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DEVELOPMENT OF SPEECH INPUT/OUTPUT INTERFACES FOR TACTICAL AIRCRAFT

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This report covers the methods and the results in the selection of tasks for speech input/output (I/O) in the fighter cockpit of the future. A description is given of the candidate speech tasks derived from interviews with experienced F-16 pilots, an analysis of a composite air-to-ground scenario, and a questionnaire survey of F-16 pilots at Nellis AFB.

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PREFACE

This report describes the results of an analysis of the application of automated speech technology in future tactical aircraft. The study was sponsored by the Air Force Wright Aeronautical Laboratory, AFWAL/FIGR under contract F33615-81-C-3622 to Canyon Research Group, Inc. Mr. Eric Werkowitz was the AFWAL project engineer for the first half of the study, followed by Mr. David Williamson for the second half. Their encouragement and support are gratefully acknowledged. Dr. Robert North of Honeywell, Systems and Research Center participated as a subcontractor. Mr. Melvin I. Strieb was a consultant to the project. Ms. S. Joy Mountford of Honeywell SRC provided significant input to the development of the initial questionnaire. Mr. Brian Shaw provided software support for the data analysis.

The authors are indebted to the Air Force personnel who contributed their time and energy in providing imaginative and informative answers to many questions about potential applications of speech technology. We are especially grateful to LtCol Harry Heimple and LtCol Joe-Bill Dryden of the F-16 AFTI Joint Test Force at Edwards AFB, and the F-16 pilots at Nellis AFB attached to the Fighter Weapons School and the 474th Tactical Fighter Wing.

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BACKGROUND

INTRODUCTION

The objective of this study was to investigate potential applications of speech as an information input/output (I/O) mode between the pilot and future tactical aircraft systems. At the inception, the project team was directed to assume that computer speech recognition and generation technology would be capable of operating in the tactical environment at the time the aircraft came into service. The question, then, was how to use the technology effectively.

The characteristics of "future tactical aircraft" were divided into two classifications, Near Term (1980-1990) and Far Term (1990-2000). The Near Term aircraft study focused on the F-16A cockpit as the baseline design, but was projected through the F-16C (MSIP) configuration and the F-16E design. The F-16E may be the most likely aircraft for the first application of speech I/O in the fighter cockpit. The basis for this assertion is that the F-16C cockpit design was already "set in concrete" (February 1982) and that, while limited speech I/O is foreseen as a potential F-16C retrofit program, the full capability of speech I/O could only be realized if it were designed as part of a revised concept for cockpit information flow.

The speech I/O functions in the Far Term aircraft will be an extension of the F-16E applications, although new methods for integrating the speech I/O will be likely. In the Near Term aircraft, the speech I/O system would interface with other aircraft systems which use speech I/O functions. In the Far Term aircraft, speech I/O could be an integral service system, analogous to electrical or hydraulic power.

This work expands previous studies of the use of speech I/O to reduce pilot workload and/or provide new cockpit capabilities (North and Lea, 1981).

APPROACH

Three actions were taken to identify and verify potential speech I/O applications for fighter cockpit design. First, we surveyed part of the F-16 pilot community to identify candidate tasks that could be accomplished by speech I/O. Second, we developed generic criteria for speech I/O task verification which could be applied to a variety of future aircraft designs. Third we verified the selection of the F-16 speech tasks using a different part of the F-16 pilot community.

Three top-level criteria were identified to provide guidance in speech I/O task selection. These criteria were intended to be applicable to both the Near Term and Far Term aircraft. The criteria were that speech I/O would have a place in future cockpit designs only if: 1) mission performance were improved; 2) survivability were improved; and 3) pilots' skills could be utilized more efficiently.

Diverse professional opinion exists as to how speech I/O should be used in cockpits (or whether it should be used at all). The project team believes that speech I/O is not necessarily the panacea for more efficient, safer system design. For instance, speech I/O should not be considered a mere replacement for manual actions, but on the other hand, one word could replace many manual actions. Sometimes it is faster doing things manually than by speech input, but speech may help to keep the pilot's eyes out of the cockpit and hands on the flight controls at a critical time. In summary, just because a task can be performed by speech I/O it does not mean it should be. All speech I/O tasks must be considered in the full mission context.

We anticipated that detailed analysis of cockpit speech I/O would uncover research issues not previously addressed by the aviation or speech R&D communities. For example, although speech output in the cockpit is a natural way of communicating system information to the pilot, it can be a source of great annoyance if it competes with essential radio communications. A difficult research issue, then, is how to prioritize the radio communication and system message flow under all mission circumstances. Such research issues generally would fall beyond the scope of this study. However, they could not be neglected because of their potential negative impact on the progressive development of cockpit speech applications. Consequently, research issues were identified during the study.

STUDY PHASES

In the broader perspective of the program, the study was conducted in five phases which are depicted in Figure 1:

1. Analyze Cockpit Activities - In this phase we studied the F-16A and F-16C (MSIP projected) aircraft systems through the available flight manuals. We also developed a mission scenario (modified European short range interdiction) which enabled us to interview a group of F-16A instructor and operational test and evaluation pilots to identify candidate cockpit tasks for speech I/O.

2. Speech I/O Selection - First, the candidate tasks identified in 1 above, were sorted and classified. Second, the candidate tasks were examined with respect to a set of implementation criteria. Third, potential speech I/O research issues were identified and fourth, these were verified by the pilots in F16-A operational squadrons.

3. Technical Feasibility - In this phase the vocabulary and syntax were developed for the speech recognition systems. Although the vocabulary and syntax were developed around the requirements foreseen for the F-16 MSIP development simulation (see 4), the structure will accommodate generic groupings of tasks. Engineering implementation criteria also were applied as a dimension for evaluating technical feasibility. The criteria were set up to select tasks for F-16C retrofit, Near Term and Far Term aircraft (based on complexity and cost).

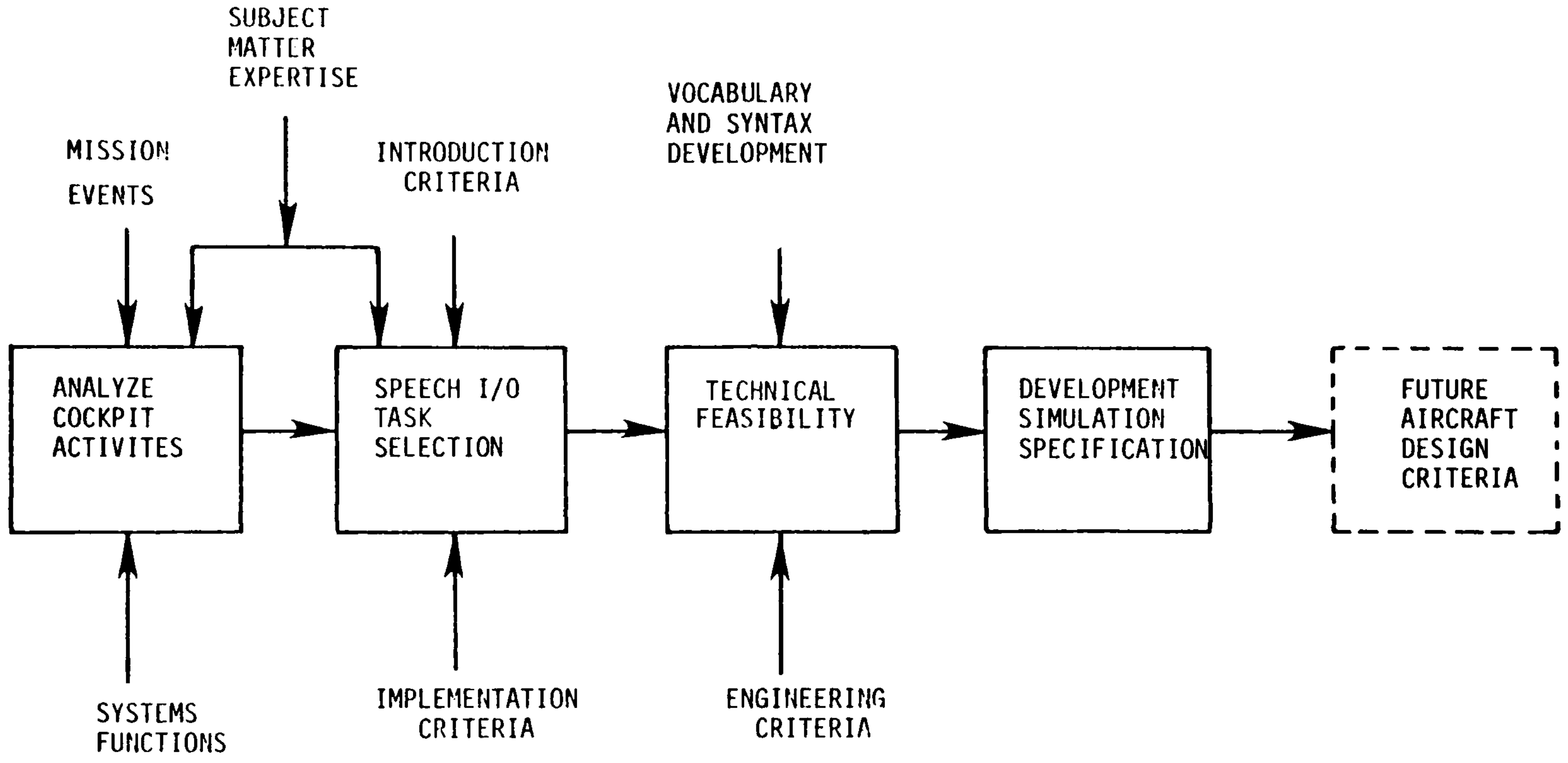


Figure 1. Project Phases for Speech Technology Applications in Future Tactical Aircraft Cockpit Design.

4. Development Simulation Specification - A work statement was generated which delineated the requirements for a development simulation to advance the findings of this study. The work statement assumed that this work would be done in a pseudo operational environment (like an operational flight trainer). Although the statement was directed at validating the findings of the study, we also identified those research issues which are amenable to resolution as part of the simulation.

5. Future Aircraft Design Criteria - In this final phase we attempted to identify the design criteria for the introduction of speech as an information input/output mode between the pilot and systems of future tactical aircraft (both Near Term and Far Term). Retrofit of existing aircraft configurations (like the F-16C) was not considered.

INFORMATION SOURCES

Two sources of information were available for the study, tactical aircraft documents and subject matter experts (qualified fighter pilots).

Documents

The following documents were available:

1. F-16A Flight Manual USAF T.O. 1F-16A-1 and T.O. 1F-16A-34-1-1 which described the aircraft systems and their performance. This information was considered to be baseline systems data.

2. Minutes of the F-16 C/D Avionics System Design Review meeting in February 1982 between General Dynamics and the USAF described the avionic systems to be used in the F-16C and cockpit configuration.

3. Mission scenarios for the Near Term and Far Term aircraft have been produced by both Rockwell International and General Dynamics Corporation for the USAF. These studies provided the basis for developing a composite scenario to evaluate the viability of cockpit speech I/O in a European short range interdiction setting. The composite scenario was then used as the focus of discussions with the operational fighter pilot community.

4. Automation in Combat Aircraft cockpits, the proceedings of an industry workshop conducted under the auspices of the National Research Council in 1981.

Subject Matter Experts (SME)

SMEs were drawn from the fighter pilot community at different levels of duties, experience in tactical aircraft and experience in the F-16A aircraft. Pilots from Edwards and Nellis Air Force Bases participated in discussion, structured interviews, group testing and general advise on the subject matter. The pilots represented a variety of duties with respect to the F-16, including operational test and evaluation, tactical instruction and operational squadrons.

SCENARIO DEVELOPMENT

Knowledge of cockpit activities was essential to enable selection of speech I/O candidate tasks and to develop criteria on which the implementation of these tasks should be based. Figure 2 shows the relationship and magnitude of cockpit activities and the mission. The multiplicity of cockpit activities carried out by a pilot during various missions was often difficult for him to describe.

A variety of scenarios were developed as focal points to help extract the cockpit activity information. Six scenarios were examined, covering Near Term and Far Term aircraft operations in VFR/IFR and Day/Night conditions. It became clear that each scenario was written at a level too high (general) to facilitate the extraction of cockpit activity commensurate with the analysis of speech I/O tasks. Eventually, one composite scenario was developed, based on a European short range interdiction in a combination of day/night VFR/IFR conditions. The study strategy was to analyze the modifying effect of other scenarios, such as a night time mission with an advanced system like LANTIRN.

SPEECH I/O CANDIDATE TASK SELECTION

The task selection process is shown in block diagram format in Figure 3. Candidate task identification was based primarily on the outcome of structured interviews of 13 pilots at Nellis AFB during April 1982. The survey used the composite scenario as the focus to ask each pilot to evaluate each listed cockpit task for speech I/O suitability. A total of 71 tasks were used in the survey for the following mission segments:

- Cruise Out
- Penetrate
- Attack
- Egress
- Air-to-Air Engagement
- Air Refueling
- Equipment Failure (during approach)

These mission segments were chosen as being representative of periods when cockpit activities would be high. During this survey the pilot also was asked to consider the use of speech I/O in relationship to an "intelligent" black box equivalent to having a second person in the back seat. This black box concept was identified as a "Black Box Back Seater," referred to as "B3." Much additional information was gathered about B3 functions as enhancements to a speech I/O interface.

Candidate task selection also was influenced by the opinions expressed by the 16 F-16 pilots who were interviewed at Nellis and Edwards AFBs during the study. Over 200 comments were recorded by the study team, although some were considered duplications or variations of a common theme. The process of sorting the 200 comments provided much information which eventually crystalized as candidate applications and research issues for the use of speech as an information input/output mode.

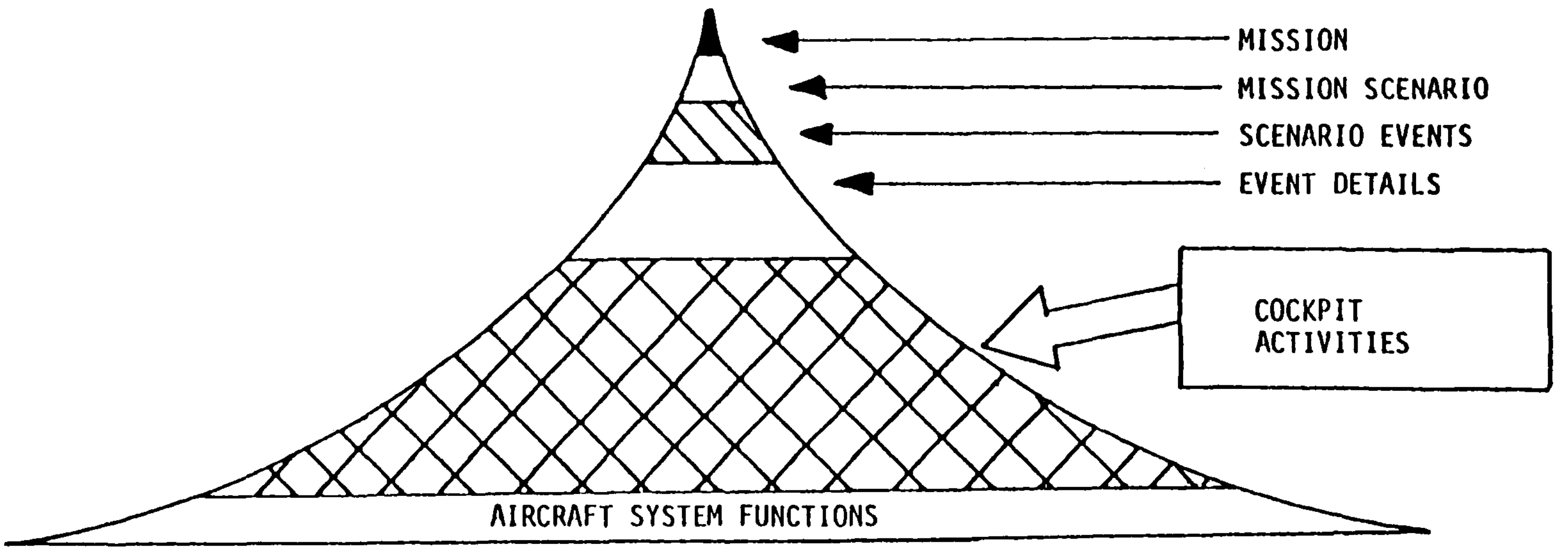


Figure 2. The "Top Down" Relationship Between a Mission, Cockpit Activities and Related Aircraft System Functions.

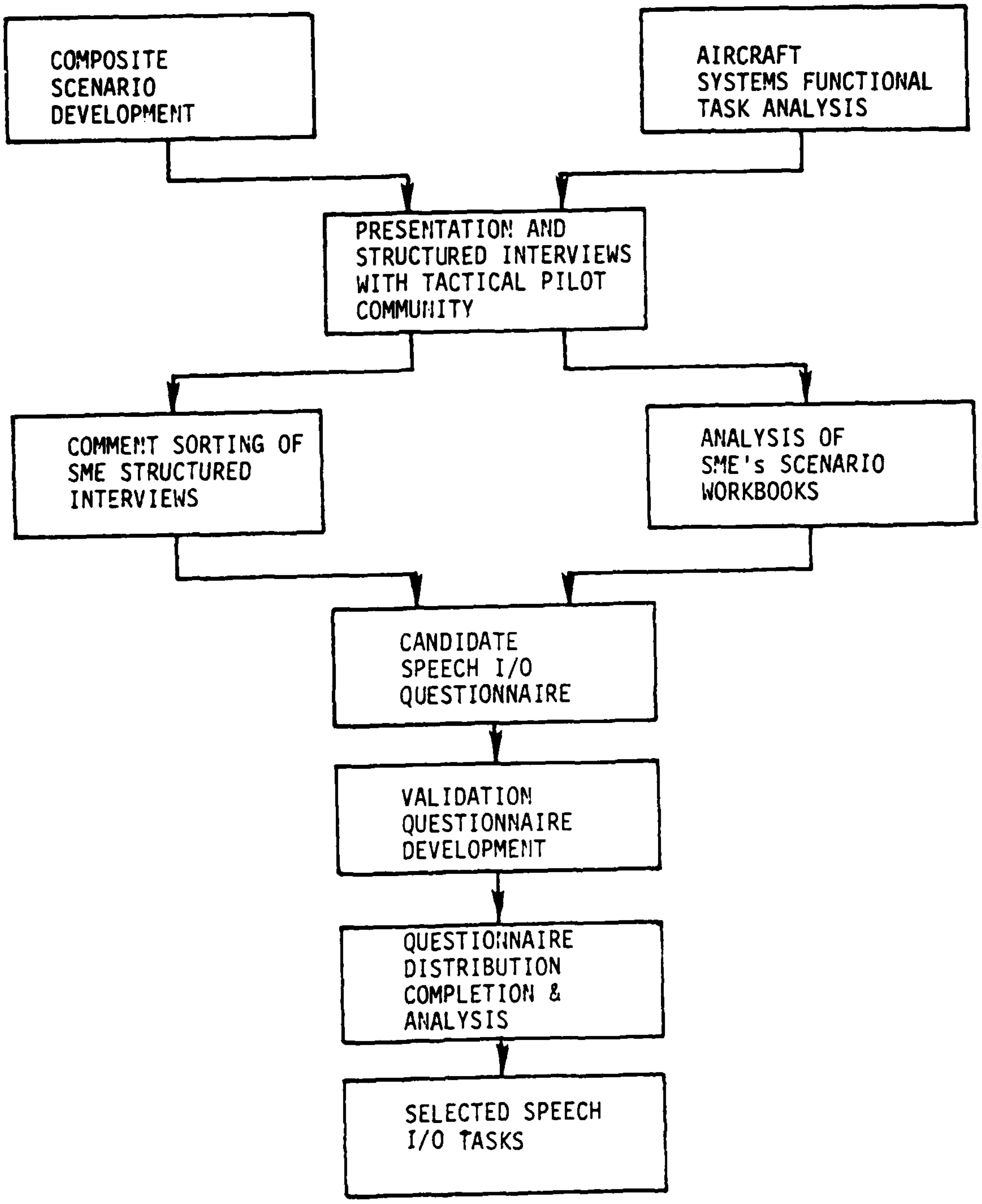


Figure 3. Selection Process for Speech I/O Tasks.

Based on the candidate task selection data, a questionnaire was developed and distributed to pilots who had been briefed on the study. This questionnaire solicited ratings for each speech application on a scale of 1-6 representing the usefulness of the application. Questionnaires were given only to the nine pilots who had previously participated in the study because the in-depth interviews on speech I/O applications prepared them to respond meaningfully.

A streamlined version of the questionnaire was administered to a larger number of F-16 pilots in operational squadrons to validate the candidate speech tasks selected by the initial sample at the Fighter Weapons School.

SYNTAX AND VOCABULARY DEVELOPMENT

One of the most important human interface issues in mechanizing speech I/O for airborne systems is the design of the dialogue between the speech recognition system, speech generation system, and the pilot. This process consists of selecting the vocabulary, governing the content of the commands, and establishing the rules of syntax. In order to minimize pilot training requirements and ensure pilot acceptance, vocabulary selection must follow the common nomenclature of the particular aircraft. A proposed speech input and output vocabulary for tactical aircraft speech application is shown in Table 1.

The manner in which the speech recognition system recognizes single words and words strung together into phrases or expressions relies on three different levels of logical rules. The rules consist of:

- Front-end speech recognizer rules
- Grammatical rules (syntax)
- Situational logic rules.

These rules can be described as comprising a speech understanding logic, as depicted in Figure 4. The majority of short phrases (e.g., one or two words) can be handled directly by the rules of speech pattern recognition provided by the acoustical front-end processing of the recognizer.

Longer sequences of speech input are handled initially according to the same set of acoustical pattern recognition rules. However, when recognition confusion or ambiguity exists, a more sophisticated set of rules must be applied. These are known as grammatical rules which describe the relationships among the vocabulary units. An example of a set of these syntactical rules which apply to tactical aircraft is shown in Table 2 and Figure 5.

The third set of rules are based on the status of the aircraft systems, the flight regime and mission phase. These provide the check and balance (shown as feedback in Figure 4) of the accuracy of the speech recognition system. For the safety of flight, and the continuing acceptance of the speech interface by the pilot, it is considered essential that each recognition input be checked against the operational status of the

TABLE 1. COMPOSITE SCENARIO

PRESTART CHECK
ENGINE START
PRETAXI
TAKEOFF
RENDEZVOUS
CLIMB

CRUISE OUT
PENETRATE
STRIKE
EGRESS

CLIMB & DECELERATE
*AIR-TO-AIR ENGAGMENT
CRUISE BACK
*AIR REFUELLING
APPROACH
*AIRCRAFT SYSTEM FAILURE
FINAL APPROACH
GROUND ROLL
TAXI
SHUT DOWN

NOTE: 1. Boxed events were considered for high cockpit activity.

2. *Events added to the European S.R.I. and also considered for potential high cockpit activity

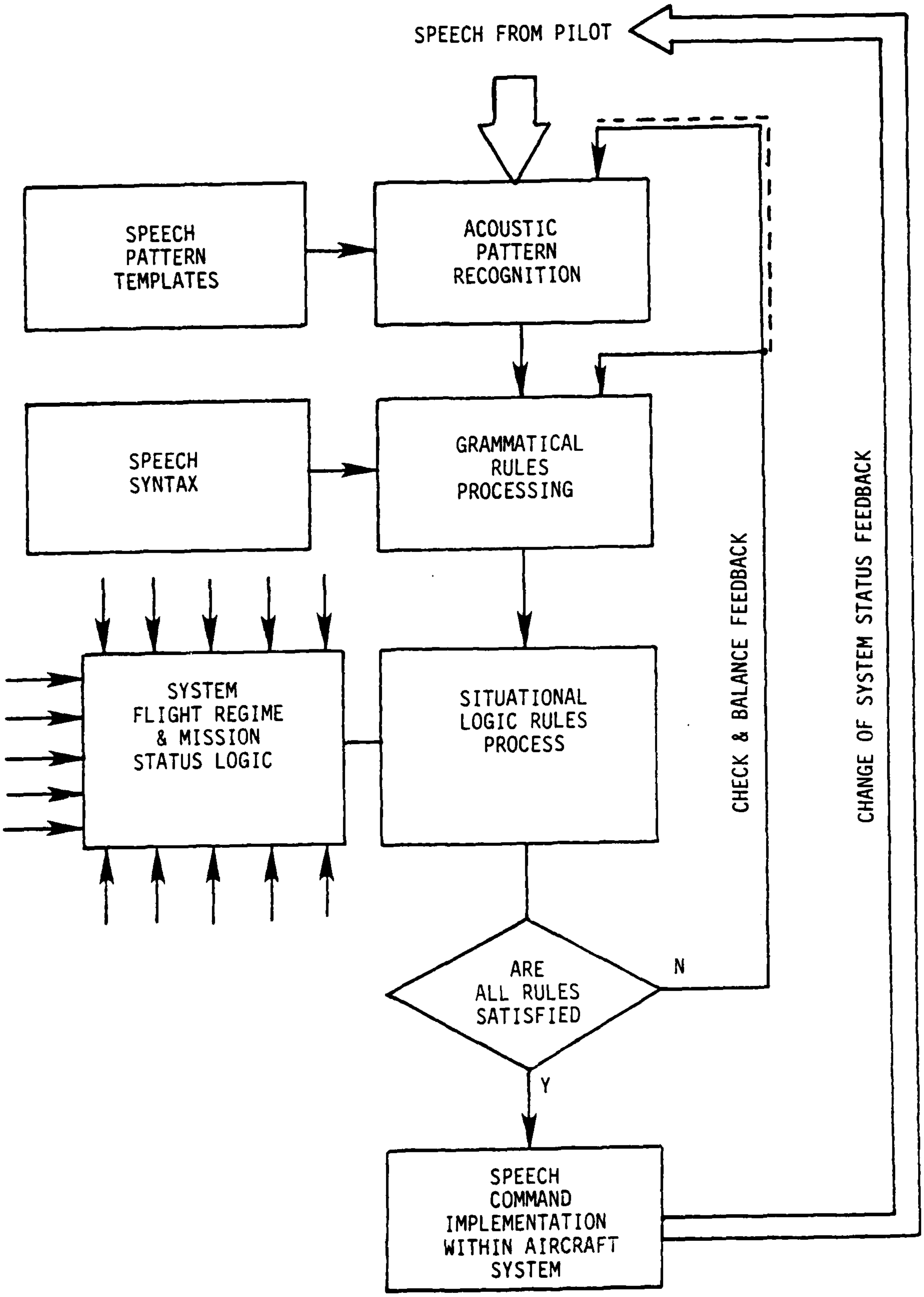


Figure 4. Speech Understanding Logic Relationships.

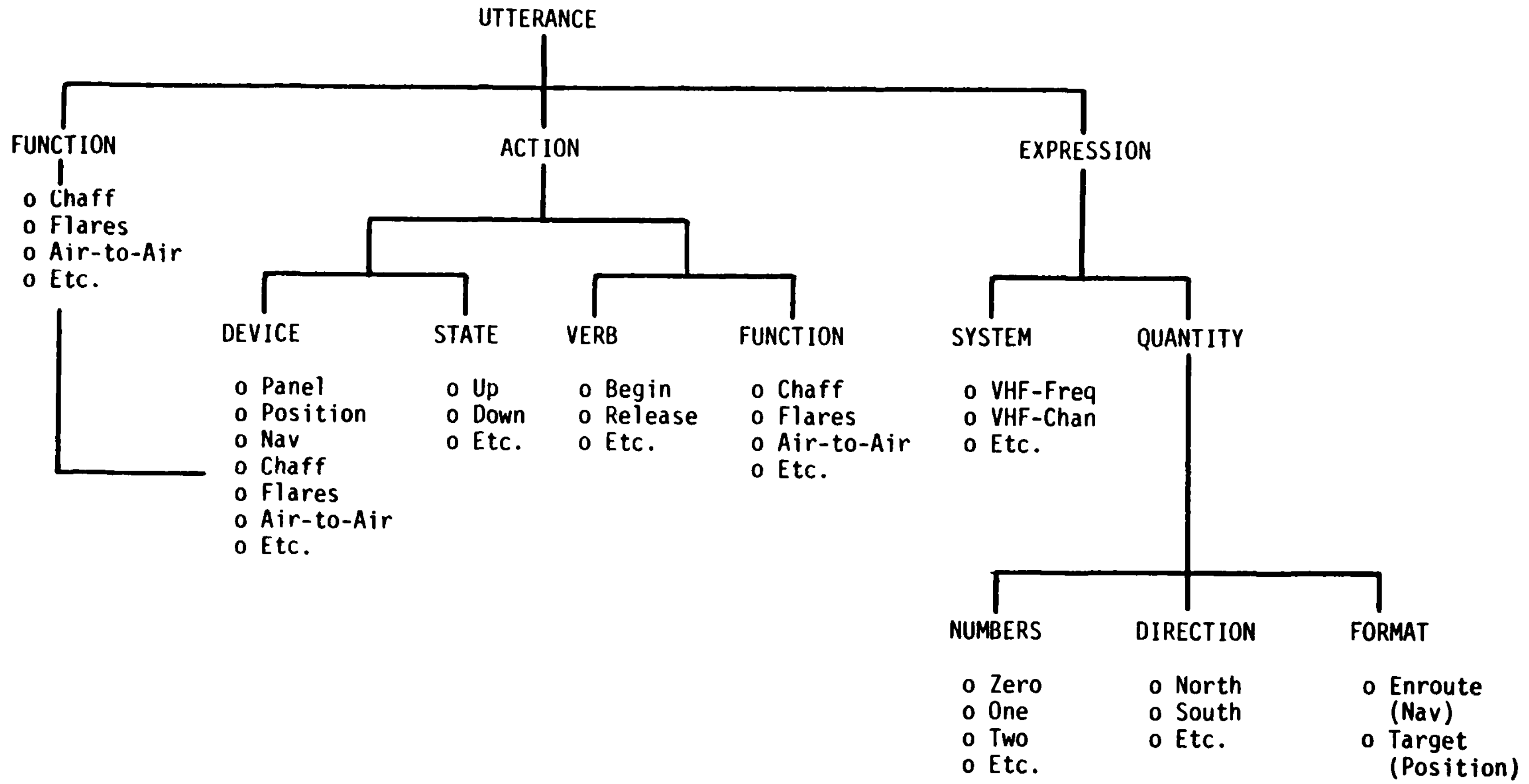


Figure 5. Depiction of Syntax.

TABLE 2. PROPOSED SPEECH INPUT SYNTAX

```
UTTERANCE ::=  function | action | expression

FUNCTION   ::= CHAFF | FLARES | ECM | MASTER-ARM | LANTIRN-SEARCH |
               AIR-TO-GROUND | AIR-TO-AIR    | ... | FUEL-REMAINING |
               STORES-REMAINING | HEADING-TO-ALTERNATE | CLIMB | DESCENT

ACTION     ::= device + state | verb + function

DEVICE     ::= function | PANEL(LIGHTS) | POSITION(LIGHTS) |
               NAV(LIGHTS)

STATE      ::= UP | DOWN | OFF | ON | MODE | RELEASED

VERB       ::= BEGIN | RELEASE | BEGIN-CHECKLIST | HALT-CHECKLIST |
               RESUME-CHECKLIST

EXPRESSION::= system + quantity + OVER

SYSTEM     ::= VHF-FREQUENCY | VHF-CHANNEL | UHF-FREQUENCY | UHF-CHANNEL |
               TACAN | AIM | (LOAD)-DP | (LOAD)-FUEL | DISPLAY |
               UPDATE-DP |

QUANTITY   ::= number [units] [direction] [quantity] | format [direction]

NUMBER     ::= ZERO | ONE | TWO | THREE | FOUR | FIVE | SIX | SEVEN |
               EIGHT | NINER | TEN | ELEVEN | TWELVE | THIRTEEN |
               FOURTEEN | FIFTEEN | SIXTEEN | SEVENTEEN | EIGHTEEN |
               NINETEEN | TWENTY | THIRTY | FORTY | FIFTY | SIXTY |
               SEVENTY | EIGHTY | NINETY | HUNDRED | THOUSAND |
               PLUS | MINUS | POINT

DIRECTION ::= NORTH | SOUTH | EAST | WEST | RIGHT | LEFT | MARK |
               FORWARD(TANK) | AFT(TANK)

UNITS      ::= DEGREES | POUNDS | ALPHA | BRAVO | CHARLIE | ... | ZULU |

FORMAT     ::= ENROUTE(NAV) | TARGET-(POSITION) | CLIMB-(PROFILE) |
               JTIDS-(UPDATE) | STORES-(CONFIGURATION) | FENCE-(CHECKLIST)
```

NOTE: Parentheses indicate a specific example and brackets indicate a generic category.

aircraft before it is executed. The basis for such an intelligent speech recognition system exists in the vast amount of information that the aircraft already "knows" about itself. When this information is made available to the speech system, each speech recognition can be tested for compliance with predefined situational parameters before the specific command is implemented. This concept is the origin of intelligent system operation. As computer intelligence capability grows, we can anticipate a trend toward allowing the pilot to speak in free-format phrases with less adherence to syntactical rules dictating the order of verbs, nouns, and modifiers. Until the "natural language understanding" capability is reality, we must anticipate a need to either (1) "lockstep" the user through a complex speech I/O transaction using prompts and menus, or (2) dictate a syntactical structure that must be followed to execute the desired actions. It seems clear that the second alternative is preferred in the tactical cockpit.

VALIDATION AND VERIFICATION OF SELECTED SPEECH I/O TASKS

Initial selection of speech I/O tasks was accomplished by a questionnaire survey of F-16 pilots at Fighter Weapons School, which was used to select "candidate" speech I/O tasks. The selected tasks were then subject to a technical feasibility phase which judged whether they could be engineered into the aircraft systems. The selected tasks were then subjected to validation/verification by a larger segment of the population of F-16A pilots by administering a shortened form of the questionnaire survey to three operational squadrons of the 474th Tactical Fighter Wing at Nellis AFB.

RESEARCH ISSUE DEVELOPMENT

A total of 18 research issues were identified during this study. They have been classified into six broad groups: planning, role of speech I/O in the cockpit, cognitive limitations, acoustic environment, operational environment and information queueing. The timing has been identified between the research issue and the need for the related speech system implementation. This has been done to foster the generation of future milestones for the organization responsible for addressing the research issues. These R&D issues are presented in Appendix A.

An OFT or full mission simulator seems to be the most suitable environment to resolve many of the issues generated by the study.

