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Prepared statement by:

Bryan Clark
Senior Fellow, Hudson Institute

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October 14, 2023

Chairman Gallagher, Ranking Member Khanna, and distinguished members of the committee, thank you for the opportunity to discuss the Replicator initiative and DoD's overall efforts to field uncrewed systems. Since its announcement last month, Pentagon officials have said little about Replicator, except that it is intended to field thousands of uncrewed systems during the next two years. The initiative's main goal, according to Deputy Defense Secretary Hicks, is to provide attritable mass that can counter the geographic and capacity advantages enjoyed by China's People's Liberation Army (PLA) in potential western Pacific confrontations.[1]

There is little evidence the DoD and its industry partners can field thousands of operationally-relevant uncrewed systems in the next two years. The Pentagon's anemic procurement of uncrewed systems has generally discouraged industry from ramping up its production capacity.[2] And in those cases where privately-funded companies or traditional defense contractors have invested in manufacturing infrastructure, they have lost money or exited the sector entirely.[3]

But production capacity is not the biggest problem. Even if Replicator is successful, simply adding mass to today's US military is unlikely to improve its ability to deter or defeat China. With its proximity to likely areas of conflict, lack of global responsibilities, and ability to focus on US forces, the PLA can field targets at a lower cost and greater scale than the US military can generate successful shots on target. If it competes only in terms of mass, the DoD will find itself perpetually playing catch-up.[4]

However, there are glimmers of hope. In her discussion of Replicator, Deputy Secretary of Defense Hicks suggested the initiative is designed to exploit the creativity of US warfighters in addressing problems faced by today's operational commanders. Compared to chasing mass, this approach offers a better path to gaining advantage over the PLA and could mitigate the challenges US industry will likely face in rapidly producing thousands of militarily-relevant uncrewed systems. But unlocking Replicator's ability to deliver innovative solutions for pressing operational problems will require the DoD to integrate uncrewed systems into the mainline force rather than continuing to treat them only as surveillance systems or extensions of crewed ships and aircraft.

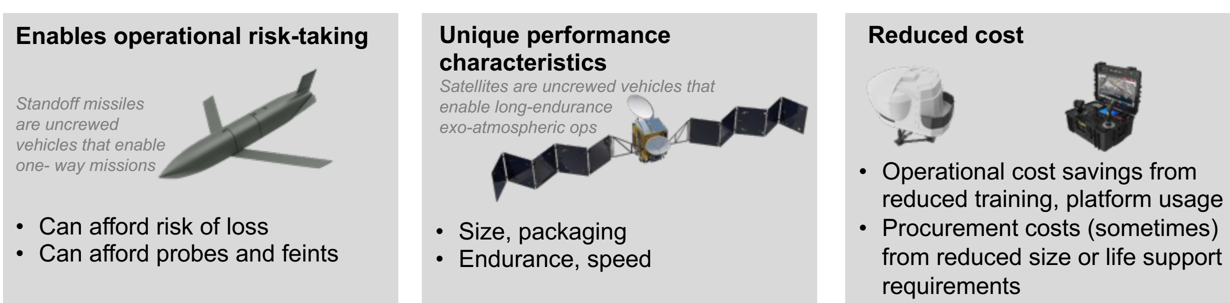
Until the twenty-first century, the DoD mainly accomplished integration by aligning doctrine and procedures because humans operated nearly all equipment. Today, automation and machine-to-machine communication between vehicles, platforms, and systems reduce the need for human operators to act as intermediaries—in most missions, increasing operator involvement is more likely to reduce performance than to improve it.

Integration, rather than long-term research and development (R&D), should therefore be the Pentagon's focus for Replicator. The DoD does not have time to develop sophisticated new uncrewed systems from scratch, nor does it need to. Existing and emerging uncrewed technologies can give US and allied militaries the edge they need against the PLA if combined with existing units and orchestrated in ways that create adaptability for friendly forces and uncertainty for the enemy.

Replicator should pursue adaptability, not mass

In prioritizing mass, Replicator seems to rely on the same uncrewed system characteristics US forces have exploited for decades, summarized in figure 1. Because they do not carry human operators, even expensive uncrewed vehicles may be lost to combat or equipment failure with little regret.[5] Without the confines of human limitations, uncrewed systems can operate in unforgiving environments or circumstances such as space. And without human operators, uncrewed vehicles can be less expensive than their manned counterparts due to fewer requirements for life support, protection, live training, or multi-mission capability.

Figure 1: System-Level Value Proposition For Pursuing Uncrewed Solutions



High-priority uncrewed systems being developed by the DoD like the Air Force's Autonomous Combat Platform (ACP) (formerly Collaborative Combat Aircraft), Army Air-Launched Effects (ALE), and Navy Large Uncrewed Surface Vessel (LUSV) are exploiting these characteristics to extend the reach and persistence of their crewed ship, aircraft, or artillery teammates.[6] Such manned-unmanned teaming (MUM-T) made sense when the US military was dominant and trying to maximize efficiencies.[7] However, this approach also tends to perpetuate the limitations of crewed systems, which operate in standardized formations for sustainment and protection and rely on well-defined doctrine and procedures that facilitate training.[8]

Binding uncrewed systems to the predictable operations of their crewed counterparts plays into the PLA's concept of system destruction warfare, or systems warfare. Under this approach, the PLA assesses the systems of systems (SoS) US forces are likely to use in combat and their potential vulnerabilities. The PLA then develops and fields capabilities that can attack what it perceives as US weaknesses and undermine the ability of US and allied militaries to intervene on behalf of allies like Taiwan.[9] For example, the PLA fields a variety of electronic warfare systems that target key US networks and has exploited commercial and proliferated military technologies to undermine traditional US advantages in air defense, precision strike, and long-range power projection.[10]

