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Information Detail and Display Concepts for Critical Decisions in Ballistic Missile Defense Command and Control

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The theater high altitude area defense (THAAD) system is a missile defense system being developed for the United States Army. Previous studies have been conducted regarding (a) information categorization, (b) attention direction and focusing, and (c) information criticality in order to aid designers in interface display design for the THAAD operator system interface (OSI). In particular, results from these studies have told designers (a) what information areas were critical and needed to be presented at a high level in the display, and (b) what information items within these information areas were critical and needed to be displayed in a prominent manner. In certain cases, an information area is displayed as its own individual window (e.g., threat engagement queue and track amplification windows). The objective of the experiment described here was to determine which information items in the engagement queue and track amplification windows of the THAAD OSI are critical enough to demand being displayed in prominent locations within the windows. Designers can take these results and redesign the engagement queue and track amplification windows, ensuring that important information items are displayed prominently and allowing less important items to be displayed less prominently.

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INFORMATION DETAIL AND DISPLAY CONCEPTS FOR CRITICAL DECISIONS IN BALLISTIC MISSILE DEFENSE COMMAND AND CONTROL

INTRODUCTION

Commanders and operators in command and control (C2) centers for theater-level ballistic missile defense (BMD) are responsible for monitoring a largely automated engagement process. Their actions include monitoring the current situation, as well as intervening in near-real time during anomalous situations or when new information is received. The displays for these missile defense systems need to support the human operators in performing these actions. Displays can accomplish this by ensuring that critical information items needed to monitor a situation are always displayed and that detailed or amplified information to support this monitoring or to intervene when needed is available to the operators.

The theater high altitude area defense (THAAD) system is a missile defense system being developed for the United States Army. Previous U.S. Army Research Laboratory (ARL) studies and experiments have been conducted to derive the C2 information requirements for this system (Knapp, Ensing, & Reynolds, 1995). These studies addressed the issues of (a) information categorization, (b) attention direction and focusing, and (c) information criticality. Results from the experiments have given designers important information regarding interface display design for the THAAD system. In particular, these results have told designers (a) what information areas were critical and needed to be presented at a high level in the display, and (b) what information items within these information areas were critical and needed to be displayed in a prominent manner.

In the THAAD system, an information area is often displayed as its own individual window (e.g., threat engagement queue and track amplification windows). In designing these windows, designers need to know what information is critical and needs to be displayed on the first page of the window. Information that is less critical or unimportant can then be delegated to subsequent window pages, accessible to the operator via scrolling, or to a lower display level, accessible to the operator via mouse clicks.

OBJECTIVE

The objective of the experiment described here was to determine which information items in the engagement queue and track amplification windows of the THAAD operator system interface (OSI) are critical enough to demand being displayed in prominent locations within the windows. Because different information items are critical in different situations, two situations were presented for each window to determine which items are critical in several representative tasks. Before this experiment is described, however, a brief explanation of the task domain, ballistic missile defense, and the THAAD OSI follows.

BACKGROUND: BALLISTIC MISSILE DEFENSE AND THE THAAD OSI

Ballistic missile defense incorporates the means needed to intercept enemy ballistic missiles deployed against friendly forces or assets. Theater missile defense takes this a step further by requiring the defense to be "portable" and flexible enough to be deployed rapidly to different theaters or different locations within a theater. THAAD is being developed to work with the Patriot missile system to provide such a defense. They are intended to provide a two-tiered defense in order to provide a more "leakproof" defense—THAAD at the upper level and Patriot at the lower level. Together, these two systems will be able to defend a large area, increase defense effectiveness by destroying targets farther away from assets, and provide for multiple shot opportunities (Kilgore, 1994).

The THAAD OSI prototype has been used to develop the design features for the actual THAAD tactical operations center (TOC). Version 2.1 of the prototype software is being revised. This version allows users to perform some initial force operations (FO) tasks, needed for current operations management, and engagement operations (EO) tasks, needed for current battle (engagements) management. The main focus of this current work is on engagement operations, so this description is limited to those functions (see Litton Systems, Inc., 1994, for more information). During EO, the operator can manage engagements of tactical ballistic missiles (TBMs), monitor the air situation, and control launcher and sensor operations. Two engagement modes can be chosen: automatic, when the system automatically launches THAAD interceptors in response to threats; and semiautomatic, when the operator needs to authorize all interceptor launches.

One of the main features of the current OSI version is an air display map, which displays a graphical view of the area under THAAD's protection, as well as the incoming TBMs (threats) and any outgoing THAAD interceptors. Other features include a menu bar at the top of the screen and a status bar at the bottom left of the screen. The rest of this section describes two windows accessible from the menu bar: the engagement queue window and the track amplification window.

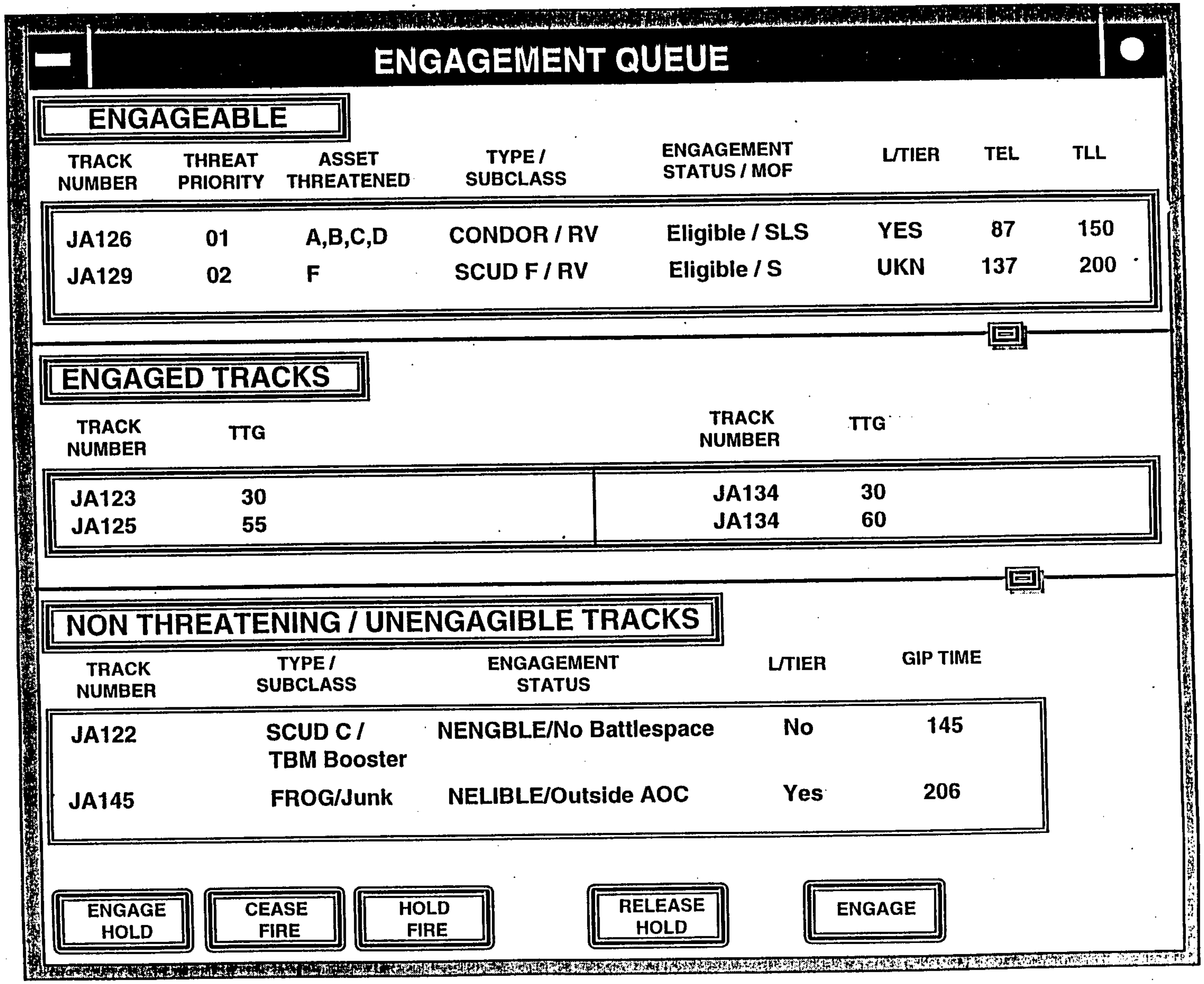

Figure 1. Tabular engagement queue window.

