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Single Integrated Air Picture (SIAP)
Measures of Effectiveness (MOEs)
and Measures of Performance (MOPs)

OCTOBER 2001

SINGLE INTEGRATED AIR PICTURE (SIAP)
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FOREWORD

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The SIAP MOEs and MOPs Technical Report is the result of collective efforts of members of the SIAP Attributes and Metrics Working Group, who drafted the content of the report through several face-to-face meetings, teleconferences, and electronic mail exchanges spanning the period from May to October, 2001. The following individuals contributed to the report through their participation in the Working Group:

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EXECUTIVE SUMMARY

PROBLEM

The SIAP Implementation Plan states that the overarching objective of the SIAP SE TF is "to identify incremental improvements in the … SIAP capability that will provide commensurate incremental improvements in warfighting capabilities." Quantification of the impact of improvements in SIAP capability from MOPs through attributes to MOEs in evaluative, predictive, and prescriptive terms is a necessary step towards assessment of such improvements.

OBJECTIVES/PURPOSE

Complete the SIAP metrics hierarchy by establishing additional levels of measurement in order to provide the linkage between system performance to warfighting benefit. Specifically:

- Define a precise set of MOEs that measure warfighting benefit.
- Provide functional groupings of MOPs that measure system performance as derived in the TAMD Integrated Architecture.
- Establish the context for MOP measurement.
- Discuss the relationship between MOEs/MOPs and SIAP attributes.
- Provide the framework that enables analysis of the impacts of incremental system level improvements on SIAP attributes, and the effect of those improvements on MOEs.
- Conform to definitions contained in the Theater Air and Missile Defense Capstone Requirements Document (TAMD CRD) and Combat Identification Capstone Requirements Document (CID CRD) definitions.

APPROACH

1) Establish joint consensus on a small well-defined set of MOEs that are likely to be affected by the air picture quality as measured by the SIAP attributes.
2) Provide a representative list of MOPs, partitioned into functional areas that directly map from the TAMD Integrated Architecture, and allow measurement of system level performance based on specific engineering changes/improvements. Use issues pertaining to specific data links such as Link-16 to initially guide the MOP selection process, while providing sufficient flexibility for refinement and adaptation of definitions to other contexts.
3) Modify metrics as necessary as SIAP analysis matures. Annual updates of this technical report should answer to further system-specific and data-link-specific issues that may be raised in the interim.

FINDINGS

The multi-level description of MOPs and MOEs establish an understandable, disciplined process of tracing effects of system performance to warfighting benefits. It is also acknowledged that these metrics will undoubtedly evolve over time as SIAP analysis matures.

CONCLUSIONS

The MOPs and MOEs provide a common framework for greater SIAP community analysis and communication and directly support the development of the TAMD Integrated Architecture.

RECOMMENDATIONS

“Institutionalize” the metrics definitions and their corresponding hierarchy within the joint community. Update the list of SIAP metrics and refine their definitions on a periodic basis as warranted by the progress of analysis efforts.

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1. INTRODUCTION

This report describes Measures of Effectiveness (MOEs) and Measures of Performance (MOPs) to be used in assessing the warfighting benefits of a Single Integrated Air Picture (SIAP) and in controlling the system engineering process by which a SIAP capability is achieved. Together with the SIAP attributes, which are defined in SIAP SE TF Technical Report 2001-001, these MOEs and MOPs form a hierarchy of metrics for evaluating SIAP capability, predicting the performance of SIAP-related improvements in terms of warfighting benefit, and prescribing system modifications for improving performance. MOEs will be used to quantify specific warfighting benefits of a SIAP, and MOPs will be used to identify and characterize system performance for achieving a SIAP. The term “metric” used throughout this report will refer generically to any quantitative datum used in the course of SIAP assessments.

For this report, MOEs, SIAP attributes, and MOPs will be defined as follows:

> MOE – measure of operational success that must be closely related to the objective of the mission or operation being evaluated. (DSMC Glossary, 2001)

A meaningful MOE must be quantifiable and a measure to what degree a mission objective is achieved.

> SIAP Attribute – measure of a quantifiable property of a SIAP that is derived from TAMD and CID CRD requirements and associated Key Performance Parameters (KPPs).

> MOP – measure of a system's technical performance, for example, expressed as speed, payload, range, time on station, frequency, or other distinctly quantifiable performance feature. (DSMC Glossary, 2001)

As shown in Figure 1, MOEs, attributes, and MOPs form a metrics hierarchy. MOEs describe, in warfighting terms, the benefit of achieving a SIAP (note, however, that there may be motivations other than warfighting – for example, commercial air applications). Reduction in fratricide and increased weapon efficiency are examples of MOEs that are expected to improve with improved air picture quality. The SIAP attributes provide a standard means of characterizing the SIAP. The SIAP attributes derive from the TAMD and CID CRDs. Examples of SIAP attributes include completeness, clarity, accuracy, continuity, and commonality. The MOPs quantify aspects of system and subsystem performance that may be used in the analysis of SIAP shortfalls or the prescription of SIAP improvements.

