FCS Technology Investigation Status

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Introduction & Outline

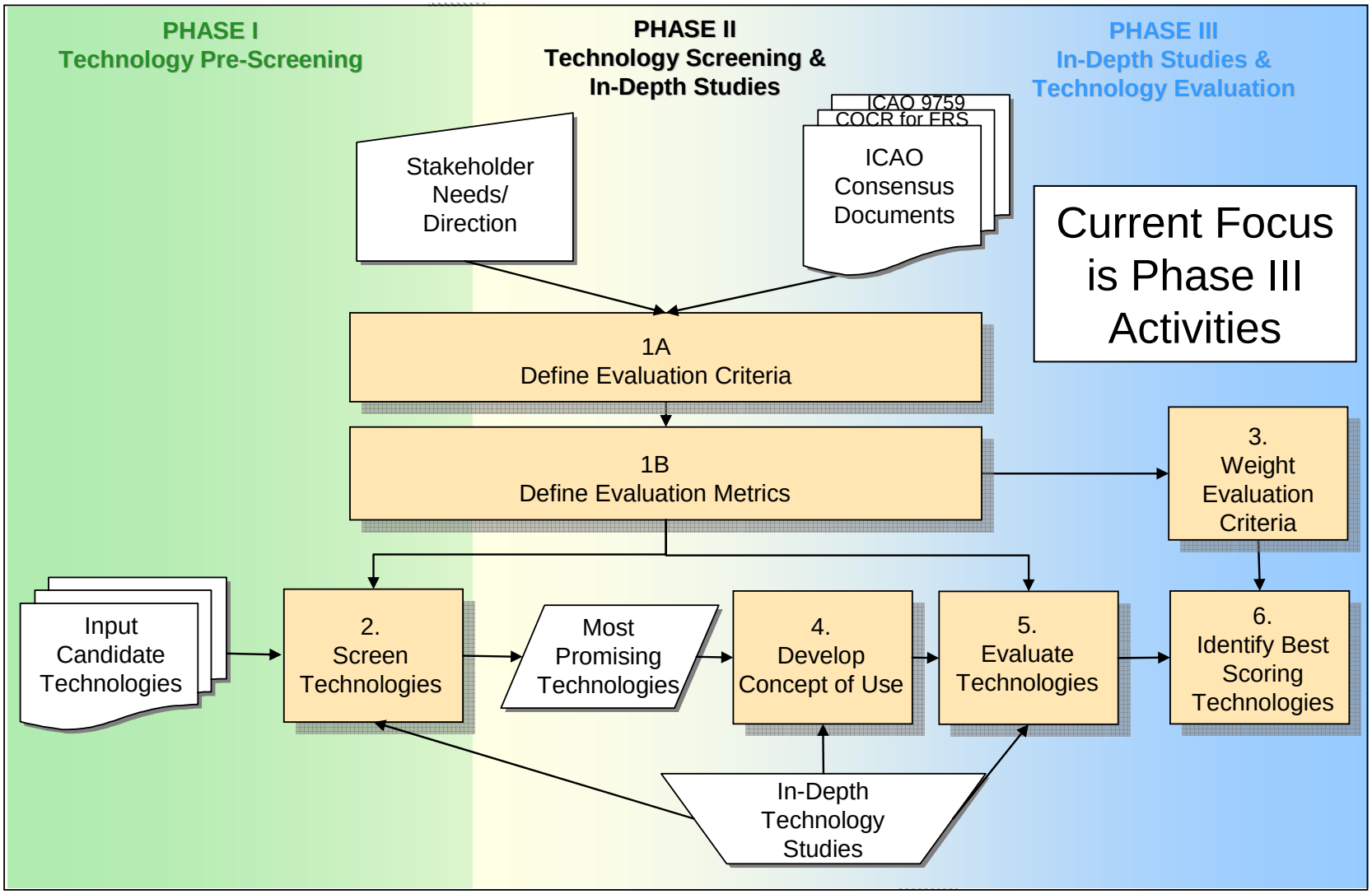
- This briefing describes work supported a cooperative research program among NASA, FAA & EUROCONTROL to identify technologies for future aeronautical mobile radio communications

- Outline
  - Background
  - Methodology
  - Evaluation Criteria
  - Technology Screening
  - In-Depth Technology Investigations
  - Technology Evaluations & Next Steps

