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TECHNOLOGY STRATEGY

1.0 OVERVIEW

Space and Naval Warfare Systems Center (SPAWARSYSCEN) Atlantic develops, delivers and supports information warfare missions in support of naval, joint, national, and coalition operations. This requires the command to develop expertise in a variety of enabling technologies, skillsets, and creating laboratory infrastructure critical to our ability to offer the best solutions to the warfighter. The technologies we use to cultivate these capabilities are advancing at an exponential rate. We must address the need to effectively implement and integrate these technologies across a spectrum of naval missions by shaping our organization to adeptly support the warfighter.

As a systems center of the Space and Naval Warfare Systems Command (SPAWARSYSOCOM), it is imperative that we align with our headquarters (HQ) strategic vision. The latest version (2018-2027) has three strategic objectives:

1. Accelerate and streamline delivery.
2. Drive cyber resiliency.
3. Optimize our organization, operations, and workforce.

Further, this technology strategy will align to SPAWARSYSCEN Atlantic strategic guidance to:

1. Shape our work on Naval capabilities for today and tomorrow.
2. Increase systems engineering and project management discipline.
3. Accelerate and streamline capability delivery.
4. Employ, develop, and retain a credentialed workforce, building technical leadership.
5. Optimize a secure lab, information technology (IT), and warehouse infrastructure.
6. Improve the processes the Leadership Council considers most essential to IPT success.

Our technology strategy must support these objectives through execution.

SPAWARSYSCEN Atlantic is also a member of the Naval Research & Development Establishment (NR&DE). The NR&DE includes the Navy’s Warfare Centers, Systems Centers, and laboratories, and is uniquely equipped with qualified world-class scientists and engineers who deliver solutions to complex warfighting problems. The NR&DE is positioned to leverage established relationships across its members, Federally Funded Research and Development Centers (FFRDCs), academia including University Affiliated Research Centers (UARCs), small businesses, and the broader defense industry. These relationships support collaboration as well as rapid prototyping and experimentation of advanced technologies. As a member of this establishment, our strengths and capabilities are aligned to NR&DE goals, and we leverage relationships within the establishment to ensure we can increase the body of knowledge in the
technologies outlined in this strategy across the Navy, as well as apply workforce and solutions wherever they reside.

Our imagination is unlimited, but our resources are not. We must be prudent in our investments but employ our ingenuity in technology areas relevant to naval needs. The technology strategy outlined in this document is the framework for how we focus and harness our imagination, take risks, and proactively address the needs of our warfighters. The strategy provides a roadmap for how we will adapt our technical workforce to technology changes.

This technology strategy, along with our organizational and business strategies, will guide our strategic initiatives, which will provide direction for external work acceptance and internal innovation programs. They will also be valuable communication tools to share our work and expertise with our workforce and outside customers.

Unlike previous years, this technology strategy’s themes primarily focus on workforce, culture, process improvements, and infrastructure to actively improve our technical health as an organization, and the products we provide our customers. The strategy will provide a blueprint for how the Technical Execution Strategic Steering Committee (TESSC) will govern those themes as part of a long-term endeavor.

2.0 PURPOSE

The distinctive capabilities of SPAWARSYSCEN Atlantic, operating across the science and engineering spectrum, uniquely position us to explore technologies for new and legacy systems and offer a unique opportunity to bring new research and strong engineering together to provide our warfighter innovative solutions in new ways. The SPAWARSYSCEN Atlantic Technology Strategy provides:

1. The goals, outcomes, and strategic initiatives that position SPAWARSYSCEN Atlantic to rapidly respond to the exponential change in technologies we deliver to our customers.

2. Our list of Technology Growth Areas (TGAs) and the specific disciplines within them (i.e., sub-elements) where we must develop knowledge, skills, abilities, and resources (e.g., tools and laboratories) through education and execution.

To achieve our stated goals, it is imperative that we evolve and shape our organization, its workforce, and the solutions we provide the warfighter with purpose and consistency. This includes our culture, competence with emerging technologies, total workforce management (TWM) construct, processes, tools, and facilities. This strategy guides our path forward in these areas. It defines such things as the changes in culture we seek to enact, our technologies of interest, and focus on hiring and retention. It will link holistically to broader strategies, such as
our business strategy and business thrust areas, which will guide the innovative capabilities we provide the warfighter.

Clearly, we are stronger in some areas of this strategy than others but we have not quantified our strengths. This plan will guide our Naval Innovative Science and Engineering (NISE) program, internal discretionary investments, Defense Acquisition Workforce Development Fund (Section 852), Competency Development Models (CDMs) and Career Progression Models (CPMs), training/education opportunities, and hiring goals. It will also drive work acceptance and lab/facility infrastructure allocations and tools.

The proper skills and programmatic emphasis will provide SPAWARSYSCEN Atlantic scientists, engineers, specialists, technicians, and logisticians opportunities to influence acquisition programs early in a project’s conception, planning, and execution. This enables our technical workforce to offer important insights and advice in technology innovations, solutions (operations and sustainment), design patterns, and best practices.

