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Human Engineering Recommendations for Data Link Systems

RATIONALE

This document has been determined to contain basic and stable technology which is not dynamic in nature.

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FOREWORD

The following members of the G-10K, Flight Deck Information Management Subcommittee, made significant contributions to the development of this document:

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1. SCOPE:

This document sets forth general, functional, procedural, and design criteria and recommendations concerning human engineering of data link systems. The recommendations are based on limited evidence from empirical and analytic studies of simulated data link communication, and on experience from operational tests and actual use of data link. However, because data are not yet available to support recommendations on all potentially critical human engineering issues these recommendations necessarily go beyond the data link research and include requirements based on related research and human factors engineering practice. It is also recognized that evolution of these recommendations will be appropriate as experience with data link accumulates and new applications are implemented.

1. (Continued):

This document focuses primarily on recommendations for data link communications between an air traffic specialist and a pilot, i.e., air traffic services communications, although some recommendations address use of data link for flight information services. Unless otherwise specified within the text, all recommendations apply to both flight deck and ground-based data link systems.

This document is intended as a guide for development and evaluation of data link systems. Human engineering considerations are an important element of data link system performance. As illustrated in Figure 1, human engineering recommendations address many component functions required for effective data link communication services in the operational environment. For presentation purposes, the recommendations are divided into five sections: General, functional, procedures, flight deck/air traffic service (ATS) workstation integration, and human-computer interface. To facilitate understanding and use of this document appropriate cross-references to interrelated recommendations appear in parentheses throughout the text.

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, FAA, RTCA, and ICAO documents shall apply. The documents are generally applicable to the subjects of flight deck and ATS workstation integration, human interface design, and procedures for data link. Appendix A contains a list of references that provide detailed support for the requirements.

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

AS425C	Nomenclature and Abbreviations for Use on the Flight Deck
ARP4102/6	Communication and Navigation Equipment
ARP4101/2	Pilot Visibility from the Flight Deck
ARP4102/8	Flight Deck, Head-Up Displays
AIR1093	Numeral, Letter, and Symbol Dimensions for Aircraft Instrument Displays
ARP1782	Photometric and Calorimetric Measurement Procedures for Airborne Direct View CRT
ARP4032	Human Engineering Considerations in the Application of Color to Electronic Aircraft Displays
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

