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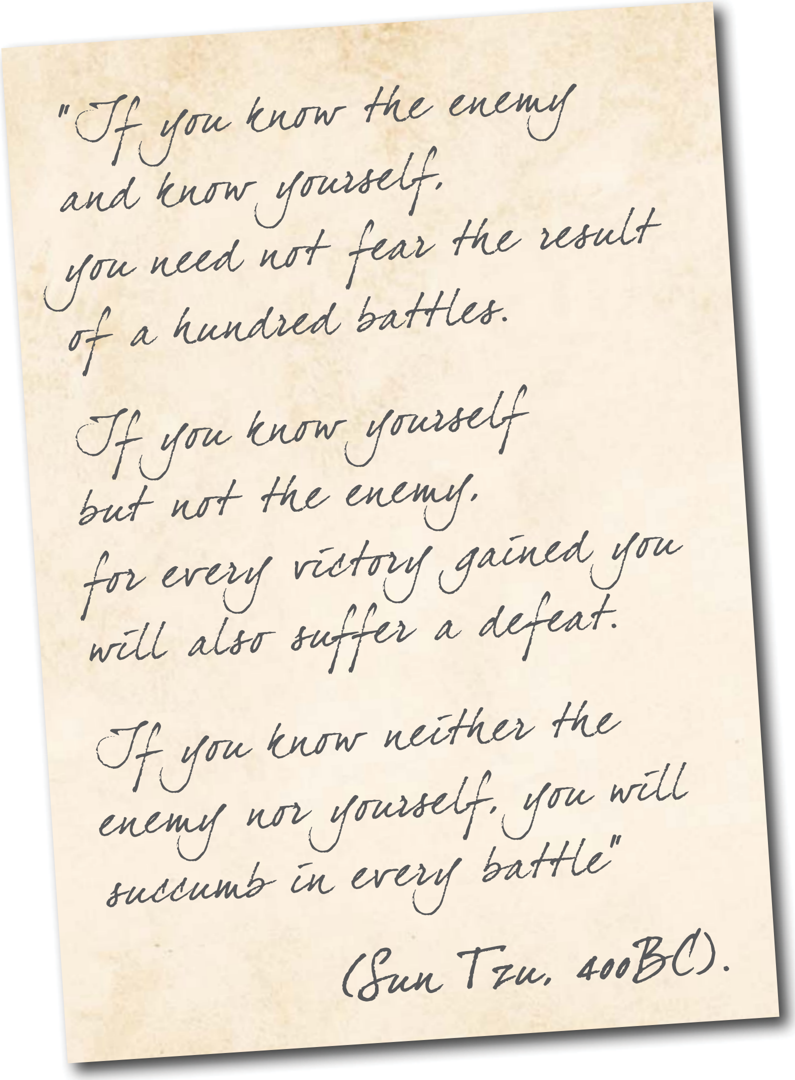

Toward a Systems Thinking Model of Decision Dominance

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Having a better understanding of the environment, information, and state of military operations has always been critical in warfare. Understanding the operational environment allows leaders to make informed decisions with the necessary situational awareness to maximize their possibility of success. Traditionally, this understanding has focused on the physical realm, such as troops, maneuver, and logistics, allowing a direct observation of a battlefield and more immediate feedback on the consequences of a decision. However, with the recent expansion of the digital domain, military organizations now have the challenge of accessing, processing, storing, and analyzing data at a never-before-seen scale and pace to achieve situational awareness in an operational environment.

Several papers have been written about how *information advantage* (IA) and *decision dominance* (DD) are critical for successful operations, both now and in the future (Paul, 2020; Powell, 2014). FM 3-0 provides a useful overview wherein successful military operations rely on gaining the initiative through decision dominance, which is a "desired state in which a force generates decisions, counters threat information warfare capabilities, strengthens friendly morale and will, and affects threat decision making more effectively than the opponent" (Headquarters, Department of the Army, 2022). It further suggests that DD is achieved by developing and exploiting a variety of information advantages. While this is a useful conceptual description, how can commanders assess if they have achieved a state of decision dominance? There is currently no straightforward way to model these abstract concepts in such a way as to provide actionable input to a commander's decision-making process. Our goal in this article is to propose a model for IA and DD that provides measurable quantities and actionable insights

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for commanders. To achieve this, we propose a series of measurable definitions for these concepts and a systems thinking model that formalizes their relationships.

