Implementation Plan

2023

IAGOS

IN-SERVICE AIRCRAFT FOR A GLOBAL OBSERVING SYSTEM

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Contents

Members of IAGOS-AISBL

Acronym	Member	Country
FZJ	Forschungszentrum Jülich GmbH	Germany
CNRS	Centre National de la Recherche Scientifique	France
MPG	Max-Planck Gesellschaft zur Förderung der Wissenschaften e.V.	Germany
MF	Météo France	France
UMAN	University of Manchester	U.K.
DLR	Deutsches Zentrum für Luft- und Raumfahrt e.V.	Germany
TROPOS	Leibniz-Institut für Troposphärenforschung e.V.	Germany
KIT	Karlsruher Institut für Technologie	Germany

Note: MPG is contributing to IAGOS with two of its institutes:
MPI-C: Max-Planck Institute for Chemistry, Mainz
MPI-BGC Max-Planck Institute for Biogeochemistry, Jena

Technical Set-up

IAGOS combines the expertise of two successful European research projects, MOZAIC and CARIBIC. The complementary methodology developed in these projects is continued in IAGOS in order to fully exploit the advantages of both approaches. As detailed below, IAGOS-CORE provides continuous data of key constituents with quasi global coverage from many aircraft, whereas IAGOS-CARIBIC provides additional information for a deeper scientific understanding from one aircraft.

IAGOS-CORE

The ultimate goal of IAGOS is to equip 15 long-range aircraft of internationally operating airlines with IAGOS-CORE equipment for continuous deployment. In order to reach this goal, several conditions must be fulfilled:

1. Aeronautic Certification of the IAGOS equipment for installation aboard commercial long-range aircraft (Supplemental Type Certificate, STC)
2. Acquisition of the necessary equipment with EASA Form 1
3. Cooperation contracts with suitable airlines
4. Cooperation contracts with aeronautic companies for continued airworthiness
5. Logistics for maintenance and quality assurance.

For each aircraft modification, the following components are required (see Fig. 1):

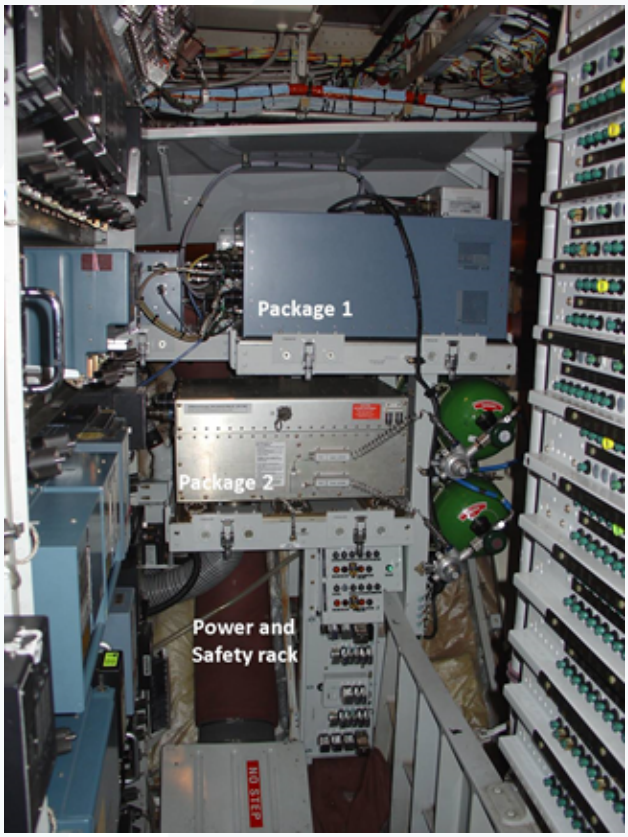

Fig. 1: IAGOS-CORE rack with instruments (P1, H2O, BCP and P2a) installed in an Airbus A340-300 operated by Lufthansa (left) and outside view of the IAGOS-CORE Inlet Plate (top).

Technical Set-up

1. IAGOS-CORE modification kit, comprising the mechanical, electrical and safety provisions for installation of the instruments and a special inlet plate with the probes for connecting the different instruments to ambient air.
2. Engineering support by the airline's maintenance department and by the design organisation in charge of the IAGOS STC.
3. Scientific instruments:
   I. Package 1 (denoted P1), which contains the central data acquisition and transmission as well as the instruments for measuring ozone (O_3) and carbon monoxide (CO).
   II. Water vapour sensor (H_2O)
   III. Backscatter Cloud Probe (BCP)
   IV. Package 2 in one of four possible options:
      a. Instrument for the measurement of nitrogen oxides denoted NOx (P2b)
      b. Instrument for the measurement of aerosol number density (P2c)
      c. Instrument for the measurement of greenhouse gases, i.e. CO_2, CH_4, CO and H_2O (P2d)
      d. Instrument for the measurement of aerosol extinction and NO_2 (P2e, under certification)
   V. Unit for data transmission in real real-time via a satellite link to the WMO Information system (RTTU). Deployment has been limited to one aircraft and has been operational for a limited period of time. Real-time transmission technologies are being investigated.

