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AIRBORNE RESEARCH WITH DLR FLIGHT FACILITIES

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ABSTRACT

Airborne research is one of the main pillars of remote sensing. Specially designed research aircraft can offer a versatile platform for various kinds of instruments and applications allowing remarkable flexibility in terms of test site location, date, time and repetition of data acquisitions.

DLR flight department with its facilities in Oberpfaffenhofen and Braunschweig is Europe's largest civil operator of research aircraft for earth observation and atmospheric research. The strongly modified aircraft fleet consisting of 11 aircraft and 2 helicopters operates worldwide for various research organisations, public authorities and private companies.

Together with the aircraft itself DLR flight department offers highly specialized personnel covering a range of complementary services like science-oriented operations, flight test engineering, aircraft modification, certification of new instrumentation.

Also maintenance to a large extent is done in-house to allow at most flexibility and short maintenance periods. The flight department is strongly engaged in European networks (EUFAR) and programmes, offering our long-year experience and service to a broad user community.

Ongoing research in all kinds of applications brings up the development of new sensors and also new requirements to research aircraft. DLR flight department takes the challenge to keep up with these new demands in order to provide comprehensive, user-oriented and professional service to its customers.

INTRODUCTION

Earth observation is getting more and more important these days in a big variety of applications and objectives. Airborne remote sensing is a highly useful tool to investigate relatively large areas in a flexible and quick way. In addition with airborne sensors spaceborne data can be simulated, allowing the validation of these sensors if carried by a satellite and estimation of usability of specific airborne technology for spaceborne systems.

DLR Flight Operations with its facilities in Oberpfaffenhofen and Braunschweig is Europe's largest civil operator of research aircraft for earth observation and atmospheric research. The highly modified aircraft fleet operates worldwide for various research organisations, public authorities and private companies.

The Flight Facility Oberpfaffenhofen has operated in the field of research-flight-operation for more than 30 years. The research aircraft are mainly used as flying laboratories. The clients are researchers in the field of atmospheric research, air-chemistry, remote-sensing-technique etc. For remote sensing applications the aircraft carry for example radiometers, SAR-systems, scatterometers and also all types of scanners, imaging spectrometers or cameras.

Beside this standard operation DLR Flight Facility Oberpfaffenhofen and its counterpart in Braunschweig are also the operator of two special aircraft of type Dornier 228-101 (D-CAWI, D-CICE) owned by the Alfred-Wegener-Institute for Polar and Marine Research in Bremerhaven (AWI) since

1990. These two airplanes are devoted to research work in Antarctica and the Arctic region, operated under extreme conditions and very often with ski-gear instead of normal landing-gear.

DLR RESEARCH FLIGHT FACILITIES

Structure and Tasks

DLR research Flight Facilities has two locations in Germany: Oberpfaffenhofen and Braunschweig. Traditionally and due to the research focus of the associated DLR institutes the emphasis of activity in both facilities is quite different:

In Braunschweig the aircraft itself is the object of research in the fields of

- Aerodynamics
- In-Flight-Simulation
- Navigation System Development
- Air Traffic Management

In Oberpfaffenhofen the aircraft serves as a versatile platform for research, emphasizing on

- Atmospheric Research
- Earth Observation
- Ecological Environmental Research
- Sensor Technologies

Fleet

The different emphasis of activity is also reflected in the composition of the fleet

Braunschweig:

- EC 135 fly-by-light in-flight-simulator, flying simulator
- BO 105
- VFW 614, flying simulator
- Dornier 228-101, D-CODE
- Dornier 228-101, D-CAWI, owned by the Alfred Wegener Institute of Polar and Marine Research (AWI), operated by DLR)
- 2 small airplanes / motor gliders
- 2 gliders

Oberpfaffenhofen:

- Dassault Falcon E 20, D-CMET
- Dornier 228-212, D-CFFU
- Dornier 228-101, D-CICE, owned by the Alfred Wegener Institute of Polar and Marine Research (AWI), operated by DLR)
- Cessna C 208 B Grand Caravan, D-FDLR

DLR's Dornier 228-101, D-CALM, is currently operated by the Natural Environment Research Council (NERC), UK

Figure 1: from left to right: C-CMET, D-CFFU, D-CALM, D-FDLR at the apron, Oberpfaffenhofen

Figure 2: Dornier 228-101, D-CICE of AWI

DO 228, Call Sign D-CFFU, D-CODE and Cessna 208B, Call Sign D-FDLR

For earth observation mainly the Dornier 228 and Cessna C 208B Grand Caravan are used. With a Dornier 228-212 in Oberpfaffenhofen (D-CFFU) and a Dornier 228-101 in Braunschweig (D-CODE) the requests of more than one user group can be met at the same time. This is especially interesting in the peak seasons. Although they are not identical and the Dornier 228-101's fuselage is about 1.5 meters shorter than that of the Dornier 228-212 almost all experiments can be transferred from one aircraft to the other (additional certification required).

