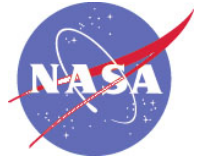




ITT



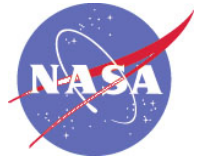
FCS Technology Investigation Conclusions and Recommendations

**Presented by
Steve Henriksen, ITT Corp.
James Budinger, NASA Glen Research Center**

ICNS 2008



Outline

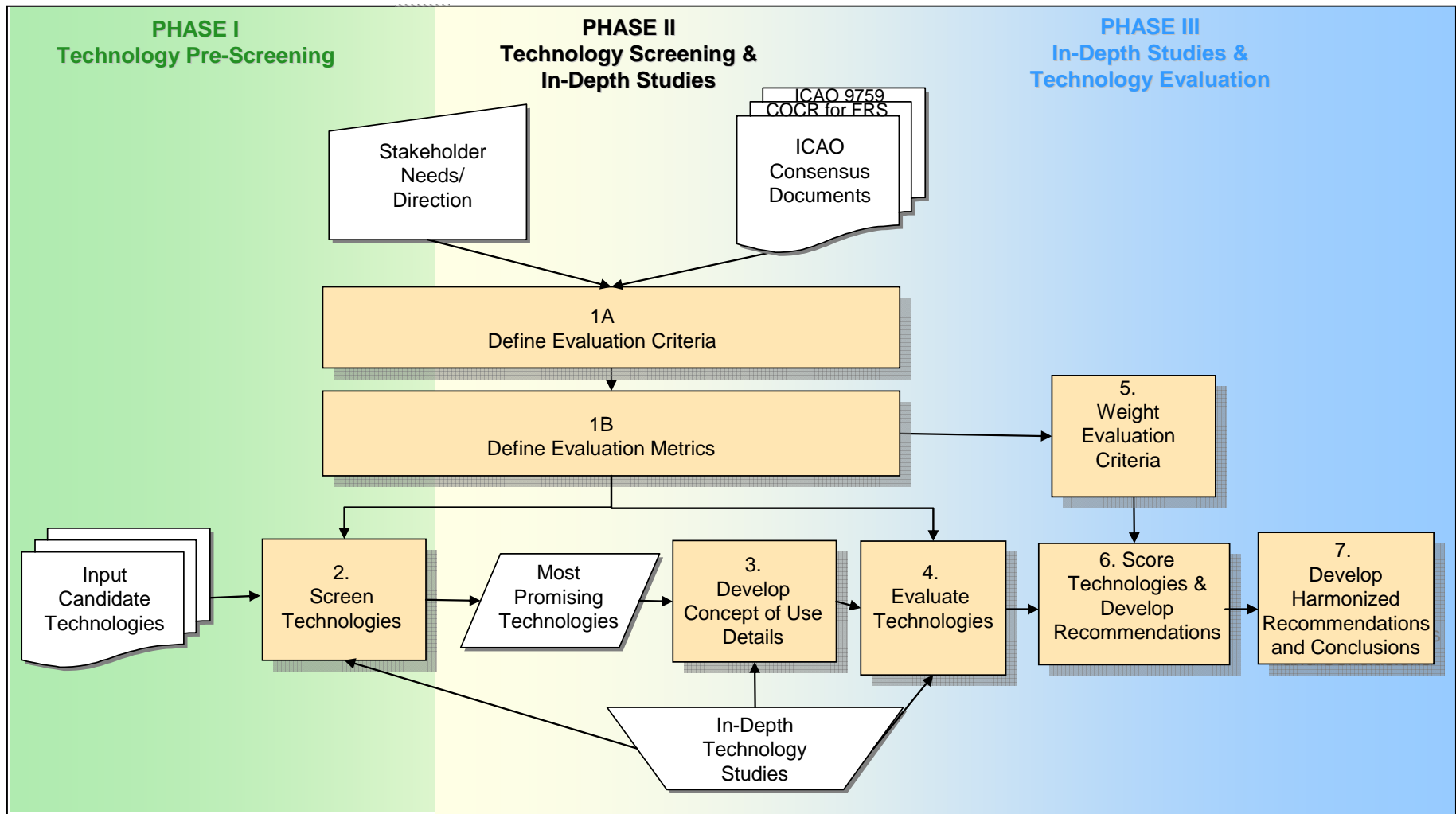


- Background
- Approach
- Evaluation Criteria
- Technology Inventory
- Technologies in Focus
- ITT In-Depth Technology Studies
- Technology Evaluations
- Evaluation Results
- Observations
- Recommendations
- Harmonized Recommendations