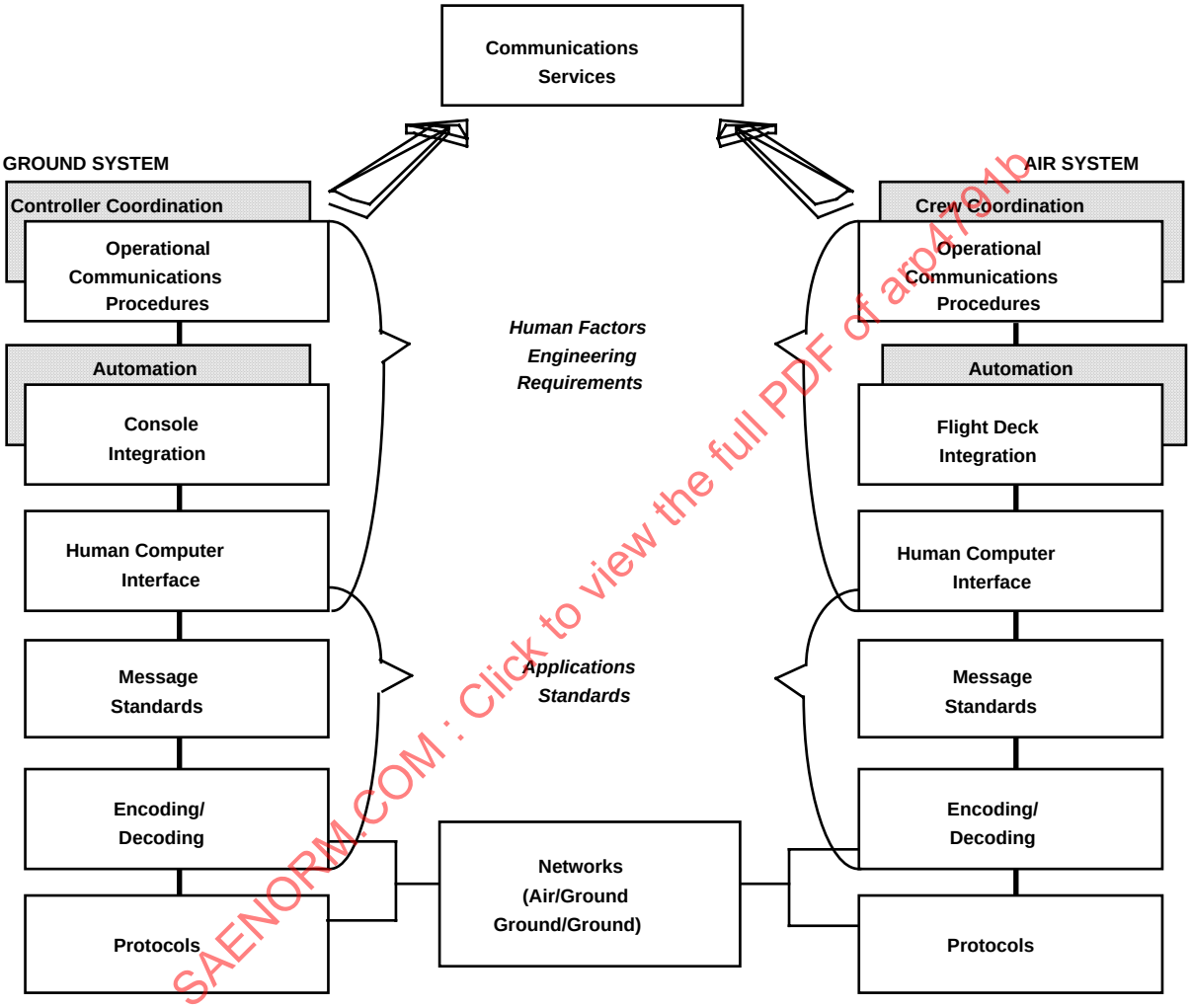

FIGURE 1 - Human Engineering Requirements in the Context of General Functional Requirements for Data Link Communication

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

FAA Order 7110.65	Air Traffic Control
FAA Order 7110.83	Oceanic Air Traffic Control
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
FAA-ER-130-006	Display System Replacement System Specification
FAA-AC-20..DC (Draft)	Guidelines for Airworthiness Approval of Airborne Data Link Systems and Applications
FAA-AC-120.COM (Draft)	Interim Air Carrier Operational Approval for Use of Data Link, SATCOM, and Other Communication Systems Other Than Conventional VHF/HF Voice Systems

2.1.3 RTCA Publications: Available from RTCA, 1140 Connecticut Avenue, NW, Suite 1020, Washington, DC 20036.

RTCA DO-219	Minimum Operational Performance Standard for Two-Way Data Link Communications
RTCA (Draft)	Minimum Operational Performance Standards for Flight Information Service Data Link Request/Reply Communications
RTCA DO-212	Minimum Operational Performance Standards for Airborne Automatic Dependent Surveillance (ADS) Equipment

2.1.4 ICAO Publications: Available from ICAO, 1000 Sherbrooke Street West, Montreal Quebec, Canada H3A-2R2.

ICAO (Draft)	ICAO Manual of Air Traffic Services Data Link Applications
ICAO Circular 216	Fundamental Human Factors Concepts
ICAO Circular 234	Operational Implications of Automation in Advanced Technology Flight Decks
ICAO Circular 249	Human Factors in CNS/ATM Systems

2.2 Definitions:

ATS MESSAGE: A clearance or flight plan message. Included in this category are strategic messages associated with establishing the initial ATS clearance (user flight plan) and messages associated with revisions to the initial clearance. Also included in this category are tactical messages such as: (1) horizontal, vertical, or speed/time/delay instructions, (2) procedure-based instructions (instrument approach procedure), and (3) traffic and urgent advisories.

BROADCAST VERSUS DISCRETE ADDRESSED COMMUNICATIONS SERVICES: Broadcast services are carried over free-radiating media which transfer information intended for simultaneous receipt by multiple users; in contrast, discrete addressed services are carried over media which direct information between specific pairs of users.

2.2 (Continued):

COMMUNICATION TRANSACTION: The cycle of ground- and air-initiated messages required for the full handshake that constitutes an information exchange between ground and airborne ATS system elements. The transaction cycles vary according to message types. For air traffic specialist-pilot communications, a typical cycle begins with message transmission and concludes with the return, to the sender, of an acknowledgment or reply from the intended receiver.

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

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

FLIGHT 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.

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 air traffic specialist staffing an en route, terminal, tower, or oceanic operational position.

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

3. GENERAL REQUIREMENTS:

Included in this section are ATS system-level requirements that must be supported during and after the transition to data link as a supplementary or primary communication system. They address safety-related concerns and concerns that arise from transitional stages of implementation in which aircraft and ground systems may have varying levels of data link capabilities.

