Strategy Research Project

Integrating Game Theory into Strategy, Design, and Joint Operational Planning

by

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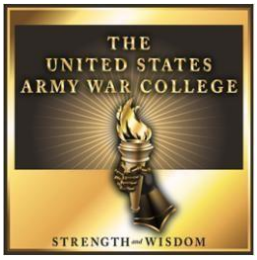
United States Army



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Strategists and planners can improve the effectiveness of strategy, design, and joint operational planning by integrating game theory into current processes. Integrating game theory into current processes provides strategists an additional perspective that is focused on outcomes and the information and decisions that drive them. It provides a stimulus for thinking deeply about who the critical players and decision-makers are and what their values, interests, and expectations are relevant to the situation. Most importantly, it creates conditions that can lead to creating Courses of Action that are focused on information and decision-making from conception. This has the potential to reduce risks and costs while achieving the best potential outcome.

Integrating Game Theory into Strategy, Design, and Joint Operational Planning

> Game theory is concerned with situations - games of "strategy," in contrast to games of skill or chance - in which the best course of action for each participant depends on what he expects the other participants to do.
>
> —Thomas Schelling[1]
> *The Strategy of Conflict*

Sir B.H. Liddell Hart captured a truth that all good strategists and planners know to be true but find difficult to implement when he said, "The most effective indirect approach is one that lures or startles the opponent into a false move—so that, as in ju-jitsu, his own effort is turned into the lever of his overthrow."[2] Integrating the use of game theory into strategy development, design, and joint operational planning creates the opportunity to develop, systematically and purposefully, Courses of Action that put into practice that truth. Game theory seeks to understand and explain the interaction of multiple decision-makers whose outcomes are based on interdependent decision-making.[3] Game theory brings to the strategic process an information-focused frame of reference and allows an analysis of the interdependence of decision-making at the strategic and operational level.

Game theory is currently used in strategy in a variety of fields, and it was hugely influential in informing United States (U.S.) nuclear and conventional deterrence strategies during the Cold War.[4] The U.S. military does not integrate game theory as widely or as deeply into strategy, design, and joint operational planning as it does other intellectual constructs such as critical and creative thinking, systems theory, international relations theory, and historically derived analysis. This may be in part because the simple elegance of the early work on deterrence was lost in the growing complexity of both game theory and the strategic and operational art.

Current U.S. military doctrine and thinking on strategy, design, and joint operational planning is both highly evolved and widely inculcated into a military that has developed nuanced strategic and operational judgment over two decades of high tempo peacekeeping and combat operations. There is opportunity to improve current military doctrine and thinking skills and to inform strategic and operational judgment with game theory. Similarly, civilian strategists and planners would benefit from the ability to interweave game theory with the deep reservoir of strategic and joint operational experience that underlies current military thinking and doctrine.[5] This opportunity can be realized if strategists and planners understand the fundamentals of game theory and how they can integrate game theory into existing strategy and planning constructs.

An Introduction to Game Theory for Military Strategists and Planners

Understanding Game Theory

In *Game Theory: Analysis of Conflic*t, Roger Myerson defines game theory as, "The study of mathematical models of conflict and cooperation between intelligent rational decision-makers" and he suggests that the seriousness of this field of study might have been better reflected by a name such as "conflict analysis" or "interactive decision theory."[6] For the purposes of the strategist and planner, game theory is a field of study that seeks to understand and explain the interaction of multiple rational actors as they attempt to achieve the best outcome for themselves. The interaction occurs in situations where the outcome results not solely from their own decision-making but from the interaction of multiple competitive and/or cooperative decision-makers. Eric Rasmussen makes the important distinction that game theory differs from decision theory and other fields because ". . . game theory is concerned with the actions of decision-makers who are conscious that their actions affect each other. . . . game theory

is not useful when decision-makers ignore the reactions of others or treat them as impersonal market forces."[7]

In game theory, each actor is rational, at least in accordance with its own value system and within the limits of bounded rationality established in the rules of the game. Based on the available information, actors must choose among potential actions based not only what they think would yield them the best personal outcome but also on their expectations of how other actors will decide. The interaction of multiple decision-makers leads to an outcome that may be different from the outcome that one or both parties most desire; therefore, the rational parties must act strategically to achieve the best outcome for themselves that is possible given their expectations of the others action. They should not decide as if they were directly seeking the theoretically best outcome for themselves in a situation where other actors did not have a say in the outcome. According to Thomas Schelling, "This interdependence of expectation is precisely what distinguishes a game of strategy from a game of chance or a game of skill."[8] There are minor differences between how Schelling uses the term strategy and the current U.S. military definition of strategy, but the essential point is that the strategist and planner must account for the decisions of others. The desirability of accounting for interdependent expectations in making military decisions is self-evident and is deeply ingrained in military theory, but it is difficult to do well in practice.

