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An examination of data link autoload and message length

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AN EXAMINATION OF DATA LINK AUTOLOAD AND MESSAGE LENGTH

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ABSTRACT

AN EXAMINATION OF DATA LINK AUTOLOAD AND MESSAGE LENGTH

by Elizabeth Waller Logsdon

This thesis examined the effect of loading short and long Air Traffic Control (ATC) messages directly into the Mode Control Panel (autoload) on total transaction time between air traffic controllers and pilots. In addition to timing data, pilot situation awareness, as impacted by message length and loading procedure, was also examined.

This research revealed that allowing the pilots to directly load message elements into the MCP produced faster mean total transaction times than when message elements were manually loaded regardless of message length. Length of ATC messages interacted with loading procedure. When pilots were presented long messages that could be autoloaded, mean transaction times were fastest. Conversely, when pilots manually loaded elements contained within a long message, the mean total transaction times were longest. While timing was faster with autoload, pilots were more likely to accept an erroneous message when they were flying in the autoload condition than in the manual load condition.

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Abstract

The Federal Aviation Administration (FAA) has proposed the addition of data link to the National Airspace System (NAS) as a means of communication between flight crews and air traffic controllers. Potential benefits of data link include the reduction of frequency congestion and information transfer problems associated with voice communication. Two issues associated with the implementation of data link are the length of a message and the ability to load message elements into aircraft systems. Twelve current glass-cockpit pilots flew four flight legs using a part-task simulator. The loading procedure was varied so that each pilot flew two flights with manual load and two flights with autoload. Total transaction time was collected for short and long data link messages. While there was no specific hypothesis about timing, the data revealed that pilots had the fastest mean total transaction times when they were presented long messages with autoload capability as compared to the sum of two short messages and manual load. Conversely, pilots had the longest total transaction times when they manually loaded long messages. While timing was faster, pilots incorrectly accepted erroneous messages more often in the autoload condition than in the manual load condition.

An Examination of Data Link Autoload and Message Length

Currently, pilots and air traffic controllers communicate future plans and current instructions by means of radiotelephone. Based on both rules and practiced procedures, pilots and controllers expect and follow a standard format for communicating. For example, the controller may issue a message of "Southwest 33, fly heading 250, vector for traffic" after which the pilot would most likely read back the message including the aircraft call sign. The read back is a confirmation that the message was received and that both the pilot and controller agree on its content. One procedure that has developed on the open frequency is for no other pilot to speak until the designated flight crew has responded to their message. This procedure encourages timeliness of response from pilots to controllers. However, with this two-way exchange of information and the ever increasing number of aircraft operating on a frequency, frequency channels have become saturated.

Frequency congestion is one of the primary reasons the Federal Aviation Administration (FAA) has mandated that communication, in part, be handled by some means other than radiotelephone. In addition to frequency congestion, problems associated with voice communication include missed calls, acting on a misunderstood clearance, and call sign confusion as a result of similar sounding aircraft call signs. Billings (1981) reported that human factors such as expectations and forgetting have been shown to negatively affect communication. By off-loading some communication to digitized transmission of information (data link) some of the current problems associated with congested frequencies should be reduced or eliminated (Federal Aviation Administration (FAA), 1995).

Data link is analogous to electronic mail in that information is transferred digitally from one system to another which can then be displayed for viewing. Similar characteristics of data link and electronic mail are the following: each has some type of visual or aural alert that a message has arrived; both require access by the recipient; acknowledgments are usually made within the same communication mode in which the message was received; and, finally, there can be system delays associated with message transmission.

One proposed use of data link in the National Airspace System (NAS) is for the communication of messages from air traffic controllers to pilots. With data link, the serial structure of communication present with voice may change to a more parallel flow of information. Controllers may send multiple messages to several aircraft before receiving a response from one. They may also send more information within a message than is currently sent via voice. Frequency congestion should be reduced as well as the call sign confusion problem through the use of data link. By displaying message information on the flight deck for presentation and review pilots should be less likely to forget message contents and act on misunderstood messages. Potential implementation methods for data link include synthetic voice, a dedicated display, or a retrofit display for textual, graphical, or some combination of both types of information.

Data Link Issues

A proposed retrofit location for data link presentation is the Control Display Unit (CDU) found on advanced transport aircraft. The CDU is an interface for pilots to communicate with the Flight Management Computer (FMC), one component of the Flight Management System (FMS). The CDU utilizes a computer screen to display alphanumeric information which the pilot can manipulate through the use of the various mode and function keys located below the CDU screen. Line select keys, six on each side of the screen, are used to select or insert information on the screen. Alphanumeric function keys are used for developing information for entry into the CDU while the mode keys are used to change the pages of the CDU (see Figure 1 for a picture of a typical

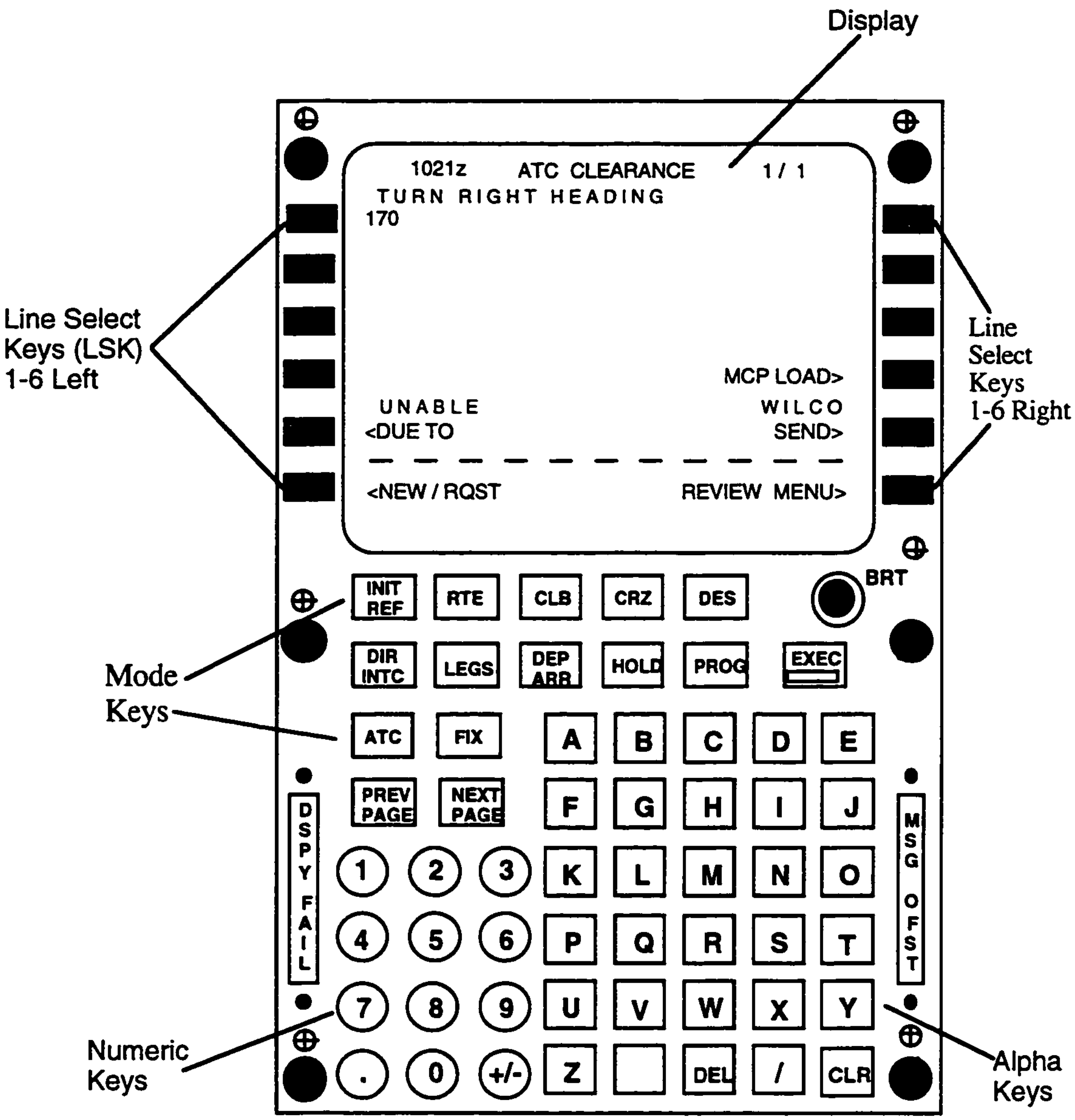

Figure 1. A description of the keys found on a Control Display Unit.