- Under EUROCONTROL/FAA Action Plan 17 (AP17), Three themes for Future Communications Study (FCS)
 - (1) Identification of requirements and operating concepts
 - (2) [Identification of enabling technologies](#)
 - (3) Development of a future communications roadmap
- Joint effort between US team (FAA, NASA, ITT) and Europe team focused on the second theme
 - To identify technologies that can meet future needs of aviation for air-ground communications in the year 2015+
- Three Phases
 - Phase I, Technology Pre-Screening (December 2004)
 - Phase II, Technology Screening and In-Depth Studies (May 2005)
 - Phase III, Additional In-Depth Studies & Evaluation (May/Oct. 2007)



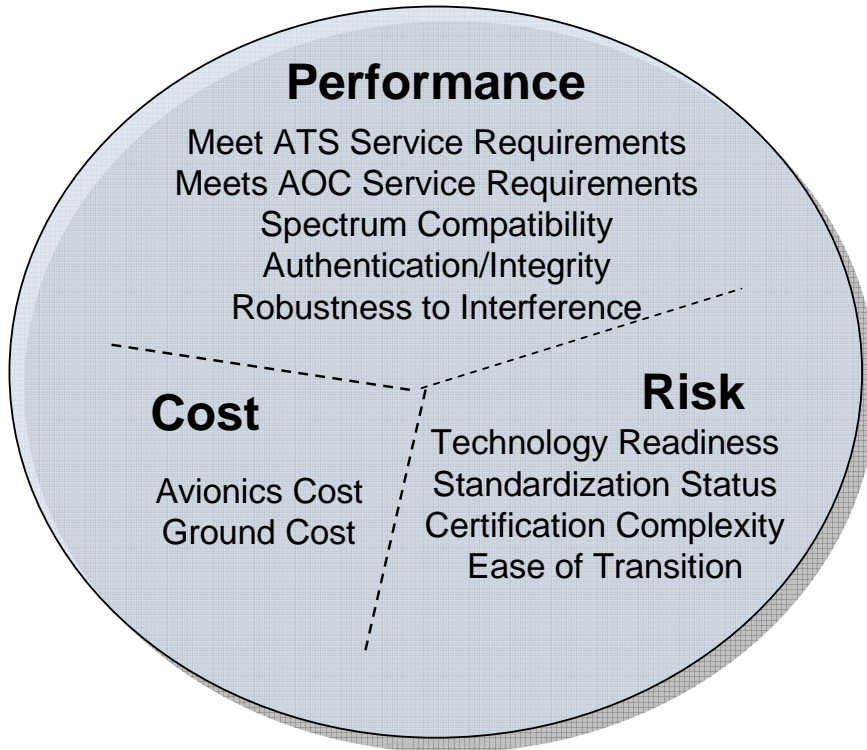
ITTT Approach: ITT Methodology



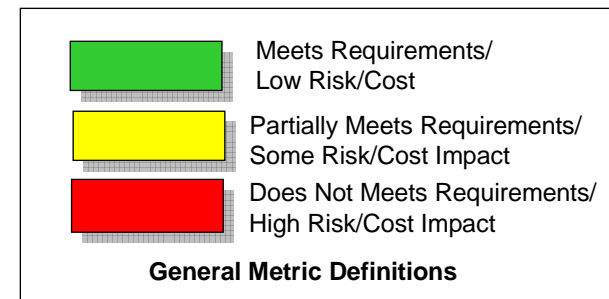
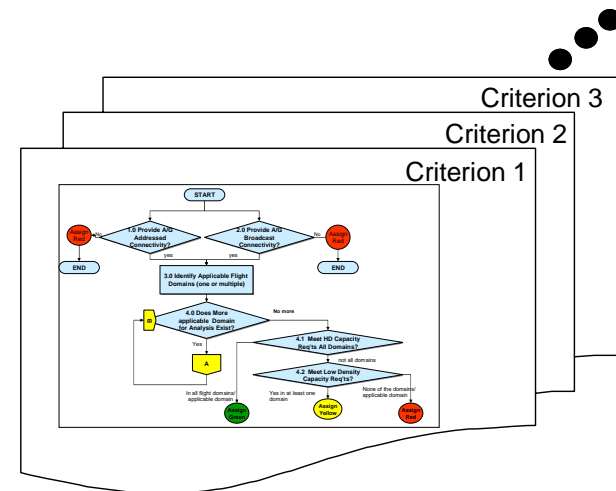


