

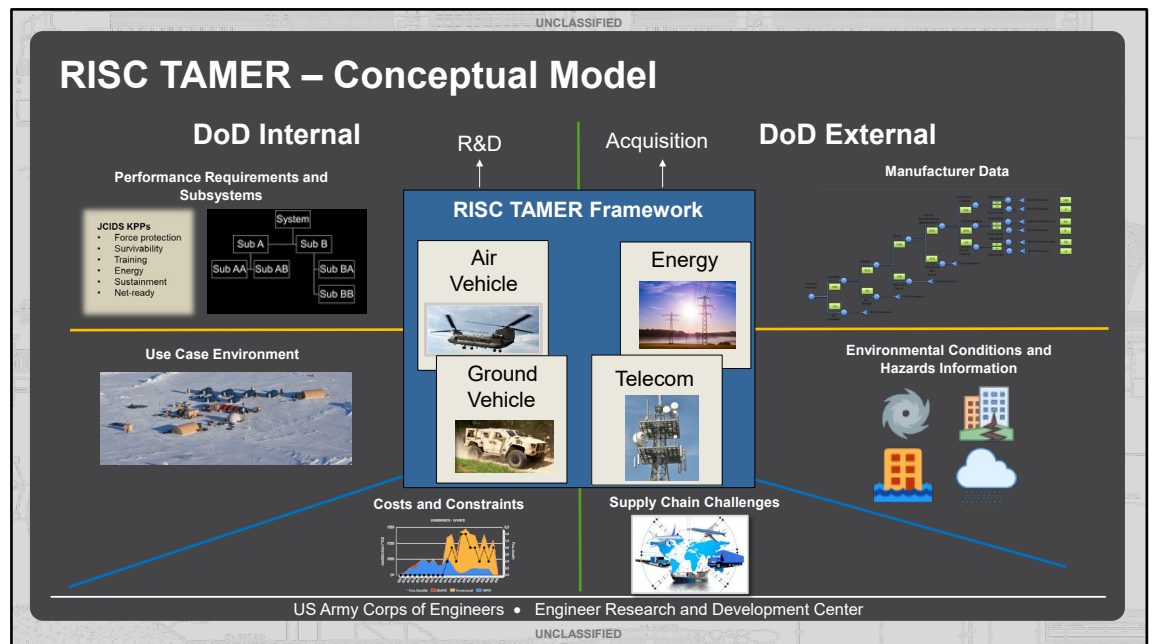
Cold Regions Energy RDTE Program

RISC TAMER Framework

Resilient Installation Support Against Compound Threats Analysis and Mitigation for Equipment and Resources Framework

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Caitlin A. Callaghan, and Peter H. Larsen

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Abstract

Every day, decision-makers must allocate resources based on the best available information at the time. Military installations face a variety of threats which challenge sustained functionality of their supporting and supported deployable systems. Considering the compounding and interdependent impacts of the threats, both specified (what is known) and unspecified (what is not known) and the investments needed to address these threats adds value to the decision-making process. Current risk management practices are generally evaluated via scenario analyses that do not consider compound threats, resulting in limited risk management solutions. Current practices also challenge the ability of decision-makers to increase resilience against such threats. The Resilient Installation Support against Compound Threats Analysis and Mitigation for Equipment and Resources (RISC TAMER) Framework establishes a decision support structure to identify and categorize system components, compound threats and risks, and system relationships to provide decision-makers with more complete and comprehensive information from which to base resilience-related decisions, for prevention and response. This paper focuses on the development process for RISC TAMER framework to optimize resilience enhancements for a wide variety of deployable systems in order to implement resilience strategies to protect assets, to increase adaptability, and to support power projection and global operations.

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Contents

Abstract	ii
Figures and Tables	v
Preface	vi
1 Introduction	1
1.1 Background.....	1
1.2 Objective.....	2
1.3 Approach	3
1.4 Impact to DoD and the Army	3
2 Literature Review	5
2.1 Decision Support Tools.....	5
2.2 Development of a Sustainment Management System for Deployable Assets and Systems.....	7
2.3 Incorporate Natural Hazard Risk into the Sustainment Management System (SMS).....	8
2.4 Terminology.....	9
2.4.1 Resilience	9
2.4.2 Risk Management.....	10
2.4.3 Deployable Asset Threats and Hazards.....	11
2.5 Vehicle Management.....	13
3 Technical Approach Overview	16
3.1 Technical Approach and Results	16
3.2 Stakeholder Engagement.....	18
3.2.1 DoD Agency Level	18
3.2.2 Army Level	19
3.2.3 Combatant Command Level.....	19
3.2.4 Commercial	20
4 RISC TAMER Framework	21
4.1 Design.....	21
4.2 Functions.....	23
4.2.1 Mission Resource Dimension.....	23
4.2.2 Threat Event Dimension	26
4.2.3 Mission Consequence and Mitigation Dimension.....	27
4.2.4 Total Risk Score	29
5 Illustrative Use Case	30
5.1 Scenario	30
5.2 Summary of Illustrative Case Study.....	33
6 Next Steps	34

7 Conclusions.....	36
Bibliography.....	37
Abbreviations.....	41
Report Documentation Page (SF 298).....	43

Figures and Tables

Figures

1. Resilient Installation Support against Compound Threats Analysis and Mitigation for Equipment and Resources (RISC TAMER) Framework overview.	17
2. RISC TAMER Framework interactions.	17
3. RISC TAMER Framework development methodology.	22
4. Mission resource dimension—deployable systems mission criticality.....	24
5. Mission resource dimension—deployable systems vulnerability.	24
6. Mission resource dimension—infrastructure.	25
7. Threat event dimension—intensity.....	26
8. Threat event dimension—likelihood of occurrence.....	26
9. Mission consequence and mitigation dimension—mission resource impact.	27
10. Mission consequence and mitigation dimension—impact controllability.....	28
11. Mission consequence and mitigation dimension—consequence.	28
12. Illustrative use case; mission resources dimension—deployable systems.	30
13. Illustrative use case; mission resources dimension—infrastructure systems.....	31
14. Illustrative use case; threat event dimension.....	31
15. Illustrative use case; mission consequence and mitigation dimension.....	32

Tables

1. Example of singular threats and risks to ground vehicle systems due to cold weather.	12
2. <i>Technical Manual – Unit Maintenance High Mobility Multi-Purpose Wheeled Vehicle (HMMWV)</i> example. (Reproduced from DA TM-9-2320-280-20-1 1996. Public domain.).....	15
3. Deployable system mission criticality category and score.	24
4. Deployable system vulnerability category and score.	25
5. Infrastructure criticality and vulnerability category and score.	25
6. Threat event intensity, likelihood categories, and scores.	27
7. Mission resource impact category and score.	27
8. Impact controllability category and score.	28
9. Consequence category and score.	28
10. Illustrative case study; dimension scores and total risk score table.....	33

Preface

This study was conducted for Headquarters, US Army Corps of Engineers, under Program Element Number O633119A, Project Number B03, Task Number A1050.

The work was performed by the Institute for Systems Engineering Research of the Computational Science and Engineering Division, US Army Engineer Research and Development Center–Information Technology Laboratory (ERDC-ITL). At the time of publication, Mr. Willie Brown was institute director; Dr. Jeffrey L. Hensley was division chief; and Dr. Robert M. Wallace was the technical director. The deputy director of ERDC-ITL was Dr. Jackie S. Pettway, and the director was Dr. David A. Horner.

The work was also performed by the Engineering Resources Branch of the Research and Engineering Division, ERDC–Cold Regions Research and Engineering Laboratory (CRREL). At the time of publication, Dr. Melisa Nallar was branch chief; and Dr. John W. Weatherly was acting division chief. The deputy director of ERDC-CRREL was Dr. Ivan P. Beckman, and the director was Dr. Joseph L. Corriveau.

COL Christian Patterson was commander of ERDC, and Dr. David W. Pittman was the director.

1 Introduction

1.1 Background

DoD installations face a variety of threats which, when compounded, challenge their sustained functionality. Current practice is to evaluate risk generally via scenario analyses which do not consider compound threats, resulting in limited risk management solutions. This current practice also challenges an installation's ability to increase its resilience against such threats. Most installation risk analysis approaches focus on assessing the fixed infrastructure of an installation, not the deployable assets that support the installation's mission or are projected as combat power. Deployable assets, in broad terms, are the soldiers and equipment that are "able to be moved to a place where they can be used when they are needed" (Cambridge Dictionary 2023). For this framework, the focus is on military combat vehicles.

