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AIR INTERCEPT CONTROLLER TRAINING: A PRELIMINARY REVIEW.(U)

JUL 77 M W GRADY, M B HICKLIN, R M MILLER N61339-77-M-1058

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Technical Report NAVTRAEQUIPCEN 77-M-1058-1

AIR INTERCEPT CONTROLLER TRAINING:

A Preliminary Review

Logicon, Inc.
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This report describes the current Air Intercept Controller (AIC) course conducted by the Navy. The report discusses the utilization of advanced technologies and training system designs to improve the AIC training program.

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INTRODUCTION

Background

The Naval Training Equipment Center (NAVTRAEQUIPCEN) has continually been investigating the application of new technologies to the Navy's training requirements. As part of this program, the Human Factors Laboratory has been experimenting with speech understanding and synthesis as applied to the training of controller tasks. The degree of automation allowed by these computer-based speech technologies enables the development of automated-adaptive training systems for Ground Controlled Approch (GCA) controllers, etc. The GCA-Controller Training System (GCA-CTS), developed by NAVTRAEQUIPCEN and Logicon, was and continues to be an important test bed for exploring both the application of the speech technologies to controller-type tasks, and the specification of training requirements and critical functional features of advanced speech-technology-based systems.

The next step in NAVTRAEQUIPCEN's research program is the study and development of an automated training capability for air-intercept controllers (AIC). Not only is the AIC vocabulary significantly more complex than the GCA vocabulary, but the performance and learning requirements of the AIC are more involved than in the final segments of Precision Approach Radar/GCA (PAR-GCA). The automated AIC training problem thus represents a significant advance in both the application of the speech technologies as well as training system design.

At the same time, the fleet's requirements are both real and immediate. AIC training is currently conducted at the Fleet Combat Training Centers in San Diego (FCTCP) and Dam Neck. The training is supported in large measure by the Tactical Advanced Combat Direction and Electronic Warfare (TACDEW) training system developed in the 1960s. Modern training approaches and technologies have, for the most part not impacted AIC training. The high cost and low availability of live-air training makes it even more difficult to meet the fleet's readiness requirements. Relief is required.

Toward that end, the FCTCP has defined the requirement for a large scale Air Intercept Controller/Antisubmarine Aircraft Controller (AIC/ASAC) training complex to be developed in the 1980 time frame. In support of this effort, the Center has conducted an analysis of the AIC operational responsibilities. Results of the analysis constitute an evolving document, of course, but complete and accurate descriptions have been provided of the learning objectives and performance requirements currently being used at FCTCP. These represent a good first step toward defining the eventual requirements of the AIC portion of the 1980 AIC/ASAC trainer.

To satisfy the more immediate manpower and training time restrictions being felt at FCTCP, a "quick-fix" capability has been identified. It is believed that if the existing TACDEW operators (pseudo pilots) could be replaced by a very limited speech recognition capability, that some limited training can be conducted and manpower costs decreased. Computer grading, objective performance measurement, self-paced instruction, etc. will not be addressed by the quick fix; and yet these and other instructional and system features are desired for the later AIC/ASAC trainer. NAVTRAEQUIPCEN's training research program can provide design guidelines and specifications for these aspects of the device.

Purpose of the Study

Prior to immediate commencement of design and implementation activities, NAVTRAEQUIPCEN has sponsored a short study/planning effort which has had the following principal goals:

a. Review and document the existing task analysis performed by FCTCP, paying particular attention to the AIC "controller model" and the AIC vocabulary.

b. Specify the general system requirements imposed by the quick-fix solution to FCTCP's needs.

c. Delineate the tasks that must yet be accomplished prior to full-scale development of NAVTRAEQUIPCEN's training/research system, and suggest a management plan for their implementation.

Overview of this Report

Logicon reviewed the AIC training and training research problems, and in support of the goals mentioned above has documented the findings in this technical report. Following this brief introduction, the report describes the current AIC course structure at FCTCP. One particular level (level twelve), is singled out for detailed review because of its impact on both

FCTCP's quick fix and (potentially) NAVTRAEQUIPCEN's research oriented Air Control Training System (ACTS). This section also provides an overview of the training environment provided at FCTCP, focussing on the AIC inputs/outputs and processing associated with the simulation programs.

Section III discusses the AIC vocabulary, especially in terms of the requirements imposed by this vocabulary on the speech recognition technology. The report then goes on (in section IV) to describe the system requirements imposed by the FCTCP quick fix scheme. The training tasks that can be supported as well as hardware/software considerations are discussed.

Section V briefly discusses the AIC/ASAC trainer, and section VI reviews the requirements of ACTS. The report concludes with recommended courses of action for both NAVTRAEQUIPCEN and FCTCP.

A secondary consideration in writing this report has been to exclude any classified information. All references to detailed actions on the NTDS UYA-4 consoles, for example, have consequently been avoided. The AIC task analysis performed by FCTCP is classified confidential, and yet this document provides a wealth of detailed information which is only summarized herein. NAVTRAEQUIPCEN is encouraged to review a copy of these task listings to supplement this report.

SECTION II

AIC TRAINING AT FCTCP

Introduction

The Fleet Combat Training Center, Pacific (FCTCP) is responsible for providing the fleet with qualified air intercept controllers. Toward that end, they have established a course, designated K-221-0027, with the stated objective to "train officers and senior enlisted to effectively control fleet intercept aircraft in combatting hostile airborne threats." A full-scale simulation environment supports this course. The following subsections describe the AIC training program at FCTCP.

Entry-Level Qualifications

Many students entering AIC training are Naval Tactical Data System (NTDS) qualified. This NTDS training consists of a brief exposure to all the various responsibilities in the typical NTDS-based Combat Information Center (CIC). The primary importance of this training to the AIC student is that he will have been exposed to the various modes of NTDS operation and will not need to be familiarized with its basic concepts. On those occasions when a student has entered AIC training without prior NTDS experience, his subsequent success in the AIC program appears to depend on a number of factors, the most important of which are maturity and experience in the Navy. Among those who fail to complete the AIC course, the lack of familiarity with NTDS plays a significant role. Therefore, the present intention is to establish NTDS qualification as an entry level requirement for all students. In addition, it is preferred (though not a formal requirement) that all students entering the program have 2 – 4 years general experience in the Navy.

Student Load

Presently one AIC class is started each week. The class consists of two NTDS students who start and progress together through 6 seeks of AIC training.

In addition to the 2 NTDS students, 2 students are also started each week in a "conventional" class. These students supply the diminishing demand for AICs aboard the few remaining non-NTDS-equipped ships in the fleet. It is important to note that future plans call for dropping conventional training altogether and adding these students to the NTDS group. This will result in an additional 2 NTDS students who are starting each week. The present study did not address "conventional" AIC training.

The AIC training program is also responsible for providing refresher and supervisor training which must be conducted on the same equipment. These courses account for 1 to 2 students per week, which brings the long-term expected student load up to 5 to 6 students per week. These students are all trained on the same equipment and in a very similar fashion.

AIC Course Philosophy

The major stepping stone between previous AIC training (prior to January 1977) and the existing course was the emphasis on teaching a job rather than equipment. The majority of operators have traditionally been taught using equipment technical manuals. Instruction often consisted of simple demonstrations to the student that indeed if switch A was thrown, then A' resulted. One AIC instructor muses that when he attended AIC school in the early 1960s, all instruction was essentially presented during the first week! If the proper button pushing sequences were learned during that time, the course was essentially complete!

By comparison, the current AIC course is strictly task oriented. This becomes clear when the specific learning objectives are presented in the following subsection, but a specific example is also illuminating. Consider the problem of teaching the Identification Friend or Foe (IFF) system to the controller. Previously this was taught by describing the various switches (explaining what each one did) one row at a time. If problems developed, the instructors dug deeper into the equipment manuals and explained the system block diagram: trigger pulses, timing, responses, etc.

The current system, on the other hand, identifies the jobs that IFF supports. IFF "experts" found it difficult to name them all, but persistence resulted in clearly defined tasks. Given a checklist to set up the IFF equipment, the following tasks can be performed:

a. Assist in tracking friendly aircraft using IFF.

b. Identify an emergency using IFF.

c. Identify one friendly aircraft from another using IFF.

d. Obtain the altitude of friendly aircraft using IFF.

e. Make a positive identification using IFF.

Each job is explained; each step is explained. The actual operation of the equipment is discussed only in terms of its contribution to the job.

In addition to defining the AIC responsibilities in terms of functional tasks rather than equipment operation, the current AIC course places heavy emphasis on proper motivation of the student. Each task is structured to begin with the easy and progress to the difficult. Basic skills are taught before moving on to the more complex interactions. Because air intercept control has a reputation in the fleet and training centers for being particularly difficult, the trainee is too often too willing to give up. By starting with the easy and simple tasks, the student learns that he can do the job. By the time he has progressed to the challenging Air Combat Maneuvers (ACM), he is motivated and self confident so that the learning experience becomes less threatening.

By approaching all of the AIC's responsibilities in these ways, the existing AIC course was developed. The results have been rewarding. The instructors feel less harried and the students are better trained.

Course Structure

The first three weeks of the AIC course consist of classroom instruction and synthetic (simulated) air control. The second three weeks consist of actual air control using real aircraft and pilots engaged in their own training exercises out of nearby Miramar NAS. Synthetic training has been the primary interest in this present study.

As just described, the course is designed to gradually introduce the student to the jobs of an AIC. Thirteen levels are identified in the synthetic portion of the course, progressing from easy to hard, simple to complex. (Three additional levels concern "live" training.) Each level is designed with a specific objective (or objectives) in mind, and the student is expected to complete each learning objective before proceeding to the next level.

Levels 1 – 6 cover the intercept phase; levels 7 – 11 the engagement phase; and levels 12 and 13 prepare the student for "live" air control by covering set-ups and tanker join-ups. The content of each level is described in detail in the following paragraphs, and summarized in table 1.

TABLE 1. SUMMARY OF AIC COURSE LEVELS

Level	Content
1	Range and bearing from ownship to target
2	Target track and speed
3	Jinking – drastic changes in track, speed, or altitude
4	Range and bearing from interceptor to target
4a	NTDS failure – perform above without NTDS support
5	Update TAO/SWC. Respond to "Contact," "Judy," "Lost Contact," "Stranger" calls
6	Splitting bogeys
7	Composition and formations
8	ACM
9	Missions for CAPs other than intercepts and engagements
10	Jamming and interference
11	F-14 one-way data link
12	The training environment: set ups, breakaways, and check-in procedures
13	Friendly/tanker join ups

Level One

a. Terminal Objective: Transmit magnetic bearing and range to a target from ownship.

b. Standard: Magnetic bearing and range reported every sweep (~10 seconds) accurate within ±2 degrees and ±1 mile, within 5 seconds after the sweep passes the target.

c. Enabling Objectives:

1. Set up NTDS console for target detection and tracking in the Air Control (AC) mode.

2. Set up console radio.

3. Interpret magnetic variation.

4. Enter air target.

5. Interpret magnetic bearing and range.

6. Observe rules for clarity on radio/telephone (R/T) circuits.

7. Track air target.

Level Two

a. Terminal Objective: Transmit target track and ground speed.

b. Standard: Track ±10 degrees and speed ±0.1 Mach, within one minute of detection.

c. Enabling Objectives: Interpret target track and ground speed.

Level Three

a. Terminal Objectives:

1. Transmit target track jink direction. (A jink is a drastic change in track, speed or altitude.)

2. Transmit updated target track.

3. Transmit target ground speed jink, increase/decrease.

4. Transmit updated ground speed.

5. Obtain target altitude.

6. Transmit target altitude.

b. Standards:

1. Track jink direction: correct direction (left/right) within one minute of jink.

2. Update track: within 1-1/2 minutes, ±10 degrees.

3. Ground speed jink: increase/decrease within one minute.

4. Updated ground speed: within 1-1/2 minutes, ±0.1 Mach.

5. Altitude request: within 1 minute of target detection and 1 minute of ground speed jink.

6. Transmit target altitude: within 30 seconds upon receipt.

c. Enabling Objectives:

1. Maintain a track history of target's track.
2. Recognize a track jink.
3. Interpret magnetic track.
4. Recognize ground speed jink.
5. Request target altitude update.
6. Enter new altitude as required.

Level Four

a. Terminal Objectives:

1. Using Link 4A with voice (R/T) as a backup, transmit magnetic bearing and range to a target from an interceptor (CAP – Combat Air Patrol).

2. Transmit "in-the-dark" calls, i.e., when radar video fades.

b. Standards:

1. Transmit magnetic bearing and range: from the CAP to the target, 8 out of every 10 sweeps, accurate ±2 degrees and ±1 mile.

2. Call in the dark: within 2 sweeps of the fade.

c. Enabling Objectives:

1. Enter interceptor.
2. Track interceptor.
3. Determine magnetic bearing and range from CAP to target.
4. Maintain smallest range scale for tracking CAP and target.
5. Transmit in-the-dark calls.

Level Four a

a. Terminal Objectives:

1. Transmit an estimated magnetic bearing and range from a CAP to a target without the use of an NTDS program.

2. Transmit target track and ground speed without the use of an NTDS program.

b. Standards:

1. Magnetic bearing and range: from the CAP to the target 8 out of 10 sweeps, accurate ±6 degrees and ±6 miles.

2. Track and ground speed: ±10 degrees and 0.2 Mach within 1-1/2 minutes of detection.

c. Enabling Objectives:

1. Adjust plotting head intensity.
2. Align plotting head for magnetic bearing.
3. Determine magnetic bearing.
4. Determine target tracks and ground speed.
5. Determine jinks.

Level Five

a. Terminal Objectives:

1. Update the air picture to TAO/SWC (Tactical Action Officer/ Ship's Weapon Coordinator).

2. Relay orders from TAO/SWC to CAP via Link 4A with voice back up.

3. Respond to "Contact," "Judy," "Lost Contact" calls.

4. Call "Strangers" to aircraft.

b. Standards:

1. Inform SWC/TAO of CAP call and type of interceptor within 1-1/2 minutes after receipt by voice communications.

2. Inform SWC/TAO of interceptor state and status within 2 minutes after receipt.

3. Relay engagement orders from TAO/SWC within 30 seconds of receipt.

4. Determine probability of intercept 9 out of 10 times.

5. Respond to "Contact," "Judy," "Lost Contact" calls within 5 seconds of the time received.

6. Call "Strangers" to aircraft 100 percent of time.

c. Enabling Objectives:

1. Enter CAP type and Selective Identification Feature (SIF).

2. Enter CAP state.

3. Relay engagement orders from SWC/TAO.

4. Interpret progress of intercept.

Level Six

Introducing splitting bogey. Call splits and recognize the priority threat; track more than two aircraft.

a. Terminal Objectives:

1. Transmit target splits (two or more radar returns splitting from a single return) via Link 4A with voice backup.

2. Maintain track on more than two aircraft.

b. Standards:

1. Transmit target splits:

a) Report within 20 seconds of splits.

b) Report bogey dope on the most threatening bogey 8 out of 10 sweeps.

c) Report the other aircraft upon request within six seconds.

d) Four out of five transmissions must be interpreted correctly.

2. Maintain track on more than two aircraft: update the track for each aircraft at least 8 out of 10 sweeps.

c. Enabling Objectives:

1. Direct target splits.
2. Determine most threatening target.
3. Call bogey dope on additional targets on request.

Level Seven

a. Terminal Objectives:

1. Transmit bogey composition.
2. Transmit bogey formation.

b. Standards:

1. Transmit bogey composition: reported within 30 seconds, accurate 9 out of 10 times.

2. Transmit bogey formation: reported within 45 seconds, accurate 9 out of 10 times.

c. Enabling Objectives:

1. Obtain bogey composition.
2. Interpret bogey composition.
3. Obtain bogey formation.
4. Interpret bogey formation.

Level Eight

a. Terminal Objectives:

1. Update TAO/SWC on progress of engagement.
2. Transmit time in fight.
3. Transmit aircraft out of fight.

b. Standards:

1. Update TAO/SWC on progress of engagement: report accurate progress to TAO 9 out of 10 times. Interpret:

"BURNER"	"DRAG HIM"
"VISUAL"	"SWITCH"
"TALLY HO"	"BREAK LEFT/RIGHT"
"EYEBALL"	"REVERSE"
"CLEAR"	"COME BACK"
"ENGAGED"	"PITCH BACK"
"FREE"	"EXTEND"
"OFF"	"PADLOCK"
"IN"	"KNOCK IT OFF"
"PRESS HIM"	"BUG OUT"
"UNLOAD"	"LAST DITCH"
"ACM GUARD"	

2. Transmit time in fight: accuracy +5 seconds.

3. Transmit aircraft out of the fight: separation from a merged plot reported within 5 seconds.

c. Enabling Objectives:

1. Interpret ACM communications.
2. Time the engagement.
3. Detect splits out of a fight.

<u>Level Nine</u>

a. Terminal Objectives:

1. Track synthetic video using overlapping live radar.
2. Track friendly aircraft with the assistance of IFF.
3. Distinguish one friendly aircraft from another using IFF.
4. Recommend heading to maintain a specific track.
5. Transmit information on weather points.
6. Relay pilot weather reports, case recoveries and flight conditions.

7. Transmit stranger information.

8. Identify an emergency response.

9. Transmit required information to assist in emergencies.

10. Transmit required information to assist in search and rescue.

b. Standards:

1. Track synthetic video using overlapping live radar: maintain track of CAP and strangers 8 out of 10 sweeps.

2. Track friendly aircraft with the assistance of IFF: IFF equipment must be set up correctly prior to any flight.

3. Identify one friendly aircraft from another using IFF:

a) Transmit "Squawk Ident" if PIF is unknown.

b) Reset equipment for tracking.

4. Recommend heading to maintain a specific track: accuracy ±5 degrees.

5. Transmit information on weather points: accuracy ±5 degrees ±2 miles.

6. Relay pilot weather reports, case recoveries and flight conditions: accuracy 100 percent.

7. Transmit stranger information:

a) All strangers must be reported prior to 5 miles from interceptor 100 percent of the time.

b) Accuracy ±5 degrees ±2 miles.

8. Identify an emergency response: accuracy 100 percent.

9. Transmit required information to assist in emergencies 100 percent.

10. Transmit required information to assist in search and rescue 100 percent.

c. Enabling Objectives:

1. Determine aircraft's mission.

2. Plot a geographic picture on a radar repeater.

3. Determine offset from desired track.

4. Compensate for offset (winds aloft).

5. Interpret pilot weather reports, case recoveries and flight conditions.

6. Detect strangers.

7. Plot strangers.

8. Estimate magnetic bearing and range to a stranger.

9. Detect an emergency.

10. Transmit search and rescue information on down aircrews.

<u>Level Ten</u>

a. Terminal Objectives:

1. Provide assistance to aircrews while experiencing radar jamming.

2. Provide assistance to aircrews while experiencing radio jamming.

b. Standards:

1. Provide assistance to aircrews while experiencing radar jamming:

a) Jamming – able to complete mission: transmit bearing and range to weather points. Accuracy ±5 degrees, ±2 miles.

b) Jamming – unable to complete mission: transmit bearing and range to weather points. Accuracy ±10 degrees, ±5 miles.

c) Provide BARCAP with bearing and range to jammer. Accuracy ±5 degrees and ±5 miles.

2. (Classified)

c. Enabling Objectives: (Classified)

Level Eleven

a. Terminal Objectives:

1. Up date the aircrew of the F-14 interceptor via one way data link.

2. Relay force and TAO orders concerning CAP/missile coordination.

3. Transmit MIG/Surface-to-Air Missile (MIG/SAM) warnings.

4. Recommend return to force headings.

b. Standards:

1. Establish one-way link with section of F-14s: within 1 minute after check in.

2. Up link radar track information to F-14s: within 30 seconds after detection.

3. Relay force orders and TAO orders concerning Combat Air Patrol/Surface-to-Air Missile coordination: with 100 percent accuracy.

4. Transmit SAM/MIG trap warnings: within 5 seconds of receipt.

5. Recommend return to force headings: ±5 degrees

c. Enabling Objectives:

1. Establish one-way link with a section of F-14s.

2. Up link geographical data to a section of F-14s.

3. Up link radar track information to a section of F-14s.

4. Relay force and TAO orders concerning CAP/Missile coordination both by data link and voice.

5. Enter MIG/SAM traps in program.

6. Transmit MIG/SAM traps.

7. Transmit return to force headings.

Level Twelve

a. Terminal Objectives:

1. Pick up assigned aircraft.

2. Transmit headings for training set-ups via Link 4A with voice backup.

3. Transmit headings for area control via Link 4A with voice backup.

b. Standards:

1. Locate aircraft using IFF and/or Tactical Air Navigation (TACAN): within 1 minute after communications established (100 percent of the time).

2. Provide headings to station or area: within 30 seconds after locating aircraft.

3. Transmit headings via Link 4A with voice backup: with an accuracy of ±10 degrees within 5 miles of desired range of separation.

4. Transmit headings for breakaways, and area control: with an accuracy to remain in the area at all times.

c. Enabling Objectives:

1. Locate aircraft.

2. Determine lost communications.

3. Provide headings to stay in the area.

4. Planning bearing, target aspect angle, angles off, and track crossing angle.

5. Plot fighter heading, bogey heading, and reciprocal.
6. Determine the area of the intercept.
7. Turn bogey.
8. Turn fighter.
9. Determine headings for breakaway and area control.

Level Thirteen

a. Terminal Objectives:

1. Assist in an aircraft rendezvous.
2. Relay state and status reports.

b. Standards: Recommend headings ±5 degrees within 1 minute of request.

c. Enabling Objectives:

1. Locate tanker or friendly aircraft for rendezvous.
2. Recommend headings to both aircraft.
3. Ensure altitudes are known.
4. If a tanker determine:
   a) Condition of package.
   b) Amount of give away before and after refueling.
   c) If not Navy, is tanker basket capable?
5. Interpret state and status reports.

A Typical Scenario

Throughout this study, level twelve has been the subject of particularly close study because of its impact on both the FCTCP quick fix as well as on the potential design of ACTS. Recall that level twelve covers setups (establishing various aspect angles to support aircrew training), breakaways (recommended headings to remain in an assigned area), and check in procedures. Moreover, all skills gained in the intercept phase (levels one through six) as well as emergencies, area control and stranger reports, are practiced during this level.

During level twelve the student communicates with a pseudo pilot who is interacting directly with the training system, e.g., TACDEW. The pseudo pilot is typically controlling two "aircraft."

The detailed requirements of level twelve are fully documented in the classified task listings associated with this level. Table 2 presents a typical sequence of events during the training session.

