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Report

Sensor network for polar research aircraft

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Abstract: Scientific observations from the disciplines of geophysics, meteorology, air chemistry and oceanography can easily be realized by means of airborne sensor systems over large remote areas and up to high altitudes. The Foundation Alfred Wegener Institute for Polar and Marine Research (AWI) owns two research aircraft of type Dornier 228-101 for scientific and logistic applications during Arctic and Antarctic surveys. Since May 2001 the OPTIMARE Sensorsysteme AG is responsible for the scientific equipment onboard both aircraft. The main task of this contract is the maintenance and integration of existing and new sensors together with the operation on polar expeditions. The data acquisition system MEDUSA-P was developed and integrated at both aircraft. MEDUSA-P originally was designed for airborne routine oil spill detection and was adapted to the operational conditions at the polar environment, where temperature, flight altitude and rough landing strips were the most challenging aspect. MEDUSA-P facilitates the integration of scientific sensors into the data network onboard the aircraft by a simple add-on architecture. Meanwhile, it was successfully operated during seven surveys in the disciplines of geophysics, meteorology and air chemistry.

key words: airborne measurements, data acquisition system, polar environment, ASTAR2004

1. Background

In-situ and remote measurements of meteorological, geophysical and oceanographic features can easily be performed by airborne platforms. Airborne data of high temporal and spatial resolution can be used either to analyze local phenomena or to link ground based with satellite borne measurements.

The Foundation Alfred Wegener Institute for Polar and Marine Research (AWI), Bremerhaven, Germany owns 2 research aircraft of type Dornier 228-101, whose missions are dedicated to meteorological, geophysical, oceanographic and logistic topics at Arctic and Antarctic regions. Since May 2001 the OPTIMARE Sensorsysteme AG, Bremerhaven, Germany is responsible for the scientific equipment onboard both aircraft

Fig. 1. Integration of scientific equipment at the two polar research aircraft in the hangar of the OPTIMARE Sensorsysteme AG at the regional airport Bremerhaven.

(see Fig. 1)

The main aspect of this responsibility are maintenance and integration of existing and new sensors but also their operation during field missions. Furthermore, the sensor network MEDUSA-P was integrated at both aircraft as central scientific data acquisition and power supply (Zielinski *et al*., 2005).

The following environmental conditions must be faced by aircraft, crew and equipment during polar missions:

- Operational temperatures below -40°C.
- Flight altitudes up to 24.000 ft without pressurization.
- Starts and landings on rough ice runways.

Therefore a robust, but nevertheless compact design of equipment and high standards for data quality are required. All systems are documented and certified according to German regulations.

2. Instrumentation

Both aircraft are basically equipped with standard meteorological sensors for wind speed, temperature and humidity. Furthermore, data of primary navigation systems of the aircraft such as GPS, Inertial Navigation System (INS Honeywell Lasernav and GNS-X Global-Wulfsberg) and radio altimeter (Sperry AA-300) are recorded for scientific data analysis.

The large variety of mission setups dedicated to meteorology, air chemistry and geophysics covers a large spectrum of individual sensors whose data need to be managed by the central data acquisition system. In the following, the key equipment of the several scientific disciplines is summarized:

Geophysics:

- ice thickness radar
- aerogravimeter
- aeromagnetometer
- several laser altimeter und laser scanner
- video camera