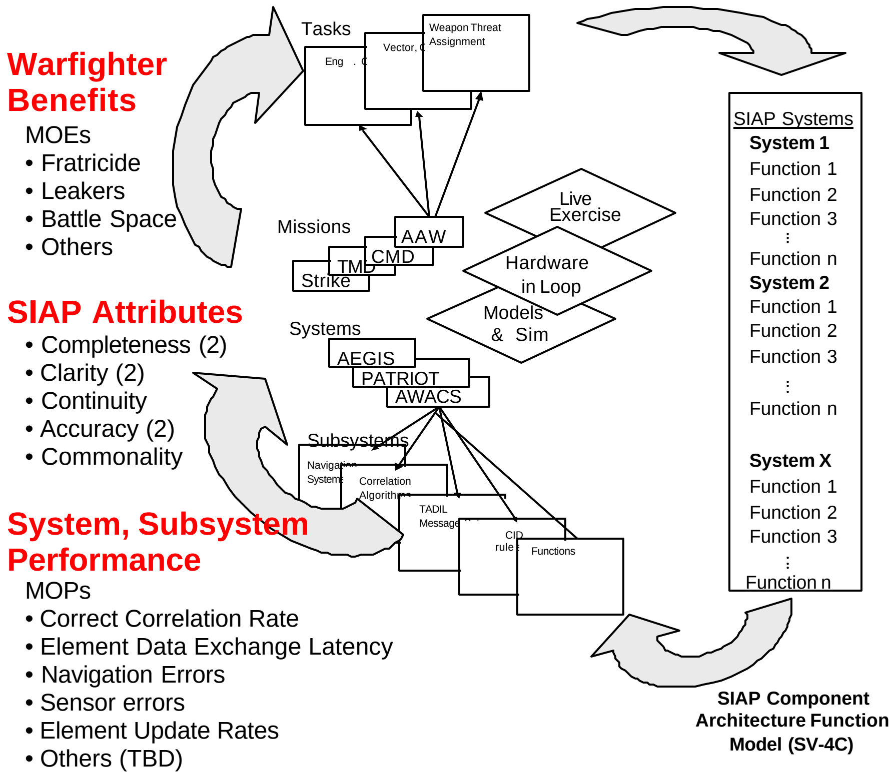

Figure 1. Relationships among SIAP metrics.

The SIAP SE TF uses a collection of tools to define and develop a disciplined joint system engineering approach and methodology. Tools include models, simulations, hardware in the loop (HWIL) experiments, operator in the loop (OITL) experiments, and live exercises. These tools can be used to measure a wide variety of characteristics throughout a prescribed metrics hierarchy. Some tools provide a high fidelity assessment of system or subsystem performance as a function of engineering configuration. These tools expedite the determination of the root cause of SIAP deficiencies. The metrics that enter into the quantitative assessment process at this level are the SIAP MOPs. The sensitivities of the SIAP attributes to the MOPs associated with a particular system (or subsystem) give an indication of that system's contribution to the SIAP.

A suite of tools will also be required to characterize and assess the warfighting benefit derived from a SIAP. Through the use of such tools, the SIAP attributes can be linked to metrics (MOEs) that more directly describe and quantify warfighting capabilities. A few tools, such as live exercises, span the entire metric range, and can relate system/subsystem level MOPs to mission/campaign warfighting level MOEs directly. Because there will be fewer opportunities to employ live exercises due to schedule and cost considerations, most tools will use some degree of modeling and simulation and will make the linkage between MOPs and MOEs through the intermediate level of SIAP attributes. The ultimate goal of prescribing engineering performance improvements which result in significant warfighting benefit translates analytically into identifying feasible changes in system-level MOPs that correlate, through a testing and modeling process, with meaningful improvements in MOEs.

This paper defines MOEs and MOPs and relates MOEs, SIAP attributes, and MOPs within an overall metrics hierarchy. It should be understood however, that the MOEs and MOPs provided in this paper are not exhaustive, and will be modified as analysis efforts dictate. Changes will initially be documented through the development of the system and technical views (SV &TV) of the SIAP component of the TAMD Integrated Architecture, and this report will be updated on an annual basis. The functional categories are intended to remain fixed, but the definitions of specific metrics may need to be adapted. This paper is meant to be limited in scope, and will not make any specific recommendations as to how these metrics are to be implemented, or what role they may play in particular models used in the SIAP system engineering process. The summary overview of that process given in Section 2.2 clarifies terminology and illustrates the roles of the different levels of metrics. Details of metrics implementation and a quantitative treatment of some of the modeling issues will be the subjects of SIAP SE TF Technical Reports 2001-003 and 2001-004, with which this document will eventually be linked.

2. THE SIAP METRICS HIERARCHY

The "SIAP Metrics Hierarchy" refers to the SIAP metrics structure described above, together with a further sub-classification within the MOE and MOP levels. The sub-classification is a means to identify the level at which warfighting effectiveness is considered (in the case of MOEs), or the particular system-level function being assessed (in the case of MOPs). The definitions provided in the next section are meant to provide a standard for SIAP system engineering usage.