The Dornier 228 is a twin engine turboprop. Powerful engines, excellent handling qualities and the unpressurized spacious rectangular cabin make it an ideal platform for any kind of airborne research. DLR's Dorniers have undergone a number of modifications to allow internal and external installation of research equipment. Due to the modern wing they can travel fast and use short run-

ways. As a twin engine aircraft they are capable to perform extended missions overhead remote areas and open water. Range strongly depends on remaining fuel capacity with a given scientific payload. Airline-like equipment, like modern avionic systems, allows world wide operation.

Openings in the roof and bottom allow installation of different sensors, antennas or other measurement equipment. In addition hardpoints at the aircraft tail, under and at the side of the fuselage and under the wing offer possibilities to mount instrumentation externally (number and position of hardpoints is different between the two Dornier 228 of DLR).

Figure 3: Dornier 228-212, D-CFFU

Figure 4: Dornier 228-101, D-CODE in configuration for project HYLTEC (camera on stand, camera at the wing, device to measure number of insects under the wing)

For lighter equipment and less remote operation the Cessna C 208B Grand Caravan offers a cheaper alternative. It is a single engine turboprop, also with unpressurized cabin. The rectangular cross section gives ample room for instrumentation. For some experiments the smaller minimum flight speed is an interesting aspect. Similar to the Dornier 228 it also has been strongly modified: openings on top and bottom of the fuselage, under wing hardpoints and a special exhaust system (to prevent measurement interference) make it a highly suitable platform for airborne research.

For aerial survey flight missions all 3 aircraft are operated with a special computer controlled navigation system (by IGI GmbH, Germany) which makes possible exact flights following an optimized flight pattern, camera management and delivers GPS and attitude data for online processing or postprocessing.

Figure 5: Dornier 228-101, D-CICE of AWI

FLIGHT FACILITY OBERPFAFFENHOFEN

DLR flight facilities offers not only a fleet of aircraft but a wide range of complementary services for scientists to help them carry out their experiments. Highly specialized personnel cover the fields of science-oriented operations, flight test engineering, aircraft modification, certification of new instrumentation and operation of basic meteorological sensors on the aircraft. As the facility in Oberpfaffenhofen is more engaged in earth observation than Braunschweig the following sections will mainly deal with the infrastructure and service offered here. Of course both facilities work together closely and interchange crew, aircraft, equipment and expertise.

Expertise and Service

DLR Flight Facility employs all kinds of experts like engineers, scientists, pilots, mechanics and operations-officers which enable the facility to operate throughout the world. Links to the appropriate international Civil Aviation Agencies and Air-Traffic-Control-Units have been established to get as quickly as possible approval for operation in the respective countries and to coordinate our flights with normal air traffic.

The Facilities' expertise rests upon experienced and highly specialized personnel, motivated and interested in the user's needs and aims. The groups of operations, maintenance, flight test engineering and sensor & data all contribute to the success of a mission:

- Operations

Pilots, aircraft operation, user support, acquisition, logistics, campaign management

- Maintenance

Maintenance and repair, avionics workshop, ground equipment

- Flight Test Engineering

System integration, certification, documentation, interfaces

- Sensor and Data

Sensor development and operation (meteorological and basic aircraft sensors), testing, calibration, data acquisition, electrical interface, data processing

The facility is authorised to perform full certification of user instrumentation on its own aircraft, including external installations. So our users do not have to deal with third parties in terms of this but will find the respective experts and groups within DLR:

- DLR Approved Design Organisation (EB)
- DLR Airworthiness Office (MPL) in Braunschweig
- Design Engineers and Design Responsible Engineers at Flight Facility and within the research institutes of DLR

Since 1986 more than 480 certifications have been issued.

Infrastructure

The department is located at the airport of Oberpfaffenhofen which is not generally open to the public but can be opened for visitors and customers of DLR or the other companies at the airport. The airport is certified for IFR Cat I and with its runway of 2286 metres also big aircraft can land and take-off.

