PBCS Workshop

Federal Aviation Administration

Presented to: ICAO ESAF Workshop on Operation of Aircraft

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Outline

- Overview
- ICAO Documentation
- Aeronautical Communications
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- Performance of Voice and Data Communications
- Implementation vs. Performance
- Performance-based operations (PBO)
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- FAA Aircraft Approvals
- Post Monitoring Results

Overview

Types of Aeronautical Communications

Safety and regularity of flight Communications

- **Air Traffic Services (ATS) communications**
  - ATS messages between aircraft and ATS facility
- **Aeronautical Operational Control (AOC) communications**
  - AOC messages between aircraft and dispatch office (operations)

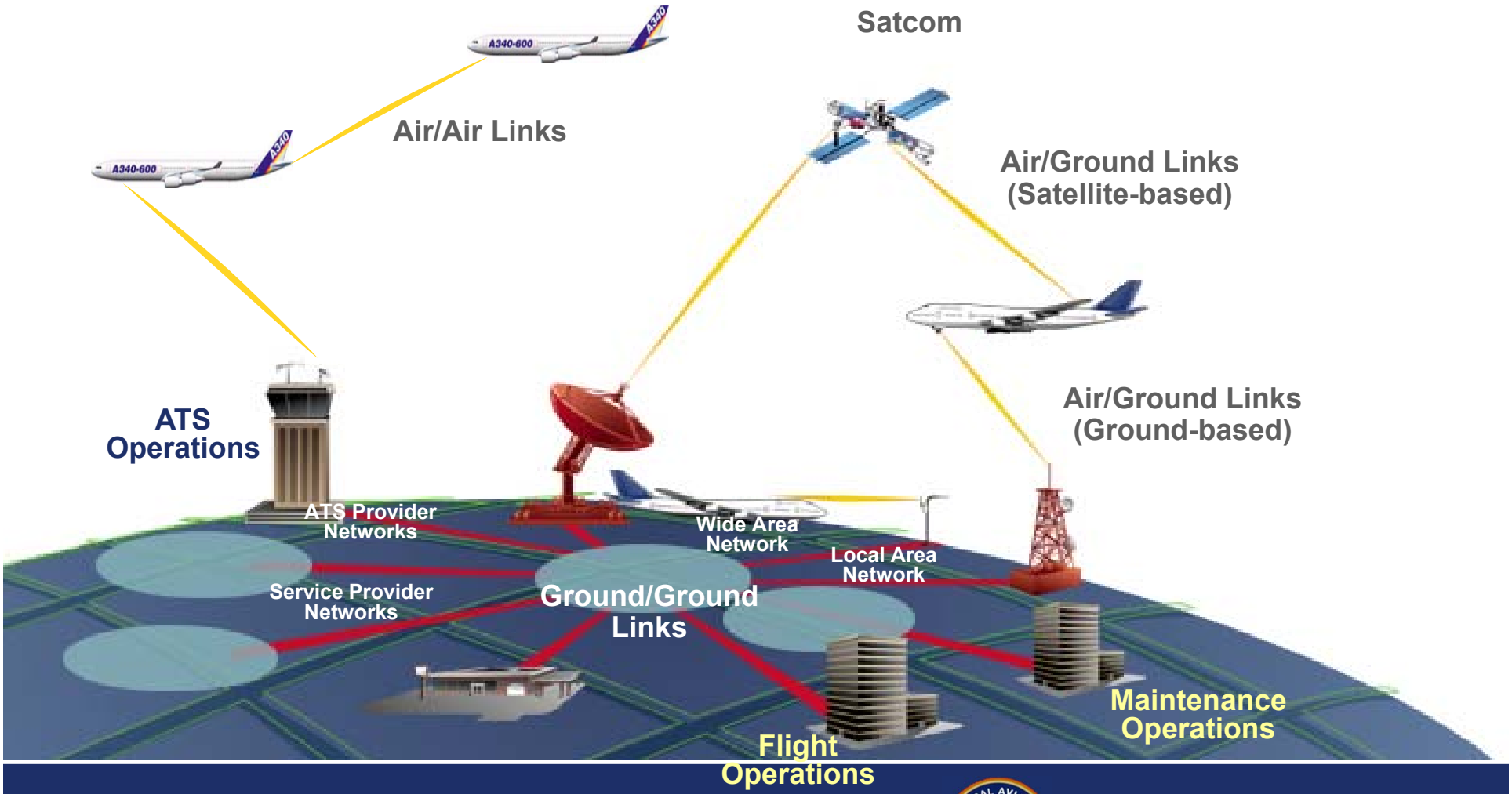
Non Safety and regularity of flight Communications