Defining Games

Applying game theory to real world situations requires the translation of potential or actual situations of conflict and/or cooperation into mathematical models referred to simply as games. Eric Rasmussen summarizes the process of game definition as:

> The essential elements of a game are players, actions, payoffs, and information – PAPI, for short. These are collectively known as the rules of the game, and the modeler's objective is to describe a situation in terms of the rules of a game to explain what will happen in that situation. Trying to maximize their payoffs, the players will devise plans known as strategies that pick actions depending on the information that has arrived at each moment. The combination of strategies chosen by each player is known as the equilibrium. Given an equilibrium, the modeler can see what actions come out of the conjunction of all the players' plans, and this tells him the outcome of the game.[9]

Applying this process in the military context of strategy requires the application of professional judgment to model the real world and to update the model as understanding of the situation changes or new information becomes available. Fortunately, existing military strategy and planning systems produce products that will inform this judgment and which can themselves be subsequently refined based on the analysis of the game. This translation is ultimately subjective and must be treated with the same degree of managed skepticism and critical thinking that is currently part of the strategic art.

Given time and a combination of military and game theory expertise, very elaborate games are definable, including those featuring multiple players and many actions. Even when it is not feasible to define a situation fully and definitively as a game, the intellectual process of defining the game as far as possible will provide strategic and joint operational insight.

An example of how a real world situation can be modeled as a game is shown in Figure 1, which depicts a situation based loosely on the nuclear confrontation between the US and the USSR in the early days of the Cold War. Building the game can be accomplished in the seven steps described below.[10] This technique seeks to integrate

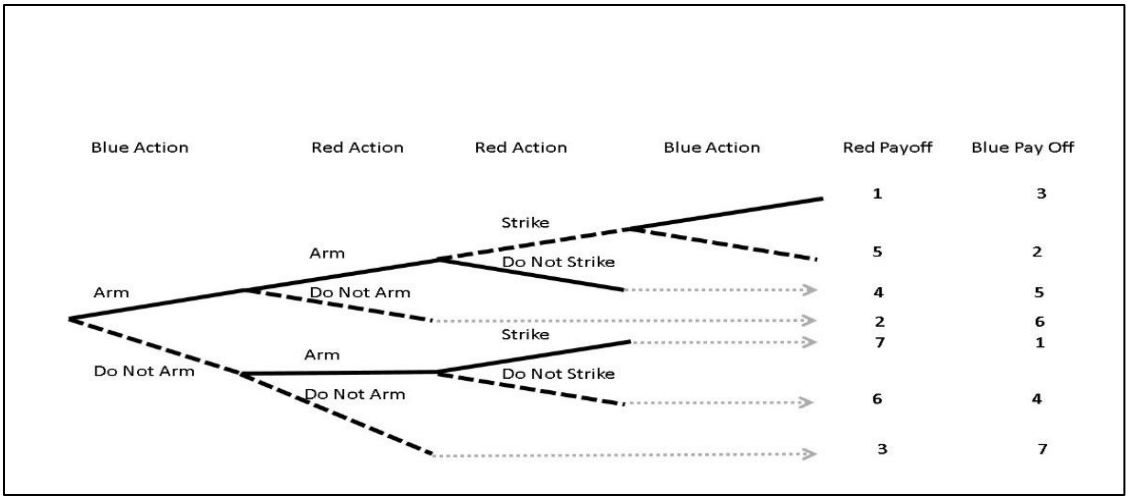

Figure 1. Nuclear Deterrence Strategy Translated into Game Theory[11]

Rasmussen's "PAPI" construct of players, actions, payoffs and information with military strategic and joint operational concepts in order to allow for the subsequent application of the full range of game theory tools and concepts.[12] While the example below employs only elementary game theory, it does demonstrate the feasibility and usefulness of integrating game theory into the processes of strategy, design, and joint operational planning. Further insight into a situation can be derived from more advanced applications of game theory. Eric Rasmussen provides a more detailed and comprehensive introduction to the mechanics of game theory in *Games and Information*. This work can provide insight into more complex applications of game theory that are possible once the translation of a military situation into a game has been achieved.[13]

Step one is to determine who the players are and understand their values, interests, and expectations relevant to the situation. In this case, the players are Blue and Red. Blue most values its own survival and then its own freedom. Blue therefore has an interest in deterring Red aggression and, if deterrence fails, in defeating Red.

