FUTURES

> "*Everything changes so fast and the rules are against us... But I am confident enough in the intellect and advice, that we will come up with the right solution, even if it is only 80 percent. If we do nothing, we lose. I am willing to take risk.*"
>
> **—General Robert B. Neller, 37th Commandant of the Marine Corps CMC, Innovation Symposium 23 February 2016**

Introduction

The Marine Corps' 2015 Force Development Strategic Plan stated that the Marine Corps must innovate and adapt to a fast, unpredictable moving future to remain ahead of our adversaries. The Commandant reinforced these ideas when he spoke at the Marine Corps Warfighting Lab's Innovation Symposium stating,

"The system is broken. The Pentagon can't fix itself, let alone these emerging issues. There are an increasing number of hot spots around the world; no two are alike, and the circumstances are ever changing and increasingly complex. Technologies that could help have often evolved before older technologies are even fielded."

These statements demonstrate the Marine Corps' commitment to innovation and determination to be technologically ahead of its adversaries and competitors. To do this, the Marine Corps must be capable of innovation across the range of military operations (ROMO) and the full spectrum of domain capabilities, to include maritime, land, air, space and cyber, as well as the human domain.

The PEO monitors Marine Corps, Navy, the other Services and Joint efforts that relate to

futures assessment, concept development and innovation that assist in articulating potential impacts and influences that span the PEO LS portfolio. This effort supports and enables the identification and prioritization of the PEO LS top program issues and associated technology needs that will in turn inform, influence, and align S&T investment.

Guiding Documents

Two recent guidance documents have proven to be especially impactful in this effort. In November 2014, the Secretary of Defense published the Defense Innovation Initiative, which included guidance "to pursue innovative ways to sustain and advance our military superiority for the 21st century and improve business operations throughout the Department." Referencing advancements in stealth, networked precision strike, and surveillance in the 1970s and 1980s, the Secretary directed the identification of a "third offset strategy that puts the competitive advantage firmly in the hands of American power projection over the coming decades." The Third Offset Strategy describes the broad nature of capabilities that the Department of Defense expects to realize over the coming years by pursuing developments in advanced technologies, conducting experimentation with

prototype systems, and increasing emphasis on war gaming. This strategy will help the DoD better understand new concepts and the need to innovate across the entire DoD enterprise.

Wargaming

The Deputy Secretary of Defense addressed concerns with the DoD's decreased ability to test concepts, capabilities, and plans using simulation and other techniques, such as – Wargaming – in his memorandum "Wargaming and Innovation." The Deputy directed that, "To most effectively pursue an innovative third offset strategy, avoid operational and technological surprise, and make the best use of our limited resources, we need to reinvigorate, institutionalize, and systematize wargaming across the Department." He further explained that revitalizing wargaming across the DoD enterprise fits well with the DoD's Innovation Initiative and bolsters the Department's ability to field military relevant systems and technologies, adapting to dynamic tactical and operations challenges.

Concept-to-Capability Process

PEO LS continues to pursue the goals outlined in these two important directives as part of its Concept-to-Capability process. This process, depicted in Figure 2-1 in section 2 (S&T Collaboration and Engagement), provides a validated, repeatable process for addressing an uncertain future within the context of the Service's current force development system. This process is also executed in conjunction with the Deputy Commandant for Combat Development and Integration, Marine Corps Warfighting Laboratory/Futures Directorate (MCWL/FD) and the Capabilities Development Directorate (CDD). Ultimately this collaboration is conducted within the overarching Planning Programming, Budget and Execution (PPBE) and Service force development processes. The PEO LS approach further gains valuable insight from a series of recently conducted wargames designed to examine aspects of the Marine Corps' new Expeditionary Force

21 (EF 21) capstone concept, which included: Ground Warrior 2015, Expeditionary Advanced Base Operations 2015, and MAGTF Warrior 2016 wargames. These efforts also assist in mitigating future risks by providing well-researched areas for focused investment based on technical issues that share common warfighting connections to multiple programs within the PEO. Focusing S&T funding on these key areas enables the Marine Corps to maximize its Return on Investment (ROI) and to better prepare for the future.

The Combat Developer (represented by DC CD&I's MCWL/FD) depicted in Figure 3-1 initiates Concept to Capability process outlined in this plan. PEO LS engages with the MCWL/FD to understand and contribute to futures assessments, concept development, and other force development actions to include experimentation and wargaming. This engagement and communication helps inform future required capabilities. Those concepts, and the process that follows to produce the capabilities needed, are driven by wide-ranging assessments of the future that include everything from adversary capabilities to fiscal constraints.