- **Aeronautical Administrative Communications (AAC)**
  - All other operational messages not having to do with flight safety and regularity
- **Aeronautical Passenger Communications (APC)**
  - Messages related to the non-safety voice and data services to passengers and crew members for personal communication

ICAO Documentation

Document ID	Description
Annex 6	Operation of Aircraft
Part 1	Commercial Air Transport - Aeroplanes
Part 2	General Aviation - Aeroplanes
Part 3	Operations - Helicopters
Annex 11	Air Traffic Services
Doc 4444	PANS – Air Traffic Management
Doc 7030	Regional Supplementary Procedures
Doc 9869	Performance-based Communication and Surveillance (PBCS) Manual
Doc 10037	Global Operational Data Link (GOLD) Manual

Aeronautical Communications



Aeronautical Communications

History of implementations

1917	Voice communications using VHF
1920's	Voice communications using HF
1978	ACARS
1980's	Voice communications using Inmarsat Classic Aero (3 Satellites)
1990's	Voice communications using Iridium Satcom (66 Satellites)
1990's	FANS 1/A (includes CPDLC & ADS-C)
2000's	Pre-ATN B1 CPDLC (Pioneer)
2007	Performance based communications for reduced separation, weather deviation, reroute using FANS 1/A
2013	ATN B1 (includes CPDLC)
2019	B2 (includes CPDLC & ADS-C)

Types of Communication

	Voice Comm	Data Comm
	English	ACARS, FANS 1/A+, ATN B1 and B2
VHF	8.33 kHz	Plain Old ACARS (POA)
	25 kHz	VDL Mode 2
HF	Single Side Band (SSB) Double Side Band (DSB)	HFDL
SATCOM	I-3 Classic Aero	I-3 Classic Aero, Swift 64
	I-4 Classic Aero & Swiftbroadband	I-4 Classic Aero & Swiftbroadband
	I-5 GX	I-5 GX
	Iridium	Iridium
	Iridium Certus	Iridium Certus

Performance of Voice and Data Communications

- **Nature of Voice and Data Communications is drastically different (i.e. technically and operationally)**
- **Performance of Voice Communication messages can be assessed real-time**
- **Data Communication messages necessitates the need to support post-implementation monitoring (statistical) to determine compliance to an RCP Specification and pursue corrective action activity when applicable**
- **Proposed Parameters for a Voice Perf Spec to characterize Voice Communications**
  - Establishment of a dialog
  - Latency
  - Audio Quality
  - Availability
  - Integrity
  - Monitoring and Alerting Criteria

Implementation vs. Performance

- **Aviation standards are published to define applicable criteria for each type of communication system/equipment identified in slide 7 of this presentation**
- **Actual operational performance varies for each type of comm system/equipment identified in slide 7 of this presentation**
- **ICAO and various State CAAs have thus embraced a Performance Based concept**

Implementation vs. Performance

- **Contributing factors affecting Performance that cannot be accomplished with defined implementation criteria**
  - Natural obstacle by terrain (e.g. mountain),
  - Man made obstacle (e.g. buildings),
  - Electromagnetic Interference (EMI)
  - Congestion (e.g. presence of too many aircraft or proximity of ground system antennas or Air Traffic Service Providers (ATSPs a.k.a. ANSPs))
  - Route of flight

Performance-based operations (PBO)

- **PBO ≠ PBN**
  - 50 NM longitudinal
  - 30 NM longitudinal
  - 30 NM lateral
  - ½ degree lateral (25 NM lateral)
  - 5 min longitudinal
  - ADS-C CDP

