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Application of System Capabilities Analytic Process (SCAP) to Battlefield Obscurants

by James F. Nealon

ARL-TR-6068 August 2012

ERRATA SHEET

re: ARL-TR-6068, Application of System Capabilities Analytic Process (SCAP) to Battlefield Obscurants
August 2012, by James F. Nealon

This is an errata sheet for ARL-TR-6068. Please replace the old distribution list of the report with the new distribution list.

Page	Should Read
23	The single hardcopy for the RDRL SLE-E distribution was removed. Instead of 1 HC, 5 PDFs, it now reads 5 PDFs.
23	Name spelling for P. Dietz was changed to P. Deitz.

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ARL-TR-6068 **August 2012**

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14. ABSTRACT The System Capabilities Analytic Process (SCAP) was developed to analyze ballistic (permanent) threats to a system. This report described how SCAP concepts and structures were extended and applied to self-defense obscurants, to map transient effects into system capabilities and the mission context. System and component functions were described, with respect to the threat attributes to be defeated. Some often-overlooked properties and desired results were found by examining the mission context and threat capabilities. SCAP can be applied to permanent or transient changes of system capabilities or functions, but must be applied with respect to mission context. A brief demonstration was given of how SCAP's transient effects can map into Mission and Means Framework (MMF) analysis, to allow application in simulations or system evaluation at higher levels.			
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1. Introduction

The challenge for battlefield obscuration is to demonstrate that it is relevant to the Warfighter's mission needs for the 21st century. This challenge can be met by relating the obscurant's technical performance (as a subset of the platform) to how it may be best used in a mission context. The technical performance parameters need to be measureable and need to be related to the system's technical metrics. The system's technical metrics, in turn, must show how they aid in meeting the mission parameters and success criteria. This report shows how an emerging U.S. Army Research Laboratory (ARL)/Survivability/Lethality Analysis Directorate (SLAD) methodology known as System Capabilities Analytic Process (SCAP) can relate the obscurant technical performance (requirements, testing, and modeling/simulation) to platform and user needs. SCAP is a recent initiative of SLAD; it is a methodology that allows for mapping the components (or discrete subsystems, such as obscurants) of a system to the functions/capabilities that are produced by that system. These components can be undamaged or may have received damage/insult from combat or incidental damage. In turn, these system functions or capabilities can be related to the mission requirements with the desired mission context. SCAP can be used as a stand-alone methodology or in conjunction with analytical processes such as Missions and Means Framework (MMF).

SCAP has been used to examine ballistic damage effects for combat systems. This type of damage is a permanent effect within mission context, requiring time after the mission to repair battle damage or failed components. For this case, SCAP will be applied to a non-ballistic context (improved self-defense obscurant protection for a combat platform), to examine the non-ballistic effects (transient condition) on threat weapon systems. The intended result is a set of bounds for the problem space derived from the Functional Skeleton (FS) (a SCAP product), in terms of the combat missions envisioned. The bounds and FS can then be used by the combat developer, user, materiel developer, and tester to improve acquisition, fielding, and training for battlefield obscurants.

2. Background

The 21st century Warfighter will operate in a set of conditions similar but not identical to those of the 20th century. The type and pace of combat operations, mission objectives and outcomes, and success or victory conditions are not necessarily focused on large-scale combat operations against opposing nation-states. The opposition may include irregular or guerilla actors, leveraged actions through clients, or trans-national or non-national agents. These opposing forces may be armed with light weapons, such as machine guns, rocket-propelled grenades

(RPGs), or older generation anti-tank guided missiles (ATGMs); however, technology insertion can put advanced weapon systems into the hands of (apparently) unsophisticated threat forces. These advanced weapons may have performance capabilities similar or equal to those used by friendly forces and can provide a technological surprise.

Shifts from large-unit operations to small units, linked small operations, or other distributed combat would mean considerable re-thinking of the involved operations, logistics, and force requirements. The missions and anticipated force-level engagements have changed over the past 20–35 years, from the doctrine, manuals, and handbooks used to develop obscurant use for large-scale engagements (brigade, division and above); have the mission assumptions been updated as well? Obscuration can play an important role in small-scale actions, but this depends on understanding the combat mission to accomplish and the technical means to provide such support. Obscuration may be a secondary task for combat forces used to support primary missions such as maneuver, reconnaissance, engagement with fires, etc. This secondary role makes it easy to overlook obscuration's benefits, because obscurants prevent a threat from taking action against friendly forces instead of providing a positive action of its own.

The obscurant combat mission should be expressed in terms of desired outcome. It can then be broken into mission tasks or operations relevant to the Soldier's training or procedures for the mission. The missions drive the development, procurement, and logistics of obscurants. If the mission is not considered in context, the logistic burden can make it prohibitive to conduct small or large-scale obscuration. There is considerable literature available for the context of large-scale obscuration, such as the series of handbooks and primers issued by the Smoke and Aerosol Working Group (SAWG) of the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME). These handbooks discuss operational considerations for obscurant effects in engagements (JTCG/ME, 1981), methods to formulate concept plans in expected smoke conditions for AirLand doctrine (engagement with Soviet forces) (JTCG/ME, 1989), and combat environment effects with a focus on Central Europe (JTCG/ME, 1986). Obscuration use in Operation Desert Storm (AirLand doctrine applied for offensive operations, for brigade, division and above) was also discussed in open literature publications and books (Mauroni, 1999). These documents date from the mid 1970s to the late 1980s and were focused on large-scale forces. For smaller-scale forces (brigade, battalion, or below), do these methods need review or update to the mission context of interest now?

The obscuration technical means come from improved or new materiel capabilities to generate obscurants. Materiel development relies on user requirements as the justification for research, development, and acquisition; however, it is easy to require "more than the previous …" without considering the mission context. Obscuration technical means (munitions and delivery systems) can be tested or modeled, but the results can be difficult to quantify for mission tasks. Obscurant testing can measure the transient properties as a cloud grows and disperses; this includes obscuration properties, local meteorological conditions, and data on any test targets used. This test data can also be used to develop or improve models or simulations of obscurant performance. The models (such as Combined Obscuration Model for Battlefield-Induced Contaminants [COMBIC]) in the Electro-Optical Systems Atmospheric Effects Library (EOSAEL) (Hoock and Sutherland, 1987) are based on data from field tests, can produce probabilistic results for small- to large-scale environments, but require careful use for engagements with moving targets. The testing and modeling results provide information on the obscurant's transient effects. These obscurant effects must then be related to transient effects concerning how well the platform is protected. Platform protection, however, depends on the threat weapon systems to be encountered in a mission, the way these weapon systems may be used, and the mission context for both friendly and threat forces.

Mission-based Test and Evaluation (MBT&E) is a methodology developed by the U.S. Army Test and Evaluation Command (ATEC), with assistance from ARL/SLAD, U.S. Army Materiel Systems Analysis Agency (AMSAA), and other groups. MBT&E updates the evaluation process to obtain more early information, and more information at system milestones, for a system's performance, effectiveness, and supportability in terms of the user requirements (Wilcox, 2009). It provides ways to link system performance specifications to system operational requirements, although more work is needed here. This provides a way to defend requirements, analytical issues, and test resources needed to obtain data.

