Comparing Individual and Team Judgment Accuracy for Target Identification Under Heavy Cognitive Demand

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The proper and effective use of information is critical to various command and control situations. When information is unavailable or is used improperly, a variety of problems arise such as fratricide, when friendly forces are inaccurately identified as enemy combatants and are attacked and killed by their compatriots (BBC News, 2003, 2004; CBS News, 2006; Morgret, 2002). This fratricide has long been a concern of military and police forces (American War Library, 1996; DOD, 1992; Garamone, 1999), and ways of eliminating attacks on friendly forces have attracted much attention. Many of these efforts have focused on technological advancements and devices that are used to identify friendly forces during combat (e.g., Radio-Frequency Identification tags and GPS; Kime, 2003; PMM, 2003). In this chapter we consider how the processing of available information and how command and control can be modified to supplement implemented technology. In particular, we apply models of information processing in teams to show how teams can use and remember more information and thus make more accurate judgments than individuals (Hinsz, 1990; Hinsz, Tindale, & Vollrath, 1997).

A purpose of command and control is to gather information that leads to decisions to act. Consequently, information processing and decision making are two critical components of command and control. When flawed decisions are made, such as mistaking friends for foes (e.g., two U.S. Army helicopters downed by U.S. fighters in northern Iraq; Gordon, 1994), information processing is often to blame. Similarly, in target identification during combat, if the information provided is erroneous, a mistake can occur (e.g., attack on the Chinese embassy in Belgrade; BBC, 1999). In the midst of combat, the accurate identification of a target as friendly or hostile is a vital issue for pursuit of the enemy as well as protection of friendly forces. The proper identification of a target involves cognitive processes associated with knowing, recognizing, and remembering details about the target. However, these cognitive processes can be overwhelmed when identification of a large number of targets is required in a dynamically changing and threatening battlespace.

Airborne Warning and Control Station (AWACS) operations are one arena in which target identification occurs routinely (Fahey, Rowe, Dunlap, & deBoom, 2000; Klinger, Thordsen, & Copeland, 1998). AWACS weapons directors are Air Force personnel that control and direct aircraft assets (e.g., fighters, refueling tankers) from airborne AWACS platforms (Fahey et al., 2000). AWACS operations involve both the information processing and decision making aspects of command and control. In modern battle situations, AWACS weapons directors have to gather and monitor information about a large number of friendly and enemy targets, identify and discriminate between the types of targets, and then make decisions about the aircraft that will be directed to which targets. The misidentification of a target can mean a fighter will not get refueled in a timely fashion, an enemy incursion will not be met with force, or ground troops will not receive appropriate air support. Also of interest to the current volume, a friendly force could be misidentified as an enemy target, and the decision made to engage the target (i.e., friendly fire). Misidentifications of targets are more likely when massive amounts of information has to be digested by AWACS operators (Klinger et al., 1998). This overwhelming information is also complicated by the reality that targets can be moving quickly through the battlespace.

How can AWACS weapons directors cope with so much constantly changing information? What can operators do when there are too many targets to accurately identify and discriminate as friend and foe? Given this overwhelming situation, how do AWACS weapons directors use available information to make decisions about what weapons will be released and to which targets they will be directed? When weapons directors face a large number of targets of unknown designation, they need to have techniques and technologies that help them deal with this cognitively taxing situation (Fahey et al., 2000). One way that AWACS weapons directors might effectively confront a cognitively demanding situation is to collaborate and cooperate as a team. By working as a team, the members can apply a division of labor (e.g., specific weapons directors direct their attention at particular sectors). In addition, working as a team allows the members to draw upon their larger, collective cognitive resources to deal with cognitively demanding situations. Therefore, teams might be effective when confronted with large amounts of information because they can draw on a larger pool of cognitive resources as well as use a division of labor.