Require FANS 1/A+ at RCP 240 & RSP 180
Require RNP 4

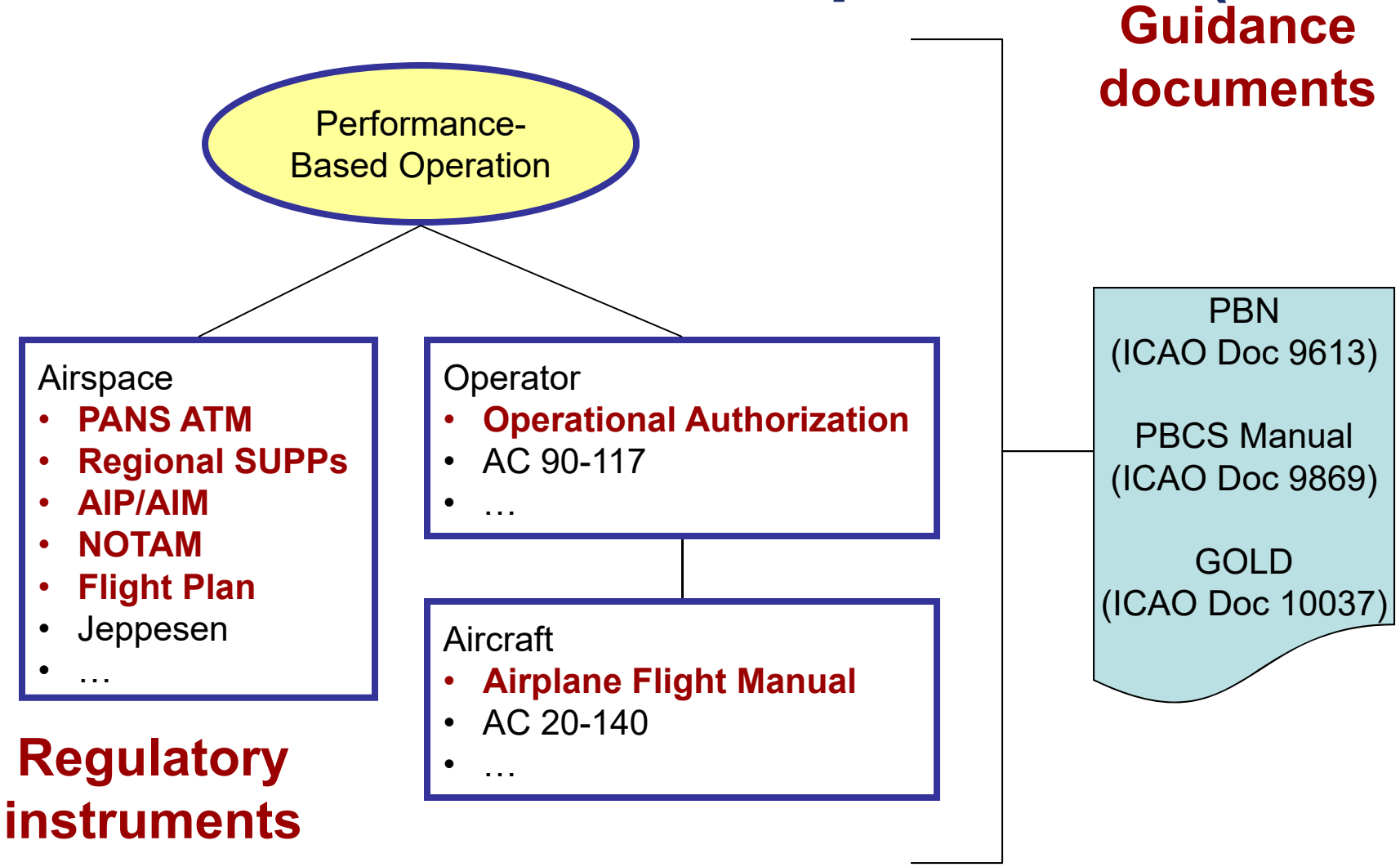
Performance-based operations (PBO)

- **Inclusively Communication, Navigation and Surveillance performance is required for Performance-Based Operations**
- **Communication Performance specified via RCP xxx**
- **Navigation Performance specified via RNP xxx**
- **Surveillance Performance specified via RSP xxx**

Performance-based operations (PBO)

- **The transition to a performance-based airspace system was determined to be "a critical aspect of the evolution to a safe and efficient global air traffic management (ATM) environment" making it "necessary to ensure acceptable operational performance, taking into account changing technologies"**
- **The PBCS concept originated from RCP and was developed in response to:**
  - increased use and dependency of commercial communication services in the provision of air traffic services
  - critical need for objective oversight of the performance and safety of the highly complex system

