Technology Assessment Results of the Eurocontrol/FAA Future Communications Study

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Abstract—The US Federal Aviation Administration (FAA) and Eurocontrol jointly initiated the Future Communications Study (FCS) to develop a common approach for a globally harmonized air traffic management (ATM) communications system. The FCS includes operational concepts and communications requirements development, analysis of business and institutional elements, and identification and assessment of technology alternatives. The FCS technology assessment determined the best set of available technologies for aviation safety communications for ATM given key constraints such as cost, transition feasibility, technical requirements, and spectrum availability. From 2004 to 2007, the assessment progressed in three phases, yielding technical results and recommendations for development and phased implementation of a future aviation communications infrastructure.

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1. INTRODUCTION

The continued global growth in air traffic has prompted concerns that current methods of air traffic management (ATM) will be unable to safely manage future traffic levels, especially in heavily congested airspace. This concern has manifested itself in the emergence of major efforts to define and develop advanced air traffic management methods and supporting infrastructure within the last several years. In the United States, the Joint Planning and Development Office (JPDO) is defining the Next Generation Air Transportations System (NextGen) [1]. A parallel European effort, the Single European Sky ATM Research Program (SESAR), has the objectives to eliminate the fragmented approach to ATM, transform the European ATM system, synchronize plans and actions of the different partners and federate resources [2].

Although these two programs, along with other efforts, are intended to include coordination and collaboration, past experience has demonstrated a tendency toward regional technical solutions which meet specific technical and political constraints but penalize global aviation by requiring multiple sets of avionics on aircraft operating in multiple regions, differing procedures and regulations, and other aspects resulting in higher costs and potential safety problems. In the area of air-to-ground communications, a critical infrastructure for air traffic management, the International Civil Aviation Organization (ICAO) Air Navigation Commission (ANC) meeting 11 (August 2003), recognized the need to identify a future air-ground communications system for air traffic management (ATM) communications on which different regions of the world could eventually converge, and requested members to collaborate on a solution.

To address this request, the US Federal Aviation Administration (FAA) and Eurocontrol initiated a joint activity called the Future Communications Study (FCS) to develop solutions to the need identified by the ANC. The FCS exists under the auspices of the FAA and Eurocontrol cooperative research and development program Action Plan 17 (AP17-04), developed to provide a joint framework to define a future Global Aeronautical Communications System to support ATM operations. The FAA requested the National Aeronautics and Space Administration (NASA) Glenn Research Center (GRC) to conduct the FCS technology assessment and sign the AP17-04 as a collaborator on the cooperative research and development agreement. The FCS includes operational concepts and communications requirements development, analysis of business and institutional elements, and identification and assessment of communications technology alternatives.

The FCS technology identification and assessment consisted of three phases with some additional follow-on work, all of which has been completed. The first phase identified all relevant communications technologies that could be applied to the aeronautical safety communications requirements and screened those technologies against a set of evaluation criteria to determine the best candidates. The second phase performed detailed technical evaluations of a subset of those candidates to determine their potential performance under the expected conditions and operational scenarios envisioned under the FCS. The third phase focused on in-depth studies of particularly important technical details of the top-ranked technologies.

This paper provides background on the FCS and presents an overview of the Phase I and II results. The primary focus of this paper is on the results of Phase III, which have not previously been reported, and presents the final FCS technology assessment results and recommendations.

2. FUTURE COMMUNICATIONS STUDY TECHNOLOGY ASSESSMENT OVERVIEW

NASA GRC has provided technical support to the FAA for the technology identification and assessment portion of the FCS. NASA contracted to ITT Industries Advanced Engineering & Sciences Division for technical analyses in support of the FCS technology assessment activities.

Technology assessments were carried out by both the FAA (supported by NASA and ITT) and Eurocontrol (supported by QinetiQ). This paper primarily discusses the NASA-ITT technology assessment performed for the FAA, although Eurocontrol results are summarized in section 6.

The technology assessment process as conducted jointly by the US and Europe under AP-17 is depicted in Figure 1. The development of initial evaluation criteria, identification of candidate technologies and FCS Technology Assessment Phase 1 technology pre-screening were close collaborations between the US and Europe, and produced a reduced set of candidate technologies. What was referred to as Phase 2 of the technology assessment in the US was conducted independently of a parallel effort, referred to as Step 2, conducted by Europe. The US effort (Phase 2) and European effort (Step 1) both examined the reduced set of candidate technologies and down-selected a set of "Most Promising Candidates" and a "Technology Shortlist", respectively, which were very similar.

At the same time, US and European members jointly developed the Communications Operating Concept and Requirements (COCR) which provided communications technical and performance to help guide the assessment of candidate technologies. The COCR is an FCS product that identifies and documents consensus future operational requirements and derives the communications required to enable those concepts [3]. The COCR describes two phases of the operational concepts. COCR Phase 1 operations begin in 2015 and are characterized by the evolution of communications services from voice to data and the ATM operational paradigm from "management by intervention" to "management by planning and intervention by exception." COCR Phase 2 operations are phased in beginning in 2020 and involve the evolution of communications services to support 4-D trajectory-based ATM, where ATM evolves to a monitoring function instead of active control, heavily dependent on network-centric operations and system wide information management. The COCR developed communications capacity and performance requirements based on operational requirements and future aviation traffic models for Phase 1 and Phase 2. The results enabled further refinement of the evaluation criteria applied to the technology assessment process.

The US Phase III technology assessment and the parallel Step 2 in Europe performed detailed technology evaluation of the remaining communication technology candidates. The US Phase III study included a more comprehensive application of the evaluation criteria to assess the most promising technologies available for evaluation at the time, as shown in Figure 2. In the European Step 2, the technologies were evaluated against two levels of criteria: essential and desirable.

A brief follow-on effort evaluated at two additional technology candidates recently developed in Europe that were deemed of sufficient value to add to the set of potential communications technologies under consideration.

