TARGET ACQUISITION FOR OFFENSIVE SYSTEMS

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Abstract

In order to better evaluate the cost effectiveness of offensive weapon systems, increased attention should be paid to quantifying target acquisition (TA) by the shooters. Recent conflicts such as the Gulf War and Kosovo have illustrated the importance of proper TA. The calculation of the probability of target acquisition is difficult. It should start with an understanding of the five elements in the process, especially, the rules of engagement. Information on target characteristics in a battle setting (signatures) needs to be assessed. Determination must be made as to the contributions (cueing) from support systems not on the attack platform along with the effectiveness of the command, control, communications, intelligence (C3I) net. Next, the on-board equipment, whether pods or integral, and procedures should be investigated based upon test results including pilot proficiency. Then the estimate needs to be degraded for wartime factors such as lighting (day or night), weather (clouds), dust, camouflage, terrain, decoys and stress. The analyst should specify the assumptions, describe the logic, and note the operational environment in order to improve the confidence in the estimates. Equal cost force analyses can be useful for assessing system alternatives and trade-offs among the probabilities.

Systems Analysis

The analytic community has done well in determining weapon system effectiveness for hardware. There is considerable experience with analyses including models and tests. Consideration of software aspects are improving as the importance is recognized. Also, partially as a result of the Gulf War, there is emphasis upon trying to integrate the many weapons, support, and decision systems.

While platforms such as the F-22 are glamorous, a very key factor relating to weapon system performance needs more attention: acquisition of ground targets by the shooters. This has become more important due to the increased emphasis on avoiding side effects. In the old days that meant not hitting nearby friendly forces. Now, in addition, it is desired to reduce casualties on both sides and collateral damage must be minimized.

The advent of short range stand-off weapons complicates the issues. Interdiction targeting, e.g., for long-range stand-off missiles such as the Joint Air to Surface Stand-off Missile (JASSM) is beyond the scope of this paper.

A little history is revealing. Figure 1 shows a typical weapon system cost effectiveness analysis plan. It covers the extension from one-on-one to force-on-force (M on N) together with cost and risk analyses. It is heavy on hardware aspects such as aircraft performance, hardness, and avionics. Target acquisition is buried in two elements: Off avionics capability and targets killed.

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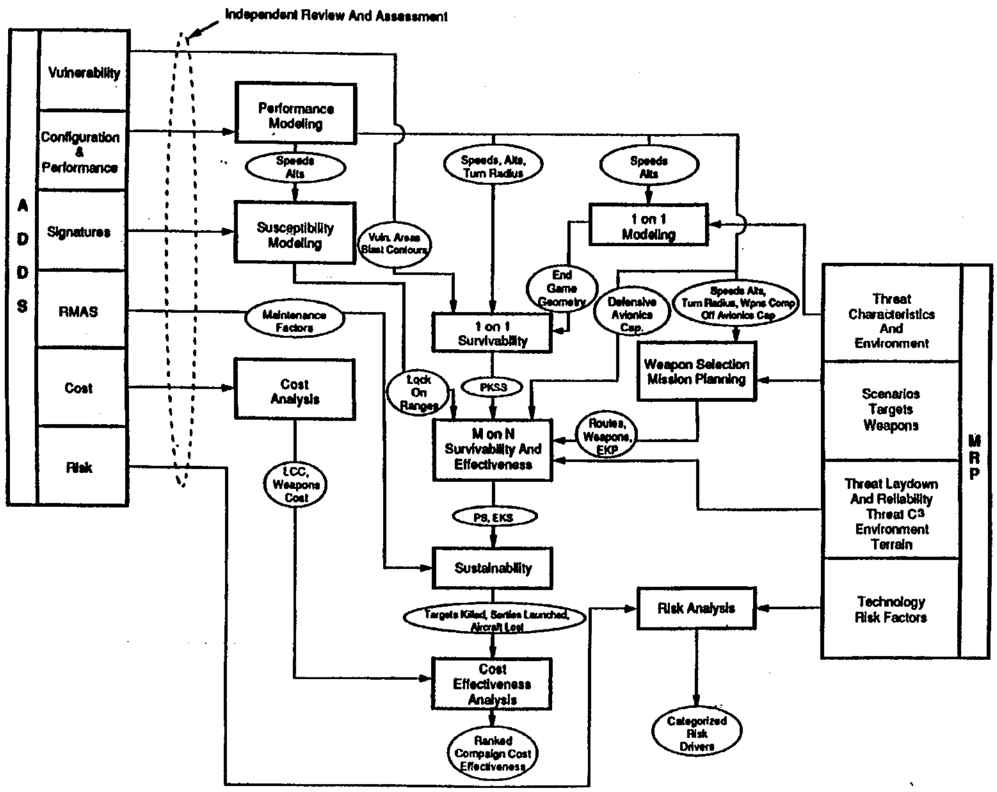