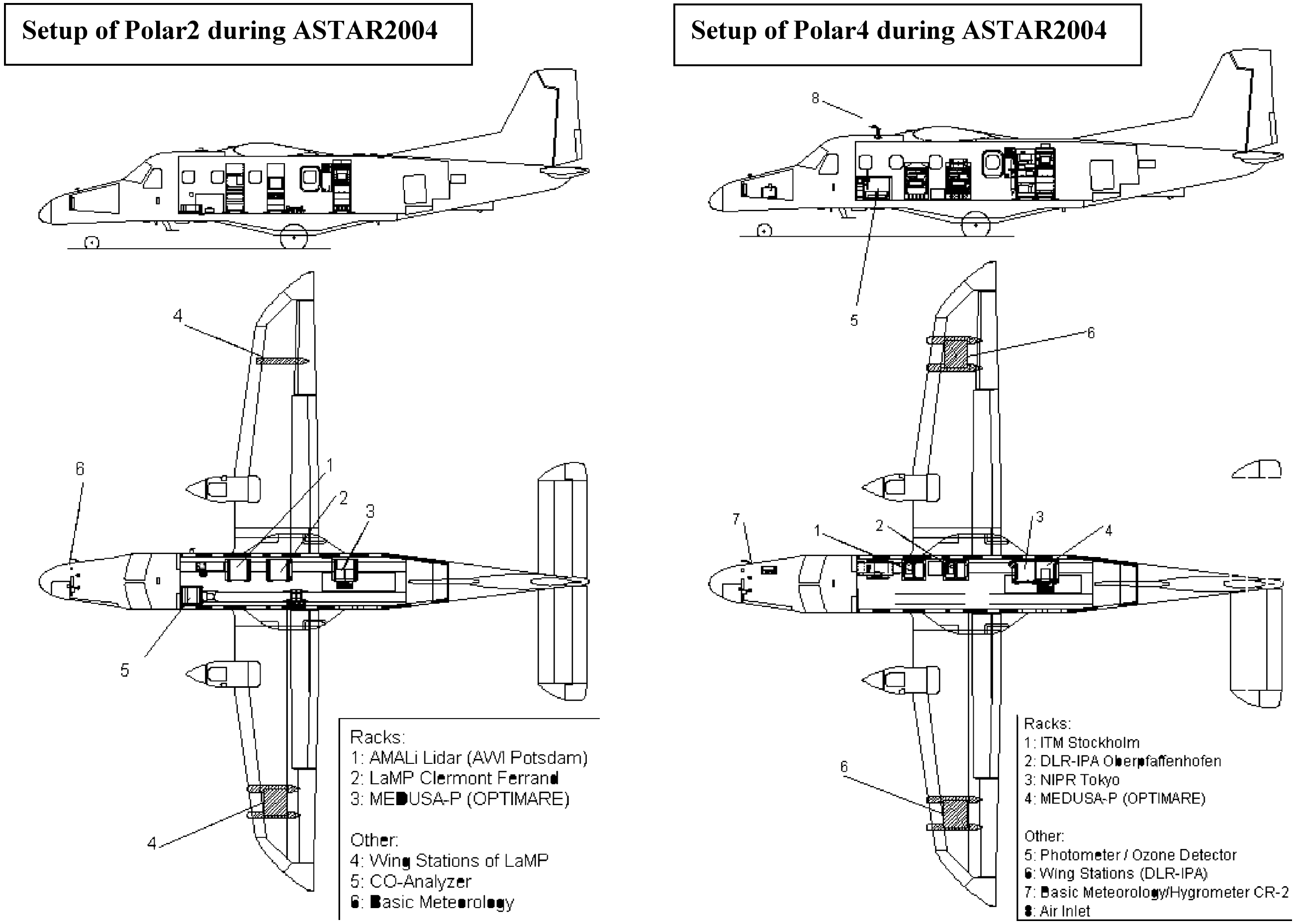

Fig. 2. *Cabin layout of Polar2 and Polar4 designed for ASTAR2004.*

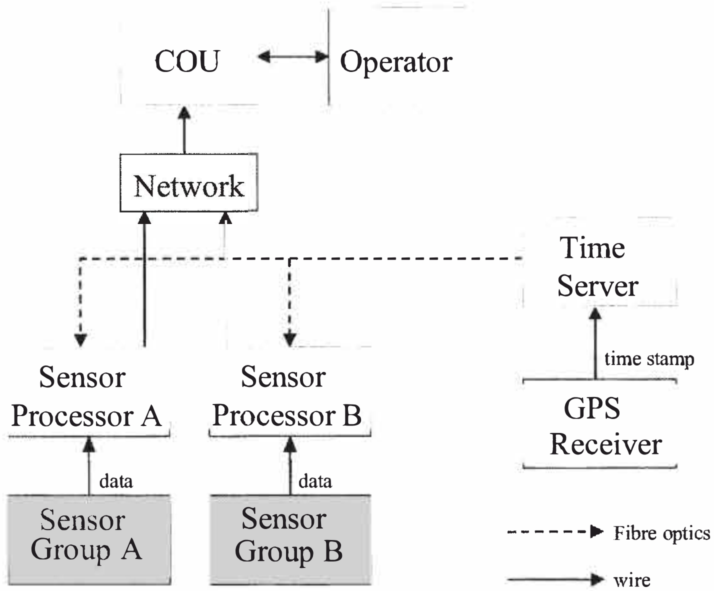

Fig. 3. Block diagramm of the sensor network MEDUSA-P.

