



Final Project Report

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Task contributors

[[Honeywel](#)]

Abstract

[The 09.19 project aimed at connecting aircraft to the System Wide Information Management (SWIM) network to support SWIM operational aspects. The project defined generic means of information exchange between aircraft systems and the ground SWIM segment using Internet Protocol (IP) based technologies and networks. The proposed generic architecture was then refined into aircraft concept and airborne system architecture for both mainline and regional aircraft, implemented with two prototypes and verified using these prototypes.]

Authoring & Approval

Prepared By - Authors of the document.		
Name & Company	Position & Title	Date
[REDACTED] Honeywell	[REDACTED]	21/09/2016

Reviewed By - Reviewers internal to the project.		
Name & Company	Position & Title	Date
[REDACTED] Airbus	[REDACTED]	13/07/2016
[REDACTED] Finmeccanica		13/07/2016
[REDACTED] Thales Avionics		06/07/2016
[REDACTED] Honeywell		10/08/2016
[REDACTED] Honeywell		10/08/2016
[REDACTED] Honeywell		10/08/2016
[REDACTED] Honeywell		28/07/2016

Reviewed By - Other SESAR projects, Airspace Users, staff association, military, Industrial Support, other organisations.		
Name & Company	Position & Title	Date
Available for review to:		
[REDACTED] Eurocontrol	[REDACTED]	31/08/2016
[REDACTED] Eurocontrol		05/09/2016
[REDACTED] Airbus		11/08/2016
[REDACTED] Finmeccanica		11/08/2016
[REDACTED] Eurocontrol		05/09/2016
[REDACTED] Indra		11/08/2016

Approved for submission to the SJU By - Representatives of the company involved in the project.		
Name & Company	Position & Title	Date
[REDACTED] Airbus	[REDACTED]	23/09/2016
[REDACTED] Finmeccanica		22/09/2016
[REDACTED] Thales Avionics		22/09/2016
[REDACTED] Honeywell		21/09/2016

Rejected By - Representatives of the company involved in the project.		
Name & Company	Position & Title	Date
None.		

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Intellectual Property Rights (foreground)

This deliverable consists of SJU foreground.

Acronyms

Acronym	Definition
ACSP	Air Communication Service Provider
AGDLGMS	Air-Ground Datalink Ground Management System
AIS	Aeronautical Information Service
AMQP	Advanced Message Queuing Protocol
ATM	Air Traffic Management
COTS	Commercial Off-The-Shelf
EFB	Electronic Flight Bag
FOC	Flight Operations Centre
GBCS	Ground Broker Configuration Service
IP	Internet Protocol
ISRM	Information Service Reference Model
JMS	Java Messaging Service
MET	Meteorological
METAR	Meteorological Aviation Report (Meteorological Aerodrome Report)
MQSP	Message Queuing Service Provider
PKI	Public Key Infrastructure
POSRPT	Position Report
SESAR	Single European Sky ATM Research
SJU	SESAR Joint Undertaking
SWIM	System Wide Information Management
SWIM-TI	SWIM Technical Infrastructure
TRL	Technology Readiness Level
WISP	Wide Information Service Provider
WS	Web Services

1 Project Overview

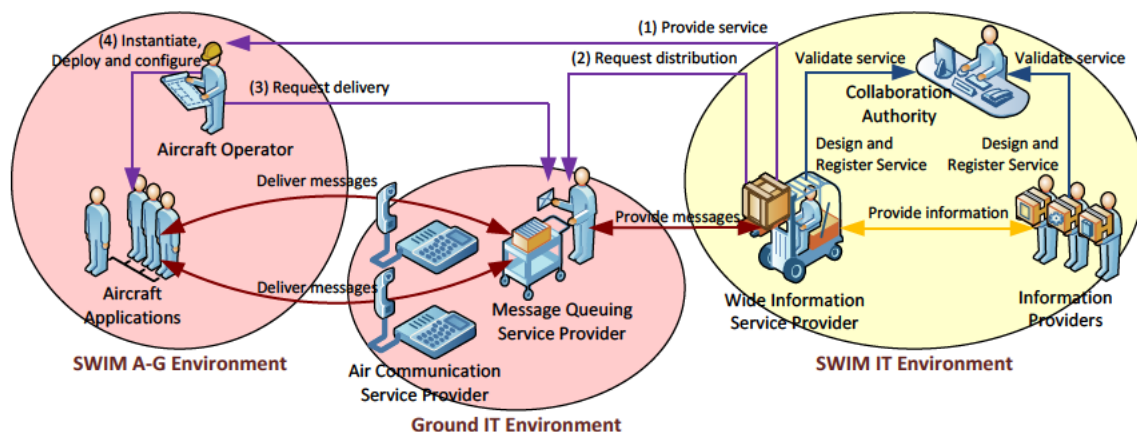
The project aimed at connecting aircraft to the SWIM network to support SWIM operational aspects. The project developed generic means of information exchange between aircraft systems and the ground SWIM segment.