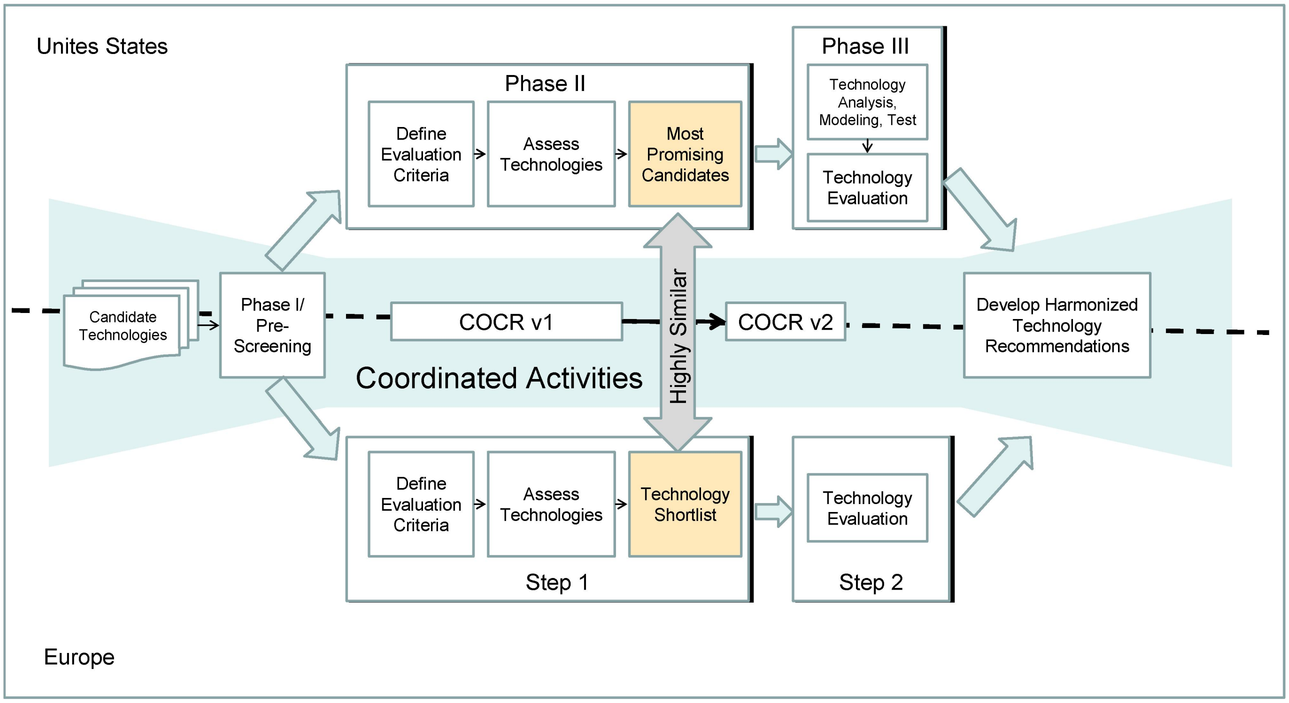

Figure 1: FCS Technology Investigation Study Approach

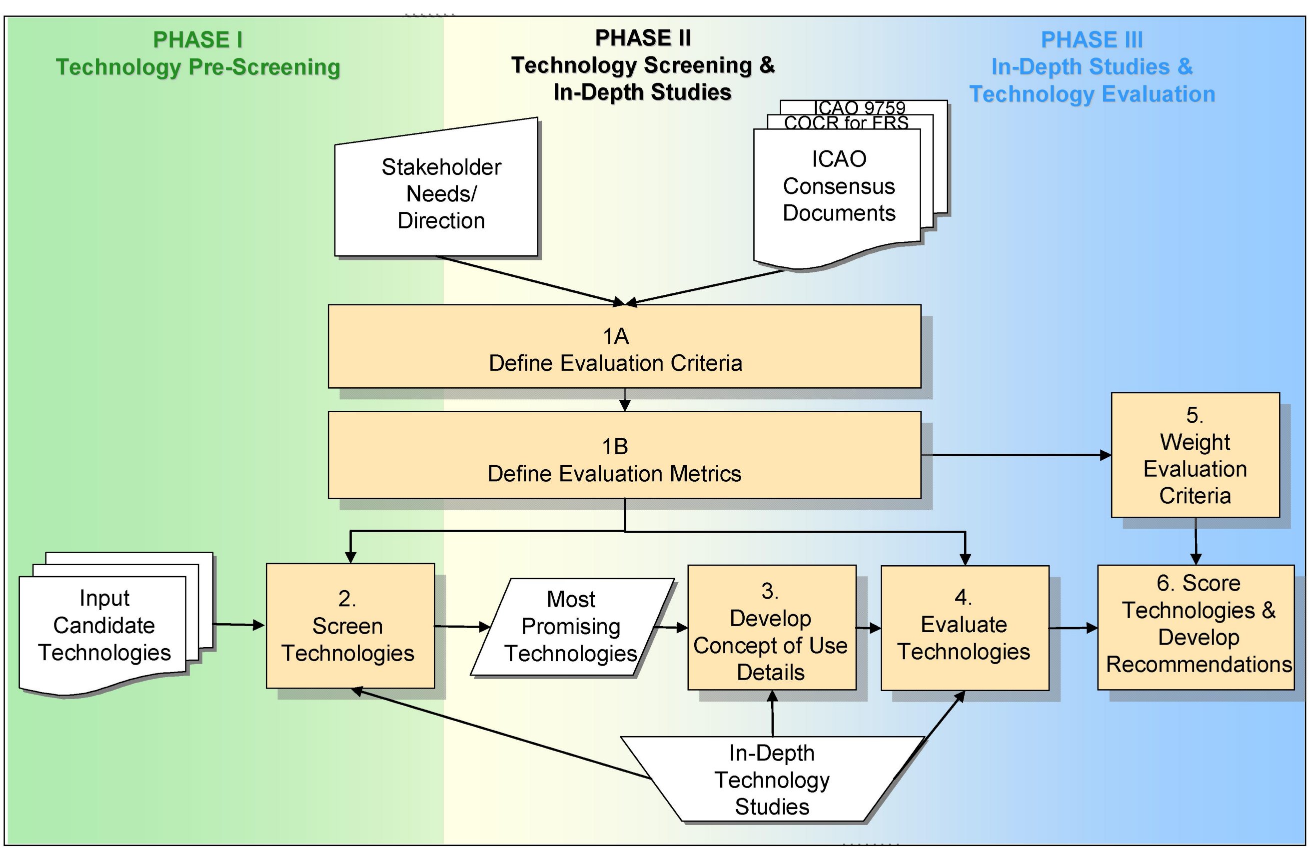

Figure 2: Overview of Technology Evaluation Approach for U.S./ITT Evaluation Team

