ARI Research Note 92-40

Observing Team Coordination Within Army Rotary-Wing Aircraft Crews

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May 1992

United States Army
Research Institute for the Behavioral and Social Sciences

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Accesion For		
NTIS CRA&I	☑	
DTIC TAB	☐	
Unannounced	☐	
Justification		
By		
Distribution /		
Availability Codes		
Dist	Avail and / or Special	
A-1		

NOTICES

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
1992, May

3. REPORT TYPE AND DATES COVERED
Interim Apr 90 - Oct 90

4. TITLE AND SUBTITLE
Observing Team Coordination Within Army Rotary-Wing Aircraft Crews

5. FUNDING NUMBERS
MDA903-87-C-0523
62785A
791
1211
C05

6. AUTHOR(S)
Thordsen, Marvin L.; Klein, Gary A.; and Wolf, Steve (Klein Assoc., Inc.)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Klein Associates, Inc.
Yellow Springs, OH 45387

8. PERFORMING ORGANIZATION REPORT NUMBER
--

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Research Institute for the Behavioral and Social Sciences
ATTN: PERI-SR
5001 Eisenhower Avenue
Alexandria, VA 22312-5600

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
ARI Research Note 92-40

11. SUPPLEMENTARY NOTES
Contracting Officer's Representative, Charles A. Gainer

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE
--

13. ABSTRACT *(Maximum 200 words)*

The purpose of this project was to demonstrate the feasibility of using team decision models to help train crew coordination in the tactical helicopter domain. Ten aircrews were studied as they performed a tactical mission in a UH-60 simulator facility at Fort Campbell, Kentucky. The results indicate that the methods can be adapted for observing team decision-making processes during some types of helicopter missions. Five opportunities for aircrew coordination training were identified: rehearsing mission functional profiles, analyzing commander's intent during pre-planning sessions, focusing the time horizon, avoiding micromanagement, and getting cues for anticipation/confirmation during the actual mission. Recommendations were presented for training observers and instructors to use these categories.

14. SUBJECT TERMS
Helicopters
Metacognition
Time horizon
Commander's intent
Premission planning
Crew coordination

15. NUMBER OF PAGES
41

16. PRICE CODE
--

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std Z39-18

ACKNOWLEDGMENTS

We would like to thank Dennis Leedom of the U.S. ARI Fort Rucker Field Unit; George Kaempf and Joe Zeller of Anacapa Sciences, Inc.; and Robert Simon and Eugene Pawlik, Sr., of Dynamics Research Corporation who provided us with direction, coordination, and assistance throughout this project. We would also like to express our appreciation for the cooperation and assistance of everyone at the UH-60 Flight Simulator Facility at Fort Campbell, Kentucky, and the pilots of the 101st Aviation Regiment, 5th and 9th Battalions. This project would not have been possible without their cooperation.

OBSERVING TEAM COORDINATION WITHIN ARMY ROTARY-WING AIRCRAFT CREWS

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OBSERVING TEAM COORDINATION WITHIN ARMY ROTARY-WING AIRCRAFT CREWS

INTRODUCTION

The goal of this effort was to identify training requirements for helicopter crew coordination. We wanted to define a set of theory-based categories that instructors could use in evaluating team decision making in order to provide training feedback.

Crew coordination is vital for mission success in a variety of domains. Rarely is a single decision maker responsible for accomplishing an important task. Usually, groups will be involved. In this project our emphasis is on teams, a sub-class of groups in which there are several information sources, interdependence and coordination among team members, adaptive management of internal resources, common goals, and defined roles (Orasanu, Duffy, & Salas, in preparation). Specifically, we attempted to learn more about aircrew teams: two-person, rotary-wing aircrews. We attempted to understand how they worked together to perform missions and to learn what distinguished effective and ineffective teams.

We must learn how to observe crew coordination in order to improve it. If we want to train aircrew coordination we need to specify the types of behaviors we want to promote and the behaviors we want to minimize. Whether instructors work in simulators, in classrooms or in actual training flights, they must be prepared with training objectives so they will know what to look for and what types of feedback to provide. It is easy for instructors to emphasize procedures. Crew coordination is more subtle, and instructors may just neglect this aspect of performance. Moreover, the observations must be made and interpreted rapidly in order to have training value. Feedback delays can limit the usefulness of the lessons.

We also want to make sure that the instructors understand the reasons for the observations. If instructor pilots are simply given lists of unrelated categories to observe, their burden is increased substantially. Anyone can make up lists of factors that seem to relate to crew coordination. For coherence, ease of application, and ease of modification, it is important that the categories used for observation and evaluation be linked to theories of team performance and team decision making.

Many researchers have tackled the problems of crew coordination. We cannot review this literature here. The interested reader is directed to recent work by Orasanu, Duffy, and Salas (in preparation) and Swezey and Salas (in preparation) for more comprehensive reviews. These sources document the need for theory-based methods for observing and evaluating team decision making.

The current effort to develop a theory-based approach to evaluating aircrew coordination was sponsored by the Ft. Rucker Field Unit of the Army Research Institute. The rationale for this effort was a set of projects we had recently performed (Thordsen & Calderwood, 1989; Thordsen, Galushka, Klein, Young, & Brezovic, 1990; Thordsen, Klein, & Calderwood, 1990) studying team decision making in commercial aircraft, and in command-and-control settings. In addition, we have developed a cognitive model of team decision making (Klein & Thordsen, 1990; Thordsen & Klein, 1989).

Our goal for this project was to apply our cognitive model of team decision making to the task of describing when rotary-wing aircrews are showing effective versus ineffective coordination. We were not attempting to collect data systematically, but rather to determine which of the team decision-making dimensions seemed useful for the domain of Army helicopter missions. In the next section we describe the model we used to guide the research.

COGNITIVE MODEL OF TEAM DECISION MAKING

A cognitive model of Team Decision Making (TDM) has been proposed by Thordsen and Klein (1989), who assert that a team can be studied and understood using concepts derived from cognitive science.

The cognitive model of TDM treats the team as an emergent entity. A UH-60 helicopter crew can be considered to consist of three entities: the Pilot Flying (PF), the Pilot Not Flying (PNF), and the team of both of them together. The value of this formulation is in helping the observer focus on the team as an entity rather than becoming engrossed with the individual team members. We want observers to be able to think about how a team perceives its world, how the team's behavior is directed, how the team makes inferences, and how the team uses its resources efficiently to solve problems and make decisions. In other words, if an instructor can learn to think of the way the team is thinking, using cognitive processes typically applied to individuals, then it may be easier to notice team coordination problems.

The cognitive model of TDM attempts to map a set of cognitive processes from the individual level to the level of team coordination. Accordingly, the following assertions can be made:

1. <u>The mind of a team can be treated as analogous to the mind of a person</u>. The goal of this analogy is to help us understand, study, and represent the performance of a team. The unit of analysis is the team, a group of individuals with common goals and coordinated roles. A team may have extensive experience working together, e.g., an Army division-level headquarters, or, like the crew of a commercial airliner, the members may be meeting each other for the first time just prior to takeoff. In contrast to a team, a group of individuals may not have consensus on goals and roles so that interesting features of teamwork do not emerge.

2. <u>The team needs to perceive its environment</u>. Just as an individual depends on perception, so does the team, and limited perceptual and attentional resources come into play at both levels. The team members can each be aware of a great many cues, but only a few of these can be communicated to the entire team, otherwise everyone would be talking simultaneously and continuously. We are positing a "spotlight" model of consciousness for the team mind, in which team members publicly share only a

part of what they are noticing, which results in selective attention for the team as a whole.

Perception is an active process, so a team is not just receiving information, it is also focusing its attention on events in the future, and on critical cues that must be monitored. The way a team perceives a complex environment can be described as its "situation assessment." We feel that a team's ability to form accurate situation assessment, and to share this understanding, affects its success. The sharing of situation assessment is also referred to as a shared mental model (e.g., Salas chapter in Swezey & Salas, in press).

3. Memory retrieval is important to teams. The wide range of experiences offers teams the strength of a large available memory base. The burden is for the team to know where particular items of information can be retrieved, and to develop strategies for storing information with just enough redundancy; you may want several team members to know about critical facts, but it is distracting to tell everything to everybody.

4. The team mind depends on metacognition. Metacognition is thinking about thinking, and refers to the way we size up a problem and select a strategy that takes into account our limited working memory capacity, time pressure, likelihood of interruptions, and so on. At the team level, metacognition refers to the team's ability to manage itself as it carries out a task. The team must be careful not to create excessive workload for individual members, and know how to monitor what is going on. We have seen teams where the leader spent so much time checking on progress that the team members couldn't get any work done. Another type of metacognition issue is how to assign tasks so that supervision is effective without leading to micromanagement. The management of teams is parallel to the metacognitive management of individual cognitive resources.

5. The team mind is affected by motivation. Here we are interested in the way motivation directs performance. One type of motivation is the intent of the leader. If intent is understood, then teams can readily adjust to unanticipated events thereby improvising effectively rather than being bound to an obsolete plan of action. We have been able to evaluate the team's understanding of its intent by conducting interviews after a decision-making activity and asking each member of a team what the leader wanted to do at a given moment. In a poorly running team, the intent will not be communicated or understood.

6. Sensori-motor coordination is analogous to the way the team coordinates the actions of individuals. A smoothly functioning team can be identified by its positive efforts to improve coordination. Here the "team mind" would be seen as synchronizing the actions of the individual team members.