Figure 1. Force Analysis Steps

Figure 2 is a brief Army layout of these elements. It notes that weapons and munitions are part of a larger "System of Systems." One virtue of this figure is that target acquisition is highlighted at the top. While this paper focuses on Close Air Support, the principles apply to Army tanks and artillery that are also engaged in Close Support.

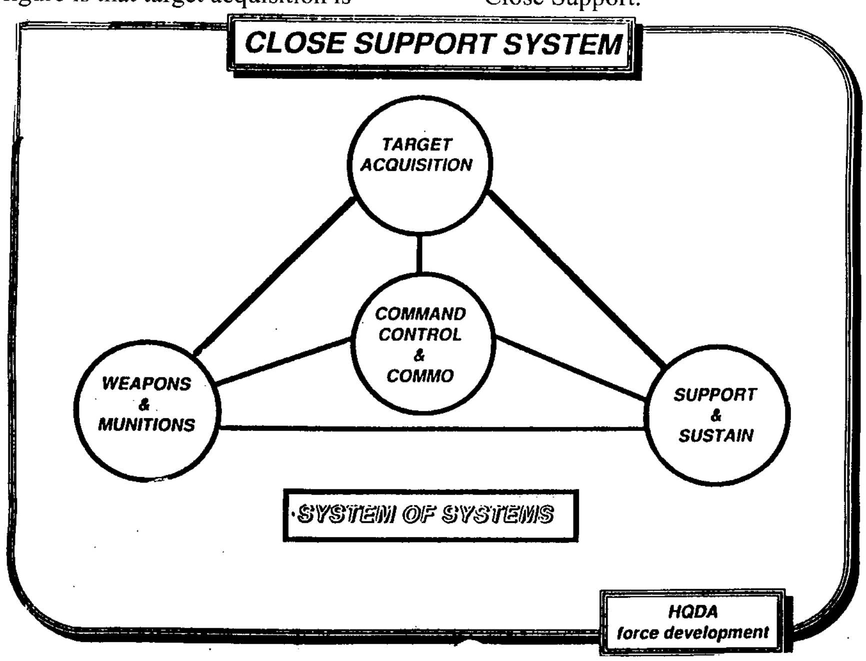
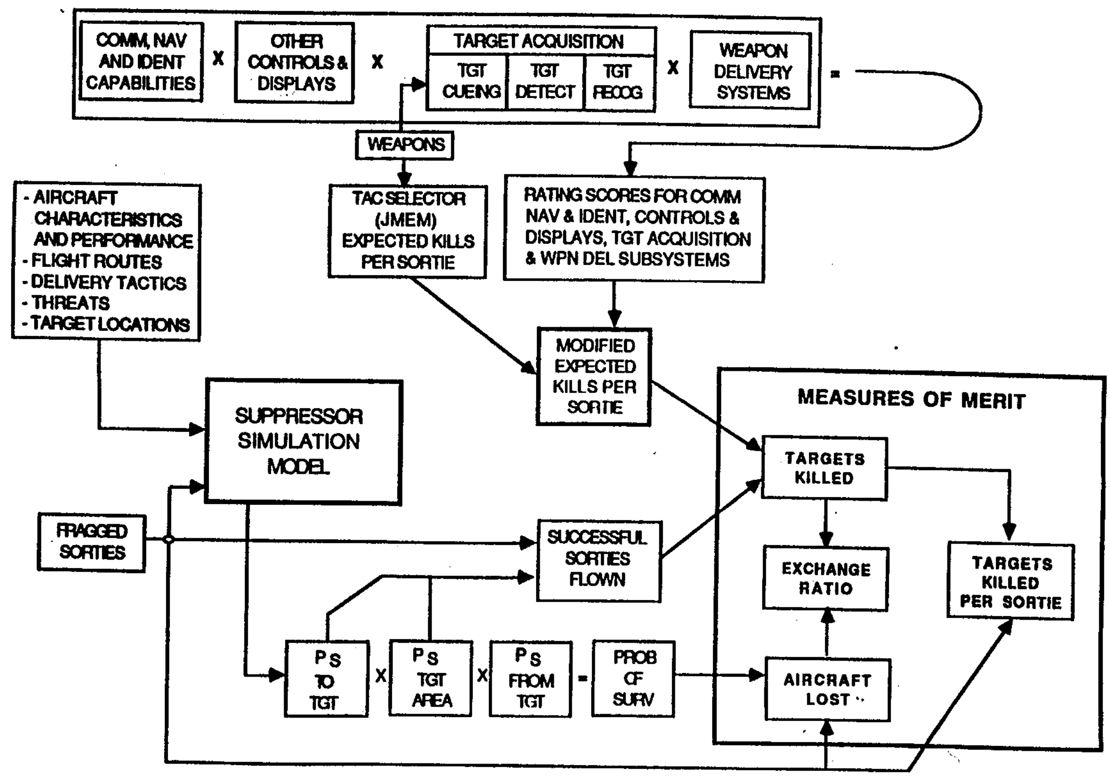


