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Concept for Multilevel Command-and-Control Performance Assessment in Air and Missile Defense Operations Centers

by John Hawley

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14. ABSTRACT
Valid performance assessment is the foundation of effective research, operations analysis, or performance improvement in tactical units. Used in this context, "valid" refers to the extent to which the assessment process in question provides results accurately representing the variables or concepts it is intended to assess. Without valid performance measurement, directions for potential performance improvement tend to reflect observer opinion rather than objective or other evidence-based results. The goal of this technical note is to outline a concept for multilevel performance assessment that can be used to assess command-and-control performance in Air and Missile Defense operations centers.

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1. INTRODUCTION

Valid performance assessment is the foundation of effective research, operations analysis, or performance improvement in tactical units. Used in this context, "valid" refers to the extent to which the assessment process in question provides results accurately representing the variables or concepts it is intended to assess. Without valid performance measurement, directions for potential performance improvement tend to reflect observer opinion rather than objective or other evidence-based results. The goal of this technical note is to outline a concept for multilevel performance assessment that can be used to assess command and control (C2) performance in Air and Missile Defense (AMD) operations centers. The concept is relatively straightforward and readily implementable in a simulation-based performance setting. Research and experience have indicated that simplicity is a virtue in performance assessment in complex performance domains such as C2 (Hawley, Howard, & Martellaro, 1982). Complex performance-assessment schemes tend to be difficult and costly to implement and employ. They often fall into disuse primarily attributable to excessive complexity and cognitive load on users. Simply put, they are too hard to support and use even when allegedly fully "automated".

Most discussions of Soldier performance measurement address individual performance. It has been noted, however, that teams and units, not individuals, are the basis of warfare competence. This is not to say that individual performance is not important. Competent individual performance is an important aspect of team and unit performance. But, in most situations, individuals do not perform missions; teams and units do. The concept for performance assessment outlined in this technical note addresses performance at the unit, team, and individual levels in a linked manner that supports performance diagnosis. Team-performance measurement is typically the most neglected aspect of this trilogy of performance assessment levels. Yet, team performance has been demonstrated to be the most important contributor to overall C2 effectiveness (Olmstead, 1992[1]). C2 (or more broadly, mission command) is team-based cognitive work.

There is an increasing body of evidence indicating high levels of team proficiency are best developed within the context of intact teams operating in a realistic performance setting. It is also true that an effective team is more than the sum of its individual parts. Melding the disparate parts into a high-performing team takes time working together plus specific interventions focused on developing teamwork skills. Competent performance at the team level requires that individual team members be aware of their

[1] This Institute for Defense Analysis paper is a capstone report summarizing J. Olmstead's seminal C2 work conducted mostly during the 1970s and early 1980s.

interdependencies and be able to back each other up. Highly skilled and integrated teams are “workload sponges” in the sense that team workload often is less than the sum of the aggregate load on team members considered individually.

Team-training research also highlights the importance of highly skilled team leaders in the development of effective teams. Effective team leadership is a key factor in melding individual technical and tactical experts into a high-performing team. Team leaders foster effective team performance by (1) melding individuals into a coherent team, (2) fostering the development of an adaptive network of roles, and (3) assisting the crew in becoming a self-learning system. These three features—coherency, or a clear understanding of team roles and interdependencies; an adaptive (as opposed to a prescribed and rigid) network of roles; and a self-learning system—differentiate effective teams from a simple aggregation of individuals. Effective teams work together toward common goals, learn as a group, and adjust their intrateam roles to reflect changing operational circumstances. Team leaders facilitate the development of these capabilities by performing as intrateam instructors and mentors.