1.1 Project progress and contribution to the Master Plan

The project execution followed a two phase iterative approach. Each phase started with generic considerations on specific aspects of the Air-Ground SWIM concept and architecture, which were then refined into aircraft concept and airborne system architecture specific for mainline and regional aircraft. The proposed solution was implemented with two prototypes, devoted to the mainline and regional aircraft architectures, and each phase culminated with verification activities, where meeting the project objectives was verified using the two prototypes.

The first phase was dedicated to defining the technological basis for the Air-Ground SWIM, more specifically for information sharing between aircraft systems and ground Air Traffic Management (ATM) systems. Through detailed analysis of available messaging options, the Advanced Message Queuing Protocol (AMQP) version 0-9-1 was selected as the best candidate technology. The selection was then successfully evaluated both from functional and performance perspectives and adopted by SESAR for the SWIM Technical Infrastructure (SWIM-TI) Purple Profile Technical Specification [26].

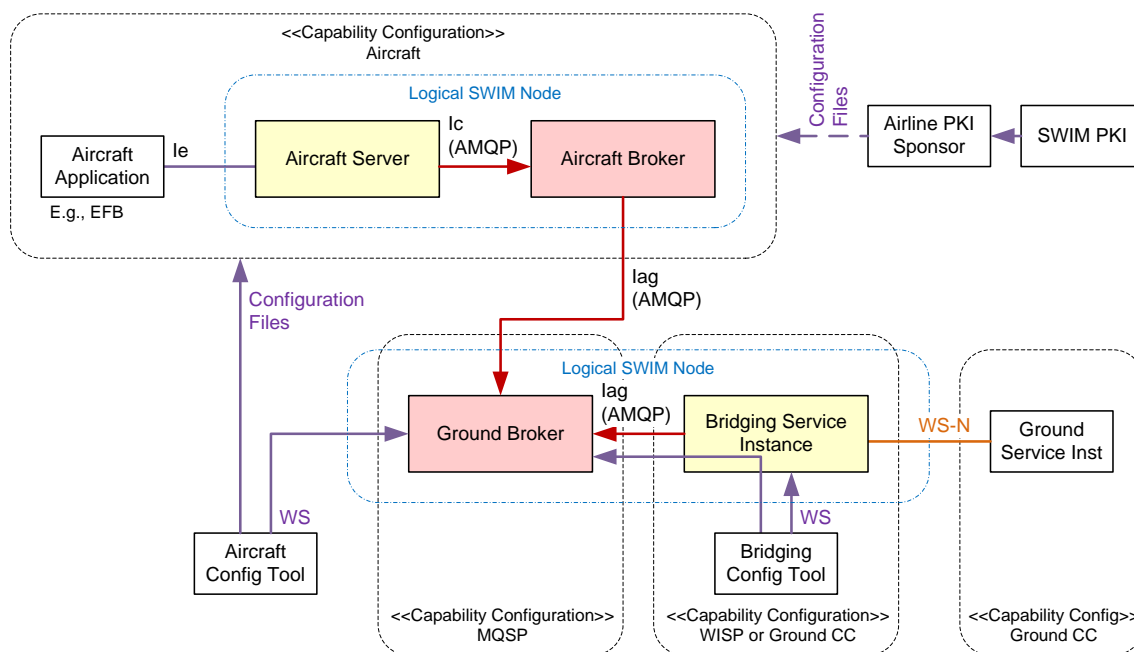
Further project advancements were driven by the Air-Ground SWIM Concept of Operations [24], introduced by the project at the beginning of the second phase. The Air-Ground SWIM Concept of Operations [24] complements the general SWIM Concept of Operations [25], formulated earlier in SESAR, by identifying the actors involved specifically in the Air-Ground SWIM, capabilities these actors operate and their interactions (see the figure below).