Weapons directors collaborate and coordinate with other weapons directors so they work as a team. Weapons directors monitor the activities of aircraft that are their responsibility from screen displays at workstations. However, at particular times, weapons directors can lose their screen displays and have to perform their tasks “blind”. Memory is therefore a critical cognitive process in the multiple tasks performed by weapons directors (Fahey, et al., 2000). For example, weapons directors may need to compensate for equipment glitches or environmental factors that require them to rely on their memory to be able to monitor, command, control, and communicate with designated aircraft. Failure to remember the location, attributes, or mission of an aircraft can be considered target misidentification. Members of a weapons director team may use other team members to aid them in remembering where aircraft are, what their missions are, where they are heading, possible conflicts that might exist in the flight corridor, and the existence of threatening conditions (e.g., fighter running out of fuel). In this sense, teams may act as a technology to improve target identification. We investigate how collaboration in target identification may enhance weapons directors’ performance under conditions of overwhelming information, thereby demonstrating how teams can be used to improve target identification and reduce potential misidentification errors.

There is a substantial literature demonstrating that teams deal more effectively with information than individuals (Hinsz et al., 1997). In the context of AWACS operations, a single weapons director might be responsible for processing the available information and making a decision to release weapons. Alternatively, a weapons director team could be assigned to collectively process the information and make decisions. There are a number of reasons why teams might be preferred to individuals in this situation (Hinsz, 1990): Teams are expected to be superior because they can pool information from different members (Hastie, 1986), teams are likely to correct errors that individual members might make (Laughlin, 1980), and teams can engage in better strategies for coming to a response (Hinsz, 2004; Laughlin, Bonner, & Miner, 2002). Consequently, in cognitive task performance, teams will remember more of the information (Hinsz, 1990), more exhaustively deliberate the information (Hinsz et al., 1997), and be less biased in their judgments (Kerr, MacCoun, & Kramer, 1996). For these reasons, it is reasonable to believe that involving teams in the processing of information and making judgments will result in better target identification and discrimination than individuals.

A number of theoretical models predict that teams will outperform individuals on the cognitive tasks that confront teams such as weapons directors (e.g., ideal group model, Sorkin & Dai, 1994; social decision schemes theory, Hinsz, 1990). Using some assumptions based on social decision scheme theory, Figure 1 illustrates how team performance is expected to be superior to that of individuals. The x-axis shows the probability of an individual responding appropriately on the cognitive task. The y-axis shows the probability of a team responding appropriately under similar circumstances. (For illustrative purposes, a five-person team is assumed to perform a task for which it is difficult to tell if a response is correct.) Note that across a wide range, teams are predicted to outperform individuals. Therefore, there is a research and theoretical basis for believing that teams will make better target identification judgments.

The comparison of team and individual judgments about targets in the weapons directors' zones of operation also provides a means of examining differences between individual and team situational awareness (Endsley, 1995; Endsley & Jones, 2001). The situational awareness of weapons directors reflects their perception of the targets and the existing threats, an understanding of the relationships among various targets, and an ability to predict upcoming events that involve the targets. In the case of weapons directors, situational awareness is greatly influenced by the information processing of the individual or weapons director teams (Hinsz, 2001). By focusing on the processing of information and judgments of individuals and teams in a situation with heavy cognitive demands, it is possible to examine critical features of command and control. Moreover, such an examination can inform us how the proper identification of targets might be facilitated by the use of teams in command and control.

The general conclusion is that teams should be superior to individuals at identification and discrimination of targets, but how broadly does this conclusion apply? Many of the cases of misidentification of targets in combat occur in situations typified by overwhelming information in a rapidly changing environment that requires decisions to act under intense time pressure. Are teams better at using information and likely to correct errors regarding target identification? Figure 1 indicates that when individuals are about equally likely as unlikely to make appropriate target identifications (approaching .50), teams would not perform much better. However, other models of team performance suggest that teams would still outperform individuals because of error correction and information pooling (e.g., Laughlin & Ellis, 1986). Whether teams and individuals differ in their ability to identify and discriminate targets and their attributes (e.g., speed, heading) under conditions of overwhelming information is a key question we investigate in the experiment described below.

In our experiment, we asked participants to act as weapons directors in a simulated

AWACS task environment in which their ability to remember attributes and make judgments about specific targets was tested. The weapons directors acted alone or as members of a team. To assess target identification, after they were presented with a situation with a large number of targets having varying attributes, we asked the participants to respond to a large set of statements about the targets and their attributes. The participants were asked whether the statement was true or false. As illustrated in Figure 1, we can use the probability of individuals and teams accurately answering the statement to test the prediction that teams make more accurate judgments than individuals. Moreover, the methodology of this experiment allows us to construct the *d'* index derived from signal detection theory (Banks, 1970; Green & Swets, 1966) to show how well the individuals and teams could discriminate accurate from inaccurate information in their judgments about these targets. By using these measures we are able to examine how teams and individuals compare in their identification judgments about targets when they are presented with a cognitively demanding situation involving a number of targets.

