# Assessing Distributed Team Performance in DARWARS Training: Challenges and Methods

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## ABSTRACT

DARWARS is envisioned to be a virtual training environment in which multiple distributed individuals will interact with each other and with synthetic entities to in order to acquire operational skills. Training in teamwork skills will be a significant component of the DARWARS experience. In particular, DARWARS will provide the capability for training multiple teams of players at the same time, where the teams will interact in a variety of ways, thereby providing training opportunities for a wide variety of skills. Accordingly, DARWARS faces a significant challenge in assessing teamwork skills as players interact with the simulation and with each other, and in providing that assessment to players in the form of coaching during a training session or feedback in an After Action Review (AAR). Assessing the performance of distributed teams in a simulation-based environment faces three major challenges: (1) creating situations in which the relevant teamwork skills are appropriate; (2) measuring behavior in these situations; and (3) providing assessment to learners at the appropriate moment and the appropriate level of detail. This paper will review our methods, discuss the measures most relevant to DARWARS, and present an example of teamwork measurement in a multi-player commercial game scenario designed to teach teamwork skills relevant to military teams.

## ABOUT THE AUTHORS

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## INTRODUCTION

DARWARS is being developed as an integrated training platform that combines a unified infrastructure with advanced computerized training and simulation systems. Within DARWARS, users will have access to a wide range of individual training systems in which they will be exposed to subjects as varied as the tactics of Close Air Support and the fundamentals of Arabic. To be included in DARWARS, a simulator will need to provide training that is effective and relevant to the operational environments in which the users work.

However, DARWARS is envisioned as being more than a collection of simulators – at its core, DARWARS is being designed to provide users with focused training. This will be accomplished by requiring the component simulators to provide specific, targeted feedback to users to help improve performance, and by supporting the evaluation and tracking of participants throughout a full range of training experiences. Automatic evaluation of performance by Intelligent Tutoring Systems (ITS) will make training goals paramount by correlating the creation, guidance, and support of learning experiences to these goals. Intelligent tutors will also contribute assessment and instructional feedback during and after an exercise to promote learning and supplement the contributions of human instructors. Expert human evaluation will be available as well, in the form of reachback to training professionals for additional coaching. Subject matter experts will have the ability to observe user performance in real time as well as the capability to review past performance to provide targeted feedback and instruction

Ultimately, training simulators within DARWARS will be able to accommodate participation by individuals, teams, and larger units. The extent of this multi-player capability will be linked to the training goals of the simulator and modeled after the environment being simulated. The number of players envisioned to participate in a particular DARWARS event is imagined to vary from a single user in a schoolhouse simulation to potentially thousands of players in a joint virtual wargame. In fact, the strength of DARWARS lies in exploiting the potential of multi-player interaction. Participants distributed over the globe could converge in the same virtual battlefield and interact in teams of teams.

Hence, commercial computer games in general and Massive Multi-player (MMP) games in particular have inspired the design of the DARWARS training systems by illustrating the importance of engaging content in drawing learners into the learning environment. MMP games are characterized by employing many simultaneous users (60 – 1000+), who populate a virtual world that persists over time in which the players interact with other players and synthetic agents to accomplish tasks and goals. Often, these goals require multiple players with complementary skills to form ad hoc teams that need to coordinate and communicate at a very high level.

In today's massive MMP games, individual players must interact not only with the simulated environment, but also with other individuals that are playing in that environment. Different games involve different degrees of cooperation between players, ranging from very little (i.e., friendly anarchy) to disciplined group activities. Coordination levels may also vary within a single game depending upon the game scenario. Since each human player has different internal motivations and may play the game with slightly different goals, players within the game may not initially cooperate effectively when needed. However, through the process of playing the game together over multiple sessions, players may learn effective teamwork skills implicitly.