The preceding paragraphs discussed the operational missions and technical means to use obscurants in support of the mission. SCAP and the FS can map the technical relationships for platforms and subsystems, but an additional method is needed to show how the FS relates to functional capability at specific intervals in a combat mission. The MMF is a technically-focused initiative arising out of ARL/SLAD and AMSAA. MMF's heritage comes from long-term investigation and research on improved ways to portray combat damage and insults on Army platforms, and to extend this in ways that can be linked to force-level models and user mission analyses. MMF provides a way to relate the operational missions, tasks and operations to the initial and changing technical performance measures for systems and equipment used in the mission (e.g., fuel consumption, speed, and range for a truck). MMF's construction evolved with additional inputs from the operational community (Sheehan et al., 2004), to its present configuration where Blue and Red forces have mutually interacting relations (Deitz et al., 2009). The MMF provides a structure (figure 1) to determine the operational impact of obscurant use to protect friendly forces (Own Forces [OWNFOR], Blue) and to degrade threat forces (Opposing Forces [OPFOR], Red). These impacts can be related to changes in system or component capability, and to the remaining functional ability of these systems.

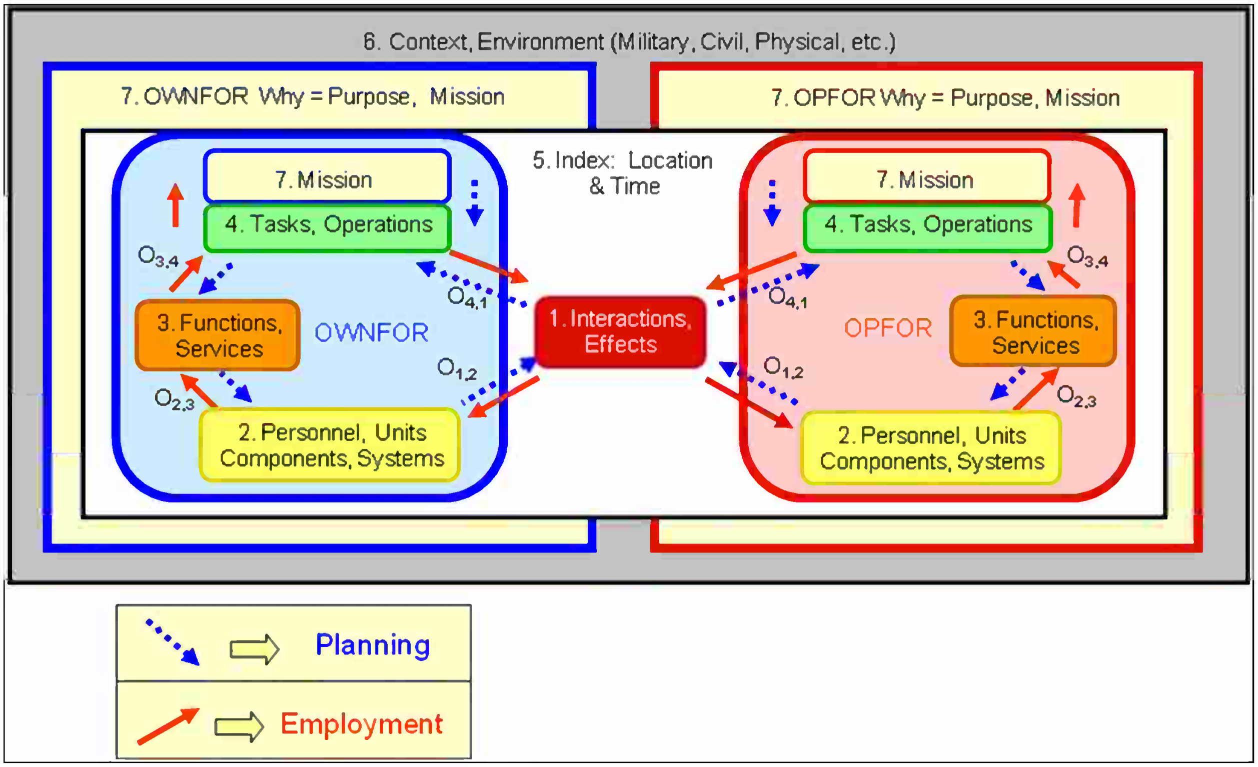

Figure 1. MMF functional diagram.

3. Obscuration Challenge and Questions

3.1 Challenge

How does obscuration stay relevant to the combat arms? The challenge for battlefield obscuration is to remain relevant to the Warfighter's mission needs while not creating a logistic or operational burden. Obscuration should be viewed with regards to the operational and support needs of the mission. These needs can be addressed by SCAP and MMF, if the correct questions are used to focus the analytical work.

3.2 Questions to Consider for Obscuration

The first set of questions involves the user's mission. If obscuration does not help the user succeed, then it is not needed. The materiel community must understand the operational limits and needs, and the user must understand what the developer can provide and the practicality of the devices provided. This should be phrased in terms of enhanced ability to survive and perform the mission.

- Is this what the user needs?
- Does the user understand what can be provided?
- Where/how is Blue platform survivability improved?

The second question set involves understanding the threat. Threat defeat should be balanced against friendly capabilities to prevent loss of friendly performance. This may be a far subtler problem than previously considered, because the threat may use new weapons that are highly capable and easy to use.

- What threat components or functions are defeated or degraded?
- What threat is the obscurant system based on, and what trends must be considered?
- Do obscurants degrade warning receivers or decision aids (either)?

The third set of questions falls out of the first two, and covers how to get there. The ability to describe what's needed must be matched with the ability to measure what is needed. Test methodology and measurement work should happen before system acquisition, so the tools to analyze or evaluate obscurant performance are available for use when needed.

- Are new or different test resources required?
- Do obscuration models or simulations answer the technical needs?
- Are the analysis methods able to relate technical means to mission parameters?

4. SCAP and Mission Needs

4.1 SCAP Definition

SCAP is an analytic process under development by ARL/SLAD (Agan, 2010). The process represents the system capabilities (ensemble response of system functions, subsystems, and components) used in operational missions. Differing types and levels of damage for the system's components can then show the remaining technical capability to support a given mission. The remaining capability is the difference between the ideal technical capability (e.g., move, sense, shoot) achievable at the beginning of a mission and at different intervals during the mission. Combat or other damage may have occurred at intervals during a mission, which could alter the technical ability to achieve the desired system capability. This damage consists of permanent conditions, where a platform is unable to recover its full capability within a specified time; it also consists of transient conditions, where a platform can regain most or all of its full capability within a specified time. Obscuration causes transient effects to components and subsystems, such as sensors and guidance mechanisms.

The result of applying SCAP to a system is a FS (figure 2), which shows the relationship between mission tasking, system capabilities and components. The mission tasks may be loosely coupled with the system's technical capabilities and component functions, because the system may be used for multiple missions. Mission tasking, for the mission under review, can be used to determine the system capabilities of interest. The system capabilities are decomposed to a set of functions, with each function comprising one or more subsystems. The subsystems, in turn, include at least one component.

