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: Development, experiences and perspectives

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

DLR

About the aircraft | Research topics | Organisation | Instruments | Future plans

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)
Max. speed.:	Ma 0.885		8800 km (3 t payload)

Max. fuel weight: 19 t

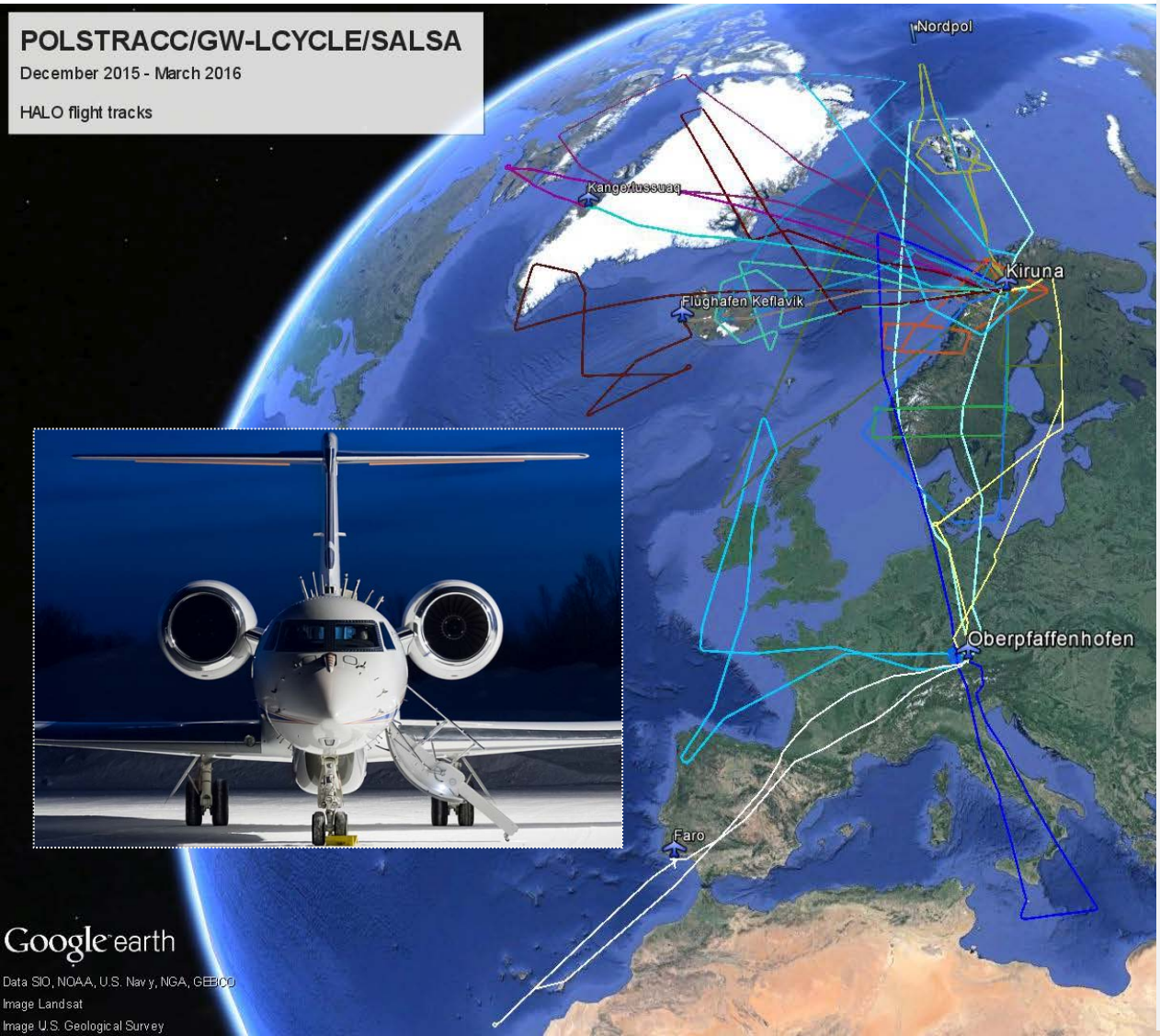
Typical fuel consumption 1800 l/h

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



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**

A short history of HALO

1999 HGF climate research reviewers recommend a new research aircraft

2001 proposal for HALO submitted by 31 German research institutstions (lead by DLR & MPG) to the German Scientific Council

HIGHER! → 15 km ceiling
FURTHER! → more that 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.