ITT

Evaluation Criteria



11 criteria traceable to the COCR and consensus ICAO documents were derived in FCS Phase II



In FCS Phase III, criteria definitions and associated metrics were revised to reflect updates to the COCR and process diagrams to defined the evaluation steps were developed



Technology Inventory



Technology Family	Candidates
Cellular Telephony Derivatives	WCDMA (US)/UMTS FDD (Europe), TD-CDMA (US)/UMTS TDD (Europe), CDMA2000 3x, CDMA2000 1xEV, GSM/GPRS/EDGE, TD-SCDMA, DECT
IEEE 802 Wireless Derivatives	IEEE 802.11, IEEE 802.15, IEEE 802.16, IEEE 802.20
Public Safety and Specialized Mobile Radio	APCO P25, TETRA Release 1, TETRAPOL, IDRA, iDEN, EDACS, APCO P34, TETRA Release 2 (TAPS), TETRA Release 2 (TEDS)
Satellite and Other Over Horizon Communication	SDLS, Swift Broadband (Aero B-GAN), Iridium, GlobalStar, Thuraya, Integrated Global Surveillance and Guidance System (IGSAGS), HF Data Link, Digital Audio Broadcast, Custom Satellite System
Custom Narrowband VHF Solutions	VDL Mode 2, VDL Mode 3, VDL Mode E, VDL Mode 4, E-TDMA
Custom Broadband	ADL, Flash-OFDM, UAT, Mode-S, B-AMC, LDL, AMACS
Military	SINCGARS, HAVEQUICK
Other	APC Telephony

- **Common Technology Inventory** including input from NASA release of RFIs, inputs from ICAO WG-C (now WG-T) ACP members, and literature reviews

United States	Common shortlist / Screening Results	Europe
Continental	<ul style="list-style-type: none"> •TIA-902 (P34) •LDL •W-CDMA 	Continental
Oceanic/Remote	<ul style="list-style-type: none"> •Inmarsat SBB •Custom Satellite 	Oceanic/Remote
Airport	<ul style="list-style-type: none"> •IEEE 802 -16e 	Airport



ITT In-Depth Technology Studies



	In-Depth Study Topic	Note
1	L-Band Air/Ground Communication Channel Characterization	Created ray-tracing simulation to develop tap-delay line models of the L-band (960-1024 MHz) supporting evaluation of LDL and P34
2	L-Band Digital Link (LDL) Technology Performance Assessment	MATLAB Simulink® model developed to assess LDL physical layer performance in the defined L-Band A/G channel
3	L-Band Technology Cost Assessment for Ground Infrastructure	L-Band business case analysis for an L-Band ground infrastructure
4	L-Band Interference Testing	<ol style="list-style-type: none"> 1. UAT, Mode S interference modeling and simulation using SPW modeling tool for P34 and LDL waveforms 2. Bench tests conducted to evaluate DME susceptibility to candidate FCS waveforms (based on WCDMA, P34, LDL definitions)
5	TIA_902 (P34) Technology Performance Assessment	<ol style="list-style-type: none"> 1. OPNET simulation of P34 net entry and data transfer performance 2. MATLAB Simulink® model developed to assess P34/TIA-902 physical layer performance in the defined L-Band A/G channel
6	P34/TIA-902 Technology Intellectual Property Assessment	Assessment of IP impact for patents claimed in TIA-902 (P34) standards
7	Wideband Code Division Multiple Access (WCDMA) Functional Assessment	Functional analysis of UMTS/WCDMA network architecture
8	Satellite Technology Availability Performance	Evaluation of satellite technology availability performance using fault-tree model of RTCA DO-270
9	IEEE 802.16e Performance Assessment in Aeronautical C-Band Channel	MATLAB Simulink® modeling of 802.16e on the surface environment implementing OU aeronautical C-band channel model