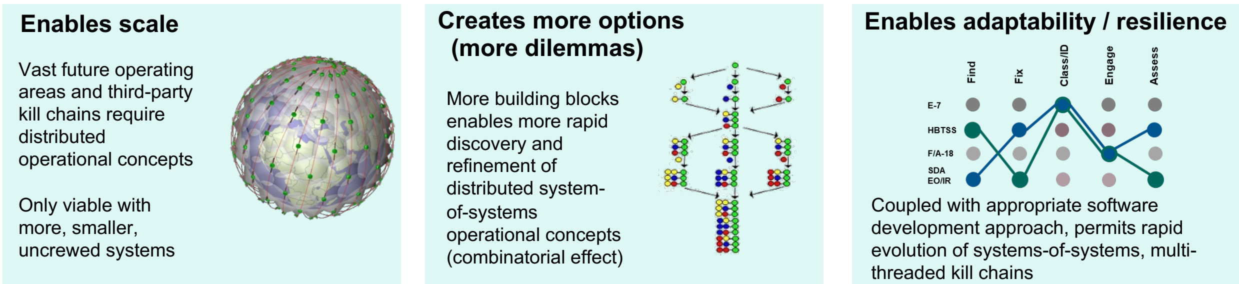
The US military will need to be less predictable and more adaptable to gain an edge against the PLA. Replicator could help if it prioritizes operational innovation, as Secretary Hicks noted in her announcements, and seeks advantages from force employment and associated command, control, and communications (C3) capabilities instead of strictly through superior weapon, sensor, or platform technology. This, rather than mass, is the goal of the Ukrainian military in fielding uncrewed systems, whose efforts Secretary Hicks cited in her Replicator announcement. Uncrewed systems on the sea and in the air have provided Ukraine's military modes of attack and fires coordination that Russian forces have often been unable to anticipate or counter.[11]

The US military is already pursuing more adaptable operational approaches that could employ systems emerging from the Replicator initiative. The Joint Warfighting Concept (JWC), Distributed Maritime Operations (DMO) concept, and Joint All-Domain Command and Control (JADC2) initiative rely on distribution; recomposable force packages; and long-range effects chains connecting sensors, commanders, and weapons or electronic warfare systems to undermine PLA systems warfare.[12] By degrading an opponent's sensing and sense-making while affording US forces more options for offensive action, these initiatives aim to increase the US military's lethality and resilience.

Budget constraints will prevent the US military from becoming more distributed and recomposable by simply growing the existing, mostly crewed, force. To surmount this obstacle, the DoD will need to expand the proportion of the force that is uncrewed while investing in the ability to identify and integrate new effects chains using AI-enabled C3 software.[13] Rather than acting as extensions of crewed units, uncrewed systems in future effects chains will need to perform as independent elements of force packages or SoS.[14]

As figure 2 summarizes, adopting an SoS approach to force employment will allow the US military to fully exploit the characteristics of uncrewed systems. Because they are less expensive compared to crewed units, uncrewed systems can enable scaling the force to increase distribution. The advent of a robust commercial robotics technology ecosystem further expands this opportunity by lowering costs and avoiding time-consuming R&D. With their scale and expendability, uncrewed systems can expand the variety of effects chains available to commanders and the dilemmas they impose on adversaries—provided forces treat them as independent players in an SoS. And because uncrewed systems can be more specialized and modular compared to crewed units that require multi-mission capability, forces can more easily plug them into effects chains to adapt an SoS to new missions or environments.

Figure 2: Systems-Of-Systems Value Proposition For Replicator



A useful comparison is Australia, which faces similar military challenges from the PLA as the United States and is pursuing a range of uncrewed technologies, some of which are encompassed under the Australia-United Kingdom-United States (AUKUS) agreement's Pillar Two. Hudson Institute is working with the Australia Department of Defence (ADoD) to refine its efforts at fielding uncrewed systems. Because it lacks the resources of the US DoD, the ADoD has had to scope its uncrewed system development to emphasize relatively mature technologies and near-term challenges faced in its near-abroad, such as defending Australia's northern approaches from intrusion or attack. Perhaps the most innovative dimension of Australia's uncrewed system development is its equal promotion of opportunities to gain asymmetric advantage, rather than simply fill gaps in current capabilities. By using uncrewed systems to open up new concepts, the ADoD seems to exemplify the characteristics needed in the Replicator initiative.[15]