Figure 2. Army View of Weapons Analysis

General Larry D. Welch, former Chief of Staff, USAF, has summarized the process using logic similar to Figure 2: "I suggest that the operational effectiveness of a weapon system is made up of four fundamental elements: the potential of the machines, the capability of the humans operating the machines, the combat support, and the ability to focus all that on the right targets at the right time."[1]

A blowup of the effectiveness elements is shown in Figure 3. Here Target Acquisition is shown at the top. Acquisition is expanded into three elements: cueing, target detection, and target recognition.



Effectiveness Analysis Flow Diagram

Figure 3. Effectiveness Analysis Flow Diagram

Elements of Target Acquisition

The concept of target acquisition should be considered in more detail based upon five elements. Cueing sets the stage to direct the pilot to look in the general location of the suspected target, perhaps in relation to some more easily identified object. There are many external sources of information possible. These have varying accuracy and timeliness plus the problem of getting the proper data from the cuer, e.g., reconnaissance device or Forward Air Controller (FAC), to the shooter is not easy in a multi-plane attack against a well-equipped and trained enemy force.

Elements not illustrated in Figure 3 relate to shooter search and localization, which depend upon the accuracy and timeliness of the cueing. Eyeballs and onboard sensors are employed to narrow the examination. Typically, for successful attack, the pilot needs some eleven items of information such as attack direction and altitude. Now the information may be transferred as data, e.g., a moving target indicator (MTI) map from JSTARS.

It should be noted that, buried in the information needed, is the matter of rules of engagement. There may be limits on the approach, as for example in the Korean War, US aircraft were not allowed to cross the Yalu River into China and then turn back to attack the enemy border from that direction.

There are many trade-offs among the sensors for target acquisition. Non-integral sensors, such as JSTARS, have great capability and potential for addressing one of the key problems in the Gulf War - finding shoot and scoot mobile missiles. However, the cueing relies upon command, control, and communication (C3) nets that can be compromised. The more elements in the chain, the less the reliability. Adding on-board sensors reduces the C3 problem and may increase the likelihood of correct and timely target acquisition but also decreases the reliability and increases the platform cost for procurement, training and maintenance. The matter of pilot workload also should be considered. Modern displays and interfaces, such as cueing the pilot head-up projection, are helpful.

That leads to detection of something that might be the target. Then come classification, e.g., vehicle type (truck or tank), and finally, identification as to the correct target. This is called Target Recognition in Figure 3. In prior times the concept was Identification Friend or Foe (IFF) to insure that a US or allied asset was not attacked. With the advent of the Global Positioning System (GPS) and secure reporting nets, the problem of IFF is less severe.

The matter is more complicated today. The target could be a particular enemy item, possibly among other non-targets, for example, a command center, whether stationary in a group of buildings or in a mobile center. Civilian casualties should be minimized. Complying with the rules of engagement specified in the air task orders, e.g., positive visual identification, can take time and the shooter is exposed to an increasingly hazardous environment (threat). Hence, there might be a reduction in survivability (the susceptibility and vulnerability terms).

