



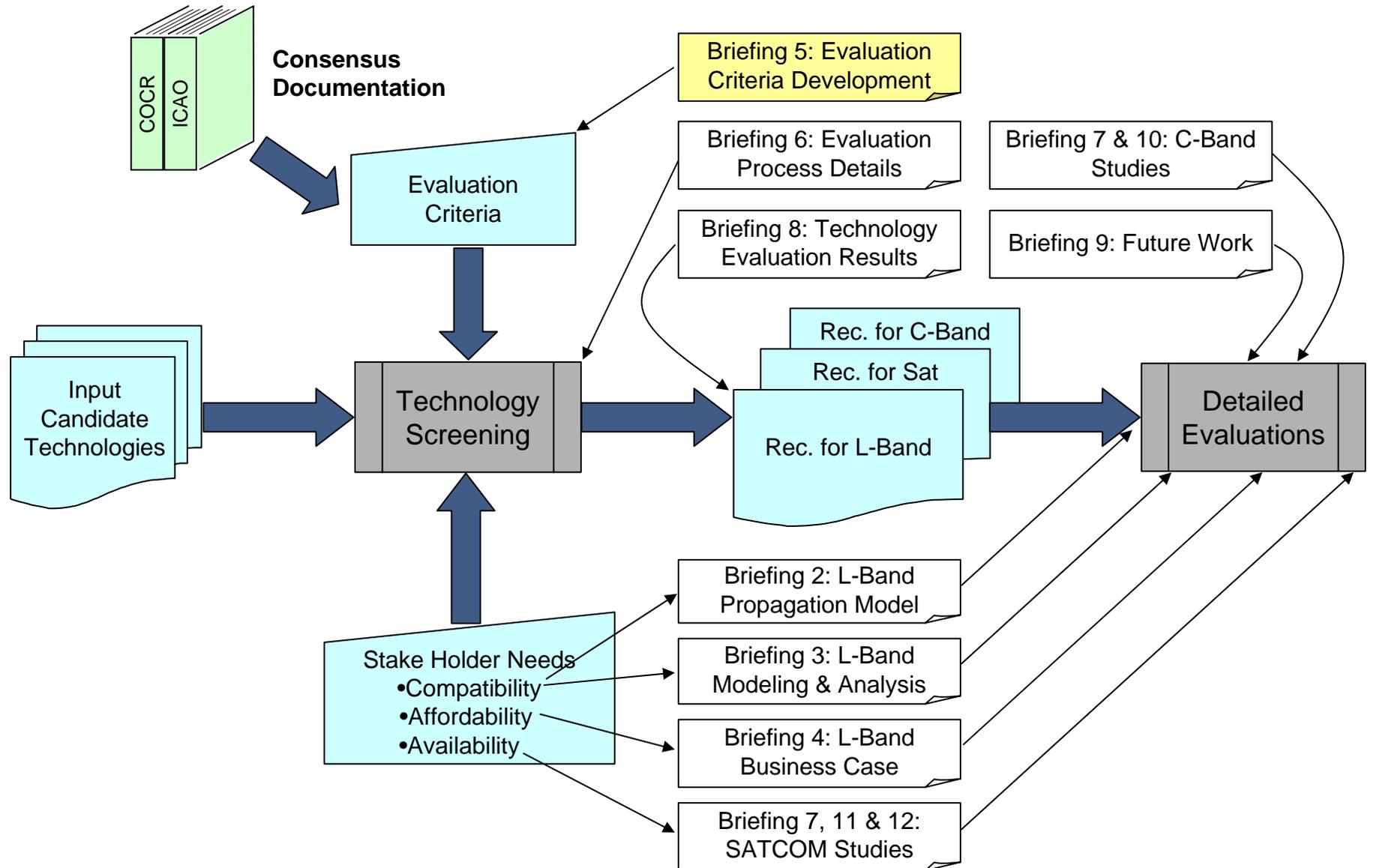
*NASA Support for the Future
Communications Study*



*Briefing #5 - Evaluation Criteria
Development*

Future Communications Study
Phase II End of Task Briefing

June 21, 2006



- Evaluation Criteria Derivation
 - Step A: Review COCR
 - Step B: Derive Technical Evaluation Criteria/Metrics
 - Step C: Review ICAO Consensus Documents/ Recommendations
 - Step D: Derive Institutional Evaluation Criteria/Metrics

