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NATIONAL DEFENSE RESEARCH INSTITUTE

Increasing Flexibility and Agility at the National Reconnaissance Office

Lessons from Modular Design, Occupational Surprise, and Commercial Research and Development Processes

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Prepared for the National Reconnaissance Office

The research described in this report was prepared for the National Reconnaissance Office. The research was conducted within the RAND National Defense Research Institute, a federally funded research and development center sponsored by the Office of the Secretary of Defense, the Joint Staff, the Unified Combatant Commands, the Navy, the Marine Corps, the defense agencies, and the defense Intelligence Community under Contract NRO-000-12-C-0187.

Library of Congress Control Number: 2013946197

ISBN: 978-0-8330-8102-5

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Summary

The U.S. Intelligence Community (IC) is now facing a larger number of unknown threats than at any other time in its history. During the Cold War, the IC faced one primary, well-identified threat, along with a few second-order concerns. Today, the biggest surprises facing the IC are likely to come from places of which the community may not even be aware.

To help address these challenges, the Advanced Systems and Technology (AS&T) Directorate at the National Reconnaissance Office (NRO) asked RAND to perform research to help it develop strategic plans that will yield insights on becoming more flexible and adaptable. We settled on three research questions, specifically designed to target three different aspects of the NRO enterprise:

- How can the NRO build more-flexible hardware?
- How can NRO personnel become better prepared to deal with uncertainty?
- How can the NRO's organizational structures be used to promote innovation and creative thought?

How Can the NRO Build More-Flexible Hardware?

To investigate this question, we first hypothesized that there are two ways to build more-flexible hardware: (1) by building in excess capability and (2) by using a modular architecture. Excess capability gives operators the freedom to develop new tactics, techniques, and procedures as needs change. However, it can be challenging to convince decisionmakers to support excess capability when budgets and resources are becoming increasingly constrained. Therefore, for this project, we investigated the suitability of implementing a modular architecture for the NRO's space systems.

Modularity Provides Flexibility, But at a Cost

Modularity is the engineering equivalent of a financial option: Like a financial option, modularity permits a product designer to invoke some flexibility in the future in exchange for a cost premium that is paid up front. For space systems, this premium is

paid in the form of additional systems engineering that is needed to plan and design a set of standardized interfaces. These interfaces must be designed in their final form at the onset of the project so that the modules are ready for future use, providing the potential for added flexibility and responsiveness.

However, modular systems do not provide all this flexibility for free. Typically, a modular system will not perform each function as well as the equivalent individual (singular) systems. For example, a Swiss Army knife allows the user to carry a number of tools around in one small package. However, this flexibility comes at a price: The tools in the Swiss Army knife will never perform as well as a dedicated knife, corkscrew, or pair of scissors.

Different Classes of Systems Provide Different Levels of Functionality and Benefit

We researched several examples of modular systems and found that different classes of systems provide different levels of functionality and benefits. For example, dry-cell AA batteries and carpet are designed to be readily scaled based on user needs, but the primary functions of each never change. In contrast, an electronics breadboard with resistors, capacitors, and transistors offers nearly infinite functional possibilities to the user.

However, we observed that, while modular systems that offer changes in function are certainly more flexible, they also place greater responsibility on the user. For example, in order to use a breadboard kit to build an electronic device, the user needs a high degree of knowledge and experience. This is an important factor that designers should weigh when considering a modular architecture: The use of more-flexible systems often requires more-knowledgeable users.

NRO Space Systems Do Not Appear to Be Strong Candidates for Modularization

Our findings suggest that some systems might be better suited for modularity than others. To apply this knowledge about modular systems to the NRO, we developed a list of factors to help system designers determine if a system is a good candidate for modularity.

When we applied our factors to the NRO's space-based collection systems, we reached an inconclusive result: While some factors seem to encourage modularization, others seem to discourage it or are neutral. On one hand, the NRO faces uncertain future user needs, along with a customer base that desires a highly flexible product. Both of these factors encourage a modular architecture. On the other hand, the NRO relies on cutting-edge, state-of-the-art technologies in its systems, and these technologies do not lend themselves well to modularity. This is because rapid changes in technology can quickly outgrow the static interfaces in a modular architecture, rendering the entire system useless.

The NRO Needs to Be Able to Quantify the Value of Its Intelligence-Gathering Systems

So what can be done to move forward and make progress toward a more satisfying solution? What is really needed to provide a satisfying answer is a mathematical relationship that relates desired flexibility with the likelihood of investment gain or loss. To gain some perspective, we looked at how this calculation is done in another industry: parking garage design. The parking garage designer can easily quantify the balance between flexibility and investment risk. Revenue (in dollars) is a measure of value, and an interest rate is used to determine the change in value over time.

However, there is an important difference between commercial systems and the NRO's intelligence systems: It is very difficult to evaluate the *value* of intelligence systems and how that value *changes over time*. This observation leads to a key conclusion: It is not possible to find the optimum "knee in the curve" for implementing modularity if one is not able to assess the value of the intelligence resulting from the subject system.

How Can NRO Personnel Become Better Prepared to Deal with Uncertainty?

To investigate our second question, we started by thinking about other professionals who are regularly surrounded by uncertainty: stock traders; U.S. Navy Sea, Air, Land (SEAL) teams; and emergency room (ER) doctors. Practitioners of all three occupations must be comfortable dealing with surprise, and this idea yielded the two research questions that we sought to address in this work:

- Can people become more adept at planning for an uncertain future by studying surprise?
- Are there lessons for the IC in how different professionals respond to surprise?