Air-Ground SWIM actor interactions (Ground Publishing – Aircraft Subscribing) [24]

Thus, the second project phase refined the SWIM-TI Purple Profile concept for AIS/MET operations, proposed an initial deployment method and targeted the Air-Ground SWIM interoperability verification.

Both project phases concluded with successful verification exercises. To verify the proposed solution, the project developed two iterative prototype branches, dedicated to mainline and regional aircraft architectures, allowing an on-board logical SWIM node, composed of the messaging broker and the information server interfacing with aircraft systems. Both prototypes also include a tool for automated aircraft configuration.

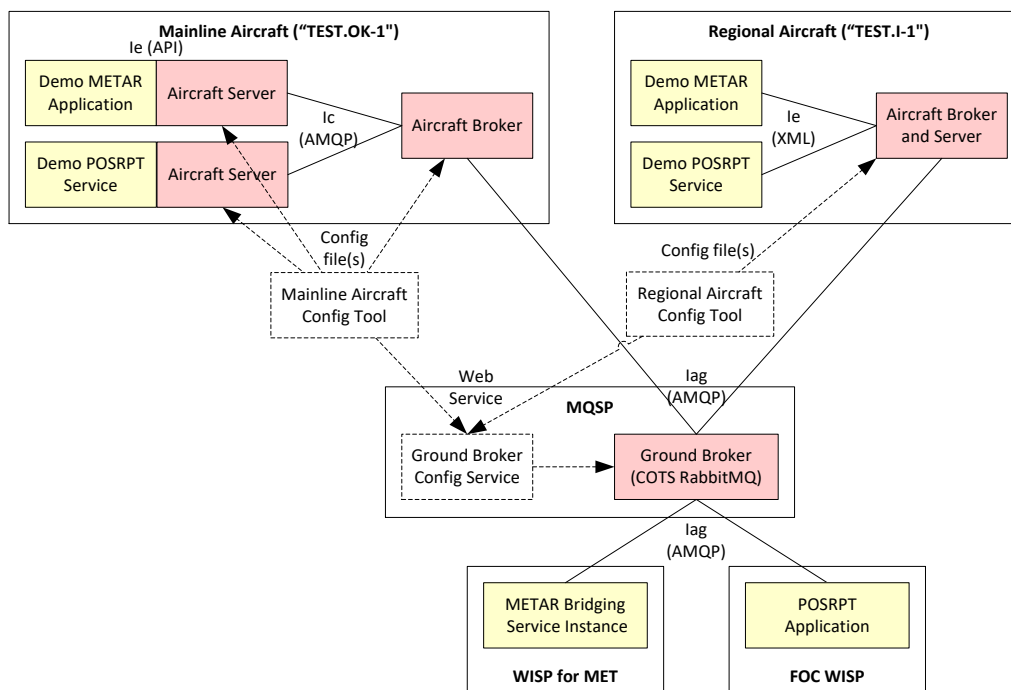


Architecture of the Air-Ground SWIM messaging functions [17]

Besides the actual aircraft prototypes, the project also developed stubs and tools emulating the complete Air-Ground SWIM information environment (see the Air-Ground SWIM actors in the figure on the previous page), including:

- Air Communication Service Provider (ACSP);
- Message Queuing Service Provider (MQSP);
- Wide Information Service Provider (WISP).

Verification activities were performed over three test benches representing the information management environment of regional and mainline aircraft. The benches were located in Honeywell (Brno, CZ), Thales Avionics (Toulouse, FR) and Finmeccanica (Torino, IT) premises.



System architecture of the verification environment [17]

The project has contributed to the following ATM Master Plan system enablers [4]:

Code	Name	Project contribution	Maturity at project start	Maturity at project end
AGSWIM-38	SWIM enabled services for AGDLGMS	The project contributed to information exchanges between ground and air systems by defining an Air-Ground SWIM concept and prototyping a possible preliminary deployment method.	None	TRL 3
A/C-57	Onboard migration from existing air-ground data link to air-ground SWIM for AIS/MET services	The project contributed by defining two possible implementations dedicated to mainline and regional architectures and proposing a common functional Air-Ground SWIM interface to aircraft end systems.	None	TRL 3
SWIM-INFR-06b	AIR/GROUND SWIM Services infrastructure Support and Connectivity	The project contributed to the Air-Ground SWIM supporting functionalities by defining deployment methods based on a ground-located administrative facility, the Ground Broker Configuration Service (GBCS, [11]), and by prototyping a preliminary deployment method interoperable for mainline and regional architectures over this service.	None	TRL 3

Project contribution to system enablers

1.2 Project achievements

The project defined the Air-Ground SWIM environment and established a technological basis for the Air-Ground SWIM information exchanges. This is documented in project deliverables, namely in the Concept of operations, System architecture specifications, Mainline and Regional architectural specifications and System verification plans.