SIMULATION GUIDELINES

The analyses conducted for the present study provided the formulation for generating a framework for further development of speech I/O in the fighter cockpit. This development process was deemed most suitable for a simulation environment. Consequently, the results of the present study were formulated into preliminary guidelines for simulation in support of speech I/O development, given in Appendix B.

SECTION II

DETERMINING AIRCRAFT SYSTEM FUNCTIONS

INTRODUCTION

A thorough evaluation of speech as a cockpit I/O mode must be based on an understanding of: 1) each system function which the pilot must perform or respond to; 2) the relationship among system functions (intra or inter system).

Although the F-16A cockpit was used as the baseline for this phase of the study, the cockpit was already being redesigned in both the Multi Stage Improvement Program (MSIP) and the Advanced Fighter Technology Integration (AFTI) programs. However, very similar functions must be performed irrespective of the F-16 model (or any other tactical aircraft). In summary, it was essential to know what activities occurred in the cockpit and how the various aircraft system functions related to the conduct of a mission.

METHOD OF TASK ASSESSMENT

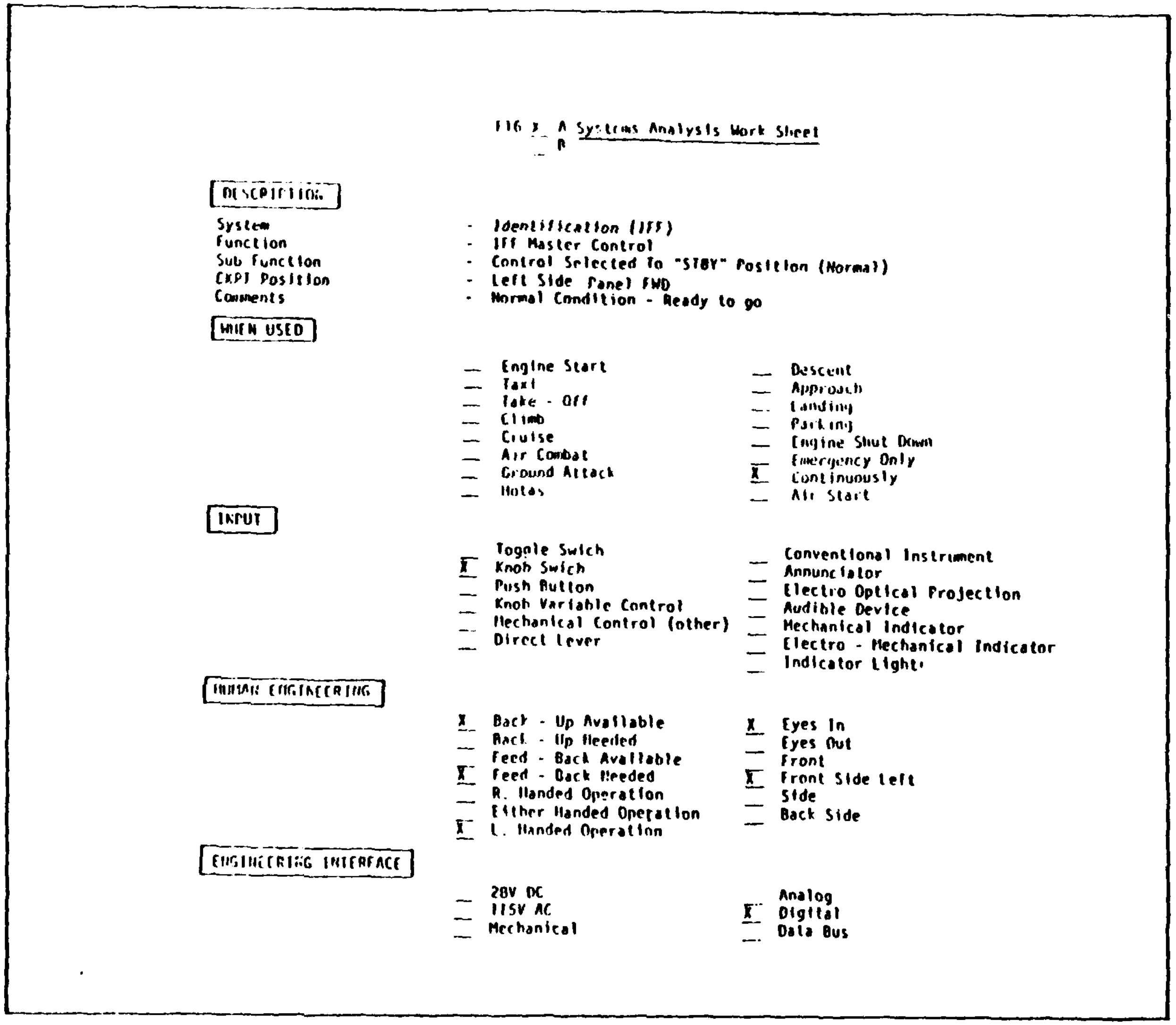
Each F-16A system was studied using the aircraft flight manuals. (Nuclear stores management and release were excluded). Each discrete event such as switch position, knob position, light on/off condition, instrument reading, digital readout, was analyzed for type, functional content, human engineering factors, and system interface design. Each task was recorded on a separate form, an example of which is shown in Figure 6. A total of 37 systems were analyzed; 726 system input/output tasks were identified and documented.

IDENTIFYING THE MORE COMPLEX SYSTEMS

Initially the analysis was directed at understanding the aircraft systems and their use during a mission. Subsequent analysis of the data identified potential speech I/O areas based on their complexity as represented by the number of unique tasks in each system. The results of this analysis is shown in Figure 7. Note that the ten hatched areas account for 68% of all discrete functional tasks (The escape system was considered inappropriate for speech I/O). The ten top ranked systems based on discrete functional task content are also shown in Table 3.

PILOT/SYSTEM INTERFACING DEVICES

One outcome of the F-16 cockpit function analysis was the evidence of the many types of interfacing devices with which the pilot must contend. There is no standard panel layout or switch. For example, a spring-loaded switch and a push button can both be used to establish a momentary contact. The shape of many devices like knobs and levers are intentionally made different to enable the pilot to discriminate among them tactually, while flying "heads out."



F16 ☒ A Systems Analysis Work Sheet
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DESCRIPTION

System	- Identification (IFF)
Function	- IFF Master Control
Sub Function	- Control Selected To "STBY" Position (Normal)
CKPT Position	- Left Side Panel FWD
Comments	- Normal Condition - Ready to go

WHEN USED

- ☐ Engine Start
- ☐ Taxi
- ☐ Take - Off
- ☐ Climb
- ☐ Cruise
- ☐ Air Combat
- ☐ Ground Attack
- ☐ Hotas
- ☐ Descent
- ☐ Approach
- ☐ Landing
- ☐ Parking
- ☐ Engine Shut Down
- ☐ Emergency Only
- ☒ Continuously
- ☐ Air Start

INPUT

- ☐ Toggle Swich
- ☒ Knob Swich
- ☐ Push Button
- ☐ Knob Variable Control
- ☐ Mechanical Control (other)
- ☐ Direct Lever
- ☐ Conventional Instrument
- ☐ Annunciator
- ☐ Electro Optical Projection
- ☐ Audible Device
- ☐ Mechanical Indicator
- ☐ Electro - Mechanical Indicator
- ☐ Indicator Light

HUMAN ENGINEERING

- ☒ Back - Up Available
- ☐ Back - Up Needed
- ☐ Feed - Back Available
- ☒ Feed - Back Needed
- ☐ R. Handed Operation
- ☐ Either Handed Operation
- ☒ L. Handed Operation
- ☒ Eyes In
- ☐ Eyes Out
- ☐ Front
- ☒ Front Side Left
- ☐ Side
- ☐ Back Side

ENGINEERING INTERFACE

- ☐ 28V DC
- ☐ 115V AC
- ☐ Mechanical
- ☐ Analog
- ☒ Digital
- ☐ Data Bus

Figure 6. Typical Completed Form Used in F-16 Aircraft System Functional Task Analysis.

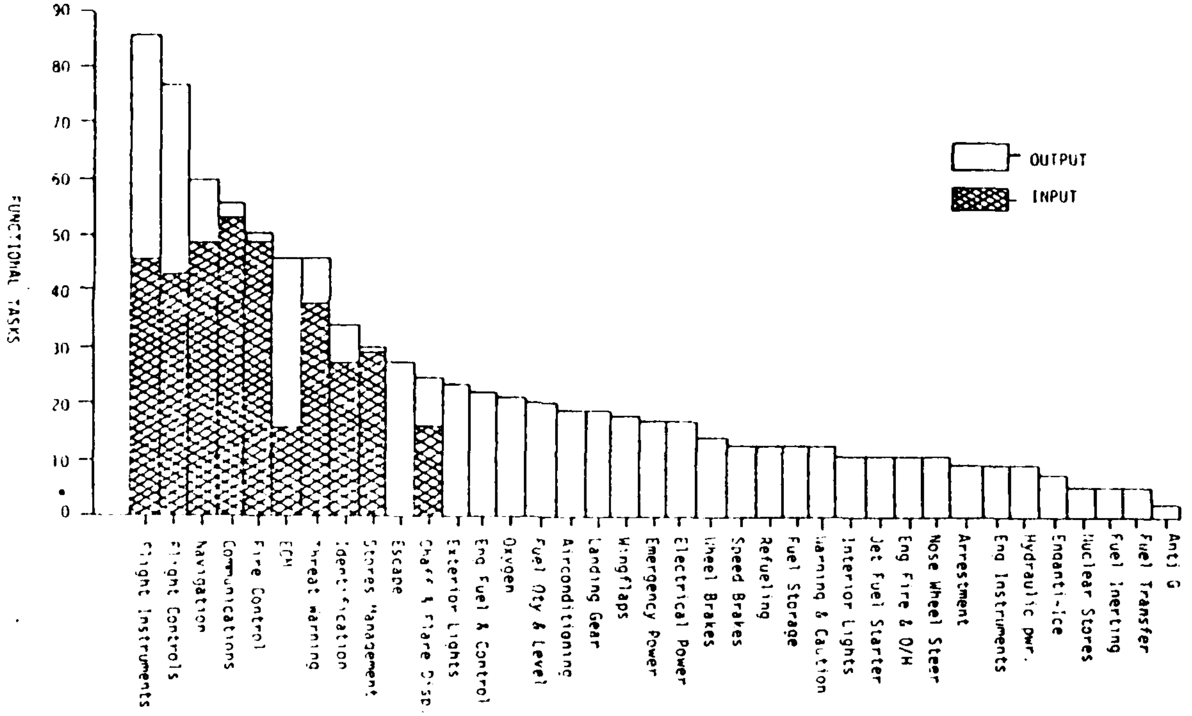


Figure 7. F-16A Cockpit Functional Task Ranking (N=726).

TABLE 3. F-16A TOP TEN FUNCTIONAL SYSTEMS BY TASK COUNT

	PERCENT	
	INPUT	OUTPUT
FLIGHT INSTRUMENTS	5.92	5.92
FLIGHT CONTROLS	5.51	5.10
NAVIGATIONS	6.61	1.52
COMMUNICATIONS	7.03	0.04
FIRE CONTROL	6.47	0.14
ELECTRONIC COUNTER MEASURES	1.65	4.13
THREAT WARNING	4.82	0.96
IDENTIFICATION	3.58	0.83
STORES MANAGEMENT	3.86	0.04
CHAFF & FLARE DISPENSING	1.79	1.38

NOTE: THESE 10 SYSTEMS ACCOUNT FOR 68% OF FUNCTIONAL TASKS

How does this situation apply to speech I/O? When a speech input is used to change system status, feedback must be provided to the pilot. For the F-16A and F-16C cockpits, in many cases, this will mean mechanically moving a toggle switch, turning a knob or rotating a thumbwheel to a new position. It is a difficult design problem to accomplish these actions automatically in the confinement of the F-16 cockpit. We suspect that if a trade-off is made, (which includes cost) the evidence will be against incorporating the speech interfaces which involve changing the status of toggle switches and knobs to be compatible with changes in system status which are achieved by voice command.

For a viable speech input interface in a cockpit, new types of switches must be integrated into the control panel. Touch switches and push switches with rear-lit annunciation are potential candidates to solve the problem in new cockpit designs. Spring-loaded switches with remote annunciation of system status may provide a solution when retrofitting speech input to existing "toggle and knob" cockpits.

SYSTEM ENGINEERING CONSIDERATIONS

Basically the F-16A and F-16C aircraft are designed with inter and intra system connection based on analog principles. A powerful digital bus system services the more complex navigation, fire control, HUD, ECM and threat warning systems. It is the latter systems which are identified for speech input/output and, from an engineering standpoint, are attractive interfaces to design because the speech input/output can be another digital signal on an existing bus system. However, researchers often think that just because a digital bus exists, every piece of information is available continually on the bus. Not so, only those parameters which need to be interchanged between subsystems normally appear on the bus.

Although we did not study the purpose of each parameter on the F-16A and F-16C bus systems, we would be surprised if the existing bus information were adequate for retrofitting a limited speech I/O system including an intelligent black box (B3). However, there may be word address and timing limitations for additional signals which would be convenient for speech I/O.

The F-16 aircraft system study raises two issues in the area of digital engineering research. First, future aircraft which use speech I/O should have a bus system that is commensurately flexible with the demands that the pilot and/or the related aircraft systems can place on it. Second, the redundancy afforded speech I/O functions must be equal to or better than the functions of the systems it is controlling. The latter suggests distributing the speech I/O function around the networked systems rather than concentrating it in one "black box."

SECTION III

SCENARIO DEVELOPMENT FOR SPEECH I/O ANALYSES

AVAILABLE SCENARIOS

Two documents were provided by the Government to provide mission scenario data. These were:

1. Air-to-Ground Cockpit Design. Rockwell International for AFFDL, 1979. (Secret)

2. Flight Management for Air-to-Surface Weapon Delivery: Mission Scenarios. General Dynamics for AFWAL/FIGR, 1981. (Secret)

The first document was developed for the Near Term timeframe; the second document was developed for the Far Term timeframe. Neither document was developed in sufficient detail so that it could be directly applied to the study. They were written at the mission event level and did not provide details that could be developed into a sequence of cockpit activities. Furthermore, the far term document was even more lacking in detail because critical events like a surface-to-air missile evasive action were developed around aircraft/missile technology which is nebulous at this time.

Originally the program proposal called for modifying the Near Term and Far Term scenarios to make them compatible with evaluating cockpit activities related to speech I/O. After reviewing the Government documentation, it became obvious that scenario data would have to be developed rather than modifying existing material.

SCENARIO DEVELOPMENT

First, a composite scenario was selected based on a Near Term European short range interdiction mission. The profile of this scenario is shown in Figure 8 and Table 4. Other scenario events, suspected to have speech I/O applications, were added to form a composite scenario. These events were air-to-air engagement, air refueling and an aircraft system failure.

Second, an attempt was made to expand the critical segments in the scenario (i.e., cruise out, penetrate, strike and egress) to achieve a level of detail that would be related to cockpit activities. It was intended that the data could be corrobrated by operational pilots and provide sufficient detail to elicit speech I/O considerations for each listed task. However, the number of tasks became overwhelming. At the first rudimentary pass through the four critical segments, over 150 activities were documented. The use of such a document for eliciting pilot's comments about speech I/O was considered to be too detailed and overly burdensome for the pilots.

The speech I/O scenario was developed with the assistance of senior operational test and evaluation pilots with F-16 experience. An example from the resultant scenario is shown in workbook format in Figure 9.

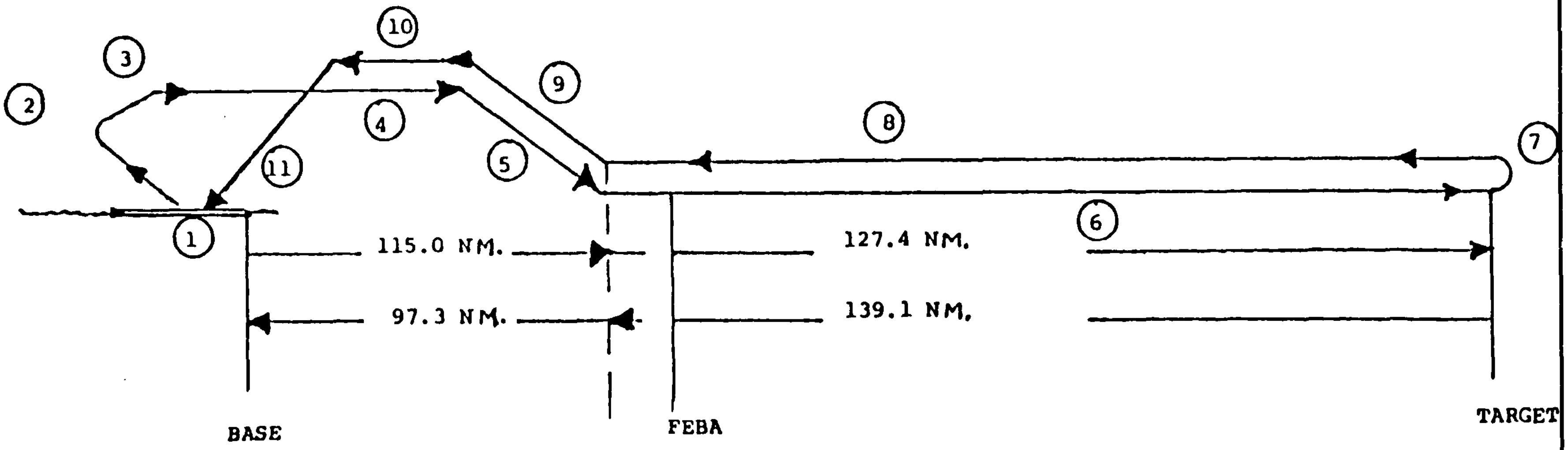


Figure 8. Short Range Interdiction Profile.

TABLE 4. COMPOSITE SCENARIO

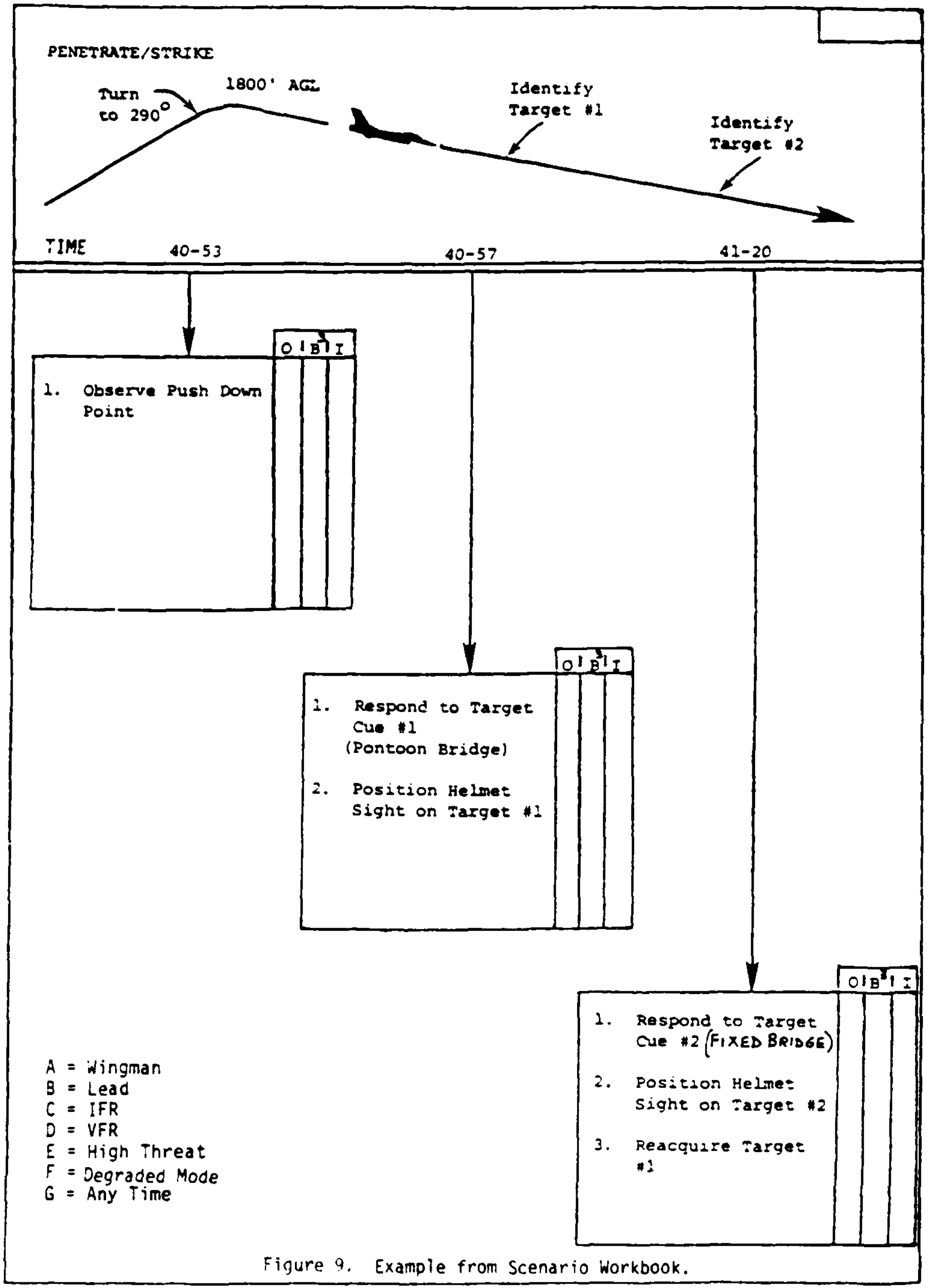
PRESTART CHECK
ENGINE START
PRETAXI
TAKEOFF
RENDEZVOUS
CLIMB

CRUISE OUT
PENETRATE
STRIKE
EGRESS

CLIMB & DECELERATE
*AIR-TO-AIR ENGAGMENT
CRUISE BACK
*AIR REFUELLING
APPROACH
*AIRCRAFT SYSTEM FAILURE
FINAL APPROACH
GROUND ROLL
TAXI
SHUT DOWN

NOTE: 1. Boxed events were considered for high cockpit activity.

2. *Events added to the European S.R.I. and also considered for potential high cockpit activity



PENETRATE/STRIKE

Turn to 290°

1800' AGL

Identify Target #1

Identify Target #2

TIME 40-53 40-57 41-20

O | B | I

1. Observe Push Down Point

O | B | I

1. Respond to Target Cue #1 (Pontoon Bridge)
2. Position Helmet Sight on Target #1

O | B | I

1. Respond to Target Cue #2 (FIXED BRIDGE)
2. Position Helmet Sight on Target #2
3. Reacquire Target #1

A = Wingman
B = Lead
C = IFR
D = VFR
E = High Threat
F = Degraded Mode
G = Any Time

Figure 9. Example from Scenario Workbook.

Subsequent evaluation of the scenario by instructor pilots at the Fighter Weapons School and the #422 Test and Evaluation Squadron (TES) at Nellis AFB suggest that it was at an appropriate level of detail for the study.

The scenario included both IFR and VFR daylight segments. Additional scenario events to include night operations with specialized equipment (LANTIRN) were not developed in a formal manner. However, specific requirements arising out of night operation events and special systems were included in the data gathered at the structured interviews with the pilot community.

Structured Interviews

These interviews took place in conjunction with presenting the scenario work book to individual pilots. The interviews were facilitated by a group meeting in which a demonstration of the speech I/O concept was given. The demonstration system, developed previously by Honeywell SRC and the Flight Dynamics Laboratory, included a stores management scenario executed by computer graphics and an off-the-shelf speech system driven by a microprocessor. The demonstration enabled the pilots to understand the potential role of speech I/O by providing concrete examples.

The structured interviews also were used to solicit other operational variations which could modify the opinions expressed in the scenario work books. These operational variations included:

1. Wearing CBR gear.
2. Use of LANTIRN.
3. Debriefing and briefing during short turn arounds.

SCENARIO SUMMARY

The composite scenario, which had a tenuous beginning, stood up well to operational critique.

The available Far Term scenario material was not sufficiently robust to facilitate the development of a speech I/O specific scenario. It is likely that the generic categories which have been developed for the Near Term aircraft will be applicable to the Far Term aircraft. Thus, the need for a hypothetical far term scenario is not clear at this time.

SECTION IV

SPEECH I/O APPLICATIONS DEVELOPMENT

UNDERSTANDING THE COCKPIT OPERATING PROBLEM

Pilot Workload

The number of cockpit functions available to the fighter pilot have increased enormously since World War II. Advances in technology have created multi-modal systems, multi-function displays and a potential information overload for the pilot (Frazier and Crombie, 1982). It is no longer simply a matter of stick and throttle, seat-of-the-pants, and nerves of steel. A pilot must understand the mission objectives and the strategy and tactics available to him. His basic goals are to optimize mission success and to survive. To achieve these goals he must operate, manage, and control a large number of aircraft systems.

Visual and manual channels are highly loaded for the pilot of the present day fighter. Visual search occurs not only outside the cockpit, in searching for destination points, targets, and air traffic, but also within the cockpit, scanning the displays for information. Inside the cockpit the information obtained visually consists of both system status information as well as symbology that represents the outside world, such as radar. The pilot must visually monitor a large amount of information to achieve the desired enabling objectives of his mission.

Although the pilot is confronted with a vast array of information, his eyes can only perceive with good acuity in foveal vision which subtends only a few degrees of visual angle. Without being aware of it, the pilot is extremely busy in sampling information by eye movements during flight. This relates to one of the most important characteristics of the highly trained fighter pilot which is his control over his own attention shifts. He must know what information is needed, when it is needed, and where he can get it.

The pilot controls his aircraft systems almost entirely by means of manual input. The manual input may be discrete, such as button pushes or rotary switch positions, or it may be continuous as in stick and throttle control.

Speech I/O provides a method for off-loading the extremely busy channel of eyes/hands. Asking for information and receiving it verbally is a very natural form of human communication. It has been used routinely in two-seat fighters, but it has never been available to the pilot of a single seat fighter. Advances in technology now make this form of information exchange possible. Speech I/O may be a valuable asset to the pilot when he desires to input a command or to extract information from an onboard computer while keeping his eyes out of the cockpit and/or while keeping his hands on the throttle and stick (HOTAS).

Eyes In/Out

An eye movement requires 200 msec. on the average. One cycle of eyes-in, look at a gauge or instrument, and eyes back out, probably takes a minimum of one second. At an air speed of 500 knots this one second translates to a meaningful distance, particularly at low altitude. In certain situations, such as low level flight or flying wing, the pilot may prefer not to interact with an onboard computer by looking down into the cockpit at a keyboard, taking his hand off the stick or throttle, and keying-in the information. Speech input allows the pilot an alternative method for data input while remaining eyes-out.

Wingman/Lead

The pilot of the lead aircraft has more opportunity to fly eyes-in than the pilot flying on the wing. The wingman may wish to accomplish some cockpit functions while remaining HOTAS and eyes-out. This is particularly true when flying a tight formation, or when flying formation in deteriorating weather or relatively low level. In otherwords, combinations of circumstances may induce a strong desire to remain eyes-out and HOTAS.

High Threat

Information about high threat is of utmost interest to the pilot. It has high survival value. Accurate and timely information about the threat type and location would be very useful to the pilot. Speech output provides a possible way to present this information. This assumes, however, that the speech output is driven by very accurate threat assessment information. In a high threat environment the pilot would like to spend minimum time with eyes in the cockpit. Speech output represents a valuable method for presenting information to the pilot in a high-threat environment. The HUD, of course, remains another medium for displaying important information while remaining eyes-out. The potential difficulty of using speech output in a high-threat environment is to avoid "communications clutter."

Communication Clutter

Although the pilot receives most information visually, our F-16 SMEs report that a considerable amount of communications clutter occurs during periods of heavy action. At that time radio communications may include the ground, FAC, friendlies, etc. The pilot must process all of this information, often over noisy radios, and he must integrate it within the context of the current tactical situation. Meanwhile, he must fly his aircraft, accomplish the mission, and survive. Speech output must <u>not</u> interfere with these tasks. Speech output, however, can contribute to success when it is available to provide information about high threats, or other information as requested by the pilot.

The challenge is how to design the audio world of the cockpit to provide: 1) alerting tones; 2) prioritization of messages; 3) infomation presentation; and 4) allow for pilot control over the message queue.

Caution/Warning

There are at least two stages of information that must be given to the pilot for caution or warnings. The first is to get his attention. This simply indicates to him that there is some problem. The second is to provide information about the nature of the problem. This type of information must be prioritized relative to other information that the pilot is processing at the time. For example, many caution messages would not be appreciated by the pilot during a high threat environment. There is, therefore, a need for the pilot to be able to control the caution/warning information flow relative to his current situation.

Auditory tones can be used for the first function mentioned above i.e., alerting or attention getting. Speech output is well suited to the second type of information i.e., identifying the problem. The use of voice warnings is being studied for the F-16 (Davis and Stockton, 1982), and the use of tones and verbal information in the cockpit has been studied by Simpson and Williams (1980).

Information Flow

Speech I/O capabilities should be added to the fighter cockpit only through the careful integration of visual and auditory information presentation to pilot. Adequate feedback must be provided for each pilot action. This feedback may be either visual, auditory, or haptic (by feel). An analysis of the information flow in the cockpit also must consider the need for the pilot to access needed information. His information sources include his own memory, his knee board, all the cockpit instruments, various modes of MFDs, and radio communication. These sources can be supplemented by an intelligent interactive system which enables the pilot to ask for information verbally and receive it through speech output or visual display.

The temporal aspects of pilot tasks are important in the analyses of cockpit information flow. The sequences of activities which the pilot performs, including perceptual, cognitive and motor activities, must be understood in order to design the information presentation optimally. Such analyses should occur at all task levels in the hierarchy, from macro, such as mission objectives, to micro, such as pushing a button. Additionally, the temporal analysis of cockpit information flow must allow for individual variation among pilots in their inherent characteristics, training, experience, and personal styles.

The impact of speech I/O in this area occurs in several ways: information input can be achieved by speech; the time required for speech input and recognition may be different from manual input; and the time/location/modality of recognition status feedback must be considered.

Similarly, speech output provides another avenue for information presentation to the pilot, and the characteristics of speech output as it effects information flow and cockpit activities must be considered. Speech output can be given when a system reaches a certain status (tactical or system limits, as in a caution). Speech output can be implemented in several different ways: a) preset/fixed for an aircraft type; b) preset before each flight as part of routine aircraft preparation; c) preset before flight by pilot preference; and d) requested during the flight by the pilot. These various implementation strategies range from extremely fixed to extremely flexible with respect to variation in the information flow and the control allocated to the pilot.

Anthropometry

Cockpit real estate is valuable. Information of high importance or high frequency must be readily available to the pilot. Such information currently is most likely to be found on the HUD or central and high in the cockpit. The lowest priority information tends to be available to the side and to the rear of the cockpit where it is difficult to see and to reach without twisting or turning.

Speech I/O may prove beneficial when applied to cockpit functions that need to be upgraded in terms of their real estate allocation, i.e., they are either more important or more frequent than the position to which they have been allocated. Speech I/O allows access without real estate.

Summary of the Cockpit Operating Problem

Speech I/O integration must emphasize the pilot as the central limitation on information flow through the fighter aircraft system. Speech I/O must be designed within the context of the specific aircraft systems and the mission, while maintaining the perspective of information flow through the pilot. This analysis must include: a) sensory modality - vision, hearing, touch; b) temporal requirements for detection/perception, decision making, and action; c) feedback - close the loop around the pilot to verify that the desired state was achieved by his action.

Speech I/O provides a way of putting into the cockpit a natural human medium of information exchange, thereby off-loading the overburdened eyes and hands of the pilot.

THE POTENTIAL CAPABILITIES OF SPEECH I/O TECHNOLOGY IN THE TACTICAL AIRCRAFT COCKPIT

The capabilities and limitations of current speech recognition systems place constraints on certain candidate applications. It is likely that the first airborne recognition system will be an isolated word, speaker dependent system, requiring the user to speak words or short phrases of less than one to two seconds duration, and to "train the system" prior to use.

A discrete word recognition (DWR) system will be quite sufficient for fighter cockpit applications because brief utterances and a relatively limited vocabulary domain are foreseen. However, the requirement to pause between utterances may be uncomfortable for the pilot when he wants to rapidly input a string of digits. For other applications (e.g., mode switching, quick activation) DWR pausing constraints will not impact implementation because one or two word commands will suffice.

The second requirement, system training (also called speech sampling, speech data collection, or enrollment), should be done on the ground (or during a training flight) by storing a pilot's speech data on a miniaturized storage device. Henceforth, the system can be initialized by placing the pilot's card or chip in the airborne computer prior to takeoff.

Speech Synthesis and Digitized Speech Generation (Output)

Verbal outputs can be programmed to cue the pilot when an action is appropriate, warn him of out-of-tolerance conditions, and act as feedback and prompting when making a transaction with the onboard computer (Werkowitz, 1980). There are two categories of hardware techniques that are currently used to produce intelligible speech sounds by machine -- synthesized and digitized waveforms. Synthesized speech requires less computer memory, but produces characteristically metallic, or non-human sounding speech. Digital speech is much more natural, but requires mass storage of digital waveform codes. Digitized speech is created from input by a human speaker, and sounds very natural except at very low bit rates. Compression of digital speech using techniques such as Linear Predictive Coding (LPC) look promising for achieving natural-sounding speech with reduced storage requirements.

Our interview data have indicated that the metallic, unnatural quality of synthesized speech may actually be desirable to the pilot, because it reduces potential confusion with normal radio communications. With either type of system, the computer will have the capability to output any length or content of verbal message to the pilot. Recent research has indicated good response times when pilots are presented with information through speech synthesis (Simpson and Williams, 1980).

APPROACHES TO THE SELECTION OF SPEECH I/O CANDIDATE TASKS

At the initial stages of selecting candidate speech I/O tasks, a decision must be made as to whether an objective or subjective approach will be adopted.

An objective approach, used by North and Lea (1981) focused on using detailed mission profile and timeline data in conjunction with a set of objective criteria for deciding whether given activities were suitable candidates for speech technology consideration. These objective criteria centered around workload reduction (visual/manual task overload and anthropometric constraints). In the above study, objective criteria were used to select tasks that were then verified by subjective procedures using pilot questionnaires.

In the present study less rigid data were available (i.e., mission profile and timelines) because of the variations encountered in typical F-16 sortie procedures. Therefore, the emphasis was shifted to obtaining candidate tasks through intensive, structured subjective procedures. A mission profile/timeline approach was used to guide the subject matter experts in their choice of candidate tasks, but no formal task-sorting procedure was used.