Performance-based operations (PBO)



Performance-based operations (PBO)

Hazard Class	Catastrophic (i.e. Severity Class 1)	Hazardous (i.e. Severity Class 2)	Major (i.e. Severity Class 3)	Minor (i.e. Severity Class 4)	No Safety Effect (i.e. Severity Class 5)
Effect on Operations	Normally with hull loss. Total loss of flight control, mid-air collision, flight into terrain or high speed surface movement collision.	Large reduction in safety margins or aircraft functional capabilities.	Significant reduction in safety margins or aircraft functional capabilities.	Slight reduction in safety margins or aircraft functional capabilities.	No effect on operational capabilities or safety.
Effect on Occupants	Multiple fatalities.	Serious or fatal injury to a small number of passengers or cabin crew.	Physical distress, possibly including injuries.	Physical discomfort.	Inconvenience.
Effect on Flight Crew	Fatalities or incapacitation.	Physical distress or excessive workload impairs ability to perform tasks.	Physical discomfort, possibly including injuries or significant increase in workload.	Slight increase in workload.	No effect on flight crew.
Effects on Air Traffic Service	Total loss of separation.	Large reduction in separation or a total loss of air traffic control for a significant period of time.	Significant reduction in separation or significant reduction in air traffic control capability.	Slight reduction in separation or slight reduction in air traffic control capability. Significant increase in air traffic controller workload.	Slight increase in air traffic controller workload.
Allowable probability of occurrence per flight hour					
Allowable Qualitative Probability	Extremely Improbable	Extremely Remote	Remote	Probable	No Probability Requirement
Allowable Quantitative Probability	$<1 \times 10^{-9}$ per flight hour or expressed when functionally available 0.999999999 (i.e. $1-1\times10^{-9}$)	$<1 \times 10^{-7}$ per flight hour or expressed when functionally available 0.9999999 (i.e. $1-1\times10^{-7}$)	$<1 \times 10^{-5}$ per flight hour or expressed when functionally available 0.99999 (i.e. $1-1\times10^{-5}$)	$<1 \times 10^{-3}$ per flight hour or expressed when functionally available 0.999 (i.e. $1-1\times10^{-3}$)	No Probability Requirement
Relationship of Hazard Classification to Hardware/Software Development Assurance Level (DAL)					
	A failure condition categorization of "catastrophic" for the aircraft is associated with hazards occurring no more frequently than "extremely improbable." Hardware/Software Development Assurance Level (DAL) to be developed to at least the level consistent with an "extremely improbable" failure condition.	A failure condition categorization of "hazardous" for the aircraft is associated with hazards occurring no more frequently than "extremely remote." Hardware/Software Development Assurance Level (DAL) to be developed to at least the level consistent with an "extremely remote" failure condition.	A failure condition categorization of "major" for the aircraft is associated with hazards occurring no more frequently than "remote." Hardware/Software Development Assurance Level (DAL) to be developed to at least the level consistent with a "major" failure condition.	A failure condition categorization of "minor" for the aircraft is associated with hazards occurring no more frequently than "probable." Hardware/Software Development Assurance Level (DAL) to be developed to at least the level consistent with a "probable" failure condition.	A failure condition categorization of "no effect" for the aircraft is associated with hazards with no established safety objective. Hardware/Software Development Assurance Level (DAL) to be developed to at least the level consistent with a "no effect" failure condition.