7. Teams show other cognitive phenomena such as reasoning. When various team members know different things the team must be able to integrate information from all of these sources. The team must be able to recognize

patterns--when different components are presented to different team members the team mind must be able to integrate the pieces in order to find the pattern. The "team mind" is capable of learning, and team members must be careful about how they store new information to be sure that it is accessible for efficient retrieval. The "team mind" must be able to perform mental simulations to evaluate proposed courses of action. At Ft. Leavenworth we observed an example of a request from Corps to move a division line of defense forward. The Division Commander was unsure whether this was feasible but the Operations Officer insisted it could be done, and contacted Corps headquarters to confirm compliance. The instructor for this exercise was watching and simply asked the team what was the risk of trying to move a line of defense forward with little notice and barely enough time. Upon reflection, even the Operations Officer could see it was a poor idea--if the roads were damaged, or if they encountered air attacks or artillery, there was a possibility they would not reach their objective in time and would have to use a hasty defense rather than the prepared defense they had already developed. Until the instructor asked this simple question, the team simply did not attempt to simulate the risks in the course of action they were committing.

In addition to these aspects of a "team mind," there are three levels of observing team processes: behavioral level, pre-conscious level, and conscious level.

1. The team's cognitive processes are linked to behavior. The team acts, as does a person. The decision to shut down an engine is a team action, regardless of whether the suggestion was made by the Captain or the Flight Engineer. Any action or message is considered to come from the single entity, the team.

The embodiment of the team is its observable, recordable behavior. If the Air Traffic Controller issues a directive to any one of the three team members, it is assumed that the directive will be acted on by the whole team. If a distress signal is sent out, it is considered to come from the whole team regardless of which crew member made the announcement. For a command-and-control team, the embodiment is the set of plans it issues.

2. Part of the team mind is pre-conscious. This refers to knowledge held by one person but not shared with others. It is important to note that we are using "pre-conscious" to refer to any material that is fully conscious for one or more team members but has not been publicly brought to the attention of the team.

The phenomenon of pre-conscious awareness is more easily studied at the team level than at the individual level. Videotapes and interviews will show when one team member had knowledge not available to the others. For example, in our NASA/Ames study (Thordsen & Calderwood, 1989) the Flight Engineer noticed that the number 7 slot was not extending as they were getting ready to land. He dug out his checklist before saying anything to the other two team members, who quickly detected the problem themselves. He assumed they would find the problem, and he was preparing for their inevitable request that he go through his checklist of landing problems. But until the other team members noticed the problem, it was pre-conscious in the team mind.

The determination of what information has not been retrieved into the team's working memory, i.e., the team's attention, can be made through observations of videotapes and through interviews that enable us to learn what an individual knew that was not communicated to the other team members. We have also used formal strategies, namely a Critical Decision method (Klein, Calderwood, & MacGregor, 1989) to perform cognitive probes of individual decision-making strategies.

3. The team's consciousness is whatever is publicly articulated, or signaled--so the collective consciousness of a team can usually be studied by listening. In other words, the content of collective consciousness is directly accessible while the team is performing a task. It can be studied without interfering with the task. For example, in the NASA/Ames study (Thordsen & Calderwood, 1989) one malfunction was a leaking fuel tank. When this was detected by the Flight Engineer it was immediately brought to the attention of the other two teammates, the Captain and the First Officer. At that point it entered the collective consciousness of the team and we could observe this consciousness on videotape.

An item of information has entered the team's situation assessment when all or most of the team members are aware of the information and/or intentions. This joint awareness is achieved by discussion, or by watching for non-verbal cues, including sounds of switches being thrown or the sounds of flap wheels turning. Cues are shared and crew members know the cues have been shared and observers can generally detect the sharing as well.

The model of team mind is intended to help observers become sensitive to the functioning of the team, rather than the performance of individuals within the team. We can present a partial list of cognitive functions that seem applicable to team decision making. Doubtless there will be additional cognitive phenomena that will be identified. As we evaluate these phenomena we hope to clarify a number of team performance issues.

LINK COGNITIVE MODEL OF TEAM DECISION MAKING TO THE DOMAIN OF ROTARY-WING CREW COORDINATION

We wanted to use the cognitive model of team decision making as the basis for the project. While there has been a substantial amount of research on individual and team decision making that has not been anchored to specific cognitive models, one requirement of this project was to make sure it was built on a cognitive foundation.

Based on our observations of various team decision activities, particularly our research at NASA/Ames studying Boeing 727 crews, we identified four cognitive processes as particularly relevant for the rotary-wing exercises we were going to observe at Ft. Campbell. These processes or dimensions appeared to be the most salient for distinguishing effective and ineffective teams: perception, metacognition, motivation, and reasoning.

Perception. We hypothesized that there would be two ways that perception affected crew coordination for the mission we were studying: communication of new inputs, and situation assessment.

We expected to see differences in the way crews described new data. For example, aircrew members rely upon instrumentation to provide them with information about things that they are not able to perceive directly, such as the Radar Warning Receiver (RWR) which provides a crew with information concerning enemy threats to their aircraft. Because the ship often is flying very close to the ground, it is critical that the individual who is actually flying the aircraft keep his/her attention "outside" the cockpit. Therefore, when the RWR goes off, transmission of the information on the RWR screen by the person not flying to the person flying becomes an important crew coordination issue. Otherwise, the person flying will have to come "inside" the cockpit and look at the RWR indicator to know which direction the threat is coming from, which in turn helps determine the necessary direction and type of evasive maneuver.

We also expected to see differences between crews in the way they formulated and communicated their shared mental model, or shared situation assessment. Situation assessment (SA) is the attempt to take perception of the current state, along with knowledge of previous experiences, and evaluate this information to reach some understanding of: critical cues that should be attended to, what to expect if the appraisal is correct, and possible actions that can be taken.

We anticipated that it would be important for aircrews to learn how to coordinate their understanding of expectancies and cues. Because of the elevation and speed at which the aircraft is flying, there will be a need for the navigator (PNF) to inform the person flying about what types of terrain features s/he should expect to see if they are still on course. Simultaneously, the person flying needs to inform the person navigating about the terrain features (cues) that can be observed. That is, the navigator needs to provide expectancy information while the person flying needs to provide actual visual sighting information so that they can determine whether the expectancies are confirmed or not.

Metacognition. Almost all teams require some metacognitive processes to keep the team itself operating smoothly. That is, some effort must go towards keeping the team functioning as a team, for example, making sure that workload is reasonably distributed, seeing that communication is flowing adequately, assuring that elements of the team have (at least minimally) an understanding of what the other components of the team are doing, and so forth. In this domain we anticipated a possible problem regarding role confusion. Since helicopter crew members are comparably trained and they interchange roles during the mission (person flying versus person not flying) there may be difficulties if crew members inadvertently or unexpectedly shift roles, leaving some tasks unattended. This should require special diligence on their parts to make sure they are aware of the current roles and tasks each other is fulfilling. Therefore, we need to be open to the possibility that metacognitive issues might be important in this setting. Conversely, the fact that these teams were very small (two members of the crew), were not geographically distributed (which helps to avoid many complex communication problems and simultaneously allows non-verbal communication to contribute to the metacognition of the team), were in well-defined roles (pilot flying, pilot not flying), and were flying a well-defined mission (improving the probabilities that the team conducted the exercise with a fairly good overall understanding to begin with) made us feel that while metacognitive issues would be present, they would not be as critical as in some other domains.

Motivation. On an overall mission level, there should be a fairly good understanding of the goals since these should be clearly stated in the mission plan. However, there could be confusion about sub-goals when the crews are confronted with unexpected situations such as becoming lost. In these cases, it may be important to attend closely to whether and how crews communicate the emergence of sub-goals.

The Army's term for the directive function of motivation is Commander's Intent (CI). CI is important since plans seldom work as well as anticipated. In fact, in many settings, the plan is obsolete within hours of implementation. The statement of intent should provide the participants with a broader perspective that includes not only the plan itself, but some of the logic and reasoning behind it. The importance of this is to provide a framework from which to resolve points of confusion and to assist in determining how to continue (i.e., improvise) in the event that the planned actions no longer appear appropriate. In an ideal situation, if confusion arises or if the plan falls apart, the crew members could contact their headquarters, ask for clarification or additional orders, and continue accordingly. However, this presupposes two things: their communication channels are working properly and time is available to make the call. In any tactical, military domain it is not prudent to assume the former, and as mentioned earlier, the latter is not necessarily true during many stages of these helicopter missions. Therefore, comprehension and, if necessary, clarification, of the CI is considered important in mission coordination (i.e., not just for their own ship) since the crews' understanding of intent will impact their interpretation of the mission goals which in turn guides any improvisation determined necessary.

Reasoning. The form of inference most relevant here is mental simulation. After the situation assessment has taken place, there are usually some potential options identified. Mentally rehearsing the execution of these options is often a key component in the decision-making process. Sometimes it may be possible to begin implementing the option immediately, anticipating that if difficulties arise mental simulation and problem-solving techniques can be brought to bear to help modify the planned actions. Planning to make adjustments during implementation may be reasonable in a domain where there is time available for troubleshooting. However, in the tactical helicopter domain this is seldom the case. In fact, there is often barely time to make critical adjustments to the flight path to avoid collisions with obstacles. The implication is that there are many stages of flights when crews cannot count on being able to do mental simulation and problem solving. These apparent restrictions on using mental simulation during many stages of the mission could contribute to coordination errors. That is, when difficulties arise that are not anticipated (e.g., through mental simulation) the workload demands are such that many other tasks (including coordination) will be neglected.

There is another cognitive process that should be discussed here because of its potential relevance: sensori-motor coordination. This refers to the synchronization of actions for different team members. Since members of these crews are not geographically distributed and are directly connected through communication sets, many of the synchronization problems are minimized. Both pilots are briefed on the mission's overall goals and are instrumental in planning how they will accomplish it. Thus, some of the implementation problems that could occur because of misunderstandings are reduced. In addition, the pilots also have direct visual contact with the environment which reduces some potential problems since crews do not have to rely as heavily on "third party" descriptions of their environment. While coordination most definitely is important in the successful implementation of a plan, because of the mentioned factors, we did not anticipate that it would be a major area of difficulty for these crews.

OBSERVATIONS OF THE UH-60 SIMULATION EXERCISE

The UH-60 Blackhawk helicopter simulator facility at Ft. Campbell, Kentucky, was the site of the simulation exercise. Three observers from Klein Associates were present during 10 flights having the same mission.