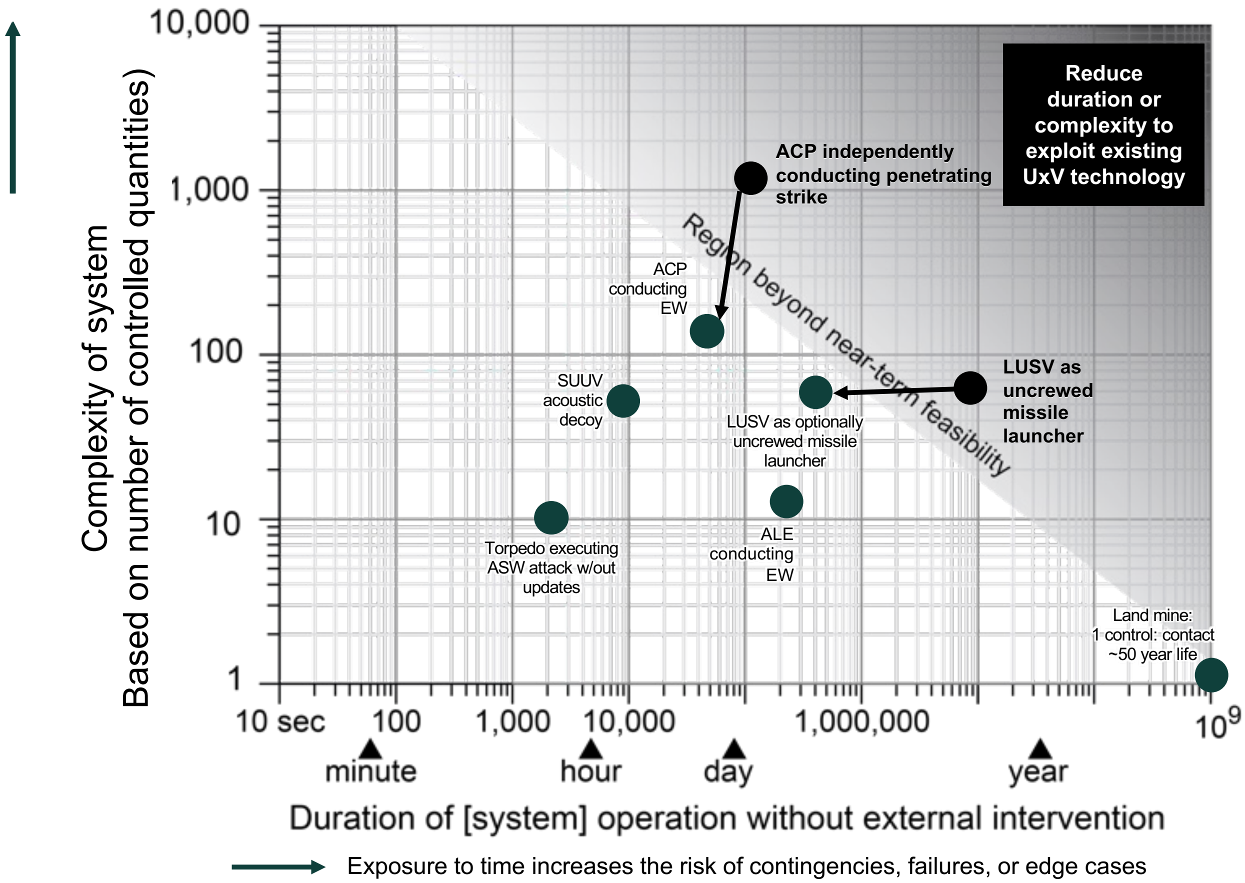
Replicator should align requirements with limits on autonomy

Adopting a SoS context in Replicator will also help field uncrewed systems more quickly, because together the elements of a SoS can mitigate limitations in uncrewed system autonomy, or *the degree to which a system can be self-governing or operate without outside support in executing a task or function*. A popular characterization of uncrewed systems is that they are "autonomous," but this is an overstatement because uncrewed systems depend on other force elements for essential support functions, from navigation to logistics.[16]

Crewed ships, aircraft, or ground vehicles are also limited in their autonomy, but the constraints on uncrewed system autonomy are often more severe in degree depending on the mission, operating environment, and sophistication of the unit in question, as shown in Figure 3. Some combinations of complexity and duration will be unachievable with available uncrewed vehicle technology, as indicated in the figure's upper right. Systems that need to operate in this region, including several of the DoD's high-profile uncrewed vehicle programs, drive R&D efforts that take years to culminate.

Although hardware will define the upper limit of how many variables a machine like an uncrewed vehicle seeks to control (e.g., how many control loops or similar control logic implementations are in its hardware and software), the use case dictates the number of necessary control loops. For example, driverless automobiles that operate outside known environments require a very large number of controlled variables, and with current technology they cannot operate for long periods without operator intervention, as recent accidents suggest.[17] So for now driverless automobiles can only conduct short trips in environments like urban centers that are well mapped and where the vehicles can gather large amounts of data regarding local traffic patterns and behaviors.

Figure 3: Relationship between Vehicle Sophistication and Endurance[1]



Instead of treating the limitations on autonomy as a problem that more expensive and sophisticated platforms and systems are needed to solve, the DoD should embrace the inherent constraints on uncrewed autonomy as a necessary corollary of using already-available systems. Revising its requirements for uncrewed systems to make them achievable with today's technology—as the US Congress directed in its FY2023 appropriations—would help the DoD speed its fielding of uncrewed vehicles and associated SoS.[18] For example, as shown in Figure 3, the Air Force could lower the sophistication needed in ACPs by using them to conduct stand-in

[1] SUUV=Small uncrewed undersea vehicle; ASW: Anti-submarine warfare

electronic warfare (EW) jamming rather than expecting them to evade threats and deliver weapons into highly-contested areas. Conversely, the Navy could reduce the time its LUSV needs to operate autonomously as a missile magazine by making it an optionally-uncrewed vessel that is only automated for short periods.

Commercial developers sometimes use threshold use cases to ensure a new system can deliver a minimum viable capability for its most important application.[19] Other use cases can come later. For example, the reference use case for the initial iPhone was to provide the functionality of the iPod mp3 player, access the web, and make telephone calls.[20] Today, iPhones and other smartphones can support hundreds of different use cases.