Being an “Approved Aeronautical Workshop” DLR Flight Facilities can do maintenance of its aircraft in-house with own staff. For bigger technical issues the Falcon is maintained by Jet Aviation in Basel, CH. Support for the Dornier-228 is guaranteed by the RUAG AG directly at the airport if required (RUAG AG is one of the companies which took over part of the former company Fairchild-Dornier).

Two hangars give room for both the aircraft of the flight department and DLR aero club. Sensor installations can be done comfortably in the heated hangar with the support of staff of the flight facilities (FB). Offices of FB staff are close to the hangar. Also directly adjoined to the hangar is a mechanical workshop where adapter units to mount instruments into the aircraft can be manufactured according to the specific needs of the respective sensors. Instruments and avionic system workshop complete the range of aircraft-related infrastructure directly in the hangar.

In a building close the hangar two rooms with network access are available to our users as laboratory or office rooms.

The same building also houses an environmental simulation chamber (-70 deg, 0 mbar) and sensor calibration systems (pressure, temperature, humidity).

The sensor and data group is responsible for the provision of basic aircraft data as well as meteorological data gained from respective sensors on the aircraft. Most DLR aircraft are equipped with a data acquisition system which collects data from the aircraft avionic systems (Flight Management, Air Data, Inertial Reference) as well as from different temperature, pressure and humidity sensors., some of them developed by DLR. Calibration, test and installation of these sensors as well as on-site data processing and provision are part of the flight facility expertise to support a user project with accurate data from wind vectors via high speed humidity to aircraft attitude.

Area of Operation and Recent Major Projects

DLR flight facilities operate throughout the world, including polar and tropical regions. In remote areas this can include the shipment of big amounts of equipment to the site of operation in order to build up the required infrastructure and technical support there.

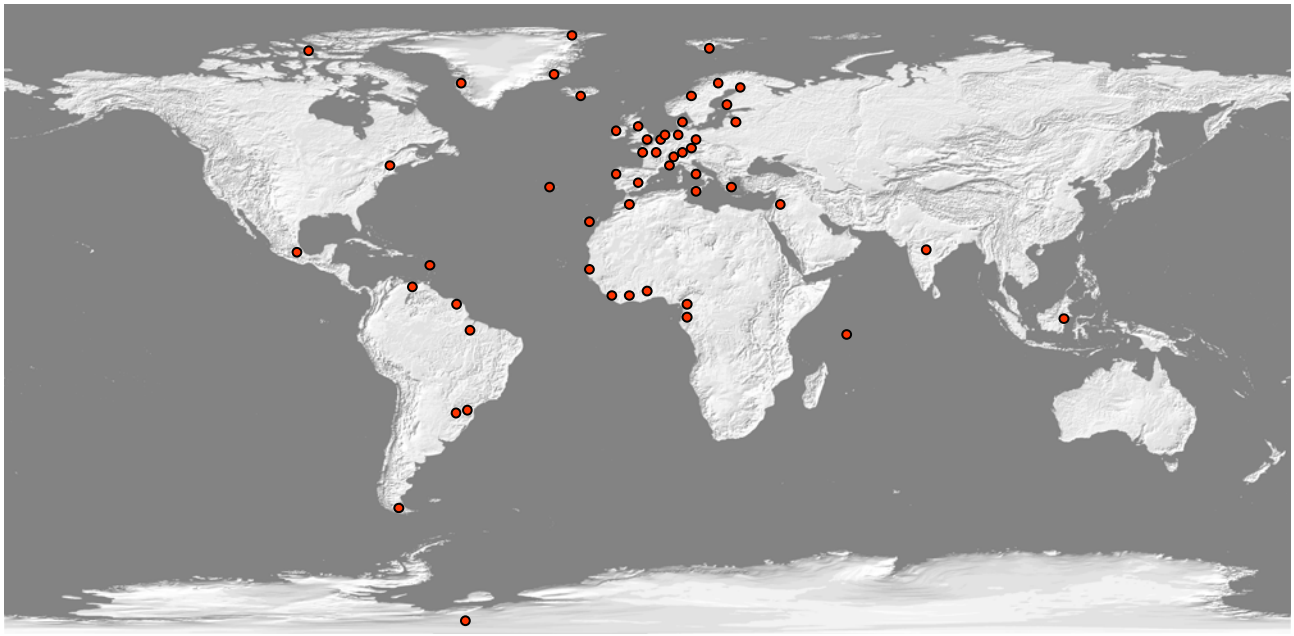

Figure 6: places of operation until 2004, all aircraft (including those of AWI)

The following tables show a choice of campaigns with DLR aircraft within the last 5 years.

