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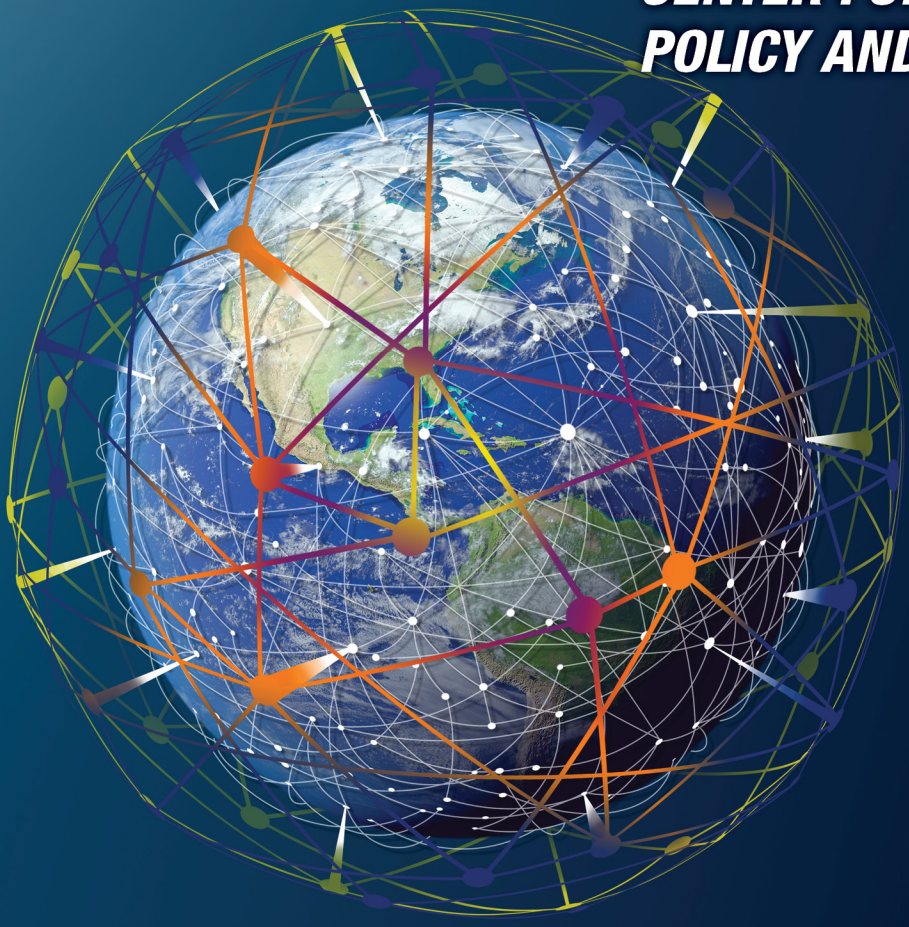

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# A FRAMEWORK FOR RESILIENCE

KRISTI J. BRADFORD, PAUL C. FRAKES, AND CHRISTOPHER R. MAY
THE AEROSPACE CORPORATION



AEROSPACE

### KRISTI J. BRADFORD

Kristi Bradford is a senior member of the technical staff in The Aerospace Corporation's Space Architecture Department, where she performs strategic technical assessments, cross-program evaluation, and space enterprise analyses for civil and national security customers. Previously, Bradford worked at Planetary Resources and Columbia University doing instrument systems engineering for ground-based, aircraft-based, balloon-based, and space-based scientific instrumentation. Bradford holds a bachelor's degree in astrophysics, earth & planetary sciences from Harvard University and a master's degree in exploration systems design (systems engineering) from Arizona State University.

### PAUL C. FRAKES

Paul Frakes is a project engineer with Project West Wing at The Aerospace Corporation. As a recent member of the Space Architecture Department, he performed resilience analysis, requirements development, and risk management for several U.S. government space programs. Previously, he was a member of NASA's Conjunction Assessment Risk Analysis team, whose work regularly resulted in the execution of on-orbit collision avoidance maneuvers. Frakes holds a bachelor's degree in aeronautical and astronautical engineering from Purdue University and is working toward a master's degree in systems engineering from Johns Hopkins University.

### CHRISTOPHER R. MAY

Christopher May is a senior member of the technical staff in The Aerospace Corporation's System of Systems Engineering Office. In this position, he performs enterprise and system of systems level analysis, model-based systems engineering, and architecture development and evaluation for civil and national security customers. May holds master's and bachelor's degrees in aerospace engineering from Georgia Institute of Technology and is currently working on a master's in space policy at George Washington University.