Each instrument must be approved for installation on commercial aircraft by Supplemental Type Certificate and must be manufactured by a company with EASA Part 21 approval. For maintenance of the equipment, companies with EASA Part 145 approval are required.

The EASA-STC for installation of the IAGOS-CORE rack with P1, H_2O, and BCP was obtained in 2011 for A340 aircraft and in 2013 for A330 aircraft. The EASA-STC has been approved by the authorities of Taiwan, Hong Kong and USA.

The installation of P2b was certified in 2011 for Deutsche Lufthansa A340 MSN304 only. The EASA-STC for installation of P2d obtained in December 2016 for all aircraft equipped with the IAGOS-CORE system. The first P2d unit was installed and activated in September 2018 Deutsche Lufthansa D-AIKO.

A revised P2d STC was issued by EASA in December 2021, to allow minor modifications on P2d serial numbers SN003 and above.

The P2b STC was issued by EASA in January 2022 using HelOx bottles in place of oxygen bottles.

The EASA-STC for the P2e is in progress and expected soon.

All instruments have been successfully operated on different research aircraft during scientific campaigns.

IAGOS has established a Technical Planning Group (TPG) for the coordination of aircraft installations, and the development of the future fleet and future equipment, and a Technical Operations Group (TOG) for instrument operations, certification issues and maintenance of the equipment. The TOG oversees the IAGOS Maintenance Centre lead by Enviscope.

IAGOS-CARIBIC

The Lufthansa aircraft A340-600 "Leverkusen" (D-AIHE) that carried the CARIBIC Container-Laboratory since 2005 was retired in April 2020 due to the COVID-19 pandemic. After an intense planning phase the Lufthansa Group's most fuel-efficient long-haul aircraft A350-900 named "Erfurt" (D-AIXJ) could be identified to house the next generation of IAGOS-CARIBIC – a new Container-Lab with an updated payload. The changeover to the A350 D-AIXJ is divided into three steps:

1. Modification of the A350 to operate the Container-Lab and to attach the air intake.
2. Installation of air intake
3. Installation of Container-Lab

The first of three steps of the modifications of the A350 "Erfurt" has been carried out successfully despite the critical COVID-19 situation in Malta in March 2021 and in Munich in November 2021.

The new IAGOS-CARIBIC system (see Fig 2) will include 20 state-of-the art instruments for in-situ measurements and for collecting whole air samples. The samples are analysed in different European laboratories, e.g. halogenated compounds (CFCs, HCFCs etc.) and organic compounds (done by the MPI-C, Mainz, and GUF, Frankfurt). The A350 "Erfurt" will carry a new multi-inlet air intake system (see Fig. 2), which is connected to the instruments inside the laboratory.

The new CARIBIC laboratory will still be operated discontinuously for about 500 flight hours per year, but the number of consecutive flights per sequence should be extended from 4 to 8. IAGOS-CARIBIC is operated and coordinated by KIT (Germany) with further 11 partners 3 from Europe (11) and the US (1).

The instruments deployed in the new CARIBIC Container-Lab are or will be designed for in-situ measurements of ozone, water vapour, cloud water/ice, carbon monoxide, carbon dioxide, methane, ethane, water isotopologues, nitrogen oxides, sulphur dioxide, hydrogen cyanide, volatile organic compounds, and aerosol particle properties, including number concentration, size, elemental composition, soot, and biogenic particles. In addition, a slot for IAGOS-CORE two Package-2 instruments will be provided. The whole air samples will be analysed (after flight) using different gas chromatographic systems for a large suite of organic compounds and fluorocarbons. The aerosol particle filter samples will be analysed (after flight) in the laboratory for ice nucleating particles (INP).