A significant component of our current and future success is our ability to support today’s mission and maintain a level of expertise relevant to the existing systems of our naval forces. A robust and thorough understanding of our legacy systems, in addition to a forward-leaning, innovative workforce, will ensure SPAWARSYSCEN Atlantic is postured to provide a relevant laboratory capability well into the future. As we continue to strengthen our alignment to our sponsors’ technical needs today, we must prepare for the anticipated demands of tomorrow. It is imperative we choose and execute a strategy that provides the most leverage to answer tomorrow’s critical needs. We must be mindful and deliberate in how we select and complete projects such that we create key skillsets in technology areas for future requirements. Our work must also strike the right balance of representative skills across the engineering lifecycle. This technology strategy provides the basis to ensure we are accepting and doing work correctly, continuing to position SPAWARSYSCEN Atlantic as a premier solutions provider for information warfare.

3.0 GOALS, OUTCOMES, AND STRATEGIC INITIATIVES

The technology strategy is focused on four core goals/outcomes that represent our long-term, multi-faceted approach to TGA adoption. Achieving them will improve our ability to fulfill our primary purpose—providing the warfighter with capabilities that enable them to outpace the threat and dominate our adversaries. Note that the implementation of these goals will leverage existing command governance bodies and current execution teams wherever possible.

For a definitive list of the governance structure (i.e., TESSC, Business Board), please refer to the COG. The TESSC will, as part of TGA execution, define strategic initiatives to develop processes, metrics, and measures with TGA community leaders to prioritize and coordinate TGA
requirements with the appropriate governance bodies. Our ability to allocate and/or acquire resources is a key dependency to the success of TGA adoption. As part of this effort, the TESSC will assist with streamlining and adapting command policy and procedure to reduce organizational friction and increase velocity of solutions.

3.1 EVOLUTION TO A LEARNING ORGANIZATION AND COMMUNITY CULTURE

Our first goal is to shape SPAWARSYSCEN Atlantic’s culture into one skilled at creating, acquiring, and transferring knowledge, and at modifying its behavior to reflect new knowledge and insights. In a learning organization, every person considers himself or herself a valued knowledge worker who contributes to the learning potential of the organization without fear of judgment and/or reprisal. Gathering and sharing of knowledge and solutions becomes a natural part of day-to-day activity, not something simply done through formal training models. The technical workforce and the organization’s leadership evolves faster due to the maturity of the communications and the ability to set goals, receive substantive feedback, and adjust to new outcomes. A community culture is necessary to successfully transition to a learning driven organization. A community culture is characterized by trust, a drive to share within cross-functional teams. Cross-functional teams are characterized by full transparency, and supportive, non-attributional behavior.

To drive SPAWARSYSCEN Atlantic toward a learning organization with community culture, [we] will implement the following strategic initiatives:

1. Train, educate, and incentivize the workforce to gather and share knowledge across the organization.
2. Review and evolve command policies and processes to promote and protect proper risk taking, risk management, collaboration, and sharing of solutions, knowledge, and wisdom.
3. Align our technology strategy efforts (e.g., experimentation, process, tools) within the context of our new culture construct.
4. Establish a community-driven governance model to ensure the whole organization is brought to bear in all work execution.

3.1.1 EXPECTATIONS OF COMMUNITY LEADERSHIP

Given the nature of modern system design, no technology squarely resides in a singular competency. A primary competency is delegated as a TGA community lead (see paragraph 4.1). Other impacted competencies will provide supplemental support to ensure that considerations
are made for all relevant technical interests. When investigating new technologies/methodologies, a standard set of feedback is expected to be reported back to the command for tracking and planning purposes. That feedback includes:

1. TGA sub-element and core competency targets assessment
2. Technical maturity (i.e. how soon will the technology be adequately mature for operational use)
3. Technical opportunities and shortfalls
4. Risks/considerations
5. Personnel preparedness:
   - Training shortfalls
   - Hiring considerations
6. Suggested/standard use cases
7. Solution development options
8. Business opportunity communication for department consumption
9. Path forward recommendations

### 3.2 TOTAL WORKFORCE MANAGEMENT

Our second goal is to have a rigorous, instrumented total workforce management (TWM) framework that holistically addresses technology workforce requirements across the command (e.g., workforce development and retraining). The TWM processes will include continually developing CDMs, as well as models for cross-functional education and career progression.

The command has a number of efforts focused on our workforce. This strategy will provide an enterprise focus and consolidate individual competency activities into a coordinated whole.

1. Develop and implement a process ensuring TGAs are mapped into competency and workforce development models, department mission thrust areas, command S&T and training investments (e.g., NISE, IDPs, training programs), and employee individual development plans through TWM efforts.
2. Institutionalize processes for TGA analyses as part of work acceptance, NISE, and 852 funded efforts throughout the command.