- Summary of Derived Evaluation Criteria



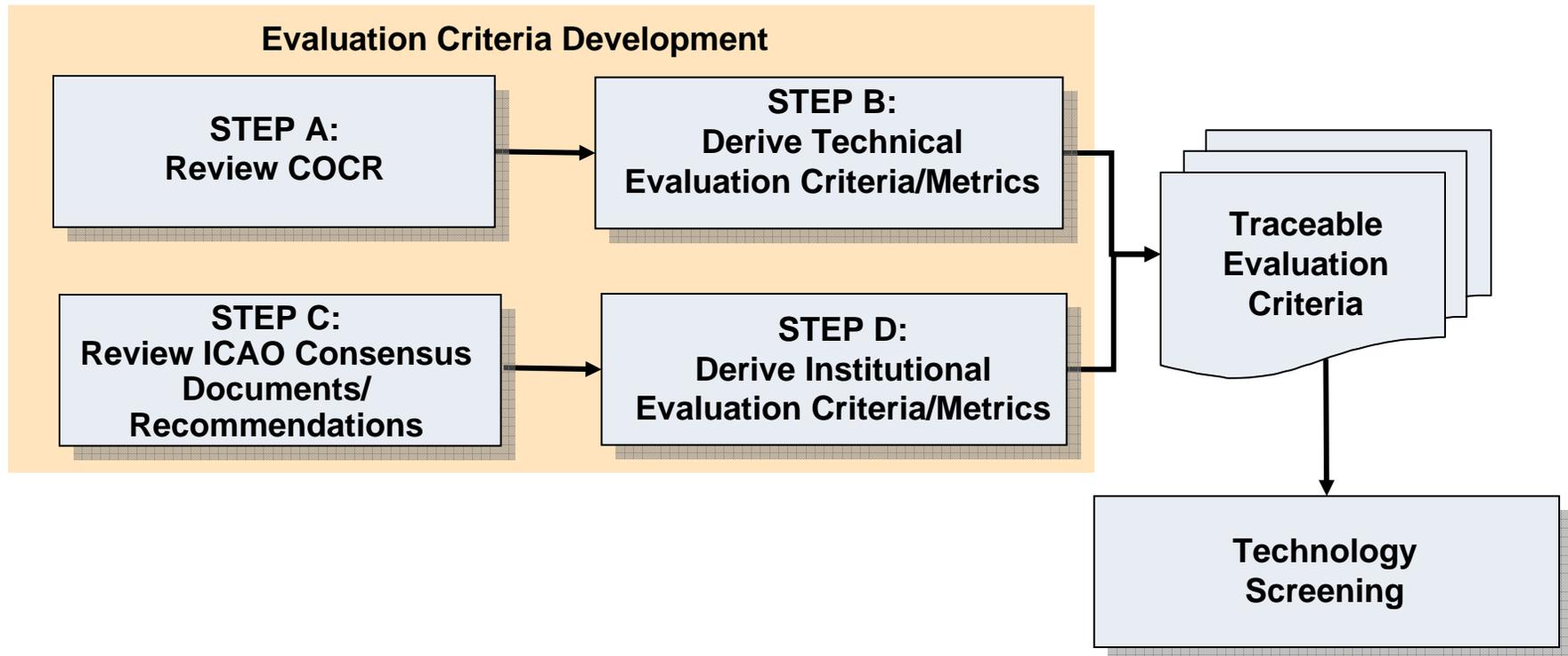
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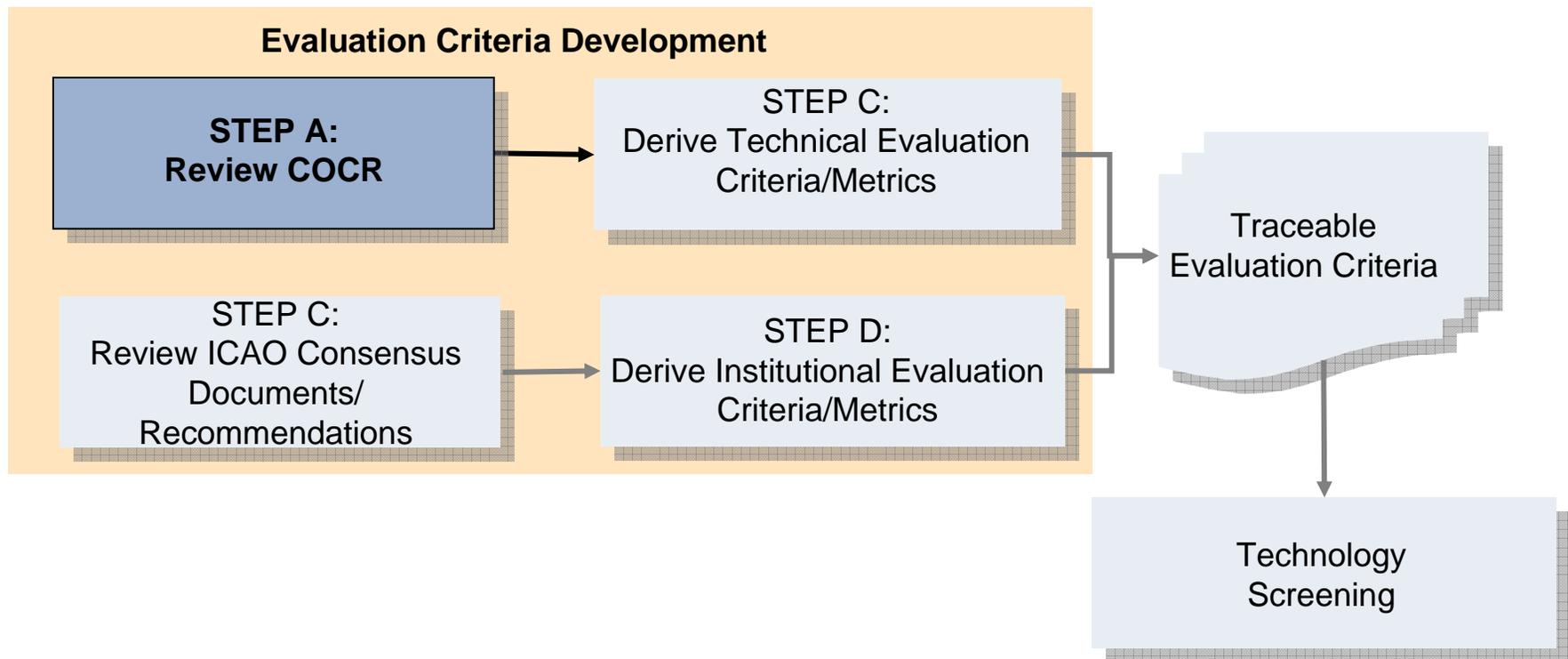
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Evaluation Criteria Derivation

- Analysis of existing evaluation criteria indicated two types of criteria had been applied in the past to accommodate technical and strategic objectives of a future communication system
 - **Technical Criteria** – Address the required performance and functions of the future radio system. These criteria are derived from user requirements, as documented in the COCR
 - **Institutional Criteria** – These criteria address the elements of a technology that make it a viable solution, and are derived from consensus ICAO documents
 - Principle source of these requirements are the ICAO ANC-11 recommendations that precipitated the FCS







Evaluation Criteria Derivation – Step A (2)