Note that in level twelve, as in all the AIC training, the student must acquire verbal, cognitive, and motor skills. The verbal skills required are amply demonstrated in table 2. As an example of cognitive skills, consider the problem of determining the proper "planning bearing" (the bearing to the bogey taking into consideration bearing drift), the "target aspect angle" (the angle from the bogey's track to bearing-to-CAP), and the "angle off" (the angle from the CAP's heading to bearing-to-bogey). The student is then required (while aircraft are opening out) to:

a. Determine the planning bearing.

b. Determine the area the intercept should occur.

c. Add/subtract angle off from planning bearing.

d. Add the target aspect angle in the other direction from the planning bearing and mark it (R) for the bogey reciprocal.

e. Find reciprocal of (R) to determine bogey heading.

To appreciate the level of motor skill development that must simultaneously be acquired, consider the following sequence that must be performed to report a stranger:

a. Student sees stranger aircraft.

b. Student depresses Sequence button and sequences to CAP.

c. Student depresses Ball Tab button, enabling ball tab.

d. Utilizing ball-tab roller, student rolls ball tab to position of stranger.

e. Student depresses a variable action button.

f. Student reads bearing and range from console.

g. Student observes direction of stranger's track.

h. Student depresses radio transmitter foot pedal.

i. Student transmits stranger position and track to CAP.

j. Student releases foot pedal.

TABLE 2. SAMPLE SCENARIO FOR LEVEL TWELVE MISSION.

Event	Voice Source	Sample Voice Messages
1. Two aircraft enroute from Miramar to training area appear on radar, approximately 270 degrees at 15 miles, tracking 260 degrees speed 0.6. Communications established.	Pilot	Ruth, this is Skyking 302 and 303 up for your control.
	AIC	Roger. Mark your TACAN.
	Pilot	302 (is on the) 275 (at) 20.
	AIC	Roger. Radar contact. Port 240 for the area.
	Pilot	Roger.
2. Establish lost communications procedure.	AIC	302, say lost communications intentions, over.
	Pilot	This is 302. Point Whiskey, twenty, port orbit.
	AIC	302, Tango 1, Tango 2 hot, Recommend rendezvouz Point Sierra.
	Pilot	Roger.
3. Mode 3 IFF assignment.	AIC	302 squawk 5741. 303 squawk 5742.
	Pilots	302 roger, out. 303 roger, out.
4. Unidentified, friendly stranger.	AIC	302, stranger, 320, eight, heading south, altitude eighteen thousand.
	Pilot	302, tally stranger.
5. Practice separation.	AIC	303 (detach) starboard 340, over.
	Pilot	303 roger, 340 out.
	AIC	302 port 160 (for separation).
	Pilot	302, 160 roger.
6. Turn for intercept.	AIC	303 port 160 as bogey, over.
	Pilot	303 roger 160.
	AIC	302 starboard 340 for bogey.
	Pilot	302 roger, 340.

TABLE 2. SAMPLE SCENARIO FOR LEVEL TWELVE MISSION (Cont).

Event	Voice Source	Sample Voice Messages
7. Fighter makes contact with bogey	Pilot	302 has a contact 340, twenty-seven.
	AIC	That is your bogey. Tracking 160.
8. Lock-on.	Pilot	302 Judy.
9. Lost contact	Pilot	Lost contact.
	AIC	302 bogey 340, twenty. 302 bogey tracking 160 speed 0.6. 302 bogey altitude twenty two thousand. Range and bearing messages continue until contact or at pilot's request.
10. After contact, lock-on and missile launch	Pilot	Fox 2, breakaway.
	AIC	302 breakaway 330.
	Pilot	Roger.
11. Advise bogey of breakaway heading for separation.	AIC	303 continue 160.
	Pilot	Roger.
12. State report	AIC	302 what state?
	Pilot	302 eight point five.
	AIC	303 what state?
	Pilot	303 tiger.
13. Cancel order; etc.	AIC	Disregard.
14. Garbled transmission	AIC	Say again.
15. Increase turn rate from 3^{o}/sec to 6^{o}/sec.	AIC	302 tighten turn.
16. Contact is not bogey; etc.	AIC	302 negative, your bogey 340, 14.
17. Hold in port turn at fixed point.	AIC	303 anchor port.

The AIC training problem is clearly a varied and complex one. This fact must be kept in mind during the subsequent discussions of the various training systems: the FCTCP "quick-fix," the AIC/ASAC Trainer, and ACTS.

Training Facilities(1)

The training environment for the AIC course described in the preceeding subsections is provided by:

a. Mockups of the AIC Centers aboard a typical carrier or Naval Air Station.

b. An NTDS program, and related equipment.

c. An environment simulation program, and related equipment. Three principal programs are available: TACDEW, the Master Simulation Program (MSP), and the AIC Simulation Program (ASP).

The following paragraphs describe these facilities in greater detail. See Figure 1.

The Mockups – Two mockups are dedicated to AIC training at FCTCP. One mockup is used principally for synthetic training and contains ten NTDS console positions. The other mockup is used principally for live training, and contains 6 NTDS positions as well as 10 "conventional" stations. Because of the switching capabilities at FCTCP, however, any console can receive either simulated radar video, real radar video, or a combination of both. Each station includes a radio phone unit (RPU) for communication with other AICs, with the TAO/SWC, and with the pilots (real or pseudo). The instructors can monitor the RPU from a variety of locations.

Note 1. Only simulated (synthetic) training facilities are discussed here.

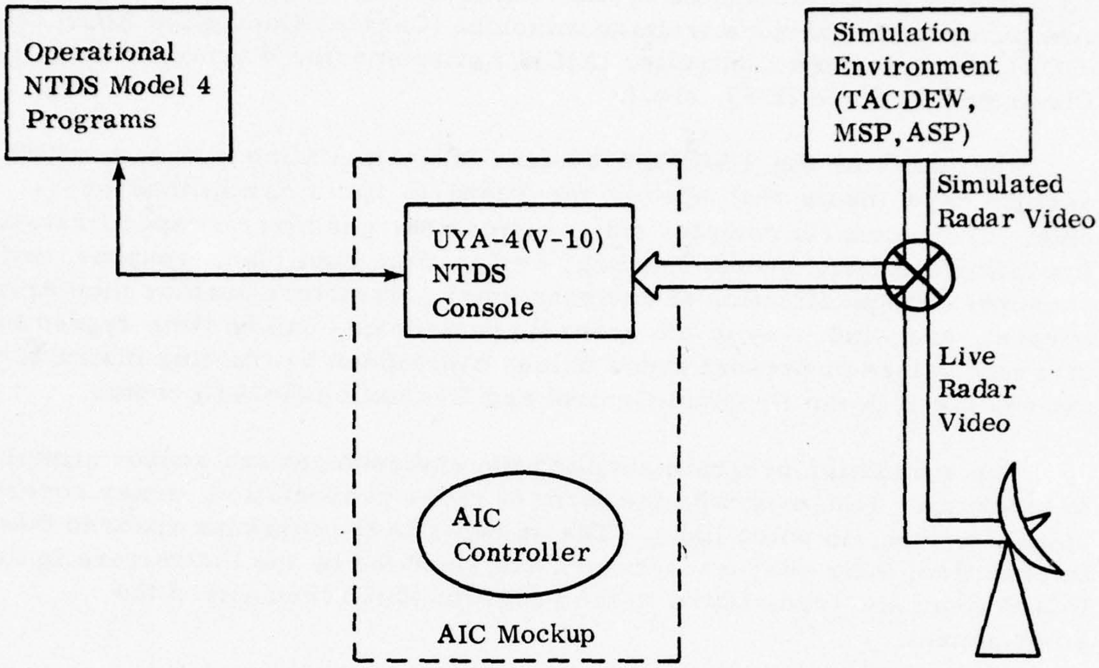


Figure 1. AIC Training Environment.

The NTDS Program[2] – AIC training is supported by a reduced capability NTDS Model 4 carrier program. The program is strictly operational, in the sense that it consists solely of modules used in the operational (shipboard) systems. The software is not modified for the training environment in any way.

The Simulation Programs – Three simulation programs are available to the AIC instructors to support their training mission. Each of these was originally developed by Logicon, though Fleet Combat Direction Support System Activity (FCDSSA) has maintained and (presumably) modified the programs over the past few years.

TACDEW – The Tactical Advanced Combat Direction and Electronic Warfare (TACDEW) training system provides the most capability, and is the primary simulation program currently used to support AIC training.

Note 2. If the reader is not familiar with NTDS operation, he is encouraged to refer to the (classified) documentation.

TACDEW is a multicomputer system that simultaneously provides simulated environments for various training missions (Carrier Controlled Approach (CCA), Air Intercept Controller (AIC), Antisubmarine Warfare (ASW), Electronic Warfare (EW), etc.).

The heart of the TACDEW system is a simulation program which accepts tape inputs that specify the scenario for a preplanned exercise. This scenario contains ship, submarine, and aircraft specifications (including location, speed, heading, designation, fuel load, weapons, and sensors) and specification of environmental parameters such as map area, current, and wind. Any of the scenario parameters can be time tagged to give new values at present times unless overridden by training instructor actions taken in the Problem Control and Evaluation (PC&E) room.

The simulation program supplies the environment and sensor stimuli to mockups. This may take the form of radar presentation, sonar reports, ships' sensors, or voice links. The students in the mockups react to this information; their responses in turn are received by the instructors in the PC&E room and transmitted to the program which then alters the environment.

The problem control personnel in the PC&E room not only act as the second half of voice links and enter student responses into the computer, but also monitor and control the progress and environment of the exercise. They can add or delete ships, submarines, or aircraft; alter fuel, sensor, or weapons load of any vehicle; alter probabilities of detection, lock-on, and kill; or change the sensor capabilities on any vehicle.

MSP (AICOC) – The AIC One-Computer system, was developed to provide an AIC training capability without tying up the personnel and equipment necessary to operate the four- or five-computer TACDEW system.

The MSP program is a modification of the large TACDEW and contains all the target commands from the large system applicable to non data-link AIC training. There are some limitations as to the number and type of targets. These restrictions primarily concern the exercise author. Further, because the primary TACDEW system exercise control device, the UYA-4 Data Utilization (DU) Display Console, is not used with this system, the system operating procedures are quite different. The functions performed by the DU console in the large TACDEW system are either not available in the MSP system or are performed at the computer console.

Tables 3 and 4 show the commands available to the instructors and pseudo pilots using the MSP. Figures 2 and 3, and table 5 demonstrate the outputs associated with AIC training. These inputs and outputs are facilitated by a CRT Target Control Subsystem, Device 15G17.

ASP – A requirement was identified to support synthetic AIC training using Link-4A equipped aircraft. This program, known as the ASP (Air Control Training System Simulation Program) is also a one-computer offshoot from the larger TACDEW system, but differs significantly from the MSP (AICOC). Figure 4 is a block diagram of the system configuration. Notice that both the student and instructors utilize UYA-4 display consoles. This heavy requirement on the consoles, together with complex instructor interactions with the program, have resulted in the rare utilization of the ASP.

AIC Command Decoding – To gain an appreciation for the level of sophistication required of the simulation programs (TACDEW, MSP, or ASP), one need only review the AIC Command Decoding modules of these systems. These modules provide the "pilot model" and simulate the AIC environment by:

a. Interpreting the air controller messages that are exclusive to AIC (the Basic Command Decoder interprets the other messages).

b. Generating replies that a pilot would make during the course of an intercept.

c. Computing and executing heading, speed, and altitude changes that the pilot would make without the direction of the air controller.

d. Generating other functions that add to the realism of the AIC/ Anti-Air Warfare (AAW) exercise (probability of detection, probability of kill, etc.).

AIC Messages – The messages which the AIC module receives and decodes are the following:

a. "Vector for Bogey." This is the first command given to an interceptor at the beginning of an intercept. It is the same as a vector command except that it is done at the maximum turn rate.

b. "Speed" as desired.

c. "Angels." Altitude as desired.

TABLE 3. GENERAL COMMANDS.

Entry Code	Program Response	Modifying Data	Meaning
T	TURN	Heading (000-360) required.	Turn in the shortest direction to indicated heading.
TP	TURN PORT-	Heading (000-360) required.	Turn port to indicated heading.
TS	TURN STBD-	Heading (000-360) required.	Turn starboard to indicated heading.
TP(s)H	TURN PORT (STBD)-HARD-	Heading (000-360) required.	Turn port (stbd) to indicated heading at increased rate of turn.
TP(s)C	TURN PORT (STBD)-CONTINUE-	Heading (000-360) required.	Do not stop at previously entered heading, but continue port (stbd) to new heading.
TE	TURN EASE	None permitted.	Decrease rate of turn.
TT	TURN TIGHTEN	None permitted.	Increase rate of turn.
TD	TURN STEADY=	Heading (000-360) optional.	Steady on present heading or heading indicated.
SK	SPEED KNOTS-	Knots (0-999) required.	Change speed to knots indicated.
SM	SPEED MACH-	Mach (0.00-5.00) required.	Change speed to mach indicated.
SA	SPEED AS DESIRED	None permitted.	Take desired speed.
SS	SPEED SAUNTER	None permitted.	Change speed to "saunter."
SL	SPEED LINER	None permitted.	Change speed to "liner."
SP	SPEED BUSTER	None permitted.	Change speed to "buster."
SG	SPEED GATE	None permitted.	Change speed to "gate."
A	ANGELS	Altitude in ft x 1000 (00-96) required.	Change altitude to altitude indicated.
AA	ANGELS AS DESIRED	None permitted.	Take desired altitude.
QF	SQUAWK FLASH	None permitted.	Squawk flash.
Q1	SQUAWK MODE 1-	Code (XY) required (X = 1-7, Y = 1-3).	Squawk Mode 1.
Q2	SQUAWK MODE 2-	Code ($0000\text{-}7777_8$) required.	Squawk Mode 2.
Q3	SQUAWK MODE 3-	Code ($00\text{-}77_8$) required.	Squawk Mode 3.

TABLE 4. AIC COMMANDS.

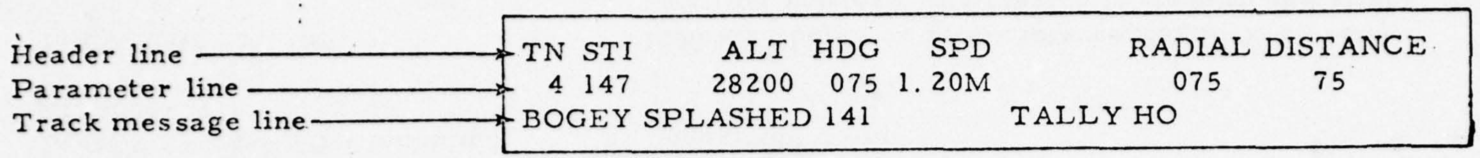
Entry Code	Program Response	Modifying Data	Meaning
BA	BOGEY ALTITUDE-	Altitude in ft x 1000 (00-96)	Gives bogey's altitude to interceptor
BB	BOGEY BRNG= RNG=	Bearing (00-360), range in radar miles (000-999) required.	Gives bogey's position to the interceptor.
BH	BOGEY HEADING-	Heading (000-360) required.	Gives bogey's heading to interceptor.
BK	BOGEY SPEED (KNOTS)-	Knots (000-999) required.	Gives bogey's speed in knots to the interceptor.
BM	BOGEY SPEED (MACH)-	Mach (0.00-5.00) required.	Gives bogey's speed in machs to the interceptor.
BJ	BOGEY JINXING	None permitted.	Tell interceptor that bogey is jinxing.
BV	BOGEY VECTOR	Heading (000-360) required.	Turn to the indicated heading.
R	REPORT BOGEY ALT	None permitted.	Report bogey's altitude.
KAL	SPECIAL ANGLE OFF-L-DEG= RNG=	Angle (00-90), range in radar miles (000-999) required.	Gives bogey's position relative to interceptor.
KAR	SPECIAL ANGLE OFF-R-DEG= RNG=	Angle (00-90), range in radar miles (000-999) required.	Gives bogey's position relative to interceptor.
KJ	SPECIAL JUDY	None permitted.	Authorizes the pilot to complete the intercept and launch an attack.
KK	SPECIAL SKIP IT	None permitted.	Break off the intercept.
KT	SPECIAL CONFIRM TARGET-BRNG= RNG=	Bearing (000-360), range in radar miles (000-999) required.	Requests the pilot to confirm that he is attacking the correct target.
KCC	SPECIAL CONTACT CONFIRMED=	Contact number (1-3) optional.	Confirms that the contact is the controlled track's bogey.
KCN	SPECIAL CONTACT NEGATE	None permitted.	Indicates to the pilot that the contact he reported is not his bogey.
KO	SPECIAL ORBIT	None permitted.	Orbit.
KS	SPECIAL STEER-BRNG= RNG=	Bearing (000-360), range in radar miles (000-999) required.	Fly to the position indicated.
KH	SPECIAL STEER HOMEPLATE	None permitted.	Fly to homeplate.
KI	SPECIAL ID RUN	None permitted.	Requests the pilot to identify the bogey visually.
KN	SPECIAL NEGATE ID	None permitted.	Pilot is to ignore the previous ID RUN request.
KR	SPECIAL REPOS BRG (DLRP)= RNG (DLRP)=	Bearing (000-360) and range (000-999) miles from DLRP are required.	Repositions the target to the indicated location.
KP	SPECIAL HOMEPLATE STI=	STI of homeplate required	Assign a homeplate to the target under close control.
KM	SPECIAL INCPTR L.O. RNG= SRCH RNG=	Lock on range (000-999) miles and search range (000-999) miles are optional. If none given, standard ranges for that track type will be assigned.	Make the target under close control an interceptor.
KD	SPECIAL ANGLE OFF DATA STI=	STI of the track to which the angle off data is requested, is required.	Print angle off and range from the track in close control to any other track. Refer to Section 6 for the format of this message.

```
Command entry information --> 2 TURN PORT HARD 400
Error indication ------------> ILLEGAL HEADING
                              TN STI     ALT  HDG   SPD          RADIAL DISTANCE
                               1 267   22495 P250 1.55M            301      66
                              HEADS UP                     WRONG CONTACT FAMISHED

                              TN STI     ALT  HDG   SPD          RADIAL DISTANCE
                               2 305   10400  350   220            185      10
Target information
                              TN STI     ALT  HDG   SPD          RADIAL DISTANCE
                               3 123    6300 P295   160            200       8

                              TN STI     ALT  HDG   SPD          RADIAL DISTANCE
                               4 147   28200  075 1.45M            075      75
                              BOGEY SPLASHED 141           TALLY HO

Operator aids (constant)      FOR COMMAND LISTS ENTER Z(GEN),  I(AIC)
                              FOR SYSTEM ENTRIES ENTER X
```

NOTES:

1. Underscored entries are made by operator.
2. Track number of the track in close control will blink.

Figure 2. Main Display.



NOTES:

1. Track Number = 4.
2. STI = 147.
3. Because the AICOC program can only handle one exercise, no exercise number is displayed.
4. Altitude = 28, 200 feet.
5. Heading = 075° steady (if target was turning, heading would be P075).
6. Speed = Mach 1.2 (speed in knots is shown as a three digit number without an M).
7. Position is 075°, 75 miles from the TACAN station.
8. Target shot down STI 141 after making visual contact with it.
9. Because fuel and weapons load is unlimited STATE is left blank.

Figure 3. Sample Track Information Section of Main Display.

TABLE 5. TRACK STATUS MESSAGES (AIC TARGETS).

Message	Meaning
CONTACT - including:	Indicates existence of contact(s) and its position relative to interceptor. Bearing indicated relative to interceptor's heading. Position information will be repeated for up to three contacts.
Relative angle from track heading to contact (L or R 00-99)	
Radar range to contact (000-300 miles).	— — —
CONTACT - including:	Same as above, except bearing is magnetic.
Magnetic bearing of contact (001-360°).	
Radar range to contact (000-300 miles).	— — —
FOX -	Interceptor has fired air-to-air missile(s) at bogey.
BOGEY SPLASHED - including: STI (000-777).	Bogey shot down.
LOCK-ON?	Indicates bogey is in the interceptor lock-on cone and pilot requests permission to lock-on and attack bogey.

TABLE 5. TRACK STATUS MESSAGES (AIC TARGETS) (Cont).

Message	Meaning
HEADS UP	Interceptor did not shoot down bogey and cannot attack again.
LOST CONTACT	Bogey has left lock-on cone or search cone and pilot needs more information on bogey position.
CONTINUE BOGEY DOPE	Pilot requests more bogey information after he has commenced an attack.
JUDY	Pilot is going to complete intercept.
WRONG CONTACT FAMISHED	Pilot has been attacking wrong target and needs more information to locate bogey.
MAYDAY	Pilot has transmitted MAYDAY alert.
TALLY HO - including STI of bogey	Pilot has made visual identification of bogey.