Mission. The mission consisted of two distinct legs. The first leg involved picking up fuel blivets (refueling tanks) from the assembly area (AA) and moving them to a forward arming and refueling point (FARP). After the blivets were placed, the helicopter was to return to the assembly area to begin the second leg of the mission.

Leg Two of the mission was more complicated and dangerous than Leg One. In this leg, the helicopter was to lead a five-helicopter mission. The helicopter was to carry eleven soldiers to a landing zone (LZ) inside enemy territory. From there it was to recross the forward line of troops (FLOT) back into friendly territory, and refuel at the temporary (or jump) FARP created by the first leg of the mission. Finally, it was to link up with another helicopter to fly a possible follow-on mission. Several tasks and conditions that made this leg more difficult to complete follow.

1) The helicopter was to be flown across the FLOT. This would require the transponder (IFF) to be turned off going into enemy territory and back on when recrossing into friendly territory.

2) At several points enroute to the LZ, the helicopter would be within range of enemy Air Defense Assets (ADA).

3) Radio calls to be made on several different frequencies were required at various points in the mission (no radio calls were required on first leg).

4) The primary LZ was actually unavailable. If a radio call was not made on the correct frequency, the crew could not receive instructions to go to the alternate landing zone.

5) There was a "hard time" established for reaching the LZ. Shelling in the area would cease for only one minute (the precise time for this was set prior to the mission) while troops were inserted by the helicopter crew.

6) During the follow-on mission, the helicopter the crew was following gets shot down. The crew members must avoid enemy fire and follow correct procedures for the situation.

7) The helicopter encounters an inadvertent instrument meteorological condition (IMC) on the way back to its airbase. This required a conversion to all-instrument flight by the crew.

Mission characteristics. The characteristics of this helicopter mission differed from other team decision-making exercises we have observed. Table 1 presents a set of task features that we have found useful for distinguishing different domains, along with our evaluation of this task. Compared to other domains such as commercial aviation and military planning, we felt there was a low margin for error, along with high risk and extreme time pressure.

Table 1

Key Domain Attributes for Tactical Helicopter Domain

ATTRIBUTE	RATING	
margin for error	low	(errors could result in immediate crashes)
geographical distribution	low	(crew members were seated next to each other)
uncertainty	medium	(task was dynamic, but mission was carefully planned)
risk	high	(errors could lead to crashes)
adversary	yes	(enemy air defense assets were employed)
time pressure	high	
team cohesion	high	(team members understood roles and goals)
individual expertise	high	(crew members had 190-2500 hours flying)

Data collection. We have stated that the primary objective of this subcontract was to aid in the development of a training method for team coordination. It appeared that the most effective way to conduct this research was to make observations of the crew members while they were actually performing their tasks. To approximate a real-world environment, observations were made using the UH-60 Blackhawk simulators at Ft. Campbell.

The Ft. Campbell data collection took place between May 14-18, 1990. Three researchers from Klein Associates were present to conduct the observations. Ten crews comprised of two pilots each were observed as they carried out their mission in the simulator, and were then interviewed about particular portions of the mission as well as coordination issues not directly tied to that mission. The pilots interviewed included mainly W01s and W02s, although there were several Lieutenants and one Captain. The Klein Associates researchers worked either individually or in teams of two for each aircrew observed.

The crew observations were conducted via a monitor that tracked four cameras inside the simulator cockpit. Cameras 1 and 2 filmed each of the two pilots from the lower torso up to his/her head. Camera 3 was positioned behind the pilots to catch their hands moving to different areas of the instrument panel. Camera 4 recorded, from a remote location, the forward display seen by the pilots in the cockpit. The monitor used to make observations was capable of displaying four quadrants containing pictures from each of the four cameras or could allow the image from any one of the cameras to cover the entire monitor screen.

The crews were given a two-hour time period for the mission briefing and planning. Next, they flew the mission in the simulator, typically taking between 1.5 and 2.0 hours to complete. They were then debriefed by an Instructor Pilot (IP) who made observations from the back of the simulator during the mission. After debriefing, the pilots were given questionnaires to complete. At this point, interviews were conducted lasting from 45 minutes to 2 hours. All told, the pilots made themselves available for about 6 hours.

After several days of observing mission flights, we requested permission to observe the mission briefing and planning sessions held before flight. We received permission for this and observed three crews during this portion of exercise. As stated, pre-mission briefing took about two hours and proved to contain many of the planning and coordination issues that would manifest themselves during the actual mission.

The goal of the observations and interviews was to generate hypotheses about critical observation categories and potential aircrew training opportunities. We did not attempt to collect objective data (with a few exceptions noted below) on team behaviors, and we did not obtain data on team performance.

RESULTS AND DISCUSSION

This section examines four topics. First we discuss primary and secondary training recommendations--training the aircrews and also training the trainers. Second, we link these recommendations to categories for observing team decision making--the dimensions we expected to use, the dimensions we actually used, and the reasons for the differences. Third, we present some of the direct observations we were able to make. Fourth, we describe some indirect techniques we used to provide a different perspective of the team performance.

Training Recommendations

This section will cover two issues: primary training refers to how to train the aircrews, and secondary training refers to how to train observers and instructors.

Primary training. Primary training has to be accomplished using material collected during direct observations. We have identified five key objectives for training aircrew coordination: improving the time horizon so the crew is not behind the power curve, reducing micromanagement in the cockpit, encouraging feedback such as confirmations, improving the understanding of commander's intent, and using rehearsal strategies to anticipate changes in the functional mission profile. The first three (time horizon, micromanagement, and confirmations) would be trained during the mission, whereas the last two (rehearsal strategies and commander's intent) would be trained during the pre-planning session. Again, these recommendations are based on subjective impressions in which we compared performance in this domain to other team performance domains we have observed.

Time horizon. The ability of a crew to focus on an appropriate time horizon falls under the category of perceptual functioning. The concept of time horizon refers to how far ahead the aircrew is directing its attention. If it is not looking far enough ahead, it will continually be surprised by cues it failed to anticipate. If it looks too far ahead it may confuse itself and may fail to pay sufficient attention to important details of the immediate visual scene.

Our informal observations suggest that the ineffective aircrews are flying behind the aircraft, whereas the more effective crews are actively moving the perceptual horizon forward, ahead of the aircraft. It appears that the optimal horizon is just ahead of the visual horizon, about one navigational instruction in advance. This provides a lead time of about 30-60 seconds, but it depends on the terrain, speed, and complexity of the route the pilot was flying.

Below are two examples of time horizon. The first demonstrates a helicopter crew flying with a time horizon near zero. Note the pilot flying is leading the pilot not flying.

Example 1.

PNF: O.K. come back around left and follow the river up.

RADIO: Whiskey 41 this is Whiskey 17 I have us at grid 87-90 . . correction 87-80.

PNF: Yea, that's about where . . . well that's the LZ, lo' and behold. I thought we were down about 3 grids but we're in the right AO.

PF: O.K. which way?

PNF: O.K. turn around.

PF: Right, left?
PNF: Left.

PF: Coming left.

The second example shows a crew that is operating comfortably within the time horizon of the helicopter. The pilot not flying provides a directive to the pilot flying and receives a rhetorical question in return indicating that the pilot flying has understood the directive.

Example 2.

PNF: O.K. Swing around to the left just a tad bit. Looking for a road intersection up here.

PNF: And there it is right there. (points)
PNF: O.K. come around to the left just a tad.

PNF: I hope that's not too far off. O.K. roll out.

PNF: Sort of parallel this road coming through here (looks out window).

PNF: We'll be crossing over it numerous times. It's gonna zig-zag back and forth in front of us.

PF: O.K. so we're going to the right of those hills?

PNF: Yes.

The concept of time horizon can be more broadly applied in this domain, since the pilots need to become sensitive to several different time horizons, each conditioned by delay cycles. There is the time horizon for maneuvering and navigating the helicopter, the time horizon for coordinating the actions of the other helicopters in the mission, and the time horizon for coordinating with the Tactical Operations Center. In each case, there is likely to be a tendency to focus farther in, and to assume that the system is more responsive than it really is. The training requirement is to learn how to counter this tendency and push the focus farther out.

It is difficult to learn how to coordinate the different time horizons, but we do not feel it is practical to teach crew members to adopt an overall mental model. This is something that will have to come through experience.

All that can be done is to provide the training opportunities for encountering each different type of time horizon, so that the crew members can capitalize on their experience.

We hypothesize that more experienced pilots would be able to use longer time horizons. Therefore, it would be counterproductive to try to teach any "optimal" horizons that would just have to be unlearned as the crew members became able to anticipate events farther into the future. Another complicating factor is that pilots can be overloaded if they are asked to anticipate events too far into the future. For these reasons, the training should simply attempt to help the crew members fly ahead of their aircraft, and to counter tendencies to fly behind the aircraft.

Micromanagement. This is one aspect of metacognition that we observed--the autonomy given by the PNF (usually the pilot in command) to the PF. In some crews, the navigator gave the pilot sufficient information to perform his mission, whereas in other crews the navigator (pilot in command) tried to do both jobs, with poor results. Crew 15 was a prime example of micromanagement. The pilot not flying (also the pilot in command) gave the pilot flying minimal guidance about what was happening. Instead, the directions to the pilot flying were all at a micro level: turn left here, stop, turn, etc. Because the pilot flying had no idea where they were in the mission, the PNF had to continually provide detailed instructions. This effort left little opportunity to navigate the helicopter. Not surprisingly, this crew was lost for much of the mission, and had little success in re-orienting its position. The PNF created his own problem by micromanaging the pilot flying, a clear metacognitive error. Furthermore, the instructor pilot never mentioned this problem during the After-Action briefing. The term "micromanagement" seems appropriate here.