Resilience is a concept rooted in ecosystem studies to understand the non-linear dynamics observed in ecosystems (Gunderson 2000). While resilience can be viewed in very specific terms, depending on its context, it is more generally considered to be the ability to recover from a disruption or difficulty. The complex and interdependent nature of ecosystems has presented challenges for risk assessment of multiple stressors, leading to new approaches in risk and impact assessments (Van den Brink et al. 2016). Previous research has examined the compound nature of risks and their assessment; however, there has been limited research looking at how such an assessment and understanding can inform resilience planning for DoD decision-makers. Leveraging such examples and systems thinking will help identify vulnerabilities across a system for which potential compound threats should be assessed.

Decision matrices are tools to evaluate and prioritize a list of options, based on an established list of weighted criteria against which each option can be compared. A decision matrix is useful when a list of options must be narrowed to one choice, when the decision must be made based on several criteria, and after a list of options has been reduced to a manageable number. In the context of decision support, such tools may be employed by decision-makers to help streamline the decision-making process. The use of a decision matrix can also be beneficial in enhancing options for addressing the issue, rather than solely pinpointing a specific

resolution. This is important when considering compound threats and risks since the most effective approach may ultimately consist of a range of possible remedies.

There are several gaps in the research on the resilience relationships between deployable assets and installation infrastructure. The first is the need to catalogue existing maintenance and acquisition planning tools specifically for deployable assets. There is a significant amount of data on the maintenance of these systems, but few tools to integrate and analyze the data into support risk and resilience assessments. Second, since risk and resilience incorporation for planning does not exist within the tools, there is a need for systematically cataloging the age, remaining lifespan, condition, mission dependency scores, and replacement value of existing deployable infrastructure across the DoD (i.e., develop a Sustainment Management System [SMS]). There is a need to develop a risk-based framework that can be readily applied to existing deployable asset systems and leverage existing system and cost data.

1.2 Objective

DoD installations face a variety of threats which, when compounded, challenge sustained functionality, even of critical installation functions. The Resilient Installation Support against Compound Threats Analysis and Mitigation for Equipment and Resources (RISC TAMER) Framework establishes a decision support framework to help provide decision-makers with more complete and comprehensive information from which they may base their resilience-related decisions, both for prevention and response. Current risk management practice is generally via scenario analysis, which can be lacking for unspecified compound threats, resulting in limited risk management solutions. This current practice also challenges an installation's ability to increase its resilience against such threats.

The long-term objectives of this project involve establishing, implementing, and integrating a decision support framework to help provide decision-makers with more complete and comprehensive information from which they may base their resilience-related decisions, both for prevention and response. The project examines the interactions and interconnectivity of deployable assets, which may be defined as the assets used to operate, maintain, and project power from a military installation (e.g., power projection platform), and their related vulnerabilities and collective risk

associated with a set of hazards. Further, this project identifies how mitigation options, as well as their associated costs and benefits, may be identified and considered to inform DoD resilience decisions for equipment and resources supporting deployable assets.

1.3 Approach

RISC TAMER Framework considers compound risks, both specified (what is known) and unspecified (what is not known, but may be interdependent), and resilience to such risks. Such an understanding informs DoD's critical need to optimize resilience enhancements and improve situational awareness in order to implement resilience strategies for major catastrophes, protect assets, increase adaptability, and support power projection for global operations.

In addition to understanding the compound risks, their relationships within the system, and mitigation options, RISC TAMER Framework incorporates the concept of a decision matrix to provide structure to the weighing of solution options.

A ground vehicle system case study is used to illustrate how the framework can inform DoD maintenance and acquisition program lifecycle decisions under a range of hazard threats.

1.4 Impact to DoD and the Army

Every day, DoD decision-makers—whether planning or reacting—must make decisions based on the best available information at the time. Consideration of compound threats and the investments needed to address these threats would add tremendous value to the decision-making process. These considerations facilitate increased resilience, produce a more sustainable functionality of an installation, and provide a more complete picture of the options available. To enable this, decision-makers can benefit from a decision support framework that considers compound risks—and considers resilience to such risks. Such an understanding informs DoD's critical need to optimize resilience enhancements and improve understanding in order to implement resilience strategies for major catastrophes, to protect assets, to increase adaptability, and to support power projection and global operations.

While RISC TAMER Framework was initially developed for a specific type of asset, there are natural extensions to other types of applications. Further, the relationships identified within the framework include consideration of future integration into existing decision support tools for mission assurance assessment, infrastructure investment, or new deployable asset design.

2 Literature Review

2.1 Decision Support Tools

The purpose of decision support tools is to help improve access and usability of information and, consequently, improve the information available to decision-makers. Decision support tools vary in scope, function, and intended user groups. Given the breadth of relevant information available, decision support tools may be designed to work with other tools or assessments, e.g., data inputs for analysis or visualization tools. In general, such tools are developed, ultimately, to help decision-makers make the best-informed judgement possible.

There exist a variety of data sources and tools to leverage for supporting decisions. Depending on the decision under evaluation, the data source and availability will vary. For example, when considering impacts of environmental variables, data sources could include National Weather Service data feeds, meteorological model data, or even historical weather data for analysis. Determinations related to cost may leverage data sources to include prior procurement, operations, maintenance, and sustainment costs. This data may reside in disparate locations depending on the asset or item under analysis. As an example, the Office of the Secretary of Defense Cost Assessment and Program Evaluation (OSD CAPE) maintains a data system that contains authoritative defense contractor cost data in the Cost Assessment Data Enterprise (CADE) (DoD 2021).

Decision support tools have been established for a broad range of decisions across a wide range of problem spaces. Prior research developed an Excel based decision support tool to support the 2005 Base Realignment and Closure (BRAC) study (Harris et al. 2004). Recent research leveraged a weather data, installation social media posts, and machine learning algorithms to establish a cloud-based data-driven framework for installation decisions (Buchanan et al. 2023). Other sources of data could include other data collected at an installation (e.g., equipment status information) that may be managed by a weapon system program office or by other supply management services. The Defense Logistics Agency (DLA) announced increasing use of the Advana software to integrate data from disparate sources in order to support data driven determinations (DLA 2022). The Advana platform “a modern data platform that pulls data from hundreds of business systems to make data

discoverable, understandable, and usable for advanced analytics aligned to the National Defense Strategy” (McCrodden 2021). Similarly, the Army Vantage platform allows for integrating and visualizing Army data to support decisions (US Army, n.d.).

DoD program managers have access to tools for managing risks throughout the acquisition and system engineering process. The different options include the “traceability and embedded reporting, supporting qualitative and quantitative assessment of risks and management activities, and providing a risk management audit trail” (DASD[SE] 2017). Examples of available DoD tools include Project Recon and Army Material Systems Analysis Activity (AMSAA) Reliability Scorecards.

Project Recon is a US Army developed tool that covers risk management, issue management, and opportunity management. The web accessible tool leverages the 5×5 risk matrix and provides the capability to include mitigation plans, generate reports, and link items (Leece 2016).

The AMSAA Reliability Scorecard, managed by the Combat Capabilities Development Command Data and Analysis Center (CCDC DAC), provides an opportunity to evaluate reliability in relation to risk assessment. The scorecard allows assessors to evaluate eight categories with an overall 40 subcategories. The eight categories include “reliability requirements and planning, training and development, reliability analysis, reliability testing, supply chain management, failure tracking and reporting, verification and validation, and reliability improvements” (Bond 2022). The scorecard illuminates risk ratings for the category areas while also providing an overall risk assessment score.

Both Project Recon and the AMSAA scorecard rely on the subject matter experts to input information within the system to generate the ratings or assign the relevant risks. Project Recon provides an overall framework to capture, track, and develop mitigation plans for addressing risk. The AMSAA scorecard, on the other hand, provides guidance for evaluating forty specific elements related to reliability, and also provides guidance for the high, medium, and low ratings in each element.

Decision support tools provide organizations with optimization and risk analysis for making more informed decision making. Climate change and extreme weather has started to become an important consideration in risk

analysis tools for infrastructure. Several studies have started to incorporate climate change risks into planning and decision support tools, such as military resilience planning (Allen 2017). This study connected the importance military places on infrastructure resilience with the increased needs to incorporate climate resilience as a part of that overall resilience (Allen 2017). A recent Military Operations Research Society Climate Resilience Meeting 2022 also presented current research on work in decision support that is including climate change risks. For instance, the Climate Readiness Framework and the Department of Homeland Security Resilience Framework both incorporate climate hazards as related to infrastructure (Best 2022; Bull 2022). Another presentation from the Argonne National Laboratory discussed regional disaster planning with the development of a Climate Risk and Resilience Portal (Pfeiffer 2022). Finally, another presentation looked at current research at the US Army Engineer Research and Development Center (ERDC) both in infrastructure adaptation and infrastructure mitigation (Urban 2022). However, this study and presentations that are incorporating climate change risk do not consider the risks that could affect deployable assets.