In defining its uncrewed system reference use cases, the DoD should learn from commercial industry. In the last few years, at least ten companies attempting to develop universally applicable self-driving vehicles have failed or have been sold.[21] Meanwhile, a robust industry has flourished around driver assistance technologies, including sensing, object recognition, automated steering, and braking.[22] If self-driving cars eventually become viable from an economic and regulatory standpoint, it will be because these underlying technologies achieved scale in simpler use cases like hands-free highway driving.[23]

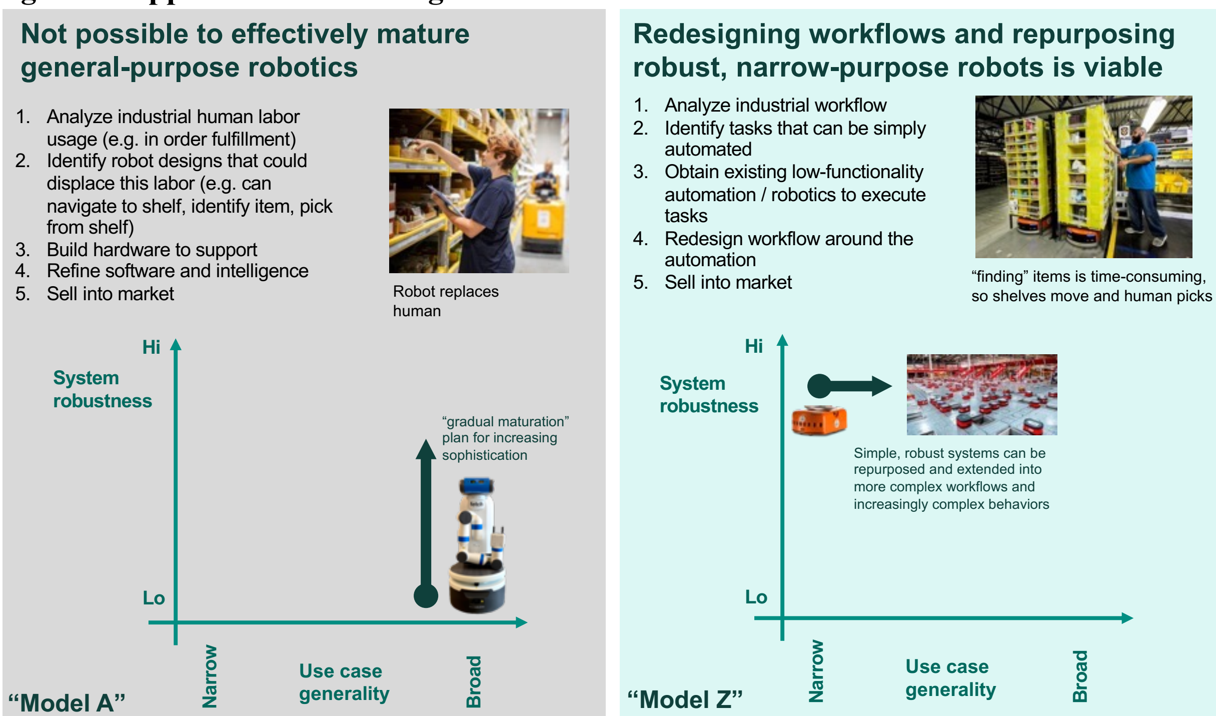
Replicator should leverage existing systems

Defining threshold use cases and reconciling DoD's uncrewed system requirements with their autonomy limitations in the abstract would be cumbersome and time-consuming. Like technologists in commercial industry, Replicator could streamline it by focusing, as Secretary Hicks says, on combatant commander's operational problems. Rather than developing new uncrewed systems to address predictions of future need as directed by the DoD's requirements process, Replicator should use commander's highest priority challenges as a starting point. The Replicator process would then assess how existing and emerging systems could solve them and then prototype potential SoS solutions.

This approach has a parallel in the commercial world. Manufacturing and logistics companies began employing robots widely in the 1990s to gain a competitive advantage by improving the speed, repeatability, or cost of their processes. For example, the regional hub of a package delivery company receives packages, sorts them, and routes them to the intended recipients as efficiently as possible. Although the company can routinize the hub's workflow, it will need to accommodate changing volumes, sizes, and types of packages; respond to seasonal variability in demand; and adapt to the timing requirements of customers and suppliers.

An initiative to expand the use of robotics in a warehouse can take one of two paths, as figure 4 shows. The left side depicts the option of replacing workers with machines that mimic the roles and actions of humans. If successful, this top-down approach would develop robots that could replace workers in any task they currently conduct. In addition to enabling the incorporation of robots into existing workflows, this approach would simplify scaling of the hub's operations. However, efforts to develop versatile human-like robots have failed to produce mature, useful systems.[24] Although researchers can integrate sufficiently capable hardware, albeit at a high cost, software that enables such systems to operate robustly has been elusive. The DoD is arguably taking this approach with its ACP and LUSV programs, which require the same endurance, speed, and ability to avoid or defeat threats as their crewed counterparts.

Figure 4: Approaches to Fielding Robots in a Distribution Center



The right side of figure 4 depicts an alternative path to introducing robots into the warehouse's workflow. In this bottom-up approach, existing robots with limited functionality, range, endurance, and sophistication perform simple tasks, and the company organizes the workflow around their capabilities. While the model on the left requires a robot to move, think, and pick up objects like a human, the model on the right demands only that robots perform tasks they can already do, like move from one location to another based on direction from a central routing management computer. In the model on the right, humans continue to conduct functions that are easy for them but are hard to enable a robot to do, like recognize and pick up various-sized objects and place them in a specific location.