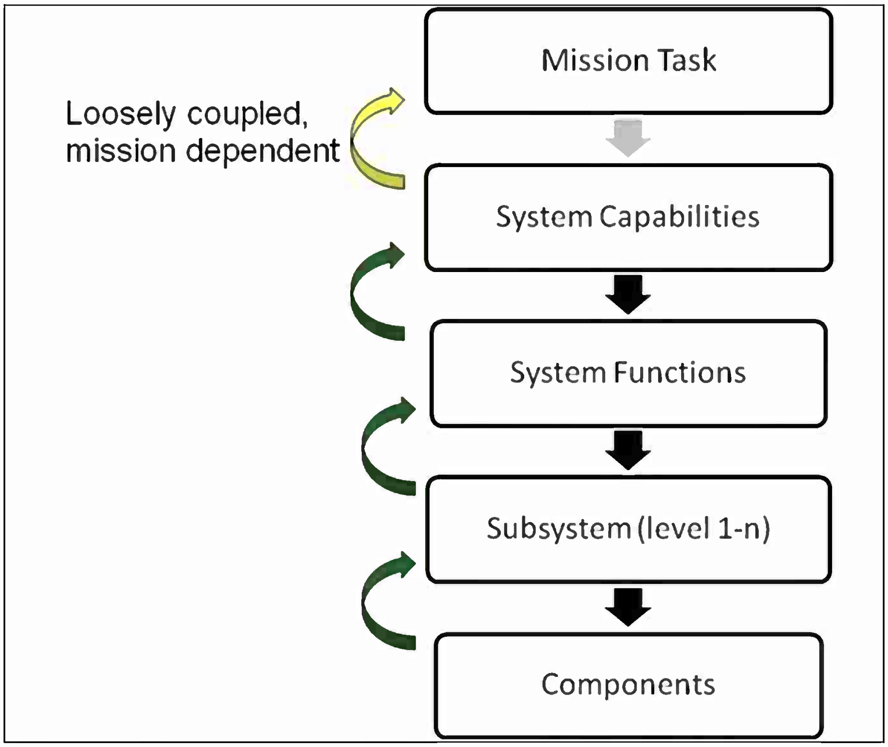

Figure 2. SCAP FS.

4.2 Mission and Capabilities

SCAP can be applied to obscurant use in a mission for manned platforms, where a desired set of success conditions are described. The mission(s) context should be defined first, so the system capabilities and other parameters have a basis in a defined operation and outcomes.

The context can be best described by a hypothetical scenario. Let the Blue operation be to assault an objective in a quiet, lightly-held area, with a mission context of a raid on a Red position. The raid is intended to destroy the combat capability of a Red force and recover with minimal Blue losses. Blue advances (using ground forces only) to contact while mounted, but conducts segments of the raid with vehicles and dismounted troops. Let the Red operation be defense of a bridge, with the mission context of hasty defense. The Red defense is to perform local security for a key terrain feature and resist Blue efforts to destroy forces or seize terrain.

Red defends with dismounted weapons and light combat vehicles; the weapon mix can include RPGs, ATGMs, cannon, and machine guns. Possible success conditions are in table 1.

Table 1. Mission conditions for success.

Main	Blue	Red
Damage to opposing forces	XX% of threat armor ID'd is killed. XX% of threat light vehicles ID'd are killed	XX% of threat armor recognized is killed XX% of threat light vehicles recognized are killed
RELATED		
Blue recovery	YY% are recoverable and return	YY% of Blue force is not recoverable
Platform kills		Blue forces: K or M, then F
Information		"Dramatic" video of Blue vehicle kills posted to Internet

The mission success conditions involve main conditions that must be met, but also some related conditions that introduce unintended consequences. The mission context is a raid; a Blue raid implies that the raiding force is quick, agile, and able to strike and recover out of unfriendly areas. If Blue vehicles are damaged, then they must be able to limp out, be repaired to move at limited speed, or be towed by another Blue platform. This slows down the raiders, allowing Red a follow-up opportunity to cause more damage. Hence the disparate kill criteria: Blue desires a Red kill by any means (catastrophic [K], mobility [M], or firepower [F]), but Red can obtain more overall kills if the Blue force is slowed down (M kills).

In addition to mission success, there may be other mission asymmetry to consider (figure 3). This asymmetry involves detection, recognition, and identification (ID) probabilities (Pd, Pr, Pi). Blue may be required by institutional or national pressures to fire only upon ID of a target as a "threat" through a combat ID system or crew training. Red may be able to fire upon recognition of a platform as 'not friendly' platform, gaining the advantage from firing and killing first. This ability to fire upon recognition gives Red an advantage in range and time (clock time and decision space time), by being able to engage Blue forces first. Blue's ability to use on-board obscurants can be used to degrade Red's advantage by making Red use more time or let the range close before recognizing Blue.

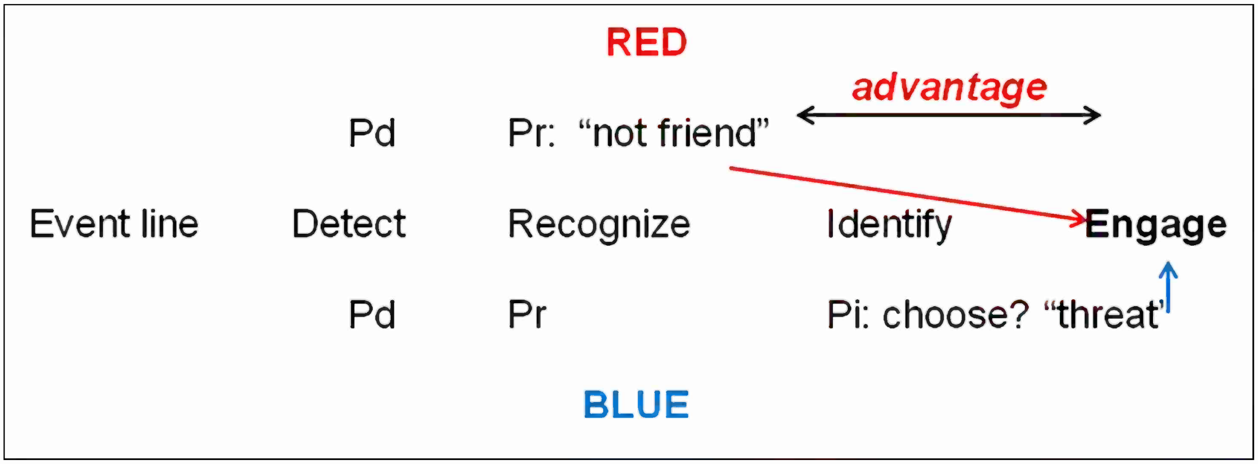

Figure 3. Firing asymmetry.

4.3 System Capabilities and Subsystems Affected for a Mission

The needed battlefield capability for obscurants is shaped by the mission. The mission context described above is an example of what can be described. For this context, let a single Red-Blue pairing be described in figure 4. Self-defense obscurant effects, for a single Blue platform or a networked unit, need to operate in context with the two mission goals as listed below.