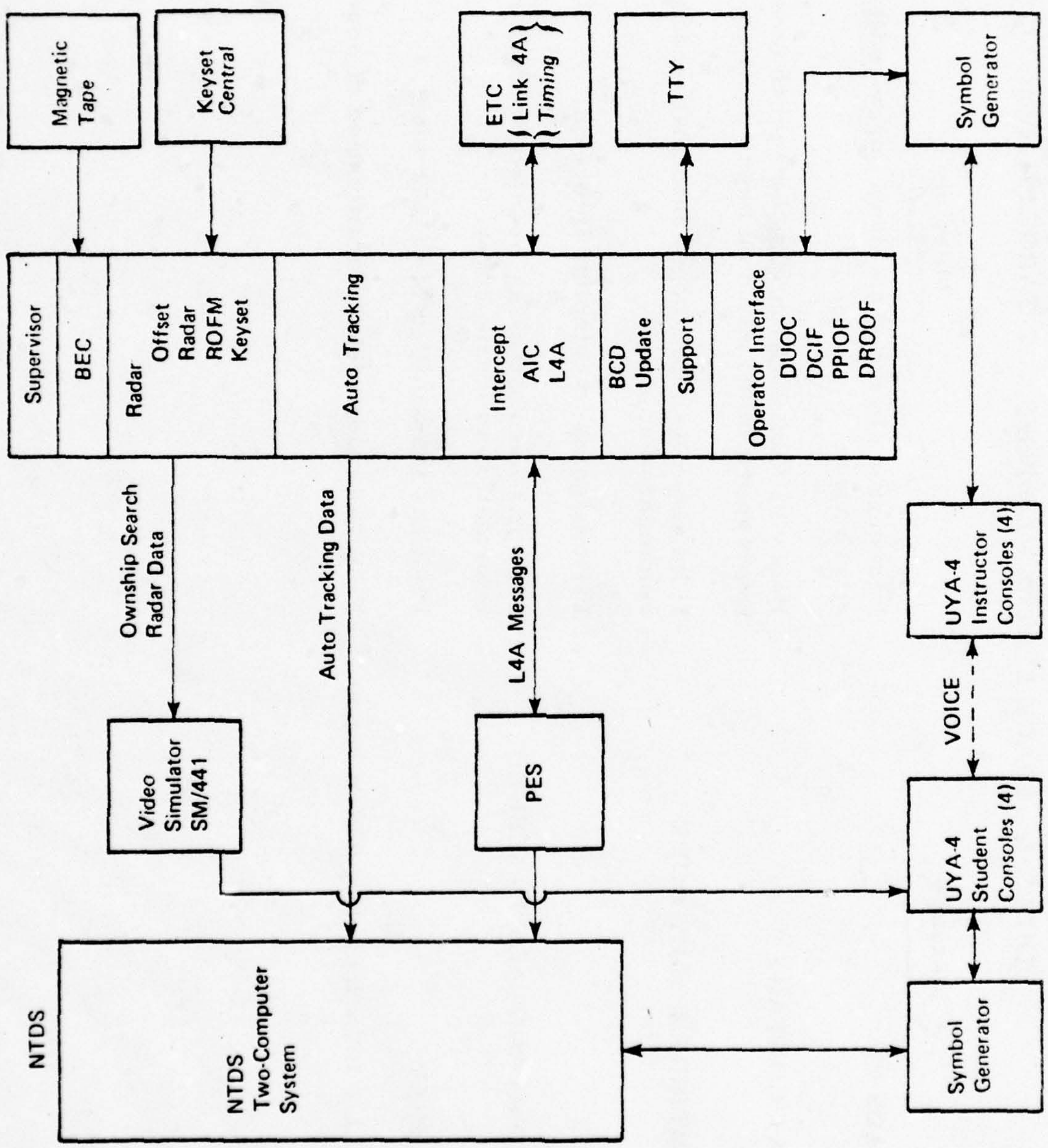


Figure 4. AIC Simulation Program (ASP) Configuration

d. "Angle Off and Distance." This rarely used message from the air controller gives the pilot the location of the bogey in degrees left or right of the interceptor's nose and the distance in radar miles. This message is given correctly only when the interceptor is not turning.

f. "Contact Confirmed (Your Bogey)." This message from the air controller is given to the pilot when they agree on which of the contacts on the pilot's radar is his bogey.

g. "Contact Negated (Not Your Bogey)." A message from the air controller to the pilot indicating that the contact the pilot reported is not his bogey.

h. "Skip It." A message from the air controller to the pilot to break off the intercept.

i. "Judy." A message from the pilot to the air controller indicating that the pilot is going to complete the intercept and launch an attack.

j. "Confirm Target." This message, which includes a bearing and range, is given to the pilot when the air controller thinks the pilot may be attacking the wrong bogey.

k. "ID Run." A command from the air controller to the pilot to identify the bogey visually.

l. "Negate ID Run."

m. "Bogey Jinking." A message from the air controller to the pilot indicating that the bogey is turning, accelerating, or changing altitude.

n. "Bogey Altitude." A message from the air controller giving the pilot the estimated altitude of the bogey.

o. "Bogey Speed." A message from the air controller giving the pilot the speed of the bogey.

p. "Report Bogey Altitude." A message from the air controller to the pilot requesting the altitude of the bogey. This request can be made only after the pilot has acquired the bogey on the interceptor's search radar.

Intercept Phases – For purposes of validation and interpretation of AIC messages, an intercept is broken down into the following six phases:

a. Phase 1: CAP Vectoring Phase. An interceptor is in phase 1 if it is not in an offensive situation (in orbit, returning to carrier, etc.) or if it is in an offensive situation but the bogey is outside of the Air Intercept (AI) radar search cone.

Entry to phase 1 is by exercise definition or by shift from another phase. Phase 1 is shifted to phase 2 when the bogey is in the search cone of the AI radar.

b. Phase 2: CAP Radar Search and Confirm Phase. Every time the bearing-and-range message is sent to the CAP in phase 2, a search is made by the computer in a "box" about the point defined by the position message. If a contact is found which is within both the box and the geometrical limits of the AI radar, it is reported to the pseudo pilot. The pseudo pilot relays it to the air controller as "Contact (bearing, range)." If no contacts are found, no reply is made.

When the pseudo pilot and the air controller agree on which contact is the bogey, the air controller gives a "Contact Confirmed (Your Bogey)" message. The CAP and bogey are linked for the phases to follow; phase 2 is terminated and phase 3 is entered.

c. Phase 3: CAP Radar Lock-on Phase. During this phase, the CAP is still receiving advisories from the air controller. Periodic checks are made to confirm that the bogey is maintained in the search cone of the CAP radar. If the bogey comes out of the search cone, a "Lost Contact" message is sent from the computer to the pseudo pilot and the phase shifts back to phase 1. If the bogey remains in the search cone, a check is made to see if the bogey is within the lock-on cone of the CAP radar; if it is not, no further action is taken.

If the bogey is within the lock-on cone, the phase shifts to phase 4 and the computer asks permission of the exercise controller to attack the bogey by displaying a LOCK ON? flag in the Digital Read Out (DRO).

d. Phase 4: "Judy" Phase. Commands will be accepted from the AIC as in phase 3. Periodic checks are made to confirm that the bogey is maintained in the lock-on cone. If the bogey comes out of the search cone, the LOCK ON? message is retracted, a "Lost Contact" message is sent, and phase shifts back to phase 1. If the bogey comes out of the lock-on cone but remains in the search cone, the LOCK ON? message is retracted and phase shifts back to phase 3.

If the bogey remains in the lock-on cone, nothing is done until the pseudo pilot punches JUDY into the computer. At receipt of a "Judy" message, the computer (simulating a pilot) takes control of the interceptor, attacks the bogey, and shifts to phase 5.

A "Judy" message cannot be punched into the computer unless the LOCK ON? message is displayed.

e. Phase 5: Attack Phase. During this phase, the computer flies the CAP and attempts to get into position for a missile launch. No pilot commands that would affect the attack on the confirmed bogey are accepted except a speed command.

AIC commands that indicate the CAP is attacking the wrong bogey are accepted and cause a phase shift back to phase 1. If the bogey comes out of the search cone or the lock-on cone due to bogey jinking, a "Lost Contact" message is sent to the AIC and the phase shifts to phase 1 or phase 3.

When in position, a missile is launched, "Fox" message is sent to the AIC, and the outcome of the intercept is determined. The type of missile launched depends on weapon stores and attack geometry.

Phase 5 is ended and the phase shifts to phase 1 if a "Skip It" command is received or if the bogey or the CAP is shot down.

f. Phase 6: Simulated "Lost Contact" Phase. During the attack phase of a random number of intercepts, a "Continue Bogey Dope" or "Lost Contract" message is sent to the AIC (even though the CAP maintains radar lock-on) and the phase is shifted to phase 6.

In this phase 6, all the commands that are legal in phase 5 are accepted and interpreted as in phase 5. In addition, turn recommendations and position messages are accepted. The turn commands are recorded but not executed. The position message is recorded and the actual bearing and range are computed and recorded.

Conditions that cause phase shifts in phase 5 will cause the same shifts in phase 6.

Course Limitations

In general, everyone concerned (especially the instructors and students) are very pleased with the new AIC course structured around the levels presented earlier. Nevertheless, some problem areas can be identified, and these are presented in the following paragraphs.

TACDEW – The TACDEW system is currently limited to only two channels to support AIC training. One channel supports levels 1 – 6 and 12 – 13; the other channel rotates through levels 7 – 11. This results in some confusion between the week-1 students (levels 1 – 6) and the week-3 students (levels 12 and 13) especially when the latter are working on overlapping video (mixing live and synthetic radar). The week-2 students (levels 7 – 11) must step through the levels in rigid fashion, causing both the slow and fast learners to become frustrated.

PC&E Support – The quality of pseudo-pilot support in relation to usable time during the training day (0715–1115, 1230 – 1515) has improved this year. Nevertheless the "pilots" are not well trained and even the good ones get bored and make mistakes. It is difficult for the controllers to be convinced they are operating in a realistic situation. A rhythm must be established between the controller and aircrew; this is difficult to learn using the pseudo pilots.

Scenario Preparation – Updating the training scenarios is a long and difficult process. The examples used in each level are limited and need to be expanded. Level six, for example, has only two examples. The trainee will memorize them in an hour and training essentially ceases.

Special Purpose Training – The present AIC course does not address some of the special training problems, such as:

a. Refresher training for fleet controllers.

b. Supervisor training.

c. Advanced synthetic training during the second three-weeks of the course.

d. Remedial training – there is no second shift and hence slower students cannot get extra training time.

L-TRAN – Training in the basic NTDS environment requires teaching manual and functional operation of the NTDS display consoles. Currently, considerable time is spent in classroom lectures explaining the uses of console modes. Often much time passes before the student receives any "hands on" practice in those modes. Such a teaching schedule can be time consuming, because part of the lecture material might have to be reviewed at the console. (The student probably will not remember the entire lecture.) A more efficient and effective situation would allow the student to try out a console action at the same time he is learning about the capability. The Lesson Translator (L-TRAN) Program is an off-line computer program that accepts lesson material written by NTDS instructors in their familiar Navy language while following a few simple format rules. L-TRAN is presently limited in its usefulness to the AIC course, but it could be very useful if updated. L-TRAN programs which are available cover too many modes and situations, and are equipment oriented rather than job oriented.

Fleet Feedback – No formal fleet feedback is being used at this time. It may be useful to establish a system such that reports on former students can be received at 3, 6, and 12 month intervals after completion of the AIC school.

SECTION III

AIC VOCABULARY

Introduction

The AIC vocabulary has been of particular interest in this study because of its impact on the system requirements for computer-based speech recognition. Whether viewed as simply an automated replacement for pseudo-pilots, or as the foundation of a fully automated-adaptive training system, speech recognition can improve system efficiency and training effectiveness. But not all verbalizations can be automatically understood by a computer; the feasibility of effectively applying this new technology to training tasks is, in large measure, based on the specific phraseology associated with that task. The development of such design guidelines for incorporating computer speech understanding in training systems is at the heart of NAVTRAEQUIPCEN's continuing research programs.

The following subsection discusses the AIC phraseology in specific detail. It should be pointed out at the outset that the recognition requirement imposed by the AIC vocabulary is significantly more complex than, for example, that imposed by the GCA vocabulary. Indeed, the complete AIC vocabulary cannot be recognized by any currently available speech recognition device, unless very unnatural speech stylizations are rigidly enforced. Nevertheless, the technology is moving ahead rapidly; and the section continues with a more complete discussion of the AIC vocabulary requirements vis-a-vis existing and future speech recognition systems. Moreover, the speech recognition problem can be eased by various procedural accommodations, the use of which will not deteriorate the training mission. These will also be discussed. Specific recommendations for further study are not made in this section, but are delayed until later sections of the report.

The Phraseology

The methodology employed to extract the AIC vocabulary was to list all terminal objectives that were associated with a verbal skill, and then to list sample phraseology associated with each objective. Table 6 shows the results of this process (refer also to the level twelve scenario in table 2). Table 6 does not show all possible combinations, of course; nor does it show that aircraft call signs, such as "Skyking two zero three" or "Viper," can precede any message; and that "over" can follow any message. Phrases are often combined too, for example "vector 220 for bogey, tracking 135, speed point six." The present effort could not support an exhaustive study of all AIC phraseology for all mission segments. However, sufficient information was gathered to gain insight into the speech recognition problems associated with the AIC task.

Speech Recognition; State-of-the-Art

It is not our intention here to present a complete review of the state-of-the-art in speech recognition. Indeed, NAVTRAEQUIPCEN is already undoubtedly aware of the current state of affairs. But for the less informed reader, the following paragraphs briefly highlight what can and cannot be done today, and what extensions to the existing capabilities can be expected in the near future.

Today's speech recognition units are phrase recognizers: they start listening when the student starts talking, and they stop listening when the student stops talking. Everything in between is then taken as a unit and is compared with a priori data representing the phrases to be recognized. When a reasonably close match is found, the student's voicing is identified. This scheme imposes certain restrictions on the speech recognition capability, viz:

a. The entire recognition vocabulary must be composed of well defined phrase elements.

b. The system can not recognize individual key words embedded within an utterance.

c. The speaker must pause between each identifiable element in a multiword phrase.

d. The number of unique identifiable elements is limited by both practical considerations (e.g., core space to hold the reference data) and the potential of intra-phrase confusions (many phrases which differ only slightly can be easily misrecognized).

e. The system assumes that all inputs are potentially recognizable, and hence has a tendancy to "guess" at nonsense inputs.

TABLE 6. AIC PHRASEOLOGY

Terminal Objective	Level	Sample Messages
Transmit magnetic bearing and range to a target from ownship.	1	"Bogey – one six zero, fifty" "Bogey southwest, seven" "Bogey your 3 o'clock, seven"
Transmit target track and ground speed.	2	"Bogey-tracking two zero zero, speed point six" "Bogey tracking northwest" "Bogey jinking left"
Transmit target track jink direction.	3	"Bogey jinking left"
Transmit target ground speed jink.	3	"Bogey jinking, speed increasing" "Bogey speed decreasing"
Transmit target altitude.	3	"Bogey altitude thirty thousand" "Bogey climbing" "Bogey descending"
Transmit in-the-dark calls.	4	"You're in-the-dark" "Bogey in-the-dark"
Relay orders from TAO/SWC to CAP.	5	"Vector two two zero for bogey" "Cleared to fire" "Anchor port/starboard" "Tighten turn"
Respond to "Contact," "Judy."	5	"That is your bogey"
Transmit target splits.	6	"Bogey splitting"
Transmit bogey composition and formation.	7	"Bogey in a combat spread, 2 miles" "Bogeys in a right echelon 3 miles" "Bogeys in trail, 1 mile"

TABLE 6. AIC PHRASEOLOGY (Cont).

Terminal Objective	Level	Sample Messages
Transmit time in fight.	8	"One minute" (given every minute)
Transmit aircraft out of fight.	8	"Aircraft out of fight"
Identify one friendly aircraft from another using IFF.	9	"Squawk ident" "Squawk five seven four one"
Recommend heading to maintain a specific track.	9	"Port three two zero to maintain track" "Tighten turn"
Transmit information on weather points.	9	"Point B 270-25"
Transmit stranger information.	9	"Stranger 210/7, tracking 320, speed point 6 altitude 30 thousand"
Transmit information to assist in emergencies and search and rescue operations.	9	Various – not well defined
Provide assistance to aircrews experiencing radar and/or radio jamming.	10	No new vocabulary.
Transmit MIG/SAM warnings.	11	No new vocabulary.
Recommend return to force headings.	11	"Vector three two zero for the area" "Breakaway two seven zero"
Establish communication with aircraft.	12	"Roger, radar contact" "Mark your TACAN" "Say lost communication intentions"
Transmit headings for training set-ups.	12	"Anchor port"

TABLE 6. AIC PHRASEOLOGY (Cont).

Terminal Objective	Level	Sample Messages
Transmit headings for area control.	12	"Vector three two zero for the area" "Breakaway two seven zero"
Relay state and status reports.	13	"What state?"

These and other "restrictions" have provided the impetus for various research programs to extend the capability of speech recognition systems. Many groups are attempting to develop a nearly unrestricted continuous speech recognition capability, but the probability that these efforts will realize truly useful (applicable) systems in the near future (next five years) is very low. NAVTRAEQUIPCEN, on the other hand, has taken the position that a more limited continuous speech recognition (LCSR) capability is both technically feasible and extremely useful, and can be developed in the very near future (within two years). They are currently supporting such an effort, with the hopes of realizing a real-time capability for recognizing continuous strings of digits and the word "point" before 1979.

Speech Recognition and the AIC Vocabulary

Surveying the AIC phraseology documented in a previous subsection, together with an understanding of the speech recognition technology, has led to the following conclusions:

a. Only isolated portions of the AIC training tasks can be supported by the currently available phrase recognition systems; and even here, some form of speech stylization (pausing) would be required (e. g., establishing communications with aircraft).

b. The complete AIC phraseology, as currently defined, without modification (including stylization), cannot be automatically recognized even with a basic LCSR capability (e. g., "Stranger 210/7, tracking 320, speed point 6, altitude 30 thousand").

c. A significantly large portion of the AIC vocabulary can be recognized by using a mixed strategy of isolated phrase recognition, an expanded LCSR capability, and minimal stylization constraints (e. g., "Port 320 . . . to maintain track").

d. A "word spotting" capability could usefully augment understanding the intent of an AIC message, when the precise recognition of the entire message is not feasible (e.g., when transmitting information to assist in emergencies).

It is the case, in short, that the capabilities and limitations of speech recognition, even assuming the successful development of an LCSR system, must impact the functional specification of an AIC automated training capability. This conclusion applies to both the "quick-fix" as well as ACTS. The impact of this conclusion will become apparent when these systems are discussed in sections IV and VI.

Cther Accommodations

It is interesting to note that in the AIC course currently conducted at FCTCP, pseudo-pilots (i.e., human recognition systems!), are utilized only during levels twelve and thirteen. Of course the instructors often monitor the student's transmissions for scoring and evaluation purposes. But nevertheless, one is led to suspect that significant procedural accommodations can be made to ease the burden on speech recognition components of the system. This conjecture is confirmed in conversation with the AIC instructional cadre at FCTCP. Call signs can be shortened from "Skyking 203" to "Snake." Altitudes and speeds can be kept fixed. Stranger reports can be abbreviated, etc. Of course any restrictions of this sort must be considered from the perspective of the training requirements of the system at hand.

Another accommodation which could significantly increase the scope of the applicable (feasible) technology is establishing a greater degree of conformity to the AIC phraseology. Although, to some extent, this is related to the definition of required stylizations; one could "legislate" that, for example, call sign will or will not be used, that "over" will not be used, that bearings such as "northwest" or "your 9 o'clock" will not be used, etc.

SECTION IV

THE FCTCP "QUICK-FIX"

The Problem and the Solution

As noted in the introduction to this report, FCTCP is suffering from the familiar problems of limited trainer availability and a shortage (and the expense) of qualified pseudo-pilots. A simple application of speech recognition was investigated as a means of relieving these problems. The conceived system has been termed the "quick-fix." The design and implementation of the quick-fix has been briefly studied during this effort from three perspectives: functional requirements, hardware considerations, and software considerations. The guiding assumption made throughout this review has been to determine what can quickly and easily be done to provide remedial training support.

The quick-fix scheme will only replace the pseudo pilot and not concern itself with performance monitoring or evaluation. No "technology breakthroughs" are required prior to implementation of the system.

Functional Requirements

Pseudo pilots are currently used to support levels 12 and 13 training, and hence a study of the quick-fix begins there. During these levels, the student is introduced to new material such as area control as well as given practice on procedures previously covered in earlier levels. The functional requirements of any useful new capability must at least address the bulk of this new material, and, if possible, support the other aspects of the run.

<u>Minimum Requirements</u> – The minimum useful capability for the quick-fix is to support the training of "set-ups:" that is, transmitting headings to two aircraft for practice intercepts and area control. This consists of (see figure 5):

a. Establishing position of two aircraft.

b. Separating the aircraft.

c. Turning the aircraft to intercept each other.

d. Re-separate and begin again.

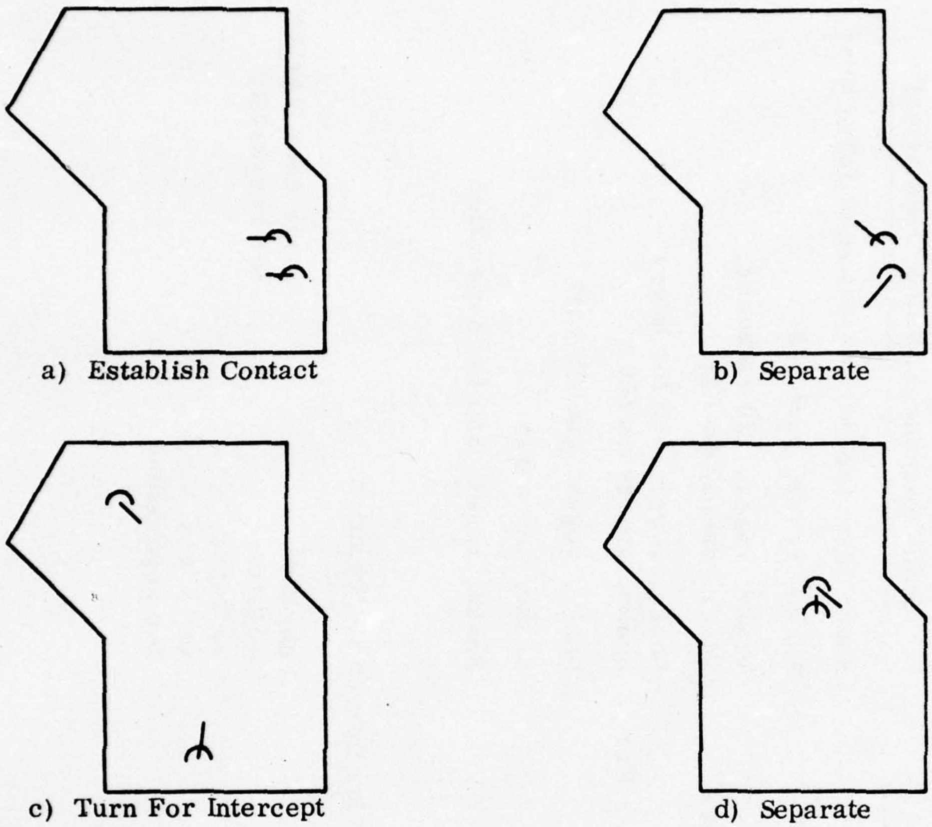


Figure 5. Minimum Quick Fix Requirements.

The vocabulary (for both recognition and generation) implied by these requirements are shown in table 7. The table also shows the stylization that would be required in order to implement the automatic speech recognition using the available isolated word systems.

Notice that a built-in confirmation of the recognized phrase is provided by the pilot's response. If a phrase is misrecognized, the student can transmit a "negative." If a phrase is not recognized, the pilot can transmit "say again." Note too, that the rejection criteria must be fairly stringent. That is, the student will be issuing various advisories to the pilot which require no action on the part of the system (e.g., tracking information) and hence must be disregarded by the recognition system.