3. Review of FCS Phase I and Phase II

Phase I of the FCS technology assessment consisted of a prescreening of communications technologies with potential application to future air traffic management requirements [4]. A set of candidate technologies was developed for evaluation including all potentially relevant communications technologies for which a sufficient technical description was available. It is important to note that only technologies already developed were considered because the timeline for development and certification of technology for aviation is too long to allow new technologies to be developed, certified and implemented by the 2015-2020 timeframe when they are expected to be needed. The level of development, or technical maturity, was a key evaluation criterion. The purpose of this prescreening activity was to identify a reduced set of best possible technologies for detailed analyses in the second and third technology assessment phases.

Once the technologies were properly characterized, they were assessed against evaluation criteria, developed jointly between the FAA and Eurocontrol. The 11 criteria cover required communications capabilities, level of technical maturity, cost, availability of protected spectrum, ability to meet security requirements, and ability to accommodate a realistic transition strategy. Technologies that could not meet minimum threshold criteria were eliminated. Technologies that passed this threshold were then analyzed more rigorously and given numerical scores based on their performance relative to the criteria. Comparative and sensitivity analyses were performed and the best potential technologies were identified.

The technology prescreening results are summarized in Table 1. A key result obtained is that no technology solution offered adequate performance in all aviation flight domains. Hence the results are different for continental, oceanic and airport surface operations. The FAA/NASA/ITT prescreening results are similar to the results obtained by Eurocontrol.

Phase II of the technology assessment process consisted of a detailed evaluation of selected technologies that scored well in the technology prescreening phase [5]. Key areas of concern were studied in detail for four of the technologies recommended in Phase I - P34/TIA-902, LDL, IEEE 802.16e, and satellite communications systems.

For LDL and P34/TIA-902, the evaluation activities included definition of a channel model that could be used for common characterization of waveform performance in an air-ground channel; definition of a framework for specifying the infrastructure costs associated with an L-Band system; and analysis of P34/TIA-902 and LDL performance with a common channel model and the potential to interfere with incumbent users of the band. The focus of the satellite analysis was system availability, and the focus of the 802.16e analysis was its performance in an airport environment at C-Band.

The analyses of LDL and P34/TIA-902 were centered on their potential performance in the 960 – 1024 MHz portion of L-Band. Analysis of the propagation characteristics for an aeronautical channel in this band enabled creation of a channel model. A physical layer simulation of the two technologies allowed an assessment of their performance in the L-Band based on the channel model. P34/TIA-902 performed well in these simulations, indicating that good performance can be achieved in an aeronautical channel.

Table 1 - Summary of Technology Prescreening Results

FAA/NASA/ITT Recommendations	Common Recommendations	Eurocontrol Recommendations
	Continental Airspace	
L-band Datalink - LDL (VHF Digital Link Mode 3 shifted to L-band)	P-34/TIA-902 (Public Safety Communications Standard APCO Project 34, based on Telecommunications Industry Association Standard 902)	Inmarsat SwiftBroadband
	XDL-4 (VHF Digital Link Mode 4 shifted to L-band)	Custom Satellite
	Enhanced TDMA (E-TDMA)	
	Wideband CDMA (W-CDMA)	
	Broadband VHF (shifted to L-Band)	
	Oceanic and Remote Airspace	
	Inmarsat SwiftBroadband	
	Custom Satellite	
	Airport Surface	
	IEEE 802.16e	Airport Data Link (ADL)

For LDL, the effects of the air-ground L-band channel are such that equalization will be required to achieve good performance.

Interference analysis considered potential interference with other systems operating in the 960-1024 MHz band, such as Distance Measuring Equipment (DME), Mode-S, and Universal Access Transceiver (UAT). Achievable carrier-to-interference ratios to avoid interference with the Mode-S and UAT systems were derived for P34/TIA-902 and LDL. Results for DME were inconclusive due to incomplete receiver design specifications, so additional work is required. Interference with on-board Global Positioning System (GPS) and Wide Area Augmentation System (WAAS) equipment was not analyzed in this study.

The development of a first order costs model for an aeronautical communications infrastructure at L-Band concluded that a business case for the ground infrastructure for an L-band system providing air-ground aeronautical communications can potentially be closed within 4 years, assuming annual revenues of $42M obtained for services provided based on an initial investment of approximately $135M and annual operations and maintenance costs of approximately $4M.

Satellite communications system analysis in Phase II considered such existing systems as Inmarsat SwiftBroadband (SBB) service, based on the recently deployed Inmarsat 4 spacecraft, and the Iridium constellation system, as these systems can operate in the designated aeronautical communications safety spectrum as required for aviation safety communications associated with ATM. The performance requirements specified in the COCR include data capacity; latency; quality of service; number of users; security and availability. The key factors limiting availability are satellite equipment failures and link events, capacity overload, and interference. This assessment concluded that Inmarsat SBB and perhaps Iridium may provide sufficient availability performance to meet a subset of COCR service availability performance requirements in limited applications, in particular in oceanic, remote and polar (Iridium only) domains. However, these systems will not provide sufficient availability to provision most if not all of the COCR services defined for Phase 2I operations.

The analysis of the IEEE 802.16e technology considered its performance in an airport surface environment in the 5091 to 5150 MHz band. Channel models for the airport surface developed by Ohio University under investigations granted by NASA, based on airport surface measurements at C-Band, were incorporated into the waveform simulation, and the performance of IEEE 802.16e was assessed. The simulations indicated that 802.16e at C-band in the airport surface environment can meet expected performance requirements for both stationary and mobile applications.

4. FCS PHASE III IN-DEPTH STUDIES

The Phase III effort included three in-depth studies to support the FCS technology evaluation process and to gain a better understanding of the applicability of the most promising technologies to the future aeronautical communication environment. The in-depth studies are the L-band interference testing, the WCDMA functional assessment and the P34/TIA-902 intellectual property assessment.

