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A COMPREHENSIVE VOICE MESSAGE VOCABULARY FOR AIR FORCE TACTICAL AIRCRAFT

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NOTICES

TECHNICAL REVIEW AND APPROVAL

AAMRL-TR-86-033

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

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Associate Director
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Surveys of airframe manufacturers and Air Force tactical aircraft pilots regarding the use of voice messages in current and future tactical aircraft are reported. The results of these surveys are used to recommend voice message ensembles for the primary Air Force tactical aircraft: the F-4, F-15, and F-16. The basic 38-item vocabulary necessary to generate those messages (except threat-warning messages) is presented and the usage of each vocabulary item is summarized by voice message function and by aircraft. An additional 35-item vocabulary for use in threat-warning messages is also presented. Conclusions and recommendations for further research are discussed.

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PREFACE

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1.0 INTRODUCTION

1.1 Background

Pilots of modern tactical aircraft must devote much of their visual attention to surveillance outside the aircraft during certain mission segments, such as air combat maneuvering and low-level flight. The need to inform the pilot of various critical conditions that might arise during these segments has resulted in numerous auditory signals designed to attract the pilot's attention regardless of the location of his visual gaze. Most of these auditory signals are non-speech signals such as bells, horns, and buzzers. To reasonably expect a pilot to remember the meaning of a large number of such signals is questionable (Patterson & Milroy, 1980), especially if one considers the low frequency of occurrence of many signals and the potential effect of stressful situations on such recollection. The auditory information systems in certain military aircraft have been reviewed in detail elsewhere (Doll, Folds, & Leiker, 1984); it will suffice here to say there is little consistency either within or across aircraft in how auditory signals are used.

Synthesized voice messages are perhaps the most attractive alternative to the continued proliferation of non-speech auditory signals. Innovations such as Head-Up Displays (HUD's) and multi-function CRT's have improved the use of the visual channel in the cockpit by reducing the number of dials and gauges that must be scanned by the pilot, and by allowing greater flexibility in the display of information. Voice messages offer similar improvements in the use of the auditory channel. They can be formulated with words and phrases familiar to the pilot populations of interest, thereby virtually eliminating concern that the signal might be misinterpreted. They also retain the advantages of other auditory signals: independence of visual gaze, superiority in conditions of anoxia and high positive g forces, and immunity to glare. The relative maturity of speech synthesis technology, and other advances in microelectronics, currently allows unprecedented flexibility in the use of the auditory channel to convey information to pilots. The increasing sophistication of onboard sensors and computers allows earlier and more accurate detection of potential problems, and the use of the highly natural medium of language to convey salient information to the pilot should result in more timely and effective responses to problems that arise during flight.

Synthesized voice messages are already implemented in some tactical aircraft. For example, the F-4D has a "Canopy, canopy" message to alert the crew that the canopy is unsecured at an inappropriate time, and an "Altitude, altitude" message that is presented whenever radar altitude drops below a preset value. The F-16 has a "Warning, warning--warning, warning" message that accompanies several warning lights and a "Caution, caution" message that accompanies the master caution light. The F-15 uses voice messages to inform the pilot of engine fire, accessory drive fire, fan turbine inlet temperature (FTIT), low fuel, "Bingo" fuel, and "over g" conditions. It is obvious that these three message ensembles represent quite different uses of voice messages. The F-16 messages simply indicate the criticality of conditions and direct the pilot's attention to an annunciator panel for details. The F-15 messages are far more specific and do not require the pilot to look at a visual display, but they do not cover the wide range of conditions that are covered by the F-16 messages. The F-4 messages alert the pilot to conditions that are certainly of interest, but there is no obvious rationale for the selection of these two functions from the assortment of candidate functions.

Additional uses of voice messages in tactical aircraft have been investigated. Butler, Manaker, and Obert-Thorn (1981) analyzed the time line of a typical air-to-air engagement for the F-14. They concluded that an F-14 pilot could have serious problems if certain malfunctions occurred when his full attention is required outside the aircraft. They observed that it would be helpful to inform the pilot of such malfunctions in a way that would allow his visual contact with the hostile aircraft to continue without interruption, thereby allowing a decision to continue or abort the engagement to be made without losing visual contact with the threat. They described several possible configurations of a voice message system that would help alleviate these problems. The baseline configuration simply supplemented existing warning and caution lights with voice messages. The second configuration included the baseline messages and added six other messages. A third configuration included only warning messages that are of particular concern during air-to-air combat.

Davis and Stockton (1982) described a proposed voice message system for the F-16. They selected messages pertaining to safety of flight and reflecting conditions that are considered warnings (immediate corrective action required) or cautions (conditions that could become critical if the pilot is not promptly informed). They specifically recommended that a "Master caution" message that does not differentiate among the various caution conditions not be used.

Standardization of avionics systems in general, and crew station controls and displays in particular, has been a subject of discussion for some time. Systems are now being developed which will provide the capacity for broad distribution of tactical information through digital data links. It seems likely that audio information may also be transmitted through those links; hence it appears probable that tactical aircraft of the relatively near future will be outfitted with standardized equipment capable of delivering audio transmissions to the pilot. Although many details of such a system are not yet determined, it is reasonable to anticipate that such a system may be used to deliver all audio signals to the pilot's headset, including synthesized voice messages. It therefore seems judicious to determine the vocabulary necessary to generate all of the voice messages that such a system should be capable of producing. The development of such a vocabulary would eliminate the need for the incorporation of speech synthesizers in each subsystem that utilizes voice messages, thereby reducing cost and encouraging a comprehensive assessment of the role of voice messages in tactical cockpits.

The need for a comprehensive vocabulary is not bound to the development of a new audio distribution system - it also has certain positive features in its own right. Among these positive features are reduced development costs, the easing of pilot transition from one aircraft to another (the pilot would already be familiar with many of the messages and with the sound of the "voice of his plane"), and greater ease in ensuring flexibility, expansion capability, and compatibility with future systems (e.g., voice recognition systems). The purpose of the present research is to assess the role of voice messages in tactical aircraft and recommend a comprehensive vocabulary as a first step toward realizing these potential benefits.

The existing and proposed implementations of voice messages in tactical aircraft, as described above, are obviously quite diverse. The prospect of standardizing voice messages in tactical aircraft is therefore immediately taxed with the problem of choosing which strategy to follow in the selection of functions for a voice message system. Strict standardization (i.e., identical message ensembles for all aircraft subject to the standardization) also poses additional problems. First, such a system would have difficulty reflecting the different avionics systems onboard the subject aircraft as well as the different mission contexts in which the aircraft and crew are expected to operate. Second, such a system would be less able to take advantage of pilot "lingo" in wording the messages, in that the terms used for the same generic functions may differ across aircraft types. Third, it would be necessary to disallow different approaches to the use of voice messages in different aircraft, even if differing approaches were appropriate (e.g., different approaches for a one-man crew vs. two-man crew).

It is perhaps more advantageous to envision a comprehensive, partially standardized system that circumvents the problems mentioned above while maintaining many of the positive features of standardization. Such a system would allow standardization of hardware and would deliver standardized voice messages where appropriate, but would also allow the tailoring of the message ensemble for each aircraft type in accordance with the operational requirements for that aircraft. This approach also encourages a systems viewpoint for each aircraft and discourages "piecemeal" implementation of voice messages.

1.2 Scope of the Present Research

The arguments advanced above for a comprehensive assessment of the role of voice messages in tactical aircraft are, of course, also applicable to other types of military aircraft. The present investigation, however, is limited to such an assessment for the primary tactical aircraft in the Air Force fleet. There are a number of difficulties inherent in this assessment, including the following:

1. The anticipation of new systems and functions that might make use of voice messages in tactical aircraft.

2. The selection of appropriate sources of information to guide the assessment. There are few previous investigations specifically concerned with tactical aircraft; the applicability of studies in other contexts must be carefully assessed.

3. Problems in evaluating the costs and benefits of implementing new voice displays in existing aircraft, particularly if new sensors or major re-wiring efforts are required to implement them.

In the present investigation, these difficulties were resolved as follows. First, it was decided that new systems and capabilities would be considered and accommodated only if scheduled for deployment or availability by the early 1990's. These technologies are now in testing and evaluation; projections further into the future might prove unreliable. Second, three primary sources of information were selected: the research literature, airframe manufacturers, and active Air Force tactical pilots. These sources represent distinct, yet complementary, viewpoints on the use of voice messages in aircraft. Finally, rather than attempt to estimate the cost effectiveness of implementing various voice messages in existing aircraft, the desirable uses of voice messages were determined irrespective of cost, but within the other constraints of this investigation. The costs of implementing the various messages can be more accurately assessed when the particular context of implementation is actually specified.

Given the goal of developing comprehensive voice message ensembles for the primary tactical aircraft in the Air Force inventory, two of the many important questions that arise are (1) for which functions should voice messages be used in each aircraft, and (2) how should those messages be worded? In addressing these questions, the present research was guided by the following principles:

1. The selected functions should be based on current technology, not futuristic projections. In particular, no assumptions about speech recognition or artificial intelligence capabilities would form the basis of a selected function.

2. Functions associated with new avionics systems scheduled for deployment in the near-term (c. 1990) should be considered.

3. The selection of functions should be based on input from the research literature, aircraft manufacturers, and Air Force tactical pilots.

4. The wording of the messages should be based on the preferences of Air Force tactical pilots and guided by research findings.

The remainder of this report is organized as follows. Section 2 reviews guidelines and recommendations offered in the literature for the use of voice messages in general, and for the use of voice messages in aircraft in particular. Section 3 presents the method and results of a survey of human factors and crewstation technology professionals employed by manufacturers of fixed-wing tactical aircraft, conducted as part of the present effort. Section 4 presents the method and results of a survey of tactical pilots also conducted in the present effort. In Section 5 the recommended vocabulary and message ensembles for the primary Air Force tactical aircraft are presented. Section 6 includes discussion of remaining issues, conclusions, and recommendations for further research. The appendices contain the survey forms used in both surveys and a summary of comments and suggestions obtained in those surveys.

2.0 REVIEW OF GUIDELINES AND RECOMMENDATIONS FOR VOICE MESSAGES

2.1 General Guidelines

Section 5.3 of MIL-STD-1472C contains guidelines for the general use of voice messages in engineered systems. They may be summarized as follows:

1. A verbal warning shall consist of an initial non-speech signal to attract attention and a brief, standardized message which identifies the specific condition and suggests appropriate action (5.3.5.1).

2. Verbal warnings for critical functions shall be at least 20 dB above the speech interference level at the operating position of the intended receiver (5.3.5.2).

3. The voice used shall be distinctive and mature (5.3.5.3.1).

4. Verbal warnings shall be presented in a formal, impersonal manner (5.3.5.3.2).

5. The selection of words to be used in the message should be based on intelligibility, aptness, and conciseness in that order (5.3.5.5).

The usefulness of these guidelines for implementing voice messages in aircraft is limited. The requirement that a verbal message be preceded by an alerting tone has been questioned by Simpson and Williams (1980). They measured the time from the onset of a warning signal to the initiation of the pilot's response under tone and no-tone conditions in a flight simulator. They found the addition of 1 sec for the alerting tone (0.5 sec duration of the tone and 0.5 sec of silence to preclude forward masking) resulted in an increase in total response time, although the latency measured from the onset of the voice message was shorter for messages preceded by a tone. As they point out, however, the time required to present the alerting tone cannot be ignored. The requirement that the message indicate appropriate actions is also problematic in the aviation context; although some conditions invariably should be followed by a certain procedure, it is often the case that the proper action cannot be specified without knowledge of the pragmatic context. Onboard computers are not yet sophisticated enough to make those decisions, although they may be in the future. Presenting voice messages 20 dB above interference levels in aircraft may result in disruption, or at least annoyance, at a time when proper actions are critical (Patterson, 1982, Patterson & Milroy, 1980). Quieter messages may be less disruptive and annoying during these crucial times, and sounds only 15 dB above threshold are difficult to miss (Patterson, 1982). The requirement that the voice be distinctive certainly has intuitive appeal, but the requirement that the voice also be "mature" is difficult to interpret in the context of computer-generated voices that are not necessarily human-like.

Deatherage (1972) recommends speech over non-speech messages under the following conditions:

1. When flexibility is desirable.

2. To identify a message source.

3. When listeners are without special training in coded signals.

4. There is a necessity for rapid two-way communication.

5. The message deals with a future time requiring preparation.

6. Situations of stress might cause the listener to forget the meaning of a coded signal.

The usefulness of these guidelines is also limited, but the latter condition (stress) is certainly of concern in aircraft. During routine segments of flight the modality or format of a signal may make little difference. In stressful, high workload situations, however, the proper choice of modality and format may be crucial. In these situations a visual indicator may not be detected promptly, and the meaning of a non-speech auditory signal might not be remembered immediately. Voice messages are unlikely to result in either of those problems. Information functions that may be critical during these situations must be considered prime candidates for association with a voice message.

2.2 Recommendations for Voice Messages in Aircraft

The use of voice messages in aircraft has been the subject of research and discussion since the early 1960's. A voice message system, which used messages recorded on tape, was installed in the B-58 fleet in 1961. Operational difficulties developed, apparently due to tape brittleness produced by the cold temperatures encountered during high altitude missions. Pilot response was favorable, however, and a similar system was tested in an F-111 simulator (Kemmerling, Geiselhart, Thorburn, & Cronburg, 1969). The test results indicated that response times to voice messages were faster than responses to tones, and that the pilots tended to cross-check the annunciator panel before responding to tones, but did not tend to do so for voice messages. It was recommended that the use of voice messages in aircraft be further investigated.

Brown, Bertone, and Obermayer (1968) recommended a detailed methodology for investigating the proper use of voice messages in Army helicopters. Their methodology may be summarized as follows:

1. Perform an information requirements analysis for each emergency of interest in the subject aircraft. The information requirements are determined by a task analysis of the response to each emergency.

2. Survey pilots to verify the accuracy of the information requirements and to obtain preferred wordings for each voice message to be used to provide the necessary information.

3. Check the accident statistics for the subject aircraft to ensure that the system addresses the problems actually encountered during flight.

4. Determine what is necessary to integrate the system into the cockpit of the aircraft.

5. Analyze the content of the message ensemble to aid in the selection of messages that are maximally informative, easily discriminable, and capable of eliciting rapid responses.

Although this methodology was developed and applied in the context of tape-based message systems, it remains applicable in the current context of computer-generated speech. Information requirements, pilot opinion, accident trends, system integration, and message content are important considerations in the design of voice message systems.

The advent of computer-generated speech as a technologically feasible option led to an increased interest in the use of voice messages in aircraft. This interest has been accompanied by a great deal of research. Although no set of criteria for the selection of voice message functions has been formalized, a number of recommendations - based on research findings - may be gleaned from the literature. Furthermore, it is advantageous to consider the methodologies employed in various studies of voice messages in aircraft, in order to identify the factors other researchers have considered of importance in their investigations. It should be noted that many of these studies have considered speech recognition as well as speech generation; only the latter is of concern here. A complete review of this literature is beyond the scope of this report. Findings important to the selection and wording of voice messsages are reviewed below.

Simpson and her associates have systematically studied various aspects of voice messages in aircraft, including the effects of linguistic redundancy (Hart & Simpson, 1976), familiarity with phraseology (Simpson, 1975), and rate and pitch (Simpson & Marchionda-Frost, 1984) on the intelligibility and comprehensibility of voice messages. This program of research was recently summarized by Simpson and Navarro (1984). Salient findings include the following:

1. Familiar phraseology should be used in the messages.

2. The pilot should be familiar with the accent (sound) of the voice.

3. Pilots should be aware of the range of possible messages.

4. If key-word (rather than sentence) format is used, the messages should contain a minimum of 4-7 syllables.

Bucher, Karl, Vorhees, and Werner (1984) examined the effect of various alerting prefixes on responses to voice messages. They compared responses to messages with no prefix, a 0.5 sec tone prefix, a single word prefix ("attention") for all messages, or a single word prefix that differed across message types ("warning," "threat," or "alert"). They found no differences in reaction time (measured from the beginning of the message, ignoring the prefix) as a function of prefix type. These results, along with the Simpson and Williams (17) finding that the time required to present the prefix increases total response time, cast doubts on the utility of using any kind of prefix for voice messages. The argument advanced in both reports is that some quality of the synthesized voice, as compared with human voice, apparently performs the alerting function. However, Hakkinen and Williges (1982), studying a simulated air traffic control task, found that an alerting tone does shorten response time if voice messages are used for other functions as well as for warnings. It seems that the total ensemble of messages must be considered in evaluating the utility of prefixes.

North and Lea (1982) investigated possible uses of voice messages in the B-52. They performed a time-based activity analysis to identify high workload flight segments. They identified the information requirements during these segments and recommended the use of voice messages for functions that met one of the following criteria:

1. The current visual display was not located in the central visual zone of the cockpit.

2. It was likely that other information would be simultaneously needed.

3. It could be coupled with a voice input function to form an interactive dialogue.

An additional requirement was that the information could be transmitted in a short phrase. They subsequently asked pilots to rate the utility of using voice messages for the recommended functions and obtained good agreement between the pilots' ratings and the objective ratings derived from the task analyses.

The voice message system study for the F-14 (Butler, et al., 1981), discussed in Section 1, also used a time-based task analysis to identify high workload flight segments. The design options presented in that report would simply supplement existing cautions and warnings with voice messages, use voice messages to present information of particular importance during the high workload segments (air combat maneuvering), or a combination of the two. The F-16 study (Davis & Stockton, 1982), also discussed in Section 1, simply used criticality as the criterion: synthesized voice was recommended for warnings and cautions, but not for other functions.

