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HUMAN FACTORS IN COCKPIT INPUT AND DISPLAY FOR DATA LINK

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16. Abstract

Problems associated with the entry of air-ground-air messages via keyboard for transmission by Data Link are discussed. The ARINC proposal for a keyboard is presented, and an alternative method for coding keys is proposed for comparative evaluation. A sizeable vocabulary of messages requiring a minimum of keying is developed and justified. An alternative layout for a keyboard is proposed and its rationale explained. Some display problems are noted. Plans for experimental evaluation of several keyboard codes and layouts are noted.

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PREFACE

This Technical Memorandum is submitted as the required technical milestone for Task 1a, "Concept Development", of Project FA 16-0 "Human Factors Cockpit Input and Display for Data Link", covering work performed in the period July 1970 through January 1971.

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ILLUSTRATIONS

1.0 INTRODUCTION

The introduction of digital data link for air-ground communication will make possible, and in some cases will require, changes in the man-machine interfaces in the communications system. Since voice communications now predominate, some transactions performed by voice will or may be carried out via visual displays and manual controls in the future. This change of input/output media can have both positive and negative effects on the user's workload. An important task in the human factors program is to anticipate and evaluate the impact of these changes.

This report focuses primarily on the transfer of information from man to machine via manually operated keyboards, addressing itself also to the coding of messages in such a way that the user can transmit a variety of messages accurately with a minimum of training. Typical air-ground-air communications will be described and categorized as guidance for suggested coding techniques and vocabulary requirements. An input technique recommended by ARINC will be described and discussed. An alternative coding of keys will be proposed and a vocabulary of messages developed requiring a minimum of keying. Standard keyboard layouts will be noted and an alternative arrangement proposed. Some remarks will be added on displays, and plans for evaluation of the proposed techniques will be reviewed.

Digital Data Link techniques using manual entry provide an attractive interim solution to the problem of present ATC communication systems overload. Since the hardware to implement a Data Link requires little or no extension of existing technology, the problem becomes one of gaining user acceptance. Unless the man-machine interface is so designed as to reduce rather than to increase user workload, microphones will continue to be the preferred means for information transfer.

Although the several problem areas requiring consideration in developing a workable Data Link system are intimately interrelated, it is necessary for purposes of this discussion to treat them somewhat separately and discretely. Subsequent sections of this report accordingly are concerned with (1) message content analysis, (2) input devices, (3) coding including message vocabulary, (4) output devices, and (5) other cockpit keyboard requirements. This will be followed by a discussion of other systems considerations and future program plans.

2.0 MESSAGE CONTENT ANALYSIS.

A prime consideration in the development of a Data Link system is that the system must be able to convey the same types of information as that presently exchanged via voice link, and with growth potential for adding other message categories should this become necessary at a later date. Because of the numbers of variables involved and the manpower limitations on this project, the material discussed here must necessarily be somewhat qualitative. Even though the emphasis on this project is directed toward the airborne portion of the system, message content analysis must give equal consideration to the ground-originated information which is transmitted to the aircraft. Similarly, even though Data Link will without a doubt be implemented first at the ARTC Center, its later extension to major airports should not be overlooked as a possibility, particularly for those controller positions such as Approach and Departure where there is a pronounced similarity to procedures used by ARTCC.

The approach has been to examine transcripts of air-ground-air transactions and to listen to live transactions. The data base for this analysis is approximately as follows:

Source	# of Transactions
Tower: Philadelphia International Airport. (transcripts)	1300
New York ARTCC (transcripts)	900
Boston ARTCC (live & transcripts)	2500*
Tower: Logan International Airport (live & transcripts)	1000*

The types of messages have been categorized, and the parameters most critical in determining the frequency of each type of transaction have been determined.

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* Portions of these data represent casual listening at home during evenings, week-ends, and early morning, with recording for later analysis confined to periods where particularly interesting situations evolved.