Deployable assets are an important piece of infrastructure, although they may not be traditionally understood as infrastructure. If there is an extreme weather event, installations need to be resilient against the event. However, the deployable assets, such as vehicles or helicopters, also need to be resilient in the face of extreme weather events. One blog from the US Government Accountability Office (GAO) highlighted that out of date and inadequate risk assessment can lead to drivers having lowered perceived risk levels (GAO 2021). For example, the DoD have faced issues with extreme cold in Alaska and vehicles becoming inoperable (Vergun 2017). To prevent engine oil and transmission fluid from freezing, vehicles will be plugged into outlets with heating pads, but batteries can force the heating pads to also fail in extreme cold (Vergun 2017). Batteries in GPS are another issue in extreme cold, leaving soldiers without an important source of data (Vergun 2017).

2.2 Development of a Sustainment Management System for Deployable Assets and Systems

In September 2013, the Under Secretary of Defense for Acquisition, Technology, and Logistics issued a policy memorandum for standardizing facility condition assessments (ASD 2013). That policy requires the

Defense Components to adopt a common process that catalogs component inventory and condition assessments via a SMS. This policy memorandum resulted in a significant portion of the DoD’s facility footprint collected within the BUILDER SMS—developed by the Construction Engineering Research Laboratory (CERL) at ERDC. The BUILDER SMS currently includes more than 100,000 buildings, representing more than one billion square feet of facility floor area and \$300+ billion in total replacement value (WELDER 2021). Currently, there is no similar resource for deployable assets to collect and catalog component and condition assets.

To address the gap created by the lack of a maintenance and acquisition decision support tools for deployable assets or systems that incorporates risk and resilience, an SMS could be developed for these systems akin to the SMSs developed by the U.S. Army Corps of Engineers for other infrastructure asset classes including ROOFER (Asset Management for Roofs), BUILDER (Asset Management for Buildings), RAILER (Asset Management for Rails), and PAVER (Asset Management for Pavements).

According to CERL (n.d.), these web-based SMSs

help all real property asset manager stakeholders—from civil engineers, technicians and managers to headquarters—decide when, where, and how to best maintain existing infrastructure...the process starts with a collection of real-property data, a detailed component inventory that identifies their key cycle attributes such as the age and material, and typically a field assessment to gather real-world performance of these components. From this information, condition index metrics for each component are predicted...provid[ing] users with recommended work candidates and their estimated cost up to 10 years into the future.

2.3 Incorporate Natural Hazard Risk into the Sustainment Management System (SMS)

In January 2021, President Biden issued the Executive Order (EO) 14008, *Tackling the Climate Crisis at Home and Abroad*, indicating that the “United States will move quickly to build resilience, both home and

abroad, against the impacts of climate change that are already manifest and will continue to intensify according to current trajectories.” EO 14008 also directs federal agencies, including DoD, to conduct “climate risk analysis that can be incorporated into modeling, simulation, war-gaming, and other analysis, as well as relevant strategy, planning, and programming documents and processes” (WELDER 2021). It should be noted that the BUILDER SMS is currently being upgraded—via a DoD Environmental Security Technology Certification Program (ESTCP)—funded project called WELDER (RC19-5264)—to incorporate extreme weather risk into facility maintenance and acquisition decisions (WELDER 2021). The final research gap involves incorporating natural hazard risk into long-term maintenance and acquisition decisions around deployable assets. This research task could involve plugging into an existing decision support system via an application programming interface (API), with projected impacts from natural hazards.

In addition to understanding the compound risks, their relationships within the system, and mitigation options, this research effort incorporates the concept of a decision matrix to provide structure to the weighting of solution options to be employed in deployable asset decision-making processes. A decision matrix can also be useful to improve solution options rather than just identify a specific solution. This is important for consideration of compound threats and risks, because the most effective solution may, ultimately, be a suite of solutions.

2.4 Terminology

2.4.1 Resilience

Resilience is a concept rooted in ecosystem studies to understand the nonlinear dynamics observed in ecosystems. While resilience can be viewed in very specific terms, depending on its context, it is more generally considered to be the ability and speed to recover from a disruption. The complex and interdependent nature of ecosystems has presented challenges for risk assessment of multiple stressors, leading to new approaches in risk and impact assessments (Gunderson 2000). Leveraging such examples and systems-level thinking will help identify vulnerabilities of a deployable asset for which potential compound threats should be assessed, especially given the time-dependent nature of resilience as it addresses the prepare, absorb, recover, and adapt phases.

2.4.2 Risk Management

The RISC TAMER Framework aims to assist DoD decision-makers tasked with risk management by providing more complete and comprehensive information. Risks can be identified and responded to in a manner that is appropriate to the following: (1) the nature of the risks faced by the DoD, (2) the DoD's ability to accept and manage risk(s), (3) the resources available to manage risks within the DoD, and (4) the DoD's risk and resilience management processes. Since risk management is not a stand-alone discipline, it needs to be integrated with existing processes (e.g., internal audit, budgeting, performance management, and strategic planning) to maximize risk management benefits and opportunities. Ultimately, risk needs to be managed so that the DoD can improve its ability to meet its strategic objectives as well as associated operational targets and goals (HQDA 2014).

The DoD, must be able to calculate the value of risk management, which is essentially the cost of risk management activities subtracted from the benefits as expressed in Equation (1):

$$\text{Value of Risk Management} = \text{Benefits} - \text{Costs.} \quad (1)$$

The cost component of the equation can be quantified relatively easily by estimating the direct and indirect costs. Direct costs are associated with increasing the maturity of the DoD's risk management framework and maintaining the desired level of risk management maturity. Examples of direct costs could include the costs associated with portions of the system life cycle costs (e.g., research and development, procurement, or operations and maintenance costs). These direct costs may be integrated into the life cycle maintenance and sustainment plans activities of the system. Indirect costs are associated with increased focus on risk management activities. Examples of indirect costs are the opportunity costs associated with the additional time spent on risk management activities by management and staff.

When determining the DoD's desired risk management maturity, the objective will be to maximize the value created through the risk management framework and practices. Some of the benefits of risk management achieved by the DoD with the RISC TAMER Framework will be improved decision-making, improvement in performance and mission assurance, and cost avoidance. For example, a key benefit of RISC TAMER

is the avoided capital and operations and maintenance (O&M) costs due to proactive adaptation of deployable assets. The benefit of tools like RISC TAMER could be monetized by calculating the natural hazard-related damage costs to deployable infrastructure and subtracting any proactive adaptation costs that mitigate the natural hazard risk. The result of this calculation represents the avoided damage to deployable assets from more informed decision-making (i.e., RISC TAMER). A similar avoided cost valuation approach to address Arctic natural hazard risk to infrastructure was documented by Larsen et al. (2008) and Melvin et al. (2016).

Within the RISC TAMER framework, individual risks are placed into a register that includes the how and why the risk can occur, as well as a risk-level rating based on preestablished criteria (i.e., the likelihood and consequences of the risk to the DoD). Project-specific consequence descriptors are time (timeframes exceeded), cost (budget overruns), quality (project does not deliver predefined quality and functionality criteria), and reputation (e.g., adverse publicity, laws breached). Internally—and externally developed risk management tools and technologies are inputs into this framework and will help the DoD capture, analyze and communicate risk-related information. Various risk management systems that meet different requirements are available in the market, but to be the most suitable option, these key areas will be considered in our framework, (1) costs, (2) functionality, (3) accessibility, and (4) scalability (e.g., expanding the scope of the framework).

2.4.3 Deployable Asset Threats and Hazards

Understanding the requirements and performance expectations of deployable assets is critical to the development of the RISC TAMER Framework. The possibilities of the vehicle being in a hazardous situation that can cause harm to people and property is called likelihood or exposure. The impact to safety or lives of people (drivers and bystanders) as well as property are the consequence. Although these two risk parameters are irreplaceable in a risk matrix, adding another parameter or dimension is also possible. Controllability determines the extent to which the driver of the vehicle can control the vehicle if a safety goal is breached due to failure of any automotive component being evaluated. The data obtained from various Army vehicle driver trainings reveals the serious risks that soldiers need to be aware of related to controllability parameters, such as operator experience and training, crew rest, vehicle maneuverability and limitations, and terrain restrictions (US Army, n.d.).

Initially, the RISC TAMER framework specifically focuses on ground vehicle systems operating on installations and associated threats to these systems. Initial analysis consisted of identifying threats to ground vehicle systems and associated impacts caused by natural hazards (i.e., extreme weather) such as saltwater (corrosion), sun (erodes the protective properties Chemical Agent Resistant Coatings), excessive precipitation (corrosion and electrical damage), and abnormally cold weather. Cold weather specifically possesses a significant risk to ground vehicle systems. Particular cold weather risks, likelihood and consequences are displayed in Table 1.

Table 1. Example of singular threats and risks to ground vehicle systems due to cold weather.

