FAA Airborne Data Link
Human Factors Research Plan

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16. Abstract

This report contains a five-year plan to perform research of human factors issues and topics related to Data Link implementations in general aviation and transport category aircraft. Elements such as resource allocation and management and coordinated cooperative research efforts are considered to be critical and are carefully developed.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAS	Advanced Automation System
ACF	Area Control Facility
ADL	Airborne Data Link
ADLP	Airborne Data Link Processor
ADS	Automatic Dependent Surveillance
AERA	Automated En Route Air Traffic Control
AIAA	American Institute of Aeronautics and Astronautics
ALPA	Air Line Pilots Association
APA	Allied Pilots Association
ARINC	Aeronautical Radio, Inc.
ARTCC	Air Route Traffic Control Center
ASRS	Aviation Safety Reporting System
ATA	Air Transport Association
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
ATN	Aeronautical Telecommunications Network
AVPAC	Aviation Packet
CIG	Computer Image Generation
CIP	Capital Investment Plan
CONUS	Continental United States
CRDA	Cooperative Research and Development Agreements
CSN	Cockpit Simulation Network
DLP	Data Link Processor
DTIC	Defense Technical Information Center
EICAS	Engine Information and Crew Alerting System
ELS	Electronic Library System
F&E	Facilities and Equipment
FAA	Federal Aviation Administration
FMC	Flight Management Computer
FMS	Flight Management System
FTD	Flight Training Device
FTMI	Flight Operations and Air Traffic Management Integration
GA	General Aviation
GAT	General Aviation Trainer
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HFCC	Human Factors Coordinating Committee
HFS	Human Factors Society
HUD	Head-Up Display
IAA	Inter-Agency Agreement
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ISSS	Initial Sector Suite System
KDP	Key Decision Point
LLWAS	Low Level Wind Shear Alert System
MMI	Man-Machine Interface
NAS	National Airspace System

NASA	National Aeronautical & Space Administration
NTIS	National Technical Information Service

NSSF	National Simulation Support Facility
NTSB	National Transportation Safety Board
OT&E	Operational Test and Evaluation
R&D	Research and Development
RCS	Reconfigurable Cockpit Simulator
RE&D	Research, Engineering, and Development
RPS	Rapid Prototyping Software
RTCA	Radio Technical Commission for Aeronautics
SA	Situation Awareness
SAE	Society of Automotive Engineers
SARPS	Suggested and Recommended Practices
SATCOM	Satellite Communications
SBIR	Small Business Innovative Research
T&E	Test and Evaluation
TCAS	Traffic Alert and Collision Avoidance System
TRACON	Terminal Radar Approach Control
UGP	University Grant Programs
USAF	United States Air Force
VAPS	Virtual Applications Prototyping Software
VHF	Very High Frequency

EXECUTIVE SUMMARY

This plan contains the Federal Aviation Administration (FAA) Technical Center's five-year research agenda for flight deck human factors research. The purposes of the plan are to establish a coherent research approach, manage resources, provide a means to communicate Technical Center planning, and trace study results to National Human Factors Plan research requirements.

The philosophy of the plan is based on the needs of its customers, who include: FAA Aircraft Certification and Standards Services, Capital Investment Plan program offices, and the users of the National Airspace System (NAS). Customer requirements determine research questions and priorities, allocation of resources, and motivation for cooperation with government and industry organizations.

Prior to writing this plan, a substantial amount of effort was expended to determine salient near term issues, in addition to longer term projections of aircraft capability and air traffic control (ATC) system technology. This perspective was adopted for two reasons: (1) the focus of planned studies can be more applicable to a broader range of technology, and (2) the scope of studies actually performed can be increased to provide greater efficiency and enhanced realism. Thus, the studies defined in this plan are based on information acquisition through literature searches, simulations of varying degrees of fidelity, and flight test of prototype avionics.

A cornerstone of this plan is cumulative knowledge. Through its involvement with industry committees, the Technical Center will strive for common measures so that results of research can be compared in context, whether the research is performed by the FAA or by National Aeronautical & Space Administration (NASA) or other government or industry organizations.

1. INTRODUCTION.

This document defines a five-year research plan to be pursued by the Federal Aviation Administration (FAA) Technical Center's Airborne Data Link (ADL) program. The emphasis is on examining flight deck human factors issues and building/testing associated avionics. While the emphasis is on Data Link and the flight deck, a systems level awareness will be established and maintained. This is an absolute requirement for several reasons. One reason is the range of technologies and systems on or available for the flight deck. Another is the range of flight deck types that must be addressed: air transport, commuter, and general aviation.

The FAA Technical Center has traditionally performed test and evaluation (T&E) activities. In the area of ADL, the FAA Technical Center has adopted a research posture through centralized expertise. The recently established Human Factors Laboratory is a major step. Another step is the aggressive staffing of specialized human factors and systems personnel within the project office. In addition, the use of existing testbeds for research and development adds realism to the Data Link development process.

Data Link represents but one major change on the horizon for aviation. Examples of new or future systems that need to be considered in the flight deck Data Link development process include the following: Traffic Alert and Collision Avoidance System (TCAS), Low Level Wind Shear Alert System (LLWAS), Global Positioning System/Global Navigation Satellite System (GPS/GNSS), and the Electronic Library System (ELS). Examples of new or future systems that need to be considered in the air traffic control (ATC) Data Link development process include the following: Automated En Route Air Traffic Control (AERA) Automation System, Automatic Dependent Surveillance (ADS), and the Advanced Automation System (AAS).

Existing National Airspace System (NAS) support facilities will be used by a multidisciplined group of personnel to address the multitude of issues relative to the implementation of an air-to-ground Data Link system. FAA Technical Center ATC simulation resources, coupled with both internal and external aircraft simulation resources, provide a capability to conduct full scale "end-to-end" testing. The flexibility inherent in these testbed systems permit rapid reconfiguration to support fast track FAA system implementations.

The development of additional testbeds, and enhancements to existing testbeds, will be proposed. This will be accomplished to help in the transition from today's NAS to the AAS of the future. Further, the flight deck testbeds will be enhanced to permit examination of a full range of aircraft types, including currently defined aircraft through future generation aircraft. This plan will recommend both internal and external research efforts. Cooperative research programs with airlines, other government, and industry will be proposed where clear benefits can be identified for all interested parties. A cornerstone in this plan is the idea of cumulative knowledge and common measures. Every research effort will contribute to and build on a central knowledge base. Since a variety of organizations are, and will continue performing Data Link research, a common set of human performance measures will be proposed to allow interagency comparisons. Ultimately, the research performed must provide material for regulatory activities and future ATC systems design efforts.

1.1 ORGANIZATION OF THE PLAN.

It is the intent of this document to provide the reader with a picture of the FAA Technical Center Data Link human factors research roadmap. Section 1 is a detailed introduction of the plan. Areas of discussion include purpose, philosophy, customer identification and their requirements, research tools, objectives, and products.

Section 2 describes the research methodology. This section specifies the major parts to the systems design model being adopted by the FAA Technical Center. A Statement of Need is provided. Functional requirements are established. Sections are included to discuss knowledge acquisition, problem definition, concept exploration, and demonstration/validation.

Section 3 contains an extensive discussion on the evaluation efforts planned over the next five years. This section gives the actual research roadmap that will be followed by the airborne Data Link group at the FAA Technical Center and a specification of the research tools to be used. Also provided is a Gantt chart of both airborne research activities and the joint end-to-end test activities (FAA Technical Center airborne and ground Data Link groups). This section also indicates which National Plan for Aviation Human Factors requirements are satisfied as a result of the FAA Technical Center research. A conformance matrix lists research activities, issues, and National Plan references.

Section 4 contains information on basic resource requirements including people, equipment, and funding. Finally, references are provided along with several appendixes to support the plan.

1.2 PURPOSE OF THE PLAN.

There are several reasons for this plan. One reason is to establish a definitive research approach. Another reason is to provide a framework to manage resources, including facilities,

equipment, and personnel. A third reason for the plan is to insure that the requirements in the National Plan for Aviation Human Factors are satisfied by FAA Technical Center research efforts. Finally, the plan identifies the need for cooperative research efforts and methods of implementation of the cooperative efforts. An overview of each of the reasons is found below.

1.2.1 Establish Research Approach.

The plan is to provide a coherent and systematic method for achieving specific levels of Data Link implementation in the NAS at specific points in the future, out to five years, at least. The plan and future revisions will be coordinated with system user groups and other interested parties so that all current requirements are being addressed and that new issues are tracked. A systems engineering model has been adopted to guide this multifaceted program. This approach defines a building block approach and demonstrates the notion of cumulative knowledge which will be discussed later in more detail.

Figure 1 presents a block diagram which shows the major parts of the approach. The four major sections are: problem definition, scenario development, evaluations, and support tools. Problem definition involves identifying needs, services, mediums, issues, and defining research groups and measurement criteria. Scenario development involves defining classes of flight scenarios which include both routine and abnormal events. Scenarios will be necessary that involve domestic en route, domestic terminal, domestic gate-to-gate, oceanic, and foreign environments. Commercial and general aviation aircraft must be represented in the development process.

The support tools section involves testbed development. The evaluation section involves the meat of the research. A related effort that is necessary is knowledge acquisition, that is, literature searches, technology and systems awareness, surveys and interviews, and industry awareness. Each of these sections are discussed in detail in the remainder of this research plan.

1.2.2 Manage Resources.

A program of the size and complexity proposed by this document requires the careful allocation of resources, including facilities, equipment, and personnel. FAA Technical Center facilities and equipment (F&E) must frequently be scheduled several months in advance; cooperating research agencies require similar advanced schedules.