The parameter analysis shows us that to obtain a comprehensive picture of air-ground-air transactions, we must concern ourselves with examining the effects at:

1. ARTCC High Altitude Sectors
2. ARTCC Transition Sectors
3. ARTCC Low Altitude Sectors
4. Local Airport Approach Control
5. Local Airport Departure Control
6. Other Controller Positions, where applicable,

in terms of:

1. Relative frequency of message types
2. Message duration
3. Total amount of information transmitted
4. Amount of information per transaction
5. Number of transactions per aircraft
6. Ratio of ground to air-originated transactions
7. Number of transactions per aircraft

as a function of:

1. Time of day, particularly as it reflects traffic density
2. Local airport differences
3. Seasonal differences
4. Sudden changes in weather patterns
5. Number of aircraft in sector
6. Ratio of commercial to general to military aviation.

In terms of efficiency of data acquisition, it is tempting to analyze message content during peak traffic periods, but such data cannot be generalized. Weather variability, in particular, forces pronounced procedural changes, most noticeable in the message content from and to the Airport Approach Controller. As a saturation level at this position approaches, it is reflected by a procedural change at the ARTCC Low Altitude Sectors, who must vector aircraft in holding patterns, and if this becomes too serious, it can force similar changes in Transition, and even High Altitude Sectors.

Because this message content variability is most pronounced at the Approach Controller's position, some emphasis has been placed on message analysis of this position. As a result of the ease of reception of signals from Boston's Logan Airport, this has conveniently served as a model, but the similarity of content of the transcripts supplied by NAFEC of communications at Philadelphia Airport for the same controller position and during a peak traffic period suggests that the use of this model has some validity. Purists may note that during periods of good visibility, the position of local traffic may be specified in terms of known geographical landmarks. This same information could be supplied in terms of radial and distance from a VOR to make it more nearly compatible with ARTC Centers.

The most noticeable feature of the Logan transmission has been the change of ratio of air to ground-originated messages as a function of traffic density. During the 4:00 A.M. doldrums, when arrivals may be at the rate of only four or five per hour, the pilot's report of entering a sector may be acknowledged by the controller with "Boston altimeter 29.76. Proceed at your discretion for landing on Runway 15. Wind west-northwest at 20." At the appropriate time, the controller will later originate the message, "Contact Tower, 119.1." Here the ratio of air to ground-originated messages is 1:2. At the other extreme, during peak periods, the controller may request as many as 10 changes of altitude, heading, and speed for a particular aircraft, and the ratio of air to ground-originated messages becomes more nearly 1:10.

There are also noticeable differences between controllers in their method for handling high-density traffic in a manner to maintain safe aircraft separation. Since this can be accomplished by various combinations of altitude, speed, and heading change, individual controllers have developed and use the combination which proves most satisfactory to them.

It should be stressed that data based upon the high density northeast corridor are not necessarily universal. In-flight changes of flight plan, for example, do not occur with any regularity in this area. Such changes might well be anticipated as a requirement in Florida during mid-summer because of the numbers of strictly local thunderstorms of short duration. Other similar examples should occur to the reader.

The data reported by NAFEC on "Manual Operations at Jacksonville ARTCC, Project 167-641-01X" provide a valuable baseline for measuring any changes which may occur as automation is introduced into the ATC system. However, the data concerning the relative frequency of message types, even when augmented by the data from their ongoing analysis of transactions at New York ARTCC and at Philadelphia Airport should not serve as sufficient justification for the assignment of simpler or shorter codes to what appears to be the more widely used messages in the Data Link application, nor has NAFEC suggested any such implication. Rather, any coding scheme evolved for standard messages for Data Link should concentrate on providing equal simplicity for <u>all</u> messages which qualify as "standard." Similarly, equal emphasis should be placed on providing equal coding and data entry simplicity for both air and ground-originated messages.

3.0 INPUT DEVICES

It cannot be anticipated that the state-of-the-art of voice recognition equipment will have evolved sufficiently to render this a likely candidate for the time frame in which Data Link may be implemented, and we are accordingly faced with a need for some kind of manual input device.

Space constraints within the cockpit effectively rule out consideration of the use of a standard typewriter keyboard, as does the general requirement for one-handed operation. Even without these constraints, the relegation of part of the pilot's workload to what he might consider to be purely stenographic tasks would certainly not be looked on with favor.