This inverse association between survivability and target acquisition was discussed by the General Accounting Office in its report on Desert Storm: "Aircraft and pilot losses were historically low, partly owing to the use of medium and high-altitude munitions delivery tactics that nonetheless both reduced the accuracy of guided and unguided munitions and hindered target identification and acquisition, because of clouds, dust, smoke, and high humidity. Air power was inhibited by the limited ability of aircraft sensors to identify and acquire targets, the failure to gather intelligence on critical targets, and the inability to collect and disseminate BDA (bomb damage assessment) in a timely manner."[2] On the other hand, procuring and employing additional defense suppression assets can raise both the probability of survival and the probability of successful target acquisition, at increased cost of course.

The five elements of TA are summarized in Figure 4. Even if each step in the acquisition process is well done, say a probability of 0.9, the end result for the probability of target acquisition is 0.9^5 or 0.59.

1. Cueing
2. Search and Localization
3. Detection
4. Classification
5. Identification

Figure 4. Elements of Target Acquisition

Equipment Categories

In order to estimate a probability of target acquisition, the analyst must be familiar with the equipments employed. As shown in Figure 5, these may be grouped into three categories: support (not on the attack platform); pods; and integral with the airframe (internal).

1. Off the Attack Platform
   Ex: JSTARS
2. Pods
   Ex: Litening II
3. Integral
   Ex: Helicopter Mast Mount

Figure 5. TA Asset Categories

The equipments not attached to the attack platform (helicopter or fixed wing aircraft) can range from a forward observer with a laser range finder and global positioning system, through the scout helicopter OH-58, to full capability such as JSTARS. These have varying performance depending upon the target and the environment. Assessing promptness involves consideration of the communication and especially the decision net. Maj. Gen. John Corder (USAF, Ret) has stated: "We've been working on time-critical targeting for (almost a decade), but we hit a plateau. The hard part is getting at targets that aren't on the air tasking order, that pop up. We need to get down to hitting them in single-digit minutes...and that (requires) a near-real-time, starting and dwelling, constantly refreshed picture of the ground."[3]

Pod performance has improved substantially from a single sensor like a long range TV through LANTIRN to Litening II. The latter includes a third generation forward-looking infrared sensor (FLIR), laser spot tracker/range finder, laser marker for identifying targets, laser designator and dual field of view charge coupled device television system. It is environmentally controlled, highly reliable and easily maintained.[3]

Current first-line airframes have an array of built-in sensors with computers and displays including special goggles.

Figure 6 is an expansion to portray the interplay of the many weapons, support and command/control systems for air warfare. The designations, emphases, and capabilities change over time but the functions to be analyzed remain. Many of these systems contribute not only to target acquisition but also to bomb damage assessment, another difficult task.