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# Summary

**Increasing the resilience of the United States is a major element of recent strategy documents, with "Promote American Resilience" a primary objective of the 2017 National Security Strategy[1] and the need for "a more lethal, resilient, and rapidly innovating Joint Force," outlined in the 2018 National Defense Strategy.[2] Resilience has been a priority for several years. For the space community, it was formally introduced into the vernacular in the 2010 National Space Policy of the United States of America (2010 space policy), which called for the "resilience of mission-essential functions."[3]**

**The framework was developed using the original intent of resilience as laid out in the 2010 space policy and studies of resilience beyond the space domain. There are four key points on resilience that the framework is intended to elucidate:**

1. ***Resilience exists at multiple scopes of responsibility.*** **One can consider resilience at a national/whole of government scope; at a department or agency scope; at a division or directorate scope; at a program, initiative, or project scope; and at scopes of responsibility in a nongovernmental context. Thus, for clarity in communication about resilience, it is important to identify the relevant scope of responsibility because the meaning and interpretation of key resilience-related terminology varies with scope.**

2. ***The scope of responsibility matters.*** **The options space for increasing resilience is directly dependent on the scope of responsibility (i.e., the options available to the interagency for resilience are considerably different than the options available to a program for resilience). Likewise, the impact of increased resilience is dependent on the scope of responsibility (i.e., resilience of a program does not make the space enterprise resilient; resilience of the space enterprise does not make a program resilient).**

3. ***Each scope of responsibility is interconnected with every other scope.*** **The approaches employed at wide scopes of responsibility will flow down and influence how narrower scopes of responsibility operate (i.e., whole of government resilience strategies will influence how resilience is considered within agencies and departments). Likewise, the outcomes at narrow scopes of responsibility will flow up and influence the approaches of wider scopes of responsibility (i.e., diminished resilience within an agency or department will have an impact on whole of government resilience).**

4. ***Resilience necessitates a multi-disciplinary approach, regardless of the scope of responsibility.*** **Resilience requires examination of materiel and nonmateriel aspects of any scope of responsibility, such as training, education, tactics, procedures,**

**communication channels, logistics, acquisition, R&D, organizational culture, policies, processes, and facilities, as well as a multitude of other facets depending on the nature of the enterprise.**

**The concepts and key points presented throughout this paper are meant to provide a theoretical framework for future discussions of resilience. The purpose is for it to be a flexible structure that can be adapted to a diverse set of complex applications without losing track of the core tenets of resilience. This framework is not a turnkey solution, as resilience does not lend itself to turnkey solutions. However, this framework is meant to be a first step in bringing more structure to discussions, planning, and methodologies for increasing resilience.**

## Introduction

"Resiliency has finally entered the lexicon of American political leaders."[4] The aftermath of 9/11 placed a new emphasis on increasing resilience across all aspects of American society for the purpose of preserving the American way of life. For instance, the 2006 National Infrastructure Protection Plan (NIPP) states that "since the terrorist attacks of September 11, 2001, government and private sector expenditures to improve [Critical Infrastructure and Key Resource] protection and resilience have increased among security partners across sectors and jurisdictional levels." In fact, the primary goal of the NIPP was to "build a safer, more secure, and more resilient America."[5] The most recent NIPP, published in 2013, continues the resilience focus stating, "our national well-being relies upon secure and resilient critical infrastructure."[6] In addition, for 2016, 2017, and 2018, there has been a NIPP Security and Resilience Challenge to "help develop technology, tools, processes, and methods that address immediate needs and strengthen the long-term security and resilience of critical infrastructure."[7] This imperative on increasing resilience eventually grew to include an oft overlooked, but critical, component of national infrastructure, namely space capabilities.

Resilience was formally introduced into the national space enterprise vernacular by the 2010 space policy. One of the main goals laid out in the policy reads, "Increase assurance and resilience of mission-essential functions enabled by commercial, civil, scientific, and national security spacecraft and supporting infrastructure against disruption, degradation, and destruction, whether from environmental, mechanical, electronic, or hostile causes."[3] This inclusion of space capability resilience in the larger goal of U.S. societal resilience is obvious given the ubiquitous nature of space in the lives of Americans. Although the average American may be unaware of their use of space on a daily basis, space capabilities have become engrained in American society. Space has

become an American value. Thus, space resilience is a component of American societal resilience.

Since this initial introduction of resilience terminology into the space community at a national scope, subsequent policy and strategies at narrower scopes have evolved, though primarily within the national security community. The 2011 National Security Space Strategy states the need to "strengthen the resilience of our architectures to deny the benefits of an attack" and further describes ways in which this directive can be implemented, including "space system protection," "hosting payloads," "drawing on distributed international and commercial partner capabilities," and "develop[ing] mission-effective alternatives including land, sea, air, space, and cyber-based alternatives for critical capabilities currently delivered primarily through space-based platforms."[8] Further guidance on resilience was developed by the Department of Defense (DOD) in a 2015 white paper on "Space Domain Mission Assurance: A Resilience Taxonomy." This document highlighted the importance of "making resilience a consideration in all architectural planning and evaluation, as well as in all system planning and development activities for DoD space capabilities."[9] Furthermore, the document defines resilience as "an internally-focused characteristic of an architecture," including "on-board protection elements."[9]

