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HUMAN ENGINEERING RECOMMENDATIONS FOR DATA LINK SYSTEMS

1. SCOPE:

This document sets forth functional, procedural, and design criteria and recommendations concerning human engineering of data link systems. For the most part, the recommendations are based on evidence from empirical and analytic studies of data link communication, and on experience from operational tests, and actual use of data link. Because the recommendations deal only with the available research, they are not comprehensive; data are not yet available to support recommendations on all potentially critical human engineering issues. Citations for the supporting research are embedded within the recommendations and a full list of references appears in Section 2 of this document.

Consistent with the focus of the research and operational development, this document focuses on recommendations for Air Traffic Control (ATC) communications, although data link systems are being designed to support flight information services, airline operational and administrative services, and passenger communication services. Unless otherwise specified within the text, all recommendations apply to both flight deck and ground-based data link systems.

2. REFERENCES:

2.1 Applicable Documents:

The following publications form a part of this specification to the extent specified herein. The latest issue of all SAE Technical Reports shall apply. The documents are generally applicable to the subjects of flight deck and ATC console integration and human interface design for data link.

2.1.1 SAE Documents: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

ARP268	Location and Actuation of Flight Deck Controls for Transport Aircraft
AS425	Nomenclature and Abbreviations for Use on the Flight Deck
ARP571	Flight Deck Controls and Displays for Communication and Navigation Equipment for Transport Aircraft
AS580	Pilot Visibility from the Flight Deck Design Objectives for Commercial Transport Aircraft
ARP1068	Flight Deck Instrumentation, Display Criteria, and Associated Controls for Transport Aircraft
ARP1093	Numeral, Letter, and Symbol Dimensions for Aircraft Instrument Displays
ARP1782	Color and Light Intensity Measurements for Direct View CRT
ARP4032	Human Integration for Color Criteria and Standards
ARP4101	Flight Deck Layout & Facilities
ARP4102	Flight Deck Panels, Controls, and Displays
ARP4102/4	Flight Deck Alerting Systems
ARP4102/6	Communication and Navigation Equipment
ARP4102/7	Electronic Displays
AS8034	Minimum Performance Standard for Airborne Multipurpose Electronic Displays
ARD50027	Human Engineering Issues for Data Link Systems

2.1.2 FAA Documents: Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591.

FAA-RD-81-38	Aircraft Alerting System Standardization Study: Volumes I, II, and III
FAA-AP-1992-2287	FAA Advanced Automation System Controller Interaction and Task Analysis: Volume I

2.2 Information References:

The following publications are provided for information purposes only and are not a required part of this document.

Berson, B. L., D. A. Po-Chedley, G. P. Boucek, D. C. Hanson, M. F. Leffler, and R. L. Wasson, 1981, Aircraft Alerting Systems Standardization Study Volume II: Aircraft Alerting Systems Design Guidelines, FAA-RD-81-38, Washington, D.C., Federal Aviation Administration

Blassic, E. and K. Kerns, 1990, Controller Evaluation of Terminal Data Link Services: Study 1, MTR-90W00215, McLean, V.A., The MITRE Corporation

Conrad, R., 1964, Acoustic confusions in immediate memory, British Journal of Psychology, 55, 75-84

Data Link Development Team, 1991, Controller Evaluation of Initial Data Link Terminal Air Traffic Control Services, FAA-CT-90-29, Atlantic City, N.J., Federal Aviation Administration Technical Center

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Diehl, J. M., 1975, Human Factors Experiments for Data Link, Interim Report No. 6: An Evaluation of Data Link Input/Output Devices Using Airline Flight Simulators, FAA-RD-75-160, Washington, D.C., Federal Aviation Administration

Flathers, G. W., 1987, Development of an Air-Ground Data Exchange Concept: Flight Deck Perspective, NASA CR-4074, Hampton, V.A., Langley Research Center

