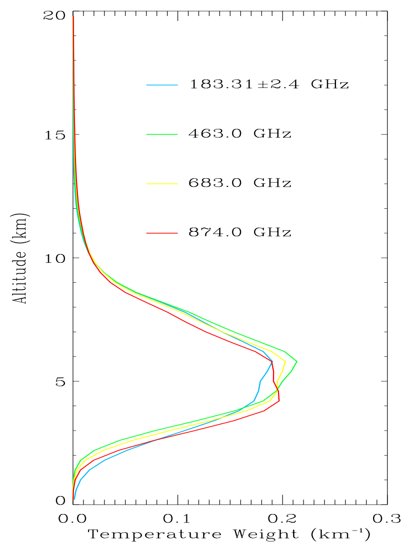
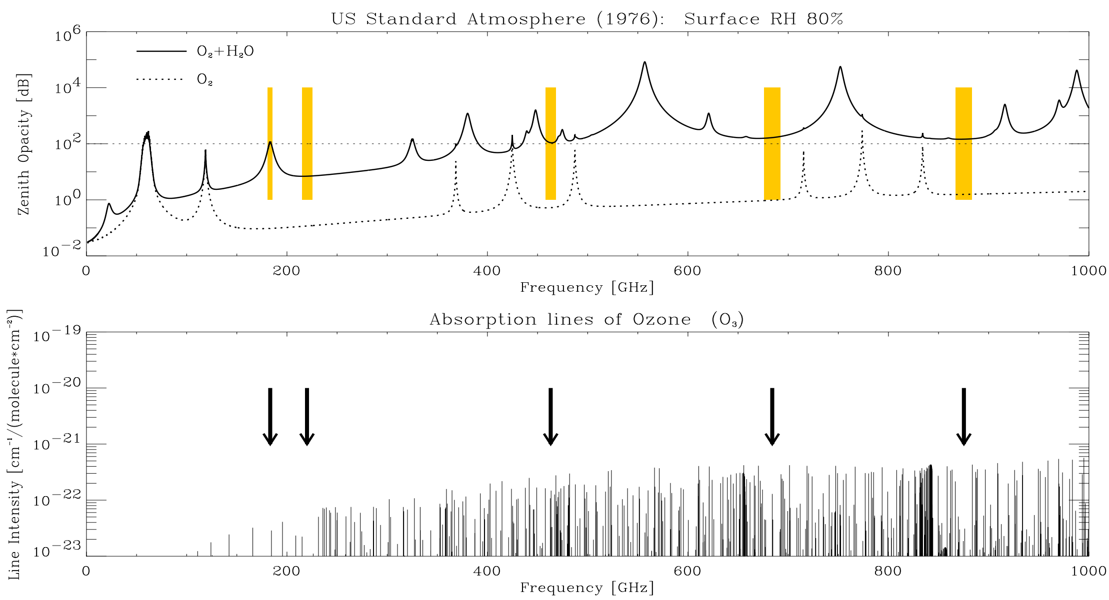



***Fig. B.1*** *- The temperature weighting functions for the US standard atmosphere at the four frequencies which are found for a best match and are therefore proposed for CIWSIR .*

***Fig. B.2:*** *Locations of the CIWSIR sub-millimetre channels in relation to spectra of atmospheric oxygen, water vapour (top), and ozone (bottom) within the frequency range of 0-1000 GHz. Ozone data from Rothman, L.S. et al., 1998 - The HITRAN molecular spectroscopic database and HAWKS (HITRAN Atmospheric Workstation): 1996 Edition - J. Quant. Spectrosc. Radiat. Transfer, v.60, pp.665-710.*




**Other mission characteristics:** A sun-synchronous orbit is suggested allowing for a field of view of the order of magnitude of cirrus clouds (10km, Table C.2). To get information about the temperature and humidity profile, the mission should fly in tandem with an operational meteorological sensor. Among the various possible tandem partners , a strong candidate offering a multitude of sensors with a high potential synergy is the METOP mission. If it is possible to operate and manoeuvre CIWSIR in a fashion to fly in a short and constant distance from METOP so that both satellites scan the Earth in a distance of not more that 10 minutes, (i.e., well below the typical 10 km displacement time of cirrus clouds) this innovative technique can spare additional water vapour channels on CIWSIR. Among the sensors aboard METOP offering a synergy with CIWSIR are MHS (183 and 150 GHz channels providing all weather humidity profiles), AVHRR/3 (cloud detection), and IASI (high vertical resolution temperature soundings). A mission duration of three years would allow for an initial assessment of the global cirrus Climatology, which may eventually lead to an operational sensor on later meteorological satellites.