A focus on resilience has continued in recent years with the 2017 National Security Strategy focused on "Promot[ing] American Resilience" through "improv[ed] risk management," "build[ing] a culture of preparedness," "improv[ing] planning," and "incentiviz[ing] information sharing."[1] The document explicitly mentions resilience in space as it relates to "the US Government partner[ing] with US commercial space capabilities to improve resiliency of our space architectures." Most recently, the 2018 National Defense Strategy calls for "a more lethal, resilient, and rapidly innovating Joint Force."[2]

Each of these policy and strategy documents discuss resilience at varying scopes of responsibility, including whole of government, national security, space enterprise, department-specific, and program or space system scopes. This diversity in the use of resilience terminology indicates that resilience is important at multiple scopes of responsibility. However, specific definitions of resilience vary across organizations and scopes of responsibility leading to confusion. Each use of resilience in these policy and strategy documents is intended to support the ultimate goal of preserving the American way of life (that is, societal resilience), but societal resilience will not share the same definition, interpretation, and attributes of resilience as, for example, program resilience, because the drastically different scopes of responsibility.

Due to this variability in interpretations of resilience, an intentionally broad definition of resilience is used in this paper: *the ability to tend toward positive outcomes regardless of negative developments.* This broad definition is intended to encompass, and not conflict with, the numerous definitions and interpretations of resilience found across the space enterprise and beyond.

However, to provide clarity on the diverse uses of the term *resilience* across the space enterprise and improve communication and discussions on resilience, this paper has three goals: (1) understand the original intent behind introducing resilience into the space enterprise vernacular, (2) develop a framework for managing the ambiguity and complexity of resilience across any scope of responsibility, and (3) derive key points from the framework that can be used by space professionals at any scope of responsibility.

## Intent of Resilience

Since the first formal introduction of resilience terminology into the space community came in the 2010 space policy, it is useful to consider what led

to its inclusion in that policy to understand the original intent of resilience with regard to space.

Discussions surrounding the application of deterrence theory to space were prevalent throughout the development of the policy.[10] Modern deterrence theory posits that an aggressor may be deterred through imposition of cost and denial of benefit. In other words, credible signaling to an adversary that specific actions or behavior will have painful consequences and gain them no advantage, may influence an adversary's decision to take such action. Additionally, an aggressor must know that its actions can be attributed. The impetus for including resilience in the national space policy was to develop a credible denial of benefit to enhance the nation's ability to deter.[10] Resilience, an element of denial of benefit, was one part of the larger policy guidance to create cost imposition capabilities as well as increasing attribution through enhanced Space Situational Awareness.[10] Although resilience may enhance deterrence, resilience should not be seen as interchangeable with deterrence, because resilience remains critical when deterrence fails.

The language on resilience in the 2010 space policy was primarily intended for an interagency audience.[10] It was aimed at increasing coordination across multiple agencies. In other words, a whole of government approach toward increasing resilience was the intent of the policy, which should include considering options beyond space and analyzing cross-domain solutions for increasing the resilience of critical capabilities currently enabled by space systems, because of the possibility of a denied space environment.[10] Furthermore, it is important to recognize that engineering resilience, while useful, is insufficient for achieving the intended goals of the policy. Engineering solutions, such as satellites, are merely tactical solutions to achieve strategic goals. It is essential to incorporate solutions and capabilities across multiple departments, domains, and disciplines to increase resilience and achieve the broader strategic goals of deterrence and ensure the availability of mission-essential functions when deterrence fails.[10]

## Framework

Since the policy calling for resilience of the space enterprise was targeting an interagency audience, it is useful to first study the case where increasing resilience is the responsibility of the interagency. Thus, consider a national scope of responsibility represented by three levels: the national level, the interagency level, and the agency/department level. Figure 1 shows a diagram of this breakdown.

From a top-down perspective, the role of each level is as follows:

- **National,** where the White House and Congress examine national interests based on the values of the American public and determine government objectives for advancing national interests.
- **Interagency,** where whole of government coordination occurs to determine a plan for meeting objectives set at the national level and provides directives and instructions to individual departments and agencies for achieving government objectives.
- **Agency/department,** where departments and agencies implement instructions from the interagency process to produce desired materiel or nonmateriel deliverables.

From a bottom-up perspective, the role of each level is as follows:

- **Agency/department,** where departments and agencies analyze the performance of materiel or nonmateriel deliverables and report the effectiveness of each deliverable.
- **Interagency,** where the effectiveness of deliverables across all relevant agencies and departments are evaluated to determine the overall cross-agency utility.

