

HALO – „High Altitude and Longe Range Research Aircraft“

HALO as a platform for atmospheric and geophysical research after the first 5 years of intensive deployment

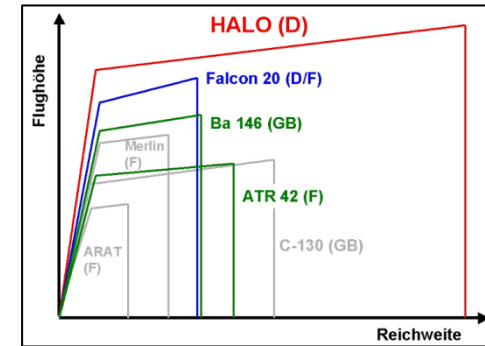
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HALO project management team
DLR Flight Experiments (FX), Oberpfaffenhofen



[About the aircraft](#) | [Research topics](#) | [Organisation](#) | [Instruments](#) | [Future plans](#)

A short history of HALO

- 1999 HGF climate research reviewers recommend a new research aircraft
- 2001 proposal for HALO submitted by 31 German research institutions (lead by DLR & MPG) to the German Scientific Council
- HIGHER!** → 15 km ceiling
FURTHER! → more than 8000 km range
MORE! → Scientific payload up to 3 t
- 2002 Positive vote of the German Scientific Council
- 2003 Invitation to tender
- 2005 January: Contract of purchase
December: green aircraft build by Gulfstream Aerospace and first transfer to Oberpfaffenhofen.
- 2006-2007 19 month conversion work at RUAG (apertures, fuselage strengthening, electrics, ...)
- 2008 Paintwork and further conversion at Gulfstream
24. Januar 2009 Delivery of HALO
- 2009 ff. Design and certification of of many external provisions (Aerostruktur and DLR)
- 2012 First „full“ scientific missions (GEOHALO, TACTS/ESMVal)



HALO facts

Gulfstream
G550



Wing span:	28.5 m	Max. take-off weight:	91400 lbs (42.3 t)
Length:	30.9 m	Max. science payload:	3000 kg
Height:	7.9 m	Max. flight altitude:	51000 ft (15.5 km)
		Max. range:	10500 km (1 t payload) 8800 km (3 t payload)
Max. speed.:	Ma 0.885		
Max. fuel weight:	19 t	Typical fuel consumption	1800 l/h
Max. electrical power for science payload:	40 kW		

<http://www.halo.dlr.de/>

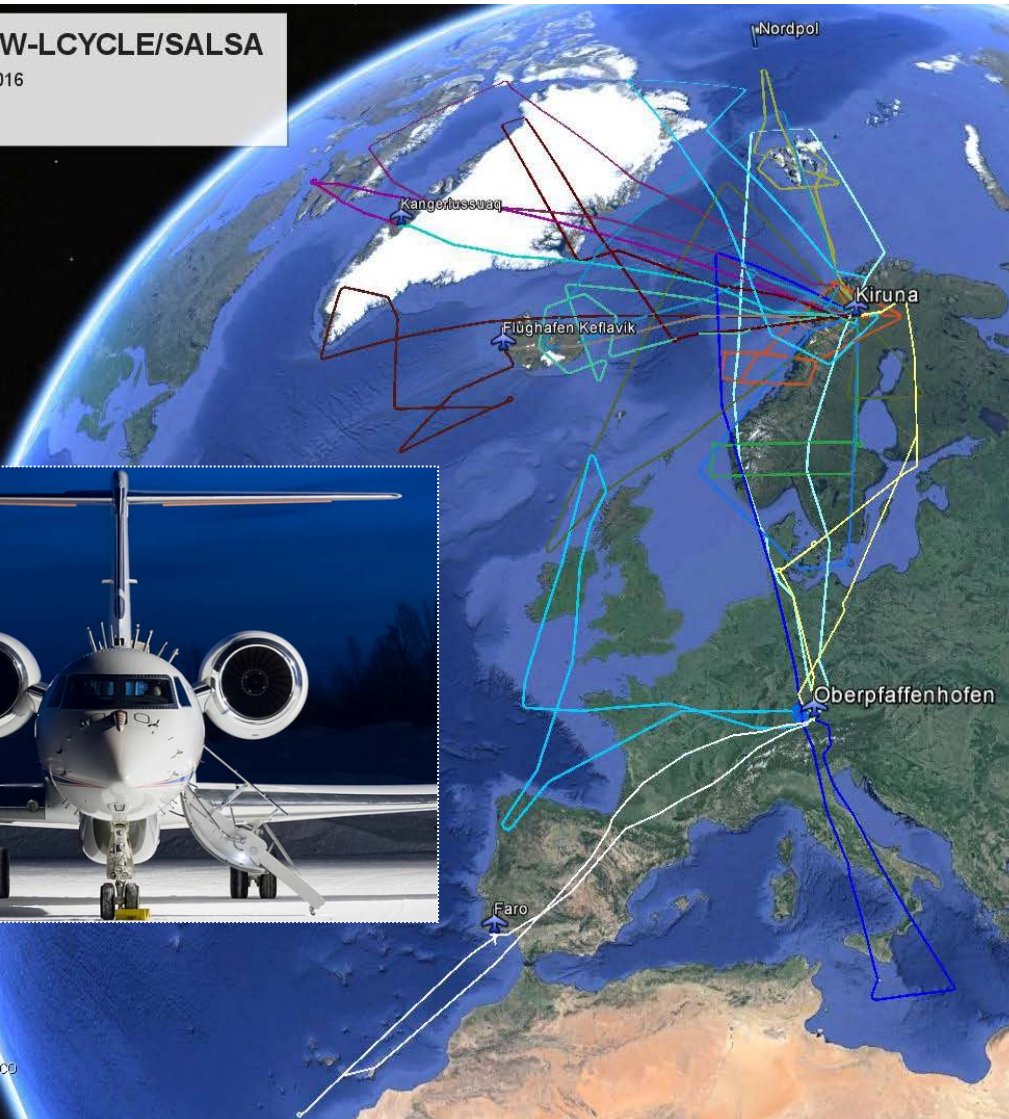


Does HALO deliver?

Example: HALO flight tracks during „POLSTRACC / GW-LCYCLE / SALSA“ (PGS) mission



POLSTRACC/GW-LCYCLE/SALSA
December 2015 - March 2016
HALO flight tracks



Long range and high altitude of HALO successfully demonstrated (and scientifically needed!)