### 3.3 CAO/IPT PROCESSES AND CONOPs

For our third goal, the command will have standardized approaches to streamline and improve outcomes of all internal workflows and processes dealing with quickly advancing technology needs. All internally defined processes will facilitate the growth of these technical priorities and support the acquisition, learning, collaboration, and dissemination of technical capabilities to the maximum extent allowed by authoritative policy.
The responsibility for developing competence in technology (especially the TGAs) belongs to the competencies. The responsibility for delivery to the customer belongs to the departments. The IPTs are where department and competency “meet in the middle” and where the true execution occurs. The TESSC provides the TGAs, and the departments provide opportunities to employ those technologies on behalf of the customers. The strength and efficiency of this symbiosis is key to command health. The ultimate evolution of our work-shaping, acceptance, and IPT execution is a joint effort across all command governance bodies, and will use TGAs as their foundation. More specifically, strategic initiative execution will ensure:

1. TGA alignment and resource capacity will be tightly integrated and prioritized in work shaping, acceptance, and execution processes.

2. Processes for staffing IPTs will incorporate a more rigorous definition of needed skillsets based on a more detailed CDM/CPM framework, as part of an overarching, TGA-focused Human Capital Management plan.

3. IPT health assessments will include alignment to and leveraging of TGAs in the IPT’s work.

4. TGA processes as a whole will be integrate with command Continuous Process Improvement (CPI).

### 3.4 TOOLS AND FACILITIES

Fourth, we will adapt and build facilities to support the cross-functional teaming and potential site requirements that our technical capabilities as a whole will require (e.g., Assured Communications transport, on-demand manufacturing gear and laboratory spaces, and Navy Cyber Range). Requirements and priorities for technology growth targets will be injected into the command’s investments in its facilities.

We will also provide rapid access to each technology we promote in this strategy. Our command tools will shift to support ease of adoption, consistency, resiliency, and predictability of technology implementation. We will reduce man-hours spent on non-technical tasks in technology experimentation, and facilitate knowledge sharing and community engagement.

### 4.0 TECHNOLOGY AREAS OF FOCUS

The technology strategy is primarily focused on how we develop new technology-based core competency in harmony with our existing technology skills. In this way the command will rapidly and consistently deliver new technical capabilities (personnel resources and technology) to our customers through its Competency Aligned Organization (CAO)/Integrated Product Team (IPT) construct.
4.1 **TGA Graduation to Core Competency**

As above, TGAs are technology areas that we must develop into command core competencies. But how is “core competency” defined? A TGA, or one of its sub-elements, will be graduated into core competency status when the command demonstrates the following:

1. Consistent, clear and managed innovation investments and workforce development structure/models that are being used to develop our workforce and enable them to deliver rapidly prototyped capability to our customers.
2. Consistent ability to fulfill staffing requirements for resources in that technology area.
3. A healthy community (i.e., a community with a managed and shared knowledge resource, which engages internally and externally).
4. Demand on command resources for customer work in the TGA meet Business Board approved goals.

This technology strategy is wholly focused on developing and communicating consistent methodologies and metrics to transition a TGA, or a sub-element to a core competency and convey overall technical health of SPAWARSYSCEN Atlantic.

Note that the authoritative list of the command’s core competencies will continue to be developed, refined, and supported through the broader strategic planning and workforce development activities owned by the Business Board.

If the command is unable to hire or grow workforce in a particular TGA, or it is deemed irrelevant to customer needs, it will be abandoned. The process by which TGAs are governed and assessed is owned and implemented by the TESSC.

4.2 **Technology Growth Areas (TGAs)**

SPAWARSYSCEN Atlantic has core competencies in many technologies and disciplines. Core competencies are defined as groupings of knowledge, skills, and abilities, not to be confused with Competency Aligned Organization entities (e.g., Competency 4.x, 5.x). They are imperative for us to deliver our current capabilities to our customers. TGAs represent technologies and disciplines where we must increase our competency and capacity (i.e., future core competencies of the command). They are related to future requirements, leading and maturing technologies, and IT service models. Once these TGAs or sub-elements of the TGAs become part of our core competency, they will cease to be TGAs, much like the other technology areas the command has heavily invested in. New TGAs will take their place as we continually evolve and develop our skills in support of our customers.
Our current list of TGAs and corresponding champion organizations is as follows:

- Assured Communications Competency 5.5
- Autonomy Competency 7.0
- Cloud Computing Competency 5.5
- Collaboration and Social Networking Competency 5.4
- Cyber Warfare Competency 5.9
- Data Sciences and Analytics Technologies Competency 5.6
- Enterprise Resource Tools Competency 5.4
- Internet of Things (IoT) and Embedded Systems Competency 5.6
- Mobility Competency 5.5
- Model-Based Systems Engineering (MBSE) Competency 5.2
- On-Demand Manufacturing Competency 4.7

The listed organizations are the main points of contact regarding TGA community leadership, and are responsible for the development and growth of these TGAs across all competencies. They are also responsible for ensuring communication and coordination of the TGAs across the command.

Appendix A contains amplifying details regarding the TGAs, but the community leaders will maintain living content on each of the TGAs on the Command Operating Guide.