## C. Technical Outline

CIWSIR is a five frequency, nine-channel microwave radiometer - one mm channel for the water vapour background radiation (near 183 GHz), and eight channels for measuring ice clouds (near 220, 463, 683, and 874 GHz, each frequency with two polarizations). For the frequency splitting of the beams, two quasi-optical multiplexers are implemented (one for the mm- channels, one for the sub-mm- channels) making use of dichroic plates. The separation of the two polarisations (horizontal and vertical) is implemented by using wire grids, which offer low losses and almost frequency-independent performance. The radiometer is equipped with two built-in calibration systems utilising ambient temperature loads and cold sky (2.7 K) as standards. The receivers are using uncooled fundamentally pumped Schottky type mixers for the sub-mm channels with quasi-optical diplexers for local oscillator (LO) injection. The LO's for the sub-mm channels are based on Gunn oscillators with appropriate frequency multipliers. The mm-wave channels are making use of sub-harmonic mixers, providing a sufficient signal to noise.

The CIWSIR instrument has been studied in a Phase-A study within the CLOUDS project supported by the European Union. The technical feasibility has been analysed in quite some detail and the industrial contractors have not identified any critical areas. Similar technology is already used in space (operational NOAA weather satellites, SWAS, and ODIN) and has been used extensively on the ground, in aircraft and balloons.

All receivers will operate in a double sideband mode. It should be noted that the receivers for CIWSIR are quite simple when compared to instruments used for limb sounding, because the broadband and uncritical centre frequency allows to use free running LO's. This design reduces the overall complexity of the receiver design. Since the two pass bands are located either symmetrically across the water vapour line (for the 183.31 GHz channel) or in a flat window (for the other four channels), the effect in one sideband due to a L.O. frequency drift will be compensated to a large extent by the corresponding change in the image band. Simulations using the US standard atmosphere show that an LO frequency drift of 100 MHz causes the brightness temperature to change by less than 0.05 K for all channels.

Also the back end does not require a real time spectral analysis, because each channel (both upper and lower sidebands) is combined to one output signal. Furthermore, the observing geometry using conical scanning allows using rather small antennas with diameters of 40 cm and 16 cm.

The main instrument features of CIWSIR, and its expected performances compared with requirements, are reported in table C.1.

**Table C.1 -** Instrument features and expected performance

| Channel centre | Bandwidth | Polarisations | NEΔT (Required) | NEΔT (Estimated) |
|---|---|---|---|---|
| 874.38 ± 6.0 GHz | 3.0 GHz | two | 1.8 K @ 240 K | 2.0 K @ 240 K |
| 682.95 ± 6.0 GHz | 3.0 GHz | two | 1.5 K @ 240 K | 1.2 K @ 240 K |
| 462.64 ± 3.0 GHz | 2.0 GHz | two | 1.2 K @ 240 K | 1.0 K @ 240 K |
| 220.50 ± 3.0 GHz | 2.0 GHz | two | 1.0 K @ 250 K | 0.9 K @ 250 K |
| 183.31 ± 2.4 GHz | 1.0 GHz | one | 1.0 K @ 240 K | 1.0 K @ 240 K |

With the exception of the 874 GHz all requirements concerning the sensitivity can be met. A reanalysis of the estimation leading to the required accuracies showed that the slightly lower sensitivity of the 874 GHz has a minor impact on the retrieval accuracy.

Table C.2 lists a summary of the technical specifications of the CIWSIR instrument. The instrument consists of two RF units the low frequency part comprising the channels up to 220 GHz and the 3 sub-mm channels. The whole instrument is connected to the satellite main frame with a slip ring assembly. The whole CIWSIR package rotates continuously allowing for scanning the surface in the forward and aft positions. The conical scanning scheme allows a nearly complete global coverage every day using a near polar sunsynchronuous orbit.