Cold Weather Risks	Likelihood and Consequence
Battery, vehicle start and operation	The likelihood increases that a battery may not be capable of supporting vehicle starts and will have reduced efficiencies.
Oil viscosity	If the temperature falls to -20°F, the engine's oil pump may have trouble circulating the oil as it becomes more viscous.
Tires	As tires get colder, the air inside the tires contract (less pressure).
Transmission	The transmission system can freeze, and eventually, the transmission can slip.
Fuel lines	The fuel lines that lead to the fuel tank can freeze, reducing flow to the engine.
Engine coolant, a.k.a. antifreeze	Reduced ability to protect the engine in extreme cold if it is old or has an improper ratio of coolant to water.
Engine belts	Engine belts may break as they become more frigid and do not bend as readily.
Windshield visibility	Visibility may be reduced due to the vehicle defrost function not working properly allowing condensation on the inside of the windshield to freeze. Subfreezing temperatures can cause the rubber on windshield wiper blades to become brittle, tear, or crack. Washer fluid may freeze on the windshield or not work as well.
LCD screen	LCD screens can have increased lag due to a slowdown in the molecules in liquid crystals when the temperatures drop.
Corrosion	Salt used to deice roads accelerates the rusting process by lowering the electrical resistance of water on the metal body of vehicles, which can damage the undercarriage, wheel wells, and brakes.
Leakage	Water the lines for systems like power steering, brake, and engine transmission may freeze and expand leading to leaks in high and low-pressure systems.

The ground vehicle systems operating on installations are usually designed to withstand local weather and climate. However, *Climate Impacts on Transportation*, which was published by the United States Environmental Protection Agency (EPA) in 2017, shows that the historical climate is no longer a reliable predictor of future risk due to climate change (EPA 2017). Our comprehensive decision support framework will cover various natural hazards and help mitigate the risk for all conditions. It will also include cost impacts, such as a rise in fuel consumption and costs due to lowered tire pressure and longer vehicle idle times which cause higher fuel consumption.

Deployable asset performance against specific threats and hazards of a unique area of operation should also be considered, such as the condition of existing infrastructure (roads and bridges), operating speeds, maneuverability restrictions due to terrain, and actions on contact. The area of operation, along with the environmental conditions, that the deployable asset will operate in will greatly impact its performance and influence risk to and resilience of the system.

2.5 Vehicle Management

Vehicle management is a complex system that incorporates many different interacting aspects from the design requirements and capabilities to maintenance and inspections. The motivation for developing RISC TAMER Framework is to capture information about risk for military deployable assets in a way that the information can be readily used by risk decision-makers. Here, we consider the case of a ground vehicle. The Joint Capabilities Integration and Development System (JCIDS) provides oversight for the acquisition of military systems, including ground vehicles. For each deployable system in the acquisition process, such as the Mobile Protected Firepower System, various key performance parameters, development thresholds, and development objects are specified in a capability development document (CDD) to meet the vehicle's Operational Mode Summary/Mission Profile (CJCSI 2018). Another important aspect of the CDD is breaking the components of the system down into a work breakdown structure, which helps determine and categorize the level of detail for a vehicle's risk assessment (DoD 2011). A vehicle's performance requirements and capabilities are important to determine the expected performance from each vehicle. The term "performance requirement" means a performance attribute of a system considered critical or essential to the development of an effective military

capability required to meet an organization's roles, functions, and missions in current or future operations. (CJCSI 2018).

There are many different scenarios a vehicle can experience and deploying the appropriate vehicle for the mission is critical for mission success. A vehicle will have performance parameters and attributes that must meet thresholds and objectives. These thresholds and objectives must be met regardless of the threat, which is defined in the JCIDS as the sum of the potential strengths, capabilities, and strategic objectives of any adversary that can limit or negate mission accomplishment or reduce force, system, or equipment effectiveness (CJCSI 2018). One key issue of the JCIDS definition of threat is that it does not include natural or environmental factors affecting the ability of the system to function or support mission accomplishment; this is one of the key gaps that this research seeks to fill (CJCSI 2018).

An additional information element that can be included into the framework is the Preventative Maintenance Checks and Services section of each individual vehicle's Technical Manual-Unit Maintenance. These comprehensive checks cover various parts of the vehicle and describe what makes that specific part not fully mission capable. The individual part's problem can be determined by identifying the failure diagnoses and the consequence to the vehicle performance. Table 2 displays a ground vehicle example of consequences associated with a few sample parts.

Combining the various systems and components with their specific performance requirements and potential failure mechanisms and consequences allows the integration into our decision support framework.

Table 2. *Technical Manual – Unit Maintenance High Mobility Multi-Purpose Wheeled Vehicle (HMMWV) example.* (Reproduced from DA TM-9-2320-280-20-1 1996. Public domain.)

Technical Manual Unit Maintenance				User Input	
Interval	Item	Part	Not Fully Mission Capable	Problem	Consequence
Semiannual	Road Test	Starter	Excessive Grinding	Vehicle will not start.	Stranded
		Engine	Knocks, Rattles or smokes excessively	Engine failure. Vehicle will not run.	Stranded
		Transmission	Improper shifting, does not shift, excessive noises	Wrong gear, stuck and stranded	Stranded/Stuck
		Transfer	Lever inoperable or does not engage in all ranges with engine not running	Will not be able to shift into proper gear range, get stuck	Stranded/Stuck
		Accelerator	Pedal sticking or binding	Vehicle will not be able to move or travel too fast and loose control and crash	Crash/Stranded
		Steering	Steering binds, grabs, wanders or has excessive free play	Will not be able to steer, loose control and crash	Crash
		Brakes	Brakes chatter, pull to one side, or inoperative. Brakes will not release.	Will not be able to stop	Crash

3 Technical Approach Overview

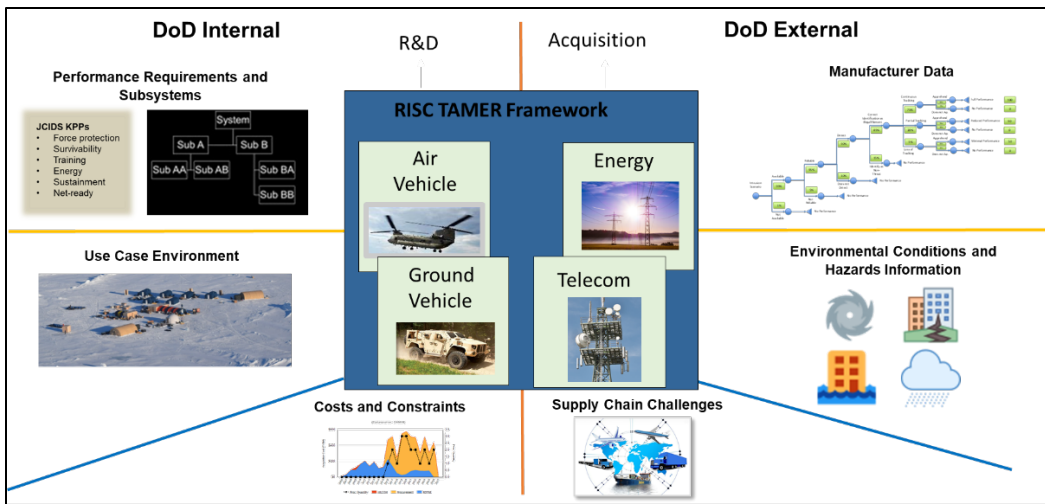
3.1 Technical Approach and Results

The RISC TAMER framework provides a platform through which information about deployable assets' requirements and performance data along with the compound effects and impacts of various threats and hazards to can be integrated. Additionally, RISC TAMER framework to create a multi-dimensional decision analysis environment to mitigate risk and incorporate resilience. Together, these features offer a decision support tool for deployable assets and systems that

- accepts data from existing stakeholder platforms,
- considers the impact of compound risks,
- integrates the inputs into a tool that supports user decision making, and
- maps databases and uses the taxonomy for risk-informed and resilience-incorporated decision-making.