TABLE 7. VOICE REQUIREMENTS FOR MINIMAL QUICK-FIX SUPPORT.

Student Transmissions (Speech Recognition)	Pilot Responses (Voice Generation)
Snake ... Mark your TACAN	Snake is on the two seven five at fifty, over.
Snake ... Port ... two ... four ... zero ... For separation (or for breakaway)	Snake, roger, port 240
Viper ... Vector ... one ... two ... zero ... As bogey	Viper, roger, 120 as bogey Viper, steady on 120
Snake ... Vector ... three ... zero ... zero ... For bogey	Snake, roger, 300 for bogey Snake, steady on 300
Viper ... Anchor ... Port	Snake, roger, anchor port
Viper ... Negative	Snake, say again
Snake ... Vector ... three ... six ... zero ... For separation	Snake, roger, 360 for separation

Vocabulary List for Speech Recognition

one	six	snake	anchor	mark your TACAN
two	seven	viper	negative	for breakaway
three	eight	port	as bogey	
four	nine	starboard	for bogey	
five	zero	vector	for separation	

Expanded Support – A number of other features have been identified that would significantly enhance the training usefulness of the quick-fix (while still maintaining the notion of providing only remedial support). These embellishments, for the most part, involve the procedures of establishing communication with the pilot and assisting during the intercept phase. The associated vocabulary requirements were shown in table 2, and the related vocabulary list is presented in table 8. The voice generation capability must be more sophisticated with the expanded capability. But this involves low technical risk and has impact only on the time and cost of developing the system.

The vocabulary listed in table 8 was implemented in a test configuration using a Threshold Technology VIP-100 speech recognition system. Recognition accuracy for a speaker experienced in using this system was good, though the necessary pausing required some familiarization. The test was performed in a laboratory environment with little ambient noise using a high-quality, low noise, microphone.

Level 13 – The requirements associated with providing remedial support for level 13 (tanker join-ups) were not addressed during this study. A cursory view, however, indicates that no significant risk is involved. This level might be included in the formal functional analysis of the quick-fix.

TABLE 8. VOCABULARY LIST FOR EXPANDED QUICK-FIX SUPPORT.

one	snake	mark your TACAN
two	viper	radar contact
three	port	say lost communications intentions
four	starboard	for the area
five	vector	roger . . . that is your bogey
six	anchor	breakaway
seven	negative	tighten turn
eight	as bogey	ease turn
nine	for bogey	continue
zero	for separation	what state?
	for breakaway	

Design Considerations

As described in section II, the synthetic portion of the AIC course is currently supported by an NTDS configuration with simulated video provided by TACDEW, MSP, or ASP. In an effort to keep system development costs to a minimum, the quick-fix scheme should make maximum use of these programs. In this and the following subsections, the modifications and additions to the existing systems which are required to support the quick-fix are reviewed. The intent here is not to perform even a preliminary system design, but rather to scope the problem sufficiently to provide both technical and budgetary visibility.

A variety of alternative configurations were reviewed. A principal design consideration throughout has been to impact the existing programs in a minimal way. Another consideration championed by FCTCP personnel, was to provide the quick-fix capability in addition to the usual TACDEW training. The configuration depicted in figure 6 meets these goals. Essentially, the existing 15G17 (the CRT Target Control Subsystem) is replaced by an entirely new subsystem, nicknamed EGOR. By utilizing the one computer MSP for AIC training, the multicomputer TACDEW plus the 15G17 can be simultaneously used to support other FCTCP training (e.g., CCA, etc.). Indeed, TACDEW could still support AIC training not associated with the quick fix (level 12). Note too that if EGOR is properly designed, no modifications will be required to the USQ-20 software (NTDS and the MSP). The data exchange between the MSP and EGOR becomes a subset of the existing exchange between the 15G17 and the MSP.

Hardware Requirements

The hardware requirements for EGOR are briefly reviewed in the following paragraphs. Figure 7 shows a possible interrelationship of the various components. Table 9 itemizes the specific equipment required.

Computer Communications Interface Circuit Board (CCICB) – The CCICB is a 15" by 15" printed circuit board manufactured by Logicon, Inc. residing in the Programmable Buffered Multiplexer (PBM) which provides the interface between the USQ-20 in the MSP and the PBM (Nova) in EGOR. Because of the differences of such characteristics as word size, processor speed, and input/output (I/O) parameters between the USQ-20 and the PBM, there is no direct means of communication possible on the I/O channels of the two computers. The CCICB functions to make the two systems compatible and communications efficient.

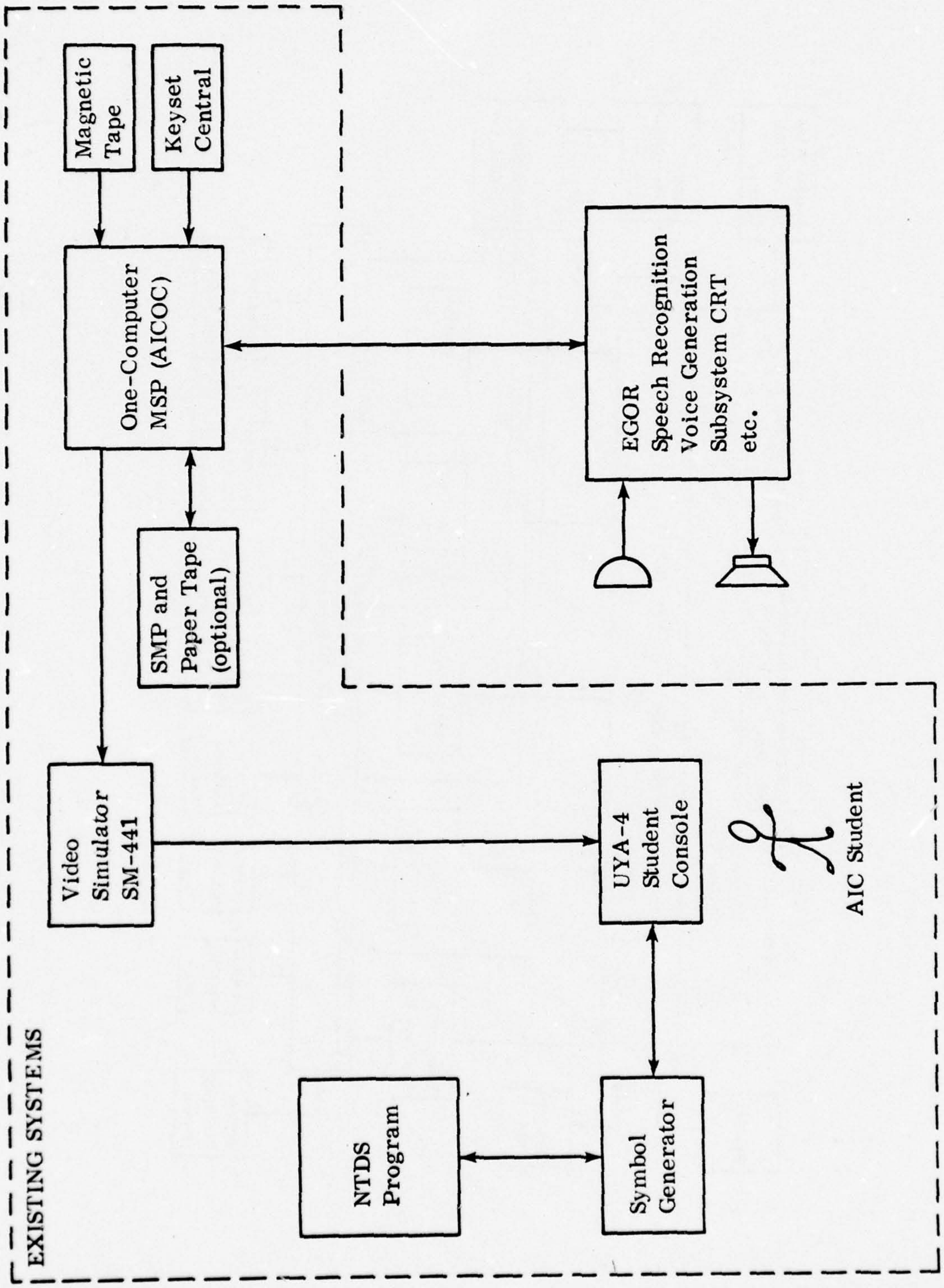


Figure 6. FCTCP Quick-Fix Configuration.

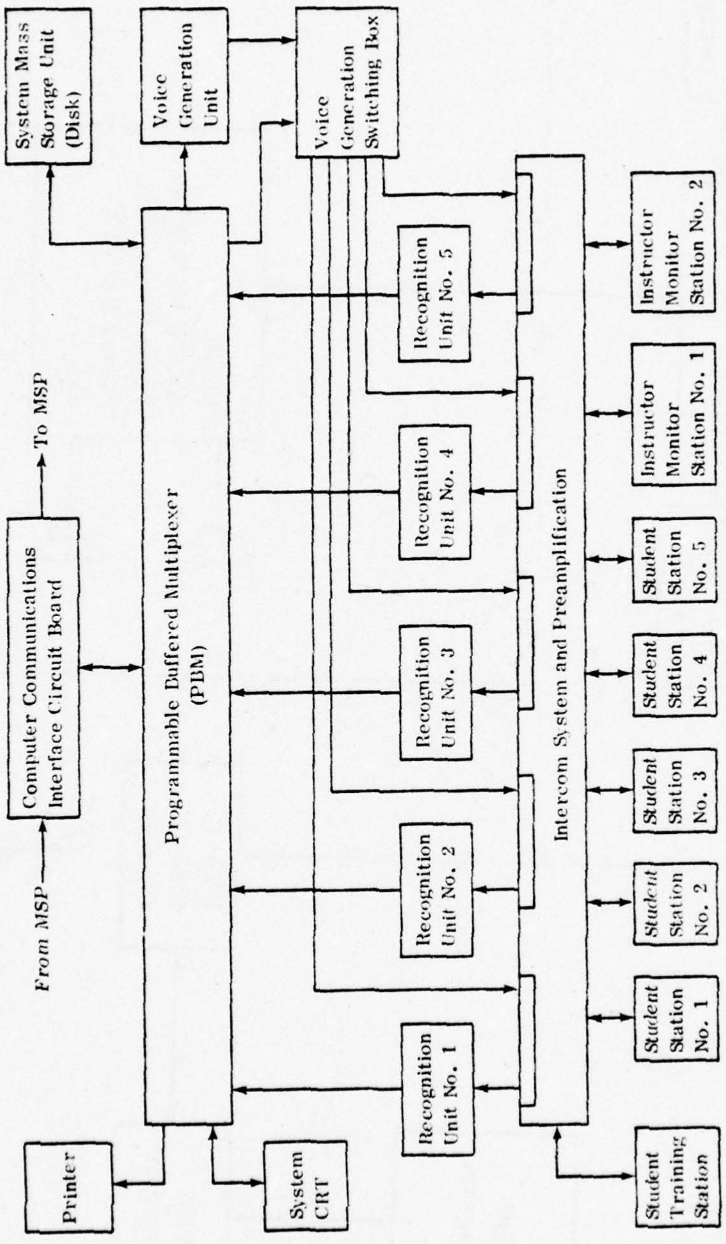


Figure 7. EGOR Hardware Configuration.

TABLE 9. EGOR HARDWARE COMPONENTS.

Quantity	Equipment	Manufacturer	Estimated List Cost
1	CCICB	Logicon, Inc.	$ 3,300
1	PBM	Data General Corp.	17,500
6	Speech Recognition Units	Threshold Technology, Inc.	56,000
1	Voice Generation Unit	Vocal Interface Division, Federal Screw Works	5,000
1	Mass Storage	Data General Corp.	14,000
1	System CRT	TEC	2,000
1	Printer	Tally Corp.	3,600
1	Intercom System and Switching Unit		4,600
5	Student Stations		2,400
2	Instructor Stations		500
1	Equipment Cabinet, miscellaneous equipment	Various	3,000
	Total		$112,000

– Estimated Engineering Labor – 8 labor weeks

Programmable Buffered Multiplexer (PBM) – The PBM is a commercially produced minicomputer manufactured by Data General Corporation. The PBM is the nerve center of EGOR. In general it controls the primary hardware associated with the subsystem and processes the messages sent between the MSP and EGOR. The PBM also acts as the link between the students and instructors and the MSP. To accomplish this, the PBM will:

a. Accept inputs from the speech recognition units and the CRT, convert these inputs into the proper format and relay them to the MSP.

b. Store and retrieve voice reference data from the mass storage unit and relay these data on to the recognition units.

c. Receive data from the MSP, convert it to the appropriate format, and output to the voice generation unit and/or CRT display.

d. Support student voice data collection in an off-line mode.

Speech Recognition Units – The speech recognition units are commercially produced by Threshold Technology, Inc. (designated the Threshold 500). Each Threshold 500 receives an analog speech signal from the student; converts it into a digital form; and detects the presence or absence of thirty-two speech features. These data are then used to determine the word or phrase spoken by the student. The Threshold system cannot be multiplexed; and hence, there must be as many recognition units as there are input stations. FCTCP has determined the need for five units.

Note that the Threshold 500 is available both with and without a microprocessor to perform the actual recognition algorithm. With the microprocessor, the output of the recognition unit is an American Standard Code for Information Interchange (ASCII) character representing the recognized word. Without the microprocessor, the output is 32 parallel bits of data every 2 milliseconds, representing the 32 speech features. In the latter case, the recognition algorithm must be performed in the PBM. Because of PBM memory and PBM processor considerations, especially interrupt processing rates, it appears that the Threshold 500 with the microprocessor should be utilized in this application.

However, to support the off-line Voice Data Collection program (discussed later in this section) one of the Speech Recognition Units should be capable of providing the raw feature data, as well as the microprocessor/ASCII code output. It may be desirable to provide a separate Threshold 500 for this data collection purpose, in which case the microprocessor on this unit would not be necessary.

Voice Generation Unit – The voice generation unit is a Votrax VS-6 manufactured by the Voice Interface Division of Federal Screw Works. The Votrax electronically synthesizes the basic building blocks of spoken English, and hence can speak any word by joining together these sounds under software control. A single Votrax may be sufficient in this application, provided the output can be multiplexed to the appropriate student station, but this must be confirmed during system design. The functional purpose of the voice generation unit is to simulate the voice transmissions normally issued by a pilot or pseudo-pilot.

Voice Generation Switching Box – This unit contains special purpose switching circuitry which accepts a command word from the PBM, together with the output of the voice generation unit, to direct the synthesized speech to the appropriate channel of the intercommunication and preamplification system (ICS). This unit may be built into the ICS.

System Mass Storage Unit – Off-line storage will be needed to store the voice reference data for the students. In addition, storage is required for the PBM programs, software development aids, and system diagnostics. A disk system is recommended; such as the 10 megabyte cartridge disk system marketed by Data General Corporation. Detailed system design may demonstrate that a floppy disk system is sufficient, however, which is approximately half the cost of the larger disk.

System CRT – The primary system terminal is a CRT similar to those currently employed in the 15G17 (i.e., an Infoton or TEC data terminal). The CRT will be used to initialize EGOR, as well as input a variety of system and AIC commands (as in the 15G17) which are not handled by the speech recognition units.

Printer – The 15G17 utilizes an Inktronic Printer, manufactured by the Teletype Corporation, to display general information messages or those required for MSP operation. A similar function will be performed by EGOR's printer.

Intercom System and Preamplification (ICS) – The existing Radio Phone Units at FCTCP were tested for noise level and found to be unsatisfactory (too noisy: approximately 26 db signal-to-noise ratio) for utilization by the speech recognition units. Indeed, the instructors at FCTCP indicated that the cross talk between stations is sometimes so bad that it is difficult to determine with which "pilot" the AIC is communicating!

The need for a totally separable ICS appears clear. At least eight ports should be provided: 5 student locations, 2 instructor monitoring stations, and one remote station near the system CRT for student voice "training" (collecting the reference data for speech recognition). On the system side, the ICS must accept the five inputs from the Voice Generation Switching Box and also interface to the five Speech Recognition Units. Appropriate preamplification and equalization of these inputs will be required. A switching arrangement must be designed into the ICS so that any recognition unit can be associated with any student station to maximize system reliability in the event of hardware (UYA-4 console or EGOR component) malfunction.

Student and Instructor Stations — Adjacent to each UYA-4 console will be a headset station containing both input and output level controls, an input level indicator, and a headset jack. The input level controls and indicator are needed to ensure that the student speaks at proper volume for speech recognition purposes. Special headsets should also be provided to benefit from the noise cancelling microphones which optimize the recognition accuracy. At other key locations, instructor monitoring stations must be provided consisting of a switch to enable monitoring of any student station, a speaker, a volume control, and headphone jack. The instructor must be able to communicate with the student through the monitoring station. Finally, an additional student input station must be located next to the system CRT to facilitate voice reference data collection.

Data Flow Across the Interface

It is especially important to preserve the existing data format across the USQ-20/EGOR interface. Recall that this transfer will be affected by the CCICB. The following paragraphs describe the data flow more specifically. Refer to figure 8.

CCICB/USQ-20 Inputs to the PBM — CCICB inputs consist primarily of the following:

a. Track parameter of targets being controlled.

b. Error diagnostics of errors found by the MSP.

c. Track status messages generated by the MSP.

d. System status messages (e.g., "Drop Track" and "Freeze Exercise").

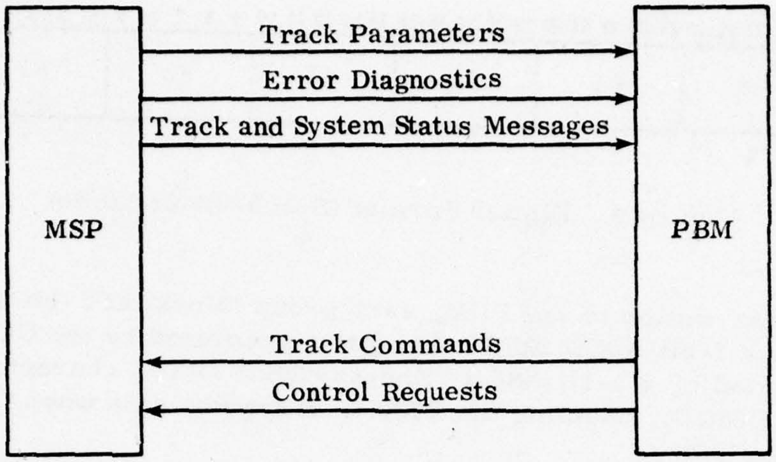


Figure 8. Data Flow Between the MSP and PBM.

e. System messages for the printer.

f. Various control signals to facilitate communication between the USQ-20 and PBM. Note that the CCICB is just a sophisticated relay device and as such does not originate or generate data. It only relays data received from the USQ-20 and processes it sufficiently to make it acceptable to the PBM.

Input from the CCICB to the PBM will be in the synchronous digital transmission mode (i.e., continuous data transmission versus asynchronous or "as required" mode). Data will be input on one line in serial format.

Information coming to the CCICB from the USQ-20 will be contained in data blocks similar in format to MSP intermodule messages. They will be transferred from the USQ-20 to the CCICB one 30-bit word at a time over 30 parallel data lines. After the CCICB receives a 30-bit word, it will break it into six 5-bit units (figure 9); add up to three dummy bits to each unit; and then transmit each 8-bit unit to the PBM. This is necessary to ensure ASCII character compatibility.

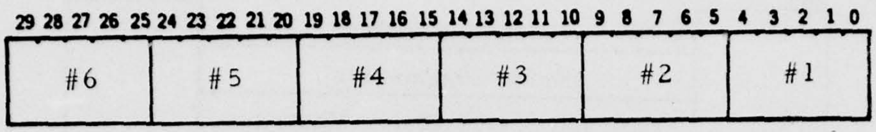


Figure 9. Digital Format (Synchronous Mode).

When transmitted to the PBM, each group (block) of 8-bit units will be preceded by a 7-bit ASCII SYNC character (generated by the CCICB). This will be followed by a 7-bit ASCII "End-Of-Text" (ETX) character (generated by the CCICB), enabling the PBM to recognize data when they are received (figure 10).

PBM Outputs to the CCICB/USQ-20 – Outputs from the PBM to the CCICB consist primarily of control requests and commands for further transfer to the MSP. These control requests and commands are in blocks of data in format similar to MSP intermodule messages.

Output to the CCICB will be in the synchronous digital transmission mode and will include special signals to control CCICB functions. Data will be output on a single line in serial format.

Data transfer from the PBM to the MSP is processed somewhat the reverse of that described previously. Data are transferred as 8-bit units from the PBM to the CCICB. A group (block) of 8-bit units is preceded by two SYNC codes and followed by an ETX code. The CCICB retrieves the first five bits of each 8-bit unit as data, and builds a 30-bit, USQ-20 word from them. The CCICB then transfers the word to the USQ-20 on 30-parallel data lines.

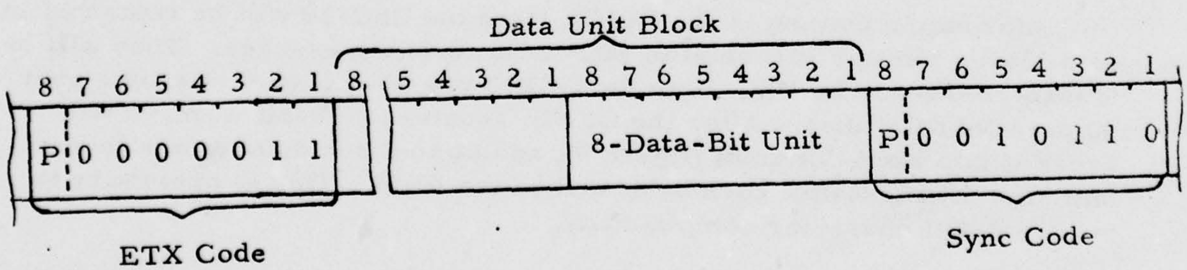


Figure 10. CCICB/PBM Synchronous Data Transmission.

Software Requirements

This section describes, in very general terms, the software requirements of the PBM. An off-line program will be required to support the generation of voice reference data. This will be discussed first followed by the various functions that the PBM program must perform during the actual training exercise. Table 10 suggests estimated labor-hours required for software development.