Even though the same space constraints may not occur at the controller's position, we should be concerned with providing him with an entry device compatible with his present habits. The use of a device requiring two-handed operation for extended periods of time with the concurrent elimination of any possibility for cigarette smoking or coffee drinking should be avoided if at all possible.

Further analysis of the problem indicates that the ultimate input device should attempt to provide the following features:

1. Capable of one-handed operation, if possible,
2. Capable of easy encoding of "standard" messages.
3. Capable of modification of these messages, or even of the generation of non-standard messages with a minimum number of key activations.
4. Having compatible design for air and ground use, so as to minimize engineering design costs and permit the manufacture of quantities of identical units.
5. Having compatible design among various ATC stations.
6. Capable of rapid training and eventual high operator proficiency.
7. Using mnemonic coding so as to avoid requirements for memorizing lists of numeric equivalents.
8. Using to the greatest extent possible, the existing ATC vocabulary.
9. Having utility for other airborne tasks requiring data entry, such as area navigation and flight management.
10. Providing rapid but controlled input of emergency messages for collision avoidance.

This tabulation of implied constraints does not *per se* limit the input device to a single configuration. Further consideration is necessary.

The use of a single-button keyboard employing Morse code could, for example, be considered. Aside from the training requirements which would exist for a majority of user personnel, the reliability and accuracy of digital decoding from a Morse code input which might be entered at variable speeds would be open to question.

Chord keying represents a second possibility. A five-key keyboard can generate all of the alphas, and with the use of a message format employing coding restrictions, automatic shift to numerics could be accomplished for the appropriate messages. Despite the extremely high speed which can be attained by a trained operator employing chord keying, the training period required is probably too long for the Data Link application. Stenotype operators, for example, generally required about two years to attain proficiency.

At the other extreme, both in terms of training time and data entry speed, are thumbwheel switches. These can be extremely useful for operations such as dialing of radio frequency settings, but the slowness of data entry makes them a poor candidate for Data Link applications.

Some version of a ten-key keyboard probably represents the most suitable compromise. These presently exist in two versions, each utilizing a 3 x 3 array, plus a 10th key in the fourth row for the numeral "zero." For the Bell Touchtone Keyboard, the numerals "one", "two" and "three" appear in the top row. For ten-key desk calculators, the numerals "seven," "eight" and "nine" typically occupy these same positions. Comparative evaluations by several investigators have yielded little in the way of differences in keying speed or accuracy.

For all practical purposes, however, these keysets have been strictly digital, even though alphas appear on the Bell Touchtone Keyset in these days of all-digit dialling. If alphas are to be located sequentially on the keyset, there is good reason for locating them in the same sequence as the numerals.

ARINC, in their Data Link Newsletter #121, has already suggested the use of such a keyboard, with three additional keys below to permit selection of the right, center or left alpha on each of the alphanumeric keys. This vertical extension of the key matrix makes necessary both hand and finger movements for data entry. By the use of an encoding scheme now proposed by TSC, and explained more fully in the next section of this report, the requirements for this bottom row of keys can be eliminated, thereby reducing the amount of required hand movement.

Even with this reduction in the number of keys required, more than one layout is possible, in that a ten-key set may employ either a 4 x 3 or a 3 x 4 matrix, as depicted in Figure 1.

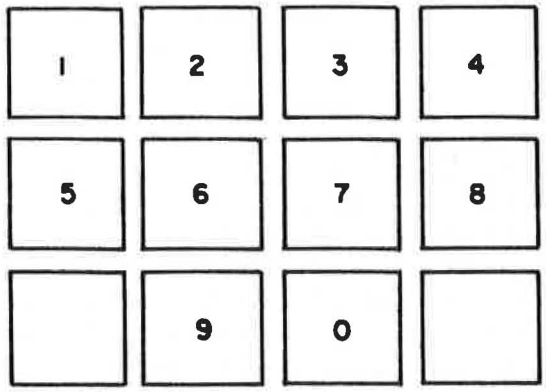
Human factors literature, unfortunately, provides little in the way of data concerning the relative merits of these two layouts, and comparative evaluation will be required as a part of this program. The 4 x 3 array permits the use of all four fingers and requires essentially nothing in the way of hand movement. The 3 x 4 array increases the amount of hand movement required for data entry, but eliminates the use of the little finger, which may be somewhat weak in non-typists. Since the coding scheme to be discussed in the next section of this report is equally applicable to either of these layouts, the evaluation of the two configurations may be run on a completely independent basis.