Cotton, McCauley, North, and Strieb (1983) investigated near-term and far-term applications of speech technology, in the context of the AFTI F-16 program. They had pilots rate the "helpfulness" of voice messages and voice control for a variety of functions. Voice message functions rated highly by the pilots include the following: Threat Information, Bingo Fuel, Task Prompts, Bogey Location, Low Altitude, Master Caution, and Engine Overtemp. They also suggested that an "individualized" speech input/output system be considered in future applications. Such a system would allow a pilot to select the voice messages he wanted to hear, and the voice commands he wanted to use.

Finally, Werkowitz (1981) reviewed the literature concerning the aircraft use of voice messages and offered the following recommendations:

1. Use voice warnings to enhance safety.

2. Require voice message systems to be expandable, to allow for evolutionary improvement.

3. Ensure that the messages say the right thing at the right time.

4. Maximize the intelligibility and discriminability of the messages through experimentation and standardization.

5. Investigate uses of voice messages other than the presentation of warnings.

6. Incorporate pilot opinions and preferences into the design process.

2.3 Summary

As discussed in Section 1, the focus of the present research is to identify the functions most suitable for voice messages and to determine the proper wording of those messages. Although no single set of guidelines or criteria for the selection of voice message is available, there are a number of principles endorsed by various studies that seem useful and logical. They may be summarized as follows:

1. Use voice messages that pertain to safety of flight to convey critical information to the pilot during periods of high workload or stress.

2. Select voice messages in accordance with the information requirements of those critical periods. Do not use voice to convey information that cannot be expressed in a brief message.

3. Use words or phrases familiar to the pilots. Ensure that the pilot is familiar with the sound of the voice and with the range of possible messages.

4. Involve pilots in the processes of selecting functions and composing the wording of the messages.

5. Ensure that each message has enough syllables to be acceptably intelligible and comprehensible. Maximize the discriminability of each message through experimental testing.

These five principles form a solid foundation for the selection of voice messages to be used in tactical aircraft. Although there are a number of related issues not addressed by these principles, these related issues typically must be investigated in the context of a defined ensemble of messages in a particular application. Examples of such issues include the potential saturation of the auditory channel, the extent of pilot control over the system, the prioritizing of simultaneous messages, and the competition between voice messages and other forms of audio communications.

3.0 SURVEY OF MANUFACTURERS

3.1 Rationale

The selection of voice message functions for a particular aircraft requires knowledge of the current displays in that aircraft, the environment in which the aircraft is intended to operate, and the internal and external sensor capabilities built into the avionics systems. Projection of future uses of voice messages requires knowledge of the planned changes in future versions of the aircraft and/or major retrofitting efforts planned for current models. Aircraft manufacturers must be considered prime sources of such information. These manufacturers typically employ researchers and engineers to study cockpit design. Any implementation of voice messages will certainly require the involvement of the manufacturers; thus it seems wise to obtain their input early in the development of such a system.

3.2 Participants

Five companies were identified as appropriate participants in this survey. Three of these companies (General Dynamics, McDonnell Douglas, and Fairchild Republic) are the primary manufacturers of tactical and attack aircraft in the current Air Force inventory. The other two companies (Northrop and Grumman) are current manufacturers of fixed-wing tactical aircraft for other customers and are participants in the Advanced Tactical Fighter (ATF) program for the Air Force. These companies and their applicable aircraft are shown in Table 1. Key individuals in each company were contacted, first by a letter that described the research project and the goals of the survey, and subsequently by phone. All of the companies agreed to participate. Scheduling difficulties, however, prevented the participation of Northrop. The remaining companies were asked to select the individuals in their employ best suited to respond to the survey. No specific qualifications for selection were stated, although it was requested that the respondents have experience in speech technology research, human factors, or general crew-station design. The number of respondents selected per company ranged from one to four. The total number of participants was eleven.

TABLE 1

COMPANIES SELECTED FOR PARTICIPATION IN THE SURVEY OF MANUFACTURERS

Company	Aircraft
Fairchild Republic	A-10[a], T-46[b]
General Dynamics[c]	F-16, F-111
Grumman[c]	F-14 (U.S. Navy)
McDonnell Douglas[c]	F-4, F-15, F/A-18 (U.S. Navy)
Northrop[c]	F-5, F-20[d]

a - Delivery of the final A-10s ordered by the USAF was completed in 1984.

b - Designated as the next-generation trainer for the USAF.

c - Also a participant in the Advanced Tactical Fighter (ATF) program.

d - Not currently in the military fleet, but under consideration.

3.3 Survey Instrument Design

The primary purpose of the survey was to determine what functions voice is likely to be used for in near-term (c. 1990) systems. To this end, a list of candidate functions was compiled from four sources: (1) existing speech voice messages in Air Force tactical aircraft; (2) existing functions currently allocated to non-speech (visual or auditory) signals, but included in proposed voice message systems; (3) functions not currently implemented in any form, but suggested as functions for voice messages in the literature; and (4) functions associated with new avionics systems scheduled for deployment by the early 1990's. This list is shown in Table 2, and includes 61 candidate functions.

A secondary purpose of the survey was to obtain input from these professionals concerning important related issues. Questions were included which solicited opinion on the extent to which voice messages should be used, how criticality should be indicated, what type voice should be used, and what criteria should be used to evaluate the effectiveness of voice messages. Two open-ended questions were included in which respondents were asked their advice on the type of information that should be obtained from pilots, and for their comments on any major issue(s) that should be resolved before a voice message system is implemented.

The development of a scale for rating the candidate functions posed a unique problem: the participants could not be expected to authoritatively state what their company would do in the future, and they differed as to the extent their recommendations could be expected to impact design decisions. We therefore asked the participants to rate the likelihood that they would recommend the use of a voice message for a given function, rather than their impression of the company's position concerning the use of voice for the function. The scale therefore indicates the extent to which individual respondents believe that it would be a good idea to use a voice message for each function. The following scale was presented for each candidate voice function:

NA .... Not Applicable or No Opinion
DY .... Definitely Yes - Definitely a Good Idea
L .... Likely - Likely to be a Good Idea
NL .... Not Likely - Not Likely to be a Good Idea
DN .... Definitely No - Definitely Not a Good Idea

TABLE 2

CANDIDATE FUNCTIONS INCLUDED IN THE SURVEY OF MANUFACTURERS

Existing Speech Messages	
Engine Fire	Low Altitude
Fuel Low	FTIT
Bingo Fuel	AMAD Fire
Over g	Canopy Unlocked

Proposed Speech Messages

Landing Gear	Fuel Pressure	Nose Wheel Steering
Departure Warning	Oil Temperature	Auto Throttle Disengaged
Angle of Attack	Oil Pressure	Low Tail Authority
Low Speed	Inlet Ice	Glove Vane Disabled
Brake Failure	Oxygen Low	Spoilers Locked Down
Wing Sweep	Hydraulic Pressure	Overspeed Valve
"Reduce Speed"	ACLS/AP	Bleed Duct Overheat
Generator Failure	Flaps	Pitch Stability
Flameout	Autopilot Failure	Roll Stability
CADC Failure	Engine Stagnation	Yaw Stability
Electrical System	Stores Configuration	Ladder Not Stowed
EEC Failure	Air Refuel Door	Incorrect Configuration
Obstacle Warning	TF Radar	Weapons Information
Dual Flight Control		

Suggested Functions

Altitude Callouts
Emergency Checklists
Task Prompts

TABLE 2
(concluded)

Functions Associated with New Avionics

LANTIRN:	Obstacle Warning
	Laser Lock-on
New Radar Warning Receivers:	Highest-Priority Threat Display
	New Threat ("New Guy")
	Missile Launch
Ground Proximity Warning System[a] for Tactical Aircraft:	Descent Rate
	Terrain Closure Rate
	Glideslope
	Excessive Altitude Loss
	Radar Altitude Too Low

a - currently designated as the Ground Collision Avoidance System (GCAS).

The responses obtained using this scale should not be interpreted as official statements of company plans. Rather, they are the professional judgements of the participants which may, to some extent, foretell future trends. A draft of the survey was pre-tested at Lockheed-Georgia Company and minor modifications were made. A sample form appears in Appendix A.

3.4 Procedure

The survey team visited each organization and administered the survey to the participants individually or in small groups. The purpose of the survey was explained, and respondents were asked to focus on technology available in the near-term. When the survey was administered to a single individual, the interviewer marked the booklet. In small groups, the respondents marked the booklets themselves. In either case, the interviewer controlled the pace of responding by reading aloud each item and answering any requests for clarification that arose. Completion of the booklet took approximately one hour.

3.5 *Results and Discussion*

The ratings of the candidate functions are summarized for each company in Tables 3-6. A master list of 47 functions rated favorably (DY or L) by at least one-half of the participants from any one company was compiled. This list, along with the number of favorable ratings obtained from each company, appears in Table 7. The list was used to develop the items included in the pilot survey, presented in Section 4. Two functions not applicable to Air Force aircraft are omitted from this list.

Ten of the eleven respondents rated Engine Fire and Threat Information functions favorably. Nine respondents rated Canopy Unlocked, Obstacle Warning, and Radar Altitude Too Low favorably. Other functions rated favorably by six or more respondents include FTIT, Bingo Fuel, Over g, Landing Gear Malfunction, Autopilot Failure, Stores Configuration, Terrain-Following (TF) Radar Failure, and Emergency Checklists. Thus, the functions with the strongest support are those that involve the potential loss of life or aircraft (Fire, Threat, Obstacle, and Altitude) and some functions that are potentially hazardous if the pilot is not immediately informed (Over g, Gear, and FTIT). The Canopy, Autopilot, Stores, and TF Radar functions represent

TABLE 3

RATINGS FOR CANDIDATE FUNCTIONS: FAIRCHILD REPUBLIC RESPONDENTS

Function	Rating NA	DY	L	NL	DN
Engine Fire	0	2	1	1	0
FTIT	0	0	1	2	1
AMAD Fire	0	0	1	2	1
Fuel Low	0	0	0	3	1
Bingo Fuel	0	1	1	2	0
Over g	0	0	1	2	1
Canopy	0	1	2	1	0
Low Altitude	0	2	2	0	0
Landing Gear	0	1	1	1	1
Departure Warning	1	0	0	2	1
Angle of Attack	0	0	1	2	1
Low Speed Warning	0	0	1	2	1
Brake Failure	0	0	0	3	1
Wing Sweep	2	0	2	0	0
"Reduce Speed"	0	0	1	1	2
Fuel Pressure	0	0	1	1	2
Oil Temperature	0	0	1	1	2
Oil Pressure	0	0	1	1	2
Inlet Ice	0	1	0	2	1
Oxygen Low	0	0	2	0	2
Hydraulic Pressure	0	0	0	2	2
ACLS/AP	1	0	0	2	1
Generator Failure	0	0	1	1	2
Flaps	0	0	0	2	2

TABLE 3
(continued)

Function	NA	DY	Rating L	NL	DN
Nose Wheel Steering	0	1	0	2	1
Auto Throttle Disengaged	2	0	2	0	0
Low Tail Authority	2	0	0	2	0
Glove Vane Disabled	3	0	0	1	0
Low Rudder Authority	1	0	0	2	1
Spoilers Locked Down	0	0	0	2	2
Overspeed Valve	2	0	1	1	0
Bleed Duct Overheat	0	1	1	1	1
Pitch Stability	0	0	0	2	2
Roll Stability	0	0	0	2	2
Yaw Stability Degraded	0	0	0	2	2
Yaw Stability Out	0	0	0	2	2
Autopilot Failure	0	0	2	1	1
Ladder Not Stowed	0	0	1	1	2
CADC Failure	0	0	1	1	2
Engine Stagnation	0	0	0	2	2
Dual Flight Control	1	0	0	2	1
Stores Configuration	0	0	2	0	2
Flameout Warning	0	1	0	1	2
Electrical System	0	2	0	1	1
EEC Failure	0	0	2	1	1
Air Refuel Door	0	0	1	1	2
Incorrect Configuration	0	0	0	2	2
Obstacle Warning	0	1	1	1	1

TABLE 3
(concluded)

Function	NA	DY	Rating L	NL	DN
TF Radar Failure	0	1	2	0	1
Weapons Information	0	1	2	0	1
Altitude Callouts	0	0	1	1	2
Emergency Checklists	0	0	2	0	2
Task Prompts	0	0	0	2	2
LANTIRN Obstacle	0	2	0	1	1
LANTIRN Laser Lock-on	0	1	0	1	2
Threat Display[a]	0	1	1	1	1
New Guy[a]	0	2	1	1	0
Launch Warning[a]	0	2	2	0	0
Descent Rate[b]	0	1	1	1	1
Terrain Closure Rate[b]	0	2	0	1	1
Glideslope[b]	0	0	1	1	2
Excessive Altitude Loss[b]	0	2	0	1	1
Radar Altitude Too Low[b]	1	1	2	0	0

a - Function associated with Radar Warning Receivers

b - Function associated with GCAS

TABLE 4

RATINGS FOR CANDIDATE FUNCTIONS: GENERAL DYNAMICS RESPONDENTS

	Rating				
Function	NA	DY	L	NL	DN
Engine Fire	0	2	0	0	0
FTIT	0	0	1	1	0
AMAD Fire	0	1	0	1	0
Fuel Low	0	0	2	0	0
Bingo Fuel	0	0	1	1	0
Over g	0	0	1	1	0
Canopy	0	1	1	0	0
Low Altitude	0	0	1	1	0
Landing Gear	0	1	1	0	0
Departure Warning	0	0	0	1	1
Angle of Attack	0	0	0	2	0
Low Speed Warning	0	0	2	0	0
Brake Failure	0	0	1	1	0
Wing Sweep	2	0	0	0	0
"Reduce Speed"	0	0	0	2	0
Fuel Pressure	0	0	1	1	0
Oil Temperature	0	0	2	0	0
Oil Pressure	0	0	2	0	0
Inlet Ice	0	0	2	0	0
Oxygen Low	0	0	2	0	0
Hydraulic Pressure	0	0	2	0	0
ACLS/AP	2	0	0	0	0
Generator Failure	0	0	1	1	0
Flaps	0	0	0	2	0

TABLE 4
(continued)

Function	Rating NA	DY	L	NL	DN
Nose Wheel Steering	0	0	1	1	0
Auto Throttle Disengaged	0	0	0	1	1
Low Tail Authority	0	0	1	0	1
Glove Vane Disabled	2	0	0	0	0
Low Rudder Authority	0	0	1	0	1
Spoilers Locked Down	0	0	1	1	0
Overspeed Valve	1	0	0	0	1
Bleed Duct Overheat	1	0	0	1	0
Pitch Stability	2	0	0	0	0
Roll Stability	2	0	0	0	0
Yaw Stability Degraded	2	0	0	0	0
Yaw Stability Out	2	0	0	0	0
Autopilot Failure	0	0	1	1	0
Ladder Not Stowed	1	0	0	1	0
CADC Failure	0	0	0	1	1
Engine Stagnation	0	0	0	1	1
Dual Flight Control	1	0	0	0	1
Stores Configuration	0	0	2	0	0
Flameout Warning	0	0	1	1	0
Electrical System	0	0	2	0	0
EEC Failure	0	0	1	1	0
Air Refuel Door	1	1	0	0	0
Incorrect Configuration	0	0	2	0	0
Obstacle Warning	0	1	1	0	0

TABLE 4
(concluded)

Function	NA	DY	Rating L	NL	DN
TF Radar Failure	0	1	0	1	0
Weapons Information	0	1	0	0	1
Altitude Callouts	0	0	1	0	1
Emergency Checklists	0	0	1	1	0
Task Prompts	0	1	0	1	0
LANTIRN Obstacle	0	0	2	0	0
LANTIRN Laser Lock-on	0	0	1	1	0
Threat Display[a]	0	0	0	2	0
New Guy[a]	0	1	1	0	0
Launch Warning[a]	0	1	1	0	0
Descent Rate[b]	0	1	0	1	0
Terrain Closure Rate[b]	0	1	1	0	0
Glideslope[b]	0	1	0	1	0
Excessive Altitude Loss[b]	0	0	0	2	0
Radar Altitude Too Low[b]	0	1	1	0	0

a - Function associated with Radar Warning Receivers

b - Function associated with GCAS

TABLE 5

RATINGS FOR CANDIDATE FUNCTIONS: GRUMMAN RESPONDENTS

Function	Rating NA	DY	L	NL	DN
Engine Fire	0	4	0	0	0
FTIT	0	1	2	1	0
AMAD Fire	2	0	0	2	0
Fuel Low	0	2	2	0	0
Bingo Fuel	0	4	0	0	0
Over g	0	4	0	0	0
Canopy	0	1	1	1	1
Low Altitude					
Landing Gear	0	1	2	0	1
Departure Warning	1	0	0	1	2
Angle of Attack	1	0	0	1	2
Low Speed Warning	1	1	0	0	2
Brake Failure	0	1	2	0	1
Wing Sweep	0	1	1	0	2
"Reduce Speed"	1	0	0	1	2
Fuel Pressure	1	0	1	0	2
Oil Temperature	1	0	1	1	1
Oil Pressure	1	0	1	1	1
Inlet Ice	1	0	1	1	1
Oxygen Low	1	0	1	1	1
Hydraulic Pressure	1	0	2	0	1
ACLS/AP	1	0	0	2	1
Generator Failure	1	0	0	2	1
Flaps	1	0	0	1	2

TABLE 5
(continued)