Voice Data Collection – Recall that the speech recognition algorithms require an a priori data base against which to compare unknown (input) speech data and make a selection of the word or phrase spoken. These reference data are formed in an off-line process with the help of the Voice Data Collection program. Briefly, the procedure is to prompt the student to say a word or phrase a number of times (5 to 10), saving the voice data generated by each vocalization. Finally, the data for each vocabulary item are merged or averaged together to form the reference data. The student then enters a validation/practice phase wherein he checks the accuracy of the extracted data. The process is repeated until good recognition is achieved. One or two hours is generally required to bring accuracy levels up to the high 90% region.

TABLE 10. LABOR ESTIMATES FOR FCTCP QUICK-FIX SOFTWARE DEVELOPMENT.

Software Development	Labor (weeks)
Voice Data Collection	
Functional Definition	2
Design and Implementation	5
Software Documentation	2
User Handbook	3
PBM On-Line Software	
Functional Definition	6
Design	6
Implementation	12
Software Documentation	4
Operator Handbook	4
Subtotal	44
Software Management	6
Total	50

NAVTRAEQUIPCEN has conducted a considerable amount of research in this area. They have determined that the best results (highest accuracy) is achieved by presenting the words and phrases in the context in which they will be used during recognition. Instead of saying a word, such as "Viper", ten times in succession, the word should be used in a typical phrase ten times, interspersed with other phrases. This procedure has the added benefit of teaching the student the proper vocabulary and required stylizations, at the same time as the computer is learning the student's voice characteristics. This approach, though slightly more costly than simple serial repetitions, is strongly recommended for the FCTCP quick-fix.

The FCTCP Voice Data Collection program can be modeled after NAVTRAEQUIPCEN software, which is fully described in NAVTRAEQUIPCEN report 74-C-0048-1: The Use of Computer Speech Understanding in Training: A Demonstration Training System for the Ground Controlled Approach Controller.

On-Line, Real-Time Software – The remainder of this subsection discusses, in very general terms, the routines and their interrelationships that will support the actual on-line system. Further study of the existing (15G17) PBM software will be needed to determine its usefulness as a design guide.

An executive (EXEC) routine will control processing in the PBM. The EXEC will have basic control of the processor and will schedule all other processing as demanded. Processing will generally be triggered by inputs from external sources (i.e., the CRT, USQ 20, or Speech Recognition Units). Upon receipt of an input, the EXEC will make a basic interpretation of the request and call the proper processing routine:

a. CRT character input interpreter.

b. Recognition unit input interpreter.

c. CRT input decoding.

d. Recognition unit input decoding.

e. CCICB input decoding.

Routines such as the following will be called as a result of the input decoding:

a. CRT output (including command line, directory, parameters, and error responses).

b. Voice generation unit output.

c. USQ-20 intermodule message formatting and output.

d. Printer output.

e. Basic conversion routines.

To allow the programs to correlate the tracks to the proper device, a series of status and bookkeeping routines is required.

Input Interpreters – The EXEC will call these routines whenever the CRT or voice recognition routines signal receipt of a character. The routine will check for certain special characters requiring immediate action (e.g., "negative" or <backspace>). If the input character is not one of the special characters, it is checked for legality according to the command directories. If legal, it is stored for future decoding. If illegal, an error response routine is called.

CRT and Voice Recognition Input Decoders – These routines (called upon receiving legal command characters) determine the output required to the command line of the CRT or the voice generation unit and issue the request for output. They then determine the next set of legal characters for the input interpreter routine to use. If the command is complete, the routine will retrieve all characters associated with the command and form it into data acceptable to the MSP. The command will be associated with the proper track. Conversion routines will be called as needed to convert input data into MSP units.

CCICB Input Decoding – This routine will be called whenever data are received from the MSP via the CCICB. It will inspect each data grouping and call the proper routine to decode the data. The following types of data are received from the MSP:

a. Track parameter changes.

b. Track messages.

c. Error responses.

d. System status changes.

e. System messages for the printer.

CRT Output — Routines will output command directories, exercise parameters and certain track parameters on the CRT. When an illegal entry is made at the CRT, an error response routine is called. It will display the illegal character, followed by two blinking question marks. The CRT will be initialized to start a new command.

Voice Generation Output — When a message is received from the MSP for a track, this routine is called. It will determine the location of the track and output the message via the voice generation unit.

Printout Output — This routine is called when a message is received from the MSP for output on the printer. It will handle conversion to the proper format and output to the printer.

Conversion Routines — In the process of formatting data for the MSP and decoding data from the MSP, the following conversion routines will be required:

a. Degrees to BAMS x 2^{15}.

b. Feet to radar miles x 2^{10}.

c. Knots to radar miles/sec x 2^{14}.

d. Mach X 100 to mach x 2^{15}.

e. Decimal to octal.

f. Radar miles to radar miles x 2^{10}.

g. Hours to seconds x 2^{10}.

h. Minutes to seconds x 2^{10}.

Input/Output Handlers — This set of routines and their associated subroutines handle all actual input/output between the PBM and the peripheral devices.

System Integration

EGOR will require a fair amount of wiring/installation of FCTCP. NAVELEX should be tasked to perform this function. The ICS and student/instructor stations will be located in NTDS-6: the AIC Synthetic Mockup.

The CRT should, ideally, also be located there. The other equipment elements can be housed in a twin bay 19" rack cabinet occupying approximately 12 sq. ft. of floor space. The location of this equipment is not especially critical except that the distance from NTDS-6 should be minimized to facilitate start up of the computer and to prevent noise from "creeping into" the audio signals. The MSP will presumably run in C&S-2, one floor directly below the AIC mockup, and hence a cable must run from there to the EGOR equipment cabinet.

No functional changes are expected to be needed to the existing MSP, but nevertheless very minor modifications may be required. The PBM will probably not be loaded from the MACON built MSP Tape, for example. FCDSSA, Code 4, should be tasked to provide support for MSP changes.

Overall system test and integration should be the responsibility of the EGOR system developers. Eight to ten labor weeks should be allocated for the task.

SECTION V

THE AIC/ASAC TRAINER

Introduction

A large scale training device has been proposed by FCTCP and NAVTRAEQUIPCEN to support air intercept controller training and antisubmarine air controller (ASAC) training during the 1980's. This present effort has very briefly studied the requirements for this trainer in order to 1) establish the framework in which the AIC research program (ACTS) can be most effective; and 2) determine if any other preliminary activity should concurrently be performed as precursor to the development of the actual trainer.

Purpose of the Trainer

The AIC/ASAC trainer will provide a high fidelity shipboard simulation environment consisting of: operational AIC and ASAC equipment; simulated aircraft; surface and subsurface ships; simulated environmental effects (e.g., weather); etc.

In addition to synthetic or simulated environments, the AIC/ASAC trainer will still support training using live aircraft. A primary concern of the instructional cadre regarding live training, is that there are long periods of "dead" time between the airborne communities training missions. During these periods the AIC student remains idle at his console. Though at FCTCP there are currently an average of 25 training flights per day allowing the AIC student live practice, the distribution of the flights is awkward for efficient AIC training. Moreover, though the intercept missions flown range from simple to complex for the pilots, AIC instructors indicated the range of training provided for their own students is limited. They also indicate that these limitations on training are profoundly more severe at the AIC training facility at Dam Neck, where opportunities for live practice are limited to 2 or 3 intercept missions per week. Hopefully, the projected AIC/ASAC joint trainer will alleviate some of these problems. For example, it would be convenient to intersperse live and synthetic training during the period presently devoted exclusively to live training. AIC instructors have expressed a preference for a system capable of switching over quickly to a synthetically generated training environment for the periods of time between live intercept missions. Short duration training exercises tailored to a specific level of training would be required.

It is expected that trainees using the device will primarily develop proficiency in the procedures associated with controlling:

a. ASW helicopters (e.g., LAMPS) and airplanes (e.g., P-3C) enroute to, localizing, tracking and attacking submarines.

b. Fighter aircraft (e.g., F-14) during air interceptions.

In addition, trainees will develop skills in controlling aircraft in various other missions such as search and rescue, mine laying, and so forth. From a training standpoint ASAC job responsibilities are similar to those of the AIC. Though not explored in detail, the following factors have been noted:

a. Amount of training required for the ASAC student is estimated to be the same or greater than the AIC.

b. Student load factor will probably be about the same as for AIC.

c. Present utilization of training devices is not as extensive as is the case with AIC, though it should be as extensive or more so.

FCTCP has identified the need for a stand-alone trainer (i.e., not tied to the existing TACDEW complex) which can run 19 hours a day and teach approximately a dozen students, each student at differing or the same "levels." This requirement, in turn, practically demands the utilization of speech recognition and generation to avoid the costs associated with providing pseudo-pilots, and some form of automated and adaptive training to provide relief to the instructors. The proposed trainer will ideally incorporate all of these features.

Current Status of the Trainer

Implementation of the AIC/ASAC trainer has been scheduled to begin in July, 1980. The Analysis and Design branch of the Systems Engineering Division at NAVTRAEQUIPCEN, Code N2211, is in the process of developing a functional statement for the trainer. NAVTRAEQUIPCEN's research program discussed in the following section, will yield further design specifications; particularly in the areas of the automated speech technologies, objective performance measurement, syllabus control, and student-instructor feedback.

Lessons Learned

During the development of the GCA controller training system, some interesting lessons were learned which are certainly applicable to the AIC/ASAC development cycle. Particularly interesting are some reflections on the design of training systems; and these are discussed below.

As in any R&D program designed to improve an existing system, whether it be hardware, software, or methodology, a basic requirement is to take a long, hard look at the existing training methods in order to realistically design a superseding, or complementary, system optimized by advanced technology and/or knowledge. Typically, systems engineering requires constraint analysis, and the development of techniques and methods to minimize the effects of such constraints, in degrading the program objectives. Repeated looks at existing training methods reveal in some cases that they have indeed been compromised by hardware systems limitations, instructor availability, instructor/student ratios, cost/benefit ratios, and similar problems which were real and valid at the time of development. In this fluxional world, all of the constraining factors have varied to a lesser or greater extent. The analysis of these factors, while certainly useful from both a historical point of view and for providing a starting point for a new design, should revalidate all of the assumptions prior to the establishment of a new design baseline. Prior system inadequacies must be reviewed in the light of today's knowledge.

Ideally, training system design begins with a fundamental description of the problem and definition of the training objectives to be addressed. These objectives include the criteria to be used as a measure of their attainment. While training objectives may be the same in automated and nonautomated systems, the means taken to realize them may be very different. For the former determinations, interaction between instructors and training analysts is an essential element. It is the instructor who knows what can be expected of the student at each stage in the training process, and who has an enormous reservoir of empirical knowledge about what must be taught. The training analyst quantifies these objectives, where possible, and sifts idiosyncratic knowledge and skills from uniformly useful or necessary ones. He also matches the objectives with the instructional features of the entire system and provides guidelines as to the optimum means for realizing the objectives. This process requires a participative team interaction among hardware and software specialists and instructional cadre. It is through this interaction among specialists that a good training system design and implementation comes about. Experience has shown that, when one of these contributors is left out, the results are evident in the training system. For example, a system designed and built without solicitation of the ideas and suggestions of the ultimate users suffers an understandable lack of acceptance, even though training objectives are met as measured by objective evaluation of student performance. There is sometimes an understandable reluctance by users to vary from the old "tried and true" methods by which they either consciously or unconsciously compensated for known system deficiencies. This is indeed one of the main advantages of a potentially open-ended, reprogrammable design of the advanced automated system trainer. Empirical data from a myriad of advanced development projects consistently show that, once the user grasps the enormous potential for improved training of a modern automated system, a wellspring of ideas for more sophisticated application is tapped. The system must be designed to adapt to this change with minimal effort. User acceptability rises dramatically when this capacity for change is specified. This honing of the prototype product in the grit of user application and modification is the means by which the ultimate product is sharpened and shined into a highly effective device.

In summary, the field instructors contribute to the development of advanced training systems by providing a statement of training objectives, by helping to establish objective performance measurement criteria, by offering advice on training methods, and by suggesting improvements to the existing system based upon their experience.

The training systems analyst takes a fresh look at the training problem; specifically defines and objectifies training requirements to be addressed; selects all that is valuable from existing methods; suggests and even sells new methods and problem solutions; supplies a clear statement of the functional capability requirements of the proposed system to the hardware and software specialists; and, finally, devises and executes experiments to establish whether or not training requirements are met and cost-effectiveness enhanced by the use of the system.

The hardware and software specialists advise on the technical feasibility of the proposed system; uncover areas wherein system potential might be better used; suggest the use of new technologies where appropriate; select the most cost-effective hardware suite needed to perform the specified tasks with due regard to potential added capabilities; and design, implement, and test a system to perform the tasks specified.

ASAC Training Analysis

Unfortunately ASAC training is in the same condition now that AIC training was in a year ago, prior to development of the course structure described in section II. ASAC trainees are being taught equipment rather than a job. A task oriented training requirements analysis is an essential step prior to the development of an effective training system such as the one being envisioned for AIC and ASAC. Moreover, a task analysis will provide greater visibility to NAVTRAEQUIPCEN's research efforts in terms of identifying the applicability of AIC-related research efforts to similar aspects of the ASAC problem.

The training requirements are derived at the functional level by the application of the principles of task analysis. Task analysis starts with the generic or broadscale tasks or responsibilities of the operator and utilizes a series of analytic steps to explicate all the task elements which are, in turn, translated into learning objectives. These objectives are stated in behavioral terms, each of which is accompanied by a description of the conditions under which the behavior is performed and the standards to which it is performed.

At the present time the AIC training community has completed the task analysis through the level of enabling objectives down to the level of terminal objectives; that is, the level at which the ultimate level of proficiency expected of the student is described. In addition, as described in section II, these objectives have been sequenced into blocks of instruction (for eventual presentation to the student) which range upward in calculated levels of task difficulty. Increasing levels of difficulty are obtained: by stepwise increases in learning task complexity; from partial-to-full scope responsibility; from single to increasing numbers of targets on the scope; etc.

These analytic-task listings of objectives, conditions and standards have not been developed as yet by the ASAC community. Since they constitute the backbone reference for all further system development work, this effort should be initiated as soon as possible. It should be emphasized here that the formal ASAC task analysis should be initiated prior to final specification of the AIC/ASAC trainer. Just as the current AIC course at FCTCP is benefiting now from the AIC analysis, so too can current ASAC training receive immediate benefit from a thorough and complete training requirements exercise. The following steps are intended to outline recommended steps for accomplishing this effort. They are based on both Logicon's experience and upon Navy in-house experience with the derivation of AIC learning objectives. Implementation of these tasks could easily occupy a training analyst and subject matter expert (SME) for the better part of a year.

Step 1: Preparation of Research Questions — ASAC responsibilities are not well defined, even within the ASAC community. Previous experience with AIC has shown that the best solution to this problem lies in an innovative approach to task analysis. That is, rather than rely exclusively upon the knowledge and experience of operationally qualified ASAC SME's, the effort must also involve the cooperation of the airborne communities serviced by ASAC. These include LAMPS-HELO, P-3 and S-3. The joint definition effort starts with obtaining concise and complete statements of what each of these user communities wants or expects from the ASAC controller in the operational environment. This derived information must be combined with the information already available within the ASAC operational community.

This effort is best initiated by the preparation of research questionnaires to be submitted to each of the communities in turn. These questionnaires must include a means of getting at all the types of information required (to be integrated with information existing within the ASAC community) to establish the complete set of ASAC responsibilities.

Step 2: Interview S-3, P-3, LAMPS, and Helo Communities – This effort is required for the user communities to complete the questionnaires. Due to the general lack of definition regarding exact ASAC responsibilities, many of the terms contained on the questionnaires are expected to generate controversy. This controversy must be resolved both within the user communities and between each user community and the ASAC community. Both the training analyst and the SME play important roles in this process by guiding the investigation into each item of responsibility in question.

Step 3: Compile Research Data – The interview data from step 2 must next be compiled and ordered for review by all interested parties. These processes provide an orderly framework for the process of deriving learning objectives from the listings of ASAC responsibilities.

Step 4: Interview TAO/ASAC Communities/Determine ASAC Responsibilities to Tactical Action Officer (TAO) – This step is similar to step 2, above. ASAC responsibilities include that of reporting to the TAO on ownship, and these responsibilities must be defined as a joint effort of representatives of each of the two communities. The questionnaire/interview technique should be used in this effort as it was for establishing the responsibilities to the airborne communities. Roles of the training analyst and SME are similar to those noted in step 2. This step also allows time for the compilation of the data as discussed in step 3 above.

Step 5: Development of Job Performance Task Statements – This step consists of translating all responsibilities data into concise and accurate statements of performance requirements. These requirements must be stated at the mission/function level of detail and must include all functions upon which the student must ultimately be trained. Training analyst/SME responsibilities for this step are those of ensuring that all compiled data are eventually stated in both objective and operational terms and that the final listing of requirements is complete. Culmination of this effort results in an inventory of performance requirements.

Step 6: Submit Performance Requirements Inventory to User Communities – The listings or inventory of performance requirements must be submitted to each of the user communities for a final check regarding accuracy and completeness. Any revisions made to the inventory at this time must be a joint effort of the training analyst (or SME) and a qualified representative of the user community. When the revisions are completed and rechecked, the complete listing of performance requirements must be submitted to training analysts and SMEs for the following steps to be completed.

Step 7: Select Performance Requirements to be Taught by the System/Device – This effort can partially overlap that of step 6 and in fact, may involve the same personnel, given a joint effort of both the ASAC and user communities. The selection process itself, at this stage of the program, will be determined primarily by the entry-level qualifications of the students. Performance requirements already mastered by entry-level students will not need to be taught, though some later performance measurement or evaluation on these requirements may be advisable. Primary responsibility in this step will be borne by the SME who will rely upon both experiences and technical advice of the training analyst.

Step 8: Conduct Task Analysis – Either Instructional Systems Development (ISD) or Systems Approach to Training (SAT) techniques are required for the completion of this effort, which consists of analyzing job performance requirements in terms of functions, task-within-functions and task-elements-within-tasks. The analysis continues until every element of every task is specified, at which point the data are translated into learning objectives. These objectives are stated in terms of knowledge, skills, conditions, and standards of performance, and may be specified in a number of ways, such as terminal objectives and associated enabling objectives. Moreover, they are stated in behavioral, observable terms. The output of this step must be a complete listing or inventory of all items of performance to be taught within the training course itself. Each of these items must be accompanied by a statement of the conditions under which it must be performed and the standards to which it must be performed. The role of the training analyst is primary in this task, insofar as he must specify the procedures for the analysis itself, as well as those required to translate the task elements into learning objectives. The analytic task is greatly facilitated, however, if he has access to the operational expertise of the SME, who, by this point in the project, will have developed a familiarity with the procedures and techniques of task analysis. Under these optimal conditions the analyst and SME can function jointly or independently.

Step 9: Instructional Sequencing and Blocking — This step is of critical importance in aligning the ASAC program with that of the AIC. By way of explanation, the joint AIC/ASAC trainer is expected to have both automated and adaptive instructional features as well as speech recognition/generation capabilities. Since the trainer itself will constitute the primary learning medium for the entire training system, it is reasonable at this point to sequence/block the learning objectives in accordance with what is known about the trainer. Learning objectives for the AIC program have already been sequenced from the simple to the complex, and in increasing levels of task difficulty, in accordance with the adaptive features of the projected system. They are specified in objective/quantitative terms and are accompanied by appropriate voice communication requirements in accordance with the other instructional features of the projected system. Once derived, the ASAC learning objectives must be sequenced in the same manner in order to ensure that the training programs can share the instructional features of the system. The similarities of AIC and ASAC operational responsibilities and the set of instructional features to be provided on the joint trainer constitute the basis of justification for the commonality of training. These must be carefully defined in order for both controller communities to obtain maximum benefits from the trainer.

This step will require extremely close cooperation between the training anayst and SMEs. At least 1 SME is required from each of the two controller communities in order to provide a balanced merger of the common training requirements to be addressed by the joint trainer.

Step 10: Media/Training Aid Selection/Specification — For present purposes the media selection process, which is normally a major and formalized effort within the framework of ISD, need address most specifically the separation of those performance items to be presented on the joint trainer from those which are not. Though the final detailed specification of the trainer is not possible until further R&D efforts have been accomplished, enough data will be available at the conclusion of the task analysis for a reasonable approximation to be made regarding which performance items are likely to be implemented on the trainer.

At the same time, a formal media selection process can be implemented regarding other training media to be used, such as classroom lecture, sound-slide and video-tape, etc. Complete definition of this formal process is beyond the scope of the present report. Suffice to say it must be initiated at some point after the derivation of the total set of learning objectives.

In general, the role of the training analyst is primary in the definition of media requirements insofar as these must be based upon the nature of the learning objectives. Heavy reliance must be placed as usual, however, upon the operational expertise of the SME.

Step 11: Development of Student Handout and Supervisor Written Material — Completion of this task results in the development of all necessary supporting textual information for the training program. At the completion of training the accomplished student will have assimilated a well-defined repertoire of knowledge items and skills which prepare him for operational responsibilities. This step is on the side of the knowledge items he must possess to accomplish the various tasks. In general terms these items directly support the verbal and motor skills required and are considered to be acceptable for inclusion into the program only if they are need-to-know (as opposed to nice-to-know) items. Also in general terms, these items usually consist of theoretical and/or background types of information not amenable to treatment by "hands-on" training devices.

Primary responsibilities for developing these materials rest with the SME who is uniquely qualified to know specifically which information is required for the successful completion of controller tasks. Structuring and formatting of the information is more within the province of the training analyst, though the entire effort must be accomplished jointly.

Step 12: Conduct Pilot Course for Students and Instruction Staff — This step requires the cooperation of both the students and instructional staff and is intended to validate the learning objectives, structure, media etc., for the entire curriculum. For present purposes the major concern will be the subset of learning objectives and other factors which are specific to the projected AIC/ASAC trainer. Optimal results will be obtained, however, only with the validation of the entire program, the complete discussion of which is outside the scope of the present effort.

Analysis of the data obtained in this step will be a joint effort of the training analyst, SME, students and instructional staff. Results of the analysis itself will be provided as input to the following step.

Step 13: Revisions and Update of the Curriculum — This step requires the cooperation of the students and instructional staff and is intended to feed the results of the previous step into the training program for the purposes of refinement. In some instances several iterations of this and the previous step are required before the instructional curriculum is finalized. Experience with AIC indicates, however, that a reasonably reliable definition of the curriculum may be obtained from the results of one pilot course and revision/update, although the development of an optimal curriculum is a continuing evolutionary process.

Primary responsibilities for this effort are jointly shared by the training analyst and SME. Additional responsibilities are those associated with the revision and update of the textual material identified in step 12.