To research this topic, we designed a framework to classify different professions based on the following two factors: (1) how quickly they typically have to respond to surprise and (2) the complexity of their work environment. We then conducted discussions with several professionals across a variety of fields to test our hypotheses.

We Identified Two Broad Categories of Responses to Surprise Among Different Professions

We found that most professionals who have to respond to surprises within seconds or minutes are usually skilled in touch labor—i.e., they work with their hands. This category includes surgeons, Navy SEALs, test pilots, and professional athletes. Practitioners in this category usually must control feelings of fear and anxiety when they encounter unexpected events, and they all have mental and physical rituals to help them manage these emotions.

Professionals who typically have more time to respond to surprises (e.g., hours, days, or weeks) are usually valued for their knowledge capital. This category includes chief executive officers (CEOs), ambassadors, military officers, and engineers. When encountering surprise, these practitioners must control ego, anger, and overreaction, and the most successful and agile practitioners in this category have typically developed mental rituals to help them manage these specific emotions.

The Level of Chaos in the Environment Also Affects People's Response to Surprise

We found that the level of chaos in the environment has a big effect on how people prepare for surprise. For example, those working in the most controlled environments, such as an athletic stadium, often have the luxury of being able to prepare a "what if" plan for every possible unexpected scenario because the range of possibilities is discrete and manageable. We found that professionals working in moderately chaotic environments tend to develop "what if" plans for the most likely scenarios, along with any scenario that represents an existential threat. When a professional of this sort encounters something in the environment that was not planned for, he or she relies on experience or training.

The Most Complex and Chaotic Situations Are Caused by Other Humans, Rather Than Something in the Environment

Regarding those working in the most complex environments, we arrived at an unexpected observation: All the individuals working in the most complex environments face surprises that are generated by other humans. A CEO, an ambassador, a Special Weapons and Tactics (SWAT) team captain, a Navy SEAL, and military general officers all fall within this category. We found that all of these professions face such complex operating environments—with an infinite number of things that can go wrong—that it does not make sense to develop comprehensive "what if" plans. Instead, the successful members of this group develop generalized frameworks that they can use to deal with surprise, regardless of the specifics of the surprise.

The Biggest Surprises Tend to Come from Third Parties

The final key finding from our research on surprise is that the biggest surprises are most likely to come from third parties—i.e., people and effects outside the immediate field of view. A Navy SEAL was the first to make this point to us, but nearly everyone else made the same observation.

The intuitive reason for this is that practitioners often spend a lot of time thinking about their adversaries, competitors, or key challenges and therefore develop a good understanding of how these forces are likely to behave. One way to address the threat of the unexpected third party is to conduct exercises to widen the organization's field of view and highlight potential alternative possibilities.

How Can the NRO's Organizational Processes Be Used to Promote Responsiveness and Creative Thought?

Our research on this final topic was motivated by the following objective: How did some organizations that have taken steps to become more responsive in promoting innovation and creative thought achieve this?

We looked at three companies suggested to us by NRO/AS&T: Pfizer, IBM, and Caterpillar. These companies have all been recently recognized in the media as having gone through transformations in order to better respond to pressures in the marketplace. However, each company reached a very different end state: Pfizer become more centralized, IBM started selling a completely different product, and Caterpillar became more decentralized. With all three companies looking to innovate, why did they take such different approaches?

Innovation Occurs for Many Reasons, Each Requiring a Different Approach

We found that innovation occurs for many reasons, and every situation requires a different approach. For example, one company might innovate to become more efficient (make better use of resources), another to become more effective (enhance current capabilities), and a third to become more agile (quickly adopt new technology). The reason for the innovation will help determine the approach taken.

As an example, we found that Pfizer decided to concentrate on anticancer and Alzheimer's drugs. To do this, it sold off and divested all of its unrelated properties so that it could concentrate on this high-risk, high-reward goal. In the process, it centralized its organization and processes to pursue a single mission.

By contrast, Caterpillar was interested in becoming more responsive to its customers' needs. To do this, the company decentralized and set up fully contained Caterpillar offices around the country, each containing everything needed to run the business: product experts, sales and maintenance teams, and finance and accounting personnel. In doing this, Caterpillar was able to customize its service to the local market, but this end goal required a different approach than that taken by Pfizer.

Conclusions

We conclude our research by noting that, even though all three topics appear to be very different, we observed three common lessons.

Modularity and Innovation Are Not Goals in Themselves

The first observation is that modularity and innovative methods are not goals by themselves—they are tools for meeting a particular goal. Instead of saying that the organization "needs to innovate" or "needs to implement a modular architecture,"

strategists should first set the priorities and the mission objectives. Then their organization will be in a position to determine what mechanisms should be used to meet the priorities.

Strategic Planning Would Be Beneficial for All Three Areas Discussed

The second observation is that success in modularity, innovation, and reacting to surprise all benefit from at least a partial ability to predict the future. Therefore, we conclude that any investments in developing strategic plans or visions, along with exercises designed to probe the future, can advance all three topics.

Solutions in All Three Areas Require Not Just Hardware, But Also People and Organizational Structures

Modularity, surprise, and innovative processes yield ways to evolve hardware, people, and corporate structures, respectively. Merely developing flexible hardware will not suffice because the hardware will require an equally flexible staff and organizational structure to design, implement, and operate it.