Groce, J. L. and G. P. Boucek, 1987, Air Transport Crew Tasking in an ATC Data Link Environment, SAE Technical Paper Series - ISSN-0148-7191, Warrendale, P.A., Society of Automotive Engineers

Hahn, E. C. and R. J. Hansman, 1992, Experimental Studies on the Effect of Automation on Pilot Situational Awareness in the Datalink ATC Environment, SAE Technical Paper Series - ISSN-0148-7191, Warrendale, P.A., Society of Automotive Engineers

Hilborne, E. H., 1975, Human Factors Experiments for Data Link, Final Report, FAA-RD-75-170, Washington, D.C., Federal Aviation Administration

Kerns, K., 1990, Data Link Communication between Controllers and Pilots: A Review and Synthesis of the Simulation Literature, MP-90W00027, McLean, V.A., The MITRE Corporation

Knox, C. E. and C. H. Scanlon, 1991, Flight Tests with a Data Link Used for Air Traffic Control Information Exchange, NASA Technical Paper-3135, Hampton, V.A., Langley Research Center

Lee, A. T., 1989, Display-Based Communications for Advanced Transportation Aircraft, NASA Technical Memorandum-102187, Moffett Field, C.A., Ames Research Center

Lee, A. T., February 1991, Aircrew decision-making behavior in hazardous weather avoidance, Aviation, Space, and Environmental Medicine, 158-161

Midkiff, A. H. and R. J. Hansman, 1992, Identification of Important "Party Line" Information Elements and the Implications for Situational Awareness in the Datalink Environment, SAE Technical Paper Series, ISSN-0148-7191, Warrendale, P.A., Society of Automotive Engineers

Rossiter, S., R. Wiseman, M. Connelly, and T. Morgan, 1975, The Controller/Computer Interface with an Air-Ground Data Link, FAA-RD-75-133, Atlantic City, N.J., Federal Aviation Administration Technical Center

Talotta, et. al., 1988, Controller Evaluation of Initial Data Link Air Traffic Control Services: Mini-Study 1, FAA-CT-89-25, Atlantic City, N.J., Federal Aviation Administration Technical Center

Talotta, et. al., 1989, Controller Evaluation of Initial Data Link Air Traffic Control Services: Mini Study 2, FAA-CT-89-14, Atlantic City, N.J., Federal Aviation Administration Technical Center

2.2 (Continued):

Talotta, et. al., 1990, Operational Evaluation of Initial Data Link En Route Services, FAA-CT-90-1, Atlantic City, N.J., Federal Aviation Administration Technical Center

Waller, M. C., 1992, Flight Deck Benefits of Integrated Data Link Communication, NASA Technical Paper-3219, Hampton, V.A., Langley Research Center

Waller, M. C. and G. W. Lohr, 1989, A Piloted Simulation of Data Link ATC Message Exchange, NASA Technical Paper-2859, Hampton, V.A., Langley Research Center

Wanke, C., D. Chandra, R. J. Hansman, and S. R. Bussolari, November 1990, A Comparison of Voice and Data Link for ATC Amendments and Hazardous Windshear Alerts, Paper presented at the 4th International Symposium on Aviation and Space Safety, Toulouse, France

Wickelgren, W. A., 1965, Acoustic similarity and intrusion errors in short-term memory, Journal of Experimental Psychology, 70, 102-108

2.3 Definitions:

DATA LINK SYSTEM: Digital telecommunications capability which supports communication between airborne and ground-based computers and their operators.

COMMUNICATION TRANSACTION: The cycle of ground- and air-initiated messages required for the full handshake that constitutes an information exchange between ground and airborne ATC system elements. A typical cycle begins with message transmission and concludes with the return, to the sender, of an acknowledgement or reply from the intended receiver.

INFORMATION MESSAGE: An informational message that does not imply any change in operating behavior on the part of the pilot or the controller. Information messages are generally not time-critical. Included in this category are routine weather observations and forecasts, reports on the status of facilities and equipment, and routine position reports (Flathers, 1987).