Confirmation. An obvious training need is to sensitize the aircrew members to the potential for confusion in the other pilot. This type of concern is also linked to metacognition--thinking about how the crew members need to signal each other. The crews that appeared to do better were more careful to anticipate information needs, and especially to confirm that instructions and comments were heard. We also observed some crew members cross-checking to remind the other crew member about a task that might have been forgotten. Many aspects of communication can be trained as rote responses, e.g., how to shift controls, how to request a turn. We are interested in the less procedural aspects of communication, where the pilots must learn to appreciate what the other team member needs to know. The capability of shifting perspectives will enable a pilot to sense when to confirm an instruction, and when to initiate a cross-check.

Instructors can easily make note of instances where cross-checking is provided, or where confirmation is offered or omitted. For purposes of training, the term "metacognition" is a poor one to use in an operational setting. The terms "anticipation," "preparation," and "confirmation" are much more descriptive.

During the After-Action briefing, the instructor could present the mission observations. The instructor could explain what was noted in terms of time horizon, anticipation, and confirmation, and can use specific instances where these have been noted.

We also found the use of videotapes to be very helpful. The trainees themselves commented on the "awesome" potential of the videotapes. Clearly, it is not efficient to spend 90 minutes reviewing a 90-minute training session. However, the videotaping took little effort, and the videotapes were readily available as soon as the mission was completed. If instructors were shown how to correlate their notes with the videotape counter, they could perform a very effective debriefing by fast forwarding to the training segments they want to review. The tapes can help focus the training on specific examples of crew actions rather than just ratings or frequency counts. Good vs. bad instances can be replayed and discussed. Another use of the videotapes is to present examples of aircrews that were considered good exemplars for flying a particular simulator mission. Other crews can be shown these and can be asked to contrast aspects of their own performance with the exemplar performance.

Mental simulation and functional mission segments. During the pre-planning session, crews have the opportunity to build a shared mental model in advance of the mission. Such preparation would support crew coordination at critical points in the mission where there is no time to think through what is happening.

Some crews did a good job of this, but our observation was that a number of crews were failing to visualize the mission adequately. This represents a failure to derive important inferences about features of the mission. This lack of mental rehearsal extracted a toll on the crew's mission performance because in effect it left them ill-prepared to handle difficulties that they may have been able to anticipate with simulation. Thus when they ran into a problem in the actual mission, they had to either ignore the problem or divert attention from other critical tasks to make corrections or adjustments. When we questioned crews about this, they complained that they had much less time to plan than they would in an actual mission. This may be true of peacetime training missions, but it is unclear how much planning time would be available during combat. Moreover, the personnel responsible for preparing the task used planning durations that appeared consistent with operational constraints.

We also received the impression that there was little instruction in how to perform useful mental simulations of a mission, and that instructors were not prepared to critique the planning approach a crew took.

The ideal would be a crew that looked over the mission and the map and tried to imagine how they would fly through each functional segment of the mission. For example, in handling segments marked by difficult navigation they would visualize what the terrain would look like, and what terrain features to search for. Segments marked by exposure to enemy air defense could be studied in order to imagine how to use terrain features for masking. The aircrews would perform this type of visualization and would discuss it so that each crew member knew what to expect during the different functional stages of the mission.

In actuality, the mission was planned around check points that were major geographical features. These features were useful for tracking progress but they did not divide the mission into functional units. Thus, the helicopters crossed the FLOT between two check points. It is essential to turn off the transponder when flying into enemy territory, but many of the crews we observed failed to do this. Their attention was focused on the check points, and the change in mission status (flying over hostile territory) was not a part of their mental model. Similarly, there were no markers for returning to friendly territory, and many crews failed to turn their transponders back on.

Even worse, we saw pre-planning sessions where the pilot in command did the route planning, and spent less than three minutes showing the map to the pilot flying.

Therefore, we recommend the use of functional mission segments in rehearsing a mission, to supplement the geographical check points. The mission segments can help draw attention to segments where the time pressure will be great, communication demands will be high, navigation demands will be severe, concealment will be necessary, and so on. In this way, the unique problems of each segment can be anticipated by the two crew members. They could share their identification of problems and strategies.

It should be noted that mental rehearsal can be conducted during the mission itself, and not just during the pre-mission planning phase. There are periods of low workload during missions (e.g., waiting for planned takeoff times), when the crew members could be actively preparing for different functions. Because it is not feasible to provide active instruction during the simulated mission, we see the pre-mission phase as offering the best opportunity for training in mental rehearsal. During such instruction, crews could be told that they could take advantage of low workload periods during the mission. Once the mission is over the aircrews could be given feedback about whether they made effective use of slack times.

It is necessary but not sufficient to have crews that look at the mission from a check-point to check-point perspective. The check-point strategy, by itself, tends to collapse too much information into too small a package. It does nothing to help the crew members recognize the differing demands that different subsegments of the mission will place on their skills, attention, and needs. To simplify communication, we recommend that the term "mental simulation" be avoided, and replaced by terms that are less technical and more understandable, e.g., "active rehearsal" or "visualization," or "analysis of mission segments."

Commander's intent and improvisation. We did not see much confusion between the two pilots about what was intended, but there was a clear gap in understanding of intent between the aircrew and the Tactical Operations Center (where the mission plan was issued). The aircrews appeared to take an alarmingly uncurious attitude about commander's intent. The mission was described (i.e., drop off the fuel blivets during Leg One, and transfer the infantry to the LZ on Leg Two), and the only additional advice was to "Conduct (the) operation with speed, surprise, and precision." We contend that this advice was fairly useless, and in some ways contradictory since speed, surprise, and precision may represent conflicting goals. For example, the aircrews seemed to have little sense of how to proceed (and how to improvise) during Leg Two when complications arose--should they abort the mission if unable to make the drop during the scheduled one-minute period? If detected, thereby losing surprise, should they press on anyway? If they are not exactly sure of the drop zone, is it more important to make a drop on time or at the precise location, and how much margin of error is acceptable?

An example comes from one particular crew that found itself well off course and being tracked by the enemy. The crew abruptly changed the mission and shifted to the alternate landing zone without requesting permission or even checking with anyone.

> The Radar Warning Receiver (RWR) begins to beep slowly, increasing in speed as time goes on indicating that the enemy is tracking the aircraft.
>
> Person Flying (PF): [The RWR shows] us heading right towards an ADA site.
>
> Person Not Flying (PNF): Just use the hill as a backdrop out the right here.
>
> (beeps continue)
>
> PF: What the heck!?
>
> PNF: Do you see it? . . . . There it is over there (points towards missile site).
>
> PNF: Come left, come left.
>
> PF: Uh, we don't want to be here.
>
> PNF: No.
>
> PNF: We're gonna have to go to the alternate LZ.

One reason the plan was improvised to go to the alternate landing zone was because the crew recognized how far off course they were (near an ADA site) and that by the time they got to the primary landing zone they would have missed the one minute window. However, it was not clear from the intent statement that missing the hard-time window provided just cause to abandon the primary landing zone. Clarification of the intent statement may have prepared the crew for a situation such as this and helped them to avoid confusion about which LZ would be the proper one.

It is likely that the aircrews did not request mission-related information because they didn't conduct a meaningful mental simulation. Had they tried to imagine how the mission could run into difficulties, they might have noticed some of the ambiguities and asked for clarifications in advance.

We contend that aircrews can be trained to notice ambiguity and incompleteness during the pre-planning session, and that they will be able to take active steps to understand what constitutes mission success in order to improvise effectively.

These first two training recommendations are linked to the pre-planning. During the mission stage, the training can focus on time horizon and metacognition.

Secondary training. The goal of secondary training is to teach observers and instructors how to apply these five categories. Instructors are often prepared to attend to the content of performance, rather than the team decision processes. Our impression was that instructors typically do not notice or mention team coordination issues. Yet the instructors participating in the ARI study at Ft. Campbell did become sensitive to aircrew coordination. They were able to learn how to notice aspects of effective and ineffective coordination. Therefore, we feel that instructors can be readily trained to observe critical team coordination behaviors.

There may also be value in training researchers who are attempting to answer questions concerning the adequacy of different cockpit configurations for improving crew coordination. We have presented some compiled and indirect measures in order to illustrate what can be done to analyze crew coordination data. Careful research seems to depend on getting transcripts of the comments made by the aircrews, and these are expensive and time-consuming. We have no shortcuts to offer for improving the process of transcription.

Since it is desired that the training be handled by operational personnel (e.g., instructor pilots) during routine check-rides and simulator sessions, it is necessary to identify ways to pass on these methods to these personnel, that is, training the trainers. This will include helping them learn the data collection techniques (observation methods, note taking, what to be alert for), methods of collapsing the data into meaningful categories and summarizing it (identifying and using the underlying dimensions, etc.), and ways to present what they observed and summarize back to the trainees to optimize their learning potential (videotapes, reference to notes, questioning, and interviewing techniques, etc.).

Once the most important primary training objectives are defined, these secondary training materials can be developed. In initial attempts to present the observational dimensions to ARI personnel, we found that specially prepared videotapes could be a useful instructional material. For each dimension of interest, we were able to find positive and negative examples from the crews we had observed. It was relatively straightforward to put together a "highlight film" of these positive and negative instances as contrast sets to help people learn what each dimension consisted of. This training video was developed for demonstration purposes only, and if there was a requirement, a more carefully prepared video would be developed.

Review of Cognitive Categories

A number of the dimensions we expected to use turned out to be inappropriate for this domain. From our earlier experiences observing teams in operational settings and from the models we have developed from these experiences (Thordsen, Galushka, Klein, Young, & Brezovic, 1990; Thordsen & Calderwood, 1989; Taynor, Klein & Thordsen, 1987) we expected that aircrew coordination would be affected by perception, metacognition, motivation, and inference (mental simulation). We were correct about the importance of some of these categories but we failed to observe some categories we expected to find, and we did not anticipate others that turned out to be salient. The specific characteristics of the tactical helicopter mission were different from other domains we had studied, especially with regard to the need for rapid and coordinated action under extreme time pressure. The closest we have seen to this is in the domain of commercial aviation, for malfunctions occurring during takeoff and landing. In the subsections below we review some of our expectations, and link the five categories of observation described above to the cognitive model of team decision making.