Ultimately, task selection must progress to carefully controlled simulation tests to check the validity of choices. These tests should be made with pilots, and under realistic mission profile conditions. Part-task mock-up simulations of the voice task exchanges may be useful in designing the best exchanges between pilot and system, but care must be exercised in extrapolating results to operational settings. A pilot loading task may be used in these part task simulations to increase time-sharing realism (North and Mountford, 1981). A highly demanding manual/visual control task (e.g., compensatory tracking) may be used to obtain a higher workload level representing flight control, for example.

CANDIDATE SPEECH I/O TASK PRESELECTION PROCESS

Preselecting speech I/O tasks based on previous work on the B-52 (North and Lea, 1981) originally seemed to be an attractive approach to reduce the number of functional tasks involved (over 700). Because of the large differences in tasks between the single-seat fighter and the manned penetration bomber, however, the present study did not rely on prior approaches to the preselection of speech I/O tasks.

The mission scenario which was eventually used for data collection was based on the assumption that potential speech I/O candidates would be identified from the conjunction of the aircraft system functions and the scenario task demands.

The intensive interviews conducted with pilots prior to handing out the scenario workbooks corroborated the validity of the speech I/O selection methodology. However, there were cockpit situations, especially those involving emergency procedures or equipment failure, which suggest that speech I/O could be a viable option for all system functional tasks when a degraded situation exists. These situations are difficult to cover adequately by a scenario/workbook approach. In the present study, we relied on the intensive interviews to extract the candidate speech I/O functions in these emergency equipment failure situations.

DATA COLLECTION AT THE FIGHTER WEAPONS SCHOOL AND 422nd TES

Structured interviews and the completion of the scenario work book were conducted during April 1982 with 13 pilots from the Fighter Weapons School and 422 Operational Test and Evaluation Squadron. All pilots were current in the F-16A. Some were familiar with the F-16C cockpit configuration and later developments such as MSIP and LANTIRN. There were three Majors, one First Lieutenent, and the rest Captains. Most of these pilots had the majority of their flight time in the F-4 aircraft, and 100-800 hours in the F-16.

A general briefing on speech I/O and a demonstration using laboratory equipment preceded the structured interviews. The interviews were conducted with small groups of pilots, usually two or three per group. Following the interviews, the pilots filled out the scenario workbook.

DATA COLLECTION AT EDWARDS AFB

Scenario work books were also completed by three F-16 test pilots from the F-16 Test Program and the F-16 AFTI Joint Test Force. These personnel were included because each had contributed subject matter in prior interviews which led to the eventual development of the work book scenario.

DATA REDUCTION AND IDENTIFICATION OF CANDIDATE SPEECH I/O TASKS

Two types of raw data were reduced; interview notes and completed scenario workbooks. The candidate speech tasks were selected from the combination of these data.

Structured Interview Notes

Over 200 separate notes were produced from the foregoing interviews. This comment data base represents the qualitative assessment of 13 highly experienced tactical pilots giving their opinions about how speech I/O should be used in future tactical aircraft. In generating these subjective opinions the pilots were weighing many factors such as mission events, communications procedures, pilot workload, physical access (anthropometry), and operational constraints.

The data base was divided into the following generic categories:

Speech Input	Number of Items
Information Retrieval Request	15
Data Entry	9
Function Selection	26
Quick Reaction	9
Operating Information Request	3
Speech Output	
Abnormality Information	12
Warning Information	3
Reminder Service	5
Memory Aiding	1
Tactical Information	13
Maneuvering Critical Information	6
State Change Feedback for Cockpit Functions	3

Recorded comments also were sorted for the following research oriented categories, details of which are shown in Appendix A.

Research Issues	Number of Items
Speech I/O Introduction Master Planning	2
Role of Speech I/O in Cockpit	14
Cognitive Limitations for Speech I/O Mode	5
Cognitive Interpretation in Speech I/O	6
Physiological Reactions When Using Speech Mode	3
Speech I/O in Low/High Task Load Situations	5
Speech Output Information Priority	2

This data base became the basis for the discussion of research and development issues presented in Appendix A.

Note that during the sorting process, no attempt was made to remove duplications. Multiple comments on the same subject were treated as corroboration of the importance of the topic.

Scenario Workbooks

The completed workbooks were processed and the data reduced to develop a candidate speech I/O listing based on the scenario. This is shown in Table 5. The "NOs" are shown in Table 6.

Although the scenario workbooks made the pilots consider the importance of speech I/O in each phase of the mission, they did not reflect the wealth of diverse information gathered at the structured interviews. Therefore, the development of the validation questionnaire was weighted in favor of the structured interview data rather than the outcome of the scenario workbooks.

QUESTIONNAIRE DEVELOPMENT

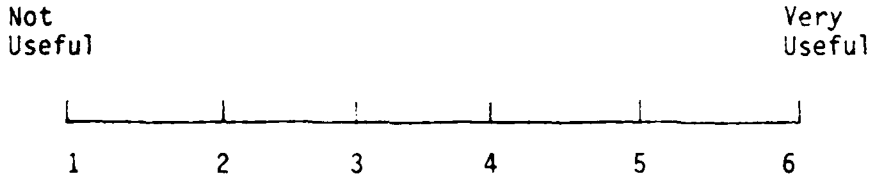
A questionnaire was designed to allow F-16 pilots to assess the utility of speech I/O for a selected group of candidate task applications. The applications were compiled from the pilot interviews described above. Redundancy in pilot commentary was eliminated to produce a final set of 53 potential speech I/O applications for the F-16. Each question addressed certain attributes of the utility of these applications.

The first of three questions for each candidate application asked the pilot to address the utility of switching the task or activity from conventional methods to speech input (or output). This question was answered by marking a six point scale anchored by the descriptions "very useful" and "never useful."

SELECTION OF SPEECH I/O APPLICATIONS AND THEIR VERIFICATION

The results of the questionnaire provided the best basis for selecting candidate speech I/O applications.

The data presented in the table are more readily understood by reference to the scaling on the original questionnaire, which was as follows:



The pilots were asked to circle only on the cross-hatches, not between them.

The questions can be indexed to the question numbers by referring to a copy of the questionnaire given in Appendix C.

In terms of ranking the total set of questions, the following items were rated most useful (mean rating over 4.0) by the nine FWS instructors:

TABLE 5. CANDIDATE SPEECH TASKS

INPUT	TYPES OF APPLICATION
SELECT TACAN MODES	NAVIGATION FUNCTION SELECT
SELECT RADIO FREQUENCIES	COMMUNICATION DATA ENTRY
SELECT SECURE VOICE MODE	COMMUNICATIONS FUNCTION SELECT
SELECT TF/TA MODE	FLIGHT CONTROL FUNCTION SELECT
SELECT TERRAIN FOLLOWING ALTITUDE	FLIGHT CONTROL DATA ENTRY
REPROGRAM CHAFF RELEASE	E.C.M. DATA ENTRY
RELEASE CHAFF	E.C.M. QUICK ACTION
NAVIGATION UPDATE USING H.U.D.	NAVIGATION DATA ENTRY/QUICK ACTION
NAVIGATION UPDATE USING OVERFLY	NAVIGATION DATA ENTRY/QUICK ACTION
ENTERING TARGET COORDINATES & ELEVATION	NAVIGATION DATA ENTRY
INTERCHANGING THE IDENTIFICATION OF TARGETS	FIRE CONTROL DATA ENTRY
SELECTING STORES & WEAPONS FOR DELIVERY	FIRE CONTROL DATA ENTRY
MODIFY WEAPONS DELIVERY PROGRAMS	FIRE CONTROL DATA ENTRY
CHANGE IFF MODE	IDENTIFICATION MODE SELECT/DATA ENTRY
OUTPUT	
THREAT LAUNCH WARNING	THREAT INFORMATION
THREAT WARNING	THREAT INFORMATION
MASTER CAUTION LIGHT OPERATION	PRIMARY LEVEL WARNING
INDIVIDUAL SYSTEM WARNING & CAUTION LIGHT OPERATION	SECONDARY LEVEL WARNING
BLACKBOX BACK-SEATER (B3)	
CHECK AVIONICS AND ARAMAMENT STATUS	INTERACTIVE REQUEST
MONITOR NAVIGATION SYSTEM FOR ERRORS	INTELLIGENT BOX PRODUCT
MONITOR A.T.C. OR F.A.C. FOR PROJECTED TARGET OR THREAT UPDATES	INTELLIGENT BOX PRODUCTS (WITH JTIDS)
ON-REQUEST FUEL COMPUTATIONS OR BINGO FUEL	INTERACTIVE REQUEST

TABLE 6. STRUCTURED INTERVIEW BREAKDOWN FOR SPEECH INPUT/OUTPUT

NEGATIVE REACTIONS ("NO's")
SELECT AIR-COMBAT MODES
OBSERVE PUSH DOWN POINTS
OBSERVE PUSH UP POINTS
SELECT ARMAMENTS
SELECT TERRAIN FOLLOWING MODE
SELECT TARGETS ON HUD OR MFD
POSITION SYMBOLS ON IDENTIFIED TARGETS
CONFIRM WEAPONS RELEASE
SELECT AIR-TO-AIR ATTACK GEOMETRIES
OPEN REFUELLING DOOR
CAUTION ON FUEL/CG LIMIT EXCEEDANCE
DISCONNECT FROM TANKER
PRIMARY AIRCRAFT SYSTEM CONTROL SWITCHING

Q#	Mean Ratings	Standard Deviation	Speech I/O	Content
24	4.44	1.81	(SI)	Release Chaff; Release Flares
34	4.33	1.00	(SI)	Change TACAN __ __ __
2	4.33	1.41	(SO)	Provide high threat information (Type and Direction)
31	4.22	1.56	(SI)	Activate ECM
33	4.22	1.64	(SI)	Select VHF _, _, _ . _
4	4.11	1.62	(SO)	Bogey information
28	4.11	2.09	(SI)	Call for approach plates
45	4.11	2.03	(SI)	Aircraft lighting control "kill exterior lights,"

At the other end of the scale, the speech applications that were given the lowest ratings (Mean rating less than 2.0) by the nine F-16 pilots were as follows:

Q#	Mean Ratings	Standard Deviation	Speech I/O	Content
14	1.22	0.67	(SO)	Reports hung ordnance info
22	1.33	1.00	(SO)	Reports CG info for air refuelling
51	1.33	0.71	(SI/O)	Ask for report on bingo fuel
26	1.67	1.32	(SI)	Ask for Air Terminal Information Service (ATIS)
12	1.78	1.09	(SO)	Report critical point for pull out
13	1.89	1.26	(SO)	Report ECM mode

Clearly, high threat information is rated as a useful application, as is the capability to change radio and TACAN selections. The high rating of Release Chaff/Flares" probably is related to the usefulness of a quick access to these functions during a high-threat environment without going eyes-in and taking the left hand off the throttle.

VALIDATION SAMPLE

A subsequent sample of F-16 pilots from the three operational squadrons (428, 429, 430) of the 474th Tactical Fighter Wing at Nellis AFB was used to expand and validate the original sample from FWS. This was termed the "OPS" validation sample.

According to traditional validation techniques, the relationship between the mean ratings on each question for the FWS and the OPS samples was calculated. The result was a validation coefficient of r = .814. This shows a strong relationship between the ratings of the two groups, particularly considering the small size (N = 9) of the FWS sample. We can have confidence, therefore, in the ratings of the combined samples with respect to their validity for speech I/O application in the fighter cockpit.

QUESTIONNAIRE RESULTS

The questionnaire ratings from the samples were pooled to provide the best data, based on a sample size of N = 62. Table 7 presents the data from both samples. Rankings of the most and least preferred applications of speech input and output were examined. See Appendix C for definition of question numbers.

Speech Input

Questions 24 - 49 pertained to speech input applications. The 26 mean ratings for speech input are presented in rank order in Table 8.

Again, it should be noted that the ratings were based on a six-point scale ranging from 1 (Not Useful) to 6 (Very Useful). There are two ways to consider the rating data -- relative ratings among the items or absolute ratings anchored to the six-point scale.

The relative ratings among questions are shown adequately in the previous table. The speech input applications that received the highest ratings tended to be functions that:

(1) were inconvenient for the pilot to accomplish in an eyes-out, HOTAS situation (e.g., high threat, low-altitude, or wing/weather),

(2) were awkward (or unfamiliar) to reach/access (e.g., "Chaff/Flares"),

(3) were discrete entries, not involved with flight control.

Observation of the mean ratings for the 26 items on speech input indicates a relatively uniform dispersion of the ratings through the top 23 items. The bottom three ratings (Questions #26, 29, and 32) were noticeably lower than the rest.

When the speech input ratings are viewed with respect to the anchor-points of the rating scale, it can be seen that 15 items received a mean rating above 4.0, i.e., "useful" applications. Furthermore, if the mid-point of the scale (approximately 3.5) is considered as the division between useful and not-useful applications, 23 of the 26 items fall within that bracket. The three items mentioned above (#26, 29, 32) were the only ones rated well-below the "useful" half of the scale.

TABLE 7. MEAN RATINGS OF THE QUESTIONNAIRE ITEMS BY THE FWS SAMPLE, THE OPS SAMPLE, AND THE TWO SAMPLES COMBINED

	FWS (N=9)		OPS (N=52)		Total (N=61)	
Question No.	Mean	SD	Mean	SD	Mean	SD
1	3.44	1.74	4.51	1.54	4.35	1.61
2	4.33	1.41	5.08	1.22	4.97	1.26
3	2.89	1.54	4.54	1.35	4.30	1.49
4	4.11	1.62	4.52	1.45	4.46	1.47
5	3.33	1.73	4.89	1.18	4.66	1.38
6	2.56	1.42	3.56	1.66	3.41	1.66
7	3.44	1.81	4.33	1.54	4.20	1.60
8	3.22	1.56	3.98	1.54	3.87	1.55
9	2.33	1.66	3.42	1.49	3.26	1.55
10	3.89	2.09	4.60	1.35	4.49	1.48
11	2.00	1.85	3.17	1.36	3.00	1.48
12	1.78	1.09	3.62	1.57	3.34	1.64
13	1.89	1.27	3.20	1.61	3.00	1.63
14	1.22	0.67	3.17	1.48	2.89	1.55
15	3.13	2.10	4.00	1.58	3.88	1.67
16	2.78	1.99	3.49	1.64	3.38	1.70
17	3.22	1.79	4.43	1.40	4.25	1.50
18	2.00	1.32	4.00	1.50	3.68	1.64
19	3.33	2.00	4.56	1.53	4.38	1.64
20	2.89	2.21	3.87	1.70	3.72	1.80
21	2.44	2.01	3.12	1.95	3.02	1.95
22	1.33	1.00	1.78	1.06	1.72	1.06
23	2.89	1.45	3.31	1.75	3.24	1.70
24	4.44	1.81	5.14	1.33	5.03	1.41
25	2.56	1.81	3.71	1.80	3.53	1.84
26	1.66	1.32	2.94	1.79	2.75	1.78
27	4.00	1.55	3.61	1.52	3.49	1.53
28	4.11	2.09	4.80	1.27	4.70	1.42
29	2.00	1.41	3.00	1.38	2.85	1.42
30	3.44	1.94	4.14	1.46	4.03	1.54
31	4.22	1.56	4.44	1.63	4.41	1.61
32	2.33	2.06	3.02	1.77	2.92	1.81
33	4.22	1.64	5.21	1.27	5.07	1.37
34	4.33	1.00	4.81	1.44	4.74	1.39
35	3.89	1.62	4.70	1.55	4.58	1.55
36	3.67	1.80	5.02	1.18	4.82	1.36
37	2.44	1.88	4.57	1.57	4.25	1.77
38	2.78	1.99	4.51	1.69	4.25	1.83
39	2.78	1.99	3.92	1.86	3.75	1.90
40	3.78	1.72	4.61	1.28	4.48	1.37
41	2.11	1.54	3.92	1.38	3.66	1.54

TABLE 7. MEAN RATINGS OF THE QUESTIONNAIRE ITEMS BY THE FWS SAMPLE, THE OPS SAMPLE, AND THE TWO SAMPLES COMBINED (Continued)

	FWS (N=9)		OPS (N=52)		Total (N=61)	
Question No.	Mean	SD	Mean	SD	Mean	SD
42	3.00	1.87	4.04	1.62	3.88	1.68
43	3.67	1.94	4.48	1.48	4.36	1.56
44	3.22	1.99	3.90	1.62	3.80	1.68
45	4.11	2.03	4.23	1.65	4.21	1.69
46	3.00	2.24	4.81	1.60	4.54	1.80
47	2.89	2.15	3.92	1.76	3.77	1.84
48	3.14	1.57	4.30	1.30	4.14	1.39
49	2.78	1.99	3.96	1.79	3.79	1.85
50	3.00	1.94	3.98	1.62	3.86	1.69
51	1.33	0.71	3.25	1.77	2.97	1.79
52	3.67	1.80	4.08	1.63	4.02	1.65
53	3.50	2.27	3.83	1.42	3.78	1.54

TABLE 8. RANK ORDER OF SPEECH INPUT APPLICATIONS
(FWS AND OPS SAMPLES COMBINED)

RANK	QUESTION NO.	MEAN	APPLICATION IDENTIFICATION
1	33	5.07	Select/change radio channels/freqs.
2	24	5.03	Deploy chaff/flares
3	36	4.82	Input NAV updates and other FCNP key
4	34	4.74	Change TACAN channels
5	28	4.70	Display approach plates
6	35	4.58	Input pre-flight data
7	46	4.54	Call-up (display or report) checklists
8	40	4.48	Request status of aircraft systems
9	31	4.41	Activate ECM pod
10	43	4.36	Fly over mark, e.g., "Mark Position"
11.5	37	4.25	Mode selection, e.g., "Select Air-to-Air"
12.5	38	4.25	Select radar coverage or radar display
13	45	4.21	Control interior/exterior lights
14	48	4.14	Control/select LANTIRN parameters
15	30	4.03	Select MFD displays, e.g., "Display radar, left"
16	42	3.88	Endurance
17	44	3.80	Select individual MFD pages
18	49	3.79	Cage/uncage missile
19	47	3.77	Weapon deployment/control, e.g., "Go Slewable"
20	39	3.75	Stores management, e.g., "Select Master Arm"
21	41	3.66	Request "Fence Check" items
22	25	3.53	Jettison stores
23	27	3.49	Access JTIDS info., e.g., "Display JTIDS"
24	32	2.92	Open/close air refuel door
25	29	2.85	Mission Review
26	26	2.75	Access the Air Terminal Info. Service (ATIS)

Accordingly, it can be concluded that the sample of 62 qualified F-16 pilots rated 88% of the potential speech input applications as "useful." Because the results of this survey represent only one step toward successful cockpit application of speech technology, we recommend that all of the 23 items be considered viable applications, worthy of further analysis in a simulation environment (see Appendix B).

Speech Output

Questions 1 - 23 pertained to speech output applications. The mean ratings for these questions are given in Table 9 in rank order.

TABLE 9. HIGHEST-RATED APPLICATIONS OF SPEECH OUTPUT IN RANK ORDER

RANK	QUESTION NO.	MEAN	APPLICATION IDENTIFICATION
1	2	4.97	Provide threat info., e.g., "SA-10 launch, 4 O'Clock"
2	5	4.66	"Bingo Fuel"
3	10	4.49	Task prompts, e.g., "Change IFF Code"
4	4	4.46	Bogey location, e.g., "Threat at 2 O'Clock High"
5	19	4.38	Bogey location (reliability check on Q #4)
6	1	4.35	Ground proximity warning (selectable altitude)
7	3	4.30	New threats, e.g., "New Guy, Quad Two"
8	17	4.25	Master cautions announced
9	7	4.20	Engine over-temp. limit
10	15	3.88	NAV system drift
11	8	3.87	Report degraded threat warning system
12	20	3.72	Report flight control battery low
13	18	3.68	Report ECM status
14	6	3.41	Reminder of Fence Check
15	16	3.38	Suggest options when system(s) degraded
16	12	3.34	Solve and remind "pull out" point
17	23	3.24	Warn of masking of laser-designated target
18	9	3.26	Report abnormal fuel distribution
19	21	3.02	Spin-direction announced
20.5	13	3.00	Mode changes confirmed
20.5	11	3.00	ECM mode spoken upon request
22	14	2.89	Hung ordnance reported
23	22	1.72	Reports CG change during air refueling

It is clear from the data that threat warning/management information was viewed by the pilots as a useful application of speech output. Three of the top five questions (and four of the top seven) are related to announcing threat information. This result was corroborated in interviews, where the pilots emphasized that the one thing they would like most to hear is high threat information because of its immediate survival value.

Nine of the 23 questions dealing with speech output were given a mean rating above 4.0, and 13 questions were rated above 3.5. This means that slightly more than half (57%) of the candidate speech output applications were rated as potentially "useful."

It is difficult to make an arbitrary cut-off of the mean values to indicate potential usefulness of the speech output applications. The only item that was clearly rejected was #22 -- report CG change during air refueling. Based on a liberal decision strategy to include all items with potential usefulness, all of the remaining 22 items could be pursued through simulation. Adopting a more stringent decision strategy, where only items with a mean rating above 4.0 are accepted, nine speech output applications can be recommended for further development through simulation.

It should be noted that several of the suggested applications of speech output are based on the assumption of an "intelligent" system. For example, providing accurate threat information (Q #2, 4, 19, and 3) presupposes a system capable of detecting, classifying, and locating the threat. The pilots' ratings on the questionnaire were based on the usefulness of having a speech output device provide the information. The ratings, therefore, reflect the value of both the information itself and the method of communicating it (computer speech generation). Other items which were highly rated, however, appear to be straightforward in their implementation, such as "Bingo Fuel," "Engine Over-Temp," etc.

Comments from the pilots, both in person and written on the questionnaire, reflected a desire that speech output should be used sparingly in the fighter cockpit. Many expressed concern that a "chatty" computer would become a nuisance in the busy cockpit environment.

Speech Input and Output Compared

A comparison of the overall mean ratings of the questions pertaining to speech input and output are given in Table 10.

TABLE 10. OVERALL MEAN AND STANDARD DEVIATION OF SPEECH INPUT AND SPEECH OUTPUT RATINGS

ITEM	MEAN	SD
Speech Input	4.07	1.02
Speech Output	3.73	0.94

Speech I/O Questions

Although many questions in both the I and the O portions of the questionnaire assumed or implied a two-way voice interaction, the four questions (Q #50 - 53) that specifically addressed the linking of speech I and O received moderate ratings, with one exception. Question #51 referred to a verbal request for bingo fuel, with a verbal reply by the system. The mean rating of this question (2.97) would place it in the less-useful category.

Generic Applications Questions

Several additional questions were added to the questionnaire for the validation sample. The new questions were in a different format, allowing the pilots to provide general comments about speech I/O. Question 54 requested the pilots to rate generic applications of speech I/O in three categories -- Very Helpful, Possibly Helpful, and Not Helpful. The results of this question are given in Table 11.

It is clear from the data presented in the table that the F-16 pilots considered speech I/O most helpful for threat management and fire control. Not surprisingly, speech I/O was considered least helpful for vehicle control. This result is consistent with the fundamental principle that speech I/O is not well-suited to continuous tasks such as manual flight control. Tasks involving discrete changes or data rates (throughout) of less than about 20 per minute are better-suited for speech I/O.

One interpretation of the data in Table 11 is that for all tasks except vehicle control, over 90% of the pilots felt that speech I/O could be either "possibly" or "very" helpful.

TABLE 11. RATINGS OF GENERIC SPEECH I/O APPLICATIONS
(N = 50 - 52)

	RATING*		
COCKPIT FUNCTION	Very Helpful (%)	Possibly Helpful (%)	Not Helpful (%)
Threat Management	70	28	2
Fire Control	63	35	2
Navigation	48	46	6
R/T Communications	44	48	8
Weapons Delivery	42	52	6
Subsystem Management	32	62	6
Target Acquisition	29	67	4
Vehicle Control	8	61	31

*Data represent the percentage of responses in each rating category.

Pilots' Written Comments

The OPS validation sample was encouraged to write comments on the questionnaire whenever they wished. A transcription of those comments is given in Appendix D.

The authors wish to emphasize that these comments can be very helpful in the analysis of speech I/O design issues. The information included in Appendix D should be considered as an important aspect of the data collected in the study.

AGE HYPOTHESIS

The original sample of pilots at FWS was relatively uniform in composition, with Captains and Majors who had the majority of their flight time in F-4s, before transitioning to the F-16. Informal discussion with several pilots led to a question of whether younger pilots might be more open to new technology than their more experienced peers. Consequently, the questionnaire data from both samples combined were analyzed for a relationship between age and mean-rating, based on the hypothesis that higher ratings of speech I/O applications would be given by the younger pilots, i.e., a negative correlation was predicted.

Results of the analysis showed a very weak ($r = -.106$) and statistically nonsignificant ($p = .20$) relationship between age and mean rating on the 53 questions for the combined OPS and FWS sample ($N = 61$).

Several factors may have contributed to the experimenters' perception that the older, more experienced pilots were less accepting of the speech I/O concept: (1) senior people may be more likely to speak out about system development difficulties, (2) several senior pilots expressed great satisfaction with the F-16 (relative to the F-4) and were pessimistic about spending money on further refinement to an excellent airplane.

Acceptance of New Technology

Whether or not age is a factor in the introduction of speech I/O in the cockpit, the acceptance of new technology by operational personnel can be an important issue (Wylie and Mackie, 1982). Initial testing and development may most appropriately be done by the more senior personnel, such as instructor - or test-pilots. The participation of experienced personnel can contribute to the quality of the applications development and can ease the transition of the new technology by fostering acceptance in the operational community. For these reasons, it is recommended that at least some of the participants in the simulation development of the speech I/O interface (see Appendix B) be respected, experienced fighter pilots.

SPECIAL CONSIDERATIONS

The structured interviews were used to solicit SME opinion on three special speech I/O considerations for future tactical aircraft operations. They were:

1. Wearing CBR gear.

2. LANTIRN.

3. Debriefing and briefing during short turn arounds.

CBR Gear

Several pilots confirmed that speech input might be particularly useful when wearing CBR gear because of the difficulty of pushing buttons while wearing bulky gloves. The majority of pilots did not expect a decrement in speech I/O system performance due to CBR gear because the vocal and auditory channels remain essentially the same. It is recommended, however, that empirical tests be conducted on the effect of CBR gear on speech recognition performance.

LANTIRN

Pilots who had been exposed to LANTIRN vigorously commented that the speech I/O system requirement would be substantially different when a LANTIRN pod was fitted. Their opinions were based on LANTIRN missions being single plane, night flights with little or no communications with the outside world. Therefore, speech I/O could be helpful in solving the mission management problem which they expect to experience on LANTIRN types of missions.

Due to security classification, the project team remains unfamiliar with the nuances of LANTIRN operations. However, LANTIRN should be subjected to a separate speech I/O study during the operational test and evaluation phase of its development. Further, evaluation should be conducted on a LANTIRN part-task trainer or a full mission simulator which includes a simulated LANTIRN system.

Short Turn-Arounds

European operations for tactical aircraft call for short turn arounds between missions. During this period the aircraft must be refueled and configured for the next mission. In this same period the pilot must debrief on the previous mission and obtain a briefing on the next.

The project team was asked to investigate the practicality of using speech I/O to reduce the pilot's on-ground work schedule and presumably reduce the turn around time.

If the pilot is prepared to remain in the cockpit during turn around, the use of data linked information between the operations center and the aircraft can be developed as a debriefing/briefing channel. There is no doubt that speech I/O could contribute to this process. It is conceivable that the debrief could commence even before landing. Appropriate questions could be displayed on one of the MFDs, allowing the pilot to answer them using speech input.

For briefing, the pilot could use speech input to ask for additional information which is not available from the next mission's flight data cassette. However, such a scheme introduces larger, more complicated vocabularies which the speech recognizer subsystem must accommodate. It also presupposes the availability of accurate and rapidly updated information.

In summary, a case can be made for using speech I/O for short turn arounds, including maintenance log entries. Before any development on these guidelines is conducted, the time required for pilots to be debriefed/rebriefed should be assessed and compared with the normal time to ready the aircraft for the next mission.

IMPACT OF OF THE F-16 AFTI SPEECH CONTROL PROGRAM

A benchmark speech input program is being demonstrated on the F-16 AFTI aircraft during 1982/83. In the first part of the program a limited speech recognition device manufactaured by Lear Seigler Inc. will be installed to control the sixteen MFD mode select buttons which surround the display. In the second part of the program the Lear Seigler unit will be replaced by an ITT unit.

The program is a benchmark because it represents the introduction into an operating cockpit of speech input avionics built to stringent environmental specifications.

The speech input device is functionally limited to single words which control the MFD modes. To the best of our knowledge there is no speech output capability in either the LSI or ITT units. However, voice warnings have been recommended for the F-16 (Davis and Stockton, 1982), and speech output may be included in subsequent phases of the AFTI program.

Limiting the vocabulary to a small set of control words is a prudent first step for the harsh requirements of the figher cockpit.

Although the program has very visible benchmark characteristics, it should not be mistaken as a demonstration of what speech I/O and intelligent interfaces will do in the future.

Control of the MFD modes by speech was an easy and expedient choice because of the digital data bus interface between the MFD and the speech input system. However, the development of speech I/O functional applications, especially those which involve human engineering research issues, were not the objective of the program.

In summary, the AFTI F-16 program is quite valuable as an engineering demonstration, but too limited (and not intended) to provide data on optimal applications of speech I/O in the fighter cockpit of the future.

SECTION V

SPEECH APPLICATIONS IN NEAR TERM AIRCRAFT

CONCEPT FOR SPEECH I/O IN NEW AIRCRAFT DESIGN

We have assumed that the Near Term aircraft will be more automated than the current tactical aircraft. Further, automation will occur by the Far Term aircraft primarily in the areas of subsystem management, monitoring, and tactics (which includes planning). Further, we have assumed that a speech I/O interface will be an integrated element of this automation and that it will be interactive (B3 concept).

The basic automation architecture will be reflected in a "core" design associated with standardized software and hardware which is applicable to more than one aircraft. This is depicted in Figure 10.

The approach to the speech I/O interface will not be piecemeal; rather it will be in parallel with nearly all other aircraft systems. This design will provide the pilot with an effective alternate strategy for commanding, monitoring and managing the aircraft of the future.

RATIONALE FOR THE SPEECH I/O IN NEAR TERM AIRCRAFT

There are three main considerations which must be carefully weighed before speech I/O is introduced. These are:

1. Not to introduce speech I/O at all. This decision is indicated if no advantages have been demonstrated, in terms of total system performance, through the use of speech I/O.

2. Introduce speech I/O for a limited number of cockpit functional tasks.

3. Introduce speech I/O so that it is an alternative (parallel) I/O mode which is available to the pilot as the task situation dictates.

In regard to the first point above, even though this study has recommended some candidate speech I/O tasks, subsequent development simulation may indicate that speech I/O for future tactical aircraft cockpit does not enable more efficient or safer system design. It may simply add more functions to the cockpit. Point 2 assumes that developmental simulation will show that the speech I/O capability provides practical human engineering benefits for the pilot. Although this report identifies generic categories of functional tasks which can be conducted through a speech I/O (eyes out, HOTAS, etc.), the selection of these tasks involved a number of subjective variables, primarily the opinions of the subject matter experts sampled. Diverse opinion on speech I/O existed in the pilot community sampled by this study. This variability of opinion about speech I/O plus the fact that the benefit of speech I/O is situation-specific supports the notion of designing an individualized cockpit for future tactical aircraft.

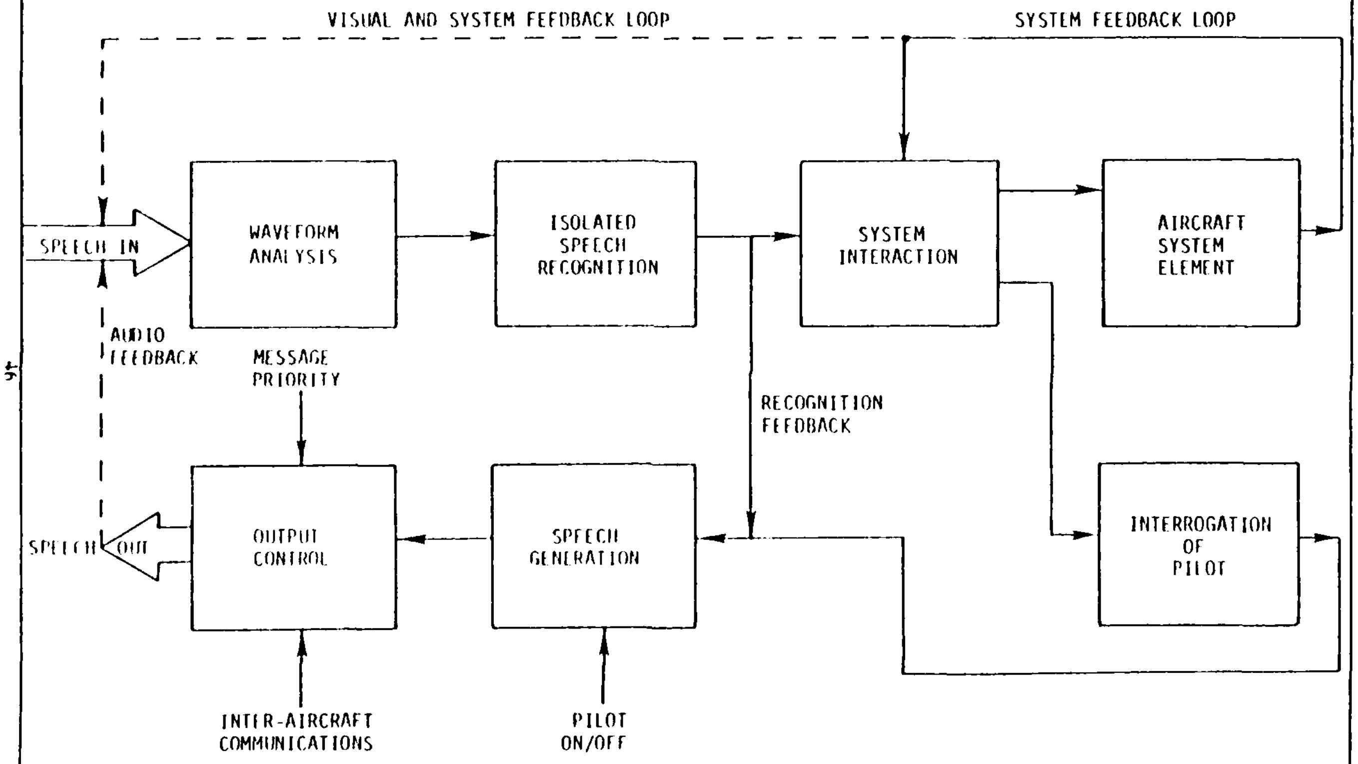


Figure 10. Man/Machine Interface for Aircraft Speech Interactive System.