Method

Participants and Design

Participants were 116 students from North Dakota State University with about equal numbers being male and female. Participants either received extra credit for their lower level psychology classes or were paid for their participation. This experiment involved comparisons of weapons directors performing alone with teams of three or five members. There were 26 participants in the individual condition, 15 three-person teams (45 participants), and 9 five-person teams (45 participants). All participants performed the target identification test initially alone. Following that, the individuals performed a filler task, and then performed the target identification test again. Members of the teams performed the target identification test the second time as an interacting team.

Task Environment

An AWACS synthetic task environment that simulates features of weapons director tasks served as the research platform (Entin & Rubineau, 2002). The research scenario involved little contact with enemy forces and focused on a humanitarian relief effort in an allied nation after it suffered a devastating earthquake. A number of villages and cities were located in the region of responsibility, and humanitarian relief (e.g., food and medical supplies) needed to be delivered by air transports. This complex scenario required the efforts of a number of AWACS weapons directors so that it would be reasonable to compare performance of three and five person teams.

In general, the information displayed to the weapons directors fell into four categories: (1) Aircraft that were under the supervision of the weapons directors on the AWACS (e.g., fighters, helicopters). (2) Targets that were friendly, enemy, or of unknown disposition. (3) Background information about the lay of the land and other features of the place and space in the AWACS area of responsibility (e.g., national boundaries, villages). Much of this information was displayed on a grid with aircraft identified with icons and alpha-numerical labels (see Figure 2). In addition, colors were used to indicate the aircraft under a specific weapon director's supervision. (4) Operators could also open pop-up menus that provided specific information about the aircraft (i.e., speed, heading, mission, altitude, and coordinate location). Based on these seven attributes of the aircraft for a large number of targets (call sign, speed, heading, mission, altitude, location on grid map, and coordinate location), we generated a large number of unique target identification test items (i.e., 114) for testing the hypotheses and deriving measures.

Procedure

The training of participants in performing the tasks associated with the weapons directors had a number of components. The participants initially received a general description of the synthetic task environment and were told about the different features of the workstation, screen, and controls. After this, the specific features of weapons director's operations were described. This training was interactive allowing the participants to learn about different types of aircraft, their symbols, the functions the aircraft serves, and how the weapons director interacts with that type of aircraft.

After this initial training, the participants performed the weapons director tasks in a number of exercises and were given time to become familiar with their workstations. During these exercises, the participants were quizzed to make sure they understood the correct way to perform their functions. Problems, errors, and questions were addressed by the experimenter. Finally, a set of exercises were conducted to ensure that the participants achieved criterion levels of competence on the different tasks a weapons director performs in this synthetic task environment. Once the participant reached these criterion levels, participation in the actual experiment began.

The experimental session continued with a pre-briefing regarding the situation the weapons directors would confront. The participants were told that an allied nation had suffered a devastating earthquake and requested assistance from the United States. The U.S. was providing food and water, medical assistance, construction equipment, and search and rescue teams. A country neighboring the allied nation had shown hostility in the past, requiring patrol aircraft for that border. The aircraft under the AWACS's control pursued five different missions: 1) Air-drop food and water, 2) combat air patrol, 3) transport construction equipment, 4) transport medical teams and supplies, and 5) transport search and rescue teams. The cover story suggested that another AWACS was transferring control to the participants' AWACS because it was shifting off mission. During this exchange period, no critical events occurred so the participants would gain situational awareness in their task environment as well as focus on the attributes of the aircraft upon which they would be tested. The transfer of aircraft from the departing AWACS to the weapons directors occurred at a methodical pace so that the weapons directors had time to interact and respond to each of the aircraft operating in the scenario.