CDU). One advantage of using the CDU for data link is that it already exists in many aircraft and additional space would not be required for the new communication mode. Pomykacz (1991) reported that one airline is planning on using a dedicated CDU for data link presentation. While using a dedicated CDU will eliminate timesharing issues associated with sharing data link with other CDU functions, the CDU will still have space and paging constraints.

Display space and message length. Timing of data link acknowledgments and the ground-side technology for constructing data link messages may drive controllers to send more lengthy clearances than they would typically send via radiotelephone. As mentioned previously, with the current procedure for two-way communication in which the pilot responds immediately to a controller's message, there is often instantaneous feedback to the controller that may not be present with data link. Based on previous research (Kerns, 1991), it appears that controllers will have to wait longer for a data link acknowledgment than for a voice acknowledgment. Kerns (1991) accumulated results from previous research on transaction times and found that on the average, communicating with data link tends to double the response time as compared to voice. Further delays may occur due to system design.

With the first stage of Mode S data link, a mechanically rotating antenna will be used which may delay transmission of a message by at least a few seconds (FAA Technical Center, n.d.). Proposed data link displays for controllers may require that they be heads-away from their radar screen while constructing a message (Air Transport Association (ATA), 1992). In order to minimize heads-away time in addition to reducing the impact of delayed response times, the controller may choose to include as much information as possible in one message. For example, the pilot may receive weather and landing runway information along with their final approach clearance, which itself often contains multiple elements. A typical final approach clearance would read something similar to "Sun 123, 5 miles from MAYON, turn right 160, descend and maintain 5000 until established on the localizer, cleared for the ILS 26L approach, contact the tower at MAYON." This clearance alone is lengthy; any additional information would further increase the message length and thus the display space required for message presentation. Controllers may also be inclined to send longer messages knowing that, with data link, pilots can view or save a permanent record of the message.

Given the likely near-term location of data link on the CDU, the present study examined data link textual messages on this device. One constraint of using this display is the space available on the screen to display all the required information. The display arrangement on the 5-in monochrome cathode ray tube (CRT) is 14 lines by 24 characters. Information most likely included in this space will be the time stamp, message title, page number(s), message, and possible response options (ATA, 1992). Due to the amount of information included with each message, a lengthy message may not fit onto one page of the CDU thus requiring a second or third page for the entire message to be displayed (see Figure 2 for an example of a message that would require several CDU pages for message presentation).

In order to read a lengthy message and respond, the pilot will be required to page through the CDU at least once. In addition to the initial paging step required, pilots may page back and forth between the first and second page of a lengthy message in order to retrieve and recall message information. An alternative to multiple-page messages might be to change the font size; however, the ability for the pilot to read the message might be negatively impacted. Another alternative might be for controllers to send limited information that would require only one page for message display, however, the time required to access and respond to several messages may be longer than receiving one long message.

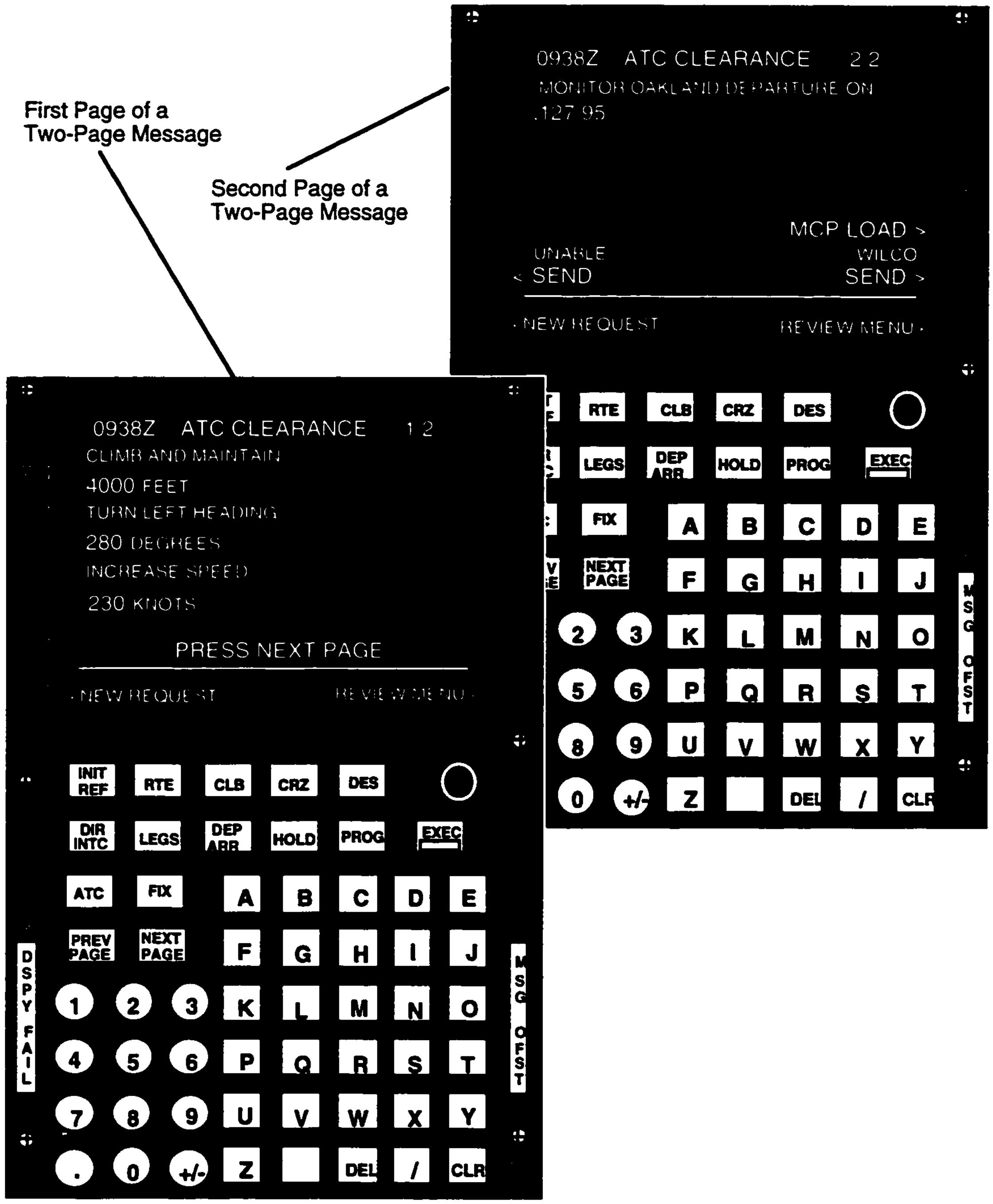

Figure 2. An example of a two-page message displayed on the Control Display Unit.

McGann, Lozito, and Corker (1996) found that when pilots were given short and long data link messages in succession, they were more likely to request clarification on the first short message as compared to the second short message or a longer message sent alone. McGann et al. state that "sending messages quickly in succession (within 15 seconds of acknowledging the first short message) may overload pilot cognitive resources and mitigate some of the benefits of data link. Hence, breaking down longer messages into smaller components may result in longer overall response times" (p. 13). In their study, long data link messages were always presented on one page due to the type of display they used.

One purpose of the present study was to examine how long messages presented on two pages of the CDU would affect pilot and controller communication. Because the CDU is a potential near-term location for data link and the messages used in this study were consistent with today's current environment, this is a realistic issue. Another purpose of this study was to determine whether message elements being loaded (see below) directly into the Mode Control Panel (MCP) might interact with message length to affect timing and pilot awareness of message content.

Loading data link messages. Messages received by pilots can be strategic or tactical. For example, a strategic message would include the upcoming route the pilot should expect to fly. A tactical message would include a specific change in heading, speed, or altitude that must be accomplished in a timely manner. It is likely that both strategic and tactical messages could be more than one page in length. However, since the tactical message must be acted upon immediately, the pilot would need to take the message information and enter it into the MCP and if applicable into the FMC. Data link may provide the ability to gate message elements directly (autoload) into the MCP and/or the FMC which will be partially dictated by message type (strategic or tactical).

Potential advantages of automating the task of loading elements of a message into related systems include a reduction in the number of entry errors and possible time savings. However, there are potential disadvantages with this procedure. Previous research (Parasuraman, 1987) indicates that performance with automated systems is often negatively affected because of "vigilance decrements over time or sustained low levels of vigilance" (p. 695). Current generation aircraft have advanced automation which allows the pilot to monitor most of a flight. In today's environment, control of the aircraft is often accomplished by entering values into either the MCP or the FMC versus making control inputs to the yoke. By automating the procedure of entering information into the FMS, the pilot becomes even more of a monitor and less of a controller, possibly increasing the already present vigilance effects.