Background

- Genesis of current aeronautical communications objectives can be traced to ICAO 11th Air Navigation Conference (2003)
  - Conference recommendations included:
    - Develop evolutionary approach for globally interoperable air/ground communications
    - Investigate future technology alternatives for air/ground communications
- FAA and EUROCONTROL cooperative research and development program, the Future Communication Study, addresses these recommendations
  - Three technical research themes relate to identification of most suitable technology candidates for the future communication infrastructure (2020 and beyond)
    - 1) Identification of requirements and operating concepts
    - 2) Technology alternatives assessment
    - 3) Development of a future communications roadmap

Methodology



Evaluation Criteria

- Evaluation criteria derived through structured analysis of:
  - FCS Operating Concept and Communication Requirements for the Future Radio System (COCR)
  - ICAO recommendations for future communications
    - ANConf/11 Recommendations
    - Global Air Navigation Plan for CNS/ATM Systems, Doc 9750

	Evaluation Criterion	Description
1	Meets ATS Data Link Needs	Measure of the ability of a technology to provide sufficient functional and performance capability to meet operational and environmental requirements of the COCR for ATS services
2	Meets AOC Data Link Needs (in addition to ATS Data Link Needs)	Measure of the ability of a technology to provide sufficient functional and performance capability to meet operational and environmental requirements of the COCR for AOC services (in addition to ATS services)
3	Technical Readiness Level	Provides an indication of the technical maturity of the proposed technology in the context of the FCS communication roadmap
4	Standardization Status	Indicates the relevance and maturity of a proposed technology's standardization status.
5	Certification	Provides a relative measure of the candidate's complexity.
6	Ground Infrastructure Cost	Estimates relative cost to service provider to provision services to a geographically large area
7	Cost to Aircraft	Estimates relative cost to upgrade avionics with new technology
8	Spectrum	Gauges the likelihood of obtaining the proper allocation of the target spectrum and the compatibility of proposed technology with existing aeronautical systems in target band (second component not included in pre-screening)
9	Security – A&I	Provides an assessment of technology authentication and data integrity capabilities
10	Security – Robustness to Interference	Provides a relative assessment of technology robustness to interference
11	Transition	Assesses acceptable transition characteristics, including: Return on partial investment Ease of technical migration (spectral, physical) Ease of operational migration (air and ground users)

Technology Screening

Technology Family	Candidates
Cellular Telephony Derivatives	TDMA (IS-136); CDMA (IS-95A); CDMAone (IS-95B); CDMA2000 1xRTT; W-CDMA (US)/UMTS FDD (Europe); TD-CDMA (US)/UMTS (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; ETST HIPERPAN; ETSI HIPERLAN; ESTI HIPERMAN
Public Safety and Specialized Mobile Radio	APCO P25 Phase 1; APCO P25 Phase 2; TETRA Release 1; TETRAPOL; IDRA; IDEN; EDACS; APCO P34; TETRA Release 2 (TAPS); TETRA Release 2 (TEDS); Project MESA
Satellite and Other Over the Horizon Communication	SDLS; Connexion by Boeing; Aero B-GAN; Iridium; GlobalStar; Thuraya; Integrated Global Surveillance and Guidance System (IGSAGS); HF Datalink; Custom Satellite System; Digital Audio Broadcast
Custom Narrowband VHF Solutions	VDL Mode 2; VDL Mode 3; VDL Mode 3 w/SAIC; VDL Mode E; VDL Mode 4 ; E-TDMA
Custom Broadband Solutions	ADL; Flash-OFDM; UAT; Mode-S; B-VHF (MC-CDMA); LDL; (E-TDMA in L-Band)
Military	Link 16; SINCGARS; EPLRS; HAVEQUICK; JTRS;
Other	APC Phone (Airphone, Aircell, SkyWay)

- Over 50 candidate technologies were screened to identify most promising candidates
  - Screening process applied a subset of metrics associated with select evaluation criteria including:
    - Meet ATS (and AOC) data link functional and performance requirements
    - Cost (ground station requirements)
    - Spectrum

Technology Screening (2)

		Screened Technologies
General	Continental Domain (Airport, Terminal, En Route)	APCO P34 (TIA 902) LDL W-CDMA *B-AMC** *AMACS**
Domain-Specific	Oceanic/ Remote Domain	Inmarsat SBB Custom Satellite System (e.g. SDLS)
	Airport Domain	IEEE 802.16e

* Screening process applied to technical specifications under development; fully screening will be applied when technical details are finalized