3.1 Safety is a function of the interaction of numerous factors, including communication, navigation, and surveillance systems; flight crews; air traffic specialists; and the operating environment. There shall be no reduction in the overall level of safety related to the use of data communications as measured by testing and operational evaluation. After implementation, the level of safety shall continue to be monitored through means such as the “Aviation Safety Reporting System” and other safety data reporting sources (5.1, 5.2, 5.7, 6.1, 6.2, 6.8).

3.2 Some means shall be available for urgent communications. A backup means of communication shall be provided and procedures shall be maintained for cases where no communications are available (4.12, 5.1, 5.13, 7.2.6).

3.3 The traffic and obstacle separation environment shall allow safe recovery from response delays, nonresponse or unable responses, data link failures, and other data link management errors, to at least match the current level of safety (4.4, 4.6, 4.19, 5.1, 5.10, 5.13, 7.2.1, 7.2.2, 7.2.6, 7.4.3).

3.4 To the extent that data link system performance can vary based on subnetwork performance and message urgency attributes (see RTCA DO-219), it is important that data link messages are reviewed in sequence. Furthermore, the sequence must be based on the time at which the message was sent. If a data link system detects an out of sequence situation, the receiver should be notified of the problem and the situation should be clarified as soon as possible (4.5, 4.6, 4.12, 4.14, 4.16, 4.15, 7.7.8).

3.5 Party line communications in the voice environment currently provide information used by pilots for situation awareness. In a data link environment, some means shall be provided to compensate for the loss of party line information without placing additional demands on pilots or on air traffic specialists. For example, the data link system should be used to enhance or partially replace party line as a source of information on weather and traffic information. This could include windshear, convective activity, turbulence, aircraft positions, and traffic flow management information such as congestion reports, or holding and speed restrictions (5.11).

3.6 Information about risk levels, controller workload, traffic densities, request urgency, and other aspects of the situation can be inferred from characteristics of voice communications and should be available in the data link environment as appropriate to the application. For example, an indication of sector workload may be provided. To the extent that such inferences are valid and useful, safety and efficiency should not be compromised due to the unavailability of such information.

3.7 Data link transmission of weather information must be timely and reliable. Transmission must not be subject to delays or nontransmission due to air traffic specialist workload, unavailability of weather personnel, or other factors. Flight crews must be notified as soon as possible of critical weather conditions which may affect them. Immediate notification of known windshear, microburst, visibility minima, crosswinds, or other automatically derived critical weather information may require a direct channel from weather sensing/processing systems to the aircraft. The air traffic specialist should have the same weather information available in order to maintain awareness of pilot constraints (7.6.1).

3.8 Air traffic specialists must be notified of advisories or other hazardous weather information that is broadcast over a data link channel automatically and may affect their operation. A means for air traffic specialist review of recently transmitted broadcast messages shall be available (7.6.1).

3.9 The system shall facilitate the air traffic specialist's ability to communicate with each aircraft and the pilot’s ability to communicate with each ATS facility in the most appropriate mode (voice or data link) and using the data link capabilities most appropriate for a particular aircraft or facility. The system shall indicate to the air traffic specialist and pilot what mode of communication is available and which capabilities are appropriate (5.1, 7.2.1, 7.2.3).

3.10 The system should be developed to minimize undue complication due to specific mixes of equipage and services (5.9, 6.16).

3.11 Differences in the air traffic specialist’s management of communications information and related tasks for equipped and unequipped aircraft should be minimized (5.2, 5.4, 5.9, 6.1, 6.5, 6.13, 7.2.4).

3.12 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/international) (7.2.3).

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

3.14 A data communication system shall meet the performance required for the area, airspace, route, operation, or procedure to be used.

4. FUNCTIONAL REQUIREMENTS:

Included in this section are high-level functional requirements for information management capabilities that will enable air traffic specialists and pilots to carry out communications tasks using the data link system.

4.1 The data link system shall be capable of receiving and sending ATS messages between airborne and ground-based end-systems.

4.2 The data link system shall be capable of communication and fully compatible with the ground-based ATS systems. Communication between ground-based systems is also required to support data link services in accordance with International Civil Aviation Authority agreements.

4.3 The data link system shall automatically manage the communication subnetworks (e.g., HF, VHF, Satellite, Mode S) to ensure system availability, integrity, and acceptable performance (4.12, 7.2.3).

4.4 Although automatic management of communication subnetworks by the data link system is required, this function shall not preclude manual override of the automatic function (7.2.1).

4.5 Within any given priority level and from any given sender, messages shall be delivered to the receiver in the order they were sent (3.4, 4.12, 4.15, 6.9, 7.3.1, 7.7.8).