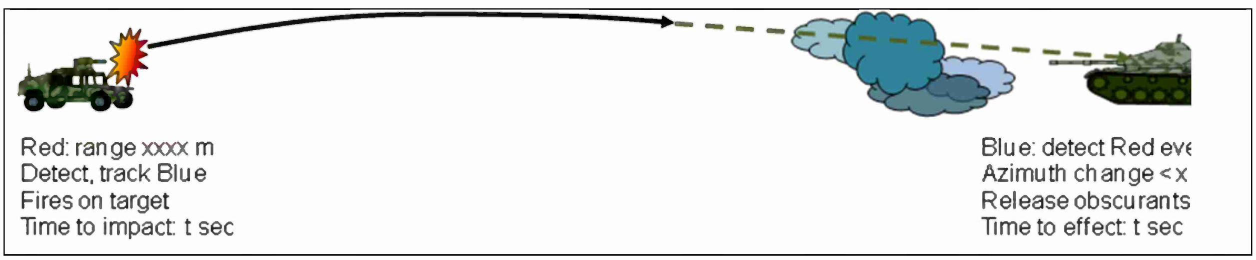

Figure 4. Red-Blue engagement example.

- Red’s goal: kill Blue platforms first to keep Blue from completing its mission.
  - Important measures for Red to kill Blue: range, time to hit, velocity.
  - Implied measures for Red to kill Blue: guidance, target acquisition, detection.
- Blue’s goal: do not let Red kill or cripple platforms so Blue can perform its mission.
  - Important measures for Blue to stop Red: range, time to impact, decision time.
  - Shot defeat implies Red acquisition, fire detection, Blue countermeasure.

The goal measures involve target acquisition, fire control, and possibly guidance for Red, and launch/fire detection, decision aids, and countermeasures for Blue. The measures are straightforward: range to target, time until hit (projectile velocity), and decision time remaining.

5. SCAP Decomposition for Obscurant Effects

5.1 Red Weapon System

Red's weapon system has a specific mission with a defined set of system capabilities (figure 5). The dashed line shows where Red's weapon system becomes active and makes an energy signature that Blue can detect. The mission and top-level capability statements have associated measurements. The highlighted boxes are those capabilities, which can be affected by obscurants.

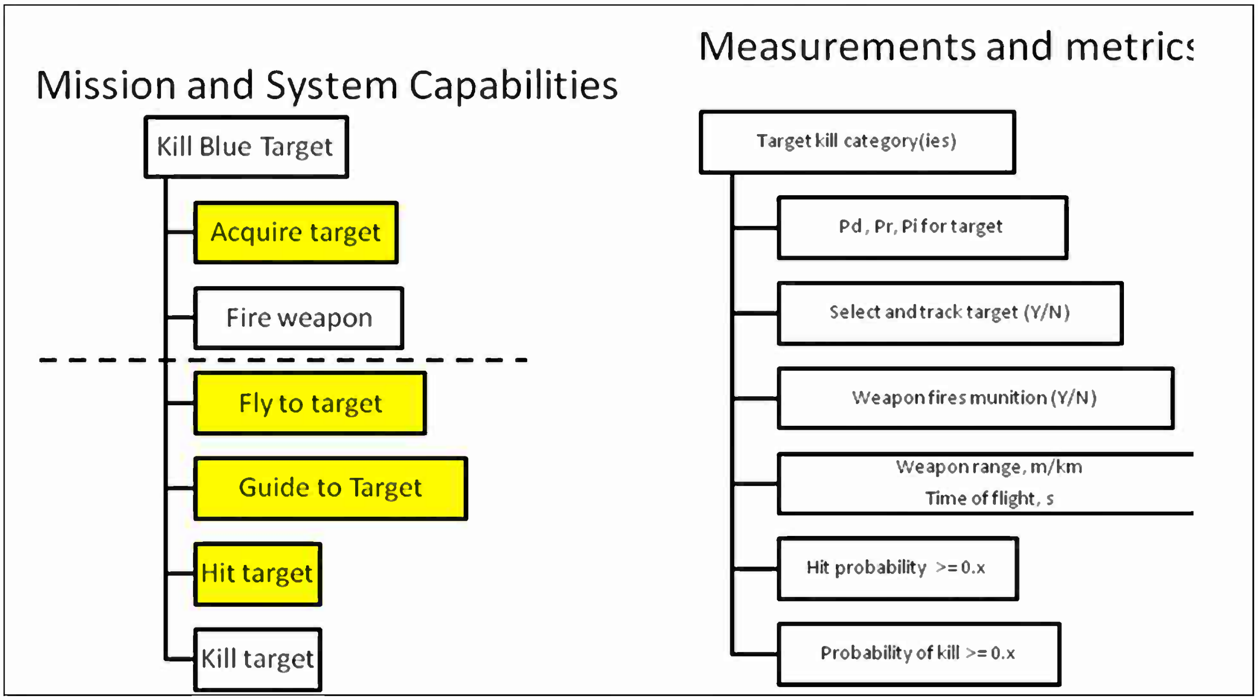

Figure 5. Red mission and capabilities.

5.1.1 Red Munition Subsystem

The munition subsystem portion (figure 6) covers the subsystem set from launch to hitting the target. If the munition is not on a ballistic trajectory (e.g., unguided), then it involves a guidance and control (G&C) loop to keep the munition locked on target and tracking to a desired hit point.

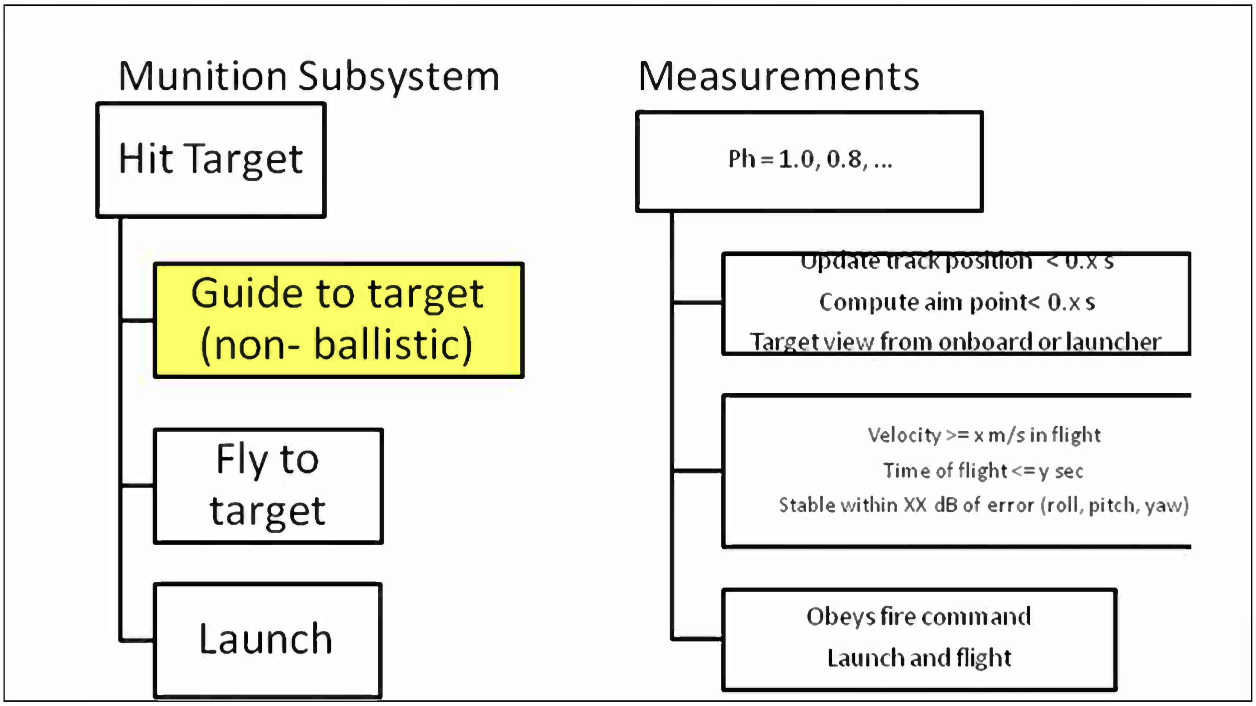

Figure 6. Red munition subsystem.