Finally, the use of a full alphanumeric keyboard requiring two-handed operation should not be ruled out at this time for at least certain limited applications. Where extensive revisions of a filed flight plan are made by ATC prior to clearance of an aircraft, the extensive text which might be required may well be more compatible with the use of a full typewriter keyboard.

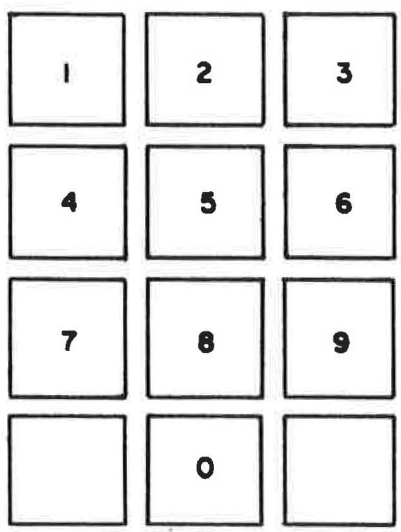
4.0 MESSAGE CODING.

As mentioned previously, the keyboard suggested by ARINC in Data Link Newsletter #121 utilizes essentially the standard Bell Touchtone system, with added keys to permit selection of the right, center or left alpha indicated on the keys of the 10-key set. This keyboard thus requires the activation of two keys for each alpha selected. For the pilot, this does not impose a severe burden, since he is supplied with a list of 21 standard messages, each identifiable by a two-digit number (unless he loses or forgets these numeric equivalents). Only four of these standard messages are followed by a requirement for additional alpha designations. For the ground controller, the opposite situation exists. The messages for the most part are designed to fit a 7 or 14-character window display, and this could require 14 to as many as 28 key activations to generate a message unit.

Since a keyboard layout of this type is already familiar to telephone users, its use as a Data Link input device cannot immediately be discounted. At the same time, the requirement for double keying to select alphas justifies the exploration of other configurations and coding schemes which might be superior for use with the restricted vocabulary of the Data Link application.



4 x 3 Matrix



3 x 4 Matrix

Figure 1.- Matrixes

The ongoing analysis of message content of ATC communications does not indicate that a requirement for the designation of individual alphas occurs with high frequency, but such occasions arise. While a pilot in the Boston area is normally concerned with the weather at Logan Airport, others may at times request information concerning the weather at Providence or Bangor, and this would necessitate the input of specific alphas. To the extent that such information can be encoded without unduly increasing the complexity of the balance of the system, the inclusion of alpha capability should be provided.

Similarly, for standard messages, it is obvious that training time can be reduced if mnemonic coding using key letters of words can be employed so that memorizing of numerical equivalents can be avoided.

Thirdly, but equally as important, the coding used should minimize the number of keyboard activations required to produce any standard message.

Fourthly, to the extent that pilots and ATC personnel are more familiar with certain specialized coding than is the general population, this should be incorporated if it can reduce training requirements.