Red most values its own survival and then world domination. Red thus has an interest in deterring an attack on itself and on defeating Blue, if it can do so and survive.

Step two is to determine the actions available and their sequence. In this case, Blue is the first mover and may choose to arm itself with a strategic nuclear arsenal or not to arm itself. Red may then choose to arm itself with a strategic nuclear arsenal or not to arm itself. Once armed either may choose to launch a nuclear strike on the other party. Because of Blue's values and interests it will not strike first. Red might strike first because of its values and interests. Therefore, after the decisions on arming, Red is the first mover on the decision to strike and may choose either to launch a first strike or not to launch. Blue may decide to retaliate if attacked, but will not attack if left alone.

Step three is to create a depiction of the players and actions. Game theory provides several formats for this depiction. In this example, a version of the extensive style is used to depict two players making up to two decisions each on actions that lead to seven possible outcomes.[14]

Step four is to assess the payoffs for each player of each outcome by using the values and interests we have assigned each player to calculate how they value each outcome for themselves (without considering the other's outcome). Customarily, game modelers assign an absolute value to the payoff. In some cases, intelligence and mission analysis will provide sufficient information to assign an absolute value to payoffs using a technique logically similar to the current doctrinal process of weighting criteria within a Course of Action analysis.[15] In this example, it is sufficient to rank the outcomes in relative order of preference for each party. Relative ranking, when appropriate, reduces the complexity of the assessment. The assessment of even relative payoff

values requires an act of military judgment. However, it is no bolder a judgment than that already considered manageable when applied in quantitatively analyzing and comparing Courses of Action.[16] In Figure 1, the relative payoffs of each outcome are ranked from a most preferred ranking of seven to a least preferred ranking of one. Red's payoff is depicted first and then Blue's payoff.

Step five is to determine the information available to each player at each decision point. In this game, no player knows what the other player will do in the future. They always know what they and the other player have already chosen to do. Military processes include systems to develop information requirements, which are logically connected to this stage of defining the game. Once game theory is integrated into the planning process, the information requirements of the interdependent decision-makers become apparent. This additional insight into information requirements makes it relatively easier to develop Courses of Action that include from conception a focus on shaping the information perceived by the decision-makers. This offers a chance for a more sophisticated and indirect approach than is the case if information requirements and information operations are considered later in planning and only serve to support a preexisting Course of Action.

Step six is to work backward through each decision for or against an action by each actor. In each case where there is a decision point, the player will choose the one that leads to the highest relative payoff value for themselves, regardless of the outcome for others. Paths not chosen are eliminated. The payoffs downstream from those paths are no longer possible. Those outcomes have been eliminated from the realm of the possible due to the interdependence of decision-making. Figure 1 depicts the path

chosen with a solid line and the path not chosen with a dotted line. Paths that are no longer possible because of decisions are shown with dotted arrows pointing to the theoretical payoffs that were developed in step four.

Actions must be carefully managed so that they do not become a de facto selection of Courses of Action prior to Mission Analysis. Actions are in most cases more general and abstract than Courses of Action. In some cases, the game results may allow planners to infer what types of Courses of Action are probably not feasible due to the interdependence of decision-making. Planners may also infer which outcomes can only be achieved if the Course of Action shapes the opponent's perceptions in a way that contributes to the desired outcome.

Step seven is to play the game in chronological order to find the actual outcome of interdependent decision-making. The game is played by following the path from left to right that was built from right to left in step six. This leads to a Blue decision to arm, and then a Red decision to arm. Next, Red decides not to launch a first strike, so Blue does not need to decide about retaliation.

Understanding the Outcome of a Game

Each party in Figure 1 had potentially better outcomes for themselves but could not achieve them because the interplay of the decisions by the two parties rendered those outcomes unobtainable. In military strategy terms, the eliminated payoffs show us that some series of actions are not valid as potential sources of inspiration for Courses of Action for the two parties. By virtue of not achieving a desirable end they are unsuitable and fail the Feasible, Acceptable, and Suitable (FAS) test, which requires a valid Course of Action to be feasible in terms of means, acceptable in terms of ways,

and suitable in terms of achieving the ends .[17] The result is that even though they both decide to arm, the parties deter each other from using those arms.