5.1.2 Red Guidance Subsystem

Red guidance subsystems (figure 7) come into play for munitions, such as ATGMs, guided projectiles, or others where an internal G&C method is used to increase the ability to hit a target. This is usually accomplished through a negative feedback guidance loop to ensure stability. The G&C works to minimize overall errors and drift from a desired hit point; this requires an initial estimate of range and location, and subsequent hit point updates from a view of the environment. More error in the G&C loop forces the use of more time, power, and range to correct course for the desired location.

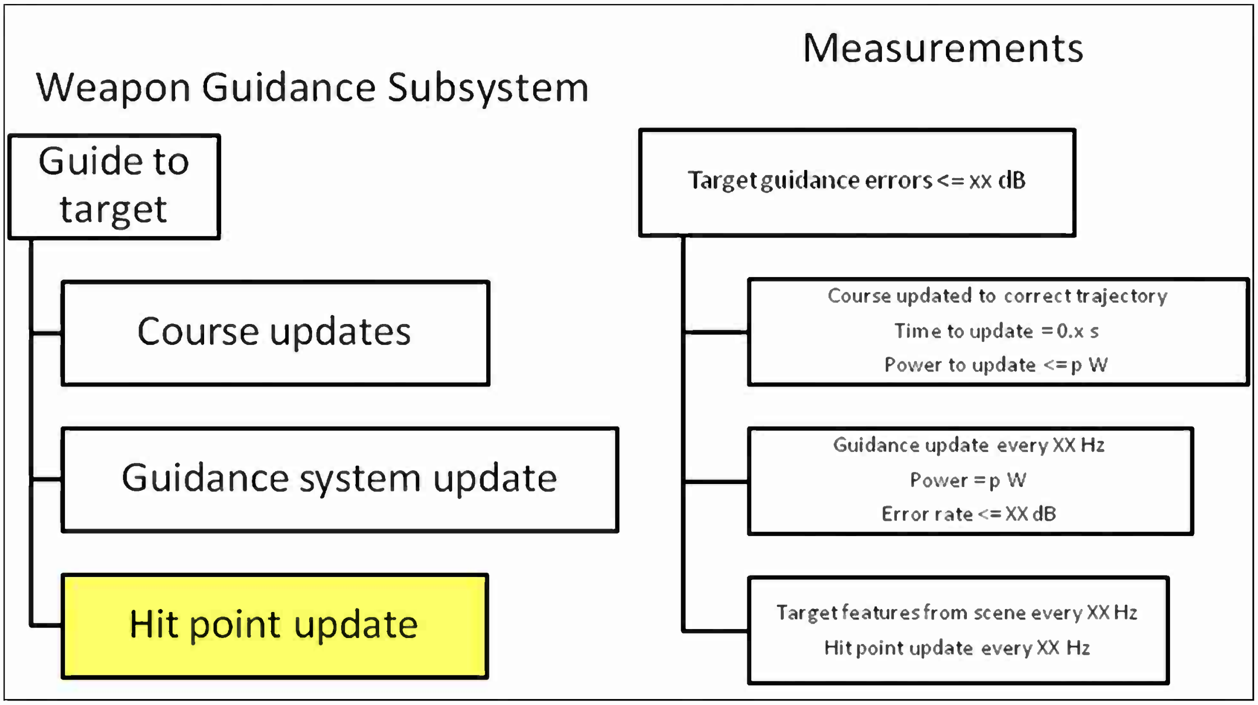

Figure 7. Red guidance subsystem.

5.1.3 Red Hit Point Subsystem

The hit point update subsystem (figure 8) is where guided munitions obtain an updated view. This view includes the target, its background, and any atmospheric or environment modifiers. Features are extracted, processed for target presence, and passed to the G&C loop as position updates. Degrading this environment view, or altering a human's command update, can induce more error into the G&C loop.

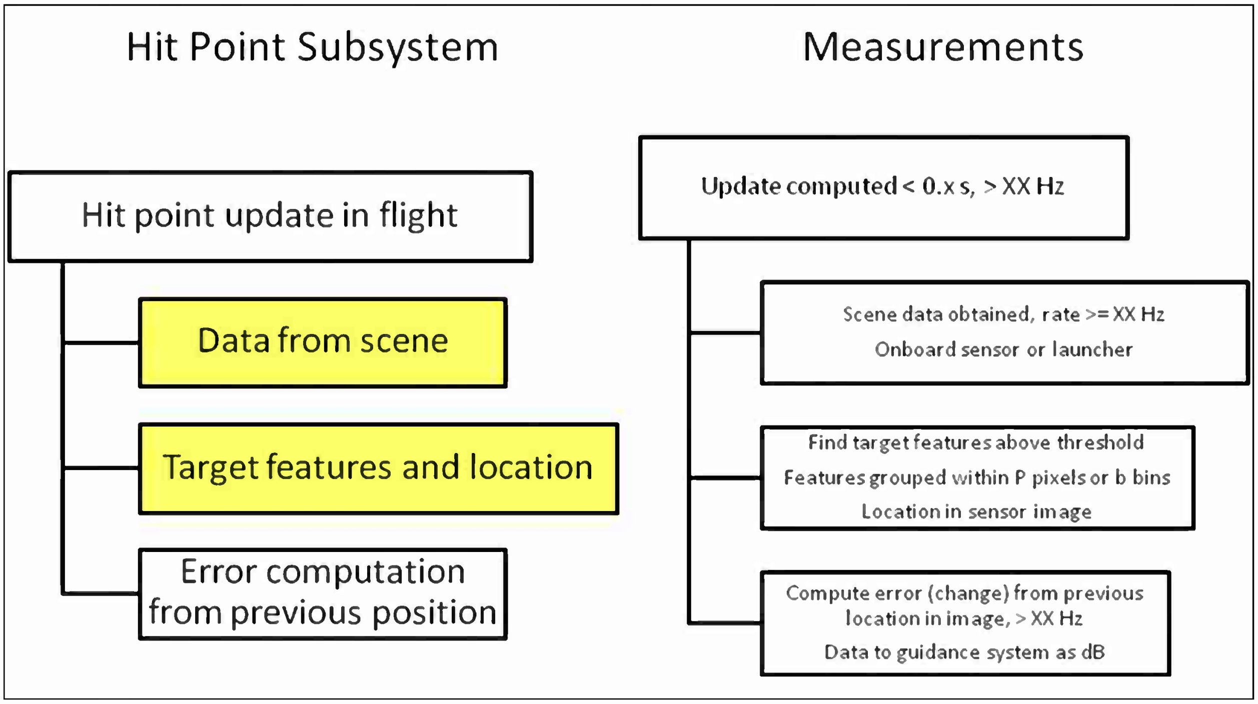

Figure 8. Hit point selection subsystem.