Building workflows around existing technology also enables more adaptable workflows. The warehouse on the left side of figure 4 can add robots to increase production, but costs will increase linearly with productivity. In contrast, the warehouse on the right could scale by deploying additional inexpensive robotic carts and software to make each human worker more efficient; costs in that case would increase less than linearly with productivity. As new robotics or automation software becomes available, the company can decompose and reallocate tasks to incorporate new systems and technology. This allows businesses to view automation not as a one-time efficiency improvement but as a tool to achieve continual, year-over-year advances in not only efficiency but also other metrics like resilience and adaptability.[25] However, realizing the sustained benefits of this approach requires the ability to integrate never-ending combinations of robots and information technologies into ongoing operations.

Addressing operational needs by combining existing crewed platforms and available uncrewed systems into SoS is nearly the opposite of the US military's current approach to fielding new capabilities. Today, the DoD often uses a top-down process of defining requirements based on projected future scenarios and analyses of predicted US and adversary system performance. This process could be an appropriate method of SoS development if many of the necessary systems do not exist and if there is sufficient time to develop, integrate, and field them.[26] However, neither of those conditions exists today. A wide variety of sophisticated capabilities are available from government, defense industry, or commercial providers. Meanwhile, defense officials regularly note that the US military needs to be prepared for a conflict with China within this decade.[27]

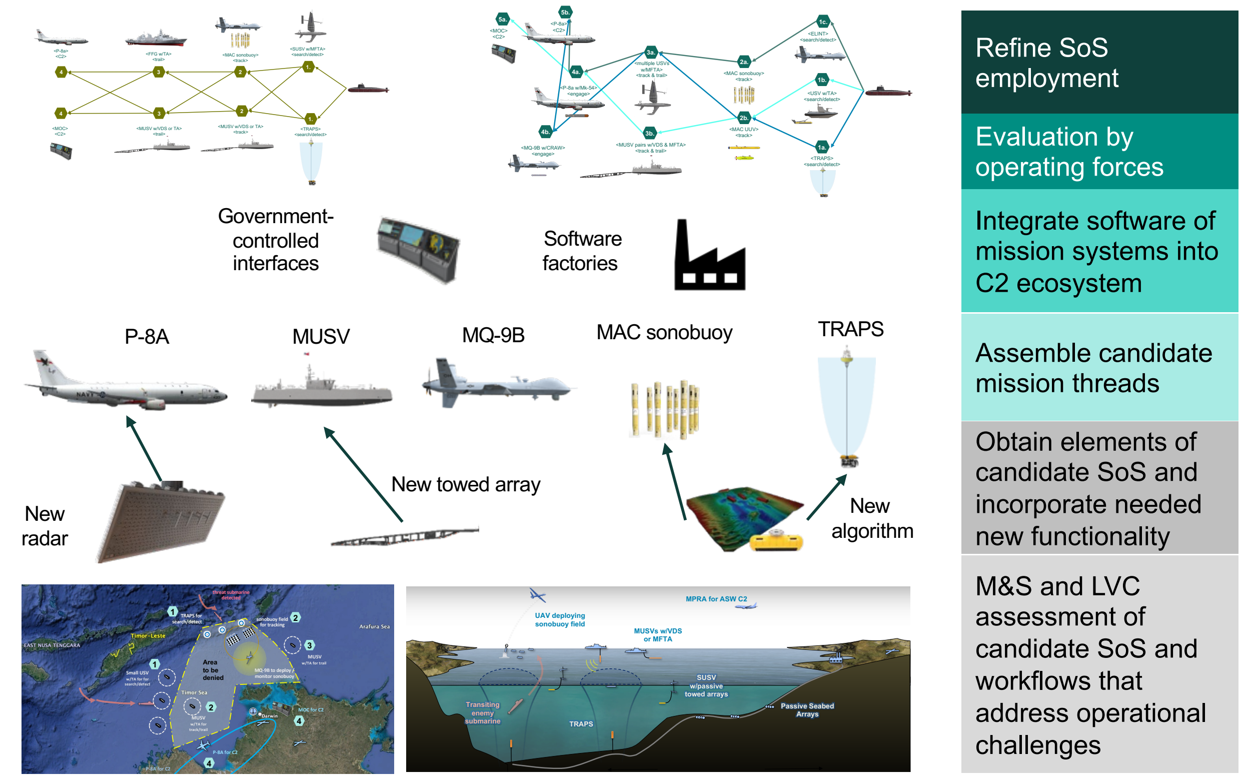
Therefore, the DoD should shift the focus of its technology development from long-term development of exquisite individual systems to *integration* of those that already exist to focus on high-priority *missions* that today's commanders have identified.[28]

Replicator should be a process for solving operational problems

Mature uncrewed systems in all domains are available but generally lack the combination of speed, functionality, range, and payload common in crewed platforms. As a result, DoD's prevailing top-down methodology would inevitably create requirements that do not align with existing uncrewed systems' specifications and lead to either a long-term R&D project or a protracted process, like the Navy's Requirements Evaluation Teams (RET), that refine requirements to align with a program's technological or fiscal constraints.[29]

A bottom-up approach of *mission integration* would be better suited for developing SoS that incorporate uncrewed systems. As in the example of a package distribution center, Replicator should be a process that composes extant systems, or slightly modified versions of them, into viable workflows to address operational problems and that evolve as new technology emerges. Figure 5 summarizes the technical aspects of this approach.