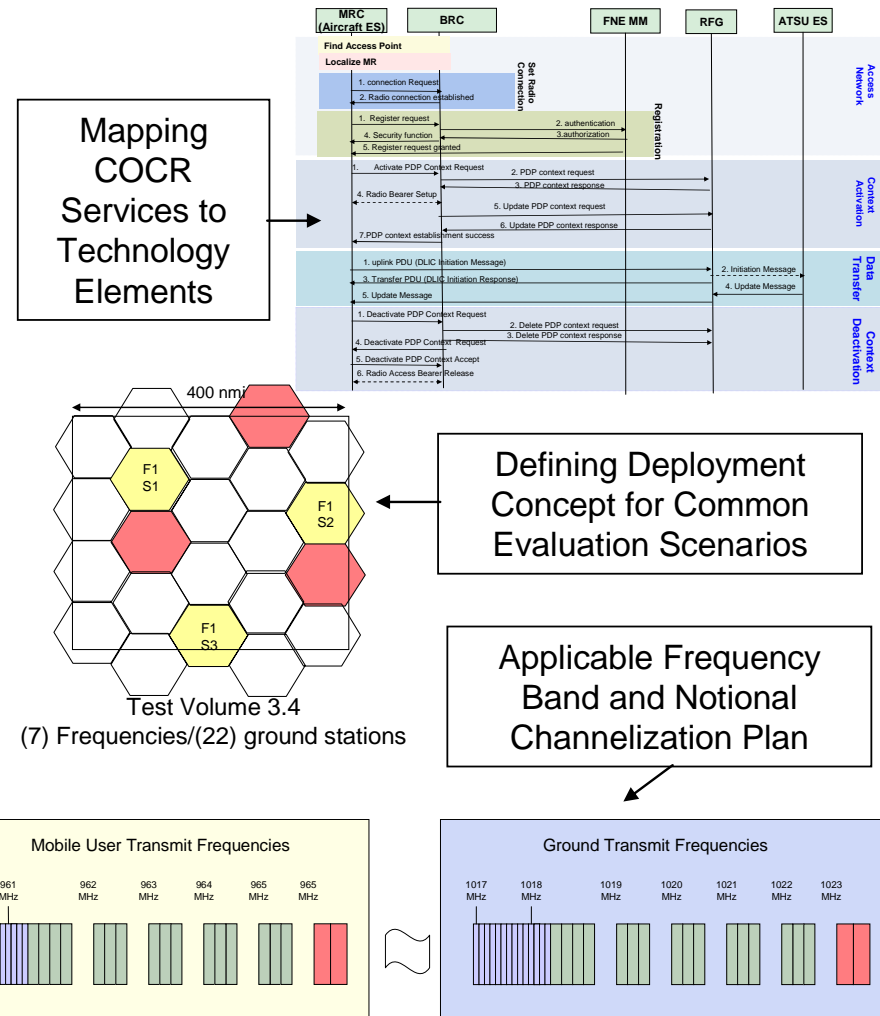


ITT

Technology Evaluations (1)



- Develop Concept of Use for the selected technologies (P34, LDL, WCDMA, B-AMC, AMACS)
- Each Concept of Use includes:
 - Applicable technology features/specifications
 - Functional architecture
 - Deployment concept for common evaluation scenarios
 - Deployment frequency band and channelization considerations





ITT Technology Evaluations (2)



- Assess technologies using the process diagrams defined for each evaluation criterion

Component Specifications

- Packet Data Spec 2003
- Mobility Ma 5/c
- Link Layer Control 2/02
- MAC/Radio Link Adaptation 2/02
- Physical Layer 2/03

Concept of Use Information

Criteria Evaluation Results Table

		Candidate 1	Candidate 2	Candidate 3
Provides ATS Services within Requirements (sans A-EXEC)	A Capacity	Green	Green	Green
	B # of Users	Green	Green	Green
	C QoS	Green	Green	Green
	D Environment	Yellow	Yellow	Yellow
Provides ATS & AOC Services within Requirements (sans A-EXEC)	A Capacity	Green	Green	Green
	B # of Users	Green	Green	Green
	C QoS	Green	Green	Green
	D Environment	Yellow	Yellow	Yellow
TRL		Green	Green	
Standardization Status		Yellow	Red	
Certification		Yellow	Yellow	
Gnd Cost		Green	Green	
Avionics Cost		Yellow	Yellow	
Spectrum		Yellow	Red	
Authentication & Integrity		Green	Green	
Robustness to Interference		Yellow	Yellow	
Transition		Green	Green	

Evaluation Process Flow Diagrams



ITT Evaluation Results (Unweighted)