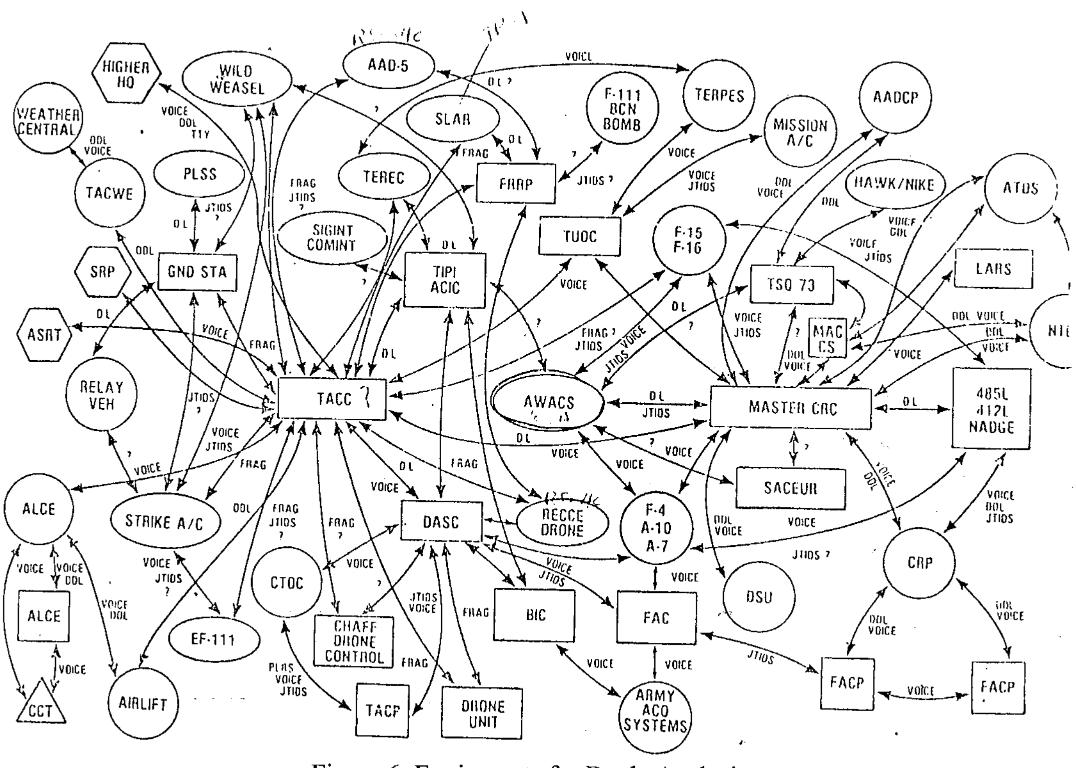


Figure 6. Equipments for Battle Analysis

In this dated diagram target acquisition is distributed among many systems: Recce/Drone, FAC, SLAR, TEREC, etc. which have other functions also. Today the JSTARS integrates many of these functions and, if available and survivable, has the potential for providing outstanding support to the shooters against both stationary and moving targets.

There are advantages and disadvantages for sensor pods compared to internal installation, assuming there is room for internal installation of new or improved gear. The pods enhance the probability of target acquisition but diminish some of the other probabilities. An aircraft festooned with sensor pod, electronic countermeasures (ECM) pod, fuel tank, bombs or air-to-surface missiles, and their associated ejector racks reduces the performance as well as diminishes the aesthetics. This arrangement may make the attack/fighter into a dual role weapon systems but the effectiveness depends also upon the pilot's ability to master the two roles. The pod has the advantage that it can be removed when not needed and is transferable. There does not have to be a procurement of 100% to match the squadron aircraft one for one. Another pod option is to have a few aircraft in the squadron equipped with the best pods act as designators. Then other aircraft, having pods of modest capabilities, could follow behind.

In spite of the sophistication of the sensor suites, combat experience has shown limitations. Frank Fernandez, director for the Defense Advanced Research Projects Agency (DARPA), listed the following areas for improvement:

- Improving the ability of sensors to accurately identify targets and see through camoflage;
- Finding better ways to combine and pass target data through a network to bombing aircraft or guided weapons;
- Establishing tactics for accurately striking moving targets through heavy cloud layers.[5]

Thus it can be seen that the analyst should specify the scenario, ground rules, and assumptions so the reader can better understand the scope and limitations.

Numerical Evaluation of Target Acquisition

The analyst must know the equipment capabilities. Three levels of performance may be considered. First, the contractor claims may be attractive. Less optimistic are the test results at ranges with skilled test operators searching for known target arrays in a good environment. More realistic settings include search for fixed and moving targets at night, in bad weather, and with difficult terrain. During Desert Storm, "of the more than 28,000 U.S. combat strikes and British Tornado strikes, about 13,000 (46%) were flown at night."[6]

It is important to consider the impact of terrain on target acquisition. Terrain works both ways. Masking aids survivability but complicates target acquisition when making low altitude approaches by making it harder to see at a distance and restricting the time available for search. The mast-mounted sensors set on the AH-64 takes advantage of the masking but still enables searching. For very low altitude attacks, terrain avoidance sensors are required. These may provide some assistance in the search phase. If the sensors have off-axis capabillty and variable field of view, the attacker can better take advantage of the terrain. High altitude attacks permit search at longer ranges with different angles and shadows but the resolution may be less good and the exposure is greater.

Simulation can be a useful assessment and training tool. Large size map boards with moving optics, as well as virtual scenes, have been employed to practice techniques for finding targets in varying clutter. Nevertheless, live instrumented tests are superior if conducted properly.