L-Band DME Interference Testing

The L-band interference testing extended the interference analysis performed in Phase II. Interference measurements for three candidate technologies against the DME, a navigation system currently operating in the aeronautical L-band spectrum were conducted. There are several possible interference scenarios, including co-site (onboard the aircraft), air-to-air, air-to-ground/ground-to-air, and ground-to-ground.

For the interference measurements of this study, the co site interference scenario was emulated. The co-site interference scenario serves as a guide for specifying the bounds of interference power used when taking measurements. The signal levels used for interference measurements should encompass the power ranges that will be seen in practice and these levels are greatest in the co-site scenario. By contrast, ground stations are generally separated by large distances to mitigate the effects of interference, whereas antennae onboard the aircraft are necessarily much more closely spaced. Figure 3 illustrates the co-site scenario.

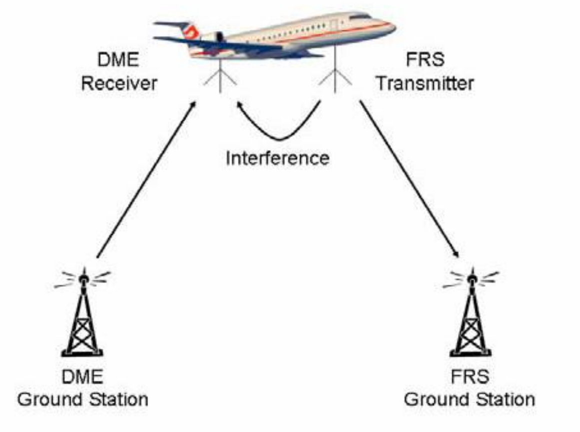

Figure 3 – Co-site Interference Scenario

The three candidate technologies selected for this interference study are WCDMA, LDL, and P34/TIA-902. These three technologies use fundamentally different waveform structures: ultra-wideband, narrowband, and orthogonal frequency division multiplexing (OFDM), respectively.

The DME system is the interference victim in these evaluations. DME is a navigational aid that provides slant range distance to aircraft, consisting of airborne equipment and ground-based equipment, which are called interrogators and transponders, respectively. The interrogator transmits paired pulses to the transponder which replies with its own paired pulse message. The interrogator measures the time elapsed between its own transmission and reception of the transponder's response, which is then used to calculate the slant range distance.

The DME system operates in the frequency band 960–1215 MHz. The interrogation and reply frequencies are always offset by 63 MHz. The entire band allows 126 channels for interrogation and 126 channels for transponder replies. Interrogations are sent on frequencies 1025–1150 MHz. Replies from the transponders are sent on frequencies 962–1024 MHz and 1151–1213 MHz. DME channels are spaced 1 MHz apart on center, with bandwidths of 0.5 MHz.

The interference is characterized by observing the response of the DME Interrogator in the presence of the interfering signals. The interfering waveforms are injected into the system at various frequency separations and the signal levels are incrementally adjusted in order to determine the power thresholds that induce a standard response from the DME unit under test.

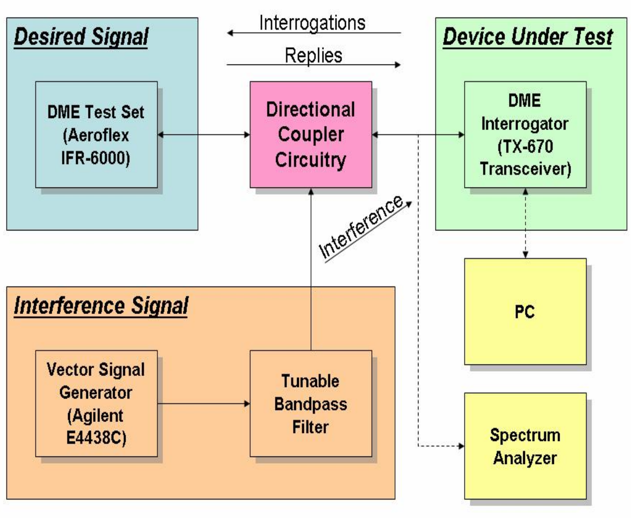

Figure 4 – Test Setup for DME Interference Measurements

The test setup for the interference measurements is illustrated in Figure 4. Interrogations are sent from the DME interrogator to the DME test set. The DME test set replies to interrogations with a DME reply signal. The DME reply signal is coupled with the interference signal and the DUT is observed. The interference signal undergoes bandpass filtering before it is coupled with the DME reply signal to reduce transmitter broadband noise that produced by the vector signal generator.

For DME, the standard response is described by two metrics: Acquire Stable Operating Point (ASOP) and Break Stable Operating Point (BSOP). ASOP is defined as the maximum interfering signal level where the DME Interrogator consistently locks on and provides bearing, identification, and range information. BSOP is defined as the minimum interfering signal level that causes the DME Interrogator to lose lock by failing to provide bearing, identification, or range information.

Summary of L-Band DME Interference Testing Results

The DME interference testing provided an improved understanding of the interference environment associated with DME. While limitations in the test equipment do not provide enough to information to address specific channelization techniques for FCS communications technology candidates, the interference measurements do suggest that the addition of an FCS communications system in the DME band may be feasible. Three major findings of the interference measurements study are as follows:

The power levels expected from continuously transmitting communications equipment on-board the aircraft may be sufficiently high as to cause desensitization in the DME interrogator. This phenomenon was evident for all of the FCS communications technology candidates even at large frequency separations for the DME that was tested. This finding is not favorable for the candidate technologies whose concept of use assumes continuous transmissions (e.g., WCDMA).

The data also indicate that the DME interrogator is more tolerant to gated transmissions (i.e. there is potential for implementation of a technology with a gated waveform; but off-set channels may still be required). A majority of the measurements used 100% duty-cycles, resulting in a conservative analysis. Lesser duty-cycles may be expected in practice. It is expected that low-to-moderate duty-cycles will interfere less with DME compared to high duty-cycles. This finding may be favorable for candidate technologies whose concept of use assumes non-continuous transmissions (i.e., LDL & P34/TIA-902).