	Evaluation Criterion		TIA-902 (P34)	LDL	WCDMA	B-AMC	AMACS
1	Provides ATS A/G Data Services within Requirements (sans A-EXEC)	A - Capacity	Green	Green	Green	Green	Green
		B - PIAC	Green	Green	Green	Green	Green
		C - QoS	Green	Green	Green	Green	Green
		D - Environment	Yellow	Yellow	Yellow	Green	Green
2	Provides ATS AOC A/G Data Services within Requirements (sans A-EXEC)	A - Capacity	Green	Yellow	Green	Green	Yellow
		B - PIAC	Green	Green	Green	Green	Yellow
		C - QoS	Green	Green	Green	Green	Green
		D - Environment	Yellow	Yellow	Yellow	Green	Green
3	Technical Readiness Level		Yellow	Yellow	Green	Yellow	Red
4	Standardization Status		Yellow	Yellow	Yellow	Red	Red
5	Certification		Yellow	Yellow	Red	Red	Red
6	Ground Infrastructure Cost		Green	Yellow	Red	Yellow	Yellow
7	Avionics Cost		Yellow	Yellow	Yellow	Yellow	Yellow
8	Spectrum		Yellow	Yellow	Red	Yellow	Yellow
9	Authentication and Integrity		Green	Yellow	Green	Gray	Gray
10	Robustness to Interference		Yellow	Yellow	Yellow	Yellow	Yellow
11	Transition		Green	Green	Yellow	Yellow	Yellow

* Gray indicates insufficient information at the time of evaluation



ITT

Evaluation Results -- Weighted Criteria

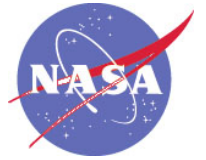


	No.	Evaluation Criterion		TIA-902 (P34)	LDL	WCDMA	B-AMC	AMACS
Most Important	8	Spectrum						
	1	Provides ATS A/G Data Services within Requirements (sans A-EXEC)	A - Capacity					
			B - PIAC					
			C - QoS					
			D - Environment					
Very Important	3	Technical Readiness Level						
	6	Ground Infrastructure Cost						
	7	Avionics Cost						
	2	Provides ATS AOC A/G Data Services within Requirements (sans A-EXEC)	A - Capacity					
			B - PIAC					
			C - QoS					
			D - Environment					
Important	4	Standardization Status						
	5	Certification						
	9	Authentication and Integrity						
	10	Robustness to Interference						
	11	Transition						



ITT

Observations: General and VHF Band

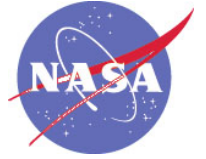


1. The new communication components introduced into the FCI should reuse emerging data communications technology and standards to the maximum extent possible
2. No single technology meets all requirements across all operational flight domains
 - Future aeronautical operating concept requires a complementary set of communications capabilities across multiple frequency bands
 - Four operational flight domains: Airport surface, Airport zone/TMA/En route, Oceanic/Remote/Polar, Autonomous Operation Area
 - To some extent, the propagation conditions determine which frequency band is able to support which flight domain
3. Existing technologies providing dedicated voice and data services should be used to their fullest extent
 - VHF aeronautical spectrum will continue to support DSB-AM voice communications and preserve the option for an initial data link capability
 - A long-term strategy for use of the VHF aeronautical band requires further consideration



ITT

Observations: Aeronautical L-band (1)

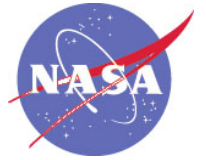


4. The aeronautical L-band spectrum (960 MHz – 1164 MHz) is a candidate band for supporting a new data link communication capability
 - This spectrum provides an opportunity to support objectives for future global communication systems; however no evaluated technology in L-band (as defined) fully addresses all requirements and limitations of the operating environment
5. No one evaluated technology meets all requirements for the defined data link; instead, technology options for an L-band Digital Aeronautical Communication System (L-DACS) have been defined based on evaluations drawing on features of evaluated systems

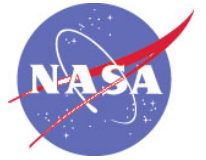


ITT

Observations: Aeronautical L-band (2)



6. Desirable features for an aeronautical L-band (960-1024 [1164] MHz) technology include:
- Existing standard for safety application with some validation work performed
 - Multi-carrier modulation (power efficient modulation for the aeronautical L-band fading environment)
 - Low duty cycle waveform with narrow-to-broadband channels (more likely to achieve successful compatibility with legacy L-band systems without clearing spectrum)
 - Adaptable/scalable features (improving flexibility in deployment and implementation, and adaptability to accommodate future demands)
 - Native mobility management and native IP interface (increasing flexibility and providing critical upper layers compatibility with worldwide data networking standards)