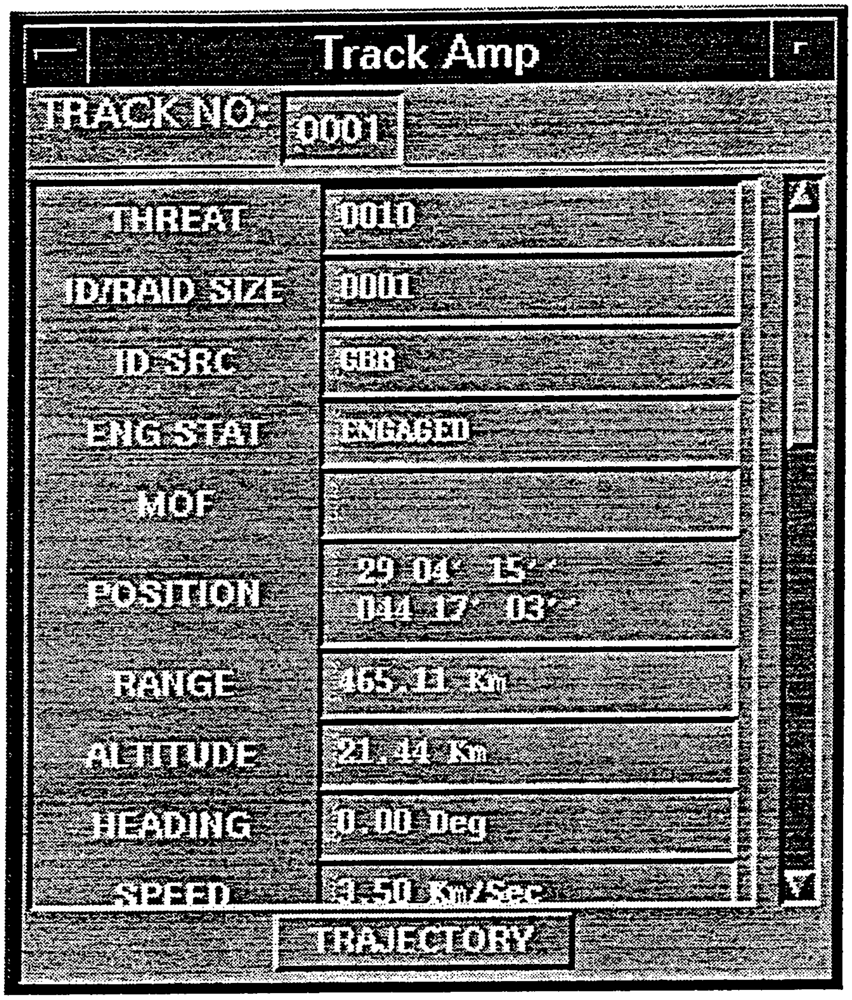

Figure 2. Tabular track amplification window.

Apparatus and Stimuli

The study was conducted using a series of paper-and-pencil comparative judgment tasks. Each task consisted of a written situation or scenario for the subjects to read and a representation of a window for the engagement queue or track amplification window in the THAAD OSI. Inside the windows were listed the information items currently in the engagement queue window or track amplification window (drawn from the OSI Prototype Version 2.1). Ten items were listed inside an engagement queue "window," while 18 to 25 items were listed in a track amplification "window"; the number of amplification items varied according to whether the operator was viewing an unengaged track (18 items shown in the window) or an engaged track (25 items shown in the window). Also included was a practice drill in which the operators viewed the "map utilities" window. The practice drill was included to allow the subjects to become comfortable with the experimental task.

Procedure

The method used for refining the items displayed in the engagement queue and track amplification windows for the THAAD OSI was based on that determined by Knapp et al. (1995). The original method for determining information criticality involved using the method of paired comparisons. Once it was determined which information items were grouped together logically (forming information clusters) and which information clusters were critical to particular decision tasks, then each of the information items in an information cluster was paired together with the other items and rated as to which item in the pair was more important for each decision task.

The paired comparisons method has given valid and reliable results. However, for this experiment, the number of information items in the engagement queue (10) and track amplification (18 through 25) clusters would require too many comparisons (45 and 153 through 300, respectively) to be made comfortably within the confines of one experiment. Therefore, this method of comparison was modified so that each subject was presented with a static engagement queue (or track amplification) "window" for two decision task situations: (a) general situation monitoring and assessment, and (b) assessing impact of new intelligence—threat capabilities data. Inside each window was listed each of the information items in the cluster (10 for the engagement queue and 18 through 25 for the track amplification). The subjects were instructed to read the decision task and quickly compare all items to determine the items that were the most important to them in addressing the situation, and which items were unnecessary or unimportant. The subjects were then instructed to select the three *most* important and three *least* important items for the engagement queue, and the five *most* important and five *least* important items for the track amplification window.

Each subject received the experimental situation sheets in the same order. However, the items presented in the engagement queue and track amplification windows were in a randomized order.

Each subject first received a practice drill and was told to read the given situation. He or she was then given 20 seconds to scan the items in the map utilities window, determine which three items they were likely to use first, and to circle these three items with a pen or pencil (provided).

After the practice drill, each subject received a sheet of paper with two situations asking him or her to use the THAAD engagement queue window. The subjects were asked to read Situation 1 (involving situation assessment and monitoring) and were then given 20 seconds to scan the engagement queue window, determine the top three items they would consult first, to circle these items, determine the very last three items they would use or could do without, and to cross out those three items. Subjects were then asked to read Situation 2, involving unexpected threat capabilities. They were then given the same directions regarding the engagement queue window and the items in that window.

After completing the tasks involving the engagement queue, subjects were given three sheets of paper with tasks involving the track amplification. Subjects were told to read Situation 1 (on the first sheet), involving situation awareness of an *unengaged* track. They were then told they had 60 seconds to scan the items in the track amplification window, to determine which five items would be most useful in that situation, to circle those items, to determine which five items they did not really need, and to cross out those five items.

The second sheet of paper involved the same situation (Situation 1), but with the operator viewing an *engaged* track. Participants received the same directions to select the five most useful and the five "not needed" items.

The last sheet of paper each subject viewed contained Situation 2 for the track amplification, having to do with unexpected new threats and the impact on an *engaged* track. Participants then received the same directions to select the five *most* useful and five *least* useful items.

Data Analysis

The resulting data were then tabulated into a matrix for each participant. An item indicated as being important was given a "score" of +1, an item indicated as being unimportant was given a "score" of -1, and the remaining items received a score of 0. These scores were then summed across all participants in each of the two groups and recorded in a matrix of data item scores for each situation (first for the engagement queue and then for the track amplification window). The resulting matrices indicate which items could be considered important and which unimportant (with importance being determined by positive total scores) for each of the windows. To make the items' rating summary score directly comparable, differences in sample sizes between the military user group and the Litton design engineering group were normalized by conversion to item group rating percentages. For example, if four of the five soldiers rated "method of fire" as important, then 80% of the group agreed. A group agreement value of 60% was used as the criterion to determine whether an item was critically important.

RESULTS

Engagement Queue

Situation 1 (situation assessment and monitoring)

Looking at Figure 3, four information items were indicated as important in the engagement queue window for Situation 1 by the military participants (asset threatened, TBM type/subtype, time to ground impact/point, and time to earliest launch [TEL]). Referring to Figure 4, of these four, one item was deemed critical by at least 60% of the military group for a general situation assessment and monitoring situation.

Again referring to Figure 3, the design engineers rated three information items as important for the engagement queue during Situation 1. These items were asset threatened, engagement status and time to last launch (TLL). Based on the presentation in Figure 4, all three items were rated as critical by at least 60% of the engineering group.

The lower half of Figure 3 shows which information items were rated as unimportant for general monitoring. For the military user group, two items in the engagement queue (method of fire and lower tier coverage) were found to have consistently low priority. Both of these information items were rated as having low priority by at least 60% of the military group (see Figure 4, lower half).

Design engineers rated four items (method of fire, lower tier coverage, time to intercept, and TEL) as the least important items for a general assessment and monitoring situation.