Figure 5: A Bottom-Up Mission Integration Process

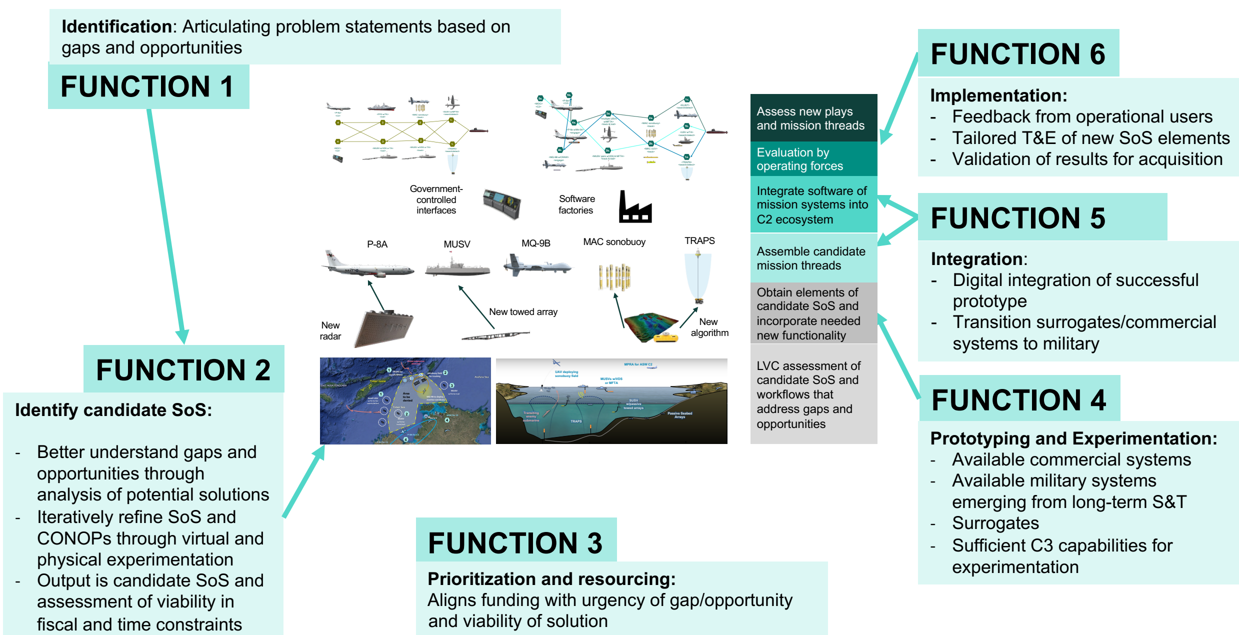


The DoD already performs the activities described in Figure 5, but focused on traditional crewed platforms and associated systems. With regard to uncrewed systems, these efforts are largely ad-hoc, uncoordinated, and lack resources.[30] Organizations or offices will need to be empowered with orchestrating the process of mission integration for Replicator to deliver uncrewed SoS in its planned timeline of less than 2 years.

In Section 904 of its FY2024 National Defense Authorization Act (NDAA) the Senate proposes a promising solution. The approach would charge Assistant Secretary of Defense for Mission Capabilities (ASD(MC)), Executive Director for Acquisition Integration and Interoperability (AI2), and DoD Chief Data and AI Officer (CDAO) with managing a process for joint integration that would tackle combatant commander operational problems.[31] This construct could be applied to support the Replicator initiative.

Building on the Senate's proposed approach, Figure 6 summarizes the functions needed to implement a mission integration process like that associated with Replicator. The process starts with **Function 1**, in which a commander such US Indo-Pacific Command (INDOPACOM) identifies a key operational problem for Replicator to address. **Function 2** assesses potential SoS solutions to commander's problems using modeling and simulation (M&S) and live, virtual, and constructive (LVC) capabilities. In addition to the analytic capabilities embedded in combatant commanders like INDOPACOM and agencies like the Defense Advanced Research Projects Agency (DARPA) or the Strategic Capabilities Office (SCO), Replicator could draw upon analysis support from industry providers or service organizations such as Air Force Research Laboratory and Navy Surface Warfare Center. Turning to the Senate NDAA's model, ASD(MC) could lead Functions 1 and 2, since it will have insight into the kinds of uncrewed system capabilities available or emerging from DoD research efforts.

Figure 6: A Functional View of Mission Integration for Replicator



Function 3 is an activity largely missing from today's DoD uncrewed system development efforts—resourcing and orchestrating the process of integrating new capabilities into the force. The implementation of JADC2 has prompted military services to establish more deliberate integration activities, such as the Navy's Project Overmatch, but these efforts largely focus on more effectively integrating the existing force. New capabilities are introduced through lengthy testing, delivery, and training processes that would be appropriate for fielding major programs such as crewed platforms that demand substantial preparation. But these cumbersome processes are likely not necessary or appropriate for incorporating existing capabilities such as uncrewed systems that solve near-term challenges and integrate largely through machine-to-machine communication.

These are some service organizations that could take on the role of performing Function 3 to coordinate and fund the process of mission integration, such as the Air Force Rapid Capability Office, Army Rapid Capabilities and Critical Technologies Office, or the Navy's new Disruptive Capabilities Office.[32] However, there is no activity for managing the type of joint or DoD-level process Replicator would require. The construct proposed by the Senate NDAA could provide this process.