Further analysis is needed to characterize the relationship between duty-cycle and interference susceptibility (the duty-cycle investigation should include more variables than just overall duty-cycle; there may be some combination of specific time-scales of on/off pulses and overall duty-cycle that results a seemingly "invisible" waveform from the DME interrogator's perspective); in the context of this investigation, identification of collocation constraints can also be investigated.

WCDMA Function Assessment

The objective of the WCDMA study was to perform a functional analysis of the technology and identify how it can be used to support COCR services. Results of this analysis were used to determine the necessary elements of the architecture and protocol stack required to provision COCR services, which further supports the assessment of cost, certification and standardization impact for applying WCDMA in aeronautical applications.

The overall approach applied for the WCDMA study consisted of the examination of WCDMA network architecture, protocols and functions based on Universal Mobile Telecommunications Service/ 3G technology (UMTS) WCDMA network architectures and 3GPP technical specifications; the selection of COCR air traffic data link services for consideration based; and the mapping of data link services to WCDMA network functions.

The WCDMA network architecture was examined in terms of four primary hierarchical functions. The "access network" function provides such capabilities as finding access point; localizing user equipment; establishing connectivity for signaling; registration, and authentication and authorization. The "routing and transferring of data" function includes establishment of connectivity for data transfer; routing; address translating; encryption and decryption; compression; and resource management. "Detachment from the network" and "mobility management" are the other primary functions.

A set of air traffic data link services is selected for the analysis. These services support the implementation of aeronautical communications and are used to identify the required WCDMA protocol and functional elements. Two sources of service information were used in the analysis: the COCR as the primary source and RTCA document DO-290 which provides a secondary source of service descriptions. The identified COCR services for consideration in this study are intended to be part of a future CNS/ATM implementation. The COCR services are organized into 3 major categories: Air Traffic Service, Airline Operational Control, and Network Management. For this study, the selection of data link services is focused on the ATS category.

Eight data link services derived from the COCR were mapped against the WCDMA network functionality. WCDMA specific services that support aircraft movement through the ATC system were also been examined. Through this process the WCDMA functional elements required to support the COCR requirements were identified and examined.

Applying the WCDMA standards as defined, it was found that a full complement of WCDMA functional elements is required to provision COCR services. Not only the air interface and elements of the radio network controller are needed, but also elements of the core network such as Home Location Register (HLR), Serving General-packet-radio-service (GPRS) Support Node (SGSN) and Gateway GPRS Support Node (GGSN).

P34/TIA-902 Intellectual Property Assessment

The Phase III P34/TIA-902 Intellectual Property (IP) assessment evaluated the potential impact of the P34/TIA-902 Telecommunications Industry Association Standard 902 (P34/TIA-902) IP in the context of a future aviation safety communications implementation. This assessment was necessary in order to determine whether existing patents or other intellectual property issues would create restrictions in the implementation of a P34/TIA-902 system for civil aviation, especially in the context of international use. This study consisted of a thorough review of the patents and consultation with a patent counsel. The following conclusions were developed.

The concept of use defined for P34/TIA-902 makes some patents not applicable. For example Isotropic Orthogonal Transform Algorithm (IOTA) physical layer would not be used in the aviation safety communications application and associated patents would not apply. Also, recommended tailoring of physical layer standard for the aviation application results in bypassing of most physical layer patents.

The study showed that only one patent is assessed as desirable to implement, a methodology proposed for power amplifier linearization, the modification of which would influence definition of the MAC framing structure. Most if not all patents will expire before timeframe of FCS, and these patents are not applicable to companies outside US. The conclusion is that intellectual property associated with P34/TIA-902 standard is deemed to have little or no impact on the aviation safety communications application if it is an implementation based on this standard.

5. FCS Technology Assessment Results and Recommendations

The FCS Technology Assessment was a coordinated and cooperative effort of two teams: a European team and an FAA/NASA/ITT team, from 2004 through 2007. The activities were coordinated through the AP-17 document with the results to be delivered to the ICAO Aeronautical Communications Panel (ACP) for international acceptance and coordination.

While some aspects of the technology assessment were conducted jointly, others were independent activities for which results were coordinated and harmonized at several