STRATEGIC MESSAGE: A clearance or flight plan message concerned with the overall mission of the flight. Strategic messages define the basic agreement between the ATC system and the airspace user concerning the actions each will take to accommodate the joint objectives of the flight and the ATC system. Strategic messages are not overly sensitive to time delays. Included in this category are messages associated with establishing the initial ATC clearance (user flight plan) and messages associated with revisions to the initial clearance (Flathers, 1987).

2.3 (Continued):

TACTICAL MESSAGE: A clearance message relating to a situation of a local nature. Tactical messages do not generally change the established strategic agreement, although they may fill-in unspecified details. Tactical messages may be time critical. Included in this category are: (1) horizontal, vertical, or speed/time/delay instructions, (2) procedure-based instructions (instrument approach procedure), and 3) traffic and urgent advisories (Flathers, 1987).

OPERATOR: Term that refers to the human responsible for handling data link communications. In actual operations, the operator could be an aircraft flight crew member or an ATC specialist staffing an en route, terminal, tower, or oceanic operational position.

END-SYSTEM: System which originates a message or is designated as the recipient of a message.

SUBNETWORK: One of the interoperable communications networks, such as VHF, satellite, or Mode S Secondary Radar, that will support aeronautical data communications.

3. FUNCTIONAL REQUIREMENTS:

3.1 The system shall be integrated with the existing ATC voice radio communications system (Kerns, 1990).

3.2 The system shall be capable of receiving and sending ATC messages between airborne and ground-based end-systems.

3.3 The system shall be capable of communication and compatible with the ground-based Air Traffic Control (ATC) systems and consoles and capable of communication with other ground-based entities.

3.4 The system shall automatically manage and control the communication subnetworks (e.g., VHF, Satellite, Mode S) to ensure system availability and acceptable performance.

3.5 Although automatic management of communication subnetworks by the data link system is recommended, this function should not preclude operator selection of a subnetwork.

3.6 In order to minimize operator reentry of data, it is recommended that the data link system be integrated with airborne flight management, control, and information systems (Groce & Boucek, 1987; Knox & Scanlon, 1991; Waller, 1992).

3.7 In order to minimize operator reentry of data, it is recommended that the data link system be integrated with ground-based flight path planning and control functions (Talotta et al., 1988; Kerns, 1990).

3.8 The system shall inform the operator of its current operational status (service availability) and be capable of displaying its current configuration including active connections to subnetworks, end-systems, and active automatic functions (Kerns, 1990).

3.9 The system shall notify the operator of incoming messages, display the message to the operator, send data to other ATC or flight deck systems (with explicit operator approval), and maintain a log of messages.

3.9.1 The system shall have the capability to manage message routing to flight deck and ATC end-user displays, to order queues of pending messages, and to vary operator notification according to established alerting schemes (Kerns, 1990).

3.9.2 The system shall ensure the integrity of all received messages before making them available to the operator.

3.9.3 The system shall provide a preview of all messages as they are composed, and before they are sent by the operator; the system shall support editing of operator-composed messages (Talotta et. al., 1988; 1989; 1990).

3.9.4 The system shall provide feedback to the operator on the status of data link transactions (Talotta et. al., 1990; Kerns, 1990).

3.9.5 The system shall be capable of recording, storing, and retrieving received and sent messages, grouped by transaction. That is, request-reply and instruction-reply sequences should be associated in a message history log (Kerns, 1990; Blassic & Kerns, 1990).

4. PROCEDURES:

The optimal system for ATC communication should include both voice and data link capabilities. Research shows that voice can be faster and more flexible while data link can be more concise and precise. However, the availability of two communication media will create additional complexity in the communication system and procedures should provide guidance on the appropriate use of the media.

4.1 In domestic U.S. airspace, voice communication between ATC and the flight deck shall be established and maintained according to current procedural requirements after data link is introduced (Kerns, 1990; Knox & Scanlon, 1991).