5.2 Blue Self-defense System

Blue's weapon system has a specific mission (figure 9) with a limited set of system capabilities. Blue relies on Red's energy signature being detectable when a weapon is fired (munition event). The mission and top-level capability statements have certain measurements and metrics associated. The highlighted boxes for all Blue descriptions are those capabilities, which can be affected by obscurants, or where obscurants are deliberately released.

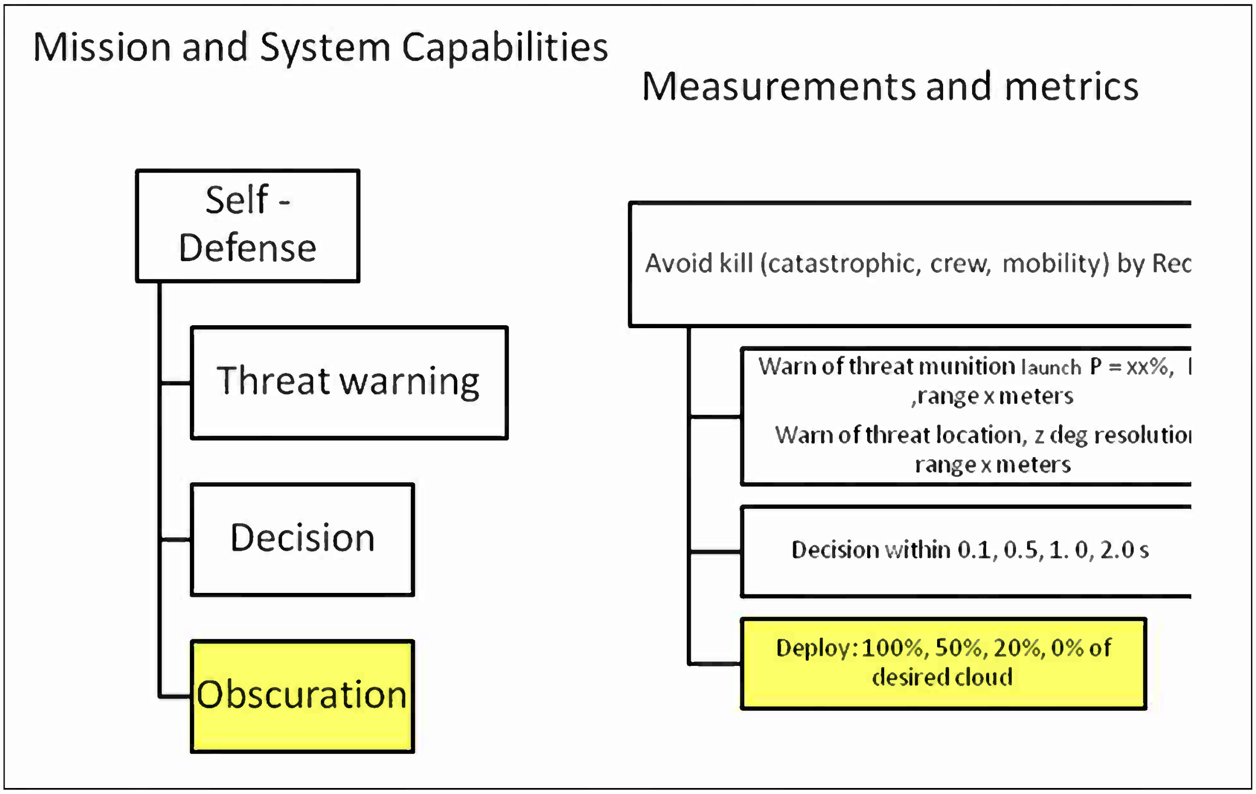

Figure 9. Blue self-defense system.

5.2.1 Blue Threat Warning Subsystem

Blue can employ a threat warning subsystem (figure 10), to inform a vehicle commander or crew of a threat munition launch in his area and if the munition is targeted for his platform. Two cases are included: unaided human and automated sensors. The difference in warning time could be crucial, depending on the velocity and launch range. Some of the sensors are highlighted; if obscuration is on the threat line of sight, these threat warning sensors and any updates are altered.

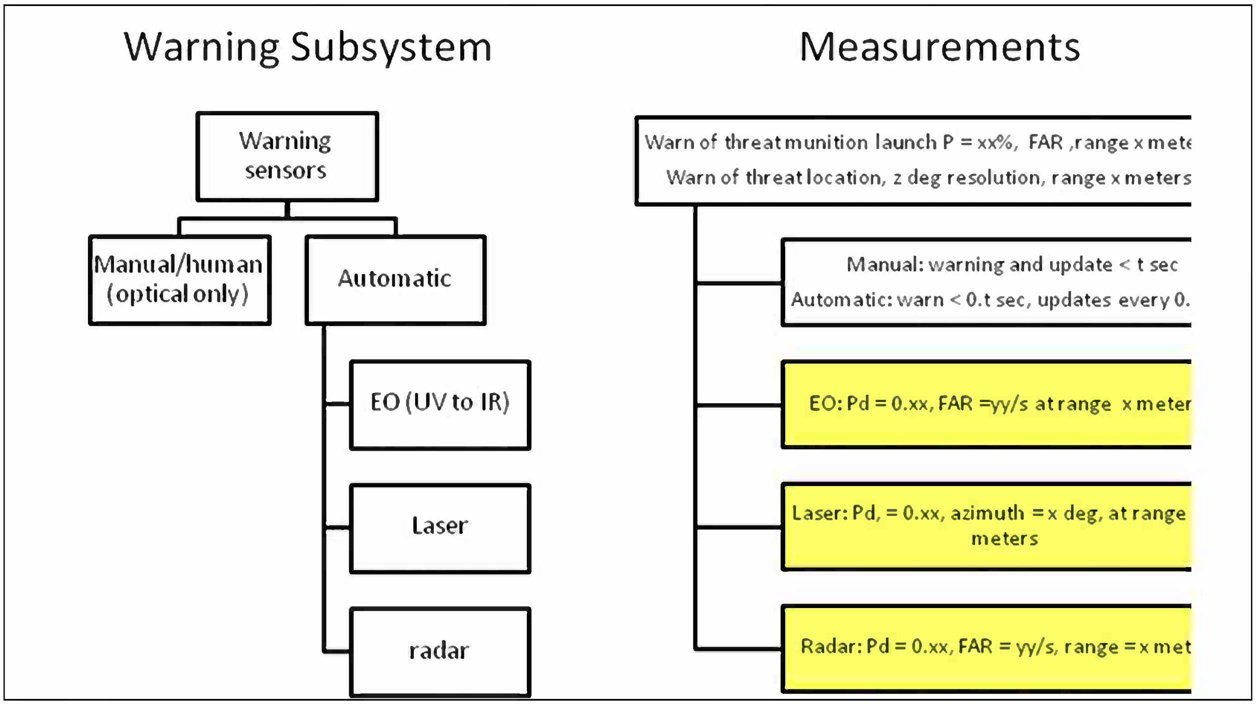

Figure 10. Threat warning subsystem.