### 4.2.1 TGA Selection

Operating from the context of the SPAWARSYSCEN Atlantic mission, the technology guidance presented in this document is developed from three major perspectives: line-of-sight to strategic guidance from leadership, technology needs, and technology availability. Naval technology needs are primarily assessed using overarching DoD, naval, and SPAWARSYSCOM strategic plans, investment budgets, and formal naval needs and gaps statements. Available and emerging technologies are evaluated using a significant literature review as well as consideration of technology adoption in commercial markets (Figure 1), in addition to customer demand. Using this approach, it is possible to predict technology, skillsets, and laboratory capabilities needed to support the warfighter now and in the foreseeable future.
While broad DoD and Department of the Navy (DON) strategies encompass many technology areas, not all are well aligned to our information warfare mission. This strategic document focuses on enabling technologies relevant to the SPAWARSYSCEN Atlantic mission and is anticipated to play a significant role in current and future naval systems. To gain an understanding of naval needs, various requirements and technology gaps were studied, as well as strategic roadmaps from various resource sponsors. Additionally, numerous research and technology publications were studied to determine the current state of the art and maturity of relevant technologies. Many TGAs will be broad, but while integrating them into our organization, we will define core competency TGA sub-elements. We recognize that each of these areas overlap and interact with other areas.

5.0 OVERARCHING GUIDANCE AND MANAGEMENT

In the process of embedding our TGAs into our execution culture, we will take a fresh look at our core competencies, and how we share capabilities and solutions across all technology areas under our purview. We must:

1. Ensure development and understanding of our TGAs, their value, and their future as a collaborative endeavor up, down, and across our organization.
2. Unlock the potential of our workforce in alignment with the TGAs.
3. Engage our external customers and partners in sharing technology, problem sets, and solutions within the TGAs. Create and implement sections within the communications
plan and governance model to prioritize our customers’ and partners’ engagement in TGA exploration and application within the command.

The TESSC will shape and communicate overall progress on technology strategy implementation to the Business Board. This pillar is owned by TESSC leadership and will:

1. Create and implement a communication plan to ensure all command stakeholders (department and competency), have full cognizance of the TGAs (specifically command specializations within the TGAs), as well as our plans and progress towards their maturation.
2. Ensure the creation, consolidation, instrumentation, and formalization of processes relevant to TGA and core competency management and technology strategy execution.
3. Define and collect metrics and measures and establish dashboards for all elements of TGA and core competency integration (efficacy and efficiency) to track and report progress and improve efficiencies regarding technology health to the command and external partners. Appendix B contains an initial high-level look at metrics relevant to TGA implementation and overall workforce assessment.
4. Provide guidelines and protections to promote acceptable risk taking. This will include setting limits, defining smart risks, rewarding smart failures and creating a safe environment for risk taking.
5. Resolve conflicts and remove impediments.

5.1 Technology Strategy Resourcing

Technology strategy implementation will require significant resources to complete. The implementation plan that will accompany the strategy will outline:

1. Expectations of aligned, currently funded internal activities and efforts (e.g., Total Workforce Management TATs, NISE efforts, CDM working group) that support technology strategy execution.
2. Any relevant external activities that may impact technology strategy execution (e.g., DoN talent management system acquisition, customer execution/usage of TGAs, Department Thrust Areas).
3. Additional resources/funding required for governance, tooling.
4. Additional resources/funding for training and education.
6.0 SUMMARY

SPAWARSYSCEN Atlantic delivers and supports information warfare solutions for naval, joint, national, and coalition warfighters. The command’s information warfare mission requires expertise in a variety of enabling technologies, skillsets, and laboratory infrastructure critical to our ability to offer the best solutions to the warfighter. SPAWARSYSCOM and SPAWARSYSCEN Atlantic’s strategic visions and guidance includes the objectives: accelerate and streamline delivery, drive cyber resiliency, and optimize our organization, operations, and workforce. We must evolve SPAWARSYSCEN Atlantic’s command culture into a learning-driven culture skilled at creating, acquiring, and transferring knowledge, and at modifying its behavior to reflect new knowledge and insights. The end-result is good work for the command, good work for the workforce, and a customer that can exceed its mission parameters and outpace its threat. This strategy provides the framework by which this will be accomplished.
APPENDIX A

1.0 OVERVIEW OF SPECIFIC TECHNOLOGY GROWTH AREAS (TGAS)

As a solution provider of technical expertise and services, it is imperative that we strive to achieve the necessary balance of technical personnel, laboratory infrastructure, work acceptance, and contract augmentation (to supplement our workforce where we lack available capabilities) to enable growth in relevant technical areas while meeting current command demands. Various steering committees under the Business Board are responsible for ensuring processes, metrics, and expectation thresholds are established to assess progress in achieving these goals. Based on studies referenced earlier in Figure 1, some TGAs are, or are projected to be, of significant importance to our naval customers. TGAs are intended to be broad and overarching in a given functional area facilitating current work alignment without creating significant exceptions where alignment may not exist. Using broad TGA definitions also minimizes the number of TGAs for ease of understanding and usefulness. The maturation of sub-elements of each TGA will occur at different rates, and so will graduate to core competency at different times. The current TGAs are introduced and defined below.