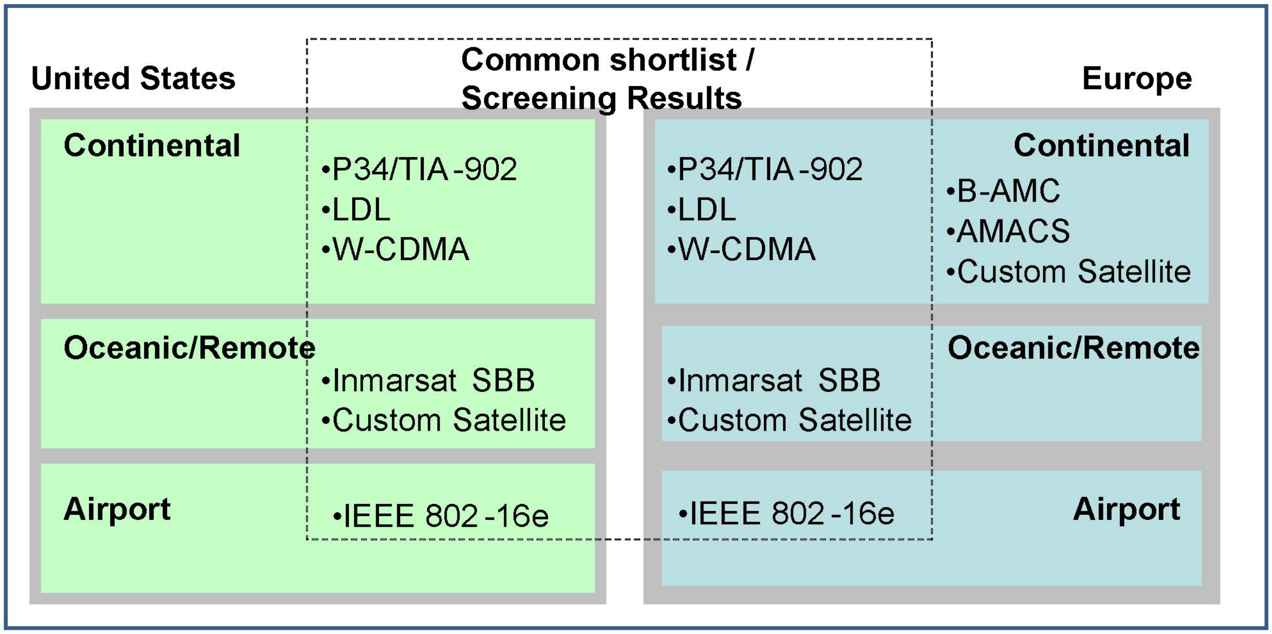

Figure 5 - Candidate Technology Short List as a Function of Airspace Domain

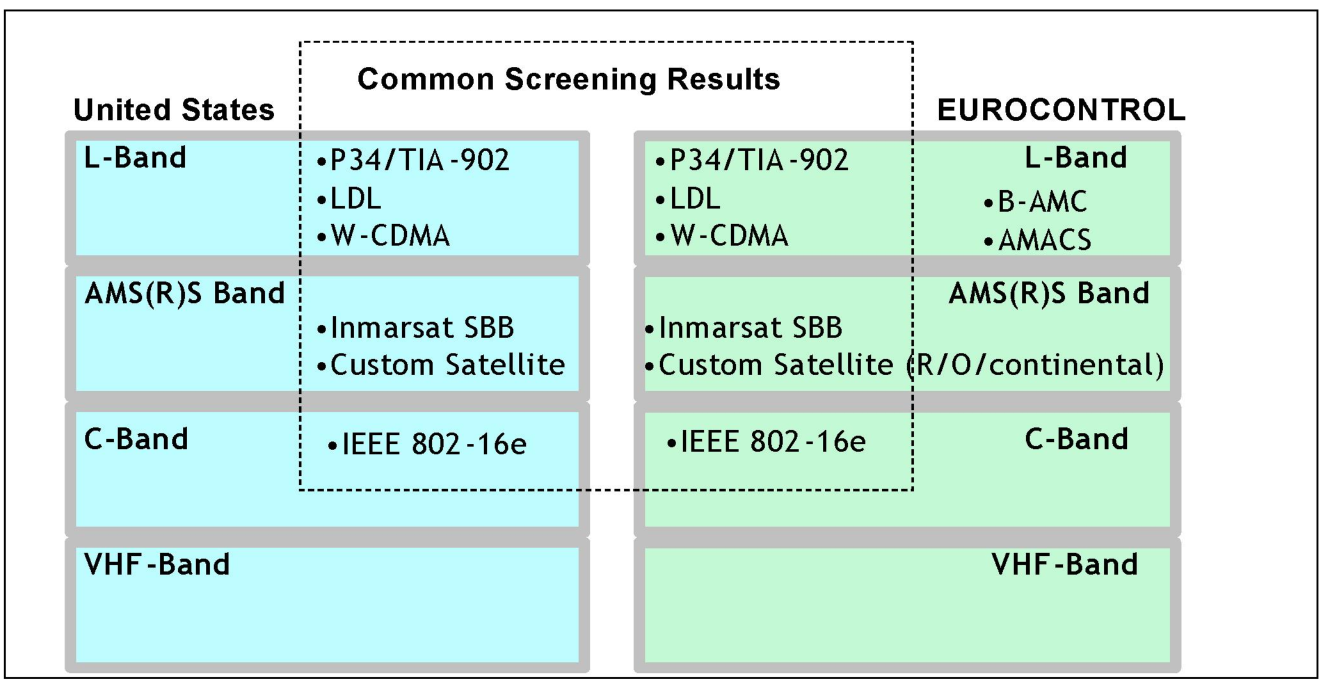

Figure 6 - Candidate Technology Short List as a Function of Frequency Band

times during the study. This enabled a joint result and set of recommendations to be developed and presented to the ICAO ACP.

During the Phase II investigations (Step 2 in Europe), work was reviewed to identify the most promising technologies for further investigation, resulting in a set of most promising technologies (called the technology shortlist by the European team). As shown in Figure 5, there is considerable overlap between the two sets. The technologies assessed in this Phase of the work were: P34/TIA-902; LDL; WCDMA; INMARSAT SwiftBroadband (SSB); Custom Satellite and IEEE 802.16e. The Broadband Aeronautical Multi-carrier Communications system (B-AMC) and the All-purpose Multi-channel Aeronautical Communication System (AMACS) have also been investigated primarily in the frame of the European activities. B-AMC is an evolution of the Broadband-VHF (B-VHF) proposal [8], and AMACS is a combination of the VDL4 system and the ETDMA (Enhanced TDMA) proposal [9]. The term, "Custom Satellite," refers to both new commercial satellite offerings specifically designed to address FCI requirements as well as government/private initiatives for satellite designs specific to aviation communications.

It is useful to organize the down-selected list of technologies by proposed operating frequency bands, as shown in Figure 6. This organization still roughly parallels operational domain, but groups technologies such that they can be compared in terms of the characteristics of the proposed operating frequency band as well. The technology assessment results grouped by proposed operating frequency bands are presented in the following paragraphs.

C-band

The IEEE 802.16e standard was jointly identified by the US and European teams as the recommended solution for the provision of dedicated aeronautical communication services on the airport surface utilizing proposed aeronautical C-band allocations. This technology is well matched to the airport environment, designed for short-range, high data rate communications in C-band.

The C-band recommendations presented to the ACP are:

• Identify the portions of the IEEE 802.16e standard best suited for airport surface wireless mobile communications and propose an aviation specific standard to appropriate standardization bodies;

• Evaluate and validate the performance of aviation specific standard to support wireless mobile communications networks operating in the relevant airport surface environments through trials and test bed development; and

• 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.