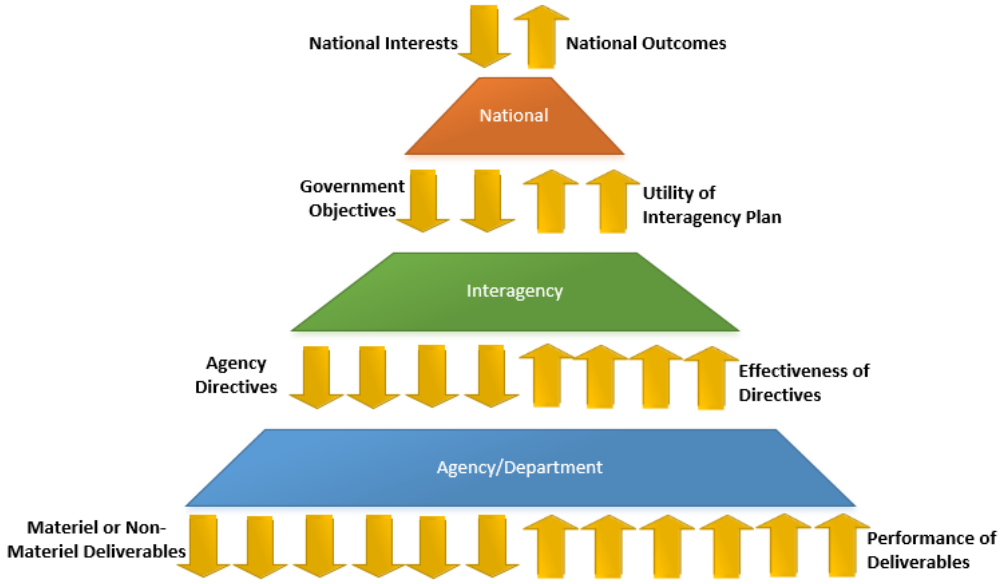


*Figure 1: Framework for interagency case.*

- **National,** where the White House and Congress evaluate the utility of the whole of government plan and deliver outcomes that advance national interests, adjusting objectives as outcomes play out.

Although this framework is a gross simplification of reality, it does offer a utility for framing complex topics. For instance, consider the timely issue of a congested space environment. The continuity and growth of U.S. public and private space capabilities is in the best interest of the United States, but this interest is threatened by growing congestion in space. Thus, a national-level objective could be to assure operability of U.S space assets in the face of growing congestion, both physical and frequency congestion.

There are a multitude of options for advancing this objective: space traffic management; international agreements on orbital debris mitigation; negotiations with the International Telecommunications Union (ITU) to ensure sufficient spectrum allocation; maturation of alternative communication technologies and architectures; data sharing across public, private, and international actors; development of debris removal technologies; incentivizing the private sector to pursue orbital debris removal business models; requiring spacecraft to be more armored and/or maneuverable; increasing requirements for launch licenses to reduce the number of space objects; and many others. None of these options are likely to achieve the objective alone, and some have detrimental ramifications and should not be pursued at all.

No one department or agency can achieve the objective alone; thus, a multi-faceted, whole of government solution is needed. It is the responsibility of the interagency to analyze the options space and determine which set of options to pursue, who is responsible for acting on a given option, and provide direction to departments and agencies on how to implement it. Each agency or department would then implement the aspects of the plan for which they are responsible according to the direction provided.

From this example, the responsibility for increased resilience being with the interagency makes sense. The option space for addressing the national objective spans numerous agencies and departments. If a single agency or department attempted to address the problem alone, it may advance the objective, but it would not be a resilient approach. Pursuing an interagency plan for addressing the threat of congestion does increase resilience, because, if the actions taken by one department hit a major roadblock, or are simply not as effective as desired, the actions of other agencies and departments are still able to advance the objective.

It also important to note that this interagency approach demonstrates a distinction between resilience and redundancy. In a resilient interagency plan, the agencies and departments are not all pursuing the same option. They are pursuing diverse, complementary options, all working toward a common goal.

### *Sociotechnical Systems*

The space enterprise considered at a whole of government perspective, as presented in the framework above, can be usefully characterized as a highly complex sociotechnical system of systems. A sociotechnical system is an entity consisting of social and technological dimensions with complex interactions between the human, organizational, and technological aspects of the entity.[11] The resilience of sociotechnical and similar complex systems has been researched in the academic community for several decades.[12] Thus, throughout the remaining discussion, lessons from research into sociotechnical resilience and related studies will be drawn upon to expand the single-scope framework presented above into a multi-dimensional framework that can span many scopes of responsibility.

The reason for this framework expansion is that sociotechnical systems are made up of "different groups [that] adopt different interpretations [of common terminology] to fit their understanding and purpose."[13] To model each of the groups within the sociotechnical system and understand how each might view resilience differently, an abstraction of the framework at a national scope of responsibility is needed so that it can be applied to groups at any scope of responsibility.

### *Abstracted Framework*

The framework for a national scope of responsibility places resilience responsibility with the interagency, which exists at the mid level of the framework. The mid level effectively translates high-level objectives into actionable directives across multiple low-level organizations with narrower scopes of responsibility. It is in this translational and cross-entity process where increased resilience can be achieved. By abstracting this framework to simply be composed of high, mid, and low levels, it can then be applied to organizations at any scope of responsibility.