Assessment of Plausible Future Security Environments

PEO LS S&T must access a wide variety of sources and perspectives to develop and validate future threats and opportunities as they apply to the PEO LS portfolio. To obtain a tailored perspective of the future, the S&T Director uses the Assessment of Plausible Future Security Environments (Figure 3-2), which examines the wide range of potential futures: preferable, probable, and alternative. The assessment of plausible futures helps to augment existing concepts as part of the initial steps of the Concept-to-Capability process.

This methodology examines current and future capability gaps to inform the ATIP, providing relevant context by identifying the most likely future security environment as
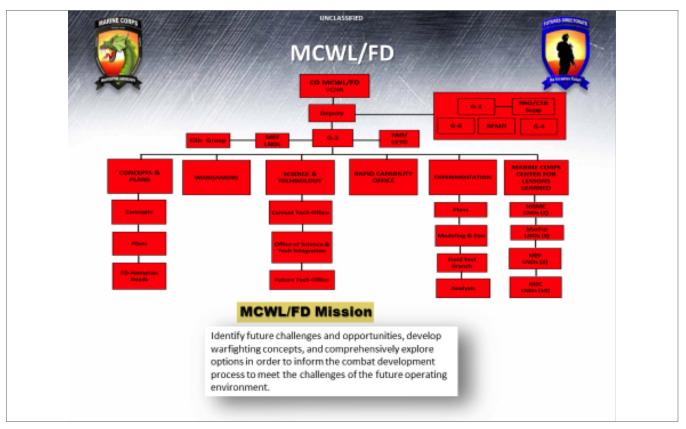
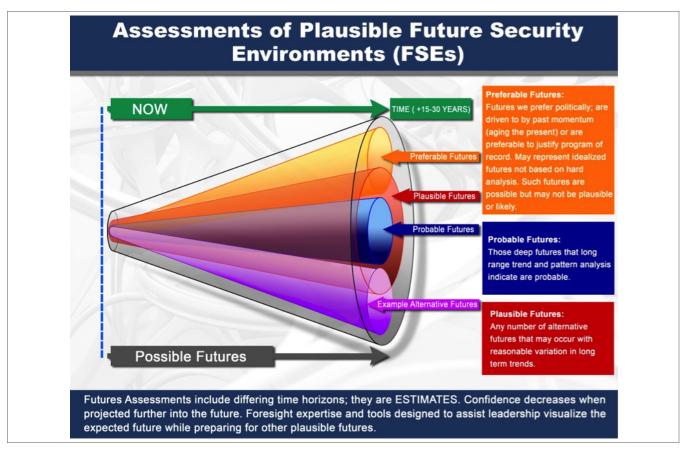Figure 3-1. Futures Directorate Organizational Chart

Figure 3-2. Assessments of Plausible Future Security Environments (FSEs)

well as the capabilities required to address the challenges the future force will likely face. The process references and responds to Department of Defense, Joint, and Service assessments and guidance relative to what the future is expected to hold. It also considers other likely and plausible futures (as well as less probable scenarios) from industry, academia, and international community experts.

These probable futures are derived from baseline forecasts that project existing trends into the out years. Trends and forecasts used to support PEO LS' examination of the most likely future security environments are outlined in the following key U.S. defense-related publications:

➤ *Sustaining U.S. Global Leadership: Priorities for 21st Century Defense (DoD 2012).*

➤ *Capstone Concept for Joint Operations: Joint Force 2020 (CCJO 2012).*

➤ *Joint Operational Access Concept (JOAC2012).*

➤ *Mission Command White Paper (CJCS 2012).*

➤ *2012 U.S. Marine Corps S&T Strategic Plan.*

➤ *Gaining and Maintaining Access: An Army-Marine Corps Concept (ARCIC/MCCDC 2012).*