- Six technologies emerge from screening process
  - Organized into two categories:
    - General solution for FRS (called continental domain)
    - Best performers in the context of specific flight domains with unique environments
- Two additional general solution technologies will be considered further when technical details are finalized
  - B-AMC and AMACS

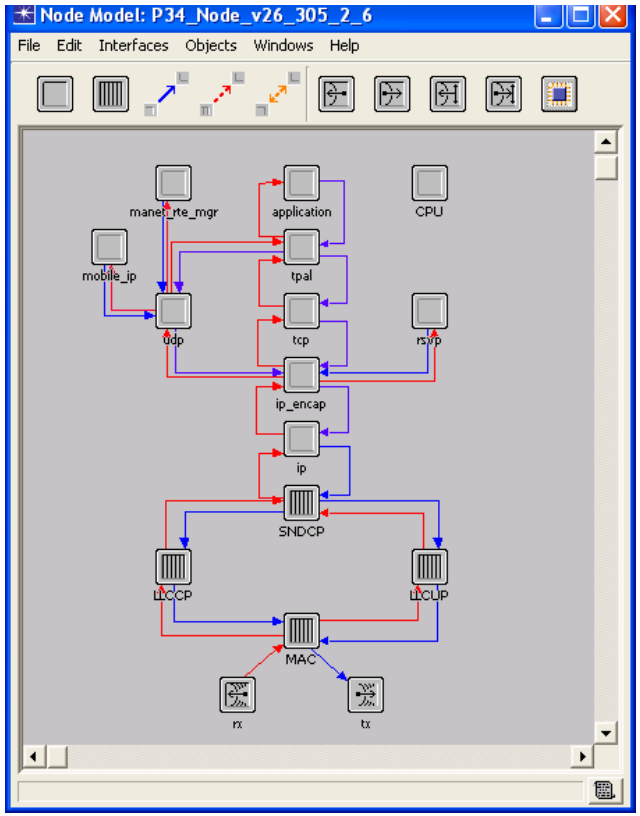
In-Depth Technology Investigations

- In-depth technologies were conducted to support technology evaluations and assess applicability of technologies to meet specific needs and requirement for the Future Radio System
  - 1) L-Band Aeronautical Channel Model Definition
    - Develop channel model to support evaluation of technology performance in anticipated channel environment
  - 2) Technology Investigations
    - APCO P34 (TIA 902) Performance Evaluations
      - Evaluation of upper layer (layer 2/3) protocols (OPNET simulation)
      - Evaluation of performance in L-Band channel (MATLAB SIMULINK)
    - LDL Performance Evaluation
      - Evaluation of performance in L-Band channel (MATLAB SIMULINK)
    - W-CDMA Service Modeling
      - Mapping Future Radio System services to W-CDMA service context
    - 802.16e Performance Evaluation
      - Evaluation of performance in aeronautical C-Band channel (MATLAB SIMULINK)
    - Satellite Availability Investigations
      - Identification of failure event drivers in availability calculations
  - 3) L-Band Technology Business Case Assessment
  - 4) Definition of Technology Concept of Use for FCI

P34 Performance Assessment

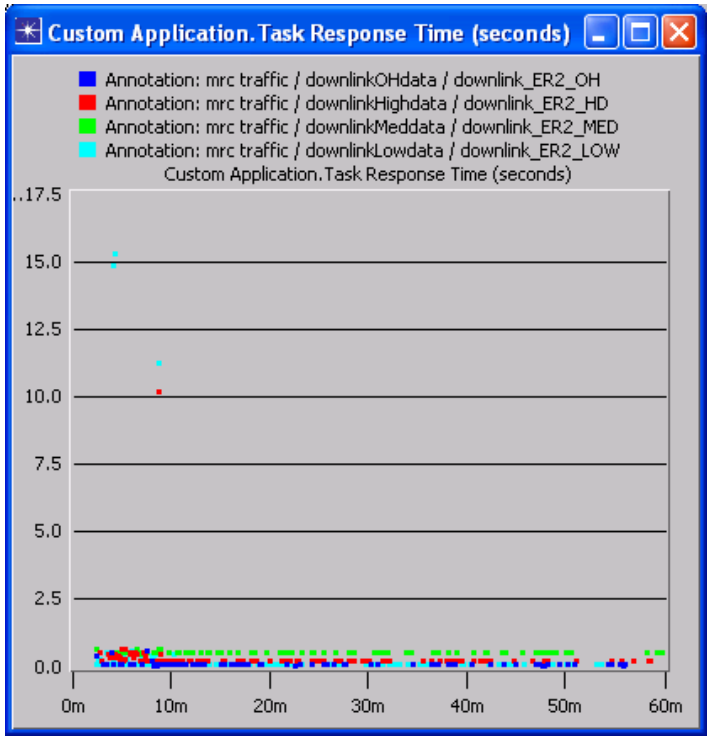
Simulation Node Model

- Based on OPNET wireless LAN server node model
- Customized SNDCP, LLC CP, LLC UP, and MAC processes