1.0.1 Assured Communications

The Assured Communications TGA addresses technologies providing robust, protected, resilient, and reliable information infrastructure undergirding the Navy’s overall information environment and allowing uninterrupted worldwide communication between deployed units and forces ashore. The Navy’s information infrastructure must maintain essential network and data link services across secured segments of the electromagnetic spectrum to transport, share, store, protect, and disseminate critical combat information.

The assured communications area of interest focuses on technologies that explore transmission methods and datalinks enabling greater information bandwidth and increasing security, range, and power efficiency. Exploitation of unused radio spectrum and development of Radio Frequency (RF) sensing capability will be essential in promoting multiband dynamic spectrum agility. Advanced modulation and spread spectrum techniques, as well as low probability of intercept, low probability of detection, and electromagnetic countermeasures resistance approaches are of particular interest. Technologies will include application in multiple transmission spectrums, including RF, acoustics, and optical. This growth area includes networking technologies promoting stable and efficient networks. Networking techniques such as application awareness, resilient and dynamic routing, and attack tolerance supporting the Cyber Warfare TGA are also included in this technology focus.

Key technology opportunities to achieve assured communications include robust waveforms and networks, converged communications and electronic maneuver warfare, and resilience...
through autonomous adaptation. Position, navigation and timing system sensor fusion technologies and Global Positioning System (GPS) alternatives to supplement in Precision Navigation and Timing (PNT) denied areas are required for assured communications.

**Robust Waveforms and Networks**

- Make links stronger against threats
  - Signal processing improvements
  - Adaptation in multiple areas
  - Antenna technologies
  - Multiple frequencies: VLF, HF, UHF, VHF, SHF, EHF to include L, S, Ku, Ka, X, W, and optical
  - Identify jamming or interference versus other network impairments
  - RF spectral density control
- Classification of jamming techniques and localization of interfering emitters
- Maintaining capacity in a robust anti-jam waveform and achieving spectrum efficiency
- Adaptive routing
- Covert communication modes
- Overall robust network architecture
- Incorporation of resiliency into waveform design

**Converged Communications & Electronic Warfare**

- Cooperation among blue force communications, jamming, and sensing
  - Information sharing of network terrain
  - Multi-function jamming operations
  - Waveform adaptation
  - Spectrum sharing, awareness, and agility
  - Scheduling of disparate asynchronous signals among numerous nodes
  - Reliable signal reception
  - Interference alignment
- Continuous contingency planning at the network and physical layers
Resilience through Autonomous Adaptation

- Make the collection of links stronger than the sum of the individual parts
  - Heterogeneous networking
  - Network interface and control
  - Rapid network adaptation
  - Software defined networking
  - Collective reporting and efficient dissemination of the radio environment characteristics
  - Sensing at a fast time scale to detect communications and network attacks
  - Vigilant monitoring of networks to detect compromises and attempts for intrusions

1.0.2 Autonomy

The Autonomy TGA covers techniques applicable to systems, enabling them to adapt their actions to changes in their mission and operating environment without the intervention of a human operator. This TGA includes assistants and decision support systems implemented through Artificial Intelligence (AI) and machine learning. Autonomous systems typically use embedded sensors and onboard preprocessing to survey the environment and make course changes or changes to initial objectives based on the situation they encounter. More specifically, this TGA includes technologies to thwart against autonomous systems such as small form factor detection, as well as, swarm and counter swarm autonomous algorithms, control (e.g., multi/best path analysis), techniques, and tactics. Autonomy has been broadened to include autonomous AI systems, assisted decision aids, and information aggregators and advisors.

1.0.3 Cloud Computing

Bottom line up front, is that cloud computing equals IT of the 21st Century. If you’re doing IT, you’re “using” cloud in one form or another. It is imperative that we remain at the leading edge of “cloud” technologies, design patterns, practices, and service models. As IT service models such as “cloud” continue to evolve and be embraced by the DoD, their use in mission-critical operations will become more prevalent. Security, flexibility/agility, cost savings, and innovation are our leadership’s top drivers for cloud adoption. The strategic use of the cloud for IT modernization and digital transformation will be realized through the implementation and use of resilient infrastructure, platform, and software services. Coupling SecDevOps—a secure software engineering practice that securely (Sec) unifies software development (Dev) and software operations (Ops)—processes and continuous deployment capabilities with
emerging cloud vendors will provide greater capability and speed to operations for our customers at a further reduced cost.

National Institute of Standards and Technology Special Publication 800-145 defines cloud computing as a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources such as networks, servers, storage, applications, and services that can be rapidly provisioned and released with minimal management effort or service provider interaction.