23 flights, 156 science flight hours

Payload
→ **3.0 t**
→ **Belly pod & six inlets**
→ **8 persons onboard**
(3 flight crew + 5 science crew)

Max. flight altitude
→ **14.6 km (FL480)**

Max. trip
→ **8060 km, 9.7 h flight time**

Max. trip with refueling stop
→ **9332 km, 11.5 h flight time**

Coldest temperature
→ **-76 °C**

Flying in remote polar region
→ **few alternates**

How a proper Gulfstream 550 should look like



However, this is what we got



Looks much more cozy if you get the appropriate furniture in



Research topics for HALO



HALO is mainly used for

- primarily: environmental & climate research
- also: geophysical research & earth observation

Atmospheric chemistry, Air quality,
Long range transport of pollutants

Dynamics & chemistry
upper troposphere / lower stratosphere

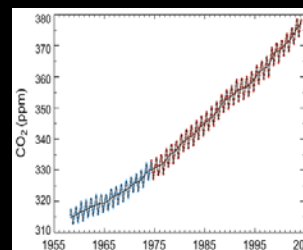
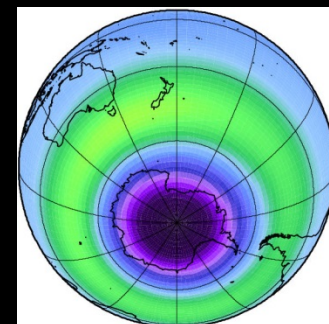
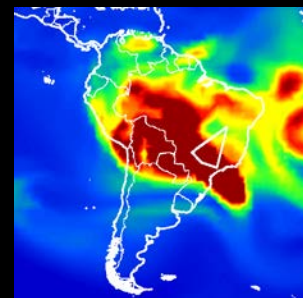
Aerosols, clouds and water cycle

Emissions (traffic etc.)

Carbon / green house gases in the climate system

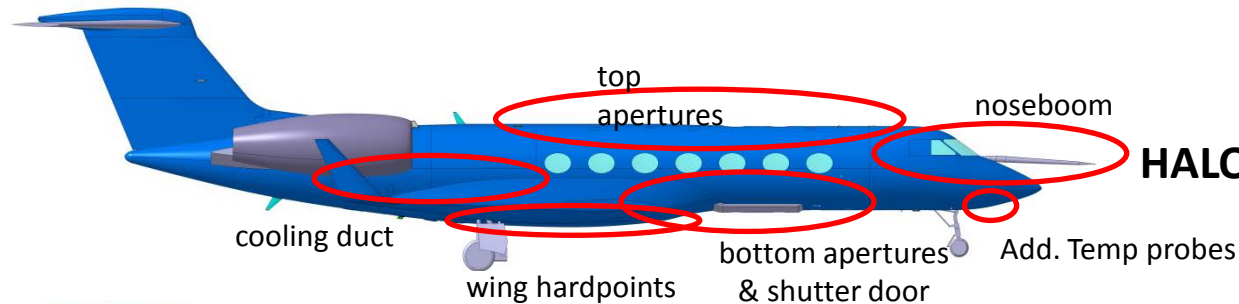
Dynamics of the atmosphere / Extreme weather

Earth observation / geophysics

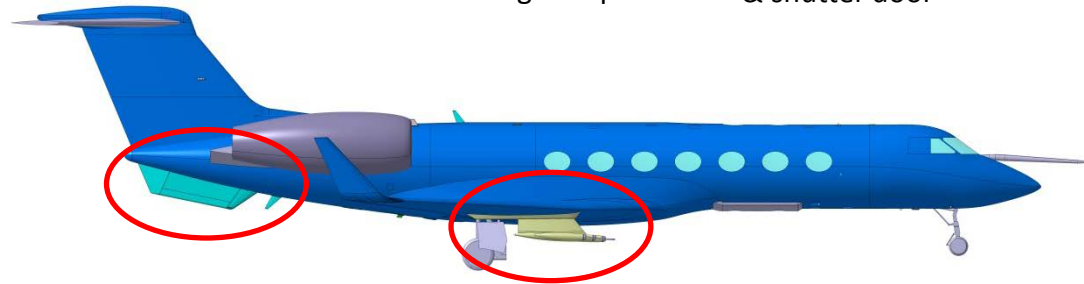




Modifications to the aircraft exterior

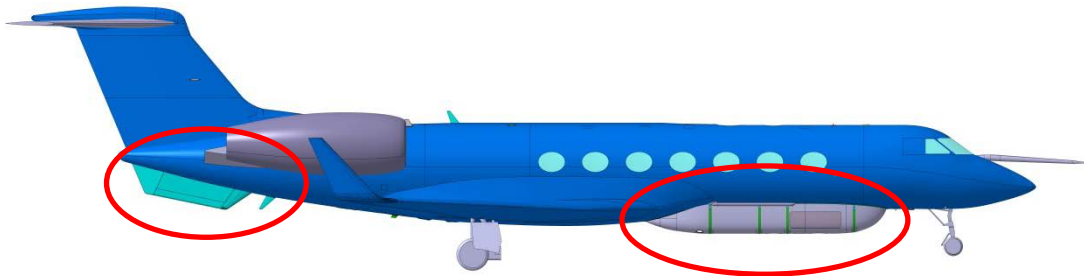


HALO Baseline (GAC)



Wing pods

- DLR PMS carriers (not certified)
- NCAR PMS carriers
- Large wing pod (not certified)



Belly Pod + Ventral fin



Many apertures ... for mounting of inlets, antennas, sensors, special windows etc.

?





GLORIA

Gimballed Limb Observer for Imaging of the Atmosphere



HAMP - The HALO Microwave Package



passive microwave radiometers
with 26 frequencies in different bands
between 22.24 and 183.31 ± 12.5 GHz

cloud radar at 36 GHz

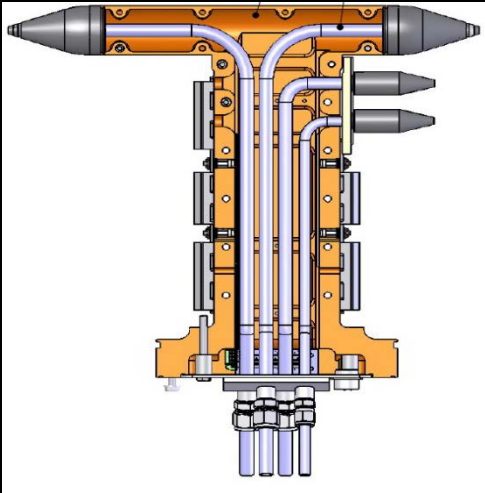
ML-CIRRUS configuration in 2014
with inlets and PMS probes