4.6 The data link system shall be capable of delivering messages associated with error identification, notification, and recovery within the time required for safe recovery. Optimally, data link delivery, priority transmission, and alerting should facilitate error identification, notification, and recovery (3.3, 4.14).

4.7 The data link 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 (7.2.1, 8.2.2, 7.2.3, 7.2.4, 7.2.5, 7.2.6, 7.4.2).

4.8 The data link system shall notify the operator of incoming messages, maintain a queue of pending messages, display messages to the operator, and maintain a history log of messages that have been viewed, including the associated operator responses where applicable (4.12, 7.3.6, 7.6.2, 7.6.3, 7.6.4, 7.6.5).

4.9 The data link system shall have the capability to unambiguously identify the source and destination of all transmitted messages. The system must ensure that messages are coming from a legitimate source.

4.10 The data link system shall provide the capability for a sender to include a reference to a previous message when composing a new message and for the receiver's display to present the reference information along with the new message (5.14, 7.7.9, 5.15).

4.11 All incoming data link messages shall be retained in the message queue until operator requirements for viewing or response established in ATS procedures (FAA, 7110.65; FAA, 7110.83) and Data Link Standards (DO219) have been met (5.5, 5.12, 7.7.9).

4.12 The data link system shall have the capability to manage message routing to flight deck and ATS end-user applications, to order queues of pending messages, and to vary operator notification according to established alerting schemes (3.4, 4.5, 4.12, 6.10, 7.3.1, 7.3.2, 7.3.3, 7.3.4, 7.3.5, 7.3.6).

4.13 The data link system shall support the capability for an operator to send a message with an urgent or distress status that triggers a unique alert to indicate that immediate attention to that message is required (3.2, 5.8, 6.10, 7.1.8, 7.3.1, 7.3.4, 7.3.5, 7.7.8).

4.14 The data link system shall ensure the data integrity of all received messages before making them available for display to the operator. If an error is detected, the system shall notify the sender with an informative, diagnostic error message (3.3, 3.4, 4.6, 5.11, 6.6, 7.1.2).

4.15 All times contained in data link messages should be referenced to Universal Coordinated Time (3.4, 4.5, 4.15, 7.5.1, 7.6.2).

4.16 An indication of message send time or age based on send time must be available for display on the message display to help operators estimate data validity and for coordination. If the age of the message, makes its validity suspect, the operator should verify the validity of that message before acting upon it (3.4, 4.5, 4.14, 4.15, 4.21, 5.15, 7.7.8).

4.17 The data link message display formatting function shall ensure that the sender's message and intent is fully and accurately represented on the receiver's display (5.12, 6.13).

4.18 The data link system shall provide capabilities for message generation such as the following:

a. Form-filling - either operator entry or retrieval of stored parameters to fill in predefined message templates
b. Free-form message text entry
c. Selection of predefined messages and phrases from a menu
d. Entry of commands or use of function keys to quickly format messages
e. Selection of computer generated message data (7.1.8)

4.19 The data link system shall provide the capability for an operator to transmit an "unable"/"reject" response to a clearance over data link. Along with the "unable"/"reject" response or immediately following it, the operator shall provide an explanation and/or begin negotiations by voice or data link. It is desirable that the data link system provide the means to append both preformatted and free text explanations over data link. Additionally, it may be desirable to provide the means to append free text for carrying out negotiations and communicating unanticipated reasons (3.3, 5.9, 7.4.3, 7.7.9).

4.20 Because the various parts of a multipart ATS message (e.g., clearance or instruction) may be interdependent, the data link system shall not permit the pilot to accept or reject only parts of the message. Additionally, it may be desirable to provide a data link procedure for negotiating individual parts of the ATS message. Such a procedure could entail a means for indicating which parts are acceptable and which are not, providing explanations for why parts are not acceptable, and providing suggestions for parameters that would be acceptable (5.9, 7.3.4, 7.5.10, 7.7.9).

4.21 All data link messages shall contain a message send time. The send time shall be generated by the sender's action to transmit the message.

5. PROCEDURES:

Included in this section are requirements for air traffic specialist-pilot operational communications procedures and procedural requirements for coordination of communications tasks among multiple operators working on ground-based and flight deck workstations.

5.1 Flight deck procedures, ATS procedures, and data link Human Computer Interface (HCI) designs shall accommodate all possible mixes of data link services and voice communications. All aspects of data link operations must be designed so that when any one or any combination of them fails, the procedures required to perform the tasks and functions usually supported by them can be done manually without compromising safety, requiring an undue amount of operator attention, or incurring errors (3.1, 3.2, 3.3, 3.9, 5.11, 5.12, 6.1, 6.2, 6.8, 7.2.1, 7.2.2, 7.2.6).