In addition to maintaining vigilance, the task of manually loading an element may influence the pilot to analyze more closely the appropriateness of the message information. Buxton (1986) describes computer users' interactions with devices as haptic, meaning physical contact is involved for their operation. Evidence suggests that the muscular tension required for manipulation of the device is accompanied by a heightened state of attentiveness to the task and improved performance (Buxton, 1986).

One possible consequence of gating information directly into these systems is that pilots will take a less active role in controlling the aircraft, become less vigilant, and ultimately become less situationally aware. For example, an aircraft could receive a vector message from Air Traffic Control (ATC) with the intention of aligning the plane with the instrument landing system (ILS). A final vector in this situation should be approximately 30 degrees from the approach course and be received prior to the outer marker of the approach procedure. With autoload, the pilot may be more likely to accept a vector which is an inappropriate intercept heading. Additionally, if the message is lengthy, the pilot may be less likely to note any discrepancy in heading.

The Present Study

The purpose of the present study was to investigate how the length of a message and the ability to gate message elements directly into the MCP affect communication timing, aircraft control, and situation awareness. There were two levels of the independent variable length of message, short and long. Message length was defined by the number of elements in a message. Longer messages included four elements. With the CDU being used as the location for data link, longer element messages were presented on two CDU pages versus one page for short messages. Shorter messages included two elements. Two short messages were summed for comparison to a long message.

The two levels for the second independent variable, loading procedure, were autoload and manual load. Autoload was defined as the ability for the pilot to load information into the MCP by selecting the "load" prompt at the end of an ATC message on the CDU (see Figure 1 for the location of the MCP prompt). Manual load required the pilot to enter values directly into each MCP system. For example, a change in speed required the pilot to enter the new speed into the speed window on the MCP (see Figure 3 for a picture of the MCP).

In addition to the two independent variables, each of the four scripts contained an erroneous message. The error manipulation was designed to be a probe of pilot situational awareness. Hahn and Hansman (1992) conducted a simulation to test pilot situation awareness by issuing ATC messages which contained unacceptable elements intermixed with nominally acceptable messages. They were interested in the pilots' abilities to detect the errors based on loading procedure. Their data were not analyzed inferentially. Instead, they presented percentage of errors detected. The percentage of weather related errors detected was similar for the manual load and autoload conditions. With regard to routing errors, there was a higher percentage of correct rejections in the

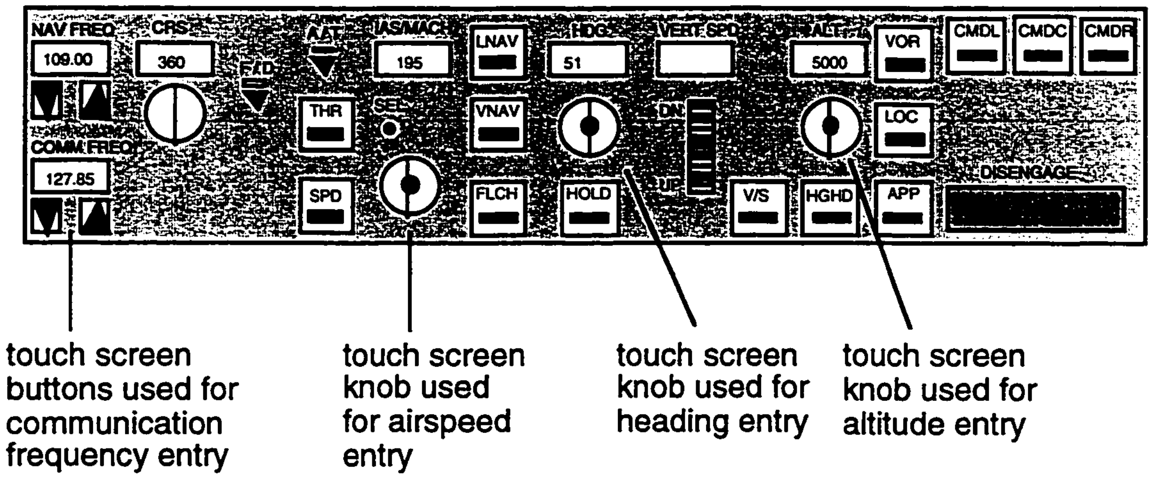

Figure 3. A picture of the simulated Mode Control Panel and the location where information could be entered.

autoload condition than in the manual load condition, 64% and 42% respectively. Based on their results, they believed that autoload may have an advantage over manual load with regard to pilot situation awareness. Hahn and Hansman (1992) noted that there was a potential bias against manual load detection performance because the simulator CDU differed from the CDU pilots were familiar with using. The pilots attention may have been diverted from message content to CDU operations. Pilots may have had a higher percentage of correct rejections if they were using a CDU with which they were familiar.

The dependent measures in the present study were communication timing, control timing, paging, and situation awareness. Communication time was defined as the time required for the message transaction; i.e., the time from receipt of the message to the acknowledgment of that message. Control time consisted of the time to load message information. Total transaction time included both the time to acknowledge the message and the time to load the elements into the MCP. Paging was defined as the number of times pilots paged back and forth after the initial paging step from the first to the second page of a long message. Situation awareness was defined by the detection of erroneous messages intentionally sent to the pilot.

For long messages (displayed on two pages), it was hypothesized that pilots would page back and forth from the first and second pages of the messages more frequently to reference elements that required MCP input more times in the manual load condition than in the autoload condition, thus possibly increasing the total transaction time. It was hypothesized that pilots would accept erroneous messages more often in the autoload condition than in the manual load condition. It was also hypothesized that the pilots would accept an erroneous element more often when the error was contained within a message which was two pages in length *and* when the pilots autoloaded the elements. While there were no specific hypotheses regarding total transaction time, the researcher intended to analyze these data for differences caused by varying message length and loading procedure. It was likely that total transaction time would be faster in the autoload condition than in the manual load condition due to the number of button presses required to enter information. Only one button press was required to enter message elements into the MCP in the autoload condition while multiple button presses, depending on the number of elements to be entered, were required in the manual load condition. However, Hahn and Hansman (1992) believed that autoload allowed pilots to spend less time on the task of loading and thus have more time for analyzing the appropriateness of message content. The time required for pilots to analyze message content may offset the time savings produced with the reduction in the number of button presses. In terms of the effect of message length on total transaction time, there was no specific hypothesis due to the time trade-off between the added time for accessing and acknowledging two short messages versus the added time required to page back and forth between the first and second page of a long message.

Method

Participants

Twelve current glass-cockpit pilots were paid to participate in this study. Glass cockpit in this investigation refers to aircraft that have a FMS for control of the aircraft with Electronic Flight Indication System (EFIS) displays such as Boeing 757s and Boeing 747-400s. Each pilot flew four flight scenarios on a part-task flight simulator. This was a single pilot operation in which nine Captains and three First Officers participated. Of the twelve pilots, one pilot's data were dropped due to a data collection error. This pilot was a Captain and the participant's data were not included in any of the analyses or in the demographic data. Of the eleven participants whose data were used for the analyses, the average number of years as a professional pilot was 25, the average number of years with their current airline was 19, the average total flight time was 13,136 hours, and the average age was 51. Participants were treated in accordance with the ethical standards and guidelines employed by San Jose State University and the National Aeronautics and Space Agency (NASA)-Ames Research Center.

Apparatus and Procedure

The experimental facility consisted of a pilot workstation, controller workstation, and an experimenter workstation. The pilot and controller workstations were integrated to provide an environment for realistic communication and control of the subject aircraft (Pisanich, Lee, & Beck, 1994).

Pilot workstation. The flight deck simulation ran on two Silicon Graphics XZ4000 Indigo workstations with touch screen displays (see Figures 4 and 5). These systems provided a glass cockpit interface, advanced automation, and realistic flight dynamics. Located on one monitor was the Attitude Direction Indicator (ADI), Horizontal Situation Indication (HSI), Engine Indication Display, Surface Position Display and the MCP. Map controls, flaps, gear, speed brakes, a CDU and a tracking task were located on the second screen. Pilots flew in autopilot and autothrottle modes as manipulated by controls on the MCP.

ATC workstation. The controller station consisted of radar for the San Francisco Area (Bay TRACON) including Sacramento Airport. An interface for sending and receiving data link messages was displayed on the same screen. These systems ran on a Silicon Graphics XZ4000 Indigo workstation. Voice communication was available to both the controller and pilot as a back-up means of communicating when sending a data link message was not feasible. For example, if the pilot wanted to request a new heading but did not want to use the downlink option he or she could have elected to use voice radio.