The most promising SoS identified in the analysis of Function 2 would be assessed as prototype SoS through experiments in **Function 4**. The DoD conducts many experiments today, but they are generally not part of a sustained effort to solve pressing operational problems; are too infrequent for findings of one experiment to be evaluated in the next; lack the preparatory analysis needed for the experiment to be conclusive; or only assess new equipment, rather than the whole SoS and its associated workflow.

Replicator could provide a process that focuses DoD's uncrewed systems experimentation on operational problems and addresses the above shortfalls in its current prototype and experimentation efforts. Better conceptualizing and assessing new SoS in Function 2 would improve the likelihood experiments yield useful results. Establishing organizations and associated program managers through Function 3 to orchestrate SoS integration would provide a way to identify and obtain prospective SoS elements from organizations such as DARPA, SCO, the Defense Innovation Unit (DIU), and the services.

To assess prototype SoS, Replicator could take advantage of existing experimentation campaigns such as those under the Rapid Defense Experimentation Reserve (RDER) that are managed by the ASD(MC). To increase the tempo of experimentation, SoS to be evaluated might rely on physical and digital surrogates, sidecar computing, and workarounds that enable interoperability without modifying underlying software to show whether a particular workflow is useful and executable. For example, civilian ships or aircraft could stand-in for military platforms and developers could temporarily modify the software of a developmental multi-function RF system to test new behaviors or waveforms necessary in the new use case without making class-wide changes to those systems. The Navy is pursuing experiments like this already with US Central Command's Task Force 59 in the Persian Gulf and with the US Third Fleet's series of integrated battle problems.[33]

Perhaps the most important aspect of Replicator is digitally integrating successful prototype SoS in **Function 5** to support operational evaluations by the commanders that originated the problem to be solved. As noted above, machine-to-machine communication is increasingly central to military operations. The role of digital integration is to provide the environments, infrastructure, tools, and processes that enable development of the software necessary to connect, share data, and coordinate the elements of a SoS. In its role leading the technical aspects of JADC2, the CDAO would be an appropriate lead for the Replicator digital integration effort.

New software advancements will likely emerge faster than fixed standards can evolve to accommodate. Therefore, in contrast to prime contractor models where a single vendor provides the hardware and software for a new system, software for SoS developed through Replicator will need to come from a variety of developers within and outside the DoD. The function of digital integration will then need to treat the overall software environment as a separate product from the platforms and systems that interact with it. This will help lower barriers to entry for developers, including those outside the traditional defense industry.

For example, the Apple iOS operating system is a distinct project from the iPhone and from applications in the Apple AppStore. Apple publishes the interfaces that applications need to use within iOS and provides developmental toolkits for vendors to create applications. Companies proposing applications and peripherals for the iPhone need to prove that they can effectively and securely integrate with iOS before they gain approval for use.[34] For the government, the integration challenge is more daunting. Whereas Apple has only a dozen iPhone versions using iOS, the US military has tens of thousands of existing mission systems and crewed platforms it may need to integrate with hundreds of emerging uncrewed systems, creating a web of data engineering, radio interoperability, and security issues. The DoD's JADC2 strategy wrongly assumed that all these legacy and new systems would eventually need to integrate with one another. In contrast, the bottom-up model of Function 5 would instead integrate only those SoS that demonstrate value in solving near-term operational problems.[35]

After a new SoS succeeds in the field, the DoD will need to promptly acquire the elements not already extent in the force at sufficient scale to be operationally relevant. **Function 6** would consist of commanders assessing a prototype SoS in the field and either validating its requirements or proposing refinements. Under the Senate NDAA model, the Executive Director of AI2 could take on the task of initially procuring the SoS elements needed to field it at an operationally-relevant scale until the necessary programs can be established.

Successful mission integration will depend on iteratively evolving SoS in response to new technologies and operator feedback. Therefore, although Figure 6 implies Functions 1 through 6 happen in series, they would actually occur in parallel and interactively. For example, Function 1 of defining operational problems and initial solutions depends on uncrewed vehicles and mission systems that the DoD identifies and obtains as part of Function 4. Function 6 will provide insights back to Functions 2 and 4 regarding useful operational concepts and systems. The process of concept development in Function 2 can be informed by efforts at digital integration in Function 5, which will highlight SoS combinations that are harder or easier to create. And conversely, the use of detailed digital model-based analysis in Function 2 can make digital integration easier to perform in Function 5.

Recommendations for Replicator

The US military cannot rely on its historical dominance to deter and defeat aggression against a major power like the PRC in its own back yard. Instead, the DoD will need to use a force that is less predictable, more adaptable, and increasingly resilient to attack the PLA's strategy of system destruction warfare and its decision-making processes. By rapidly growing the variety of effects chains that are possible with US military forces without the costs associated with crewed platforms, uncrewed systems can undermine PLA planning and concepts and afford US forces the capacity to sustain a protracted conflict.

But realizing the low cost, attritability, and scale associated with uncrewed systems depends on accepting their limitations in terms of autonomy and multi-mission capability. Therefore, the DoD will need to employ them as part of SoS with other uncrewed systems and crewed platforms. This will exacerbate the US military's long-standing struggles to combine forces between and within each service branch. The DoD should establish through Replicator a routinized processes for integrating new SoS. Otherwise, the US military services will continue treating uncrewed systems as separate from the mainline force and fail to achieve Replicator's objectives of enabling innovative solutions to commander's operational problems.