**Table C.2 –** Summary instrument features of CIWSIR (H = 840 km)

| | |
|---|---|
| **Channels** | 9 in the range 183-880 GHz |
| **IFOV** | 0.35° corresponding to an ellipse of 13 km x 7.8 km of area equivalent to 10 km circular |
| **Scanning** | Conical, $\alpha$ = 45°, $\zeta$ = 53.2°, fore- and aft- views by > ± 45° in azimuth, swath ~ 1400 km |
| **Sampling** | 1 scan / 2 s, 1 feed/channel, readings at 2.5 ms intervals |
| **Antennae** | L = 40 cm for channels 183 to 220 GHz, L = 16 cm for channels 463 to 874 GHz |
| **Detection** | Subharmonic Schottky-mixers for mm- channels. Fundamentally pumped mixers for sub-mm- channels |
| **Resources** | Mass: 79 kg; volume (cylindrical): Ø 110 cm, h = 43 cm. Electrical power: 110 W; data rate 58 kbps + HK |

A schematic view of CIWSIR is shown in the figure C.1.

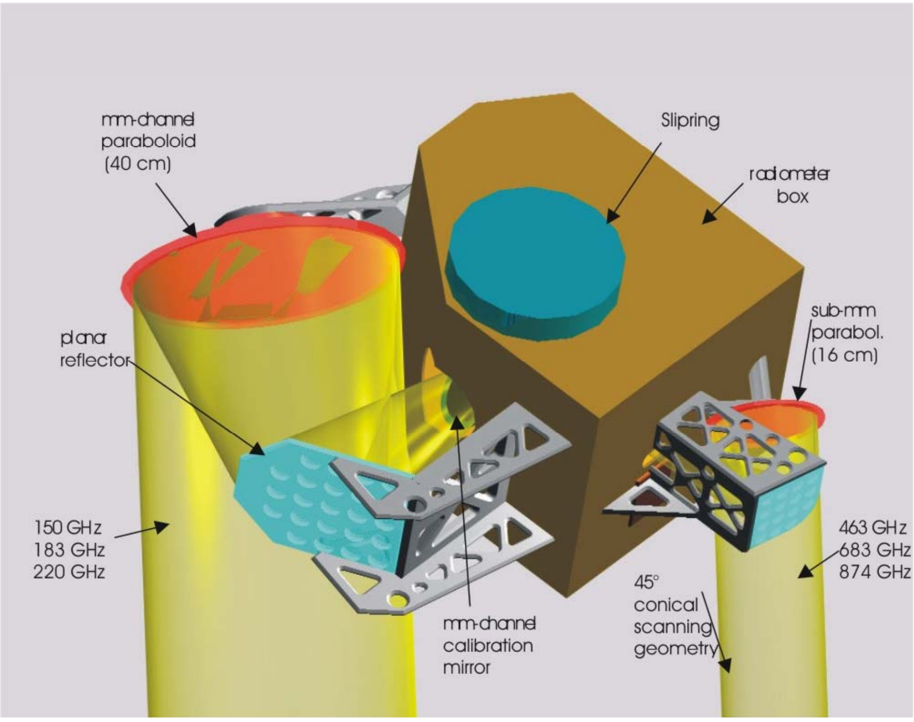



**Figure C.1 –** Schematic view of CIWSIR instrument

Derived from the instrument mass and power of 80 kg and 110W, a small satellite platform is estimated to be in the 500kg class in order to provide the required accommodation, nadir pointing, orbit control , power supply and data downlink for this instrument. This could be implemented as standard LEO platform (e.g. MITA upgrade).

Therefore also a small LEO launcher (e.g. COSMOS or Rockot type of launcher) or a shared LEO launch with an other satellite is possible for this mission.

For the ground segment the existing infrastructure of ESA is assumed as baseline for Operation (e.g ESOC) with S-Band TT&C station, for Data Reception (e.g. KIRUNA) with X-Band station and for Data Pre-processing and Archiving of Level 1 Products (geometric corrected and radiometric calibrated, e.g. ESRIN).