Function	Rating NA	DY	L	NL	DN
Nose Wheel Steering	1	0	0	2	1
Auto Throttle Disengaged	1	0	1	0	2
Low Tail Authority	1	0	0	1	2
Glove Vane Disabled	1	0	0	1	2
Low Rudder Authority	1	0	0	1	2
Spoilers Locked Down	1	0	1	0	2
Overspeed Valve	1	0	0	1	2
Bleed Duct Overheat	1	0	1	0	2
Pitch Stability	1	0	0	1	2
Roll Stability	1	0	0	1	2
Yaw Stability Degraded	1	0	0	1	2
Yaw Stability Out	1	0	0	1	2
Autopilot Failure	1	1	2	0	0
Ladder Not Stowed	1	0	0	1	2
CADC Failure	1	0	0	1	2
Engine Stagnation	1	0	1	0	2
Dual Flight Control	1	0	0	1	2
Stores Configuration	1	0	1	0	2
Flameout Warning	1	0	2	0	1
Electrical System	1	0	1	1	1
EEC Failure	1	0	1	0	2
Air Refuel Door	1	0	0	1	2
Incorrect Configuration	1	0	1	0	2
Obstacle Warning	0	2	0	0	0

TABLE 5
(concluded)

Function	Rating NA	DY	L	NL	DN
TF Radar Failure	1	2	0	0	1
Weapons Information	0	1	2	1	0
Altitude Callouts	1	0	1	0	2
Emergency Checklists	0	0	3	1	0
Task Prompts	1	0	1	0	2
LANTIRN Obstacle	1	3	0	0	0
LANTIRN Laser Lock-on	1	1	1	0	1
Threat Display[a]	0	2	2	0	0
New Guy[a]	0	2	2	0	0
Launch Warning[a]	0	3	1	0	0
Descent Rate[b]	1	0	0	2	1
Terrain Closure Rate[b]	1	0	0	2	1
Glideslope[b]	0	0	1	2	1
Excessive Altitude Loss[b]	1	1	0	1	1
Radar Altitude Too Low[b]	0	2	1	1	0

a - Function associated with Radar Warning Receivers

b - Function associated with GCAS

TABLE 6

RATINGS FOR CANDIDATE FUNCTIONS: MCDONNELL DOUGLAS RESPONDENTS

Function	Rating NA	DY	L	NL	DN
Engine Fire	0	1	0	0	0
FTIT	0	1	0	0	0
AMAD Fire	0	1	0	0	0
Fuel Low	0	0	1	0	0
Bingo Fuel	0	0	1	0	0
Over g	0	0	0	0	1
Canopy	0	0	0	1	0
Low Altitude	0	1	0	0	0
Landing Gear	0	0	0	0	1
Departure Warning	0	0	0	0	1
Angle of Attack	0	0	0	0	1
Low Speed Warning	0	0	1	0	0
Brake Failure	0	0	0	1	0
Wing Sweep	0	0	0	1	0
"Reduce Speed"	0	0	0	1	0
Fuel Pressure	0	0	0	1	0
Oil Temperature	0	0	0	1	0
Oil Pressure	0	0	0	1	0
Inlet Ice	0	0	0	1	0
Oxygen Low	1	0	0	0	0
Hydraulic Pressure	0	0	0	1	0
ACLS/AP	0	0	1	0	0
Generator Failure	0	0	0	1	0
Flaps	0	0	1	0	0

TABLE 6
(continued)

Function	Rating NA	DY	L	NL	DN
Nose Wheel Steering	0	0	0	1	0
Auto Throttle Disengaged	0	0	0	1	0
Low Tail Authority	0	0	0	1	0
Glove Vane Disabled	0	0	0	1	0
Low Rudder Authority	0	0	0	1	0
Spoilers Locked Down	0	0	0	1	0
Overspeed Valve	0	0	0	1	0
Bleed Duct Overheat	0	0	1	0	0
Pitch Stability	0	0	0	1	0
Roll Stability	0	0	0	1	0
Yaw Stability Degraded	0	0	0	1	0
Yaw Stability Out	0	0	0	1	0
Autopilot Failure	0	0	0	1	0
Ladder Not Stowed	0	0	0	1	0
CADC Failure	0	0	0	1	0
Engine Stagnation	0	0	1	0	0
Dual Flight Control	0	0	1	0	0
Stores Configuration	0	0	1	0	0
Flameout Warning	0	1	0	0	0
Electrical System	0	0	0	0	1
EEC Failure	0	0	1	0	0
Air Refuel Door	0	1	0	0	0
Incorrect Configuration	0	1	0	0	0
Obstacle Warning	0	1	0	0	0

TABLE 6
(concluded)

Function	NA	DY	Rating L	NL	DN
TF Radar Failure	0	1	0	0	0
Weapons Information	0	1	0	0	0
Altitude Callouts	0	1	0	0	0
Emergency Checklists	0	1	0	0	0
Task Prompts	0	1	0	0	0
LANTIRN Obstacle	0	0	1	0	0
LANTIRN Laser Lock-on	0	0	1	0	0
Threat Display[a]	0	1	0	0	0
New Guy[a]	0	1	0	0	0
Launch Warning[a]	0	1	0	0	0
Descent Rate[b]	0	0	0	0	1
Terrain Closure Rate[b]	0	0	0	0	1
Glideslope[b]	0	0	0	0	1
Excessive Altitude Loss[b]	0	1	0	0	0
Radar Altitude Too Low[b]	0	1	0	0	0

a - Function associated with Radar Warning Receivers

b - Function associated with GCAS

TABLE 7

FUNCTIONS RECOMMENDED IN SURVEY OF MANUFACTURERS[a]

Function	Fairchild Republic (n = 4)	General Dynamics (n = 2)	Grumman (n = 4)	McDonnell Douglas (n = 1)	Total
Engine Fire	3	2	4	1	10
FTIT	1	1	3	1	6
AMAD Fire	1	1	0	1	3
Fuel Low	0	2	4	1	7
Bingo Fuel	2	1	4	1	8
Over g	1	1	4	0	6
Low Altitude	4	1	2	1	8
Canopy	3	2	4	0	9
Landing Gear Malfunction	2	2	3	0	7
Low Speed	1	2	1	1	5
Brake Failure	0	1	3	0	4
Wing Sweep	2	0	2	0	4
Fuel Pressure	1	1	1	0	3
Oil Temperature	1	2	1	0	4
Oil Pressure	1	2	1	0	4
Inlet Ice	1	2	1	0	4
Oxygen Low	2	2	1	0	5
Hydraulic Pressure	0	2	2	0	4
Generator Failure	1	1	0	0	2
Flaps	0	0	0	1	1
Nose Wheel Steering	1	1	0	0	2
Auto Throttle Disengaged	2	0	1	0	3
Low Tail Authority	0	1	0	0	1
Spoilers Locked Down	0	2	1	0	3
Bleed Duct Overheat	2	0	1	1	4
Autopilot Failure	2	1	3	1	6
Dual Flight Control	0	0	0	1	1

TABLE 7
(concluded)

Function	Fairchild Republic (n = 4)	General Dynamics (n = 2)	Grumman (n = 4)	McDonnell Douglas (n = 1)	Total
Stores Configuration	2	2	1	1	6
Flameout	1	1	2	1	5
Electrical System	2	2	1	0	5
EEC Failure	2	1	1	1	5
Air Refuel Door	1	1	0	1	3
Configuration	0	2	1	1	4
Obstacle Warning	2	2	4	1	9
TF Radar	3	1	2	1	7
Weapons Information	3	1	3	1	8
Altitude Callouts	1	1	1	1	4
Emergency Checklists	2	1	3	1	7
Task Prompts	0	1	1	1	3
LANTIRN Obstacle	2	2	3	1	8
LANTIRN Laser Lock-on	1	1	2	1	5
Threat Information	3	2	4	1	10
Descent Rate	2	1	0	0	3
Terrain Closure	2	2	0	0	4
Glideslope	1	1	1	0	3
Excessive Altitude Loss	2	0	1	1	4
Radar Altitude Too Low	3	2	3	1	9

a - Table entries are the number of respondents rating each candidate function as "Definitely Yes" (DY) or "Likely" (L).

conditions that are not necessarily hazardous but might endanger mission success if not noticed by the pilot. The use of voice messages to present emergency checklists is discussed in Section 6.

The opinions expressed by the respondents on related issues are not directly related to the development of a comprehensive vocabulary, but they are useful in clarifying needs for further research. The first question concerned the extent to which voice messages should be used in the cockpit. The individuals were asked to consider five statements which represent different philosophies concerning extent of usage, and to indicate which statement is a more accurate expression of their own philosophy. The statements are as follows:

1. Synthetic speech messages should be used very little, if at all, in cockpits of tactical and attack aircraft.

2. Synthetic speech messages should be used only for a very limited class of functions, such as the presentation of emergency warnings.

3. Synthetic speech messages should be used moderately, restricted to relatively high-priority functions such as emergency warnings, caution messages, and important advisories.

4. Synthetic speech messages should be used for a fairly large number of functions, including some low-priority functions as well as high-priority functions.

5. Synthetic speech messages should be used extensively, encompassing a wide variety of functions at both high- and low-priority levels.

Five of the eleven respondents chose statement 3 as representative of their philosophy. Three respondents chose statement 4. Statements 1, 2, and 5 were selected once each. Thus, the prevailing philosophy of extent of usage was to use voice messages moderately.

The second question concerned the choice of message prefaces. The respondents were asked to indicate how critical messages should be distinguished from other messages. Five respondents indicated that a preface word (e.g., "warning") should be used. Three expressed preference for an alerting tone. The remaining three participants did not respond to this question.

The third question asked for the respondents' opinions regarding the type of voice that should be used. Three individuals expressed a preference for female voice, and three preferred a machine-like voice that is neither male nor female. Four preferred that the voice be male or female, but not machine-like. One individual did not respond to this question.

The fourth question asked participants to indicate what criteria should be used in evaluating the utility of voice messages in the cockpit. Specification of more than one criteria was allowed. Eight of the eleven selected pilot reaction time as an important criteria. Six selected system response time, seven selected response accuracy, and two selected pilot opinion. No other criteria were suggested. Thus it seems that response time - both the pilot's reaction time considered alone and together with the time required to deliver the message - is considered to be of great importance in evaluating voice messages.

The comments obtained concerning the types of information that should be solicited from pilots are summarized in Appendix B. Prevalent themes are desirable control features and selection of functions. The comments concerning issues that should be resolved before voice messages are fully implemented are also summarized in Appendix B. Prevalent themes are impact on safety and cockpit integration issues.

4.0 SURVEY OF AIR FORCE TACTICAL PILOTS

4.1 Rationale

The successful introduction of new technology to any population of users requires the acceptance of that technology by the users. The users may also provide valuable information concerning how the technology can be used in a beneficial way. Pilots are the ultimate users of a voice message system in the cockpit. Therefore, the pilot community is a valuable source of information concerning the proper use of voice messages in the cockpit. The selection of functions for voice messages should consider pilots' assessments of the types of information appropriately presented by voice. The pilot community must also be considered an authoritative source of information concerning the terminology to be used in wording those messages.

4.2 Participants

A total of 135 aircrew members participated in the survey. Of this total, 58 were F-16 pilots, 39 were F-15 pilots, 33 were F-4 pilots or weapons systems officers, and 5 were A-10 pilots. An effort was made to sample pilots with diverse levels of experience and exposure to current tactical operating environments. Thus, the sample included aircrews from operational tactical units, test and evaluation units, and an Air National Guard unit. The breakdown of the sample according to these categories appears in Table 8. Throughout the remainder of this report, the aircrews will be grouped merely by their current qualifications (F-16, F-15, F-4, or A-10). For brevity of expression, the term "pilot survey" is used throughout this report, although some of the F-4 participants are weapons systems officers. The experience levels (self-report of total flight hours) are summarized for each group in Table 9.

4.3 Survey Instrument Design

This survey was designed to elicit two types of information from the pilots: their preferences for the choice of functions and for the wording of the specific messages. A list of candidate functions was compiled from three sources: (1) the functions rated favorably in the survey of manufacturers (see Table 7) that could be expressed in a single message, (2) other specific

TABLE 8

NUMBER OF PILOTS IN THE SURVEY SAMPLE
BY UNIT AND AIRCRAFT FLOWN

Unit	Aircraft A-10	F-4	F-15	F-16	Total
33rd TFW, Eglin AFB	0	0	34	0	34
56th TTW, MacDill AFB	1[a]	1[a]	0	54	56
116th TFW[b], Dobbins AFB	0	19	0	0	19
3246th TW, Eglin AFB	0	2	2	1	5
4485th TS, TAWC, Eglin AFB	4	11	3	3	21
Totals	5	33	39	58	135

a - These pilots were in training for F-16 duty.

b - A Georgia Air National Guard unit.

TABLE 9

FLIGHT EXPERIENCE OF THE PILOT SURVEY PARTICIPANTS

Aircraft Flown	Number of Pilots	Flight Hours[a]		
		Mean	Minimum	Maximum
A-10	5	2344.0	820	3200
F-4	33	2475.8	1000	6000
F-15	39	1590.1	220	4100
F-16	56	1829.2	200	4700
Overall	135	1937.3	200	6000

a - Obtained by self-report and includes experience in other aircraft.

functions suggested by participants in the manufacturer survey or by a project team member with F-4 flight experience, and (3) various task prompts and other informational items. This third class of items was included in response to the support for task prompts and important advisories evidenced in the literature and the survey of manufacturers. The specific task prompts and advisories were obtained by informally examining the time lines of typical mission scenarios and flight segments. The candidate functions were grouped into three categories:

1. General functions - warnings and cautions not associated with a particular segment of flight or mission context.

2. Context-specific functions - warnings and cautions typically associated with a specific context in flight.

3. Informational functions - task prompts, advisories, and information feedback items.

The candidate functions so grouped are shown in Table 10. It should be noted that some of the items were difficult to classify because some advisories can be considered cautions under certain conditions. Such items were classified as cautions for the purpose of this survey.

For each of the general and context-specific functions, a prototypical wording of the message was determined. For those functions that already use a voice message in some aircraft, the actual wording served as the prototypical wording, with the exceptions that the preface words were omitted and the message was not repeated in the prototypical wording. For functions included in a proposed voice message system, the proposed wording was used with the same exceptions noted previously. The prototypical wordings for the remaining functions were composed of brief, direct statements of the activating conditions. They followed the same pattern as the existing and proposed wordings.

TABLE 10

CANDIDATE FUNCTIONS INCLUDED IN THE PILOT SURVEY

Category	Functions	
General Functions	Engine Fire	Flameout
	Fuel Low	Radio Malfunction
	Fuel Pressure Low	ADI Malfunction
	Oil Temperature Low	Bleed Duct Overheat
	Oil Pressure	Low Speed
	Hydraulic Pressure	External Tanks Empty
	Generator Failure	Autothrottle Disengaged
	CADC Failure	Spoilers Locked Down
	EEC Failure	FTIT
	Electrical System	AMAD Fire
	Inlet Ice	Wing Sweep
	Oxygen Low	Dual Flight Control
Context-Specific Functions	Canopy Unlocked	Descent Rate
	Brake Failure	Terrain Closure
	Nose Wheel Steering	Low Altitude
	Landing Gear Malfunction	Missile Launch
	Flap Malfunction	Threat Display
	Excessive Altitude Loss	New Threat
	Incorrect Configuration	Bingo Fuel
	Autopilot Failure	Over g
	TF Radar Failure	Glideslope
	Obstacle Warning	

TABLE 10
(Concluded)

Category	Functions	
Informational Functions	Preflight Checklists	Periodic "Check Six"
	INS Coordinates	Low Ammunition
	Speed Check	Bogey Lock-on
	Gear Up and Locked	"Drop External Tanks"
	Flaps Up	Loft Bombing Cue
	Approaching Level-off Altitude	Laser Inoperative/Ready
	Autopilot Engaged/ Disengaged	Refuel System Ready
	Periodic "Check Fuel"	Air Refuel Door
	Fence Check	Level-off Altitude Calls
	Point Approach	Descent Checklists
	Next Heading	Laser Lock-on
	Joker Fuel	Gear Down and Locked
	Weapons Selected/Armed	Weapons Station Selection

The same scale used in the survey of manufacturers (see p. 20) was used for the general and context-specific messages. A total of 43 items (24 general functions and 19 context-specific functions) were rated using this scale. For each function rated favorably (DY or L), the respondent was asked to consider the prototypical wording and to offer an alternate wording if he felt the message could be better stated. Six items had follow-up questions concerning the proper specificity of the message; for example, one follow-up question asked whether the Engine Fire message in multi-engine aircraft should indicate which engine is on fire.

The 26 informational functions were organized according to flight segment and mission context, and the respondents were asked to indicate (Yes or No) whether the implementation of a voice message for a given function should be considered.

During the administration of the survey to the first units (the test and evaluation units at Eglin AFB and the Air National Guard unit at Dobbins AFB - a total of 45 participants), the survey team conducted follow-up interviews with many of the participants. As a result of these interviews, two additional items were added to the booklets used by the final 90 respondents (the F-15 unit at Eglin AFB and the F-16 training unit at MacDill AFB). These later respondents were asked their opinion on using voice to present emergency checklists, and to indicate their preferences for the control features (e.g., on/off, volume) that should be included in a voice message system. A sample form, which includes these two items, is contained in Appendix C.

4.4 Procedure

The survey team visited each unit and administered the survey to the aircrews individually or in small groups, typically groups of five to ten. The administration occurred during free time and did not interfere with the normal duties of the aircrews. The purpose of the survey was explained and instructions for completing the booklet were given. It was noted that several functions in the booklet are not applicable to all aircraft, and that some are associated with systems currently in development. The respondents were told to mark "NA" for any of those items that they did not feel qualified to rate. The respondents were especially encouraged to try to think of better wordings for the messages that they rated favorably. Ample space was provided for comments and suggestions. Respondents took approximately 30 minutes to complete the survey booklet.