The flight deck equipment support devices to conduct Data Link research is frequently special order in nature and must be requested months in advance. Staff requirements in the form of government and contractor personnel must be carefully considered

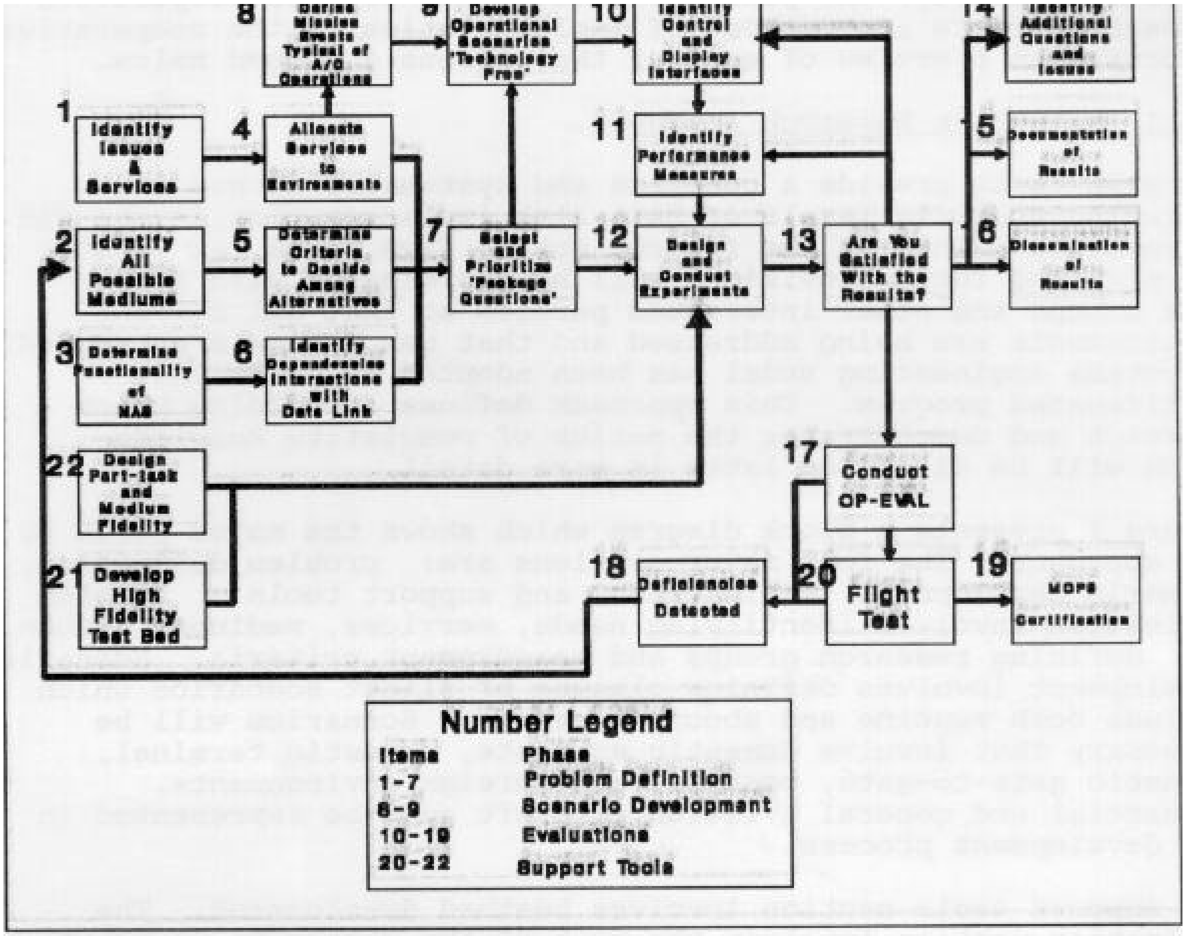

FIGURE 1. FAA TECHNICAL CENTER DATA LINK RESEARCH APPROACH

in terms of numbers and skill levels. All resources must be scrutinized continuously to decide when changes are needed so as to meet schedule deadlines.

1.2.3 Satisfy National Human Factors Research Plan Requirements.

The activities described in this FAA Technical Center plan are intended to fulfill the global requirements specified in the Flight Deck and Flight Deck/ATC Integration sections of the National Human Factors Research Plan developed by FAA headquarters. The Flight Deck Environment section of the National Plan describes six "domains" that are groups of related efforts. Appendix A lists the six domains and the associated projects. Section 3.3 will provide a discussion on how components of the plan relate to selected National Plan requirements and how the requirements are met by FAA Technical Center research.

The ATC section of the National Plan describes four research "domains" that are groups of related efforts. Appendix B lists the four domains and the associated projects. A separate FAA Technical Center research plan covering ATC issues exists; these ATC domains are listed only for the convenience of the reader. The Flight Deck/ATC Integration section of the National plan discusses four "plans"; each plan has several goals. Appendix C lists these plans and associated goals.

A variety of people skills and experience levels must be maintained. FAA personnel, cooperating agency personnel, and support contractors will form a multidisciplined team to address the implementation of Data Link communications.

1.2.4 Establish Cooperative Research Agreements.

A key element of this research plan is the ability to establish research agreements with contractors, government research laboratories, military, and universities in a timely manner. Some of these groups will be international in nature. The FAA Technical Center's ADL Group, organizationally designated ACD-320, has the following agreements in place or available as options:

a. Cooperative Research and Development Agreements (CRDA) - technology transfer agreements between the FAA Technical Center and various avionics manufacturers.

b. Small Business Innovative Research (SBIR) efforts - Small business contract awards for limited scope research programs.

c. Interagency Agreements (IAA) - IAA's with the National Aeronautics and Space Administration and the United States Air Force (USAF) are currently in place, and provide the Technical Center with access to research ongoing in the military community.

d. Intergovernment Agreements - An annex to a Memorandum of Cooperation between the United States government and the Kingdom of the Netherlands has been established, and is useful to assure consistent Data Link operations in U.S. Domestic and European airspace .

e. University Grant Programs (UGP) - The FAA Technical Center has an aggressive UGP that also establishes Centers of Excellence. Centers of Excellence are consortia of universities teamed to amalgamate resources. University grants are awarded to individual universities to capture a particular aviation expertise.

1.3 DATA LINK HUMAN FACTORS RESEARCH PHILOSOPHY.

In its system development process, the FAA stresses the criticality of user inputs at the specification stage, before the systems design is completed. Human factors considerations accounted for early in the design process, before Key Decision Point (KDP)-3, are much less costly to incorporate than at a later stage, Operational Test and Evaluation (OT&E). The ability to incorporate human factors early requires a facility equipped to evaluate design ideas under consideration in a timely and efficient manner. One such facility is provided by the gathering of rapid prototyping software (RPS) and graphics workstations.

RPS and graphics workstations provide a simulation capability of almost an unlimited nature. Current concepts can be simulated and tested. Furthermore, concepts beyond the capability of current fielded systems can be investigated for potential usefulness in the real world.

Where financially and technically feasible, existing flight deck subsystems will be used along with RPS. This will provide the ultimate in research and design capability. Some reasons for using a mix of real and simulated equipment are as follows:

a. Prototype designers have ready access to operations equipment to study limitations, and more closely emulate existing systems without guessing.

b. Controller teams participating in concept testing can develop a mental context baseline by "warming up" on existing systems before moving to the prototypes.

The FAA Technical Center has existing NAS equipment in its National Simulation Support Facility (NSSF). The addition of prototyping equipment is a comparatively small and inexpensive step to complete this facility.

1.4 CUSTOMER IDENTIFICATION.

The primary customer of the Technical Center is FAA Certification and Flight Standards. Certification personnel in the FAA anticipate the need for additional information about Data Link human factors. The other customer of the Technical Center is FAA Capital Investment Program (CIP) office. Longer term systems development projects under the CIP will especially require inputs from the human factors community. Also, the needs of the aviation community must be taken into consideration. The range of users and the capabilities must be accounted for in both current and future systems developments. Systems and procedures will be developed that must be incorporated into the airspace system.

1.5 CUSTOMER REQUIREMENTS.

This FAA Technical Center research plan addresses several problem areas. The basic motives of the FAA are to maintain or enhance the safety, efficiency, and capacity of the nation's airspace system. These motives can only be obtained through careful study of the systems issues surrounding aviation Data Link. Human factors issues account for many of these systems issues. Current voice radio network problems, coupled with the projected worldwide growth in air traffic, point to the need for research on Data Link systems. The implementation of a Data Link into the airspace system demands the careful application of human factors engineering principles into the system design process.

The term "Data Link" has purposely been kept ambiguous. This is because Data Link may be either a satellite-based system, a very high frequency (VHF) system, a Mode S radar beacon system, or some combination. This research plan will be written with this awareness. Research will be conducted to assess the differences between the link modalities. Also, the effects on the flight deck during technology transitions or transitions between modality coverages (e.g., oceanic satellite to domestic Mode S) will be studied.

1.6 RESEARCH TOOLS.

One effort to be accomplished in conjunction with this plan is to develop additional research testbeds and perform enhancements to existing testbeds. This effort is to insure that the FAA Technical Center remains at the forefront of aviation research capability. The heart of the testbed is the NSSF. The FAA Technical Center hosts tenant FAA organizations charged with NAS component maintenance and software control. The FAA Technical Center maintains en route (Host) and terminal ATC systems in operational status in the NSSF. As operational site problems arise, FAA Technical Center personnel use these systems to reproduce the problem and develop "fixes" either in hardware or software. All affected systems nationwide are patched into the fix.

These same ATC simulation systems are available for research and development of Data Link products and services. Such a facility is indispensable for sizing, performance, or benefits studies of Data Link services implementations. Access to specific aircraft types is required depending on the Data Link/aircraft configuration being studied. Phase II and Phase III cockpit simulators have been training tools for a number of years and can be made available for research purposes. Finding increased utility, however, are cockpit trainers based on a computer image generation (CIG) of instruments and visual scenes. The thinking here is that a graphics- based cockpit simulation will offer sufficient fidelity for Data Link applications studies. The

process of matching simulation devices to testing efforts will be a continuous effort in order to remain current with advances in capabilities and requirements.

1.6.1 Reconfigurable Cockpit System (RCS).

The FAA Technical Center will soon complete the development of the RCS. This RCS, located at the FAA Technical Center, will be reconfigurable by virtue of its CIG capability and will be classified as a Flight Training Device (FTD). A second RCS is desired which could be configured to the "side-stick" style common to Airbus aircraft.

A goal of the RCS is to provide a research tool to the FAA Technical Center testbed that supplies the flexibility to support CIP and certification office requirements from a human centered flight deck perspective. To a degree, the fidelity of RCS can be varied by the addition of various hardware components, e.g., radio control panels, electromechanical instruments, etc. This is in addition to the RCS capability to mimic, through software, essentially any flight deck.

1.6.2 Cockpit Simulation Network (CSN).

A full fidelity cockpit simulator facility is expensive and difficult to maintain and the center does not currently have the capability. To gain the capability without the associated expense, a number of aircraft simulators has been networked via high speed telephone circuits back to the FAA Technical Center NSSF. Under this proposal, access to almost any aircraft simulator is provided for the cost of the telephone lines and a nominal cost per flight hour.