## D. Mission Elements and Assumed Funding Sources

A cost estimate based on the results of the earlier mentioned Phase-A study has been made by industry. The cost for the CIWSIR mission, including the instrument, the satellite bus, integration and launch, however excluding the ground segment and data exploitation is estimated to be 84 M€ with an expected contribution from ESA of **77 M€** (details of the cost estimate can be found in the Annex).

In table D.1 the *Scope of mission elements and activities* are given, and table D.2 contains the *Mission elements and activities: implementation and funding source assumptions.*

**Table D.1 –** Mission elements and activities: Implementation and funding source assumptions

| Mission Elements | | Scope |
|---|---|---|
| Science preparation | Scientific definition studies | More detailed radiative transfer calculations for scattering media with aspherical scatteres |
| | Campaigns | Airborne campaigns with CIWSIR simulator |
| System engineering and assembly integration and test | | Overall management, system engineering, assembly, integration and test |
| Space segment | Instruments | CIWSIR |
| | Platform | Dedicated small platform |
| | Launcher | tbd |
| Ground segment facilities | Command & acquisition stations | ESA |
| | Operations centre | ESA |
| | Processing and archiving | ESA |
| Mission control and Data exploitation | Mission control | ESA |
| | Data utilisation | Airborne campaigns to collect correlative data |

**Table D.2 –** Mission elements and activities: Implementation and funding source assumptions

| Mission Elements | | Implementation | Assumed Funding Source |
|---|---|---|---|
| Science preparation | Scientific definition studies | Scientific Inst.<br>Research Centres | ESA, National, EC |
| | Campaigns | Industry & Scientific Inst. | ESA |
| System engineering and assembly integration and test | | Industry<br>ESTEC | ESA |
| Space segment | Instruments | Industry (RPG) | ESA |
| | Platform | Industry (OHB) | ESA |
| | Launcher | Industry (OHB) | ESA |
| Ground segment facilities | Command & acquisition stations | ESA | ESA |
| | Operations centre | ESA | ESA |
| | Processing and archiving | ESRIN | ESA |
| Mission control and data exploitation | Mission control | ESA | ESA |
| | Data utilisation | Science team and<br>Scientific community<br>Operational services | National, EC |

## ANNEX: Team Composition

The scientific core team members listed in part A submit this preliminary Proposal outline. The whole science team informed on this outline proposal is listed in part B, in order to limit the size of the proposal only the names and addresses are listed in part B. The two industrial companies involved in the preparation of the proposal are listed in part C.

### Part A: Core team members:

In alphabetical order:

Dr. S. A. Bühler

*Date of birth:* 29 October 1969
*Nationality:* German
*Address:* University of Bremen
Fachbereich 1
Institute of Environmental Physics
P.O. Box 33 04 40
D-28334 Bremen, Germany
e-mail: sbuehler@uni-bremen.de

Phone: +49 (421) 218-4417
+49 (421) 218-4065 (Sec.)
Fax: +49 (421) 218-4555

*Professional Interests and Experience:*

Interests:

- Radiative transfer modelling
- Inversion algorithms
- Millimetre and sub-millimetre limb and nadir sounding
- Water vapour and other continuum emitters
- Distribution of water vapour in the atmosphere
- Climate feedback of water vapour and cirrus clouds

Project Experience:

| | |
|---|---|
| Since 1995: | Work on ESTEC projects:<br>ESTEC/Contract No 10998/94/NL/CN (Continuum Study)<br>ESTEC/Contract No 11581/95/NL/CN (Spectroscopy Study)<br>ESTEC/Contract No 12053/97/NL/CN (MASTER Study)<br>ESTEC/Contract No 11979/97/NL/CN (SOPRANO Study)<br>ESTEC/Contract No 13348/98/NL/GD (MASTER Study Extension) |
| Since 1998: | Member of COST 712 Workshop and project group 2 |
| Since 1998: | Project manager of DLR Project 50 EE 9815 (JEM / SMILES) |
| April 1999: | Organizer of international radiative transfer workshop (Bredbeck I) |
| June 2000: | Organizer of international radiative transfer workshop (Bredbeck II) |
| Since 2000: | Funding by AFO 2000-C, Project 07 ATC 04 (UTH-MOS) |
| Since 2001: | Assistant Professor at the University of Bremen |