To verify the proposed solution, the project developed two airborne Air-Ground SWIM prototypes, dedicated to mainline and regional aircraft architectures. The prototypes were deployed to three benches, able to support the demonstration and verification exercises for the Air-Ground SWIM information exchanges. The verification exercises performed with these prototypes resulted in reports, documenting the messaging performance at phase 1 and evaluating initial Air-Ground SWIM deployment at phase 2.

Besides the actual technical work, the project supported also coordination with the US/FAA NextGen SWIM project, with SESAR airspace users and provided inputs to the SWIM-TI Purple Profile specification. To support project results dissemination, the project participated actively in multiple public events, including SWIM Demonstration (2012), ATM World Congress (2013), SWIM Master Class (2013, 2014) and SWIM Global Demonstration (2016).

1.3 Project Deliverables

The following table presents the relevant deliverables that have been produced by the project.

Reference	Title	Description
[D01-002]	Air-Ground Interoperability SWIM	[This whitepaper identifies functions required for interoperability between Air-Ground SWIM and Ground-Ground SWIM protocols and related deployment options. It does not intend to propose architectural choices as well as to describe any particular element of the ground SWIM infrastructure.]
[D02]	High-Level SWIM A-G Architecture and Functional Requirement Specification]	[This deliverable consolidates and analyses Air-Ground SWIM relevant information coming from various SESAR work packages and external projects. It describes airborne assumed initial requirements on the overall concept for Air-Ground SWIM and derives an initial set of functional requirements. This document also provides initial deployment options for Air-Ground SWIM and analyses impacts on airborne communication systems architecture. It identifies possible candidate services for Air-Ground SWIM and provides an extensive overview of systems and technologies that are available to support information management.]
[D03]	High-Level SWIM A-G Architecture and Functional Requirement Specification]	[This document defines functional requirements for information sharing and asynchronous information exchange (air/ground information management) between aircraft and ground-based systems. It will enable the Air-Ground SWIM capability (initially for the AIS/MET services) and will be reusable by airline custom applications. This document summarizes operational and business objectives, describes operational scenarios and airborne/ground environment and then derives the functional requirements.]
[D04]	Air-Ground Data Link Security Context Definition, Risk Assessment and Security Requirements]	[The air-ground information management provides information sharing between aircraft and ground systems and enables the Air-Ground SWIM capability. This document performs assessment of information security risks related to integration of the air/ground information management into aircraft. It performs a high-level risk assessment for the end-to-end information exchanges between aircraft and ground, identifies the most vulnerable areas and supports derivation of high-level security requirements.]
[D05]	Air-Ground Security Context Definition, Risk Assessment and Security Requirements]	[This document performs an assessment of information security risks related to integration of the air/ground information management into aircraft. It updates the high-level risk assessment performed in D04 and identifies an initial set of security controls.]
[D06]	SWIM A-G System Architecture, Functional Specification and Technical Requirement Specification]	[This document provides end-to-end functional specification, describes system architecture and derives aircraft architectures for mainline, regional and business aircraft and general aviation.]