Perception. We did not anticipate that the team's initial perception of its situation would be that critical since both team members would have access to much the same information (directly outside and inside the cockpit). This was not entirely true. The pilot often had little knowledge of navigation data other than what the pilot not flying described. So there were some additional burdens upon the "inside" crewmember regarding how s/he conveyed this information to the person flying. Another problem was that the simulator masked information--the person in the left-hand seat could not see much out of the right-hand window and vice versa.

We failed to anticipate a crucial dimension of a team's perception--time horizon. This refers to how far in advance the crew is functioning with respect to the real-time of the aircraft. For example, if the navigator gives navigational instructions that barely give the person flying time to make the proper adjustments it could be argued that they are operating with a near zero time horizon. While we have always been aware of time horizon as an important function of team performance, we have never seen it as critical as in this domain, because of the extremely low margin of error and the need to keep the pilot flying alert to the next landmark about to come into view, which is a demanding task for the navigator.

The problem of time horizon may be seen as a breakdown in shared situation assessment. We have seen this in our prior research, where one team member may hold information that is needed by others. In this case, navigators had trouble communicating cues that were about to appear, and describing expectancies, and as a result some teams flew behind their aircraft.

Metacognition. The primary shortcoming in metacognition that we observed was micromanagement, and we had not anticipated this. The difficulty we had expected was that there would be some role confusion. In this setting, both crew members are pilots and they interchange flying/not-flying roles during the mission. Each time they switch roles or tasks they must be careful to clearly communicate the transition to each other. The pilot not flying is always responsible for tracking information inside the cockpit, while the pilot flying is not to bring his/her attention inside the cockpit at any time.

An example of the crew members not recognizing the transition in roles follows: During one simulated mission the pilot not flying gave a series of instructions such as, 'go to the north side of the mountain,' 'slow your airspeed back a little,' and 'stop turn here.' After giving these instructions the pilot not flying finished with 'What's your time?'. This statement pulled the pilot flying into the cockpit for a moment to check the clock. In this brief instant the helicopter flew straight into the ground. Had the pilot not flying recognized that this request would pull the pilot flying into the cockpit, the resulting crash would have been avoided.

Another area that seemed to be important concerning self-management focused on specific communication techniques that the crews used. This centered largely on whether they provided information to each other in anticipation of needs, whether they confirmed for the other individual real-time information in response to anticipatory remarks or on their own, and whether they double-checked tasks and actions the other crew member was responsible for. There seemed to be differences in the way crews provided such feedback. In particular, some crews were very good about confirming instructions, whereas others rarely made any confirming comments at all. This topic is presented in more detail below.

Motivation. The ability of the team members to understand the commander's intent generally impacts a team's coordination. A good and common understanding of the overall mission goals allows a team to press on regardless of whether the original operational plan becomes obsolete. Intent provides the framework for any improvisation in the event things do not go as anticipated. Shared and accurate understanding of intent is especially important in situations where the implementors of the planned actions are geographically distributed. Since the two crew members were side-by-side, intent was not a problem inside the cockpit but it was a problem for the aircrew in understanding the mission.

Reasoning. Mental simulation is a form of inference in which a team can learn about the complexities of a task before it is performed. This is normally considered as one sign that a team is functioning effectively. We had anticipated that we would see some types of mental simulation within this domain. However, because of the extreme high time pressure and low margin for error, we observed little of this taking place during the mission itself. It was during the pre-planning session that mental simulation and rehearsal seemed most important.

Opportunities for Collecting Observations

In this section we describe in more detail what we actually looked for and observed during the data collection. This section describes the different observations and data that can be collected during the four phases of the exercise: the pre-mission planning, the mission, the after-action briefing, and the post-exercise analysis of videotapes and transcripts.

The pre-mission. The first two hours of the session were set aside for pre-mission planning and equipment checks. It is during this stage that the crews have the greatest opportunity to do the actual planning for the mission, to anticipate what might take place including problems they may encounter, and to clarify any confusion or misunderstandings that they may have. From an observational point of view, it is the best time to see what the crews plan to do, whether they mentally rehearse components of the plan's execution to identify weaknesses, whether they use imagery (a form of mental simulation) to envision situations where their instructions would be inadequate to help them make proper decisions (thus the need for additional clarification), and so forth. In other words, it is a good stage to watch how they do their planning, mental simulation and rehearsal, and clarify misunderstandings.

The mission. The second two hours of the session involved the crew actually implementing the flight plan that was finalized during the pre-mission planning. During this stage the crews are totally immersed in their mission execution, specifically flying and navigation. There is no time for intervention and questioning on the part of the observers thus data collection techniques must rely on observation alone. Things that can be observed include mission performance measures such as whether stages of the mission were completed, whether they were executed within the framework of the commander's intent, how the crews communicated between themselves and the nature of these communications, how much advance information they provided each other, and how well they maintained an understanding of the tasks the other was doing. The data collection techniques must focus on performance and communication issues. This stage of data collection can be augmented by flagging things during the pre-mission period that deserve special attention during the mission execution.

After-action briefing. The final two hours of the session involved debriefing, questionnaire completion, and 45 minutes of interviewing time. It was during this latter period that the crews and observers could freely speak about specifics of the pre-mission planning and the mission execution. This afforded us the opportunity to show them playbacks of the mission tapes, to question how various things helped or hurt their performance, and to explore with them how well or poorly they shared mental models during certain periods of the mission. This stage provided the greatest opportunity to interact directly with the crew members although the information collected was subject to the crews' recall accuracy. Using videotapes of portions of the mission, the crew can help minimize some of these inaccuracies.

Tables 2, 3, and 4 present many of the specifics we looked for during the mission simulation and are separated according to the stage of the mission during which they were observed. Table 2 addresses mental simulation issues including commander's intent, mission segments, and specific tasks; Table 3 presents shared mental model factors such as the communication techniques including anticipatory, confirmatory, and cross-checking remarks; and Table 4 covers metacognition, with a focus on time horizon issues.

Table 2

MENTAL SIMULATION

	Pre-Mission	Mission	Briefing
Commander's Intent	-Do they concentrate at all on interpreting the commander's intent? -Do they concentrate at all on looking for weaknesses or points of confusion in the intent? -Do they clarify the commander's intent at all? -Do they identify critical areas where the plan may fail and see if the intent gives them good enough guidance to improvise?	-Did the mission succeed within the framework of the commander's intent?	-Would clarification of the intent, with respect to critical portions of the mission, have helped?
Mission Segment Profiles	-Do they break the mission into functional segments? -Do they identify the more difficult segments for mental simulation/rehearsal? -Do they look for areas where the time horizon will be at or near zero? Do they rehearse these types of situations? -Do they look at the plan from the enemy perspective, or at least elements of it? -Do they consider at all how to regain geographical orientation?	-Do they remind each other when transitioning into mission segment with different profile? -Do they miss tasks such as radio calls, switching on/off IFF, etc. that may have been covered if they simulated the mission in advance? -Did critical segments of the mission go well/poorly?	-Use tape to provide good and bad examples. -Contrast critical segment planning with actual execution. -If good/good: examine what about PMP that helped mission go well. -If bad/bad: examine what about the PMP that may have helped the mission go well (mental simulation. etc.). -If good/bad: Probe for why and how it could have been done better. -If bad/good: Probe for how they pulled it off. -General discussion regarding mission segment profiles and use of mental simulation.
Tasks	-Did they mentally simulate/rehearse any key tasks of the mission (e.g., landing, radio calls, etc.)?	-Did they successfully complete rehearsed portions of the mission? -Make notes of other tasks that they did successfully or unsuccessfully complete.	-Discuss how much simulation/rehearsal helped with successful areas. -Discuss whether simulation/rehearsal would have helped with problem areas. -Tape: examples of good/bad.

Table 3

COMMUNICATIONS

	Pre-Mission	Mission	Briefing
Anticipation	-Do they discuss any communications protocols?	-Did the crew members provide each other with information in advance of their needs/requests?	-Show tape and discuss how this helped/hurt. -Did they desire more or less? -How could it have been better?
Confirmation	-Do they discuss any communications protocols?	-Did the crew members confirm for the other member real-time information, actions, etc. --> either in response to anticipatory remarks or on their own?	-Show tape and discuss how this helped or hurt. -Did they desire more or less? -How could it have been better?
Cross-Check	-Do they discuss any communications protocols? -Do crew members double check tasks/actions the other crew member is responsible for?	-Do the crew members double check tasks/actions the other crew member is responsible for? -When they cross check, is it done in a way that does not pull the pilot flying into the cockpit?	-Show tape and discuss how this helped or hurt. -Look at how they handled this. -Use examples such as: -Without pulling PF inside. -When pulling PF inside. -Note: verbal versus visual cross checking.

Table 4

TIME HORIZON

	Pre-Mission	Mission	Briefing
Time Horizon	-Nothing-	-Is the navigator providing advanced information? -Does the PF ask for more (too short a time horizon)? -Does the PF: ask to have it repeated, ask to repeat what is first, forget or confuse the instructions (too long a time horizon)? -Do they adjust the time horizon when dealing with outside ships/agencies?	-Show tapes and discuss how this helped or hurt (good and bad examples). -Show requests for more. -Show requests for less. -If available, show examples of zero or negative time horizons and ask them to calculate how far back the time horizon should have been.

Indirect Techniques

There are two additional data analysis approaches that may be beneficial in some settings. Neither of these techniques is recommended for direct training since it takes time to compile the data and this rules out immediate feedback. The two types of analyses are decision behavior graphs and time horizon frequency data.