The process of adding simulators reflects the need to add the correct or appropriate simulators for the research being performed. Advisory circulars 120-40B (Airplane Simulator Qualification) and 120-45A (Airplane Flight Training Device Qualification) describe the level of simulator fidelity requirements given a task requirement. For example, procedural issues can be investigated in an FTD, while emergency management or operator certification must be performed in a high level simulator (Phase IV) of the aircraft under investigation. It is interesting to note that motion and terrain visuals are really not factors in simulator fidelity requirements.

The current network of simulators is composed of a Boeing Seattle B-747-400, a NASA Ames B-727, a Delta Airlines B-737, an FAA B-727 (Oklahoma City), the FAA Technical Center General Aviation Trainer (GAT), and an Avia Corporation B-727. Other simulators can be tied into the FAA Technical Center as the need warrants. Additional simulators in the United States and Europe will be added to the network in the future. A B-747 simulator located at the National Aerospace Laboratory in the Netherlands is expected to be added to the network soon.

An area that will soon need attention is how the modification of simulators for Data Link evaluations might affect certification of the devices used in experiments. A number of agencies will be a part of the process of linking simulators together: flight standards (FAA HQ), aircraft certification (FAA HQ), procedures (FAA HQ), training (FAA HQ), the simulator owner, etc. The process will be involved and will require time. Again, the advisory circulars discussed will be consulted for relevant information.

1.7 RESEARCH OBJECTIVES.

Specific objectives can be defined as a result of reviewing National Human Factors Aviation Research Plan requirements and an awareness of customer requirements. The primary objectives of this research are to perform cooperative research, establish a cumulative knowledge database, and satisfy CIP motives. A basic premise of human factors will be followed, that is, the systems developed must accentuate human capabilities while accounting for human limitations. Tests and evaluations will be based on accepted human factors principles and methodologies.

An extensive network of testbed facilities and associated evaluation tools will be established from cooperating organizations around the world. All research will be cumulative in nature, i.e., knowledge will increase with each study. The FAA charter to maintain and/or increase safety, efficiency, and capacity is paramount in the FAA Technical Center plan. The definition of goals and objectives then leads to a specification of research products (section 1.8).

1.7.1 Conduct Cooperative Research.

Cooperative research becomes the first clear objective. It is not enough to say that the FAA Technical Center is going to perform research that will support certification and satisfy the National Plan, etc. Synergistic gains, finite resources, and national interests in technology leadership mandate cooperative research with government and industry laboratories. Cooperation among research centers implies common measures of human performance, and agreements for data collection and distribution in published form.

1.7.2 Establish Cumulative Knowledge Database.

The second clear objective is an information base of cumulative knowledge. Cumulative knowledge results from both the FAA Technical Center research to satisfy stated requirements and the cooperative research efforts. The product of the cumulative knowledge base should be structured toward customer support, National Plan data requirements, etc. The cumulative nature of the knowledge base mandates that common human performance measures be collected.

1.7.3 Satisfy CIP Motives.

A third objective is to ensure that safety, efficiency, and capacity are maintained at current levels, and where possible, they should be increased. Data Link will represent a significant change in aviation; the change must be positive.

1.8 RESEARCH PRODUCTS.

The main product of the research proposed in this plan is information. The information will be contained in a relation database (as discussed in the National Plan). The information will take the form of exhaustive research reports which specify design recommendations. The information must meet the requirements of the identified customers, the information must be provided in a timely manner, and the results must be above reproach.

2. RESEARCH METHODOLOGY.

There are some fundamental areas that need to be addressed in the near term. These areas will influence the commitment of FAA resources and dictate the manner in which research will be conducted. Again, a systems engineering model has been adopted to guide this multifaceted program and this is evident in the research methodology outlined below.

2.1 STATEMENT OF NEED.

A large portion of all aviation incidents are a result of communications problems. Aviation communications must be enhanced to reduce these errors. Human factors principles must be applied to the design of the next generation aviation communications system.

2.2 ESTABLISH FUNCTIONAL REQUIREMENTS.

The establishment of functional requirements in this situation results in a rather broad based statement. The Data Link interface will be somewhat unique to each aircraft type. The interface will need to meet a minimum level of operational capability in terms of message display and pilot response.

2.3 KNOWLEDGE ACQUISITION.

The process of gathering information will involve literature searches and surveys of relevant organizations such as airframers, avionics manufacturers, industry, pilot, and controller groups. Design information will be gathered by assessing information available in the National Aeronautical & Space Administration (NASA)/FAA Aviation Safety Reporting System. National Transportation Safety Board (NTSB) accident reports will be reviewed as appropriate to glean data useful to systems designers.

Aviation research has produced an abundance of literature in topics regarding human performance. The amount of supporting literature will continue to grow. It will be necessary for the researchers to follow most of this literature if possible, or have rapid access when needed. A central "library" for Data Link will be established at the FAA Technical Center. The library will permit quality research through knowledge of past research and projections of future requirements and technologies.

The National Plan has an objective of developing and maintaining a relational database of issues, projects, and related Research and Development (R&D) efforts. The FAA Technical Center will develop such a Data Link human factors database and library.

2.3.1 Literature Searches.

An enormous body of literature exists on aviation issues. An organized search effort must be performed to find that information relative to this Data Link project. Searches will be performed on data bases at the National Technical Information Service (NTIS), the Defense Technical Information Center (DTIC) and various libraries at the FAA and cooperating organizations (e.g., NASA, USAF, universities).

2.3.2 Industry Awareness.

Several organizations exist which have extensive knowledge to bear on Data Link and human factors in aviation. Table 1 contains an abbreviated list of these organizations. These organizations have unique skills and knowledge to bear upon the area of Data Link human factors and as such will be used as appropriate. Other organizations will be involved in Data Link as appropriate to maintain a systems approach in the development of flight deck Data Link systems.

TABLE 1. INDUSTRY ORGANIZATIONS

ALPA	Air Line Pilots Association
ATA	Air Transport Association
APA	Allied Pilots Association
AIAA	American Institute of Aeronautics and Astronautics
HFS	Human Factors Society
IATA	International Air Transport Association
RTCA	Radio Technical Commission for Aeronautics

SAE Society of Automotive Engineers

The FAA Technical Center supports several committees within these organizations, for example, the RTCA SC-169 Committee, the ATA Human Factors Task Force, and the G-10/Human Behavioral Technology committee of the SAE. These organizations help to define pertinent issues, questions, and associated priorities. A general note regarding committee involvement is appropriate at this time. FAA Technical Center researchers strive to remain current in issues by attending many meetings and symposiums. In strictest terms however, FAA policy guidance is to come only through Federal Advisory Committees (RTCA is such a committee).

The FAA's Human Factors Coordinating Committee (HFCC) in the office of Chief Scientific and Technical Advisor for Human Factors (AXD-4), also provides research requirements. Organization support by the FAA means regular attendance and participation in the primary ad-hoc teams. The teams work to address action items and to prepare limited-scope written material for inclusion into minutes. Attendance at other organizational meetings will occur as resources permit.

2.3.3 Technology Awareness.

This section contains an analysis of anticipated FAA products as obtained from the CIP, FAA Research, Engineering, and Development (RE&D) plan, and Data Link program office projections of service evolution. Figure 2 links the products of these three areas together. It shows projections for the transport and commuter fleet on the same time scale as the NAS development plans. The information contained is useful in determining priorities to place on research issues. For example, the figure indicates that two-engine narrow body aircraft will number approximately 1900 by 1995 when en route and terminal Data Link service begins. Issues relative to certification of these aircraft are considered high priority research items.

Significant airspace capacity gains mandate increased use of automation in the air and on the ground. Future aircraft flight management system (FMS) functions, such as preferred routings, and four-dimensional functions, require Data Link access to the FMS. A function analogous to a Flight Management Computer (FMC) built in simulation is perceived to be very useful. FAA projects such as Flight Operations and Air Traffic Management Integration (FTMI) see the usefulness in having an FMC function available for concept development purposes before incurring the expense of flight trials. Simulated FMS is an important first step. Future generation aircraft will have distributed information processing and display capability so that the FMS computer function will not be centralized. The development of an FMS simulation facility should track the distributed avionics functionality philosophy.