5.2.2 Blue Decision Aid Subsystem

Blue is also postulated to have a decision aid subsystem (figure 11), linked with the threat warning system and the obscurant (or other countermeasure) subsystems. The decision aid subsystem is a method to unload some of the decision processing from the platform commander allowing machine logic to provide simple response steps (automatic or semi-automatic) under high stress conditions. The decision aid subsystem would need to retain memory of events and threat tracking over the course of the engagement.

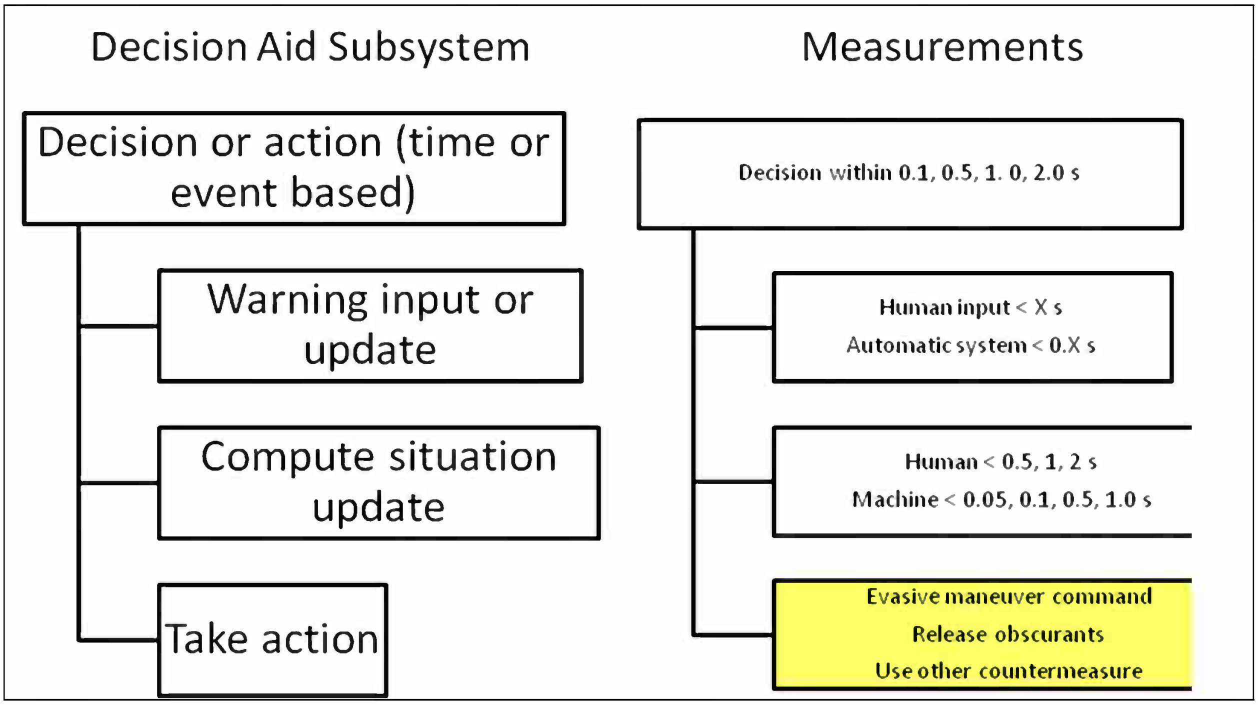

Figure 11. Blue decision aid subsystem.

5.2.3 Blue Obscurant Subsystem

The obscurant subsystem (figure 12) is where the obscurant community has traditionally placed its main focus for obvious reasons. The obscurant was usually described in terms of a capability and characteristics as opposed to measurements and metrics. The obscurant needs to be released at sufficient distance from the platform being defended so the cloud forms and disperses enough to allow the platform to hide or maneuver behind the cloud. The obscurant properties (transmission along lines of sight) are dependent on the local meteorological conditions and terrain. These properties (characteristics) can be collected in field tests or modeled.

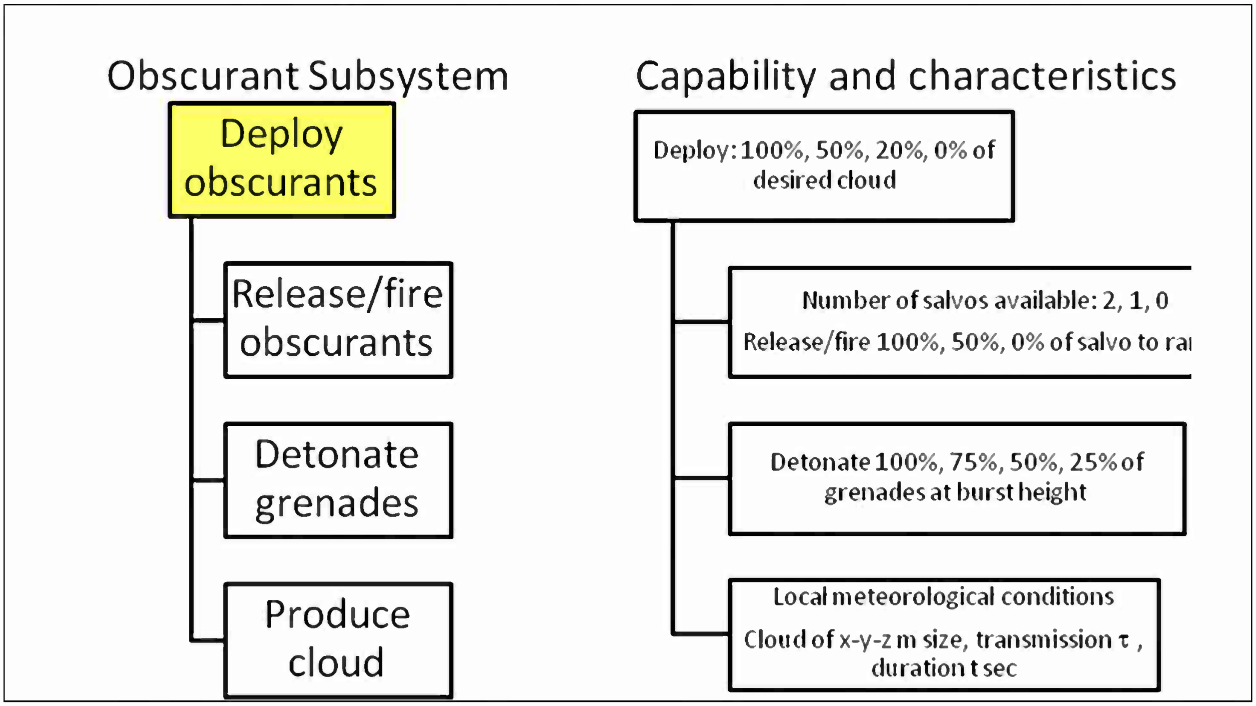

Figure 12. Blue obscuration subsystem.

5.3 FS Relations for Red and Blue

The best summary is to depict the relations (figure 13) between Red and Blue FSs, and denote where the system functions and capabilities interact most strongly. The interactions are event or time-based steps.