Each party also had potential outcomes worse than the one that occurred. Given the context of this game, this is excellent news. The outcome of being destroyed themselves rather obviously fails the FAS test, as it is not suitable. For Blue, destroying Red with a strategic nuclear strike while surviving themselves is not acceptable given the post-strike consequences. There is not an achievable sequence of decisions that allows Blue protect its values and interests unless Blue arms.

Three Approaches to Integrating Game Theory

Three approaches can be used to model a situation as a game or games and to integrate the game or games into strategy, design, or joint operational planning. The first approach is simply to define the fundamental game the friendly force is engaged in using the technique described earlier. The second approach is to begin with the technique above but include not one set of payoffs but two. The two sets of Red and Blue payoffs are shown in two separate columns. In the first column, the payoffs for each player are shown as the friendly force assess the payoffs, in the second column the payoffs are shown as the friendly force perceives the opponent assesses them. This approach sets the conditions for creating strategies and operations intended to take advantage of the information and perception asymmetry between the payoff assessments. The third approach is to envision the environment as a system of games occurring at all the levels of analysis of the international system (international system, international subsystems, units, subunits, individuals) and at all the levels of war (strategic, operational, tactical).[18]

From this system, the strategist picks out a manageable number of critical games to model. The strategist then groups the games into four game sets. The first three of the game sets reflect the friendly forces assessed views of the critical games from the perspective of friendly actors, hostile actors, and third party actors. A separate friendly strategist or group, such as a Red Team, develops and continually updates the fourth set. The modeler of this set seeks to identify and avoid potential blue misperceptions shaping the selection and definition of games in the first three sets.[19]

The First Approach: Define and Analyze the Fundamental game

The ideal technique is to define a single game that is the fundamental description of the situation. This approach is the quickest but requires balancing the advantage of clarity with the risk of over simplicity. Determining the fundamental game is most appropriate and easiest in cases where the players are a small number of distinct actors or can logically be grouped into a small number of highly similar groups. This requires that the values and interests shaping how payoffs are viewed are consistent for each defined player, even if the player is not an individual but instead a complex organization, such as a state. Such a case is an opportunity to define one fundamental game between the two parties and use this to gain insight. Often this will not be true, for example, a dictator's interest in personal survival may lead him to value payoffs differently than the populace at large or than the leaders of the nation's security forces. If so, it is better to use the second or third approach. These will better highlight the contradictions created by the interests of different individuals and groups within the enemy state.

In situations with where the confrontation is sufficiently large, in scale or scope, there can be different fundamental games at the various level of war, which would result

in nested fundamental games played by various levels of command. For example at the strategic level, two opponents could be engaged in a game of nuclear deterrence that leads to stability. However, for opposing subnational headquarters at the theater strategic or operational level, the fundamental game may be a limited war or a proxy conflict. In cases like this it would be possible for logically nested fundamental games to exist at the various levels. Each level of command would focus primarily on the one fundamental game occurring at its level. However, lower level games would have always to be considered in the context of their potential second and third order effects on higher level games whose importance will generally be greater. Additionally, lower level games would have to be monitored in case actions chosen in them signal a change in the opponent's thinking in the higher-level games.

The Second Approach: Define and Analyze One Game with Two Sets of Payoffs

The second approach to integrating game theory into military strategy, design, and joint operational planning is for planners to define and analyze the conflict in question as a game with two sets of payoffs. The first set depicts the payoffs that the friendly force assess as true and a second set of payoffs depicts the payoffs that the friendly force assesses are the opponents perception of the payoffs. The purpose of this technique is to inform the development of strategies and plans that seek victory, at least in part, through outthinking, deceiving, and/or achieving information superiority over the enemy rather than through a purely physical approach. This approach is most appropriate where a limited number of actions are available, and they are clear to both players.

An example of this technique, shown in Figure 2, depicts a traditional definition of a game in terms of the players, the actions, and the information. It then adds to this both

the payoffs that the modeler of the game assesses to be true and a separate set of payoffs that the modeler assesses their enemy assesses to be true. In the example, the Allies are successful in conducting security and deception operations to reinforce the German perception that they wish to invade Calais. In truth, they prefer to invade Normandy and to avoid doing so in the face of the German's main defensive effort.