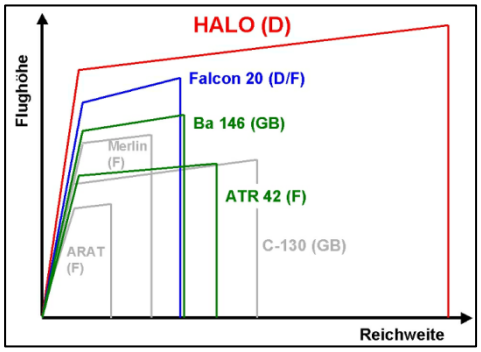
2006-2007 19 month conversion work at RUAG (apertures, fuselage strengthening, electrics, …)

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)



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 ….

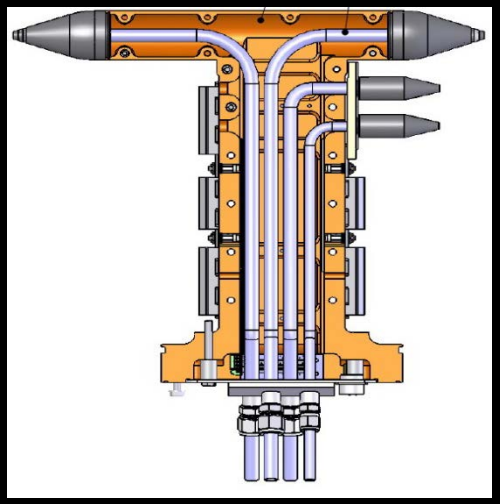

ML-CIRRUS configuration in 2014
with inlets and PMS probes ….

HALO with belly pod and ventral fin …. carrying GLORIA or HAMP

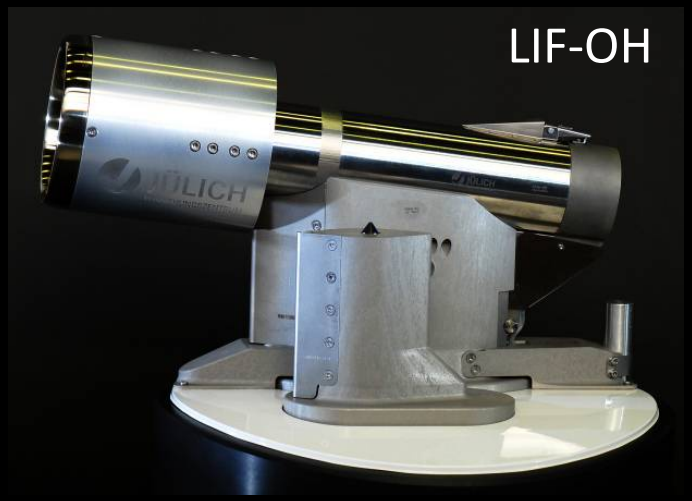
Many apertures … for mounting of inlets, antennas, sensors, special windows etc.

?

Some of the HALO inlet systems developed in the last years



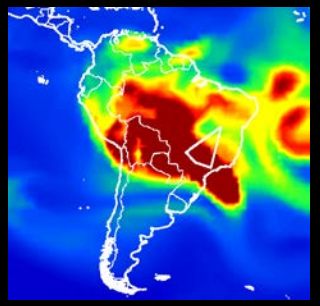
TGI (Trace gas inlet)

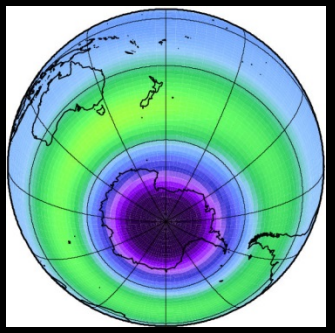


Research topics for HALO

HALO is mainly used for

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





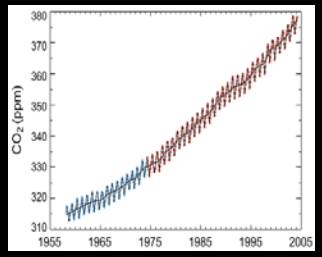
Atmospheric chemistry, Air quality,
Long range transport of pollutants