D07	SWIM A-G System Architecture, Functional and Technical Requirement Specification	The Air-Ground SWIM facilitates information sharing between aircraft and ground ATM systems. The air/ground data transport connection is not established directly between information provider and consumer. Instead, the providing and consuming ATM systems exchange information through an Air-Ground SWIM technical infrastructure that consists of aircraft server, ground bridging service and message brokers, routing (storing and forwarding) messages between aircraft and bridging services. This document describes system architecture and requirements, aiming at interoperability between mainline, regional and other aircraft architectures.
D08	SWIM A-G Mainline Aircraft Concept	<p>This document provides a detailed specification of a technical infrastructure for aircraft access to SWIM using enterprise messaging (JMS, AMQP). The concept is designed for mainline aircraft and can be downscaled to other aircraft architectures.</p> <p>This document assumes JMS or AMQP compliant services or SWIM access points and a standard (COTS) AMQP compliant ground broker. It describes components and functions of the aircraft broker and also suggests (optional) extensions to the ground broker that improve performance of the entire solution.</p>
D09	SWIM A-G Mainline Aircraft Concept	This document complements deliverable D08 by addressing integration aspects of the technical infrastructure for Air-Ground SWIM using enterprise messaging. The concept is designed for mainline aircraft and can be downscaled to other aircraft architectures.
D10	SWIM A-G Regional Aircraft Concept	This document describes SWIM airborne components architecture in the scope of regional operations based on examples needed air-to-ground and ground-to-air information publication. From this architecture, design constraints on airborne client applications, architecture of the airborne broker fitted for regional aircrafts and design constraints against ground systems are detailed. Finally, the step1 regional prototype is specified focusing on key and critical requirements that should be evaluated against the picked regional operations.
D11	SWIM A-G Regional Aircraft Concept and Airborne System Architecture - Step 2	This document describes regional aircraft system architecture and requirements, aiming at interoperability between regional aircraft and SWIM technical infrastructures.
D18	SWIM A-G Technical Verification Report for Mainline Aircraft	The goal of this verification activity was to verify the air/ground information management concept, i.e. to assess the Air-Ground SWIM technology in terms of functionality, architecture, security, and data link or hardware performance. We successfully verified that the AMQP protocol is suitable for Air-Ground SWIM and the open AMQP implementation (RabbitMQ) is capable to run in constrained environments similar to avionics hardware. This document also suggests topics for further investigation.

D19	SWIM A-G Technical Verification Report for Mainline Aircraft - version 2	The goal of this verification activity was to verify that the Air-Ground SWIM technology, specifically the functional requirements provided in D07, ensure interoperability among various aircraft implementations through a synchronised static configuration model. This was successfully verified for each of the Air-Ground SWIM operations, identified in the Air-Ground SWIM Concept of Operations (D29).
D20	SWIM A-G Technical Verification Report for Regional Aircraft	This document aims at verifying the air-ground information management concepts developed by the project. Among them, this report aims at verifying the suitability of AMQP protocol for regional Air-Ground SWIM messaging and at giving first performance results. This document proposes possible further investigation for next step of the Regional prototype.
D21	SWIM A-G Technical Verification Report for Regional Aircraft	This document provides the technical Verification report for standalone verification of the air-ground information management concepts developed by the project. The verification activities aim to validate the technical choices made in terms of protocols and architecture of the Air-Ground SWIM system and assess the feasibility of the requirements in D03 and D06 documents.
D22	SWIM A-G Regional Aircraft Prototype Technical Verification Report	This document is the verification report of the Air-Ground SWIM regional aircraft prototype for the second step of the project. The verification has been performed by Thales using Honeywell ground broker and ground application as test environment. This document marks the end of phase 2 prototype verification.
D23	SWIM A-G Regional Aircraft Prototype Technical Verification Report	This document is the verification report of the Air-Ground SWIM regional aircraft prototype for the second step of the project. Finmeccanica integrated its demo aircraft systems with the regional Air-Ground SWIM prototype and verified air-ground information exchanges with the complete regional aircraft prototype.
D29	SWIM A-G Concept of Operations	This document describes the concept of operations for the Air-Ground SWIM capability in SESAR step 2. It identifies actors involved in Air-Ground SWIM, capabilities these actors operate and their interactions. It describes operations during Air-Ground SWIM provisioning and the air-ground information exchanges in both aircraft to ground and ground to aircraft directions.

1.4 Contribution to Standardisation

Standardization of the air-ground SWIM segment is lagging behind the ground-ground SWIM segment. No formal standardization body is currently active in this area, a global consensus on the need of standardization was not reached.

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Avenue de Cortenbergh 100 | B -1000 Bruxelles
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1.5 Project Conclusion and Recommendations

High-level project objectives were met, as it was demonstrated that the prototypes, implementing the proposed functional requirements, can share information with ground WISP(s) using Air-Ground SWIM services.

The AMQP 0-9-1 protocol was selected as the technological basis for the Air-Ground SWIM communication. Although the AMQP specification evolved during the project execution, the project decided to stay with the 0-9-1 version because the later versions diverged significantly from the original scope of the AMQP protocol. The performed verification activities clearly showed that the proposed Air-Ground SWIM architecture together with the selected technology allow effective deployment of AIS/MET services and ensure interoperability among various aircraft implementations. Experiments with real aeronautical data links (Inmarsat SwiftBroadband, Gatelink) confirmed also suitability of the selected technology for these underlying networks.