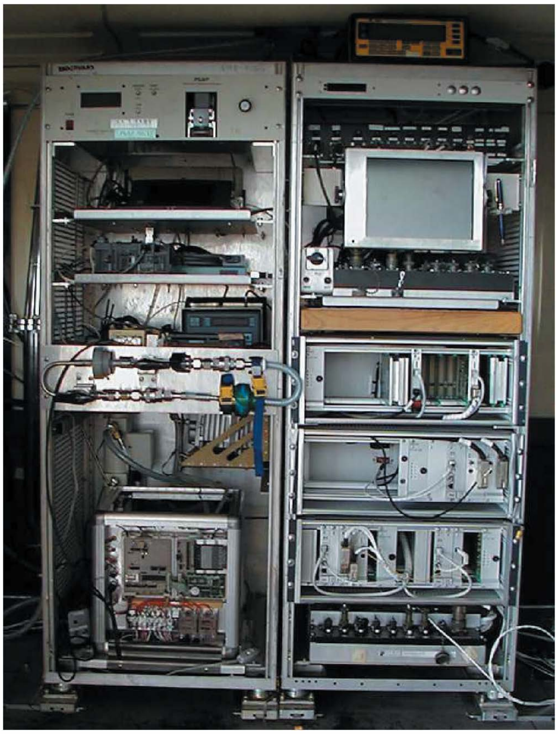

Fig. 4. R/H side: Rack of MEDUSA-P inside the aircraft Polar4 (front covers removed). L/H side: Rack of National Institute of Polar Research, Tokyo, Japan.

Table 1. Sensor setup of Polar2 (above) and Polar4 (below) designed for ASTAR2004.

Polar2

Institute	Instrumentation
OPTIMARE, Bremerhaven, Germany	Central Data Acquisition MEDUSA-P
AWI Bremerhaven, Germany	Basic Meteorology Navigation + Position CO Analyzer Pyranometer + Pyrgeometer (downward+upward) Nevzorov Probe
AWI Potsdam, Germany	Lidar AMALI
LaMP Clermont Ferrand, France	Polar Nephelometer Forward Scattering Spectrometer Probe (FSSP-100) 2DC-Probe Cloud Particle Imager CPI

Polar4

Institute	Instrumentation
OPTIMARE, Bremerhaven, Germany	Central Data Acquisition MEDUSA-P
AWI Bremerhaven, Germany	Basic Meteorology Navigation + Position Ozone Analyzer Pyranometer + Pyrgeometer (downward+upward) Sun Photometer
NIPR Tokyo, Japan	Absorption Photometer Integrating Nephelometer Optical Particle Counter Aerosol Filter Sampling System Aerosol Impactor Hygrometer CR2
ITM Stockholm, Sweden	Optical Partical Counter (OPC) 2x Condensation Particle Counter (CPC 3010) Differential Mobility Particle Sizer
IPA Oberpfaffenhofen, Germany	Passive Cavity Aerosol Spectrometer Probe (PCASP-100X) Forward Scattering Spectrometer Probe (FSSP-300) Condensation Particle Size Analyzer

Meteorology and air chemistry:
- turbulence probe Meteopod
- radiation sensors pyranometer and pyrgeometer
- wing stations for PMS probes
- laser altimeter for detection of surface roughness
- drop sonde system
- several hygrometers and humidity sensors
- photometer and trace gas detectors
- color-line-scanner and IR-scanner

OPTIMARE supports the AWI as well as its national and international partners in the electrical and mechanical integration of new systems, develops solutions for data storage and prepares the documentation being required for the aeronautical certification.

Samples of recent sensor configurations are shown in Figs. 2, 3, 4 and Table 1 for the Polar 2 and Polar 4 configurations during ASTAR2004.

3. Data acquisition system MEDUSA-P

The power supply for sensors onboard as well as the acquisition and exact synchronization of all collected data is the crucial task of MEDUSA-P. All integrated sensors are being arranged into thematically and spatially related sensor groups. Each of these sensor groups is administrated by a individual sensor processor which digitizes and stores the data on an internal buffer.

The data rate of most sensors ranges between 20 or 100 Hz. Especially the analysis of turbulent structures or geophysical surveys demands for an exact synchronization of different sensors which has to be met by the data acquisition system. Therefore central time information generated by the time server (connected to a GPS-Receiver) is distributed throughout the aircraft via optical fibers. Each sensor-processor links the sensor data to the time signal and transfers the coupled data-time-information via network to the central operating unit (COU). Here the information is stored in a database and transferred to a graphical user interface (GUI) for the operator. Hence, the operator has permanent control on data quality and gives advice on flight patterns based on the online data. Due to redundant data storage on both the sensor processor and the COU database a high reliability is achieved.

MEDUSA-P is the advancement of the network concept MEDUSA, which has proven its capabilities during longtime operational application in maritime surveillance and pollution control over North and Baltic Sea (Zielinski, 2003; Robbe and Zielinski, 2004). Especially the extreme environmental conditions during polar missions such as operational temperatures below $-40°C$ and flight altitudes of up to 24.000 ft were considered for the new concept of MEDUSA-P. Up to now the system has been applied on seven surveys in the disciplines of meteorology, air chemistry and geophysics.

The main conception of MEDUSA can easily be adapted to further applications and simultaneously benefits from other types of applications. For example as a next step, MEDUSA will be adapted to bio-optical floats (Hengstermann *et al*., 2005 in preparation) being designed to drift in the ocean for several years. This application requires an extreme minimization of weight, dimensions and power consumption which on the other hand will lead to much more efficient solutions for airborne platforms.

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