*Education:*

| | |
|---|---|
| 1990-1993: | Undergraduate student, University of Tübingen, Dept. of Physics |
| 1993: | Vordiplom, University of Tübingen |
| 1993-1994: | Graduate student, State University of New York at Stony Brook, Dept. of Physics |
| 1994: | Master, SUNY at Stony Brook. Thesis: A Study of Atmospheric Opacity near 275 GHz at very low Temperatures |
| 1994-1998: | PhD student, University of Bremen, Institute of Remote Sensing |
| August 1998: | PhD, University of Bremen. Thesis: Microwave Limb Sounding of the Stratosphere and Upper Troposphere |

*Publications:*
So far 15 publications. A detailed list can be found on http://www.sat.uni-bremen.de/members/sab.

Dr. Georg Heygster

Date of birth: 22 February, 1951
Nationality: German
Address: University of Bremen
Fachbereich 1
Institute of Environmental Physics
P.O. Box 33 04 40
D-28334 Bremen, Germany
Email: heygster@uni-bremen.de
Phone: +49 (421)218-3910
+49(421)218-4065 (Sec.)
Fax: +49(421)218-4555

*Professional Interests and Experience:*
Research and Teaching in Remote Sensing and Geophysics. Of particular interest are applications in Meteorology, Atmospheric Physics, studies on remote sensing of the Cryosphere and Polar Atmosphere.

In charge of many research projects funded by EU, ESA, DFG, BMBF, DLR and others. These projects include the development of retrieval algorithms for microwave and other sensors, conducting campaigns and the interpretation and application of these results.

| | |
|---|---|
| 1988 - | Senior scientist at the University of Bremen, Institute of Environmental Physics |
| 1979-1987 | Computer Centre of the University of Bremen, Germany |
| 1976-1979 | Max-Planck-Institute of experimental medicine, Göttingen, Ph.D. thesis in image processing |
| 1972-1973 | University of Grenoble, France |

*Education:*

| | |
|---|---|
| 1979: | Dr. rer. nat. (Ph.D.) in Physics from the University of Göttingen, Germany |
| 1975: | Diploma (MS) in Physics from the University of Göttingen, Germany |
| 1969: | Abitur (Matriculation Examination), Tellkampfschule Hannover |

Selected Publications:

R. Fuhrhop, T.C. Grenfell, G. Heygster, K.-P. Johnsen, P. Schlüssel, Meeno Schrader, C. Simmer: A combined radiative transfer model for sea ice, open ocean, and atmosphere. Radio Science 33,2 (March 1998), 303-316

T. Hunewinkel, T. Markus, G. Heygster: Improved Determination of the Sea Ice Edge with SSM/I Data for Small-Scale Analysis. IEEE Tr. GRS 36,5 (Sept. 1998) 1795-1808

J. Miao, K.-P. Johnsen, S. Kern, G. Heygster, K. Kunzi: Signature of Clouds over Antarctic Sea Ice Detected by the Special Sensor Microwave/Imager. IEEE Tr. GRS 38,5 (Sep. 2000) 2333-2344

J. Miao, K. Kunzi, G. Heygster, T.A. Lachlan-Cope, J. Turner: Atmospheric water vapor over Antarctica derived from Special Sensor Microwave/Temperature 2 data. JGR 106, D10 (May 2001) 10287-10203

Prof. Dr. K. Kunzi



| | | |
|---|---|---|
| *Date of birth:* | 19 February 1939 | |
| *Nationality:* | Swiss | |
| *Address:* | University of Bremen | Phone: +49 (421) 218-3909 |
| | Fachbereich 1 | +49 (421) 218-4065 (Sec.) |
| | Institute of Environmental Physics | Fax: +49 (421) 218-4555 |
| | P.O. Box 33 04 40 | |
| | D-28334 Bremen, Germany | |
| | e-mail: kunzi@uni-bremen.de | |



*Professional Interests and Experience:*

Research and Teaching in Remote Sensing and Geophysics. Of particular interest are applications in Meteorology, Atmospheric-Physics and -Chemistry, studies of the Ocean and Cryosphere, and the design and development of remote sensing instrumentation to be used on the ground, in aircraft and on space-platforms.