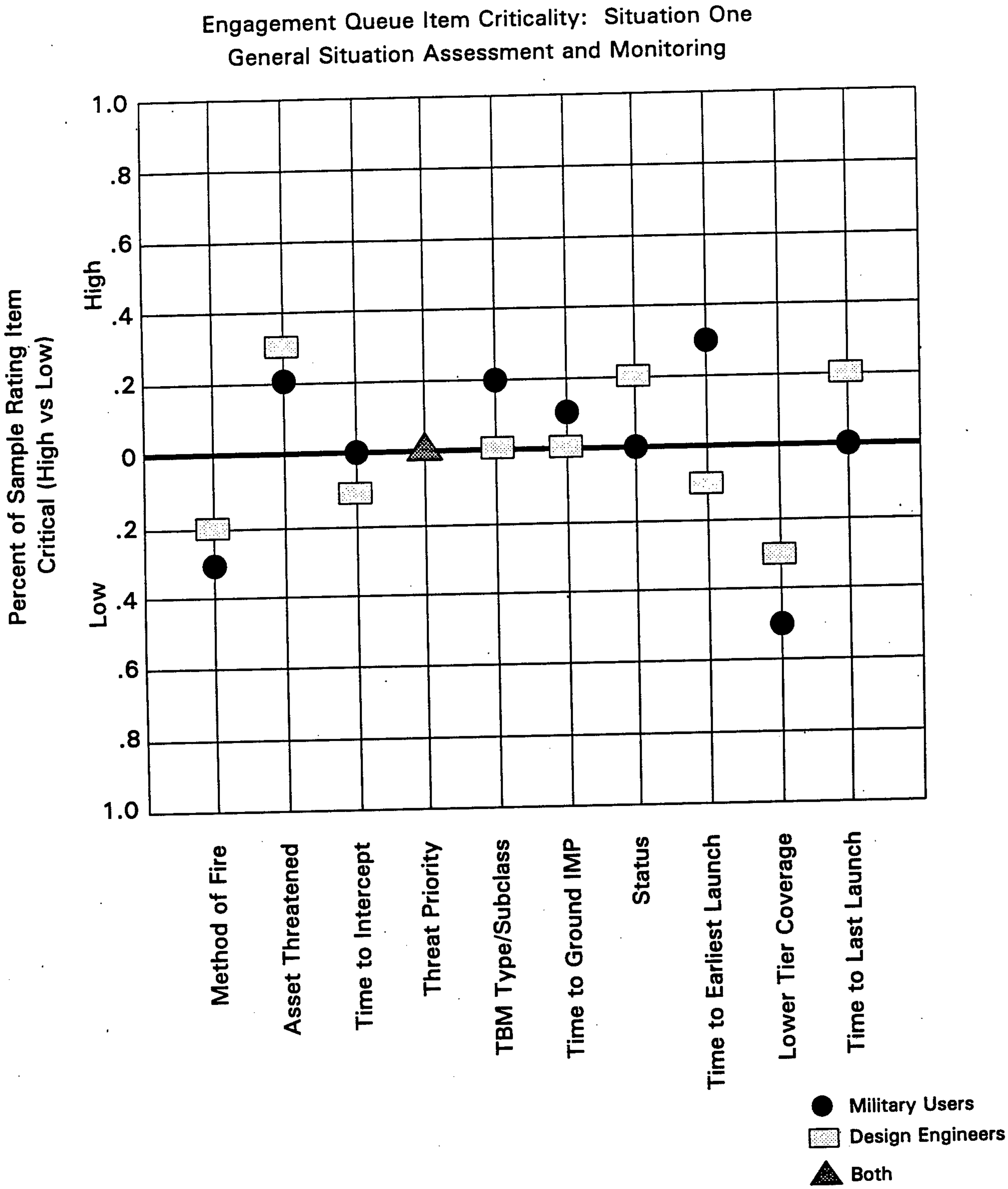

Figure 3. Data matrix for the engagement queue (Situation 1).

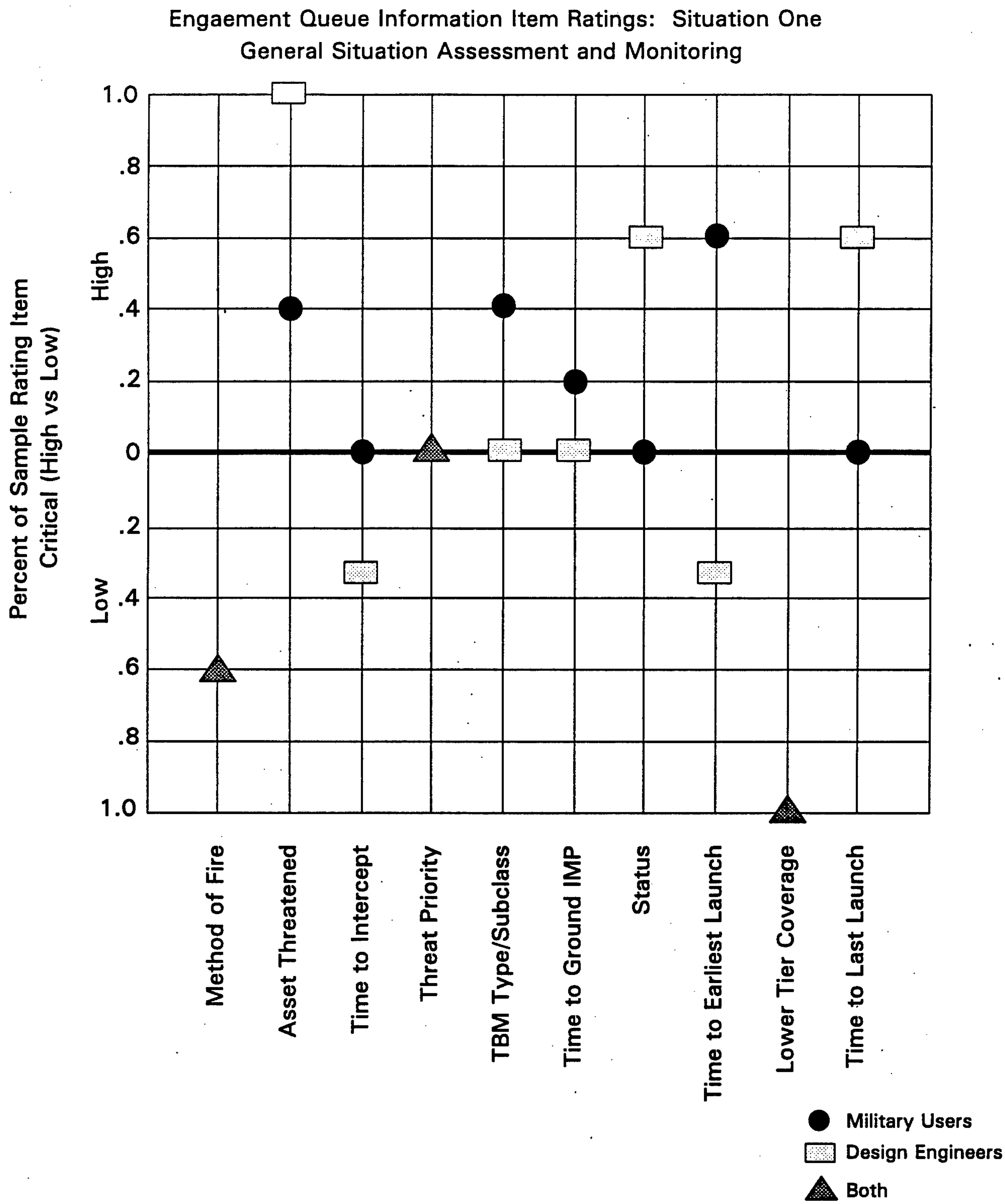

Figure 4. Data matrix for the engagement queue group percentages (Situation 1).

Figure 4 shows that two items (method of fire and lower tier coverage) received low ratings by 60% of the group.

Situation 2 (new intelligence about unexpected threat capabilities)

Looking at Figure 5, four information items were indicated as important in the engagement queue window for Situation 2 (asset threatened, TBM type/subtype, time to intercept, and threat priority). Figure 6 reveals that three of these four were deemed critical by at least 60% of the military participants. These critical items were asset threatened, TBM type/subtype, and threat priority.

Figure 5 shows that design engineers rated two information items as important to "responding to new intelligence about threat capabilities" (Situation 2). These items were asset threatened and TLL, both of which exceed the 60% criterion (see Figure 6).

The lower half of Figure 5 shows which information items were rated as unimportant for Situation 2. For the military user group, six items in the engagement queue (method of fire, time to ground impact/point, status [of the engagement], TEL, lower tier coverage, and TLL) were found to have consistently low priority in this "new intelligence information" situation by military users. As Figure 6 shows, two of these items (status and lower tier coverage) were rated as having low priority by at least 60% of the military user group.

For this same situation, design engineers rated four items (method of fire, threat priority, time to ground impact/point, and lower tier coverage) as the least important. Figure 6 indicates that method of fire, time to ground impact/point, and lower tier coverage were rated as having low priority by at least 60% of the group.

Summary

Figure 7 presents a summary of the military group agreement percentages displayed in Figures 4 and 6. Figure 8 summarizes the design group percentages presented in Figures 4 and 6. For Figures 7 and 8, plus and minus signs in front of percentage values are only to indicate relative importance. They carry no mathematical significance. A plus sign denotes relative importance whereas a minus sign symbolizes relative unimportance. Rank order values were derived from the average group percentage ratings of all situations rated. The rank order information is addressed later in the Discussion section. No information item rated as critical by soldiers for the engagement queue window were common to both of the situations tested. For BMC3 system design engineers, asset threatened and TLL were rated as important by at least 60% of the group across both situations.