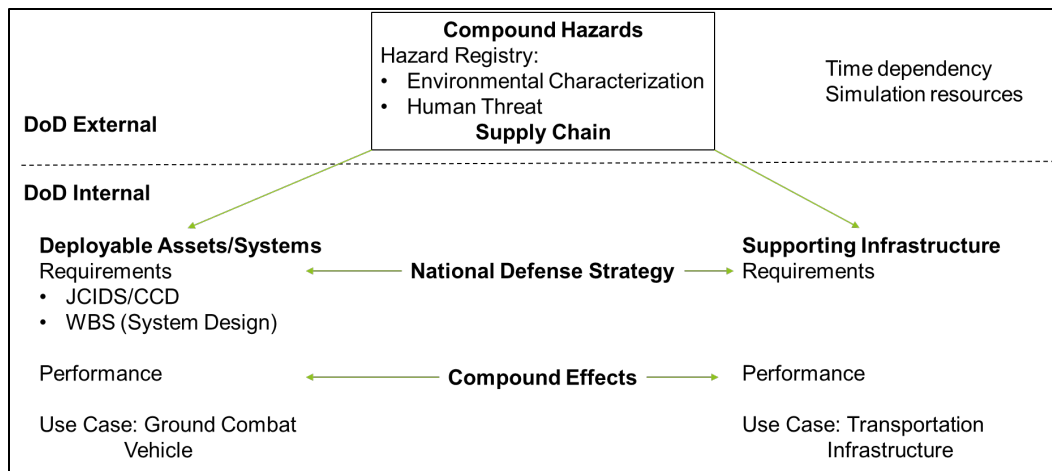
A conceptual overview of the various interactions between DoD internal and external systems and environments is provided in Figure 1 below. Internal systems and environments include the deployable asset performance requirements, the costs and constraints, and the use case environment. An example would be a ground combat vehicle operating in an Arctic environment. The DoD external systems encompass the deployable asset manufacture data for performance, the environmental hazards (both natural and manmade), and the supply chain required to support the deployable asset operations.

Figure 1. Resilient Installation Support against Compound Threats Analysis and Mitigation for Equipment and Resources (RISC TAMER) Framework overview.



The DoD internal systems were further decomposed to identify various relationships between these systems and the DoD external hazards and supply chain. The linkages and influence of the National Defense Strategy and the compounding effects of the hazards are identified in Figure 2.

Figure 2. RISC TAMER Framework interactions.



The final task in the development of RISC TAMER requires integrating these various aspects into a decision support tool while providing the framework to combine and assess the compounding impact of the risks and hazards on components and systems of a deployable asset.

The ratings of these compound threats will be generated from existing data sources for environmental conditions and deployable system performance. Additionally, several foundational principles will guide the

data acquisition and integration into the framework; (1) the information that feeds into the framework must be identified; (2) relevant data must exist and be accessible; (3) the framework must be accessible and easy to use and understand; (4) the framework's usefulness is dependent on it being extendable to a range of threats and deployable assets; and (5) the value can be demonstrated by comparing costs before and after the framework was applied to inform mitigation. Unfortunately, due to controls on the military vehicle systems specifications and performance data, it is not shown here in the paper. Because of the nature of the data, it is either sensitive or classified or the integration of data puts in a sensitive or classified category, so unable to add it to the report. There highlights the challenge in the ability to access and connect data.

3.2 Stakeholder Engagement

The goal for this framework is to be a tool that mission commanders and their staffs can use in allocating resources. To ensure alignment with that goal, the team engaged with several stakeholders at various levels within the DoD, from the agency level, which is the strategic level that makes overall resourcing and acquisition and procurement decisions) down the combatant command level, who are the operational level and tasked with assessing their infrastructure, allocating resources to make improvements, and conducting operations to meet mission accomplishment. The team also connoted with extremal stakeholders who are also working in the resilience data gathering and visualization space.

The intent of the conduct the engagements with both DoD internal and external stakeholders was to ascertain how to construct the framework to inform risk mitigation, resilience integration and resource prioritization based on the user, deployable asset, and operating environment. One significant challenge identified through the stakeholder analysis process was the gap in ability to access and connect data. Integration and aggregation of these types of data pulls into a classified environment, which restricts access and the ability to share data.

3.2.1 DoD Agency Level

North American Aerospace Defense Command (NORAD) Science and Technology (S&T)—Discussion with personnel involved in cyber security and modeling and simulation (M&S) focused on challenges in the Arctic region, which due to the large distances require resiliency. It is very critical

to perform risk assessments in the Arctic region; time and distance equation comes to the forefront in those areas. Additionally, the concept of “Fort to Port” M&S discussed. Finally, potential next steps included capturing the preference landscape, implies an understanding of resilient (objective function). From there, use data and create how to prioritize resources (allocating) and then act; scenario results provide insights to impact of decisions. The use of a framework as a workflow; various data flows feed into the framework that informs decision-makers as also highlighted.

US Space Force Deputy for S&T and Cyber Subject Matter Expert—Discussions with personnel involved relating risk assessments, mitigations, and costs as related to operations in space. In general, the space operations within extreme temperatures and large distances. Furthermore, the general cyber related risks exist when considering the equipment operating in space operations.

Office of the Secretary of Defense (OSD) Physical Security Enterprise and Analysis Group—Participants in this discussion expressed an interest in this type of framework. Specifically, the discussion emphasized usability of a future tool such that it easily integrates and accommodates the sensitivity of the data that the customer owns.

3.2.2 Army Level

Army Vantage Data Analytics Platform—Discussions related to Vantage focused primarily on the capabilities of the Vantage tool along with the data that the system plans to pull from. The Vantage system plans to pull from systems across multiple Army domains. The Vantage system serves as a potential platform for potential use cases to implement the framework. Access to data within the system requires approval.

3.2.3 Combatant Command Level

Northern Command J34 Mission Assurance Section—In general, this team shared the same concerns as this research supports. Discussion focused on the threats, to include threat capabilities and their intent to use, and how that can change, environmental threat (data available already), and that enemy threat data is not available. Stakeholder priorities vary across region and agencies. Other government agencies, such as the Department of Homeland Security, have their critical infrastructure data, (e.g., population centers and population densities across the US). Potential next

steps discussed were potentially sharing information on the Secret Internet Protocol Router (SIPR) side, follow-up to request “shell” info for unclassified use, determine the scope of what information is included as critical, and that the framework needs to include stakeholder priorities and value to accommodate different user viewpoints and changes.

NORAD J8 & J8o (S&T)—This discussion focused on a framework as a workflow and that various data flows feed into the framework that informs decision-makers and capturing the preference landscape implies an understanding of resilience. The process should use data and create resource allocations and then act. The results from the scenario that the framework implements should provide insights to impact of decisions.

3.2.4 Commercial

Re:Public (commercial application developer for community risk and resilience)—Re:Public is a web-based software platform designed to support communities in making practical resilience investment decisions.

4 RISC TAMER Framework

4.1 Design

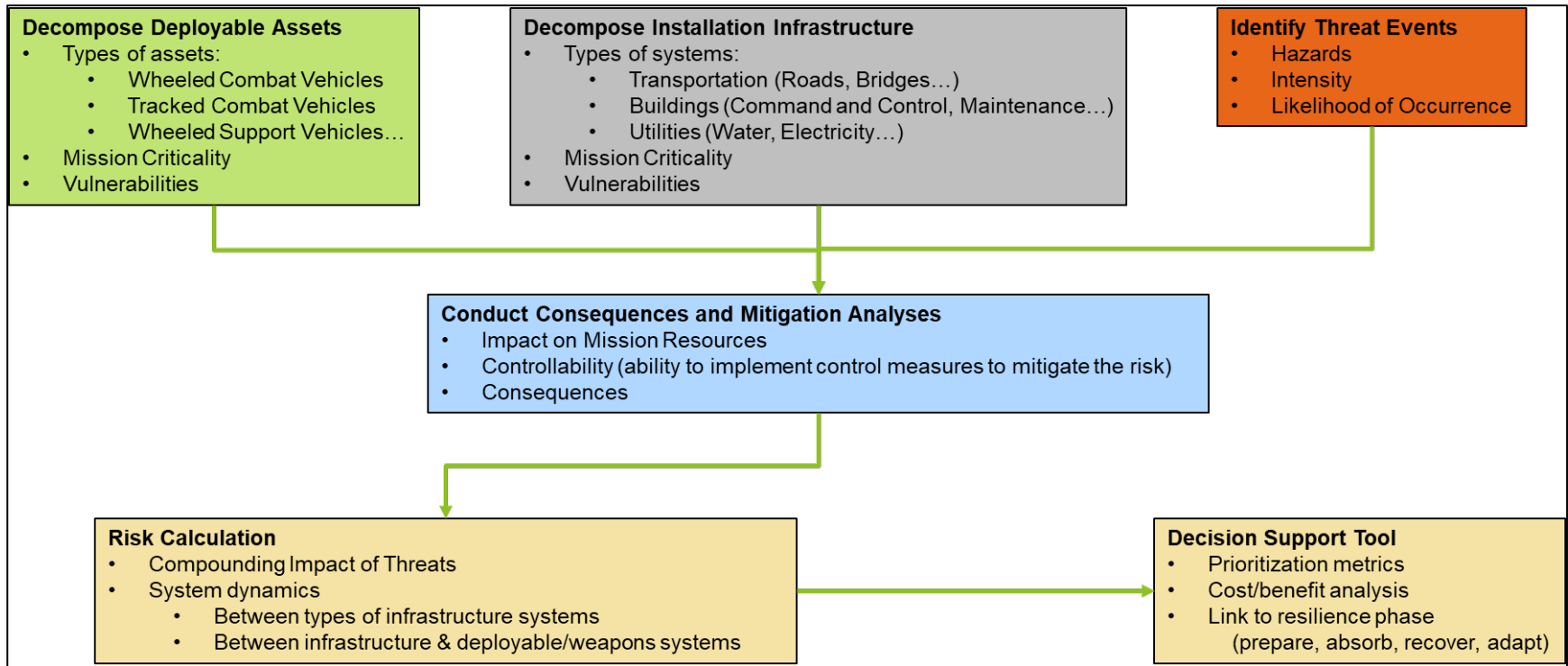
The object of the design of the RISC TAMER Framework is to establish a risk assessment and decision support framework that assists decision-makers to make resilience-related decisions, both for prevention and response. This is done through the following steps:

1. Accept installation infrastructure, deployable assets, and hazard data from existing stakeholder platforms.
2. Examine interconnectivity of installation infrastructure and deployable assets and their related vulnerabilities.
3. Investigate compound risks due to typical specified and known (primary) threats and unspecified and unknown (secondary) threats, both environmental and man-made.
4. Evaluate mitigation options.
5. Integrate the inputs to support user decision making tools.