ICAO Doc 9869, PBCS Manual

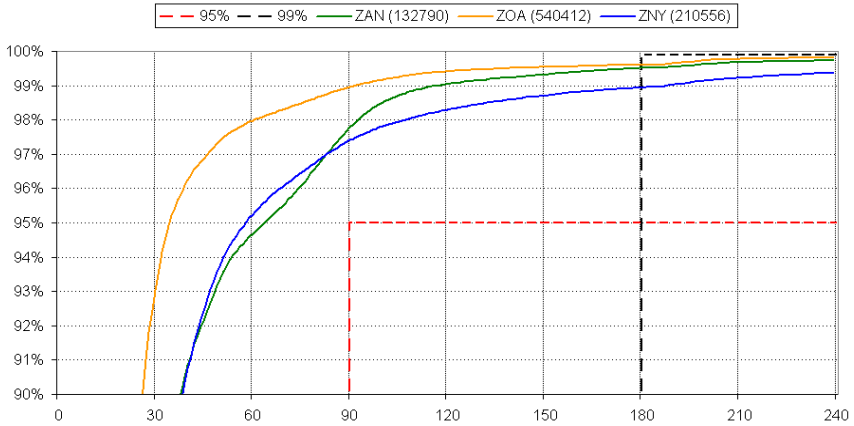
- **Performance Specification provide an objective operational criteria to evaluate different and emerging communication and surveillance technologies, intended for evolving air traffic management (ATM) operations**
- **Performance Specification characterizes performance of the end-to-end data message (i.e. Controller/Pilot) with five parameters and associated criteria**
  - Transaction time
  - Availability
  - Monitoring and Alerting
  - Continuity
  - Integrity
- **A Performance Specification also includes defined allocations to the ATSU, CSP, Aircraft, and Operator which are all involved for a end-to-end data message. The defined allocations allow the ATSU, CSP, Aircraft, and Operator to be implemented/used independently and still be confident the performance of the end-to-end data message (i.e. Controller/Pilot) is satisfied.**
- **Data Communication messages needs to support post-implementation monitoring (statistical) to determine compliance to an RCP Specification and corrective action activity when applicable**

Post Monitoring Results
CPDLC (RCP) & ADS-C (RSP)

Jan to Mar 2011

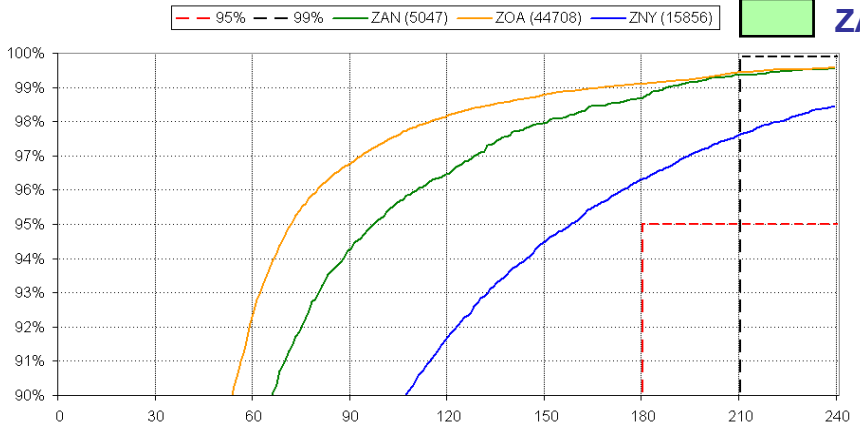
FIR	ACP		ACTP		ADS-C	
	% within 180 sec (95%)	% within 210 sec (99.9%)	% within 120 sec (95%)	% within 150 sec (99.9%)	% within 90 sec (95%)	% within 180 sec (99.9%)
ZNY	96.31	97.57	98.77	99.26	97.36	98.94
ZOA	99.10	99.43	99.60	99.70	98.94	99.60
ZAN	98.67	99.37	99.43	99.72	97.68	99.51