The ICAO code represents an example of this last category, and effort has accordingly been directed toward using this as a part of an encoding scheme for Data Link. With proper selection of combinations of alphas on individual keys, the first two letters of the words used in the ICAO code can yield unique combinations. Since "foxtrot", "golf" and "hotel" all have the same second letter (and other similar situations occur with other letter combinations), the assignment of three sequential letters to each key in the manner of the Bell Touchtone Keyboard precludes this sort of coding. However, since airline pilots and ATC personnel are already completely familiar with this alphabetic representation, further exploration of the concept seemed warranted. For example, keys might be allocated as follows to yield non-redundant coding for individual alphas:

Key	Alphas	Numerical Equivalents
1	ABC	16, 18, 14
2	DEF	22, 21, 27
3	G	37
4	H	47
5	IJK	57, 58, 55
6	L	65
7	MNO	75, 77, 78
8	PQRS	81, 89, 87, 85
9	TUV	91, 97, 95
0	WXYZ	04, 08, 01, 09

It should be pointed out here that these letter-numeric combinations for coding purposes are completely independent of keyboard layout, and are equally useful with either the 4 x 3 or 3 x 4 matrices discussed earlier.

The coding scheme used above immediately permits the elimination of the three keys required in the ARINC concept for specification of "right", "center" and "left"; permits the generation of any unique alpha without increasing the number of key activations required over that of the ARINC concept, and permits a more compact keyboard, with resulting decrease in the requirements for hand travel.

The above thus utilizes 26 of the 100 possible two-digit combinations as follows:

Second Digit

First Digit	0	1	2	3	4	5	6	7	8	9
0		X			X				X	X
1					X		X		X	
2		X	X					X		
3								X		
4								X		
5						X		X		X
6						X				
7						X		X	X	
8		X				X		X		X
9		X				X		X		

By the use of reasonably simple digital logic, it is possible to specify that each of these two digit combinations should result in the appearance and later transmission of a single alpha. However, by utilizing similar logic, other unique two-digit conbinations can result in the appearance of two alphas which can be useful in a mnemonic coding scheme. Thus, by using the following, standard messages may be encoded without too great departure from the vocabulary presently in use. For example:

Characters	Ground to Air	Air to Ground
02 = WE	WEather (provides automatic transmission of weather information.*	Request for WEather info.

*As a minimum, altimeter setting should be provided. However, with the greater transmission efficiency of data link, a canned message could be transmitted including wind speed and direction, RVR, and runway conditions such as icing. Not all of this can presently be provided to every aircraft during peak traffic periods.

Characters	Ground to Air	Air to Ground
05 = WK	squaWK ident. (May be followed by a numeric code)	Not used
07 = YM	You May (permission granted).	Not used
10 - CW	Contact Wide area control ARTCC)	Not used
11 = CA	Contact Approach control.	Not used
12 = CD	Contact Departure control.	Not used
13 = CG	Contact Ground control.	Not used
15 = AK	AcKnowledge(ment)	AcKnowledge(ment)
19 = CT	Contact Tower	Not used. Or this may be a request for the frequency if it is not automatically supplied by the ground.
25 = DI	Dump Information (means for clearing the display (Not a transmitted message) or transfer to another controller)	
26 = FL	Flight Level? (Request for altitude information)	Not used in two-character format.
28 = ER	Not used	Emergency Request for priority in use of voice channel.
34 = GH	Not used	may I Go Higher? (request for a higher altitude.
36 = GL	Not used	may I Go Lower? (request for a lower altitude).
46 = HL	Hold Level (maintain present altitude	Holding present Level (might be followed by digits to indicate reaching a requested altitude).
49 = HT	Hold after Taxiing	Holding after Taxiing.
51 = IC	Not used.	Initial Contact with a new controller. (should automatically provide flight #, aircraft type and other pertinent info.
52 = IF	If Feasible	If Feasible
56 = IL	I Locate you (radar contact)	I Locate the traffic you have pointed out.
62 = LE	LEave a hold or restriction.	LEaving (rolling, taking off, departing, etc.)
67 = LM	Lost Message (Request for retransmission	Lost Message (Request for retransmission).
68 = LS	What is your Lowest Speed possible?	Not used in two-character format

Characters	Ground to Air	Air to Ground
71 = NC	You are Now Cleared	Not used.
76 = NL	Not Located (can't find you on radar).	traffic Not Located.
79 = OU	Not used in two-character format.	report of reaching the OUter marker.
80 = SW	Stay With me (remain on this frequency	Not used.
83 = RG	Restriction Gone (lifted)	Not used.
90 = TY	Thank You	Thank You
92 = TD	Not used in two-character format.	estimated Traffic Delay requested
99 = TU	TUrbulence (possible from wake of a previous aircraft.	TUrbulence report.