Data link. The data link communications sent by the controller were displayed on the pilot's CDU (see Figure 1). Messages consisted of a title, page number relative to the number of pages in that message, the message, and the unable/wilco response set. There

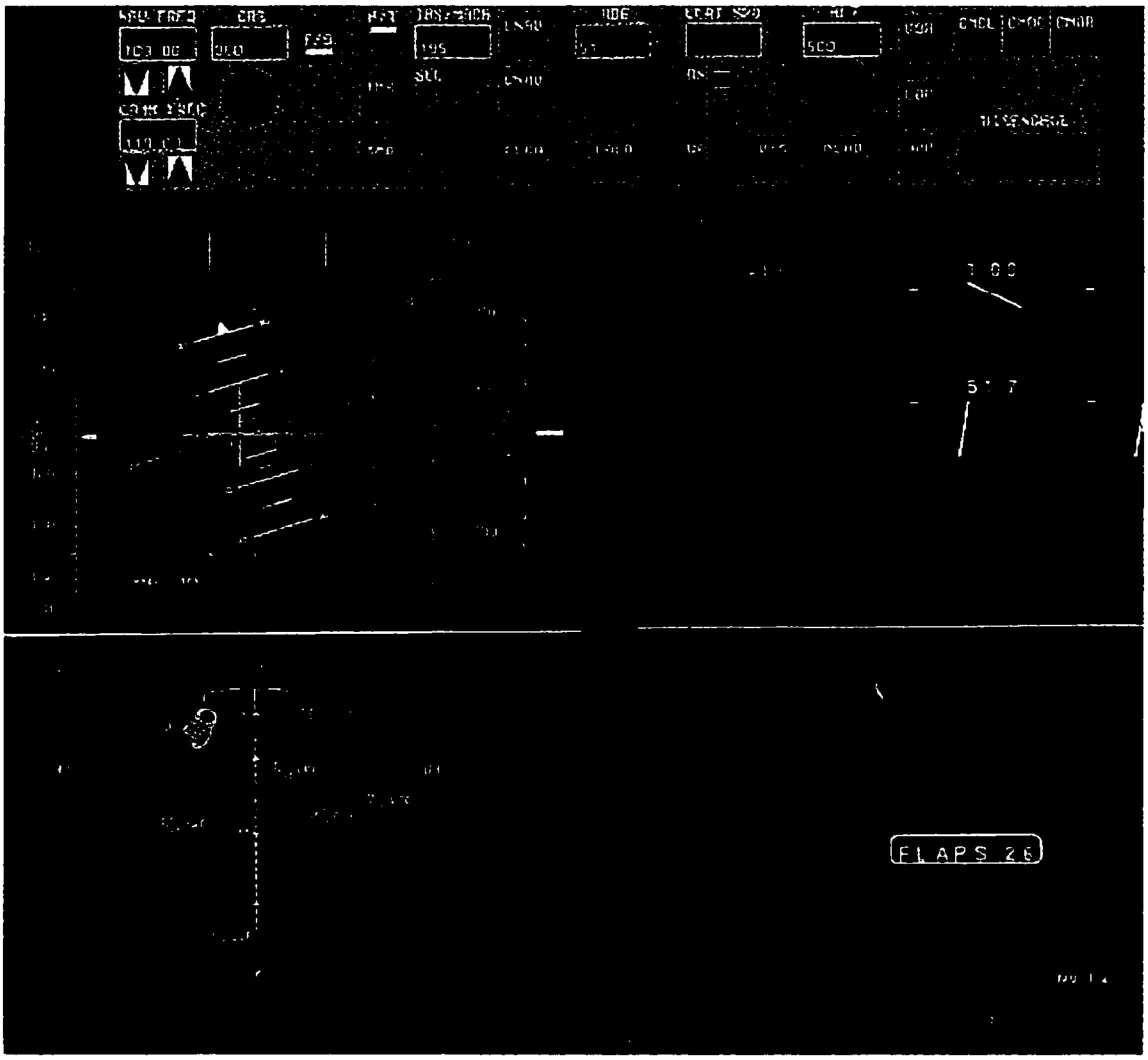

Figure 4. Screen One: Primary flight display, Mode Control Panel, engine instruments, and surface position.

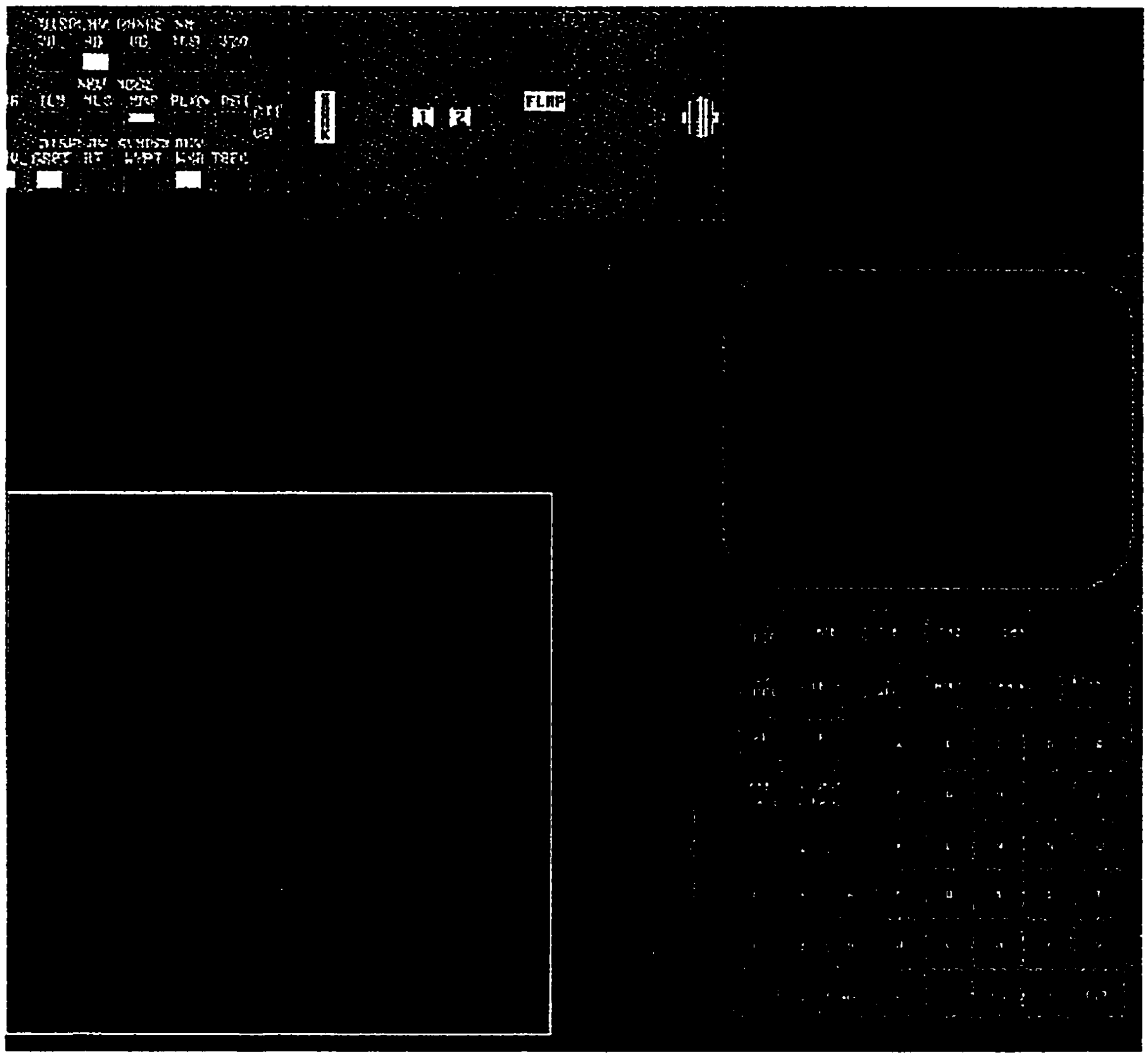

Figure 5. Screen Two: Map controls, gear, flaps, and speed brake controls, tracking task, and Control Display Unit.

were six line select keys on each side of the screen. All message information was contained on the CDU screen. When a data link message was sent to a pilot both an aural and visual alert were present. The aural alert was a selcal chime and the visual alert was "ATC Message" displayed on the scratch pad of the CDU. The pilot accessed the message by hitting the 1-right line select key from the message log. After reading the message, the pilot could acknowledge the message using the 5-right (accept) or 5-left (reject) line select keys. Depending on the experimental condition, "Load MCP'" was displayed on the CDU screen next to the 4-right line select key. In the manual load condition, the load MCP prompt was not shown. Pilots had the ability to make requests via data link to the controller by use of the alpha-numeric key pad on the CDU. Also available was the ability to review a previous message.