Information Advantage and Decision Dominance

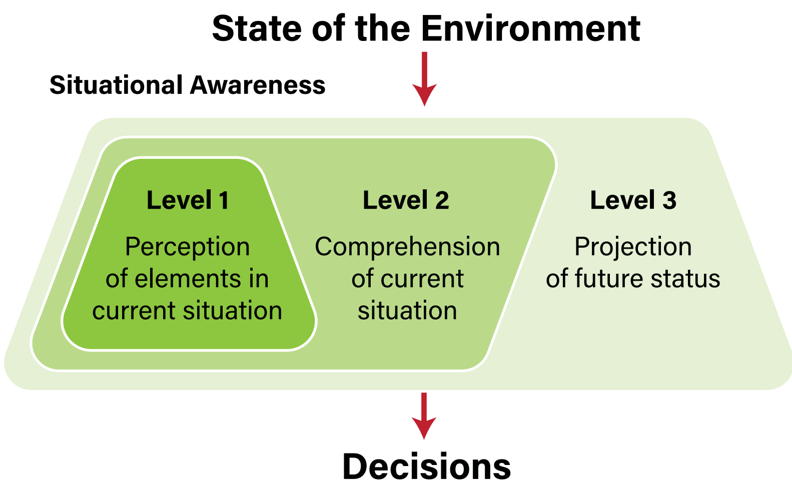
Before presenting the systems thinking model for decision dominance and its constituent elements, we first need to review some relevant concepts. As FM 3-0 suggests, the primary concept is information advantage itself. There are several proposed definitions for IA, including "a condition of relative advantage that enables a more complete operational picture and leads to decision dominance, the sensing, understanding, deciding, and acting faster and more effectively than the adversary" (Ross, 2022) and "a condition when a force holds the initiative in terms of situational understanding, decision making, and relevant actor behavior through the use of all relevant military capability" (Ross, 2022). These definitions share some components, notably a relativity to an adversary, and a notion of understanding, while varying in what that condition looks like when achieved. Unlike in the land domain, where assessing the initiative is more tangible, how does a commander know if they have achieved an advantage in the information environment?

IA is a multifaceted concept that, depending on the source, relies on the two interconnected tasks—the ability to sense, assess, and make decisions at speed, while also influencing our adversary's ability to do so. These two related tasks occur in a continuous environment and need to be measured to fully understand our relative advantage or disadvantage in the decision space. Army cyber leadership currently lists five activities as essential in gaining and maintaining IA: enable, protect, inform, influence, and attack (Pomerleau, 2021). While each of these activities is a necessary component of IA, it's not clear if they are sufficient to achieve IA and how they relate to DD.

Situational Awareness and Measuring IA

While there has been little literature quantifying or measuring IA, there is research in situational awareness (SA) that may be relevant as a proxy to measuring a relative advantage or disadvantage in decision making. Using Mica Endsley's model, SA can be broken down into three levels: perception, comprehension, and projection (Endsley, 1995). The first level of SA, **perception**, is "perception of the elements in the environment," meaning the ability to perceive the "status, attributes, and dynamics of relevant elements in the environment" (Endsley, 1995). In the information space, this could include perception of data points from news sources, social media, or local leaders. The second level of SA, **comprehension** is "comprehension of the current situation" (Endsley, 1995). Comprehension allows a decision maker to form a holistic picture of an environment based off the combination of elements and their significance. The ability to combine data points from disparate sources to gain a better understanding of the environment is crucial for the IA space, particularly for a commander's understanding of the environment. The third level of SA, **projection**, is "projection of future status," meaning the "ability to project future actions of the elements in the environment at least in the very near term" (Endsley, 1995). Figure 1 depicts Endsley's three-level SA model (Beck et al., 2011).

Figure 1. Endsley's three-level SA model (Beck et al., 2011).



The ability to project future status through a greater understanding of the environment is used by humans and machines every day, both consciously and subconsciously. For example, the decision a platoon leader makes to take a different route due to the absence of kids who normally play outside (perception) is the synthesis of an atmospheric condition with experience (comprehension) informing a potential future event (projection). In a similar manner, using news, sentiment, and historical trends to predict future stock prices for quantitative trading is humans using machines to gain greater SA through multiple relevant elements in the environment to project short term future status.