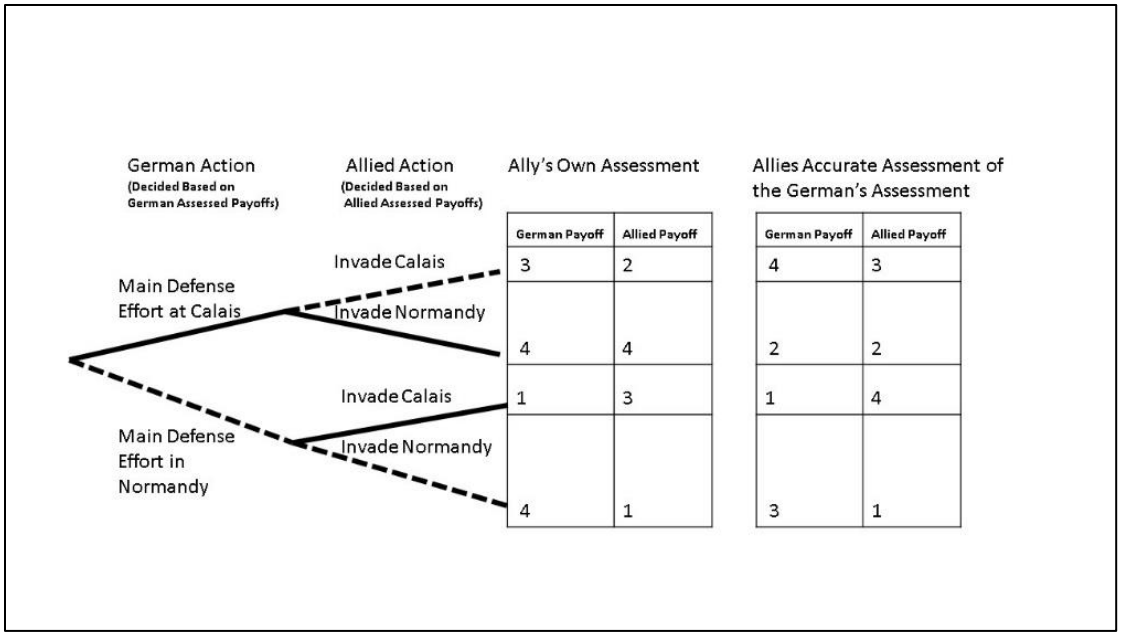

Figure 2. Allied Deception and Security Reinforce German Misperceptions[20]

That this is approach is achievable was demonstrated in the example of the misdirection of the German leadership over Allied invasion intentions in 1944. That effort also highlights that determining and shaping perceptions with intelligence, security and deception operations require a major commitment of resources and the ability to understand the opponents perceptions. It also requires limiting who on the Blue force knows the full nature of the operation.

This approach is most appropriate when the modeler thinks that both parties will view the players and actions similarly. If this is not the case, two separate games that

depict the two player's views are necessary to serve a similar purpose. If necessary, more than two players and a large number of actions can be shown. This is limited only by the difficulty that possible actions can grow beyond reasonable consideration if too many steps and players are included and there is a corresponding problem of displaying the game in a useable format.

The Third Approach: Conceptualize a System of Games and Model Important Games

The most elaborate, labor-intensive yet potentially insightful approach is to build multiple games that include the games played by important individual and collective actors at the strategic and joint operational level. In practice, this approach has similarities to the way systems theory is integrated into strategy and plans through the detailed mapping of the political, military, economic, social, information and infrastructure network in design and joint operational planning.[21]

In the third approach, strategists conceptualize the strategic/joint operational environment as a complex adaptive system in which all individual and collective actors are engaged in real and perceived games that interact in nonlinear ways.[22] Chaos theory suggests that this system will be too complex and dynamic to be perfectly understood and for reliable predictions to be made.[23] However, circumstances compel the strategist to seek a reasonable understanding of the system while remembering that the understanding can always be improved and that predictions may not be born out in reality. Rather than attempt to model and depict the entire system, the system must be thought through in broad terms. The modeler must arrive at conclusions about what the most important games are at the appropriate levels of war and across time periods. A manageable number of important games that are likely to significantly influence the outcome of the strategy or plan must be selected and modeled. These could be both

games played by individuals, such as that played by a head of state to remain in power, or games played by collective actors, such as the decision of an alliance to act or not act in a crisis. The games could also address different levels of war or different portions of a larger campaign either geographically or temporally.