Step 14: Submit Revised Course Curriculum and Begin New Course – Revision and update of the curriculum must be approved by all training personnel in the program prior to the initiation of the new course. At this point the training program is ready for the first non-pilot group of students. These are milestone items only, and have no associated labor/time requirements.

SECTION VI

THE NTEC PROTOTYPE TRAINING RESEARCH SYSTEM-ACTS

Introduction

The general goals of NAVTRAEQUIPCEN's research program are fairly well understood, and surely certain aspects of the AIC training program clearly require well defined R&D effort prior to production of the eventual training device. These areas were broadly-scoped and studied during the present effort.

But the more specific and detailed requirements of the research program, especially when viewed as the experimental prototype of the AIC/ASAC trainer, are not as clear, and indeed are perhaps still undefined. Consequently it has been necessary to avoid the temptation to "over-spec" the research training system at this early date, since clearly this would be premature when the research objectives are not completely understood and/or defined, let alone validated against the AIC/ASAC trainer development program and the always present time/cost constraints. Questions have arisen such as: "Should the R&D program be concerned with motor skill development?"; or "Should the research be conducted using operational NTDS components, e.g., the UYA-4 console?"; or "Can the research objectives be met by studying only levels 1 – 6 and level 12 – 13?". Definitive answers to these questions at this time would be clearly presumptuous, although pro and con discussions are certainly in order. In this particular section, therefore, we wish to stimulate thought and discussion, present the clearly defined material, but at the same time not imply that we have all the answers.

The section is organized as follows. Following this introduction the general goals of ACTS, as currently understood, are described. The areas of speech recognition, performance measurement, and the AIC controller model are discussed. We then reiterate the need to carefully define and validate the specific R&D objectives for this large program. Using the question of NTDS participation as an example, a training system divorced from NTDS and the UYA-4 console is described. This discussion is followed with the arguments for utilization of the console. A compromise is described which essentially suggests using commercial graphics for early development, but the NTDS console for final integration and evaluation. Specific recommendations (one of which will be a formal training research requirements analysis/validation/review effort) are discussed in the final section of the report.

The Purpose and Goals of ACTS

The previous section described the need to take a long, hard look at existing training systems and to develop fresh approaches to the training problems, aided now by advances in technology, methodology, and training system design. The advantages of "automated-adaptive" training systems for aircraft pilots and weapons officers have been established for some time. Only recently, however, have these techniques been applied to controller training tasks. The GCA controller training system being developed by NAVTRAEQUIPCEN is in fact the first integration of objective performance measurement, adaptive syllabus control, computer assisted coaching, etc. in a controller training system. The development of this laboratory tool has been made possible by the emergence of reliable speech recognition technologies.

The development of the AIC/ASAC trainer should be preceded by a similar prototype effort which addresses the application of speech recognition and automated-adaptive training strategies to the air control training problem. The AIC (and presumably ASAC) tasks are significantly different than the GCA-PAR tasks; and while the experience and design guidelines learned during the GCA-CTS program will of course be useful and important, further R&D is required.

Given the desire to incorporate advanced training methodology into the AIC/ASAC trainer, then, the purpose of ACTS is to examine in detail some nontrivial aspects of the total air control training problem, to develop detailed design guidelines, and further develop the needed technologies which will ensure an effective air controller trainer during the 1980's. In general terms, NAVTRAEQUIPCEN will gain preproduction experience in the application of the following elements to the AIC training problem:

a. The automated speech technologies: Speech recognition and speech generation (though the latter represents low technical risk).

b. Objective performance measurement: Based upon a model of correct controller behavior, the performance of the student can be measured and compared to established standards.

c. Teaching strategies: Given that the student's performance is available (known) to the system, various techniques can be applied to develop a training system uniquely tailored to the strengths and weaknesses of the individual trainee (e.g., syllabus control, remedial coaching, feedback, etc.).

Development of Speech Recognition Techniques

Recall that typical AIC vocabulary was presented in section III of this report, together with some general conclusions about the feasibility of automatically recognizing this vocabulary using state-of-the-art and projected computer speech recognition systems.

An established goal of NAVTRAEQUIPCEN's research program is to develop a recognition capability that will support AIC training in an effective way. The definition of "effective" remains to be resolved, but nevertheless it is possible to discuss areas of development which will almost surely need to be addressed during the course of the R&D program.

Basic Limited Continuous Speech Recognition (LCSR) – A significant amount of information transmitted to the pilot is represented by numerical data. It is entirely unreasonable to expect the AIC trainee to pause between every digit in these reports. The ability to recognize strings of digits (usually three digits) is essential. As mentioned in section III, NAVTRAEQUIPCEN is currently funding such a development effort, and this program should continue.

Expanded LCSR – Regardless of the eventual content of the R&D program (in terms of the AIC tasks which will be studied) a basic LCSR capability as described above, plus isolated word recognition, plus forced stylizations, will result in a minimally acceptable training environment. By expanding the LCSR vocabulary beyond the ten digits, however, a significantly more acceptable system will result. Table 11 suggests an expaned LCSR vocabulary which would increase the effectiveness of speech recognition in an AIC training environment.

The feasibility of developing such a recognition capability should be studied. It may be possible to combine smaller sets of vocabulary words together with syntax rules to effectively limit the vocabulary size to a branching factor of 10 – 12. If this were the case, one might argue that a successful basic LCSR system portends the successful development of an expanded LCSR capability.

Word Spotting – Depending upon the specific functional requirements of ACTS (which, in turn, will depend upon identified research objectives) a word spotting capability may prove to be a required outgrowth of NAVTRAEQUIPCEN's R&D program. The total AIC vocabulary, unlike, for example, the GCA/PAR vocabulary, does not consist solely of specific (even loosely defined) phraseology. The AIC must, for example, identify

TABLE 11. EXPANDED LCSR VOCABULARY.

zero	point	squawk
one	bogey	twenty
two	stranger	thirty
three	port	forty
four	starboard	fifty
five	vector	sixty
six	breakaway	seventy
seven	tracking	eighty
eight	speed	ninety
nine	altitude	

an emergency condition and inform the TAO. No specific phraseology is defined, and there appears to be reluctance among the instructors to force predefined phrases upon the student. The training system may only need to know that the AIC is indeed reporting the emergency. Spotting the word "emergency" in a long utterance may be sufficient. Fortunately the speech recognition research currently being sponsored by NAVTRAEQUIPCEN will yield insights into the word spotting problem. Again, depending upon the definitization of ACTS functions, this is another area that should be investigated.

Isolated Word Recognition (IWR) – IWR will continue to play an important role in the AIC training research system. The AIC vocabulary does consist of perhaps as many as one hundred definable phrases that are (or can be reasonably made so) isolated on both ends by silence. Problems arise in the utilization of vocabulary sizes this large, however. Most significant is the problem of configuring the recognition system to the voice data patterns associated with each vocabulary item. As the vocabulary size grows, the problem of effectively integrating the voice data collection process into the total training scenario, becomes more complex.

Combining IWR with LCSR is also an area that will have to be addressed in the R&D program. Some stylization will almost surely be required. The development goal will be to define these stylizations in a way which allows for the most natural speaking styles; and to define techniques to teach the student these stylizations without unnecessary hardship.

Development Schedule. The development of all the various speech recognition techniques that are seen (at this time) as enabling or enhancing the AIC training situation, will constitute an important and sizeable portion of the ACTS program. But because of the technical risks associated with some of these recognition techniques, together with the difficulty of accurately predicting a development schedule[1], the following approach might be considered.

The speech recognition portion of ACTS can be designed to be a self-standing module within the whole system, just as the Speech Understanding Subsystem (SUS) was designed in the GCA-CTS. By doing so, the entire training research system could be developed independently of the speech recognition functions. An IWR capability with extreme stylizations could be used during development of the performance measurement, exercise control and other subsystems. The recognition work would proceed in parallel to this effort. As new recognition techniques become available, they could be integrated into ACTS in piecemeal fashion, with only minimal impact on the design of other system elements.

Performance Measurement

In addition to development of computer based speech recognition, an important element of NAVTRAEQUIPCEN's prototype effort will be development of a performance measurement subsystem for the air intercept controller.

Performance measurement implies that some aspect of the controller's behavior can be monitored by the system (the function facilitated by speech recognition); that some standard against which to measure the student's performance can be defined (the function of the controller model described in the following subsection); and finally that some yardstick is available for performing the actual measurement (the function of a scoring model, not specifically addressed in this study).

A basic consideration in the specification and design of the performance measurement subsystem is the depth to which automated measurement is effective. AIC instructors at FCTCP have expressed the fear that the system may be over-complicated by attempting to measure every minute

Note 1. See section VII for preliminary estimates.

controller function. Instead, they suggest that the system sample only the final decisions and outputs of the trainee. In other words, for example, verify that the student issues a stranger report in an accurate and timely manner, rather than monitoring each of the dozen or so steps that must be executed prior to issuing the report. If the output is not correct or timely, the FCTCP instructors feel that the trainee knows what he did wrong (at least in general terms) 99 percent of the time. The automated performance monitoring system should simply:

a. Make known the mistake, with the option of continuing unless safety is involved; and/or

b. Give the trainee a chance to exercise the particular problem area again without going through the entire problem.

c. Provide and monitor a remedial exercise to ensure compliance with standards.

When the function of the performance measurement system is viewed in this way, an apparent development approach is to examine just the terminal objectives and associated standards, listed in section II of this report, and suggest that they constitute the basis for the controller model and scoring model. If a more detailed performance measurement system is required, then the controller model must be derived from both the terminal and enabling objectives, supplemented by a more detailed representative training scenario. These subjects are discussed at length in the following subsection.

Also, given that performance measurement occurs only at the higher levels, the question arises as to the extent that these terminal objectives can be monitored entirely by understanding the controller's verbal behavior. Phrased another way, to what extent can the needed performance measurement system be based solely on inputs from the speech recognition system? A review of the training levels show that levels 1 – 5, 7, 8, 10 – 12 can clearly be totally monitored using only the speech inputs. A level 6 objective (to maintain track on more than two aircraft) can only partially be handled by voice alone; use of IFF equipment (level 9) does not lend itself to speech based performance measurement. In level 11, updating the aircrew of the F-14 interceptor via one-way data link, is not at all amenable.

Despite these few exceptions, a remarkable proportion of the AIC tasks can be effectively monitored at the highest level solely by observing the verbal transmissions. This augers well for the ultimate success of a speech-based AIC automated-adaptive training system.

Another consideration regarding performance measurement and its relation to monitoring system parameters, is the distinction between evaluating the student and providing remedial, diagnostic help. While it may be sufficient to observe the trainee's verbal behavior at the terminal objective level to determine that he has, or has not, performed the task properly; it may be necessary to observe the trainee to really adequately determine precisely why he performed the task improperly. If detailed diagnostics are indeed required and are of interest to NAVTRAEQUIPCEN's research program, then a detailed performance measurement system may be required.

A final consideration regarding performance measurement involves the extent to which it can, or should, augment and support speech recognition. An important feature of the GCA-CTS is the interface between the performance measurement subsystem (PMS) and speech understanding subsystem (SUS). Similar design could be useful in the AIC environment. The extent that data available to the PMS could support the SUS may depend upon the level at which performance measurement occurs. This is an area that must be more fully investigated in the early phases of NAVTRAEQUIPCEN's research program.

The AIC Model Controller

The ACTS functional requirements must be derived from AIC training requirements. At this time these training requirements have been defined in terms of terminal level training objectives and supporting enabling objectives. Their analytic level of detail is at the function/task level, and they are further supported by the specification of conditions and standards of performance for each of the terminal objectives.

Given the case that a training system already exists to provide a means for meeting learning objectives, it is useful to structure these objectives into a controller model; that is, a model of the controller's behavior as he is engaged in performing his task responsibilities. In the case that some aspects of the student's performance are subject to measurement, evaluation or scoring/grading by computer-based technology, it is also necessary to define a codable model of controller behavior. In addition, performance conditions and standards must be incorporated with scoring and weighting algorithms, reference points, etc. in order to define a computer grader or scoring model for assessing student performance. Given the case that no training system exists, these steps and others must be accomplished, for the systematic specification of the desired system.

Definition of Controller Model – "Controller model" can be translated as "Codable model of controller behavior," as noted in the above paragraphs. Its purpose is to provide a basis for communication between computer programmers and training psychologists. The phychologist's job in this respect is to look at performance requirements and their derived learning objectives. He must determine that the appropriate learning objectives have been derived from the correct performance requirements. The learning objectives along with their associated conditions and standards constitute the controller model at the functional level. When these learning objectives are codable (programmable) they constitute the codable model.

It is important to know that at this level of definition, controller model is defined exclusively in terms of the characteristics of the performance data, not in terms of characteristics of the system. Characteristics of the performance data which qualify it as codable are:

a. Objectivity – The data can be directly pointed to as opposed to being inferred or otherwise subjectively treated.

b. Quantifiability – The data are subject to numeric treatment or measurement (in some units of measure).

c. Digitizability – The data are specifiable in such a way as to be subject to treatment by digital computer-based technology.

d. Discreteness – The digital data associated with one performance task are distinguishable from those associated with another performance task (e.g., start and stop points are clearly specificable for each separate task to be trained, measured, evaluated, etc.).

Thus, in the strictest sense, the controller model is a codable model of controller behavior, is independent of any system, yet at the same time, is subject to a wide range of possible treatments by digital-computer-based systems. Among these treatments are:

a. Performance monitoring – observing student behavior only.

b. Performance monitor and measurement – observing and making low-grade decisions (e.g., did he complete the task?).

c. Performance monitoring, measurement and evaluation – observing, making decisions and scoring or grading performance.

d. Performance prompting, feedback, measurement, monitoring, evaluation, etc.

e. Beyond the provision of purely monitoring capabilities, data display and formatting capabilities must be addressed — such considerations involve systems specifications in terms of CRT's, hardcopy, and other capabilities.

Once completed, in detail, the controller model constitutes the complete set of stimulus response elements upon which the functional specification of the proposed system may be based. Integration of these elements with the specific R&D goals of the system as established by NAVTRAEQUIP CEN, provides a virtually complete data base for system specification.

Representative Scenarios: Derivation of a Controller Model — The first approximation to a precise definition of a complete controller model (including enabling objectives) must start with the existing task listings. From this start point, a proven approach from the perspective of system specification is to structure the objectives into a time lined sequence of events about which a typical or representative training scenario may be structured.

This representative scenario must include all the stimulus and response elements associated with the AIC's performance of his responsibilities, and must be referenced to an operational performance baseline. Thus, starting with existing terminal objectives in their appropriate operational sequence, the effort consists of supplying the missing detail, particularly that associated with the training or exercise environment. When these relevant stimuli and target response elements have been specified in detail, and the irrelevant or noise stimuli (which may interact with relevant stimuli) also have been specified, then it becomes possible to design an effective means of eliciting the AIC's behavior when the relevant stimuli is present. For simple tasks, this may involve explaining the concept to the student, then affording him with practical applications of the concept. For more complex tasks, good training may be facilitated by simplifying the introductory problems so that only relevant stimuli are presented. As the trainee masters the concepts, the irrelevant stimuli normally present in the environment can be phased in adaptively, notably those stimuli which serve as distracting influences. The difficulty of the assigned task depends, in part, upon the nature of the irrelevant stimuli presented. A measure of the influence of these factors therefore contributes to the decisions made by the instructor model and to the scores calculated by the grader.

In this way each operator action is located within a completely defined contextual framework consisting of all the salient features of the training environment. In behavioral terms the completed scenario must consist of both, all of the console operator responses, and all of the system supplied stimulus elements or cues to which the responses are made. In the absence of any existing system the complete definition of all the stimulus elements is equally as important as the definition of student responses because it is a primary function of the system itself to provide the total stimulus environment.

Some of the detail required to construct a representative training scenario which is not supplied by the terminal objectives, may be supplied by the enabling objectives. In some cases, enabling objectives may be constituted primarily of knowledge items, which must be learned in order for subsequent behavioral objectives to be accomplished. In other cases, enabling objectives may be intermediate level behavioral objectives which support the accomplishment of later objectives (e. g., terminal objectives).

In the existing AIC task listings enabling objectives are noted for each of the terminal objectives listed. However, they are not specified in enough detail for the completion of a representative scenario. In the more complex levels of training, both conditions and standards of performance of these enabling objectives remain unspecified, as do the environmental (stimulus) factors. Though conditions and standards may in some cases be derived by referring back to earlier levels of training in the task listings, environmental features such as number and types of "targets" on the radar scope during the actual performance of the enabling objective remain undefined.

Therefore, in order to support the complete specification of a representative scenario, enabling objectives must be analyzed to a finer level of detail and, where they are behavioral as opposed to strictly knowledge items, must be associated with the appropriate conditions and standards.

Implementation of the proposed system will ultimately require the definition of training (or research) scenarios which are appropriate to each level of task difficulty or complexity to be addressed by the system. However, the functional specification of the system does not require this level of effort in the present case. Sequencing/blocking strategies utilized for the existing listings were such that selected learning levels contain all the essential elements of preceding levels. Thus, the careful selection of an appropriate level, and the subsequent structuring of a detailed scenario for that level, will provide an adequate data base for the specification of system functional capabilities.

Defining a Representative Scenario – The level-of-training appropriate to the definition of a representative scenario must be based upon specific R&D goals. Levels 11 and 12, as outlined in the existing AIC course task listings, integrate all the basic skills and knowledge accumulated by the student into complete tasks which are typical of those required for operational performance. Thus, all the basic performance items are represented.

Level 11 also includes representative examples of shared responsibilities among two or more AIC students. That it is important to include these shared responsibilities is evidenced by the fact that in practice AIC's virtually never work alone. Thus, the division of labor in a complex exercise is of critical importance and merits consideration as a research issue. NAVTRAEQUIPCEN must determine early on if their research interests extend to the interaction of more than one AIC student. If so, the system design must encompass the multiple student case; if not, the above 3 steps may be considerably simplified. Preliminary discussions with AIC instructors indicate that the training level selected will submit equally well to the development of either single-student or two-student scenarios. Though the single-student scenario would require considerably less complexity than would the two-student case, the level of training would remain the same with regard to task difficulty and complexity.

Several steps are required to complete a representative scenario from level 11 of training. The following paragraphs describe the culminating steps in the development of a functional specification for a computer grader model. This grader model can be integrated into the training system so that it has the capability to grade performance based on the dynamic, evolving elements of the real-time simulation of the total environment.

Step 1 – Specification of complete set of concepts to be learned – the description of each concept includes the enumeration of the relevant stimuli or conditions, the rule to be employed, and the exact behavior to be performed, including the standards to be met. This performance may involve several task elements and may require their sequential performance; hence, this required sequencing also must be specified. These task elements may include operator verbal responses which must be similarly specified. If alterative responses are allowed, they also must be specified.

Step 2 – Specification of the sequence of concept presentation – when the concepts to be learned have been identified and their associated task elements specified in detail, their interrelation can be determined. This interrelation provides the basis for arranging the concepts' presentation in accordance with a step-by-step concept and skill acquisition philosophy. It also provides the basis for the design of automatic remedial problem selection logic.

Step 3 – Specification of complete set of scenario environmental factors – this step consists of defining the characteristics of the environment to which the trainee must respond. These must include the definition and description of all tracks appearing on the radar scope, time of appearance, direction, velocity, distracting stimuli, etc. for each problem. These stimulus events must be interspersed with the operator responses noted in step 1, above, in their proper order and in appropriate relation to the responses themselves.

All dependencies and contingencies between the operator responses and the stimulus items must be noted; for example, given that the AIC student conducts an intercept mission correctly such that the interceptor scores a kill, the "hostile" video is faded from the radar scope. It should be noted that this scenario is not the operational syllabus, rather, this detailed scenario is required for specification purposes, i.e., the functional design of the computer grader model and the environmental simulator. The actual training exercise will begin with a precise environmental set-up similar to that defined here. Following the commencements of the training exercise, the dynamic situation will be dependent on the actual responses of the trainee.

Step 4 — Specification of computer grader model — the completion of the three tasks noted above, in effect, provides the basis for the specification of the model controller and computer grader. What remains is a final selection or verification of specifically which operator task performances are to be measured and/or evaluated, development of scoring criteria, and formatting of all the data for maximumutility by system design and software implementation personnel. This step would probably best be accomplished in two short phases, the first being that of selection of the performance items to be measured, the second that of formatting all the data. The end product of this phase would be a software implementation workbook.

ACTS Configuration

As noted earlier, specific research objectives and development goals for the prototype research system are still being formulated. This precise delineation of the most effective contributions that NAVTRAEQUIPCEN's R&D program can make toward the eventual production of the AIC/ASAC trainer, is of critical importance. Without such clearly defined and stated objectives, it becomes an exercise in frustration to analyze the myrid trade-offs that are a part of the functional and design specification process.

One such decision known to be of concern at this time, is centered upon whether or not to use the existing NTDS student console in the experimental prototype system. One alternative to using the NTDS console is to provide the student with a modern graphic CRT terminal upon which various AIC task functions may be simulated, and which provides some means by which the student may respond to the simulation. Another approach is to use both types of consoles: the commercial unit for system development; the UYA-4 for system evaluation.

Since this decision does affect system configuration radically, the various alternatives are discussed in the following subsections. The approach taken here is to describe the types of problems which might be addressed on a CRT-graphics-based system. This discussion will include an example of the types of training problems which are amenable to exploration on the CRT-graphics-based system. Following this discussion, a rationale will be provided for utilization of the NTDS console. Finally, the combined console approach is reviewed.

Note that the question of student console has little or no impact on the ACTS goals associated with exploring the automated speech technologies.

Non-NTDS ACTS

Introduction – The possibility of producing an AIC training system which is divorced from NTDS and the UYA-4 console is investigated in the following paragraphs. A non-NTDS based system would have use in the experimental laboratory for investigating aspects of cognitive and verbal skill acquisition, although some precautions should be used to prevent negative transfer if "real" AIC's are part of the subject pool. The methods which prove effective in the laboratory could then be implemented on the operational training system. In this subsection, one particular lesson in the current AIC training program is examined in some detail and suggestions are offered for implementing it independently of NTDS and the UYA-4 console. The discussion will highlight the flexibility that this approach allows. In particular, a plan is suggested for training the cognitive and verbal skills which are acquired at level 12 in the current AIC training program. These tasks are broken down into their component parts and are introduced one step at a time. Purely synthetic intermediate steps have been added to illustrate the fact that novel training plans can be implemented easily.