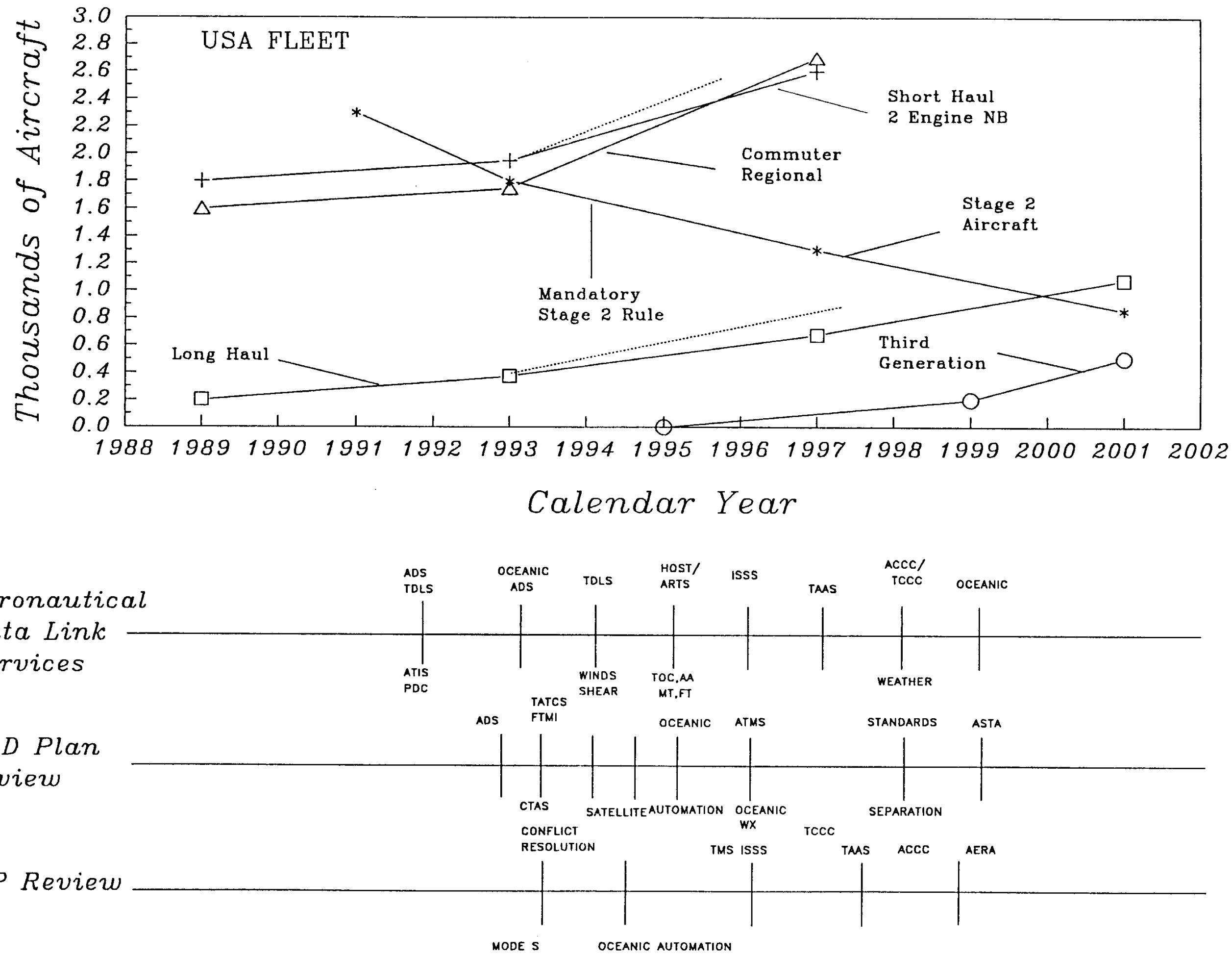

FIGURE 12. FAA SYSTEMS DEVELOPMENT AND AIRLINE FLEET PROJECTIONS

2.3.4 Airline Surveys.

Data Link will continuously evolve into the NAS as systems become available and economic considerations permit. ADL avionics must be made available for a variety of aircraft classes including all commercial, military, and general aviation aircraft. In the commercial aviation area, for example, there are many flight deck configurations that are unique and will require specific research and avionics. The possible flight deck configurations include electromechanical (first-generation), "glass" (second-generation, e.g., B-767), "glass/fly-by-wire" (third generation, e.g., B-777).

The current mix of flight decks in the NAS, according to Townsend (1992), is about 60 percent electromechanical and the rest first generation glass. This mix is under constant change as airlines upgrade their fleet to include the more efficient "glass" aircraft. The glass flight deck presents opportunities for integrated Data Link that electromechanical aircraft do not. Electromechanical aircraft will require retrofitting of systems to support Data Link functions. A constant awareness of the fleet composition is required to best direct research activities. The FAA Technical Center will constantly monitor the fleet composition and the plans by the airlines in terms of Data Link systems. In addition to the commercial fleet, an awareness of the other aircraft classes and the flight deck capabilities will be maintained.

2.3.5 Aviation Safety Reporting System (ASRS).

Extensive use of the ASRS will occur to support Data Link research activities. Specific areas of interest that will be researched as soon as possible are crew alerting, party line content and quality, and crew workload. When appropriate, NTSB incident reports will be studied for data pertinent to the design process.

2 4 PROBLEM DEFINITION

The FAA Technical Center will take an active role in the identification of Data Link issues that require research. Potential issues will be determined in a variety of methods, as discussed above. The issues identified will be fed into the FAA Technical center issues data base.

2.4.1 Identify and Prioritize Issues.

Data Link implementation is a multilayered problem. The augmentation of voice with Data Link involves several aircraft specific issues. Examples include avionics systems integration, flight crew interaction, emergency and error recovery, and clearance negotiation based on aircraft performance. Similarly, airspace system issues such as situation awareness (SA), simultaneous multiple approaches, and preferred routing among mixed performance aircraft dictate studies using type specific aircraft or aircraft simulators.

In the evolution of ATC, the controlling body has been not only the primary source of situational information, e.g., weather and traffic, but also had ultimate control over the pace at which information was delivered. Control pace per aircraft and rhythm among several aircraft caused the party line and, more importantly, kept pilots and controllers in a common mental framework or context. As aircraft make increasing use of automation, situation information will be derived from diverse electronic sources, which may arrive in clusters triggered by uncorrelated external events and possibly without controller knowledge or intention. Critical problems to be studied include the separation of pilot-controller mental context and unmanaged information loading.

The testbed required to study this context problem is a cockpit where automated systems including Data Link may be progressively added (perhaps in a pick and choose fashion) to analyze the information loading and system interaction.

The implementation of Data Link into the NAS has raised several research issues relative to the flight deck, the crew, the controller, and the "system." This attention will primarily be some level of formal research. Some issues may be "talkable" however, that is, may be addressed through analysis by appropriate subject matter experts. The various organizations mentioned earlier (i.e., RTCA, ATA, and SAE) have been instrumental in developing and documenting these issues. These three organizations have prepared issues lists to track research progress. Of the three lists, the ATA Data Link human factors issues list has been selected as the primary list for this research plan. Appendix D contains the results of a recent task by the FAA Technical Center that compared and contrasted the issues lists.

The ATA Data Link group has determined that the most efficient method to address the issues would be to develop task groups or classes of issues. These groups would then lend themselves to defining the pertinent research questions that could be attacked. Defined in the ATA list are four groups: procedures, errors, human interface design, and SA. This task grouping approach was chosen for a variety of reasons:

a. Provides a framework to link research activities together.

b. Identifies studies not contained in any issues list.

c. Establishes priorities and sequences of research activities.

d. Better match of FAA Technical Center resources to the research requirements.

e. Selects the proper research tools/methods for the issue under consideration.

The FAA Technical Center selected this ATA list and grouping methodology to achieve the following:

a. Group task structures from the perspective of end-to-end testing.

b. Group task structures to show how studies such as ASRS searches support other more extensive research efforts.

c. Group task structures to be aircraft and ATC independent, complete and homogeneous, and decomposable into element tasks.

d. Task groupings must make sense from the needs of ATC designers, aircraft certification, and the FAA's major mission motives of safety, efficiency, economy, and security.

e. Task groupings must capture the "rubber-meets-the road" modality of actual flight conditions.

Table 2 contains the ATA list of Data Link human factors issues; the issues are categorized by the four task groups. The ATA conducted a survey in which respondents ranked the issues in order of research importance. Several groups responded to the survey, e.g., certification, airframe manufacturer, aviation research, etc. Table 2 lists the numbers that correspond to the importance ranking of the issue. Much work has been done by these organizations to list, discuss, order, and publish these lists. The interested reader is encouraged to obtain the original document for further information.

Given the FAA aircraft certification and standards are the primary customers of the FAA Technical Center, their rankings were specifically identified (see table 3). Only those issues rated in the two highest categories (of five) are listed. Also, in consideration of these rankings and the Data Link implementation schedules, the issues have been further categorized (see figure 3). The numbers listed refer to the rankings provided by the survey's respondents (see table 2).

2.4.1.1 Procedures.

The incorporation of Data Link into the flight deck will represent a significant change in roles and responsibilities

TABLE 2. DATA LINK HUMAN FACTORS ISSUES BY GROUPS

Numbers correspond to overall importance ranking.

Procedures

1	Data Link protocols
8	Effects of delayed unables
14	Modifications to clearances
15	Function allocation
17	Data distribution
18	Data Link implementation evolution
24	Emergencies and transitions between emergency and nonemergency states
27	Pilot flying/Pilot not flying procedures
28	Mixed environment
36	Negotiations
37	Currently nonexecutable clearances

Errors

9	Effects of controller errors
11	Opportunities for error checking
12	Pilot detection of controller errors
16	Communication sequence errors
19	Pilot detection of other pilot errors
23	Error recovery procedures
26	Controller detection of flight crew errors
35	Levels of involvement
42	Proficiency loss
45	Pilot detection of other aircraft errors

Human interface design

2	Display surfaces, types and locations
3	Shared displays
6	Crew alerting mechanisms
7	Expiration times
10	Formats and contents
13	Priority displays
21	Standardization
25	Message displacement
29	Menu design
30	Synthetic voice displays
31	Clearance evaluations
32	Recovery from accept/reject errors
33	Definition of inhibit Logic
38	Link status displays
39	Display ordering and response facilitation
40	Discrepancies
41	“Too quiet flight deck
44	Selection of information sources

Situation Awareness (SA)

4	Effects of response delays on controller SA
5	Crew information transfer
20	Data Link integration with other cockpit technologies
22	Party line compensation
34	Situation awareness recovery
43	Independent confirmation

TABLE 3. FAA CERTIFICATION AND STANDARDS SURVEY RESPONDENTS RANKINGS

1	Data Link protocols
2	Display surfaces, types and locations
3	Shared displays
5	Crew information transfer
6	Crew alerting mechanisms
7	Expiration times
8	Effects of delayed unables
9	Effects of controller errors
10	Formats and contents
11	Opportunities for error checking
14	Modifications to clearances
18	Data Link implementation evolution
21	Standardization
22	Party line compensation
24	Emergencies and transitions between emergency and nonemergency status.
26	Controller detection of flight crew errors
27	Pilot flying/Pilot not flying procedures
30	Synthetic voice displays
36	Negotiators

Data Link Issues
Airspace vs. Research Priority

Airspace

Research Priority	Oceanic	En route	Terminal
High Priority	1,2,3,9,10,11, 12,14,19,23,26, 31,36,37,41	1,2,3,5,9,11,12, 19,23,26	1,4,5,6,8,9, 11,12,13,19, 22,23,25,26, 27,32,33,34
Medium Priority	4,5,16,17,20, 21,24	4,6,8,10,13,14, 16,17,20,21,22, 24,25,27,28,31, 32,34,36,37,41	2,3,10,17,20, 21,24,30,39, 40,45
Low Priority	6,7,8,13,15,18, 22,25,27,28,29, 30,32,33,34,35, 38,39,40,42,43, 44,45	7,15,18,29,30,33, 35,38,39,40,42,43 44,45	7,14,15,16,18, 28,29,31,35,36 37,38,41,42,43 44

Numbers refer to ATA Data Link Survey rankings - document dated 8/25/31

FIGURE 3. ATA ISSUES WITHIN AN AIRSPACE BY RESEARCH PRIORITY MATRIX

among other things. Procedures will need to be developed, examined, and validated to meet the needs of a new flight deck environment. Consideration will need to be given on a reallocation of man and machine roles. These procedures must be finalized prior to flight deck implementation.

2.4.1.2 Errors.

The issue of errors is increasingly critical given the increases in automation on the flight deck (and controller's console). The transfer of information from the Data Link to other flight deck systems (for example, the autopilot flight director system) must be done with the complete awareness of the crew. Errors can manifest themselves at many points within the system; the originator can be the controller, the crew, and other aircraft crews. The system must have checking mechanisms and recovery routines.