2.1 Definition of Terms and Assumptions

The following key terms are either used in this report or are generally relevant to the discussion of the SIAP metrics hierarchy:

> <u>Functional Area</u> – a subcategory of MOPs measuring related aspects of SIAP system performance as defined by the Systems View (SV) of the SIAP component of the TAMD Integrated Architecture.
>
> <u>Strategic Level of War</u> – The level of war at which a nation, often as a member of a group of nations, determines national or multinational (alliance or coalition) security objectives and

guidance, and develops and uses national resources to accomplish those objectives. Activities at this level establish national and multinational military objectives; sequence initiatives; define limits and assess risks for the use of military and other instruments of power; develop global or theater war plans to achieve those objectives; and provide military forces and other capabilities in accordance with strategic plans. (JP 1-02, 2001)

Operational Level of War – The level of war at which campaigns and major operations are planned, conducted, and sustained to accomplish strategic objectives within theaters or areas of operations. Activities at this level link tactics and strategy by establishing operational objectives needed to accomplish the strategic objectives, sequencing events to achieve the operational objectives, initiating actions, and applying resources to bring about and sustain these events. These activities imply a broader dimension of time or space than do tactics; they ensure the logistic and administrative support of tactical forces, and provide the means by which tactical successes are exploited to achieve strategic objectives. (JP 1-02, 2001)

Tactical Level of War – The level of war at which battles and engagements are planned and executed to accomplish military objectives assigned to tactical units or task forces. Activities at this level focus on the ordered arrangement and maneuver of combat elements in relation to each other and to the enemy to achieve combat objectives. (JP 1-02, 2001)

Campaign – A series of related military operations aimed at accomplishing a strategic or operational objective within a given time and space. (JP 1-02, 2001)

Operation – 1. A military action or the carrying out of a strategic, operational, tactical, service, training, or administrative military mission. 2. The process of carrying on combat, including, movement, supply, attack, defense, and maneuvers needed to gain the objectives of any battle or campaign. (JP 1-02, 2001)

Engagement – In air defense, an attack with guns or air-to-air missiles by an interceptor aircraft, or the launch of an air defense missile by air defense artillery and the missile's subsequent travel to intercept. (JP 1-02, 2001)

The position of the various categories of SIAP metrics within the metrics hierarchy is suggested by Figure 2.

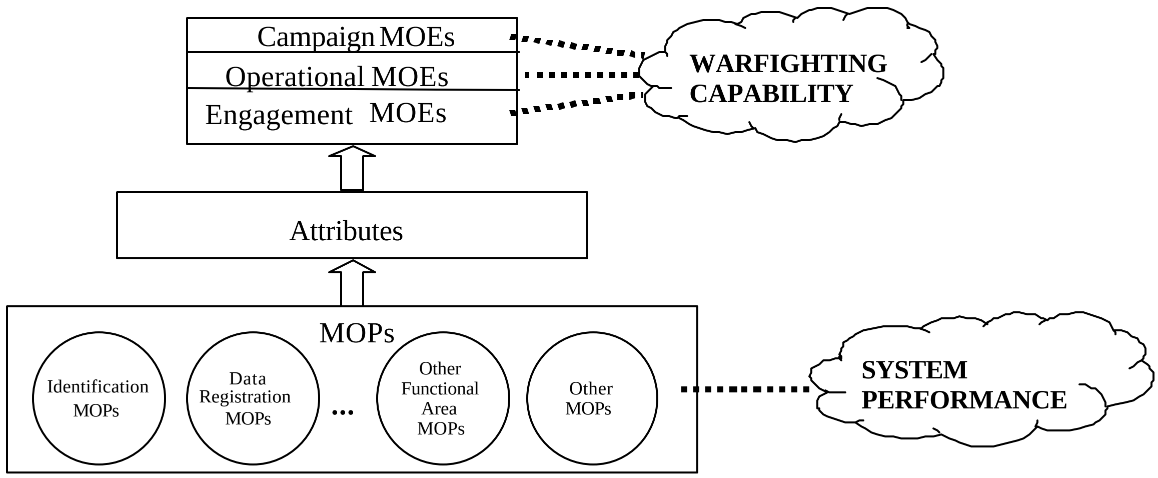

Figure 2. Metrics hierarchy.

2.2 Metrics Traceability Process

The "metrics traceability process" refers to the process of establishing quantitative functional relationships between metrics at different levels in the hierarchy, but most especially between MOPs directly associated with testable system performance characteristics and MOEs quantifying warfighting capability. With such a process in place, the impact of incremental improvements at the system MOP level should be observed (if such functional relationships exist) at the higher levels. The goal is to identify system the performance impacts on warfighting capability.