The major drawback to the proposed system is that motor skill development is not addressed. The UYA-4 console is an extremely complicated piece of equipment with which the AIC must interact constantly. While it is possible that the AIC's performance can be partitioned on a theoretical basis into verbal, cognitive and motor components, no such simple trichotomy necessarily exists in fact. A system such as this one which focuses on only a part of the learning task could lead to biased estimates of the training problem, and the overall contribution to training effectiveness is unclear. Therefore the following discussion is in no way intended to undermine the Navy's commitment to providing training experiences in a realistic environment.

Assumptions – The system described is intended to provide training comparable to that presently provided at level 12, but restricted to the cognitive and verbal aspects of that training. Therefore the system described in the following paragraphs utilizes a minicomputer-based graphics simulation of the radar display. The problem of providing a realistic environment for motor skill development by simulating the UYA-4 console and the NTDS program is not addressed.

. The AIC must learn to act as an effective member of a tactical information team. A complete training system must address this problem. The performance of missing team members can be simulated with techniques similar to those for simulating the pilot's verbal behavior as described in the following paragraphs. (Reference to such an approach also is described in Technical Note NAVTRAEQUIPCEN TN-52.) This aspect of training is not emphasized in level 12 to which the following discussion is limited; therefore, no provision is made for training the skills needed for interacting with other controllers (the fire control personnel, supervisory personnel etc.).

Because this is a laboratory system, and because the problem is focused on those tasks in which the AIC functions autonomoulsy, a single station configuration is assumed to be sufficient. There is no need for a multistation environment, nor even a separate instructor's console.

Finally, throughout the discussion, it is assumed that a speech recognition capability exists which can recognize the controller's instructions. The problems inherent in providing this capability are addressed in a separate section.

Hardware Configuration — The following paragraphs describe the hardware components of a laboratory version AIC training system designed on the foregoing assumptions.

The Training System Controller — The training system controller is a commercial minicomputer. The exact specifications of this controller depend upon the processing requirements demanded by the training problem, the record keeping requirements, and the peripheral support requirements. Significant contributing factors in the choice of the controller include the extent to which speech and graphics display processing will require controller resources.

Disk — Implementation of a sophisticated real-time training system on a minicomputer is made possible by an overlay management capability. This requires peripheral support in the form of a relatively fast access disk. In addition, training records are easily maintained on disk. Finally, the simulation of many tracks on a radar display is probably best accomplished by means of table-driven aircraft and vessel simulations. An extensive data base can be maintained on disk to provide a variety of training problems.

Speech Recognition Equipment – The system described depends upon a speech recognition system capable of recognizing AIC terminology in real time. This may require a processor separate from the training system controller, and an interface between the two processors.

Graphics Display – A good quality refresh graphics display terminal is required to provide the simulated radar display and the information normally provided by NTDS. In the system described here, there is also a console data entry requirement which demands that there be a provision whereby the student can convey to the system that he believes he is in contact with a specific aircraft. This is most easily accomplished by a light pen or ball tab data entry capability. Finally, since the one display unit will most likely serve as both the instructional console and system development terminal, it must have an alphanumeric keyboard associated with it.

Speech Generation Unit – The AIC is in constant communication with one or more pilots. The pilots' verbal communication will be simulated using a speech generation unit such as the Votrax or perhaps a fast random-access audio playback system. While it is not absolutely necessary to provide different voices for each pilot since the pilot gives his call sign with each transmission, it would be a nice feature. The programmable variable pitch option on the Votrax would serve the purpose. It is probably not necessary to simulate the extraneous communication normally present on the voice channel.

Printer – A medium speed line printer is required for training system data output and also as an adjunct to training system development work.

Magnetic Tape Unit – Magnetic tape is an inexpensive data storage medium, and is almost a necessity in any development system for routine disk backup maintenance.

Foot Pedal Microphone Activator – The AIC selects the appropriate radio channel via foot pedal actuators. This mechanism should be provided in the training system.

Training System Capabilities – A brief description of some of the important capabilities of the training system (exclusive of the speech recognition capability) is given in the following paragraphs.

Radar Display Simulation – A major portion of the graphics display area will be devoted to the radar simulation. This is intended to be a fairly simple display showing the tracks in the system and perhaps a very simple landmark display. Although there is no need to fade the display behind the radar sweep, the sweep itself provides the stimulus which elicits some of the AIC's verbal behavior. Therefore a similar stimulus must be provided.

A simple solution is to provide a dot which circles the periphery of the display at the same rate the radar sweep would. The effectiveness of the stimulus would have to be determined empirically.

Symbols — The symbology normally available over the radar display must be provided.

NTDS Information — A great deal of information is available to the AIC and is normally retrieved through complex interactions with the UYA-4 console. Much of this information is transmitted to the pilot over secure voice channels, and this verbal behavior will be required in the training system described. Since there is no simulation of the UYA-4 console, this information will always be displayed on the graphics terminal, except under simulated radar loss conditions.

Data Entry — A provision must be made for specialized data entry so that the AIC can effectively point to specific areas on his radar display. In general, this method will be used to inform the training system of the AIC's decisions during the training exercises. A light pen, ball tab or joy stick would provide an effective data entry method.

Tracks — The system must provide a moderately complex display of subsurface, surface and airborne tracks including missiles in order to provide the fullest range of training experiences. Several modules will contribute to this primarily table-driven track display. A track update module will utilize the current set of parameters associated with each track to update its position, and will cause that update to appear as the radar sweep passes through the track. These navigation parameters will be derived from four sources. These are described below and shown in figure 11:

a. Parameter Update Module — A track parameter table will reside on disk and be the primary source of information for most tracks. It will be read by the parameter update module. The track position information will be computed on the basis of this table information unless one of the modules described below takes over control of the track. The table provides the track start points, then the relevant navigation information such as speed, heading, altitude, etc. A parameter indicates the time the next change in any of the parameters is to be made and the system will retrieve the new data at the specified time by means of the parameter update module. Another parameter will serve as an indicator which specifies whether or not the track will respond to the AIC.

b. Fighter Pilot Simulation Module — A copy of this module will exist for each track under AIC control. As soon as communications have been established, this module will take control of the track fromthe parameter update module. It will decipher AIC commands and cause the aircraft to

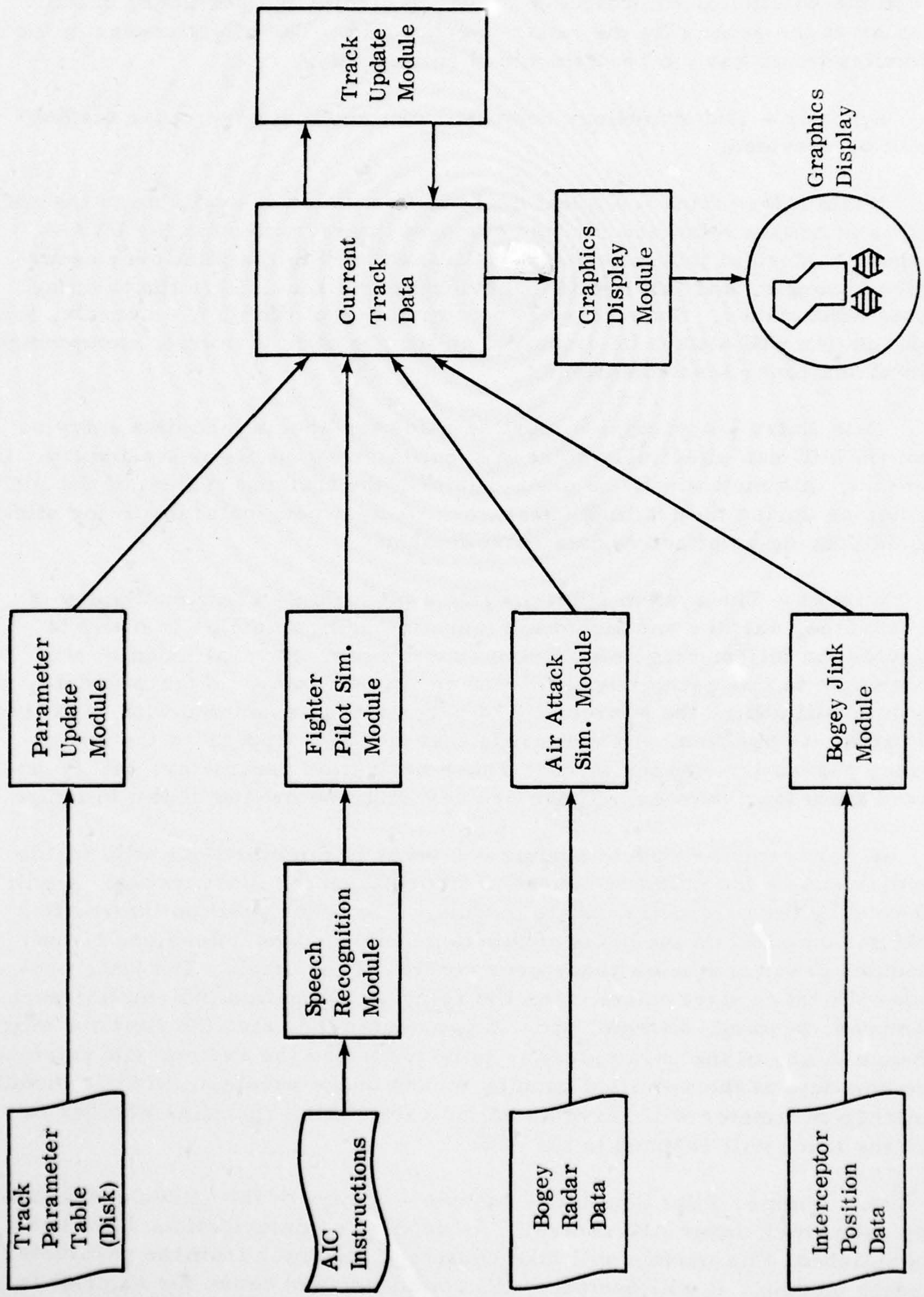


Figure 11. Graphics Display Support.

respond to them by changing the aforementioned parameters. When this module detects lock-on, it reports this to the AIC and gives over control of the track to the Air Attack Module.

c. Air Attack Simulation Module – This module will direct offensive maneuvers during lock-on, and will return control to the fighter pilot module for breakaway procedures.

d. Bogey Jink Module – One of the options available in the track parameter table will allow a hostile track to come under the control of the jink module. This module will maneuver the track to counter the offensive being marshaled by the AIC.

Other Displays – Special Displays are required during training. One example is the intercept track display described for step 3 of level 12 training.

Level 12 Description – Level 12 was chosen to provide an illustration of the training which could be provided given the preceding constraints. The completion requirements for level 12 are shown in table 12. Of these, only those numbered 7 and 8 involve new skills. The others have been built up systematically in previous levels. It is at this level that the AIC student has his first experience with controlling aircraft. His control instructions are actually carried out by pseudo-pilots who control the simulated aircraft he sees on his NTDS display. The purpose of this level is to give him experience in controlling "live" aircraft, to teach him to select training set-ups, and to enable him to become proficient in coordinating practice set-ups for student pilots.

The Steps – In the laboratory training system, the new skills required for completion of level 12 will be built up gradually. The intermediate steps are specified in more detail than is given in the current training syllabus. The presentation is based upon hypothetical constructs about the dynamics of skill acquisition, and not upon a training analysis. Therefore, it should be emphasized that the actual steps chosen are not meant to be used as the training system specification. Rather, they serve to illustrate the capability and flexibility of the described system.

The new tasks required for completion of level 12 are introduced in six steps, listed in table 13. Some of these steps are purely synthetic in the sense that the system provides prompts and/or feedback. As complete a description of these steps as possible in this unclassified report is given, along with a brief discussion of previously acquired skills.

Baseline Skills – The first six requirements listed in table 12 represent skills acquired at previous levels, and mastery of these is assumed. Therefore the realistic portions of the exercise will be conducted in a way that

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TABLE 12. COMPLETION REQUIREMENTS FOR LEVEL 12.

1. Properly locate assigned aircraft within 1 minute after communications established.

2. Transmit target data:

a. Magnetic bearing and range 8 out of 10 sweeps ±2 degrees ±2 miles.

b. Track and ground speed within ±10 degrees and 0.1 Mach within 1-1/2 minutes.

c. Altitude within 1-1/2 minutes.

d. Direction of jink within 1 minute.

3. Transmit-in-the dark calls accurate within 1 mile.

4. Respond to "Contact"/"Judy"/"Lost Contact" calls within 5 seconds, 100 percent of the time.

5. Stranger information prior to 10 miles from CAP 100 percent of the time, accurate ±5 degrees and ±2 miles.

6. Locate aircraft using IFF and TACAN within 1 minute after communications established, 100 percent of the time.

7. Transmit headings for training set ups within ± 10 degrees, 100 percent of the time.

8. Transmit headings for area control to remain in assigned area, 100 percent of the time.

TABLE 13. STEPS REQUIRED FOR MASTERY OF LEVEL 12.

Step 1.	Rough control within assigned area.
Step 2.	Precise control to a designated point.
Step 3.	Intercept point determination.
Step 4.	Breakaway heading selection.
Step 5.	"Live" bogey intercept.
Step 6.	Control of bogey and fighter.

requires these skills to be employed. Performance on each will be measured, and remedial tasks will be suggested upon failure at any one of them:

Step 1: Rough Control Within Assigned Area – at this step the student will control one aircraft. The radar display will be marked to show an area to which he is to vector the aircraft (once he has identified it) and hot areas. The problem will be to vector the aircraft into the area and keep it within the area. Hot areas, traffic, etc. must be avoided. The student will be given practice with aircraft flying at different speeds and altitudes and making turns at various rates.

Step 2: Precise Control to Designated Point – for this task, the student will be required to vector his aircraft in such a way that is passes through a specified point marked on the radar display. Again a variety of problems will be provided so that the student can become proficient at precise aircraft control.

Step 3: Intercept Point Determination – this task introduces the intercept problem. The student will be required to determine the best intercept point given the geometry of the tactical situation. He will convey his choice to the system by ball-tab on light pen entry and will be given immediate feedback in the form of a track display of both interceptor and bogey to the system selected intercept point.

Step 4: Breakaway Heading Selection – intercept geometry will be displayed and the student will be required to compute and send the breakaway heading. Enough examples will be provided to allow proficiency to develop. The Step 3 and Step 4 tasks might best be intermixed for variety. Neither depends upon the other and practicing them one at a time might induce boredom.

Step 5: "Live" Bogey – at this step, a live bogey will be introduced. The student will have developed all the skills needed to marshal the intercept. He will be: capable of directing the interceptor to a point he chooses; capable of choosing a good intercept point; and able to given breakaway instructions. As he becomes proficient, the problems will become more difficult. Jinking bogeys, jamming, loss of the program, etc. all may be simulated.

Step 6: Control of both Bogey and Fighter – one of the AIC's tasks is to coordinate safe practice setups for student pilots. He will acquire this skill during this final step in level 12.

Variables – Within each step, a number of problems will be provided. For example, the first few problems in Step 5 may consist of only fighter and bogey with no drift, no jinks, no traffic etc. in order to facilitate concept acquisition. As concept mastery is achieved, further practice will emphasize its application in a more realistic and complex environment, including the simulation of the "in-the-dark" condition. Table 14 shows the list of the types of variables available for problem setup, and the steps in which they can be used.

Performance Measurement – The previous paragraph demonstrated that a syllabus of training problems could be devised for the AIC training system. A relatively small number of parameters can be varied to provide a large number of different training experiences. Performance on each aspect of the problem can be measured objectively and output to the instructor. In addition, the combined results can serve as the criterion for the automatic selection of the next training problem.

A preliminary set of performance measurement variables has been extracted from the current set of training lessons which would support level 12 training. It is shown in table 15. Notice that the level 12 completion requirements shown in table 12 can be expressed in terms of specified levels of performance on selected performance measurement variables. The

TABLE 14. VARIABLES AVAILABLE AT PROBLEM SETUP, LEVEL 12.

Variables	Applicable Steps
Location of play area	1, 2, 6
Location of hot areas	All
Number of aircraft responding to AIC control	
Number of tracks	All
Types of tracks	All
Drift	All
Track starting point	All
AOB, speed, altitude, etc.	All
In the dark	1, 2, 5, 6
Jink	5
Weapons	5, 6
Lost communications	1, 2, 5, 6
Jamming	5, 6

TABLE 15. PRELIMINARY SET OF PERFORMANCE MEASUREMENT VARIABLES.

PMV	Level 12 Step	When Sampled	Accuracy (Example Only)	Criterion (Example Only)
1. Locate aircraft, IFF	1, 5, 6	At ball tab entry	Cursor touching A/C	Correct ID within 1 minute after communications establisthed: Pass
2. Locate aircraft, TACAN	1, 5, 6	At ball tab entry	Cursor touching A/C	Correc ID within 1 minute after communications established: Pass
3. Transmit magnetic bearing and range with program aid	1, 5, 6	At voice transmission	±2 degrees ±2 miles	Correct transmission 8 of 10 sweeps till Judy: Pass
4. Transmit magnetic bearing and range in the dark	1, 2, 5, 6	At voice transmission	±2 degrees ±2 miles	Correct transmission 8 of 10 sweeps till Judy: Pass
5. Transmit track and groundspeed with program aid	5, 6	At voice transmission	±10 degrees ± 0. 1 mach	Correct transmission within 1. 5 minutes of target detection till Judy: Pass
6. Transmit altitude with program aid	5, 6	At voice transmission		Correct transmission within 1. 5 minutes of target detection till Judy: Pass

TABLE 15. PRELIMINARY SET OF PERFORMANCE MEASUREMENT VARIABLES (Cont).

PMV	Level 12 Step	When Sampled	Accuracy (Example Only)	Criterion (Example Only)
7. Transmit track jink	5, 6	At voice transmission		Correct transmission within 1 minute of jink: Pass
8. Transmit speed jink	5, 6	At voice transmission		Correct transmission within 1 minute of jink: Pass
9. Transmit altitude jink	5, 6	At voice transmission		Correct transmission within 1 minute of Jink: Pass
10. Correct response to contact	5, 6	At voice transmission after contact		Roger if correct and Negative if not: Pass
11. Correct response to Judy	5, 6	At voice transmissions after Judy		Transmit new information appropriate to lock on: Pass
12. Correct response to lost contact	5, 6	At voice transmissions after lost contact		Revert to inter cept control: Pass
13. Vector to play area	1, 6	30 seconds after locating A/C to arrival in area		Arrival in play area: Pass

TABLE 15. PRELIMINARY SET OF PERFORMANCE MEASUREMENT VARIABLES (Cont).

PMV	Level 12 Step	When Sampled	Accuracy (Example Only)	Criterion (Example Only)
14. Request lost communication procedure	1, 5, 6	At voice transmission		Within 2 minutes after locating A/C: Pass
15. Respond to lost com munication condition	5, 6	At voice transmission		Vector playmate to proper area: Pass
16. Control A/C within boundaries of play	1	Regular A/C position checks		Outside boundaries: fail
17. Vector to displayed point	2	Regular A/C position checks	Within X miles of point	A/C arrival at point: Pass
18. Detect intercept point	3	At ball tab entry	Within X miles	Correct entry within 1 minute after prob lem presentation: Pass
19. Determine breakaway heading	4	At voice transmission		Correct heading depending on type of attack, etc.: Pass
20. Intercept Bogey	5, 6	Regular A/C position checks	Bring A/C within radar contact	Correct contact before bogey disappears from radar: Pass

TABLE 15. PRELIMINARY SET OF PERFORMANCE MEASUREMENT VARIABLES (Cont).

	PMV	Level 12 Step	When Sampled	Accuracy (Example Only)	Criterion (Example Only)
21.	Crash	all	Regular A/C position checks		Collison with ground: Fail
22.	Interference with other air traffic	all	Regular A/C position checks		Close calls or collision with air traffic: Fail
23.	Stranger calls	1, 5, 6	At voice transmission		Initiation within X minutes after appearance: Pass
24.	Hot area avoidance	all	Regular A/C position checks		Hot area penetration: Fail

advantage of describing the training problem in this way is that separate modules can be defined for each performance measurement variable and can be called into operation as needed in the real-time environment.

Conclusion — This brief description of a laboratory version of an AIC training system focused on the requirements for level 12 training. It gives an idea of the types of training which could be studied if the training system were divorced from NTDS and the UYA-4 console. The system would have limited usefulness in an actual training environment because of the fact that it does not provide for motor skill development. These drawbacks must be weighed against the flexibility such a system would provide for syllabus development and performance measurement variable definition, and development of training system design guidelines in general.

Arguments in Favor of an NTDS-Based Prototype

These are essentially two arguments to be made in favor of using the NTDS console in NAVTRAEQUIPCEN's research program. The validity of these arguments depend in large measure on the specific research objectives of the program.

One argument depends upon the depth to which the exploration of performance measurement and evaluation features are to be studied. Exploration of the greatest range of AIC training parameters will require either use of the NTDS console or a highly realistic (and hence costly) replica of all or part of the UYA-4 characteristics. Primary consideration is the degree to which cognitive-verbal skills take precedence over motor skills in the research issues of concern to NAVTRAEQUIPCEN. Unless the NTDS console is used, many of the direct measures of performance will be lost. Thus, the measurement methodology employed must be inferential. In this case, care must be exercised in the selection of the tasks to be measured for the sake of guarding against both negative transfer and the later spontaneous recovery of motor skills appropriate only to the UYA-4 console.

From the perspective of motor skill development, this issue regarding utilization of the NTDS console is a subset of an issue raised earlier (the depth to which performance measurement should occur). Many of the enabling objectives are related to console functions. If these are to be measured, then use of the NTDS system, together with some form of data acquisition, is probably required. The converse is not necessarily true, however.

The second argument in favor of using the NTDS console is valid even if performance measurement is limited to the verbal-skill terminal-objective level, as discussed in a previous subsection. Recall the trainees are normally dropped from the AIC school because they lack the ability to manipulate the console; receive required data accurately; and, then to transmit this data to the aircraft in timely fashion. And all this time the AIC is keeping track of at least two and often several aircraft, and receiving and issuing reports to the TAO. Any individual task can usally be taught; without difficulty, but combine the tasks in an operational-like environment, and the learning problems develop.

In short, it is not enough to "simply" determine which tasks can be automated and which ones can't, to solve the speech recognition problems and to develop a computer grader. Rather the effort must address the above tasks and then go on to observe the trainee in a realistic training environment and determine how to tie together the system capabilities previously developed. The R&D effort must determine how the training system can:

a. Motivate the trainee, show him that he can accomplish the job.

b. Challenge the trainee without overburdening him.

c. Teach individual skills and then tie them together into a cohesive whole.

d. Recognize that the standards for performance are valid in the simulated operational environment.