Principal Investigator or Co-Investigator for a number of space experiments. Member in international and national advisory bodies (e.g., European Union EU, European Space Agency ESA/ESTEC and the Deutsche Forschungsgemeinschaft DFG). Member in several professional organizations such as IEEE, AGU, EGS, DPG, SPG etc.

In charge of many research projects funded by EU, ESA, DFG, BMBF, DLR and others. These projects include the development of sensor hardware and software, conducting campaigns, includes the final data analysis from sensor data to Geophysical parameters, and the interpretation and application of these results.

| | |
|---|---|
| 1988- | Full Professor at the University of Bremen, Institute of Environmental Physics and Institute of Remote Sensing, Germany |
| 1983 | Guest Professor at the Technical University of Denmark, Lyngby/Copenhagen |
| 1974-1988 | University of Bern, Institute of Applied Physics, Switzerland |
| 1972-1974 | Research Associate, MIT Electrical Engineering Dept., Boston, USA |
| 1971-1972 | Visiting scientist (fellowship from the University of Bern) at MIT Research Laboratory of Electronics, Boston, USA |
| 1966-1971 | University of Bern, Switzerland. |

*Education:*

| | |
|---|---|
| 1970: | Dr. Phil. Nat. (Ph.D.) in Physics from the University of Bern, Switzerland |
| 1966: | Diploma (MS) in Physics from the University of Bern, Switzerland. |
| 1959: | Matura (Matriculation Examination) Type C, Realgymnasium Bern, Switzerland. |

*Publications:* Over 200 Publications, contributions to books and conferences.

for more information: http://www.iup.physik.uni-bremen.de

Dr. J. Miao

| | | |
|---|---|---|
| *Date of birth:* | 18 July 1963 | |
| *Nationality:* | Chinese | |
| *Address:* | University of Bremen | Phone: +49 (421) 218-4520 |
| | Fachbereich 1 | +49 (421) 218-4065 (Sec.) |
| | Institute of Environmental Physics | Fax: +49 (421) 218-4555 |
| | P.O. Box 33 04 40 | |
| | D-28334 Bremen, Germany | |
| | e-mail: jmiao@uni-bremen.de | |


*Professional Interests and Experience:*

Interests:

- Modelling of scattering from non-spherical particles and rough surfaces
- Algorithm development for geophysical parameters retrieval from satellite data
- Radiometer system evaluation and design

Working Experience:

1982-1984: Engineer at the Institute of Remote Sensing Instrumentation, Chinese Aerospace, Beijing, China.
1984-1993: Research associate at the Electromagnetic Laboratory of the Beijing University of Aeronautics and Astronautics, Beijing, China.
Since 1998: Research associate at the Institute of Environmental Physics, University of Bremen, Bremen, Germany

*Education:*

July 1982: B.S.E.E. degree, National University of Defence Technology, Dept. of Electrical Engineering.
Jan. 1987: M.S.E.E. degree, Beijing University of Aeronautics and Astronautics, Dept. of Electrical Engineering.
July 1998: Ph.D. degree, University of Bremen, Institute of Environmental Physics.

*Publications:*
So far 11 publications

Priv.-Doz. Dr. Ulrike Wacker

Date of birth: 24 June 1954
Nationality: german
Address: Stiftung Alfred-Wegener-Institut fuer Polar- und Meeresforschung (AWI)
(Alfred Wegener Institute Foundation for Polar- and Marine Research)
P.O. Box 120161
27515 Bremerhaven, Germany
e-mail: uwacker@awi-bremerhaven.de

Phone ++49 471 4831-1813
-1750 (Secr.)
Fax -1797

Professional Interests and Experience:
Research and teaching in atmospheric sciences, especially in dynamic meteorology, atmospheric thermodynamics, cloud physics, and numerical modelling.
Head of the Section 'Large Scale Circulation' in the Department 'Climate System' at the AWI.