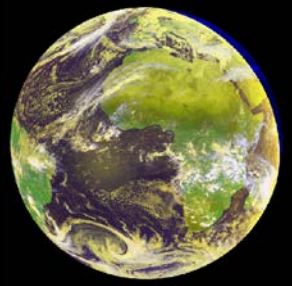
Dynamics & chemistry
upper troüosphere / lower stratosphere

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

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	

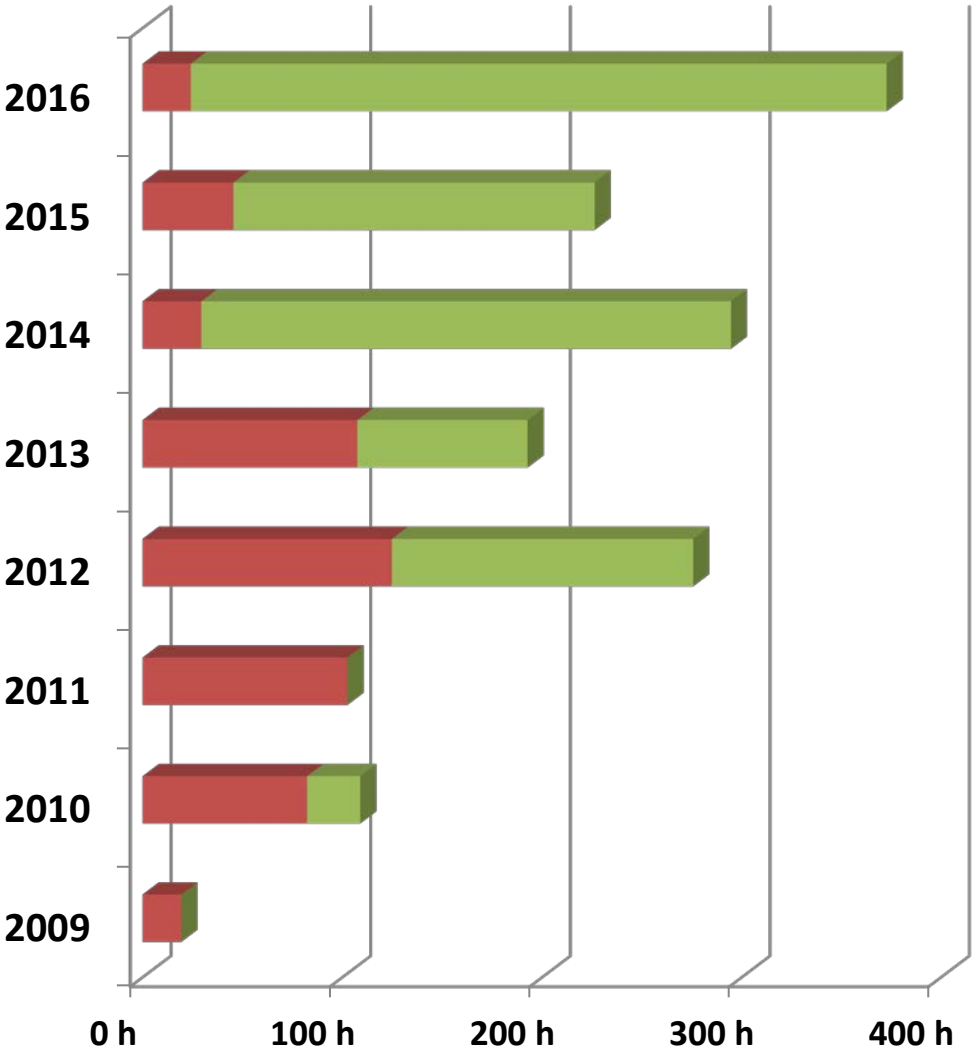
HALO has flown **18 scientific missions since 2012** until now (depending on how you count);
9 campaigns out of Oberpfaffenhofen, 7 out of airports abroad; 5 continents overflown

Scientific HALO missions 2010-2016

Year (of mission start)	HALO-Mission	Time period		Included projects	Mission partners: HALO consortium partners without DFG						Mission partners: DFG funded university institutions												Science topic				
					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	A: Aerosols, Clouds and Precipitation	B: Transport and Dynamics in the troposphere & UT/LS	C: Transport and Transformation of Chemical Composition	D: Geodesy and Geophysics	E: Technical / Engineering
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

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

DFG 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 Helmholtz Centre 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

HALO operator

Betreiber
DLR

Koordinator
Betreiber

Katrin Witte, DLR-FX

HALO consortium

Kuratorium

Finanz-
ausschuss

Koordinator
Nutzer

Wissenschaftlicher
Lenkungsausschuss

WLA-Vorsitzender:
Markus Rapp, DLR-IPA

Jörg Schmidt, Univ. Leipzig

Konsortium

Betreiber

*Projekt-
management*

Mission 1

Projektleitung M-PI

AG 1 | AG 2 | AG ..