➤ *The Marine Corps Service Campaign Plan 2014-2022 (2014).*

➤ *Quadrennial Defense Review 2014 (QDR).*

➤ *Expeditionary Force 21 (HQMC 2014).*

➤ *The Defense Innovation Initiative (Secretary of Defense memo, 2014).*

➤ *36th Commandant's Planning Guidance 2015.*

➤ *Wargaming and Innovation (Deputy Secretary of Defense memo, 2015).*

➤ *The National Military Strategy of the United States of America 2015 (NMS).*

➤ *Naval S&T Strategy: Innovations for the Future Force (ONR 2015).*

➤ *A Cooperative Strategy for 21st Century Seapower (SecNav 2015).*

➤ *National Security Strategy (NSS 2015).*

➤ *2015 Marine Corps Security Environment Forecast (MCSEF).*

➤ *Joint Concept for Rapid Aggregation (CJCS 2015).*

➤ *Force Development Strategic Plan (CG MCCDC, DC CD&I 2015).*

➤ *Marine Corps Operating Concept, "How an Expeditionary Force Operates in the 21st Century" (HQMC 2016)*

Relevant trends and forecasts outlined in these documents include:

➤ An era of fiscal austerity and national debt.

➤ Cyber threats from governments and non-government actors.

➤ Technological diffusion/weapons of mass destruction proliferation.

➤ Increased urbanization, particularly in the littorals.

➤ The traditional view of the three primary domains (air, land and sea) within the "global commons," with the increasingly important addition of the space, cyberspace, and human domains.

➤ The demand for critical resources is likely to continue to exceed supply, even with advanced conservation and efficiency measures coupled with alternative sources.

➤ Transnational crime, regional instability, and violent extremism.

> "The future requires Marines to embrace change to leverage the rapid advancements in technology at the pace of the 21st Century in order to gain an operational advantage over any potential adversary we may face in the future."
>
> **—General Robert B. Neller,**
> **37th Commandant of the Marine Corps CMC PB17 Posture Written Testimony**

➤ An increased emphasis on a forward-postured crisis response force in readiness to address an unstable and uncertain operating environment, with an emphasis on Phases 0 through 2 (Shape, Deter, Seize Initiative).

Influences within the Marine Corps on Future Development

The Commandant of the Marine Corps has said the Marine Corps must be able to innovate, adapt and win with the equipment that we currently have in our inventory. The ATIP is designed to leverage efforts throughout the S&T enterprise, to find solutions to the current technology needs of the PEO LS PORs, and to look into the future to see what is in the "Realm of the Possible." This Futures Section is intended to inform where the Marine Corps could go with its investment funding if the technology proves to be worth the needed investment and suggest technology trends that may influence the way the Marine Corps will fight in the future.

3.1 Autonomy

Why Is Autonomy Important?

Autonomous systems, unmanned systems and other associated technologies are beginning to have a significant impact on warfare as we know it today. Many feel that with the proper level of Research and Development (R&D), the physical and cognitive burdens placed on today's warfighter can be considerably reduced through the development and application of appropriately focused autonomous technologies. These newly designed and appropriately focused autonomous systems will not replace the warfighter but complement these future warriors by extending their reach as well as providing potentially unlimited persistent capabilities without degradation due to warfighter fatigue or without loss of situational awareness. Additionally, these systems will help the warfighter perform certain functions with speed, reliability and precision beyond existing human capability. Drs. David and Nielsen concluded in the Defense Science Board 2016 Summer Study on Autonomy that,

"*While difficult to quantify, the study concluded that autonomy—fueled by advances in artificial intelligence—has attained a 'tipping point' in value. Autonomous capabilities are increasingly ubiquitous and are readily available to allies and adversaries alike. The study therefore concluded that DoD must take immediate action to accelerate its exploitation of autonomy while also preparing to counter autonomy employed by adversaries.*"

What Is Autonomy?

As we bring the topic of autonomy into focus, it is useful to provide a few definitions to ensure there is a clear understanding of what we are discussing as well as the relationships between the topics. Below is a list of definitions delivered by Dr. Lawrence G. Shattuck, Director, Human Systems Integration Program, Naval Postgraduate School, Monterey, CA in his presentation at NASA's Human Systems Integration Division 2015 workshop on Transitioning to Autonomy: Changes in Role of Humans in Air Transportation.

Autonomy is the ability of an intelligent system to independently compose and select among different courses of action to accomplish goals based on its knowledge and understanding of the world, itself, and the situation.

Artificial Intelligence (AI) is the ability of a system to act appropriately in an uncertain environment, where an appropriate action is that which increases the probability of success, and success is the achievement of behavioral sub-goals that support the system's ultimate goal.

Intelligent System is an application of AI to a particular problem domain. Usually very specialized -- not "general intelligence".