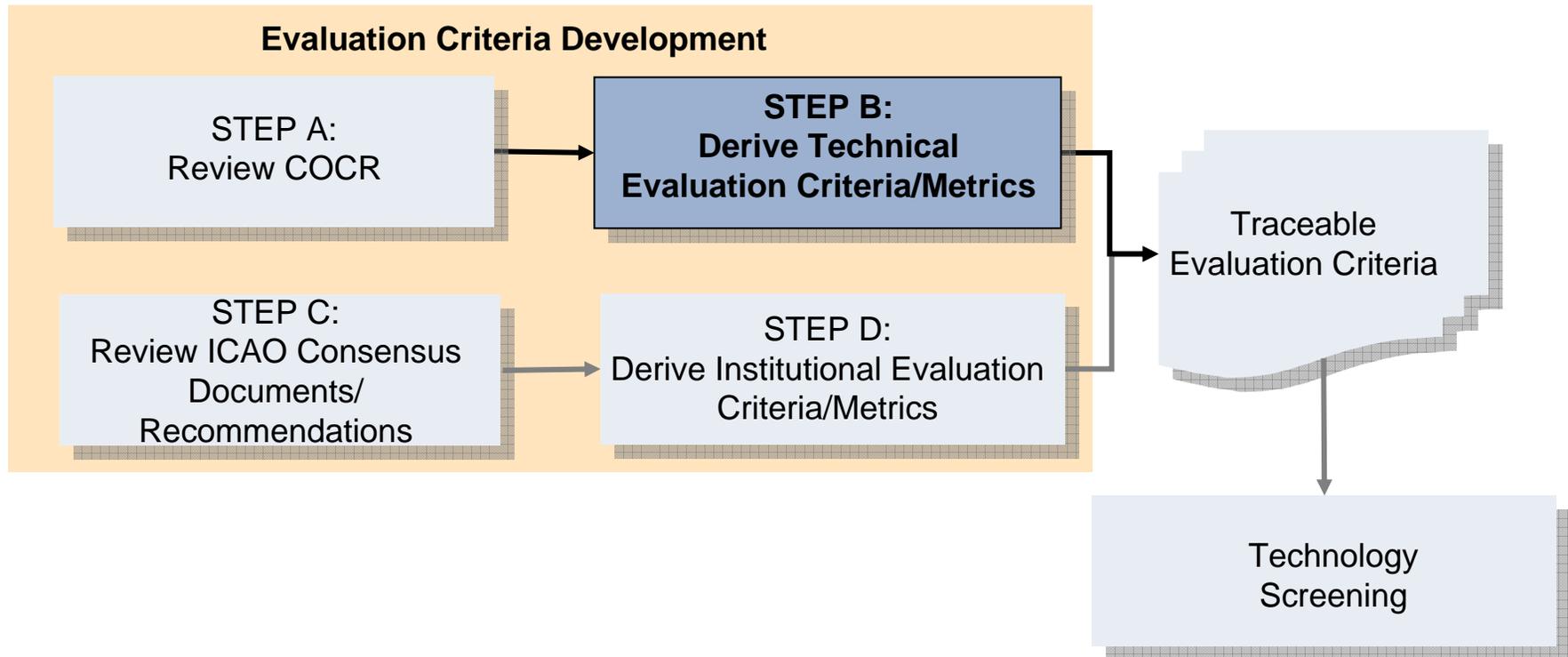
- COCR Version 1.0 document includes:
 - **Operational services and environment for communications**
(Sections 2 & 3)
 - Describes service capabilities implemented in phases
 - Phase I
 - » Expanded collaborative decision making (CDM) and data sharing
 - » Beginning of a shift from tactical intervention to reliable planning
 - » Implementation of seamless layered flight planning process
 - Phase II
 - » Layered planning and CDM are routine
 - » Use of trajectory negotiation has become the norm (supported by airspace reorganization and avionics that support 4-D trajectories)
 - » Data is primary means of communication
 - Material is a source for identifying FRS ***required functionality***



Evaluation Criteria Derivation – Step A (3)



- COCR review (cont'd)
 - **Operational safety/security and performance requirements** (Sections 4 and 5)
 - Identifies operational service safety requirements and FRS security requirements
 - Defines communication performance (latency, availability, integrity, confidentiality) by operational service
 - Also includes class of service definitions and association of operational services to classes
 - Material is a source for ***security and performance requirements***
 - **Communication loading analysis** (Section 6)
 - Includes Peak Instantaneous Aircraft Counts (PIACs) and Aircraft Densities for Phase I and Phase II by flight domains (e.g., airport, terminal maneuvering area, en route)
 - Defines capacity requirements (for ATS services, AOC services and combined for Phase I and Phase II, high and low density airspace, by flight domain) for:
 - For all A/G operational services
 - For all A/A operational services
 - Material is a source for ***number of users/loading requirements***





Evaluation Criteria Derivation – Step B (2)



- Inspection of COCR led to further distinction in defining Technical-Evaluation Criteria:
 - Technical-Evaluation Criteria (*Functional*)
 - Technical-Evaluation Criteria (*Performance*)

COCR Section	Criteria	Comment
1. Introduction	--	--
2. Operational Services	Functional Requirements	Ability of the FRS to enable defined services
3. Operational Environment for Communication	Functional Requirements	Ability of the FRS to support the described operational environment
4. Safety and Security Requirements	Security	Assess provision of authentication, data integrity check & resistance to jamming (Note: safety requirements are specific to operational services and used to derive communication system & procedural requirements)
5. Operational Performance Requirements	QoS Priority Provisions (Performance); Latency (Performance)	Assess provision of classes of service and achievement of defined RCP (integrity/availability not utilized – discussion to follow)
6. Communication Loading Analysis	Number of Users (Capacity); Data Rate (Capacity)	Ability to service the number of users identified and accommodate the defined communication load (data rate)
7. Relationship of the Results to a Real World Environment	--	--
8. Conclusions	--	--

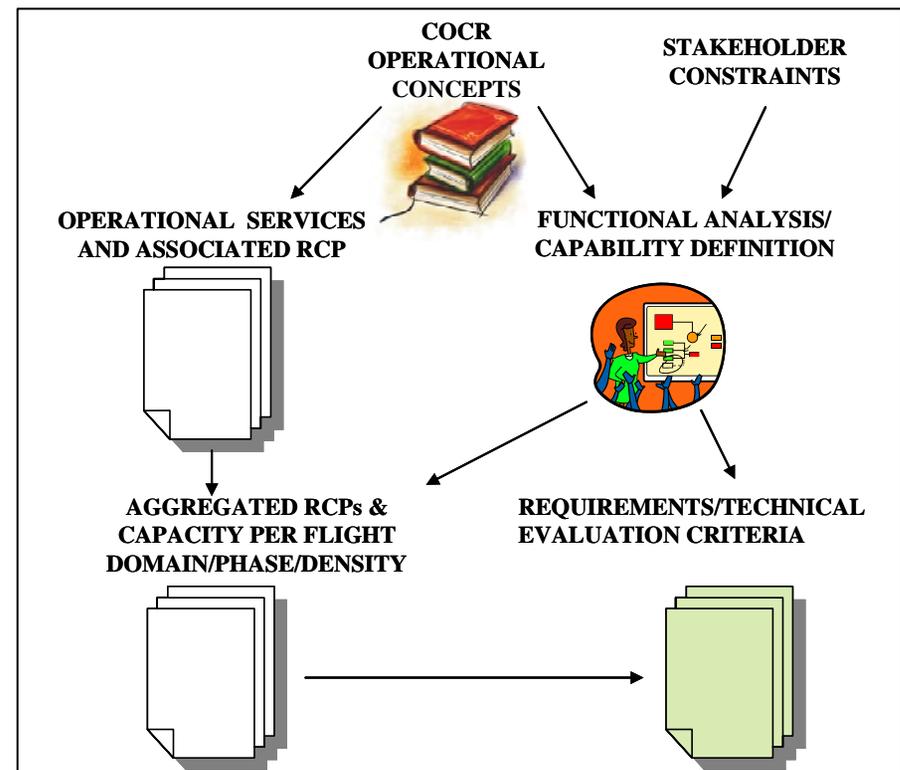


Evaluation Criteria Derivation – Step B (3)