Instructions and training. Participants were given an overview of the FAA's data link implementation plans. They were also given a written overview of the study which explained that the researcher was interested in issues associated with the option for pilots to autoload message elements into their aircraft systems. They were not briefed on the other variable of interest, length of messages. In addition to the overview described above, it was written that the researcher understood that the pilot would be asked to do more tasks than he or she "normally" does. Traditionally, one pilot handles communication while the other flies, but in this experiment the pilot was asked to think of this as a situation in which he or she was required to do both. The pilot also performed a manual tracking task, adopted from Andre and Cashion (1993), as an additional work load.

Training was divided into three stages. The first stage consisted of training on the flight simulator differences and similarities to the current aircraft he or she normally flew. After this discussion, the pilot practiced using the touch screen for flight operations.

The next stage of training was on the tracking task. Participants were told to view the compensatory tracking task as a manual formation flying task. A circle was displayed and the participants were told that it was the aircraft they were to follow and that the cross on the screen was their aircraft. They were instructed to track continuously throughout the flights. Once they felt comfortable with the tracking task, a practice flight was flown in which they took off from San Francisco and were radar vectored for the ILS 28R approach back into San Francisco. They were asked to perform the tracking task while they flew this practice scenario.

After reaching 500 ft on the approach, the simulator was stopped and pilots started the third stage of training on the data link system. The CDU was not used for flight planning and control as it is in regular operations; rather, it was used strictly as the interface for the ATC messages. Before their participation in the experiment, all participants were familiar with basic operations of the CDU based on their current flight experience. Training consisted only of how the messages were displayed and how to maneuver throughout the data link pages, including responding to the message, reviewing a message, and making a request to ATC. After completion of the data link training, pilots flew one more practice flight from San Francisco to Stockton. This flight incorporated all tasks of flying, tracking, and communicating via data link. After completion of the practice flights, pilots began the experimental flight legs. By the time the pilot began the experimental flights, he or she knew how to use data link, the simulator, and was familiar with the tracking task.

Experimental procedure. Type of loading (manual or auto load of message elements into the MCP) and length of messages (two or four elements) were the variables of interest in this study. Pilots flew four flight scenarios, two flights from San Francisco to Sacramento and two return flights. To counter possible effects of learning, scripts were slightly varied. Embedded within the scripts were messages that were used for the analyses. Over the four scripts, there were six messages that contained four elements located on two pages of the CDU and 12 messages that contained only two elements on one page of the CDU. Two scripts contained messages that had two-element messages that directly corresponded to four-element messages in the other two scripts. For example, a script contained a four-element message composed of a heading, speed, altitude, and frequency change. In the corresponding two-element script, there was one two-element message which contained heading and speed and a second two-element message which contained altitude and frequency. The intent was to compare the effect of message length and not message content.

In order to understand the results of the analyses, a description of the actions used for handling a data link message is presented. For the total transaction time analysis, two short messages were summed for comparison with one long message. Message elements were equal in content between short and long messages. Summing the short messages meant that the time to access a message was doubled. Also doubled was the action of acknowledging the message. Each short message required a separate access and acknowledgment. With the long messages, there was only one action for access and acknowledgment. However, the long messages were displayed on two pages, so there was minimally the additional action of paging to the second page. The following formulas illustrate the total transaction times for short and long messages:

$$TTT_{Short} = TTT_{FM} + TTT_{SM}$$

$$TTT_{FM} = T_{acc} + T_{view} + T_{ack} + T_{load}$$

$$TTT_{SM} = T_{acc} + T_{view} + T_{ack} + T_{load}$$

$$TTT_{Long} = T_{acc} + T_{view} + T_{page} + T_{ack} + T_{load}$$

with TTT_{FM} equal to the total transaction time for the first short message, TTT_{SM} equal to the total transaction time for the second short message, T_{acc} equal to access time, T_{view}

equal to view time, T_{ack} equal to acknowledgment time, T_{load} equal to loading time, and T_{page} equal to paging time.

Each pilot flew two flights with autoload and two flights with manual load capability. In the manual load condition, pilots had to enter each message element into the appropriate window on the MCP. In the autoload condition, pilots hit the 4-right line select key which had the "load MCP" prompt located next to it. By hitting this button once, all message elements were loaded into the MCP. If there were four elements in a message, hitting the 4-right line select key once loaded all four elements. The load condition (two flights with autoload available and two with only manual load available) and message length were counterbalanced across pilots and the script order was randomly assigned.

In the autoload condition, regardless of the number of elements, only one button press was required to load elements. If there were four elements to load into the MCP the pilot in the manual load condition would have to use the touch screen to load each element. The absolute number of button presses was different for each condition. Short messages had twice as many button presses for access and acknowledgment as the long messages. Long messages had a button press for moving from the first and second page of the message. The following formulas contain the button presses required for each condition:

$$B_{SM} = B_{acc1} + B_{ack1} + B_{mcp1}{}^{n} + B_{acc2} + B_{ack2} + B_{mcp2}{}^{n}$$

$$B_{SA} = B_{acc1} + B_{ack1} + B_{load1} + B_{acc2} + B_{ack2} + B_{load2}$$

$$B_{LM} = B_{acc1} + B_{page1} + B_{ack1} + B_{mcp1}{}^{n}$$

$$B_{LA} = B_{acc1} + B_{page1} + B_{ack1} + B_{load1}$$

where B_{SM} is the total button presses for the short manual condition, B_{SA} is the total number of button presses for the short autoload condition, B_{LM} is the total number of button presses for the long manual condition, B_{LA} is the total number of button presses for the long autoload condition, B_{acc1} is the button press for the first access, B_{ack1} is the button press for the first acknowledgment, $B_{mcp1}{}^{n}$ represents all the button presses required to enter all elements into the MCP (if the message had two elements than two button presses were required), B_{acc2} is the button press to access the second short message, B_{ack2} is the button press to acknowledge the second short message, B_{mcp2n} represents all the button presses required to enter all elements into the MCP from the second message, and B_{page1} is the button press to move from the first to the second page of the message.

Each leg contained one erroneous element. One element read "Descend to and Maintain 5000'" which the pilot received when he or she was at 4000'. Another element read "Increase Speed to 230" which was received when the pilot was flying at 250 knots. The third erroneous element was a vector into a weather cell. Finally, the fourth element was a vector that sent the pilot in the opposite direction than one necessary to align with the approach course.

Each flight began at 500 ft, speed 195 knots, flaps 15, gear up and ended on the approach to the destination airport at 500 ft. Pilots entered message elements into the MCP either manually or through the "load MCP" prompt next to 4-right line select key on the CDU. They flew using the autopilot and the autothrottle. Airports, very high frequency omnidirectional range stations (VORs), and weather were displayed on the HSI.

After completing the four experimental flights, each pilot completed a questionnaire. There were demographic questions and questions concerning loading procedure and message length (see Appendix C for a copy of the questionnaire).

Results

In order to compare message length, messages from the two short-message scripts were compared to messages from the two long-message scripts. Short messages contained two elements. Long messages were comprised of four elements. Two short messages were summed and then compared with long messages. As a control for information equivalence, the information contained within the two summed short messages matched the information contained in the one long message. For example, one short message contained both a speed and heading element while the second short message contained both a frequency and altitude element. The two short messages were than compared to the one long message which contained the same elements found in the two short messages with the caveat that the long message was displayed on two pages. The number of times pilots accepted an erroneous message, total transaction time, and frequency of paging were the dependent measures.

Communication time and the time required for the pilot to input message elements were included in the measure for the first analysis on total transaction time. Statistical differences found in the first analysis lead to further examinations of the timing component. Increased paging could translate into additional total transaction time and additional attention to the message. An analysis was conducted on the number of times pilots paged back and forth from the first to the second page of a long message. A descriptive examination of the order in which pilots loaded and acknowledged a message was conducted. While communication timing is one important aspect of data link, a related issue is the impact of loading procedure and length of message on pilot situation awareness. In addition to the timing component, data were collected and analyzed for the number of times pilots accepted an erroneous message.

Total Transaction Time

Total data link transaction times were collected for both loading procedures and both message lengths. Total transaction time included the time from message receipt, and the time taken to access, read, load, and acknowledge the message. Pilots could load the message prior to acknowledging or they could acknowledge and then load. Regardless of order this analysis included both times. Two participants had one missing data point because the controller never sent the message to the pilot. These missing data points were replaced using the following formula (adapted from Winer, 1971):

$$\overline{TTT_e} = \overline{TTT_{La}} + \overline{TTT_{Ld}} - \overline{TTT_G},$$

where TTT_e is the mean estimated total transaction time, TTT_{La} is equal to the mean total transaction time for length (short or long dependent on which cell had the missing data point), TTT_{Ld} is the mean total transaction time for loading procedure (autoload or manual), and TTT_G is the grand mean total transaction time. From the entire data set there were two outliers (more than 3 SD above the mean). These two data points were also replaced using the previous formula. Both outliers were from the manual load condition, one was from the short message condition and the other was from the long message condition. The likelihood of an interruption was greater with manual load based on the fact that each element required separate entry and thus increased the duration during which an interruption could occur. This may explain why there were two outliers in this condition.