2. OVERVIEW OF C2 PERFORMANCE-MEASUREMENT METHODS

The C2 performance-assessment literature suggests effective performance measurement is best approached as a multilevel, hierarchical process (Crumley, 1989; Olmstead, 1992). The top level of the performance-assessment hierarchy typically addresses the unit of interest's overall success in its mission environment. For AMD C2, these measures typically consist of objective (i.e., countable) indices such as hostile tracks engaged, fratricides, missed threats, missiles fired resulting in a track kill, missed or incorrect track identifications, latencies among individual steps in the engagement process, and the like. In AMD, top-level measures such as these are closely associated with C2 team effectiveness and are readily obtainable in a contemporary simulation environment. However, such top-level measures are not particularly diagnostic for purposes of subsequent performance improvement.

Several prototype performance-assessment capabilities for AMD that address such top-level objective measures of C2 effectiveness have been proposed—one was partially implemented to support a research effort—but none have been widely adopted or applied operationally (Hawley, Howard, & Martellaro, 1982; Brett & Allender, 1990; Roney, 2007). AMD lends itself to such "countable" indicators of C2 effectiveness more readily than is the case in combined-arms maneuver situations. That is because objective criteria for C2 effectiveness are easier to define for AMD than for combined-arms maneuver operations. In AMD, assets are either defended or they are not; threatening tracks are either engaged and destroyed or they are not. Overall combat effectiveness in combined-arms maneuver operations is not as readily defined or meaningfully quantifiable (Crumley, 1989). The so-called criterion problem in performance measurement is less of an issue for AMD than in other warfighting domains.

The second level of C2 performance assessment addresses intrateam process measures such as those alluded to in this technical note's introduction. These include measures of C2 team performance such as teamwork (vs. task-work) skills, patterns of communication, mutual support, and the like. Measures of intrateam performance such as these are difficult to score efficiently or effectively in an automated fashion. Rather, observer–controllers provide ratings using paper scorecards or using hand-held digital devices. Numerous scorecard methods have been developed for use in military C2 settings (Crumley, 1989; Olmstead, 1992; Sanders, 2003). Using scorecards, there is an obvious trade-off between assessment validity and the cognitive load imposed on raters. Scorecards also require a high level of job-related expertise on the part of raters. Raters have to be expert job performers to adequately assess team performance. They must know "what right looks like" in the target performance setting.

Team-process measures are less objective than the top-level measures of C2 performance discussed in previous paragraphs, but that does not diminish their potential value in performance assessment. Evidence demonstrates such measures are highly useful for diagnostic purposes (Olmstead, 1992). When properly applied, they also are correlated with objective measures of C2 effectiveness.

In spite of the problems associated with scorecards and rater burden, several existing methods hold promise for effectively balancing valid measurement of C2 team processes with rater burden and can be adapted to a wide variety of team-based situations. One method appearing to have direct applicability to AMD C2 team process assessment is the Anti-Air Teamwork Observation Measure, or ATOM (Johnston et al., 1997). ATOM consists of 11 behavioral items corresponding to 4 dimensions of team process: information exchange, communication, supporting behavior, and initiative. ATOM was developed by the US Navy as part of its Tactical Decision Making Under Stress research program initiated in the aftermath of the shoot-down of an Iranian airliner by the USS Vincennes in 1988. Extensive studies using ATOM provide evidence for its internal consistency, reliability, construct validity, convergent validity, discriminant validity, and other indices of psychometric merit (Straus et al., 2019). The method's diagnostic utility in assessing critical aspects of both team and overall C2 performance has also been demonstrated (Johnston et al., 2013).

One obvious limitation associated with the use of team-process assessment methods such as ATOM is that C2 teams must be trained on essential teamwork skills for team-process results to have any validity or potential for diagnostic use. Research and operational experience suggest that managing team interdependencies and developing teamwork skills requires team-process training similar to the Crew Resource Management (CRM) programs prevalent in the aviation community. Once almost exclusively an aviation program, CRM is now broadly viewed as the use of all available human, informational, and equipment resources toward effective and efficient operations in work domains such as AMD C2 that depend on competent team performance. Without such teamwork-oriented training, teams of proficient individuals will not necessarily evolve into integrated C2 crews. Consequently, team-process assessment results will reflect mostly random noise: A high level of idiosyncratic inter-team process variability with little consistent "signal" across teams. As noted, individual task-work training is only part of what is required for effective C2 team performance; team-process training directed at team integration also is necessary (Hawley, 2021).