For standard messages, the above permits their generation by the actuation of only two keys and using an easily remembered coding scheme.

A few words may be in order concerning the use of "AK" for acknowledgement. With present voice transmissions, any commands or advisories from the ground are repeated by the pilot to assure the accuracy of reception. With Data Link, "AK" could cause automatic retransmission and automatic parity check against the original transmission. This could have a major impact on present procedures. At present, transactions are possible with only one aircraft at a time. With appropriate display to a controller that parity had been achieved and that the acknowledgement had not been delayed more than a few seconds, the busy controller could turn his attention to a second aircraft even before the receipt of acknowledgement from the first.

A number of the standard messages require subsequent transmission of digits. This should be accomplished by an automatic shift when the decoding logic recognizes these particular combinations. Such messages include:

Characters	Ground to Air	Air to Ground
17 = AM	AltiMeter setting is XXXX	Not used
26 = FL	Not used in this format.	Flight Level is XXX
39 = GT	Go To (altitude XXX)	Going To (altitude) XXX
41 = HA	Hold at Altitude XXX	Holding Altitude XXX
44 = HH	Hold Heading XXX	Holding Heading XXX
48 = HS	Hold Speed at XXX	Holding Speed at XXX
58 = IS	Increase Speed to XXX	Increasing Speed to XXX
68 = LS	Not used in this format.	Lowest Speed possible is XXX

Characters	Ground to Air	Air to Ground
69 = LT	Locate Traffic at XXX	Not used in this format.
79 = OU	OUter marker is XX miles.	Not used in this format.
82 = SD	Slow Down to XXX knots.	Slowing Down to XXX knots.
86 = RL	Report at Level (alt)XXX	Reporting at Level XXX
92 = TD	Traffic Delay estimate is XX.	Not used in this format.
96 = TL	Turn Left to XXX heading.	Turning Left to XXX heading
98 = TR	Turn Right to XXX heading.	Turning Right to XXX heading.

For standard messages, the requirement for subsequent alpha designations does not seem to occur with any great degree of regularity. Possible examples include:

29 = ET	Continue Enroute To XXX (fix)	Reporting Enroute To XXX (fix).
42 = HF	Hold at Fix XXX	Holding at Fix XXX
	(426 = left turns: 428 = right turns).	

The inclusion of specific alpha capabilities does, however, permit modification of standard messages. Thus, using the earlier example, a plane in the Boston area normally is concerned with the WEather at BOS, and the BOS designation should not be required in this case. If, however, he desires WEather information at Providence, he might inquire from the Boston tower concerning "WE-PApa VIctor DElta".

Although drastic maneuvers for collision avoidance fortunately are not required with any great frequency, it seems important to allocate certain combinations for this purpose, and to make these allocations such that the input requirement is as rapid and unambiguous as possible. With this in mind, the combinations 33 (fly up), 66 (fly left), 88 (fly right) and 00 (dive) have been reserved. The location of these keys in the matrix is indicative of the direction of the required maneuver, and for the 4 x 3 matrix, the arrangement is symmetric. It is further suggested that to avoid inadvertent transmission of a false alarm, these messages should require that the reserved keys should be activated more than twice, and within a specified total time period.

Since all of the standard messages started with alphas, but may end with numerics, a dash or space key should be provided to permit the generation of multiple message units. In this case, this key would serve as an automatic shift key to return to alphas for the start of the next message unit.

Furthermore, because the messages are so short, it does not seem necessary to include a backspace key. Instead, when an entry error is made, the cancel key should eliminate the entire message, or the portion of the message back to the previous dash.