The mean total transaction time data are presented as a function of message length and load condition in Table 1. An examination of the means suggested that participants who received long data link messages (four elements presented on two pages) that could be autoloaded into the MCP had the fastest total transaction times. The means also indicated that by changing the procedure from autoload to manual load the total transaction times were lengthened.

The total transaction times were examined in a 2 (loading procedure) x 2 (length of message) repeated measures Analysis of Variance (ANOVA). The main effect for message length was not statistically significant. The main effect for loading procedure was statistically significant, $F(1,10) = 470.27$, $p < .001$, indicating that the mean total transaction time for the manual load condition was longer than the mean total transaction

Table 1

Total Transaction Time - Means and Standard Errors

Total Transaction Time (seconds)	Mean	Standard Error
Autoload-Short	29.9	1.7
Autoload-Long	20.9	0.9
Manual Load-Short	69.2	3.6
Manual Load-Long	79.2	3.1

time for the autoload condition. The interaction between loading procedure and message length was also significant, $F(1,10) = 22.98$, $p < .001$, indicating that the effect of loading procedure on total transaction time changed when message length was changed. The means suggested that autoload with long messages resulted in the fastest times while manual load with long messages resulted in the longest times. This interaction is presented in Figure 6.

Simple effects were computed to isolate the combinations of loading procedure and message length responsible for the significant interaction. Total transaction times for long messages in the autoload condition were significantly shorter than the total transaction times for the sum of the comparable autoloaded-short messages, $F(1, 10) = 16.26$, $p < .01$. This analysis indicated that the fastest total transaction times were found with longer messages that could be autoloaded into the MCP. Additionally, the total transaction times for long messages in the manual load condition were significantly longer than total transaction times for the sum of two short messages which were manually loaded, $F(1,10) = 6.01$, $p < .05$, indicating that sending long messages that had to be manually loaded into the MCP significantly increased the total transaction time.

Further simple effects for loading procedure at short and long messages were computed. Total transaction times for short messages in the autoload condition were statistically faster than in the manual condition, $F(1,10) = 241.79$, $p < .001$, suggesting that even with short messages, autoload capability resulted in faster total transaction times.

In summary, the analyses revealed that using autoload for entering values into the MCP produced the fastest transaction times regardless of message length. Summing the two short messages for comparison to the long message created longer total transaction times in the autoload condition only. In the manual load condition, however, the sum of the two short messages resulted in faster total transaction times than one long message.

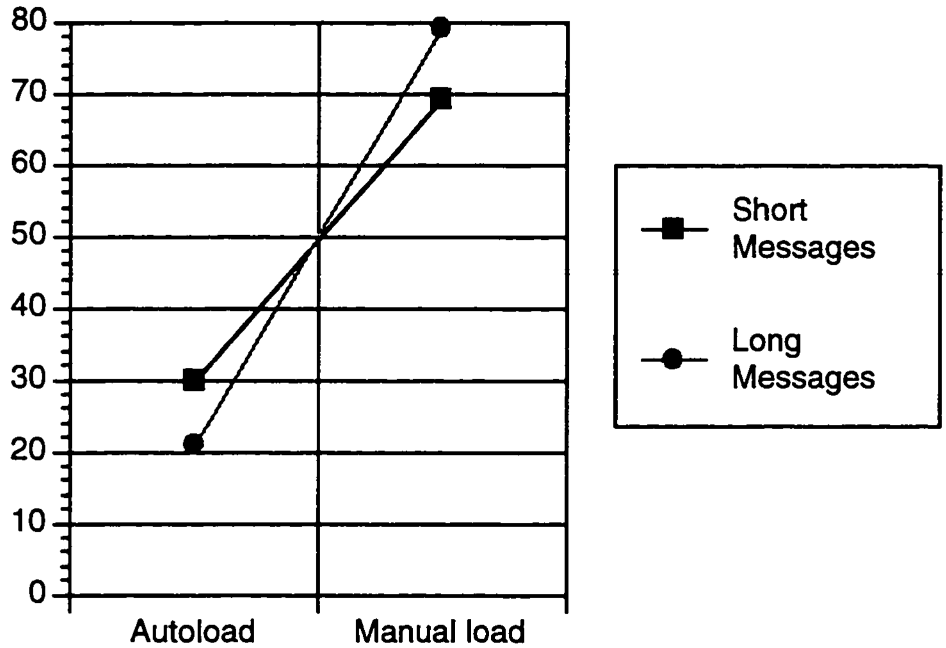

Figure 6. The interaction of message length and loading procedure on total transaction time in seconds.

The combination of manual load and long clearances produced total transaction times that were significantly longer than all other combinations. Conversely, pilots had significantly faster total transaction times when given a long clearance with autoload capability.

Paging-Long Messages

In order for pilots to view a long message, they were required to page from the first page to the second page. The response options for long messages were always presented at the end of the message on the second page. Beyond the initial paging step, pilots had the option to page back to the first page and return, using the "previous page" and "next page" keys on the CDU, as often as they desired regardless of when they acknowledged the message. For the 11 participants, there were three long messages in the autoload condition and three in the manual load condition per subject. The number of times the pilot paged per message, beyond the initial paging requirement, was tallied.

In order to test the effect of loading procedure on paging, a 2 (loading procedure: manual or auto) x 3 (replication) within subjects repeated measures ANOVA was performed on the data for the long message trials only. Pilots paged significantly more often in the manual load condition than in the autoload condition, $F(1,10) = 5.07$, $p < .05$. These data indicated that pilots viewed message information on each page more often when data link message elements were required to be manually loaded into the MCP than when they were autoloaded into the MCP. The mean for paging in the manual condition was 1.52 ($SE = .27$) while the mean in the autoload condition was .82 ($SE = .20$). This behavior was reflected in the total transaction time results described above.

Acknowledgment and Loading Order

In this study, pilots were instructed to load message elements and acknowledge the message in either order. Presented in Table 2 are the percentages for the acknowledgment/load order that was used in the manual and autoload conditions. With

Table 2

Acknowledgment and Loading Order

Acknowledgment/Load Order	Manual Load	Autoload
Load First	22%	74%
Acknowledge First	78%	26%

autoload, pilots loaded message elements using the autoload prompt 74% of the time prior to message acknowledgment. In the manual load condition, pilots used the touch screen to enter message elements 22% of the time prior to message acknowledgment. These data suggested that pilots were handling the message differently based on the loading procedure with possibly more attention being given to the message content when manual load was required. The erroneous message data presented next were intended to examine the pilots' attention to the message content.

Erroneous Messages

Of the 44 potential data points for the erroneous messages, two participants did not receive one of the erroneous messages leaving a total of 42 data points. The dependent measure was number of times pilots accepted erroneous messages when they should have rejected them. If a pilot accepted a message initially but eventually rejected the message, it was not included in the total number of erroneous messages accepted for that pilot.

Table 3 presents the number of times pilots accepted an erroneous message. These data reflect both length of message and loading procedure. An examination of the overall percentages for loading procedure indicated that pilots accepted erroneous messages that could be autoloaded 73% of the time. When the loading procedure changed from autoload to manual load, the number of times the pilots accepted the erroneous messages decreased to 35%, suggesting a greater awareness of the appropriateness of the message content as it related to the current state of the aircraft simulation. Across loading procedure, there was relatively little difference in the number of times pilots accepted erroneous messages between the short and long message length conditions.

A 2 (message length) X 2 (loading procedure) within subjects ANOVA was used to analyze the number of times pilots accepted erroneous messages. Due to the two

Table 3

Percentage of Times Pilots Incorrectly Accepted An Erroneous Message

Accept Erroneous Clearance	Short	Long	Total
Autoload	91% (10/11)	55% (6/11)	73%
Manual Load	22% (2/9)	45% (5/11)	35%
Total	60%	50%	

participants who each had one missing data point and were thus dropped from the analysis, nine participants' data were analyzed. The only statistically significant effect was a main effect for loading procedure, with $F(1, 8) = 8.26, p < .05$, indicating that in the autoload condition pilots accepted the erroneous message more often than in the manual load condition.

One potential problem with the erroneous message data was the fact that message content was not counterbalanced with short and long messages; thus, content may have influenced the pilots' behavior. However, when comparing loading procedure, each message type was present in both procedures.