Mission 2

Projektleitung M-PI

AG 1 | AG 2 | AG ..

Mission 3

Projektleitung M-PI

AG 1 | AG 2 | AG ..

M-PI = Mission Principal Investigator

How HALO is funded

Purchase project completed
2004-2011

Purchase of the aircraft
Conversion
Tests & flight tests

Bundesministerium für Bildung und Forschung
HELMHOLTZ GEMEINSCHAFT
DLR
JÜLICH FORSCHUNGSZENTRUM
KIT Karlsruher Institut für Technologie
MAX-PLANCK-GESELLSCHAFT

ca. 70 Mio. Euro

HALO running costs

Standby costs

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

Funded by
the **HALO consortium:**

DFG Deutsche Forschungsgemeinschaft
MAX-PLANCK-GESELLSCHAFT
DLR
JÜLICH FORSCHUNGSZENTRUM
KIT Karlsruher Institut für Technologie
TROPOS Leibniz Institute for Tropospheric Research
GFZ Helmholtz Centre Potsdam

ca. 3.8 Mio. Euro/Year

Missions (HALO campaigns)

preparation, certifcation, 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

Idea

Feasibility check

- Technical feasibility?
- Operational feasibility?
- Timing ok?
- Approval by scientific steering committee (WLA)

Pilot study (operational preparations, certification flight tests, …)

- Specification
- Quotation
- Contract
- Pilot study
- Reporting Invoicing

Mission (flight project)

- Specification
- Cost estimate
- Iteration & solving funding
- final quotation
- Contract
- Campaign preparation
- Campaign
- Reporting Invoicing

change request → Anpassungen inhaltl./admin.

Customer responsibility

DLR-FX responsibility
*(**Project Management**)*

Contract work by FX

Managing a HALO project

Feasibility check

Technical feasibility? → Operational feasibility? → Timing ok? → Approval by scientific steering committee (WLA)

Pilot study (operational preparations, certification flight tests, …)

Specification → Quotation → Contract → Pilot study → Reporting Invoicing

Mission (flight project)

Specific… → Cost estimate → Iteration & solving funding → final quotation → Contract → Campaign preparation → Campaign → Reporting Invoicing

change request → Anpassungen inhaltl./admin.

Time scale 2-3 years

Customer responsibility

DLR-FX responsibility (***Project Management***)

Contract work by FX

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

Scientific payoad 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

See the posters today!

- ***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**.

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 payoad for HALO: Currently approx. 60 certified modifications

(requiring about 20 additional certifications for instrument provisions)

Belly pod instruments instruments

- HAMP
- GLORIA
- BP-Instr.-Prov. GLORIA
- BP-Fenster
- Belly Pod & Ventral Fin

Sample air Inlets

- CVI
- DUALER
- HAI
- HASI
- LIF-OH
- TGI
- TGI-Varianten

PMS wing station instruments

- CAS-DPOL
- CCP
- MTP
- NIXE-CAPS
- PCASP-100X
- PHIPS-HALO
- PIP
- SID3
- UHSAS-A
- NCAR PMS carrier
- PRU

Cabin-mounted remote sensing instrum.

- CHARM-F
- Dropsonde DS
- EAGLE-HAWK
- KITsonde
- miniDOAS
- SMART
- specMACS
- SR
- WALES
- Fenster für Viewports
- H2O-DIAL-Kühlflansch
- LIF-OH-Peripherie
- Nose-Boom
- Trailing cone