Part of the individualization process would be to provide speech I/O as an alternative for nearly all functional tasks performed by the pilot, as indicated in Point 3, above. Tasks requiring manual inputs could be accomplished manually or by speech command. Tasks requiring visual data acquisition by the pilot could be accomplished through speech generation. Pilots could choose the most convenient mode for accomplishing a task in a given situation. For each task performed by speech input, feedback would be provided to the pilot. For each task performed by speech I/O there would have to be a manual or visual backup. This very generic but powerful speech I/O design concept has been identified for the purpose of this study as the "parallel speech I/O concept."

It is obvious from the foregoing discussion that speech I/O as a parallel mode requires development simulation. One issue is whether the simulation required for points 1, 2, and 3 should be done in a part task environment or in the full mission simulation context. As the parallel speech I/O concept, by definition, includes all functions (with the exception of maneuvering the aircraft) then the simulation should be conducted in the full mission context. Figure 11 illustrates a two step approach to a development simulation program which will meet the needs of Points 1, 2, and 3.

UNCONNECTED SPEECH INPUT/OUTPUT SYSTEMS

The Near Term aircraft is likely to be designed with a speaker dependent speech recognition subsystem that will have a vocabulary of control expressions which probably will not exceed 250 words and phrases. On the basis of informed opinion, we estimate that recognition accuracy must be approximately 99% in order to achieve system effectiveness and user acceptance. Each control input will be followed by feedback to the pilot consisting of a visible system action or by data displayed on the MFD and/or a statement over the speech output system.

System understanding of the speech recognition subsystem outputs will be accomplished by a set of syntactical rules which are dependent on mission phase and system status. This phase of system development is probably the largest and most complex for the program. All system functions, except those which control engine thrust and maneuvering flight, can be achieved through speech I/O at the discretion of the pilot.

Speech output will be integrated and prioritized with the aircraft communications and emergency audio warning systems. The pilot will be able to select the degree of message priority he requires for a specific mission segment. Waiting messages, flagging, or message details will be displayed on a dedicated location of one MFD. An audio tone will be used to indicate the presence of speech output messages. The speech generation subsystem will use a digitally encoded vocabulary commensurate with the systems status information. The terminology used in the speech output system will be standardized and compatible with the speech input system vocabulary. The naturalness of the voice used for speech output is undecided at this stage of system development. Less than natural may be beneficial to avoid confusion with radio communications.

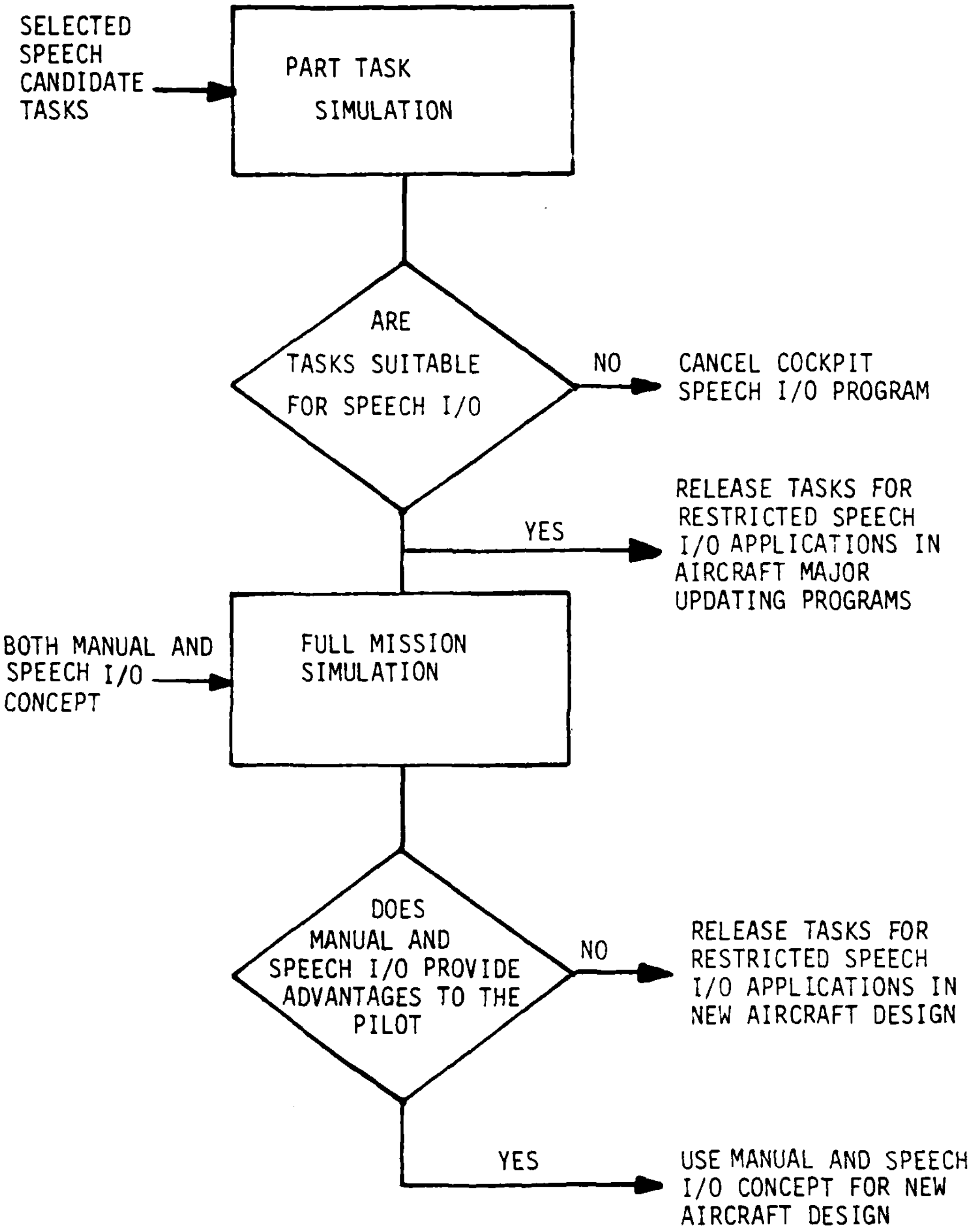


Figure 11. An Approach to Speech I/O Development Simulation .

An additional purpose of the speech recognition and generation subsystem is to facilitate the flow of information between the aircraft systems, the pilot, and an intelligent system referred to earlier as B3 (black box back seater).

Functional details of the system concept is shown in Figure 12. Further discussion of this concept is given in Appendix A (Cockpit Speech I/O Research Issues).

INTELLIGENT SPEECH SYSTEMS APPLICATIONS

Intelligent speech systems monitor system status inputs and translate the findings into speech output messages. Figure 13 depicts an intelligent system providing a simple caution message. Figure 14 depicts the same caution message said with diagnosic information. The intelligent system can be programmed to give a warning and remedial action, the example given in Figure 15 assumes that the aircraft is in the uncontrollable flight regime and that a specific action should be taken to rectify the situation.

INTERACTIVE SPEECH LOOPS

Figure 16 depicts a speech input/output interface with no interconnection between the I/O system elements. Examples of generic speech output applications have been given in the previous paragraph. Simple examples of speech input control of systems are given in Figures 17 and 18.

The speech input and output interfaces can be made to interact in a powerful combination by closing a speech loop around the system elements. Figure 19 depicts this interactive concept. Inputs from aircraft systems are analyzed by the intelligent system which triggers a speech output message and at the same time asks the pilot what action should be taken. Examples of this concept are is shown in Figures 20 and 21.

In summary, the speech I/O is a natural interface between the aircraft and the pilot. This interface can be enhanced when it is combined with a intelligent system.

RELATIONSHIP TO SPEECH I/O RETROFIT

For the purposes of this study, Near Term aircraft precludes retrofit of speech I/O equipment to such aircraft as the F-16 A/B and F-16 C/D configurations. The Near Term aircraft is considered to be a vehicle that has its genesis in an aircraft like the F-16E.

As mentioned in Section III of this report, the speech I/O retrofit to existing or immediate production aircraft is a difficult problem. Some reasons for this are as follows:

- Feedback to the pilot by altering the position of toggle and knob switches for input commands
- Indication of spring loaded toggle or push switch operation for input commands

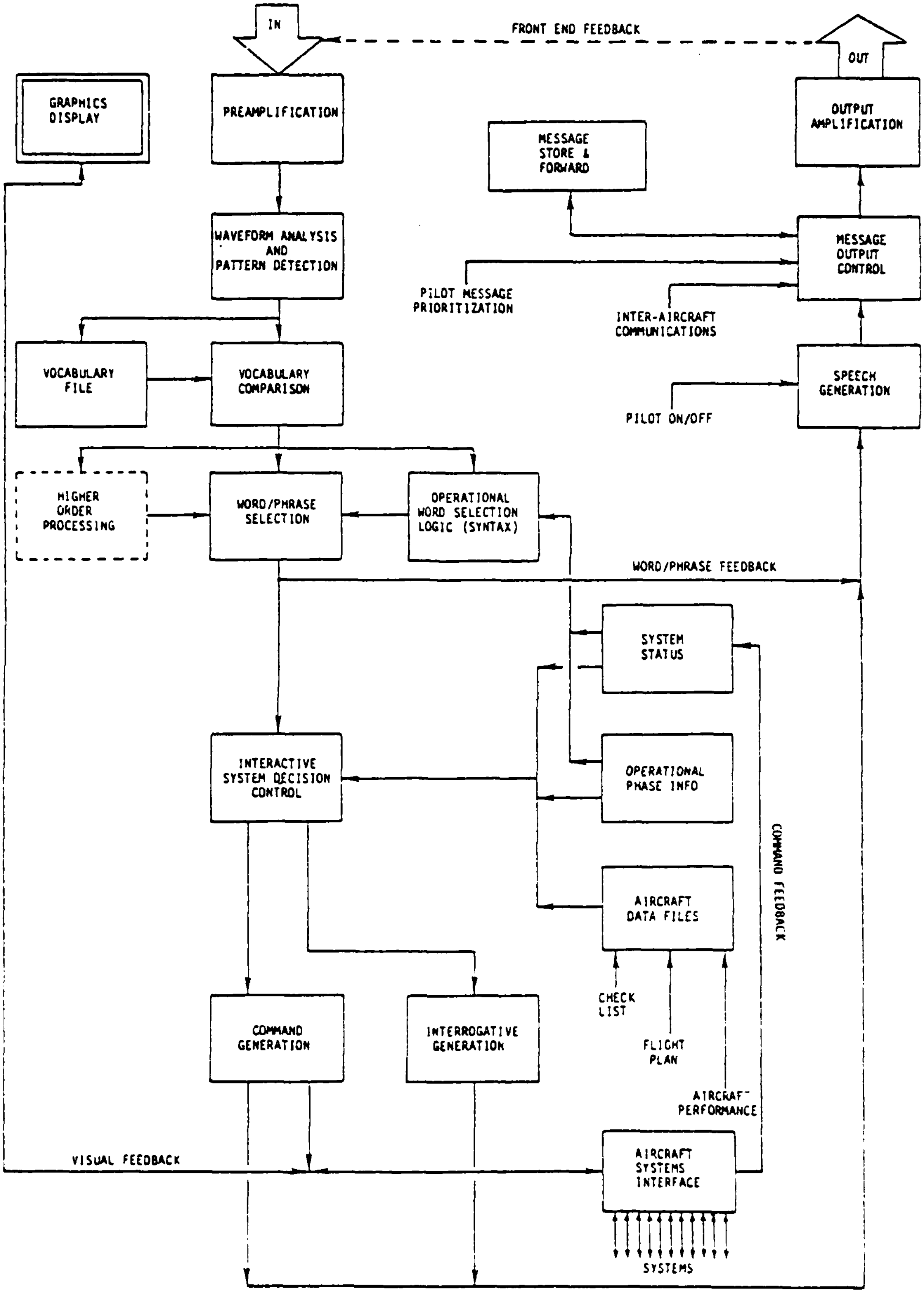


Figure 12. Speech Interactive System Functional Design for Tactical Aircraft.

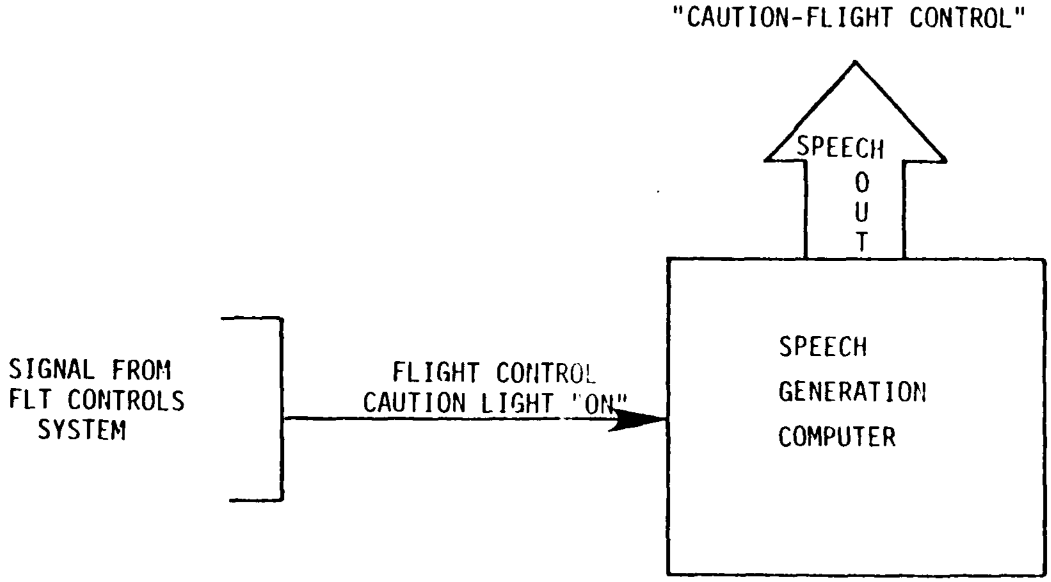


Figure 13. An Example of an "Intelligent" Caution Message.

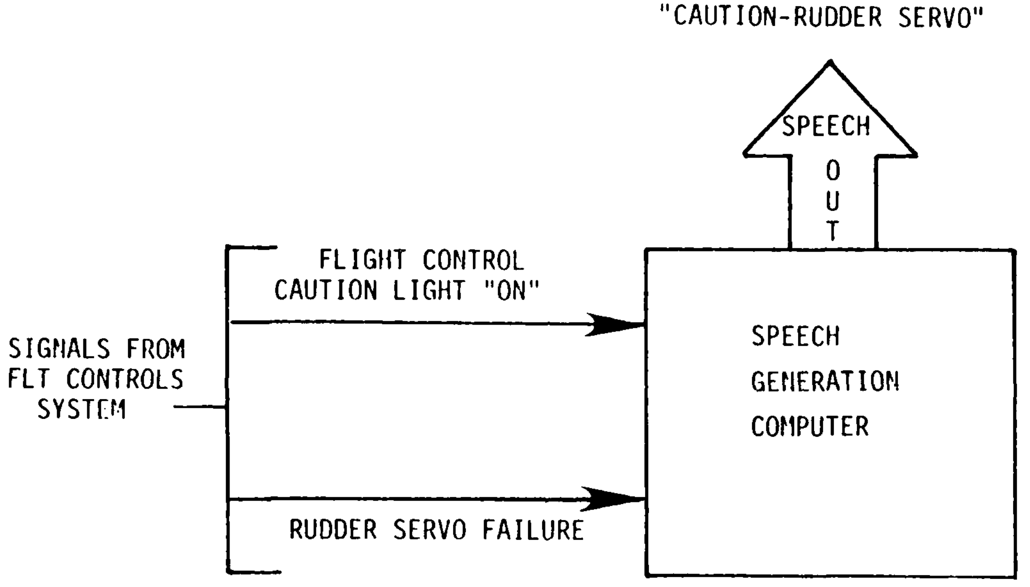


Figure 14. Smart Speech System Diagnostic Cautioning.

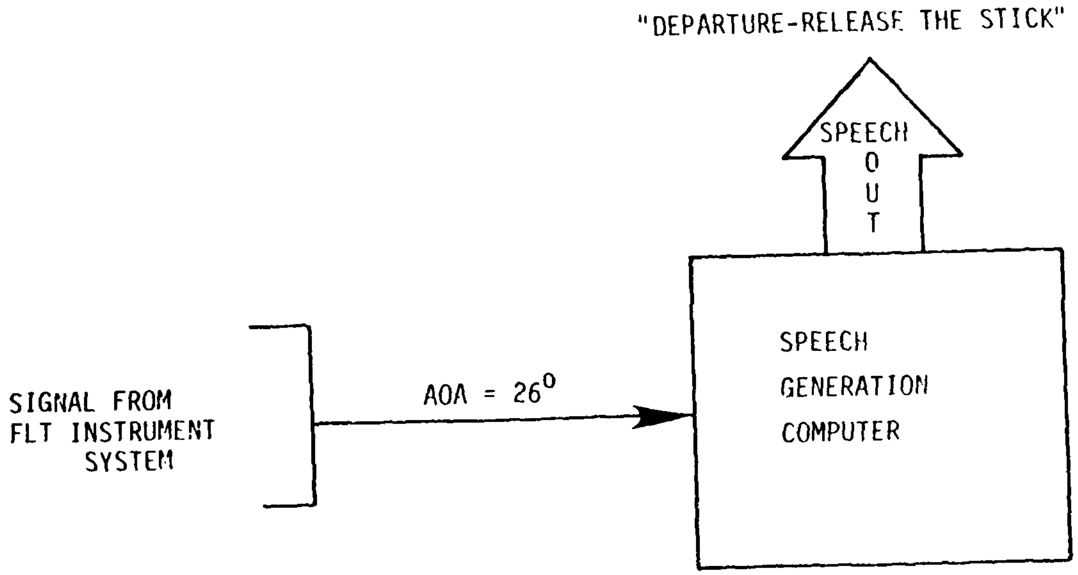


Figure 15. Non Standard Warning with Recommendations.

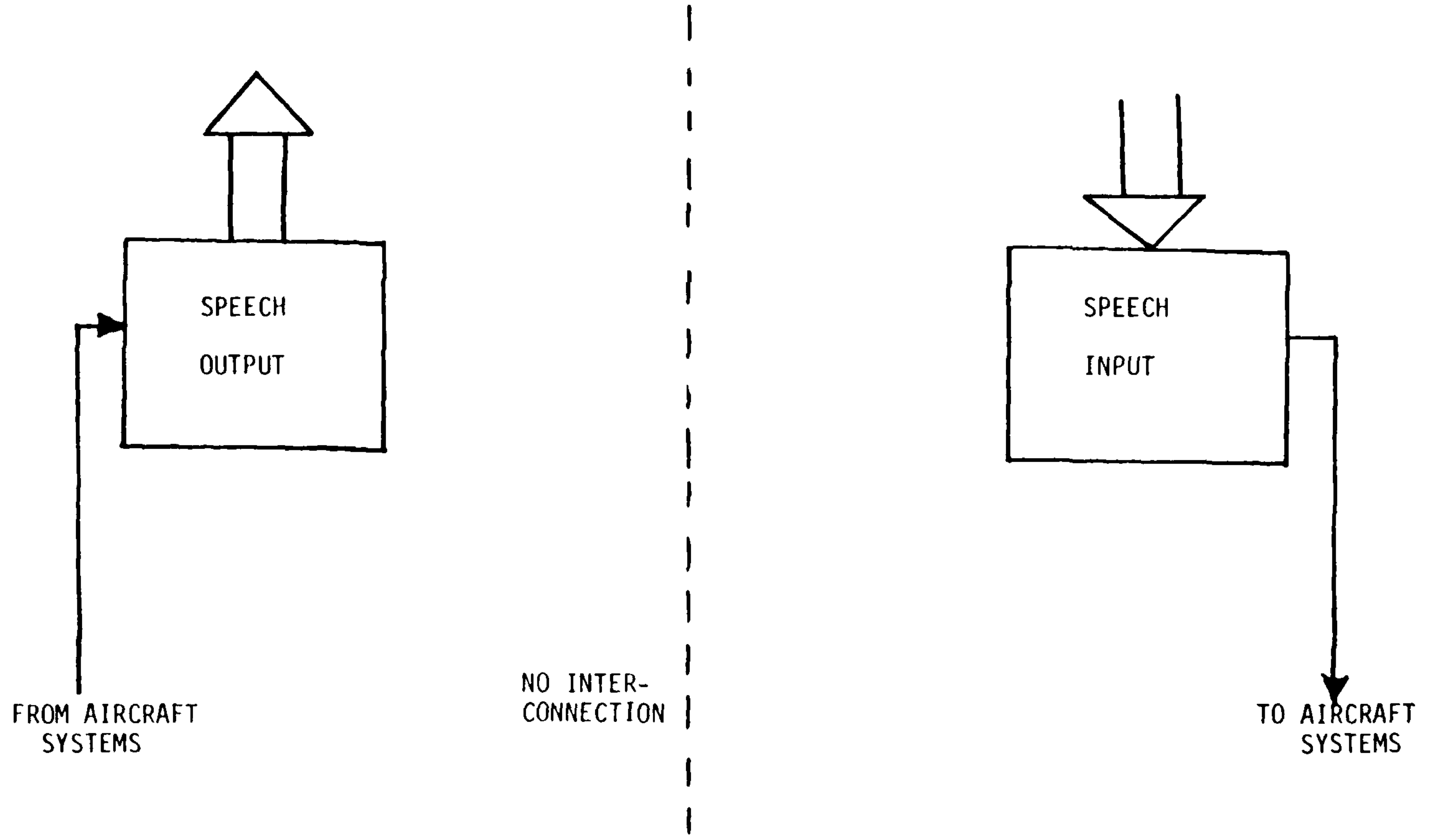


Figure 16. Simple Generic Application of Cockpit Speech I/O.

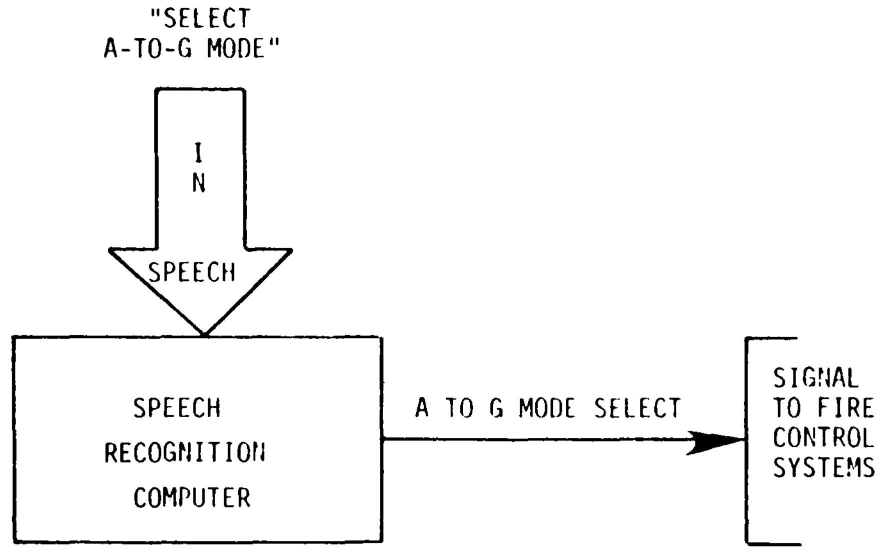


Figure 17. Simple Speech Input System Control.

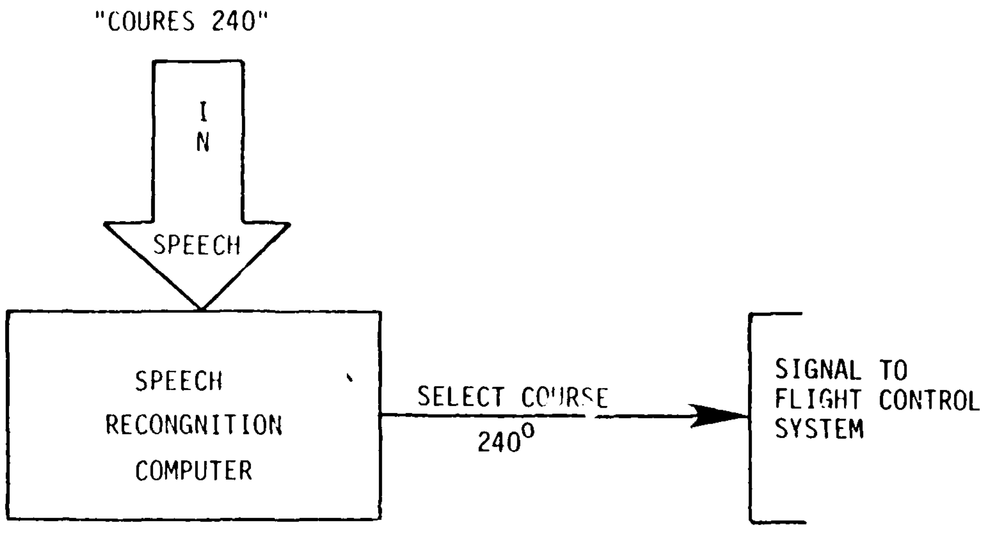


Figure 18. Simple Speech Input System Control With Variable Quantity.

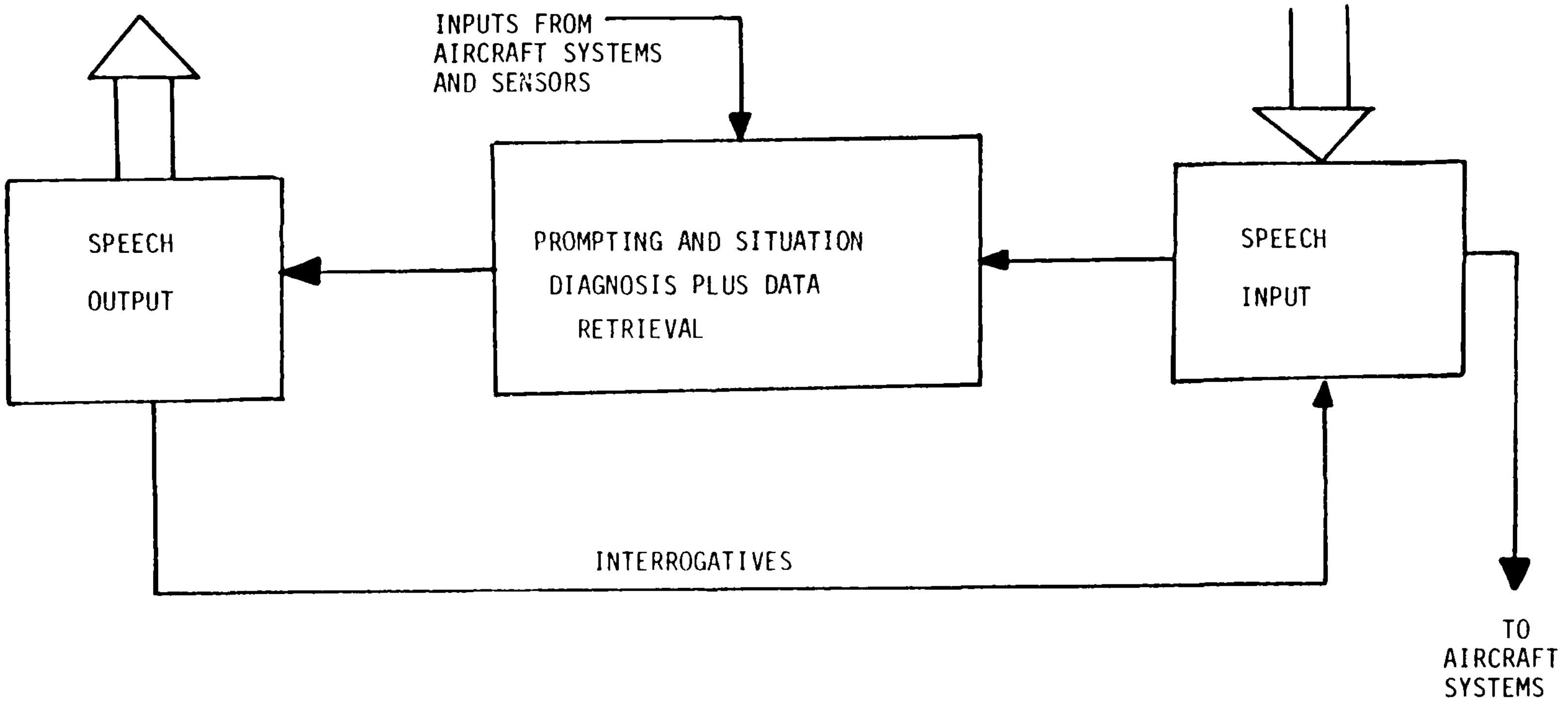


Figure 19. Generic System Design for an Interactive Speech Loop.

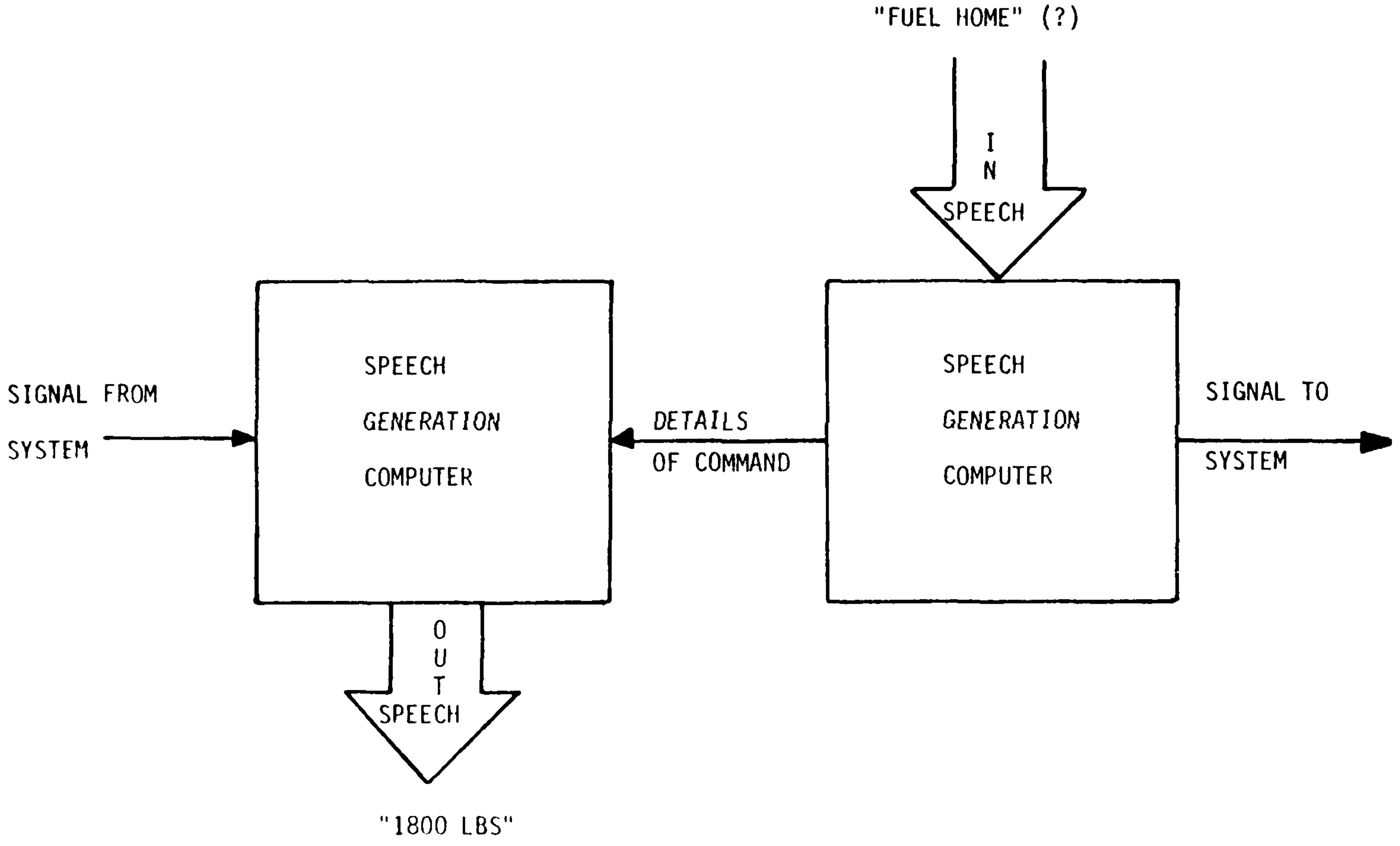


Figure 20. Application of Speech I/O to Data Retrieval.