ADS-C Report Delivery

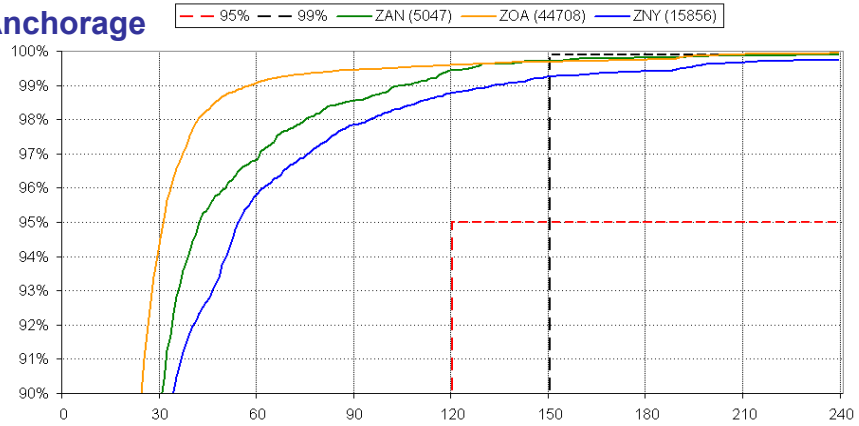


ZNY – New York
ZOA – Oakland
ZAN – Anchorage

CPDLC ACP



CPDLC ACTP



ICAO Doc 9869, PBCS Manual

- **RCP/RSP monitoring can tell us the system was "bad" yesterday**
- **We need confidence the system will perform as expected today**
  - Demonstrate stability of actual performance over time
  - Prescribe airspace requirements and approve components
  - And fix problems when they are found
- **Post Monitoring Requirements (external of ICAO Doc 9869, PBCS Manual)**

Annex 11, Air Traffic Services

3.3.5.2 Where RCP/RSP specifications are applied, programmes shall be instituted for monitoring the performance of the infrastructure and the participating aircraft against the appropriate RCP and/or RSP specifications, to ensure that operations in the applicable airspace continue to meet safety objectives. The scope of monitoring programmes shall be adequate to evaluate communication and/or surveillance performance, as applicable.

Annex 6, Operation of Aircraft, Part I

7.1.5 The State of the Operator shall ensure that, in respect of those aeroplanes mentioned in 7.1.3, adequate provisions exist for:

a) receiving the reports of observed communication performance issued by monitoring programmes established in accordance with Annex 11, Chapter 3, 3.3.5.2; and

b) taking immediate corrective action for individual aircraft, aircraft types or operators, identified in such reports as not complying with the RCP specification(s).

Note: corresponding requirements in Part I, paragraph 7.3.4, and Part II, paragraphs 2.5.1.9 and 2.5.3.5

ICAO Doc 9869, PBCS Manual

Clip of Table B-5 in Doc 9869 Edition 3 (draft)

Table B-5: CPDLC Performance Requirements

RCP Specifications						
	RCP 130		RCP 240		RCP 400	
Parameter	ET	$TT_{95\%}$	ET	$TT_{95\%}$	ET	$TT_{95\%}$
Transaction Time (Sec)	130	67	240	210	400	350
Continuity (C)	0.999	0.95	0.999	0.95	0.999	0.95
Availability (A)	0.999		0.999 (safety) 0.9999 (efficiency)		0.999	
Integrity (I)	1E-5 per FH		1E-5 per FH		1E-5 per FH	
RCP Monitoring and Alerting Criteria						
MA-1	The system shall be capable of detecting failures and configurations changes that would cause the communication service to no longer meet the RCP specification for the intended use.					
MA-2	When the communication service can no longer meet the RCP specification for the intended function, the flight crew and/or the controller shall take appropriate actions.					
Defined Allocations for RCP Specifications						
	RCP 130/D		**RCP 240/D**		**RCP 400/D**	
Parameter	ET	$TT_{95\%}$	ET	$TT_{95\%}$	ET	$TT_{95\%}$
Transaction Time (Sec)						
Initiator	30	13	30	30	30	30
RCMP	120	60	210	180	370	320
Responder	100	44	60	60	60	60
RCTP	32	20	150	120	310	260
$RCTP_{ATSU}$	14	6	15	10	15	10
$RCTP_{CSP}$	18	10	120	100	280	240
$RCTP_{Aircraft}$	23	10	15	10	15	10
Continuity (C)						
C_{ATSU}, C_{CSP}, & $C_{Aircraft}$	0.999	0.95	0.999	0.95	0.999	0.95
Availability (A)						
A_{ATSU}	0.9995		0.999 (safety) 0.9999 (efficiency)		n/a	
A_{CSP}	0.9995		0.999 (safety) 0.9999 (efficiency)		0.999	
$A_{Aircraft}$	0.999		0.999		0.999	