Cabin-mounted in situ instruments

- AIMS
- AirLIF
- ALABAMA
- AMETYST
- AMTEX_TDS
- BAHAMAS-Base
- CCN
- CPC
- C-ToF-AMS
- CVI-Rack
- FAIRO
- FINCH
- FISH
- GFR
- GhOST
- HAGAR
- HAI
- HORUS
- IPA-NOY
- ISOWAT
- JIG
- KMS
- MGC
- MIRAH
- PAN-MS
- PERCEAS
- SNOOPY
- SVP
- TRIHOP
- Abgassammelleitung
- BAHAMAS-Bits
- BAHAMAS-Boom
- BAHAMAS-Box
- Drop-Sonden-Dispenser
- FTI
- GSB
- PR
- RPDB

Current planning, conclusions & outlook

HALO calendar 2015-2018

2015

Month	Jan				Feb					Mar				Apr				May				Jun				Jul				Aug					Sep				Oct					Nov				Dec			
Calendar week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
Monday date	Dec 29	Jan 5	Jan 12	Jan 19	Jan 26	Feb 2	Feb 9	Feb 16	Feb 23	Mar 2	Mar 9	Mar 16	Mar 23	Mar 30	Apr 6	Apr 13	Apr 20	Apr 27	May 4	May 11	May 18	May 25	Jun 1	Jun 8	Jun 15	Jun 22	Jun 29	Jul 6	Jul 13	Jul 20	Jul 27	Aug 3	Aug 10	Aug 17	Aug 24	Aug 31	Sep 7	Sep 14	Sep 21	Sep 28	Oct 5	Oct 12	Oct 19	Oct 26	Nov 2	Nov 9	Nov 16	Nov 23	Nov 30	Dec 7	Dec 14	Dec 21
Mission	OMO-EU					POLSTR.	Flight tests GLORIA certification							Flight tests POLSTR.				CHARM-F				OMO-Asia													maintenance check flights								POLSTRACC/...							
				OP								OP						OP													Paphos, Gan																OP			

2016

Month	Jan				Feb					Mar				Apr				May				Jun				Jul				Aug					Sep				Oct					Nov				Dec			
Calendar week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
Monday date	Jan 4	Jan 11	Jan 18	Jan 25	Feb 1	Feb 8	Feb 15	Feb 22	Feb 29	Mar 7	Mar 14	Mar 21	Mar 28	Apr 4	Apr 11	Apr 18	Apr 25	May 2	May 9	May 16	May 23	May 30	Jun 6	Jun 13	Jun 20	Jun 27	Jul 4	Jul 11	Jul 18	Jul 25	Aug 1	Aug 8	Aug 15	Aug 22	Aug 29	Sep 5	Sep 12	Sep 19	Sep 26	Oct 3	Oct 10	Oct 17	Oct 24	Oct 31	Nov 7	Nov 14	Nov 21	Nov 28	Dec 5	Dec 12	Dec 19	Dec 26
Mission	POLSTRACC/GW-LCYCLE/SALSA													iLOADS				maintenance, check flights								NARVAL 2										NAWDEX					flight tests ext. config. EMeRGe	fit check EMeRGe	check flights	internal flights		KITsonde flight test			
	12.01.-13.03., Kiruna; 14.-21.03., Oberpfaffenhofen													OP																8.-31.08., Barbados					15.09.-18.10., Keflavik					OP					OP			

2017

Month	Jan					Feb				Mar				Apr				May					Jun				Jul					Aug				Sep				Oct					Nov				Dec			
Calendar week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
Monday date	Jan 2	Jan 9	Jan 16	Jan 23	Jan 30	Feb 6	Feb 13	Feb 20	Feb 27	Mar 6	Mar 13	Mar 20	Mar 27	Apr 3	Apr 10	Apr 17	Apr 24	May 1	May 8	May 15	May 22	May 29	Jun 5	Jun 12	Jun 19	Jun 26	Jul 3	Jul 10	Jul 17	Jul 24	Jul 31	Aug 7	Aug 14	Aug 21	Aug 28	Sep 4	Sep 11	Sep 18	Sep 25	Oct 2	Oct 9	Oct 16	Oct 23	Oct 30	Nov 6	Nov 13	Nov 20	Nov 27	Dec 4	Dec 11	Dec 18	Dec 25
Mission		maintenance, check flights							flight tests ext. config. CAFE	COMET								EMeRGe-EU									WISE														check flights	fit check CAFE	fit check AMTHAL	ANTHALO-BI								
									OP					OP													OP										Shannon or Prestwick										OP, Troll			