A complete characterization of all such relationships is often not practical (the number of metrics being enormous and their interrelationships extremely complex). Therefore, a practical traceability study will typically involve just a few representative metrics from two or more subcategories within the hierarchy. MOEs will be chosen to capture the most relevant indications of mission or campaign outcome for the operational scenario under consideration. Given the likelihood of insufficient data to make a direct connection with any system-level MOPs, the study might begin with a preliminary "top-down" scoping analysis. The SIAP attributes believed to have the strongest effect on the MOEs of interest would be identified, along with the principal MOPs on which these attributes appear to depend. The result would be a preliminary (but quantitative) functional dependence of selected SIAP attributes on a few key MOPs. It should be noted that such cause-effect relationships between MOPs and SIAP attribute measures do not generally follow from the definitions of the metrics, but will need to be supported (even in their preliminary form) through some degree of testing and modeling. This process has been characterized as “Root-Cause” analysis.

A separate modeling procedure will be used to quantify the dependence of the key MOEs on the attributes in question. Combining the two analyses yields a (probably implicit) quantitative functional connection between a few MOEs and a few MOPs. Finally, discernment of any gaps in the analysis process (where the quantitative links are believed to be tenuous) could suggest further tests to obtain the data needed to strengthen the claims of the analysis. Several studies of this sort, focusing on different groups of MOPs, would be needed to arrive at a firm basis for comparison of system engineering alternatives with regard to warfighting payoffs.

A study incorporating an example of the metrics traceability process is being undertaken concurrently with the writing of this report. It focuses on the functional area of data registration in the context of a mission-level vignette. The results of this study are to be published in SIAP SE TF Technical Report 2001-004.

3. MOEs

3.1 Definition of Terms and Assumptions

Specific definitions relating to the MOEs are as follows:

Commit – The process of committing one or more air interceptors or surface-to-air missiles for interception against a target track. (JP 1-02, 2001)

Decision Time – Time from establishment of firm track (i.e., the time at which the track first acquires a track number in a participant's central track store) to the commitment. While this measure does not specifically enter into the discussion of MOEs presented in the following section, decision time is a frequently used concept, and it is important to distinguish it from the other time measures introduced in this report.

3.2 Warfighting Capability

As explained in the Introduction, the scope of this report does not allow for an exhaustive treatment of metrics, nor is such a treatment warranted. The selection of MOEs, in particular, should take into account details of the scenario being analyzed. These details are still under development (scenarios will be described in the SIAP Common Reference Scenario Technical Report, 2001-005, in preparation). However, the Joint Theater Air and Missile Defense

Organization (JTAMDO) has endorsed a representative list of MOEs, which can be expected to cover most warfighting capabilities that are relevant to air warfare, irrespective of the scenario details. It is the intent of this section to present these generally applicable MOEs, and to provide some guidance on their intended use in traceability analysis. To this end, examples of one or more specific quantitative metrics are provided for each MOE, with the understanding that the definitions of these specific metrics may change slightly in accordance with the scenario details or the nature of the analysis undertaken. It should be noted that MOEs are not exclusively SIAP measures, and most of the ones described in this section have been used to assess warfighting capability in other contexts.

As discussed in Section 2.1, the U.S. Department of Defense (DoD) provides definitions of engagement, operation, and campaign that can be used for categorizing MOEs. Table 1 provides MOEs, endorsed by JTAMDO, many of which are applicable at multiple levels, and definitions of one or more specific quantitative metrics pertaining to each MOE.

MOE	**Metric Examples**
Leakers	Total number of Hostile weapon systems (manned or unmanned) that reach their ordnance release points: by type
Hostile Attrition	Total number of Hostile targets killed: by target type
Friendly Attrition	Total number of Friendly targets killed: by asset type
Fratricide	Total number of Friendly targets killed by Friendly forces: by asset type and shooter type
	Total number of Neutral targets killed by Friendly forces: by asset type and shooter type
Weapon Expenditures	Total number of weapons expended: by type
C2	Total number of engagements ordered: by type and by target
	Blue sortie rates ordered: by mission, force, and function
Battlespace	Location/Time of weapon commit
	Time/Distance from initial detection to commit
	Time/Distance from ID (other than unknown) to commit
	Location/Time of intercept (engagement)

Table 1. MOEs.