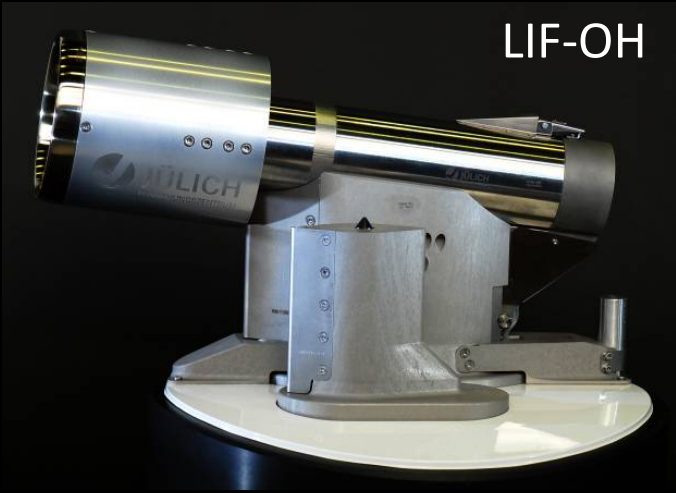
PMS type instruments in HALO wing carriers (NCAR design)



Some of the HALO inlet systems developed in the last years



TGI (Trace gas inlet)



LIF-OH



HAI

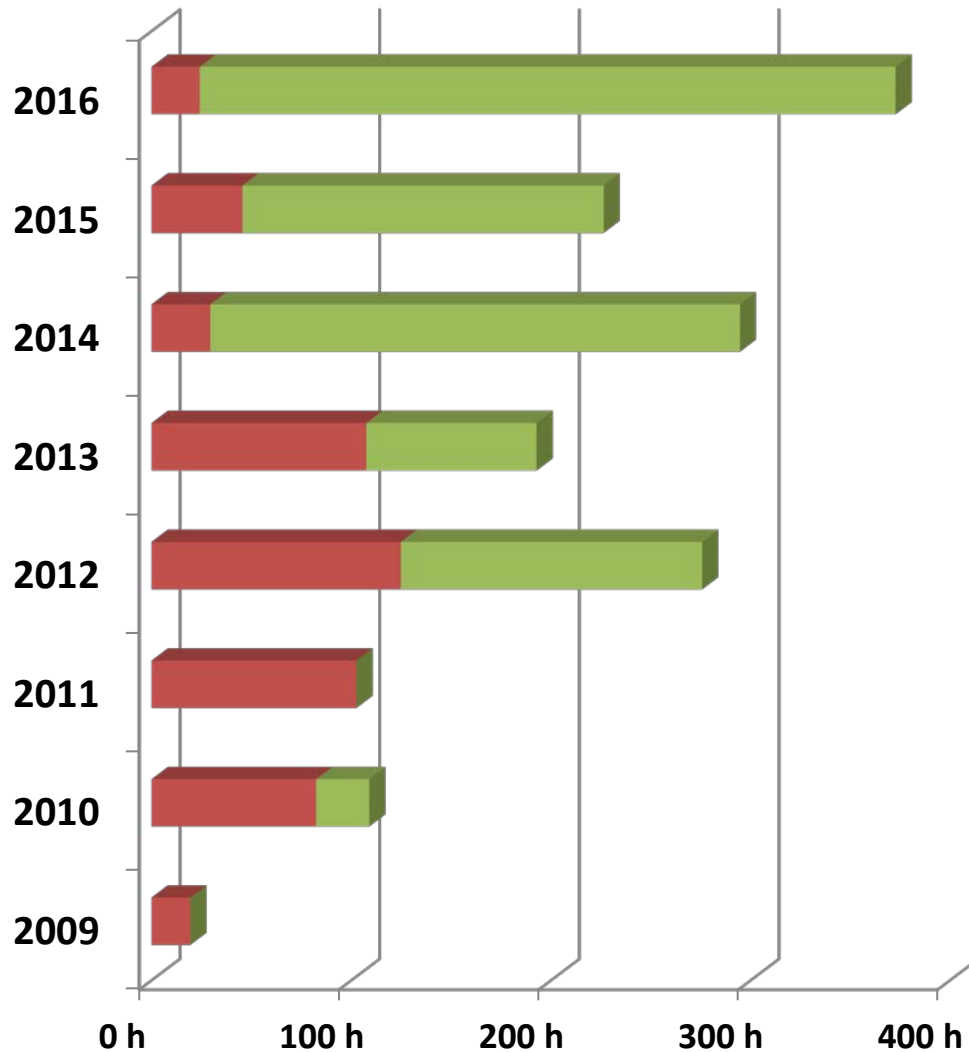


CVI



HASI

HALO yearly flight hours so far



- Development & certification, operational flights
- Mission preparation and science flights