Table 1: choice of campaigns with DLR aircraft (2000 – 2005)

Campaign	**Time Period**	**Area of Operation**	**Aircraft**
LOFZY	03 / 2005	Norway	D-CMET
TROCCINOX II	01, 02 / 2005	Brazil	D-CMET
AIRFLEX	2004, 2005	Germany; Spain	D-FDLR
INDREX-II	10, 11 / 2005	Kalimantan, Indonesia	D-CFFU
INDSAR	09, 10 / 2005	India	D-CFFU
TROCCIONOX	02, 03 / 2005	Brazil	D-CMET
HyEurope	2003, 2004	Europe	D-CFFU, D-CODE
ACSYS ABSIS	04 / 2003	Svalbard, Norway	D-CMET
A-TOST	11 / 2003	Iceland	D-CMET
EUPLEX	01, 02 / 2003	Kiruna, Sweden	D-CMET
SCIA VALUE	02, 03 / 2003	Germany, Africa, Maledives	D-CMET
ISOCROP	2002, 2003	Spain, UK	D-CFFU
HySens	2000 – 2002	Europe	D-CFFU
STARRS	2002	Italy	D-FDLR
IHOP	09 / 2002	USA	D-CMET
VAPSCIA	2001, 2002	Seychelles, Sweden	D-CMET
CAATER	2001, 2002	Europe	D-CMET

Table 2: recent major campaigns for AWI (2000 – 2005, AWI and DLR aircraft)

Campaign	Time Period	Area of Operation	Aircraft
ASIRAS	03 / 2005	Finland	D-CODE
ANT XXII	11 / 2004 – 02 / 2005	Antactic	D-CICE, D-CAWI
ASIRAS 3	08, 09 / 2004	Svalbard, Norway, Greenland, Denmark, Canada	D-CICE
NGRIP	06, 07 / 2004	Greenland	D-CAWI
ASTAR	05, 06 / 2004	Svalbard, Norway	D-CICE, D-CAWI
ASIRAS 2	04, 05 / 2004	Svalbard, Norway, Greenland, Denmark, Canaca	D-CICE
ASIRAS 1	03, 04 / 2004	Svalbard, Norway	D-CODE
ANT XXI	11 / 2003 – 03 / 2004	Antarctic	D-CICE, D-CAWI
ANT XX	11 / 2002 – 03 / 2003	Antactic	D-CICE, D-CAWI
IGLOS	06, 07 / 2002	Greenland	D-CAWI
ANT XIX	11 / 2001 – 03 / 2002	Antarctic	D-CICE, D-CAWI
ANT XVIII	11 / 2000 – 03 / 2001	Antactic	D-CICE, D-CAWI

Latest Highlights with D-CFFU

Big campaign in Asia: 201 flight hours in total

- INDSAR in India (September/October 2004) for Indian Space Research Organisation; E-SAR (Experimental Synthetic Aperture Radar) was flown for applications in the fields of agriculture, forestry, oceanology, urban development, soil moisture, geology, hydrology; preparation for future satellite radar
- INDREX-II in Indonesia (November/December 2004) for ESA; E-SAR was flown for different investigations referring to tropical rain forest

Connections within DLR – access to sensors

DLR also has profound expertise in sensor development, operation and subsequent data processing and evaluation. The German Remote Sensing Data Center (DFD), Remote Sensing Technology Institute (IPF), Microwaves and Radar Institute (IHR), Institute of Planetary Research (IPF) offer

- Laboratory calibration (also for non-DLR sensors)
- Aircraft adaptation and installation
- Sensor operation during flight
- Ground based validation
- Data processing (to different levels / data products)

The range of sensors covers photogrammetric cameras (RMK), stereo cameras (ADS 40, HRSC-AX), multispectral scanners (ATM), hyperspectral scanners (ROSIS, ARES (from 2006)), and radar systems (E-SAR, FSAR being developed).