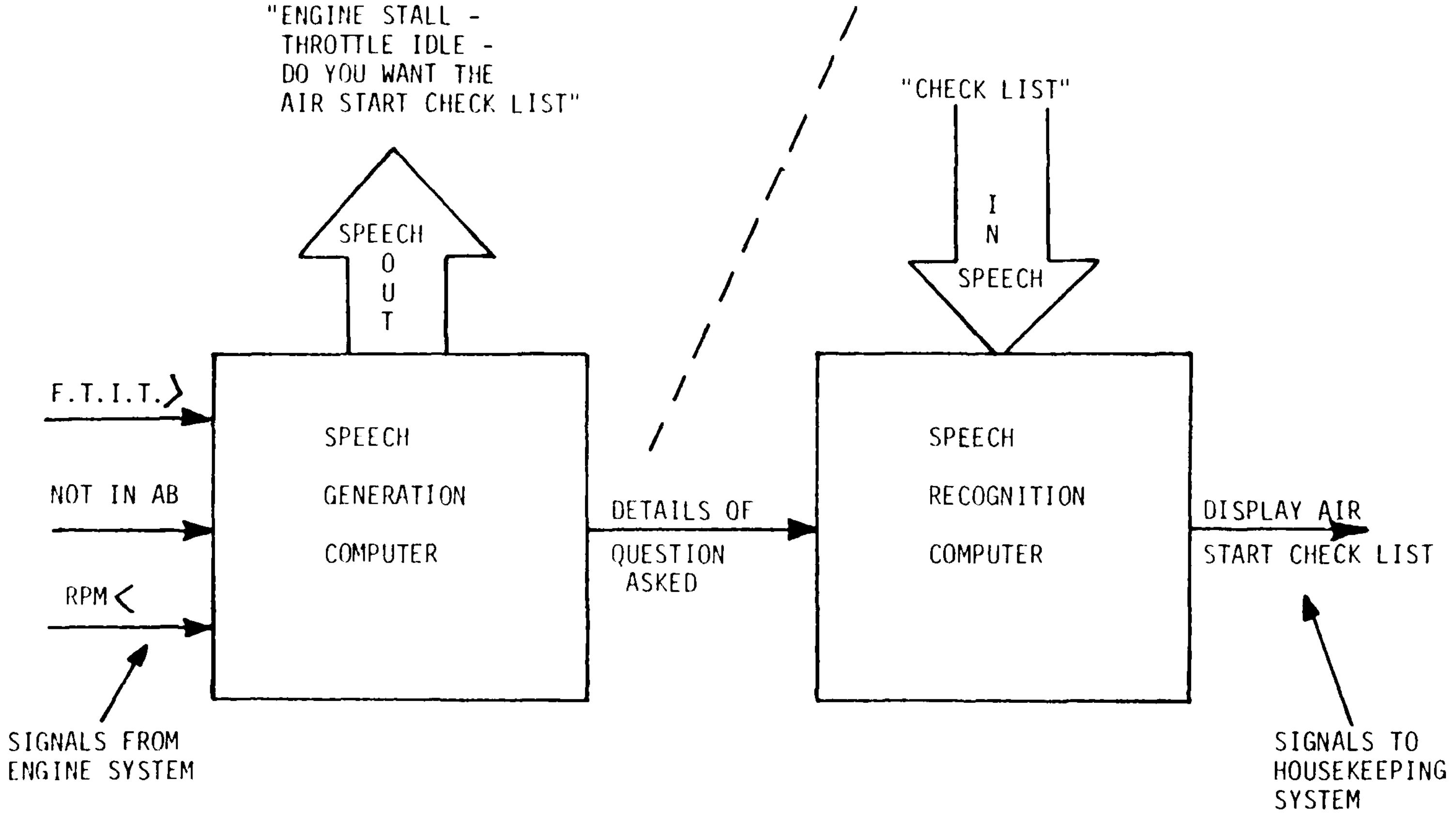


Figure 21. Application of Speech I/O to an Emergency Situation.

- Suitable display and control of speech output messages to the pilot

- Installation and aircraft wiring complexity of proliferating digital speech I/O intefaces with analog aircraft systems

- *The potential requirement for speech I/O system redundancy*

- Potential parameter signal addressing and timing limitations on existing digital bus systems.

All of these problems have solutions, providing time and money are available.

The near term speech I/O design is conceived as transcending the foregoing retrofit problems by innovative design of the cockpit and its system controls during the aircraft detailed design phase. Ideally, we believe that the speech I/O for the Near Term aircraft should be conceived as an alternate input/output control interface between the pilot and the aircraft. In summary, if the pilot wants to use speech to convey manual actions or visual information then he has the freedom to do so. However, a generic system concept of this type requires a basic speech I/O interface design technology to be developed.

IMPACT OF THE PARALLEL SPEECH I/O CONCEPT FOR NEW AIRCRAFT DESIGN

Two major considerations are involved for Near Term aircraft design. These are:

1. The effect the parallel speech I/O concept will have on the cockpit design.

2. The effect it will have on the aircraft subsystem design.

Cockpit Design

The cockpit design will require an entirely new approach to be taken to the design of switches, knobs, and levers which occupy much of today's aircraft cockpit space. Touch switches with back lit annunication will replace many of the toggles, knobs and buttons found in present aircraft. Current advances in touch-panel and membrane switches are compatible with the digital requirements for speech I/O implementation. Likewise, advanced displays such as HUD and MFDs will be compatible with speech I/O.

For each manual action a speech input expression will be available. The manual or speech input will be accompanined by a feedback message to the pilot, either visual or aural. For each discrete signal from the aircraft subsystems there will be a visual indication and/or a speech message provided to the pilot. The visual indication may be shown on a master panel, on an MFD/HUD, or on an individual switch. The speech message may occur either without pilot control or the pilot can be informed visually or aurally that a message is waiting for his attention.

Aircraft Subsystem Design

For a new aircraft that will enter service before the later part of the 1980 decade, aircraft subsystem design is expected to be similar to current configurations, i.e., the utility systems (electrical, hydraulic, etc.), will have analog controls. The avionics will be more closely integrated into a total system concept with control by digital signals. However, each system will continue to have a black box or control unit which is unique to its function.

In this dedicated box/system environment, the speech subsystem will interface with all other aircraft systems. A high degree of system isolation will have to be maintained in the speech unit because of potential common mode failure. Failure probability will have to be exteremly low. The speech system will interface digitally with the avionics system and through digital analog conversion with all other subsystems for system isolation. It is probably prudent to design the A/D and D/A interfaces as part of each parent subsystem.

The intelligent characteristics of the speech subsystem will depend on the desires of the individual pilot and will be mission dependent. These characteristics will be programmable for each mission through the data transfer unit (DTU) which is "loaded" into the aircraft before each flight.

In summary, the Near Term aircraft design can capitalize on the emerging display and speech I/O technologies to provide:

- An alternate interface between the pilot and the aircraft subsystems.
- A speech system which will provide speech commands, warnings, caution, diagnostics, recommendations, calculations, information retrieval, checklists and debriefing facilities.
- Individualized outputs and priorities to suit individual pilots and mission requirements.

SECTION VI

SPEECH APPLICATIONS IN FAR TERM AIRCRAFT

COCKPIT MAN-MACHINE INTERFACE CONCEPT

During the study we experienced difficulties in obtaining information on the mission roles which discriminate between Near Term and Far Term aircraft. The primary source of information on which differences in speech I/O requirements could be formulated was the "Automation in Combat Aircraft" published by the Committee on Automation in Combat Aircraft, Air Force Studies Board, Assembly of Engineering, National Research Council, 1982. This study was directed to examine automation issues in combat aircraft for 1980 and beyond.

Fundamentally, the speech I/O concept described as "the parallel speech I/O concept" as discussed in Section V of this report, is not expected to differ for the Far Term aircraft cockpit. However, it is hypothesized that the aircraft subsystem interface with the speech system will change radically. A methodology for the progressive development of the parallel speech I/O concept for the far term aircraft is shown in Figure 22.

FAR TERM AIRCRAFT IMPLICATIONS

The Far Term aircraft is expected to include new technology, more systems, more operating modes, and more automation to assist the pilot in managing this proliferation of cockpit functions. Although future system designs were not available for the preparation of this report, some of the potential technologies may be surmised from popular media, such as, more guided weapons, increased ECM, laser-tracking weapons, automatic target recognition, automatic terrain-following, reduced radar return ("stealth"), increased communications capability (including satellite), and increased speed and range. In a general sense, this means that more things will be happening to the pilot in less time. The need for rapid and accurate communication between the pilot and his automated systems will become essential to avoid overloading the pilot. Speech I/O can play an important role by providing an alternative to eyes-hands as an interface between the pilot and his systems.

Changes in speech technology are certain to occur during the same timeframe. Connected word recognition (CWR) exists currently in a small minority of systems. This capability can be expected to advance and thereby avoid the bothersome pauses between vocabulary items. At a minimum, the capability for recognizing connected digits should be provided to facilitate input of NAV updates, radio frequencies, etc.

Recognition systems will be capable of larger vocabularies as they advance in development. This change may not prove essential for cockpit applications, since current recognizers already are capable of vocabularies up to several hundred or even a thousand words. Overly large vocabularies might prove detrimental if they represent an increased memory load on the pilot (see Appendix A).

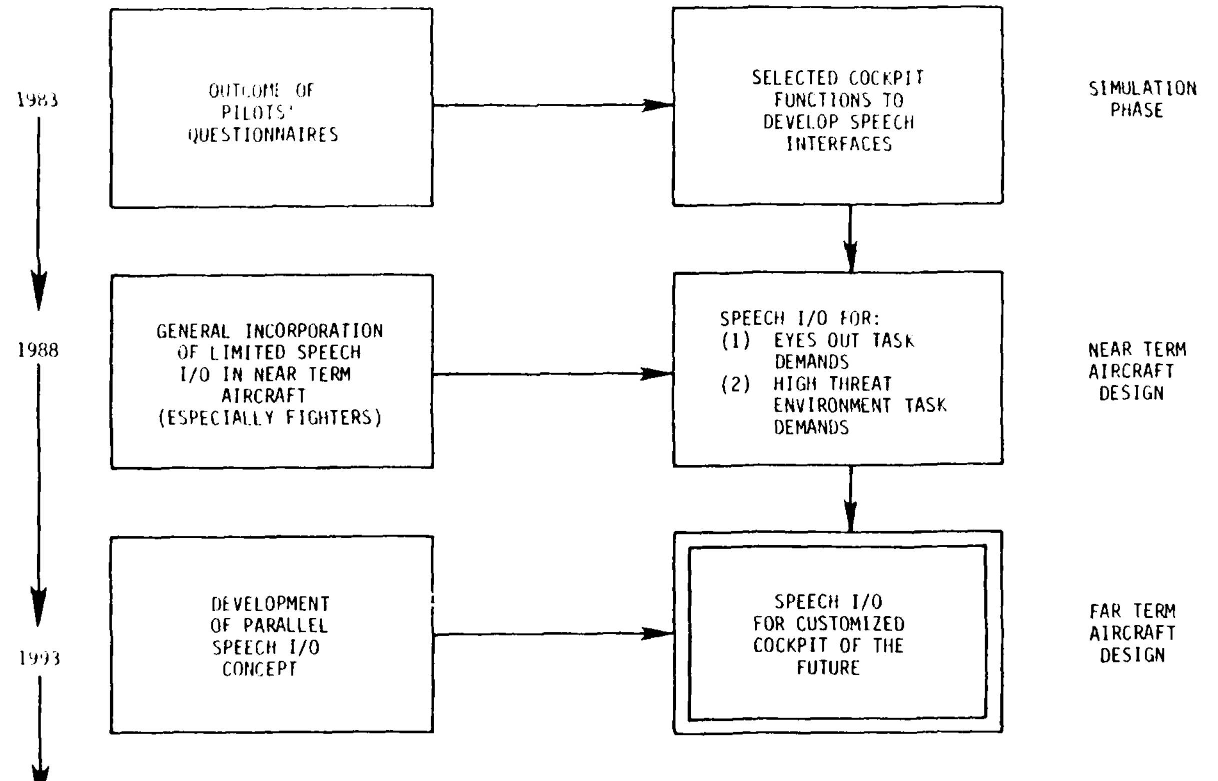


Figure 22. Progressive Development of the "Parallel" Speech I/O Concept.

Because the pilot of the Far Term aircraft will be able to accomplish nearly all cockpit functions by voice, if he chooses, the need for secure-speech will arise. The capability of others to manipulate cockpit functions by interjecting simulated speech waveforms must be prevented. Similarly, an expansion of the speech I/O system could include secure coded speech communication.

The combination of AI and speech I/O will be the area of most potential for the Far Term aircraft. The "intelligent" systems will have implications beyond assistance in correct speech recognition. They should be capable of supporting the pilot in tasks such as target detection/identification, subsystems selection/management, fault diagnosis, and even assessing the probabilities for alternative tactics. Speecn I/O would be a natural channel of communication between the pilot and his intelligent system.

It will not be surprising if speech I/O takes its place alongside eyes/hands as a primary pilot/aircraft interface in the Far Term fighter aircraft.

SPEECH I/O INTERFACE DESIGN

Increased automation in the Far Term aircraft will place the pilot in more of a tactical management role in which the emphasis will be on closer integration of the various system sensors and computers. Distributed processing of the majority of subsystem functions is a natural outcome of the integration design. Most aircraft subsystem actuation will be by digital signal using common digital bus distribution. System redundancy will be inherent in the distributed processing concept. Each distributed processor can be expected to have its own speech I/O to interface with the pilot for the functions performed by that processor. The concept is illustrated in Figure 23. Speech system backup is inherent in the design concept. If one speech processor fails, its companion unit on the bus system will take over.

During the next 15 years, improvement in speech recognition technology will begin to eliminate current constraints such as speaker dependency and restrictive vocabularies. Consequently, in the Far Term aircraft the speech system will be more flexible and more reliable.

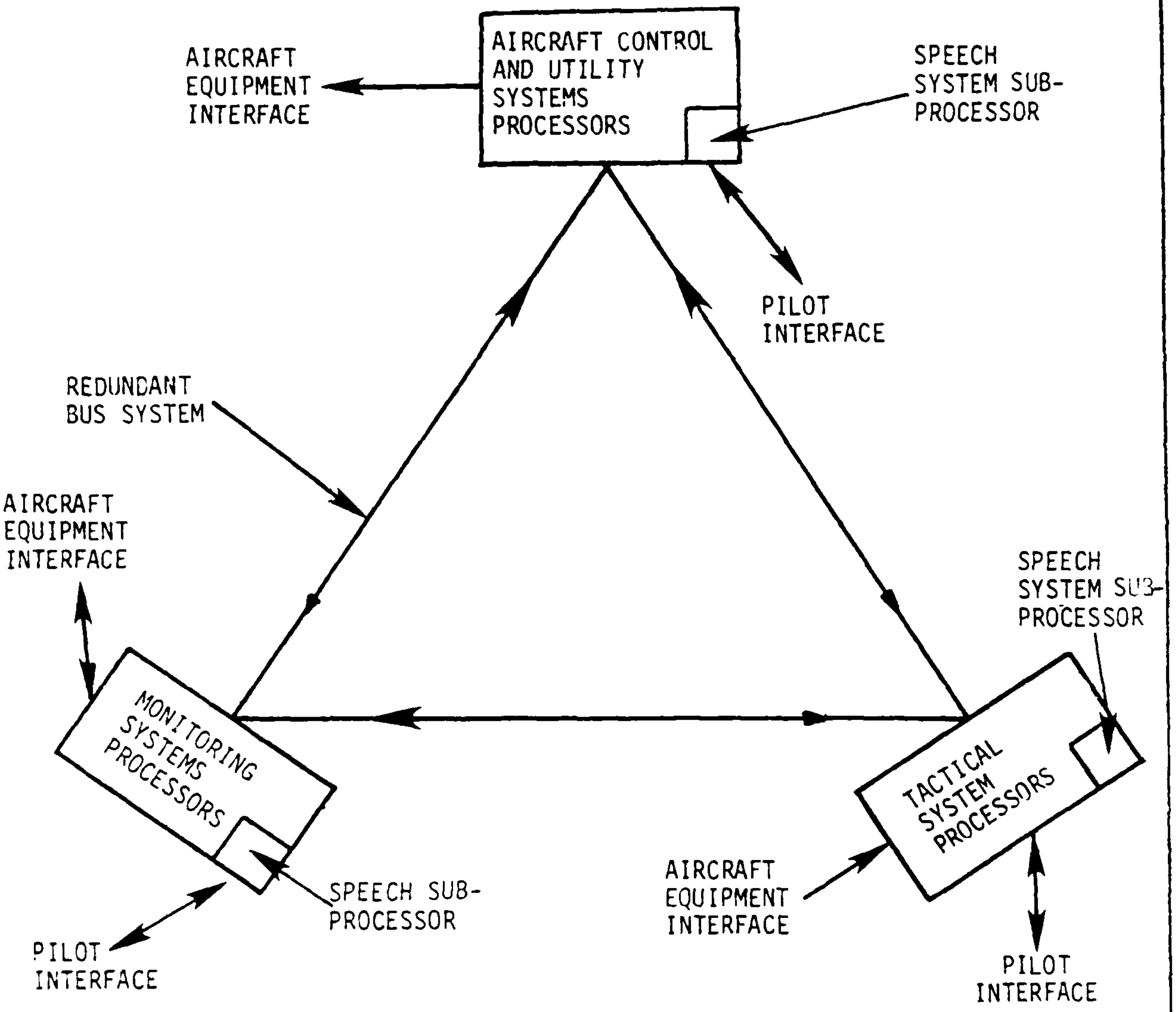


Figure 23. Conceptual Functional Speech System Design for Far Term Aircraft.

SECTION VII

SPEECH INPUT/OUTPUT IMPLEMENTATION RECOMMENDATIONS

CONSIDERATIONS

The study team believes that future tactical aircraft cockpits will become more automated. Automation will change, and hopefully reduce pilot workload. Mission effectiveness will be increased because it will allow the pilot to direct his attention to critical actions.

Speech I/O is one tool available to cockpit designers to achieve a compatible interface between the pilot and the automated systems. However, there is no systematic, widely applied technology available for allocating functions between automated systems and the pilot. Furthermore, there are no criteria which can be applied to weigh the cost of automating a particular cockpit function against the resulting improvement in mission performance.

However, while more restrictive task selection may be required for speech I/O retrofit of existing aircraft, a strong case can be made to implement the "parallel speech I/O concept" in Near Term and Far Term tactical aircraft. The "parallel" concept (see Section V) will provide the flexibility required for mission and tactical strategy development and perhaps, more importantly, suit the individual needs of overloaded combat pilot in fulfilling his mission. Speech I/O provides a parallel mode to manual and visual communications for man-machine interaction.

In reviewing current cockpit speech I/O implementation development programs, the following issues should be considered:

AFTI-16 program is a benchmark program to demonstrate the feasibility of speech recognition technology in a harsh environment. It is not necessarily representative of the best applications of speech I/O for future tactical aircraft cockpits.

F-16C (MSIP) program is too far along in cockpit design for a speech I/O interface to be considered for the production aircraft. If it is decided to introduce speech I/O into the F-16C on a retrofit basis, there is a potential danger to the future of all speech I/O, because a hasty retrofit installation may be "turned-off" more than it is used. To overcome human engineering problems, speech I/O interfaces appear to require very systematic development and integration with complex functional systems.

Airframe Prime In-House Development programs are likely to produce different approaches to implementing speech I/O interface design. No doubt each product will be serviceable because the airframe primes have the simulation resources which are necessary to develop satisfactory systems. It would appear that some form of a standardized approach to cockpit speech I/O development is warranted. Obviously this would best be accomplished by the Wright-Patterson Aeronautical

Laboratories or by independent organizations with no vested hardware interests.

An earlier figure entitled "An Approach to Speech I/O Development Simulation" has been repeated as Figure 24 on the next page to reinforce the recommended methods for systematic development. The approach uses part task simulation to evaluate the effectiveness of selected speech candidates which are an output of this study. The next step is to investigate the efficiency of the parallel concept on a full mission simulator using a wide cross section of the tactical pilot community.

If the Near Term development program is successful, then the Far Term aircraft program will be a natural evolution. If the Near Term development program is not technically feasible or is unacceptable to the pilot community, the whole subject should be shelved pending technology improvement or the changing needs of the operational community.

In summary, implementation hinges on the rigorous evaluation of the two basic concepts, restricted versus parallel implementation. Such an evaluation should be conducted in light of the research issues shown in Appendix A.

Speech I/O Interface Functional Specification

Any speech I/O interface implementation on a simulator or aircraft should meet a standard set of functional requirements. An example of such requirements is presented in Appendix B and is titled "Research Features and Design Requirements for Speech Interfaced Tactical Aircraft Simulation." Although the specification is directed at the simulation which is the outcome of this project, it is structured in a generic format which should make it usable on any other simulation/aircraft speech I/O endeavor.

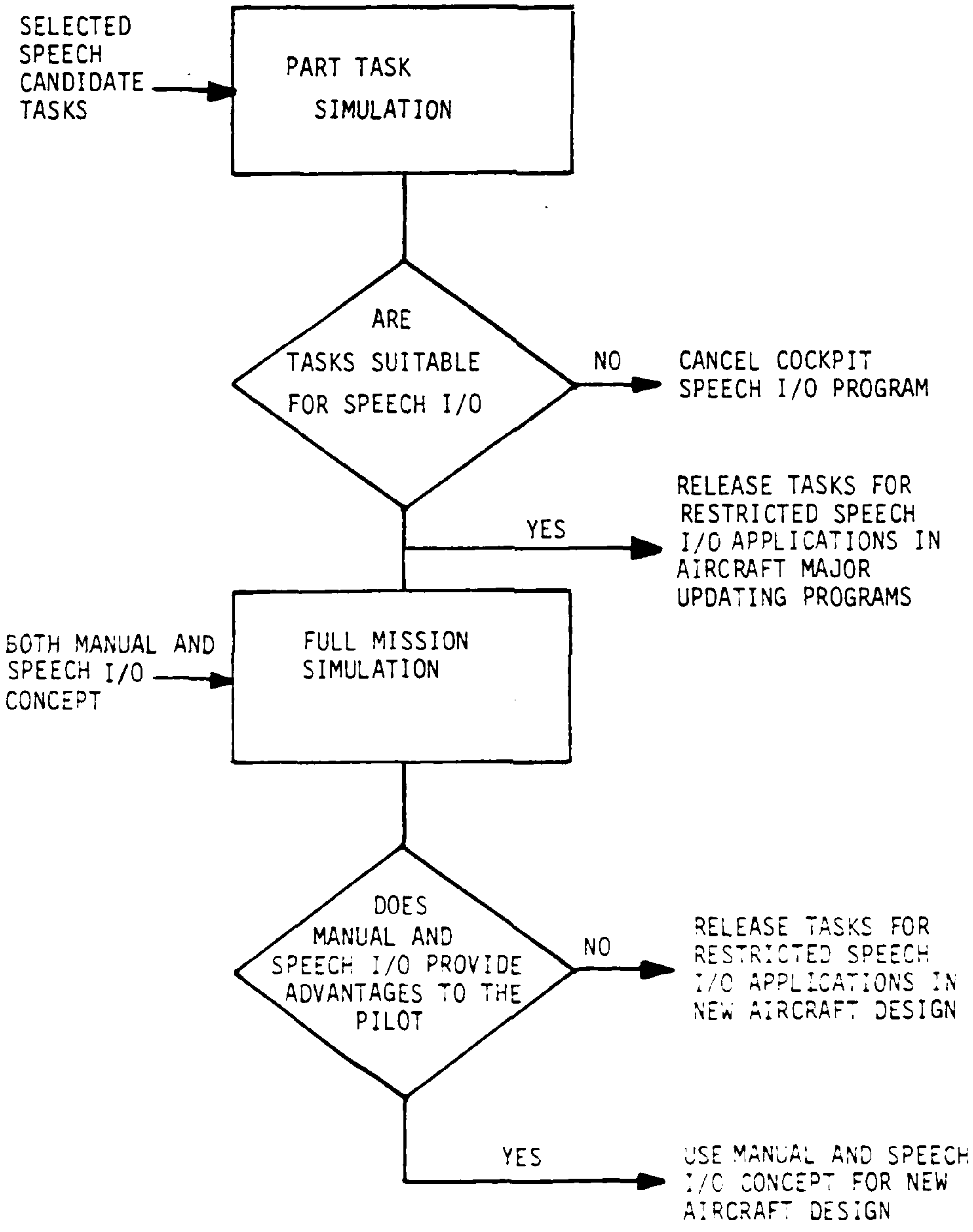


Figure 24. An Approach to Speech I/O Development Simulation.

SECTION VIII

SUMMARY AND CONCLUSIONS

The present study included a total sample of slightly over 60 pilots currently flying the F-16A. Of this sample, the vast majority (>90%) felt that speech I/O could be helpful in the cockpit for certain functions and under certain circumstances. A list of over 200 potential applications was generated from a scenario workbook and intensive interviews with 13 instructors or test pilots at Nellis AFB. This list was culled to approximately 50 potential applications, largely by eliminating duplicate or similar suggested applications.

Speech input was rated as most useful for selecting radio channels/frequencies, entering updated navigation data, and the deployment of chaff and flares. Many other applications of speech input also were rated as useful. In general, pilot comments indicated a positive attitude about speech input allowing them to accomplish certain actions in the cockpit without having to look inside and take a hand off the throttle or stick. Some pilot comments indicated a healthy skepticism about implementation problems, such as: (1) maintaining recognition accuracy despite changes in pilot's voice, i.e., yelling, "pulling Gs," etc., (2) preventing spurious recognitions, i.e., "cheer up" recognized as "gear up," and (3) overloading the pilot with too many communication responsibilities. A complete transcription of written comments by the pilots is given in Appendix D.

Speech output (computer speech generation) was rated highly in the general area of threat management. Other potential applications also were rated as useful. However, a frequent comment by the pilots was that speech output should be used sparingly. It should "speak" only when a critical situation is detected, or upon request by the pilot. Several pilots suggested that an on/off switch would be appreciated, so they could shut-off the system if it became annoying. A suggested scheme for prioritizing radio and speech-output communications is presented in Appendix B of this report.

Implementation of speech I/O in future fighter aircraft will require careful development, not only to overcome environmental factors such as noise, vibration, temperature, and acceleration, but pilot workload issues become paramount in designing an effective speech I/O system.

A number of good candidates for speech I/O tasks have been identified in the present report. These should be tested in a simulation enviroment, where system changes can be effected quickly and easily. The simulation environment should include realistic scenarios of high task-loading to determine the efficacy of confronting the pilot with combinations of speech I/O, radio communication, and visual-manual control. Guidelines for simulation in support of testing speech I/O are given in Appendix B.

It is likely that the full benefit of speech I/O in the cockpit will be attained when it becomes part of an "intelligent systems" concept (e.g., see Hopson, Zachary, and Lane, 1981). This concept would not only further speech recognition accuracy through the processing of situational variables, it would facilitate the dialogue (be it verbal or manual) between the pilot and his cockpit in light of the current mission events.

Even without the "intelligent systems" concept, however, judicious use of speech I/O in the fighter cockpit will provide an alternate interface which is beneficial to the pilot in fulfilling his mission. The present data from the F-16 pilots support that view. As stated at the outset, this study, including the conclusions, are based on the assumption that future speech recognition technology will be capable of performing in hostile environments with very high recognition accuracy.

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APPENDIX A

COCKPIT SPEECH I/O RESEARCH ISSUES

COCKPIT SPEECH I/O RESEARCH ISSUES*

During the conduct of this study, a number of issues were raised either by the F-16 pilot participants or by the authors regarding the development and implementation of speech I/O in the fighter cockpit. Often, the simple questions are the most important, both for ultimate system performance and for achieving acceptance of the technology by the operational community.

An initial list of R&D questions was compiled after intensive interviews with 13 pilots from Fighter Weapons School and 422 Operational Test & Evaluation Squadron at Nellis AFB. These questions and issues are listed on the following pages.

Subsequently, the authors developed brief "issue definitions" of selected items from that list. The selection of items from the list was essentially arbitrary. Several important and interesting questions were never expanded to an "issue definition" due to constraints on project resources. We believe that the successful solution of these issues is necessary before the potential success of cockpit speech I/O can be achieved. Taken singly, some issues appear to be straightforward, but their relationship and interaction may be critical to the successful application of speech I/O in future cockpit designs.

To coordinate a successful approach to the solution of these issues of speech I/O application, a master plan must be produced and controlled by a central agency. This plan should prioritize the attack on the R&D topics discussed herein and other speech I/O issues deemed applicable. In addition, the plan should identify milestones for the application of speech over an extended timeframe, i.e., the Far Term aircraft. It is important that the basic research components of the plan do not lag behind the more applied R&D components.

The criteria for evaluating the contribution of R&D issues should be based on its contribution to mission effectiveness and speech system performance.

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*Portions of this discussion were included in a presentation/handout at NAECON '83, Dayton, OH, May 1983.

PLANNING

1. Speech I/O Introduction Master Plan

ROLE OF SPEECH I/O IN THE COCKPIT

2. Young pilot considerations on speech I/O implementation

3. The role of the "B-3" concept, in retrofit, near term and far term aircraft cockpit design.

4. Application of speech I/O in the design of sophisticated systems operating in a down graded mode.

5. Application of speech I/O for single seat aircraft training.

6. Designation of radar indicated targets by speech input.

7. Impact of speech I/O on proficiency training.

8. Pilot selected conditional settings of speech I/O commensurate with mission purpose.

9. The construction of interrogative phrases which should be used for the speech output system (commands, suggestions or diagnostic comments).

COGNITIVE LIMITATIONS AND INTERPRETATIONS

10. Key word remembering performance for pilots in task saturated situations.

11. Use of speech output to break fixation on primary tasks.

12. Extent of information flow by speech I/O before confusion sets in (How much is too much?)

ACOUSTIC ENVIRONMENT

13. Method of reducing normal communication clutter when speech I/O is introduced.

14. Use of acoustic patterns versus speech output message to gain pilot's attention.

OPERATIONAL ENVIRONMENT

15. Use of speech I/O in high G maneuvers.

16. The value of speech I/O in the single seat cockpit for high and low task/threat environment.

INFORMATION QUEUEING

17. Prioritization of speech output messages.

18. Structure of threat warning messages, their frequency and prioritization by type.

YOUNG PILOTS AND SPEECH I/O IMPLEMENTATION

PROBLEM DEFINITION

Cockpit applications of speech I/O, particularly in the far-term aircraft, must be accomplished with careful consideration of the characteristics of the pilot population. Assuming that the far-term aircraft becomes operational in 10 to 15 years, the typical pilot who will fly the plane is now 12 years old.

New technology is having a great impact on society. Many of today's twelve-year olds are already sophisticated users of personal computers and video games. Manipulation of computer functions by voice is likely to be much less of a "gee whiz" capability to these young pilots who are nonplussed by high technology in the cockpit. The fighter pilot of the future may be more like Luke Skywalker than John Wayne.

Basic capabilities of human information processing will remain the same; evolution is a very slow process. Therefore the need for good human factors engineering in cockpit design will continue. What will change is the attitude of the typical fighter pilot with respect to rapidly changing technology. Most current pilots are justifiably reluctant to endorse the introduction of new technology, such as speech I/O, in the cockpit. This "Missouri" attitude ("show me that it works") is quite appropriate to prevent the proliferation of marginally useful functions in the cockpit, which are often accompanied by increased workload and training time for the pilot. However, once a future cockpit design is solidified (hopefully based on human factors engineering analyses) the "show me" attitude may not facilitate the pilot's task of learning how to use the new systems adeptly.

The next generation fighter pilot may be more comfortable with various facets of high technology, including speech I/O, and may have less difficulty learning to operate advanced systems to accomplish his mission. An analysis of the expected characteristics of the next generation of pilots is needed. It should focus on the implications for cockpit design, systems management, and pilot training.

RESEARCH CONDITIONS AND ENVIRONMENT

The projection of characteristics of the future generation of fighter pilots would best be addressed by an organization familiar with the following: (1) present procedures for pilot selection and training, (2) present workload and systems operation in the fighter cockpit, (3) sociological and educational impact of high technology on American youth. Familiarity with all of these areas may not exist currently within a single organization. Forming a multidisciplinary team to address this research issue is recommended.

Potential spin-offs from this study would occur in the areas of pilot selection criteria, and training techniques using new technology.

TIMING

The product of this research is needed when design decisions are to be made on the use of speech I/O (and other new technologies) in the cockpit of the far-term aircraft. The study would have to be initiated at least one year prior.

IMPACT ON OTHER RESEARCH ISSUES HEREIN

The possible capability of the next generation fighter pilot (a "video arcade master?") to rapidly learn to manipulate computer-based functions in the cockpit has widespread implications that cut across nearly all of the other research issues discussed herein, and are applicable to many cockpit design problems besides speech I/O.

THE ROLE OF 'INTELLIGENT' SPEECH I/O IN THE COCKPIT

PROBLEM DEFINITION

The concept of an intelligent speech I/O system is based on the conjunction of speech input, artificial intelligence (AI) and speech output. The term "Backseater in a black box", or B-3, was used in the present study to refer to this concept of an intelligent system to provide the pilot with information or to accomplish functions as requested. This type of pilot/system interface assumes the development of an expert system that will represent the essential knowledge of the pilot and the hypothetical backseater. It would be capable of "understanding" the mission, tracking event scenarios, and "knowing" aircraft systems status.

The characteristics of an intelligent interface for the cockpit may be considerably different for the near-term and far-term aircraft. In both cases, the purpose of the system would be to provide services to the pilot, to reduce his task saturation and increase his effectiveness. The intelligent system design, however, would be bound by the characteristics of the aircraft systems and the cockpit design.

The research issue is to develop the functional design for an intelligent interface for the near-term and the far-term aircraft.

An intelligent interface for the fighter cockpit must be based on knowledge of the current and future systems, pilot workload, and pilot/system information exchanges. The relationship between speech I/O and the intelligent interface is an important part of the design process. This research goes beyond the present study by extending the speech I/O syntax into the area of AI and expert systems.

RESEARCH CONDITIONS AND ENVIRONMENT

This research will require an interdisciplinary team including expertise in future aircraft systems, speech I/O, expert systems (knowledge representation), and human factors engineering.

TIMING

The application of intelligent systems to cockpit design should begin immediately. The proliferation of technology in the cockpit will soon reach the stage where the pilot is a definite limiting factor in system operation. Clever design of the pilot/system interface will be an increasingly important requirement. The relationship between speech I/O and an intelligent interface is complex. Now is the time to begin defining the functional design characteristics.

IMPACT ON OTHER RESEARCH ISSUES HEREIN

Assuming that the "intelligence" of a speech I/O interface will evolve over time, the level of the intelligence and the specific capabilities of the system will affect the entire role of speech in the cockpit.

APPLICATION OF SPEECH I/O FOR PILOT TRAINING IN SINGLE SEAT AIRCRAFT

PROBLEM DEFINITION

In a single seat fighter, the first flight is a solo. The potential difficulties inherent in this fact have led to progress in simulation, procedures trainers, and the costly development of two-seater trainer aircraft.

Speech I/O provides the potential to aid the new or transitioning pilot by allowing access to information about procedures, systems operating parameters, etc. The pilot could call for these information aids as needed in flight. This concept is a variation on the B-3 systems discussed previously. Rather than a tactical team member represented in the intelligent software, the training version would represent some of the characteristics of an instructor.

The research issue is to develop the functional design of an intelligent speech I/O system that could aid and support a pilot who is new to the aircraft.

Such a system could provide a wide range of services, from merely providing data when asked, to evaluating pilot performance and suggesting techniques for improvement. In short, the entire range of functions performed by an instructor-pilot are candidates for including in an on-board automated training aid.