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Endsley's three-level model is helpful in the IA and DD realms as it relies on more than how a subject perceives the environment. Instead, he emphasizes the greater understanding of an environment that an individual can gain from the combination and interaction of variables within that environment, as well as what that interaction by variables means for future events. Endsley also makes the point that the more experience, training, and education a subject has in the related environment increases their ability to understand the environment (Endsley, 1995). In some fields, measuring SA is relatively straightforward. For instance, in quantitative trading, an easy proxy for measuring SA success is return on investment. However, in the IA and DD concepts, our relative advantage compared to the adversary is much harder to quantify and requires multiple atmospheric inputs that may not all be native to the digital domain.

The Necessary Elements for a Decision Dominance Model

Based on the previous research into relevant concepts such as SA and current thinking on IA, there are several processes and concepts that form the basis of any model for DD. We propose a systems thinking model and introduce alternative definitions of several key concepts to enable modeling while attempting to remain faithful to the existing doctrinal concepts. We note that these elements are necessary, but may not be sufficient to achieve DD.

Existing definitions of IA, listed earlier, do not lend themselves to measurement for at least three reasons. First, how do we measure situational understanding when that term itself is not well defined in doctrine? Second, if we cannot measure our own situational understanding, how will we also measure the situational understanding of an adversary to determine relative advantage or initiative? Finally, which adversary are we measuring against? The operational environment has many actors against whom we could measure, and simple bilateral measurements are unlikely to prove insightful.

We propose that IA is a temporary condition in which an organization can combine a data advantage and situational awareness to define their current decision space completely and accurately. We believe this alternative definition narrows the scope to focus on internal processes that are knowable. Further, this definition allows us to measure whether IA has been achieved by assessing whether the decision space is complete and accurate. In some instances, this knowledge may only be available in hindsight; however, this framing can at least guide a contemporaneous review of the informational processes. This definition also follows from the existing doctrinal model for the relationship between data and information. If information is contextualized and synthesized data, it follows that a data advantage plus situational awareness would lead to an information advantage. This logic lends itself well to quantification as we can then measure constituent elements, DA and SA as defined below, to understand if we are in a condition of IA:

- DA is a condition in which an organization can collect, clean, correlate, and deliver all data necessary for a decision maker.
- SA is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status into the near future (Endsley, 1995).
- The decision space is the set of all plausible actions that an actor can make. This space is naturally influenced by the information at that actor's disposal and the context—both internal and external to the actor—in which that actor is making those decisions.

The output of our proposed IA definition is the decision space from which a commander can select a decision in each situation. We can then link the output of IA to the concept of DD through the concept of the decision space where DD is the ability to preserve or expand the decision space until such time as the commander makes a decision. This definition also lends itself well to assessment. In the simplest form, a commander can ask, "Was I able to make the decision that I wanted to make at the time of my choosing?" If not, then the commander has failed to achieve DD and the systems thinking model that we lay out can guide the determination on where DD was lost. We can further define the constituent elements of decision dominance:

- *Decision space preservation* is the ability of an organization to take a given decision space and preserve or expand favorable decision options against degradation. The degradation of the decision space could be a result of adversary action, changes in the context, or the passage of time.
- *Decision timing* refers to the crucial aspect of making decisions at the right time.

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The timing of a decision significantly impacts the outcome of the decision. For instance, consider a scenario where a river dam operator must decide whether or not to release water during an extreme rainfall event. If the decision is made too early, it could lead to unnecessary damage downstream. On the other hand, if the operator waits too long, the dam could fail catastrophically. The duration of a decision's existence is time bound and influenced by the situation at hand. The success of any decision is also affected by the timing of the decision. Additionally, time is an important factor in creating a decision space, which is necessary to achieve DD. An actor must position possible decisions over time to create a decision path through the decision space. Decision speed is also an essential component of decision timing, as making decisions faster than an adversary can expand a commander's timing window to alter the decision space and force the adversary to reassess their decision path. In summary, decision timing is crucial to achieving successful outcomes, and actors must carefully consider the duration of a decision's existence and the timing of their decisions to achieve decision dominance.

Finally, we also note that since there is always an element of chance in the execution of any decision, we do not consider the actual outcomes of decisions. In other words, it is possible for a decision maker to make the right decisions but fail in the execution of those decisions and thus produce an unfavorable outcome. While it follows that making better decisions through having DD is likely to lead to better decision outcomes, it may not always lead to those better outcomes. Thus, we consider DD as the ability to make better decisions, without evaluation of that dominance by the outcomes. In essence, we mirror the FM 3-0 definition of DD without making success contingent on achieving particular outcomes that are subject to chance.