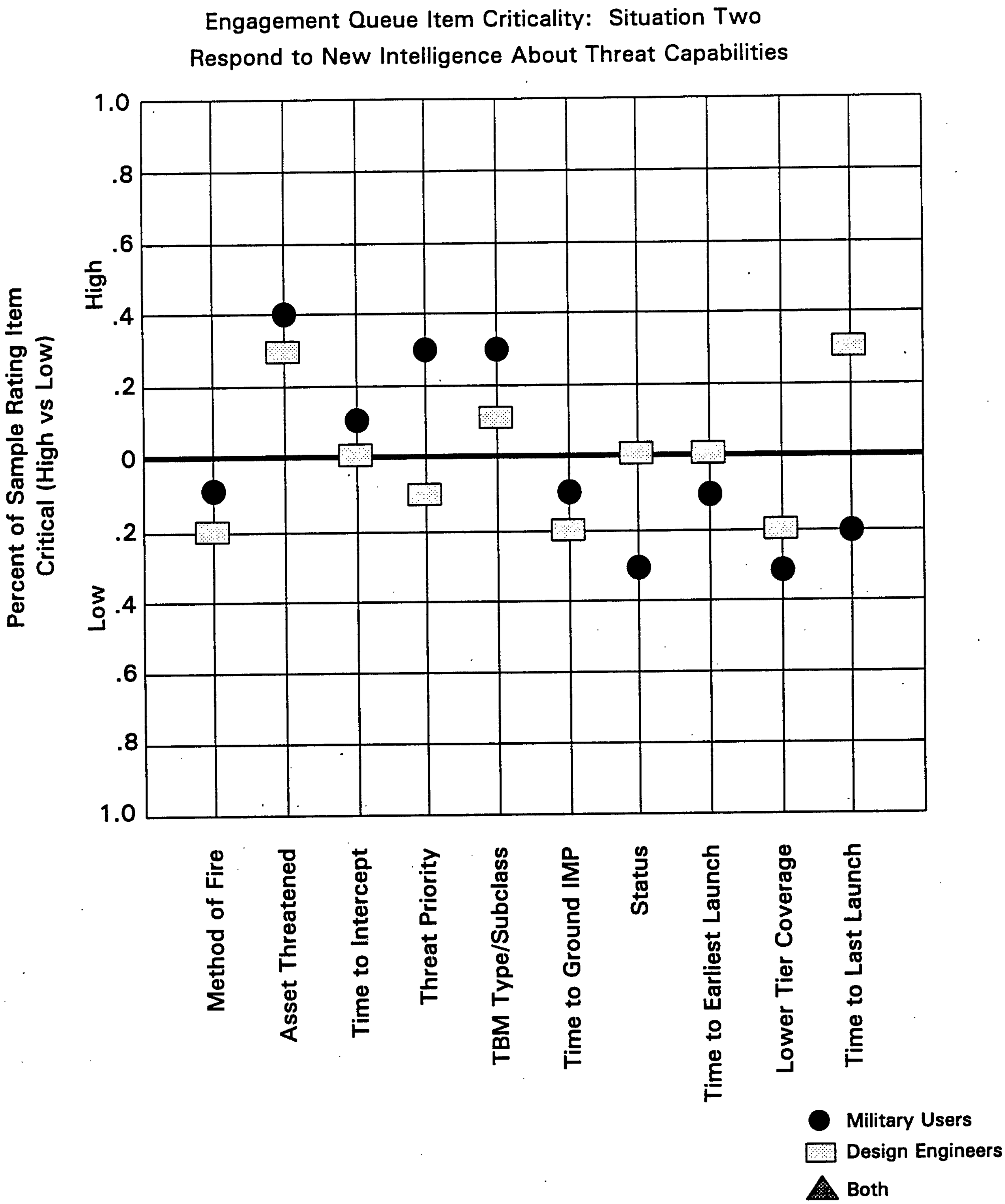

Figure 5. Data matrix for the engagement queue (Situation 2).

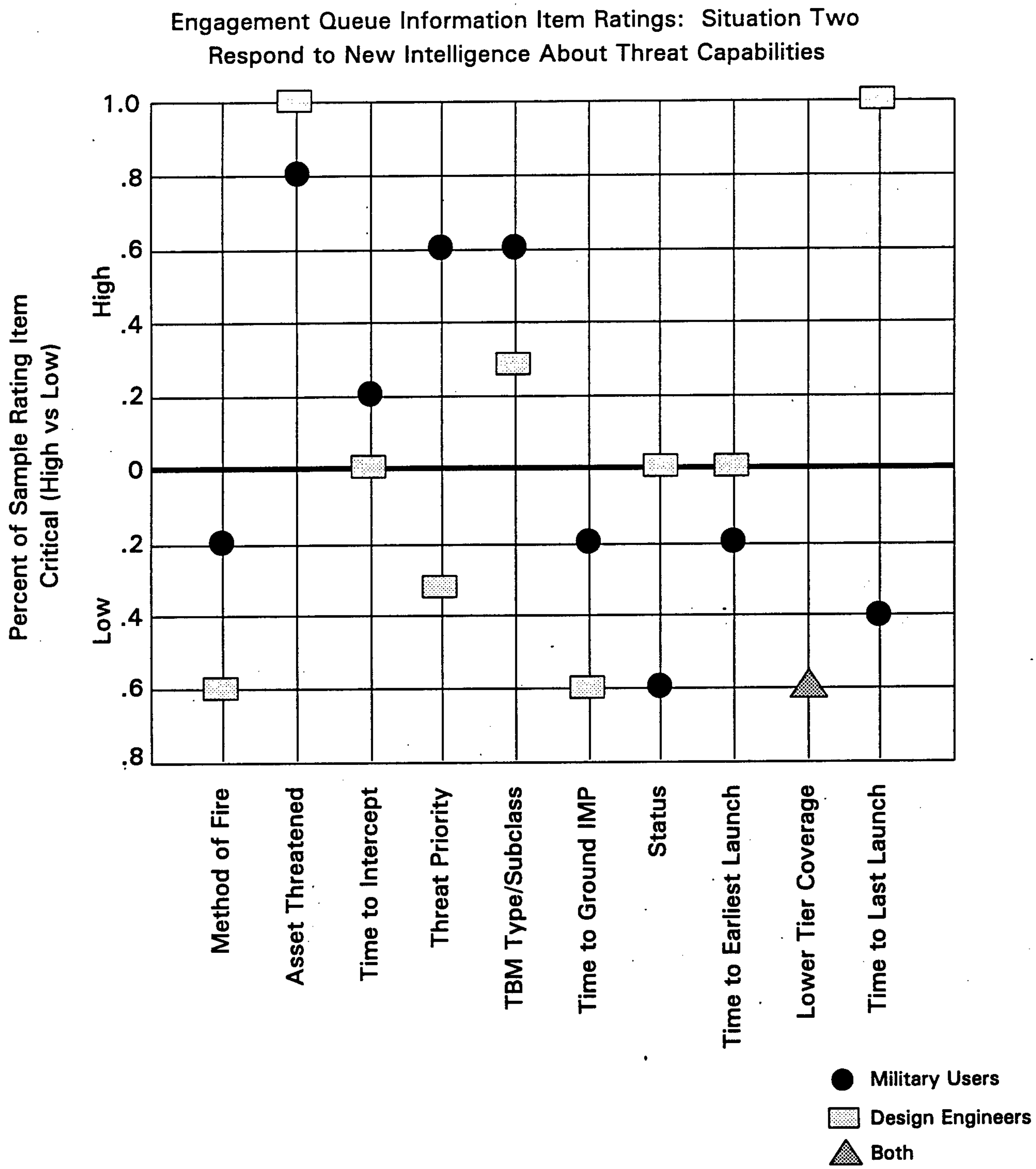

Figure 6. Data matrix for the engagement queue group percentages (Situation 2).

	Situation 1	Situation 2	Rank Order
Method of Fire	-0.6	-0.2	9
Asset Threatened	+.4	+.8	1
Time to Intercept	0	+.2	5
Threat Priority	0	+.6	3
TBM Type/Subclass	+.4	+.6	2
Time to Ground IMP	+.2	-0.2	6
Status	0	-0.6	8
Time to Earliest Launch	+.6	-0.2	4
Lower tier Coverage	-1	-0.6	10
TLL	0	-0.4	7

Figure 7. Engagement queue - information item importance rating group agreement percentages for military users.

	Situation 1	Situation 2	Rank Order
Method of Fire	-0.66	-0.66	9
Asset Threatened	+1.0	+1.0	1
Time to Intercept	-0.33	0	6
Threat Priority	0	-0.33	6
TBM Type/Subclass	0	+.33	4
Time to Ground IMP	0	-0.66	8
Status	+.66	0	3
Time to Earliest Launch	-0.33	0	6
Lower tier Coverage	-1	-0.66	10
TLL	+.66	+1.0	2

Figure 8. Engagement queue - information item importance rating group agreement percentages for design engineers.

Of the information items in the engagement queue, two were indicated by the military group as having low priority across both situations tested (method of fire and lower tier coverage). Of these two, only one (lower tier coverage) was found to have low priority across both situations by at least 60% of the military group.

Sixty percent of the design group rated method of fire and lower tier coverage as least important across both Situations 1 and 2.

Across both groups and both situations, there was agreement by at least 60% of each group on one item as least important (lower tier coverage), but 60% of both groups did not concur on any item as most important.

Track Amplification

Situation 1A (situation assessment and monitoring for unengaged tracks)

Looking at Figure 9, eight items were indicated as important in the track amplification window for Situation 1A for military users. These items included asset threatened, threat priority, engagement status, TLL, speed of track, position of track, heading of track, and classification/ID. Of these eight, Figure 10 indicates that two items (engagement status and classification/ID) were deemed critical by at least 60% of the military participants.

The lower half of Figure 9 indicates that eight items in the track amplification window (method of fire, lower tier coverage, estimated launch point, radar/source unit, trajectory profile/pop-up graphic, track quality, asset damage score, and altitude of track) were rated by military participants as having relatively low priority in Situation 1A. The lower half of Figure 10 shows that three of these eight items (method of fire, radar/source unit, and asset damage score) were rated unimportant by at least 60% of the military user group.

For design engineers, Figure 3 indicates that six information items (asset threatened, TBM type/subclass, engagement status, TLL, radar source/unit, and classification/ID) were rated as important to this window for Situation 1A. Figure 8 shows that two of these items (asset threatened and TBM type/subclass) were deemed critical by at least 60% of the design group.