Robotics focuses on systems incorporating sensors and actuators that operate autonomously or semi-autonomously in cooperation with humans. Robotics research emphasizes intelligence and adaptability to cope with unstructured environments.

Automation emphasizes efficiency, productivity, quality, and reliability, focusing on systems that operate without direct control, often in structured environments over extended periods, and on the explicit structuring of such environments.

Agent is a self-activating, self-sufficient and persistent computation:

➤ May be an intelligent system.

➤ May include significant automation.

➤ Is capable of modifying the manner in which it achieves objectives (fulfills purpose).

➤ May reside and act entirely in the cyber world, or be embodied in a device such as a robot.

History of Military Use

Since the inception of Nikola Tesla's wireless-radio technology in the 1890s, autonomous and semi-autonomous systems have found their way into military application. During World War I, Germany utilized Tesla's wireless-radio technology to guide an explosive laden motor boat into a British vessel (Singer, 2009). During World War II, the Germans again used this wireless-radio technology to remotely pilot a drone; manually steering the explosive laden drone to its target. During the Vietnam War, the U.S. flew the Firefly drone on nearly 3,500 reconnaissance missions in support of operations in South East Asia. Laser-guided munitions were a staple for forces during the Persian Gulf War and soon after, Global Position System Satellite navigation data would be introduced into a new era of smart munitions. The aftermath of the attacks on the World Trade Center 2001, provided an additional catalyst, furthering the movement towards autonomy as the Military expanded its drone fleet from less than 100 to more than 7,000 Unmanned Air Systems (UAS).

Congress got involved in movement towards autonomy when then Senator John Warner, Chairman of the Senate Armed Services Committee added in the 2001 National Defense Authorization Act that one-third of all attack aircraft to be unmanned by 2010 and one-third of all ground combat vehicles driverless by 2015. The insertion of this language demonstrated the growing acceptance and belief that robotics and autonomous systems would play a significant role on the future battlefield (Singer, 2009).

Where Are We Today?

Today, few images highlight the increasingly automated nature of modern warfare better than a photograph of the eerily opaque, windowless nose of the MQ-1 Predator drone, a centerpiece of U.S. military and counterterrorism efforts in the Middle East and Africa. Drone warfare is merely the leading edge of a broader worldwide trend toward more autonomous methods of warfighting. Evidence of this trend can be seen in South Korea's SGR-A1 armed sentry

robots guarding the DMZ, Israel's 'Iron Dome' active protection system, miniaturized lethal drones such as the U.S. Army's Switchblade, long-range intercontinental drones like the U.K. Taranis and the U.S. X47-B which are just a few examples of the versatility that these automated systems provide. Military and intelligence agencies worldwide are developing increasingly sophisticated and autonomous software algorithms for use in cyberwarfare – conflicts between electronic agents in electronic space that nevertheless have the potential to inflict considerable human losses. Incorporating the advances in algorithm development for analyzing massive datasets, systems are being developed that have the capability to outperform human calculations of threat potential, target value, operational risk, mission cost, casualty estimates and other key strategic variables. Taken together, these developments represent a profound shift in our traditional understanding of the role of human beings in the conduct of war.

Commercially, there has been a rapid expansion in the global market for robotics and other intelligent systems to address consumer and industrial applications. Autonomy is being embedded in a growing array of software systems to enhance speed and consistency of decision-making. Additionally, governmental entities, motivated by economic development opportunities as well as growing security issues, are investing basic and applied research dollars to address the projected future needs for these types of systems. Applications include commercial endeavors such as IBM's Watson, the use of robotics in ports and mines worldwide, autonomous vehicles (from autopilot drones to self-driving cars), automated logistics and supply chain management, and many more. Japanese and U.S. companies invested more than $2 billion in autonomous systems in 2014, led by Apple, Facebook, Google, Hitachi, IBM, Intel, LinkedIn, NEC, Yahoo, and Twitter.

Where Are We Going?

The DoD has strategically increased its adoption of robotics and unmanned vehicle systems in the last decade, but the vast majority of the systems are remotely operated rather than autonomous. Recent programs such as the Autonomous Aerial Cargo Utility System (AACUS), an Innovative Naval Prototype, have shown a progression from pre-programming and remote control to autonomous functionality. Initially, robotics and unmanned systems were largely driven by perceived improvements in performance and cost; however, actual advantages are proving to be more complex. Safety improves by reducing the lethality of warfare and the ability to adopt riskier tactics because a system is unmanned. Accuracy also improves, with more endurance, range, and speed in comparison to manned vehicles. Systems are also more flexible and more mobile. Autonomy also enables the execution of new missions—particularly in domains such as cyber and electronic warfare, in which decision speed is critical to success.