| | |
|---|---|
| 2000 - | Senior Scientist at the AWI, Department 'Climate System' |
| 1990 - 2000 | University of Frankfurt/Main |
| 1985 - 2000 | Deutscher Wetterdienst, Research Department, Offenbach |
| 1980 - 1985 | University of Frankfurt/Main |

Education

| | |
|---|---|
| 1996 | Habilitation for 'Meteorology' from University of Frankfurt/Main<br>2000: Transfer of Habilitation (for 'Environmental Physics') to University of Bremen |
| 1984 | Dr. phil.nat in Meteorology from University of Frankfurt/Main |
| 1979 | Diploma in Meteorology from University of Bonn |
| 1973 | Abitur, Rhein-Wied-Gymnasium Neuwied |

Publications: about 50 publications and contributions to conferences

**Part B: Science Team**

Prof. Dr. Eberhard Ruprecht
Institut fuer Meereskunde an der Universitaet Kiel
E-mail: eruprecht@ifm.uni-kiel.de

Dr. Bizzarro Bizzarri
Alenia Aerospazio
E-mail: bibizzar@tin.it

Dr. Nik Kaempfer
University of Bern
E-mail: kaempfer@mw.iap.unibe.ch

Dr. Ulrich  Leiterer
German Weather Service
E-mail: Ulrich.Leiterer@dwd.de

Dr.Susanne Crewell
Meteorologisches Institut, Universitaet Bonn
E-mail: SCREWELL@uni-bonn.de

Dr. Stephan Bakan
MAX-PLANCK-INSTITUT FÜR METEOROLOGIE
E-mail: bakan@dkrz.de

Dr. P.F.J. van Velthoven
KNMI (Royal Netherlands Meteorological Institute)
E-mail: velthove@knmi.nl

Dr. Michel Desbois, Directeur de Recherche au CNRS,
Laboratoire de Météorologie Dynamique, Ecole Polytechnique
E-mail: desbois@lmd.polytechnique.fr

Dr. D. Nagel
GKSS
E-mail: daggi_nagel@yahoo.de

Prof. Dr. Clemens Simmer
Meteorological Institute, University Bonn
Email: csimmer@uni-bonn.de

Dr. Petteri Taalas
Finish Meteorological Institute
E-mail:  Petteri.Taalas@fmi.fi

Dr. Albin J. Gasiewski
Senior Physicist and Group Leader, Microwave Radiometry
NOAA Environmental Technology Laboratory  al.gasiewski@noaa.gov

Dr. Zenobia Litynska
Polish Weather Service
E-mail: zenoblit@pol.pl

Dr. Joëlle Ovarlez
LMD Ecole Polytechnique, France
E-mail: joelle.ovarlez@polytechnique.fr

Dr. Jörg Hartmann
Alfred-Wegener-Institute for Polar and Marine Research
E-mail: jhartmann@AWI-Bremerhaven.de

Dr. Emilio Cuevas
Observatorio Atmospherico de Izana
E-mail: cuevas@inm.es

Dr. Hendrik Elbern
University of Köln
E-mail: he@eurad.Uni-Koeln.DE

Dr. Manuel Gil
Instituto Nacional de Técnica Aeroespacial, Spain
E-mail: gilm@inta.es

Dr. Bernard Legras
Laboratoire de Meteorologie Dynamique
E-mail: legras@lmd.ens.fr

Dr. David Lary
Department of Chemistry, Cambridge University
Email: djl10@cam.ac.uk

Dr. William Lahoz
Data Assimilation Research Center
Email: wal@met.reading.ac.uk

**Part C: Industrial team members, listing of industrial partners involved in the preliminary studies concerning CIWSIR**

Responsible for CIWSIR instrument:

RPG, Meckenheim, Germany

The company was found in 1978 in Meckenheim, Germany and is specialised in advanced study, design and building of remote sensing instrumentation, specifically in the microwave and sub-mm ranges. The company has built and qualified many mm and sub-mm components for space projects like MLS (NASA), ODIN (SSC), SMILES (NASDA) and EOS (NASA). In this project they will be responsible for the design and manufacture of the mm and sum-mm radiometer. RPG’s world wide activities are mainly focused on customer specified products ranging from complete radiometers and spectrometers for radio astronomy, meteorology, ESR or plasma science to radar sensors for diagnostic purposes in the centimetre, millimetre and sub-millimetre frequency range. In addition the company contributes to research programs for the development of new microwave techniques and offers consultation in the design and characterisation of complex systems and quasi-optics.