An Alternate Approach

Let's recap the important points just briefly:

a. Investigations of the automated speech technologies are essentially independent of the choice of trainee console.

b. Performance measurement at the level of terminal objectives is recommended by the AIC instructors, and this can occur for the most part by monitoring only the student's verbal behavior.

c. Use of the UYA-4 console is essential if motor skills are of interest in NAVTRAEQUIPCEN's research program

d. Evaluation of new training approaches must be conducted in a realistic operational environment, using the NTDS.

With these points in mind, and assuming motor skills are not of interest to NAVTRAEQUIPCEN, a research program which utilizes both a commercial graphic-CRT console with simulated NTDS functions, and the NTDS program with UYA-4 console, should be seriously considered by NAVTRAEQUIPCEN. By careful design of the software subsystems, it is entirely feasible to develop the ACTS and do preliminary tests, evaluation and research, using a graphic-CRT. After the basic systems are functioning, the system can easily be integrated into an operational-like environment including the use of NTDS and the UYA-4 for system level evaluation. This two-phase attack will realize all the advantages of both the non-NTDS and with-NTDS approaches. System development will be simplified while at the same time system evaluations will be meaningful and accurate.

The key to the success of this dual console approach is to design the software in such a way that all radar simulation and NTDS-related functions are modularly separated from the speech understanding, performance measurement, exercise control, and aircraft simulation functions. This can be done. See figures 12 and 13.

The hardware components of the early system development configuration of ACTS would probably be nearly identical to the hardware configuration of the prototype GCA-CTS. Additional core and processor capability may be needed to support ACTS because of the increased burden on the speech recognition requirement.

The NTDS supported system evaluation configuration of ACTS is shown in figure 15. Notice that the radar video is fed to the NTDS console through a Radar System Simulation Unit (RSSU). The RSSU is specifically designed to interface with the NTDS equipment suite. The unit, built by Logicon, Inc. around a Nova 800 computer chassis, provides radar and IFF/SIF videos to the NTDS at the proper ranges, azimuths, beamwidths, intensities, and pulse widths to stimulate the NTDS as if it were receiving live radar and IFF/SIF signals. RSSUs have previously been used to provide video to the FCTCP mockups on a variety of occasions. Utilization of the RSSU in the ACTS should be considered a low risk, low cost, situation.

FCTCP personnel have indicated that a UYA-4 console and the other NTDS support systems can be made available to NAVTRAEQUIPCEN for this research program whenever they are not in use for fleet training

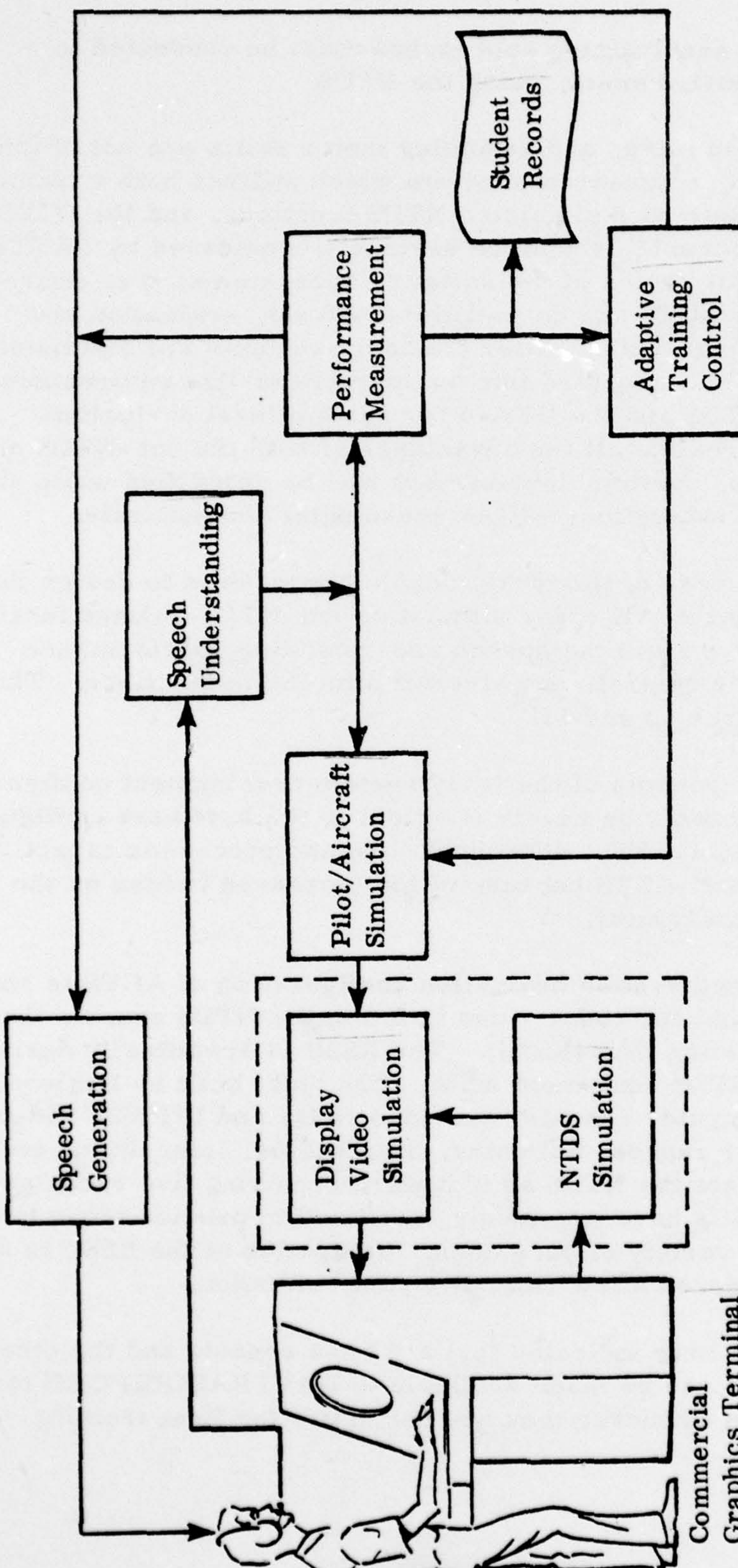

Figure 12. ACTS Development System.

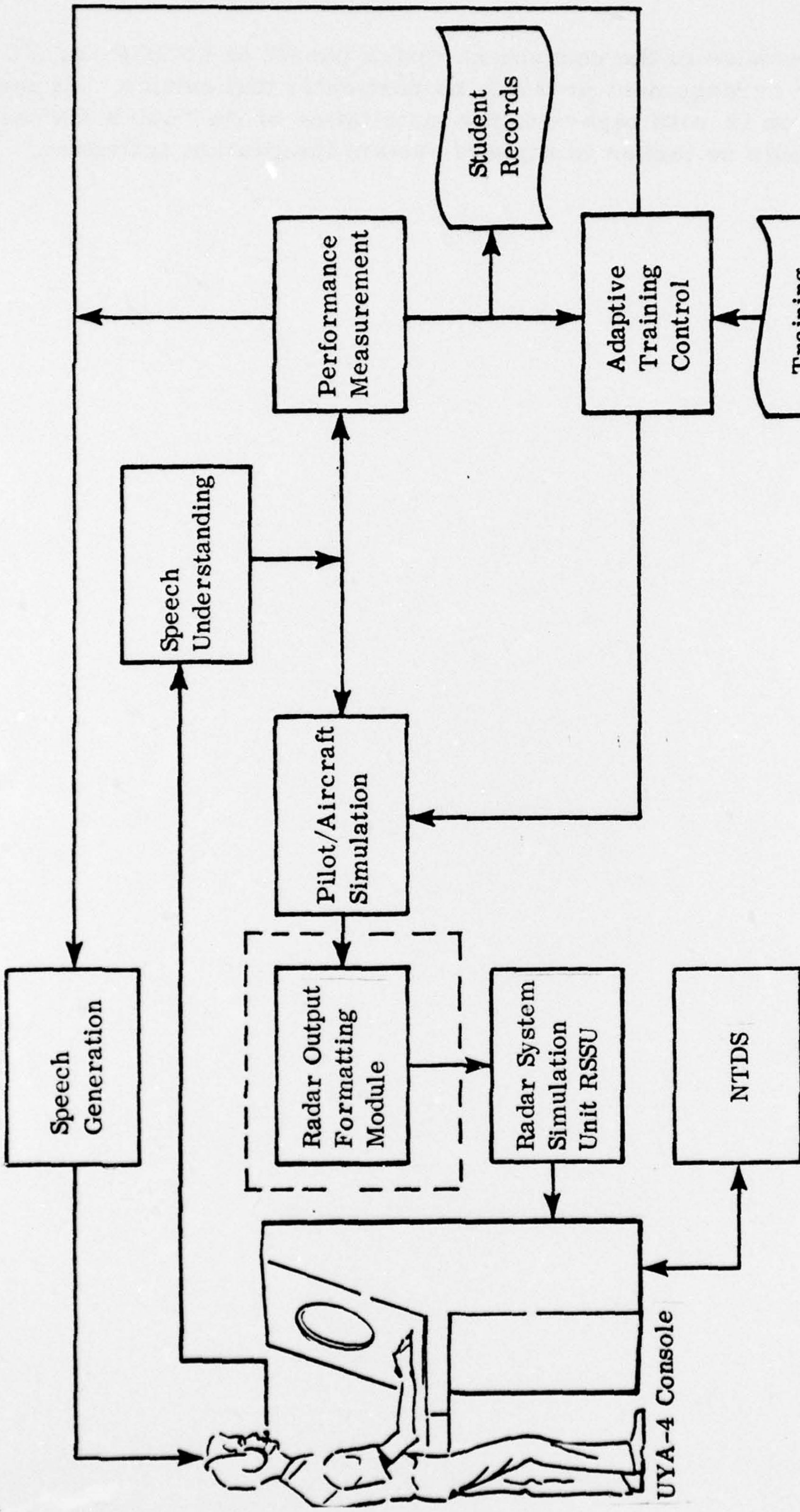

Figure 13. ACTS Evaluation System.

exercises. Because of the convenient "patch panel" at FCTCP and FCDSSA, this "sharing" arrangement presents no particular difficulties. As mentioned in section IV with regard to the installation of the "quick-fix"hardware, NAVELEX should be tasked to support system integration activities.

SECTION VII

CONCLUSIONS AND RECOMMENDATIONS

Introduction

This study covered a considerable range of material which has been reflected in the variety of topics discussed in the report. In order to preserve the focus of the original statement of work, this section will recapitulate the findings on a point-by-point basis against that statement of work. In addition, the section suggests specific action items and also a preliminary program plan for development of NAVTRAEQUIPCEN's training/research system.

Statement of Work Tasks

The FCTCP AIC Training Analysis – A task analysis of the air intercept controller was conducted by FCTCP personnel. The emphasis throughout that analysis was in defining the tasks performed by the AIC, rather than describing the equipment which he operates. As such, the resulting course was a departure from the more traditional AIC training approaches. The synthetic portion of the course is comprised of thirteen levels, blocked and sequenced such that the student is naturally led from the easy to the difficult, from the simple to the complex. Although the new course structure has been utilized for only several months, it is generally acknowledged to be a significant improvement over the previous methods.

A more complete implementation of the Instructional Systems Development (ISD) concept to the AIC training problem would proceed from these existing task listings to specify in greater detail the conditions associated with each terminal objective, and both the conditions and standards associated with each enabling objective. Specification of the conditions will document the simulation requirements imposed upon both the present and future training systems. Specification of the standards will ensure a more uniform performance grading system across all instructors, and give greater visibility to course weaknesses. Also, as discussed in section VI, a more complete specification of the conditions and standards is a prerequisite to development of automated performance measurement, computer grading and adaptive syllabus control. To the extent that these features will be included in future training systems, they should be documented in the formal ISD sense.

Based upon the task analysis developed by FCTCP, the appropriate training media should also be reviewed as part of the complete ISD process. The existing course (synthetic portion) has, for the most part, been structured around the TACDEW system. Training effectiveness may indeed be improved by re-evaluating different presentations and teaching methods in light of the identified AIC tasks.

Finally, it was determined that a task analysis has not been performed for the Antisubmarine Air Controller (ASAC). While formally not a part of the AIC program, the ASAC training program is integrated with AIC because of the similarity in simulation requirements.

The AIC Controller Model – A controller model was defined as "a codable model of controller behavior." The learning objectives, along with their associated conditions and standards, constitute the controller model at the functional level. Branching from the conclusions of the previous paragraph, therefore, the AIC controller model at the terminal objective level is largely defined by the existing task listings, except for some weaknesses in specification of relevant conditions. The controller model at the enabling objective level is largely undefined. Development of a complete controller model will require specification of a representative scenario which includes the stimulus and response elements associated with the AIC's performance of his responsibilities. The level of detail of this specification will depend upon the purpose toward which the model is being developed. As the vehicle for automated performance measurement, the controller model must be defined to the level that measurement will occur (e.g., the standards associated with terminal objectives). As the vehicle for automated diagnostics, the controller model must be defined to the level that diagnostics will be administered (e.g., the enabling objectives). Development of the controller model, therefore, should follow definition of the requirements which necessitate that development.

AIC Vocabulary – Many, though not all, of the terminal objectives of AIC tasks can be stated in terms of the verbal transmissions associated with these tasks. The specific AIC phraseology was examined and found to be only loosely defined, particulary when compared to the vocabulary associated with GCA. Moreover, there is a heavy emphasis on the transmission of numerical data. While it is possible to provide remedial training support using existing isolated word speech recognition techniques together with speech stylization, a more complete AIC training capability (including performance measurement) based on IWR would be, at best, marginally acceptable.

A mixed strategy of several speech recognition techniques were considered: expanded (30 word vocabulary) limited continuous speech recognition; isolated phrase recognition, and word spotting. These capabilities, together with some forced stylizations, restrictions as to personal variations, and procedural accommodations, should permit the development of an effective speech recognition based training system.

Near Term FCTCP Support — This study reviewed the feasibility of providing a temporary solution to FCTCP's manpower and training time problems through the use of an advanced speech technologies based system. This system would simply replace the PC&E pseudo-pilots and not include performance measurement or adaptive syllabus control. As such, the vocabulary requirement can be relaxed (to the extent that existing isolated word recognition techniques together with a clearly defined stylization rule can support the application) with low technical risk. The system as conceived would replace the current 15G17 CRT Target Control Subsystem. The one computer TACDEW-MSP and an appropriate NTDS operational program would complete the training configuration.

In addition to this "quick fix" system, additional support for FCTCP's current AIC training program was identified. More exercise scenarios could be presented to the students to increase the various learning experiences associated with each level. Also, the L-TRAN capability could be more effectively utilized to present basic console related tasks to the trainees. Finally, more advanced synthetic exercises could be developed to augment the three week "live" portion of the course, and for the benefit of current AIC's who wish to maintain their qualifications.

The NTEC AIC Research Training System

In addition to the topics discussed in the preceding subsection this report also addressed the AIC research training system being planned by NAVTRAEQUIPCEN. Indeed, it is this system, ACTS, which generated interest in AIC performance measurement, the controller model, advanced recognition capabilities, etc. A guiding assumption throughout this study was that ACTS would serve as an engineering testbed for may of the technologies and instructional features which would later be implemented on an AIC/ASAC trainer scheduled for the 1980's. Thus, rather than being an operational trainer as such, ACTS has been perceived as a research tool which would support the functional and design specifications of the ("real") AIC/ASAC trainer. The functional and design requirements of ACTS, therefore, must reflect not only AIC training goals, but also (and just as importantly) NAVTRAEQUIPCEN's research goals.

The fact that both training and research requirements will impact ACTS has caused interesting trade-off problems in terms of the configuration of ACTS. While details of the system must await a more precise specification of functional requirements, it is suggested that a dual configuration, one for system development and one for system evaluation, should be carefully considered. Unlike the GCA tasks, the air intercept controller must constantly interact with a highly sophisticated system (NTDS) through a complex console (the UYA-4). Determining the influences that these interactions cause in terms of the characteristics of the training environment is seen as an important part of the ACTS program.

The collection of AIC tasks which should be addressed by ACTS is similarly impacted by the dual character of the system. Choosing the research training scenario at this time is putting the cart before the horse. A clear and precise definition of the specific goals of the ACTS program, particularly in terms of the ACTS' relationship to the AIC/ASAC trainer, will provide the framework around which meaningful and cost effective decisions can be made.

Recommendations

Having concluded this brief study of AIC training, four areas can be identified for recommending additional work: the FCTCP "quick-fix"; the ASAC task analysis; AST developments; and ACTS development. Recommendations for each of these are discussed in the following paragraphs. See figure 14.

The FCTCP "Quick Fix" – The EGOR system described in section IV of this report represents a viable solution to FCTCP's immediate manpower and system utilization problems. System development should proceed as soon as possible.

ASAC Task Analysis – A systematic analysis of ASAC tasks is sorely needed. This information will become the basis for the functional design

	GFY 78				GFY 79				GFY 80				Maximum Labor Loading During Activity
	1	2	3	4	1	2	3	4	1	2	3	4	
FCTCP Quick Fix		—	—										3
ASAC Task Analysis		—	—	—	—								2
AST Development													
Basic LCSR	—	—	—										3
Expanded LCSR			—	—	—								3
Word Spotting				—	—								2
ACTS Development													
Requirements Analysis	—												2
System Definition		—	—										2
System Design			—	—	—								3
Programming				—	—	—	—						4
Test							—	—	—				3
Conversion to NTDS Based System								—					2
Test and Evaluate									—	—	—		2
Report										—	—		2

Figure 14. Recommended AIC Activities.

of the ASAC portion of the 1980 trainer. Moreover, relevance of AIC related research (e.g., ACTS) to the ASAC training problem, will become clear only after a ASAC task analysis is performed. Following the steps noted in section V, figure 15 shows a tentative work plan.

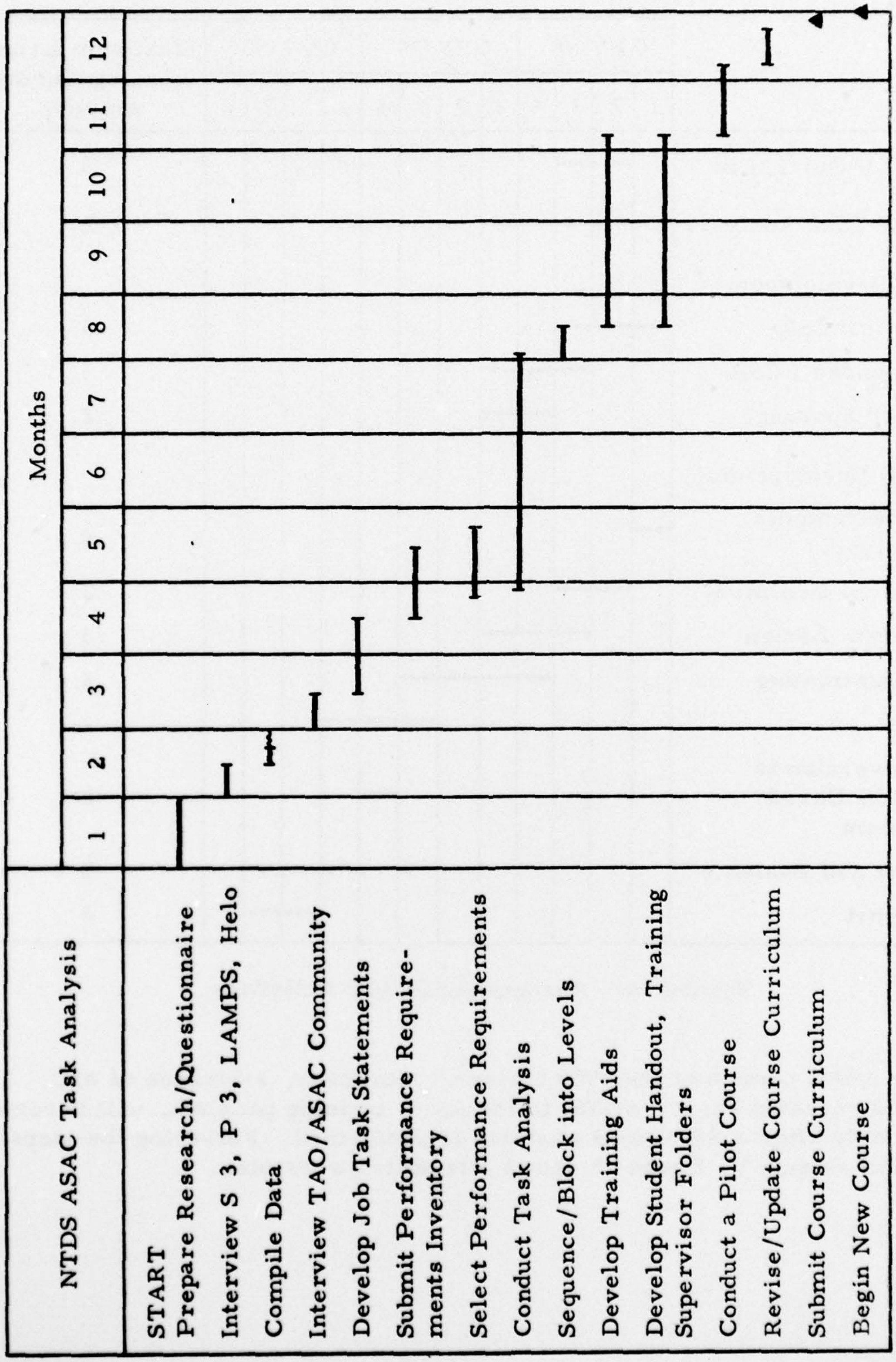

Figure 15. ASAC Task Analysis Schedule.

AST Development – A complete, automated and adaptive AIC training system cannot be supported solely by isolated phrase recognition systems. Further R&D is required, including:

a. Proceed with development of a basic LCSR capability (strings of digits).

b. Expand the basic LCSR technique to support a 30 word vocabulary.

c. Develop a word spotting capability.

ACTS Development – An AIC prototype training system is a proper stepping stone toward the AIC/ASAC trainer, as well as a worthwhile research tool in its own right. Prior to formal system development, however, a short (approximately 3 months) effort should be commenced immediately to define the specific research and training objectives of such a system; to define the specific end products that such a system should yield; and to clarify and specify the relationship of this training/research system to the AIC/ASAC trainer.

Once the requirements are established, the usual development process should commence, consisting of functional specification, design, programming, test, as shown in figure 14.

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