Decision Behavior Graphs, Figures 1-3, present schematics for three different teams flying the second leg of the mission. The actual verbalizations are omitted, and the figures show the pattern of communications between the two team members. The formalism is that the links show whether one comment directly responded to the previous comment (a vertical line) or whether the second comment added new information and perhaps changed the focus (a diagonal line). Where the same person continued to direct the activity, the successive comments are linked by horizontal lines. The mission segment is for three different teams, flying successive stages of the second leg of the mission. It can be readily seen that Crew 15 was dominated by the PNF. The three mission stages are from ACP-2 to the point where the stabilator first failed, then to RP-1, and finally to the LZ. Only the mission-relevant comments were included in the diagram. In contrast, Crew 16, with fewer overall comments, had more mission-relevant comments so the diagram is segmented into five phases. It can be seen that there was less domination by the PNF. Crew 20 had the greatest number of verbalizations of these three, and the greatest involvement of the pilot flying. It should be noted that for this crew, the pilot flying held a higher rank than the PNF.

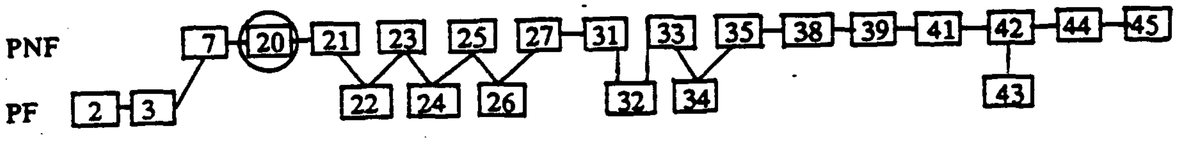
Figure 4 describes the interactions between the two crew members PF (pilot flying) and PNF (pilot not flying) for Crew 20. This is the same mission as in Figure 3, except that the comments are included.

The arrangement of these data may be useful in presenting the interaction between the two team members.

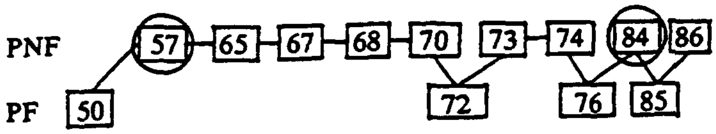
Time horizon frequency data. Our hypothesis was that ineffective teams would focus on near-term events and landmarks whereas effective teams would try to anticipate what is going to happen next. This is the difference between being ahead of the power curve or behind it. Teams that have a clear understanding of the mission seem to fly ahead of the helicopter, allowing them to plot smooth courses whereas teams that are not well organized seem to continually be reacting to events.

Time horizon refers to the way a team anticipates what it is about to perceive. Our subjective impression is that the best teams maintained a time horizon about 30-60 seconds in advance of the helicopter. The faster the helicopter was flying, the further ahead the team was looking. The teams that were behind the power curve were inside this horizon--their attention was focused on landmarks that were right in front of them, or, in some cases, behind them. The navigator would be looking at the map, trying to figure out where they were. In contrast, the teams that were ahead of the power curve were anticipating landmarks. The navigator was actively preparing the pilot

ACP-2 - Stabilator



Stabilator to RP 1



RP 1 to LZ

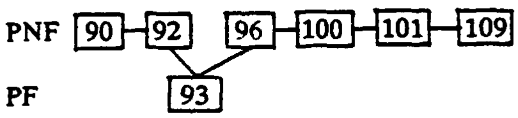
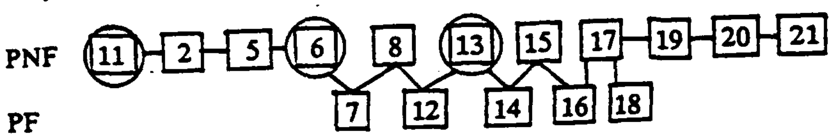
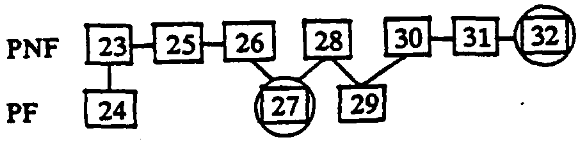