5.2 Air traffic specialist resource management will be affected when data link is introduced. New procedures, training, and means for maintaining proficiency must be designed to accommodate reallocation of air traffic specialist team tasks (3.1, 3.11).

5.3 Voice communication between the air traffic specialist and the pilot shall be established and maintained according to procedural requirements (FAA, 7110.65; FAA, 7110.83, or equivalent) after data link is introduced (7.4.5, 7.5.11).

5.4 In the multimedia communication system, air traffic specialist-pilot operational communication procedures for multiple media should be consistent. As an example, if an ATS message requires an operational acknowledgment by the receiver when using voice then it should also require an operational acknowledgment when using data link (3.11).

5.5 Explicit operator action shall be required to approve transmission and to acknowledge messages in compliance with established ATS procedures (FAA, 7110.65; FAA 7110.83) and Data Link standards (DO 219) (4.11, 5.12, 6.3).

5.6 Explicit crew action shall be required to transfer data to flight deck systems, to execute functions using that data and if appropriate, to select or approve mode changes. Mode changes that presently require explicit crew action should continue to require explicit action when a data link system is used (5.11, 5.12, 6.4, 6.6, 7.5.10).

5.7 Procedures associated with data link operations shall not require simultaneous (head down) attention by both pilots. Training should emphasize the appropriate allocation of flying tasks and communication tasks (3.1, 6.2, 6.8).

5.8 For urgent advisories and for communication during final approach 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 (4.13, 6.8, 6.9).

5.9 In the multimedia communication environment, voice and data link shall be used as alternative means of communication. Operators should not be required to transmit messages redundantly over multiple communication media. A transaction cycle normally should be opened and closed within the same medium. Switching between media should be minimized within a specific transaction cycle in order to ensure proper coordination of ground and air data link systems. However, if a data link message has been responded to by voice, the same response should also be sent over data link to update transaction status consistently for the operators (3.10, 3.11, 4.18, 4.19, 7.4.3, 7.7.9).

5.10 Data link procedures and HCI design shall provide responses to data link messages quickly enough to maintain flight crew/controller coordination and to enable the air traffic specialist to effectively manage traffic. This is particularly important when a flight crew cannot accept a clearance or instruction (3.3, 7.3.3, 7.5.3).

5.11 Data link procedures and HCI design must ensure adequate coordination and error checking (e.g., parameters are within safe operating limits of aircraft) and individual and shared situation awareness. Where appropriate, procedures shall include cross checking between operators of data link messages and responses. Flight deck procedures shall include confirmation by the flight crew that aircraft behavior is as expected after data transferred into the flight guidance system are executed (3.5, 4.13, 5.1, 5.6, 6.6).

5.12 Crew coordination of the message intent shall be effected before the operational acknowledgment is sent and before entering/executing the message data in flight deck systems (4.11, 4.17, 5.5, 5.6, 6.4).

5.13 Data link procedures shall provide guidance on how to conduct communication in non-normal situations; such as, a data link system or transaction failure (3.2, 3.3, 5.1, 7.2.6).

5.14 If a data link message references a previous message, a means is required to refer to the previous message and to ensure appropriate responses to data link messages and appropriate operational actions (4.10, 7.7.9).

5.15 When a message is referenced, it shall be referenced unambiguously, based on both its contents and message send time. For example, when a flight crew and air traffic specialist are discussing a clearance to FL 350, they shall refer to "the clearance to FL 350 sent at 1246Z" and not to "the last altitude clearance" (4.10).

6. FLIGHT DECK/ATS WORKSTATION INTEGRATION:

Included in this section are requirements for integration of the data link display and response capabilities with those of the pilot and air traffic specialist workstations. They address such considerations as the following:

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

The standardization recommended for alerting system design guidelines in FAA-AC-20.DC, 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 and FAA-ER-130-006, or equivalent should be applied to data link displays and controls on the ATS workstation.

6.1 Data link implementations shall minimize any increase in air traffic specialist visual attention to display locations that will interfere with attention to high priority tasks (3.1, 3.11, 5.1).

6.2 Data link implementations shall minimize any increase in pilot head down time. Any increase in head down time that results from data link implementation should not compromise safety or reduce pilot situation awareness. Examples of HCI design features that may help offset head down effects of data link systems include the use of speech synthesis as a data link display, speech recognition as a data link input technique, and head-up displays of data link messages (3.1, 5.1, 5.7, 7.1.5, 7.7.1).