2.4.1.3 Human Interface Design.

This task group considers the flight deck "system" and the crew interactions with automated systems and Data Link. Of particular interest is the effect of multiple systems competing for crew attention. Multiple independent systems can upset the rhythm between pilots and controllers, thus, placing high peak demands on memory and decision making abilities. A reduction in the level of voice communications is expected to upset task synchronization and error checking/task validation.

A related topic is the efforts of potentially conflicting information, for example, ATC Data Links, ATC voice, TCAS, and LLWAS. Some questions to be addressed are as follows: when and what information sources should be inhibited and how to reduce redundant or superfluous information.

Additional human performance measures may result from this group. Action sequence diagrams will be developed that describe observed flight deck events, both correct and incorrect. Given a particular flight deck configuration, an event (e.g., Data Link message alert) will initiate an action sequence. These events and the resulting outcome will define a sequence model and probabilities can be established for each branch of the sequence diagram.

2.4.1.4 SA.

The issue of SA is critical. Concerns exist that SA will be significantly degraded because of the addition of Data Link into the flight deck. Pilot-pilot and pilot-controller awareness are key areas, as are issues such as recovery from the loss of SA. The issue of SA is closely related to the "party line" concept. Party line provides SA, according to some people, and will be lost in a Data Link environment.

2.4.1.5 Airspace Requirements.

The difference between the various airspace environments are sufficient to require a close examination of each and the specific systems and services for each. The FAA's proposed aeronautical Data Link evolution in the Tower, terminal radar approach control (TRACON), and Air Route Traffic Control Center (ARTCC)/Area Control Facility (ACF) environments is shown in figure 4 (RTCA Paper 177-91). A brief discussion follows on each environment.

The oceanic airspace is an area of particular focus by users, since the benefits of a Data Link will be greatest. Oceanic ATC should result in reduced separation requirements, allow for more user selected profiles, and permit positive control of aircraft.

	1992	1993	1994	1995	1996	1997	1998	2000
TOWER	*TDLS* PDC (Phase 1) Digital ATIS		*TDLS*	Digital ATIS Windshear	*TDLS*		*TDLS* *TCCC* PDC Windshear Digital ATIS	*TCCC*
TRACON				*ARTS 3A/3E* (NOTE 1) ToC IC/TI Alt Assign Menu Text			*TRT* Toc IC/TI Alt Assign Menu Text CommBackup	*TRT*
ARTCC/ACF	*OCEANIC*			*HOST/OCEANIC (*NOTE 2) ToC Alt Assign Menu Text Comm Backup Weather ADS (Step 2)		*TAAS* ToC IC/TI Alt Assign Menu Text Comm Backup	*ACCC* IC/TI (NOTE 3)	*ACCC*

NOTE 1. These services will be provided by a communications front end processor for ARTs which will be in service in 1995.

NOTE 2. Weather services will be provided by the Data Link processor-build 2 (DLP-2).

NOTE 3. Data Link processor- build 3 (DLP-3) will be placed on line in 1998 and will provided enhanced weather products.

SOURCE: RTCA Paper 177-91

FIGURE 4. AERONAUTICAL DATA LINK EVOLUTION

The previously mentioned FAA motives of capacity, efficiency, and safety can be immediately and directly addressed.

Several airlines are active in oceanic Data Link research. The so-called Pacific Engineering Trials have shown the benefits of Data Linked position reports. The application of Data Link in the flight deck of oceanic class aircraft is the next window of opportunity.

After oceanic Data Link, the next airspace to experience Data Link has not been decided. Controllers seem to advocate the terminal airspace while pilots wish to see the en route airspace. Both groups provide convincing logic, therefore, the issue is still being debated.

Terminal airspace is probably the most communications intensive and probably will greatly benefit from Data Link. The major stumbling blocks will be SA, head down time, and link delays, to name a few.

A Data Link system in the foreign environment will reduce the confusion of accents and dialects.

2.4.2 Scenario Specification.

A data base of both routine and non-routine flight scenarios will be necessary to conduct Data Link research. A family of scenarios should be developed or obtained for future use. The scenarios should be capable of expansion to encompass the details required for any given study. A scenario data base should reduce the effort expended each time a new study is proposed. Perhaps the flight scenarios could be supplied by outside organizations, e.g., airlines and airframers. The unusual or non-routine scenario situations could be gleaned from ASRS reports and accident reports from NTSB.

2.4.3 Pilot Subject Pools.

A program of this nature will require that users (i.e., pilots and controllers) be available to evaluate system designs. A nationwide pool of pilots should be established. All categories should be covered, that is, civilian and military, commercial and general aviation, new technology ("glass"), and old technology (figure 4, Aeronautical Data Link Evolution, electromechanical). Pilots from all ranks within the commercial airline world should be solicited, e.g., management, line, and engineering/test. The RTCA organization will be consulted and asked to provide assistance in identifying and selecting pilots and pilot organizations.

2.4.4 Human Performance Measures.

This element dedicates effort to determining a set of human performance measures that are global in nature and can be applied in all experiments. The resulting list will be published for coordination with the FAA HFCC and other research organizations in the field of aviation human factors.

The intent of the coordination is to gain a consensus of at least a subset of measures so that data from independent programs can be related in absolute terms. An initial list will be derived from the ATA's human factors issues paper. The initial list will include topics such as SA, head down time, and human information processing and decision making, among others. Also, measures will be developed to express relationships between pilot actions and primary, secondary, and tertiary cockpit events. For example, loading a new altitude into the FMS mode control panel (action)) will cause possible thrust setting changes (event), a climb profile (event), and level off at a new altitude (event). Event decomposition for Data Link transactions is perceived as a way to study the effects of varying levels of automation, error effects and recovery, and relative efficacy of Data Link implementations.

2.5 CONCEPT EXPLORATION.

2.5.1 Formulate Research Questions.

The process of formulating a research question will involve writing a concise and clear question from which a test plan is written around. The question will most likely address one or two issues (see section 2.4.1) relative to a flight deck Data Link interface of some particular specification. The act of conceiving a research question is one of the most critical steps on the research process.

2.5.2 Part-Task Research.

This level of testing implies very basic research, for example, paper and pencil inquiries, pilot surveys, and PC-based studies. This research focuses in on a specific problem or concern. Care must be taken in generalizing the results since human performance will likely change in the full task environment.

2.5.3 Mockup Research.

Mockups mean different things to different people. An operational definition will be given from the FAA Technical Center's perspective. A mockup represents a generic device that can be configured to functionally represent a cockpit of particular interest albeit not usually with the actual equipment. The FAA Technical Center's RCS represents a high level mockup.

The FAA Technical Center GAT also will provide a high level mockup capability--or a low level simulator capability. As the name implies, the GAT allows the FAA to conduct research in the general aviation area.

2.6 DEMONSTRATION AND VALIDATION.

2.6.1 Simulator Research.

Again, simulation must be defined to maintain a common understanding. A simulator is generally a fixed configuration or type of aircraft, e.g., B-737, either fixed or moving base. The equipment is actual or simulated flight hardware. Out-the-window visuals are available on higher fidelity simulators. The FAA describes seven levels of simulators in appendix A of Advisory Circular 1209-45A. The FAA Technical Center is establishing a worldwide network of simulators that, if required, can be linked to ATC simulation facilities at the FAA Technical Center.

2.6.2 Flight Test Research.

Flight testing will involve FAA project aircraft and, later in the implementation process, actual airline aircraft.

The augmentation of voice with Data Link involves several aircraft-specific issues. Examples include avionics systems integration, flight crew interaction, emergency and error recovery, and clearance negotiation based on aircraft performance. Similarly, airspace system issues such as SA, simultaneous multiple approaches, and preferred routing among mixed performance aircraft dictate studies using type specific aircraft or aircraft simulators.

In the evolution of ATC, the controlling body has been not only the primary source of situational information, e.g., weather and traffic, but also had ultimate control over the pace at which information was delivered. Control pace per aircraft and rhythm among several aircraft caused the party line, and more importantly, kept pilots and controllers in a common mental framework or context. As aircraft make increasing use of automation, situation information will be derived from diverse electronic sources, which may arrive in clusters triggered by uncorrelated external events and possibly without controller knowledge or intention. Critical problems to be studied include the separation of pilot-controller mental context and unmanaged information loading.

The testbed required to study this context problem is a cockpit where automated systems including Data Link may be progressively added (perhaps in a pick and choose fashion) to analyze the information loading and system interaction.

The implementation of Data Link into the NAS has raised several research issues relative to the flight deck.

3. DISCUSSION OF EVALUATIONS.

A global roadmap and schedule of research efforts is diagrammed in figure 5. This roadmap focuses on all levels of testing except the lowest level, that is, desktop or part-task level. Part-task research is normally a last minute activity to satisfy an immediate need or respond to a "fast track" program and is not easily predicted. It is envisioned that part-task research will also be conducted to prepare for mockup and flight test projects.

The lower half of the figure shows the activities in which the airborne and ground research groups at the FAA Technical Center have joint evaluations planned. These joint tests address the en route, terminal, and interfacility environment. The upper half of figure 5 describes the airborne group's independent initiatives. Research will be conducted in en route, terminal, and oceanic environment. ATC functionality will be simulated to the level required to permit realistic examination of the flight deck issues. The goal of this independent research is to prepare for joint testing and to examine flight deck issues that are generally independent of the ATC area. An overall chart identifying the interdependencies between the various research efforts is shown in figure 6.

The previous sections identified the various levels of research ranging from part-task to flight tests. Although not specifically detailed in the program schedule (figure 5), part-task level research will be used primarily to investigate formatting issues of candidate Data Link services. This can be done in the absence of any ATC simulation. System level issues such as crew/controller expectations and pilot SA are best evaluated in a simulator environment setting. However, performance indices, test metrics, etc., for assessing system level issues can be examined in part-task or mockup level research prior to conducting simulator level research.

Results gathered from part-task/concept development efforts will feed into the major mockup evaluations identified in the program schedule (Rl-R8). In turn, the results from the mockup evaluations will feed into the simulator evaluations.