1.0.4 Collaboration and Social Networking

Commercial industry and social communities have grown beyond wikis, forums, documents, and file spaces. Social networking technologies are maturing and becoming tightly integrated into day-to-day design and execution processes as well as real world operations. When you consider current events, understanding social networking technologies and their application to warfighting and defense is essential to our operations. The Navy has already embraced “ChatOps”—the integration of open-source chat capabilities into Navy operations over naval messages—and it is imperative that we engage to be the leaders in this and other sub-elements of this maturing TGA. We must inculcate collaboration and social interaction for sharing design patterns and best practices into our engineering culture, and incorporate those supporting capabilities into the systems we deliver. The technologies of this TGA also allow social interaction to be aggregated, assessed, and pushed back into the supporting systems as structured data that can be used to support better decision-making. Current technology drivers are pushing systems to become more natural and making socially produced information more available. Technical work in this area may cover any task supporting a major commercial or open source system such as Slack, Jabber, SharePoint, Yammer, MediaWiki or any task supporting a custom solution providing social networking or collaborative technology capabilities.

1.0.5 Cyber Warfare

The cyber warfare growth area is perhaps the most broadly defined category and includes the subcategories of IT in a security context: design, development, validation, assessment and testing, deployment, and operations—attack, defense, exploitation, and intelligence. This category includes defensive and offensive technologies used to operate, configure, control, secure, maintain, and restore the infrastructures and resident data, including IP networks, RF networks, computer systems, embedded processors and controllers, operations and management processes, and physical systems, as well as how they are used specifically as “weapons” in their own right. Novel methods for cyber situational awareness and cyber rapid recovery are of interest. Industrial control systems (part of the infrastructure) require
additional cyber controls due to their expected useful life span in the field. There is a wealth of technologies and capabilities used in this domain, including other TGAs. Some examples include the protection of information on single and multilevel systems, identity management, and forensics, ensuring availability, integrity, authentication, confidentiality, and nonrepudiation of data sources. The figure below represents a thought model outlining the challenges of cyber in technology security and cyber security operational domains represented in a command, control, communications, computers, combat systems, intelligence, surveillance, and reconnaissance (C5ISR) framework.

![Figure 2: Cyber CSISR Framework](image)

### 1.0.6 Data Sciences and Analytics Technologies

The data sciences and analytics TGA and artificial intelligence (AI) are emerging technologies that are being increasingly leveraged to increase naval readiness and warfighting effectiveness. This TGA includes technologies and technical processes enabling and enhancing the reliability, assurance, integration, interoperability, delivery, value of data and information assets. This data may be high-volume, high-velocity, and/or high-variety and be derived from diverse operations concept areas (Combat, ISR, EMW, Cyber, etc.). This TGA includes specialized technology capabilities that capture, ingest, persist, analyze, and visualize data and help our
customers perceive, visualize, and make decisions about their environment. These technologies and processes will further address the transformation of physical machines and components into smart, networked devices that generate data. Data sciences and analytics include advanced approaches in data organization, machine and deep learning, applied AI, data visualization, and decision aids.

**Data Science** is an interdisciplinary field about the scientific methods, processes, and systems to extract knowledge and insight from data in various forms. Data science builds on techniques and theories from many fields, including computer science, informatics, mathematics, statistics, signal processing, psychology, and complex systems. Data science is a scientific, inquisitive, and experimental process: exploring, asking questions, doing what-if analyses, and questioning existing assumptions and processes. Data science requires leveraging an understanding of the warfighter’s mission and goals to apply data-centric, digital capabilities.

**Analytics** is the process of inspecting, cleaning, transforming, and modeling data with the goal of discovering useful information, uncovering anomalies, making predictions, and supporting decision making. Data analytics can be done with the software tools commonly used as part of advanced analytics disciplines such as business intelligence, predictive analytics, and data mining or through ad hoc, exploratory processes. This includes adapting, scaling, and applying standardized processes such as the Cross Industry Standard Process for Data Mining (CRISP-DM) to system requirements, data experiments, and problem statements. The technologies associated with data analytics cover the entire process from data acquisition to data visualization, and are generally focused on statistical techniques or applied machine and deep learning algorithms.

**Machine Learning** is the subfield of computer science that gives computers the capability to learn from and make predictions about data without being explicitly programmed. Machine learning tasks are typically classified into supervised, unsupervised, or reinforcement learning, depending on the nature of the learning signal or feedback available to a system. Machine learning starts with a body of data and uses various algorithms to derive a model generalized from learned experiences or patterns. These algorithms and techniques allow us to apply computational power to areas where it is difficult or infeasible for analysts or decision makers to be involved.

**Deep Learning** refers to algorithms attempting to model high level abstractions in data by loosely mimicking the activity of biological nervous systems and/or areas of the brain. These algorithms are based on artificial neural network concepts that were never previously realized due to technological constraints, but recent advancements and improvements in neuroscience,

1 https://en.wikipedia.org/wiki/Data_science
mathematics, and computational power have allowed for the building, training, and deployment of these specialized techniques. These networks utilize a cascade of multiple layers of nonlinear processing units for feature extraction and transformation to capture hierarchies of concepts and representations.