Some of the simpler functions, such as providing verbal or displayed information when requested, are within the current state of technology. More complex functions requiring the development of modelling instructor-pilot functions, would be more difficult, but are still within the realm of current technology.

This "instructor in a box" concept has the potential to increase safety while providing instruction. Manning requirements for instructor-pilots could be reduced, with the associated cost savings. This type of system is not seen as a replacement, but a supplement, to simulation and two-place aircraft.

RESEARCH CONDITIONS AND ENVIRONMENT

Expertise in speech I/O applications, pilot training, and instructor-modelling will be required to perform the analyses suggested by this research issue. Again, this broad range of expertise may necessitate an interdisciplinary team. Researchers and scientists in speech I/O and AI must be strongly grounded in the tactical environment to provide meaningful input to this program. This can be achieved by careful selection of the participants and/or by requiring regular interaction with operational personnel.

TIMING

Application of speech I/O as an instructional aid in the single-seat fighter could be pursued in conjunction with the first introduction of speech I/O in the near-term fighter cockpit. An independent program to develop the sophistication of the system could proceed in parallel with the development of the far-term cockpit.

IMPACT ON OTHER RESEARCH ISSUES

Unknown.

THE IMPACT OF SPEECH I/O ON TRAINING REQUIREMENTS

PROBLEM DEFINITION

The addition of speech I/O to the cockpit will place the additional burden on the pilot to learn how to use it. Even if speech I/O proves to be very beneficial as a pilot/system interface, pilots must learn how to operate the speech system, and how it relates to traditional (manual/visual) modes of information exchange.

Training personnel in the use of speech systems has been found to be critical for their effective use (see the Canyon evaluations of the PARTS and ACE systems, for examples). The development of an effective training program will be essential for the application of speech I/O in the tactical aircraft. Without a good training program, speech recognition accuracy will suffer, system effectiveness will be reduced, and user acceptance may be compromised.

The research issue here is to develop guidelines for pilot training in the use of speech I/O as the system is under development. Even at this early stage, certain training principles in the use of speech technology can be extracted and accumulated for eventual inegration into a training program. For example, the requirement for speech sampling in a speaker-dependent recognition system carries with it certain implications for pilot (user) training as well as for system design.

Speech recognition, in particular, is sensitive to the variabilities of the user. Recognition accuracy commonly increases with practice. In the same way that a pilot must learn to sense and feel the various manual controls in a new aircraft, he will have to learn the limits of voice variability that are acceptable to a speech recognition system. This process must be anticipated and encouraged by a good training program.

RESEARCH CONDITIONS AND ENVIRONMENT

Developing the training issues for the introduction of speech I/O in the cockpit should be done by an organization(s) with expertise in pilot training and speech I/O applications. Additionally, organizations involved in the development of speech I/O in the cockpit should be required, as an ancillary task, to generate a list of items or issues pertaining to pilot training.

TIMING

It would be a mistake to begin considering training issues only after the first aircraft has been delivered with speech technology in the cockpit. They should be considered at the same time the system is being developed. A core training program should be developedearly, and a list of training issues should be added as the system evolves during RDT&E.

IMPACT ON OTHER RESEARCH ISSUES

All of the research and development programs discussed herein will include factors that affect the way the system is to be designed or operated. These factors become candidates for items in a training program for the pilot, as a user of the system.

PILOTS MEMORY FOR WORDS DURING HEAVY WORKLOAD

PROBLEM DEFINITION

A pilot's memory for the location of buttons or switches is essential for operating aircraft effectively. Similarly, his memory for key words and commands will be essential for proper operation of a speech input system. The cognitive performance of pilots (memory, response time, error probability, etc.) will be different for visual/manual/spatial tasks than for auditory/verbal/serial tasks. How these two sets of skills are affected by task loading and combat stress is important for the design of the pilot/system interface.

If remembering vocabulary items or word sequence constraints is a problem in a high threat environment, for example, the interface design must account for it. Examples of design options are whether to have a manual or speech input for certain functions (or both); allowing alternative words to be used to accomplish the same function; and developing the speech syntax with flexibility to avoid strict rules of word sequences.

The research issue is to analyze and define the cognitive and memory processes of the fighter pilot, and how they are influenced by stress. these analyses should be done with the goal of optimizing the cockpit design, and particularly the integration of speech I/O in the cockpit. The implications for vocabulary size and syntax development are directly applicable. Information relevent to learning/training also should result from these analyses.

If the cognitive load created by remembering and using the speech input vocabulary is so high that it reduces the pilot's performance in other areas (i.e., target detection, communications interpretation, etc.), this would have great importance for the application of speech input. The same applies for the cognitive load created by perceiving and understanding speech output messages in a busy situation.

RESEARCH CONDITIONS AND ENVIRONMENT

This work should be led by an entity with expertise in cognitive science (a subcategory of Experimental Psychology) in close cooperation with people who are familiar with the fighter pilot's task, and with the speech technology. This could be done by some combination of university scientists and operational personnel, or by an organization with a human factors orientation, bridging the three necessary areas of expertise.

TIMING

The knowledge of expected effects of stress verbal memory and the operation of a speech I/O system should be obtained well before this technology is implemented in operational aircraft.

IMPACT ON OTHER RESEARCH ISSUES

Memory limitations and cognitive capacity in stressful situations may interact with several of the research issues discussed herein, e.g., young pilots, the intelligent interface, training objectives, and the high threat environment.

APPLICATION OF SPEECH I/O IN THE DESIGN OF SOPHISTICATED SYSTEMS OPERATING IN A DOWNGRADED MODE

PROBLEM DEFINITION

Increasingly sophisticated automated systems will be provided in future aircraft design. Such systems, while substantially redundant by design, will continue to require the intervention by the pilot when the system is operating in a downgraded mode. The frequency of downgrading will be low due to high reliability. Accordingly, the pilot exposure to downgraded system operation will be low.

It has been proposed that the internal fault monitoring system be interfaced with the speech I/O to provide communications between the system and the pilot (1) to minimize the disruptiveness of the malfunction, (2) to request the pilot to take specific actions ensuring mission safety and (3) to lead the pilot through a dowgraded system checklist procedures (if required). Speecn I/O is a more flexible interface witn the pilot than using extensive verbage on a MFD for the same purpose.

RESEARCH CONDITIONS AND ENVIRONMENT

This research should be carried out in large systems houses with experience of integrated aircraft systems. The work should be carried out under the direction of an applied cockpit speech I/O research group.

TIMING

This research should be pursued for far term aircraft only (1990-2000). However, the principles for the speech I/O interface with sophisticated systems need to be developed now, so that a design guide is available to future system designers.

IMPACT ON OTHER RESEARCH ISSUES HEREIN

The main impact will be on the vocabulary and syntax development so that the pilot will interface easily with the degraded system. A secondary effect will be the extent of initial and recurrent training the pilot will require to use a speech I/O interface infrequently.

PILOT SELECTION OF SPEECH I/O FUNCTIONS COMMENSURATE WITH MISSION PURPOSE

PROBLEM DEFINITION

Some pilots may desire to use speech I/O more frequently than others. For instance, if the mission involves serveral friendly aircraft with expected communication clutter, the pilot may desire to use the speech I/O only for new threat information and/or for verbal checklists when an emergency situation exists. If the next mission involves a single long, low level, night reconnaissance into enemy territory with little communications, then he may elect to have the total speech I/O working for him. In the far term concept the speech I/O interface could encompass all discrete manual actions which the pilot may make in a cockpit.

RESEARCH CONDITIONS AND ENVIRONMENT

In the near term, this issue of pilot selection of functions may be resolved using a tactical pilot population in a full mission training simulator in which speech I/O has been provided for those items involving high threat, high workload, eyes out environments. The analysis of pre-mission selection of speech I/O functions could determine the need for individual pilot selection. The pilot population used for this study should encompass both the unexperienced and very experienced pilots.

For the far term, speech I/O interface should be considered as an integral part of the design of future tactical aircraft cocpits. Speech I/O selection then becomes a fallout of individualized design (assuming that customization is a viable alternative).

TIMING

Resolution of this issue in the near term is important because it has a profound affect on the speech I/O interface implementation concept for aircraft in the 1985-1990 time frame.

For the far term, design guidelines for speech I/O interface implementation should be available by the end of 1985 to provide guidance on pilot/cockpit function selection, both pre-flight and in-flight.

IMPACT ON THE RESEARCH ISSUES HEREIN

The impact of this basic issue is pervasive in respect to speech I/O interface implementation. It has its origin in the designer's ability to demand pilot functional selections in an increasingly automated environment. To date no rigorous man/machine allocation procedure has been developed to make such selection in a consistently meaningful manner.

METHOD OF REDUCING NORMAL COMMUNICATIONS CLUTTER WHEN SPEECH I/O INTERFACE IS INTRODUCED

PROBLEM DEFINITION

Radio telephone (R/T) communication clutter is normal to tactical aircraft operations when more than, say, three aircraft are involved in a mission. Pilots do their own filtering and reject R/T communicated information which is not useful to them. Pilots have expressed concern that speech output from the aircraft's system could cause distraction in a communication clutter situation and under some circumstances would interfere with the mission.

The usual technique to reduce communications clutter is to provide more dedicated communications channels to the user population. The expansion of this scheme to help find a place for the speech I/O interface in the cockpit information flow, has obvious limitations.

Knowing that the need for tactical communications will always exist and that speech output also needs to have access to the pilot's brain, the issue becomes to develop different strategies of aural communications. For example, can the R/T communications clutter be reduced to only those aircraft within a certain limited air space and range volume? Alternatively, can air-to-air, air-to-ground and ground-to-air communications be allocated to a discrete address systems as intended for use in future air traffic control systems.

RESEARCH CONDITIONS AND ENVIRONMENT

Psychological research is required on how pilots derive information from aural communication. A question like, "can the right ear be used for R/T and the left ear used for speech sytem outputs?" needs to be answered in a laboratory environment. Improvement of R/T communications technqiues involving space limiting or discrete addressing, requires the expertise of communication engineers.

TIMING

The timing to find a solution is "now." It is the authors' view that the continuing problem of communications clutter in the real world tactical aircraft environment may limit the usefulness of cockpit speech output.

IMPACT ON OTHER RESEARCH ISSUES HEREIN

This issue is directly related to "Prioritization of Speech Output Messages" and to cognitive workload issues.

THE VALUE OF SPEECH I/O IN THE SINGLE SEAT COCKPIT FOR HIGH AND LOW TASK/THREAT ENVIRONMENT

PROBLEM DEFINITION

Some tactical aircraft pilots consider that if speech I/O is to be introduced in the future cockpit designs, it should be limited to those functions which are frequently used in a high workload, high threat, hands-on-throttle-and-stick heads out environment. Other tactical pilots see the speech I/O interface having a role which supports the general piloting task independent of mission phase (analogous to a second pilot in the back seat).

The design of speech I/O interface in the tactical cockpit lacks a rigorous man/machine allocation procedure. This same problem exists in the design of all aircraft automated systems which interface with the pilot. The issue then is to develop a rigorous allocation program which will perform for every aircraft system configuration and mission phase. If this issue is insoluable, then speech I/O should be allowed to propogate through all cockpit functions as an alternate mode with the choice of use being left to pilot choice dependent upon prevailing needs and operational conditions.

RESEARCH CONDITIONS AND ENVIRONMENT

For the overall and far term solution, if an appropriate man/machine task allocation program for future aircraft cockpit design exists then the speech I/O interface utilization problem should be emphasized in the context of that research.

In the near term a study similar to that of "development of speech input/output interfaces for tactical aircraft" should be undertaken by an independent aviation human factors organization who have demonstrated understanding of the tactical aircraft environment. This study should be directed at reducing the wide differential of opinion which the tactical aircraft community has about speech I/O. The pragmatism of the experienced pilot needs to be integrated with the innovativeness of youthful community (the latter stand to be the primary users of speech I/O).

TIMING

The industry need for guidance on this matter exists now. In the longer term, the solution to this problem is likely to be a product of the speech I/O configuration research for the far term aircraft.

IMPACT ON OTHER RESEARCH ISSUES HEREIN

The impact of the subject issue is far reaching as the issue is focal to the extent the speech I/O interface propogates into the cockpit's functional operation.

PRIORITIZATION OF SPEECH OUTPUT MESSAGES

PROBLEM DEFINITION

Assuming that speech output messages are communicable to the pilot through the communications clutter, the speech output system can be expected to generate more than one message at any specific instance. The importance of each message becomes the driver for a speech output message prioritization scheme.

A generic approach is required for such a prioritization scheme such that it is not type of aircraft or type of system specific.

Consideration needs to be given to the necessity for an incoming R/T signal override function at the time a speech output content is being communicated to the pilot.

At issue is the protocol for message prioritization, overriding and message repeating in a cockpit environment. The issue includes the priority which should be given to the traditional buzzers and tones that will continue to exist in most cockpits.

RESEARCH CONDITIONS AND ENVIRONMENT

A study on potential cockpit messages, generic style and content, plus a literature search into message communication priorities is required. Experiments using suitable part task simulation would bring potential prioritization schemes into focus for cockpit applicaiton. Full mission simulation using preferred schemes would then be required for system design confirmation.

TIMING

Message prioritization becomes increasingly important as the role of the speech output interface expands in the cockpit. The need for systematic work on this issue exists right now.

IMPACT ON OTHER RESEARCH ISSUES HEREIN

Message prioritization affects the interaction of speech input and output, the design of "intelligent" speech I/O, and the cognitive loading of the pilot.

APPENDIX B

RESEARCH FEATURES AND DESIGN REQUIREMENTS FOR SPEECH INTERFACED TACTICAL AIRCRAFT SIMULATION

INDEX

RESEARCH FEATURES AND DESIGN REQUIREMENTS FOR SPEECH INTERFACED TACTICAL AIRCRAFT SIMULATION

Introduction

This document attempts to provide a framework for simulating a speech input/output mode to be used in future tactical aircraft cockpits. A full mission simulator is not required for implementation of the speech I/O mode, but it is not precluded.

The simulation framework is directed at demonstrating and evaluating a speech mode in an "eyes out" and/or "high threat" environment which is the focus of the aircraft system functions selected for simulation.

The assumptions used in developing this document are summarized as follows:

1. The simulation will be used to demonstrate the feasibility and evaluate the performance of selected speech mode functions for use in an aircraft similar to the F-16 in the 1985-1990 timeframe.

2. A conventional interface between the pilot and aircraft systems will be provided for the selected speech mode functions and other system functions required to conduct eyes out/high threat mission scenarios.

3. The interface will include two multi-function displays, part of which will be dedicated for speech I/O message feedback.

4. The intent and capability of the speech mode functional interface will be selectable prior to the conduct of each demonstration, exercise or experiment.

5. The simulation will be suitable for the investigation of applied speech I/O research issues identified in Appendix B of this report. As such, the simulation will include a speech mode performance algorithm and data recording capability.

Selected Speech I/O Functions

Thirteen generic types of speech/aircraft system functions will be simulated as follows:

INPUT

- Function Selection - use of speech recognition to command all mode/function switching, knob and lever selection in the cockpit. (See SIMIN No. 1, 3, and 4 below.)

- Request Information Display - use of speech recognition to request the display of various data on the multifunction displays. (See SIMIN No. 6 below.)

- Data Entry - use of speech recognition to enter data into the aircraft systems. (See SIMIN No. 2, 5, and 7 below.)

OUTPUT

- System Advisory - use of speech generation to convey normal system events. (See SIMOUT No. 5 below.)
- System Abnormality - use of speech generation to convey abnormal system events which do not impair immediate safety of flight. (See SIMOUT No. 3 and 6 below.)
- System Critical - use of speech generation to convey critical system events which impair the immediate safety of flight. (See SIMOUT No. 9 below.)
- Mission Advisory - use of speech generation to convey normal mission events. (See SIMOUT No. 2 below.)
- Mission Abnormality - use of speech generation to convey mission events which are not planned. (See SIMOUT No. 6 below.)
- Mission Critical - use of speech generation to convey high-threat events which are critical to the success of the mission. (See SIMOUT No. 1, 4 and 7 below.)

INTERACTION

- Command feedback use of speech generation response to a previous speech input command to the aircraft systems. (See SIMOUT No. 10 below.)
- System Status - use of speech recognition and generation to determine the status of aircraft systems including automatic checking systems. (See SIMI/O No. 2 below.)
- Diagnostic Response - use of speech recognition and generation to help diagnose and remediate the effects of a downgraded or failed system. (See SIMI/O No. 4 below.)
- System Information Processing - use of speech recognition and generation to provide an interactive interface for calculation and retrieval of system and mission information. (See SIMI/O No. 1 and 3 below.)

The aircraft functions selected for speech I/O simulation which follow are predicated on the results of the F-16 pilot community survey described in Section IV of this report. The question numbers from the pilot survey are indexed to the suggested "SIM" functions in Table B-1.

SIMIN 1. Perform chaff or flare release.

This will control the order of release in accordance with a preflight programmed schedule. Simulated release of the chaff

TABLE B-1. SIMULATION SOURCE SELECTION SUMMARY

SPEECH INPUT	QUESTIONNAIRE QUESTION NUMBER
SIMIN 1	24
SIMIN 2	33, 34, 35
SIMIN 3	25, 31, 32, 37, 38, 39, 47, 48, 49
SIMIN 4	45
SIMIN 5	36
SIMIN 6	27, 28, 29, 30, 44, 46
SIMIN 7	43
SIMIN 8	42
SPEECH OUTPUT	
SIMOUT 1	2, 3, 4, 19
SIMOUT 2	6
SIMOUT 3	17
SIMOUT 4	5
SIMOUT 5	1
SIMOUT 6	7, 9, 15, 20, 8
SIMOUT 7	23
SIMOUT 8	10
SIMOUT 9	21
SIMOUT 10	11
SPEECH INPUT/OUTPUT	
SIMI/O 1	50, 52
SIMI/O 2	40, 41
SIMI/O 3	53
SIMI/O 4	16

or flares may be indicated on the applicable MFD as an alternative to speech recognition feedback. This alternative will be selected by a keyboard entry into the simulation host computer.

SIMIN 2. Initiate channel or frequency changes on nominated radio equipment (VHF, UHF, TACAN, etc.).

Actual channel or frequency, as provided on an indicator designed for this purpose, may be used as an alternative to generated speech feedback. This alternative will be selected by a keyboard entry into the simulation host computer.

SIMIN 3. Command the modes of mission critical equipment - like "ECM ON," "MASTER ARM ON," "LANTIRN SEARCH," "MISSILE UNCAGE," "AIR-TO-AIR," etc." and "MFD FORMATS."

The repetoire of mission critical modes selection will be dependent on the extent and sophistication of the simulation provided for this purpose. However, each mode should be selectable through the simulator host computer data entry keyboard.

SIMIN 4. Control interior and exterior lighting levels.

Light levels of annunciator switches, indicator lights etc., will be provided automatically as feedback. Automatic movement of incremental controls like dimmers need not be provided.

SIMIN 5. Input pre-mission data such as navigation point coordinates, fuel load, weapons types and stores configuration.

The same data may be altered in flight by identifying the variable(s) to be changed. Confirmation feedback for the verbally entered data may be by speech generation or MFD display, or both.

Selection of the desired level of feedback will be a keyboard entry into the host computer.

SIMIN 6. Call up information to be displayed on the secondary MFD. Information will include route, approach, JTIDS, checklists, available MFD formats, etc.

SIMIN 7. Updating present position over the top of a nominated navigation point by saying, for example, "DP3 MARK." Confirmation that the update took place can be displayed on the secondary MFD and/or be provided by the speech generation system.

SIMIN 8. Request aircraft system critical information like: "fuel remaining," "stores remaining," etc.

Confirmation of speech recognition which may be speech generated and/or displayed on the secondary MFD.

Selection of the desired level of feedback will be a keyboard entry into the host computer.

The selected aircraft functions for <u>output</u> simulation are:

SIMOUT 1. Provide detailed threat warning information.

This will cover the initial acquisition of each threat, identification when known, bearing sector relative to the aircraft's nose and an update of threat status. Selection of threat information, type, bearing, status, and their message queue priorities will be provided by a keyboard entry into the host simulation computer prior to the commencement of each exercise.

SIMOUT 2. Prompt the necessity to change operational identification.

This will be a "universal time" oriented general message which, for example, advises the pilot to change IFF code(s) to the appropriate setting (per the flight plan). A keyboard entry into the host computer prior to the commencement of each exercise will set the appropriate time. Message queue priority normally will be kept constant.

SIMOUT 3. Enunciate master warnings and/or caution occurrences.

There will be two levels of output. The upper level will include those primary system warnings which are not in the pilot's eye field of view, such as master caution, engine fire, etc. The lower level will provide the detailed cause of why the master warning or caution occurred, such as an "avionics" caution. A keyboard entry into the simulation host computer will determine which level of output will be used in the exercise and it's message queue priority.

SIMOUT 4. Inform when bingo fuel has been reached.

Message queue priority normally will be kept constant.

SIMOUT 5. Provide specific altitude readout below specified altitudes.

This will be a multiple level output which can be determined by the aircraft's external control configuration and/or altitude. Control configuration levels include gear and flap position. Altitude levels are suggested as:

> 10,000 ft. to 1,000 ft. - every 1,000 ft.
> 1,000 ft. to 50 ft. - every 100 ft.
> 50 ft. to 10 ft. - every 10 ft.

A keyboard data entry into the simulation host computer will be used to select the levels and message queue priority to be used in each exercise.

SIMOUT 6. Report degradation of mission critical systems.

This output is intended to identify degradation of systems which are critical to the safety and success of a mission.

Such systems are expected to include a self contained performance monitoring device which will indicate when specific criteria are exceeded.

Systems considered to be in this category include, threat warning, ECM, navigation, flight control, fuel distribution, main power plant, etc. For example, a flight control system could be operating with a failed servo.

A keyboard entry into the simulator host computer will be used to select which system is selected and the message queue priority to be used.

SIMOUT 7. Provide warning of laser designated target masking through evasive maneuvering.

This will inform the pilot when he has masked a predesignated target which is scheduled to be struck by an automatically released store.

Message priority will normally be kept constant.

SIMOUT 8. Prompt - the necessity to carry out routine mission oriented checks.

These will be navigation position or universal time oriented general message which, for example, advises the pilot to conduct a fence check.

Message queue priority will normally be kept constant.

SIMOUT 9. Inform corrective action and direction of application when the aircraft's aerodynamic performance envelope is exceeded.

This may be impractical to simulate for demonstration unless adequate visual cues are available.

SIMOUT 10. Feedback verbal input information which has been recognized by the speech system or is in the process of being recognized.

There will be three levels of control for this process. The first will repeat the input message when it has been recognized. The second level will include the first level feature but in the event that the verbal input is not recognized first time, a generated speech output will say "Say Again." A third level of control will inhibit any verbal feedback to the pilot in favor of a visually displayed message (see also the sections on input control and feedback).

A keyboard entry into the simulator host computer will be used to control the level of feedback to be provided.

The selected <u>interactive</u> functions for simulation are:

SIMI/O 1. Request critical flight planning information like "fuel home," "fuel to alternate."

This assumes a nominal cruise and/or descent profile from present position to touchdown. It will require inputs from the navigation, fuel, air data, and stores management equations for the simulation host computer to make the determination.

Message priority in the speech output queue will be kept constant.

SIMI/O 2. Request status of automatic aircraft system checkoff like "fence check status."

This requires multiple system inputs to be available to a simple equation which represents the checklist items.

Actions still required to be made by the pilot will then be speech generated and/or displayed on the secondary MFD until the procedure is completed.

No action by the pilot will stop further speech generated requests.

Message priority in the speech output queue will be kept constant.

SIMI/O 3. Request future flight plan information like "features for DP 3"; typical response would be "one tree hill."

This requires prior identification of each navigation check point in a data file held by the simulation host computer. This file would be a "scratch" type file for each mission to be conducted (this would be in contrast to the general route and approach plate information file which could be called on by route, approach, or runway ident).

If more than twenty-four characters long, data so requested will be speech generated. If less than twenty-four characters long, they may be displayed on the secondary MFD. In the latter case generated speech will also prompt the pilot to "see MFD."

SIMI/O 4. Respond to pilot's request for information to help resolve degraded performance of an aircraft system.

This is intended to suggest remedial solutions which may not be readily recalled by the pilot in high threat or high workload situations.

The feature requires storage by the simulation host computer of fault trees for flight critical and mission ciritical systems.

Speech generation will be used if the solution message is long. The secondary MFD may be used if the messges is less than twenty-four characters in length. In the latter case, generated speech will prompt the pilot to "see MFD."

Input Control

Speech input will be through a boom headset microphone which is compatible with the speech recognition equipment used in the simulation. The microphone normally will be inactive. A special microphone key will be fitted to the simulated engine throttle control to enable keying to the "ON" condition.

Selected speech functions available to the "pilot" for each exercise will be preselected by the simulator technician using a data entry keyboard associated with the simulation host computer.

Verification of each verbal input analyzed by the speech recognition system will be made in one of three ways as follows:

1. Not recognized - at which time a speech output which says "say again," will be initiated.
2. Recognized but requires further systems intelligence to fulfill command - At which time a 1/2 second 500 HZ audio tone will be initiated to indicate that action is taking place.
3. Recognized - at which time two 1/2 second 500 HZ audio tones with a 1/2 second separation will be initiated. In addition, the recognized message will be displayed unobtrusively on the secondary MFD and will remain displayed until replaced by the next recognized verbal command.

Functional and situational discrimination logic (often referred to as syntax, speech understanding, or artificial intelligence) will be provided down line from the speech recognition system by the host computer. The "say again" interrogative can be initated by either the speech recognizer or the functional situational logic. The audio tones will be initiated by discrete output(s) from the functional and situational logic.

Output Control

Output messages will be transmitted through the simulator audio channel used for communications with the pilot. The protocol for speech output queueing will have four levels of priority and radio transmissions will override system-generated messages. The four levels of queueing protocol will be as follows:

Priority #1 - Ultra important messages which assist in the safe conduct of the mission. These messages will override any other message being transmitted by the speech generation sysem even if the message is incomplete.

Priority #2 - Very important messages which assist in the management of the extraordinary events experienced during a mission, e.g., flight control system servo failure.

Priority #3 - Important messages which assist in the management of ordinary events experienced in flight, e.g., endurance/fuel remaining.

Priority #4 - Routine messages which assist the pilot in routine work, e.g., reciting checklists.

Each Priority #2 through #4 speech generated message will be completed before the next message is commenced, unless a Priority #1 message intervenes.

When more than one message is in the queue, the priority will be adjusted before the next message is transmitted. Messages which have been transmitted incompletely will be reassigned to their correct priority position and retransmitted as complete messages. Messages which are delayed by the priority hierarchy by more than 20 seconds will not be transmitted and will be cancelled.

The content of each transmitted message will be displayed unobtrusively on the secondary MFD and will remain displayed until replaced by the next generated speech message.

Priority of messages to be transmitted during each exercise will be preselected using a data entry keyboard associated with the simulation host computer. Messages with priorities not selected for transmission will be presented to the pilot by an indicator light, annunciator, or audio tone which is inherent in the design of the specific aircraft system being simulated.

The following alternative output message control schemes will be provided in the simulation design. Each alternative will be selectable through the host computer keyboard.

Alternative #1. The aircraft audio system normally will handle only radio communications unless the pilot commands differently. In the event that a speech generated message is waiting, the word "message" will be passed over the audio channel when no radio communications are present. When convenient, the pilot will verbally command the waiting speech message transmission by saying "go ahead" to the speech recognition system.

Alternative #2. The audio system normally will handle only radio communications. In the event that a systems message is waiting, the words "see MFD" will be passed over the audio channel when no radio communicaitons are present. The message will then be displayed on the secondary MFD.

Alternative #3. In the event that a speech generated message is being transmitted when an R/T incoming message commences, the R/T message will be recorded and stored. It will then be played back to the pilot when the previous speech generated message is complete. The playback R/T message will assume overriding authority in the queue.

Feedback

Feedback to the pilot of the status and content of speech system input and output messages will be made as follows:

INPUT

A 1/2 second 500 HZ audio tone will be used to advise the pilot that the transmission has been recognized and further system intelligence is being used to fulfill the command.

Two 1/2 second 500 HZ audio tones with 1/2 second separation will be used to advise that the command has been fulfilled. The recognition of the message will be displayed unobtrusively on the secondary MFD or displayed on a separate display for the purpose or be verbalized through speech generation.

Mechanical movement of appropriate controls, levers, knobs, etc. will be made in compliance with the commanded change of status of these devices.

Illumination of lights, movement of or illuminiation of annunciators will be made in compliance to the commanded change of status of these devices.

In the event that the input is not recognized by the system, a feedback message of "say again" will be generated as a Priority #1 message.

OUTPUT

Each output message will be displayed on the secondary MFD simultaneously with the speech message transmission made to the pilot.

VOCABULARY

The speech recognition subsystem will be speaker dependent and use an isolated word recognition format. An example of a speech input vocabulary is given in Table B-2. Changes to the speech input vocabulary will be accomplished through the host computer keyboard.

Two types of generated speech outputs will be provided--stored digitized words or phoneme synthesized words. Both types of outputs will use a male sounding voice. The speech output vocabulary will be based on individual words (in contrast to expressions). Individual words will be combined into expressions by the speech generation process. The speech output vocabulary is shown in Table B-3. Use of digitized or synthesized outputs will be by a keyboard entry into the host simulation computer. Changes to the speech output vocabulary will be accomplished through keyboard entry.

Examples of the speech input, output and interaction expressions expected to be used for the simulation are shown in Tables B-4 through B-6.

TABLE B-2. INPUT ISOLATED WORD VOCABULARY FOR DEVELOPMENT SIMULATION

(NOTE: Subject to Additions)

- "A"

A ALPHA
AIR-TO-AIR
AIR-TO-GROUND
AIM
AFT-TANK

- "B"

B BRAVO
BEGIN
BEGIN-CHECKLIST

- "C"

C CHARLIE
CHAFF
CLIMB
CLIMB-PROFILE
CHANNEL
CHANGE

- "D"

D DELTA
DOWN
DEGREES
DISPLAY
DESCENT

- "E"

E ECHO
EIGHT
EIGHTY
ENROUTE-NAV
ECM
ELEVEN
EIGHTEEN
EAST

- "F"

F FOX TROT
FLARES
FOURTY
FORWARD-TANK
FIFTEEN
FOUR
FIFTY
FENCE-CHECKLIST
FIVE
FUEL-REMAINING
FOURTEEN
FORMATS
FUEL

- "G"

G GOLF

- "H"

H HOTEL
HUNDRED
HEADING-TO-ALTERNATE
HALT-CHECKLIST

- "I"

I INDIA

TABLE B-2. INPUT ISOLATED WORD VOCABULARY FOR DEVELOPMENT SIMULATION (Continued)

- "J"

J JULIETT
JTIDS-UPDATE

- "K"

K KILO

- "L"

L LIMA
LANTIRN-SEARCH
LOAD-DP
LOAD-FUEL
LEFT
LIGHTS
LOAD

- "M"

M MIKE
MASTER-ARM
MODE
MARK
MINUS

- "N"

N NOVEMBER
NINER
NAV
NORTH
NINETY
NINETEEN

- "O"

O OSCAR
ON
OFF
ONE
OVER

- "P"

P PAPA
POSITION
POUNDS
POINT
PANEL
PLUS

- "Q"

Q QUEBEC

- "R"

R ROMEO
RELEASE(D)
RIGHT
RESUME-CHECKLIST

- "S"

S SIERRA
SIXTY
SEVEN
SEVENTY
STORES-REMAINING
SIX
SIXTEEN
SEVENTEEN
SOUTH
STORES-CONFIGURATION
SAY

TABLE B-2. INPUT ISOLATED WORD VOCABULARY FOR DEVELOPMENT SIMULATION (Continued)

- "T"

T TANGO
TEN
TWENTY
THREE
TACAN
TARGET(POSITION)
TWO
TWELVE
THIRTEEN
THIRTY
THOUSAND

- "U"

U UNIFORM
UP
UPDATE-DP
UHF-FREQUENCY
UHF-CHANNEL

- "V"

V VICTOR
VHF-FREQUENCY
VHF-CHANNEL

- "W"

W WHISKEY
WEST

- "X"

X X-RAY

- "Y"

Y YANKEE

- "Z"

Z ZULU
ZERO

TABLE B-3. DIGITALLY STORED WORD OUTPUT VOCABULARY FOR DEVELOPMENT SIMULATION

(NOTE: Subject to Additions)

"A"
A ALPHA
AIM
AVIONICS
AGAIN
ALL

"B"
B BEE
BRAVO
BINGO

"C"
C CEE
CHARLIE
CAUTION
COOLING
CODE
CONTROL
CHECK
CHANGE
CONTROLS
CLEAR

"D"
D DEE
DELTA
DEGRADED
DESCENT
DO

"E"
E EEE
ECHO
EIGHT
EIGHTY
ELEVEN
ELECTRICAL

TABLE B-3. DIGITALLY STORED WORD OUTPUT VOCABULARY FOR DEVELOPMENT SIMULATION (Continued)

	"F"
F	FOX TROT
	FOUR
	FIVE
	FOURTY
	FIFTY
	FUEL
	FEET
	FLIGHT
	FENCE
	"G"
F	GOLF
	"H"
H	HOTEL
	HANDS
	HIGH
	HILL
	HUNDRED
	"I"
I	INDIA
	"J"
J	JAY
	JULIETT
	"K"
K	KAY
	KILO
	"L"
L	LIMA
	LOW
	LEFT
	"M"
M	MIKE
	MASKING
	MASTER
	"N"
N	NOVEMBER
	NINER
	NINETY
	NAV

TABLE B-3. DIGITALLY STORED WORD OUTPUT VOCABULARY FOR DEVELOPMENT SIMULATION (Continued)

	"O"
O	OSCAR
	ONE
	ON
	OFF
	OF
	"P"
P	PAPA
	POUND
	POWER
	"Q"
Q	QUEBEC
	"R"
R	ROMEO
	RIGHT
	RUDDER
	REJECT
	"S"
S	SIERRA
	SIX
	SIXTY
	SEVEN
	SEVENTY
	SYSTEM
	SAY
	SEE
	"T"
T	TANGO
	TWO
	TWENTY
	THREE
	THIRTY
	TWELVE
	THREAT
	THOUSAND
	TARGET
	TOP
	TURN
	TREE
	TO
	TEN
	"U"
U	UNIFORM

TABLE B-3. DIGITALLY STORED WORD OUTPUT VOCABULARY FOR DEVELOPMENT SIMULATION (Continued)

	"V"
V	VICTOR
	"W"
W	WHISKEY
	WANT
	"Y"
Y	YANKEE
	YOU
	"Z"
Z	ZULU

TABLE B-4. DESIRED SIMULATION INPUT EXPRESSIONS

	PRIMARY EXPRESSION	ALTERNATE EXPRESSION
Chaff or Flares Release	Chaff Flares	Release Chaff Release Flares
Radio Channel or Frequency Change	VHF One One UHF Niner TACAN Five Six VHF One Three Six Point Seven Zero UHF Three Zero One Point One	VHF Channel One One UHF Channel Niner TACAN Channel Five Six VHF Frequency One Three Six Point Seven Zero UHF Frequency Three Zero One Point One
System Mode Selection	ECM Master Arm Lantirn Search Air-to-Air Air-to-Ground MFD Formats Etc.	ECM On Master Arm On Lantirn Search Mode Air-to-Air Mode Air to Ground Mode Etc.