2018

Month	Jan					Feb				Mar				Apr					May				Jun				Jul					Aug				Sep				Oct					Nov				Dec			
Calendar week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
Monday date	Jan 1	Jan 8	Jan 15	Jan 22	Jan 29	Feb 5	Feb 12	Feb 19	Feb 26	Mar 5	Mar 12	Mar 19	Mar 26	Apr 2	Apr 9	Apr 16	Apr 23	Apr 30	May 7	May 14	May 21	May 28	Jun 4	Jun 11	Jun 18	Jun 25	Jul 2	Jul 9	Jul 16	Jul 23	Jul 30	Aug 6	Aug 13	Aug 20	Aug 27	Sep 3	Sep 10	Sep 17	Sep 24	Oct 1	Oct 8	Oct 15	Oct 22	Oct 29	Nov 5	Nov 12	Nov 19	Nov 26	Dec 3	Dec 10	Dec 17	Dec 24
Mission			maintenance, check flights							EMeRGe-Asia																	CAFE												check flights															
														tbd																	tbd																					

Fit check (on ground)

Science mission

Planned (science) mission, to be confirmed

Maintenance, check flights, etc.

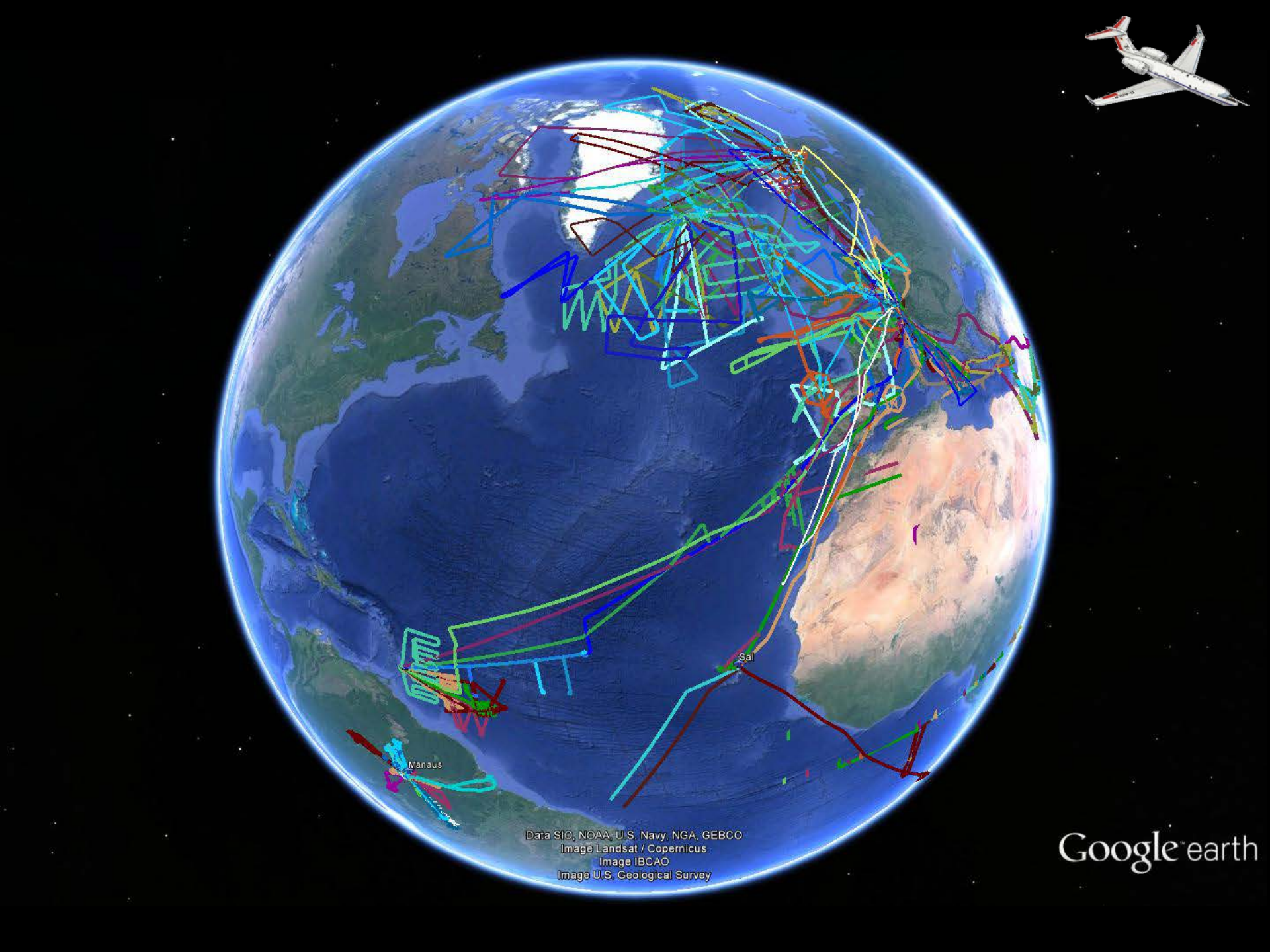
Mission flight period

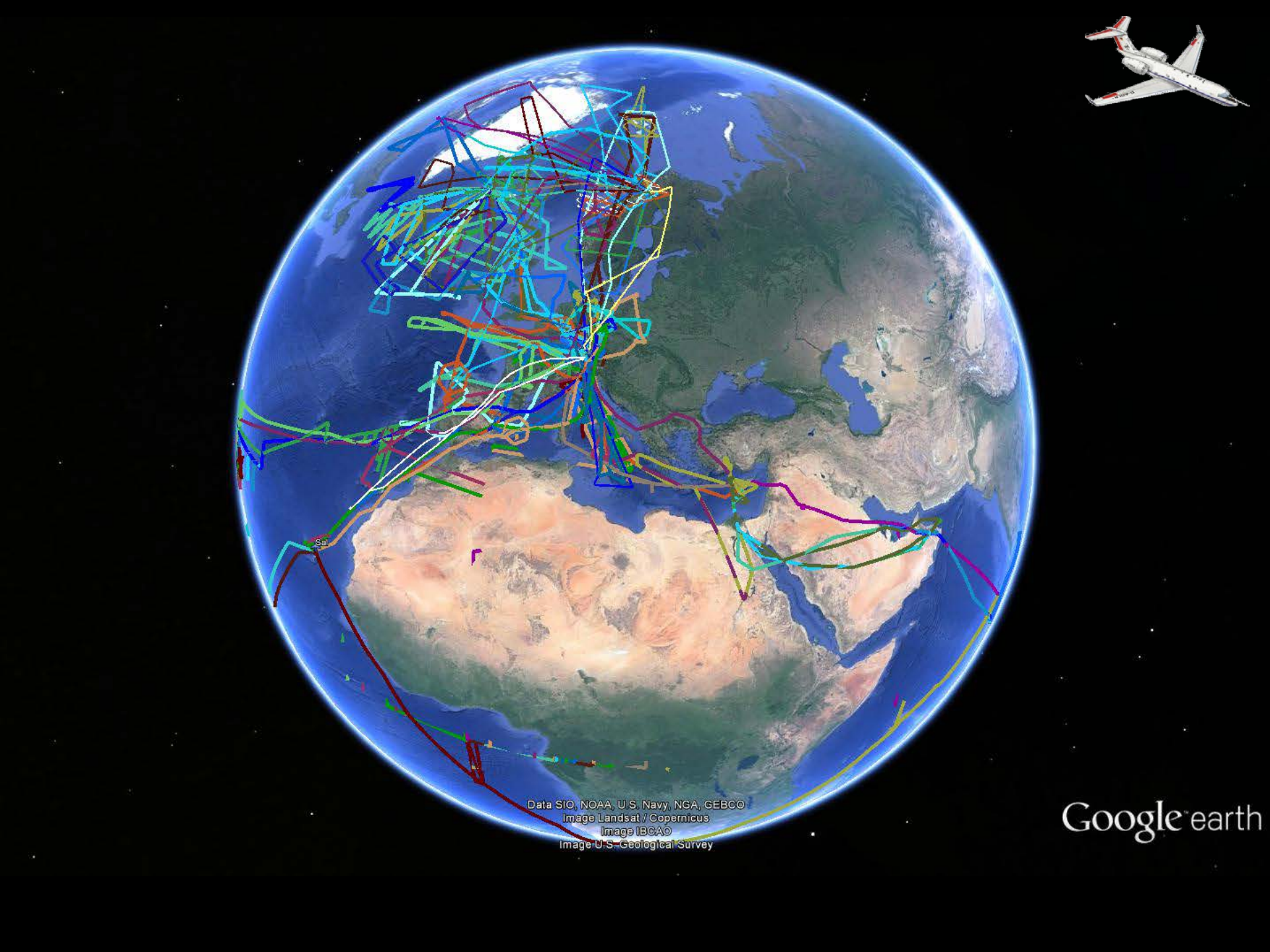
Mission on ground (e.g. for instrument integration)