To parse this from other work going on in ERDC in the areas of infrastructure resilience and engineered resilient deployable weapons systems, this project sought to investigate the interconnectivity between installation infrastructure and deployable assets under compound threat events to produce a framework that can pull in user inputs and enterprise data sources that decision-makers could utilize when making resource allocation decisions. The goal was to inform DoD's critical need to optimize resilience enhancements and improve situational awareness to implement resilience strategies.

The methodology to translate the conceptual overview to an actual framework followed this methodology (Figure 3). The first steps are to decompose the *Deployable Assets, Installation Infrastructure and Threat Hazards* (both environmental and man-made) down to the appropriate level of fidelity. Mission criticality and vulnerabilities must be identified for each of the deployable assets and infrastructure systems. The threat events must be broken down into their actual hazards and information on the intensity and likelihood of occurrence gathered.

Figure 3. RISC TAMER Framework development methodology.



Following the decomposition, the impact and consequences of the threat hazards on the mission accomplishment by the deployable assets operating within the installation infrastructure can be assessed. Also, mitigation steps and the ability to control against these impacts and consequences are incorporated.

Finally, all these pieces can be incorporated into a risk calculation for a specific set of conditions (deployable assets, infrastructure systems, under designated threat events) and the system dynamics incorporated.

This analysis and integration are captured within a decision support tool to help investigate tradeoff, cost and benefit analysis, and support prioritization of projects lined to improvements in resilience. As mentioned previously, there were significant challenges in identifying and gaining access to authoritative data sources as well as the challenges in integrating data from platforms within and external to the DoD.

4.2 Functions

This is the initial framework to incorporate and organize the decomposition of the dimensions identified in the methodology (Richards et al. 2021). We binned them into three major dimensions. The first dimension, *Mission Resources*, captures the interaction between deployable assets, such as a Humvee or tank and the installation infrastructure it is utilizing, such as a road or bridge. The second dimension, *Threat Event*, captures not only an event, such as a blizzard, but decomposes it into specific hazards, such as the snow, wind, etc. The third dimension is the *Analysis of the Consequences of Threat Hazards* on the ability the deployable assets to accomplish their mission and capture the impact of potential mitigation strategies.

4.2.1 Mission Resource Dimension

The *Mission Resource* dimension is broken into two sections, deployable systems and fixed infrastructure. The first section allows the user to list the type of deployable assets they are interested in (tactical vehicles, helicopters, tanks, nontactical vehicles, etc.) and then use drop down selections to assign a mission criticality category to each deployable system based on their expertise and understanding of the scenario being evaluated. Figure 4 is a screenshot of this dimension of the framework that

shows the dropdown menu for system mission criticality. The assigned criticality category is automatically linked to a mission criticality score (Table 3). Future work will drive this toward data driven rather than user designated assignment of the scores as well as decomposing the deployable assets down to the system and component level.

Figure 4. Mission resource dimension—deployable systems mission criticality.

Deployable System Type	Deployable System Mission Criticality	Deployable System Mission Criticality Score
		#N/A
	Extremely Critical to Mission Completion	#N/A
	Very Critical to Mission Completion	#N/A
	Somewhat Critical to Mission Completion	#N/A
	Support vehicle, not mission critical	#N/A
		#N/A

Table 3. Deployable system mission criticality category and score.

Deployable System Mission Criticality Category	Deployable System Mission Criticality Score
Extremely critical to mission completion	0.9
Very critical to mission completion	0.75
Somewhat critical to mission completion	0.5
Support vehicle, not mission critical	0.25

Additionally, the user must assign a deployable system vulnerability category to each deployable system based on their expertise and understanding of the scenario being evaluated (Figure 5), which automatically populates a deployable system vulnerability score (Table 4).

Figure 5. Mission resource dimension—deployable systems vulnerability.

Deployable System Vulnerability	Deployable System Vulnerability Score
	#N/A
Vulnerable to minor threat events	#N/A
Vulnerable to major threat events	#N/A
Vulnerable to significant threat events	#N/A
Impervious to most threat events	#N/A
	#N/A

Table 4. Deployable system vulnerability category and score.

Deployable System Vulnerability Category	Deployable System Vulnerability Score
Vulnerable to minor threat events	0.9
Vulnerable to major threat events	0.75
Vulnerable to significant threat events	0.5
Impervious to most threat events	0.25

The second section of the *Mission Resource* dimension addresses the installation infrastructure that the deployable systems will operate upon. To capture this the user selects the applicable installation infrastructure assets they are interested in from the drop down selections to assign a combined mission criticality and vulnerability category, with the associated criticality and vulnerability score automatically generated (Figure 6 and Table 5). Future work will drive this toward a more data driven approach. A system vulnerability score must also be assigned to each deployable system.

Figure 6. Mission resource dimension—infrastructure.

Infrastructure Type	Infrastructure Criticality and Vulnerability	Infrastructure Criticality and Vulnerability Score
		#N/A
	Extremely Critical to Mission Completion	#N/A
	Very Critical to Mission Completion	#N/A
	Somewhat Critical to Mission Completion	#N/A
	Support vehicle, not mission critical	#N/A
		#N/A

Table 5. Infrastructure criticality and vulnerability category and score.

Infrastructure Criticality and Vulnerability Category	Infrastructure Criticality and Vulnerability Score
Extremely critical to mission completion	0.9
Very critical to mission completion	0.75
Somewhat critical to mission completion	0.5
Support vehicle, not mission critical	0.25

For the *Mission Resource Dimension Score* for an individual combination of deployable asset and installation infrastructure (i.e., a Humvee on a road) are multiplied together and then the cube root taken to incorporate the impact of higher mission, vulnerability, and criticality scores (Equation 2).

$$\text{Mission Resource Dimension Score} = \sqrt[3]{\text{VMS} * \text{VVS} * \text{ICVS}}, \quad (2)$$

where

- VMS = vehicle mission score,
- VVS = vehicle vulnerability score, and
- ICVS = infrastructure criticality and vulnerability score.

4.2.2 Threat Event Dimension

The *Threat Event* dimension allows a user to decompose a threat event, such as a blizzard, into specific hazards, such as wind, snow, etc. Also, man-made events such as a cyber-attack or a kinetic attack could be included. Once the threat is decomposed into individual hazards, an intensity category must be assigned (Figure 7) and an associated intensity score generated (Table 5) in addition to a likelihood of occurrence category selected (Figure 8) and associated score generated (Table 6). At this point in the formulation of the framework, the threat events, hazard decomposition, intensity and likelihood of occurrence are all user selected inputs, but future work would be to drive these scores directly from threat and weather data.

Figure 7. Threat event dimension—intensity.

Threat Event	Threat Hazard	Intensity	Intensity Score
			#N/A
	Extremely High		#N/A
	High		#N/A
	Medium		#N/A
	Low		#N/A
			#N/A

Figure 8. Threat event dimension—likelihood of occurrence.

Likelihood of Occurrence	Likelihood Score
	#N/A
Extremely High	#N/A
High	#N/A
Medium	#N/A
Low	#N/A
	#N/A

Table 6. Threat event intensity, likelihood categories, and scores.

Intensity Category	Intensity Score	Likelihood of Occurrence Category	Likelihood of Occurrence Score
Extremely high	0.9	Extremely High	0.9
High	0.75	High	0.75
Medium	0.5	Medium	0.5
Low	0.25	Low	0.25

A similar process is used to combine the intensity and likelihood to calculate the *Threat Event Dimension Score* for each threat hazard (Equation 3).

$$\text{Threat Event Dimension Score} = \sqrt{\text{Intensity Score} * \text{Likelihood Score}}. \quad (3)$$

4.2.3 Mission Consequence and Mitigation Dimension

The *Mission Consequence and Mitigation* dimension allows the user to indicate their assessment of the impact of the specific threat hazard on mission completion (Figure 9 and Table 7).