Consequently, it is advantageous for DARWARS to capitalize on the MMP environment's innate capacity to foster team behavior. If teams can form organically in the commercial MMP environments, this behavior may be replicated within DARWARS with the inclusion of an MMP as one of the offered training systems. The elements of teamwork could be fostered in compelling environments. However, the requirement for DARWARS to include *explicit* training tools introduces challenges to this general approach. Which skills can be trained in such environments? How do you design the tools for training within an environment that is inherently dynamic and unpredictable? Indeed, to retain pedagogical legitimacy in the employment of MMPs as a training tool, three challenges must be met:

1) Situations must be created in which the relevant teamwork skills are exercised.
2) Behavior in these situations must be measured in some way.
3) Assessment must be provided to learners at the appropriate moment and the appropriate level of detail.

This paper discusses these issues as they relate to DARWARS and to a specific initiative within DARWARS, Gorman's Gambit.

## TEAMWORK SKILLS

The focus of our work is on the training of teamwork skills in the context of MMP environments. The central issues include the extent to which teamwork skills can be trained in such environments, and how best to design the necessary technological and pedagogical supports. Critical to both the analysis of training effectiveness and the design of training tools is the issue of what constitutes our training domain – teamwork skills.

The teamwork literature makes a clear distinction between "teamwork" and "taskwork." Taskwork refers to the individual skills necessary to perform a particular job. For instance, taskwork might include how to operate the controls associated with a particular weapon or the switches on a radar scope. In contrast, teamwork skills are viewed as existing over and above the "taskwork" skills needed to perform in any individual position on a team. According to Orasanu and Salas (1993), accepted characteristics of a team include multiple individuals, multiple information sources, interdependence among team members, defined roles, and common goals. Teamwork skills are the behavioral processes that support effective team functioning.

The research literature provides ample evidence that teamwork skills do exist, that these skills can be defined, trained, and assessed, and that teamwork skills training can improve performance (e.g., Salas & Cannon-Bowers, 2001). More specifically, several key skills have been identified that support team effectiveness (e.g., Cannon-Bowers, Tannenbaum, Salas, & Volpe, 1995; Freeman, Diedrich, Haimson, Diller, & Roberts, 2003; Serfaty, Entin, & Johnston, 1998; Sims, Salas, & Burke, 2004; Smith-Jentsch, Johnston, & Payne, 1998; Smith-Jentsch, Zeisig, Acton, & McPherson, 1998). These skills include but are not limited to such items as:

- <u>Monitoring & Back-Up</u>: Being aware of the workload and performance of teammates and providing assistance when needed.
- <u>Information Exchange</u>: Providing the required information to the right person at the right time.
- <u>Leadership</u>: Coordinating the actions of teammates and providing clear guidance regarding goals.

In the context of the work reported here, these skills are the focus of our training development. First, we ask whether these teamwork skills may be elicited and observed in MMP environments, especially for games involving multiple interacting teams of players. Next, we ask whether these teamwork skills can be learned in MMP environments and how best to support the learning of such skills in these environments. Two important issues emerge: (1) the design of scenarios that guide or influence events to create learning opportunities in the environment, and (2) the measurement of behavior in the environment in order to assess whether the desired skills have been acquired and to provide feedback to learners.

### Synthetic Environments for Team Training: Scenario Design

A central problem is how best to design training that provides the proper opportunities for learning. In other words, how can scenarios be constructed that provide opportunities for the practice of key skills, and, in the context of the work addressed here, what are the advantages and challenges associated with teamwork skills training in large, distributed multiplayer environments? Note that, while there has been a great deal of research over the past decade on how to effectively train teams (Salas & Cannon-Bowers, 2001), relatively little research has directly addressed how best to train distributed networked teams (e.g., Barnes, Elliott, & Entin, 2001; Entin, Serfaty, Elliott, & Schiflett, 2001).