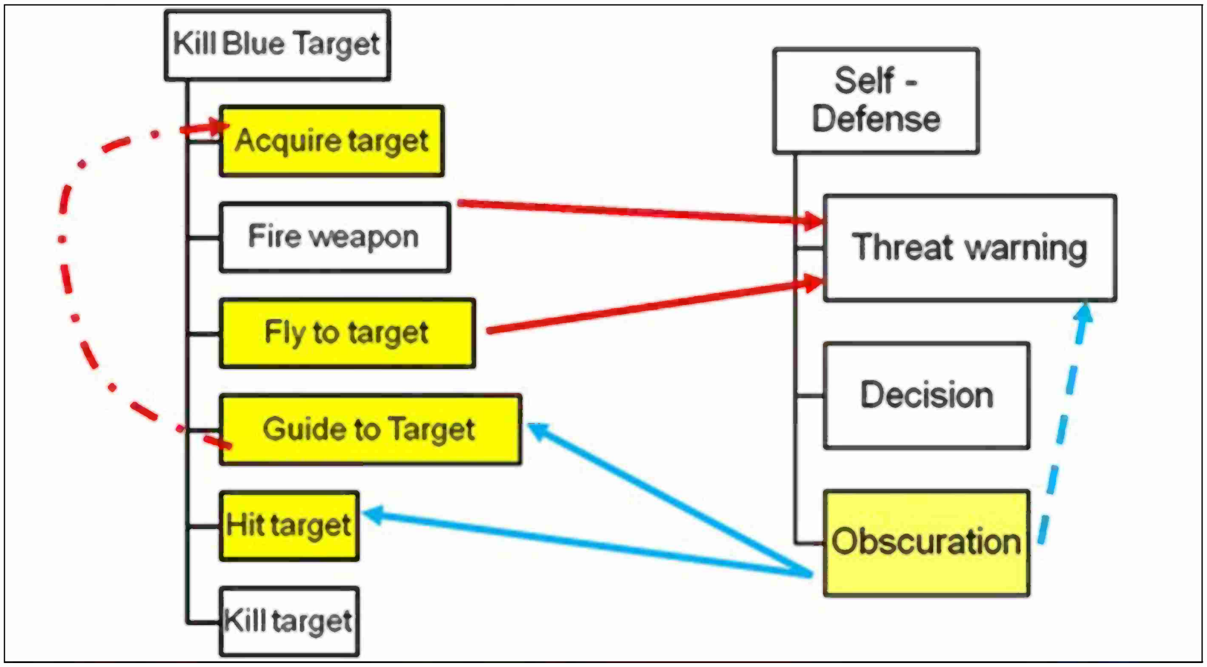

Figure 13. Red and Blue system interactions.

Red's firing a weapon creates an energy signal; Blue can detect and use this as a decision basis. Blue's use of obscurants can affect Red's guided flight and hit point on Blue. The dependencies are event- or time-stepped, and can be played out via system models or simulations. Some of the unintended effects are represented by dashed lines. Blue's obscurants can also block Blue's warning of Red flight; Blue's decision logic needs to keep track of the situation. Red may need to re-acquire a target while in flight or fire a second munition as the line of sight clears. Blue may need a second-shot capability to reinforce or replace a moving cloud. The relationships within the FS developed from SCAP gives formal functional description of why obscuration is an important subsystem and what unintended effects can occur.

5.4 SCAP Relation to MMF Process Sequence

SCAP can produce a FS and a metrics adjunct, for mapping in MMF. This relation of FS to MMF iterates between two opposing forces, proceeding until an engagement is complete. The interactions between these forces (step 5) affect the measurable performance for FS elements (metrics). This change in measureable performance, in turn, can be used to determine if systems become dysfunctional or if components become unavailable for use. Below (table 2) is a description of the indexed interaction steps for one Red and Blue pairing, showing where the outcome states raises questions that the SCAP FS can address. The questions are tractable if asked in forms that obtain the desired data from tests or modeling. Index 0 represents the initial point where Red is defined as being able to begin detecting Blue; after index 0, Red and Blue actions can be tracked as shown in table 2. When iteration ceases at index N, mission conditions in step 7 (succeed/fail) are reviewed at N+1.

Table 2. MMF indexed relations for Blue and Red.

Red Action (Steps 2–4, 7)	Index (5)	Blue Action (Steps 2–4, 7)
Detect Blue	1	—
Track Blue	2	—
Fire on Blue	3	—
Guidance Update	4	Warn of Red firing
Guidance Update	5	Decision for action
Guidance Update	6	Action-deploy smoke
Guidance Update	7	Smoke released; update situation
Track update? (situation loops for guidance, track)	8…N-1	Screened; update situation—need a second salvo?
Time or range expired?	N	Screen effective?
Energy expired?	N	Screen effective?
Blue killed?	N+1	Blue not killed?

These actions point to data sources to be drawn on. These data sources can include test data from specific sensors, model results, and simulation outputs at intervals. Blue's technical data describes the speed of detection and response to Red, as well as obscurant effectiveness in degrading the scene data with Blue and its background. Red technical data describes the weapon system performance (sensors, munition, and guidance), and ability to resist obscurant effects. The data need shown here for MMF becomes the basis for investigation and intelligence needs. The event index is left at a very coarse level for this illustration, and may contain more levels of detail for a specific combination. The index rate of change can drive the frequency of event or data collection; this helps to drive the specifications and growth capability for test instrumentation, models, and simulations. The technical and test data needs, in the end, come back to the challenge: Does this meet the user's needs for the given mission set(s)?

6. Conclusions and Future Work

The SCAP and FS can be used to describe system capabilities and functions for obscuration. This also provides early and updated information to develop test and evaluation (T&E) resources, equipment, and costs. The methods used for SCAP provide a way to tie the design of the system to the technical performance of the obscurants for a mission task. This information can be collected for multiple mission tasks and mission types, so the user may address self-protection needs by obscuration.

The FS and the questions developed in the SCAP can be used to formulate needs for testing and modeling/simulation. The metrics for obscurant subsystems can be collected in system tests, or can be extracted from model outputs. This requires more thought on the model inputs and parameters, and on the data requirements and test setup to be used. Since the obscurant effects are transient, it requires rapid data collection rates (faster than the data rate of the sensors challenged). These low-level characteristics or metrics can be used to determine what system data is collected during tests, and what assumptions and parameters are needed in weapon simulation. These weapon simulation results can be used in one-on-one force models to examine specific engagements, and can be used to feed higher-level battle simulations. In this way, the obscurant data is transformed into formats or effects that are relevant to surviving an engagement with Red systems, as understood by platform/combat developers and users.

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List of Symbols, Abbreviations, and Acronyms

AMSAA	U.S. Army Materiel Systems Analysis Agency
ARL	U.S. Army Research Laboratory
ATEC	U.S. Army Test and Evaluation Command
ATGM	anti-tank guided missiles
COMBIC	Combined Obscuration Model for Battlefield-induced Contaminants
EDSAEL	Electro-optical Systems Atmospheric Effects Library
F	firepower
FS	Functional Skeleton
G&C	guidance and control
ID	identification
JTCG	Joint Technical Coordinating Group
K	catastrophic
M	mobility
MBT&E	Mission-based Test and Evaluation
ME	Munitions Effectiveness
MMF	Missions and Means Framework
OPFOR	Opposing Forces
OWNFOR	Own Forces
RPG	rocket-propelled grenade
SAWG	Smoke and Aerosol Working Group
SCAP	System Capabilities Analytic Process
SLAD	Survivability/Lethality Analysis Directorate
T&E	test and evaluation

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