7. Two options for a L-band Digital Aeronautical Communication System (L-DACS) were identified

L-DACS Options	Access Scheme	Modulation Type	Originating Technologies
Option 1	FDD	OFDM	B-AMC, TIA 902 (P34)
Option 2	TDD	CPFSK/GMSK type	LDL, AMACS

8. High-level evaluation of economic feasibility of implementing a L-band ground infrastructure (Present Worth Simple Payback Model with MARR of 5%) indicates positive business case can be achieved for a commercial service provider within four years

9. Aeronautical C-band (5000-5030 MHz and 5091-5150 MHz)
 - There is capacity not utilized; given path loss constraints, this band is most applicable to airport surface use where communication distances are short
 - Some concepts for surface communications require substantially higher data rates than are needed in other airspace domains and may warrant a specific technology solution

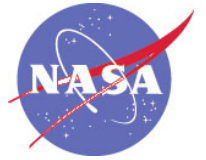
10. Specific to aeronautical C-band allocation, IEEE 802.16e is extremely well matched to the airport surface in terms of capability and performance

11. Aeronautical satellite systems offer unique services that can be applied to large and/or remote geographic areas and can provide supplemental coverage to the terrestrial communication infrastructure



ITT

Observations: FRS



12. This study assumed that the FRS will operate within an Internet Protocol (IP) networking environment

- Further work on finalizing the selection of the FRS should include verification that the required performance can be achieved on end-to-end basis within the FCI.
- This should include appropriate methods of assuring that the required quality of service for safety related applications can be maintained across the entire communication system



Recommendations: C-band

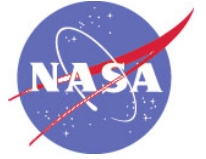


- Identify the portions of the IEEE 802.16e standard best suited for airport surface wireless mobile communications, identify and develop missing required functionalities and propose an aviation specific standard to appropriate standardization bodies
- Evaluate and validate the performance of aviation specific standard wireless mobile communications networks operating in the relevant airport surface environments through trials and test bed development
- Propose a channelization methodology for allocation of safety and regularity of flight services in the band to accommodate a range of airport classes, configurations and operational requirements
- Complete the investigation of compatibility of prototyped C-band components with existing systems in the C-band in the airport surface environment and interference with other users of the band



ITT

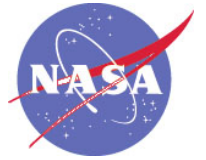
Recommendations: Satellite Band



- Continue monitoring the satellite system developments and assessment of specific technical solutions to be offered in the timeframe defined in the COCR as these next generation satellite systems become better defined
- Update existing AMS(R)S SARPs performance requirements to meet future requirements
- In order to support the new AMS(R)S SARPs, consider the development of a globally applicable air interface standard for satellite systems supporting only safety related communications



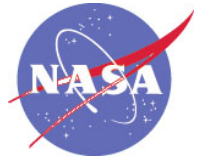
Recommendations: VHF Band



-
- In the long term reconsider the potential use of the VHF for new technologies when sufficient spectrum becomes available to support all or part of the requirements



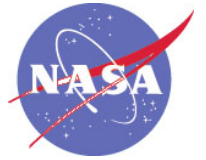
Recommendations: L-band (1)



- Define interference test requirements and associated outputs that can be used to determine compatibility of future candidate aeronautical communication technologies with existing aeronautical L-band systems
- Pursue detailed compatibility assessment of candidate physical layers for an L-band aeronautical digital link, including interference testing
- Pursue definition/validation of technology that is derived or adapted from existing standards for use as an L-band Data-link Aeronautical Communications System (L-DACS) that can be used to initiate an aeronautical standardization effort (and meet ICAO requirements for such an effort)



Recommendations: L-band (2)



- Complete the investigation of compatibility of prototyped L-DACS components with existing systems in the L-band particularly with regard to the onboard co-site interference and agree on the overall design characteristics
- Considering the design trade-offs, propose the appropriate L-DACS solution for input to a global aeronautical standardization activity
- Considering that B-AMC, AMACS and TIA-902 (P34) have provisions to support air to air services, conduct further investigation of this capability as a possible component of L-DACS