The system, at its present stage of evolution, is utilizing the following combinations without redundancy:

	Second Digit									
First Digit	0	1	2	3	4	5	6	7	8	9
0	X	X	X		X	X		X	X	X
1	X	X	X	X	X	X	X	X	X	X
2		X	X			X	X	X	X	X
3				X	X		X	X		X
4			X		X		X	X	X	X
5		X	X			X	X	X	X	X
6			X			X	X	X	X	
7		X				X	X	X	X	X
8	X	X	X	X		X	X	X	X	X
9	X	X	X			X	X	X	X	

The blanks in the above indicate that there is system growth potential. More probably, the changes which occur will not be so much in the matter of growth of the number of messages used, but rather in identifying the most useful messages and improving their mnemonic coding to avoid some of the liberties taken here by departing from presently used ATC vocabulary. Suggestions in this direction would be welcomed. Additionally, useful and non-redundant codes for a few additional frequently used terms such as RVR and Runway in Use would be desirable, although both of these particular examples could be routinely supplied as part of a canned transmission of WEather information.

The previous listing of message types in numerical order, while it demonstrates that non-redundant coding has been achieved, may be somewhat confusing. In the listing below, messages are therefore grouped according to general categories:

ALTITUDE: Maintain (46); Change to (39); Report Reaching (86); Present altitude info. or request (26).

HEADING: Maintain (44); Turn right to (98); Turn left to (96).

SPEED: Maintain (48); Increase to (58); Decrease to (82); Lowest possible speed (68).

COLLISION AVOIDANCE: Fly up (33333); Dive (00000); Sharp Right (88888); Sharp Left (66666).

RADIO FREQUENCY CONTROL: Contact Approach Control (11); Contact Departure Control (12); Contact Ground Control (13); Contact Tower (19); Contact ARTCC (10); Remain on present frequency (80).

RESTRICTIONS AND CLEARANCES: Hold at fix (42); Taxi & hold (49); Clearance (71); Restriction lifted (83); Leave (62); Permission granted (07); Continue enroute to (29).

RADAR: Radar contact (56); No radar contact (76); Squawk ident. (05).

ADVISORIES: Weather (02); Possible turbulence (99); Other aircraft (69); Estimated approach delay (92); Other marker (79).

MISCELLANEOUS: Acknowledge(ment) (15); If feasible (52); Thank you (90); Retransmission request (67).

5.0 DISPLAYS FOR DATA LINK

Under the assumption that pilots and ATC personnel have had more experience with "reading" than with "writing", the major emphasis thus far on the program has been in the direction of attempting to develop a concept for a simple and usable data entry means. The ongoing analysis of message types and content, however, suggests that it would be premature to agree upon the use of a 7-character or 14-character display as advocated by ARINC. The coding scheme for keyboard entry outlined in this document lends itself to a two character-space-three character format for many message units. Multiple message units at present are frequently combined into a single transmission, particularly by Approach Control during peak traffic periods, routinely by the Tower during takeoff clearance, and by Departure Control during certain traffic patterns. The acuteness of this problem as it relates to the number of characters requiring simultaneous display has not yet been established. If a "window" display is used, provision for the display of larger numbers of characters may be required. If a CRT, such as that used for weather radar display in an aircraft is available, it might be possible to utilize this for brief periods of time. The CRTs suggested by Collins Radio for Area Navigation, by Boeing for Flight Management, and by M.I.T. for relay of ground controller's displays offer other time sharing possibilities in the future, particularly since some of these will already be provided with a character generator.

It should not be overlooked that two separate display units are probably needed for Data Link in an aircraft, and that identical display capacity may not be required for both.

ATC should be able to present a message in the aircraft at the same time that the pilot may be composing and entering his own message. With only a single display, there would be no means for establishing which of these should receive priority. The display which permits the pilot to check the accuracy of his input prior to its transmission should preferably be located close to the input keyboard, and could be limited to the presentation of a small number of alphanumerics. The preferred location would appear to be the pedestal, since this makes the keyboard and readout available to both the captain and first officer (this providing that the first officer is willing to work left-handed). Information transmitted from ground to air would, on the other hand, preferably appear on the panel, particularly since it might thus be time shared with other existing or proposed panel displays.