For the abstracted framework (shown in Figure 2), the top-down process goes as follows:

- **High Level,** where the interests of an organization are considered and a set of objectives to advance those interests are selected.
- **Mid Level,** where various options for achieving the objectives are analyzed, a plan is selected, and instructions for implementation of the plan are developed.
- **Low Level,** where the instructions are executed and a set of materiel or nonmateriel deliverables is produced.

For the abstracted framework, the bottom-up process goes as follows:

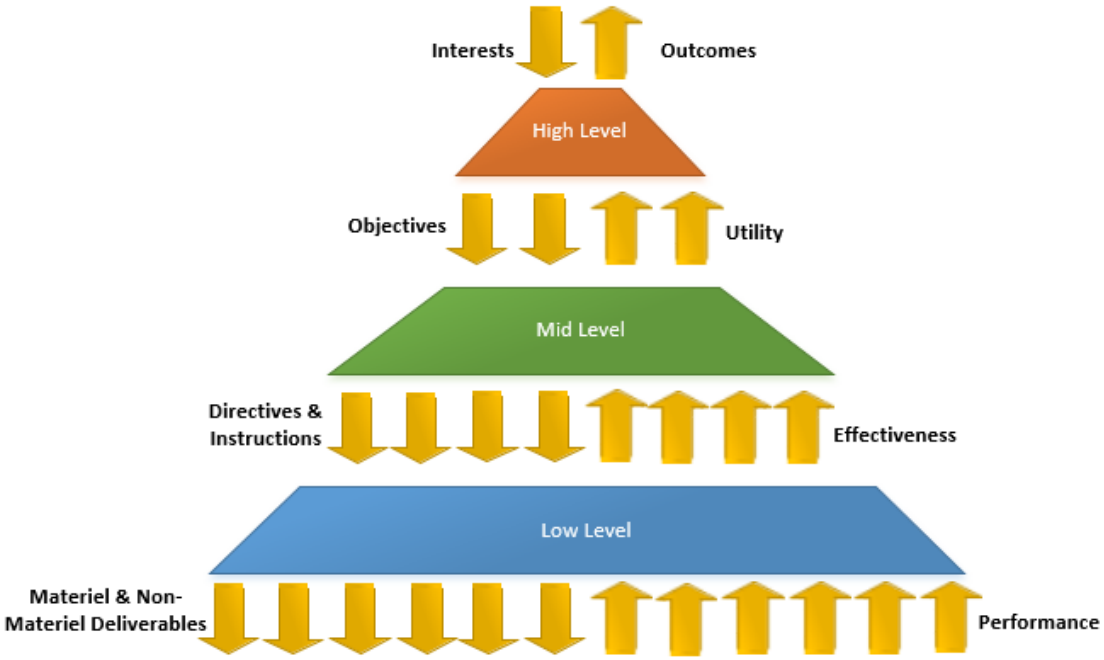


*Figure 2: Abstracted framework.*

- **Low Level,** where the performance of each materiel or nonmateriel deliverable is analyzed to determine effectiveness.

- **Mid Level,** where the effectiveness of all deliverables is evaluated to determine the utility of the enterprise.

- **High Level,** where the utility of the enterprise is evaluated in terms of its ability to deliver outcomes that advance organizational interests, adjusting objectives as outcomes play out.

The materiel and nonmateriel resources, which are outputs of the low level, as well as the low-level entities creating the outputs, can be thought of as nodes interconnected by links that make up a network. Each "node" has a specific performance that has an impact on the effectiveness of the entire "network," but there are many ways to construct the network to achieve the desired objectives. The specific construction of the network does not necessarily matter as long as it is effective at achieving the objectives. However, it is in the specific construction of the network where increased resilience can be achieved.

Academic research into resilience of complex systems supports this nodes-in-a-network view of organizational structure and dynamics. Specifically, research has shown that the number of links between nodes is proportional to the stability of the system and that having a variety of links between nodes can provide alternative functional links when a node becomes degraded or disrupted.[14] In other words, having alternative methods for accomplishing the same objectives can increase the resilience of sociotechnical systems. It is important to note the distinction between alternative methods and duplicative methods.

### *Attributes of the Low Level*

- Within the framework, the low level is responsible for each individual node. Depending on the scope of responsibility, a node could be an organization, a person, a system, a document, an agreement, an action, an expertise, or a wide

variety of other materiel or nonmateriel resources that can generate specific materiel or nonmateriel deliverables.*

- To develop, acquire, create, establish, operate and/or utilize each of the nodes, knowledge of the entire network is not necessary; only knowledge of the node's interface to other nodes is needed, as depicted in Figure 3. This node-centric perspective means the low level lacks the visibility to optimize the network. It can only optimize a given node and its links to other nodes.