The bottom half of Figure 9 shows that eight items (lower tier coverage, speed of track, position of track, heading of track, trajectory profile/pop-up graphic, track quality, asset damage score, and altitude of track) were rated as least important for the track amplification window for Situation 1A. One item (lower tier coverage) was found to be unimportant by 60% of the design group (see Figure 10).

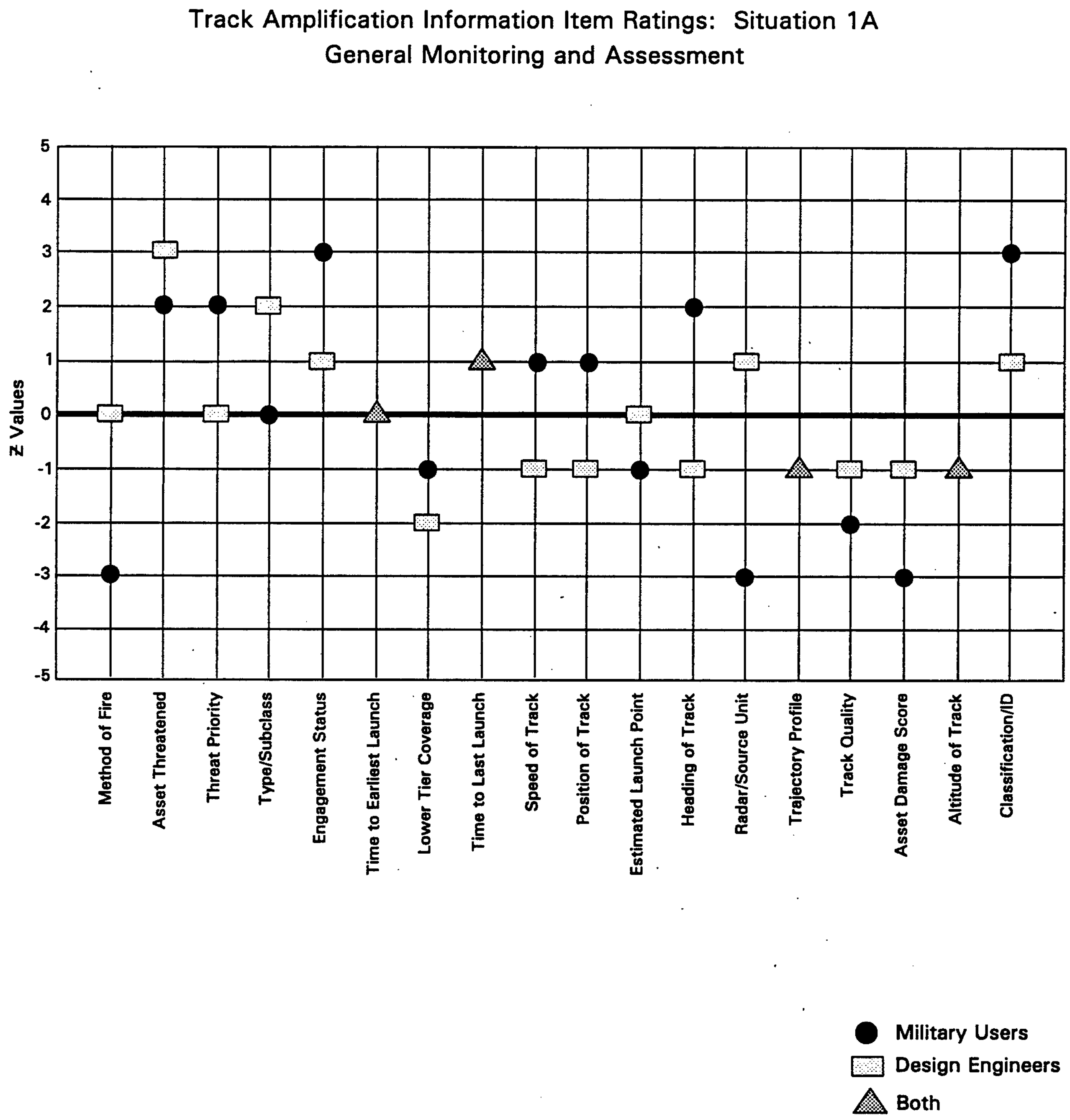

Figure 9. Data matrix for the track amplification (Situation 1A).

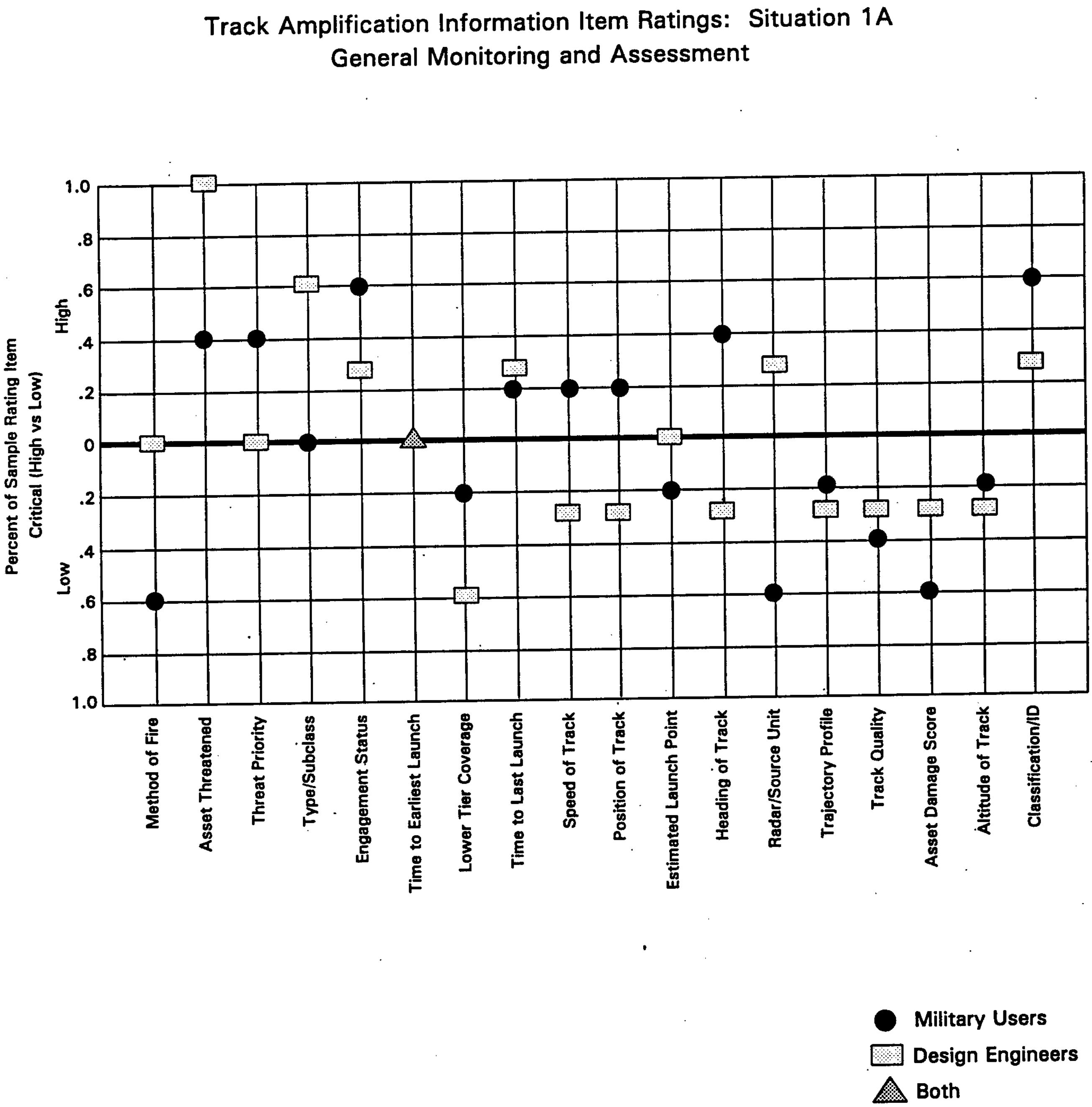

Figure 10. Data matrix for the track amplification group percentages (Situation 1A).

Situation 1B (situation assessment and monitoring for engaged tracks)

Looking at Figure 11, 11 items were rated by soldiers as important in the track amplification window for this situation. These items included asset threatened, threat priority, engagement status, type/subclass, position of track, heading of track, altitude of track, classification/ID, TEL, TLL, and status of interceptor. Referring to Figure 12, one of these 11 items (engagement status) was deemed critical by at least 60% of the military participants.

In contrast, the lower half of Figure 11 shows that eight information items in the track amplification window (method of fire, lower tier coverage, radar/source unit, track quality, trajectory profile/pop-up graphic, speed of interceptor, altitude of interceptor, and heading of interceptor) were rated by military participants as having relatively low priority in Situation 1B. The lower half of Figure 10 shows that three of these eight items (lower tier coverage, radar/source unit, and track quality) were rated unimportant by at least 60% of the military group.