- Integrity and Availability numbers in COCR not directly used as technology evaluation criteria
 - Integrity
 - Definition: The risk of non-detection of message corruption, or the probability that the transaction is completed with an undetected error (from DO-264)
 - Influencing factors: channel BER; channel coding; Frame Check Sequence (FCS);
 - Real driver for meeting integrity requirements is *BER of channel*
 - System design (i.e. closing channel link budget) becomes the issue
 - Integrity itself is not a criteria, however cost impact of architecture suitable to meet integrity requirements affects cost (accounted for in cost criteria)
 - Availability
 - Definition: The probability that the communication system between the two parties is in service when needed (from DO-264)
 - Influencing factors: architecture design
 - Availability is a design issue, but does drive cost (specific availability criteria not included, but cost has been included as an institutional criterion)
- COCR security requirements are used to define the Security criteria that are discussed later in the briefing
 - Security has been defined as an institutional criteria (rather than technical criterion)
 - Addressed in the discussion on institutional criteria

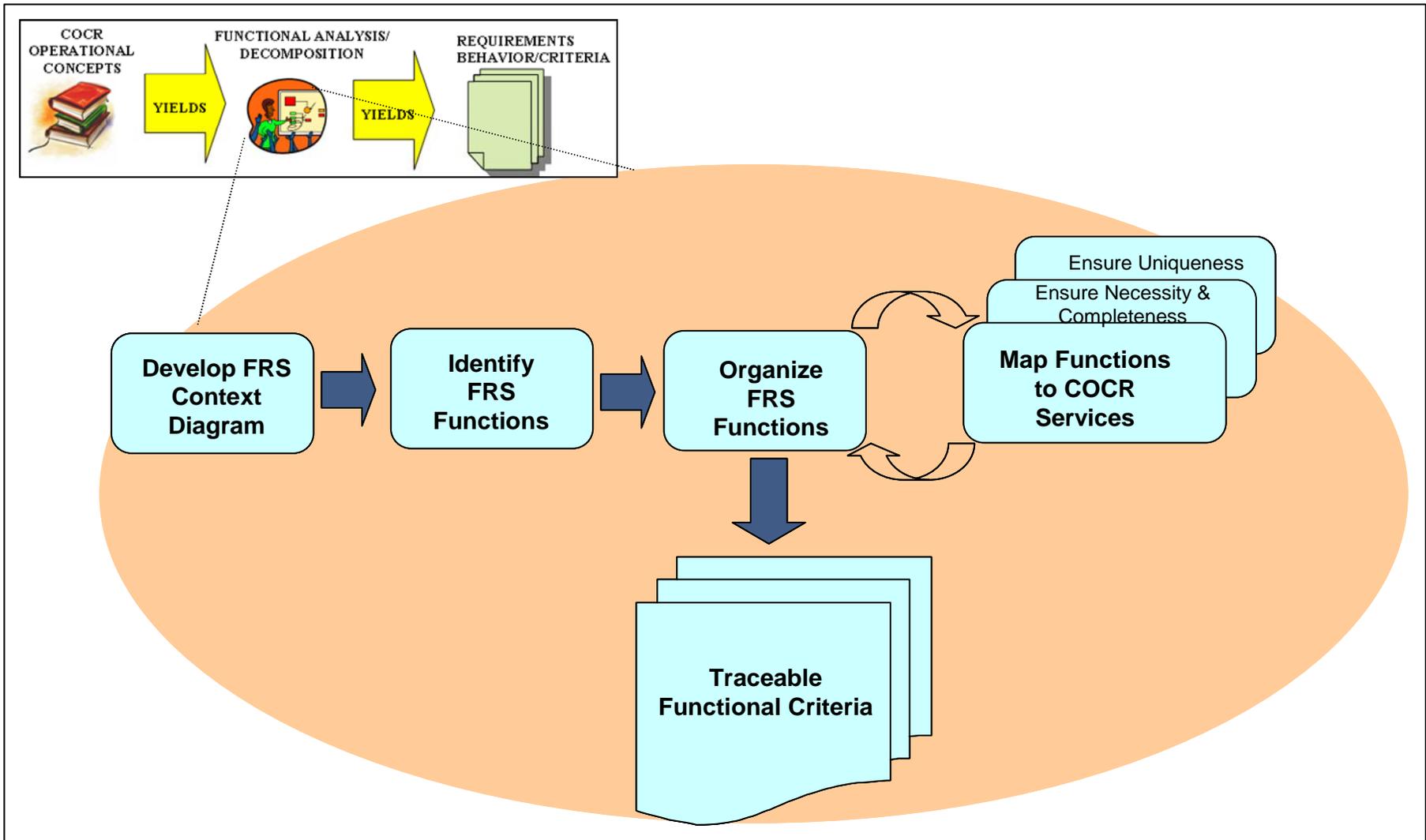
- Focus was on deriving functional, capacity and performance criteria
 - Functional analysis path identified required functions or functional groups (right path on diagram)
 - COCR operational analysis defined operational performance requirements (e.g. latency) (left path on diagram)
 - COCR loading analysis defined communication load requirements (left path on diagram)
- Functional capabilities were combined with capacity and performance requirements to define a complete set of technical evaluation criteria