It should also be pointed out that while the use of visual displays has been assumed here, the simultaneous use of auditory displays should not be ruled out. Unlike the situation at the input end of the system, where voice recognition state-of-the-art is completely inadequate for this application, synthetic speech hardware for output is presently feasible in solid-state, no-moving-part systems. With one such system, each vocabulary word required is generated on a plug-in integrated circuit chip, such that a vocabulary of reasonable size still has only modest weight, size and power requirements.

As part of the ongoing analysis of message content, a very preliminary attempt has been made to develop such a word list, and the results are supplied in Appendix A. Again, comments as to possible deletions or conspicuous omissions are invited. Personal pronouns and the parts of the verb "to be" have, for example been omitted, resulting in somewhat awkward constructions when messages are formed out of the vocabulary, but major information content remains, while the inclusion of the ICAO code words would permit any other necessary word to be spelled out, if the occasion required. Message structures, while differing somewhat from the present format should be completely intelligible without training. A message such as "alpha alpha one two three, traffic twelve o'clock, four miles, down one thousand feet, bearing northwest, tango whiskey, delta nine sierra" alerts the crew of American Airlines flight 123 to a possible conflict with a TWA flight, points out its location and heading, and identifies the aircraft type.

One might question the need for synthetic speech as a backup to visual Data Link displays. Its use may be justified in at least two ways. Firstly, even though speech is transitory and not always identified or remembered correctly, it can alert the aircrew to the fact that new information has appeared on their visual display. Secondly, Data Link as presently envisioned involves the transmission of information between ground and a specific aircraft, and if only visual display is provided, with the commands for that aircraft, the crew loses some of the information which they presently obtain by listening to the commands and advisories to other planes. The availability of a synthetic speech channel could provide some of this information, even though in busy periods, it might not be possible to provide it in real time.

6.0 DISCUSSION

Keyboards are presently being fabricated at DOT-TSC to permit controlled laboratory evaluation of the ARINC concept and the entry concepts discussed here. Pending the availability of these keyboards, ATC communication transcripts have been coded using the proposed TSC system, and a limited comparison made between the time to required to read the full transcripts aloud, and the time required by a reasonably competent typist for entry of the coded information using a standard typewriter keyboard. These brief data indicate that "standard" ground-to-air communications can be entered in about one-half the time required for normal verbalization, and air-to-ground communications in about one quarter the time. It must be emphasized that these are limited data, based upon a limited sample, but they do indicate that the system offers promise as a means for reducing both pilot and controller workload.

7.0 FUTURE PLANS

1. Continue message analysis to obtain more quantitative as opposed to qualitative data.
2. Evaluate 3 x 4 versus 4 x 3 keyboard layouts.
3. Evaluate best candidate from #2 above against the ARINC concept.
4. Co-ordinate with developers of other cockpit systems having data entry requirements, to obtain as much universality among keyboards as possible.
5. Finalize the vocabulary which might be required or most useful for synthetic speech.
6. Interview prospective users to insure the soundness of any proposed concepts.

APPENDIX

PRELIMINARY ATC VOCABULARY FOR SYNTHETIC SPEECH

above
acknowledge
affirmative
Alfa
altimeter
altitude
and
apologies
approach
ascend
at
back-course
below
Bravo
center
Charlie
cleared
clearance
contact
continue
control
correction
Delta
departure
descend
down
east
Echo
eight
eleven
emergency
expect
fast
feet
five
follow
for (four)
Foxtrot
frequency
further
Golf
ground
half
heading
hold
Hotel
hundred
ident
if able
increase
India
Juliett
Kilo
knots
left
level
lifted
Lima
locate
located
maintain
marker
Mike
miles
negative
next
nine(er)
north
November
o'clock
one
or
Oscar
outer
Papa
pass
passing
please
point
Quebec
question
radar
range
ready
request
remains
report
restriction
right
Romeo
runway
seven
Sierra
six
slippery
slow
south
speed
squawk
standby
Tango
takeoff
taxi
ten
thank you
thousand
three
to (two)
tower
traffic
transponder
turbulence
turn
twelve
Uniform
unrestricted
up
use
Victor
visual
weather
west
Whiskey
X-ray
Yankee
zero
Zulu