Organisation of HALO

Scientific operators of HALO: the HALO consortium



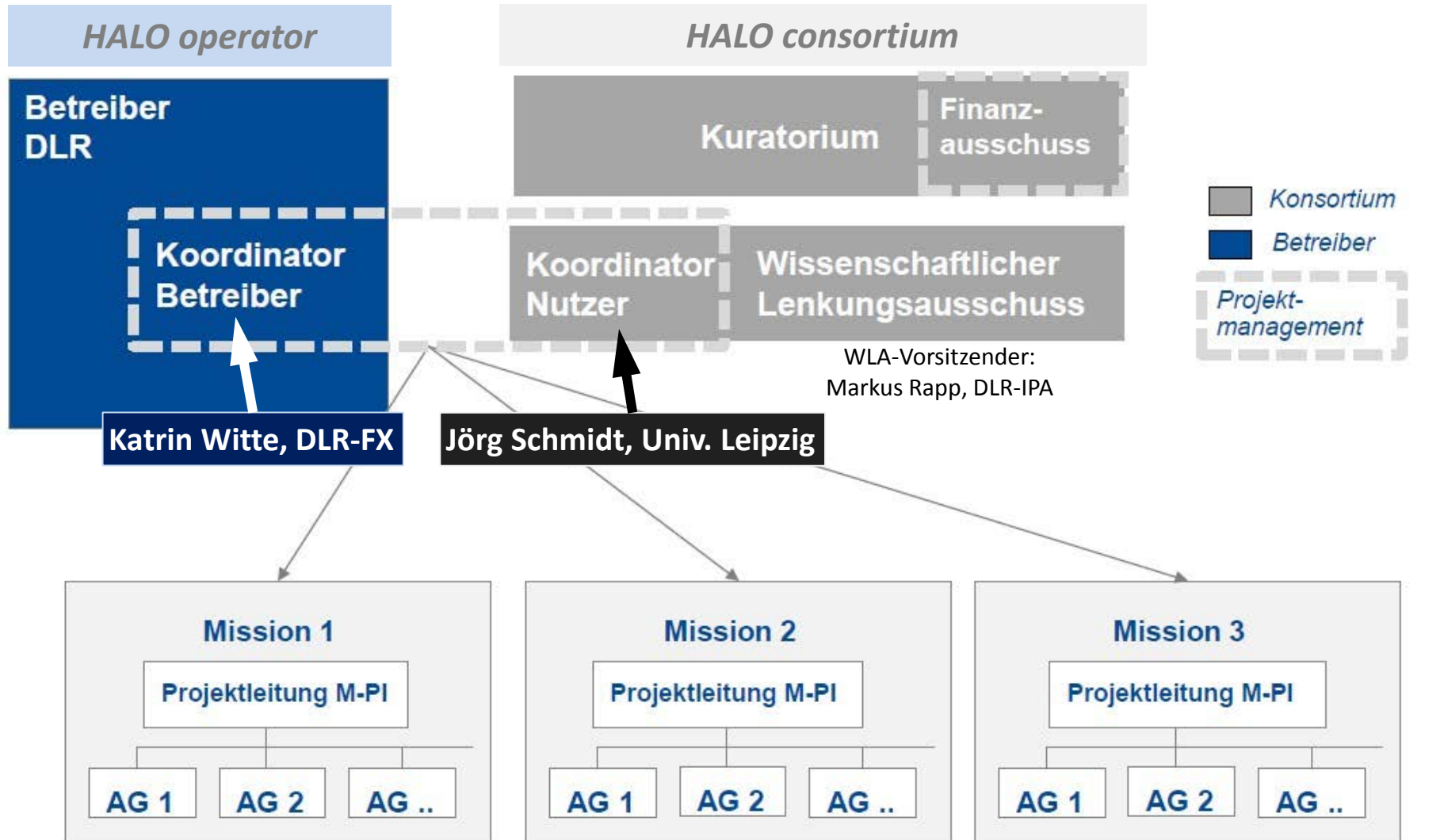
 Deutsche Forschungsgemeinschaft	Deutsche Forschungsgemeinschaft e.V. (DFG)
 DLR	Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR)
 MAX-PLANCK-GESellschaft	Max-Planck-Gesellschaft zur Förderung der Wissenschaften e.V. (MPG)
 JÜLICH FORSCHUNGSZENTRUM	Forschungszentrum Jülich GmbH (FZJ)
 KIT	Karlsruher Institut für Technologie (KIT)
 TROPOS Leibniz-Institut für Troposphärenforschung	Leibniz Institut für Troposphärenforschung e.V. Leipzig (TROPOS)
 GFZ Geophysikalisches Institut Potsdam	Helmholtz-Zentrum Potsdam Deutsches Geoforschungszentrum

The university partners of HALO (represented by the DFG in the HALO consortium)

Universities Bremen, Dresden, Frankfurt, Hamburg, Heidelberg, Köln, Leipzig, Mainz, München (LMU), Wuppertal, ... ;
Physikalisch-Technische Bundesanstalt Braunschweig

DFG priority program (**HALO-SPP**) ongoing to fund research with HALO and campaign costs for university participants (<http://www.halo-spp.de/>).

Organisational structure for HALO



M-PI = Mission Principal Investigator

How HALO is funded



Purchase project completed 2004-2011

Purchase of the aircraft
Conversion
Tests & flight tests



ca. 70 Mio. Euro



HALO running costs

Standby costs

Maintenance, insurance,
management, staff,
development, etc.

Funded by
the **HALO consortium:**



ca. 3.8 Mio. Euro/Year

Missions (HALO campaigns)

preparation, certification,
fuel, travel/subsistence,
FX staff,
mission certification etc.

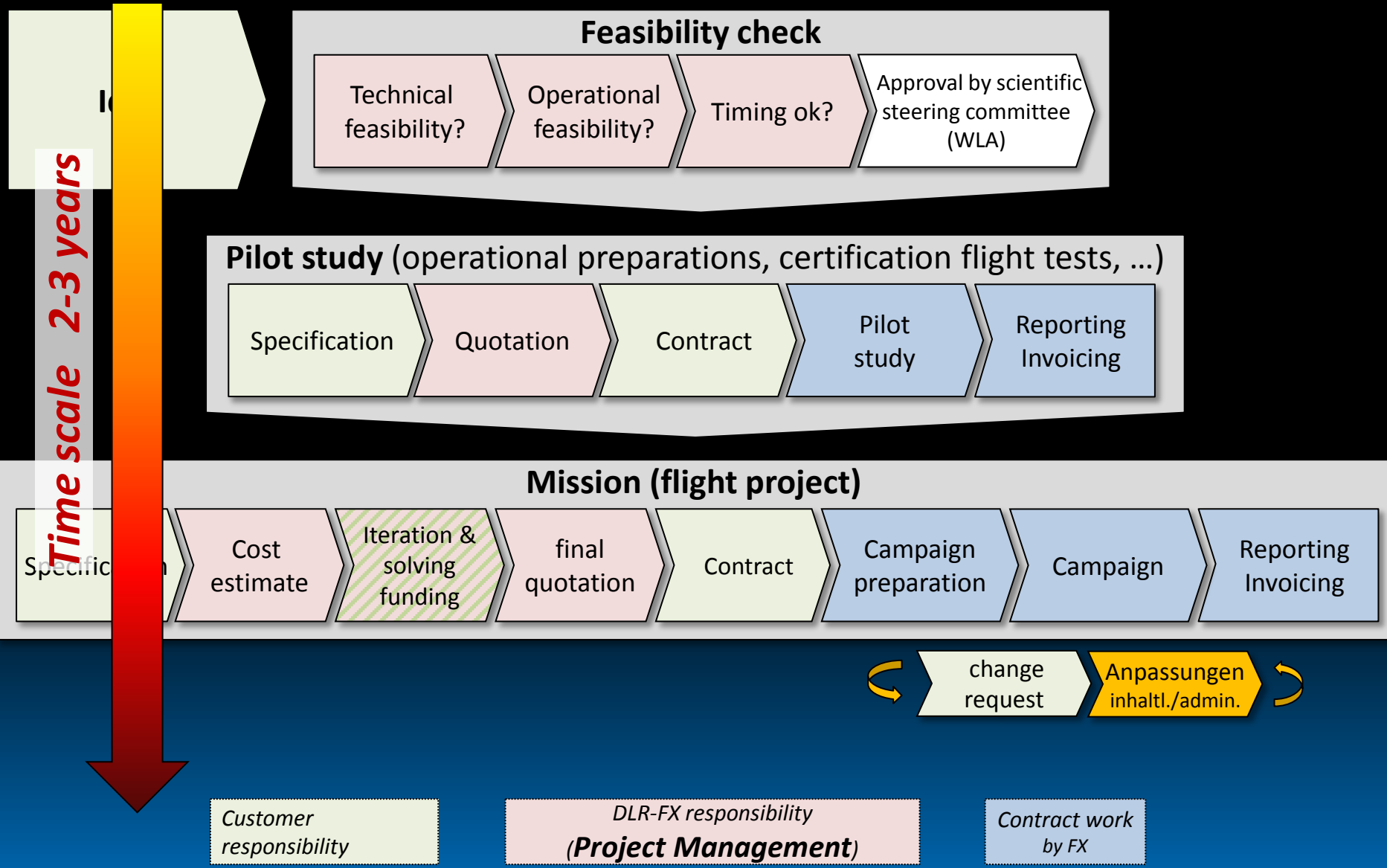
Funded by:
Partners of the mission
typically 0.5...2.5 Mio. Euro