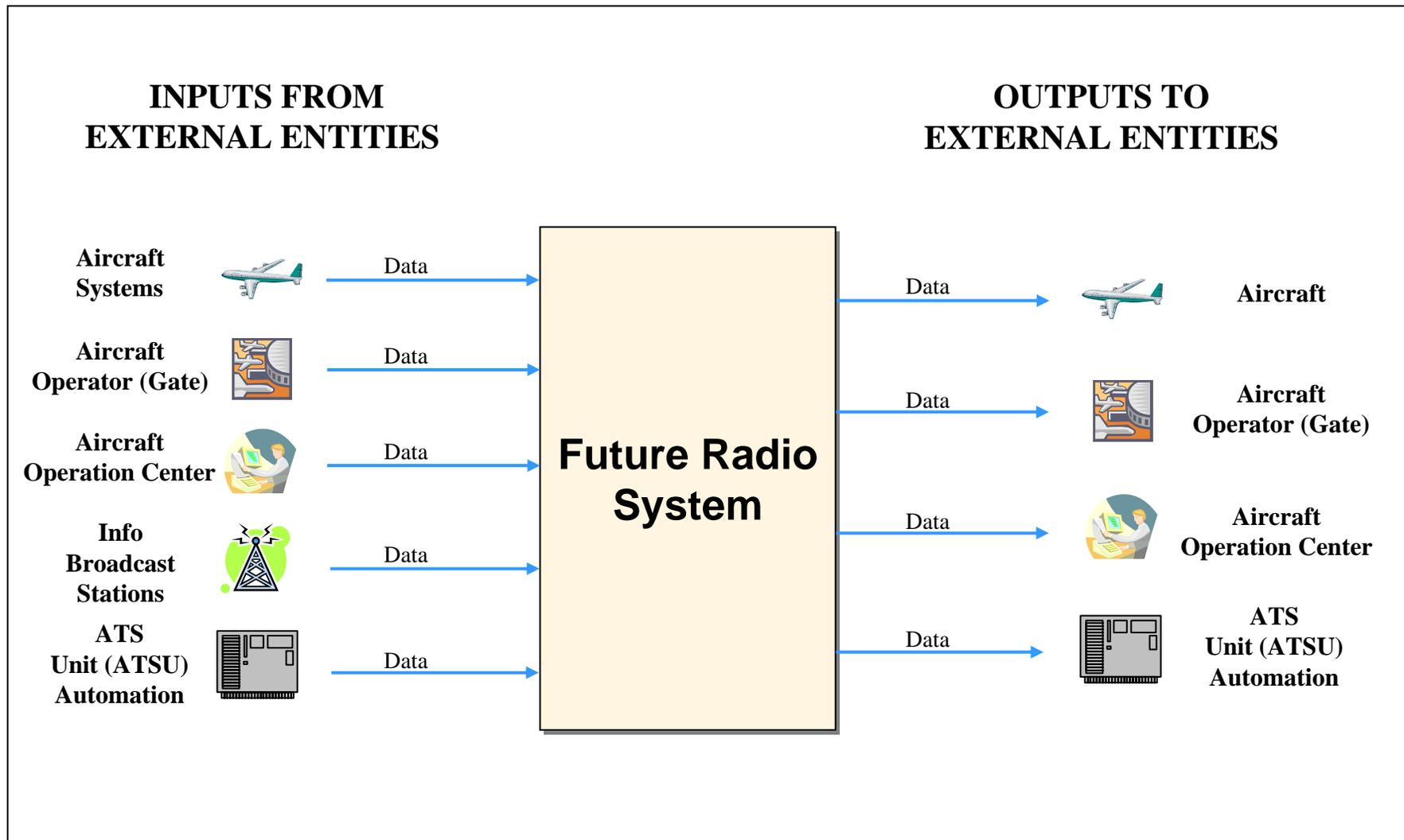


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Evaluation Criteria Derivation – Step B (5)



- The operational context diagram is used to show:
 - Actors identified in the operational concepts
 - Interfaces between the actors and the system
 - Required information flow across these interfaces
- Both actors and interfaces for the FRS were identified by parsing the COCR
 - Consideration given to stakeholder direction during context diagram development





Evaluation Criteria Derivation – Step B (8)



- The functionality of the Future Radio System (FRS) in the context diagram reflects certain assumptions that were applied during the development of the context diagram
- Assumptions include:
 - Voice Communications are allocated to 25kHz DSB-AM and 8.33 kHz DSB-AM systems per ATMAC recommendations and ICAO ACP WGW direction (not included in context of FRS)
 - Surveillance/ADS-B interfaces are allocated to legacy UAT and Mode S systems (and not included in this context of the FRS)
 - Navigation interfaces are accommodated by legacy/planned navigation systems



Evaluation Criteria Derivation – Step B (9)



- Through observation of the FRS context diagram and review of service flows over the identified interfaces, key communication functions of the FRS were identified
 - Provide aircraft to ground communications (in airport, TMA, en route, oceanic/remote, polar, and autonomous zone domains)
 - Provide ground to aircraft communications (in airport, TMA, en route, oceanic/remote, polar, and autonomous zone domains)
 - Provide aircraft to aircraft communications (in airport, TMA, en route, oceanic/remote, polar, and autonomous zone domains)
 - Provide addressed and/or broadcast communications (depending on the information payload)
 - Accommodate ATS (Controller/Flight Crew ATS, Auto Downlink, Flight Information, Traffic/Surveillance, Emergency/Ancillary, Comm Management) services and AOC services