Fig. 1: Crew 15

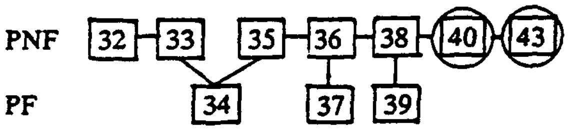
ACP-2 to Stabilator Problem



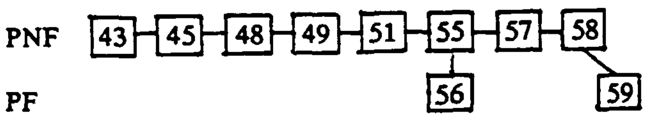
Stabilator Problem to 270° Turn



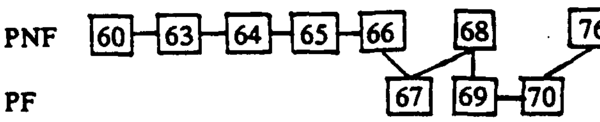
270° Turn to Road Switches



Road Switches to RP 1



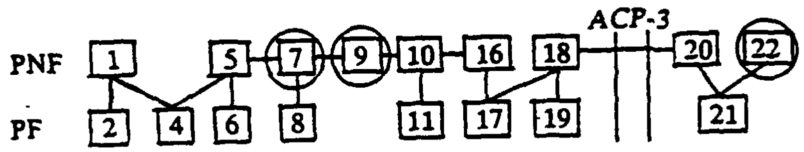
RP 1 to LZ



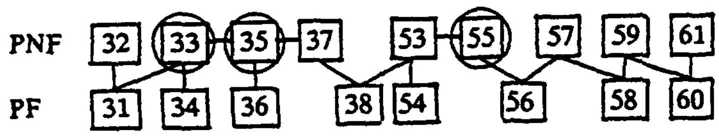
N = 54

Fig. 2: Crew 16 - Directions from FLOT to LZ

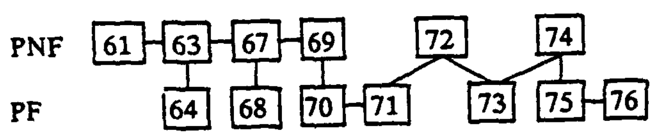
ACP-2 to ACP-3 to Stabilator Problem



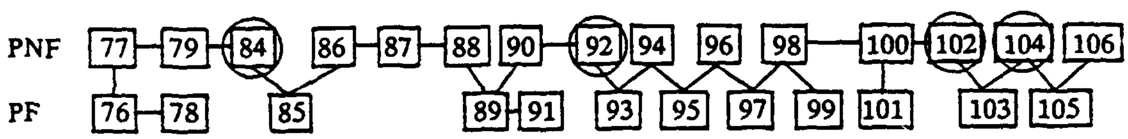
Stabilator Problem to 270° Turn



270° Turn to Road Switches



Road Switches to RP 1



RP 1 to LZ

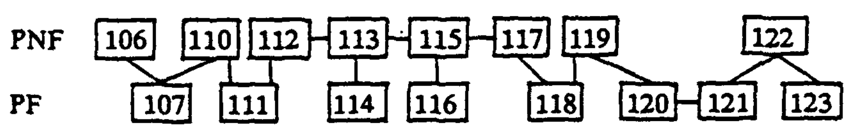


Fig. 3: Crew 20

ACP-2 to ACP-3 to Stabilator Problem

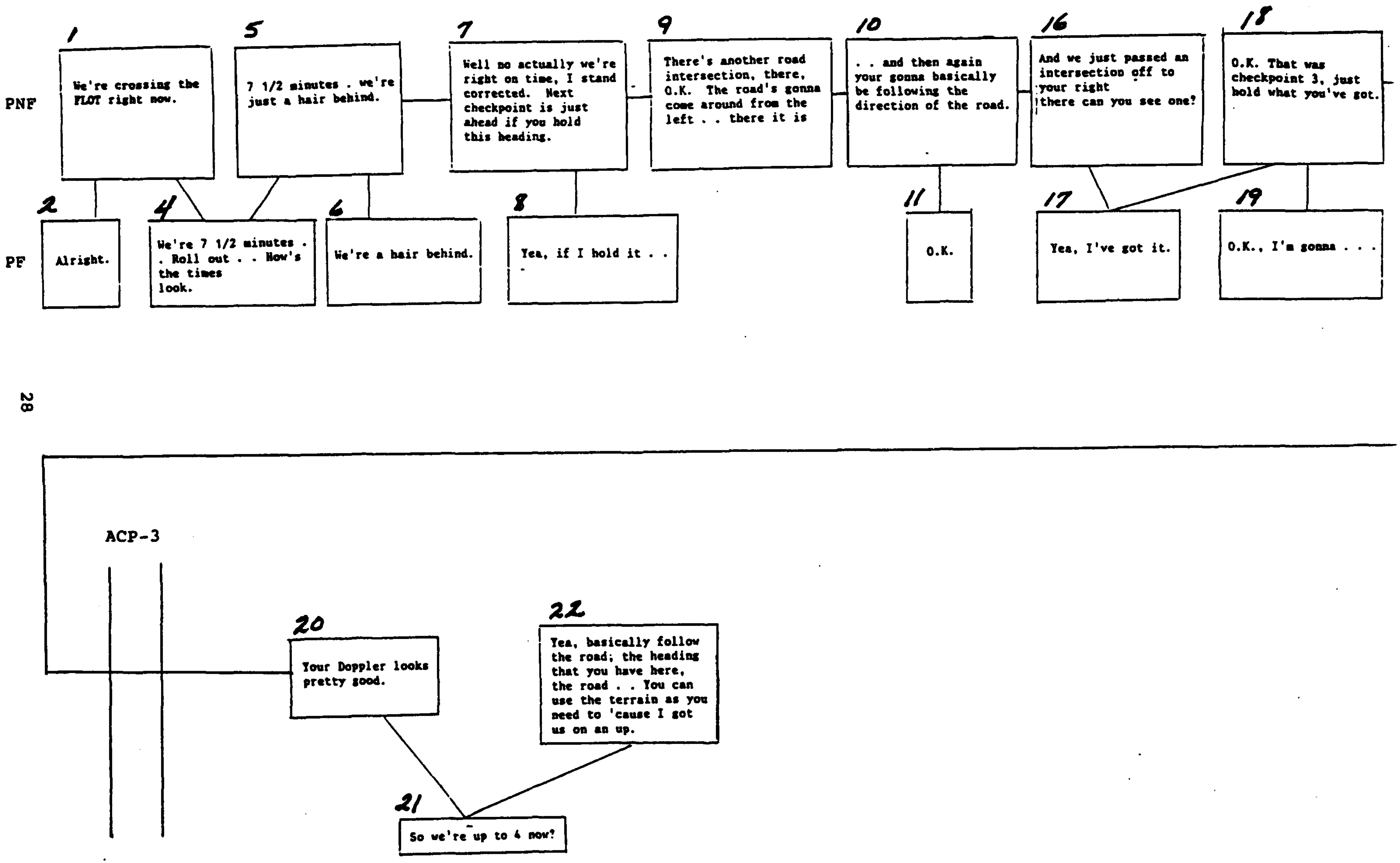


Fig. 4: Crew 20

Stabilator Problem to 270° Turn

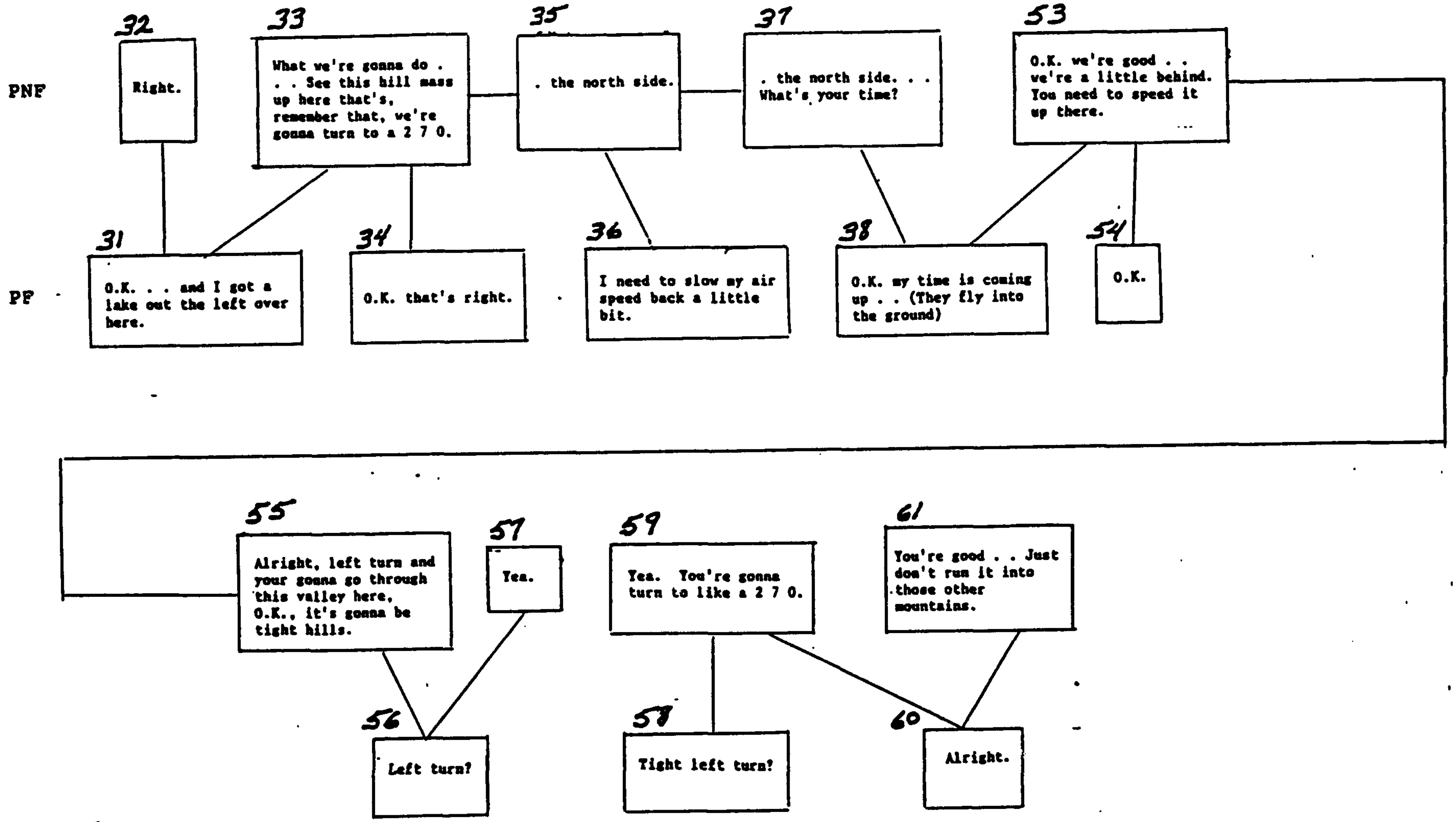


Fig. 4: Crew 20 continued

270° Turn to Road Switches

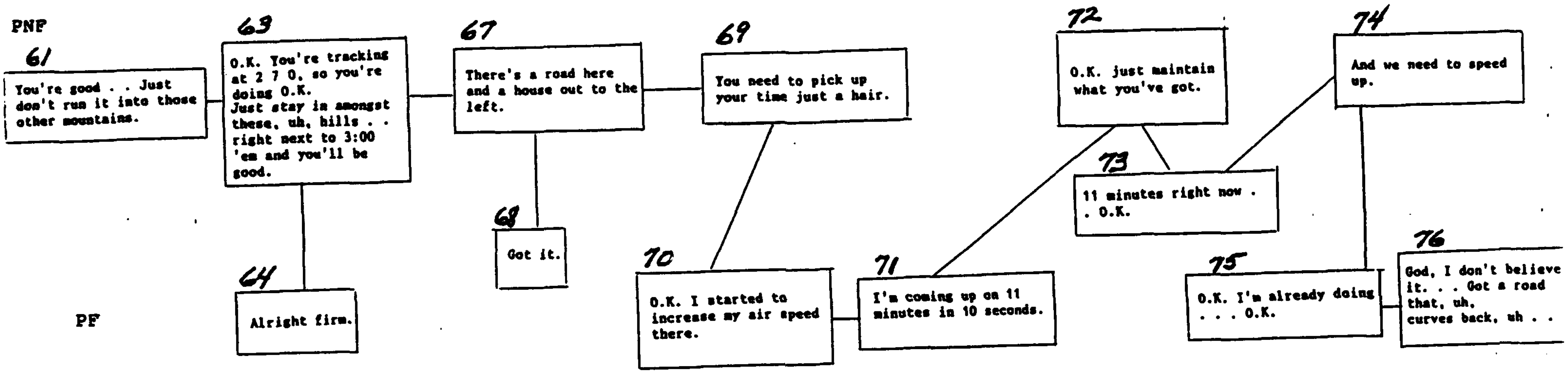


Fig. 4: Crew 20 continued

ROAD SWITCHES TO RP 1

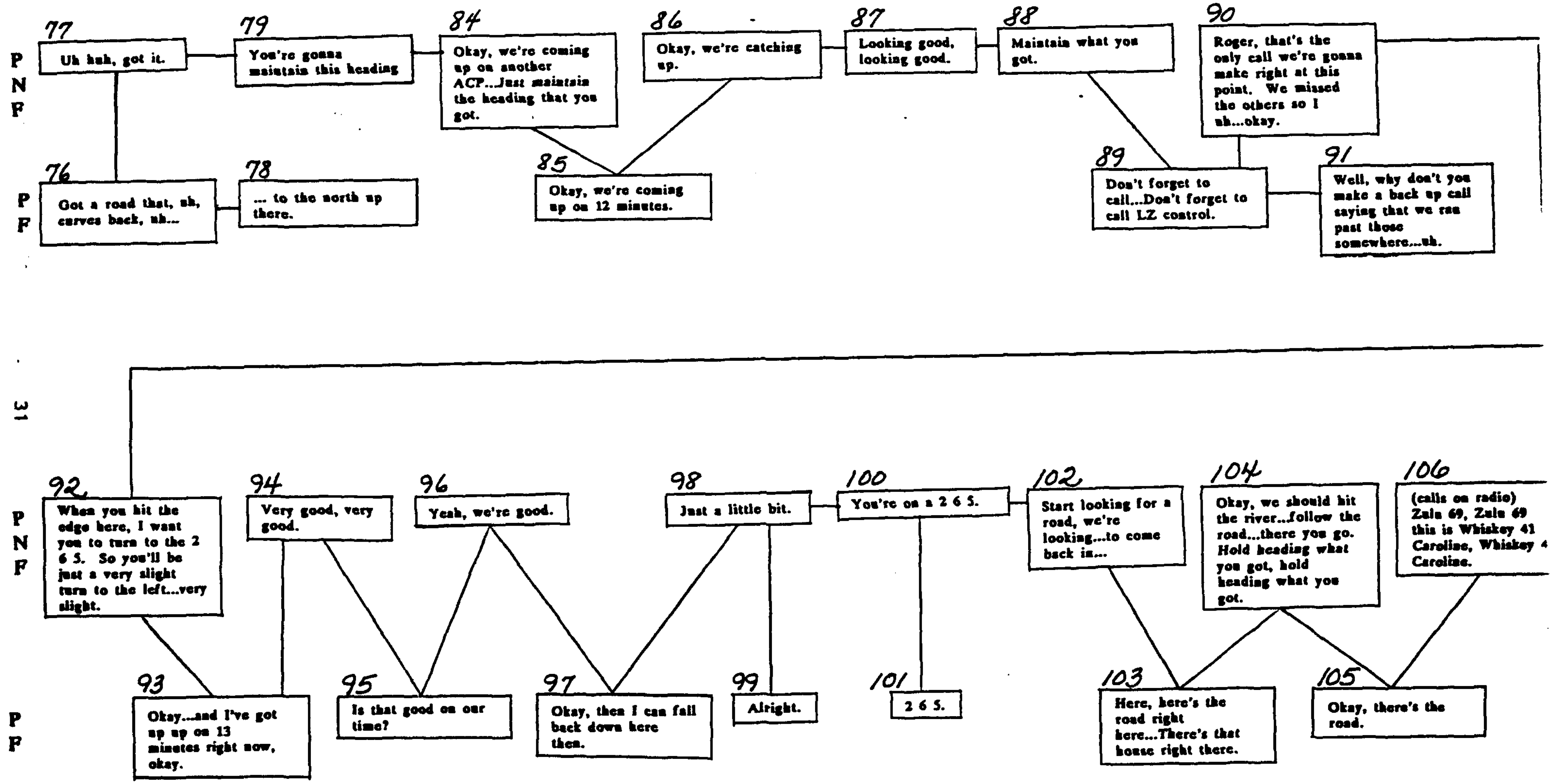


Fig. 4: Crew 20 continued

RP 1 TO LZ

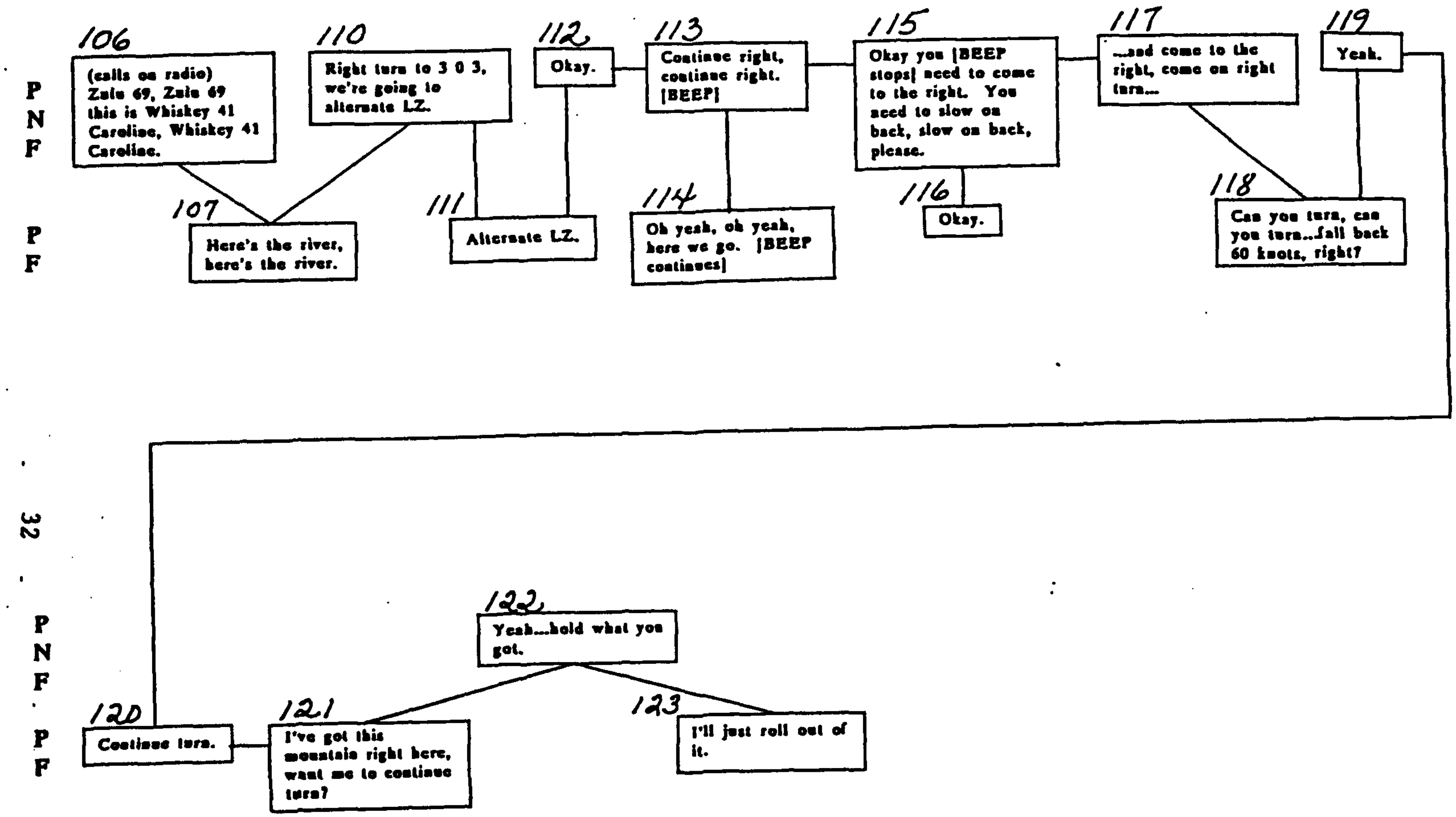


Fig. 4: Crew 20 continued

flying for landmarks that were not yet visible. In some cases, the time horizon was stretched too far, and the navigator described too many landmarks, confusing the pilot flying.

We tabulated the time horizon comments made by several teams. We counted only the comments where the navigator alerted the pilot flying about a landmark that had not yet come into view. We anticipated that better aircrews would show more of these comments than less effective aircrews. Three teams were examined. We had prepared transcripts for the second leg of the missions flown by these teams, designated as Crews 15, 16, and 20. We were not attempting to test any hypotheses since we lacked the resources tc examine an adequate sample, and because we did not have objective data evaluating the performance of these teams. All that can be said is that our subjective impression is that Crew 15 was below average, Crew 20 was strong in some ways but weak in others, and Crew 16 was among the best we had observed. This impression was supported by comments made by the instructor pilots, and by the fact that Crew 15 was lost for most of the mission, whereas Crew 16 was usually close to the planned mission profile.

Table 5 shows strong differences between the three aircrews. Crew 15 had the lowest frequency of time horizon comments, only four during the entire second leg of the mission. Since there were 109 comments in total made by this crew, we can use the total comments as the baseline and calculate that 3% of the their comments addressed landmarks that were not directly visible. In contrast, Crew 16 made 6 time horizon comments out of 76 total, for an average of 8%, and Crew 20 made 20 anticipatory comments about upcoming landmarks, out of 123 total comments, for an average of 9%. These data show the relationship we expected, but the findings must be interpreted with caution. Not only is the N negligible, but the fact that Crew 15 was lost for so much of the mission made it difficult for the navigator to anticipate anything. (It should be noted that the time horizon statements are circled in Figures 1-3 above.)

The reason for presenting these data is to demonstrate a method for measuring performance. This way of tabulating data may help to demonstrate training effects. If training in crew coordination is provided, then we might expect to see the proportion of time horizon comments increasing.