*Example:* Consider a non-space example, for instance the management of a pension fund. The low level of a pension fund would consist of the analysts that are monitoring, evaluating, and/or selecting specific investments. Each individual investment and the people concerned about the performance of individual investments exist at the low level. The concern at this level is optimizing each investment deal and not necessarily optimizing the fund as a whole.

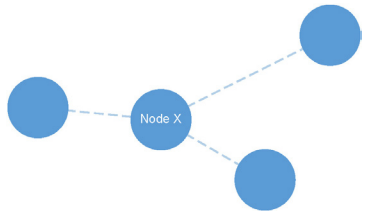


***Figure 3: Single node: the responsibility of the low level. Only knowledge of the node's interface to other nodes is needed.***

### *Attributes of the Mid Level*

- The mid level is responsible for the entire network, as depicted in Figure 4. This means that the mid level should determine:
  - The number of nodes and links in the network.
  - The purpose of each node and link.
  - The timescale on which nodes/links are added, refreshed, or changed.
  - How each node is connected or not connected to every other node.
  - Which nodes need to be hardened or have some sort of built-in protection.
  - Which nodes need some sort of protection that may require introduction of another node.
- There are a multitude of ways that a network could be set up to achieve the same objective or set of objectives. It is the mid level that analyzes the network option space and decides on how to achieve those objectives in the most resilient way possible.

*Example:* For the management of a pension fund, the mid level is responsible for developing an investment portfolio that spans various investment options, such as stocks, bonds, venture capital, private equity, hedge funds, etc. The mid level is concerned about the resilience of the fund (though it may not be referred to as resilience in the investment community). Thus, the mid level also analyzes the risks associated with each investment type to develop an investment portfolio that can meet fund objectives in the face of current and emerging economic and market conditions.

### *Attributes of the High Level*

- The high level is implementation agnostic. No individual node *should* matter to the high level.

*One way to think about materiel and nonmateriel nodes within the low level, especially in terms of the DOD, is DOTMLPF-I,P (Doctrine, Organization, Training, Materiel, Leadership and education, Personnel, Facilities, Interoperability with allies or partners, and Policy). Each of these represent a type of node that should be considered. It is important to stress that nodes, as considered by this framework, are often nonmateriel resources.

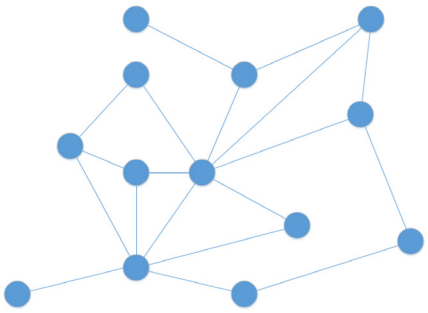

*Figure 4: A materiel and nonmateriel "network": the responsibility of the mid level.*

Even the design of the network does not matter as long as it can achieve the objectives within the resource constraints of the organization. (If objectives are not being achieved, then, under certain circumstances, the high level may dictate aspects of an implementation.)

- The high level is concerned with selecting the right objectives for advancing the interests of the organization.

*Example:* In the case of a pension fund, the fund manager exists at the high level and sets the objectives and guidelines for the fund based on the interests of the fund's stakeholders, expected return, the acceptable risks, the admissible terms of investment, and the overall strategy for the fund.

Increased resilience cannot be achieved at the high level, because the high level is agnostic to the solution. If resilience is pushed to the low level, resilience becomes node hardening, because the low level is node-centric. While node hardening is certainly valuable and could be used as a tool for increasing resilience, it is not a standalone method for resilience (e.g., in the pension fund scenario, focusing significant resources on just one investment deal will not increase the resilience of the entire fund). Furthermore, it is not possible to determine which nodes need to be hardened and which do not if the network perspective is not available (e.g., an analyst evaluating one investment in the pension fund is unlikely to have sufficient perspective to know the importance of that investment relative to other investments in the fund and, thus, must rely on the mid level to provide that perspective).

If resilience is considered at the mid level, a multitude of methods for increasing resilience becomes available because the entire network (that is, every node, its relationship to every other node, and the introduction of new nodes) can be considered. It is resilience of the ability to complete an objective—in other words, capability resilience—that matters. To achieve resilience, the network should be constructed such that no node can be a single point failure for losing a capability essential to an objective or set of objectives.

## The N-Level Scenario

Using this abstracted framework, it is now possible to model organizations at any scope of responsibility. By nesting the framework, an N-level scenario can be modeled with each application of the three-level framework in the model representing a scope of responsibility. This enables multiple scopes of responsibility to be modeled simultaneously and the interface between scopes to be analyzed. This nesting technique is not unique to the space enterprise, but commonly used in analysis of socio-technical systems: "It is important to bear in mind that 'systems' consist of nested dynamics operating at particular organizational scales – 'subsystems,' as it were."[13] In the space enterprise case, a department or agency is a subsystem within with the whole of government system (see Figure 5, a directorate may be a subsystem within a department or agency system, a division maybe a subsystem within a directorate system, and so on down to narrower and narrower scopes of responsibility. Table 1 shows an example of the resulting scopes of responsibility from framework nesting for a generic U.S. government case.