Many of the terms in a weapon system analysis can be quantified from test results. However, realistic testing of the target acquisition terms is more difficult. Target acquisition by the shooter takes practice. This is a less well understood procedure so is harder to quantify. How long does it take and how successful is it? What is an appropriate target scenario?

In September 2000 the USAF conducted the latest Joint Expeditionary Force Experiment (JEFX 2000) at Nellis Air Force Base to investigate the interaction of assets with new technologies. While emphasizing air-to-air combat, attention also was directed toward ground attack, especially time-critical targets. Such assessments are quite useful.

An alternative would be measurements obtained from exercises with instrumented fixed and rotary wing attack aircraft participating with Army attack and defense units at Ft. Irwin. The tests should include appropriate "enemy" surveillance, jamming and air defense with laser counters to record hits on the aircraft.

Cost and Effectiveness Aspects

In analyzing the probability of target acquisition it is important to specify the target set and scenario. Conflicts such as the Iraqi War are radically different from Kosovo.

The emphasis today is upon costs giving them equal weight with performance. Dr. Gansler has stated: "Just a few years ago, performance was our benchmark for developing new weapons systems; today it is performance at affordable cost - specifically at a cost that will allow us to obtain the quantities required. Today, 'cost' is a requirement that must be considered at every stage of our acquisition process - while still continuing to enhance weapons performance."[7]

Avionics costs are about 40% of the aircraft costs. The cost of a Litening II pod is on the order of $1.8 million for small qunatitites.[8] Adding one pound of payload historically adds about 3-5 pounds in empty weight of the airframe. Since cost is highly correlated with weight, adding sensors can be expensive. While the added sensors may increase the probability of target acquisition, there is also an adverse impact on aircraft performance, in terms of range and endurance, for example.

One approach to examining alternatives, considering both aspects, is an analysis of equal cost forces over a period of days (campaign analysis). Budget analysts consider a level of funding and then how to distribute the money among platforms to optimize target kills and minimize friendly losses. If the probability of successful target acquisition is aided by off-platform cueing and suppression of enemy air defenses (SEAD), then the associated assets should be included in the force costs. Survivability and target acquisition probabilities are related. The optimum path for TA may not be the best for survivability. Two passes may be needed. The better the enemy air defenses are suppressed, the easier it is to find the right targets since there is more time to search, there is a better choice of search patterns, and the attacker is able to get closer. For example, the AH-64 and the OH-58 work together as a team. Similar arrangements for the USAF would be to group together the costs for fighter/attackers, some portion of JSTARS, and possibly the SEAD weapon systems.

It should be noted that there may be a need to add to the measures of merit. As shown in Figure 3, the main criteria for success are the number of targets killed and the aircraft lost to enemy fire. In the future, there may be more emphasis on the number of friendlies, non-combatants, and local assets not killed.

As an example of cost/performance trade-offs, the proposed Unmanned Aerial Vehicles (UAV) with capabilities for dropping bombs could be attractive in some ways, e.g., lower cost and fewer friendly losses. However, the limited ability for precise and correct target acquisition could restrict the use.

Conclusion

Proper target acquisition is of increasing importance. Problems in acquiring correct ground targets have reduced attack mission success. Target acquisition may be considered to consist of five elements: cueing, search and localization; detection; classification; and identification. The interplay of the target acquisition probability with other probabilities in an effectiveness analysis should be noted.

When comparing weapon system alternatives, the scenario must be described: type of conflict, target arrays, rules of engagement, physical environment (weather, lighting, clouds) and battlefield operational environment (air defense). These basic factors provide the logic for the determination of probabilities.

Trade-offs to be examined include selection among equipments that affect key mission success probabilities: target acquisition devices (probability of successfully finding the correct target); systems for the suppression of enemy air defenses (probability of surviving); and attack weapons (probability of kill). Then, among the target acquisition equipments, there can be emphasis on either of the three categories: support (off the attack platform), pods, or integral on-board.

One approach to the comparison is an equal cost force analysis. Since off-platform equipments and systems can make a significant contribution, an appropriate share of these costs should be included.

Without improved testing and experience quantifying shooter target acquisition factors, the most elegant analysis of all the other terms may miss the mark. This is particularly true if the measures of effectiveness are expanded to include reduction of kills and damage to friendlies and non-fighting assets.

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