While the names given to the MOEs themselves are widely used terms in the defense community, there has been some inconsistency in the use of these terms specifically as MOEs. Therefore, in addition to the metric examples given in Table 1 to illustrate the intended use, the following qualitative discussion of the terminology may also help to clarify distinctions between the different MOEs. Leakers and battlespace MOEs both capture the extent to which threat objects penetrate to specific points, or into specific spatial regions, but they do so through different measurement approaches. The number of leakers of a certain type simply counts the number of hostile aerospace objects of that type which penetrate far enough to accomplish the enemy's objective – for example, the number of attacking enemy planes which reach their designated missile (or bomb) release points. The battlespace metrics, on the other hand, quantify in spatial and temporal terms exactly how far the threat objects penetrate, without regard to their effectiveness. The battlespace may either be quantified in absolute terms, or relative to where (when) the threat is detected. The example metrics provided are typical, but not the only possibilities. Attrition (hostile or friendly) is a quantification of damage done in terms of targets killed, "killing" of a target/asset for most purposes being understood as rendering the target/asset inoperable for the duration of the campaign (although the scenario details might allow for temporary kills, in which case campaign-level attrition might only count the permanently killed targets). Fratricide is a measure of friendly (or neutral, if applicable) attrition attributable to friendly fire. Weapons expenditure is fairly self-explanatory, being an absolute count of weapons used by type. A derived measure of (friendly) weapons efficiency is obtained by comparing weapons expenditure to hostile attrition (for example, targets killed per weapon used, over a particular engagement). The command and control (C2) metrics quantify the effectiveness of friendly force decision-making, or the number of command results of a type generally considered indicative of friendly force effectiveness (engagements, sorties). These metrics attempt to capture relevant higher-level consequences of the other MOEs (ability to fly sorties, for example, indicates attainment of a certain degree of air superiority – an expected consequence of air defense effectiveness as indicated by other MOEs).

Decision time, defined in Section 3.1, may be regarded as a composite measure derivable from the battlespace MOE metrics and system-level data (track initiation time).

4. SIAP MOPs

4.1 Definition of Terms and Assumptions

The following special terms are used when defining MOPs. Some of this terminology overlaps with that of SIAP SE TF Technical Report 2001-001, and is included here for completeness. Issues pertaining to specific data links such as Link-16 (and, to a lesser extent, Link-11) have been used to give the MOP definition process some initial guidance, hence the Link-16 focus in much of this terminology.

Common Reference Scenario (CRS) – a Defense Planning Guidance (DPG)-based operational context for SIAP assessments, providing a consistent baseline for evaluating current performance and proposed improvements. The CRS is consistent with the concepts of a scenario-based design, that is tailored to the SIAP component of the TAMD Integrated Architecture.

Area of Interest (AOI) – "that area of concern to the commander, including the area of influence, areas adjacent thereto, and extending into enemy territory to the objectives of current or planned operations. The area also includes areas occupied by enemy forces who could jeopardize accomplishment of the mission" (JP 1-02, 2001). The definition of an AOI will be further refined in the CRS to bound the area within which SIAP attributes will be evaluated. The AOIs in the CRS may be broken down into limited participant/mission specific AOIs for the assessment of attributes for a given participant or mission.

Reporting Criteria – will be prescribed in the SV of the SIAP component of the TAMD Integrated Architecture.

Object – any airborne missile, aircraft, large caliber rocket, or other tactically significant item in the AOI meeting reporting criteria.

Track – "(1) the graphic and/or alphanumeric representation of an object, point, or bearing whose position and/or characteristics are collated from sensors and/or other data sources; (2) a collated set of data...associated with a track number for the purpose of representing the position and/or characteristics of a specific object, point, or bearing" (MIL-STD-6016A, 1999). For SIAP assessment purposes, a track is understood as an actionable track, not to include tentative tracks or clutter tracks.

Assigned Track – an after-the-fact analysis of track data from an exercise or simulation, a track which meets a consistent condition for association with an object (addressed in SIAP SE TF Technical Report 2001-003). The assignment of tracks to objects may be time dependent.

Lost Track – a track which is not being updated on the basis of current sensor data, but which has not been deleted by the system.

Reporting Responsibility (R2) – "the requirement for the interface unit with the best positional data on a track to transmit track data on the interface" (MIL-STD-6016A, 1999). Reporting responsibility criteria may later be expanded to consideration of the best full kinematic data.

Track Quality (TQ) – "A measure of the reliability of the positional information of a reported track" (MIL-STD-6016A, 1999).

Gridlock – "a procedure for determining data registration corrective values (pads) by computing remote tracks received from a designated reference unit to local data" (MIL-STD-6011A, 1997).

Correctness – (when used as part of the name of an MOP) a measure of system output given system data and the algorithm that generates the system output. Correctness-based MOPs in this report compare a system's error or quality estimates with estimates produced offline using the same input data and the algorithm that the system is supposed to implement (does not address the quality of the data or algorithm used, and does not depend on truth data).

Consistency – (when used as part of the name of an MOP) a measure of how well a quality or error estimate represents the actual errors of the system (requires truth data to evaluate actual errors).

More general defense terms and acronyms used within the definitions in this section can be found in MIL-STD-6016A (1999) or Joint Publication 1-02 (2001).

4.2 SIAP Functional Areas and Sample MOPs

It is necessary to examine MOPs as they relate to the functional areas defined in the SV of the SIAP component of the TAMD Integrated Architecture. When considering, for example, a functional area regarding combat identification, a number of distinct MOPs, including ID assessment (a comparison of ID declarations with truth), and ID program performance (an evaluation of whether an ID procedure is functioning as designed) may be relevant. This section gives examples of functional areas and qualitative definitions of some of the associated MOPs as well as additional MOPs that stand-alone. These MOPs are also listed in tabular form for convenient reference in Appendix A. A list of critical variables needed to compute these, and possibly other, MOPs is supplied in Appendix B.