4.5 Results and Discussion

The F-4 aircrews' ratings of the general and context-specific functions are summarized in Tables 11 and 12, respectively. The general functions which were rated favorably (DY or L) by more than half of the F-4 respondents are as follows: Engine Fire, Fuel Low, Oil Pressure, Hydraulic Pressure, Generator Failure, Electrical System, Oxygen Low, Flameout, ADI Disagreement, and Bleed Duct Overheat. The context-specific functions rated favorably by more than half of the F-4 respondents are Canopy, Brakes, Landing Gear Malfunction, Flaps Malfunction, Configuration, Terrain Closure, Low Altitude, Missile Launch, Threat Display, and Bingo Fuel. The Engine Fire, Fuel Low and Bingo Fuel functions received the strongest support - well over 60% of the ratings given each of these functions were DY. Strong support was also indicated for Oil Pressure, Hydraulic Pressure, Generator Failure, Bleed Duct Overheat, and Low Altitude. Less than 10% of the respondents gave these functions an unfavorable (NL or DN) rating.

The F-4 aircrews' responses to the six follow-up questions regarding message specificity indicate a preference for the Engine Fire and Flameout messages to state which engine is on fire or not operating, and for the Threat Display and Missile Launch messages to indicate the direction of the threat. Several also indicated that the Generator Failure and Electrical Systems could be combined into a single function for the F-4. These responses are summarized, along with other comments and suggestions, in Appendix D. The few alternate wordings offered by the respondents are also summarized in Appendix D.

The F-4 aircrews' recommendations (Yes/No) for whether the informational functions should be given further consideration are summarized in Table 13. The Joker Fuel call is the only one of these functions that was clearly supported. Approximately half of the respondents expressed interest in three other informational functions: a Fence Check prompt, a Next Heading readout, and a feedback message to confirm the selection or arming of on-board weapons.

The F-15 pilots' ratings of the general and context-specific functions are summarized in Tables 14 and 15. The general functions rated favorably by

TABLE 11

F-4 AIRCREW RATINGS OF GENERAL VOICE MESSAGES[a]

Function	NA	DY	L	NL	DN	Favorable[b]	Unfavorable[c]
Engine Fire	0	25	5	2	1	30	3
Fuel Low	0	24	7	1	1	31	2
Fuel Pressure Low	9	4	8	11	1	12	12
Oil Temperature Low	11	3	5	10	4	8	14
Oil Pressure	0	18	13	2	0	31	2
Hydraulics	0	15	15	1	2	30	3
Generator Failure	1	11	16	5	0	27	5
Central Air Data Computer	3	1	15	8	6	16	14
Engine Electrical Controller	21	1	5	4	2	6	6
Electrical System	6	4	13	5	5	17	10
Inlet Ice	3	2	12	10	6	14	16
Oxygen Low	0	5	16	7	5	21	12
Flameout	0	10	10	5	8	20	13
Radio Malfunction	3	2	6	10	12	8	22
ADI Disagreement	2	7	12	5	7	19	12
Bleed Duct Overheat	1	15	15	2	0	30	2
Low Speed	0	7	9	5	12	16	17
External Tanks Empty	0	3	12	4	14	15	18
Auto Throttle Disengaged	20	1	3	3	6	4	9
Spoilers	23	0	3	4	3	3	7
Fan Turbine Inlet Temperature	19	4	6	2	2	10	4
Accessory Fire	13	7	11	1	1	18	2
Wing Sweep	24	0	4	2	3	4	5
Dual Flight Control	15	6	4	2	6	10	8

a - Table entries are the frequency tallies for each response. N = 33.

b - DY + L

c - NL + DN

TABLE 12

F-4 AIRCREW RATINGS OF CONTEXT-SPECIFIC VOICE MESSAGES[a]

Function	NA	DY	L	NL	DN	Favorable[b]	Unfavorable[c]
Canopy Unlocked	0	11	11	2	9	22	11
Brake Failure	0	12	9	6	6	21	12
Nose Steering Malfunction	1	2	9	10	11	11	21
Landing Gear Malfunction	0	10	13	5	5	23	10
Flaps Malfunction	1	6	14	7	5	20	12
Excessive Altitude Loss	3	2	8	8	12	10	20
Incorrect Configuration	0	5	14	8	6	19	14
Autopilot Failure	0	4	7	7	15	11	22
Terrain-Following Radar Failure	20	2	8	2	1	10	3
Obstacle Warning	13	3	6	6	5	9	11
Descent Rate	6	3	8	9	7	11	16
Terrain Closure	7	6	12	5	3	18	8
Low Altitude	3	6	18	1	5	24	6
Missile Launch	0	12	13	3	5	25	8
Threat Display	0	12	11	6	4	23	10
New Guy	4	4	10	6	9	14	15
Bingo Fuel	1	22	8	1	1	30	2
Over g	2	6	8	5	12	14	17
Glideslope	2	3	7	6	15	10	21

a - Table entries are the frequency tallies for each response. N = 33.

b - DY + L

c - NL + DN

TABLE 13

F-4 AIRCREW RATINGS OF ADVISORY VOICE MESSAGES[a]

Function	Yes	No	No Answer
Preflight Checklists	8	25	0
Readback of INS Coordinates	7	26	0
Speed Check	7	25	1
Gear Up and Locked	9	24	0
Flaps Up	9	24	0
Approaching Level-Off Altitude	13	19	1
Autopilot Engaged/Disengaged	3	29	1
Periodic "Check Fuel" Prompt	12	20	1
"Fence Check" Prompt	16	16	1
Point Approach	7	25	1
Next Heading	16	17	0
"Joker" Fuel	28	5	0
Weapons Selected/Armed	18	14	1
Periodic "Check Six" Reminder	5	28	0
Low Ammunition	15	18	0
Bogey Lock-On	10	22	1
"Drop External Tanks" Prompt	1	32	0
Loft Bombing Cue	7	26	0
Laser Inoperative/Ready	12	21	0
Weapons Station Selection	8	24	1
Laser Lock-On	7	23	3
Refuel System Ready	5	28	0
Air Refuel Door Still Open	9	24	0
Level-Off Altitude Calls	12	19	2
Descent Checklists	5	28	0
Gear Down and Locked	15	18	0

a - Table entries are the frequency tallies for each response. N = 33.

TABLE 14

F-15 PILOT RATINGS OF GENERAL VOICE MESSAGES[a]

Function	NA	DY	L	NL	DN	Favorable[b]	Unfavorable[c]
Engine Fire	0	36	3	0	0	39	0
Fuel Low	2	31	6	0	0	37	0
Fuel Pressure Low	4	3	11	14	7	14	21
Oil Temperature Low	6	2	6	15	10	8	25
Oil Pressure	1	12	16	4	6	28	10
Hydraulics	1	11	10	11	6	21	17
Generator Failure	0	8	6	16	9	14	25
Central Air Data Computer	0	9	9	11	10	18	21
Engine Electrical Controller	0	9	9	14	7	18	21
Electrical System	0	4	9	15	11	13	26
Inlet Ice	0	7	9	11	12	16	23
Oxygen Low	0	9	14	6	10	23	16
Flameout	1	13	9	6	10	22	16
Radio Malfunction	1	3	5	17	13	8	30
ADI Disagreement	1	8	9	13	8	17	21
Bleed Duct Overheat	4	11	11	7	6	22	13
Low Speed	3	1	7	10	18	8	28
External Tanks Empty	2	1	3	14	19	4	33
Auto Throttle Disengaged	24	0	1	6	8	1	14
Spoilers	29	0	3	3	4	3	7
Fan Turbine Inlet Temperature	1	31	5	1	1	36	2
Accessory Fire	0	35	3	0	1	38	1
Wing Sweep	33	0	2	2	2	2	4
Dual Flight Control	10	5	4	13	7	9	20

a - Table entries are the frequency tallies for each response. N = 39.

b - DY + L

c - NL + DN

TABLE 15

F-15 PILOT RATINGS OF CONTEXT-SPECIFIC VOICE MESSAGES[a]

Function	NA	DY	L	NL	DN	Favorable[b]	Unfavorable[c]
Canopy Unlocked	0	16	10	7	6	26	13
Brake Failure	0	15	14	7	3	29	10
Nose Steering Malfunction	0	5	7	18	9	12	27
Landing Gear Malfunction	1	20	7	6	5	27	11
Flaps Malfunction	0	9	7	16	7	16	23
Excessive Altitude Loss	2	5	10	12	10	15	22
Incorrect Configuration	1	15	13	5	5	28	10
Autopilot Failure	1	4	13	11	10	17	21
Terrain-Following Radar Failure	32	4	3	0	0	7	0
Obstacle Warning	20	8	4	4	3	12	7
Descent Rate	9	6	9	8	7	15	15
Terrain Closure	18	7	5	3	6	12	9
Low Altitude	6	13	14	4	2	27	6
Missile Launch	1	20	8	6	4	28	10
Threat Display	3	18	8	7	3	26	10
New Guy	10	4	10	9	6	14	15
Bingo Fuel	1	35	3	0	0	38	0
Over g	1	30	6	0	2	36	2
Glideslope	2	2	12	9	14	14	23

a - Table entries are the frequency tallies for each response. N = 39.

b - DY + L

c - NL + DN

more than half of the F-15 pilots are Engine Fire, Fuel Low, Oil Pressure, Hydraulic Pressure, Oxygen Low, Flameout, Bleed Duct Overheat, FTIT, and AMAD Fire. The context-specific functions rated favorably by more than half of the F-15 pilots are Canopy, Brakes, Landing Gear Malfunction, Configuration, Low Altitude, Missile Launch, Threat Display, Bingo Fuel, and Over g. The existing F-15 messages - Engine Fire, Fuel Low, FTIT, AMAD Fire, Bingo Fuel, and Over g - were all strongly supported. The Landing Gear Malfunction and Missile Launch functions were also strongly supported by the F-15 pilots; each of these functions received a DY rating by more than half of the respondents in this group.

The F-15 pilots' responses to the six follow-up questions indicate that the Engine Fire, Flameout, and FTIT messages should state which engine (left or right) has the problem, and that the Missile Launch and Threat Display messages should indicate the direction of the threat. These responses, the suggested alternate wordings, and other comments are summarized in Appendix D.

The F-15 pilots' recommendations for the informational functions are summarized in Table 16. The Joker Fuel call is the only function that was clearly supported by the F-15 pilots, as was the case with the F-4 aircrews. No other function in this category was recommended for further consideration by more than half of the F-15 sample.

The F-16 pilots' ratings of the general and context-specific functions are summarized in Tables 17 and 18. The general functions rated favorably by more than half of the F-16 pilots are Engine Fire, Fuel Low, Oil Pressure, Hydraulic Pressure, Generator Failure, Engine Electrical Controller (EEC), Electrical System, Oxygen Low, Flameout, ADI Disagreement, FTIT and Dual Flight Control. The context-specific functions rated favorably by more than half of the F-16 pilots are Canopy, Brakes, Landing Gear Malfunction, Flaps Malfunction, Configuration, Autopilot Failure, Low Altitude, Missile Launch, Threat Display and Bingo Fuel. The Engine Fire, Fuel Low, Missile Launch, and Bingo Fuel functions received the strongest support. Each of these functions received a DY rating from more than half of the F-16 respondents.

The F-16 pilots' responses to the follow-up questions indicate a strong preference for the Missile Launch and Threat Display messages to state the direction of the threat. The follow-up questions concerning the messages for Engine Fire, Flameout and FTIT in multi-engine aircraft are not applicable to

TABLE 16

F-15 PILOT RATINGS OF ADVISORY VOICE MESSAGES[a]

Function	Yes	No	No Answer
Preflight Checklists	8	30	1
Readback of INS Coordinates	9	28	2
Speed Check	8	30	1
Gear Up and Locked	11	28	0
Flaps Up	6	31	2
Approaching Level-Off Altitude	10	26	3
Autopilot Engaged/Disengaged	7	30	2
Periodic "Check Fuel" Prompt	11	28	0
"Fence Check" Prompt	15	22	2
Point Approach	11	26	2
Next Heading	15	21	3
"Joker" Fuel	24	14	1
Weapons Selected/Armed	17	21	1
Periodic "Check Six" Reminder	3	36	0
Low Ammunition	12	27	0
Bogey Lock-On	13	25	1
"Drop External Tanks" Prompt	1	14	24
Loft Bombing Cue	2	13	24
Laser Inoperative/Ready	4	11	24
Weapons Station Selection	3	12	24
Laser Lock-On	4	11	24
Refuel System Ready	11	28	0
Air Refuel Door Still Open	15	23	1
Level-Off Altitude Calls	15	22	2
Descent Checklists	5	32	0
Gear Down and Locked	15	21	3

a - Table entries are the frequency tallies for each response. N = 39.

TABLE 17

F-16 PILOT RATINGS OF GENERAL VOICE MESSAGES[a]

Function	NA	DY	L	NL	DN	Favorable[b]	Unfavorable[c]
Engine Fire	1	37	14	3	3	51	6
Fuel Low	3	37	12	5	1	49	6
Fuel Pressure Low	8	7	22	13	8	29	21
Oil Temperature Low	21	3	3	20	11	6	31
Oil Pressure	1	28	21	4	4	49	8
Hydraulics	3	18	21	12	4	39	16
Generator Failure	2	21	16	12	7	37	19
Central Air Data Computer	3	5	19	21	10	24	31
Engine Electrical Controller	3	15	20	14	6	35	20
Electrical System	4	17	17	12	8	34	20
Inlet Ice	3	13	14	20	8	27	28
Oxygen Low	1	14	16	14	13	30	27
Flameout	2	26	10	9	11	36	20
Radio Malfunction	6	4	6	20	22	10	42
ADI Disagreement	6	9	21	13	9	30	22
Bleed Duct Overheat	24	3	8	15	8	11	23
Low Speed	1	11	14	16	16	25	32
External Tanks Empty	3	7	20	11	17	27	28
Auto Throttle Disengaged	38	1	3	10	6	4	16
Spoilers	40	1	3	11	3	4	14
Fan Turbine Inlet Temperature	3	26	13	10	6	39	16
Accessory Fire	18	11	13	11	5	24	16
Wing Sweep	47	0	3	4	4	3	8
Dual Flight Control	2	22	21	8	5	43	13

a - Table entries are the frequency tallies for each response. N = 58.

b - DY + L

c - NL + DN

TABLE 18

F-16 PILOT RATINGS OF CONTEST-SPECIFIC VOICE MESSAGES[a]

Function	NA	DY	L	NL	DN	Favorable[b]	Unfavorable[c]
Canopy Unlocked	1	16	20	12	9	36	21
Brake Failure	2	18	21	8	9	39	17
Nose Steering Malfunction	1	7	17	20	13	24	33
Landing Gear Malfunction	2	9	21	7	9	40	16
Flaps Malfunction	5	13	19	10	11	32	21
Excessive Altitude Loss	7	7	10	18	16	17	34
Incorrect Configuration	2	19	24	7	6	43	13
Autopilot Failure	1	19	24	9	5	43	14
Terrain-Following Radar Failure	38	11	6	3	0	17	3
Obstacle Warning	17	12	12	9	8	24	17
Descent Rate	5	10	15	12	16	25	28
Terrain Closure	15	14	14	10	5	28	15
Low Altitude	7	24	23	4	0	47	4
Missile Launch	0	32	17	6	3	49	9
Threat Display	0	22	17	8	11	39	19
New Guy	1	9	20	16	12	29	28
Bingo Fuel	2	37	16	3	0	53	3
Over g	12	5	13	13	15	18	28
Glideslope	0	5	14	16	23	19	39

a - Table entries are the frequency tallies for each response. N = 58.

b - DY + L

c - NL + DN

the single-engine F-16. The responses to the follow-up question regarding the specificity of an Electrical System message indicate a preference for the message to simply state that there is an electrical system malfunction, and not identify the specific problem. These responses, alternate wordings, and other comments are summarized in Appendix D.

The F-16 pilots' recommendations for the informational functions are summarized in Table 19. The Joker Fuel call was again strongly supported by this group of pilots. Over half of this group also recommended that a Gear Down and Locked advisory be further considered. The other functions in this category were not recommended for further consideration.

A comparison of the results reveals a great deal of consistency across groups, defined by the type of aircraft flown. A total of 25 general and context-specific functions were rated favorably by at least half of the pilots in one or more groups. Of these 25 functions, 14 were rated favorably by all three groups. Six functions were rated favorably by two of the three groups. Four of the remaining five functions (that were rated favorably by only one group) are applicable to only one aircraft. One function, the Autopilot Failure, was rated favorably by the F-16 pilots, but not by the F-4 or the F-15 respondents, even though it is applicable to all three aircraft. Table 20 shows the 25 functions and indicates which group(s) of aircrews rated each function favorably.

The recommendations for informational functions are also remarkably consistent: the Joker Fuel call was recommended by all three groups and practically all of the other functions on the list were rejected by all three groups. The Joker and Bingo Fuel levels are typically determined at the pre-flight briefing and occasionally are modified during flight. The Bingo level is the amount of fuel required to return from the mission with appropriate reserves. The Joker level is some amount above the Bingo level (typically 500 lb), and represents the amount of fuel required to perform a fighting withdrawal from an air-to-air engagement and then return with appropriate reserves. The F-15 and F-16 allow the pilot to enter the Bingo level. When the fuel reaches this level in the F-15, a voice message is activated. In the F-16 the Bingo condition is indicated on the Head-Up Display (HUD). The Joker level, however, must be remembered by the pilot. The pilots in this survey apparently would like some assistance in remembering this information.