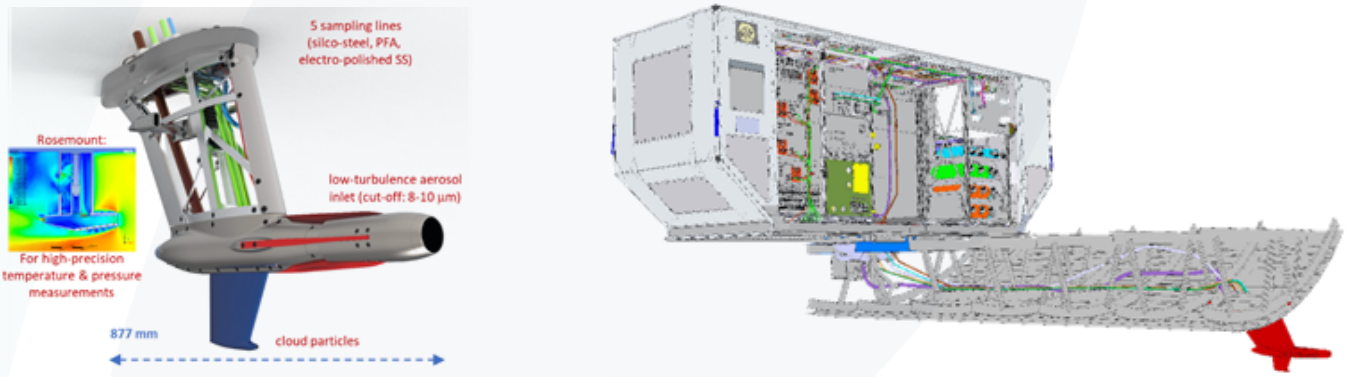

Fig. 2: CAD drawing of the new air intake system additionally equipped with a modified Rosemount (left) and of the new IAGOS-CARBIC system on the AIRBUS A350-900 "Erfurt" (right).

The CARIBIC laboratory was deployed on an A340-600 until March 2020, when the COVID-19 pandemic led to an untimely phase-out of the CARIBIC Airbus. The planning for the changeover to an Airbus A350 began in 2018, with many new features and new instruments, see next chapter.

Planning

IAGOS-CORE

Figure 3 gives an overview of the planning for aircraft installations (black bars) and the aquisition of the necessary hardware by the Members of IAGOS AISBL.

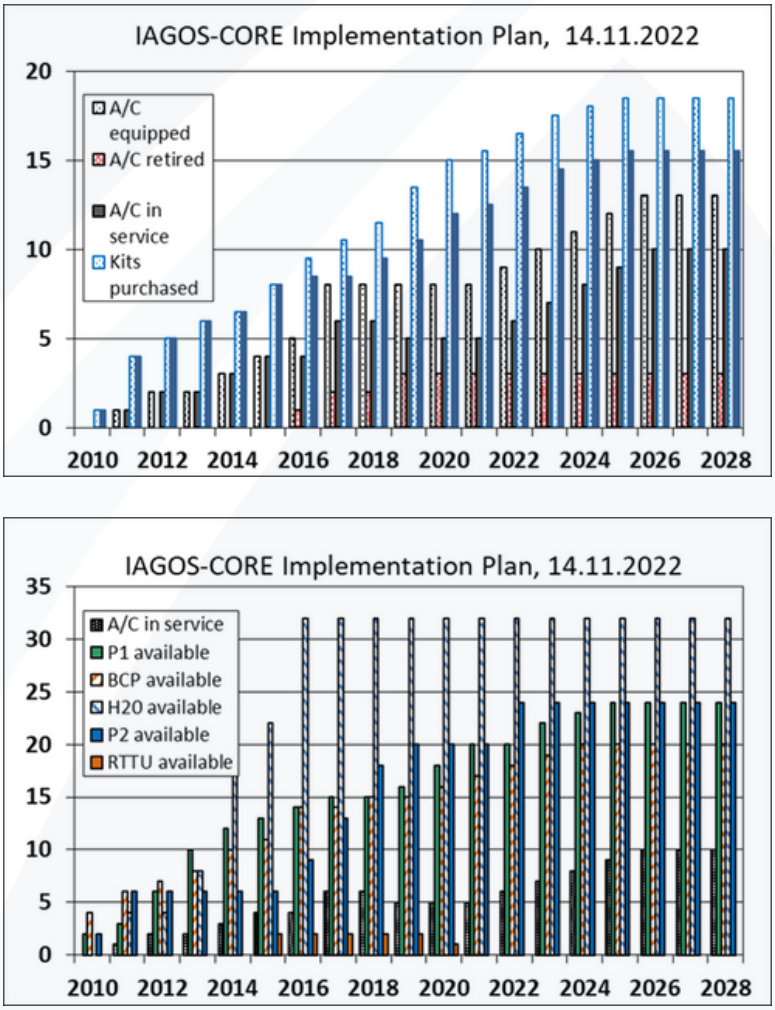

Fig.3: Planning of aircraft installations and acquisition of hardware for IAGOS-CORE.

The detailed planning, including the responsible Members, is listed in Table 1. The planning is annually revised and depends to some extent on the availability of financial resources, which are granted on an annual basis for the Members CNRS, MF and UMAN. Detailed planning also depends on the availability of suitable aircraft for integration. In order to avoid interference with airline operations, integration is usually done during a scheduled layover (C- or D-check) of the aircraft.

For the year 2023, one new installation of IAGOS-CORE equipment was foreseen on Air Canada. Preparations for one more installation have been launched.