The top half of Figure 11 indicates that design engineers rated 11 items as important in the Track Amplification Window to situation assessment and monitoring during ongoing target engagements, but none of these items were deemed critical by at least 60% of the group (see Figure 12). These 11 items included method of fire, engagement status, type/subclass, position of track, heading of track, TLL, time to go, trajectory profile, interceptor position, THAAD missile ID, and status of interceptor.

The lower half of Figure 11 shows that nine information items in the track amplification window (TEL, lower tier coverage, radar/source unit, speed of track, estimated launch point, classification/ID, interceptor speed, altitude of interceptor, and heading of interceptor) were rated by design engineering participants as having relatively low priority in Situation 1B. The lower half of Figure 12 shows that two of these nine items (altitude of interceptor and heading of interceptor) were rated unimportant by at least 60% of the design group,

Situation 2 (unexpected new threats)

Looking at Figure 13, 10 items were rated by soldiers as important in the track amplification window for this situation. These items included asset threatened, threat priority, engagement status, type/subclass, speed of track, position of track, heading of track, classification/ID, TEL, and TLL. Figure 14 shows that four of these 10 items (asset threatened, threat priority, engagement status, and type/subclass) were deemed critical by at least 60% of the military participants.

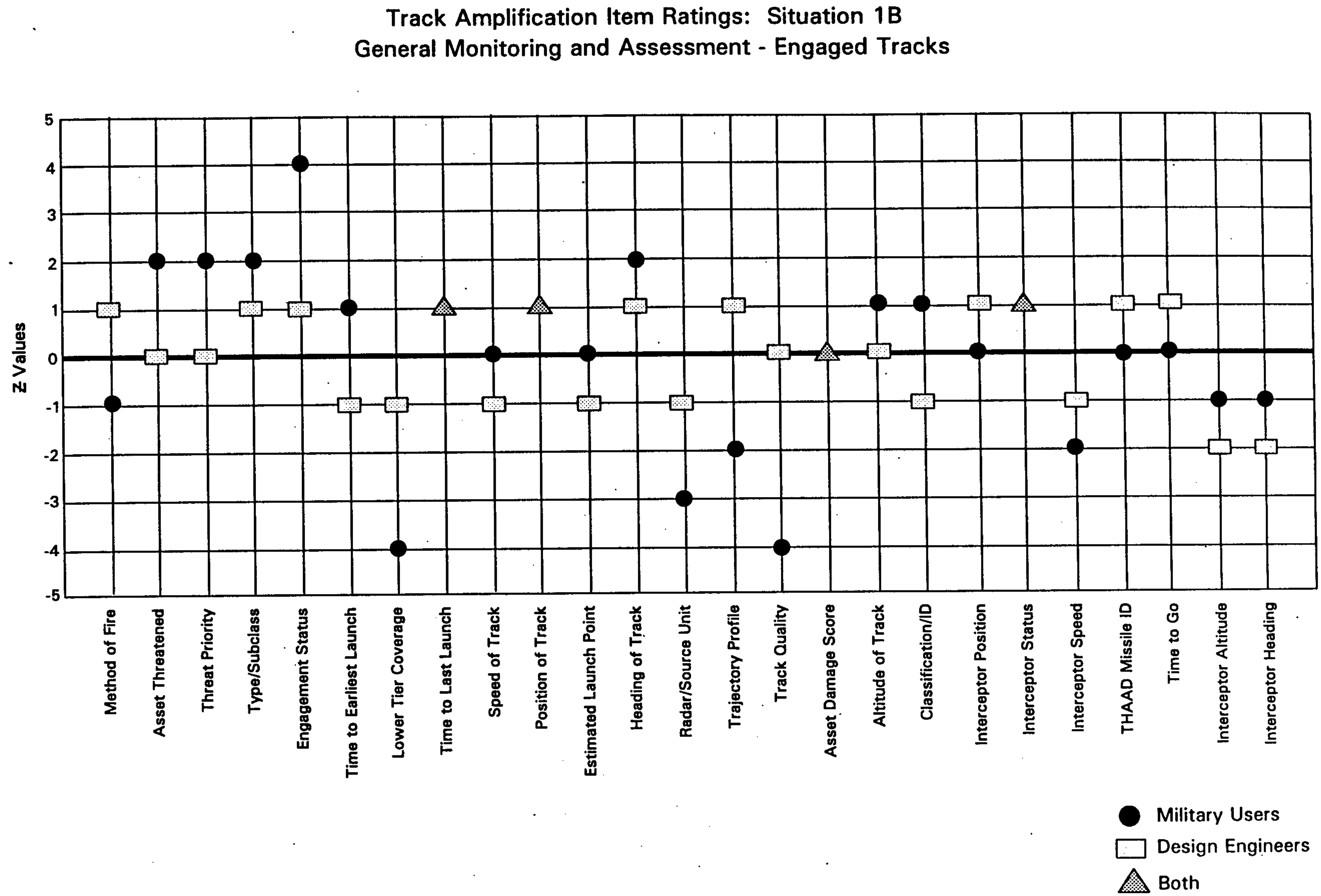

Figure 11. Data matrix for the track amplification (Situation 1B).

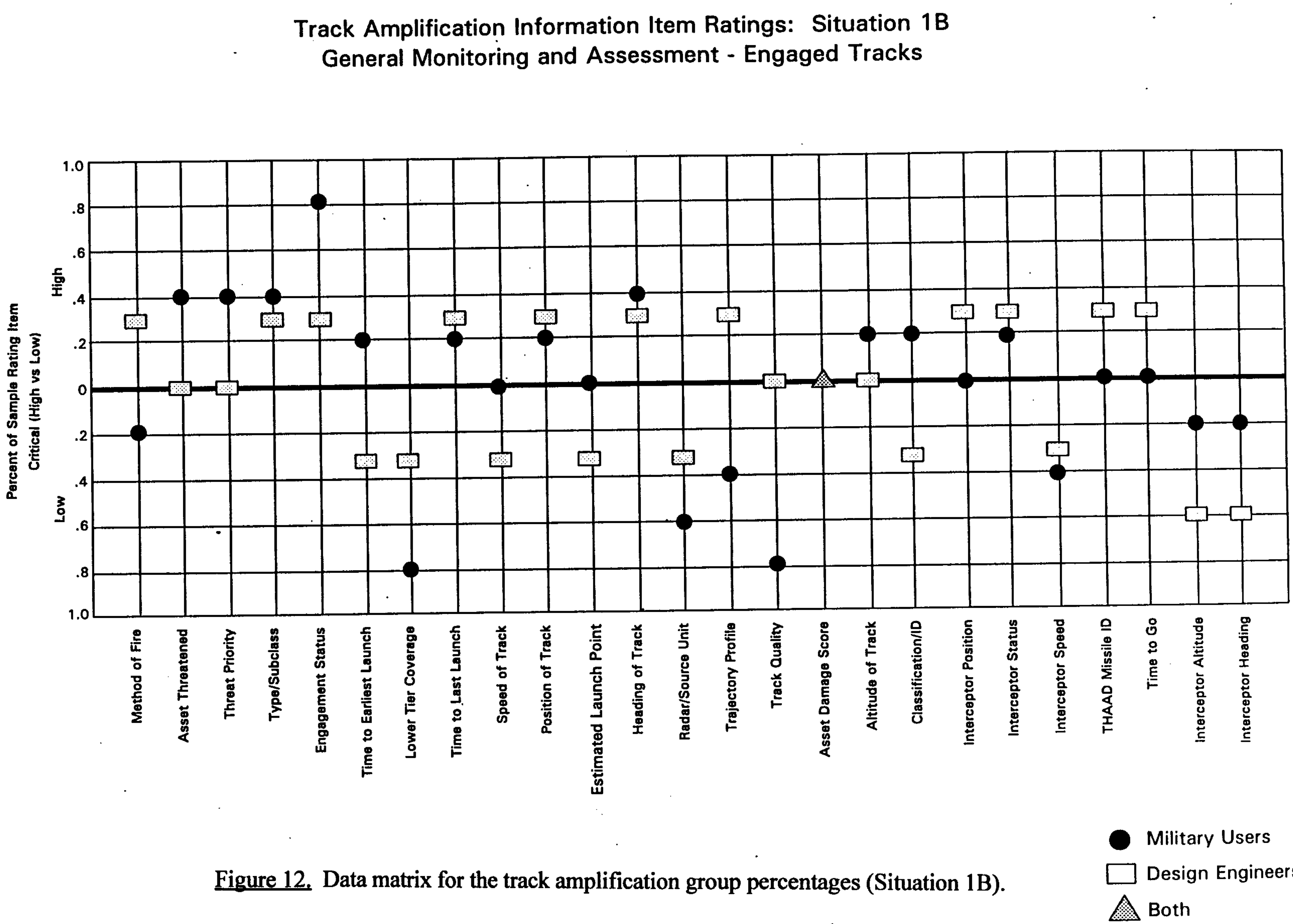

Figure 12. Data matrix for the track amplification group percentages (Situation 1B).