Defined Allocations for RCP Specifications						
	RCP 130/D		RCP 240/D		RCP 400/D	
Parameter	ET	$TT_{95\%}$	ET	$TT_{95\%}$	ET	$TT_{95\%}$
Availability (A) (continued)						
Unplanned outage duration $limit_{ATSU\ \&\ CSP}$ (min)	6		10 (CSP only)		20	
Maximum number of unplanned $outages_{ATSU}$	40		n/a		n/a	
Maximum number of unplanned $outages_{CSP}$	40		48 (safety) 4 (efficiency)		24	
Maximum accumulated unplanned outage $time_{ATSU}$ (min/yr)	240		n/a		n/a	
Maximum accumulated unplanned outage $time_{CSP}$ (min/yr)	240		520 (safety) 52 (efficiency)		520	
Unplanned outage notification $delay_{ATSU\ \&\ CSP}$ (min)	5		5		10	
Integrity (I)						
I_{ATSU} & $I_{Aircraft}$	1E-5 per FH		1E-5 per FH		1E-5 per FH	
RCP Monitoring and Alerting Criteria						
$MA\text{-}1a_{ATSP}$	The ground system shall be capable of detecting ground system failures and configuration changes that would cause the communication service to no longer meet the requirements for the intended function. ***Note:*** *If changes are made to the system capacity limits, as specified by the airspace requirements, and the changes cause the system to perform below the RCP specification, this would be considered a change in system configuration.*					
$MA\text{-}1b_{ATSP}$	When the communication service no longer meets the requirements for the intended function, the ground system shall provide indication to the controller.					
$MA\text{-}1a_{Aircraft}$	The aircraft system shall be capable of detecting aircraft system failures or loss of air/ground communication that would cause the aircraft communication capability to no longer meet the requirements for the intended function.					
$MA\text{-}1b_{Aircraft}$	When the aircraft communication capability no longer meets the requirements for the intended function, the aircraft system shall provide indication to the flight crew.					
$MA\text{-}2_{ATSP}$	When the controller receives an indication that the communication service no longer meets the requirements for the intended function (e.g., complex ATC comms), the controller shall take action to resolve the situation, (e.g., apply an alternative form of communication).					
$MA\text{-}2_{Operator}$	When the flight crew determines that the aircraft communication capability no longer meets the requirements for the intended function, e.g., loss of radio, the flight crew shall advise the ATC unit concerned.					

ICAO Doc 9869, PBCS Manual

Clip of Table C-3 in Doc 9869 Edition 3 (draft)

Table C-3: ADS-C Performance Requirements

RSP Specifications						
	RSP TBD		RSP 180		RSP 400	
Parameter	OT	$DT_{95\%}$	OT	$DT_{95\%}$	OT	$DT_{95\%}$
Transaction Time (Sec)	TBD	TBD	180	90	400	300
Continuity (C)	TBD	TBD	0.999	0.95	0.999	0.95
Availability (A)	TBD		0.999 (safety) 0.9999 (efficiency)		0.999	
Integrity (I)	TBD		1E-5 per FH		1E-5 per FH	
RCP Monitoring and Alerting Criteria						
MA-1	The system shall be capable of detecting failures and configurations changes that would cause the communication service to no longer meet the RSP specification for the intended use.					
MA-2	When the ADS-C service can no longer meet the RSP specification for the intended function, the flight crew and/or the controller shall take appropriate actions.					
Defined Allocations for RCP Specifications						
	RSP TBD/D		RSP 180/D		RSP 400/D	
Parameter	OT	$DT_{95\%}$	OT	$DT_{95\%}$	OT	$DT_{95\%}$
Transaction Time (Sec)						
RSMP = RSTP	TBD	TBD	180	90	400	300
$RSTP_{ATSU}$	TBD	TBD	5	3	30	15
$RSTP_{CSP}$	TBD	TBD	170	84	340	270
$RSTP_{Aircraft}$	TBD	TBD	5	3	30	15
Continuity (C)						
C_{ATSU}, C_{CSP}, & $C_{Aircraft}$	TBD	TBD	0.999	0.95	0.999	0.95
Availability (A)						
A_{ATSU}	TBD		0.999 (safety) 0.9999 (efficiency)		n/a	
A_{CSP}	TBD		0.999 (safety) 0.9999 (efficiency)		0.999	
$A_{Aircraft}$	TBD		0.999		0.999	
Unplanned outage duration limit ATSU & CSP (min)	TBD		10 (CSP only)		20	