Script and Order Effects

Pilots were randomly assigned to scripts. Pilots flew four flights, two flights from San Francisco to Sacramento and two return flights. The scripts were varied to counter possible effects of learning. In order to test for a script effect and order effect, a 4 (scripts: 2 short message and 2 long message scripts) x 3 (replication) repeated measures ANOVA was computed. The dependent measure for this analysis was total transaction time. No significant main effects or interactions were found for script or order.

Subjective Data

Pilots were given questionnaires at the end of the experiment. Two categories of questions relevant to this experiment asked about situation awareness and workload in regard to loading procedure. A third category of relevant questions asked pilots about their procedure for handling different message lengths.

Workload. Of the eleven pilots questioned, 82% said they preferred autoload over manual load in terms of reduced workload for this simulation. The pilots suggested several advantages of autoload including "more time to concentrate on what the aircraft is doing," "less chance of pilot error," and "less time consuming." While pilots favored autoload in this part-task simulation, many expressed concerns with autoload, such as "do not take people out of the information loop," "I missed some things when autoload was used, example, engaging approach mode and flight level change," "adverse affect on both pilots being on the same page," "time required to make sure information was loaded correctly," and "mistakes and omissions would be more easily overlooked."

Situation awareness. While the pilots' performance for erroneous message detection was worse or the same in the autoload condition as compared to the manual load condition, the majority (64%) reported that they felt autoload helped their situation awareness. A potential advantage to situation awareness was written as "more time to concentrate on location and progress of flight." Of the 36% who stated that they preferred manual load rather than autoload commented that "autoload would probably reduce situation awareness without ensuring cockpit communication prior to execution," "[pilots] must mentally concentrate more on situation awareness," and "it will lessen awareness, with a series of changes, it's easy to lose track and you have to trust that what's in the MCP is correct."

Change in procedure. Pilots were asked how their procedure for acknowledging a message was different for long versus short messages. All but one pilot (91%) said that they incorporated a different strategy for longer messages. In the manual load condition, most pilots commented that they wanted to read the entire message prior to loading, thus requiring additional time to page back to the first page to load the information. For example, one pilot stated, "I preferred one page messages. With two page messages, I would have to page back and forth to remember the clearance; thus it was more time consuming." However, another pilot commented on a different strategy, "Second page clearances required partial manual loading prior to acknowledgment to avoid page turning back and forth."

Discussion

The overall purpose of this study was to examine the impact of message length and loading procedure on communication timing, aircraft control, and pilot situation awareness. Total transaction time data were analyzed as a measure of communication time and time for pilot input of message elements. While there was no specific hypothesis regarding total transaction time, the data indicated that length of message and loading procedure had an effect on timing. In addition to timing, data were collected on the number of times pilots incorrectly accepted an erroneous message. The hypothesis that autoload would increase the number of times pilots incorrectly accepted an erroneous message was supported.

Total Transaction Time

Kerns (1991) summarized a series of studies that indicated that on the average data link doubled the response time as compared to voice. While the purpose of this study was not to examine voice versus data link differences, it was designed to examine how some aspects of data link, specifically autoload capability and message length, might affect an already lengthened response time. Total transaction time included the time from message receipt, and included the time to access, view, acknowledge, and load the message. Pilots were instructed to load and acknowledge in either order.

The results of the total transaction time analyses revealed that pilots had the longest times when given the combination of long messages and manual load. The longer time in the combination of long messages and manual load could be attributed to several factors. Manual load required pilots to enter each separate element into the associated MCP control system. With autoload, pilots had to press one CDU button which loaded all elements regardless of the number of elements. The time to manually load each element of long messages may have added to the overall total transaction time. The analysis on the paging data indicated that pilots were paging back and forth between the first and second page of long messages more often in the manual load condition than in the autoload condition. This paging most likely added to the lengthened time in the combination of long messages and manual load.

The fastest total transaction times resulted from sending pilots long messages in the autoload condition. Only having to press one key to load information as well as not having to page back and forth may have been responsible for the faster time in the autoload condition. The added time to send the content of a long message in two short messages increased the interface time so that the overall total transaction time was longer for combined short messages in the autoload condition than long messages in the autoload condition. These data suggest that with regard to total transaction time, pilots should be sent all relevant information in one message, even if multiple pages are required for message display, as long as autoload capability is provided. Without autoload, total transaction times were faster when pilots were sent short messages versus long messages.

Acknowledgment and Loading Order

In this study, pilots were given the choice of the order in which they acknowledged a message and loaded message elements. Based on the percentages in which they acknowledged prior to loading (78% in the manual load condition and 26% in the autoload condition), it appeared that pilots were changing their behavior based on loading procedure. The fact that pilots had accepted messages more often prior to loading in the autoload condition may partially explain the higher number of times pilots incorrectly accepted erroneous messages.

Pilot Workload and Situation Awareness

Lee and Lozito (1989) examined 14,000 Aviation Safety Reporting System reports and found that one out of four reports related to information transfer problems between aircraft and ATC. The examination of the descent and climb phases of flight revealed that, within these reports, the factors that contributed to information transfer problems were workload and comprehension failures. One result of these factors was deviations from assigned altitude and heading. Lee and Lozito (1989) noted that it may be difficult to separate workload from misunderstanding communications.

The FAA intends for data link to relieve some of the information transfer problems such as call sign confusion and acting on a misunderstood clearance. Data link may reduce pilot workload associated with these problems. Data link autoload may reduce pilot workload further by accomplishing the entry of information in a timely manner. Data link autoload may also provide some error checking capability which may also translate into reduced pilot workload. In the questionnaire administered in this study, 82% of the pilots felt that data link autoload reduced their workload. While data link autoload may reduce the time required to enter information and the potential for making entry errors, it may also lead to a decrease in pilot situation awareness. A majority of the pilots (64%) reported that they preferred autoload for situation awareness. At least in some cases, the pilots who preferred autoload did not appear to be aware that their situation awareness, as defined by accepting erroneous messages, was worse or the same in the autoload condition. The analysis on erroneous messages revealed that pilots accepted erroneous messages more often in the autoload condition than in the manual load condition.

These data are not consistent with Hahn and Hansman's (1992) data, which revealed that data link autoload improved situation awareness. However, they manipulated presentation of the message and readback of message. They determined that routing and weather clearances were different enough to analyze them separately. When pilots were presented with a graphical display of a weather-related erroneous message, they detected the error 100% of the time. However, when the same message was presented textually pilots detected it only 52% of the time. Their data revealed no difference in error detection of weather related errors due to loading procedure. They suggested that autoload may have increased error detection with regard to the routing clearances (64% detected with autoload versus 42% detected with manual load) due to the reduced cognitive load, and thus increased ability of the pilot to analyze the message with autoload. However, the simulated CDU they used was different than what pilots currently fly with and they suggested that the messages sent to pilots in their study required complex entry of information into a system with which they were not familiar. Thus the procedure pilots had to use in their manual load condition may have biased the results in favor of autoload. The same pattern may not have been present with a system that pilots were familiar with using.

There appeared to be a trade-off in the current study of timeliness of response and the ability to detect errors. Autoload had the advantage of faster response times, but the disadvantage of a higher number of the erroneous messages which were incorrectly accepted. Future research should address how to increase awareness in autoload conditions. Based on the results of Hahn and Hansman's (1992) study, there may be some benefit to situation awareness if pilots readback message content in conjunction with autoload. However, they did not have enough data to confirm the trend present in their study. In terms of the effects of timing only, applying these data to real-world operations would suggest that when a controller has a lot of information he or she needs to communicate to a pilot, the information should be sent in one long message versus breaking it apart as long as the crew has autoload available.

While data link as a new communication medium may relieve some of the current problems associated with voice radio, data link autoload may introduce situation awareness problems that are not currently present with voice and may not be present with manual load. There is the potential for some error checking capability with data link; however, the errors presented in this study may not be detected by an error checking system. For example, it is possible that error checking capability will only be provided for the extreme cases of values entered into their respective systems.

Generalizability of Data

Caution is suggested when generalizing these data due to some of the potential problems in this study. The aircraft was simulated on a desk-top computer. The platform is different than what pilots are familiar with flying. For example, the controls were manipulated using a touch-screen. In the manual load condition, loading time may have been exaggerated due to the touch-screen controls on the simulated MCP. Pilots may have dialed information more quickly if they were entering elements into a panel with which they were familiar. There was no auditory or kinesthetic feedback about the flight, such as the feel of acceleration or the sound of the throttles changing. Another possible significant difference between this simulation and the real world was the single pilot operation versus the pilot acting as part of a crew. This may have had an impact on timing and pilot situation awareness.