6.3 Message acknowledgment controls must be located in suitable flight deck positions for intended use (5.5, 6.3).

6.4 In order to minimize crew reentry of data, it is recommended that the data link system be integrated with airborne flight management, control, and information systems (5.6, 5.12, 7.1.6, 7.6.3).

6.5 In order to minimize air traffic specialist reentry of data, it is recommended that the data link system be integrated with appropriate ATS system functions, including ground-based flight path planning, conflict detection, and other such functions (3.11, 7.1.6).

6.6 The data link system shall be designed to detect and trap potentially critical errors as early in the communication process as possible. For example, if the data link system has the ability to transfer data to the flight management system (FMS) it is desirable for the FMS to check for out-of-range values or values that exceed aircraft performance parameters before the function is executed. As another example, if the data link system has the ability to transfer data to the ground system's flight data processing function, it is desirable for the ground system to check for out-of-range values before accepting the data for uplink to an aircraft (4.14, 5.6, 5.11).

6.7 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.

6.8 Data link installations should not prevent the operator from performing other high priority tasks by either requiring excessive devotion of the operator's attentional resources or by tying up the equipment needed for the other tasks with data link functions (3.1, 5.1, 5.7, 5.8, 7.3.2).

6.9 The data link prioritization scheme shall be compatible with all workstation functions, and inclusive of all functions that may generate workstation messages. When data link operations share display and control equipment with other functions, the priorities of messages from competing functions may themselves compete for display space and operator attention. To resolve such conflicts, the prioritization scheme adopted may need to enable high priority data link messages to displace lower priority messages generated by functions other than data link in the queue, or high priority messages from other functions to displace lower priority data link messages (4.5, 4.12, 5.8, 6.11).

6.10 The alerting function for incoming data link messages shall be easily distinguishable from any other alerts presented at the operator's workstation (4.12, 4.13, 7.1.5, 7.3.2, 7.3.5).

6.11 Maximum use of data link must not impose undue competition for display or control resources. Data link systems shall not preclude access to other functions or unduly conflict with higher priority operations (6.9).

6.12 Sharing of display and control resources between data link and other flight deck functions must not hinder flight crew coordination with each other and with ATS or company personnel.

6.13 Display symbols for graphic presentation shall be standardized within flight deck and air traffic specialist workstations. In addition, it is desirable for air traffic specialists and pilots to use a common international standard for symbolology that specifies the definition and intent of symbols (3.11, 4.17, 7.5.1, 7.5.4, 7.5.5).

6.14 Use of color for data link message display shall be consistent with established standards for flight deck and air traffic specialist workstation color coding (7.3.3).

6.15 The operator shall be able to suspend ongoing data link functions to access other functions at any time, and resume the suspended data link function at the point at which it was suspended. Clear indication shall be provided of where the operator is in the suspended operation.

6.16 If data link operations share display and control equipment with other functions, one operator's use of data link functions should not impede another operator's use of other equipment functions, particularly if there is only one of the equipment at the workstation (3.10, 6.11).

6.17 All information the operator requires in a data link operation must be available for display during the data link operation. The operator must not be required to rely solely on memory at any point during the transaction (7.1.8, 7.5.6).

6.18 Operators should always have the information needed to make a comparison and estimate the effects of a change; ideally, this information would be available on the same display at the same time. The operator should not have to switch between displays, pages, or indicators and remember one state while viewing the second state (7.1.9).

7. HUMAN-COMPUTER INTERFACE:

Included in this section are functional and design requirements for the data link system HCI. When developing data link systems, the need for error protection must be balanced against the need for ease of use. This may be a fundamental tradeoff, to the extent that automated error detection cannot trap every possible critical error. It is critical that the content of data link clearances and clearance requests be checked for reasonableness and implications to flight safety. However, because the system will be used frequently, the process of entering data into the system and transferring data to and from the data link system needs to be as simple and as easy as possible to reduce the total number of keystrokes that must be made and the amount of attention that must be paid to data link operations. The HCI design shall reflect tradeoffs made between ease of use and error protection.

7.1 General HCI Characteristics:

7.1.1 The data link system shall provide feedback for every user input in time to prevent doubt about the status of the input.

7.1.2 Any unrecognized or unreasonable entry shall prompt an error message from the system and shall not result in any data changes. The system shall provide the information needed to assist the operator in determining the nature of the error and how the error could be corrected (4.13, 4.14, 5.11, 6.6).