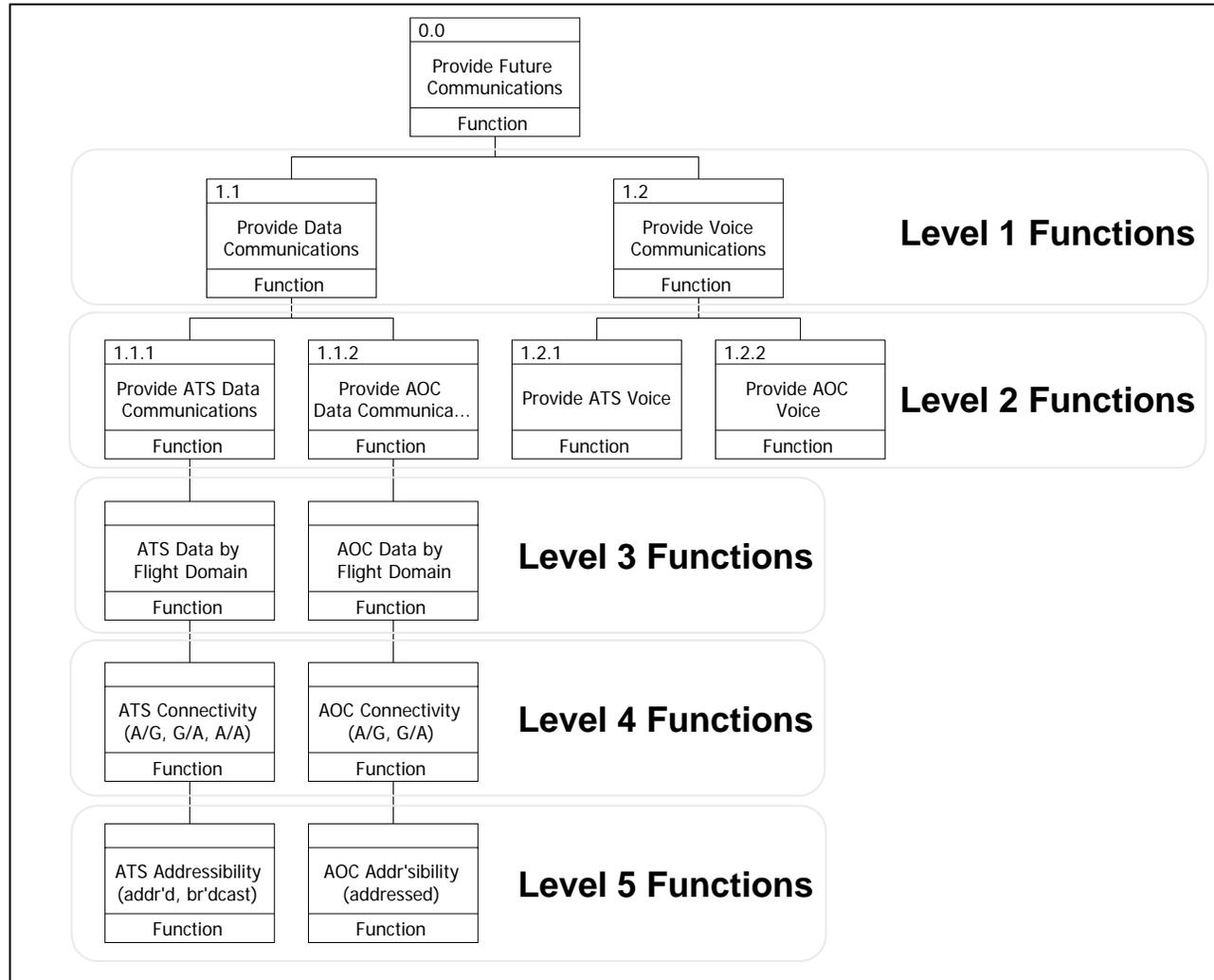


Evaluation Criteria Derivation – Step B (10)



- Inspection of the identified functions led to an abstraction of functional characteristics; they can be summarized as addressing:
 - *How: how* transaction is conducted (addressability and connectivity)
 - Addressability: Broadcast (including multicast) vs. addressed
 - Connectivity: G to A; A to G; A to A
 - *Where: where* transaction is applicable (airspace domain definition)
 - Airport; Terminal Maneuvering Area (TMA); En Route; Oceanic/Remote; Polar; Autonomous Zone
 - *What: what* information exchanged in transaction
 - Major categorical distinction: ATS services vs AOC services
 - Minor categorical distinction: different types of ATS services (e.g. Controller/Flight Crew ATS vs. Flight Info vs. Auto Downlink)

- Functional hierarchy derived from structured analysis of COCR





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Evaluation Criteria Derivation – Step B (12)



- Exploring permutations of the functional hierarchy components and mapping functions to COCR services yields FRS functions
- Mapping also captures traceability of functions to COCR
 - Forward traceability (ensure each COCR service is supported by at least one communication function)
 - Reverse traceability (ensure all defined functions are used to support at least one COCR service, i.e. they are needed)



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Evaluation Criteria Derivation – Step B (13)



- Excerpts from function-to-COCR traceability table

	COCR ATM Service	ATS A/G & G/A Addressed Airport	ATS A/G & G/A Addressed TMA	ATS A/G & G/A Addressed EnRoute	ATS A/G & G/A Addressed Oceanic/Remote	ATS A/G & G/A Addressed Polar	ATS A/G & G/A Addressed Autonomous	ATS G/A Broadcast Airport	AOC Airport	AOC TMA	AOC En Route
ATS	ATC - Clearance (ACL)	X	X	X	X	X					
ATS	ATC - Mic Check (AMC)	X	X	X	X	X		X			
ATS	ATC - DL Taxi Clearance (D-TAXI)	X	X								
ATS	ATC - Departure Clearance (DCL)	X									
ATS	ATC - Downstream Clearance (DCL)			X	X	X					
ATS	ATC - Pilot Preferences Downlink (PPD)	X	X	X	X	X					
ATS	ATC - Dynamic Route Availability (DYNAV)			X	X	X					
ATS	ATC - Arrival Manager Info (ARMAND)			X							
ATS	ATC - Common Traject. Coord. (COTRAC)		X	X	X	X	X				
ATS	Auto Downlink - FP Consist. (FLIPCY)	X	X	X	X	X					
ATS	Auto Downlink - FP Intent (FLIPINT)	X	X	X	X	X					
ATS	Auto Downlink - System Access Param (SAP)		X	X							
ATS	Flight Info - Operational Terminal Info (D-OTIS)	X	X	X				X			
AOC	Out Off On In (OOOI)								X		
AOC	NOTAM Request/NOTAMs								X		X
AOC	Free Text										X
AOC	Wx Request/Wx Report								X		X
AOC	Position Report									X	X
AOC	Flight Status								X	X	X
AOC	Fuel Status										X

- Technical-evaluation criteria (functional) are synthesized from the functional analysis and the traceability test for uniqueness and completeness

Suggested Criteria		Applicable Domains
Meets ATS Data Link Needs	A/G & G/A Addressed	APT, TMA, ENR, OPR, AOA
	Ground Originated Broadcast	APT, TMA, ENR, OPR, AOA
	A/A Addressed	APT, TMA, AOA
Meets AOC Data Link Needs	A/G & G/A Addressed	APT, TMA, ENR, OPR



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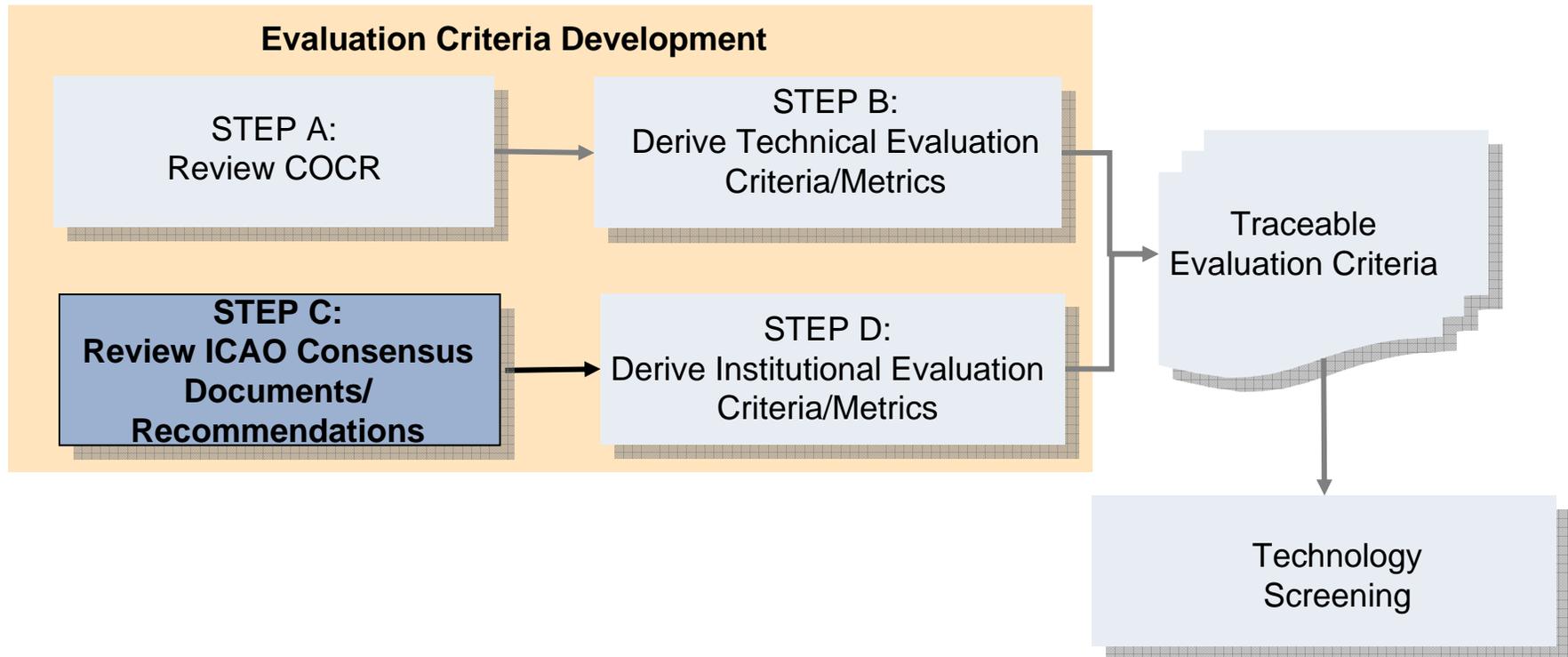
Evaluation Criteria Derivation – Step B (15)