While it is intended that this list of MOPs should remain stable with regard to the functional areas and the qualitative aspects of the individual definitions, some of the definitions will be refined mathematically as assessment needs for specific systems are clarified in specific contexts (live tests, HWIL, etc.). The needs of the data analyst in context should dictate the final definition or formula used. However, to fulfill the SIAP SE TF's objective of establishing a standardized language and consistent use of metrics across contexts, it is expected that all such refinements, as well as proposals for additional SIAP MOPs, will be addressed by the SIAP Analysis Team (SAT) during Data Management Analysis Plan (DMAP) preparation of specific analysis events.

1. TIME

Time synchronization – The time history, referenced to Coordinated Universal Time (UTC), of the instantaneous difference between a participant's clock time and UTC.

Element data exchange latency – The time required for a message/data event in an element to trigger the desired response. There are numerous latencies that could be considered, including time from measurements to local track update, time from local track update to transfer to radio for transmission, time from transfer to radio for transmission to transmission, time from receipt of message to transfer to local track store, etc.

Time to get track report on the air – The time from establishment of firm track (i.e., first appearance of reported track in some participant's CTS) to initiation of the R2 process.

Lost track persistence – The duration of time a lost track remains displayable before either being designated as dropped and being deleted from the network, or being purged from the local track stores.

2. SENSORS/TRACKERS

Sensor detection range – The slant range at which the energy received from an observed object or unresolved cluster of objects exceeds a detection threshold.

Sensor error – The instantaneous error during the entire run between an object's true kinematic data and the locally held sensor kinematic data minus any navigation errors. Sensor error may be broken down into:

- Measurement noise errors (which by definition have zero mean). These may be characterized by (correctness and consistency of) measurement error covariance over the applicable subset of azimuth, elevation, range and range-rate measurement components for a nominal signal-to-noise ratio.
- Residual biases.

A further breakdown by source of error is also admissible.

TQ correctness – The correctness with which a unit calculates track quality (TQ) based upon MIL-STD-6016A.

TQ consistency – The consistency of reported TQ with sensor error data.

3. DATA CONNECTIVITY

Time distribution of connectivity failures (radio-to-radio) – Measure of the distribution of time between failures in connectivity (radio-to-radio) between participating units.

Time distribution of duration of connectivity failures (radio-to-radio) – Measure of the distribution of duration of the connectivity failures (radio-to-radio) between participating units.

Time distribution of connectivity failures (track store-to-track store) – Measure of the distribution of time between failures in connectivity (track store-to-track store) between participating units.

Time distribution of duration of connectivity failures (track store-to-track store) – Measure of the distribution of duration of the connectivity failures (track store-to-track store) between participating units.

TADIL update rates – The rate at which periodic TADIL message occurrences are generated.

4. DATA REGISTRATION

Geodetic registration

Navigation error(s) – The instantaneous error during the entire run between a unit's true position, velocity, and body attitude (based on WGS-84) and the navigation estimates. As with sensor error, may be broken down by type or source, and separate measures may be defined for correctness and consistency.

Navigation Q_{pg} correctness – The correctness with which a unit calculates its Geodetic Position Quality (Q_{pg}), based upon the defining algorithm.

Navigation Q_{pg} consistency – The consistency of reported Geodetic Position Quality (Q_{pg}) with navigation error data.

IU Registration

IU registration error – Residual errors in the estimates from IU registration of relative horizontal position between pairs of sensor platforms and the pair-wise relative azimuth alignment between sensor apertures on those platforms (i.e. a measure of compliance with MIL-STD-6016A IU registration).

IU registration error covariance consistency – A measure, such as a normalized chi-squared statistic, of the extent to which IU registration residual error covariance is a true representation of the pair-wise relative residual biases.

Sensor Registration

Sensor registration error – Residual errors in discrete or roll-up corrections estimated by sensor registration. This MOP may be represented, if appropriate, by separate measures for individual sources of error.

Sensor registration error covariance consistency – A measure, such as a normalized chi-squared statistic, of the extent to which sensor registration residual error covariance is a true representation of the residual bias error.

Sensor Gridlock
Network-wide absolute sensor gridlock error – Residual errors in corrections estimated by network-wide absolute sensor gridlocking of the geodetic horizontal position and altitude of each sensor platform in the network, and of the geodetic angular alignment of each participating sensor aperture on those platforms.

Network-wide absolute sensor gridlock error covariance consistency – A measure, such as a normalized chi-squared statistic, of the extent to which network-wide absolute sensor gridlock residual error covariance is a true representation of the absolute residual biases.

Data Processing
Computational errors – A class of measures intended primarily to capture the effects of inaccurate algorithms or poor algorithm implementation. A comparison of the result of any system-generated computation (such as a coordinate transformation) with the result of the same computation performed accurately offline may serve as the MOP.

5. CORRELATION/DECORRELATION

Correct correlation rate – Measure of the rate of correct correlations performed by the correlation algorithm.