Accordingly, we start our work with a general process that moves from training objectives to scenario design (Figure 1). The approach shown in Figure 1 has been used by Aptima to develop, for instance, team performance assessment measures for Air Force F-16 pilots flying in a four ship simulation training environment (MacMillan, Littleton, Price, Miescher, Entin, Gentner, Tiller, & Cunningham, 2000). The process systematically decomposes training

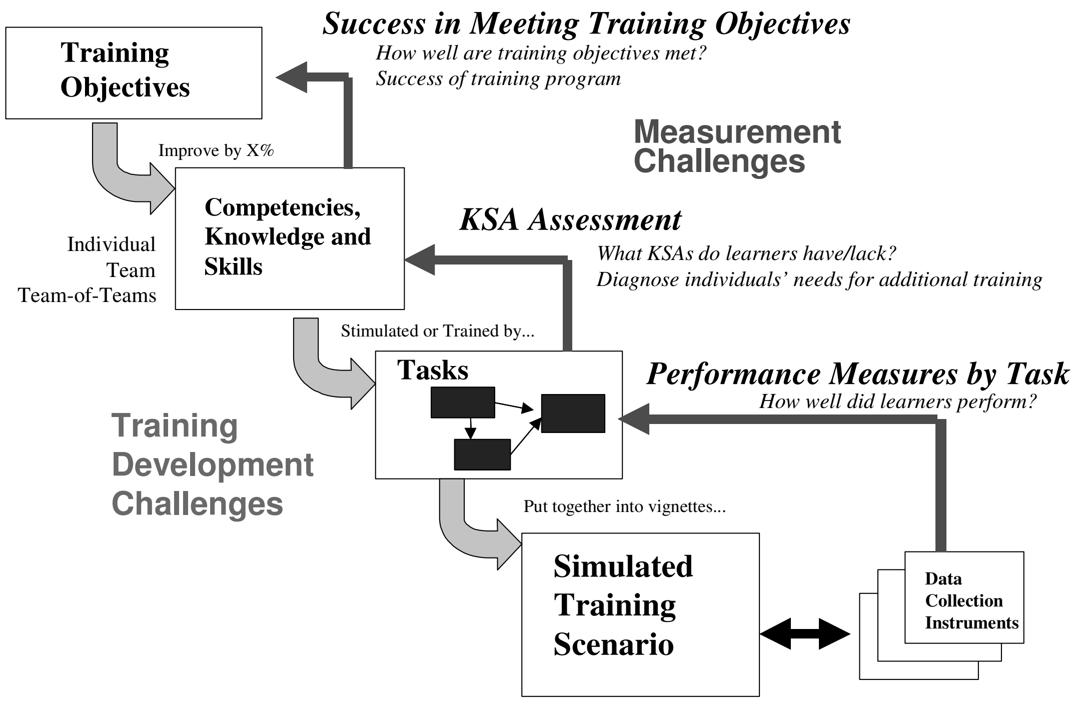


**Figure 1**. The training and measurement development process.

objectives into knowledge, skills, abilities (KSAs) that can be addressed via tasks that must be performed in the context of a particular set of training scenarios (shown in Figure 1 by arrows to the left of the diagram moving downwards). As this diagram implies, the design of teamwork training in MMP environments will hinge on the definition of training scenarios that exercise the relevant teamwork skills in a manner that is operationally identifiable.

More generally, an MMP environment is unlikely to be maximally effective in training teamwork skills in the absence of training scenarios that specifically address these skills. Participants who merely log on to an ongoing game that has no structure will be unlikely to learn the intended items in an efficient and effective manner. More specifically, this limitation exists because one cannot learn the relevant skills in isolation. By definition, teamwork skills depend on the actions of others. As an example, the teamwork skill of back-up (providing assistance) cannot be practiced if one's teammates never need assistance, or, at best, this skill can only be practiced in an opportunistic fashion. Consequently, effective training must ensure that the events needed to provide learning opportunities reliably occur.

This is no small task in an MMP environment, where the scenarios may require 50 individuals to work in concert with each other, possibly in a hierarchical manner, to solve a complex set of problems (e.g., planning the mission, executing the mission, coordinating). It is difficult to explicitly manipulate training opportunities when the very nature of the environment allows a high degree of player autonomy. It is harder still to *measure* teamwork skills in a meaningful way. In a scenario with 5-6 participants in a highly controlled environment, the need for team coordination, back-up and monitoring, and leadership can be more easily forced upon the students and the behaviors can be measured. A similar degree of control in an MMP is challenging, for the emergence of the hallmarks of teamwork are likely to be more opportunistic in nature, appearing as the specific demands of the tasks are encountered by sub-groups of players with particular characteristics.