- Technical-evaluation criteria (performance) come directly from inspection of the COCR and include
 - Capacity Criteria
 - Data Rate
 - Number of Users
 - Performance Criteria
 - QoS Priority Capability
 - Latency

- Traceability of functional technical criteria was shown previously as matrices that map functions to COCR services
- Traceability of performance criteria to COCR material is shown here

Criteria	References
Data Rate	<p><u>Table 6-19</u> A/G Capacity Requirements – Phase 1; <u>Table 6-20</u> A/G Capacity Requirements – Phase 2; <u>Table 6-21</u> A/G Capacity Requirements excluding A-EXEC service – Phase 2; <u>Table 6-22</u> A/G Capacity Requirements for each Aircraft using a Separate ‘Channel’ – Phase 1; <u>Table 6-23</u> A/G Capacity Requirements for each Aircraft using a Separate ‘Channel’ – Phase 2; <u>Table 6-24</u> A/G Capacity Requirements for each Aircraft using a Separate ‘Channel’ excluding the A-EXEC service – Phase 2</p>
Number of Users	<u>Table 6-1</u> PIAC Projections
QoS Priority	<p><u>Table 5-9</u> Data COS (Type DG – A/G Addressed); <u>Table 5-10</u> Data COS (Type DA – A/A Addressed); <u>Table 5-11</u> Data COS (Type DB – A/A Broadcast); <u>Table 5-12</u> COS Assignments (Network Management) – Phase 1 & 2 <u>Table 5-13</u> COS Assignments (ATS) – Phase 1 & 2; <u>Table 5-14</u> COS Assignments (AOC) – Phase 1 & 2</p>
Latency	<p><u>Table 5-6</u> FRS Allocated Data Performance (ATS) - Phase 1; <u>Table 5-7</u> FRS Allocated Data Performance (ATS) - Phase 2; <u>Table 5-8</u> FRS Allocated Data Performance (AOC) - Phase 1 & 2;</p>





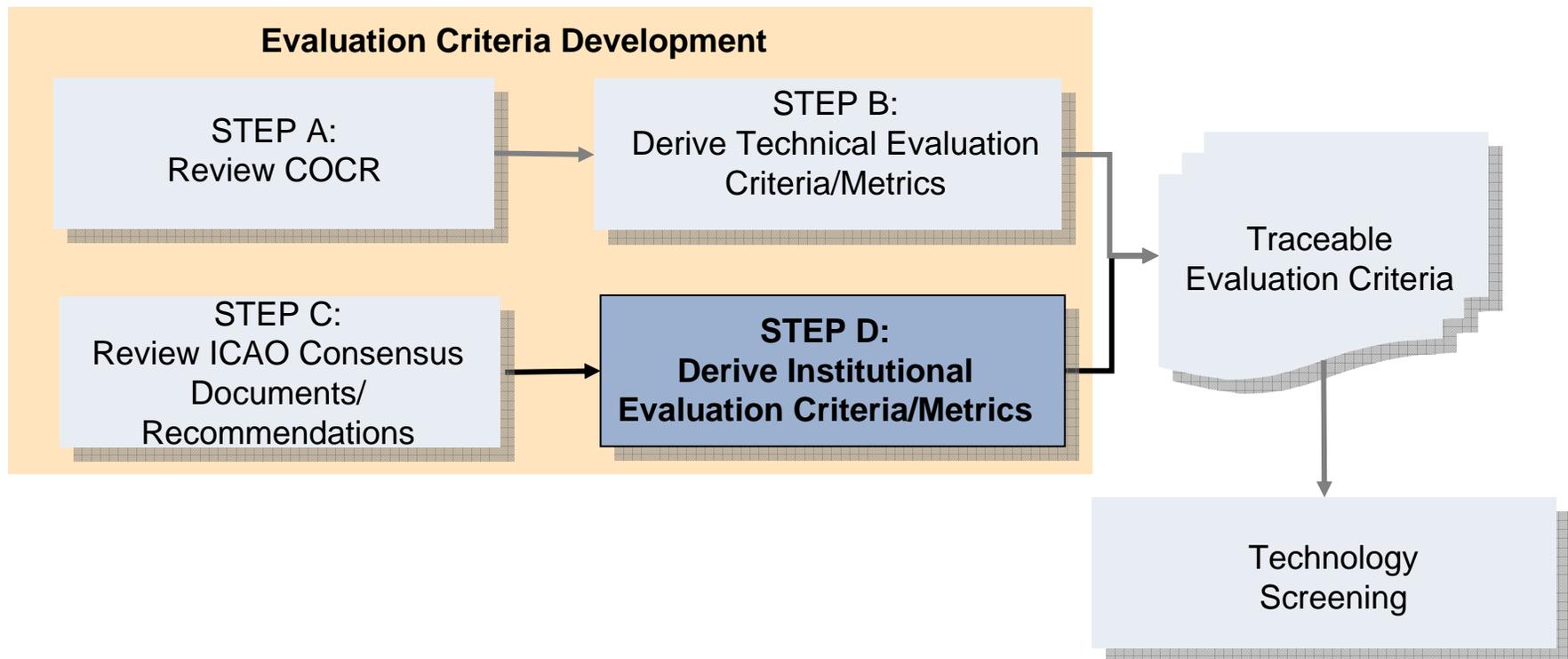
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Evaluation Criteria Derivation – Step C (2)