TABLE 19

F-16 PILOT RATINGS OF ADVISORY VOICE MESSAGES[a]

Function	Yes	No	No Answer
Preflight Checklists	4	54	0
Readback of INS Coordinates	13	44	1
Speed Check	19	39	0
Gear Up and Locked	22	35	1
Flaps Up	14	43	1
Approaching Level-Off Altitude	14	44	0
Autopilot Engaged/Disengaged	24	33	1
Periodic "Check Fuel" Prompt	21	35	2
"Fence Check" Prompt	23	35	0
Point Approach	15	42	1
Next Heading	25	33	0
"Joker" Fuel	48	10	0
Weapons Selected/Armed	25	32	1
Periodic "Check Six" Reminder	7	51	0
Low Ammunition	24	34	0
Bogey Lock-On	25	33	0
"Drop External Tanks" Prompt	7	50	1
Loft Bombing Cue	13	42	3
Laser Inoperative/Ready	10	39	9
Weapons Station Selection	8	48	2
Laser Lock-On	16	33	9
Refuel System Ready	5	53	0
Air Refuel Door Still Open	21	36	1
Level-Off Altitude Calls	13	45	0
Descent Checklists	5	53	0
Gear Down and Locked	31	27	0

a - Table entries are the frequency tallies for each response. N = 58.

TABLE 20

FUNCTIONS RATED FAVORABLY IN THE PILOT SURVEY

Function	Group F-4	Group F-15	Group F-16
General Functions			
Engine Fire	✓	✓	✓
Fuel Low	✓	✓	✓
Oil Pressure	✓	✓	✓
Hydraulic Pressure	✓	✓	✓
Generator Failure	✓		✓
Electrical System	✓		✓
EEC			✓
Oxygen Low	✓	✓	✓
Flameout	✓	✓	✓
ADI Disagreement	✓		✓
Bleed Duct Overheat	✓	✓	
FTIT		✓	✓
AMAD Fire		✓	
Dual Flight Control			✓
Context-Specific Functions			
Canopy	✓	✓	✓
Brakes	✓	✓	✓
Landing Gear Malfunction	✓	✓	✓
Flaps Malfunction	✓		✓
Configuration	✓	✓	✓
Autopilot Failure			✓
Low Altitude	✓	✓	✓
Missile Launch	✓	✓	✓
Threat Display	✓	✓	✓
Bingo Fuel	✓	✓	✓
Over g		✓	
Informational Functions			
Joker Fuel	✓	✓	✓

The ratings of the general and context-specific functions given by the A-10 pilots are summarized in Tables 21 and 22. Their recommendations for the informational functions are summarized in Table 23. Although these data follow the same trends as found in the F-4, F-15 and F-16 groups, it is perhaps unwise to draw conclusions from data obtained from only five respondents. These data are presented here for completeness.

Collapsing the data across groups reveals that four general functions and seven context-specific functions were rated favorably by at least two-thirds (i.e., 90 or more) of the 135 participants in this survey. The four general functions are Engine Fire, Fuel Low, Oil Pressure, and Hydraulic Pressure. The seven context-specific functions are Brakes, Landing Gear Malfunction, Configuration, Low Altitude, Missile Launch, Threat Display, and Bingo Fuel. Bingo Fuel received more favorable ratings (126) and fewer unfavorable ratings (5) than any other function included in the survey. The Joker Fuel call (an informational function) was also recommended by over two-thirds of the respondents.

Certain functions were consistently rated unfavorably by the aircrews. Nine functions were given unfavorable ratings by at least half (i.e., 68 or more) of the 135 participants: Oil Temperature Low, CADC Failure, Inlet Ice, Radio Malfunction, Low Speed Warning, External Tanks Empty, Nose Wheel Steering Malfunction, Excessive Altitude Loss (on take-off), and Glideslope Deviation. It should also be noted that over half of the respondents recommended that informational functions not be further considered as candidates for voice messages. The one exception was Joker Fuel, as noted earlier.

The two questions added to the booklet for the final 90 participants asked for the pilots' opinions on using voice messages to present emergency checklists and on the control features that should be incorporated into a voice message system. The pilots were generally unfavorable toward using voice messages for emergency checklists - 43 of the 90 pilots offered negative responses and 30 offered positive responses qualified with restrictions. Only nine pilots gave unqualified positive responses. Many of the pilots stated a preference for visual presentation of the checklists, either on a CRT or in the current printed format. The most commonly recommended control features were volume, on/off, and a disable for non-emergencies (similar to the de-

TABLE 21

A-10 PILOT RATINGS OF GENERAL VOICE MESSAGES[a]

Function	NA	DY	L	NL	DN	Favorable[b]	Unfavorable[c]
Engine Fire	0	5	0	0	0	5	0
Fuel Low	0	2	3	0	0	5	0
Fuel Pressure Low	0	1	3	1	0	4	1
Oil Temperature Low	1	0	1	2	1	1	3
Oil Pressure	0	1	3	1	0	4	1
Hydraulics	0	2	2	1	0	4	1
Generator Failure	0	1	1	3	0	2	3
Central Air Data Computer	0	1	2	2	0	3	2
Engine Electrical Controller	1	1	3	0	0	4	0
Electrical System	0	0	2	3	0	2	3
Inlet Ice	1	0	3	1	0	3	1
Oxygen Low	0	0	4	0	1	4	1
Flameout	0	1	2	2	0	3	2
Radio Malfunction	2	0	0	2	1	0	3
ADI Disagreement	0	2	2	1	0	4	1
Bleed Duct Overheat	0	2	2	1	0	4	1
Low Speed	0	0	2	2	1	2	3
External Tanks Empty	0	1	0	4	0	1	4
Auto Throttle Disengaged	2	1	1	0	1	2	1
Spoilers	2	0	2	1	0	2	1
Fan Turbine Inlet Temperature	1	2	2	0	0	4	0
Accessory Fire	2	2	1	0	0	3	0
Wing Sweep	3	1	1	0	0	2	0
Dual Flight Control	3	0	2	0	0	2	0

a - Table entries are the frequency tallies for each response. N = 5.

b - DY + L

c - NL + DN

TABLE 22

A-10 PILOT RATINGS OF CONTEXT-SPECIFIC VOICE MESSAGES[a]

Function	NA	DY	L	NL	DN	Favorable[b]	Unfavorable[c]
Canopy Unlocked	0	0	4	0	1	4	1
Brake Failure	0	1	3	0	1	4	1
Nose Steering Malfunction	0	1	2	1	1	3	2
Landing Gear Malfunction	0	2	3	0	0	5	0
Flaps Malfunction	0	1	2	2	0	3	2
Excessive Altitude Loss	0	1	0	3	1	1	4
Incorrect Configuration	0	2	2	1	0	4	1
Autopilot Failure	1	1	2	0	1	3	1
Terrain-Following Radar Failure	2	1	2	0	0	3	0
Obstacle Warning	1	1	0	2	1	1	3
Descent Rate	0	0	2	2	1	2	3
Terrain Closure	1	1	3	0	0	4	0
Low Altitude	0	2	3	0	0	5	0
Missile Launch	0	4	1	0	0	5	0
Threat Display	0	2	2	1	0	4	1
New Guy	0	1	2	1	1	3	2
Bingo Fuel	0	3	2	0	0	5	0
Over g	1	1	2	1	0	3	1
Glideslope	1	0	3	1	0	3	1

a - Table entries are the frequency tallies for each response. N = 5.

b - DY + L

c - NL + DN

TABLE 23

A-10 PILOT RATINGS OF ADVISORY VOICE MESSAGES[a]

Function	Yes	No	No Answer
Preflight Checklists	1	4	0
Readback of INS Coordinates	1	4	0
Speed Check	1	4	0
Gear Up and Locked	1	4	0
Flaps Up	1	4	0
Approaching Level-Off Altitude	3	2	0
Autopilot Engaged/Disengaged	2	3	0
Periodic "Check Fuel" Prompt	2	3	0
"Fence Check" Prompt	5	0	0
Point Approach	0	5	0
Next Heading	1	4	0
"Joker" Fuel	4	1	0
Weapons Selected/Armed	3	2	0
Periodic "Check Six" Reminder	1	4	0
Low Ammunition	3	1	1
Bogey Lock-On	2	3	0
"Drop External Tanks" Prompt	0	5	0
Loft Bombing Cue	1	4	0
Laser Inoperative/Ready	2	3	0
Weapons Station Selection	2	3	0
Laser Lock-On	3	2	0
Refuel System Ready	2	3	0
Air Refuel Door Still Open	3	2	0
Level-Off Altitude Calls	0	5	0
Descent Checklists	0	5	0
Gear Down and Locked	1	4	0

a - Table entries are the frequency tallies for each response. N = 5.

clutter switch proposed by Butler, et al., 1981). The comments and suggestions given by the pilots on these two issues are summarized in Appendix D. Other general comments and suggestions are also summarized in Appendix D.

5.0 RECOMMENDED MESSAGE ENSEMBLES AND VOCABULARY

5.1 Basis for Recommendation

One of the principles guiding the present research, as stated in Section 1.2, is that the selection of functions for voice messages should be based on input from the research literature, the airframe manufacturers, and Air Force tactical pilots. The literature review performed as part of the present effort revealed a large number of suggested functions for voice messages in aircraft. These functions were screened for appropriateness to the tactical environment, reviewed by participants in the manufacturer survey, and selectively incorporated in the pilot survey. Thus, the functions rated favorably by the pilots have support from the three primary information sources employed in the present research.

Some of the candidate functions studied in the pilot survey are common to all tactical aircraft (e.g., Engine Fire). The results of the pilot survey indicate clear preferences for the use of voice for certain common functions. For other common functions, voice was preferred by the aircrews of some, but not all, of the aircraft represented in this study. A number of additional functions studied in the pilot survey are applicable to only one or two of the aircraft represented in this study. For some of these functions, voice messages were recommended highly by the aircrews of the applicable aircraft. These findings suggest that the message ensemble for a given aircraft should include certain messages common to all ensembles, and additional messages tailored to the needs of the particular aircraft.

Another principle stated in Section 1.2 is that the wordings of the messages should be based on pilot preferences and guided by research findings. The research finding of particular interest here is that keyword-format messages should have a minimum of four to seven syllables (Bucher, et al., 1984). Most of the prototypical wordings included in the pilot survey meet this requirement. Relatively few alternate wordings were offered by the pilots (see Appendix D), therefore, the prototypical wordings are the basis for the messages recommended in this section. A few of the wordings were modified to be more specific, in response to suggestions received in the pilot survey and in accordance with the information contained in the relevant Technical Order ("Dash-One") manuals. It is also recommended that messages with fewer than four syllables be repeated in order to attain the minimum of four to seven syllables.

The recommended message ensembles for the F-4, F-15, and F-16 are presented below. The activating conditions for the functions associated with the recommended messages are summarized in Appendix E. The Missile Launch and Threat Display functions require a special vocabulary from which the proper message can be composed, depending on the nature of the threat. The recommended vocabulary for these functions is presented separately.

5.2 Recommended Messages for the F-4

The recommended message ensemble for the F-4 is presented in Table 24 and contains the 19 general and context-specific functions rated favorably by the F-4 aircrews. The Joker Fuel call, recommended for consideration by the F-4 respondents, is also included. It should be noted that in the F-4, the equivalent of the Electrical System malfunction in other aircraft does not constitute a serious problem when encountered alone. The major electrical system problem of concern in the F-4 is the failure of a generator in conjunction with an Electrical System malfunction. The Electrical System malfunction is called "bus-tie open". The bus tie interconnects the loads powered by the left and right generators. If a generator fails and the Bus Tie is open, important equipment will receive no power. With a generator failure and the Bus Tie closed, all systems are powered. Thus, the recommended message combines the Generator Failure and Electrical System functions and indicates which generator (left or right) failed and whether the bus tie is open or closed. The Generator/Electrical System function is the only unique component in the recommended F-4 ensemble; all other items are included in the ensembles for the F-15 and/or F-16. The Engine Fire message indicates which engine is on fire, in accordance with the preferences of the F-4 aircrews. The recommended Flameout message for the F-4 indicates which engine is not operating, also in accordance with pilot preferences.

5.3 Recommended Messages for the F-15

The recommended voice message ensemble for the F-15 is shown in Table 25. The existing F-15 voice messages are included in this ensemble. Additional messages rated favorably by the F-15 pilots, and also included in

TABLE 24

RECOMMENDED VOICE MESSAGES FOR THE F-4

Function	Message
Engine Fire	"Engine fire, left" or "Engine fire, right"
Fuel Low	"Fuel low, fuel low"
Oil Pressure	"Oil pressure, low" or "Oil pressure, high"
Hydraulic Pressure	"Hydraulic pressure, low" or "Hydraulic presure, high"
Generator/Electrical System	"Generator failure, left" or "Generator failure, right" followed by "Bus tie, open" or "Bus tie, closed"
Oxygen Low	"Oxygen low"
Flameout	"Flameout, left; flameout, left" or "flameout, right; flameout, right"
ADI Disagreement	"ADI's do not correlate"
Bleed Duct Overheat	"Bleed duct overheat"
Canopy	"Canopy, canopy"
Brakes	"Brake failure, brake failure"
Landing Gear Malfunction	"Landing gear malfunction"
Flap Malfunction	"Flap malfunction"
Configuration	"Check configuration"
Low Altitude	"Altitude, altitude"
Missile Launch[a]	-
Threat Display[a]	-
Bingo Fuel	"Bingo fuel, bingo fuel"
Joker Fuel	"Joker fuel, joker fuel"

a - The wording of these messages depends on the nature of the threat.

TABLE 25

RECOMMENDED VOICE MESSAGES FOR THE F-15

Function	Message
Engine Fire	"Engine fire, left" or "Engine fire, right"
Fuel Low	"Fuel low, fuel low"
Oil Pressure	"Oil pressure, low" or "Oil pressure, high"
Hydraulic Pressure	"Hydraulic pressure, low" or "Hydraulic presure, high"
Oxygen Low	"Oxygen Low"
Flameout	"Flameout, left; flameout, left" or "Flameout, right; flameout, right"
Bleed Duct Overheat	"Bleed duct overheat"
FTIT	"FTIT over temp, left" or "FTIT over temp, right"
AMAD Fire	"AMAD fire, AMAD fire"
Canopy	"Canopy, canopy"
Brakes	"Brake failure, brake failure"
Landing Gear Malfunction	"Landing gear malfunction"
Configuration	"Check configuration"
Low Altitude	"Altitude, altitude"
Missile Launch[a]	-
Threat Display[a]	-
Bingo Fuel	"Bingo fuel, bingo fuel"
Over g	"Over g, over g"[b]
Joker Fuel	"Joker fuel, joker fuel"

a - The wording of these messages depends on the nature of the threat.

b - Message repeats until condition is corrected.

this ensemble, are as follows: Oil Pressure, Hydraulic Pressure, Oxygen Low, Flameout, Canopy, Brakes, Landing Gear Malfunction, Configuration, Low Altitude, Missile Launch, Threat Display, and Joker Fuel. This ensemble includes two functions unique to the F-15: AMAD Fire and Over g.

As in the case of the F-4, the recommended Engine Fire and Flameout messages for the F-15 indicates which engine is on fire or is not operating.

5.4 Recommended Messages for the F-16

Table 26 presents the recommended ensemble for the F-16. The F-16 is a single-engine aircraft; thus, the Engine Fire, Flameout, and FTIT messages are slightly different than for multi-engine aircraft. The recommended Engine Fire message for the F-4 and F-15 indicates which engine compartment (left or right) is on fire. The recommended message in the F-16 is simply "Engine fire, engine fire". Similarly, the Flameout message is simply, "Flameout, flameout". The FTIT message in the F-15 also indicates which inlet (left or right) is too hot; the recommended message for the F-16 is simply "FTIT over temp". The Dual Flight Control and EEC functions are unique components of the F-16 ensemble.

5.5 Threat Messages

The Missile Launch and Threat Display functions were rated favorably by all those groups in the pilot survey. The Threat Display message, as recommended by the pilots, should state the identity (if known) and direction (if known) of the highest priority threat. The Missile Launch function is thus included under Threat Display, in that a launched ordnance is typically the highest priority threat. The recommended format for the threat message is as follows:

(Threat name) ("launch", if applicable) ("right" or "left") (clock position)

This format reflects the preference among pilots that these messages indicate the direction of the threat (see Appendix D). The vocabulary necessary to compose these messages is shown in Table 27. This vocabulary may not be complete, in that there may be additional threat system names in use. The vocabulary may also need revision as threat systems evolve and as the

TABLE 26

RECOMMENDED VOICE MESSAGES FOR THE F-16

Function	Message
Engine Fire	"Engine fire, engine fire"
Fuel Low	"Fuel low, fuel low"
Oil Pressure	"Oil pressure, low" or "Oil pressure, high"
Hydraulic Pressure	"Hydraulic pressure, low" or "Hydraulic pressure, high"
Generator Failure	"Generator failure"
Electrical System	"Electrical system malfunction"
EEC	"EEC failure, EEC failure"
Oxygen Low	"Oxygen low"
Flameout	"Flameout, flameout"
ADI Disagreement	"ADI's do not correlate"
FTIT	"FTIT over temp"
Dual Flight Control	"Dual control malfunction"
Canopy	"Canopy, canopy"
Brakes	"Brake failure, brake failure"
Landing Gear Malfunction	"Landing gear malfunction"
Flap Malfunction	"Flap malfunction"
Configuration	"Check configuration"
Autopilot Failure	"Autopilot failure"
Low Altitude	"Altitude, altitude"
Missile Launch[a]	-
Threat Display[a]	-
Bingo Fuel	"Bingo fuel, bingo fuel"
Joker Fuel	"Joker fuel, joker fuel"

a - The wording of these messages depends on the nature of the threat.