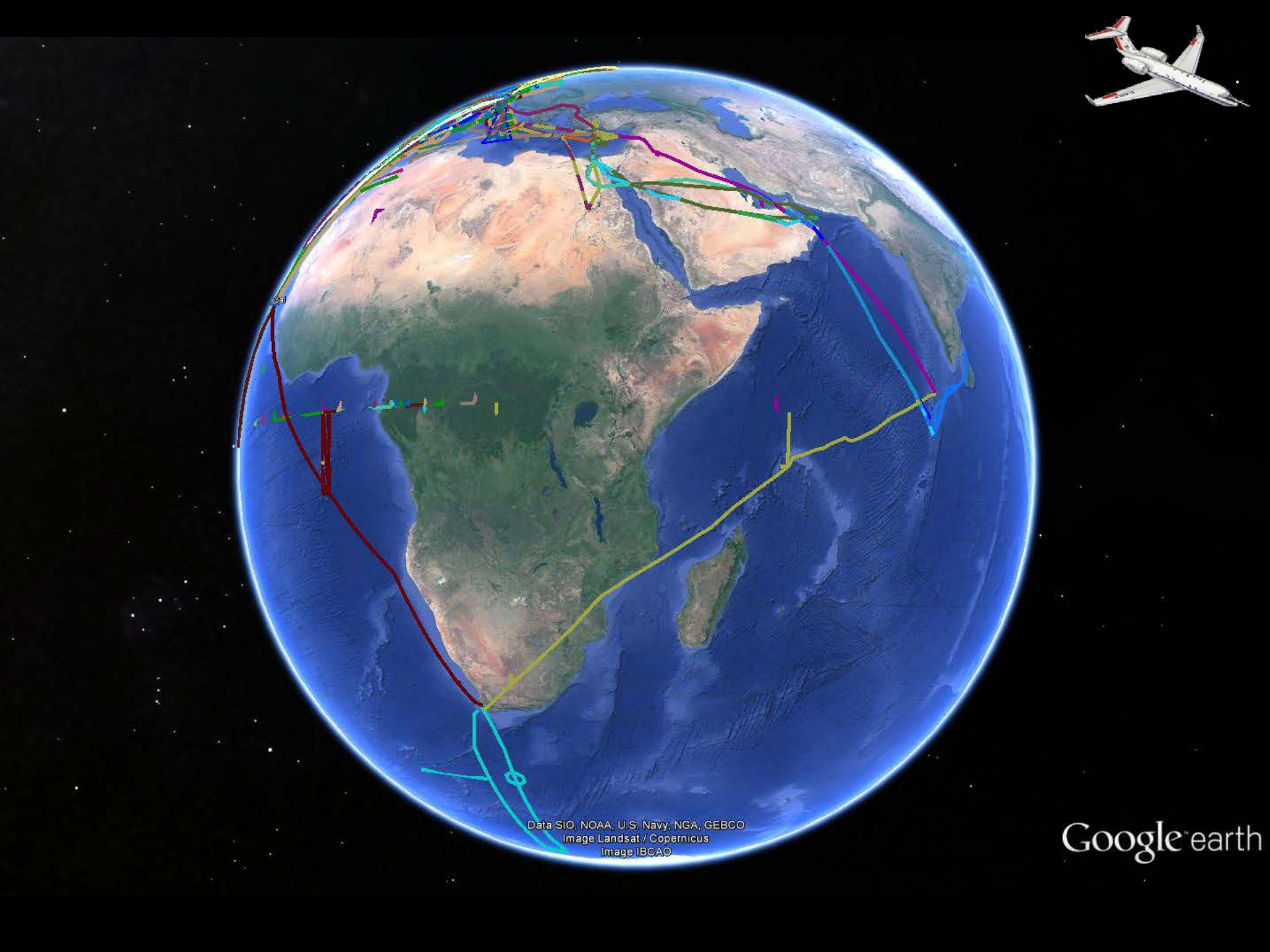
OP Oberpfaffenhofen

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


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


Sal
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

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