As we developed these definitions and our model, we made several assumptions. First, we assumed that actors would prioritize decisions that move them toward achieving their most important objective; friendly and adversarial forces make decisions with the aim of reaching at least one of their objectives, which will typically deny the other of their objectives. This is an assumption that actors will make rational decisions in response to the information they are provided and are able to successfully perform goal valuation prior to making decisions. Goal valuation includes the ability to identify all of an actor's goals, which may be competing, and select those goals that are either most beneficial or least harmful to the actor. Second, we assumed that a decision made by a rational actor would achieve the desired outcomes. This assumption was necessary to decouple the quality of the decision from the quality of the outcome. In practice, we acknowledge that a correct decision can fail to achieve the desired outcome for a variety of reasons; however, we felt that was outside the scope of the current work. Finally, we acknowledge that this definition does not include a relative component as some of the existing IA definitions do. This was a deliberate decision, as measuring friendly perception, let alone an adversary's, is sufficiently complicated.

Systemigram of Decision Dominance

As Figure 2 shows, we used a systemigram (Squires et al., 2010; Sauser and Boardman, 2014) to model decision dominance and its related factors, providing a visual representation of complex concepts with interconnected components. A systemigram is a type of systems thinking model that consists of a series of entities with relationships between those entities. In this case, we represent entities with ovals, and include super classes of entities, with ovals around other ovals. The arrows between nodes indicate notable relationships with a verb defining the relationship. Our objective with this systemigram is to graphically showcase a subset of key elements that contribute to decision dominance.

The systemigram displays feedback loops between decision dominance, real-world states, external factors, data advantage, and situational awareness. Notably, the decision maker injects their internal factors into the cyclic loops but does not necessarily change because of those loops. All nodes either directly or indirectly influence decision dominance in some manner. We contend that achieving decision dominance is a result of a complex system of systems. The most expansive fundamental systems include situational awareness, data advantage, and data dominance itself.

Situational awareness directly influences decision dominance. For SA, we adopted Endsley's widely accepted three-tiered model (Endsley, 1995), which involves a decision maker's ability to perceive a situation, comprehend it, and project the decision outcome based on provided data. Factors internal to the decision maker, such as education and experience, enhance the decision maker's

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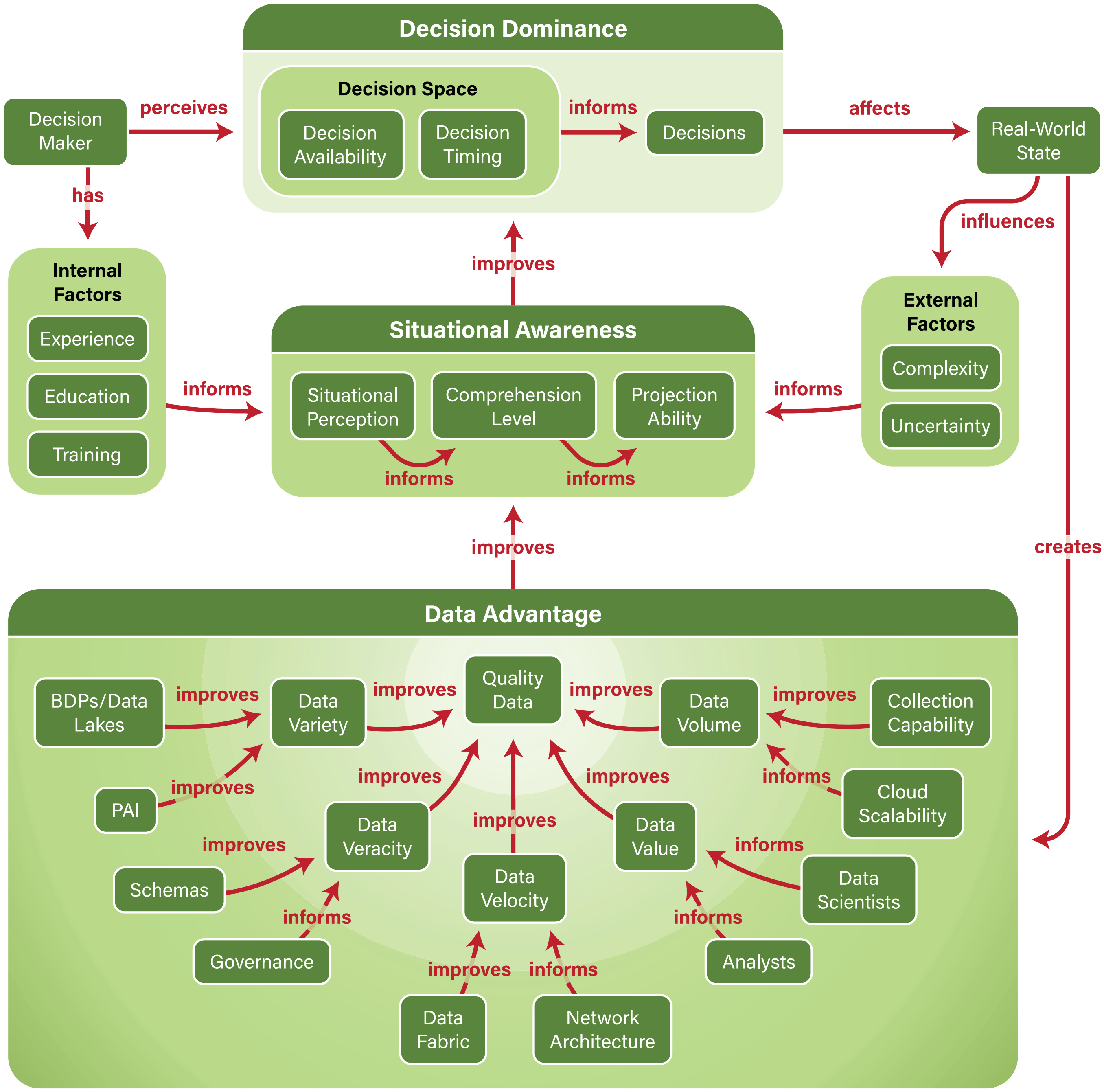
ability to understand the situation. External factors driven by the real-world state, such as probabilistic uncertainty and situational complexity, decrease the level of situational awareness a decision maker can achieve.