For details:

- http://www.dlr.de/caf (Cluster of Applied Sciences: DFD and IMF)
- http://www.dlr.de/hr (IHR)
- http://www.dlr.de/pf/institut/abteilungen/sensortechnologie (IPF)

EUROPEAN NETWORKS AND PROGRAMMES

Networking opens time and cost effective ways for transnational European access to unique infrastructures to share technology and knowledge between European researchers. In Europe since many years such networks have developed in many scientific areas. The benefit of such networks is obvious by the high response of the researcher community

DLR has a long tradition in active participation in these programmes. The Flight Facilities were/are engaged for example in

The 4th Framework Program: TMR (Training and Mobility of Researchers):

- STAAARTE (**S**cientific **T**raining and **A**ccess to **A**ircraft for **A**tmospheric **R**esearch **T**hroughout **E**urope) (aircraft from MRF, INSU, DLR)
- EURASER Concerted Action (**Eu**ropean **R**esearch **A**ircraft and **S**ensors for **E**nvironmental **R**esearch)
- The 5th Framework Program: IHP (Improvement of the Human Potential)
- CAATER (**C**o-ordinated **A**ccess to **A**ircraft for **T**ransnational **E**nvironmental **R**esearch
- EUFAR (I) **E**uropean **F**leet for **A**irborne **R**esearch (Meteo France, MRF, INSU, DLR, NLR, INTA, NERC, ENVISCOPE, ESF9
- The 6th Framework Program:
- EUFAR (II) **E**uropean **F**leet for **A**irborne **R**esearch including Transnational Access Activities, Networking Activities and Joint Research Activities: www.eufar.net

The fleet of EUFAR II offers aircraft in 5 categories for transnational access:

- 1 stratospheric aircraft (Pending)
- 4 high level jets (incl. DLR's Falcon 20)
- 2 large tropospheric aircraft
- 8 medium sized tropospheric aircraft (including DLR's Cessna C 208 B Grand Caravan and Dornier 228-101 (with NERC))
- 8 small tropospheric aircraft

EUFAR II activities start in spring 2005. More information can be found at http://www.eufar.net.

DLR flight facilities is strongly engaged in the EUFAR network. Three own aircraft are offered in the fleet of research aircraft (see above) and DLR personnel has also taken over positions in the EUFAR overall management group (Dr. M. Krautstrunk: category coordinator: high level jets; Volkert Harbers, coordinator: future of the fleet) and the working group Thermodynamics (coordinator: Dr. M. Zöger).

NEWS AND FUTURE DEVELOPMENTS

In order to broaden the range of service DLR flight facilities can offer to its customers there is ongoing work on the enhancement of specific aircraft instrumentation. Thus for both the Cessna 208B Grand Caravan and the Dornier 228 meteorology packages have been developed including a boom mounted flow angle sensor for wind vector measurement. Flight test will be done in the near future as the final step for operational use. The sensor package will allow to measure temperature, pressure, humidity, wind speed, wind direction and also turbulence. The Dornier 228 will have a nose boom, the Cessna as a single-engine aircraft will carry the boom under one of the wings.

Figure 7: D-CFFU with nose boom

Figure 8: D-FDLR with under-wing boom

In February 2005 DLR signed the contract for the acquisition of a new aircraft. HALO (**H**igh **A**lti-tude, **Lo**ng Range research Aircraft) will join the DLR aircraft fleet in 2008/2009. Although owned and operated by DLR the aircraft has been funded and supported by a consortium of 30 scientific partners representing the large German research organisations (HGF, MPG, Universities and WGL). HALO is based on an ultra long range business jet Gulfstream G550 and will undergo a 3 year modification phase, before being available for research. The spacious aircraft will give room for many instruments and allow joint missions of different research groups. The aircraft will be based at DLR Oberpfaffenhofen and operated by DLR flight facilities. First scientific missions are expected to take place in 2008.

Figure 9: HALO – schematic presentation

Figure 10: size of HALO compared to a Falcon 20

Since 2005 DLR flight facilities has a new logo:

Figure 11: new logo of DLR flight facilities

CONCLUSIONS

DLR flight facilities can offer highly developed, well equipped and versatile research platforms for a number of applications. The specialised groups within the department offer full service from sensor installation to derivation of special aircraft parameters. Long-year world-wide experience makes DLR flight facilities a strong and reliable partner for research. Together with other DLR institutes (German Remote Sensing Data Center, Remote Sensing Technology Institute, Microwaves and Radar Institute, Institute of Planetary Research) also a number of sensors and their respective data products can be offered.

ACKNOWLEDGEMENTS

DLR flight facilities would like to say ‘thank you’ to all previous and future users for interesting and successful campaigns. We are looking forward to future activities.