The games are grouped logically into four game sets as depicted in Figure 3. The first game set is termed the blue game set. It includes the game or games the friendly force perceives they are themselves playing. The second is the red game set that includes the game or games the friendly force assesses the enemy force perceives they are playing. The third set is the green game set that includes the game or games the friendly force assesses key third party actors perceive they are playing. The fourth is the black game set. This is developed by a blue force Alternative Analysis Team or a blue force Red Team, which has access to all the information available to the friendly force and actively seeks to gather additional information and perspectives. The black game set depicts an assessment of the actual reality of the game's most critical to the friendly force when the assessed misperceptions of red, blue, and green are removed. The black set serves as a check on the planning process and as an assessment tool for execution. The black game set is not expected to agree with the blue, red, or green sets. Instead, any differences these sets have with the black set should be highlighted and explored for asymmetries in information or perceptions that can be corrected or exploited.

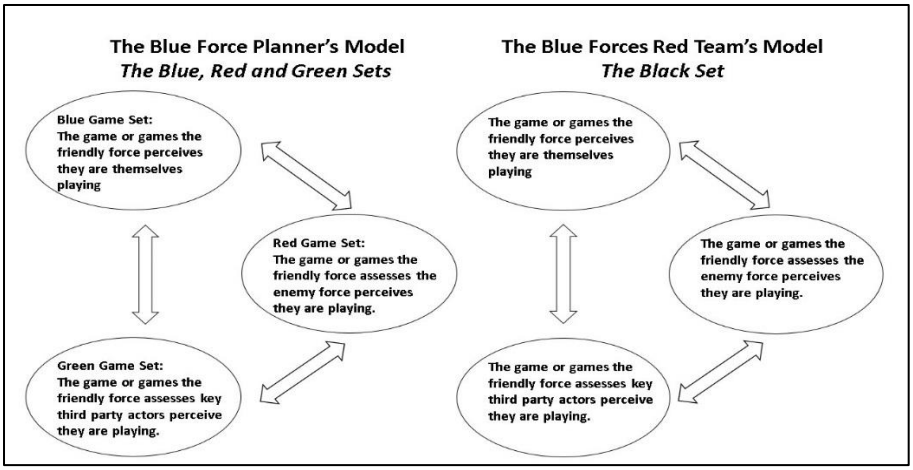

Figure 3: The Four Game Sets[24]

This approach is also useful as a check on unstated assumptions. Strategists usually try to account for the actions of multiple parties and leaders with judgment and critical thinking. The effectiveness and speed of their judgment and critical thinking are often hampered by the lack of a clear framework against which they can be applied. Defining these games and game sets, even if some can only be defined with limited fidelity, allows the planner to visualize the context of their thinking about interdependent decisions and to methodically apply judgment and critical thinking to what is otherwise a potentially murky area of unstated assumptions and inferences. In terms of time available, this approach is most useful at the strategic level where there is often considerable time for reflection and analysis between major decisions and in major campaign plan-level decisions at the joint operational level. Once built it is useful to inform shorter-term strategic and joint operational decisions and assessments. The analytical complexity and time requirements of this approach limits its usefulness in Crisis Action Planning.[25]

The Impact of Game Theory on Military Strategy, Design, and Joint operational Planning

The technique of defining a game or games and the application of one of the integration approaches to strategy, design, and joint operational planning can increase effectiveness in three ways. First, it provides strategists an additional perspective that is focused on outcomes and the information and decisions that drive them. Second, it provides a stimulus for thinking deeply about who the critical players and decision-makers are and what their values, interests, and expectations are relevant to the situation. Third, it creates conditions that can lead to creating Courses of Action that are information and decision focused from conception. For the purpose of discussing these impacts on strategy, design, and joint operational planning, the three constructs can be considered as being similar in that they share three essential components: Framing; Stating the Problem, and Proposing Solutions.

The Impact of Game Theory on Framing

Framing occurs during the process of understanding the environment early in the Strategy construct of end, ways, means, and risk; during the Understand the Environment step of design; and during the Plan Initiation and portions of the Mission Analysis steps within joint operational planning processes. Game theory offers a number of benefits at this stage. First, it focuses attention on understanding the nature and character of the players and their values, interests and expectations in the context in question. Second, it begins to structure the problem through the consideration of potential actions. Third, it forces consideration of how information availability and related perceptions and misperceptions could influence the players in the selection of actions.

All three are useful to establish a well-informed frame of reference and highlight what needed, or useful, information is not currently available.