Figure 9. Mission consequence and mitigation dimension—mission resource impact.

Mission Resource Impact	Impact Score
	#N/A
Complete loss of vehicle control or operations	#N/A
Moderate loss of vehicle control or operation	#N/A
Slight loss of vehicle control or operation	#N/A
No significant impact	#N/A
	#N/A

Table 7. Mission resource impact category and score.

Mission Resource Impact	Impact Score
Complete loss of vehicle control or operations	0.9
Moderate loss of vehicle control or operation	0.75
Slight loss of vehicle control or operation	0.5
No significant impact	0.25

The user then indicates how well they can mitigate or control against that impact (Figure 10). A higher amount of controllability will lead to a lower

score, which when combined through the calculation on the right, will lessen the impact (Table 8).

Figure 10. Mission consequence and mitigation dimension—impact controllability.

Controllability		Controllability Score
		#N/A
Extremely High		#N/A
High		#N/A
Medium		#N/A
Low		#N/A
		#N/A

Table 8. Impact controllability category and score.

Impact Controllability Category	Impact Controllability Score
Extremely high	0.25
High	0.5
Medium	0.75
Low	0.9

Finally, the user assigns the consequences for each of the impacts (Figure 11 and Table 9).

Figure 11. Mission consequence and mitigation dimension—consequence.

Consequence	Consequence Score	Mitigation & Consequence Dimension Score
	#N/A	#N/A
Personnel Death	#N/A	#N/A
Personnel Injury	#N/A	#N/A
Vehicle Replacement	#N/A	#N/A
Vehicle Repair	#N/A	#N/A
	#N/A	#N/A

Table 9. Consequence category and score.

Consequence Category	Consequence Score
Personnel death	0.9
Personnel injury	0.75
Vehicle replacement	0.5
Vehicle repair	0.25

The *Mitigation and Consequence Score* is calculated for each *Mission's Resource Impact* by multiplying its *Controllability Score* times the square root of the *Impact Score* multiplied by the *Consequence Score*. The combination of *Impact Score* and *Consequence Score* considers the mitigation of the risk (Equation 4).

$$\text{Mitiation and Consequence Score} = \left(\sqrt{\text{Impact Score} * \text{Consequence Score}} \right) * \text{Controllability Score.} \quad (4)$$

4.2.4 Total Risk Score

The three-dimension scores are then combined using a method similar to that used in the Joint Mission Assurance Assessment framework (DODI 3020.45, 2022). The Joint Mission Assurance Assessment framework calculates a risk score by taking the cube root of the product of criticality, hazard, and vulnerability scores. This RISC TAMER framework incorporates the criticality and vulnerability to the mission into one score from the product of all the scores and uses the inverse of the threat event dimension and mitigation scores. The *Mission Dimension Score* is the product of all the individual *Mission Resource Dimension Scores* (Equation 5). The *Threat Event Dimension Score* is the inverse of the product of the individual *Threat Event Dimension Scores*, which will account for the greater risk of simultaneous compound threats (Equation 6). The same process is used to calculate the *Mitigation and Consequence Score* (Equation 7). The *Total Risk Score* is then calculated from the cube root of the product of the dimension scores (Equation 8). This methodology ensures that higher impact and mitigation will not be lost.

$$\text{Mission Dimension Score} = \text{Product}(\text{Mission Resouce Scores}). \quad (5)$$

$$\text{Threat Event Dimension Score} = 1 - \text{Product}(\text{Threat Event Scores}). \quad (6)$$

$$\text{Mitigation and Consequence Dimension Score} = 1 - \text{Product}(\text{Mitigation and Consequene Scores}). \quad (7)$$

$$\text{Total Risk Score} = \sqrt[3]{((\text{Mission Dimension Score}) * (\text{Threat Event Dimension Score}) * (\text{M\&C Dimension Score}))} \quad (8)$$

5 Illustrative Use Case

The current design of the RISC TAMER Framework in an Excel based platform supports conducting scenario-based iterations to investigate how different configurations of deployable systems, infrastructure, threats and mitigations can work together. Various iterations can be compared by their Total Risk Scores to see the impacts of various decisions. To highlight the use and capability of the RISC TAMER Framework, the following illustrative use case using notional values and data.

5.1 Scenario

For this iteration, a M998 high mobility multipurpose wheeled vehicle (HMMWV) and an M1 Abrams Main Battle Tank (MBT) are input by the user as the deployable systems of interest for the *Mission Resource* dimension (Figure 12). Based on the user’s understanding of the mission, for example tactical combat operations, the HMMWV was assigned the category of “Support vehicle, not mission critical” with an associated criticality score of 0.25 and the M1 assigned the category of “Extremely Critical to Mission Completion” and the associated criticality score of 0.9. Finally, the HMMWV, since it has no armor or heavy weapons, was assigned a vulnerability category of “Vulnerable to minor threat events” with the associated vulnerability score of 0.9 and the M1, due to its heavy armor and weapons, assigned the vulnerability category of “Impervious to most threat events” and associated vulnerability score of 0.25.

Figure 12. Illustrative use case; mission resources dimension—deployable systems.

Deployable System Type	Deployable System Mission Criticality	Deployable System Mission Criticality Score	Deployable System Vulnerability	Deployable System Vulnerability Score
M998 (HMMWV)	Support vehicle, not mission critical	0.25	Vulnerable to minor threat events	0.9
M1A1 (Abrams)	Extremely Critical to Mission Completion	0.9	Impervious to most threat events	0.25

For the second section of the *Mission Resource* dimension, the user identified that HMMWV must operate on a road and the M1 must cross a bridge. For the *Infrastructure Criticality and Vulnerability*, the bridge is deemed to be in the “Extremely Critical to Mission Completion” category with an associated score of 0.9. Due to the terrain, there may be ways to bypass the road, so it is assigned an *Infrastructure Criticality and Vulnerability* category of “Somewhat Critical to Mission Completion” and an associated score of 0.5 (Figure 13).

Figure 13. Illustrative use case; mission resources dimension—infrastructure systems.

Infrastructure Type	Infrastructure Criticality and Vulnerability	Infrastructure Criticality and Vulnerability Score
Road	Extremely Critical to Mission Completion	0.9
Bridge	Somewhat Critical to Mission Completion	0.5

For this scenario, the user assesses the threats that may occur to be a blizzard, with hazards due to both snow and wind speed in addition to a cyber-attack occurring simultaneously. The user assigns the intensity and likelihood categories as “Extremely High” with a score of 0.9 for the wind speed and shut down of vehicles due to the cyber-attack and “High” with a score of 0.75 for the snowfall hazard. Finally, the likelihood of occurrence of these hazards for this scenario are assigned to be either “Medium” with a score of 0.5 for the wind speed or “Low” with a score of 0.25 for the snowfall and electrical shutdown (Figure 14).

Figure 14. Illustrative use case; threat event dimension.

Threat Event	Threat Hazard	Intensity	Intensity Score	Likelihood of Occurrence	Likelihood Score
Blizzard	Wind Speed	Extremely High	0.9	Medium	0.5
Blizzard	Snowfall	High	0.75	Low	0.25
Cyber Attack	Electrical Shutdown	Extremely High	0.9	Low	0.25

The *Mission Consequence and Mitigation* dimension allows the user to indicate their assessment of the impact of the specific threat hazard on mission completion. For this use case, the Wind Speed from a Blizzard is assessed to have an impact on complete loss of the vehicle control or operations, yielding an impact score of 0.9. The user then indicated how well they can mitigate or control against that impact knowing that a higher amount of controllability will lead to a lower controllability score. In this case, the user assigned a “Low” ability to control against the complete loss of the vehicle, yielding a controllability score of 0.9.

For the other hazards, the user assigned a moderate loss of vehicle control or operation due to snowfall (Impact Score of 0.75), and a slight loss of vehicle control or operation due to electrical shutdown (Impact Score of 0.5). The user further assigned a level of controllability to each of these impacts with an associated score. To the “Moderate loss of vehicle control or operation”, they assigned a controllability of “High” with a score 0.5 and to the “Slight loss of vehicle control or operation”, they assigned a controllability of “Extremely High” with a score of 0.25.

Finally, the user considered what the consequences would be for each of the impacts. For the “Complete loss of vehicle control or operations”, the user assigned a consequence of “Personnel Death” with a consequence score of 0.9. To the “Moderate loss of vehicle control or operation” they assigned a consequence of “Personnel Injury” with a score of 0.75 and to the “Slight loss of vehicle control or operation” they assigned a consequence of “Vehicle Replacement” with a consequence score of 0.5.