7.1.3 The HCI shall clearly distinguish between the various functions and modes of the system and indicate the type and format of data expected. To the extent possible, data link systems shall ensure that data intended for one purpose cannot be used erroneously for a different purpose (7.5.2, 7.6.3).

7.1.4 The human-computer interface shall clearly indicate functions that are available for use from those that are not available based on the current context of the system or message status. For example, applicable response options should be indicated when a specific message is selected by the operator (7.7.4).

7.1.5 If speech generation technology is used to present data link messages, it should be used redundantly with a visual display, unless research demonstrates that such redundancy is not required. Speech generation applications shall meet or exceed current levels of intelligibility and comprehensibility achieved with voice radio without increasing operator workload. If speech generation is provided, the operators shall be able to select it on and off, have the message replay, mute the message, and adjust the speech rate and volume through headsets and speakers. It is further recommended that speech presentations of messages be preceded by an aural alert such as a tone or aircraft call sign to orient the operator to attend to the message (6.2, 6.10, 7.5.11).

7.1.6 The operator shall not be required to enter the same information multiple times. In addition, it is desirable that data link systems are designed to facilitate sharing of information needed for multiple functions (6.4, 6.5).

7.1.7 The data link system shall echo operator alphanumeric inputs within 0.2 seconds and respond to operator inputs within 0.5 seconds, either by completing the processing or by providing feedback that the input is being processed, to prevent slowing tasks down and inducing entry errors such as multiple entries.

7.1.8 Data link operations must be simple. Control logic should permit completion of frequent or urgent data link-related operations with a minimum number of actions and keystrokes and minimum operator memory load. Only one action shall be required to see the next or previous display page of a data link message (4.13, 4.18, 6.17).

7.1.9 Lines of text shall be broken only at spaces or other natural delimiters. Parameters associated with text shall be adjacent to and grouped with their descriptive or explanatory text or labels, and on the same page. If the complete message cannot be presented on the same page, there should be a clear indicator to the operator that the message continues (6.18).

7.2 System Status and Failure Information:

7.2.1 Operators may need to reconfigure their data link systems to respond to selective failures. Clear, unambiguous indication of system and function operational status and transitions in mode that affect operational procedures shall be provided to all operators (3.3, 3.9, 4.4, 4.7, 5.1).

7.2.2 A positive indication of failures of the data link system and each of its functions shall be provided. The indication shall not itself be subject to silent failures. Operators shall notify affected parties of failures (3.3, 5.1, 7.2.6, 7.4.2).

7.2.3 The data link system shall provide the crew with the information needed to determine available data link services and functions in a given environment (3.9, 3.12, 4.3, 4.7, 7.2.4).

7.2.4 The air traffic specialist shall have information needed to determine which aircraft have a data link capability and the level of capability. 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 air traffic specialist. 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 air traffic specialist performance. For air traffic specialist 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 (3.11, 4.7, 7.2.3).

7.2.5 The air traffic specialist shall have access to information needed to determine the operational status of the ground data link system of other relevant/adjoining sectors/facilities (4.7).

7.2.6 In cases of failure, the operator shall have the information required to reestablish communication expeditiously (3.2, 3.3, 4.7, 5.1, 5.13, 7.2.2).

7.3 Message Prioritization and Alerting:

7.3.1 Data link prioritization mechanisms shall be consistent across the various services and types of messages available. That is, more urgent messages always have precedence over the less urgent, and alerting schemes must handle the variety of priorities correctly (4.5, 4.12, 4.13).

7.3.2 Data link messages should not distract operator attention unnecessarily. The prioritization scheme shall reliably expedite information flow based on the urgency of the communication, and trigger operator alerting devices only when appropriate (4.12, 6.8, 6.10).

7.3.3 Operators should not be required to read the actual message or even read the full message notification to determine how quickly they must respond. For example, providing an indication of message source and type in the alert should enable the operator to better manage and schedule tasks. Message urgency should be conveyed by a display code (highlight, border color, or some other visual and/or auditory coding technique) to facilitate operator recognition of urgency and the appropriate response time. The number of alerting levels shall be minimized (4.12, 5.10, 6.14).

7.3.4 On the flight deck, notification of ATS clearances shall be a single-step process. The aural alert shall direct the crew's attention to the location of the message display. Urgent and distress messages from any source shall also be identified by a unique aural and a unique visual alert. Noncritical data link alerts on the flight deck shall be inhibited during critical phases of takeoff and landing (4.12, 4.13, 4.20).

7.3.5 On the air traffic specialist's workstation, pilot-initiated data link messages shall be identified by a visual alert. Urgent and distress messages shall be discriminable from routine pilot-initiated messages by an attention getting display code (4.12, 4.13, 6.10).