TABLE B-4. DESIRED SIMULATION INPUT EXPRESSIONS (Continued)

	Primary Expression	Alternate Expression
Interior and Exterior Lighting Control	Panel Down	Panel Lights Down
	Panel Up	Panel Lights Up
	Panel On	Panel Lights On
	Panel Off	Panel Lights Off
	Position Up	Position Lights Up
	Position Down	Position Lights Down
	Position On	Position Lights On
	Position Off	Position Lights Off
	NAV On	NAV Lights On
	NAV Off	NAV Lights Off
Insertion of Data Into Systems (Permission Or In Flight)	D.P. One-North Three Three Degrees Two Niner Point Five, West One Two One Degrees Five Seven Point Two	Load D.P. One, North--- ----------------------- -----------------------
	D.P. Niner -----------	Load D.P. Niner--------
	Aim Niner C, Two Left, Two Right	Load Aim Niner C Two Left, Two Right
	Fuel, Forward Tank Zero, AFT Tank Ten Thousand	Load Fuel, Forward Tank Zero, AFT Tank Ten Thousand Pounds

TABLE B-4. DESIRED SIMULATION INPUT EXPRESSIONS (Continued)

	PRIMARY EXPRESSION	ALTERNATE EXPRESSION
Display of Data On MFD's	Display Right ------- Display Left -------- Display Change (Left to Right to Left) (Typical Format Callout) Enroute Target Climb JTIDS Stores Fence	Display Right MFD ---- Display Left MFD ----- (Typical Format Callout) Enroute NAV Target Position Climb Profile JTIDS Update Stores Configuration Fence Checklist
Update Navigation Position	D.P. One, (Pause) Mark D.P. Niner (Pause) Mark	Update DP one (Pause) Mark Update D.P., Niner (Pause) Mark
Request Critical System Information	Fuel Remaining Stores Remaining Heading to Alternate Air Start Checklist ------Checklist Etc.	Say Fuel Remaining Say Stores Remaining Say Heading to Alternate Say Airstart Checklist Say ------ Checklist Display -- Checklist Etc.

TABLE B-5. DESIRED SIMULATION OUTPUT EXPRESSIONS

	PRIMARY EXPRESSION	ALTERNATE EXPRESSION
Threat Warnings	SA Ten One O'Clock SA Ten Twelve O'Clock SA Twenty One O'Clock SA Twenty Twelve O'Clock Unidentified One O'Clock Unidentified Twelve O'Cock NOTE: Relative Bearing may be followed by "High" or "Low"	Preceed all messages with the word "THREAT"
SECURE CODE CHANGES	IFF CODE TWO CEE ETC.	CHANGE IFF CODE TO TWO CEE ETC.
Master Warning & Caution	Caution On Caution Avionics Cooling Caution -------------- Etc.	Master Caution On Master Caution Avionics Cooling Master Caution---- Etc.

TABLE B-5. DESIRED SIMULATION OUTPUT EXPRESSIONS (Continued)

	Primary Expression	Alternate Expression
Time Related Action Prompting	Update NAV Fence Check Change IFF Top of Descent Etc.	
Aerodynamic Performance Envelope Exceedance	Power Off, Left Rudder Power Off, Right Rudder Hands Off Controls Etc.	
Verbal Recognition of All Speech Inputs	(See Table F4 Input Vocabulary)	(See Table F4 Input Vocabulary)
Speech System Control	Say Again Do You Want -------- Reject See M.F.D.	

TABLE B-5. DESIRED SIMULATION OUTPUT EXPRESSIONS (Continued)

	PRIMARY EXPRESSION	ALTERNATE EXPRESSION
Critical Fuel Remaining	Bingo Fuel	
Altitude Read Out	Ten Thousand (Every 1000 Ft.) One Thousand (Every 100 Ft.) One Hundred (Every 10 Ft.) Fifty	Ten Thousand Feet (Every 1000 Ft. One Thousand Feet (Every 100 Ft.) One Hundred Feet (Every 10 Ft.) Fifty Feet
Mission Critical System Degredation	Degraded Threat Warning Degraded ECM System Degraded NAV System Degraded Flight Control Degraded Electrial Power Degraded _(Two Words)_ Etc.	
Laser Designated Target Masking	Masking	Target Masking

TABLE B-6. DESIRED OF SIMULATION INTERACTIVE SPEECH EXPRESSION

	INPUT EXPRESSION	OUTPUT EXPRESSION
Requests for System Data	Fuel Home Fuel to Alternate	Three Five Zero Zero (NOTE: Digit Expression)
Request for Status of Automatic, Semi Automatic or Manual Checking Procedures	Fence Check Status Threat Status _ _ _ _ _ _ _ _ Status (NOTE: Input Expression uses up to two words in front of "STATUS")	Turn Master Arm On All Clear _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ (NOTE: Output Expression can contain up to five words from specialized vocabulary)
Request for Flight Plan Data	Features for D.P. Three Target One Elevation (NOTE: Input Expression uses up to five words)	One Tree Hill Two Five One Feet (NOTE: Output Expression can contain up to five words)
Request Remedial Information on Degraded System Operation	Fuel Control Fix (NOTE: Input Expression uses up to five words)	Switch to BEE, U, CEE (NOTE: Output Expression can contain up to five words) (BEE U CEE = Backup Control)

SYNTAX

Functional and situation discrimination logic (SYNTAX) will conform to the generalized "grammar" shown in Table B-7. The features of this grammar are summarized as follows:

- o An "utterance" is either a function, an action or an expression.
- o Functions are, in effect, single word commands. In some cases, several individual words are strung together to yield a single word command that would be recognizable by the isolated word recognition system.
- o Actions are two word commands that identify a "device" to be acted on and a "state" to which it is to be changed. Two isolated recognitions are therefore required.
- o Expressions are multiple word commands that require more than two isolated recognitions. Typically the additional words are required in order to express a quantity consisting of one or more digits with (optionally) an associated set of units and a "direction" (or "destination").
- o Because of the nature of the items that might be referred to in an expression, it is necessary to have a terminator (e.g., the word "OVER"). The terminator is not necessary for either functions or actions.

The grammar has been designed for simple user operation. No distinctions have been made to insure that every syntactically correct statement is also semantically correct. Although the structure permits many (in fact, an infinite number of) semantically incorrect statements, at the same time there is a greater number of ways to utter a semantically correct statement. This is both good and bad--good because it gives the operator the ability to request the same information in several different ways, and bad because the operator must have a mental model of what consititutes a correct statement and what does not. This flexibility has been allowed so as, first, to capture both the primary forms and the alternate forms in the input phrase repetoire with a single grammar and, second, because the functions that are required need it. If desired, the syntax can be revised so that the structure is less flexible. However, the problem will remain that a syntactically correct sentence may be "physically unrealizable" e.g., the operator may try to "SELECT VHF-CHANNEL ZERO POINT ZERO THREE TWO." Software to support the speech input system will have to provide adequate checks for such situations.

TRAINING THE SYSTEM

Each system user will "train" the speech recognition subsystem off-line using multiple iteration of the same words spoken with different emphasis and intonation. Although further research on this issue is required, preliminary indications are that speech variability during template creation may lead to better recognition accuracy during operations.

TABLE B-7. PROPOSED SPEECH INPUT SYNTAX

```
UTTERANCE ::=  function | action | expression

FUNCTION  ::= CHAFF | FLARES | ECM | MASTER-ARM | LANTIRN-SEARCH |
              AIR-TO-GROUND | AIR-TO-AIR    | ... | FUEL-REMAINING |
              STORES-REMAINING | HEADING-TO-ALTERNATE | CLIMB | DESCENT

ACTION    ::= device + state | verb + function

DEVICE    ::= function | PANEL(LIGHTS) | POSITION(LIGHTS) |
              NAV(LIGHTS)

STATE     ::= UP | DOWN | OFF | ON | MODE | RELEASED

VERB      ::= BEGIN | RELEASE | BEGIN-CHECKLIST | HALT-CHECKLIST |
              RESUME-CHECKLIST

EXPRESSION::= system + quantity + OVER

SYSTEM    ::= VHF-FREQUENCY | VHF-CHANNEL | UHF-FREQUENCY | UHF-CHANNEL |
              TACAN | AIM | (LOAD)-DP | (LOAD)-FUEL | DISPLAY |
              UPDATE-DP |

QUANTITY  ::= number [units] [direction] [quantity] | format [direction]

NUMBER    ::= ZERO | ONE | TWO | THREE | FOUR | FIVE | SIX | SEVEN |
              EIGHT | NINER | TEN | ELEVEN | TWELVE | THIRTEEN |
              FOURTEEN | FIFTEEN | SIXTEEN | SEVENTEEN | EIGHTEEN |
              NINETEEN | TWENTY | THIRTY | FORTY | FIFTY | SIXTY |
              SEVENTY | EIGHTY | NINETY | HUNDRED | THOUSAND |
              PLUS | MINUS | POINT

DIRECTION ::= NORTH | SOUTH | EAST | WEST | RIGHT | LEFT | MARK |
              FORWARD(TANK) | AFT(TANK)

UNITS     ::= DEGREES | POUNDS | ALPHA | BRAVO | CHARLIE | ... | ZULU |

FORMAT    ::= ENROUTE(NAV) | TARGET-(POSITION) | CLIMB-(PROFILE) |
              JTIDS-(UPDATE) | STORES-(CONFIGURATION) | FENCE-(CHECKLIST)
```

NOTE: Parentheses indicate a specific example and brackets indicate a generic category.

SIGNING-ON

Prior to using the system, the user will sign-on through the host simulation computer keyboard.

APPENDIX C

EXAMPLE QUESTIONNAIRE

Canyon Research Group, Inc.

Canyon Research Group, Inc.
and
Honeywell, SRC

THE APPLICATION OF SPEECH I/O AS AN ALTERNATE MAN/MACHINE INTERFACE FOR FUTURE TACTICAL AIRCRAFT COCKPIT DESIGN

BACKGROUND

The Canyon/Honeywell team is engaged on an R&D contract with the Air Force Wright Aeronautical Laboratory (AFWAL/FIGR) to use speech as an alternate input/output (I/O) mode for eyes-out, hands-on throttle and stick (HOTAS) operations in the single-seat fighter aircraft. Because you are part of the pilot community which will use such new system concepts, we are soliciting your opinion on many aspects of the proposed design.

The concept is that you will speak to the "speech system" and command it to implement switch manipulations, request information from other aircraft systems, etc. The speech system will recognize your voice, react to your command and then advise you that the command has been fulfilled. Although the speech system may talk to you in response to your commands, R/T will always be given priority. In fact, you will be able to turn the speech output "off" at which time feedback about your speech commands could be shown on a multi-function display.

In the near-term cockpit designs (1985-1990), we anticipate that only some important functions (i.e., threat management, weapons control and certain emergency functions) will be implemented with speech I/O as an alternative (optional) mode of input.

One design option for the far-term cockpit design (1990-2000) is to provide the pilot with an optional speech I/O mode for nearly all cockpit functions, with the exception of throttle and stick control. This is an entirely new concept for cockpit design, and it implies some new approaches to the functional layout of panel space. System control would become more automated, but the back-up mode for all systems would rely heavily on manual manipulation or speech I/O, whichever is more convenient for the pilot at that time.

THIS QUESTIONNAIRE

The following questions are to provide you with an opportunity to contribute your ideas and opinions about the best ways to apply speech I/O in the fighter cockpit of the future. Your ideas are important. The information obtained from this questionnaire will be a primary factor in the cockpit design recommendations which will be submitted to the Air Force R&D community.

The personnel data (organization, name, experience, etc.) are for purposes of data analysis only. The information will be kept confidential. No answers or comments will be associated with your name.

Please take the time to answer the questions carefully. Give comments and examples on the back of the page if you have time.

The 6 point scales provided after each question represent a continuum of usefulness, not useful to very useful. The mid-points of this scale could be described as moderately useful/not useful, and in the middle, sightly useful/not useful. You should indicate your opinion on one of the 6 appropriate vertical line markers and not in-between markers.

PERSONNEL DATA

Name/Rank ____________________ Date ________________

Organization ________________ Job/Position _____________

Age _______ No. Years Military Experience ___

Pilot Experience: Please list approximate hours by type

Aircraft Type	Hours
_________	____
_________	____
_________	____
_________	____

Computer Experience: (check those that apply)

a) Major ___ b) Courses ___ c) own home computer ___ d) other ___

Other comments on attitudes, education or experience that might influence your answers to this questionnaire:

____

____

____

____

1. A voice generator could be linked with a Ground Proximity Warning System providing specific voice altitude readouts below "given" or "pre-set" altitudes.

How useful would it be to perform this task by speech?

Not Useful — Very Useful

2. The voice generator system could provide exact threat information details such as the type, direction and priority level; for example, "S A 10 Launch, 4 O'clock."

How useful would it be to perform this task by speech?

Not Useful — Very Useful

3. The voice generator system could be used to give the pilot reports of new threats; for example, "New guy, Quad two."

How useful would it be to perform this task by speech?

Not Useful — Very Useful

4. The voice system could report the position and bearing of a bogey; for example, "Threat at two O'clock high."

How useful would it be to perform this task by speech?

Not Useful — Very Useful

5. A voice message could inform you when the system has reached, "Bingo fuel."

How useful would it be to perform this task by speech?

Not Useful | | | | | | Very Useful

6. A voice message could remind the pilot of fence-check when 20 minutes out.

How useful would it be to perform this task by speech?

Not Useful | | | | | | Very Useful

7. The voice generator could inform the pilot when the temperature of the engine had reached over-heat limits.

How useful would it be to perform this task by speech?

Not Useful | | | | | | Very Useful

8. The voice generator could detect and report degradation of the threat warning system.

How useful would it be to perform this task by speech?

Not Useful | | | | | | Very Useful

9. The voice system could report an abnormal fuel distribution situation.

How useful would it be to perform this task by speech?

Not |_____|_____|_____|_____|_____| Very
Useful Useful

10. A voice message could prompt when certain tasks/items should be performed, for example, "Change IFF code."

How useful would it be to perform this task by speech?

Not |_____|_____|_____|_____|_____| Very
Useful Useful

11. The voice generator could be linked with mode changes to provide additional feedback for such confirmatory changes as "TA/TF, engaged," or "DP3 updated."

How useful would it be to perform this task by speech?

Not |_____|_____|_____|_____|_____| Very
Useful Useful

12. The voice system could remind the pilot of critical points for pull-out.

How useful would it be to perform this task by speech?

Not |_____|_____|_____|_____|_____| Very
Useful Useful

13. When requested, the voice system could announce the current ECM mode.

How useful would it be to perform this task by speech?

Not Useful ⊢────┼────┼────┼────┼────⊣ Very Useful

14. The voice generator could report hung ordnance information.

How useful would it be to perform this task by speech?

Not Useful ⊢────┼────┼────┼────┼────⊣ Very Useful

15. The voice generator could inform the pilot when the NAV system has drifted beyond acceptable limits.

How useful would it be to perform this task by speech?

Not Useful ⊢────┼────┼────┼────┼────⊣ Very Useful

16. The voice generator could provide the pilot with a solution or description to a problem caused by a degraded system; for example, if INS has large errors, the GPS should be used instead.

How useful would it be to perform this task by speech?

Not Useful ⊢────┼────┼────┼────┼────⊣ Very Useful

17. The voice system could verbally enunciate master caution panel occurrences.

How useful would it be to perform this task by speech?

Not Useful ├───┼───┼───┼───┼───┤ Very Useful

18. The voice generator should tell the pilot when the ECM is locked-on, especially when the pilot's eyes are outside the cockpit.

How useful would it be to perform this task by speech?

Not Useful ├───┼───┼───┼───┼───┤ Very Useful

19. The voice generator could inform where the bogey is by quadrant, or by "clock" indications.

How useful would it be to perform this task by speech?

Not Useful ├───┼───┼───┼───┼───┤ Very Useful

20. The voice generation unit could inform the pilot when the life of a flight control battery is getting low, below some preselected level.

How useful would it be to perform this task by speech?

Not Useful ├───┼───┼───┼───┼───┤ Very Useful

21. During a violent spin, the voice system could say which direction the plane is turning/spinning.

How useful would it be to perform this task by speech?

Not Useful | | | | | | Very Useful

22. The voice system could enunicate the center of gravity movement on an air refueling operation.

How useful would it be to perform this task by speech?

Not Useful | | | | | | Very Useful

23. Assuming that laser-guided bombs are in use, speech generation could provide warnings to a pilot that he was about to mask a laser designation with a particular part of the vehicle.

How useful would it be to perform this task by speech?

Not Useful | | | | | | Very Useful

QUESTIONS

PART II

These questions address the role that speech recognition or command could play in the fighter cockpit. Speech recognition will involve speaker dependent, (individually trained and stored) vocabulary items. The format for speaking to the speech 'box' will use individual words or 2 - 3 word phrases. Appropriate vocabulary words will be selected and used in succinct, reliably recognized phrases. Feedback to the pilot, indicating that the desired input was received, could be given either visually or auditorily.

24. The deployment of CHAFF/FLARES could be performed by voice command, for example, by speaking "Release CHAFF," or "Release FLARES."

How useful would it be to perform this task by speech?

Not Useful — Very Useful

25. A voice command could be used to jettison the stores when necessary, for example, a verbal command "Drop stores."

How useful would it be to perform this task by speech?

Not Useful — Very Useful

26. A voice command could be used to access the air terminal information service (ATIS) in the spoken form, "ATIS Check."

How useful would it be to perform this task by speech?

Not Useful — Very Useful

27. The voice command could be used to access JTIDS information as a spoken request, "Display JTIDS."

How useful would it be to perform this task by speech?

Not Useful — Very Useful

28. A voice command could call up the approach plate for suitable display access for various locations; for example, "Display Nellis Approach Two One."

How useful would it be to perform this task by speech?

Not Useful — Very Useful

29. A voice command could link the mission planning and review information, as a spoken command, "Mission Review."

How useful would it be to perform this task by speech?

Not Useful — Very Useful

30. A voice command system could change or be used to select various displays on the F-16C MFD; for example, "Display Radar Left."

How useful would it be to perform this task by speech?

Not Useful — Very Useful

31. A voice command could be used to turn the ECM POD on; for example, "Activate ACM."

How useful would it be to perform this task by speech?

Not Useful — Very Useful

32. A voice utterance could be used to open and close the air refueling doors; for example, "Open Refuel Door."

How useful would it be to perform this task by speech?

Not Useful |_____|_____|_____|_____|_____| Very Useful

33. A voice recognition system could initiate UHF/VHF radio channel charges in the form, "Select VHF, one-two-one-point-five."

How useful would it be to perform this task by speech?

Not Useful |_____|_____|_____|_____|_____| Very Useful

34. A voice command could also make TACAN channel changes by using a series of isolated word utterances; for example, "Change TACAN" . . . "eighty-six" or "Change TACAN, PANOCHE."

How useful would it be to perform this task by speech?

Not Useful |_____|_____|_____|_____|_____| Very Useful

35. A voice recognition system could be used to input or set pre-flight data information concerning route, weapons, fuel, etc.

How useful would it be to perform this task by speech?

Not Useful |_____|_____|_____|_____|_____| Very Useful

36. Many of the FCNP keystrokes could be performed by a voice recognition system for such commands as the NAV coordinates or updates by saying, "Lat. North niner degrees three two point eight . . . "

How useful would it be to perform this task by speech?

Not Useful |_____|_____|_____|_____|_____| Very Useful

37. The voice recognition system could be used to change any mode selections during flight; for example, "Select Air-to-Air," "Select Dive Toss."

How useful would it be to perform this task by speech?

Not Useful |_____|_____|_____|_____|_____| Very Useful

38. The voice recognition system could interact with radar controls to change such parameters as the range, bar scan pattern, AL-EL coverage, intensity, etc.

How useful would it be to perform this task by speech?

Not Useful |_____|_____|_____|_____|_____| Very Useful

39. The voice command system could be interfaced with the stores management system by the spoken commands, "Select Master Arm."

How useful would it be to perform this task by speech?

Not Useful |_____|_____|_____|_____|_____| Very Useful

40. A verbal command request could present the pilot with the status of any A/C system during flight (the information could be diagnostic if a fault exist).

How useful would it be to perform this task by speech?

Not |____|____|____|____|____| Very
Useful Useful

41. A voice command could be used to enunciate or display critical items before entering FEBA; for example, "Fence Check."

How useful would it be to perform this task by speech?

Not |____|____|____|____|____| Very
Useful Useful

42. A voice command could be used to request aid in endurance calculation by the spoken utterance, "Display Endurance," or "Say Endurance."

How useful would it be to perform this task by speech?

Not |____|____|____|____|____| Very
Useful Useful

43. A voice command could be used to update the pilot on a flyover by speaking; for example, "Mark Position."

How useful would it be to perform this task by speech?

Not |____|____|____|____|____| Very
Useful Useful

44. A voice command could be used to call up individual MFD control pages; for example, "Stores Management, Left."

How useful would it be to perform this task by speech?

Not Useful |-----|-----|-----|-----|-----| Very Useful

45. A voice command system could perform changes in levels of interior and exterior lighting; for example, by speaking, "Dim Interior Lights," or "Kill Exterior Lights."

How useful would it be to perform this task by speech?

Not Useful |-----|-----|-----|-----|-----| Very Useful

46. A voice command system could call up various checklists and have the appropriate one enunciated or displayed; for example, "Report Air start checklist," or "Display Air start checklists."

How useful would it be to perform this task by speech?

Not Useful |-----|-----|-----|-----|-----| Very Useful

47. A voice command could be used in weapon deployment; for example, with a verbal "Go slewable," thus activating target designator movement.

How useful would it be to perform this task by speech?

Not Useful |-----|-----|-----|-----|-----| Very Useful

48. A voice command could be interface with a LANTIRN system to activate delivery modes, weapon selection, and step from target-to-target; for example, "Step target, Pod brighter."

How useful would it be to perform this task by speech?

Not Useful | | | | | | Very Useful

49. Voice command could be used to assist in missile control, especially in a track-while-scan mode; for example, "Cage," "Uncage."

How useful would it be to perform this task by speech?

Not Useful | | | | | | Very Useful

QUESTIONS
PART III

These questions address the potential role that speech recognition and speech generation could play together, in an interactive dialogue format. Many of the preceding voice command task examples could be backed up with speech generation feedback. However, the following suggested tasks extend the voice-interactive capability to cover a more unique role or capability for the two technologies to be implemented simultaneously. The 'dialogues' will use only two or three interactions involving speech input and speech output, in short transactions, avoiding elaborate conversations.

50. A voice interactive dialogue capability would allow the pilot to ask for "fuel remaining" by voice command and receive the appropriate figure through voice generation (this may be appropriate during poor night light conditions)

How useful would it be to perform this task by speech?

Not Useful | Very Useful

51. A voice interactive system should allow the pilot to ask for "Bingo fuel," and receive the reply through speech generation.

How useful would it be to perform this task by speech?

Not Useful | Very Useful

52. A voice-interactive system could allow the pilot to ask for "fuel home" and receive the replay verbally through speech generation.

How useful would it be to perform this task by speech?

Not Useful | Very Useful

53. A voice interactive dialogue system could be used to call up a future destination point (DP) and then request a particular ground feature, the response to which may be verbal in the form:

Pilot: "D.P. three" System "One-tree hill"

Pilot: "Distance: System "Two-zero miles"

How useful would it be to perform this task by speech?

Not Useful ⊢———|———|———|———|———⊣ Very Useful

SUMMARY QUESTIONS AND COMMENTS

54. Assume you had a speech I/O system in an eyes-out/hands-on-stick and throttle (HOTAS) situation. Please rate how helpful speech I/O might be in the following functional areas: (check one of the three blanks on each line)

	VERY HELPFUL	POSSIBLY HELPFUL	NOT HELPFUL
Vehicle Control	______	______	______
Navigation	______	______	______
Fire Control	______	______	______
Subsystem Management	______	______	______
Threat Management	______	______	______
Weapons Delivery	______	______	______
Target Acquisition	______	______	______
R/T Communications	______	______	______

COMMENTS: Please comment and give examples for as many of these eight categories as you can. (use the back of the pages for extra space)

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55. The pilot will need confirmation that appropriate action has been taken for each speech command that he gives. Sometimes the feedback will be obvious, as in a display mode change. When feedback is NOT obvious, it can be given either by speech output or it can be displayed on an MFD, or both. Please comment (give examples, if possible) on how you would like to get confirmation of speech command inputs: (consider (1) speech output, (2) displayed information, and (3) both)

56. As previously indicated, R/T will have priority on the audio channel. One suggested method for prioritizing the speech system outputs is as follows:

Priority #1 - Ultra important message which assists in the safe conduct of the mission. These messages will override any other message being transmitted by the speech generation system.

Priority #2 - Very important messages which assist in the management of the extraordinary events experienced during a mission, e.g., flight control system servo failure.

Priority #3 - Important messages which assist in the management of ordinary events experienced in flight, e.g., endurance/fuel remaining.

Priority #4 - Routine messages which assist the pilot in routine work, e.g., reciting checklists.

Each priority #2 through #4 speech message will be completed before the next message is commenced, unless a priority number one message intervenes. When more than one message is in the que, the priority will be adjusted before the next message is transmitted. Incomplete messages will be reassigned to their correct priority position and retransmitted as complete messages. Messages which are delayed more than 20 seconds by the priority rules will not be transmitted and will be cancelled.

Do you agree with this priority concept?

YES _____ NO _____

COMMENTS/SUGGESTIONS: ____

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57. Please add any other comments, general or specific, on speech I/O applications in future tactical aircraft.

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APPENDIX D

PILOT COMMENTS ON THE QUESTIONNAIRE

BACKGROUND

When the validation questionnaire was distributed to over 90 pilots at the three F-16 squadrons of the 474th TFW at Nellis AFB, the pilots were requested to write comments freely on the questionnaire. While ratings benefit the needs of researchers pursuing quantification, a considerable amount of important information can be contributed by experienced operational personnel, beyond the constraints of checking one of six response categories. Consequently, the pilot comments were considered to be important for the eventual implementation of speech I/O in the cockpit. To that end, a transcription of the written comments is reproduced in this Appendix.

NELLIS AFB F-16 PILOT QUESTIONNAIRE COMMENTS

PERSONNEL DATA:

Pilot #9: Observed demeonstration of voice commanded Stores Management System (SMS) at Hill AFB, UT in May 82.

Pilot #14: Wrote concepts for future weapons systems at TAC HQ 1978-80.

Pilot #15: Masters, aerospace engineering.

Pilot #16: Engineering operations major.

Pilot #24: Electronic warfare officer/navigator for 3 years.

Pilot #25: Not really, except very aware of computer capabilities and current technology.

Pilot #27: Career fighter pilot; B.S., Physics; M.S. in Military Science, nearly completed M.S. in Information System Theory.

Pilot #37: Elec. engineer major.

Pilot #41: BSEE with good familiarity of computers.

Pilot #44: 1120 combat hours.

QUESTION #1

A voice generator could be linked with a Ground Proximity Warning System providing specific voice altitude readouts below "given" or "pre-set" altitudes.

RESPONSES:

Pilot #1: Would need to be able to set the altitude(s) in the cockpit.

Pilot #9: A number of possibilities exist for usage, however, the altitudes at which voice warnings would be initiated and the frequency of warnings should be pilot controlled.

EX: Operating in an air-to-air training environment. A base altitude of 10,000 MSL designated as the simulated ground ("Kill" floor).

EX: 10,000 AGL - emergency ejection
2,000 AGL - controlled ejection

Pilot #18:) Where gear are? Up/down.
Depends) Are you on a low level?
) Are you on a level radar delivery?

If you intend to be low, plus some voice is bothering you, it could be distracting.

Pilot #21: If you could set it and have an option of turning it off.

Pilot #26: It would be useful if a minimum altitude for low level or ACB-1 could be set.

Pilot #28: Useful if able to shut off system for gunnery mission where it would be on continuously.

Pilot #30: What about low levels?

Pilot #34: Especially if IFR.

Pilot #40: Useful for in the weather approaches to landing - provided that system was fully certified and as reliable as cockpit altimeter.

Pilot #45: Only would be useful if it was cockpit selectable.

QUESTION #2

The voice generator system could provide exact threat information details such as the type, direction and priority level; for example, "S A 10 Launch, 4 o'clock."

RESPONSES:

Pilot #2: Or even calling a break turn in the appropriate direction.

Pilot #9: System must be "fail-safe" in relation to R/T and must not further complicate an expected comm Jam environment.

Pilot #14: In a threat rich environment, it could degrade pilot performance with too many "calls."

Pilot #17: More useful if just speech for launch.

Pilot #31: In a large strike package with lots of UHF/VHF transmissions in the target drop, the voice warning may be drowned out or lost in all the excitement.

Pilot #40: Provided that voice could be distinguished from radio calls made by other flights which would be using the same terminology.

Pilot #41: Would help if "a sense of urgency" was present in the voice.

QUESTION #3

The voice generator system could be used to give the pilot reports of new threats; for example, "New guy, Quad two."

RESPONSES:

Pilot #9:	System must be "fail-safe" in relation to R/T and must not further complicate an expected comm Jam environment.
Pilot #14:	If limited - yes.
Pilot #21:	Would rather have an "o'clock" position.
Pilot #24:	Information would be especially valuable as it is not currently available in any form.
Pilot #31:	In a large strike package with lots of UHF/VHF transmissions in the target drop, the voice warning may be drowned out or lost in all the excitement.
Pilot #34:	Might be talking all the time in this case with a lot of threats present.

QUESTION #4

The voice system could report the position and bearing of a bogey; for example, "Threat at two o'clock high."

RESPONSES:

Pilot #9:	System must be "fail-safe" in relation to R/T and must not further complicate and expected comm Jam environment.
Pilot #12:	How would it know this? If I've locked T&E "threat at 2:00 High" up on the radar, then I already know where he is and the voice warning could be a distraction.
Pilot #14:	In a threat rich environment, it could degrade pilot performance with too many "calls."
Pilot #24:	Information would be especially valuable as it is not currently available in any form.
Pilot #32:	Include range.
Pilot #36:	Current threat warning systems rely on a unique audio to attract pilot attention, then require "heads-down" visual interpretation of a CRT. Straight voice-warning would eliminate the heads-down" requirement which is of particular importance while flying in a high threat area.

QUESTION #5

A voice message could inform you when the system has reached, "Bingo fuel."

RESPONSES:

Pilot #1: It would be good to have at least 2 settings available.

Pilot #9: Especially in a task saturated environment, i.e., BFM, ACM, high threat ingress/egress.

Pilot #21: Too much voice. The F-16 HUD flasher is good enough.

Pilot #22: Present cockpit indications are sufficient; however, it would be nice.

Pilot #31: Not much different from current visual HUD indications that work same way.

Pilot #41: Joker fuel would be better. Best would be 2 or 3 programmable fuel levels.

QUESTION #6

A voice message could remind the pilot of fence-check when 20 minutes out.

RESPONSES:

Pilot #21: If you could set the times. Actually, 2 times, so you could get a reminder both in and out (for mode IV, especially).

Pilot #30: Why?

Pilot #31: Fighter pilot ought to be able to handle these without something other than gauges or warning lights.

Pilot #41: Then it could run through the appropriate systems and the pilot could state what specific system settings to be used.

QUESTION #7

The voice generator could inform the pilot when the temperature of the engine had reached over-heat limits.

RESPONSES:

Pilot #22: A simple "warning warning" and then appropriate lites would be sufficient.

Pilot #30: Read the gauge.

Pilot #31: Fighter pilot ought to be able to handle these without something other than gauges or warning lights.

Pilot #41: The FTIT indicator is hard to monitor consistently.

QUESTION #8

The voice generator could detect and report degradation of the threat warning system.

RESPONSES:

Pilot #30: Test the system.

Pilot #31: Fighter pilot ought to be able to handle these without something other than gauges or warning lights.

Pilot #40: Only because most experienced pilots have learned not to rely on currrent threat warning systems. Assuming that reliability of TWS would improve to the point that a pilot no longer has to continually search visually (all quadrants) for threats, this would be very useful.

QUESTION #9

The voice system could report an abnormal fuel distribution situation.

RESPONSES:

Pilot #18: Red tape on counters make that fairly obvious.

Pilot #30: Check the tanks.

Pilot #41: Pilot can see that just as easily in F-16.

QUESTION #10

A voice message could prompt when certain tasks/items should be performed, for example, "Change IFF code."

RESPONSES:

Pilot #3: "Change IFF code" - Good.
Fence - not so useful - depends on task.

Pilot #14: Certain functions need not be left to VM, use only for items needed when pilot is "head out" of cockpit.

Pilot #22: If you could require it at certain times. Additionally, it cannot take a lot of ground time to set this in.

Pilot #28: Useful if able to shut off system for gunnery mission where it would be on continuously.

Pilot #30: In combat.

Pilot #41: Especially in combat.

QUESTION #11

The voice generator could be linked with mode changes to provide additional feedback for such confirmatory changes as "TA/TF, engaged," or "DP3 updated."

RESPONSES:

Pilot #21: "Disengaged" would be a real player, such as for the auto pilot during nite or IMC bombing.

Pilot #30: "Garbaging the radio."

QUESTION #12

The voice system could remind the pilot of critical points for pull-out.

RESPONSES:

Pilot #18: In theory very useful, but could be a detriment.

Pilot #30: Look out the window!

Pilot #36: Might be useful for preventing self-inflicted frag damage during live ord. deliveries, i.e., a "press warning" setup.