The spectrum of RPG’s products includes:

- Microwave Components
- Complete Cooled and Un-cooled Front-ends
- Spectrometers
- Electronics

## Responsible for Platform, Power, Data handling and Launch

### OHB, Bremen, Germany

#### OHB-SYSTEM

*OHB-SYSTEM* has gained extensive experience during the past years on both national and European projects. The space activities of *OHB-SYSTEM* are among others:

- Small satellite systems and subsystems for telecommunication, science and earth observation,
- System/ subsystem engineering for manned and unmanned missions,
- Advanced & High Speed Processing System for EO-Applications,
- Microgravity systems and experiment facilities for microgravity research,
- Organisation of satellite launch services,
- Mobile communication terminals and rescue buoys using LEO and GEO data transmission,
- Ground equipment for space systems.

*OHB-SYSTEM* has been very active in the last years in very relevant, up to basically similar work on space-borne remote-sensing as well as on scientific research satellite programmes. These activities are pursuant to our corporate's strategic goals:

- achieving technological excellence and leadership in the small to medium satellite classes, and
- establishing scientific and commercial satellite application services.

As a member of the *FUCHS GRUPPE, OHB-SYSTEM* has long standing experiences in small satellite mission and subsystem development and brings in their experiences in the development, launch and operations of small and medium sized satellites, such as:

- BREMSAT (Re-entry Experiment),
- SAFIR-1 & 2 (Communication System),
- DIAMANT (with an Multi-Spectral High-Resolution System - MSRS),
- MITA (Italian Technology Demonstration Platform), and
- Radar satellite constellation.

**For detailed company information refer to our homepage www.ohb-system.de.**

#### *Relevant Projects*

OHB-System has been very active in the last years in very relevant, up to basically similar work on space-borne remote-sensing as well as on scientific research satellite programmes. These activities are pursuant to our corporate's strategic goals:

- achieving technological excellence and leadership in the small to medium satellite classes, and
- establishing scientific and commercial satellite application services.

OHB-System has long standing experiences in small satellite mission and subsystem development.

As a member of the *FUCHS GRUPPE, OHB-SYSTEM* has long standing experiences in small satellite mission and subsystem development and brings in their experiences in the development, launch and operations of small and medium sized satellites, such as:

- BREMSAT (Re-entry Experiment),
- SAFIR-1 & 2 (Communication System),
- DIAMANT (with an Multi-Spectral High-Resolution System - MSRS),
- MITA (Italian Technology Demonstration Platform), and
- Radar satellite constellation.

**Cost estimate for CIWSIR Mission:**

R.O.M. cost estimate CIWSIR mission

(a) additional 5 M€ required for dedicated steering unit for tandem operation)

(b) this includes pre launch tests and post launch validation flights using NOAA and NASA aircraft instrumented with radiometers comparable to CIWSIR and auxiliary sensors to obtain correlative data)

| Item | Programme cost | Cost to ESA | Cost to others | Remarks |
|---|---|---|---|---|
| **CIWSIR Instrument** | 25 M€ | 25 M€ | | |
| **Platform** | 27 M€ [a)] | 27 M€ | | |
| **Satellite integration** | 3 M€ | 3 M€ | | |
| **Launch** | 14 M€ | 14 M€ | | |
| **Campaigns** | 5 M€ | 3 M€ | 2 M€ | Nat. funds |
| **Scientific support in Europe** | 10 M€ | 5 M€ | 5 M€ | Nat. funds and EC |
| **Totals** | **84 M€** | **77 M€** | **7 M€** | |
| **Scientific support in the USA** | NASA and NOAA activities carried out at no cost to ESA [b)] | | | |
| **Ground segment development** | Not yet considered (≈6 M€) | | | |
| **Mission exploitation** | Not yet considered | | | |