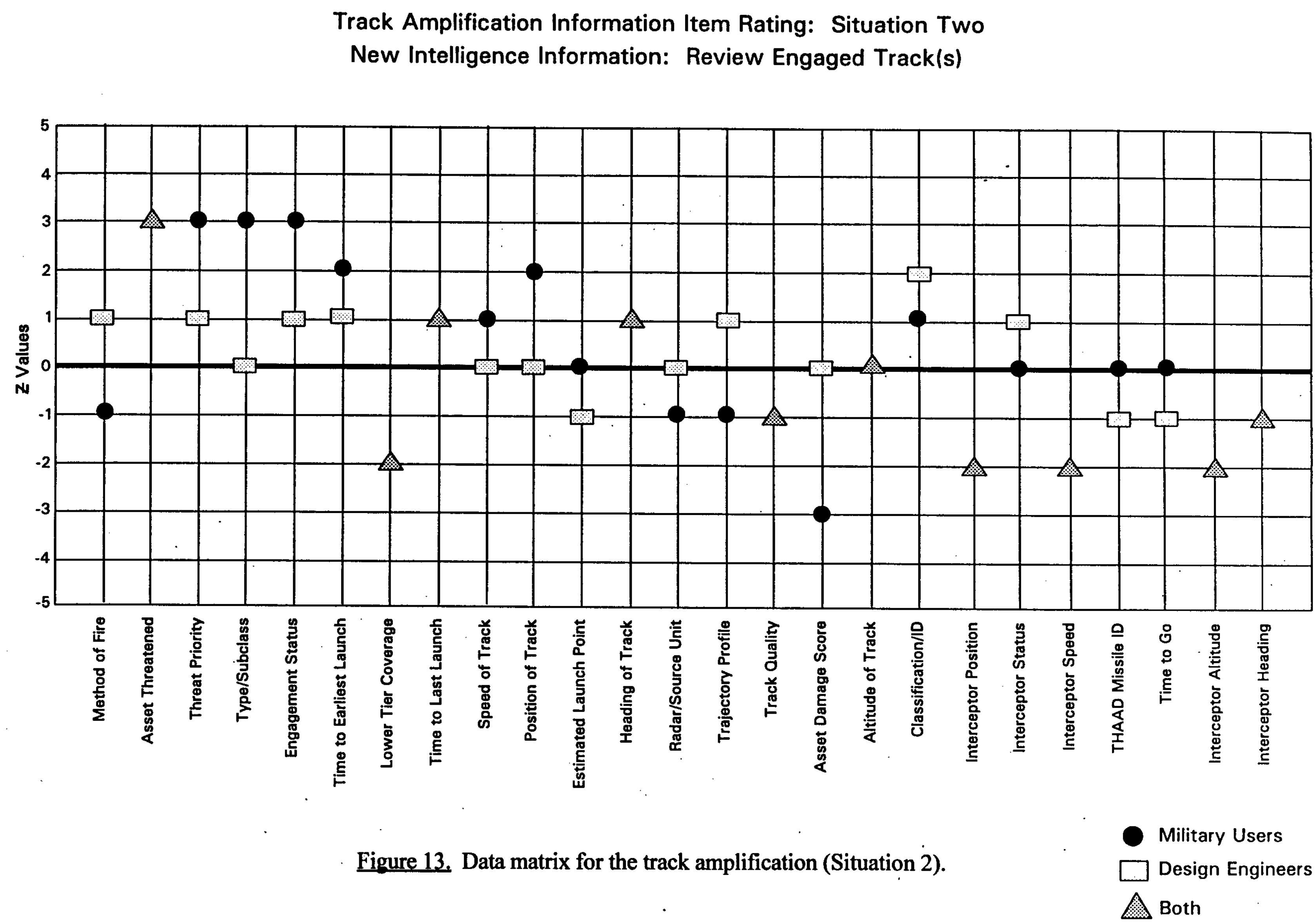

Figure 13. Data matrix for the track amplification (Situation 2).

In contrast, the lower half of Figure 13 shows that 10 information items in the track amplification window (method of fire, lower tier coverage, radar/source unit, trajectory profile/pop-up graphic, track quality, asset damage score, position of interceptor, speed of interceptor, altitude of interceptor, and heading of interceptor) were rated by military participants as having relatively low priority in Situation 2. The lower half of Figure 14 shows that one of these 10 items (asset damage score) was rated unimportant by at least 60% of the military group.

The top half of Figure 13 indicates that design engineers rated 10 information items as important in the track amplification window to the situation when new intelligence information has been received regarding the appearance of unexpected new threats. These 10 items included method of fire, asset threatened, threat priority, engagement status, TEL, TLL, heading of track, trajectory profile, classification/ID, and status of interceptor. The top half of Figure 14 shows that two of these 10 items (asset threatened and classification/ID) were rated important by at least 60% of the design group.

The lower half of Figure 13 shows that design engineers rated nine information items in the track amplification window (lower tier coverage, estimated launch point, track quality, THAAD missile ID, time to go, interceptor position, interceptor speed, altitude of interceptor, and heading of interceptor) as least important to Situation 2. Figure 14 reveals that four of these nine items (lower tier coverage, interceptor position, interceptor speed, and altitude of interceptor) were rated unimportant by at least 60% of the design group.

Summary

Figure 15 summarizes the military group agreement percentages presented in Figures 10, 12, and 14. Figure 16 summarizes the agreement percentages for the design group. Of the important information items indicated in the track amplification window by military users, seven items were indicated as important across all three situations (asset threatened, threat priority, engagement status, position of track, TLL, classification/ID, and heading of track). Three additional items were important in two situations (speed of track, type/subclass, and TEL). One item (engagement status) was deemed critical by at least 60% of the military participants across all three situations.

Of the information items in the track amplification window, five items (method of fire, lower tier coverage, radar/source unit, track quality, and trajectory profile) were indicated by military users as relatively unimportant across all three situations. In addition, four items (asset

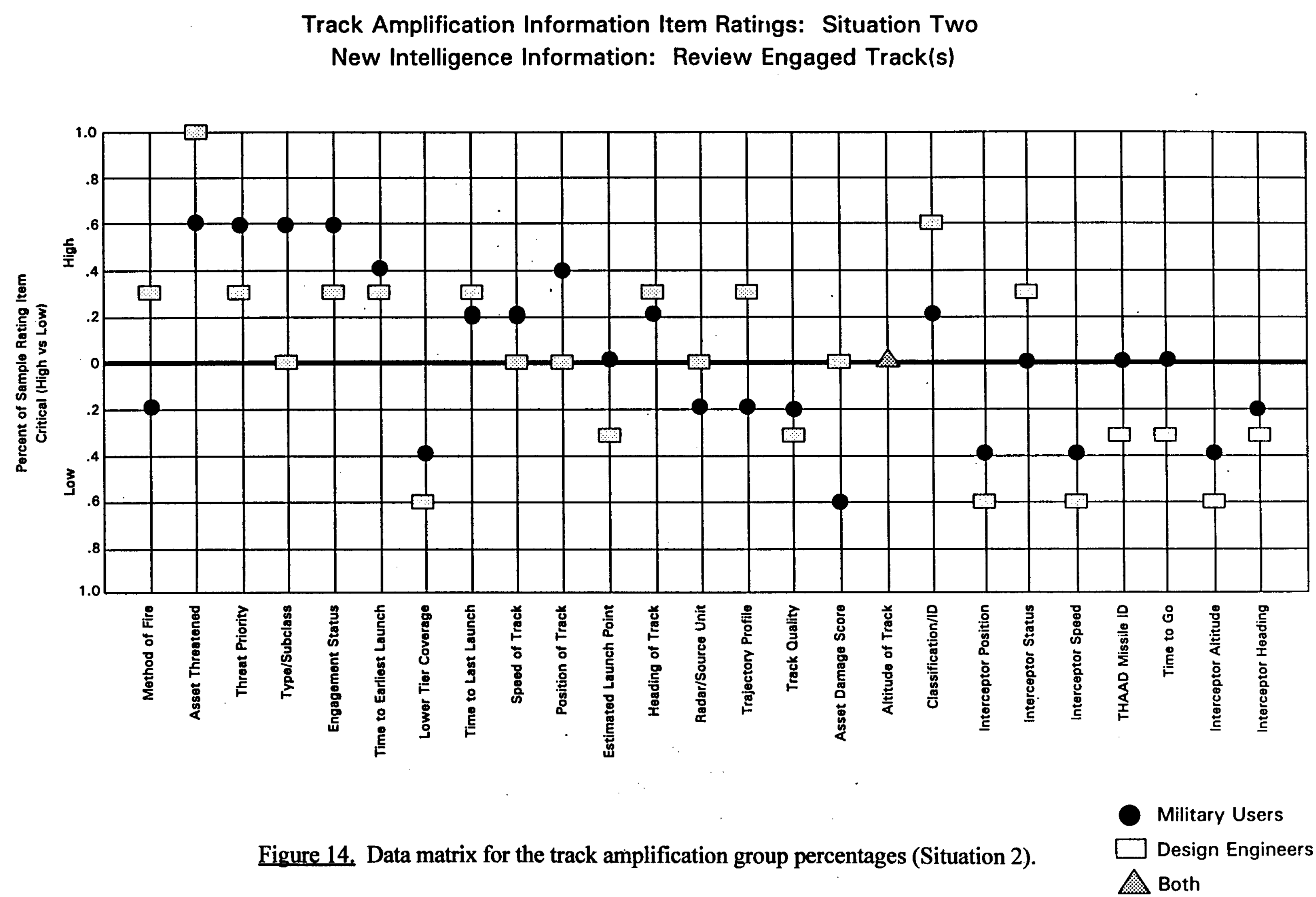

Figure 14. Data matrix for the track amplification group percentages (Situation 2).

damage score, speed of interceptor, altitude of interceptor, and heading of interceptor[2]) were noted as unimportant during two of the situations. Two items (radar/source unit and asset damage score) were deemed relatively unimportant across two situations by at least 60% of the military participants.