While procedures have not been defined with regard to crew agreement of message content, the ATA Requirements Document (1992) states that data link "procedures should include routine cross checking between pilots of data link communications and responses and confirmation by the flight crew that aircraft behavior is as expected after data gated into the flight guidance system are executed" (p. 5). The additional time for communication and potential agreement are absent from these timing and situation awareness data.

The impact of autoload on crew situation awareness was not addressed in this study. The definition of situation awareness can be extended beyond the awareness of an erroneous message. Hutchins and Klausen (1991) conducted an analysis of video and audio recordings from a simulated flight. Based on this analysis they concluded that:

> ...expectations and models organize the behavior of the crew and, when shared, permit the crew members to coordinate their actions with each other. Furthermore, the movement of information between members of the crew sometimes depends on the crew members assessments of their own states of knowledge and those of the others. The relationship between the cognitive properties of the cockpit system, as determined by the movement of representations, and the cognitive properties of the individual pilots is therefore very complex. (p. 35)

Information is distributed by many means within the cockpit. By requiring pilots to manually load information into each system on the MCP, the other pilot has the potential to receive nonverbal information about the content of the message and the other pilot's understanding of the message content. Currently, depending on the mode of flight and type of element that requires loading, standard operating procedures determine which pilot should enter the element. Not only do these procedures allow for error checking, they may also help with situation awareness. For example, if the autopilot is on and a message calls for a change in heading, one airline's procedure has the pilot-flying enter the new heading into the MCP. In the voice condition, both pilots have access to the ATC message. The pilot-not-flying would read back the clearance to ATC which would communicate to the pilot-flying that he or she received and understood the message. The pilot-flying would enter the new value into the MCP which would communicate to the pilot-not-flying that he or she received and understood the message. With autoload, procedures may need to change in order to maintain the current level of awareness. Neither this study nor the Hahn and Hansman (1992) study examined the impact of autoload on crew situation awareness. On the basis of the results of this study, and previous studies (Hahn & Hansman, 1992; McGann et al., 1996), it is suggested that situation awareness with data link autoload should be examined with pilots acting as crews versus in a single pilot capacity.

Data Link Autoload and Its Relevance to Future Air Traffic Management

Autoload timing and pilot situation awareness are likely to have relevance to the future free flight environment in which data link is considered an enabling technology. The future of air navigation and air traffic management will be different from what it is currently. Presently, pilots follow flight plans assigned to them by ATC. These flight plans can be amended in flight and frequently change from strategic to tactical once the aircraft is near the terminal area. The FAA has proposed a free flight concept that will allow for more flexibility in routing. One potential change with the free flight environment is a change in controller and pilot roles. Traffic separation in all phases of flight may change controllers' clearances from being less strategic to being more tactical.

The messages used for analyses in this study were all tactical messages that were loaded into the MCP. Regardless of message length, autoload had faster data link total transaction times than manual load. System effects from timing of both aircraft control and communication are relevant to the current air traffic system and they may have additional relevance in a free flight environment. Pilots and controllers may be using display information to determine if an aircraft, which is a potential threat to separation, is changing altitude or course in order to maintain separation; thus, timely pilot response will be required. In addition, with the potential for transfer of control between controllers and pilots, communication efficiency will be required. Data link autoload may offer the enhanced efficiency required for the changing National Airspace System. However, the potential trade-offs with situation awareness should be carefully explored.

References

Air Transportation Association. (1992). Human factors requirements for data link. Draft 7 of the Air Transportation Association Information Transfer Subcommittee.

Andre, A. D., & Cashion, P. (1993). Visual scanning in the functional visual field. Society for Information Display Digest, (pp. 114-117). Playa del Rey, CA: Society for Information Display.

Billings, C. E. (1981). Information transfer problems in the aviation system. Moffett Field, CA: National Aeronautics and Space Agency, Ames Research Center. (NASA Technical Paper 1875)

Buxton, W. (1986). Chunking and phrasing and the design of human-computer dialogues. Information Processing, 86, 475-480.

Federal Aviation Administration. (n.d.). A new era of air traffic control and communications. Atlantic City, NJ: Federal Aviation Administration Technical Center.

Federal Aviation Administration. (1995). User benefits of two-way data link ATC communications: Aircraft delay and flight efficiency in congested en route airspace. Atlantic City, NJ: Federal Aviation Administration Technical Center.

Hahn, E. C., & Hansman, R. J., Jr. (1992). Experimental studies on the effect of automation on pilot situational awareness in the data link ATC environment. The Engineering Society for Advancing Mobility Land Sea Air and Space AEROTECH Conference and Exposition, Anaheim, CA.

Hutchins, E., & Klausen, T. (1991). Distributed cognition in an airline cockpit (Grant No. NCC2-591). La Jolla, CA: University of California, San Diego, Department of Cognitive Science.

Kerns, K. (1991). Data-link communication between controllers and pilots: A review and synthesis of the simulation literature. International Journal of Aviation Psychology, 1, 181-204.

Lee, E., & Lozito, S. (1989, April). Air-Ground Information Transfer in the National Airspace System. Paper presented at the Fifth Symposium on Aviation Psychology, Columbus, OH.

McGann, A., Lozito, S., & Corker, K. (1996). Flight deck data link displays: An evaluation of textual and graphical implementation. Manuscript submitted for publication.

Parasuraman, R. (1987). Human-computer monitoring. Human Factors, 29, 695-706.

Pisanich, G., Lee, E., & Beck, L. (1994). A part-task simulator for advanced automation and communications research. Paper presented at the meeting of American Institute of Aeronautics and Astronauts, INC. Flight Simulation Technologies Conference, Scottsdale, AZ.

Pomykacz, M. A. (1991). Report of a study on airlines' anticipated near future cockpit control and display capabilities and plans for data link communication. Atlantic City, NJ: Federal Aviation Administration Technical Center. (FAA Technical Note T2003C)

Winer, B. J. (1971). Statistical principles in experimental design. New York: McGraw-Hill.

Appendix A

Signed Approval Form

SJSU SAN JOSE STATE UNIVERSITY

A campus of The California State University

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One Washington Square • San José, California 95192-0025 • 408/924-2480

TO: Elizabeth Logsdon
21 Bayview Ave.
Los Gatos, CA 95030

FROM: Adrian Rodriguez, Ph.D.
Chairperson, Human Subjects-
Institutional Review Board

DATE: March 1, 1996

The Human Subjects-Institutional Review Board has approved your request to use human subjects in the study entitled:

> "An Examination of Data Link Autoload and Message Length"

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to any and all data that may be collected from the subjects. The Board's approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Serena Stanford, Ph.D., immediately. Injury includes but is not limited to bodily harm, psychological trauma and release of potentially damaging personal information.

Please also be advised that each subject needs to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal will not affect any services the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at (408) 924-2480.

Appendix B

Pilot Questionnaire

Flight Information

How long have you been employed as a professional pilot? ______yrs ______mos

How long have you been with your current airline? ______yrs ______mos

What is your total number of flying hours? _______________

What is your age?________

Please list the average number of flight hours in your current and previous aircraft (including your experience with other than your current airline) and your crew position on that aircraft. Please put hours for each position on a separate line.

Current	Type/Model__________	Hrs. ________	CAPT___ F/O___ S/O___
Other	Type/Model__________	Hrs. ________	CAPT___ F/O___ S/O___
Other	Type/Model__________	Hrs. ________	CAPT___ F/O___ S/O___
Other	Type/Model__________	Hrs. ________	CAPT___ F/O___ S/O___
Other	Type/Model__________	Hrs. ________	CAPT___ F/O___ S/O___
Other	Type/Model__________	Hrs. ________	CAPT___ F/O___ S/O___
Other	Type/Model__________	Hrs. ________	CAPT___ F/O___ S/O___

How many times per month are you on a flight that receives a pre departure clearance through ACARS? _________

Please list any previous experiences you have had with data link.

____

____

Post-Experiment Questionnaire

Now that you have flown this simulation we would like to get your evaluation of the system and its use. It is very important that you carefully answer each question. Generally it is best to record the response that first comes to mind.

This questionnaire is meant to be a starting point for your evaluation, don't limit your responses to these question. Use the reverse sides of the pages to expand and extrapolate from these issues.

1. In terms of workload, which type of loading of a data link clearance did you prefer?
   a. autoload
   b. manual load

Please comment on how autoload may affect workload in your cockpit.

____
____
____

2. In terms of situation awareness, which type of loading of a data link clearance did you prefer?
   a. autoload
   b. manual load

Please comment on how autoload may affect situation awareness in your cockpit.

____
____
____

3. Did you find your procedure for accepting/rejecting and loading a clearance different for one page messages versus two page messages? __Yes / No__(circle one)

If you answered yes, in what way did you handle the two page clearances differently?

____
____
____