However, the potential to require and observe teamwork skills can be increased by employing innovative scenario design, through the use of confederates (who reliably need help), or even through the use of agents (NPCs, Non-Player Characters) who create training events by needing assistance (e.g., Freeman et al., 2003). From the perspective of MMP games, this implies technological supports including scenarios that can be manipulated or selected by instructors to meet training needs and systems that enable the use of confederates to create learning opportunities (NPCs or other players).

**Synthetic Environments for Team Training: Measuring Teamwork**

Similarly, Figure 1 also shows a general process by which measures of teamwork skills can be developed and extracted (shown by arrows on the right moving upwards). Assessment is a critical component of training system design, for not only do scenarios need to be designed in light of the skills that need to be exercised, but likewise, training design constrains and is constrained by the measures that can be taken. Measurement is a key part of training technology design and not merely an afterthought. It provides a mechanism to evaluate both student progress and the overall success of the training system in meeting operational objectives.

Once again referring to Figure 1, measure development is closely associated with scenario design. The general process starts with learning objectives, moves to knowledge and skills, identifies the tasks (learning spaces) that elicit these skills, and then the training scenarios that require performance of these tasks. Performance measures are associated with the learner's responses to the critical events in the scenarios. In turn, these responses are associated with specific KSAs that are linked in valid ways to the training objectives. This process ultimately enables student and system evaluation.

Note that the measurement process is constrained by system design because only certain measures may be available given the scenarios that are developed and the technological constraints of the MMP environment. However, the measurement process also influences design as decisions are made to create particular learning events or technologies to enable particular measures. In the case of teamwork skills training in MMPs, therefore, the central questions are:

1) What measures are required to adequately assess teamwork skills in MMPs?
2) What measures can be implemented given the technological constraints on MMPs?
3) What technologies need to be developed to support measurement in MMPs?

Below, we illustrate how we are addressing these issues in the context of the DARWARS program "Gorman's Gambit" and provide examples that shed light on the cores issues presented here.

## GORMAN'S GAMBIT

The Gorman's Gambit project was inspired by the thesis put forward by General Paul Gorman (US Army, Ret.) that effective training on team skills may be achieved using MMPs available on the market today, and that specifically, there is no need for the game to be realistic with regard to modern military operations (e.g., "storming a medieval castle" might teach coordinated assault tactics). The crux of the idea is that many available games have the potential to provide an experience that has pedagogical value, even though they were not initially designed with this in mind. This thesis has a firm ground in cognitive theory, in that learning by analogy is an effective means of obtaining skills that will be applied in unrelated contexts (Gentner, 1989). In short, although the level of technology and the obstacles faced are very different, the elements of teamwork may be similar for the "Siege of Camelot" and the "Siege of Baghdad."

Thus, despite some limitations related to training technology, before an MMP with specific training tools is created for DARWARS, the evaluation of an extant MMP for training is an invaluable exercise. The lessons learned will inform the design of any such system by establishing a baseline. Hence, the Gorman's Gambit project was undertaken to examine the technical, logistical, and pedagogical design issues involved in using an MMP as a basis for providing a military training exercise in which players interact virtually in teams and learn team skills through those virtual interactions. For the purposes of this paper, only the pedagogical issues are addressed. However, the technical and logistical design issues are of equal importance within DARWARS, and the lessons learned from Gorman's Gambit will greatly influence the development of the future systems. For example, technical issues include the amount of structure that may be imposed upon the game play and the types of mechanisms available for effective interaction among players and between players and trainers, while logistical issues include how to deploy the MMP for training and how to ensure that distributed players interact in a timely manner.