To achieve situational awareness, data, a necessary component to understand any decision space, must be available for evaluation. Recognizing the significance of data advantage in achieving decision dominance, we further identified contributing factors to data quality. To do so, we employed the 5 V's of big data (Ishwarappa and Anuradha, 2015) that affect data quality: variety, veracity, value, velocity, and volume. By maximizing each V's value, an organization can attain data advantage. Our labeled nodes feeding into the 5 V's pinpoint critical factors within the associated subcomponents of data quality.

Data advantage improves SA, which in turn enables DD. DD is comprised of two attributes, the decision space and the decision itself. The decision space is the set of decisions that are still available and the timing of those decisions, both of which inform the actual decision made.

Figure 2. Systemigram of decision dominance.



The systemigram facilitates the graphical representation of DD and its key contributing factors. The systemigram is representative of an essential subset of aspects. It is not exhaustive but rather reflects key factors we chose to emphasize.

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Decision dominance should result in an effect on the real-world state more closely aligned with a decision maker's end goal. This could either be to maintain the status quo or create some change. These effects in the real-world state impacts external factors and data advantage, creating feedback loops within the broader system.

Implications of Systems Thinking Model of Decision Dominance

The first implication of this model is that decision making, especially for the modern military decision maker, is a complex, adaptive system of systems. Military decision making consists of interrelated components in the information space, the situational awareness space, and decision maker characteristics. Thus, achieving DD can benefit from systems-level thinking and actions.

A second implication of the system-level model of DD is that it cannot be created by a new software tool or a purchased product. Rather, it requires system-level changes across all components of decision making to achieve DD. This result is important to keep in mind when it comes to things like acquiring new command suites or commercial technologies; while these products can aid in improving elements of decision making, they cannot by themselves produce DD.

Finally, having a systems model for DD opens new avenues for quantitative analysis and research. Being able to model decision making as a systems dynamics model allows for simulation and advanced modeling of decision making. Such quantitative methodologies can provide for new measures of decision making and DD. Furthermore, having a quantitative model that can be used in simulations provides better understanding of how proposed changes, such as new command suites or new training for military decision makers, might impact the decision-making ability to achieve DD for a military decision maker.

Never has there been more of a premium on decision making of military leaders and never has it been so difficult. As the military wrestles with new concepts for the future of warfare, it is becoming increasingly clear that the ability to make better decisions than an adversary is critical to operational success. This decision making is happening in a context of increasing amounts of data, greater quantities of automated technology, and faster operational speeds. To begin addressing this need and its challenges, we propose that modeling decision making, and DD through the lens of systems dynamics modeling provides a richer and more meaningful definition of DD as well as providing novel opportunities to apply quantitative techniques to DD.

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