7.3.6 If all pending messages are not displayed, information shall be provided to notify the operator of the existence of a queue of these messages (4.8, 4.12).

7.4 Message Transaction Status and Failure:

7.4.1 The system shall maintain and clearly display message status information to the operator, including but not limited to whether the message is pending, sent, accepted, or rejected.

7.4.2 A positive, attention getting indication shall be presented to depict interruptions, message delivery failures, or missing statuses (4.7, 7.2.2).

7.4.3 When an unable/reject response is received, the rejected messages and the response shall be highlighted on the receiver's display until the receiver takes the appropriate action and clears the display (3.3, 4.19, 5.9).

7.4.4 To declutter status displays, the system should automatically clear status indications after a transaction has been completed. Incomplete transactions, e.g., transmission failures, shall require operator action to clear status indications.

7.4.5 To support operator monitoring of transactions, transaction status information should be presented in close proximity to message displays. If messages are displayed with the aircraft's data tag, status information should be associated with that display. If messages are displayed in alphanumeric message and history lists, status information should be associated with the message text (5.3).

7.5 Message Displays:

7.5.1 Data link message content/phraseology/symbology shall be designed to prevent misinterpretation and ease interpretation of the message. For example, if a time stamp representing the time the message was accessed by the operator is added to a message display, the operator may misinterpret the stamp as representing the time the information was composed (such as a weather report in which the time might be inferred as observation time). The nature of the information should be clearly labeled (4.15, 6.13).

7.5.2 Information used in data link operations should be in the form most directly usable by the pilot and air traffic specialist and in forms consistent with those used throughout the operator’s workstation (7.1.3, 7.7.3).

7.5.3 Within an operator's workstation, standard locations and formats for data should be used to facilitate data entry and error checking and reduce the time and errors associated with reading the data (5.10, 6.3).

7.5.4 Display complete words in preference to abbreviations unless the abbreviations or acronyms are more commonly used than the words they replace. When abbreviations are used for data entry, then corresponding use of those abbreviations in data display may help the operator learn them for data entry. Do not abbreviate words that produce uncommon or ambiguous abbreviations. Define abbreviations for data link information that are consistent with abbreviations in use on the flight deck or in the ATS environment. In addition, it is desirable for air traffic specialists and pilots to use a common international standard for abbreviations (5.4, 6.13).

7.5.5 Graphic displays of data should be considered in addition to message text when the graphic format presents the data in a manner that eases the operator's task. When compatible with the operator's task, graphical formats are preferred for redundant display of spatially-oriented route and weather data. If a clearance is represented graphically on a map display, route discontinuities, restricted airspace violations, and other errors may be more apparent than if the clearance is represented in text. Furthermore, icons may capture more information in a smaller space than text (6.13).

7.5.6 Data link systems shall not require operators to perform transformations, conversions, extrapolations, or other estimations or inferences when data could be presented in a directly useful format (6.17).

7.5.7 Data link message formats shall use standard phraseology and construction with unambiguous terms as established in ATS procedures (e.g., FAA, 7110.65; FAA, 7110.83, or equivalent) and Data Link Standards (DO219). Alphanumeric message displays shall be at least as unconfusable, both conceptually and perceptually, as the current phraseology used in voice communications. Display information should not negatively interact with voice communications and other concurrent operational practices and terminology, as measured by comprehensive testing and structured operational evaluation (3.6).

7.5.8 Where appropriate, alphanumeric displays of data link messages should organize message elements and format displays according to the sequence of phrases established in ATS procedures (e.g., FAA, 7110.65; FAA, 7110.83, or equivalent). As an example, see DO219 for guidance on sequence and display message elements for the Predeparture clearance message.

7.5.9 For a specific data link service (e.g., altitude assignment), flight deck message formats and procedures shall be the same in all operational environments - terminal, en route, and oceanic/international.

7.5.10 It must be clearly indicated on the flight deck data link display which parts of a message can be transferred to other functions. Additionally, it is desirable that all appropriate parts of clearances be available for direct transfer. All transferable parts of the message must have been displayed before the transfer can occur (4.20, 5.6).

7.5.11 In general, research on flight deck message display shows that message and device characteristics affect crew performance. For most messages, CRT or display panels provide the best (shortest) operator response times and are preferred for message presentation. For lengthy messages, use of printers for message display avoids paging and supports cross reference with other displays of aircraft information. Because of concerns over potential interference with ATC frequency monitoring and increased response times, the operator's auditory task load and the time sensitivity of the message should be considered in using speech generation technology for presenting messages (5.3, 7.1.5).