AMS(R)S Band

The frequency band designated for Aeronautical Mobile Satellite (Route) Service (AMS(R)S) provides protected spectrum for aviation safety services via satellite. In the FCS technology assessment, the US and Europe accomplished a harmonized definition of the role of satellite services, particularly for support of operations in the oceanic and remote airspace domains. The operational concept defined by the COCR cannot currently be met by existing satellite service offerings. However, some existing service offerings such as INMARSAT SBB have been identified as potentially suitable for meeting the service requirements for oceanic/remote airspace in specific geographic locations. The potential of next generation satellite systems, particularly those systems customized to meet the needs of aviation (including custom commercial solutions such as Iridium-NEXT and custom government/private solutions such as the European Space Agency initiative (ATM SATCOM) was also recognized.

The satellite band recommendations are to:

• 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; and

• In order to support the new AMS(R)S SARPs, consider the development of a globally applicable air interface standard for satellite communication systems supporting safety related communications.

VHF-band

The study investigated technologies to provide future data communication capabilities in continental airspace domain (en route/terminal/surface) for deployment in the aeronautical VHF and L-bands. While none of the existing data link technologies meets the long term aeronautical requirements, some proposed technologies in the VHF-band were identified for consideration for the future radio system. However, in the end in large part due to current VHF spectrum congestion considerations, the technology investigations focused in the L-band. In the longer term, the applicability of the VHF band may also be reconsidered.

The VHF band recommendation is to:

• In the longer term, reconsider the potential use of the VHF-band for new technologies when sufficient spectrum becomes available to support all or part of the requirements.

L-band

For en route and terminal airspace, the L-band was identified as the best candidate band for meeting the future aeronautical communications, primarily due to potential spectrum availability and propagation characteristics. As a result of this finding, technology evaluation led to the recommendation to seek co-primary allocations for aeronautical mobile (route) service (AM(R)S) in the aeronautical L-band at the World Radiocommunications Conference (WRC-07).

The detailed technology evaluations of several candidate technologies in the L-band, have been described in the previous sections. As a result of the channel and interference investigations and the performance assessment of the technologies, it was concluded that a thorough evaluation of the compatibility in the band is required.

As a result it is recommended to:

• Refine and agree on the interference environment and assumptions for the L-band compatibility investigations.

As a result of the initial performance analysis of the short-list of candidate technologies in the anticipated channel and interference environment, it was found that none of the considered technologies could be fully recommended. However, the assessment of these technologies led to the identification of suitable technology features that could be used as a basis for the development of an acceptable L-band data link solution. For example, some technology features specifically address operation in a fast fading environment or have low duty cycle transmissions, which is beneficial in mitigating interference. Considering these features and the most promising candidates, two options for the L-band Digital Aeronautical Communication System (L-DACS) were identified. These options warrant further consideration before final selection of a data link technology. The first option represents the state of the art in the commercial developments employing modern modulation techniques and may lead to utilization/adaptation of commercial products and standards. The second capitalizes on experience from aviation specific systems and standards such as the VDL3, VDL4 and UAT.

The first option for L-DACS includes a frequency division duplex (FDD) configuration utilizing OFDM modulation techniques, reservation based access control and advanced network protocols. This solution is a derivative of the BAMC and P34/TIA-902 technologies. The second L-DACS option includes a time division duplex (TDD) configuration utilizing a binary modulation derivative of the implemented UAT system (CPFSK family) and of existing commercial (e.g. GSM) systems and custom protocols for lower layers providing high quality-of-service management capability. This solution is a derivative of the LDL and AMACS technologies.

In addition to air/ground communications capability, some of the assessed technologies could support air/air (point to point and/or broadcast) communications services. B-AMC, AMACS and P34/TIA-902 have provisions to support such services. However this capability needs further investigation as a possible component of L-DACS.

Follow-on activities to further characterize the proposed L-DACS solutions, validate performance, and lead to a single technology recommendation for this band are required.

To complete the selection of the L-DACS solution, it is recommended to:

• 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;

• Evaluate and validate the performance of the proposed solution in the relevant environments through trials and test bed development; and

• Considering the design trade-offs, propose the appropriate L-DACS solution for input to a global aeronautical standardization activity.

Communication roadmap

In line with the phased communications operating concept described by the COCR, the Communications Roadmap was developed to describe the evolution of the communication infrastructure. The roadmap recognizes the needs of the aviation users as well as air navigation service providers, ensures the judicious use and protection of spectrum allocated for aeronautical purposes, and focuses on the introduction of potential new technologies for specific airspace and services.

Figure 7 depicts an overview of the jointly agreed to approach for the implementation and evolution of aeronautical mobile communications to support the emerging and anticipated needs of air traffic management in both Europe and the U.S. This is intended to become the basis for globally harmonized communications.

In the near term, air traffic control operations will continue to use the VHF spectrum for voice communications, with possible expansion of the use of 8.33 kHz channel where required.

VDL Mode 2 in is being implemented European airspace to support ATC data services, such as CPDLC. In the same time frame in the US, the FAA DATACOM program will begin to develop and implement data applications in the U.S. domestic airspace, using available communications technologies (i.e.VDL2) and aircraft equipment.