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
Aircraft installations	0	1	1	0	1	1	1	3	0	0	0	0	1	1	1					13
FZJ		0,5		1		1	1	1												5,5
CNRS				1				2						1	1	1	1			7
NCU			1																	1
co-funding by EC		0,5		1																1,5
IAGOS Kits total	1	3	1	1	0,5	1,5	1,5	1	1	2	1,5	0,5	1	1	0,5	0,5	0	0	0	18,5
FZJ		2		1	0,5	0,5	0,5	1	1	2	1,5	0,5	0,5							10,5
CNRS		1				1	1							1	0,5	0,5				6
co-funding by EC	1		1																	2
Package 1 total	2	1	3	4	2	1	1	1	0	1	2	2	0	2	1	1	0	0	0	24
P1 by CNRS		1	3	4	2	1	1	1		1	2	2		2	1	1				22
co-funding by EC	2																			2
H2O total	0	4	0	4	9	5	10	0	0	0	0	0	0	0	0	0	0	0	0	32
H2O by FZJ		4		4	9	5	10													32
BCP Total	4	2	1	1	2	1	3	0	1	0	1	1	1	1	1	0	0	0	0	20
BCP by CNRS					1															1
BCP by FZJ	1	2			1		3													7
BCP by UMAN	3		1	1		1			1			1	1	1	1					12
Package 2 total	2	4	0	0	0	0	3	4	5	2	0	0	4	0	0	0	0	0	0	24
P2a/b by FZJ	2	2					2	2	1											9
P2c by FZJ		1					1	2												4
P2d by MPG		1							3	2										6
P2e by FZJ									1			4	4							5
RTTU	0	0	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	4
MeteoFrance						1														1
co-funding by EC						1														1

Table 1: Planning for aircraft installations and acquisition of hardware by the different Membres involved in IAGOS-CORE, based upon current resources estimates. Numbers in black according to long-term estimation.

IAGOS-CARIBIC

Due to the COVID-19 pandemic, the A340-600 was phased-out. Since 2018, we have been working on a changeover to a Lufthansa A350-900, including the construction of a new air inlet system (that allows the sampling of larger aerosol particles) and of a new container laboratory with new infrastructure (power supply, safety installations, ARINC and communication systems) and new instruments. The certification process at the EASA officially started in July 2020 and the first part of the technical modification of the A350-900 took place in Malta March 2021 and Munich in November 2021. Our challenging ambitious objective is to have the first measurement flights in January 2023.

Implementation Plan for IAGOS-CARIBIC													
Last Revision:	**15/11/2022**												
	Year	**≤2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
Infrastructure	**Member**												
Container upgrade	KIT	1			1					-1			
Container new	KIT										1		
Inlet exchange	KIT	1									1		
A/C changeover	KIT										1		
Instrumentation													
O3	KIT	1									a		
H2Otot	KIT	1									a		
H2Ogas	KIT	1									a		
OFCEAS (H2O isotopes)	KIT / Uni Grenoble	1			-1						(1)		
PTRMS (VOCs)	KIT	1			i						(a)		
UMAQS (N2O, C2H6, CO)	KIT / Uni Mainz										(1)		
CO	MPI-C	1									a		
HIRES (Sampler)	MPI-C	1									a		
NMHC GC-system	MPI-C	1	1										
SP2 (soot photometer)	MPI-C	1									a		
WIBS (bioaerosol)	MPI-C				1						a		
AMS (aerosol composition)	MPI-C / TROPOS				1						a		
PNC (aerosol number)	TROPOS	1							-1			1	
OPSS-1 (aerosol size)	TROPOS	1										a	
HERA4CARIBIC (INP sampler)	TROPOS											1	
NOx/NOy	DLR	1									a		
Slot for CORE P2 (no 1)	FZJ				1						a		
Slot for CORE P2 (no 2)	FZJ										1		
FUNMASS (SO2, HCN, acids,...)	FZJ										1		
PICARRO (CH4/CO2)	MPI-BGC				1						a		
CARDINO (N2O5, NO3, NO2, O3)	Cork / NOAA / KIT				1						a		
Removed instrumentation													
CH4	KIT	1			-1								
CO2	MPI-C	1			-1								
Hg	MPI-C	1			-1								
HCs	Uni UEA	1			-1								
TRAC (Sampler)	MPI-C	1								-1			
DOAS (SO2, CH2O, ...)	Uni HD	1			i					-1			
Aerosol sampler	Uni Lund	1								-1			
Notes:	1: implemented												
	-1: removed												
	(1): tentative												
	i: improved												
	a: adapted												

Table 2: Planning schedule for IAGOS-CARIBIC

Version	Published	EB approval	GA approval	Remarks
final	24.05.2023	15.11.2022	15.11.2022	

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