- The Institutional-Evaluation Criteria were essentially derived from Recommendation from the 11th Air Navigation Conference
 - 11th ICAO Air Navigation Conference (Sept/Oct 2003) recommendations were cited at ACP, Working Group C – 6th meeting (Agenda Item 6 presented by EUROCONTROL)
 - Recommendation 7/4 –a) Investigate new terrestrial and satellite-based technologies, on the basis of their potential for ICAO standardization for aeronautical mobile communications use, taking into account the safety-critical standards of aviation and the associated cost issue
 - Recommendation 7/5 – a) Continue to monitor emerging communication systems technologies but undertake standardization work only when the systems meet all of the following conditions:
 - 1) meet current and emerging ICAO ATM requirements
 - 2) be technically proven and offer proven operational benefits
 - 3) be consistent with the requirements for safety
 - 4) be cost-beneficial
 - 5) be consistent with the global plan for CNS/ATM Systems

- To further consider Recommendation 7/5 part 5, the global plan for CNS/ATM systems was reviewed
 - The global plan indicates in Section 5.14 [Future Communication] Trends,
 - “ The most important question to be asked when considering a new system is whether it meets existing or emerging operational and user requirements. Other factors to be considered are standardization, certification, harmonious deployment by various users, and cost benefit considerations”
 - The Global Plan also includes a Statement of ICAO Policy on CNS/ATM Systems Implementation and Operation (Appendix A to Chapter 2)
 - Statement outlines requirements for implementation and operation of future CNS/ATM systems including requirement for flexible transition and ability to provide continuous service with specified integrity and with required priority, security and interference protection.





Evaluation Criteria Derivation – Step D (2)



- Upon review of ANC-11 recommendations and the Global Plan for CNS/ATM systems, nine institutional evaluation criteria have been defined
 - Technical Readiness Level
 - Standardization Status
 - Certifiability
 - Cost – Ground Infrastructure
 - Cost – Aircraft
 - Spectrum Protection
 - Security – Authentication and Integrity
 - Security – Robustness to Intentional Jamming
 - Transition
- Traceability of these criteria is provided on the following slides



Evaluation Criteria Derivation – Step D (3)



	Evaluation Criterion	Description (& sub-items)	Traceability
1	Technical Readiness Level	Provides an indication of the technical maturity of the proposed technology (Technical Readiness Level)	11th ICAO Air Navigation Conference (Sept/Oct 2003) Recommendation 7/5 – Number 2
2	Standardization Status	Indicates the relevance and maturity of a proposed technologies standardization status.	Global Air Navigation Plan for CNS/ATM Systems – ICAO Doc 9750 (5.14) 11th ICAO Air Navigation Conference (Sept/Oct 2003) Recommendation 7/5 – Number 3
3	Certiifiability	Provides a relative measure of the candidate complexity.	Global Air Navigation Plan for CNS/ATM Systems – ICAO Doc 9750 (5.14) 11th ICAO Air Navigation Conference (Sept/Oct 2003) Recommendation 7/5 – Number 3
4	Ground Infrastructure Cost	Estimates cost to service provider to provide coverage to a geographically large sector.	Global Air Navigation Plan for CNS/ATM Systems – ICAO Doc 9750 (5.14) 11th ICAO Air Navigation Conference (Sept/Oct 2003) Recommendation 7/5 – Number 4



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Evaluation Criteria Derivation – Step D (4)



	Evaluation Criterion	Description (& sub-items)	Traceability
5	Cost to Aircraft	Estimates relative cost to upgrade avionics with new technology.	Global Air Navigation Plan for CNS/ATM Systems – ICAO Doc 9750 (5.14) 11th ICAO Air Navigation Conference (Sept/Oct 2003) Recommendation 7/5 – Number 4
6	Spectrum Protection	Gauges the likelihood of obtaining the proper allocation of the target spectrum.	Global Air Navigation Plan for CNS/ATM Systems – ICAO Doc 9750 (Statement of ICAO Policy on CNS/ATM Systems Implementation and Operation, Appendix A to Chapter 2, pg 1-2-8)
7	Security – A&I	Assesses whether authentication and data integrity are provided	COCR Security Requirements (Table 4-11) Global Air Navigation Plan for CNS/ATM Systems – ICAO Doc 9750 (Statement of ICAO Policy on CNS/ATM Systems Implementation and Operation, Appendix A to Chapter 2, pg 1-2-8)
8	Security – Robustness to Jamming	Assesses technology resistance to jamming.	COCR Security Requirements (Table 4-11)
9	Transition	Assesses acceptable transition characteristics, including: <ul style="list-style-type: none"> •return on partial investment •ease of technical migration (spectral, physical) •ease of operational migration (air and ground users) 	Global Air Navigation Plan for CNS/ATM Systems – ICAO Doc 9750 (Statement of ICAO Policy on CNS/ATM Systems Implementation and Operation, Appendix A to Chapter 2, pg 1-2-7)



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*Summary of Derived Evaluation
Criteria*



Derived Technical Evaluation Criteria



- Functional Criteria
 - Meets ATC Needs
 - A/G & G/A Addressed in APT, TMA, ENR, ORP & AOA Domains
 - Ground Originated Broadcast in APT, TMA, ENR, ORP & AOA Domains
 - A/A Addressed in TMA & AOA Domains
 - Meets AOC Needs
 - A/G & G/A Addressed in APT, TMA, ENR, ORP, & AOA Domains
- Performance Criteria
 - Data Rate
 - Number of Users
 - Quality of Service
 - Latency



Derived Institutional Evaluation Criteria



- Maturity for Aeronautical Environment
 - Technical Readiness Level
 - Standardization Status
 - Certification Issues
- Cost
 - Ground Infrastructure
 - Avionics equipage
- Safety and Security
 - Spectrum Protection
 - Security – Authentication and Integrity
 - Security – Robustness to Deliberate RF Interference
- Transition
 - Return on partial investment
 - Ease of technical migration (spectral, physical)
 - Ease of operational migration (air and ground users)



Using Technology Evaluation Criteria



- Derived technology evaluation criteria were presented to the ICAO Aeronautical Communication Panel in March 2006
 - Comments have been received and addressed
- Metrics for evaluation criteria and an evaluation process have been developed
 - Technical performance metrics are based on published requirements of the COCR version 1.0
- Technology Screening work has been completed; results will be briefed later today