The following areas were highlighted in the Defense Science Board's 2016 Summer Study on Autonomy as opportunities for DoD to exploit ongoing advances in autonomy:

Reduction of Manpower-realizing the promise of unmanned systems to reduce manpower and cost:

➤ Mitigation of unmanned–reduce manpower, cost, logistics of existing platforms.

➤ Reduction of operators–further reduction of manning and specially qualified operators to control more than one platform or asset.

➤ Information filtering–reduction of sheer data volume collected by unmanned systems. Systems that make decisions on what not to show.

Tactical Advantage–added advantages on the battlefield:

➤ Faster reaction time–local decisions faster than human cycle.

➤ Deeper penetration–operation in inaccessible or denied environments.

➤ Extended operation–can operate longer than human cycles.

➤ Agility and adaptation–ability to adjust to changing environments and mission goals, ability to use in secondary missions.

Trusted Companion–System capable of providing real-time, tactical and proximate support to warfighters:

➤ Faithful servant–utilization of competent mules, closer proximity to humans, operations not in contact with adversary.

➤ Loyal wingman–high tempo coordination and interaction, operations in contact with adversary.

3.1.1 Manned-Unmanned Teaming (MUM-T)

MUM-T is a term used to describe the relationships established between manned and unmanned systems while carrying out a common mission as an integrated team. More specifically, MUM-T is the overarching term used to describe platform interoperability and shared asset control to achieve a common operational mission objective. This term also includes the concepts of "loyal wingman" for air combat missions and segments of missions such as MUM air refueling. This capability is especially vital for missions such as target cueing and handoff between manned and unmanned systems, where the operators not only require direct voice communications between the participants, but also a high degree of geospatial fidelity to accurately depict each team member's location with regard to the object being monitored.

MUM-T efforts have steadily increased as technology has improved, and users have found new and innovative methods to exploit this enhanced mission capability. Current missions include reconnaissance, surveillance, and target acquisition (RSTA); transport; countermining; explosive ordnance disposal; and the use of armed unmanned tactical wheeled vehicles for checkpoint security inspections. While much of this effort has been focused on exploiting the potential of unmanned air vehicles, the MUM-T concept associated with ground operations is becoming more pervasive. These developments have been the catalyst for creating a number of key MUM-T capabilities, which include:

➤ Defeating explosive ground surface, sub surface (tunnel), and sea hazards from greater standoff distances.

➤ Developing of a squad multi-purpose Unmanned Ground Vehicle (UGV) that incorporates a modular payload architecture to rapidly adapt payload to mission needs with minimum impact to the operator's cognitive workload.

➤ Providing an organic aerial resupply capability to assure resupply for steady state and emergency operations that unburdens dismounted units over extended distances and reduces risk to personnel conducting manned resupply operations in contested terrain.

➤ Developing the capability to conduct multi-unmanned systems missions with minimal operator input providing a single operator with the ability to control multiple unmanned systems without cognitive overload.

As a technology concept, MUM-T acknowledges the capabilities and limitations of current technologies (as well as those of today's warrior) and provides a vision for how we can optimize these technologies to best support the warfighter. Future investments in effective MUM-T would greatly complement warfighters and enhance their ability, making them more effective and more survivable in the future anti-access/area denial (A2/AD) environment.

3.1.2 The Test and Evaluation Challenge for Future Autonomous Systems

Autonomous systems present significant, unique challenges to the DoD test and evaluation (T&E) community. As the level of autonomy increases, test and evaluation needs to transition away from the execution of specifically planned scenarios to a new test paradigm that understands and validates the decisions made in a dynamic environment. The challenges facing the T&E community include the ability to evaluate emerging autonomous systems' safety, suitability and performance, as well as human interaction with autonomous systems. The T&E community must be able to predict a system's behavior and decision processing. The community must also be able to characterize the environment in which the autonomous system will operate and evaluate the ability of those systems that are sensing the environment and formulating a world model based on this sensed environment. The test technology community must advance the technology readiness levels of key supporting technologies and processes needed to improve DoD's T&E capability.