**Scenario Design Issues**

A key pedagogical issue to be evaluated concerns the extent to which the exercises must train specific skills via a game scenario, or simply provide an environment in which team skills may be demonstrated and practiced. The former emphasizes effort in scripting game events to require specific team behaviors to ensure success, while the latter emphasizes effort in scripting a rich set of opportunities. Several other issues are related. One is the nature of the reward mechanisms used within the game to encourage the players to actively participate and learn. Another is the quality of the scenario authoring tools that are available. A third is the use of confederates to guide game play. In a typical MMP, all players have equal rights to influence the game play. Within a training environment, however, it is important for an instructor to have the ability to materially affect how a mission proceeds. This provides a mechanism for the instructor to ensure that training opportunities occur.

In an MMP in which the participants have differentiated skills and abilities, which is typical in commercial MMPs, it is trivial to require that individuals with divergent skills work together to accomplish a task, thus requiring coordination. In the context of a fantasy MMP, a "Warrior" character and a "Wizard" character have different skill sets. If a scenario requires four Warriors and three Wizards to work together to be successful, coordination will emerge as a consequence of the desire for success. Similarly, another scenario that may foster the teamwork skill of back-up and monitoring could include a group of Warriors that is given a task and a group of Wizards that is given another task in a second location. While they are carrying out their orders, obstacles arise that require the skills of the alternative player role. Will the teams recognize this need and change their sub-team composition accordingly?

**Teamwork Measurement Issues**

A second key pedagogical issue concerns the nature of the data collected in order to identify and analyze the training that has occurred. In particular, a key question is what type of data may be gathered directly from the game play, and what type of data needs to be gathered outside of game play, for example via questionnaires or by manual observation of player actions. A typical MMP game provides limited mechanisms for gathering data during game play. However, the potential of using games to automatically capture high fidelity information on player actions is important and will be a key aspect of DARWARS development.

For instance, among the data that could be easily captured within an MMP environment with little modification are text and spoken communications. Communications provide a key source of insight into team performance. In order to function effectively, a team must act as an information processing unit—maintaining an awareness of the situation or context in which it is functioning and acquiring and using information to act in that situation. The term "team cognition" has been used to describe this multi-person information processing activity (MacMillan, Entin, and Serfaty, 2004).

It has been shown that the characteristics of team communications can indicate critical aspects of team performance. Because of the critical role that communication plays in a team's ability to achieve coordinated action, the measurement and analysis of communication behaviors has been an on-going focus of team research. One useful approach has been the development and validation of rating scales for assessing the quality of communication behaviors in the team (Johnson, Smith-Jentsch, & Cannon-Bowers, 1997; Smith-Jentsch, Zeisig, Acton, & McPherson, 1998), and the development of behaviorally anchored rating scales for communication behaviors that are tied to specific scenario events (Dwyer, Fowlkes, Oser, Salas, & Lane, 1997; Fowlkes, Lane, Salas, Franz, & Oser, 1994). Other methods have categorized communications by type, based either on post hoc analysis of video, audio, or text records (e.g., Orasanu, 1990) or on real-time categorization performed during experiments or exercises (e.g., Serfaty, Entin, and Johnston, 1998) in order to analyze the relationship between the number of communications of different types and team performance.

Some recent approaches have focused on sequential analysis of communication using statistical sequential analysis techniques (Sanderson & Fisher, 1994) to identify communication patterns such as feedback loops (Bowers, Jentsch, Salas, and Braun, 1998). Automated text processing technology such as Latent Semantic Analysis (Laundauer, Foltz, & Laham, 1998) has been used to identify sequential communication patterns without the need for extensive hand coding of communications data (Kiekel, Cooke, Foltz, & Shope), 2000). Kiekel, Gorman, and Cooke (in press) found that more stable communication patterns were associated with better performance in distributed teams. "More stable" refers both to the number and type of transfers of information among individuals (Kiekel, Gorman, & Cooke, in press) and also potentially to the content of that communication (personal communication, Nancy Cooke).