TABLE 27

PRELIMINARY VOCABULARY REQUIREMENTS FOR THREAT MESSAGES

Type	Items	
Threat Name	"SAM"	"Hawk"
	"A-bar gun"	"Batwing"
	"Crotale"	"Plane form"
Numerals	"One"	"Eleven"
	"Two"	"Twelve"
	"Three"	"Thirteen"
	"Four"	"Fourteen"
	"Five"	"Fifteen"
	"Six"	"Sixteen"
	"Seven"	"Seventeen"
	"Eight"	"Eighteen"
	"Nine"	"Nineteen"
	"Ten"	"Twenty"
Direction	"Right"[a]	
	"Left"[a]	
	"O'clock"	
Other	"Naval"	
	"Launch"	
	"Unknown"	
	"Missile Guidance"	
	"Tracker"	
	"Triple A"	
	"Bogey"	
	"Bandit"	

a - These items are included in the vocabulary used to generate other messages.

capability for detecting and identifying threats evolves. Sample messages are shown in Table 28.

Two aspects of the threat vocabulary should be clarified. First, the word "naval" is included to allow the message to distinguish a ship-to-air system from a ground-to-air system. It may be that this item is not necessary, or that a different word for this distinction should be used. Second, the numerals one through twenty are included to accomodate the trend of designating threat systems by type and number (e.g., "SAM 8"), although current designations do not use all of these numerals. The numerals one through twelve are, of course, also used to designate clock position.

5.6 Summary of Vocabulary Requirements

The basic recommended messages shown in Tables 24-26, (excluding the threat messages), can be composed from a vocabulary of 38 items. A vocabulary item, in this sense, is either a single word or a phrase with components that invariably appear together. Thus, "bleed duct" is a single item, because neither "bleed" nor "duct" appear in any message without the other. The recommended threat messages require additional items; the preliminary vocabulary for these messages, shown in Table 27, contains 35 additional items plus two items ("right" and "left") which are included in the basic vocabulary.

Each item in the basic vocabulary is shown in Table 29, where it is cross-listed with the functions which use the item and the aircraft in which that function is present. Table 30 summarizes the usage of each item by aircraft. The recommended F-4 and F-16 ensembles each use 30 of the 38 items (79%), and the F-15 ensemble uses 28 items (74%).

The proper pronunciation of the vocabulary items which contain acronymns should be noted. "ADI's" is pronounced as "A-D-eyes". The individual letters of "FTIT" are pronounced separately (i.e., "ef-tee-eye-tee"). "AMAD" and "EEC" are pronounced as words ("a-mad" and "eek", respectively).

Additional vocabulary items may be needed to accomodate new avionics systems scheduled for near-term deployment. Several functions that might be associated with the Ground-Collison Avoidance System (GCAS) were included in the manufacturer survey and the pilot survey: TF Radar Failure, Obstacle

TABLE 28

EXAMPLES OF THREAT MESSAGES

Condition	Message
SAM 8 Launch from a relative azimuth of 060 degrees.	"SAM 8 launch, right two o'clock"
SAM 4 Radar tracking the aircraft from directly in front of the aircraft	"SAM 4, twelve o'clock"
Anti-aircraft artillary radar tracking the aircraft	"Triple A left ten o'clock"
Tracking radar not in threat files illuminating the aircraft	"Unknown tracker right five o'clock"
Airborne tracking radar illuminating the aircraft	"Batwing left seven o'clock"
Airborne tracking system launches a missile	"Batwing launch left seven o'clock"
Unknown airborne tracker illuminating the aircraft	"Bogey left eight o'clock"

TABLE 29

CROSS LISTING OF VOCABULARY ITEMS BY FUNCTION AND AIRCRAFT

	Item	Function(s)	Aircraft
1.	"ADIs' do not correlate"	ADI Disagreement	F-4, F-16
2.	"Altitude"	Low Altitude	F,4, F-15, F-16
3.	"AMAD"	AMAD Fire	F-15
4.	"Autopilot"	Autopilot Failure	F-16
5.	"Bingo"	Bingo Fuel	F-4, F-15, F-16
6.	"Bleed duct"	Bleed Duct Overheat	F-4, F-15
7.	"Brake"	Brakes	F-4, F-15, F-16
8.	"Bus tie"	Generator/Electrical System	F-4
9.	"Canopy"	Canopy	F-4, F-15, F-16
10.	"Check configuration"	Configuration	F-4, F-15, F-16
11.	"Closed"	Generator/Electrical System	F-4
12.	"Dual control"	Dual Flight Control	F-16
13.	"EEC"	EEC	F-16
14.	"Electrical system"	Electrical System	F-16
15.	"Engine"	Engine Fire	F-4, F-15, F-16
16.	"Failure"	Generator Failure	F-4, F-16
		Brakes	F-4, F-15, F-16
		EEC	F-16
		Autopilot Failure	F-16
17.	"Fire"	Engine Fire	F-4, F-15, F-16
		AMAD Fire	F-15
18.	"Flameout"	Flameout	F-4, F-15, F-16
19.	"Flap"	Flap Malfunction	F-4, F-16
20.	"FTIT"	FTIT	F-15, F-16
21.	"Fuel"	Fuel Low	F-4, F-15, F-16
		Bingo Fuel	F-4, F-15, F-16
		Joker Fuel	F-4, F-15, F-16
22.	"g"	Over g	F-15
23.	"Generator"	Generator Failure	F-4, F-16
24.	"Heat"	Bleed Duct Overheat	F-4, F-15

TABLE 29
(Concluded)

Item	Function(s)	Aircraft
25. "High"	Oil Pressure	F-4, F-15, F-16
	Hydraulic Pressure	F-4, F-15, F-16
26. "Hydraulic"	Hydraulic Pressure	F-4, F-15, F-16
27. "Joker"	Joker Fuel	F-4, F-15, F-16
28. "Landing gear"	Landing Gear Malfunction	F-4, F-15, F-16
29. "Left"	Engine Fire	F-4, F-15
	Generator/Electrical System	F-4
	FTIT	F-15
	Flameout	F-4, F-15
30. "Low"	Fuel Low	F-4, F-15, F-16
	Oil Pressure	F-4, F-15, F-16
	Hydraulic Pressure	F-4, F-15, F-16
	Oxygen Low	F-4, F-15, F-16
31. "Malfunction"	Landing Gear Malfunction	F-4, F-15, F-16
	Flap Malfunction	F-4, F-16
	Electrical System	F-16
32. "Oil"	Oil Pressure	F-4, F-15, F-16
33. "Open"	Generator/Electrical System	F-4
34. "Over"	Bleed Duct Overheat	F-4, F-15
	FTIT	F-15, F-16
	Over g	F-15
35. "Oxygen"	Oxygen Low	F-4, F-15, F-16
36. "Pressure"	Oil Pressure	F-4, F-15, F-16
	Hydraulic Pressure	F-4, F-15, F-16
37. "Right"	Engine Fire	F-4, F-15
	Generator/Electrical System	F-4
	FTIT	F-15
	Flameout	F-4, F-15
38. "Temp"	FTIT	F-15, F-16

TABLE 30

USAGE OF EACH VOCABULARY ITEM BY AIRCRAFT

Item	Number of Occurences in Message Ensemble[a]			
	F-4	F-15	F-16	Total
1. "ADI's do not correlate"	1	0	1	2
2. "Altitude"	1	1	1	3
3. "AMAD"	0	1	0	1
4. "Autopilot"	0	0	1	1
5. "Bingo"	1	1	1	3
6. "Bleed duct"	1	1	0	2
7. "Brake"	1	1	1	3
8. "Bus tie"	1	0	0	1
9. "Canopy"	1	1	1	3
10. "Check configuration"	1	1	1	3
11. "Closed"	1	0	0	1
12. "Dual control"	0	0	1	1
13. "EEC"	0	0	1	1
14. "Electrical system"	0	0	1	1
15. "Engine"	1	1	1	3
16. "Failure"	2	1	4	7
17. "Fire"	1	2	1	4
18. "Flameout"	1	1	1	3
19. "Flap"	1	0	1	2
20. "FTIT"	0	1	1	2
21. "Fuel"	3	3	3	9
22. "g"	0	0	1	1
23. "Generator"	1	0	1	2
24. "Heat"	1	1	0	2
25. "High"	2	2	2	6
26. "Hydraulic"	1	1	1	3
27. "Joker"	1	1	1	3
28. "Landing gear"	1	1	1	3
29. "Left"	3	2	0	5

TABLE 30
(Concluded)

Item	Number of Occurences in Message Ensemble[a] F-4	F-15	F-16	Total
30. "Low	4	4	4	12
31. "Malfunction"	2	1	3	6
32. "Oil"	1	1	1	3
33. "Open"	1	0	0	1
34. "Over"	1	3	1	5
35. "Oxygen"	1	1	1	3
36. "Pressure"	2	2	2	6
37. "Right"	3	2	0	5
38. "Temp"	0	1	1	2

a - Table entries do not include repetition of the item within a message.

Warning, Descent Rate, Terrain Closure, and Glidescope, as well as the Low Altitude message which is already implemented in some form on several aircraft. The pilots tended to respond "NA" for most of these functions; therefore, it is difficult to accurately assess pilot preferences from the relatively small number of aircrews which rated these functions. The ratings that were offered suggest that TF Radar Failure, Obstacle Warning, and Terrain Closure may be appropriate functions for voice messages. The Descent Rate and Glidescope functions were rated by most of the aircrews; the majority of the ratings were unfavorable for both functions. Messages that might be associated with the LANTIRN system included in the surveys are Obstacle Warning, Laser Lock-on, and Laser Inoperative/Ready. As mentioned above, the Obstacle Warning appears to have support. The survey participants tended to be unfamiliar with other possible functions associated with LANTIRN; thus, the obtained data do not permit definite recommendations for LANTIRN voice messages.

6.0 CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

This effort has addressed two fundamental issues concerning the use of voice messages in tactical aircraft: the selection of functions for voice messages and the determination of the proper wordings for those messages. A large number of candidate functions were considered. The results of the literature review and the two surveys indicate a broad consensus that voice messages are appropriate in tactical aircraft for the following functions:

Engine Fire
Fuel Low
Oil Pressure
Hydraulic Pressure
Oxygen Low
Flameout
Canopy
Brake Failure
Landing Gear Malfunction
Configuration
Low Altitude
Threat Display
Missile Launch
Bingo Fuel
Joker Fuel

It is clear that these functions should be included in any comprehensive voice message system for tactical aircraft. A number of other functions were identified as appropriate for some, but not all, tactical aircraft. Thus, it is also clear that if a comprehensive voice message system is to reflect pilot preferences, then the system must allow tailoring of the message ensembles for individual aircraft types.

There were other candidate functions that were soundly rejected by the participants in the pilot survey. Although Task Prompts and other informational functions have been suggested in the literature and were supported in the manufacturer survey, the specific examples of these functions, with the exception of Joker Fuel, were rejected in the pilot survey. The list of prompts and advisories is certainly not exhaustive, but it is representative of these types of items. Other functions were also consistently rejected: Radio Malfunction, External Tanks Empty, Nose Wheel Steering, and Glideslope were not rated favorably by any group in the pilot survey and received unfavorable ratings from over 60% of the combined sample.

The use of voice to present emergency checklists has also been suggested in the literature and was supported in the manufacturer survey. Pilot comments on this matter were generally negative (see Appendix D). Many pilots, without solicitation, stated a preference for visual presentation of emergency procedures. Emergency checklists are often lengthy and complex, and most are designed in a decision-tree format. For example, an EEC caution in the F-16 requires eleven decisions regarding flight conditions and aircraft configuration. Thus, an accurate presentation of the procedures would require that the system know the outcome of each decision. Some checklists require the completion of other checklists. In the F-4, a utility hydraulic failure coupled with a single power control failure requires the completion of six different checklists. Checklists may also change frequently throughout the life of an aircraft. If voice is used to present the checklists, the timely dissemination of the changes would likely require extensive reprogramming of the voice message system. The sheer number of conditions that require checklists is also enormous; in both the F-4 and the F-16, the number of conditions requiring checklists is over one hundred. The accurate sensing of all these conditions and the correct presentation of the items in the checklists require capabilities that are not projected in near-term aircraft. For these reasons, the use of voice to present emergency checklists cannot be recommended in the context of the present research. The possibility remains, however, that voice presentation of some checklists is appropriate. This possibility should be further investigated.

Possible voice functions associated with LANTIRN, GCAS, and other new systems should also be further investigated. Specification of the functions associated with these new systems was beyond the scope of the present effort; thus some functions of such systems were not considered in the present research. In particular, the capabilities and limitations of advanced threat warning systems should be carefully examined before the implementation of threat messages.

The three aircraft for which voice message ensembles were recommended in this report constitute over two-thirds of tactical aircraft in the current Air Force fleet. Although the number of A-10 pilots that participated in the pilot survey is too few to permit formal recommendations, the trends in their responses did not deviate from the response patterns found in the other groups. It is therefore likely that the recommended vocabulary will accommodate voice messages in the A-10. Projections for deployment of the F-111, F-5, and other tactical and attack aircraft that are relatively few in number should also be considered; it might prove beneficial to consider voice message ensembles for these aircraft as well.

The vocabulary requirements for other types of Air Force aircraft, such as bombers and cargo aircraft, should also be considered. These aircraft differ from tactical aircraft in both design aspects and operational requirements, thus it is likely that additional vocabulary items will be needed to accomodate voice messages in these aircraft. A similar argument applies to Navy and Army aircraft. These aircraft must also be reviewed if a comprehensive vocabulary for all military aircraft is to be designed.

Selection of functions and wording of messages are only the first steps in implementing voice messages in aircraft. The methods for digitizing and reconstructing the messages should be carefully selected, and the intelligibility of the messages must be thoroughly evaluated. It should also be noted that the recommendations offered in this report are based on the collective judgements of the communities of aircrews and researchers - there is no guarantee nor assertion that these recommendations represent the best possible use of voice messages in tactical aircraft. Issues such as feasibility, cost-effectiveness, and design impact must also be considered. Finally, informed opinion is no substitute for experimentation and testing. The results of the present effort should be considered an initial attempt to comprehensively define the role of voice messages in existing and near-term tactical aircraft. Experimental testing and other forms of evaluation are needed to refine, validate, and optimize the comprehensive voice message vocabulary for tactical aircraft.

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APPENDIX A

FORM USED IN MANUFACTURER SURVEY

Name: ______________________________ Date: ________________

Title: ______________________________

Company: ______________________________

Phone: (   ) ______________________________

Aircraft: ____

____

This survey is part of a research project that we at the Georgia Tech Research Institute are conducting under the sponsorship of the Air Force Aerospace Medical Research Laboratory (AMRL). Our immediate research objective is to collect fundamental information for use in the development of a comprehensive voice message vocabulary appropriate to tactical and attack aircraft. Future efforts may expand this vocabulary to include other types of aircraft, such as strategic aircraft and cargo aircraft, but the present focus is on tactical aircraft.

Our mandate in this project is to concentrate on the use of synthetic speech in near-term systems; that is, systems which will utilize current technology and will not be based on futuristic projections. Although there are many new avionics systems in various stages of design and testing, this study concerns only systems which are projected for deployment by (or around) 1990. The 1990 time-frame should also serve as your basis for the projection of your company's plans in this survey.

The interview consists of three parts. The first part consists of a few questions concerning general issues to be considered in designing a comprehensive speech message system. The second part consists of a list of 53 specific functions that are considered to be candidates for using synthetic speech messages. You will be asked to consider each function and to indicate whether that function is a likely candidate for a synthetic speech message in your aircraft. The list of functions will almost certainly include some functions that are not applicable to your aircraft and will possibly omit some that should be included. The final section consist of open-ended questions in which we will solicit your advice on future directions in this project. Feel free at any point during the interview to give additional information, explanation, or comment that might be helpful to us.

Your participation in this survey is essential to the success of this project and will benefit future researchers and users of the technology. Thank you, in advance, for your cooperation.

Now, the specific interview questions.

PART 1. GENERAL INFORMATION

A. EXTENT OF USAGE

Below are five statements that represent differing views concerning the number of functions that should be allocated to synthetic speech messages, irrespective of whether the message is accompanied by a visual indicator. Select the statement that best represents your professional judgement regarding the extent to which synthetic speech messages should be used in the cockpit.

1. Synthetic speech messages should be used very little, if at all, in cockpits of tactical and attack aircraft.

2. Synthetic speech messages should be used only for a very limited class of functions, such as the presentation of emergency warnings.

3. Synthetic speech messages should be used moderately, restricted to relatively high-priority functions such as emergency warnings, caution messages, and important advisories.

4. Synthetic speech messages should be used for a fairly large number of functions, including some low-priority functions as well as high-priority functions.

5. Synthetic speech messages should be used extensively, encompassing a wide variety of functions at both high- and low- priority levels.

B. MESSAGE PREFACES

Current military standards require that critical voice messages be preceeded by an alerting tone. Some writers have suggested that the attention-getting function of the alerting tone could be accomplished by other means, such as making the voice sound "urgent" or prefacing the message with a word that indicates criticality, for example, "warning" or "caution". Which method, in your judgement, should be used to differentiate critical voice messages from other messages?

1. Alerting tone
2. Urgency in voice
3. Preface word
4. Other (specify): ______________________

C. TYPE OF VOICE

For several years female voice was the preferred voice type for cockpit messages, both in the older systems that used pre-recorded messages and in the first implementations of synthesized voice. The usual reason given for the use of female voice was that it would be inherently distinct from the normal parade of male voices heard over the radio and intercom. More recently, it has been suggested that female voice may no longer possess such an advantage, given the increasing presence of females in air traffic control and in aircrews. It has been informally reported that at least some pilots would prefer a voice type other than female. It is now possible to produce a synthetic voice that is neither male nor female, but may be described as "machine-line" or "robotic". Which voice type, in your judgement, should be used in the cockpit?