Thus, this enabling technology clears the way for reaching the potential benefits, including optimization of flight operations through sharing information about weather conditions, activated airspaces, traffic situation etc. The proposed technology may be reused also for asynchronous information exchange between aircraft and aircraft operator ground infrastructure.

Future development of the Air-Ground SWIM concept is envisaged under SESAR 2020, targeting non-safety services in wave 1 and safety services in wave 2. This activity should be focused on increasing the maturity of the prototypes and initiating deployment to validate AIS/MET SWIM services based on the Air-Ground SWIM. This requires also extending the Information Service Reference Model (ISRM) with Air-Ground SWIM-based AIS/MET services and validation of the WISP concept by prototyping a gateway between purple and blue/yellow/green SWIM-TI profiles.

2 References

- [1] SESAR Programme Management Plan, Edition 03.00.01
- [2] [European ATM Master Plan](#)
- [3] Multilateral Framework Agreement (“MFA”) signed between the SJU, EUROCONTROL and its 15 selected members on August 11, 2009, amended on 14 June 2010, 19 October 2010 and 2 July 2012
- [4] [Integrated Roadmap/ATM Master Plan Dataset 15](#)
- [5] P09.19, Air-Ground SWIM Interoperability, 09.19-D01-002, Edition 00.02.00, 25/04/2012
- [6] P09.19, High-Level SWIM A-G Architecture and Functional Requirement Specification, 09.19-D02, Edition 00.02.00, 06/04/2011
- [7] P09.19, High-Level SWIM A-G Architecture and Functional Requirement Specification, 09.19-D03, Edition 00.03.00, 19/12/2012
- [8] P09.19, Air-Ground Data Link Security Context Definition, Risk Assessment and Security Requirements, 09.19-D04, Edition 00.01.00, 10/10/2011
- [9] P09.19, Air-Ground Security Context Definition, Risk Assessment and Security Requirements, 09.19-D05, Edition 00.02.01, 29/04/2014
- [10] P09.19, SWIM A-G System Architecture, Functional Specification and Technical Requirement Specification, 09.19-D06, Edition 00.02.00, 15/12/2011
- [11] P09.19, SWIM A-G System Architecture, Functional and Technical Requirement Specification, 09.19-D07, Edition 00.02.00, 16/06/2015
- [12] P09.19, SWIM A-G Mainline Aircraft Concept, 09.19-D08, Edition 00.02.00, 09/08/2012
- [13] P09.19, SWIM A-G Mainline Aircraft Concept, 09.19-D09, Edition 00.01.02, 01/02/2016
- [14] P09.19, SWIM A-G Regional Aircraft Concept, 09.19-D10, Edition 00.01.00, 14/12/2012
- [15] P09.19, SWIM A-G Regional Aircraft Concept and Airborne System Architecture - Step 2, 09.19-D11, 17/12/2015
- [16] P09.19, SWIM A-G Technical Verification Plan, 09.19-D16, Edition 00.01.00, 16/03/2012
- [17] P09.19, SWIM A-G Technical Verification Plan, 09.19-D17, Edition 00.01.00, 03/07/2015
- [18] P09.19, SWIM A-G Technical Verification Report for Mainline Aircraft, 09.19-D18, Edition 00.01.00, 17/03/2014
- [19] P09.19, SWIM A-G Technical Verification Report for Mainline Aircraft - version 2, 09.19-D19, Edition 00.01.00, 08/08/2016
- [20] P09.19, SWIM A-G Technical Verification Report for Regional Aircraft, 09.19-D20, Edition 00.00.03, 08/12/2014
- [21] P09.19, SWIM A-G Technical Verification Report for Regional Aircraft, 09.19-D21, Edition 00.01.01, 19/03/2015
- [22] P09.19, SWIM A-G Regional Aircraft Prototype Technical Verification Report, 09.19-D22, Edition 00.01.00, 30/06/2016
- [23] P09.19, SWIM A-G Regional Aircraft Prototype Technical Verification Report, 09.19-D23, Edition 00.01.00, 05/09/2016
- [24] P09.19, SWIM A-G Concept of Operations, 09.19-D29, Edition 00.03.00, 16/06/2015
- [25] P08.01.01, SWIM Concept of Operations, D42, Edition 00.04.06, 30/04/2014
- [26] P14.01.04, SWIM-TI Purple Profile Technical Specification, D44-006, Edition 00.01.00, 04/07/2016

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