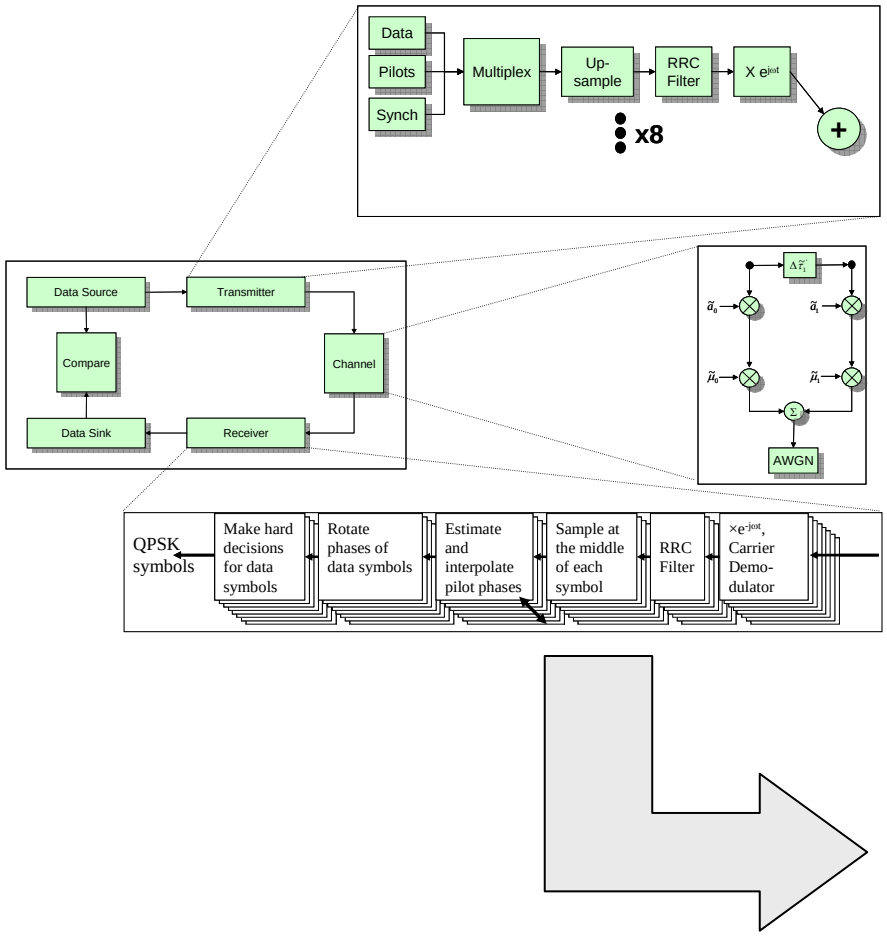
Simulation Results

- Results indicate sub-network latencies over P34 protocols (SNDCP, LLC CP, LLC UP, MAC) meet COCR latency requirements
  - Some startup outliers, but 95% is under 0.7 seconds



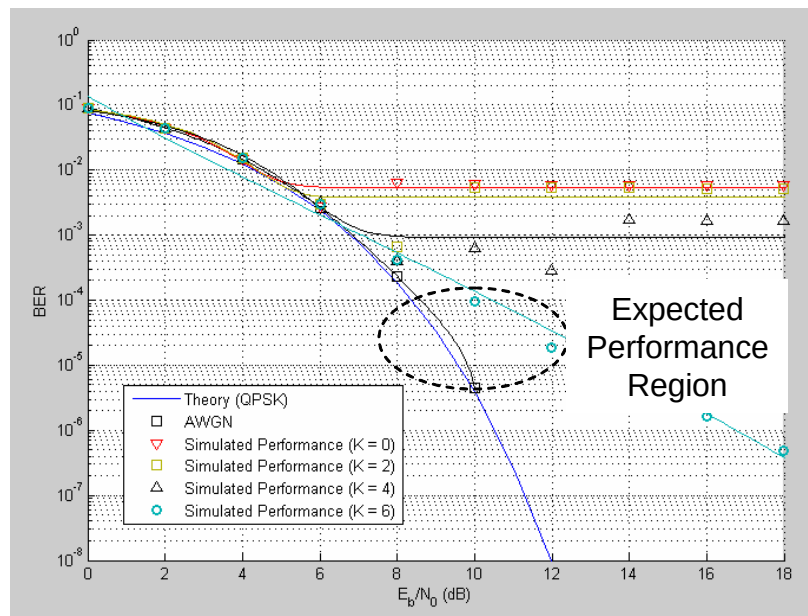
P34 Performance Assessment (2)