The Impact of Game Theory on Stating the Problem

Stating the problem roughly equates to formulating the ends component of the ends, ways, means, and risk construct; to the Understand the Problem step of design; and to Mission Analysis within joint operational planning. Game theory would positively influence the statement of the problem in four ways. First, because it considers interdependent decision-making it would contribute to framing the problem in light of human behavior and decision-making consistent with the values and interests of actors. Among other benefits, this forces a check of assumptions about other players and the degree to which we understand their motivations and capabilities. Second, it provides an additional lens to that provided by current doctrine's system engineering inspired view that the problem is the alteration of conditions within a system.[26] By adding this perspective, it leads to a more comprehensive and realistic model of the environment. Third, game theory would lead planners to frame the problem statement partially in the context of critical decisions and information. This allows ends, Operational Approaches, and Courses of Action to be developed that are information-centric or, at least, have information considerations integrated into them from the beginning rather than added on after their initial formulation. Finally, because many actions interact in ways that limit the number of potential outcomes, game theory would contribute to organizing the problem in ways that highlight risk and challenges to, or the impossibility of, certain ends, certain Operational Approaches and certain Courses of Action.

The Impact of Game Theory on Proposing Solutions

Proposing Solutions roughly equates to ways, means and risk; to Define the Operational Approach; and to Course of Action Development and to Course of Action Analysis and Wargaming. Game theory integration creates the conditions for planners to propose solutions that benefit from improved framing and problem statement because of the positive impacts of game theory earlier in the process. The impact of game theory on solutions can be considered in terms of how it offers potentially greater degrees of feasibility, acceptability, and suitability. Game theory informed solutions are more likely to prove feasible because they should leverage power and mass with deception and information superiority and so limit the requirement for physical means. They are likely to prove more acceptable because they can reduce the potential level of attrition (of both friend and foe), collateral damage, and civilian casualties. They do so by seeking victory, at least in part, through having a superior ability to execute Colonel John Boyd's "Observe, Orient, Decide, Act" loop rather than solely through physical actions.[27] This leads to the development of ways that are consistent with the values and interests of the US and helps to manage the difficult tradeoffs of various types of risk inherent in conflict. They are likely to be more suitable for achieving the desired outcome because they account for the interdependence of friendly behavior with opposition and third party behavior. This increases the likelihood that they will achieve the desired ends. Finally, game theory provides a tool to assess and manage risks created by the interdependence of decision-making in conflict.

Conclusion

Game theory provides an analytical framework that can elevate the quality of analysis at the strategic and operational level of conflict by focusing attention on the

fundamental factors driving decision-making. This can help put into practice the widely quoted but less often successfully applied advice of Sun Tzu that “what is of supreme importance in war is to attack the enemy's strategy” and of B. H. Liddell Hart that “. . . the effect to be sought is the dislocation of the opponent’s mind and dispositions.” [28] Integrating game theory into existing systems using the techniques and approaches discussed above, or through other methods, creates opportunities for strategists to develop better strategies, concepts, and plans. These opportunities result from the additional perspective provide by game theory that accounts for the interdependence of decision-making in conflict and complements the existing influence of critical and creative thinking, systems theory, and historical and international relations based perspectives. The addition of this perspective forces deliberate consideration of the nature and character of the opposing forces and their leadership, which will lead to a more nuanced understanding of the problem and a more sophisticated approach to solutions. The game theory influenced perspective will guide strategists towards Courses of Action that augment and focus the direct application or threat of force with indirect and information driven actions. These actions will shape the decision-makers information environment in ways that contribute to achieving the best feasible outcome while potentially reducing the risk of an unsatisfactory outcome and lowering the cost in lives and money.

Endnotes

[1] Thomas C. Schelling, *the Strategy of Conflict* (Cambridge, MA: Harvard University Press, 1960.) 9-10.

[2] B.H. Liddell Hart, *Strategy: Second Revised Edition* (New York: Meridian, 1991), 146.

[3] Eric Rasmussen, *Games and Information: Fourth Edition* (Malden, MA: Wiley-Blackwell, 2006), http://www.rasmusen.org/GI/chapters/chap01_basics.pdf (accessed March 7, 2015), 1-9

[4] Avinash K. Dixit and Barry J. Nalebuff, *Thinking Strategically: The Competitive Edge in Business, Politics and Everyday Lif*e (New York: Norton, 1993), ix-4, 128-131.

[5] The terms strategist and planner are used interchangeably and are intended to include all participants in strategic and operational discourse.

[6] Roger B. Myerson, *Game Theory Analysis of Conflict* (Cambridge, MA: Harvard University Press, 1991), 1.