We used the number of aircraft as a way of influencing the amount of information presented to produce a cognitively demanding situation for the weapons directors. Based on pilot work, we determined that 45 aircraft would create a cognitively demanding situation. These aircraft were present in the scenario at all times. In the five-person teams, nine aircraft were made the responsibility of each team member and were color coded with the responsible weapons director's color. For the three-person team, 15 aircraft were the assigned responsibility of each weapons director and were also similarly color coded. Participants were told to monitor all of the aircraft on the map, but that they had primary responsibility for the subset of aircraft that had an icon with their color. Participants were also told that they were eligible to win a monetary bonus related to their ability to monitor and retain knowledge concerning the attributes of each aircraft during the simulation. Specifically, participants were told that they would complete examinations following the scenario and that the top 20% of performers on each of the examinations would receive a bonus of $10.

Once all of the aircraft were transferred to the weapons directors, the scenario continued relatively uneventfully for approximately 90 seconds. At this time, the participants' display screens went blank. The participants were told that their AWACS had suffered an equipment failure. Because the weapons directors still needed to control their aircraft, it was important to know the situation they faced when screen information was lost. The participants were asked for their knowledge of the situation just before their screens went blank (first target identification test). No discussion was allowed during this test period.

The target identification test involved 114 questions presented on the weapons directors' screens. Of these items, half were true items (e.g., The altitude of the aircraft at this location was

2200 feet.) and half were false (e.g., The aircraft at this location was THUNDER 27.). The participants were asked to indicate whether the statement presented was true or false.

After completing the first target identification test, the participants in the individual condition completed a filler task before completing the second target identification test. Participants in the three- and five-person team conditions were also asked to respond to the second target identification test, but as members of a weapons director team. The member of the team seated at the center was selected to enter the team responses for an item. The teams were told they could reach their team responses in any way they desired, but they were to make sure that their responses represented the collective opinion of all members of the team. After completing all the second target identification test items, the participants' questions were answered, they were debriefed about the study, thanked for their participation, information for distributing the incentives was gathered, and they were excused from the experimental session.

Results

The responses of the participants in this experiment were analyzed in a number of similar ways. The target identification responses were aggregated to produce indices of target identification (i.e., *d'*, proportion correct, errors of omission, errors of commission). These indices were calculated for both the first and second target identification tests. Mean values for these values are presented in the two panels of Table 1. An important general pattern of the data is that both individuals and teams achieved very low levels of accuracy on the target identification tests. These rates of target identification were at or just above chance levels. This finding suggests that the cognitive load that weapons directors' faced may be very high.

It was predicted that the individuals and participants who responded as a team would not differ on any of these indices on the first target identification test because random assignment to conditions would equate the conditions. Results were consistent with these expectations (see top panel of Table 1). There were no significant differences between conditions for the proportion of items answered correctly, values of *d'*, and rates of errors of commission and omission. The results also indicated that these indices did not differ between the first and second test for the individuals.

The team responses on the second target identification test provided values for the indices of team performance on the AWACS synthetic task environment (see bottom panel of Table 1). Results indicated that the three-person teams outperformed the comparable individuals on the second test in measures of target identification: proportion of items answered correctly, F (2, 47) = 3.64, $p < .05$, and values of *d'*, F (2, 47) = 3.50, $p < .05$. However, the five-person teams did not differ from the individuals or three-person teams on any of these measures.

Another way performance on the target identification test was examined was in terms of the errors observed. It was hypothesized that teams would have fewer errors than individuals due to the error correction process inherent in teams. There were no differences in the rate in which individuals and teams were likely to produce errors of commission (incorrectly saying that a false statement is true/all false statements). Only somewhat supporting the hypothesis, three-person teams were less likely to produce errors of omission (incorrectly saying a true statement is false/all true statements) than individuals and five-person teams, F (2, 47) = 3.62, $p < .05$. Given that three-person teams achieved higher levels of performance, this observed error correction probably contributed to their better target identification.

These results suggest that five-member teams had lower levels on the measures of target identification performance (e.g., proportion correct) than the three-member teams. Likewise, the five-person weapons director teams had more errors than three-person teams. These findings are inconsistent with predictions that the five-person teams would be more accurate than individuals. However, there was a relatively small sample of five-person teams for this analysis (nine).