3.1 MOCKUP AND SIMULATOR EVALUATIONS.

The following sections will describe in general the planned mockup evaluations. Figure 6 outlines the connectivity of mockup level evaluations with en route, terminal, interfacility (FAA Technical Center Aeronautical Data Link Research Plan, 1992), and flight test level research. The first four evaluations are designed such that they feed into the scheduled simulator flight

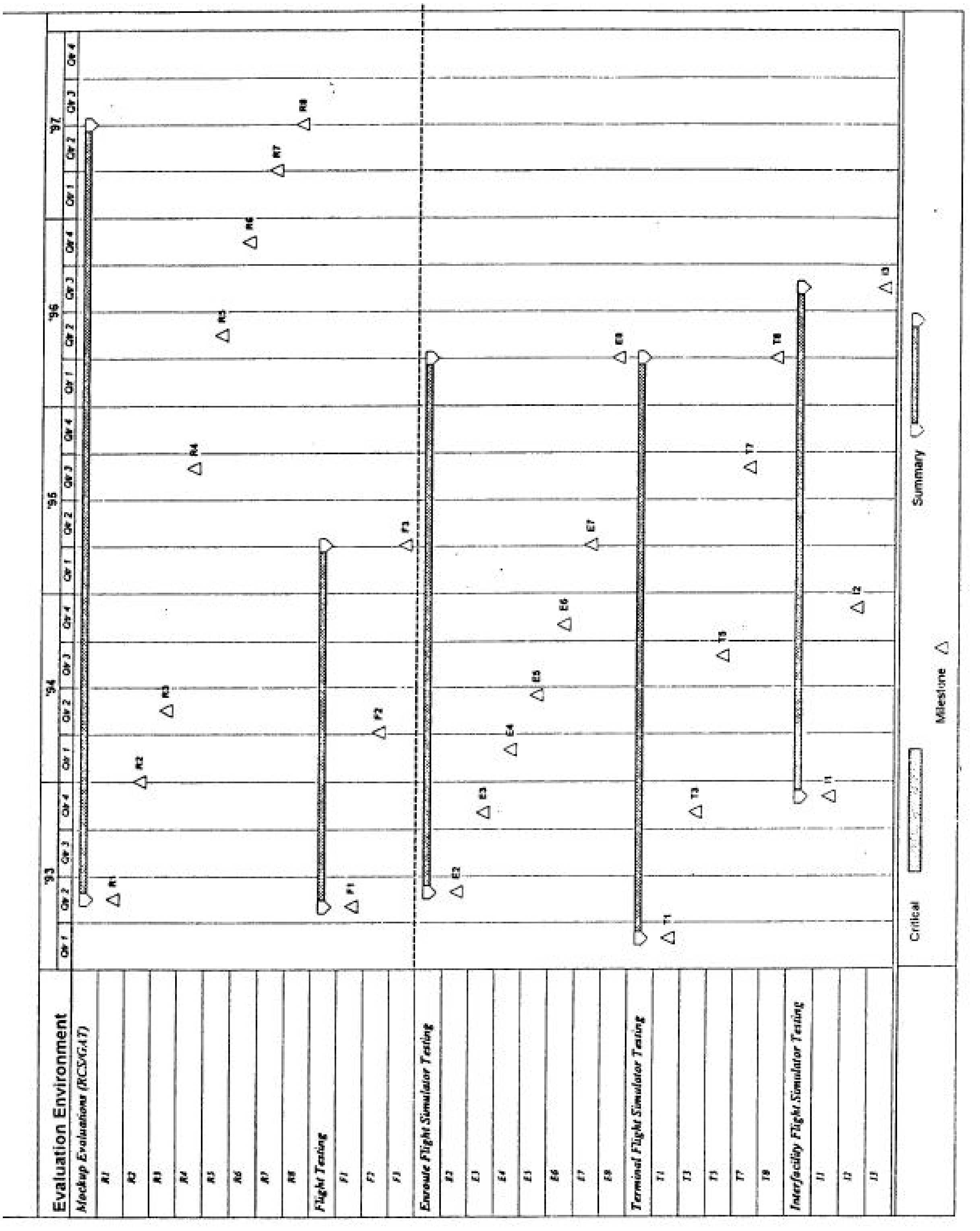

FIGURE 5. AERONAUTICAL DATA LINK PROGRAM SCHEDULE

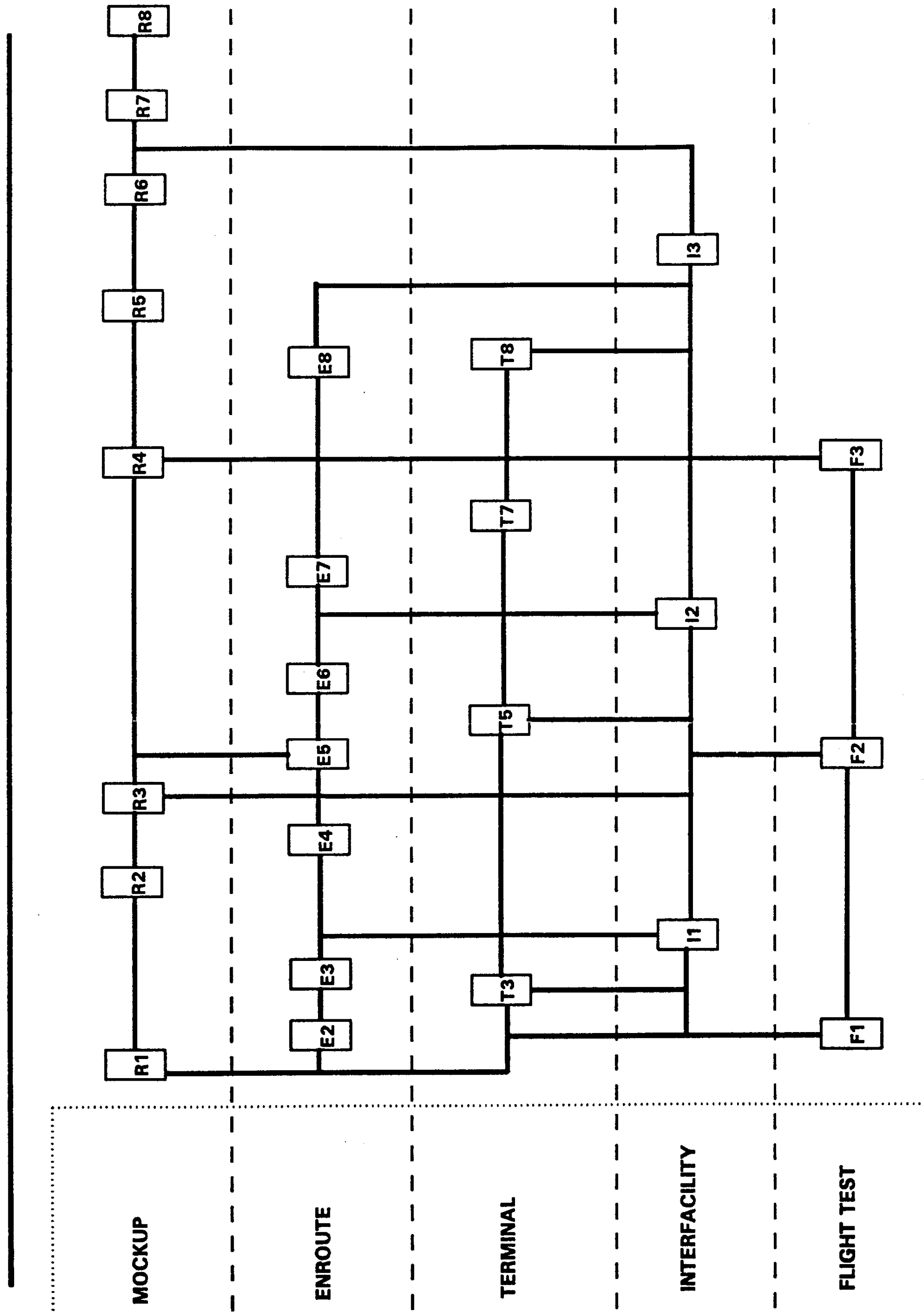
MOCKUP
ENROUTE
TERMINAL
INTERFACILITY
FLIGHT TEST
R1
R2
R3
R4
R5
R6
R7
R8
E2
E3
E4
E5
E6
E7
E8
T3
T5
T7
T8
I1
I2
I3
F1
F2
F3

FIGURE 6. AERONAUTICAL DATA LINK RESEARCH DEPENDENCIES

testing. To the extent possible, test objectives and issues identified for simulator tests will be fully met in the mockup evaluations.

The primary objective from an ATC perspective is the development of controller Data Link interfaces that work cooperatively with the new ground system facilities, such as the Interim Sector Suite System (ISSS) and ACF. From a flight deck perspective, these new ground systems may or may not result in additional Data Link service capabilities. It is from the systems point of view that the operational benefit of such systems can be realized. For example, the AERA Automation System is expected to exploit more fully the present capabilities of flight management systems. This may provide, for example, more fuel efficient routing, and additional service capabilities. In general, knowledge gained through review and assessment of ground systems has a direct impact on the development of flight deck Data Link interfaces.

The RCS will be the primary aircraft simulation tool in conducting these evaluations. ATC simulation will be provided by the FAA Technical Center Human Factors Laboratory. Each source will be designed to be adaptable to all airspace environments, including oceanic. While the RCS can mimic almost all aircraft types, the focus will be on "glass" cockpit transports. The first four studies depict such an arrangement. As a rule, each evaluation makes reference to an aircraft type configurable in the RCS. Where not specifically stated, the configuration is subject to the present research interests.

It is also the intent of this plan to include electromechanical type aircraft and general aviation (GA) type aircraft. Where possible, electromechanical and GA designs will be generalized from other designs used in the RCS. In addition, further part-task and concept development exercises will be employed in these environments.

In the following sections are descriptions of the evaluations to be conducted in the RCS. Activities Rl-4 will be considered as preparatory dry runs for later use in the higher fidelity simulator evaluations.

a. Activity R1. The RCS will be configured as a B-747-400 in which the FMS serves as the Data Link device. The FMS as a Data Link interface is a result of a survey of the air transport fleet and expected display device for the B-747-400 aircraft (Pomykacz, 1991). A scenario with a normal level of workload will be designed. The scenario will consist of a mid-air initialization over the Pacific Ocean with transitions to en route and terminal airspace on into landing. Digital Automatic Terminal Information Service (ATIS), weather, wind shear alerts, the initial en route, and terminal services will comprise the service set. ATC simulation (Virtual Applications Prototyping

Software (VAPS), Human Factors Lab) will include metering and spacing tools.