Instrument certifications

Design, documentation,
certification, etc.

Funded by:
Instrument owner/operator

Managing a HALO project



Scientific payload for HALO



DLR-FX as operator provides the basic data acquisition system **BAHAMAS** providing:

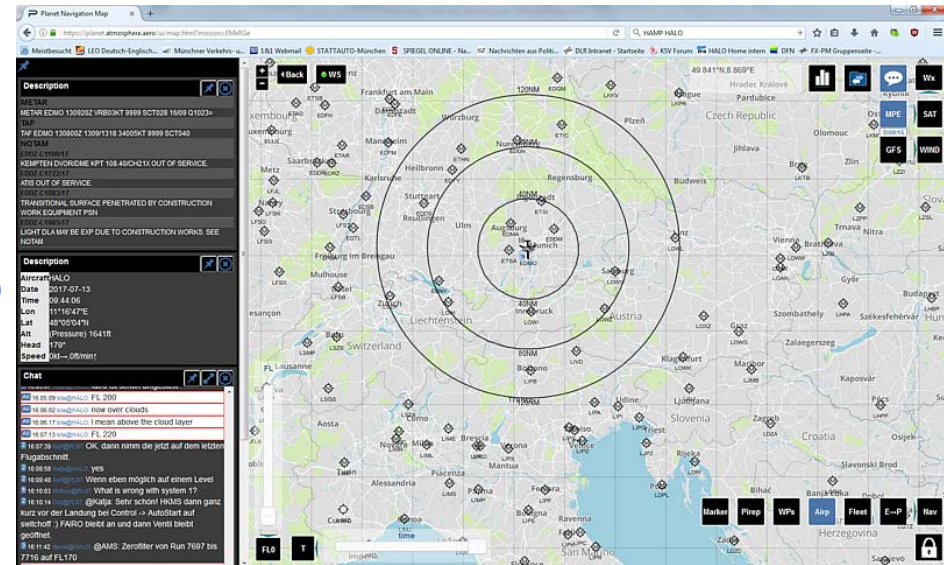
- aircraft position & attitude
- atmospheric state (pressure, temperature, wind, humidity) in 1 ..100 Hz
- local area network onboard

Conference posters!

- **Inflight Calibration of the HALO Airflow Sensor System** (Giez et al.)
- **SHARC – Sophisticated Hygrometer for Atmospheric Research** (Zöger et al.)

And in collaboration with the company Atmosphere:

- communication and data transfer between HALO and ground via Inmarsat or Iridium satellite (PLANET)



All other instruments are provided by the scientific user groups.

Examples of scientific payload elements for HALO



19" cabin racks with instruments



Instruments
in under-wing carriers



Sample air inlets, radiation sensors,
antennas



Instruments for belly pod
GLORIA / HAMP-Radar / Radiometers



Optical windows
e.g. for Lidar



Special cabin instruments



Airworthiness certification ☹️

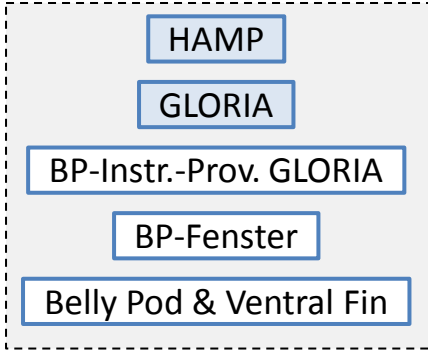
- Strict **safety requirements** by (German) aviation authority
- All instruments require certification specifically for HALO (MCA – minor change approval, STC – supplementary type certification)
- Instruments are treated as aircraft parts!
No relaxation for experimental nature of scientific equipment.
- Mission certifications for the **combination** of instruments required
- **Design Organisations** currently involved in certifications for HALO: DLR-EB, enviscope/Gomolzig, RUAG, Leichtwerk, SII, Gulfstream

Scientific payload for HALO:

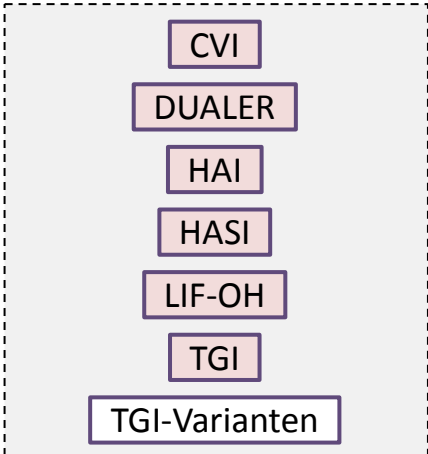
Currently approx. 60 certified modifications

(requiring about 20 additional certifications for instrument provisions)