Moreover, the probability of individuals responding correctly approached chance levels (.50). Consequently, as seen in Figure 1, teams were not expected to differ from individuals when they were chance levels of performance. The results presented in Table 1 demonstrate that the five-person teams did not improve on the initial individual levels of target identification performance. The results presented in Table 1 also demonstrate that three-person teams did improve their performance above that of the initial member responses, but not by much.

Discussion

This experiment investigated the accuracy of identifications of individuals and teams for targets displayed to weapons directors in an AWACS synthetic task environment. Perhaps the most striking aspect of this study was the low levels of accurate target identifications achieved on both the first and second target identification tests by the individuals and teams. This poor performance likely resulted from the overwhelming amount of information that the participants confronted. With 45 aircraft having seven attributes each, a total of 315 pieces of information were presented. This appears to have been a very challenging situation for participants when they responded to the target identification test. Participants apparently were unable to cope with the high demand of the situation. Performance was barely above chance levels, and many participants may have been guessing for a large number of the items. The analyses displayed in Figure 1 indicate that teams would not have better target identifications than individuals when they appeared to be guessing.

Research has consistently demonstrated teams to be superior to individuals in cognitive task performance (Hinsz et al., 1997). However, the observed results for this study differed in important ways from those associated with the comparison of team and individual judgment accuracy. One prediction held that that collaboration in target identification by teams would enhance performance over that of single weapons directors. A small performance increment was observed for the three-person teams, but not the five-person teams. Consequently, there is no clear evidence that target identification of the teams in this study was superior to that of individuals.

An interesting implication of the differences in the patterns of predicted and observed results is that the nature of the target identification task itself influences the types of team processes that emerge. If accuracy on target identifications becomes sufficiently difficult, these processes might change such that the mechanisms that contribute to team superiority may be eliminated or obscured by the difficulty of the items. Clearly the nature of the task, along with features of teams, have important influences on the ways teams perform cognitive tasks.

One feature of this experiment is that the weapons directors had responsibility for specific aircraft. Consequently, the different weapons directors had specific knowledge or expertise with regard to the different aircraft on the display. This differential knowledge could lead teams to allow the weapons director with responsibility for controlling an aircraft to have greater influence on the team responses for information about that aircraft. This suggests an expertise-based perspective: if the weapons director with responsibility for the aircraft remembers a piece of information for the aircraft, then the team accepts that piece of information as correct (see Kirchler & Davis, 1986). Further analyses to consider the role expertise has on effective team performance are warranted.

The current research investigated target identification of teams and individuals under highly cognitively demanding conditions that may more accurately mirror a typical battlespace. It is under these conditions that errors of judgment about targets often occur. These errors can be ones in which the friendly targets are misidentified, inaccurate information is held about it, a target goes unnoticed, or critical information about it is not considered. Under all types of errors, improper target identification can occur which can have devastating consequences. We found that when there was an overwhelming amount of information about the targets to consider, individuals and teams did not differ greatly in terms of errors, in spite of research suggesting teams should correct errors and hence have better performance. Thus, under high cognitive demand, perhaps some other approach or technology is necessary to reduce the kinds of errors that would contribute to friendly fire incidents. Moreover, teams placed under these cognitively demanding situations may benefit from additional training that increases expertise and situational awareness.

We argue that one must be cautious if additional technology is provided to personnel to improve target identification in combat. Before making these systems common issue to personnel, they must be trained to handle the increased information, and methods to improve the display of information will be required (Bates & Singer, 2003). This study suggests that a point can be reached at which both individuals and teams are unable to utilize additional information. If a division of labor within teams is properly implemented, it may help to lighten the cognitive load, but research would need to demonstrate that the division of labor actually enhances target identification.

In modern combat situations, a team of allied forces are directed at opposing forces. The command and control of these allied forces requires processing information and making decisions about appropriate actions to be taken. This requires sufficient accurate information to make appropriate decisions. If insufficient information or inaccurate information is used, errors in judgment during combat can occur. Moreover, if an overwhelming amount of information is provided, the human operators may not be able to respond appropriately, and mistakes can be made. Also, situational awareness can diminish. Of interest to this volume, when inappropriate or overwhelming information is provided, inaccurate identifications are made, and incidents of friendly fire may result. Not surprising, the most common causes of fratricide are human error (i.e., information processing) and misapplied technology (CSC, 1995). Thus, methods that promote error correction and appropriately apply technology may contribute to the reduction of fratricide. Research provides a strong theoretical and conceptual basis for considering the use of teams in processing information and making judgments which could have an additional contribution. Also, situational awareness might be enhanced by having teams respond to demanding situations. By having individuals come together to both train and act as teams, we may promote error correction and maximize the effectiveness of available technology.