Pilot #40: Usually, by the time the voice would say "pull out," it would be too late for pilot reaction. If it were set to a higher altitude (for given A/S, dive angle, A/C gross weight, configuration, etc.), it would become a nuisance on minimum altitude weapons delivery.

QUESTION #13

When requested, the voice system could announce the current ECM mode.

RESPONSES:

Pilot #3: Voice command to change ECM mode.

Pilot #9: If the pilot can think to request ECM data, it only takes a quick look to confirm or reset the ECM system.

Pilot #21: How? If by voice, with a voice answer, then .....

Pilot #30: Look at the switch.

Pilot #40: What would be useful is an automatic ECM function.

QUESTION #14

The voice generator could report hung ordnance information.

RESPONSES:

Pilot #9: Visual display already presented by SMS. Operating in two ship elements, a visual confirmation should/would be accomplished.

Pilot #30: SMS has that info.

QUESTION #15

The voice generator could inform the pilot when the NAV system has drifted beyond acceptable limits.

RESPONSES:

Pilot #30: Look at the map.

QUESTION #16

The voice generator could provide the pilot with a solution or description to a problem caused by a degraded system; for example, if INS has large errors, the GPS should be used instead.

RESPONSES:

Pilot #9: Pilots should have enough systems knowledge to analyze a deficient system and properly utilize backup systems.

Pilot #14: System may not have all the answers or big picture - suggesting something to pilot may be wrong thing to do.

Pilot #21: The GPS???

Pilot #30: Read the dash 1.

Pilot #41: Often, the pilot does not know the extent of the degradation.

QUESTION #17

The voice system could verbally enunciate master caution panel occurrences.

RESPONSES:

Pilot #30: In combat.

QUESTION #18

The voice generator should tell the pilot when the ECM is locked-on, especially when the pilot's eyes are outside the cockpit.

RESPONSES:

Pilot #12: ECM doesn't "lock-on," it EMITS.

Pilot #13: ?ECM lock on?

QUESTION #19

The voice generator could inform where the bogey is by quadrant, or by "clock" indications.

RESPONSES:

Pilot #12: Again, how does it know?

Pilot #19: Locator line in HUD much more useful.

Pilot #21: If exactly correct, then ..... (i.e., left 10 o'clock, slightly high).

Pilot #24: Again, the information itself would be very valuable and presentation by voice would be convenient.

Pilot #19: Clock position.

Pilot #36: Especially for deep six threats, etc.

Pilot #40: Would be better if it gave bearing, range altitude, and aspect angle of a target, but only if called to do so by the pilot.

QUESTION #20

The voice generation unit could inform the pilot when the life of a flight control battery is getting low, below some preselected level.

RESPONSES:

Pilot #13: Questionable. Great in theory, but you would have to put a measuring unit on first. A/C doesn't currently have one. Weight on A/C is a factor. Don't take away 1:1 thrust to weight.

Pilot #19: That's what the light is for.

Pilot #24: Again, the information itself would be very valuable and presentation by voice would be convenient.

Pilot #30: Why not have a volt meter with a water switch?

Pilot #38: After 17 above, a light or some video read out would be fine.

QUESTION #21

During a violent spin, the voice system could say which direction the plane is turning/spinning.

RESPONSES:

Pilot #1: The small number of times this might happen would not justify the software space.

Pilot #9: Since spins are not an everyday occurrence, such an input would provide a positive input to the pilot and possibly preclude a faulty analysis on his part.

Pilot #12: Does it override the slow speed warning horn?

Pilot #18: Distraction not required at that point.

Pilot #21: You would be too maxed out to listen.

Pilot #30: Look outside!

QUESTION #22

The voice system could enunciate the center of gravity movement on an air refueling operation.

RESPONSES:

Pilot #18: Not that critical.

Pilot #30: AOA shows that.

Pilot #40: Only on A/C with critical CG movements. Hopefully, we're smart enought not to design such an aircraft.

QUESTION #23

Assuming that laser-guided bombs are in use, speech generation could provide warnings to a pilot that he was about to mask a laser designation with a particular part of the vehicle.

RESPONSES:

Pilot #3: Not to present F-16s. May be useful to future laser capable A/C.

Pilot #18: Good idea.

Pilot #19: NA.

Pilot #30: Why not a visual alert?

QUESTION #24

The deployment of CHAFF/FLARES could be performed by voice command; for example, by speaking "Release CHAFF" or "Release FLARES."

RESPONSES:

Pilot #1: Very good idea!

Pilot #9: Highly desired capability.

Pilot #12: Will we have to be "Hot Mic" for all of this?

Pilot #19: Button on wall is much quicker.

Pilot #40: Recommend one word, "CHAFF" or "FLARES" or maybe "CHAFF and FLARES."

QUESTION #25

A voice command could be used to jettison the stores when necessary; for example, a verbal command, "Drop stores."

RESPONSES:

Pilot #1: Too large a possibility of accidental jettison.

Pilot #30: Only for emergency jettison during take off.

Pilot #40: Again, recommend one word, "Jettison," provided that when I tell my wingman on the radio to "jettison his ordnance," my stores don't all fall off.

QUESTION #26

A voice command could be used to access the air terminal information service (ATIS) in the spoken form, "ATIS Check."

RESPONSES:

Pilot #3: How about verbal freq. changes (pre-set + manual very useful) - super for WX/nite on the wing.

Pilot #7: Probably not on threat environment for an ATIS check.

Pilot #24: Nice, but hardly critical.

Pilot #25: Lazy pilots?

Pilot #30: Useless.

QUESTION #27

The voice command could be used to access JTIDS information as a spoken request, "Display JTIDS."

RESPONSES:

Pilot #30:	Useless.
Pilot #35:	JTIDS - Not familiar with this term.
Pilot #38:	Intentionally left blank.
Pilot #46:	What is JTIDS?

QUESTION #28

A voice command could call up the approach plate for suitable display access for various locations; for example, "Display Nellis Approach Two One."

RESPONSES:

Pilot #7:	Could I make this "extremely very useful," i.e., a rating greater than 6.0?
Pilot #18:	How much programming will the pilot have to do before T.O.?
Pilot #21:	There are three approaches published to R-21 at Nellis, therefore, you would have to know what to request, thus you might have to look it up to know what to ask for!
Pilot #30:	In weather.
Pilot #36:	Would be very nice, e.g., in night weather, especially in divert situations, etc.
Pilot #38:	When I want to see an approach plate, I usually can afford to push a button rather than say "Display Nellis Approach Two One."
Pilot #41:	Very useful if it displayed the approach rather than talk about it.

QUESTION #29

A voice command could link the mission planning and review information as a spoken command, "Mission Review."

RESPONSES:

Pilot #7:	Mission data card suffices - too much flexibility in flight.

Pilot #9: How is this data inputed to the computer memory with current pre-taxi computer inputs, INS coordinates, elevations, weapons delivery data, etc.? Additional manual computer inputs might require excessive chock time in a tactical situation.

Pilot #18: To what purpose?

Pilot #30: Read the DD175.

QUESTION #30

A voice command system could change or be used to select various displays on the F-16C MFD; for example, "Display Radar Left."

RESPONSES:

Pilot #19: Sounds OK, but I'm not familiar.

QUESTION #31

A voice command could be used to turn the ECM POD on; for example, "Activate ACM."

RESPONSES:

Pilot #12: ACM? How about ECM?

Pilot #19: Hands-on controls would be better.

Pilot #32: Activate ECM Program 1, Program 2, Program 3, etc.

Pilot #41: Would be better if pilot could also tell it which mode to select for ECM.

QUESTION #32

A voice utterance could be used to open and close the air refueling doors; for example, "Open Refuel Door."

RESPONSES:

Pilot #7: Not in a threat environment during air refueling.

Pilot #30: Come on! One switch.

QUESTION #33

A voice recognition system could initiate UHF/VHF radio channel charges in the form, "Select VHF, one-two-one-point-five."

RESPONSES:

Pilot #1: Would make radio channel change on the wing in the weather easy.

Pilot #7: I like this very much (present VHF radios in bad position).

Pilot #15: Especially in weather on the wing.

Pilot #18: Great.

QUESTION #34

A voice command could also make TACAN channel changes by using a series of isolated word utterances; for example, "Change TACAN" . . . "eighty-six" or "Change TACAN, PANOCHE."

RESPONSES:

Pilot #3: Numbers better, nonversatile, e.g., (AA TACAN).

Pilot #7: I like this very much! (PANOCHE)

QUESTION #35

A voice recognition system could be used to input or set pre-flight data information concerning route, weapons, fuel, etc.

RESPONSES:

Pilot #19: What we need is a card reader or magnetic strip input for the FCNP.

Pilot #22: Don't know what this means - if you could input INS lat/longs verbally - very useful!

Pilot #35: Especially INS lat/long's OAP's/VRP's.

QUESTION #36

Many of the FCNP keystrokes could be performed by a voice recognition system for such commands as the NAV coordinates or updates by saying, "Lat. North niner degrees three-two-point-eight . . ."

RESPONSES:

Pilot #3: Good for CAS scenario.

Pilot #30: For changing destination inflight.

Pilot #35: Especially INS lat/long's OAP's/VRP's.

Pilot #36: Current manual typing is time consuming and lends itself to input errors. Would be great for inflight programming.

Pilot #41: I think this would be a great asset.

QUESTION #37

The voice recognition system could be used to change any mode selections during flight; for example, "Select Air-to-Air" or "Dive Toss."

RESPONSES:

Pilot #18: How fast could it accomplish task?

Pilot #20: Depends on speed.

QUESTION #38

The voice recognition system could interact with radar controls to change such parameters as the range, bar scan pattern, AL-EL coverage, intensity, etc.

RESPONSES:

Pilot #19: Hands-on is the easiest and quickest way.

Pilot #30: We can do it now with minimal effort.

QUESTION #39

The voice command system could be interfaced with the stores management system by the spoken command, "Select Master Arm."

RESPONSES:

Pilot #14: Arming up should be done hands-on.

Pilot #19: Not sure how safe it would be.

Pilot #30: One switch.

QUESTION #40

A verbal command request could present the pilot with the status of any A/C system during flight (the information could be diagnostic if a fault exists).

RESPONSES:

Pilot #3: Emergency procedures display and commanded action.

Pilot #22: Depends on set-up and only if queried.

Pilot #35: Diagnostic - Good.

QUESTION #41

A voice command could be used to enunciate or display critical items before entering FEBA; for example, "Fence Check."

QUESTION #42

A voice command could be used to request aid in endurance calculation by the spoken utterance, "Display Endurance" or "Say Endurance."

RESPONSES:

Pilot #22: Normally, this type of function is required during low task operations and can be easily accomplished manually.

QUESTION #43

A voice command could be used to update the pilot on a flyover by speaking; for example, "Mark Position."

RESPONSES:

Pilot #22: Don't usually use this function.

QUESTION #44

A voice command could be used to call up individual MFD control pages; for example, "Stores Management, Left."

RESPONSES:

Pilot #30: One switch.

QUESTION #45

A voice command system could perform changes in levels of interior and exterior lighting; for example, by speaking, "Dim Interior Lights" or "Kill Exterior Lights."

RESPONSES:

Pilot #21: Would have to be more specific, i.e., "position lights, dim," "strobe off."

QUESTION #46

A voice command system could call up various checklists and have the appropriate one enunciated or displayed; for example, "Report Air start checklist" or "Display Air start checklists."

RESPONSES:

Pilot #12: Useful if kept current, otherwise worthless.

Pilot #18: This is pilot knowledge domain. Many times this might be distracting.

Pilot #41: Great, if up-to-date.

Pilot #48: Would be more useful in far future to say "airstart" and sit back and watch it airstart.

QUESTION #47

A voice command could be used in weapon deployment; for example, with a verbal "Go slewable," thus activating target designator movement.

RESPONSES:

Pilot #30: One switch.

Pilot #40: Takes too long in air-to-air combat. In this case, as in other cases above, the hand is not only faster than the eye (...it's faster than the voice).

Pilot #46: F-16 would not need this!

QUESTION #48

A voice command could be interfaced with a LANTIRN system to activate delivery modes, weapon selection, and step from target-to-target; for example, "Step target, Pod brighter."

RESPONSES:

Pilot #3: Not F-16 present, may be good for LANTIRN equipped aircraft.

Pilot #4: I do not know anything about LANTIRN switches and as long as I am in a single seat A/C, I do not want to find out.

Pilot #15: NA.

Pilot #20: I don't like LANTIRN.

Pilot #21: Don't know.

Pilot #35: Not familiar enough with system.

QUESTION #49

Voice command could be used to assist in missile control, especially in a track-while-scan mode; for example, "Cage," "Uncage."

RESPONSES:

Pilot #20: Hands-on is quicker.

Pilot #22: This is during extremely high task saturation and is now easily accomplished with hands-on.

Pilot #30: One switch.

QUESTION #50

A voice interactive dialogue capability would allow the pilot to ask for "fuel remaining" by voice command and receive the appropriate figure through voice generation (this may be appropirate during poor night light conditions).

RESPONSES:

Pilot #30: You can remeber that one, hopefully.

QUESTION #51

A voice interactive system should allow the pilot to ask for "Bingo fuel" and receive the reply through speech generation.

QUESTION #52

A voice interactive system could allow the pilot to ask for "fuel home" and receive the reply verbally through speech generation.

QUESTION #53

A voice interactive dialogue system could be used to call up a future destination point (DP) and then request a particular ground feature, the response to which may be verbal in the form:

Pilot: "D.P. three"	System "One-tree hill"
Pilot: "Distance"	System "Two-zero miles"

RESPONSES:

Pilot #28: Who will program this information? What if you reprogram destination points in flight?

QUESTION #54

Assume you had a speech I/O system in an eyes-out/hands-on-stick and throttle (HOTAS) situation. Please rate how helpful speech I/O might be in the following functional areas: (Check one of the three blanks on each line.)

	VERY HELPFUL	POSSIBLY HELPFUL	NOT HELPFUL
Vehicle Control	________	________	________
Navigation	________	________	________
Fire Control	________	________	________
Subsystem Management	________	________	________
Threat Management	________	________	________
Weapons Delivery	________	________	________
Target Acquisition	________	________	________
R/T Communications	________	________	________

COMMENTS: Please comment and give examples for as many of these eight categories as you can. (Use the back of the pages for extra space.)

RESPONSES:

Pilot #3: Vehicle control - command of autopilot on/off; low altitude warning; destination change and TACAN change.

Fire control - voice selection of delivery modes (AG) or radar and missile (cage/slave) (A-A) selections. Threat management would be outstanding, especially type and direction (clock) of threat.

Weapons delivery - may be good for action cues but pilot still needs to release weapons.

Target acquisition - he already gives good info.

RT - freq. changes by voice command.

Pilot #4: Vehicle control - too many different situations to use it other than to engage an auto pilot system.

Navigation - helpful, but it is easy enough now.

Fire control - great.

Subsystem management - good for ECM, CHAFF, and other things that are hard to get to.

Threats - very good idea.

Weapons - to change modes - great, but I can push the pickle button or pull the trigger faster than I can speak (more precise execution time also).

Target and R/T - possibly.

Pilot #7: Threat management - probably highest in potential in the eyes-out HOTAS environment.

Fire control/weapons delivery - also high in potential.

Navigation/R/T Comm - especially nice to have at night - in weather as a wingman on the wing. Can call up approach plates and change frequencies eyes-out in formation.

Pilot #8: Nav - useful as a back up.

Fire control - good in panic situations, but I'd always use the manual SW as well as a voice command to be sure.

Subsystem - varies by system but good as back-ups or better.

Threat management - primo, especially chaff/flares.

Weapon/Tgt. acquisition - good for changing modes.

R/T - great for freq. changes - especially VHF/FM.

Pilot #9: All of the "very helpfuls" reflect upon high threat, task saturated situations where the pilot could not look in the cockpit for switch changes, i.e., padlocked on bandit or low altitude ingress/egress at 50 ft. - 100 ft.

As for target acquisition, the system will help the pilot look in the proper direction, but he/she must still <u>see</u> the target to employ ordnance.

Pilot #14: Certain situations require instantaneous info for pilot (i.e., looks at airspeed - has info in less than second) to carry on a conversation and get a verbal response would require too much time - HOTAS is nice but not the panacea that one might think.

Pilot #15: Great idea. (Hope it doesn't confuse radio chatter for command.) Programming INS is tedious by hand; could use it there.

Pilot #18: Vehicle control - A.C. airspeed, attitude, etc. tell pilot and he will make inputs.

Pilot #19: Threat is important in that audio signal gets your attention quicker than lights.

Fire control should be hands-on as well as weapons delivery.

In combat or "Hot and Heavy" situations, the radios must be kept clear.

Pilot #21: Keep it simple or it will get in the way. Areas of small marginal value in providing information/reducing workload should be left out or the whole thing could get out of hand.

Wartime experience - when situations get tight, in critical emergencies, etc., garbaged up radios is one of the biggest problems. Critical communications get blocked of missed. This would be like adding another "radio" and it needs to have "radio disciplines" added with it, i.e., minimum talking in the "2 mayday, bingo, and lead-your-on-fire" vein. Also, inherent should be the ability to rapidly turn it off.

Pilot #22: All the things you cannot sense - you can sense vehicle motion - whereas the present audio information is not sufficient for RHAW systems.

Pilot #24: The system sounds attractive because of the nature of the information offered as well as the method of communication. There are some situations where voice comm is especially desirable - mostly in high workload situations when the pilot needs to set-up weapons system modes, countermeasures, and avionics while concentrating on outside events.

Pilot #25: Threat - as stated prior: launches, positions (o'clock), etc.

Weapon - modes, change modes.

Target acq. - clock, distance, time to pull out.

Pilot #29: System would be helpful, but problems would be with interference with other comm and having to repeat commands.

Pilot #32: The navigation area would be especially good for the 100 ft. low level regime. Threat management would be very helpful if the ambiguities can be worked out. Target acquisition would be a player in poor visibility or a camouflage environment.

Pilot #34: NAV - logging latitude/longitude (from forward air controllers, offsets and points for radar work).

Marking points - updating INS position.

Fire control - selecting type, mode of weapons.

Autopilot - control, parameters.

Emergency procedures - back up.

Pilot #35: Navigation - radar low level would really help when trying to break out of weather with low ceilings.

Fire Control and Weapons Delivery - Changing weapons or delivery mode when trying to acquire/or after finding target that pilot must remain padlocked to.

R/T - changing freqs. in weather or critical phases of tactical flight (chattermark).

Pilot #36: Vehicle control - enhance aircraft control/ease pilot workload during air time emergencies.

Navigation - enhance programming/ease workload, especially airborne reprogramming.

Fire control - would ease various mode selection/provide reliability/safety margin.

Subsystem Management - reduce requirement for "heads-down" system management.

Threat Management - voice warning for threats would be of immeasurable value, both for air and ground threats.

Weapons delivery - relates to fire control comment (above).

Target Acq. - any additional "heads-up" cues relating to target acquisition would be helpful.

R/T communications - ease pilot workload, e.g., radio changes, etc. Would be especially good for emergencies, at night, in the weather, etc.

Pilot #39: Vehicle control - I think most pilots would agree that total aircraft control is mandatory by the pilot.

Navigation, fire control, target acquisition are not difficult tasks in the F-16 (physically, the switches for operation are located in a good place).

Threat management and radio controls are placed in less than optimum places, thus voice commanded systems would be ideal.

Pilot #41: Vehicle control is, of course, the most useful, with Nav and R/T channel changes also very useful. The functional area of threat management would not be adapted well to speech I/O.

Pilot #44: Navigation - change to next destination.

Pilot #45: The system looks very promising in the threat area. Verbally informing the pilot of where to look for the most lethal threat is a very good application.

As far as fire control goes, I would not like to see it go any further than switching delivery modes and turning on and off the master arm switch.

I don't like the idea of vehicle control through voice interface.

Pilot #46: An I/O system could obviously have benefits in an eyes-out situation. But, it must be closely controlled and prioritized. You are busy enough in an eyes-out situation not to be bothered or distracted by simple replies or anything but threat calls.

Pilot #48: Target acquisition is by far the most helpful, since once you see the target you can usually strike it.

QUESTION #55

The pilot will need confirmation that appropriate action has been taken for each speech command that he gives. Sometimes the feedback will be obvious, as in a display mode change. When feedback is NOT obvious, it can be given either by speech output or it can be displayed on an MFD, or both. Please comment (give examples, if possible) on how you would like to get confirmation of speech command inputs: (Consider (1) speech output, (2) displayed information, and (3) both.)

RESPONSES:

Pilot #1: Speech output would be the best bet, i.e., when asking for fuel, TACAN channel change.

Pilot #2: The use of a response, i.e., "Received" would be good.

Pilot #3: A side tone on acceptance of the command along with even obvious display changes. You're not always looking inside when you want a change or action made.

Pilot #4: I like what you said earlier. Have it talk back, but have the capability to override it, or turn it off - possibly it could just give a beep if it did what you said, or maybe say "Done."

Pilot #5: Minimize the speech output. In air-to-ground modes, i.e., NAV - A-G. Provide feedback on Hud. Give verbal feedback on Hud.

Allow pilot to select which priorities he wants to hear.

Pilot #7: Speech output primary, but always confirmed visually.

Pilot #8: Must primarily be info display in life or killing situations (weapons deliv. threat, etc.), but speech output okay for routine/admin. items.

Pilot #9: (3) Both. Again, the tactical situation and the degree of task saturation would dictate the capability to read a display. A voice (primary) display (secondary) would be most advantageous.

Pilot #10: I think a tone could be used to confirm the actions are complete. It would be short, very easy to hear and identify, and the same for all commands.

Pilot #12: Probably both, but with a speech override so as not to conflict with UHF/VHF. Displayed for 5 sec. or 50 and then display back to norm.

Pilot #14: MFD is preferable because it could be confirmed quicker - taking less of pilot's time to digest conversation.

Pilot #15: Displayed information and audio acceptance tone, i.e., beep.

Pilot #16: Beep in headset.

Pilot #17: Some speech. Some displayed. Depends on the situation.

Pilot #18: Speech is best, but I would want a display also.

Pilot #19: It would have to be both, just in case.

Pilot #20: NA.

Pilot #21: Speech "read back" if your command after action complete would be a good way. "Display so and so" - action - "so and so displayed."

Pilot #22: Could be a tone - or could be a repetition of the command.

Pilot #25: Repeat command or short code that it is understood.

Pilot #26: Chaff/Flares (speech output - "Chaff/Flares released").

Pilot #28: Speech output.

Pilot #29: Would like option to have either one.

Pilot #30: I don't want this thing garbaging up communications.

Pilot #31: System could, in most cases, report part or all of your command when it has completed it. The visual indications, such as a change in HUD symbology, would confirm that your command had been accomplished also. I think if you could use both in as many cases as possible, it would be better.

Pilot #32: Or you could simply use a single tone generation to give confirmation.

Pilot #34: Unsure of confirmation methods.

Pilot #35: To much chatter with speech output.

Pilot #36: Speech output (as well as input) must be kept to an absolute minimum so as not to conflict with flight comm., e.g., an easily recognizable tone, confirmed with a Hud visual cue would seem adequate.

Pilot #37: (3) Some inputs need immediate feedback, such as flare dispensing or ECM activation since the tactics could change if they fail.

Pilot #38: Both.

Pilot #39: A 1/2 second medium range tone or "Beep" would be sufficient to confirm commended actions have taken place; in conjuntion with a display MFD. A high pitched 4KHZ Beep could be used as noting commanded action is not understood, cannot be complied with, etc.

Pilot #41: How about just a certain frequency tone or beep to acknowledge request (i.e., keep time to a min.) and then another when appropriate action is taken.

Pilot #44: If not speech for feedback, a small indicator light (symbol on HUD) to let you know the information has been computed and is ready to be read on an MFD.

Pilot #46: Never speech output in a high threat arena; it would be bothersome. However, it would be helpful in safe territory. Maybe the confirmation mode could change with the fence.

Pilot #47: Speech output.

Pilot #48: In most situation, I would like to actually hear that it is completed, since my eyes must be out of cockpit; otherwise, I wouldn't need the voice system in the first place.

QUESTION #56

As previously indicated, R/T will have priority on the audio channel. One suggested method for prioritizing the speech system outputs is as follows:

Priority #1 - Ultra important message which assists in the safe conduct of the mission. These messages will override any other message being transmitted by the speech generation system.

Priority #2 - Very important messages which assist in the management of the extraordinary events experienced during a mission, e.g., flight control system servo failure.

Priority #3 - Important messages which assist in the management of ordinary events experienced in flight, e.g., endurance/ fuel remaining.

Priority #4 - Routine messages which assist the pilot in routine work, e.g., reciting checklists.

Each Priority #2 through #4 speech message will be completed before the next message is commenced, unless a priority number one message intervenes. When more than one message is in the queue, the priority will be adjusted before the next message is transmitted. Incomplete messages will be reassigned to their correct priority position and retransmitted as complete messages. Messages which are delayed more than 20 seconds by the priority rules will not be transmitted and will be cancelled.

Do you agree with this priority concept? Yes ______ No ______

RESPONSES:

Pilot #3: 3 and 4 should be changed. Combat related items should have higher priority than ordinary flight items.

Pilot #7: Recommend a combat-oriented prioritization be made different than a non-combat-oriented situation. For example, "chaff-flare dispense" may step to priority one in combat.

Pilot #8: The 20 second rule must allow some info on what isn't being transmitted. Also, some combat situations will change the priorities from a peace time mission, e.g., chaff/flares vs. some warnings of syst. malfunctions.

Pilot #9: A pause mode to allow for aircraft-to-aircraft communications is required. Aircraft-to-aircraft or aircraft-to-ground communications should actuate the pause mode for any and all computer generated messages.

Pilot #10: Any radio transmission should have the highest priority and override all I/O transmissions.

Pilot #14: In high stress situations, only ultra messages should get through.

Pilot #18: Realize in combat and critical situation everything gets real busy and the voice might be a nuisance.

Pilot #21: Keep it to three.

Pilot #25: Sounds great - Flash (Gordon) never had it so good.

Pilot #30: Too much going on at once. In the F-16, when there is an electrical problem, there are usually quite a few. Results and failures don't need to be verbally informed, one after the other.

Pilot #31: The one place I can see this thing going crazy is in the target area in a big fight when there are lots of threats, radio chatter, and all kinds of things going on at once. The speech system, other aircraft warning systems, and all the radio activity may make things almost impossible.

Pilot #36: Will this priority be determined by the individual pilot/ geared to specific mission requirements?

Pilot #37: I would not cancel any messages unless computer memory space is a problem.

Pilot #41: Make the 20 secs a variable dependent on message.

Pilot #42: Potential to add to pilot workload during emergencies, etc. Don't need any more lights, bonks, whistles, etc.

Pilot #44: Still need a manual cut out in case of difficulties. I still want control over the system. In emergencies, the improper display or annoying speech could be very distracting.

Pilot #46: It will probably take a lot of refining after inputs from actual application.

Pilot #48: Since things may happen all at once, there needs to be some priority.

QUESTION #57

Please add any other comments, general or specific, on speech I/O applications in future tactical aircraft.

RESPONSES:

Pilot #3: Voice command will add a new and better dimension to new generation "heads up" fighters. Looking forward to it.

Pilot #4: Flying "hot mic" bothers me. I would like to see it so I could talk to the system "cold mic" so I wouldn't have to listen to myself breathe, grunt, etc.

Pilot #5: Speech I/O, in my opinion, has good applications in a very limited area. In general, this area is when the pilot must have his eyes outside and keep them outside, i.e., air-to-air. It is otherwise redundant at best and a possible distraction at worse. Speech activated switches could not replace HOTAS switches.

Pilot #7: I would like most of the features you mentioned. I would like to select which modes I want to use and I would like to select audio or visual confirmation for each mode.

I would also like to tell the audio confirm to shut itself off or turn itself on.

Pilot #8: I'm glad to see pilots being consulted fairly early on. Engineers/designers (unless also users) cannot fully comprehend the requirements for such a system that result from psychological and personality oriented factors.

Pilot #9: What will be the impact of pilot pitch and tone changes during highly critical situations? Will the computer voice recognize?

What "fail-safe" measure will be incorporated to assure phonetic sampling by the computer will not key it to respond to a sound-alike in its vocabulary?

EX: Two place aircraft:

Pilot-to-Navigator (WSO): "Cheer Up."

Computer I/O System: "Roger, Gear Up."

Pilot #12: How long will it take to program all this stuff in? Can it be "read" into memory with a computer tape? Can it recognize voice under the stress of high Gs? How can we keep it current (checklists, approach plates, etc.)? We would need an on/off switch in case it malfunctions. Will we have to be "Hot Mic" all the time to talk to the system? Some, non-time critical items need a confirmation message prior to implementation (examples, pilot says "nott corrs," system asks "drop stores?" Yes/No. Pilot can clear system with a panicky "NO!"

Pilot #14: Possibilities are endless - however, let's not get into the "new toy" mode with speech I/O. Let's make sure we don't overload pilot with messages.

Pilot #16: Real pilots are supposed to be able to fly their jets without the help of some clown talking in their ear. About the only good thing are freq. changes.

Pilot #18: From a safety viewpoint:

1) Refer this project to aero psychologists.
2) In many phases of flight, this could be as much a distraction as AID.
3) Leaves a lot of room for pilot error and reliance on a system that is doing some critical jobs too.

4) Will system tell pilot if it is malfunctioning? Can pilot turn it off?

5) Pilot must have positive feedback that system has accomplished task it was commanded to perform.

6) This sounds like a Weapon System Officer (WSO) in abstensia! From "Star Wars:"

   a) There will always be a happy hour!

   b) Dive toss will never work!

   c) There will always be a WSO!

Pilot #21: Cosmic, but has obvious value in a single place aircraft. Looks like an idea whose time is coming.

Pilot #23: Good ideas! Do it.

Pilot #25: Possibilities limitless.

Pilot #28: Don't take too many tasks away from the pilot. It may be more helpful if you concentrate on threat warning, such as saying what is on the RHAW when the pilot is looking outside.

Pilot #29: Sounds good on paper, but won't work until the system can understand commands from a voice under stress/pitch change/ abbreviated speech, etc.

Pilot #30: Of every fault, I can read on the panel instantly.

Pilot #31: How much or how little this thing can do for the pilot and whom will depend on individual pilot's situation awareness (SA). Fighter pilots use this as a gauge of how well you understand what is going on in the total environment around you. Your SA in a multi bogey ACM engagement or a high threat target area is what will keep you alive, and it is not hard to get maxed out quickly. SA is a function of experience, training, and, many times, just plain natural ability. The speech system may be very helpful in lots of instances like emergencies or an instrument approach in bad weather. Where it can offer valuable assistance is when the pilot is not maxed out and can use its information. Max out his SA and put him in a position where he is fighting to stay alive and pretty quickly the amount of information he can absorb and use reaches the limit of his personal SA capability. From then on, the overloaded SA system now degenerates rapidly as he is saturated. The speech system can then be more harmful than good, and he's got to use the "shut-up switch." How long each pilot can make use of the system is going to vary considerably. How you determine what information the system provides should also be dependent on this "usefulness level." I think you are on the right track in providing a "shut-up" feature because the system can reach a point where it detracts rather than adds to pilot performance.

Pilot #34: Initiating built-in tests for maintenance.

Pilot #36: Pilots must have the ultimate control of such systems, i.e., a basic ON-OFF switch. There are numerous critical inflight situations which could only be made worse by untimely voice info. The concept seems good and could go a long way in reducing mundane pilot workloads, e.g., typing waypoint coordinates, offsets, frequency changes, SMS programming, etc. This, in turn, enhances flight safety/mission accomplishment.

Pilot #39: I'm concerned about too much chatter. Excess chatter could do more harm then good. Menial tasks in a relaxed environment could be done manually (i.e., "Open air refuel door," "Request range data").

Some commands could be combined, such as "Perform Fence Check." The steps to be performed could be programmed prior to flight.

Functions which are difficult or cumbersome to perform in a particular jet would be especially adept to be performed verbally (in the F-16 maybe FCNP operations, CHAFF & FLARES, ECM, etc. any heads-down operation). Functions that a pilot may have to perform when looking over his shoulder or that require extensive heads-down time would be ideal items for verbal commands. The fire control operation in the F-16 is perfectly satisfactory; it can be operated while looking over the shoulder.

Pilot #40: As I see it, the biggest drawback to this concept is noise saturation in the cockpit. In air-to-air combat arena, pilot has already reached the saturation point (about 15 yrs. ago) with inner/inter flight UHF and VHF communications, missile tones, RWR audio, AOA and slow speed tones, and enemy noise jamming. Most pilots learned to totally tune out some of these "helpful" noises such as RWR and AOA tones.

Second problem - most pilots have difficulty talking (communicating) effectively to other flight members during a hot and heavy air battle. To ask them also to talk to their airplane during such times would be too much. Under the optional "use manual switches or voice command" concept, training pay back would be reduced, i.e., you would have to train a pilot to use the manual switches like today's training and add in training for voice command (like training an F-4 pilot and navigator to operate as a crew).

Concept has some value in areas out of the immediate combat arena. In fact, in some cases, I think it would be very valuable, but only if scrubbed by a team of combat-ready fighter pilots.

Pilot #42: Sounds like you're over-designing a system. Suggest using only for small number of critical items. Don't use for anything that can be controlled on the stick or throttle.

Pilot #48: Would be excellent if recognizer could distinguish voice when screaming as well as talking, since I will probably be screaming in stress situations.

MISCELLANEOUS COMMENTS:

Pilot #7: General comment on 1st page states: Part 1 comments - threat warning/life threats are paramount and you have indicated all these areas.

Comments on Part II cover age state: I liked most of the items in this section. A lot of them are "nice-to-haves" - others are "gotta-haves." It's incredible... the areas you've looked at are areas I have had thoughts about for some time. You've hit the primary goal on the head... pilot workload reduction in a task saturated environment.

Pilot #8: Comments on 1st page: Personal Opinion - adding another sensory demand (voice) to those already used (proprioceptive, visual, etc.) may have a negative net efficiency in some cases.

Pilot #30: I believe anything that lessens pilot workload and prevents task saturation will be helpful, but the aircraft reliability seems to be sacrificed as a result. The kids who fix up and maintain the systems are still underpaid and undereducated. Will the new "improvements" really be that reliable and capable of "front-line maintenance" and quick fixes?

Pilot #38: I am extremely interested by the concept.

LIST OF PILOTS WITHOUT ANY COMMENTS:

Pilot #6; Pilot #11; Pilot #13; Pilot #27; Pilot #33; and Pilot #43.

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