	Situation 1A	Situation 1B	Situation 2	Rank Order
Method of Fire	-0.6	-0.2	-0.2	2
Asset Threatened	+.4	+.4	+.6	2.5
Threat Priority	+.4	+.4	+.6	2.5
Type/Subclass	0	+.4	+.6	5
Engagement Status	+.6	+.8	+.6	1
Time to Earliest Launch	0	+.2	+.4	8.5
Lower Tier Coverage	-0.2	-0.8	-0.4	24
TLL	+.2	+.2	+.2	8.5
Speed of Track	+.2	0	+.2	10
Position of Track	+.2	+.2	+.4	7
Estimated Launch Point	-0.2	0	0	15
Heading of Track	+.4	+.4	+.2	5
Radar/Source Unit	-0.6	-0.6	-0.2	24
Trajectory Profile	-0.2	-0.2	-0.2	18
Track Quality	-0.4	-0.8	-0.2	24
Asset Damage Score	-0.6	0	-0.6	21.5
Altitude of Track	-0.2	+.2	0	13
Classification/ID	+.6	+.2	+.2	5
Interceptor Position	X	0	-0.4	16.5
Interceptor Status	X	+.2	0	11
Interceptor Speed	X	-0.4	-0.4	21.5
THAAD Missile ID	X	0	0	13
Time to Go	X	0	0	13
Interceptor Altitude	X	-0.2	-0.4	19
Interceptor Heading	X	-0.2	-0.2	16.5

Figure 15. Track amplification data window - information item importance rating group agreement percentages for military users.

For design engineers, two items (engagement status and TLL) were rated as important across all three situations. Seven additional items, (method of fire, asset threatened, type/subclass, heading of track, trajectory profile, classification/ID, and interceptor status) were identified as important across two situations. No item was deemed critical by at least 60% of the

[2]Note. The last three items mentioned here (speed of interceptor, altitude of interceptor, and heading of interceptor) were only available in two situations (Situations 1B and 2).

group for all three situations. Design engineers rated one item (lower tier coverage) as relatively unimportant across all three situations. Six other Items (speed of track, estimated launch point, track quality, interceptor speed, interceptor altitude, and interceptor heading) were rated as unimportant across two of the situations. No item was deemed least important by at least 60% of the group for all three situations.

	Situation 1A	Situation 1B	Situation 2	Rank Order
Method of Fire	0	+.33	+.33	6.5
Asset Threatened	+1.0	0	+1.0	1
Threat Priority	0	0	+.33	9
Type/Subclass	+.66	+.33	0	3.5
Engagement Status	+.33	+.33	+.33	3.5
Time to Earliest Launch	0	-0.33	+.33	13
Lower Tier Coverage	-0.66	-0.33	-0.66	24
TLL	+.33	+.33	+.33	3.5
Speed of Track	-0.33	-0.33	0	20
Position of Track	-0.33	+.33	0	13
Estimated Launch Point	0	-0.33	-0.33	20
Heading of Track	-0.33	+.33	+.33	9
Radar/Source Unit	+.33	-0.33	0	13
Trajectory Profile	-0.33	+.33	+.33	9
Track Quality	-0.33	0	-0.33	20
Asset Damage Score	-0.33	0	0	16.5
Altitude of Track	-0.33	0	0	16.5
Classification/ID	+.33	-0.33	+.66	6.5
Interceptor Position	X	+.33	-0.66	18
Interceptor Status	X	+.33	+.33	3.5
Interceptor Speed	X	-0.33	-0.66	22.5
THAAD Missile ID	X	+.33	-0.33	13
Time to Go	X	+.33	-0.33	13
Interceptor Altitude	X	-0.66	-0.66	2.5
Interceptor Heading	X	-0.66	-0.33	22.5

Figure 16. Track amplification data window - information item importance rating group agreement percentages for design engineers.

DISCUSSION AND CONCLUSIONS

The results from this experiment clearly provide designers with some guidelines for the design of the THAAD OSI, in particular, the engagement queue and track amplification windows. These windows had previously been identified (in OSI Prototype Version 2.1) as areas to be considered for redesign. This experiment provides specific insight into the redesign of these windows. The rank orders displayed in Figure 7 for the engagement queue and Figure 15 for the track amplification data window provide the basis for this design guidance.

The engagement queue window, currently designed as a table of rows and columns, provides the THAAD engagement operator with various information items about incoming threats, both engaged and unengaged. Each track is displayed as a separate row, and ten column headings identify various information about each track. Currently, operators may need to scan extensively or scroll through the window in order to find information not displayed on the first page of the window. Two information items in this window (asset threatened and TBM type/subtype) have been identified in this study as being the most importation items across multiple representative situations. As such, designers now know to place these highly used items in a prominent area of the display window (e.g., left-most columns of the display), limiting the amount of unnecessary scanning or searching that operators need to perform to locate them. In contrast, lower tier coverage and method of fire were identified as having the lowest priorities. These items can then be delegated to less prominent areas of the engagement queue window.

The track amplification window is also currently displayed as a table showing detailed information for a "hooked" track. Information items are displayed on different rows (18 for unengaged tracks and 25 for engaged tracks). Again, operators need to scroll through the window, searching for information that is not displayed on the first page. Seven of these information items (asset threatened, threat priority, engagement status, TBM type/subclass, classification/ID, position of track, and heading of track) were indicated in this study as being important across all situations tested. Because these seven items are used often, especially threat priority and engagement status, designers need to place them in a prominent area of the display window, specifically on the first page, limiting the amount of additional scrolling, scanning, or mouse clicks that operators need to perform to locate them. In addition, speed of track, TEL, and TLL, should also be given consideration in their placement because they were found to be important in at least two of the three situations tested.

In contrast, nine information items (method of fire, lower tier coverage, radar/source unit, track quality, asset damage score, speed of interceptor, altitude of interceptor, heading of interceptor, and trajectory profile/pop-up graphic) were identified as having the lowest priorities. These items can then be delegated to less prominent areas of the track amplification window. In addition, the implementation of the trajectory profile/pop-up graphic needs to be reconsidered. As currently implemented, this graphic is accessed by "clicking" on a button in the track amplification window. This graphic is then displayed in the window, displacing all the other information displayed by rows. Since this graphic was designated as relatively unimportant, it should not displace information that is more important.

In addition, although these windows are currently implemented as tables which operators need to scroll through, these implementations are also being evaluated and other possible implementations being considered. The results of this study still give designers guidelines that are independent of the final implementation chosen. Information items found to be important in the engagement queue and track amplification windows need to be placed in a prominent area of the display, whether displayed in a table, graphically, etc. This information needs to be presented to the operators requiring very little extra action on their part (i.e., scrolling, mouse clicks, scanning, etc.). Information deemed as relatively unimportant (e.g., information that is "nice" to have available but not needed in most cases) can be displayed less prominently.

One interesting result of this research relates to the amount of agreement in item ratings between military users and system design engineers. Comparing the group rank orderings listed in Figures 7 and 8 for the engagement queue, when one considers values attributable to tied ranks, one finds a positive amount of similarity in rankings (Gamma rank-order correlation statistic = .5238; p = .04[3]) for all the information items except two. In fact, there was perfect agreement for the most important and the two least important information items within the engagement queue. The two items that received the most divergent ratings between the two groups were Engagement Status and TLL. The design engineers consistently rated these two items as relatively more important (ranks 2 and 3) whereas users see these two items as relatively unimportant (ranks 7 and 8).

When comparing group rankings for the information in the Track Amplification Data Window, the data in Figures 15 and 16 show a fair amount of correspondence (Gamma rank-order correlation statistic = .6273; p = .000039) between groups for 10 of the items. These items are asset threatened, type/subclass, engagement status, lower tier coverage, track quality, classification/ID, interceptor position, interceptor speed, THAAD missile ID, and time to go. There was considerable divergence in group ratings for three items. These items were method of fire, radar/source unit, and speed of track. Military users consistently rate the first two items as relatively less important, but designers rate them as important. The last item, speed of track, is rated more important by users than by design engineers.

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[3]Gamma. The Gamma non-parametric correlation coefficient (variables in ranks) is preferable to Spearman *R* or Kendall *tau* when the data contain many tied observations (Siegel & Castellan, 1988).

The fact that system designers differ in their ratings, at least to some degree, from the ratings of system users indicates that users must be involved in the system design process. Second, this involvement must be early in the design process. User design input, as documented in this report, can be objectively obtained. Finally, these objective data must then be provided to the system design engineers to influence features of the final human computer interface.

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