[7] Rasmussen, *Games and Information: Fourth Edition*, 9.

[8] Schelling, *The Strategy of Conflict,* 83-86.

[9] Rasmussen, *Games and Information: Fourth,* 10.

[10] The seven step technique describes fundamental game theory processes and was derived from a briefing by Patrick Buckley, "Game Theory: A Tool for Strategy," Class Presentation Slides, West Point, New York, United States Military Academy, 2003. The terms and general approaches in the seven steps are consistent with Chapter 1 of *Games and Information.* Eric Rasmussen, *Games and Information: Fourth Edition* (Malden, MA: Wiley-Blackwell, 2006), http://www.rasmusen.org/GI/chapters/chap01_basics.pdf (accessed March 7, 2015), 1-34. West Point, New York, United States Military Academy, 2003. Any inaccuracies or incorrect applications of techniques are my responsibility.

[11] Derived from a similar slide by Patrick Buckley, "Game Theory: A Tool for Strategy," Class Presentation Slides, West Point, New York, United States Military Academy, 2003. Any inaccuracies or incorrect techniques are my responsibility.

[12] Rasmussen, *Games and Information: Fourth Edition,* 9.

[13] Derived from a briefing by Patrick Buckley, "Game Theory: A Tool for Strategy," Class Presentation Slides, West Point, New York, United States Military Academy, 2003. Any inaccuracies or incorrect techniques are my responsibility.

[14] Roger B. Myerson, *Game Theory Analysis of Conflict* (Cambridge, MA: Harvard University Press, 1991), 37-46.

[15] U.S. Joint Chiefs of Staff, *Joint Operational Planning,* Joint Publication 5-0 (Washington, DC: U.S. Joint Chiefs of Staff, 11 August 2011, G-1 to G-5.

[16] Ibid.

[17] Alan G. Stolberg, "Making National Security Strategy for the 21st Century" in *U.S. Army War College Guide to National Security Issues, Volume II: National Security Policy and Strategy, Fifth Edition* ed. J. Boone Bartholomees, Jr. (Carlisle, PA: U.S. Army War College, 2012), 51-52.

[18] Alan G. Stolberg, “The International System in the 21st Century” in *U.S. Army War College Guide to National Security Issues, Volume I: Theory of War and Strategy, Fourth Edition* ed. J. Boone Bartholomees, Jr. (Carlisle, PA: U.S. Army War College, 2012), 145. and H. Richard Yarger, “Toward a Theory of Strategy: Art Lykke and the U.S. Army War College Strategy Model” in *U.S. Army War College Guide to National Security Issues, Volume I: Theory of War and Strategy, Fourth Edition,* ed. J. Boone Bartholomees, Jr. (Carlisle, PA: U.S. Army War College, 2012), 45-51.

[19] This is done by producing as close to an objective model of the critical games as can be done with unlimited access to the information available to the friendly forces and the application of the almost countless thinking techniques commonly employed by U.S. Red Teams and NATO Alternative Analysis teams. These techniques are discussed in the U.S. Army’s *Red Team Handbook*.

[20] Derived from a similar slide by Patrick Buckley, “Game Theory: A Tool for Strategy,” Class Presentation Slides, West Point, New York, United States Military Academy, 2003. Any inaccuracies or incorrect techniques are my responsibility.

[21] U.S. Joint Chiefs of Staff, *Joint Operational Planning,* III-8 to III-11.

[22] Serena Chan, “Complex Adaptive Systems,” Online Course Notes for Massachusetts Institute of Technology Research Seminar in Engineering Systems, 2001 http://web.mit.edu/esd.83/www/notebook/Complex%20Adaptive%20Systems.pdf (accessed 28 March 2015) 1-9.

[23] James Gleick, *Chaos: Making a New Science* (New York, Viking, 1987).

[24] Developed by author. First person to use the "Four Game Sets.”

[25] U.S. Joint Chiefs of Staff, *Joint Operational Planning,* II-28 to II-34.

[26] Ibid., III-7 to III-13.

[27] Colonel John Boyd, “The Essence of Winning and Losing,” Briefing slides, Washington, DC, 1996, http://pogoarchives.org/m/dni/john_boyd_compendium/essence_of_winning_losing.pdf (accessed 27 March 2015) 1-6.

[28] Samuel B Griffith, *Sun Tzu: The Art of War* (London: Oxford University Press, 1971), 77; and B.H. Liddell Hart, *Strategy: Second Revised Edition* (New York, Meridian, 1991), 147.