Communication "efficiency" has been shown to be positively related to team performance (MacMillan, Entin, & Serfaty, 2004; Entin & Serfaty, 1999; Serfaty, Entin, & Volpe, 1993). The *anticipation ratio* is a measure of communication efficiency that has proved to be associated with effective team performance for a variety of different types of teams

(Entin, Serfaty, & Deckert, 1994; Entin & Serfaty, 1999; Entin & Entin, 2000; Serfaty, Entin, & Johnston, 1998; Entin, 1999; Entin, Entin, & Serfaty, 2000). The anticipation ratio measure calculates the ratio of the number of communications transferring information to the number of communications requesting information. Values greater than one indicate that team members "pushed" (sent) information more frequently than they "pulled" (requested) information, and that they anticipated each others' needs for information without being asked.

While it might be impractical to capture and analyze all of the communication among all players in an MMP, it may be possible to zero in on communication at points in the game in which teamwork skills are required or opportunistic teamwork skills are likely to be observed. Similarly, it might be possible to capture and analyze global patterns of communication critical to team performance (Entin, Diedrich, & Rubineau, 2003).

In addition, in previous studies of team performance (Entin, Diedrich, MacMillan, & Serfaty, 2002; MacMillan, Paley, Entin, & Entin, 2004), workload and situational awareness were queried via text probes during game play. Participants were required to assess their subjective workload and report it via a Likert scale at regular intervals. This resulted in a running measure of workload that could be correlated in time to specific mission events. Likewise, the assessment of situational awareness is also valuable in the context of MMPs. During game play, participants are asked what they are doing at specific key moments. They are also asked what their teammates are doing at that same moment. These same questions are asked to their teammates and the answers compared. The result is event-anchored assessment of situation awareness – a key indicator of team performance.

### After Action Review Issues

A third key pedagogical issue concerns the use of after-action reviews (AARs) as part of the training process. In a typical military training exercise, the AAR serves a critical role in calling out the proper behaviors and errors exhibited by the participants, and provides a mechanism for the instructor to correct problems and for the students to achieve new self-realizations. Within an MMP, therefore, it is critical to ask how best to structure and implement an AAR. For example, in a purely virtual, unscripted event, the players must be induced to reflect upon their experiences using in-game and/or chat mechanisms. In a structured, mixed-interaction event, a human instructor may explicitly conduct an AAR and players may interact via verbal and visual means as well as through in-game and/or chat mechanisms.

More generally, to address these issues, it is the goal of the Gorman's Gambit project to develop and conduct a specific training exercise, using participants that reflect the DARWARS target user base, and to obtain objective and subjective data on the relative merits of certain design choices for DARWARS MMP development. Within the context of a fantasy game, the exercise we have designed will elicit team behaviors, as illustrated in Figure 2. The entire exercise will be started with a game familiarization scenario intended to bring all the players up to a basic level of gaming skills within the MMP. The number of players will be in the range of 30 to 50. Once familiar with the game, the players will play a common game scenario. The scenario will begin with mission briefing for a single high-level mission objective, namely to infiltrate and capture a castle. We will use in-game mechanisms, namely an NPC, to deliver the mission briefing and inform the players of estimated enemy force strength and force distribution within the castle. The problem will be relatively complex so as to require identification of subtasks, planning of teams and allocating subtasks to those teams. During game play, the experimenters will observe the planning process and record instances of teamwork. Throughout execution, specific situation manipulations will be introduced to elicit teamwork responses by the players. One manipulation will be to have the real enemy force strength and distribution differ from the briefed intelligence to elicit mission re-planning, adaptation, and team coordination activities. A second manipulation will be to have confederates explicitly behave in a manner intended to elicit specific teamwork skills, such as backup. After the mission is accomplished or a fixed amount of time has elapsed, the game will conclude. An AAR will then be conducted involving all the players and the trainers. We anticipate using voice-over-IP as the medium for the AAR, if it proves feasible for distributed players. The exercise and its evaluation is expected to occur in the early Fall of 2004; the exercise scenarios are currently in development.