Preceding part-task/concept development, exercises will be used to optimize menuing and format design; the formats and message content will conform to standard Aeronautical Radio, Inc. (ARINC) 739 characteristics. For this evaluation, ATC clearance information, such as altitudes, headings, and speeds will require normal crew procedures. Later evaluations will employ automatic forwarding to mode control and flight director systems.

b. Activity R2. Future air traffic management (ATM) systems will provide direct exchange of information (digital Data Link) between aircraft FMS's and ground based ATM computers. This concept will exploit more fully the capabilities of present generation FMS's.

One research question of interest is the crew's level of involvement in exchange of Data Link information with the ground ATM and FMS systems. The level of involvement may increase or decrease as compared to current crew workload levels. This evaluation will investigate procedural and SA issues resulting from this increased level of automation under oceanic, en route, and terminal environments.

The Data Link design philosophy of the B-777 lends itself to the study of various automation issues. The RCS will be configured as a B-777, complete with cursor control device, lower and upper engine information and crew alerting displays (EICAS), and FMS's. The study of the B-777 design provides additional data on the various control devices that may be used in responding to and accessing Data Link related information. The same scenario and service set used in activity Rl will be used in this evaluation. Additional services identified in the research community that use the automation capabilities of the FMS's will be also addressed.

c. Activity R3. During the latter half of fiscal year 1993 and the beginning of the first quarter of 1994, preparatory part-task studies will be conducted to explore various human interface design issues. The studies will be germane to the expanded Data Link service sets as a result of the Host/ISSS production build. For further information on the Host/ISSS build, see the ground ADL research program.

Also expected in this time frame is the addition of a second RCS to the flight deck Data Link testbed. The second RCS will be outfitted with a "side-stick" controller, representative of an Airbus-340.

The aircraft configurations will be the Boeing-757/767 and an Airbus-340. The scenario will begin with a mid-air initialization over the North Atlantic with transitions to en

route and terminal airspace. Crew coordination as a result of scenario induced errors will be evaluated.

d. Activity R4. In order to effect an evolutionary approach, current Data Link services are considered normal routine clearances. A research question may be whether emergency/flight critical information can be conveyed rapidly enough to the crew. Crew coordination and human interface design issues as a result of receiving emergency information will be addressed in this evaluation. The B-777 (Activity R2) and Airbus-340 (Activity R3) configurations will be employed in this evaluation.

e. Activity R5. As discussed earlier, the arrival of AERA will provide direct routing and fuel efficient profiles that should increase capacity of the NAS. Future FMS's will have four-dimensional navigational capability. The result of the AERA technology will tap more fully the capabilities of the FMS.

A measure of the effectiveness of such systems will be evaluated in an RCS "glass" cockpit configuration. The increased level of automation may result in the so-called "too quiet" flight deck, and, over prolonged periods of time, may result in proficiency loss in the event of Data Link failure.

Evaluation of AERA in a Data Link environment will be conducted in two phases. For Phase I, concept development exercises will investigate potential designs to compensate for loss of party line information. The second phase will be discussed in the next section.

f. Activity R6. Phase II evaluation will focus again primarily on the loss of the party line but, perhaps, integrate other cockpit technologies. For example, TCAS could be integrated with Data Link in the terminal environment to possibly aid flight crews awareness.

g. Activity R7. An advantage of today's voice network is that the party line provides advance notice to flight crews on potential weather phenomena ahead. Knowing this information ahead of time, the crew can expect amended-clearances to divert around potentially hazardous weather. To compensate for the loss of the party line, graphic depiction of real time weather information forwarded to the cockpit through Data Link and/or provided by onboard improved weather sensors can provide that information to the flight crew. In addition, the concept of "sensor fusion" will assimilate available sensor information to provide the most complete best picture of weather.

This evaluation will address the advantages/disadvantages of Data Linked weather information. Various depictions of weather through textual, graphic and combination of both will be evaluated. In addition, Data Linked weather absence of additional onboard sensor data will be evaluated.

h. Activity R8. Alaskan Airlines presently uses a Head-Up Display (HUD) in their B-727 fleet operation. With Data Link, the amount of head-down time becomes an important issue and is often the subject of much debate. Perhaps with a HUD, Data Link information can be conveyed to the pilot crew, responded to, and forwarded to appropriate cockpit systems without resorting to "looking down." For example, Data Linked altitudes could be displayed as a marker bug on the altitude tape. Concept studies will investigate design issues prior to full mockup evaluations using a simulated HUD/Data Link display.

3.2 FLIGHT TESTS.

The FAA Technical Center will, over the next five years, take a progressive role in the area of flight testing proposed Data Link cockpit interfaces. Employing FAA project aircraft, efforts will be focused on examining crew response to Data Link during test flights. The increase in the capability of the air-ground communications link will expand the effectiveness of the flight tests.

During the next two to three years, the avionics development activities will be aimed at creating an integrated flight deck interface and communications test facility. The goals of this facility are:

a. To provide a means to test air-ground communications network interoperability.

b. To offer a platform on which experimental cockpit displays and crew interfaces can be realized.

c. To integrate the above two goals, thus, providing a flight package that can support Data Link research and operational demonstrations.

The following sections describe the proposed capabilities of the test facility and associated flight tests.

a. Activity Fl. During FY93, the technical aspects of the Mode S communications link will be validated. This work will validate the material of the International Civil Aviation Organization (ICAO) Airborne Data Link Processor (ADLP) Suggested and Recommended Practices (SARPS). These SARPS will be brought to a vote during the summer of 1993. The more testing a proposed link has experienced, the less likely there will be technical "snags" in its adoption.

Mode S Data Link testing began in the fall of 1991 with the first flight test. This test consisted of a production Data Link Processor (DLP), build 1 (DLP 1), production Mode S sensor, and commercial Data Link avionics. These tests continued in the laboratory throughout early 1993, culminating with flight test support of the FAA Technical Center DLP 1 site acceptance test in the spring of 1993.

A cockpit interface is being designed to contain a software implementation used in the November 1992 operational evaluation of terminal services. Also included in the design is the DLP 1 weather service capability. A flight certified display, procured to support the November operational evaluation simulators, is being considered for this interface. Several noncertified PC-style screens have already been installed in the cabin of project aircraft, but this will be the first attempt at installing a Data Link display in the cockpit. This step will provide researchers with the opportunity to see how the flight crew interacts with initial Mode S applications.

An interface between the ATC Data Link Test Facility and one or more Mode S sensors will provide the means for controller test subjects to interact with the FAA project aircraft flight crew. Flights will occur in a nearby warning area and will be coordinated with air traffic.

The implementation of the avionics package for Mode S terminal services support began in the first quarter of FY93. DLP 1 support was needed through March 1993, while Mode S terminal services will be available by the end of 1993.

b. Activity F2. FAA's continued support of the Aeronautical Telecommunications Network (ATN) project will become a valuable resource during this period. Efforts are currently underway in the integration of Mode S and satellite subnetworks into the ATN arena. An airborne internetwork router is being developed to gather data about the internetwork characteristics and limitations. This router, its Mode S and satellite subnetwork connections and appropriate applications, ADS, two-way Satellite Communications (SATCOM), terminal ATC, and weather services, to name a few, will become an essential part of the integrated Data Link test facility.

The results of the previous years Man-Machine Interface (MMI) cockpit simulator research pertaining to format, syntax, content, and procedures will be the focus of the cockpit display integration effort. Displays and equipment in precertification configurations will be supplied by avionics vendors for flight testing. Electrical interfaces to this equipment will be accommodated by the test facility. Characteristics of prototype and vendor equipment will be determined and modified for optimum efficiency.

The interface to the satellite avionics started in March 1993. The prototype router is scheduled for initial functional testing in September 1993 and the ATN build 1 schedule reflects ATN flight tests beginning January and extending through May 1994.

c. Activity F3. As Data Link becomes more a part of everyday domestic and international flight, more products developed by avionics vendors will appear. This equipment is required to be certified before it is flown. Results of previous Data Link experiments will be invaluable in aiding the certification effort for both the FAA and vendors.

Mode S interrogators are planned for installation in the continental United States (CONUS) during the 1994-95 time frame. By this time it is expected that several Data Link applications will be supported. A limited installation program of 20 to 30 commercial air transport aircraft is proposed. Interoperable Data Link systems, supporting gatelink, satellite, Aviation Packet (AVPAC), Mode S, and standardized routing, available from manufacturers, will be installed on these aircraft. Traffic data will be recorded at a centralized location, with the characteristics of this traffic available for further data reduction and analysis.

3.3 RESEARCH. ISSUES AND THE NATIONAL PLAN.

In developing this Data Link human factors research plan, an attempt was made to identify all the critical components and factors. A major goal was to develop a five-year plan that addressed the important issues defined by the various government and industry groups and also addressed the requirements set forth in the National Plan for Aviation Human Factors. Table 4 contains a conformance matrix that links research activities to issues and to National Plan requirements.

4. RESOURCE REQUIREMENTS.

Personnel and equipment are provided for through the program directive process. FAA personnel are accounted through Personnel Compensation & Benefits funds, while non-FAA personnel and equipment are funded through contract dollars. Contract dollar funding can be R&D or F&E.

Travel funding is provided through FAA Technical Center allocation for routine project personnel travel. Unique requirements such as travel for large groups (e.g., 10-20) of FAA, non-Technical Center personnel are funded by contract dollars.

TABLE 4. EVALUATIONS CONFORMANCE MATRIX		
Schedule Activity	ATA Issues Numerical Ranking	Human Factors National Plan Flight Deck Project No. Reference
Rl	1,2,3,5,6,27,31,34,36	1.1,1.2,1.3,3.3,4.1,5.2,6.2
R2	6,11,12,14,15,17,20,22	1.1,1.2,1.3,3.1,4.1,5.2,6.2
R3	1,6,12,14,15,17,23,27, 34,36	1.1,1.2,1.3,3.1,3.3,4.1,5.2, 6.2
R4	1,6,12,14,15,17,20,21, 23,24,27,31,34,36,37	1.1,1.2,1.4,3.1,3.3,4.1,5.2, 6.2
R5	1,2,5,11,14,15,17,18, 20,22,23,27,31,36,41	1.1,1.2,1.4,3.1,3.3,4.1,5.2, 6.2
R6	1,2,5,11,14,15,17,18 20,22,23,27,31,36,41	1.1,1.2,1.4,3.1,3.3,4.1,5.2, 6.2
R7	1,5,10,15,16,17,20,22 34,35,43,44	1.1,1.2,1.3,3.1,4.1,5.2,6.2
R8	2,5,10,14,15,17,19,20 24,30,34,39,41,44,45	1.1,1.2,1.4,3.1,3.3,4.1,5.2 6.2
F1	1,2,5,6,10,11,12,26,27 28,29	1.1,1.2,1.3,3.3,4.1,5.2,6.2
F2	1,2,5,6,10,11,15,17,20 , 23,25,27,28,29	1.1,1.2,1.3,3.3,4.1,5.2,6.2
F3	1,2,5,6,11,18,21,27	1.1,1.2,1.3,3.3,4.1,5.2,6.2

Program tracking and control is accomplished by periodic progress summaries that report work accomplished, action items completed, problem areas, coordination with industry groups, and attendance at conventions, shows, or demonstrations. The terms of tracking instrument can be stipulated in the program directive.