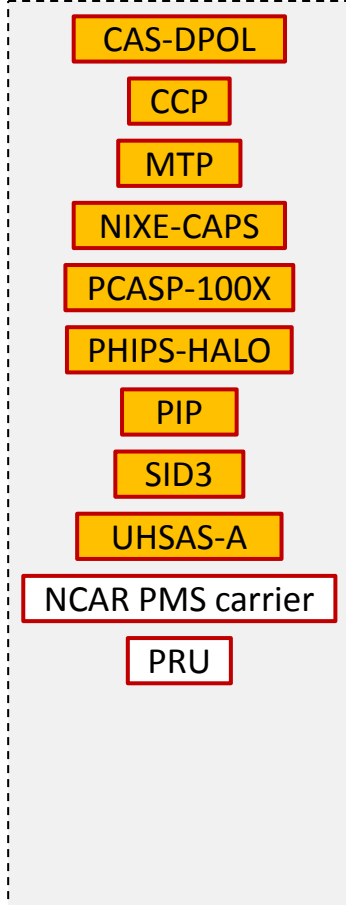
Belly pod instruments



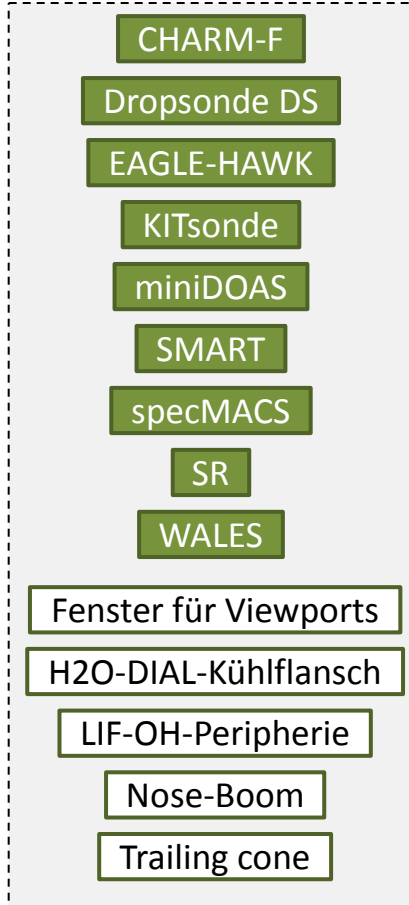
Sample air Inlets



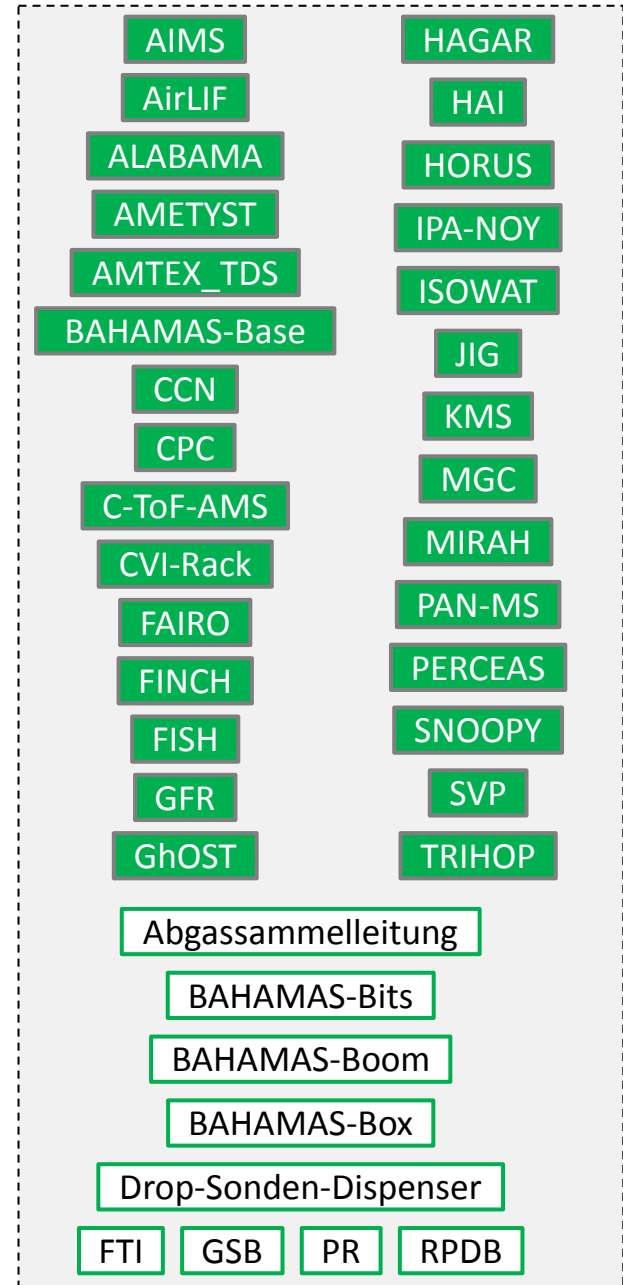
PMS wing station instruments



Cabin-mounted remote sensing instrum.



Cabin-mounted in situ instruments



Current planning, conclusions & outlook



Missions envisaged for HALO 2019-2022



Mission	Topic, Region	Similar to ...
CIRRUS-HL	Cirrus & humidity budget, North polar region	ML-CIRRUS
SOUTHTRAC	Chemistry /Dyn. Tropopause, Südl. mittl. Breiten	POLSTRACC
ANTHALO	Geophysics in Antarctica, Troll (Antarctica)	
Waveguide	Gravity waves / Dynamics, Kiruna, Northern Europe	
HALO-(AC)^3	Radiation & clouds, Kiruna, Northern Atlantic	NARVAL 2/NAWDEX
EUREC4A	Clouds / Meteorology, Barbados, tropical Atlantic	NARVAL 2/NAWDEX
CAFE Brazil & SCOOP	Air chemistry/Aerosols Manaus, Brazil	OMO/ACRIDICON
COMET 2.0 Arctic	Carbon dioxid/Methane, USA/Canada	COMET
COMET 2.0 Tropical	Carbon dioxid/Methane, Brazil, northern South America	COMET

Conclusion and Outlook

- HALO is operated by DLR (DLR-FX) and is funded (and scientifically used) by a **consortium** of German research institutions (of which DLR is also a partner)
- Technical expectations concerning „**high altitude**“ und „**long range**“ were fulfilled by HALO; HALO is technically reliable so far and quite unique as a research platform.
- Interfaces for the scientific payload (designed early in the acquisition process) proved to be well suited; very diverse payloads are possible.
- Since 2013/2014 high workload from scientific missions, all rated as very successful.
- **Are there any problems? Yes ...**
 - Funding of missions and certifications remain difficult for scientific users
 - HALO in general has long planning cycles & complex funding & complex decision making → low flexibility.

2009

2010

2011

2012

2013

2014

2015

2016

2017

2018

Future ... !?