US military services are already pursuing mission integration through initiatives in concept development, experimentation, rapid acquisition, and digital integration and JADC2. However, these efforts are generally not well synchronized, focus on long-term service objectives rather than near-term operational problems, and use a top-down approach to guide requirements for future systems rather than a bottom-up process that exploits the systems and technology that are available today.

To bring uncrewed systems into the force more quickly and to realize their benefits, the DoD will need to incorporate uncrewed systems where it can best use them, instead of attempting to build uncrewed systems that extend or replace existing crewed platforms. As in a commercial distribution warehouse, the fastest and most effective way to assimilate robotics is to adjust the organization's workflow as opposed to developing robots to replace humans in existing workflows.

Implementing Replicator will require the DoD and Congress to create processes that support integration of existing and emerging uncrewed systems into the force, specifically:

1. **Formalize Replicator as a process that would conduct the six functions of mission integration to address near-term combatant commander operational problems.**

The DoD should adopt the process suggested in Section 904 of the Senate FY2024 NDAA, and empower the ASD(MC), CDAO, and Executive Director for AI2, and to lead appropriate aspects of problem definition, solution development and experimentation, resourcing, prototyping and experimentation, digital integration, and operational refinement.

2. **Establish resource sponsors for Replicator and the mission integration process.**

As part of instituting the mission integration process for Replicator, Congress and the DoD should resource ASD(MC), AI2, and CDAO to conduct their respective parts of Functions 1-6. For example, the Senate version of the FY2024 appropriations bill includes a provision to consolidate funding for CDAO in support of JADC2 that could be employed for digital integration under Replicator.

Over the longer term, The DoD should also assign funding to ASD(MC) and AI2 in broad PE lines like those used for defense-wide R&D to enable the prompt transition of promising SoS into procurement and fielding.

3. **Establish program managers in ASD(MC) and AI2 to support Replicator and mission**

integration.

The DoD should establish program managers in ASD(MC) and AI2 to contract for services and procurement or transfer funding to other government offices for analysis under Function 2, prototype development and experimentation under Function 4, and initial procurement of successful SoS elements under Function 6.

The establishment of dedicated program managers for the integration process will mark a significant cultural shift by bringing acquisition professionals into the experimentation and requirements process. However, connecting experimentation and acquisition is appropriate when available technologies are increasingly able to meet current and anticipated military needs and when more rapid introduction of new capabilities is essential to gaining an operational advantage.

4. **Expand the cadre of software program managers in CDAO to support Replicator and mission integration.**

Software is increasingly the source of military capability and advantage in new weapons, mission systems, and vehicles. Software is also the mechanism by which military forces integrate today, much as past generations integrated through doctrine and procedure. Software program managers would own government interfaces that connect vehicle, mission system, and C2 software and would oversee integration of new systems into the ecosystem. Rather than taking more software development work into the government, the establishment of software program managers would enable the government to manage and oversee software development efforts by vendors, including software factories that maintain C3 environments and gauntlets in which new system providers demonstrate their ability to digitally integrate with the ecosystem.

In an environment where dominance is no longer a given, the US military needs to return to operational innovation. Historically, US forces have excelled when given the tools and processes to improvise and be creative. Many of the pieces necessary to enable effective innovation through mission integration are already in place. Accelerating and realizing the benefits of uncrewed systems will require better orchestration and execution of these activities to solve today's operational problems. If the Navy and DoD fail to do so, they may miss their best opportunity to gain an enduring advantage against peer opponents like China.

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[1] Jim Garamone, "Hicks Discusses Replicator Initiative," DoD News, September 7, 2023, https://www.defense.gov/News/News-Stories/Article/Article/3518827/hicks-discusses-replicator-initiative/.
[2] See Bryan Clark and Timothy A. Walton, "Fighting into the Bastions: Getting Noisier to Sustain the US Undersea Advantage," (Washington, DC: Hudson Institute, 2023), https://www.hudson.org/fighting-bastions-getting-noisier-sustain-us-undersea-advantage-submarine-bryan-clark-timothy-walton.
[3] Eric Lipton, "Pentagon Vows to Move Quickly to Buy More Drones, Citing China Threat," *The New York Times*, August 28, 2023, https://www.nytimes.com/2023/08/28/us/politics/pentagon-drones-china.html
[4] See Bryan Clark and Dan Patt, "Campaigning to Dissuade: Applying Emerging Technologies to Engage and Succeed in the Information Age Security Competition," (Washington, DC: Hudson Institute, 2023), https://www.hudson.org/defense-strategy/campaigning-dissuade-applying-emerging-technologies-engage-succeed-information-age-bryan-clark-dan-patt.

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[24] Consider the case of mobile robotic bases that transport manipulator arms. Such a robot could perform both item- or box-picking tasks and transportation tasks. However, no commercially viable solution emerged in the ten years from 2013–2023 despite many attempts. Consider, for example, the Fetch mobile manipulator, introduced in 2014, which still has not found commercial application although simpler mobile bases have; see Evan Ackerman, "Fetch Robotics Introduces Fetch and Freight: Your Warehouse Is Now Automated," IEEE Spectrum, April 29, 2015, https://spectrum.ieee.org/fetch-robotics-introduces-fetch-and-freight-your-warehouse-is-now-automated. Or consider the repeated terminations of robotics projects at Alphabet, including those that attempted to combine mobility with manipulation; see James Vincent, "Google Parent Alphabet Shuts Down Yet Another Robot Project," The Verge, February 24, 2023, https://www.theverge.com/2023/2/24/23613214/everyday-robots-google-alphabet-shut-down.

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