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Table 1. Mean Values and Standard Deviations of the Measures for Target Identification Tests 1 and 2.

First Target Identification Test			
Dependent Variable	Individual *M* (SD)	Three Coactors *M* (SD)	Five Coactors *M* (SD)
Proportion Correct	0.51 (0.05)	0.52 (0.05)	0.50 (0.05)
d′	0.06 (0.26)	0.11 (0.26)	0.03 (0.33)
Errors of Commission	.54 (.10)	.57 (.12)	.57 (.15)
Errors of Omission	.43 (.11)	.39 (.12)	.42 (.12)

Second Recognition Test			
Dependent Variable	Individual *M* (SD)	Three-Person Team *M* (SD)	Five-Person Team *M* (SD)
Proportion Correct	0.51 (0.06)	0.55 (0.05)	0.51 (0.04)
d′	0.04 (0.30)	0.27 (0.27)	0.05 (0.22)
Errors of Commission	.55 (.12)	.55 (.13)	.51 (.09)
Errors of Omission	.42 (.12)	.35 (.11)	.46 (.11)

Figure 1. Predicted Team Proportion of Correct Responses Given Values for the Proportion of Correct Individual Responses.

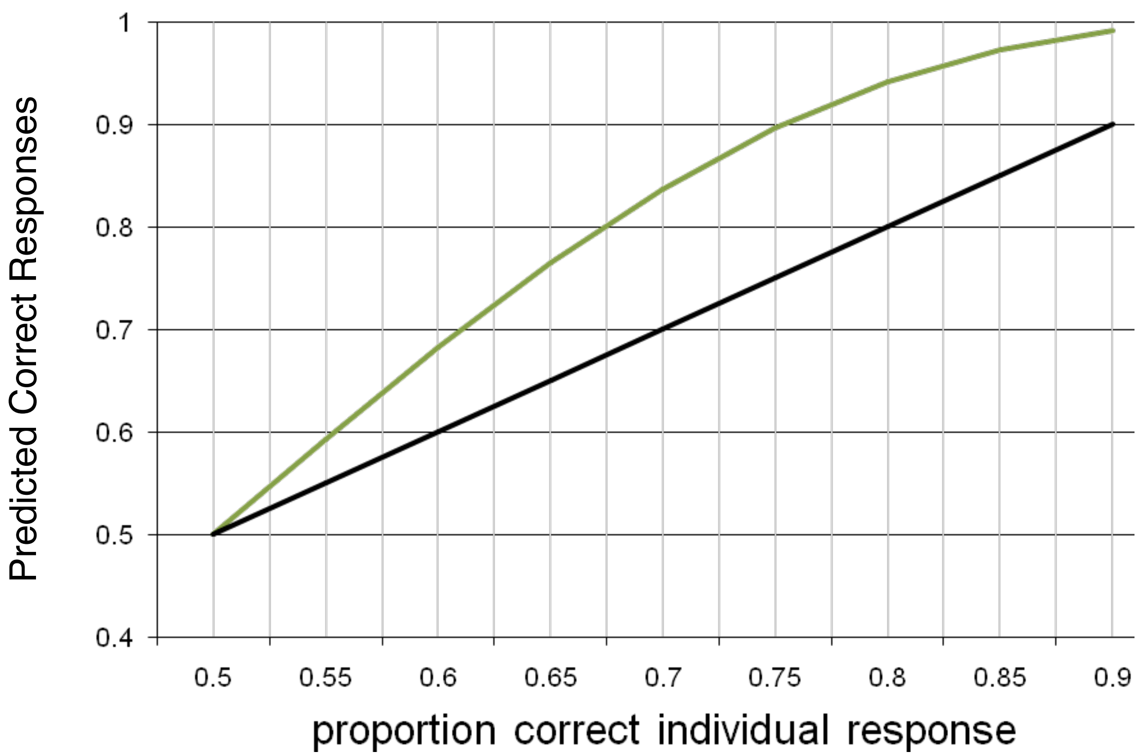
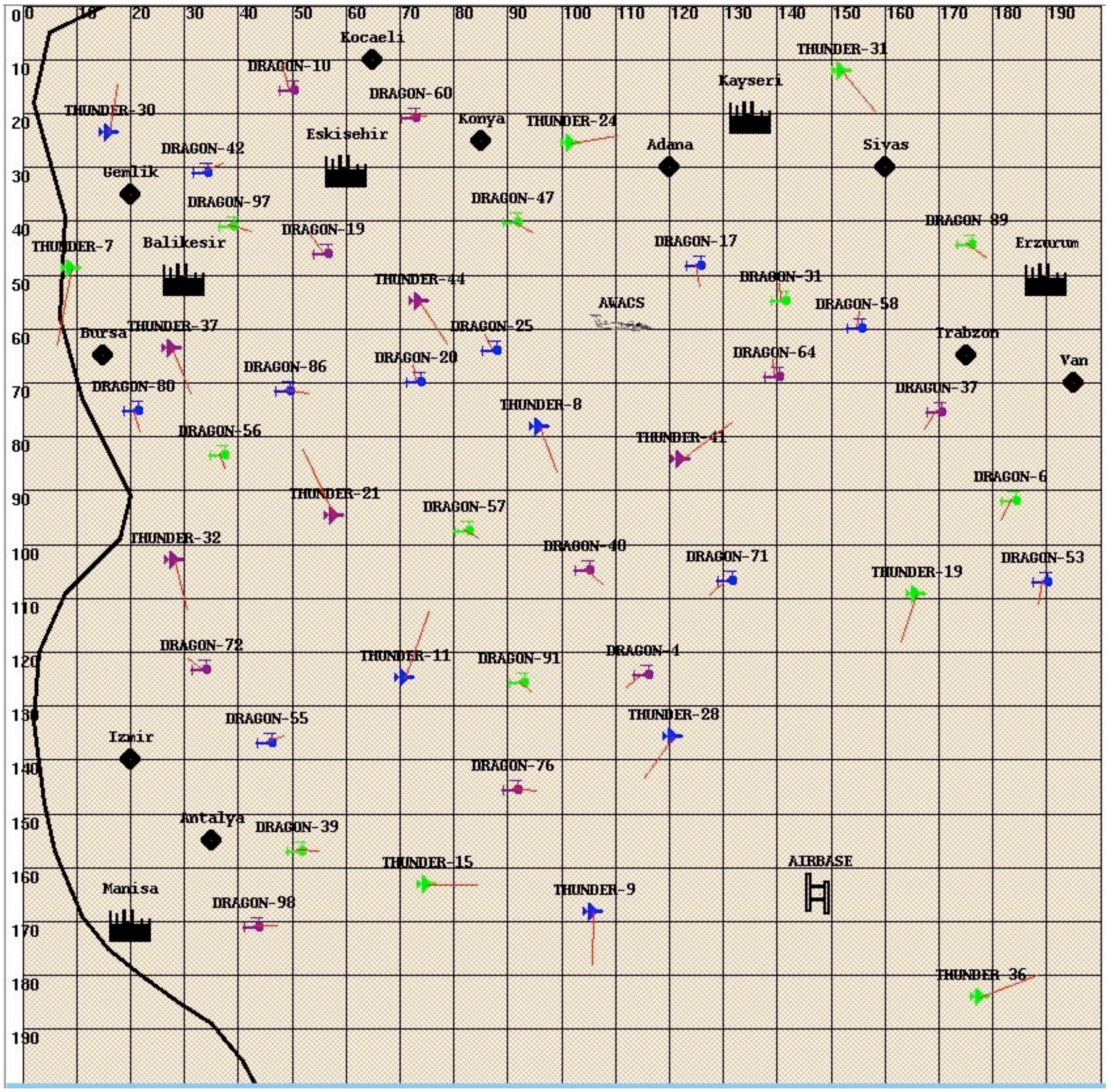


Figure 2. The layout of the grid for participants at the beginning of the scenario.



Note. The larger screen display provides the controls for the weapons directors' activities as well as the grid reflecting the locations of the aircraft and defined locations on the map.