- Mission ideas until 2022 would fully utilize the aircraft (if funded).
- There are still some important certification projects for exterior configurations open.
- There is now clear tendency to re-use existing payload configurations.
- HALO is in principle open for scientific partners outside the HALO consortium. But no such case yet.



Further (and other) informationen about HALO:

HALO-Homepage

www.halo.dlr.de

DLR-Homepage

www.dlr.de | [Überblick](#) | [Missionen](#) | [HALO](#)



Thank you!

for your attention ... and for using HALO in the first place

Scientific HALO missions 2010-2016

(excluding certification and other flight tests)



Year (of mission start)	HALO-Mission	Operation base	Time period		Number of flights	Flights hours	Included projects
2010	Techno-Mission	Oberpfaffenhofen	28.10.2010	05.11.2010	8	27 h	
2012	GEOHALO	Oberpfaffenhofen	02.06.2012	12.06.2012	6	39 h	
	TACTS	Oberpfaffenhofen	13.08.2012	26.09.2012	6	53 h	
	ESMVal	Round trip	10.09.2012	23.09.2012	7	59 h	
2013	WAKE-OP	Oberpfaffenhofen	29.04.2013	30.04.2013	4	7 h	
	NARVAL-D	Oberpfaffenhofen	21.05.2013	24.07.2013	2	9 h	
	NARVAL	Bridgetown (Barbados) Keflavik (Iceland)	10.12.2013	22.01.2014	15	118 h	NARVAL-Nord, NARVAL-Süd
2014	ML-CIRRUS	Oberpfaffenhofen	21.03.2014	15.04.2014	17	81 h	
	ACRIDICON	Manaus (Brazil)	21.08.2014	04.10.2014	23	136 h	
2015	OMO-EU	Oberpfaffenhofen	21.01.2015	27.01.2015	4	17 h	
	CHARM-F	Oberpfaffenhofen	27.04.2015	13.05.2015	5	22 h	
	OMO-Asien	Paphos (Cyprus) Gan (Maldives)	10.07.2015	27.08.2015	20	117 h	
	POLSTRACC (PGS)	Kiruna (Sweden) Oberpfaffenhofen	08.12.2015	18.03.2016	25	163 h	POLSTRACC, GW-LCYCLE, SALSA
2016	iLOADS	Oberpfaffenhofen	12.04.2016	21.04.2016	5	14 h	
	NARVAL 2	Bridgetown (Barbados)	19.07.2016	30.08.2016	11	90 h	
	NAWDEX	Keflavik (Iceland)	15.09.2016	18.10.2016	14	102 h	

HALO has flown 18 scientific missions since 2012 until now (depending on how you count); 9 campaigns out of Oberpfaffenhofen, 7 out of airports abroad; 5 continents overflown