The third level of C2 team-performance assessment addresses individual Soldier proficiency in role-specific task-work skills. Proficient, individual Soldier task-work performance is the foundation of effective team performance. But effective team performance is based on more than proficient individual Soldier performance. Both

individual task-work and teamwork skills (i.e., using those individual skills within a team context) are involved. That point emphasized, individual Soldier task-work performance assessment can be done using scorecards assessing relevant individual performance objectives on a simple go/no-go basis or using more complex rating methods such as Likert scales.

3. CONCLUSION

Used as an integrated whole, the hierarchy of methods described in this technical note can provide a valid assessment of AMD C2 performance that also can be used diagnostically. For example, C2 team-process measures (Level 2) can be used to diagnose or explain observed deficiencies in top-level, objective performances (Level 1). If critical engagement actions are not completed successfully, or if latencies among critical engagement events are too long, team-process measures can be used to indicate why. Similarly, team-process deficiencies can be traced back to deficiencies in team-training content or methods; deficiencies in individual crew-member skills and training; deficiencies in operations-center or kill-chain organization; or suboptimal engagement tactics, techniques, or procedures (TTP). Viewed holistically, these linked performance measures can provide the basis for more valid, multilevel performance assessment, performance diagnosis, training remediation, organizational modifications, or TTP changes.

4. REFERENCES

Brett, B., & Allender, L. (1990 September). *Performance assessment capability feasibility study* (ARI Research Note 90-127). U.S. Army Research Institute.

Crumley, L. (1989 January). *Review of research and methodologies relevant to Army command and control performance measurement* (Technical Report 825). U.S. Army Research Institute.

Hawley, J., Howard C., & Martellaro, A. (1982 February). *Optimizing operator performance on advanced training simulators: preliminary development of a performance assessment and modeling capability* (Technical Report 573). U.S. Army Research Institute.

Hawley, J. (2021 July). *Accelerated expertise through compression of experience: a blueprint for Air and Missile Defense command and control training* (DEVCOM DAC-TR-2021-033). DEVCOM Data & Analysis Center.

Johnston, J. H., Smith-Jentsch, A., & Cannon-Bowers, J. A. (1997). *Performance measurement tools for enhancing team decision making*. In Michael T. Brannick, Eduardo Salas, and Carolyn Prince (Eds). Team Performance Assessment and Measurement: Theory, Methods, and Applications. Psychology Press.

Johnston, J. H., Fiori, S. M., Paris, C., & Smith, C. A. P. (2013). Application of cognitive load theory to develop a measure of team cognitive efficiency. *Military Psychology*, 25(3), 252–265.

Olmstead, J. (1992 February). *Battle staff integration* (IDA Paper P-2560). Institute for Defense Analysis.

Roney, M. (2007 November). *Air defense simulator performance assessment capability*. Computer-science master's thesis, University of Texas at El Paso.

Sanders, W. (2003 April). *Measurement methods for human performance in command and control simulation experiments* (ARI Research Note 2003-11). U.S. Army Research Institute.

Straus, S. G., Lewis, M. W., Connor, K., Eden, R., Boyer, M. E., Marler, T., Carson, C. M., Grimm, G. E., Smigowski, H. (2019). *Collective simulation-based training in the US Army: user interface fidelity, costs, and training effectiveness* (RAND Report 2250). RAND Corporation.

Appendix A – List of Acronyms

AMD	Air and Missile Defense
ATOM	Anti-Air Teamwork Observation Measure
C2	command and control
CRM	Crew Resource Management
TTP	tactics, techniques, or procedures

Appendix B – Distribution List

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