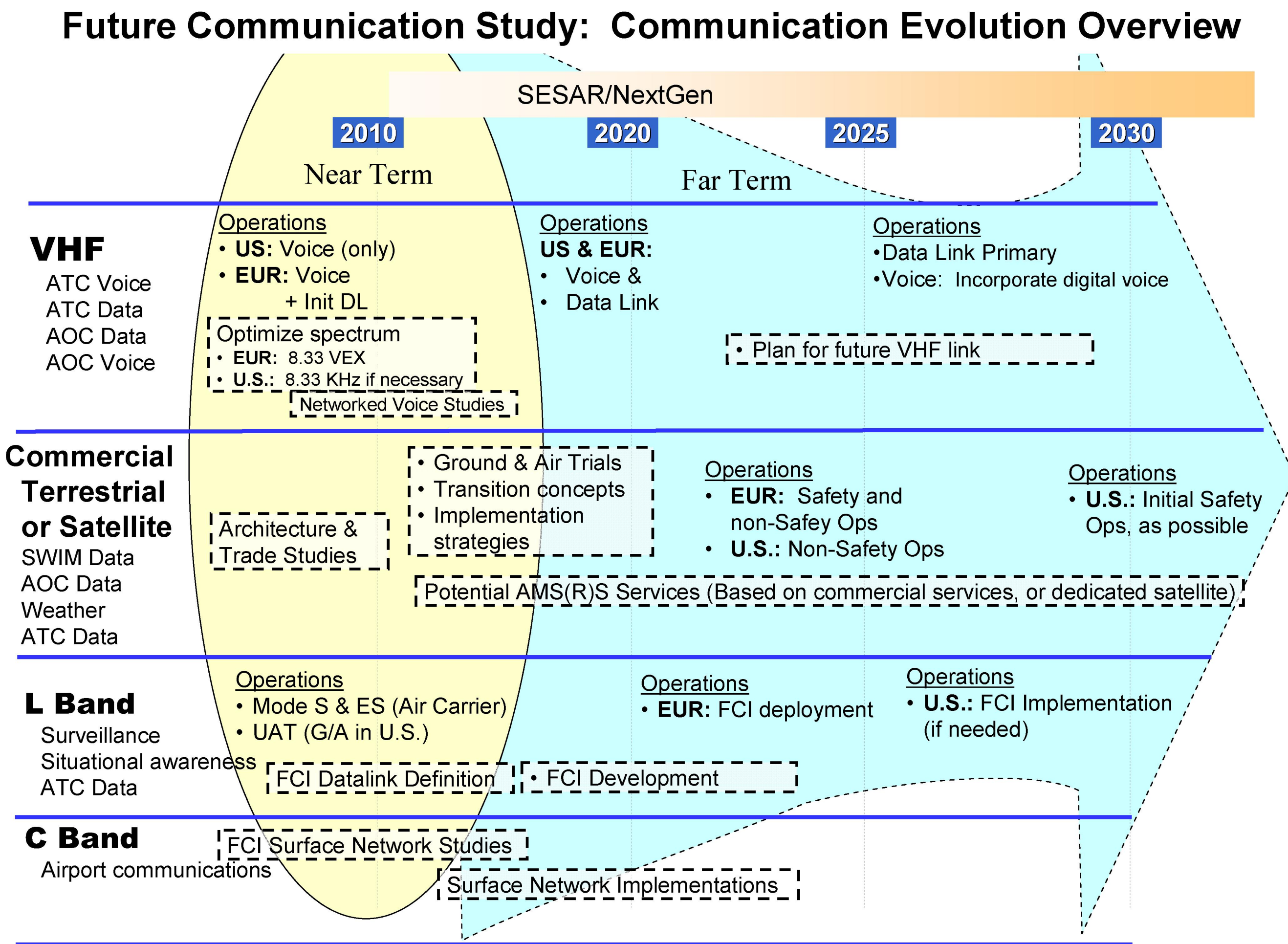

Figure 7 – Aeronautical Communications Evolution Roadmap

To prepare for the far term, FAA and Eurocontrol will continue to study the emerging commercial terrestrial-based and satellite communications technologies for non-safety communications.

The FAA and Eurocontrol will also engage in joint activities to complete selection of the terrestrial based L-band digital link (L-DACS), to provide additional aeronautical mobile communications capacity. Regional limitations of the VHF band in Europe may drive implementation of the jointly developed terrestrial L-band digital link technology in the 2020 time frame. As circumstances dictate, the FAA will also consider the L-band digital link technology for use inthe U.S. Considering the long time cycles in aviation to develop, validate, standardize and deploy a new system, it is critical that these activities are carried out expeditiously.

Implementation of future aeronautical communications systems is dependent the availability of sufficient and suitable spectrum available. The spectrum recommendations are to:

• Continue to provide rationale to spectrum regulators on the need for additional AM(R)S spectrum to facilitate advances in aeronautical communication capabilities;

• Provide support for compatibility studies between the FCI and other incumbent systems in any newly-allocated AM(R)S bands. This will include studies within ICAO regarding FCI compatibility with other aeronautical systems, and studies within the ITU regarding FCI compatibility with non-aeronautical systems; and

• Continue to support the need for priority to AMS(R)S in the satellite L-band.

Summary of Key Recommendations

The key recommendations out of AP17 for new data link developments are the following:

• Develop a new system based on the IEEE 802.16e standard operating in the C-band and supporting the airport surface environment .

• Complete investigations (with emphasis in proving the spectrum compatibility with other systems) to finalize the selection of a data link operating in L-band (L-DACS) and supporting the continental airspace environment, aiming at a final decision by 2009, to enable system availability for operational use by 2020.

• Recognizing that satellite communications remain the prime candidate to support oceanic and remote environments and that the considered future satellite systems may also be able to support continental environments possibly complementing terrestrial systems, monitor and support developments that will lead to globally available ATS satellite communications.

• Recognizing the importance of spectrum for the realization of FCI, ensure the availability of the required spectrum in the appropriate bands.

• Promote/support activities that will enable/facilitate the airborne integration of the selected technologies.

• Incorporate in any new data link system, provisions for supporting high QoS requirements in an end to end perspective.

• Continue the close cooperation between the interested stakeholders and in particular between the FAA and Eurocontrol in the realization of the above recommendations.

6. SUMMARY

The Eurocontrol/FAA Future Communications Study was a joint US-European effort to address the need for globally harmonized aeronautical communications to enable advanced air traffic management capabilities required to support the long-term growth of aviation worldwide. The US and European teams jointly developed the Communications Operating Concept and Requirements to provide necessary criteria against which potential communications technology candidates could be evaluated in the FCS technology assessment activity.

The technology assessment was performed in several stages during 2004-2007 in a highly coordinated fashion. The stages included development of evaluation criteria; technology pre-screening of a large set of possible existing technologies; down-selection to a short list of the most promising technologies; detailed evaluation of these technologies, including interference analyses and testing, development of channel models, and simulation of system performance; and assessment of candidate technologies against required COCR services. At the conclusion of the technology assessment, the US and European members developed a joint set of conclusions and recommendations that were presented to the ICAO Aeronautical Communications Panel.

The key recommendations dealt with application of the IEEE 802.16e standard for airport surface communications in C-Band; the use of satellite communications to support oceanic and remote airspace domains and the potential of future systems to support all airspace domains; the use of an L-band datalink technology to support continental airspace and the need to complete a final definition of this technology by 2009. Follow-on activities need to be defined and implemented to meet these recommendations.

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BIOGRAPHIES

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