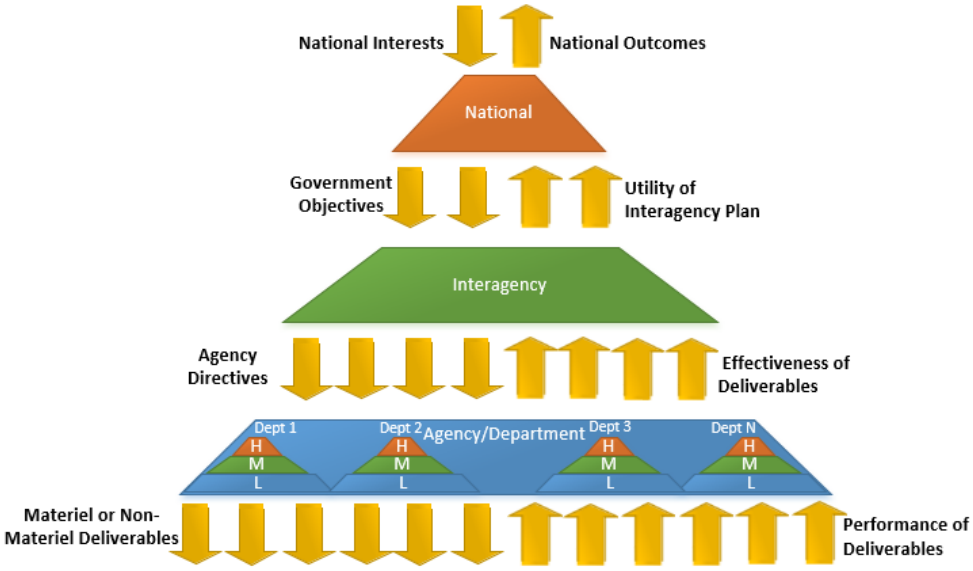


*Figure 5: Framework nesting—interagency example.*

| Table 1: Framework Nesting and Scopes of Responsibility* | | |
|---|---|---|
| **Scope of Responsibility** | **Resilience Responsibility** | **Nodes for Execution** |
| National | Cross-dept/ agency (interagency) | Departments/ agencies |
| Department/ agency | Cross-directorate/ division | Directorates/ divisions |
| Directorate/ division | Cross-program/ projects/ initiatives | Programs/ projects/ initiatives |
| Program/ projects/ initiative | Cross-deliverable | Deliverables |

*The labels used here for describing organizational subparts are merely notional. The intent is to communicate the interconnected nature of each scope of responsibility within an organization, which remains regardless of the specific labels used.

Nesting can continue down to narrower and narrower scopes of responsibility as needed for analysis. However, it is important to recognize that with each narrowing of the scope of responsibility (that is, with each nesting of the framework), terminology may remain the same, but the meaning, intent, and purpose underlying that terminology will change, and can change quite dramatically. This is supported by academic studies of sociotechnical resilience, as it has been found that "the level of abstraction of each stakeholder is an important factor in how each stakeholder views resilience," and the differences "may seem trivial, but the boundaries and purposes [associated with a level of abstraction] determined what the stakeholders identified as being most important."[12]

For instance, the mission, capability, and resilience of the U.S. space enterprise is different from the mission, capability, and resilience of NASA, which is different from the mission, capability, and resilience of NASA's Human Exploration and Operations Mission Directorate (HEOMD), which is different from the mission, capability, and resilience of HEOMD's Exploration Systems Development, which is different from the mission,

capability, and resilience of the Space Launch System (SLS) program.

These differences in common terminology across scopes of responsibility can lead to confusion, "because different groups adopt different interpretations to fit their understanding and purpose."[13] This confusion may be permeating discussions of resilience across the space enterprise, because common terminology is used in different ways depending on the specific organization and the scope of responsibility of that organization. Thus, it is important to be cognizant of both organizational and scope differences in the use of the terminology.

***It is important to recognize that with each narrowing of the scope of responsibility, terminology may remain the same, but the meaning, intent, and purpose underlying that terminology will change, and can change quite dramatically.***

Resilience will mean different things to different people, depending on their scope of responsibility; however, all scopes of responsibility are interconnected. Resilience at a lower scope of responsibility should support nodes within higher scopes of responsibility. And resilience at higher scopes of responsibility will have requirements that need to be flowed down to lower scopes of responsibility. However, it is essential to recognize that resilience responsibility is directly tied to scope of responsibility; resilience at one scope of responsibility does not translate to resilience at another. Resilience of a program does not mean resilience of the space enterprise and vice versa.