Table 5 also presents the ratios of mission-related comments, again contrasting Crew 15 with Crews 16 and 20. Finally, we tabulated the number of times where the pilot flying confirmed some expectancy articulated by the navigator. We hypothesized that in better crews, there would be more care given by the pilot flying to help the navigator do his/her job. Again, Crew 15 came out worst, with only three instances of confirmatory statements during the entire segment studied. This stands in direct contrast to crew 20, with 23 confirmatory remarks.

Table 5

Time Horizon Frequency Data

	Crew		
	15	16	20
Total comments	109	76	123
Time horizon comments	4	6	11
% time horizon comments	3%	8%	9%
Mission-directed comments	43	54	87
% mission-directed comments	40%	71%	71%
Pilot Flying:			
Confirmations	3	7	23

CONCLUSIONS

In this project we identified five key categories that appear to distinguish effective from ineffective helicopter crews: rehearsal, commander's intent, time horizon, anticipation/confirmation, and micromanagement.

These categories are an integral part of a cognitive model of team decision making. Rather than just listing target behaviors we have tried to show how we can use a cognitive model of the individual as a metaphor for understanding a team, so that an observer can try to understand the way the team receives and processes information. In an environment as dynamic as military helicopter missions, there is little opportunity for problem solving, and so planning, rehearsal, and reasoning must take place in advance of the mission. An analogy can be drawn to a basketball team, which depends on advance preparation but whose success depends on effective improvisation to meet actual conditions. For the helicopter crews, important aspects of preparation involved rehearsal and understanding the motivation for the mission. Once the mission was begun, the important categories were perceptual (having the team members exchange information to stay ahead of the aircraft) and metacognitive (managing the flow of information to reduce ambiguity without creating distraction).

We believe that observers will be able to use these categories during pre-mission and mission activities in order to provide direct feedback for instruction. The five categories are readily observed during pre-planning and during missions. The use of videotapes during After-Action Reviews seems especially helpful for training crew coordination.

Furthermore, we have presented strategies for training instructors to evaluate aircrew coordination processes. The use of specially prepared videotapes to illustrate positive and negative examples of dimensions appears to be very helpful in this regard.

Therefore, it should be possible to develop a program of instruction for aircrew coordination training. Such instruction can be provided at relatively low expense through the use of existing simulations and training exercises. Instructors can be taught to make note of crew coordination dimensions, and the After-Action Reviews can be expanded to include coverage of these factors. Therefore, current training in simulators and in actual training missions can be modified to provide additional benefits.

The next step is to develop and evaluate an instructional program for aircrew coordination. For training dimensions that appear to have major benefits, instructors can be shown how to identify and note the target behaviors, and evaluations can be performed to see whether such training results in improved performance. Because there is so little instruction on crew coordination, the opportunity to receive direct feedback on rehearsal, sharing an understanding of commander's intent, increasing time horizon, providing confirmations, and avoiding micromanagement would appear to have great impact on shaping up crew coordination skills.

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