The Defense Science Board Task Force on the Role of Autonomy in DoD Systems recommended that USD (AT&L) review the current test technology programs, including those of the Test Resource Management Center, to ensure that the unique test requirements of autonomous systems are addressed. Among the topics identified were:

➤ Creating techniques for coping with the difficulty of defining test cases and expected results for systems that operate in complex environments and do not generate deterministic responses.

➤ Measuring trust that an autonomous system will interact with its human supervisor as intended.

➤ Developing approaches that make the basis of autonomous system decisions more apparent to its users.

➤ Advancing technologies for creating and characterizing realistic operational test environments for autonomous systems.

➤ Leveraging the benefits of robust simulation to create meaningful test environments.

Based on the results of their research, it is likely that the DoD will need to improve its operational test ranges so that they can better support the evaluation of autonomous systems.

3.2 PEO LS Future Focus

Exponential Technologies

Exponential technologies are those technologies that fundamentally disrupt the 'balance of power'. These technologies typically have the following characteristics:

➤ Decentralization: The work is performed by a diverse network of individuals using mass collaboration in a virtual environment.

➤ Transparency: The work is usually open-source.

The impact of 'transparency' is further amplified when technologies coalesce into open platforms, thus enabling insertion and upgrades by rapidly building on previous versions. Furthermore, the ability to combine and recombine technologies lends itself to exponential innovation — where the combined capability is greater than the sum of its parts.

PEO Land Systems' future investments will focus heavily on exponential technologies to include:

➤ Counter UAS Technologies

➤ Active Protection System (APS)

➤ Autonomy/Robotics

➤ Big Data Analytics

➤ Additive Manufacturing (3-D Printing)

➤ Artificial Intelligence/Deep Learning

➤ Condition Based Maintenance (CBM)

Counter UAS Technologies

The list of countries that now possess and operate some type of UAS capability continues to grow with the proliferation of increasingly affordable and available technology. The widespread proliferation of Unmanned Aerial Systems (UAS) among both state and non-state actors is cause for concern to U.S. operational commanders. These unmanned aircraft are being developed with more technologically advanced systems and capabilities. Some have the ability to duplicate many of the capabilities of manned aircraft for both surveillance/ reconnaissance and attack missions. They also can be elusive, small enough and/or slow enough to elude detection by standard early warning sensor systems and in large numbers (Swarms) pose a formidable threat to friendly forces. To adequately address this growing threat the Marine Corps will have to develop an integrated, expeditionary suite of networked capabilities to detect, identify, cue, and kinetically or non-kinetically prosecute enemy unmanned air, ground, and surface / sub-surface systems.

Active Protection Systems (APS)

The rapid advancement of anti-armor systems is requiring the Marine Corps' as well as the other services to consider non-traditional protective measures as the cost and weight of traditional systems continue to rise. One of these non-traditional methods is the use of Active Protection Systems. A technology that safeguards vehicles and personnel from incoming fire by identifying warning cues, detecting threats, classifying threats and actively using countermeasures to defeat the threat.

APS technologies use sensors and/or radars, computer processing, fire control technology, interceptors and countermeasures to prevent line-of-sight guided anti-tank missiles/ projectiles from acquiring and/or destroying a target. There two categories of APS systems characterized by their defense mechanisms; "soft-kill" and "hard-kill." A Soft-kill system uses electronic countermeasures to confuse or jam the incoming missiles targeting mechanism by way of electro-optical signals, infrared, or laser jamming. While "hard-kill" countermeasures physically counteract incoming missiles and Rocket-Propelled Grenades by intercepting them at close range if needed.

The Department of the Army is looking at a range of domestically produced and allied international solutions for their Modular Active Protection Systems (MAPS) program. Rafael's Trophy system, Artis Corporation's Iron Curtain, Israeli Military Industry's Iron Fist, UBT/Rheinmetall's ADS system, and others are under consideration. The goal for the newest APS or MAPS will be to enhance the tracking sensor technology for identifying the origin and for detecting enemy optics prior to a hostile fire event. Ultimately, this will help create an autonomous or semi-autonomous shield to protect virtually any vehicle on which the system is installed.

Autonomy/Robotics

Autonomy and robotics provide capabilities that effect operational and tactical maneuver in the littorals through the use of unmanned autonomous systems with minimal human interaction and control. These capabilities include unmanned ground vehicles, robots, air vehicles, sensors, UxS swarms, and connectors that work side by side with the Warfighter. Ideally, these systems will be able to collaborate and share information to reduce the operator workload, relieving him or her of physical and cognitive burdens. The goal is to reduce risk to human life by using unmanned systems to accomplish potentially dangerous tasks.