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APPENDIX A
FLIGHT DECK ENVIRONMENT RESEARCH DOMAINS

Domain 1 - Automation/Advanced Technology. Control and Display Design.

Projects.

Human Centered Automation Concepts and Tools
Intelligent, Error Tolerant Aircraft Automation
Aircraft Situation and Environment Management
Integration of Advanced Automation in Aircraft

Domain 2 - Aviation System Safety Monitoring Capability.

Projects.

Crew and System Performance

Domain 3 - Basic Scientific Knowledge of Human Performance Factors.

Projects.

Operationally Induced Stressors
Flight Deck Environmental Stressors
Socio-Organizational Influences on Flight Crew Performance

Domain 4 - Human Performance Measurement.

Projects.

Aircrew Performance Measurement

Domain 5 - Training and Selection.

Projects.

Pilot Selection
Pilot Training

Domain 6 - Certification and Validation Standards.

Projects.

Personnel Certification
Equipment Certification

APPENDIX B
AIR TRAFFIC CONTROL (ATC) RESEARCH DOMAINS

Research Domain 1 - ATC and Human Performance.

Projects.

Description and Measurement of Controller/Team Job Performance
Approaches to Enhancements of Controller/Team Performance

Research Domain 2 - Impact of Automation on Controllers and ATC Teams.

Projects.

Effects of Increased Automation of ATC Functions
Effects of Changes in Management of ATC Information
Effects of New Ergonomic Designs for ATC

Research Domain 3 - Selection, Training. and Certification of ATC Personnel.

Projects.

Selection of ATC Personnel
Research to Assure Appropriate Training of ATC Personnel
Training for Transition to Automated ATC Systems
Certification of Air Traffic Personnel

Research Domain 4 - Safety Monitoring of ATC Activities.

Projects.

Incident Reporting
Real-Time Monitoring of Controller/Sector Activities

APPENDIX C
FLIGHT DECK/AIR TRAFFIC CONTROL (ATC) INTEGRATION PLANS

Plan 1 - Enhance Flightdeck/ATC information Transfer and Management.

Goals.

Review Issues
Determine Alternative Approaches
Determine Criteria
Evaluate Alternatives
Determine Implications
Select and Prioritize
Develop Approaches
Evaluate Alternative Approaches
Develop Selected Approach
Participate in Acquisition

Plan 2 - Decrease Frequencies/Consequences of Flight Deck/ATC Errors.

Goals.

Define Errors
Develop and Evaluate Measures
Identify Causes
Determine Frequencies/Consequences
Develop Means to Detect Errors
Develop Approaches
Evaluate Alternative Approaches
Develop Selected Approach
Participate in Acquisition

Plan 3 - Determine Appropriate Allocation of Authority and Functions Between Flight Deck and ATC.

Goals.

Define Issues
Determine Alternative Allocations
Determine Criteria
Evaluate Alternatives
Determine Implications
Select and Prioritize
Develop Approaches
Evaluate Alternative Approaches
Develop Selected Approach
Participate in Acquisition

Plan 4 Develop Required Methods, Tools, and Guidelines.

Goals.

Review Plans 1-2
Review Available Methods and Tools
Determine Alternative Means
Determine Criteria
Evaluate Alternatives
Develop Methods and Tools
Prepare Guideline Documents

APPENDIX D

COMPARISON OF AIR TRANSPORT ASSOCIATION (ATA), RADIO TECHNICAL COMMISSION FOR AERONAUTICS (RTCA), AND SOCIETY OF AUTOMOTIVE ENGINEERS (S
DATA LINK ISSUES LISTS

Table D-1 shows where common issues exist between the three organizations. In table D-2 are issues contained in the ATA list but not in either the SAE or RTCA lists. Table D-3 lists issues contained in the SAE list but not in either the ATA or RTCA lists and finally, table D-4 shows issues contained in the RTCA list but not in either the SAE or ATA lists.

TABLE D-1. DATA LINK REQUIREMENTS REFERENCED BY THE ATA, SAE, AND RTCA DOCUMENTS (SHEET 1 OF 2)

REQUIREMENT	ATA	SAE	RTCA
2.0 General			
2.1 Safety	X	X	X
2.3 Mixed Services	X	X	X
2.5 Backup Communications	X	X	
2.6 Flightpath Control	X		X
3.0 Procedures			
3.1 Error Checking	X	X	
3.2 Flight Crew Response Time	X	X	X
3.3 "Unable" Response	X	X	
3.4 Multipart Clearances	X		X
4.0 Error Management			
4.1 Data Integrity	X		X
2 Error Trapping	X	X	X
5.0 Human-Computer Interface			
5.1.1 Interference with other Responsibilities	X	X	X
5.1.2 Display/Control Competition	X	X	
.1.3 Shared Resources and Flight Crew/Control Coordination	X	X	
5.1.6 Pilot Interference with each other	X	X	
5.2.4 Review Before Sending	X	X	
5.2.5 Head Down Time	X	X	X
5.2.6 Head Away Time	X		X
5.2.9 Input Response Times	X	X	
5.2.12 Control Over System Functions	X	X	X
5.2.13 Simplicity of Control Actions	X		X
5.3.1 Misleading Information	X	X	
5.3.5 Abbreviations and Acronyms	X	X	X
5.3.7 Standard Symbology	X	X	X
5.3.8 Free Text	X		X
5.3.10 Wording	X	X	X

TABLE D-1. DATA LINK REQUIREMENTS REFERENCED BY THE ATA, SAE, AND RTCA DOCUMENTS (SHEET 2 OF 2)

REQUIREMENT		ATA	SAE	RTCA
5.4.1	Air Traffic Service Mixes	X	X	
	Flight Deck Functions	X	X	
5.4.3	Distractions	X	X	
5.5.3	Distinction of Alerts	X		X
5.5.4	Flight Phase Inhibitions	X	X	X
5.6.1	Response Facilitation	X	X	X
5.6.2	Display Displacement	X	X	X
5.7.1	Automatic Messages	X	X	X
5.7.2	Log Content, Organization and Grouping	X	X	X
5.8.1	Service Determination	X	X	X
5.8.2	Controller Indication of Aircraft Data Link Capabilities	X	X	
5.8.3	Operator Indications of Data Link Status	X	X	X
5.8.4	Controller Indications of Sector Status	X	X	
6.0	**Situation Awareness Management**			
6.1	Data Link Party Line	X	X	X
6.3	Message Age	X		X
6.4	Interference Based on Characteristics of the Communications	X	X	
6.5	Pilot/Control Shared Situation Awareness	X	X	
6.7	Data Fusion	X	X	

TABLE D-2. REQUIREMENTS IN ATA NOT REFERENCED BY SAE OR RTCA

ATA	REQUIREMENTS
2.0 General	
2.2	Management of Varying Levels of Data Link Capabilities
2.4	Urgent Communications
3.0 Procedures	
3.5	Message Identification
4.0 Error Management	
4.3	Error Recovery
4.4	Error Notification, Recovery, and Message Prioritization
4.5	Closely Spaced Sequential Messages
5.0 Human-Computer Interface	
5.1.4	Mode Errors
5.1.5	Suspended Operations
5.2.1	Feedback
5.2.2	Ease of Use vs. Error Protection
5.2.3	Error Messages
5.2.7	Speech Synthesis
5.2.8	Multiple Entry of Parameters
5.2.10	Data Comparisons
5.2.11	Data Availability
5.2.14	Grouping
5.3.2	Coding
5.3.3	Precision
5.3.4	Preformatted Data Fields
5.3.6	Graphics
5.3.9	Conversions and Extrapolations
5.3.11	Consistency Between Environments
5.5.1	Levels of Urgency
5.5.2	Emergency Messages
5.6.3	Data Entry from the Message Log into the Flight Guidance System
6.0 Situation Awareness Management	
6.2	Critical Weather Information
6.6	Controller Display of Message Response Status

TABLE D-3. REQUIREMENTS IN SAE NOT REFERENCED BY ATA OR RTCA	
SAE	**REQUIREMENTS**
2	Selection of Information Sources
3	Guidelines for Communications Procedures
4	Proficiency Loss due to Data Link Utilization by Both Pilot and Controller
13	Determine the Workload Impact of the Data Link Implementation
18	"Public" Access to Data Link Info ("Privacy")
20	The Impact of Information Requirements on System Architecture
21	Promoting a "Too Quiet" Flight Deck

TABLE D-4. REQUIREMENTS IN RTCA NOT REFERENCED BY ATA OR SAE	
RTCA	**REQUIREMENTS**
1.0 Purpose and Scope (Assumptions)	
1.3.2	ATSDLC System Assumptions
1.3.3 a,b,e	Service Assumptions
1.3.4 b,c.e	Pilot Procedural Assumptions
1.3.5	Controller/Operator Procedural Assumptions
2.0 Equipment Requirements	
2.1	Pilot Alerting
2.2	Message Display
3.0 Airplane Application Requirements	
3.1	General
3.2	Application Priority
3.3	Application Acknowledgment
3.4.a	Pilot Alerting
3.6 a-d	Pilot Response
3.7 a, b, d	Message Handling
3.12	Timers
4.0 Ground System Application	
4.1	General
4.2	Application Priority

TABLE D-4. REQUIREMENTS IN RTCA NOT REFERENCED BY ATA OR SAE (SHEET 2 OF 2)	
RTCA	**REQUIREMENTS**
4.3	Application Acknowledgment
4.6	Controller/Operator Responses
4.7 a, b	Message Handling
4.10c	Indicators
4.12	Timers
4.13	Reporting
5.0 Outstanding Issues	
5.1	Pilot Procedural Issues
5.2	Controller/Operator Procedural Issues
5.3.1	Negotiations/Responses
5.3.2	Minimum Capability
5.3.4	Message Display
5.3.6	Application Software Criticality
5.3.7	Clearance Status
5.4.1	Sequential Clearances
5.4.2	Controller/Operator Alerting
5.4.3	System Maximum Response Times