Correct non-correlation rate – Measure of the rate of correct non-correlations performed by the correlation algorithm.

Incorrect non-correlation rate – Measure of the rate of incorrect non-correlations performed by the correlation algorithm.

False correlation rate – Measure of the rate of false correlations performed by the correlation algorithm.

6. REPORTING RESPONSIBILITY

R2 correctness – Measure of whether R2 was attributed correctly according to the rules of assuming reporting responsibility as defined in MIL-STD-6016A.

7. COMBAT ID

ID program performance – Comparison of the ID declaration on a track with the ID that would be applied based on the combat identification information available and the rules of engagement. For this, and the other combat ID "performance" MOPs which follow, the means of assessing the information available will depend upon the testing/evaluation context.

ID assessment – The measure of whether the ID is incorrect, unknown, or correct, for an assigned track, as determined through ID assessment rules which are linked to the scenario under investigation (cf. discussion of the ID attributes in SIAP SE TF Technical Report 2001-001).

Category program performance – An evaluation of how well each unit's program performs environmental category (surface, land, air, space) classifications, as determined by all relevant specifications and documentation.

Category assessment – The measure of correctness of environmental category classification.

Target class/type program performance – An evaluation of how well each unit's program performs target class and type identifications, as determined by all relevant specifications and documentation.

Target class/type assessment – The measure of correctness of assessment of target class and type.

8. CAPACITY

Design capacity usage – Percentage of design capacity used, and to the extent possible, broken down by subnet and/or network participation group (NPG) by participants over time.

Number of tracks deleted due to storage limits – Total number of tracks deleted from track files due to system storage limitations.

Element update rates – The rate at which periodic element message occurrences are generated.

9. FORMATION TRACKING

Fraction of tracks which are formation tracks – The instantaneous ratio of the number of formation tracks (with strength >1 or unspecified) to the total number of tracks (measured at each participant).

Formation strength to tracks ratio – The instantaneous ratio of the sum of strengths of all tracks to the number of tracks (measured at each participant).

10. OTHERS

Data update request generation – The accuracy with which Data Update Requests (DURs) are generated and transmitted.

Data update request response – The accuracy with which DURs are received and processed, and the response message formulated, generated, and transmitted.

Drop track generation and processing – The accuracy with which Drop Track Reports (DTRs) are generated, transmitted, received and processed.

Unit status generation and processing – The accuracy with which unit status messages are generated, transmitted, received and processed.

Engagement status generation and processing – The accuracy with which Engagement Status is generated, transmitted, received, and processed.

Controlling unit report generation and processing – The accuracy with which Controlling Unit Reports (CURs) are generated, transmitted, received, and processed.

Force order generation and processing – The accuracy with which Force Orders (FOs) are generated, transmitted, received, and processed.

Change data order generation and processing – The accuracy with which Change Data Orders (CDOs) are generated, transmitted, received, and processed.

Track commonality – A Boolean measure, describing whether a track is held by all participants, satisfying some given constraints pertaining to consistency of positional and combat ID data. May be restricted to a particular group of participants (for example, a particular NPG, or a group of participants involved in a launch-on-remote engagement of the specified track).

As noted in Section 2.2, the MOPs provided do not necessarily relate directly to the SIAP attributes by virtue of their definitions. A limited number of MOPs, however, are directly involved in the computation of SIAP attributes. The remaining MOPs are expected to indirectly relate to SIAP attributes and contribute to the SIAP system engineering process through modeling of proposed system improvements, or through the experimental investigation of root cause issues. The class of MOPs on which the SIAP attributes are explicitly dependent can be regarded as a subset of the critical variables needed to evaluate the attributes. Since the details of the functional relationships involved depend on the assignment procedure used, this subject will be taken up more thoroughly under the discussion of assignment in SIAP SE TF Technical Report 2001-003, Appendix A.

5. SUMMARY

Initial lists of MOEs and MOPs have been provided, which along with the SIAP attributes previously defined, will be utilized to predict, evaluate, and prescribe engineering changes that result in improved warfighting capability. The metrics exist at multiple levels in the overall process of tracing system-level improvements to warfighting benefits. MOPs are considered measures at the engineering level, a level below SIAP attributes; that is, they will either directly or indirectly impact SIAP attributes. MOEs are at the warfighting level, a level above SIAP attributes. MOEs are expected to functionally depend on one or more SIAP attribute. The consolidated metrics are also in direct support of the TAMD Integrated Architecture, and provide the framework for analysis across all venues, including: M&S, HWIL, OITL, as well as live exercises. It is understood that modifications will be necessary as dictated by future analysis and provisions for refinement have been noted.