1. Male
2. Female
3. "Machine-like" or "robotic"

D. EVALUATION CRITERIA

There are many issues surrounding the use of synthetic speech messages in the cockpit to be addressed by research. Previous research in these areas has used a variety of dependent variables in evaluating competing design options, including the pilot's reaction time, total system response time, and pilot preference. Which variable, or variables do you consider to be most important in evaluating when and how synthetic speech should be used.

1. Pilot reaction time
2. System response time
3. Response accuracy
4. Pilot preference
5. Other (specify): ______________________

B.

C.

D.

PART 2: SPECIFIC FUNCTIONS

We will now consider several specific functions that are candidates for synthetic speech messages. These functions are divided into four groups: 1) those that already make use of synthetic speech messages in some aircraft, 2) those that currently use a non-speech signal (visual or auditory) but have been included in proposed speech systems, 3) functions that are currently not implemented in any form, but are possible, and 4) functions that will be possible when new avionics systems projected for 1990 are present. For each function, you are asked to rate the likelihood that your company's aircraft will use a synthetic speech message in conjunction with this function [hand the interviewee the response card and briefly review it]. Also, indicate your choice of preface words, if any, for the associated voice message. [Review those items on the response card.]

A. EXISTING FUNCTIONS ALLOCATED TO SPEECH:

ENGINE FIRE	N/A DY L NL DN	W WW C CC OTHER:________
LEFT VS RIGHT	N/A DY L NL DN	
FTIT	N/A DY L NL DN	W WW C CC OTHER:________
LEFT VS RIGHT	N/A DY L NL DN	
AMAD FIRE	N/A DY L NL DN	W WW C CC OTHER:________
FUEL LOW	N/A DY L NL DN	W WW C CC OTHER:________
LEFT VS RIGHT	N/A DY L NL DN	
"BINGO" FUEL	N/A DY L NL DN	W WW C CC OTHER:________
OVER G	N/A DY L NL DN	W WW C CC OTHER:________
CANOPY	N/A DY L NL DN	W WW C CC OTHER:________
LOW ALTITUDE	N/A DY L NL DN	W WW C CC OTHER:________

B. EXISTING FUNCTIONS CURRENTLY ALLOCATED TO NON-SPEECH:

LANDING GEAR	N/A DY L NL DN	W WW C CC OTHER:________
DEPARTURE WARNING	N/A DY L NL DN	W WW C CC OTHER:________
ANGLE OF ATTACK	N/A DY L NL DN	W WW C CC OTHER:________
LOW SPEED WARNING	N/A DY L NL DN	W WW C CC OTHER:________
BRAKE FAILURE	N/A DY L NL DN	W WW C CC OTHER:________
WING SWEEP	N/A DY L NL DN	W WW C CC OTHER:________
"REDUCE SPEED" WARNING	N/A DY L NL DN	W WW C CC OTHER:________
FUEL PRESSURE	N/A DY L NL DN	W WW C CC OTHER:________
LEFT VS RIGHT	N/A DY L NL DN	
OIL TEMPERATURE	N/A DY L NL DN	W WW C CC OTHER:________
LEFT VS RIGHT	N/A DY L NL DN	
OIL PRESSURE	N/A DY L NL DN	W WW C CC OTHER:________
LEFT VS RIGHT	N/A DY L NL DN	
INLET ICE	N/A DY L NL DN	W WW C CC OTHER:________
OXYGEN LOW	N/A DY L NL DN	W WW C CC OTHER:________
HYDRAULIC PRESSURE	N/A DY L NL DN	W WW C CC OTHER:________

A.

B.

ACLS/AP	N/A DY L NL DN	W WW C CC OTHER:________
GENERATOR FAILURE	N/A DY L NL DN	W WW C CC OTHER:________
LEFT VS RIGHT	N/A DY L NL DN	
FLAP PROBLEM	N/A DY L NL DN	W WW C CC OTHER:________
NOSE WHEEL STEERING	N/A DY L NL DN	W WW C CC OTHER:________
AUTO THROTTLE DISENGAGED	N/A DY L NL DN	W WW C CC OTHER:________
LOW HORIZONTAL TAIL AUTH.	N/A DY L NL DN	W WW C CC OTHER:________
GLOVE VANE DISABLED	N/A DY L NL DN	W WW C CC OTHER:________
LOW RUDDER AUTH.	N/A DY L NL DN	W WW C CC OTHER:________
SPOILERS LOCKED DOWN	N/A DY L NL DN	W WW C CC OTHER:________
OVERSPEED VALVE	N/A DY L NL DN	W WW C CC OTHER:________
LEFT VS RIGHT	N/A DY L LN DN	
BLEED DUCT OVERHEAT	N/A DY L NL DN	W WW C CC OTHER:________
PITCH STABILITY	N/A DY L NL DN	W WW C CC OTHER:________
ONE	N/A DY L NL DN	
TWO	N/A DY L NL DN	
COMPLETE	N/A DY L NL DN	
ROLL STABILITY	N/A DY L NL DN	W WW C CC OTHER:________
ONE	N/A DY L NL DN	
TWO	N/A DY L NL DN	
COMPLETE	N/A DY L NL DN	
YAW STABILITY DEGRADED	N/A DY L NL DN	W WW C CC OTHER:________
YAW STABILITY OUT	N/A DY L NL DN	W WW C CC OTHER:________
AUTO PILOT FAILURE	N/A DY L NL DN	W WW C CC OTHER:________
LADDER NOT STOWED	N/A DY L NL DN	W WW C CC OTHER:________
CADC FAILURE	N/A DY L NL DN	W WW C CC OTHER:________
ENGINE STAGNATION	N/A DY L NL DN	W WW C CC OTHER:________
DUAL FLIGHT CONTROL	N/A DY L NL DN	W WW C CC OTHER:________
STORES CONFIGURATION	N/A DY L NL DN	W WW C CC OTHER:________
FLAMEOUT WARNING	N/A DY L NL DN	W WW C CC OTHER:________
ELECTRICAL SYSTEM	N/A DY L NL DN	W WW C CC OTHER:________

EEC FAILURE	N/A DY L NL DN	W WW C CC OTHER:__________
AIR REFUEL DOOR	N/A DY L NL DN	W WW C CC OTHER:__________
INCORRECT CONFIGURATION	N/A DY L NL DN	W WW C CC OTHER:__________
OBSTACLE WARNING	N/A DY L NL DN	W WW C CC OTHER:__________
TF RADAR FAILURE	N/A DY L NL DN	W WW C CC OTHER:__________
WEAPONS INFORMATION	N/A DY L NL DN	W WW C CC OTHER:__________
RADAR GUIDED	N/A DY L NL DN	W WW C CC OTHER:__________
HEAT-SEEKING	N/A DY L NL DN	W WW C CC OTHER:__________
LOFT-BOMBING CUE	N/A DY L NL DN	W WW C CC OTHER:__________
OTHER (SPECIFY): _______________		

C. SUGGESTED FUNCTIONS NOT CURRENTLY IMPLEMENTED IN ANY FORM, BUT POSSIBLE:

ALTITUDE CALLOUTS	N/A DY L NL DN	W WW C CC OTHER:__________
EMERGENCY CHECKLISTS	N/A DY L NL DN	W WW C CC OTHER:__________
TASK PROMPTS	N/A DY L NL DN	W WW C CC OTHER:__________

OTHER SUGGESTIONS: SPECIFY

D. FUNCTIONS ASSOCIATED WITH NEW AVIONICS:

LANTIRN

OBSTACLE WARNING	N/A DY L NL DN	W WW C CC OTHER:__________
LASER LOCK-ON	N/A DY L NL DN	W WW C CC OTHER:__________

OTHER FUNCTIONS: LIST

THREAT INFORMATION	N/A DY L NL DN	W WW C CC OTHER:________
DISPLAY	N/A DY L NL DN	W WW C CC OTHER:________
NEW GUY	N/A DY L NL DN	W WW C CC OTHER:________
LAUNCH	N/A DY L NL DN	W WW C CC OTHER:________
OTHER (SPECIFY): ____________		

<u>GROUND PROXIMITY WARNING SYSTEM</u> N/A DY L NL DN

DESCENT RATE	N/A DY L NL DN	W WW C CC OTHER:________
INNER VS OUTER	N/A DY L NL DN	W WW C CC OTHER:________
TERRAIN CLOSURE RATE	N/A DY L NL DN	W WW C CC OTHER:________
INNER VS OUTER	N/A DY L NL DN	W WW C CC OTHER:________
DEV. FROM GLIDE SLOPE	N/A DY L NL DN	W WW C CC OTHER:________
INNER VS OUTER	N/A DY L NL DN	W WW C CC OTHER:________
EXCESSIVE ALT. LOSS (TAKEOFF)	N/A DY L NL DN	W WW C CC OTHER:________
RALT TOO LOW	N/A DY L NL DN	W WW C CC OTHER:________

PART 3: PILOT OPINION CONCERNS

1. Following this survey of manufacturers, we are going to conduct a survey of pilots. Pilot opinion is undoubtedly a salient concern in some aspects of the implementation of synthetic speech systems, but is perhaps less salient in other aspects. What issues, in your judgement, should be addressed by asking pilots for their preferences? In other words, when we survey the pilots, what should we ask them?

UNRESOLVED ISSUES

2. What are the major issues, in your judgement, that should be resolved before a comprehensive voice message system is implemented in the cockpit? Be as specific as you like, and feel free to suggest the method that should be used in addressing these issues.

APPENDIX B

COMMENTS AND SUGGESTIONS BY MANUFACTURER SURVEY PARTICIPANTS

Two open-ended questions concerning the type of information that should be obtained from pilots and issues that should be resolved before a voice message system is implemented were included in the manufacturer survey. The responses to these questions, and other comments and suggestions, are summarized below. The responses of each participant are summarized separately. The companies and individuals are not indicated, in order to preserve anonymity.

Information From Pilots

* In what situations are messages ignored? What functions do pilots want?
* How much control does the pilot want? What type and quality of voice is acceptable?
* What functions do they want?
* Ask pilots about priorities of functions. Do they want programmability?
* How much flexibility do they want? Determine the exact meaning of their "lingo".
* Should voice be redundant with a visual display?
* How do they feel about a standardized vocabulary?
* Determine priority of functions.
* Ask pilots to list the specific functions they would like.
* Survey pilots with combat experience.
* Will pilots attend to the messages during critical times?

Issues To Be Resolved

* Will it add to safety?
* How can it be combined with a voice-command system?
* Voice type, supplemental tones, silencing criteria, prioritization of functions.
* Task analysis to allocate functions.
* What training will be required?
* How can it be integrated into the cockpit?
* Integration with other controls and displays; false alarms.
* Experimentally decide when speech is helpful - surveys cannot be used to decide this.
* Make sure the vocabulary matches pilot lingo.
* Will voice decrease workload and increase safety? Will integration costs be acceptable?
* [One participant did not respond.]

Other Comments and Suggestions

* Develop an expert system that will control voice messages as a function of flight context.
* Make sure the voice is understandable. Pilots will complain about the voice regardless.
* Speech system must be integrated.
* Don't use a robotic voice - pilots won't like it. Needs to be natural-sounding.
* Include pilot understanding in any evaluation.
* Add low priority messages that pilots want.
* Use male voice for low priorities; female voice for high priorities.
* Message selection should be done by pilots.
* Voice should be distinctive.
* Use a tone to alert pilot to the message. Mask out other tones.
* Evaluate task-dependent factors to select functions - do not simply base selection on criticality.
* Perhaps modulate the voice to indicate urgency for high priorities.
* Don't use female voice.
* Consider S-C-R principles in function selection.

APPENDIX C

FORM USED IN PILOT SURVEY

NAME: ______________________________

UNIT: ______________________________

AIRCRAFT: ______________________________

FLIGHT HOURS (approximate): ________ ______________________

INTRODUCTION

Synthetic speech technology has advanced rapidly over the past few years, and it is now possible to design a voice message system for aircraft that will be flexible and that will produce good-quality voice messages. Some tactical aircraft already make use of voice messages, and the most likely trend in the future is that voice messages will be used more and more. The Air Force Aerospace Medical Research Laboratory (AMRL) has contracted with Georgia Tech to determine the vocabulary requirements for a comprehensive message system for tactical and attack aircraft. This system is to be based on today's technology, not futuristic projections.

We have compiled a list of functions that are considered candidates for association with a voice message in tactical aircraft. This list was drawn from three sources:

1) voice message currently in use in tactical aircraft
2) functions included in proposed voice systems for tactical aircraft
3) functions associated with new avionics systems scheduled for deployment in the next five years.

This questionnaire is designed to obtain two kinds of information from you. First, we want to identify the functions that you think voice messages should be used for. Second, for those functions you select, we want to know how the messages should be worded.

We believe that a voice message system for tactical aircraft should reflect the judgement and preferences of the pilots of those aircraft. Please keep in mind that we are trying to determine the capacity that such a system should have, that is, the various messages that the system should be capable of producing.

YOUR COOPERATION IS VERY MUCH APPRECIATED!

INSTRUCTIONS

On the following pages is a list of functions that are considered candidates for association with a voice message. Please consider each function and rate the likelihood that the use of a voice message for that function would be a good idea. Use the following scale:

NA (Not Applicable)
DY (Definitely Yes)..........Definitely a good idea
L (Likely)..................Likely to be a good idea
NL (Not Likely).............Not likely to be a good idea
DN (Definitely No)...........Definitely not a good idea

For those functions you rate as "DY" or "L", consider the prototype message listed for that function. If you are satisfied with that wording, continue on to the next function. If you think of a better way to word that message, however, write your preferred wording in the blank as indicated in the sample below. There are a few functions that also have a follow-up question concerning the proper specificity of the message.

Part 1 consists of general messages that are mostly system malfunction messages. Part 2 consists of messages that are more specific to a given flight segment or mission context. Parts 1 and 2 combined contain 43 functions for you to consider. Part 3 consists of a list of informational functions that have been informally suggested to us during the course of preparing this survey. For these, circle Yes or No to indicate whether you think we should give these functions further consideration. Please remember that this project is concerned with a comprehensive system, therefore, some functions may be listed that are not applicable to your aircraft.

Sample for Parts 1 and 2:

FUEL PRESSURE LOW NA DY (L) NL DN
prototype: "Fuel pressure low"
your preferred wording: Low fuel pressure

LEGEND: NA = Not Applicable   DY = Definitely Yes   NL = Not Likely
L = Likely   DN = Definitely No

I. GENERAL MESSAGES

1. ENGINE FIRE — NA DY L NL DN
   prototype: "Engine fire"
   your preferred wording: ______________________

   For multi-engine aircraft, should the message indicate which engine? — NA DY L NL DN

2. FUEL LOW — NA DY L NL DN
   prototype: "Fuel low"
   your preferred wording: ______________________

3. FUEL PRESSURE LOW — NA DY L NL DN
   prototype: "Fuel pressure low"
   your preferred wording: ______________________

4. OIL TEMPERATURE LOW — NA DY L NL DN
   prototype: "Oil temp low"
   your preferred wording: ______________________

5. OIL PRESSURE LOW or HIGH — NA DY L NL DN
   prototype: "Oil pressure low" or "Oil pressure high"
   your preferred wording: ______________________

6. HYDRAULIC PRESSURE LOW or HIGH — NA DY L NL DN
   prototype: "Hydraulic pressure low" or "Hydraulic pressure high"
   your preferred wording: ______________________

7. GENERATOR FAILURE — NA DY L NL DN
   prototype: "Generator failure"
   your preferred wording: ______________________

8. CENTRAL AIR DATA COMPUTER FAILURE — NA DY L NL DN
   prototype: "CADC failure"
   your preferred wording: ______________________

9. ENGINE ELECTRICAL CONTROLLER FAILURE — NA DY L NL DN
   prototype: "EEC failure"
   your preferred wording: ______________________

10. ELECTRICAL SYSTEM MALFUNCTION — NA DY L NL DN
    prototype: "Electrical system malfunction"
    your preferred wording: ______________________

    Would you prefer the message to be more specific? — NA DY L NL DN

COMMENTS

LEGEND: NA = Not Applicable DY = Definitely Yes NL = Not Likely
L = Likely DN = Definitely No

11. INLET ICE NA DY L NL DN
prototype: "Inlet ice"
your preferred wording: ____________________

12. OXYGEN LOW NA DY L NL DN
prototype: "Oxygen low"
your preferred wording: ____________________

13. FLAMEOUT NA DY L NL DN
prototype: "Flameout"
your preferred wording: ____________________

For multi-engine aircraft, would you prefer the message to be more specific? NA DY L NL DN

14. RADIO MALFUNCTION NA DY L NL DN
prototype: "Radio malfunction"
your preferred wording: ____________________

15. DIRECTION INDICATOR MALFUNCTION NA DY L NL DN
prototype: "ADIs do not correlate"
your preferred wording: ____________________

16. BLEED DUCT OVERHEAT NA DY L NL DN
prototype: "Bleed duct overheat"
your preferred wording: ____________________

17. LOW SPEED NA DY L NL DN
prototype: "Low speed"
your preferred wording: ____________________

18. EXTERNAL FUEL TANKS EMPTY NA DY L NL DN
prototype: "External tanks empty"
your preferred wording: ____________________

19. AUTO THROTTLE DISENGAGED NA DY L NL DN
prototype: "Auto throttle disengaged"
your preferred wording: ____________________