Simulation Block Diagram



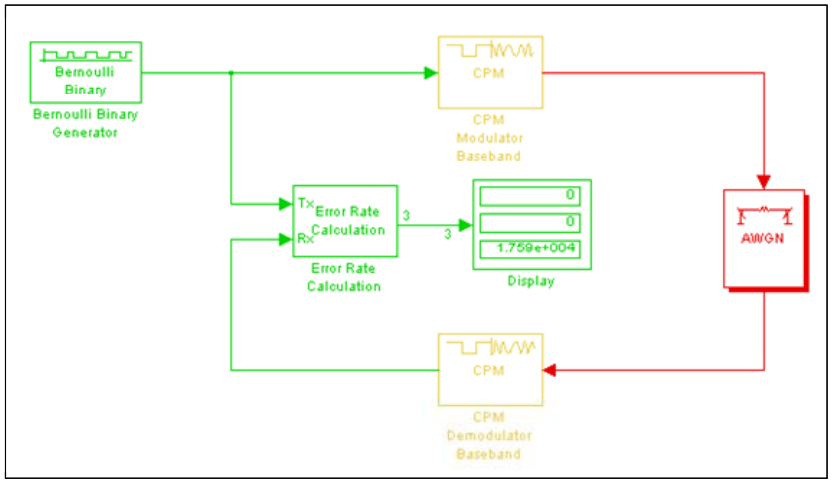
Simulation Results

- Initial simulations indicate good performance can be achieved in the aeronautical channel
  - Primarily a consequence of the strong LOS component of the received signal



LDL Performance Assessment

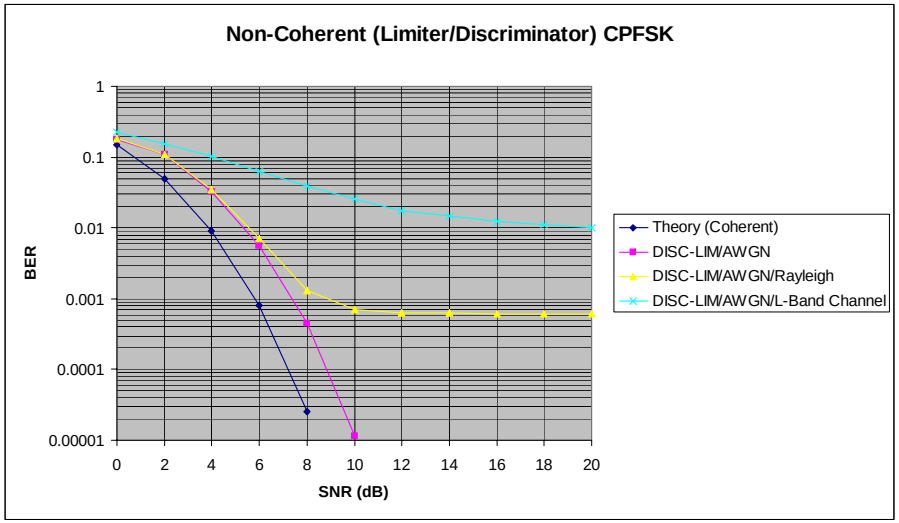
Simulation Block Diagram



Note: Block diagram shown with AWGN channel (used for model validation); performance results reflect simulation using L-Band aeronautical channel