**AI** is the study and design of systems that perceive their environment and take actions maximizing the system’s chances of success based on assigned goals. Data-driven machine learning allows for new advances, but AI is a broad field with many complex problems that will have a major impact on humanity and society. AI problems over time have generally fallen into the following taxonomy: (1) systems thinking like humans; (2) systems acting like humans; (3) systems thinking rationally; and (4) systems acting rationally. Most AI systems are targeted at specific application areas (Weak or Narrow AI) like natural language and speech processing, image recognition, or self-driving vehicles. The ultimate goal is a general solution at least as advanced as a human across the full range of cognitive tasks called Strong/Deep AI or Artificial General Intelligence (AGI). These technologies allow us to support, influence, and automate decision loops like the Observe, Orient, Decide, Act (OODA) loop and allow for collaborative interaction techniques (e.g., Human-Machine Teaming). Our first step in exploring this sub-element is the development of automated decision aids.

## 1.0.7 Enterprise Resource Tools

“Enterprise software describes a collection of computer programs with common business applications, tools for modeling how the entire organization works, and development tools for building applications unique to the organization. The software is intended to solve an enterprise-wide problem, rather than a departmental problem. Enterprise level software aims to improve the enterprise’s productivity and efficiency by providing business logic support functionality.”

“Services provided by enterprise software are typically business-oriented tools such as online shopping and online payment processing, interactive product catalogue, automated billing systems, security, ... enterprise content management, IT service management, customer relationship management, enterprise resource planning, business intelligence, project management, collaboration, human resource management, manufacturing, occupational health and safety, enterprise application integration, and enterprise forms automation. As enterprises have similar departments and systems in common, enterprise software is often available as a

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2 https://en.wikipedia.org/wiki/Artificial_intelligence
3 https://en.wikipedia.org/wiki/Enterprise_software
suite of customizable programs. Generally, the complexity of these tools requires specialist capabilities and specific knowledge.”

Generally, our Enterprise Resource Planning (ERP) technical work can be divided into two categories. The first is any task supporting a major commercial ERP system such as SAP, Oracle eBusiness Suite, PeopleSoft, Epicor, Infor, or Microsoft Dynamic ERP. The second is any task supporting a custom solution for business or logistics decision support systems across an entire enterprise such as Navy Tactical Command Support System (NTCSS). We will continue to grow our workforce to support tasking across the software life cycle, including operations support. This TGA may be the most difficult to manage because it requires a broad range and mix of expertise including the integration of credentials and skillsets such as commercial software certifications, software development, system administration and configuration activities, and business process engineering.

1.0.8 Internet of Things (IoT) and Embedded Systems

Data is generated everywhere: weapons systems on a ship, intrusion detection systems in a network, electromagnetic sensors, and devices connected to a warfighter’s body. The Internet of Things (IoT) is the meta term that defines this “everything is a sensor on the network” approach, and how the data from all of these instrumented devices can be used to gain greater understanding and situational awareness, enabling better decision making.

The IoT design pattern allows objects to be sensed or controlled remotely across an existing network infrastructure, creating opportunities for more direct integration of the physical world into computer-based systems. This has the potential to increase efficiency, accuracy, and economic benefit, and reduce human intervention. When IoT is augmented with sensors and actuators, the technology becomes an instance of the more general class of cyber-physical systems, encompassing technologies such as smart grids, virtual power plants, smart homes, intelligent transportation, and smart cities. Each thing is uniquely identifiable through its embedded computing system but is also able to interoperate within the existing Internet infrastructure.

IoT is expected to offer advanced connectivity of devices, systems, and services going beyond machine-to-machine communications and covering a variety of protocols, domains, and applications. The interconnection of these embedded devices including smart objects is expected to usher in automation in nearly all fields, making the whole of the information gathered greater than the sum of its parts.

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4 https://en.wikipedia.org/wiki/Enterprise_software
5 https://en.wikipedia.org/wiki/Internet_of_things
Smart, networked machines can enable efficiencies and create new capabilities to do more, faster, and cheaper work. Devices from thermostats to jet engines that were once strictly mechanical are now seamless blends of hardware and software—packages of microcontrollers, sensors, and, above all, networked software ingesting lots of data, understanding context, and making intelligent decisions. Machine learning and data-driven optimization will revolutionize the way we operate and exert real-time control to optimize complicated systems.

**Embedded Systems** encompasses computer systems that perform a particular function within a larger system without direct human interactions. Operation of these systems is often in real time. Processor throughput, memory management, and power-efficient software implementation are critical to meet the demands of embedded systems, particularly in small form-factor implementations. Specialized skills are required in the use of field-programmable gate arrays, digital signal processors, and advanced reduced instruction set computer machines, either individually or in conjunction with each other or with general-purpose processors. Efficient memory use and programming practices will require the ability to develop application code often tailored to reduce the number of processor cycles. Embedded systems are robust and often must perform their function in forward-deployed, remote, and energy-sparse locations. As a result, energy generation and harvesting are often part of the integrated system as well as onboard advanced sensor packages.

### 1.0.9 Mobility

The mobility TGA in a naval context is more than just the incorporation of mobile phones, tablets, and laptops as fully functional clients in the enterprise. It also focuses on providing solutions giving the warfighter the capability to engage with a dynamic mobile environment anytime and anywhere. The realization of effective mobility solutions is strongly dependent on other TGAs such as cyber, embedded systems, and assured communications. This TGA includes the wireless technology and infrastructure to connect and authenticate to the enterprise while enforcing enterprise specific security policies on mobile devices to access to enterprise data.