Defined Allocations for RSP Specifications						
	RSP TBD/D		RSP 180/D		RSP 400/D	
Parameter	OT	$DT_{95\%}$	OT	$DT_{95\%}$	OT	$DT_{95\%}$
Availability (A) (continued)						
Maximum number of unplanned $outages_{ATSU}$	TBD		n/a		n/a	
Maximum number of unplanned $outages_{CSP}$	TBD		48 (safety) 4 (efficiency)		24	
Maximum accumulated unplanned outage $time_{ATSU}$ (min/yr)	TBD		n/a		n/a	
Maximum accumulated unplanned outage $time_{CSP}$ (min/yr)	TBD		520 (safety) 52 (efficiency)		520	
Unplanned outage notification $delay_{ATSU\ \&\ CSP}$ (min)	TBD		5		10	
Integrity (I)						
I_{ATSU} & $I_{Aircraft}$	TBD		1E-5 per FH		1E-5 per FH	
Navigation Figure of Merit (FOM)	TBD		*See Note 34*		*See Note 34*	
Time at position accuracy	TBD		+/- 1 sec (UTC)		+/- 1 sec (UTC)	
RCP Monitoring and Alerting Criteria						
$MA\text{-}1a_{ATSP}$	The ground system shall be capable of detecting ground system failures and configuration changes that would cause the ADS-C service to no longer meet the requirements for the intended function. *Note: If changes are made to the system capacity limits, as specified by the airspace requirements, and the changes cause the system to perform below the RSP specification, this would be considered a change in system configuration.*					
$MA\text{-}1b_{ATSP}$	When the ADS-C service no longer meets the requirements for the intended function, the ground system shall provide indication to the controller.					
$MA\text{-}1a_{Aircraft}$	The aircraft system shall be capable of detecting aircraft system failures or loss of air/ground communication that would cause the aircraft surveillance capability to no longer meet the requirements for the intended function.					
$MA\text{-}1b_{Aircraft}$	When the aircraft surveillance capability no longer meets the requirements for the intended function, the aircraft system shall provide indication to the flight crew.					
$MA\text{-}2_{ATSP}$	When the controller receives an indication that ADS-C no longer meets the requirements for the intended function (e.g. reduced longitudinal separation), the controller shall take action to resolve the situation, (e.g. apply an alternative form of separation).					
$MA\text{-}2_{Operator}$	When the flight crew determines that the aircraft surveillance capability no longer meets the requirements for the intended function, e.g., loss of radio, the flight crew shall advise the ATC unit concerned.					

FAA Aircraft Approvals

Clip of A/RFM in AC 20-140D (draft)

9.2 **A/RFM Operating Procedures Section.**

9.2.1 Provides operating procedures in the A/RFM or A/RFM supplement consistent with the criteria you use to demonstrate the system. Figure 2 show an example A/RFM supplement for a multiple stack data link system meeting various performance criteria, Networks, and sub-networks, including FANS 1/A+ (with automation).

Figure 2. Flight Manual Example – Data Link System Capabilities

"The FAA has approved the aircraft data link system to the criteria in AC 20-140D for the following data link capabilities:

Data Link Type	Aircraft-allocated Performance	Networks	Sub-networks
ATN B1	CPDLC at RCP 130 using →	ATN/OSI or IPS using →	VDL M2
B2	CPDLC at RCP 130 using → ADS-C at RSP 160 using →	ATN/OSI or IPS using →	VDL M2
	CPDLC at RCP 240 using → ADS-C at RSP 180 using →	ATN/OSI or IPS using →	SATCOM (SBB)
FANS 1/A+ (with automation)	CPDLC at RCP 130 using → ADS-C at RSP 160 using →	ACARS using→	VDL M0/A
		ACARS or IPS using →	VDL M2
	CPDLC at RCP 240 using → ADS-C at RSP 180 using →	ACARS using→	SATCOM (Classic Aero), SATCOM (SBD)
		ACARS or IPS using →	SATCOM (SBB)
	CPDLC at RCP 400 using → ADS-C at RSP 400 using →	ACARS using→	HFDL
ACARS ATS	None, using →	ACARS using→	VDL M0/A, HFDL, SATCOM (Classic Aero), SATCOM (SBD)
		ACARS or IPS using →	VDL M2, SATCOM (SBB)

This design approval does not constitute operational authorization."

Questions