Big Data Analytics

Big Data Analytics describes the exponential growth and availability of data, both structured and unstructured, so large or complex that traditional data processes applications are inadequate. Big data analytics will help the user gain insights from a massive amount of data, enabling more accurate analysis, modeling and predictions. It will also transform the ability to draw actionable intelligence from a myriad of sensors and nodes at the tactical edge. It can provide commanders at all levels information ranging from mundane tasks, like a vehicle needs an oil change, to the immediate threat of a roadside Improvised Explosive Device. The near real-time transmitting, receiving, gathering and acting on this information can greatly benefit the Marine Corps.

Additive Manufacturing (3-D Printing)

Additive Manufacturing is the process of making a three-dimensional solid object of virtually any shape from a digital image. This is achieved by using an additive process, where successive layers of material are laid down in different shapes. 3-D printers could transform military logistics by allowing units to print equipment and spare parts in the field, greatly reducing response time. While there is a logistical burden associated with 3-D printing, it could be offset by its advantages. The Marine Corps wants to explore the potential for significantly increased efficiencies in logistics through reduction of inventories and determining other areas of military application.

Artificial Intelligence / Deep Learning

Earlier in this section we described Artificial Intelligence (AI) as the ability of a system to act appropriately in an uncertain environment, where an appropriate action is that which increases the probability of success, and success is the achievement of behavioral sub-goals that support the system's ultimate goal. One way to achieve AI is through use of Artificial Neural Networks (ANN), an advanced statistical technique that simulates learning and experience.

ANNs are statistical models directly inspired by and partially modeled on biological neural networks. They are capable of modeling and processing nonlinear relationships between inputs and outputs in parallel. The related algorithms are part of the broader field of machine learning and can be used in many applications. These artificial neural networks are characterized by containing adaptive weights along paths between neurons that can be tuned by a learning algorithm that learns from observed data in order to improve the model.

Deep learning is a process that applies ANN technologies to solve complex problems. This is done by weighting the neurons along a neural network path (a chain of neurons) to achieve the desired outcome or find the correct path. The neurons in this instance can be thought of as computational stages, where the path to the next stage is achieved through trial and error (either through supervised or unsupervised methods) until the correct outcome or path is achieved. The more complex the problem the longer the chain or computational stages and the deeper the learning.

A key area of interest for the Marine Corps lies in AI's ability to handle/analyze large volumes of decision support data, typically more than

humans can handle. Much of this low level decisions support data can go unanalyzed or be overlooked, particularly during periods of high tempo contingency operations. Developing a capability to deal with this "Big Data" issue will require the application of an AI capability that can concatenate hundreds of small rote operations/algorithms, quickly piecing together meaningful knowledge aiding decision makers at all levels make better informed decisions. The ability of a system to deal with large volumes of data and conduct rigorous repetitive, low-level tasks quickly and with minimal error has the potential of freeing the warfighter to conduct higher level tasks.

Condition Based Maintenance (CBM)

Condition Based Maintenance is a central component of Total Productive Maintenance (TPM). CBM is the application and integration of processes, technologies, and knowledge-based capabilities to achieve target availability, reliability, and operation. CBM also supports costs of Marine Corps systems and components across their life cycles. TPM is a comprehensive approach to maintenance intended not only to prevent and correct equipment failures, but also to optimize equipment performance and extend equipment life cycles. Another key component of TPM is Reliability Centered Maintenance (RCM), which is a method of analysis that captures and assesses operational and maintenance data to enable decisions that improve equipment design, operational capability, and readiness. RCM is a logical decision process that provides the "evidence of need" for both reactive and proactive maintenance tasks that support CBM processes. RCM involves performing only those maintenance tasks that will reduce the probability of a failure or mitigate the consequences of failure, based on analysis of each failure mode and the consequence of failure.

Summary

The Marine Corps' S&T investment today will enable the force to counter military threats as well as overcome any advantages that our future adversaries may seek. They can expand the options available to commanders, including options left of phase 0 that can potentially prevent conflict. The Marine Corps' ability to anticipate the mid to long term (3-5 years and 6-30 years) operating environment will be critical to finding the key technologies that will ensure the future force can adapt to win. Focusing S&T on these key technologies can provide the technological advantage the warfighter will need to succeed on the future battlefield and potentially provide a springboard to the next generation of unmatched military capabilities.

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