Interest areas consist of:

1. Communication infrastructure (e.g., 3G, 4G LTE, 5G, and 802.11x)
2. Network infrastructure: routers, switches, and firewalls
3. Mobile devices: smart phones, tablets, and laptops; mobile device managers
4. Identity management
5. Network access and authentication
6. Software development (e.g., Android and iOS)
7. Device security
8. Localization


1.0.10 Model-Based Systems Engineering (MBSE)

The MBSE TGA includes the technologies used to support the development, management, and application of virtual constructs of varying fidelity across the spectrum of systems engineering activities. This includes operational capability functions and mission threads, system requirements, design, analysis, verification, validation, operations, and maintenance activities. MBSE technologies enhance productivity by creating models that can be quickly and repeatedly run based on differing parameters to develop a wide range of data that can be analyzed and assessed for outcomes without having to create or use more costly physical resources. MBSE activities are intended to lower the risk and cost of system development and operation through analyses resulting in the ability to streamline business processes, analyze business and mission needs, refine and decompose stakeholder and system requirements, and verify and validate system design through simulations of the design within its intended operating environment. Higher fidelity MBSE techniques will use simulations, live data from field systems, and other operational data to apply predictive methodologies to identify system inefficiencies, focus maintenance activities, and reduce downtime.

1.0.11 On-Demand Manufacturing

On-Demand Manufacturing is a manufacturing process wherein products and/or components are produced, when or as they are required at the point of use, using additive and/or traditional manufacturing methods. Additive manufacturing includes processes producing parts for concept models, rapid prototypes, functional testing, and form-and-fit testing models. This technology shows great promise for the Navy in support of areas such as rapid prototyping and on-demand sparing while deployed. Additive manufacturing can choose from a wide range of materials and processes for rapid prototypes, tooling, and patterns including:

**Stereo Lithography (SLA):** “SLA produces photopolymer resin parts with a smooth surface finish”. SLA has a “wide variety of material and post-processing options” and is “ideal for concept models, rapid prototypes, master patterns, snap fit assemblies, form-and-fit testing, and tradeshow models.”


**Selective Laser Sintering (SLS):** “SLS produces nylon parts with great durability with highly complex geometries, snap fits, and living hinges.” SLS is “ideal for functional testing, rapid
prototyping, low-volume manufacturing parts, and high-heat and chemically resistant applications.”7

**Direct Metal Printing (DMP):** “DMP produces complex stainless steel and titanium metal parts that [must] be manufactured quickly, accurately, and with no costly and time consuming tooling. The fully dense printed parts have excellent surface finish and feature detail resolution.” 8

**Color Jet Printing (CJP):** “CJP produces full-color parts ideal for concept models, architectural models and demonstration models. This technology offers full-color, quick production time and parts [with clear or wax coating for a smooth finish.]” 9

**Fused Deposition Modeling (FDM):** FDM “produces plastic parts for concept models, engineering models, functional testing, consumer products, high-heat applications and initial prototypes.” FDM offers “a variety of materials that are high-strength including production-quality ABS” 10 (acrylonitrile butadiene styrene).

**3D Additive Manufacturing (AM):** 3D Printers are being used to prototype and produce parts, components, and pieces. The goal of 3D AM is to provide parts as quickly and effectively as possible, at the least cost, and at the point of use. A variety of printers are required to support different materials, such as plastics, carbon fiber, metal, aluminum, and rubber and different sizes and shapes. In addition, 3D AM requiring sophisticated software and sophisticated 3D scanning tools capable of turning a 3D scan into 3D software usable in 3D printers.

Traditional manufacturing methods include the computer numeric control machine, the circuit card milling machine, lathes, drill presses, and a wide assortment of machine shop tooling. On-Demand Manufacturing enables rapid prototyping to enhance lifecycle sustainment support.

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APPENDIX B

Relevant Metrics and Measures. Place holder for sample metrics and measures used to track technology strategy execution.

1. Community/learning driven organization. This will be largely drive by capability of the tools we choose and are focused at assessing community health/vibrancy, and impact.
   a. Avg engagements per user.
   b. Peer-peer recognition.
   c. Total active engagements per month.
   d. Sub-group community evaluations.
   e. Artifact (e.g., Code, design, and architecture content, wiki article) measures (including re-use).

2. Total Workforce Management.
   a. Workforce attributes (e.g., CDM/CPM, documentation of experience).
   b. Hiring and retention.

3. CAO/IPT CONOPs and Processes.
   a. Demand signal growth/contraction and backlog.
   b. Solutions/products in TGAs.
   c. Requests for service.
   d. Process assessment (e.g., process timelines and steps).

4. Command [physical/virtual] resources (e.g., tools and facilities).
   a. Tools acquisition and operations in line with TGA and governance process requirements.
   b. Facilities measured by normal (i.e. capability, sq. ft., equipment).