## Using the Framework to Improve Resilience

The framework is meant to provide a structure for laying out the complexity of resilience. It is purposefully abstract so that it can be applied to multiple scopes of responsibility and can be applied in multidisciplinary scenarios because the complexity of resilience requires this breadth of applicability. There are four key points about resilience that can be extracted from this framework:

1. **Resilience exists at multiple scopes of responsibility**. One can consider resilience at a national/whole of government scope; at a department or agency scope; at a division or directorate scope; at a program, initiative, or project scope; and at scopes of responsibility in a nongovernmental context. Thus, for clarity in communication about resilience, it is important to identify the relevant scope of responsibility because the meaning and interpretation of key resilience-related terminology varies with scope.

2. **The scope of responsibility matters.** The options space for increasing resilience is directly dependent on the scope of responsibility (i.e., the options available to the interagency for resilience are considerably different than the options available to a program for resilience). Likewise, the impact of increased resilience is dependent on the scope of responsibility (i.e., resilience of a program does not make the space enterprise resilient; resilience of the space enterprise does not make a program resilient).

3. **Each scope of responsibility is interconnected with every other scope.** The approaches employed at wide scopes of

responsibility will flow down and influence how narrower scopes of responsibility operate (i.e., whole of government resilience strategies will influence how resilience is considered within agencies and departments). Likewise, the outcomes at narrow scopes of responsibility will flow up and influence the approaches of wider scopes of responsibility (i.e., diminished resilience within an agency or department will have an impact on whole of government resilience).

4. **Resilience necessitates a multi-disciplinary approach,** regardless of the scope of responsibility. Resilience requires examination of materiel and nonmateriel aspects of any scope of responsibility, such as training, education, tactics, procedures, communication channels, logistics, acquisition, R&D, organizational culture, policies, processes, and facilities, as well as a multitude of other facets depending on the nature of the enterprise.

The framework enables those concerned with increasing resilience to gain situational awareness of their resilience responsibilities, relevant interfaces, and potential communication challenges. When considering the nested framework, it becomes clear that any organization or individual may simultaneously have high-, mid-, and low-level responsibilities that derive from three different scopes of responsibility. By recognizing these distinctions, organizations and individuals can take a more structured approach to increasing resilience across multiple scopes of responsibility. Thus, when using this framework, it is useful for organizations and individuals to ask questions, such as the following:

- At what scope do I have high-level responsibilities? What are my high-level responsibilities? Who are my mid-level direct reports? Have I established necessary and sufficient objectives for the mid level? Have I created policies and processes to enable the mid-level collaboration and coordination essential to effectively and efficiently achieve the objectives? How do I ensure that mid-level collaboration occurs? Is there a feedback loop to ensure top-down decisions are informed by bottom-up expertise?

- At what scope do I have mid-level responsibilities? What are my mid-level responsibilities? Who is at the high level that should be providing me objectives? Do I have clear objectives from the high level? If a mid level does not organizationally exist, which of my peers should I coordinate with to efficiently and effectively fulfill mid-level functions? Am I enabled to coordinate plans in a mid-level fashion, or is a policy change needed from the high level? What are my mid-level processes for developing coordinated directives and instructions? How do we measure results and effectiveness? Is there a feedback loop with both the high level and low level to ensure that top-down decisions are informed by bottom-up expertise? What am I doing to increase resilience? Has it been clearly articulated that resilience is my responsibility?

- At what scope do I have low-level responsibilities? What are my low-level responsibilities? With whom at the mid level do I need to interface? Which of my peers share related low-level responsibilities for this scope? Are directives and instructions received from the mid level clear and compatible? Is there a feedback loop with the mid level to ensure top-down decisions are informed by bottom-up expertise?

Questions such as these can fill in the details and nuances that cannot be captured in an intentionally flexible framework. It is important to keep in mind the limitations of this framework. In reality, the distinctions between levels can be blurred and the

process is not simply top-down execution followed by bottom-up evaluation. Feedback loops exist at each interface between levels and many iterations that occur at a single level or between levels before the process proceeds. Also, the element of time can change the players within the framework mid-process or end an effort before it is fully executed. The framework, even in a nested state, is a gross simplification of reality. Regardless of these limitations, the framework does offer utility as a sanity check to ensure all stakeholders are sharing a common understanding despite differing interpretations of terminology.

## Conclusion

The concepts presented here are meant to provide a theoretical framework for future discussions of resilience. Although the framework is simple, it should provide a flexible structure that can be adapted to a diverse set of complex applications without losing track of the core intent of resilience. This framework is just a first step in bringing more structure to discussions, planning, and methods for increasing resilience. Resilience spans multiple scopes of responsibility and a plethora of disciplines. Thus, future work will focus on application of this framework to the diversity of scenarios in which resilience matters. As more applications of the framework are studied with increasing levels of detail, the framework is likely to change, evolve, and mature. However, with any application of this framework, it is important to maintain cognizance of the overarching goal; namely, societal resilience. Resilience of the space enterprise is just one component of a much larger picture.

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