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APPENDIX A

Table of SIAP Functional Areas and MOPs

Functional Area	MOP
TIME	
	Time synchronization
	Element data exchange latency
	Time to get track report on the air
	Lost track persistence
SENSORS/TRACKERS	
	Sensor detection range
	Sensor error
	TQ correctness
	TQ consistency
DATA CONNECTIVITY	
	Time distribution of connectivity failures (radio-to-radio)
	Time distribution of duration of connectivity failures (radio-to-radio)
	Time distribution of connectivity failures (track store-to-track store)
	Time distribution of duration of connectivity failures (track store-to-track store)
	TADIL update rates
DATA REGISTRATION	
Geodetic Registration	
	Navigation error(s)
	Navigation Q_{pg} correctness
	Navigation Q_{pg} consistency
IU Registration	
	IU registration error
	IU registration error covariance consistency
Sensor Registration	
	Sensor registration error
	Sensor registration error covariance consistency
Sensor Gridlock	
	Network-wide absolute sensor gridlock error
	Network-wide absolute sensor gridlock error covariance consistency
Data Processing	
	Computational Errors

Table A-1 Functional areas and sample MOPs. (continued next page)

Functional Area	MOP
CORRELATION/ DECORRELATION	
	Correct correlation rate
	Correct non-correlation rate
	Incorrect non-correlation rate
	False correlation rate
REPORTING RESPONSIBILITY (R2)	
	R2 correctness
COMBAT ID	
	ID program performance
	ID assessment
	Category program performance
	Category assessment
	Target class/type program performance
	Target class/type assessment
CAPACITY	
	Design capacity usage
	Number of tracks deleted due to storage limits
	Element update rates
FORMATION TRACKING	
	Fraction of tracks which are formation tracks
	Formation strength to tracks ratio
OTHERS	
	Data update request generation
	Data update request response
	Drop track generation and processing
	Unit status generation and processing
	Engagement status generation and processing
	Controlling unit report generation and processing
	Force order generation and processing
	Change data order generation and processing
	Track commonality

Table A-1 Functional areas and sample MOPs. (Continued)

APPENDIX B

MOP Critical Variables

This appendix lists variables critical to computing the MOPs listed in Appendix A. They are numbered for convenience. For MOPs depending upon an assignment of tracks to objects, an appropriate tracks-to-truth assignment procedure must also be carried out (as described in SIAP SE TF Technical Report 2001-003). For such MOPs it is assumed that, in addition to the quantities specifically listed below, all track data required for the assignment procedure is available.

1. System/ID declaration (friend, hostile, unknown, etc) on each track at each evaluation time.

2. System class and type declaration on each track at each evaluation time.

3. Difference between own unit's navigation measure and WGS-84.

4. Difference between inertial navigation measure and WGS-84.

5. Difference between JTIDS navigational measure and WGS-84.

6. Difference between own unit's clock time and UTC/USNO.

7. Total number of correlation messages.

8. Total number of drop track messages.

9. Total number of PPLI reports.

10. Total number of track management messages.

11. Total number of formation tracks.

12. Number of timeslot reallocations executed. (This and the five preceding are often regarded, among others, as alternative measures of "network loading." In the approach of this report, these quantities are indirectly reflected in MOPs across several functional areas: Correlation/Decorrelation, Capacity, Formation Tracking, and Others.)

13. Proportion of real objects meeting reporting criteria that are held as a declared track at each scheduled scoring time in the scenario.

14. Time at which a particular object meeting reporting criteria has a valid declared track (track initiation time).

15. For real objects meeting reporting criteria, the cumulative number of switches (not counting breaks) of tracks for particular objects and averaged across all objects by time t into the scenario.

16. For real objects meeting reporting criteria, the cumulative number of breaks of tracks for particular objects and averaged across all objects by time t into the scenario.

17. Sensor aperture effective refractivity at mean sea level (for refractive corrections).

18. Sensor aperture range measurement offset bias.

19. Sensor aperture range measurement scale factor bias.

20. Sensor aperture range-rate measurement offset bias.

21. Sensor aperture bearing angle measurement offset bias.

22. Sensor aperture bearing angle measurement offset bias.

23. Sensor aperture bearing angle measurement scale factor bias.

24. Sensor aperture elevation angle measurement offset bias.

25. Sensor aperture elevation angle measurement scale factor bias.

26. Sensor aperture roll attitude/aperture alignment bias.

27. Sensor aperture pitch attitude/aperture alignment offset bias.

28. Sensor aperture yaw attitude/aperture alignment offset bias.

29. Sensor field of regard.

30. Search revisit rate.

31. Track maintenance revisit rate.

32. Number of correct correlations.

33. Number of correct non-correlations.

34. Number of incorrect (false) correlations.

35. Number of incorrect non-correlations.

36. In a gated non-unique assignment, the number of declared tracks that are assignable to real objects meeting reporting criteria; divided by the number of valid declared tracks.

37. In a gated non-unique assignment, the number of declared tracks that are unassignable to real objects meeting reporting criteria; divided by the number of valid declared tracks.

38. As assessed for a particular object meeting reporting criteria, the mean normalized Chi-squared statistic of the track assigned to that object.

39. Reporting responsibility declaration for each track at each evaluation time.

40. Reporting responsibility transition time.

41. Frequency of reporting responsibility transition.