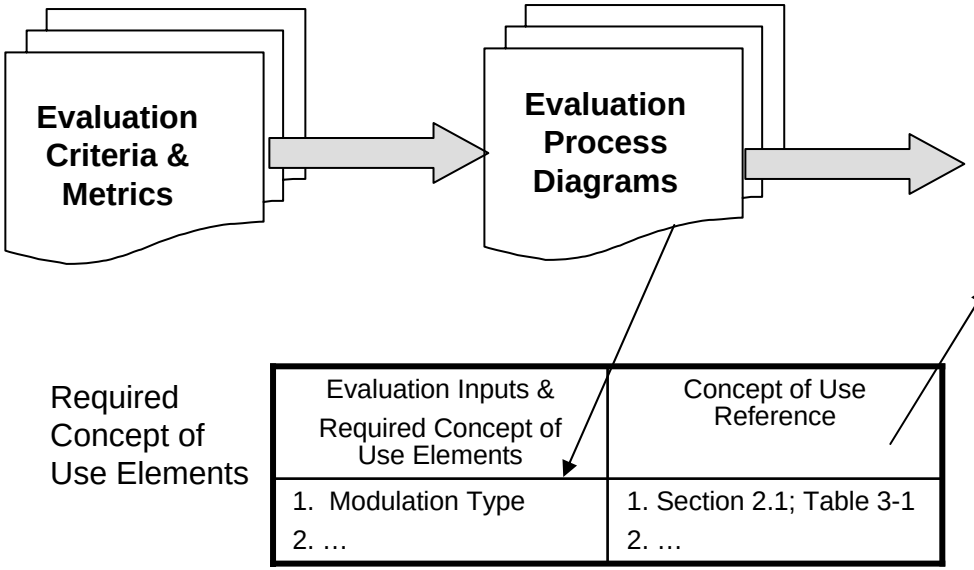
Simulation Results

- Channel model defined for LDL is a conservative model that introduces an irreducible error floor to system performance, which is consistent with a frequency-selective channel theory
- LDL may require channel equalization to mitigate the effects of the Air/Ground Aeronautical Channel in L-Band



Technology Concept of Use

- Material captured in concept of use is driven by required technology information to perform individual criteria assessments
  - Process diagrams developed for each criteria identify required technology information/inputs for analysis



Concept of Use Outline

FCS Technology Evaluation - Technology Concept of Use Outline

TECHNOLOGY NAME

1 Introduction

- Origin of technology
- Standardization body and date of standardization
- High-level functional description
- Networking Interface

2 Concept of Use for Aeronautical Communications

2.1 ***Key Technology Specifications Applied*** – describe design decisions specific to the technology (e.g. specification options, modulations, which channel size, etc) and decisions specific to each options for this application

2.2 ***Deployment/applicable Spectrum*** – describe which intended aeronautical mobile spectrum band is intended in the concept of use

2.3 ***Technology Implemented in FRS*** – describe if the technology is intended to be deploy as standardized or, if not, what tailoring is intended in the concept of use

2.4 ***COCR Service Provisioning*** – describe A) Applicable Services from COCR and Service Delivery Concept (e.g. with/without A-EXEC; addressed vs broadcast; A-G, A-A, both etc) and B) Applicable Flight Domains and Architecture Concepts (e.g. which flight domains are applicable to the described concept of use and the high-level physical architecture concept such as regular-grid, area-based service for TMA, ER and localized surface deployment or per-user circuit for large geographic area, etc)

2.5 ***Proposed Architecture Integration*** – describes how the technology architecture integrates into the architecture for aeronautical communications

2.6 ***Link Budgets and Ground Station Estimates*** – define link budgets for applicable flight domains; estimate number of ground radio stations (if applicable) for deployment in specified flight domains ; and identify other required infrastructure to support the concept of use

3 Key Technology Parameters for the Concept of Use

	Parameter	Options	FCS Concept of Use	Comments
1	Service(s)/Mode			
2	Modulation/Channelization			
3	Coding			
4	Service Concept			
5	User Data bits/frame			
6	User Data Frames/Second			
7	Physical Layer Data Rate			
8	Offered Data Rate			
9	Range			
10	Issues for further Investigation			

4 Technology Evaluation

Evaluation Criteria		Rating	Evaluation Notes
Technical Performance	Meets ATS Requirements		

Technology Evaluations

Next Steps

- The Future Communication Study is scheduled for completion in Sept 2007
- Activities for completion of technology investigations include:
  - Finalize technology evaluations
    - Identify applicability of technologies for use in the Future Radio System
    - Define areas for technology evolution or customization to meet specific future aeronautical requirements
  - Define technology evolution roadmap
    - Recommendation substantiation
    - Aeronautical standardization
    - Technology validation
  - Develop technology recommendations