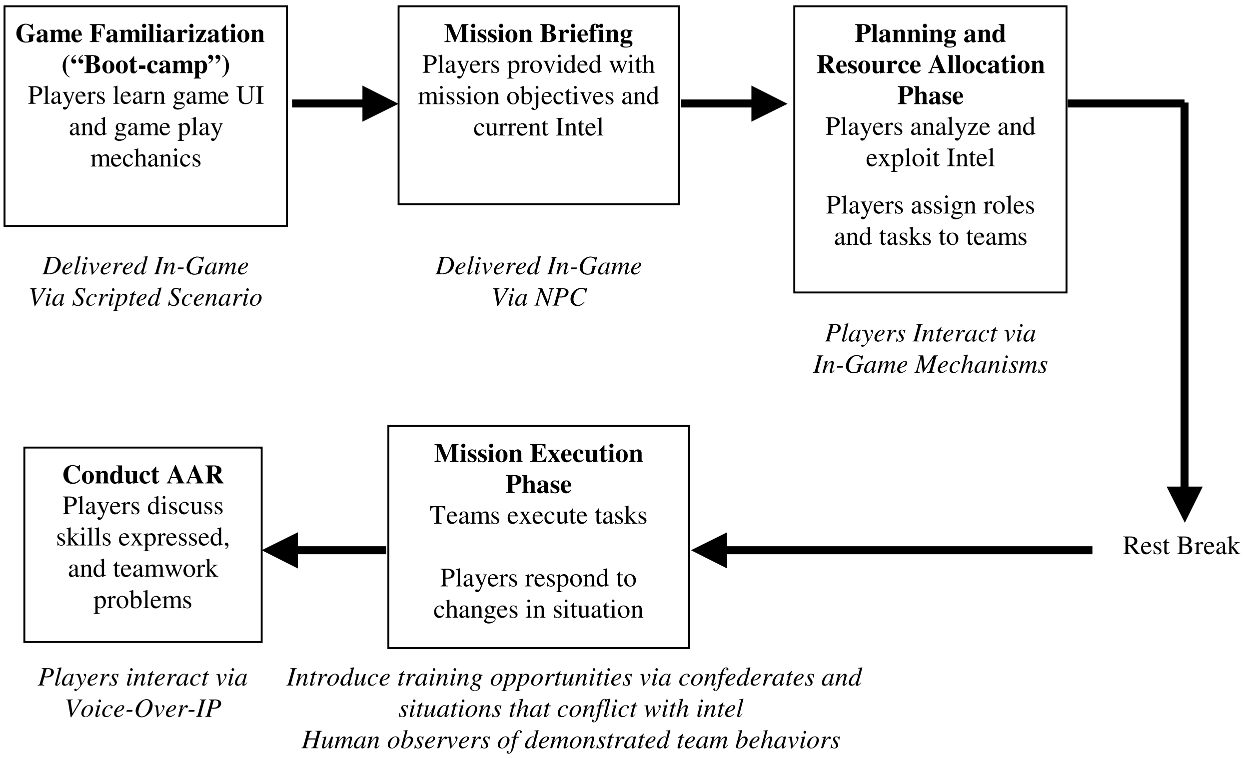


**Figure 2.** Design of Gorman's Gambit Training Exercise.

## CONCLUSIONS

It is clear that MMPs have the potential to foster teamwork skills in a setting in which individuals desire to participate and in which teams of teams may interact. In the gaming world, individuals routinely form ad-hoc groups and are required to exhibit the characteristics of successful teams in order to accomplish their mission goals. However, harvesting this potential poses some pedagogical challenges, including informed scenario design, meaningful, non-intrusive measurement, and legitimate assessment of progress. However, these challenges are not insurmountable. With innovative thinking, Gorman's Gambit will shed light on the value and challenges of MMPs in the training of teamwork skills. Based on the data collected in this exercise, DARWARS promises to provide training in an MMP that is engaging, meaningful, and effective.

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