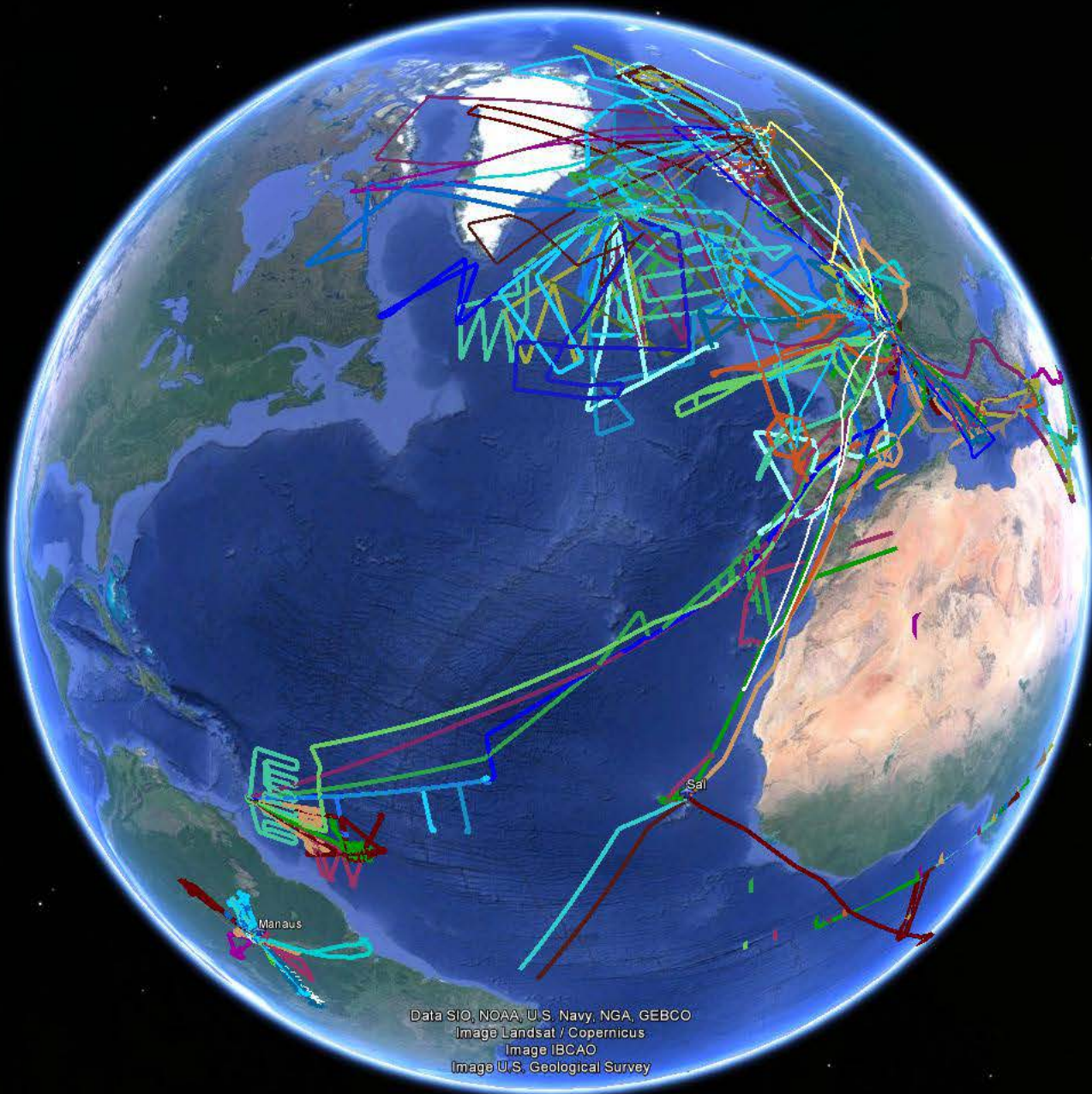
Scientific HALO missions

2010-2016

				Mission partners													Science topic						
				HALO consortium partners without DFG					DFG funded university institutions								A	B	C	D	E		
				DLR	MPG	KIT	FZJ	GFZ	TROPOS	U Bremen	TU Dresden	U Frankfurt	U Hamburg	U Heidelberg	U Köln	U Leipzig	U Mainz	LMU München	U Wuppertal	PTB	Aerosols, Clouds and Precipitation	Transport and Dynamics in the troposphere & UT/LS	Transport and Transformation of Chemical Composition
Year (of mission start)	HALO-Mission	Time period		Included projects																			
2010	Techno-Mission	28.10.2010	05.11.2010																				✓
2012	GEOHALO	02.06.2012	12.06.2012					●			◆											✓	
	TACTS	13.08.2012	26.09.2012		●		●	●				◆		●			●		●			✓	
	ESMVal	10.09.2012	23.09.2012		◆		●	●					●		●		●		●			✓	✓
2013	WAKE-OP	29.04.2013	30.04.2013		◆																		✓
	NARVAL-D	21.05.2013	24.07.2013		●	◆						●	●		●					✓			
	NARVAL	10.12.2013	22.01.2014	NARVAL-Nord, NARVAL-Süd	●	◆						●	●		●					✓			
2014	ML-CIRRUS	21.03.2014	15.04.2014		◆	●	●	●		●			●	●			●		✓				
	ACRIDICON	21.08.2014	04.10.2014		●	◆			●		●	●		◆	●	●		●		✓			
2015	OMO-EU	21.01.2015	27.01.2015		●	◆	●	●		●				●			●				✓		
	CHARM-F	27.04.2015	13.05.2015		◆	●															✓		
	OMO-Asien	10.07.2015	27.08.2015		●	◆	●	●		●				●			●			✓	✓		
	POLSTRACC (PGS)	08.12.2015	18.03.2016	POLSTRACC, GW-LCYCLE, SALSA	●		◆	●			●	●			●		●		✓	✓	✓		
2016	iLOADS	12.04.2016	21.04.2016		◆																		✓
	NARVAL 2	19.07.2016	30.08.2016		●	◆					●		●	●		●			✓				
	NAWDEX	15.09.2016	18.10.2016		●	●						●	●			◆				✓			

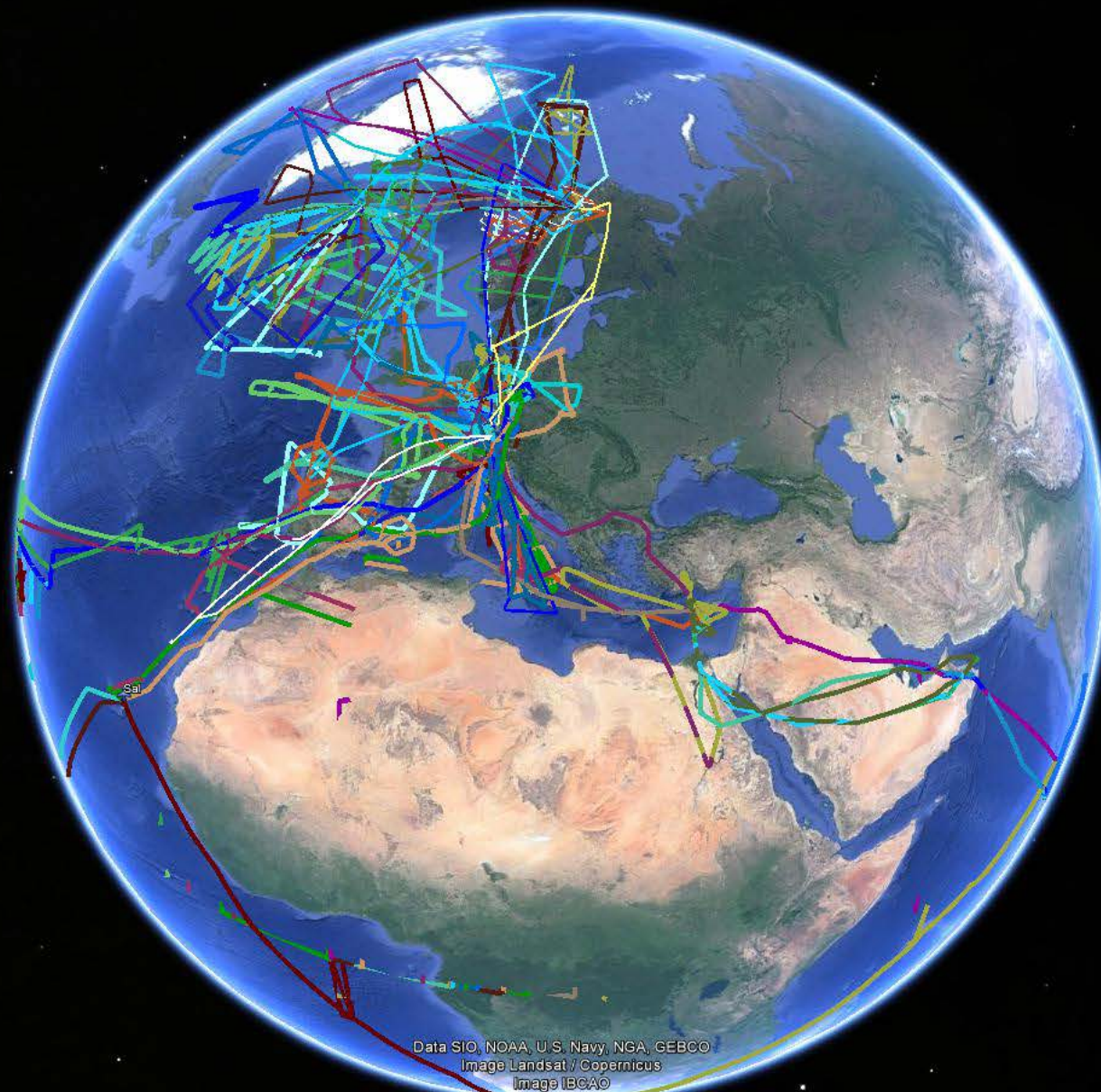
◆ Mission PI

● Mission partner



Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
Image IBCAO
Image U.S. Geological Survey

Google earth



Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
Image IBCAO
Image U.S. Geological Survey

Google earth



Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
Image IBCAO

Google earth