20. SPOILERS LOCKED DOWN NA DY L NL DN
prototype: "Spoilers locked down"
your preferred wording: ____________________

21. FAN TURBINE INLET TEMPERATURE NA DY L NL DN
prototype: "FTIT over temp"
your preferred wording: ____________________

For multi-engine aircraft, should the message indicate which engine? NA DY L NL DN

COMMENTS

LEGEND NA = Not Applicable DY = Definitely Yes NL = Not Likely
L = Likely DN = Definitely No

22. FIRE IN AIRFRAME-MOUNTED ACCESSORIES NA DY L NL DN
prototype: "AMAD fire"
your preferred wording: ____________________

23. WING SWEEP NA DY L NL DN
prototype: "Wing sweep"
your preferred wording: ____________________

24. DUAL FLIGHT CONTROL MALFUNCTION NA DY L NL DN
prototype: "Dual control malfunction"
your preferred wording: ____________________

COMMENTS

LEGEND: NA = Not Applicable   DY = Definitely Yes   NL = Not Likely
L = Likely   DN = Definitely No

II. MESSAGES SPECIFIC TO FLIGHT SEGMENT OR MISSION

GROUND OPERATIONS

25. CANOPY UNLOCKED   NA DY L NL DN
prototype: "Canopy, canopy"
your preferred wording: ______________________

26. BRAKE FAILURE   NA DY L NL DN
(also applies to landing)
prototype: "Brake failure"
your preferred wording: ______________________

TAKEOFF

27. NOSE WHEEL STEERING MALFUNCTION   NA DY L NL DN
(also applies to landing)
prototype: "Nose steering malfunction"
your preferred wording: ______________________

28. GEAR MALFUNCTION   NA DY L NL DN
(also applies to landing)
prototype: "Gear malfunction"
your preferred wording: ______________________

29. FLAP MALFUNCTION   NA DY L NL DN
prototype: "Flap malfunction"
your preferred wording: ______________________

30. EXCESSIVE ALTITUDE LOSS (TAKE-OFF)   NA DY L NL DN
prototype: "Altitude loss"
your preferred wording: ______________________

31. INCORRECT CONFIGURATION   NA DY L NL DN
(After take-off, gear or flaps not up)
(also applies to landing, with gear or flaps not down)
prototype: "Check configuration"
your preferred wording: ______________________

CRUISE

32. AUTO PILOT FAILURE   NA DY L NL DN
prototype: "Auto pilot failure"
your preferred wording: ______________________

COMMENTS

LEGEND: NA = Not Applicable   DY = Definitely Yes   NL = Not Likely
L = Likely   DN = Definitely No

LOW-LEVEL NAVIGATION

33. TERRAIN-FOLLOWING RADAR FAILURE   NA DY L NL DN
prototype: "TF radar failure"
your preferred wording: ______________________

34. OBSTACLE WARNING   NA DY L NL DN
prototype: "Obstacle, obstacle"
your preferred wording: ______________________

35. DESCENT RATE WARNING   NA DY L NL DN
(with respect to vertical speed)
prototype: "Don't sink"
your preferred wording: ______________________

36. TERRAIN CLOSURE WARNING   NA DY L NL DN
(with respect to radar altitude)
prototpe: "Terrain, terrain"
your preferred wording: ______________________

37. LOW ALTITUDE (with respect to a value you preset)   NA DY L NL DN
prototype: "Altitude, altitude"
your preferred wording: ______________________

THREAT ENCOUNTER

38. MISSILE LAUNCH   NA DY L NL DN
prototype: "SAM 6 LAUNCH" (example)
your preferred wording: ______________________

Would you like for the message to indicate *direction of the launch?*   NA DY L NL DN
(e.g. "SAM 8 launch two-o'clock right)

39. HIGHEST-PRIORITY THREAT IDENTITY   NA DY L NL DN
(Would be heard whenever a new highest-priority threat was identified)
prototype: "SAM 8"
your preferred wording: ______________________

Would you like the message to indicate the direction of the threat?   NA DY L NL DN

40. NEW GUY   NA DY L NL DN
prototype: "New guy"
your preferred wording: ______________________

COMMENTS

LEGEND: NA = Not Applicable   DY = Definitely Yes   NL = Not Likely
L = Likely   DN = Definitely No

AIR-TO-AIR

41. BINGO FUEL   NA DY L NL DN
(applies to any flight segment where BINGO level is reached)
prototype: "Bingo fuel"
your preferred wording: ________________

42. OVER G   NA DY L NL DN
prototype: "Over g, Over g"
your preferred wording: ________________

LANDING

43. DEVIATION FROM GLIDE SLOPE   NA DY L NL DN
prototype: "Glide slope, glide slope"
your preferred wording: ________________

COMMENTS

III. OTHER INFORMATIONAL MESSAGES

Indicate whether the implementation of a voice message should be considered for the following functions. Circle Yes or No.

Ground Operations

1. Yes No Preflight checklists
2. Yes No Read-back of INS coordinates

Take-off

3. Yes No Speed check at preset value
4. Yes No Gear up and locked
5. Yes No Flaps up

Climb

6. Yes No Approaching pre-set level-off altitude

Cruise

7. Yes No Auto pilot engaged/disengaged
8. Yes No Periodic "check fuel" reminder

Low-level Navigation

9. Yes No Fence check reminder
10. Yes No Point approach (e.g. "Approaching point A")
11. Yes No Next heading (e.g. "Next heading 314 degrees")

Air-to-Air

12. Yes No Joker fuel
13. Yes No Weapons selected/armed
14. Yes No Periodic "check six" reminder
15. Yes No Low ammunition message (e.g. "200 rounds remaining")
16. Yes No Bogey Lock-on

Air-to-Ground

17. Yes No "Drop external tanks" prompt
18. Yes No Loft bombing cue
19. Yes No LASER inoperative/LASER ready
20. Yes No Weapons station selection
21. Yes No LASER Lock-on (LANTIRN)

Air Refueling

22. Yes No Refuel system ready
23. Yes No Air refuel door still open

Descent

24. Yes No Level-off altitude calls
25. Yes No Descent checklists

Landing

26. Yes No Gear down and locked

What is your opinion of using voice messages to present emergency checklists?

If a voice message system is implemented, what control features (for the pilot) should it have? (Examples - volume control, on/off, disable switch for non-emergency messages, etc.

Please list below any other functions that you recommend for consideration, or any other comments or suggestions.

APPENDIX D

SUMMARY OF PILOT COMMENTS AND SUGGESTIONS

The participants in the pilot survey were encouraged to offer alternate wordings for voice messages, to indicate whether certain messages should be more specific, and to list additional functions for voice messages. Ample space was provided throughout the booklet for the respondents to make comments or suggestions. The questions concerning emergency checklists and desirable control features allowed open-ended answers to these questions. The participants' responses in each of these categories are summarized in this Appendix.

Suggested Alternate Wordings

The alternate wordings offered for each of the 26 voice message functions recommended in this report are listed below. The one exception is the Joker Fuel function, which was not associated with a proposed wording. Numbers in parentheses indicate the number of respondents which offered a given wording.

Engine Fire:	"Fire" (11)
	"Fire, fire" (5)
	"Check engine" (1)
Fuel Low:	"Low fuel" (6)
	"Check fuel" (5)
	"Emergency fuel" (2)
	"Check gas" (1)
Oil Pressure:	"Check oil" (1)
	"Check oil gauges" (1)
	"Check oil pressure" (1)
	"Oil high/low" (1)
Hydraulic Pressure:	"Check hydraulics" (3)
	"Hydraulics" (3)
	"Check hydraulic pressure" (2)
	"Hydraulic system A/B high/low"

Generator Failure:	"Generator" (6)
	"Generator, generator" (1)
	"Electrics" (1)
	"Main generator failed" (1)
EEC:	"EEC failed" (2)
	"EEC off" (1)
	"EEC, EEC" (1)
	"Engine control" (1)
Electrical System:	"Check electrics" (3)
	"Electrics" (2)
	"Electrical failure" (1)
	"Electrical malfunction"
Oxygen Low:	"Oxygen" (5)
	"Low oxygen" (2)
	"O_2 low" (1)
	"Check oxygen pressure" (1)
	"Descend now" (1)
Flameout:	"Check engine" (3)
	"Engine failure" (3)
	"Engine" (3)
ADI Disagreement:	"Check ADI" (7)
	"ADI failure" (3)
	"ADI malfunction" (2)
	"ADI failure" (2)
	"ADI check" (1)
	"Attitude failure" (1)
	"Attitude" (1)
	"ADI disagreement" (1)
	"ADI unreliable" (1)
	"Heading systems" (1)
	"Check attitude reference" (1)

"ADI error" (1)
"Attitude indicator bad" (1)
"INS degraded" (1)
"Performance instrument malfunction" (1)

<u>Bleed Duct Overheat:</u>	"Bleed air overheat" (7)
	"Bleed air" (4)
	"Bleed air hot" (1)
	"Bleed air light" (1)
	"Overheat" (1)
	"Bleed air malfunction" (1)
<u>FTIT:</u>	"Engine over temp" (6)
	"Engine over heat" (4)
	"Check engine" (2)
	"Turbine over temp" (1)
	"Fan over temp" (1)
	"Inlet over temp" (1)
	"Engine hot" (1)
<u>AMAD Fire:</u>	"Right/left AMAD fire" (1)
<u>Dual Flight Control:</u>	"Dual FC fail" (10)
	"Dual FC" (4)
	"Dual FC malfunction" (2)
	"Flight control" (2)
	"Dual flight control malfunction" (1)
<u>Canopy:</u>	"Canopy unlocked" (6)
	"Check canopy" (3)
	"Canopy unsafe" (2)
	"Canopy open" (1)

Brakes:	"Brakes" (7)
	"No brakes" (2)
	"Antiskid failure" (2)
	"Wheel brake failure" (2)
	"Antiskid off" (1)
Landing Gear Malfunction:	"Check gear" (12)
	"Gear not up/down" (3)
	"Gear" (3)
	"Landing gear" (3)
	"Gear unsafe" (2)
	"Unsafe gear" (1)
Flap Malfunction:	"Flaps" (10)
	"Flaps not up/down" (2)
	"Flap check" (1)
	"Check flaps" (1)
	"No flaps" (1)
	"Wing flaps" (1)
Configuration:	"Check gear/flaps" (5)
Autopilot Failure:	"Autopilot" (11)
	"Autopilot off" (2)
	"Autopilot fail" (1)
	"Negative autopilot" (1)
	"Flight mode failure" (1)
	"Check autopilot" (1)
Low Altitude:	"Check altitude" (4)
	"Pull up" (4)
	"Climb, climb" (2)
	"Altitude, climb" (1)
	"Climb, altitude" (1)

Missile Launch:	"SAM 8 launch right two-oclock" (17)
(example of format)	"Launch, launch" (2)
	"Launch right two-oclock, SAM 8" (1)
	"Launch" (1)
	"Threat launch" (1)
Threat Display:	"SA-8" (2)
(example of format)	"New SAM 8" (2)
	"New Threat" (2)
	"New highest threat SAM 8"
Bingo Fuel:	"Bingo" (32)
	"Bingo, bingo" (5)
	"Fuel" (1)
	"Check fuel" (1)
Over g:	"Over g" [do not repeat] (3)
	"Check g's" (2)
	"Ease off" (1)

Message Specificity

Six items in the pilot survey included a follow-up question concerning the proper specificity of the message. These questions are as follows:

1. Engine Fire - For multi-engine aircraft, should the message indicate which engine?

2. Electrical System - Should the message be more specific?

3. Flameout - For multi-engine aircraft, should the message indicate which engine?

4. FTIT - For multi-engine aircraft, should the message indicate which engine?

5. Missile Launch - Should the message indicate the direction of the launch?

6. Threat Display - Should the message indicate the direction of the threat?

The same scale used to rate the functions was listed in the survey booklet for each of these items; however, many pilots wrote a comment such as "Say which engine" or offered an alternate wording such as "Engine Fire Right/Left" instead of using the scale. It is therefore more concise to summarize the responses regarding message specificity as simply yes or no. This summary appears in Table D-1. It should be noted that alternate wordings which merely added specificity to a message are not included in the list of alternate wordings above.

Emergency Checklists

The question concerning emergency checklists appeared in 90 of the 135 booklets used in the pilot survey. These booklets were all completed by F-15 or F-16 pilots. Forty-three of the ninety pilots offered unfavorable remarks concerning the use of voice to present emergency procedures. The objections raised include a preference for seeing, rather than hearing, the checklist; interference with radio or intercom communications; and problems with the pacing and repetition of items. Thirty pilots offered favorable comments, with certain qualifications. These qualifications include allowing the pilot to select which lists should be presented (rather than automating list selection), allowing the pilot to control pacing and repetition, and duplicating the list on a CRT concurrent with voice presentation. It is evident from these comments that pilots prefer visual presentation of the lists regardless of whether the list is presented aurally, and that a principal concern is the pacing and repetition of items. Nine pilots made positive comments without qualifications, and the remaining eight responses could not be categorized or were omitted.

Control Features

The question concerning desirable control features also appeared in 90 booklets. The examples offered in the question were volume control, on/off, and a disable for non-emergencies. Sixty-eight pilots indicated a preference for volume control, fifty preferred an on/off control, and forty-eight preferred a disable switch. Thus, over half of the respondents indicated a preference for these three features. Other suggested features include a timed disable feature, a mode switch whcih would alter system operator according to flight segment or mission context, and an acknowledge button which would cancel a message in progress and suppress further presentation of that message.

Other Comments and Suggestions

Comments and suggestions offered by the aircrews on a variety of issues are summarized below. The numbers in parentheses indicate the number of pilots who offered such a comment or suggestion. Comments offered by only one respondent are not included.

* Wariness of "too much talk" from the system (10)
* Concern over false alarms and interference with other communications (10)
* Pilots might depend on the system too much, and not monitor the aircraft properly (6)
* Design the system so that a pilot can select which messages he will hear (5)
* Provide visual back-up for any voice message (3)
* Use a non-irritating voice (3)
* It will be a big improvement over the present tones (2)
* Just say "Warning" or "Caution" - nothing else (2)
* Make the system smart enough to suppress inappropriate messages during critical times (2)

TABLE D-1

SUMMARY OF RESPONSES TO QUESTIONS CONCERNING MESSAGE SPECIFICITY[a]

Question	F-4 Yes	F-4 No	F-15 Yes	F-15 No	F-16 Yes	F-16 No
1. Should the Engine Fire message indicate which engine (for multi-engine aircraft)?	22	5	34	1	17	12
2. Should the Electrical System message be more specific?	17	11	13	10	19	28
3. Should the Flameout message indicate which engine (for multi-engine aircraft)?	16	10	22	6	7	12
4. Should the FTIT message indicate which engine (for multi-engine aircraft)?	6	5	31	1	10	7
5. Should the Missile Launch message indicate direction?	24	6	24	13	45	10
6. Should the Threat Display message indicate direction?	21	7	23	8	33	19

a - Table entries are frequency tallies and include alternate wordings and written comments as well as responses using the scale provided.

APPENDIX E

DESCRIPTION OF ACTIVATING CONDITIONS FOR RECOMMENDED VOICE MESSAGE FUNCTIONS

A total of 26 functions for voice messages are recommended in this report. The generic activating conditions for each of these functions are described below. The exact conditions may vary from aircraft to aircraft.

Engine Fire: Temperature probes in an engine compartment indicate the presence of a fire.

Fuel Low: Fuel level in the engine feed tank falls below a predetermined value.

Oil Pressure: Engine oil pressure is too high or too low, according to predetermined values.

Hydraulic Pressure: Hydraulic pressure is too high or too low, according to predetermined values.

Generator Failure: One or more electric generators fail to function properly.

Electrical System: Some aircraft systems are not properly powered due to the failure of a transformer-rectifier or similar device.

EEC: The engine electric controller (an automatic fuel-scheduling system) has malfunctioned.

Oxygen Low: The onboard supply of liquid oxygen falls below a predetermined value.

Flameout: One or more engines are not in operation.

ADI Disagreement: The attitude direction indicator systems do not agree.

Bleed Duct Overheat: There is a leak in the bleed air ductwork between an engine and a heat exchanger or the bleed air temperature is too high at a point past the heat exchanger.

FTIT: Fan turbine inlet temperature exceeds a predetermined value; indicates potential engine malfunction.

AMAD Fire: Fire in an airframe-mounted accessory drive, a gearbox which transfers power from an engine to a hydraulic system.

Dual Flight Control Malfunction: A dual malfunction has occured in one of the electrical control axes or in the air data system.

Canopy: A canopy is unsecured or improperly fastened.

Brakes: Main landing gear brakes have failed.

Landing Gear Malfunction: Landing gear does not retract or extend properly.

Flap Malfunction: Wing flaps have deployed or retracted asymmetrically or leading or trailing edge flaps have not deployed.

Configuration: Landing gear is down but flaps are up, or vice versa.

Autopilot Failure: The autopilot system has disengaged, typically due to a control transient or external turbulence.

Low Altitude: Aircraft has descended below a selectable radar altitude.

Missile Launch: Received radar energy indicates that a ground or airborne ordnance has been fired at the aircraft.

Threat Display: The message states the identity (if known) and direction (if known) of the highest-priority threat system transmitting radar energy in the immediate area and is activated when the highest-priority threat changes.

Bingo Fuel: Fuel quantity reaches a value preset by the pilot; this value represents the amount of fuel required to return from a briefed mission with appropriate reserves.

Over g: Acceleration conditions exist which might cause structural damage to the aircraft.

Joker Fuel: Fuel quantity reaches a value preset by the pilot; this value represents the amount of fuel required to perform a fighting withdrawal from an engagement and then return from the mission with appropriate reserves.

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