4.2 Use of data link should be adapted to the flight phase and ATC operational domain. For routine communications between controllers and pilots, data link is recommended for strategic, tactical, and information messages in most flight phases and domains.

4.3 For urgent advisories and for communication during terminal area operations, emergencies, and other high workload situations, data link shall be used only after empirical research has been performed to establish acceptable designs and guidelines (Groce & Boucek, 1988; Kerns, 1990; Blassic & Kerns, 1991; Midkiff & Hansman, 1992).

4.4 In the dual media communication system, voice and data link procedures should be consistent; at a minimum, strategic and tactical data link messages require an operational acknowledgement by the flight crew (Kerns, 1990).

4.5 In order to maintain shared crew awareness, crew coordination of the message intent should be effected before the operational acknowledgement is sent and before entering the message data into flight deck systems (Waller & Lohr, 1989; Lee, 1989; Kerns, 1990; Hahn & Hansman, 1992).

4.6 Voice and data link shall be used in a complementary fashion. To minimize switching between media, a transaction normally should be opened and closed within the same medium (Kerns, 1990).

4.7 Data link procedures shall provide guidance on how to conduct communication in off-normal situations; such as, a data link system or transaction failure. In some domains and situations, the use of voice may be the desired backup procedure (Kerns, 1990).

4.8 Explicit operator action shall be required to approve transmission and to acknowledge compliance, for tactical messages (Rossiter, 1975; Talotta et. al., 1988, 1989; Kerns, 1990).

4.9 Explicit crew action shall be required to transfer data to flight deck systems and to execute functions using that data.

4.10 As new data link services are developed, implementation of these services should be compatible with established procedures and should promote predictable operator responses.

5. FLIGHT DECK/ATC CONSOLE INTEGRATION:

Integration of the control and display components of the data link system should include (but not be limited to) considerations of:

a. Information requirements
b. Interaction with other aircraft and ATC subsystems
c. The layout and capabilities of the target aircraft
d. The layout and capabilities of the target ATC operational position

The standardization recommended for alerting system design guidelines in FAA-RD-81-38 and in ARP4102/4 should be applied to data link displays and controls on the flight deck. The standardization and design principles recommended in FAA-AP-1992-2287 should be applied to data link displays and controls on the ATC console.

5.1 To support team operations, visual display information should be located within the forward field of view of all operators, and system controls shall be reachable by all operators (Diehl, 1975; Kerns, 1990; Knox & Scanlon, 1991; Waller, 1992).

5.2 It is recommended that the data link system provide the capability to send data to and accept data from ATC or flight deck systems; the operator shall retain control over the process which initiates the transfers (Kerns, 1990; Knox & Scanlon, 1991; Waller, 1992).

6. HUMAN INTERFACE:

6.1 Displays:

Potential system display components include: system operational status, visual and aural alerts, transaction status displays, message displays, and message history displays.

6.1.2 System Status Information:

6.1.2.1 A display indication shall be provided to notify the operator of system malfunction or failure. Information about the availability of connections to air and ground-based end-systems shall be available (Kerns, 1990).

6.1.2.2 To support controller performance, system status indications shall discriminate the smallest number of states. It is recommended that data link system availability shall be indicated only when the aircraft has the capability to receive and process all data link services provided by the controller (Kerns, 1990). The use of unique indications for multiple levels of data link capability is not precluded. However, empirical research should be undertaken to ensure that the larger number of indications does not degrade controller performance.

6.1.2.3 For ATC positions operating with a traffic situation display, indications of an aircraft's data link system status shall be associated with the aircraft's position symbol (Talotta et. al., 1990; Blassic & Kerns, 1990).

6.1.2.4 To the extent possible, data link system functions shall be consistently available and shall operate consistently across operational domains (i.e., terminal, en route, and oceanic).

6.1.2.5 In cases of failure, the operator shall have the information required to reestablish communication expeditiously.