The *Mitigation & Consequence Dimension Score* is calculated by taking the *Controllability Score* times the square root of the product of the *Impact Score* times the *Consequence Score* yielding the scores for each *Mission Resource Impact*: “Complete loss of vehicle control or operations”, a score of 0.81, “Moderate loss of vehicle control or operation” a score of 0.38, and “Slight loss of vehicle control or operation” a score of 0.13 (Figure 15).

Figure 15. Illustrative use case; mission consequence and mitigation dimension.

Mission Resource Impact	Impact Score	Controllability	Controllability Score	Consequence	Consequence Score	Mitigation & Consequence Dimension Score
Complete loss of vehicle control or operations	0.9	Low	0.9	Personnel Death	0.9	0.81
Moderate loss of vehicle control or operation	0.75	High	0.5	Personnel Injury	0.75	0.38
Slight loss of vehicle control or operation	0.5	Extremely High	0.25	Vehicle Replacement	0.5	0.13

Following the process laid out in Section 4, the framework then takes the individual scores and combines them to produce a singular risk score for an iteration.

For this iteration, the mission resource dimension score for the individual combination of deployable asset and installation infrastructure it will operate on, in this case a HMMWV on a road and a M1 on a bridge are multiplied together and then the cube root taken to incorporate the impact of higher mission, vulnerability, and criticality scores.

In this case, the HMMWV has a *Mission Resource Dimension Score* of 0.59 and the M1 has a score of 0.48.

A similar process is used to combine the intensity and likelihood to calculate the *Threat Event Dimension Score* for each threat hazard. In this case the Wind Speed has a *Threat Event Dimension Score* of 0.67, the Snowfall a score of 0.43 and the Electrical Shutdown a score of 0.47.

Finally, the *Mitigation and Consequence Score* is pulled down directly for each threat hazard to incorporate into the calculation for the *Total Risk Score* (Table 10).

This RISC TAMER framework incorporates the criticality and vulnerability to the mission into one score from the product of all the scores and uses the inverse of the threat event dimension and mitigation scores. That way higher impact and mitigation will not be lost.

Table 10. Illustrative case study; dimension scores and total risk score table.

Iteration	Deployable Systems	Infrastructure Type(s)	Mission Resource Dimension Scores	Threat Hazard Selection(s)	Threat Event Dimension Scores	Mitigation and Consequence(s)	M&C Dimension Scores
0.62	M998 (HMMWV)	Road	0.59	Wind Speed	0.67	Complete loss of vehicle control or operations	0.81
—	M1A1 (Abrams MBT)	Bridge	0.48	Snowfall	0.43	Moderate loss of vehicle control or operation	0.38
—	—	—	—	Electrical Shutdown	0.47	Slight loss of vehicle control or operation	0.13

5.2 Summary of Illustrative Case Study

To summarize the illustrative case study, the flexible supports a workflow to incorporate various modules and layers for visualizing resilience, supports tradeoff analysis, and allows for identification, adaptation, and transformation of data for decision maker use.

In this scenario, the *Total Risk Score* for the iteration is 0.62. This score could then be compared to a modified set of assumptions in order to determine which iteration would have the higher risk and require additional mitigation.

The framework incorporates various modules and layers for visualizing resilience, supports conducting tradeoff analysis of potential projects. It additionally allows for identification of installation infrastructure, deployable assets, and threat events, adaptation for simple and less complex implementations, and transformation of existing system capabilities beyond subject matter expert intuition.

6 Next Steps

In order to build out and iterate on the framework, several engagements with both DoD internal and external stakeholders were conducted as part of the research. The intent is to utilize this input to ascertain how to construct the framework to inform risk mitigation, resilience integration and resource prioritization based on the user, deployable system, and operating environment. Key findings to guide future development of RISC TAMER include the following:

- Identified that capturing potential solutions to incorporate in the decision support tool implies an understanding of resilience to identify the objective function.
- Explained the current use of data to inform scenario driven models for resource allocation decisions that provide insights to impact of potential decisions.
- Described the framework as a workflow such that various data flows feed into the framework that informs decision-makers.
- Identified the need and opportunity to link this framework to mission assurance in the cyber realm.
- Discussed the use of incorporating various modules/layers for visualizing resilience and conducting tradeoff analysis of potential projects.
- Identified that the interaction between “buyers” (the acquisition community), “operators” (from DoD Combatant Command down to individual units), and “maintainers” is critical to accurately portray the framework.
- Identified the following additional information requirements for analysis in an effort to make the framework more robust:
 - What is the status of planning systems?
 - What is the status of data to inform deployable assets, systems, and supporting infrastructure?
 - Where or how to upload existing data platforms and models into RISC TAMER?
 - How to best to incorporate outcomes from RISC TAMER into existing risk-based planning and acquisition systems?
 - How to measure the natural hazard-related capital and O&M costs with and without RISC TAMER to help determine the value of improved decision making?

Additional work is needed in the following areas:

- Refine the relationships and interactions between the framework dimensions.
- Expand the framework to incorporate cost data and higher fidelity in decomposition down to the component level.
- Connect the framework to existing data platforms and models and identify data gaps and shortfalls.
 - Natural Hazards registry (NOAA, FEMA)
 - Acquisition system documentation (Work Breakdown Structures, Technical Manuals, program failure data, product support and logistics plans)
 - Army Vantage Data Platform (assets and installations)
- Convert the decision support matrix into a dashboard to simply use and assist users to communicate asset risk and site value at risk.
- Determine how best to incorporate outcomes from the framework into existing risk-based planning and acquisition systems.
- Exercise the framework with a case study data set and measure its effectiveness to identify its strengths and weaknesses.

7 Conclusions

DoD installations face a variety of threats which, when compounded, challenge sustained functionality, including for critical installations. This project proposes to establish a decision support framework to help provide decision-makers with more complete and comprehensive information from which they may base their resilience-related decisions, both for prevention and response. In addition to understanding the compound risks, system relationships, and mitigation options, the decision support framework will also incorporate the concept of a decision matrix to provide structure to the weighting of solution options. The solution option framework will support analytics for consideration of compound threats and risks because the most effective solution may, ultimately, be a suite of solutions. This multi-objective decision analysis to mitigate risk and integrate resilience supports mission assurance assessment, infrastructure investment, and new deployable asset design decision making.

Additional research is required to further populate the framework; however, initial feedback from various stakeholders indicates that although this is a large undertaking, the results will be useful and have the potential to significantly impact risk-based decision making for deployable assets, mission assurance assessment, and infrastructure assessment.

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Abbreviations

AMSAA	Army Material Systems Analysis Activity
API	Application programming interface
ASD	Assistant Secretary of Defense
BRAC	Base realignment and closure
CADE	Cost assessment data enterprise
CCDC DAC	Combat Capabilities Development Command Data and Analysis Center
CDD	Capability development document
CERL	Construction Engineering Research Laboratory
CJCSI	Chairman of the Joint Chiefs of Staff
DASD(SE)	Office of the Deputy Assistant Secretary of Defense for Systems Engineering
DLA	Defense Logistics Agency
EO	Executive Order
EPA	Environmental Protection Agency
ERDC	US Army Engineer Research and Development Center
ESTCP	Environmental Security Technology Certification Program
GAO	Government Accountability Office
HMMWV	High mobility multipurpose wheeled vehicle
HQDA	Headquarters, Department of the Army
JCIDS	Joint Capabilities Integration and Development System
M&S	Modeling and simulation

MBT	Main battle tank
NORAD	North American Aerospace Defense Command
O&M	Operations and maintenance
OSD	Office of the Secretary of Defense
OSD CAPE	Office of the Secretary of Defense Cost Assessment and Program Evaluation
RISC TAMER	Resilient Installation Support against Compound Threats Analysis and Mitigation for Equipment and Resources
S&T	Science and Technology
SIPR	Secret Internet Protocol Router
SMS	Sustainment Management System

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14. ABSTRACT Every day, decision-makers must allocate resources based on the best available information at the time. Military installations face a variety of threats which challenge sustained functionality of their supporting and supported deployable systems. Considering the compounding and interdependent impacts of the threats, both specified (what is known) and unspecified (what is not known) and the investments needed to address these threats adds value to the decision-making process. Current risk management practices are generally evaluated via scenario analyses that do not consider compound threats, resulting in limited risk management solutions. Current practices also challenge the ability of decision-makers to increase resilience against such threats. The Resilient Installation Support against Compound Threats Analysis and Mitigation for Equipment and Resources (RISC TAMER) Framework establishes a decision support structure to identify and categorize system components, compound threats and risks, and system relationships to provide decision-makers with more complete and comprehensive information from which to base resilience-related decisions, for prevention and response. This paper focuses on the development process for RISC TAMER framework to optimize resilience enhancements for a wide variety of deployable systems in order to implement resilience strategies to protect assets, to increase adaptability, and to support power projection and global operations					
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