Research Report

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Personnel Needs for Department of the Air Force Digital Talent

A Case Study of Software Factories

In the fiscal year (FY) 2020 National Defense Authorization Act (NDAA), Congress directs the U.S. Department of Defense (DoD) "to promote and maintain digital expertise and software development as core competencies of civilian and military workforces of the Department, and as a capability to support the National Defense Strategy" (Pub. L. 116-92, 2019). To help meet this mandate, the U.S. Department of the Air Force (DAF) established a Digital Talent Taskforce in FY 2020 to help define DAF digital talent needs, including developing requirements and competencies for digital talent. To support the taskforce's efforts, RAND Project AIR FORCE was asked to conduct a case study to identify digital talent needs in the area of software development by exploring DAF software factories that use modern and agile software development practices. As of FY 2020, DAF software factories were newer organizations that were quickly growing in number and size, such that they presented a challenge for workforce planning.

The motivation for this case study stemmed, in part, from discussions that the RAND Corporation team held with DAF digital talent stakeholders, including senior leaders, on what they considered to be the need for digital talent across the DAF. During a broader FY 2020 study on digital talent, DAF stakeholders could articulate the value of digital talent across different digital domains (e.g., data science) and expressed the need for the DAF to have different levels or tiers of proficiency (e.g., basic data literacy across the force). However, actual digital talent personnel requirements were unclear, including where specific digital knowledge and skills would be needed across the DAF and how many personnel at different proficiency levels would be required to meet those needs. Software factories were cited as one type of entity within the DAF where specific types and levels of digital talent would likely be needed, but the specific requirements had still not been identified. In contrast to traditional software acquisition efforts in DoD that use contractors to deliver a product, software factories represent a growing DAF effort to provide organic software development capabilities. According to our review, most DAF software factories were still in their start-up phases as of FY 2020, with additional software factories continuing to emerge across the DAF.

In this short report, we provide an overview of DAF software factories as of FY 2020, including software factory missions, oversight structures, and current and desired digital talent. The infor-

KEY FINDINGS

- Software factories have emerged as part of DAF efforts to modernize software acquisition and development practices. With a focus on organic capabilities, the software factories attempt to draw on military and government civilians to lead their product development teams. Contractors provide software engineering expertise as part of a project team instead of providing a finished product.
- Because the software factories are start-up organizations, funding for most of the factories at the time of this study (FY 2020) appeared to be ad hoc, with the parent or owning organization providing initial funds and billets but the majority of funding coming from customers that use their software development and platform capabilities. Although software factory missions primarily focus on serving their parent or owning organization, they also have customers that expand beyond the owner, including the broader DoD.
- Software factories reported several personnel-related challenges:
  - As of FY 2020, they had some funded billets and assigned personnel but reported not having enough billets and personnel to meet what they consider their current or future needs. Toward the end of FY 2020, Air Force Materiel Command (AFMC) was beginning manpower studies to further establish the actual personnel requirements.
  - Although there is a desire to have military members at the software factories, the factories reported challenges in acquiring more military members because of the absence of a dedicated pipeline of military personnel with the necessary technical skills.
  - Information on training and development of military members that occurs at software factories was not used in a systematic way to determine future assignments.
  - Attracting and retaining top civilian talent can be difficult because of less competitive compensation and rigid degree requirements.
- Although there are frequent informal connections across many of the software factories, as of FY 2020, there was no formal oversight or coordination to ensure information sharing and prevent the potential for unhelpful competition.

mation in this report reflects our understanding of DAF software factories during the time frame of this project work (spring through summer 2020) and is based on information provided by software factory representatives. Because many of the software factories we include in our review were in the initial stages of standing up and several were in the process of an organizational realignment, the information contained in this report provides a snapshot in time.

Approach

To conduct this case study, we held discussions and follow-on communications with at least 25 experts from more than 20 DAF software factories and innovation centers. We also held discussions with three senior-level DAF personnel who represent organizations or offices that have oversight over one or more software factories. Finally, we reviewed documentation that was provided by the discussion participants or other contacts in their organizations. We note that some of the information we provide in this report reflects judgments from subject-matter experts that may require validation for accuracy and comprehensiveness from other sources of information (e.g., numbers of personnel were often estimates). We acknowledge this limitation but note that we took care to identify relevant experts for inclusion and add caveats where expert judgment is used.

The following software factories and innovation centers were included in our case study: ARCWERX, AFWERX, BESPIN (Business Enterprise Systems Product Innovation), CAMP teams (e.g., Space CAMP), Cloud One, Conjure, Corsair Ranch, CyberWorx, Extreme Digital Development Group Enterprise (EDDGE) Teams, Kessel Run, Kobayashi

Maru (including Section 31), LevelUP, Platform One, Shadow of Operations (ShOC) Innovation Directorate Software Factory, Software Engineering Groups (SWEGs), and TRON. In the next section, we define *software factory* and discuss how that definition influenced our decision about which organizations to include in the case study.

What Is a Software Factory?

According to the Defense Science Board (2018), a *software factory* is

> a set of software tools that programmers use to write their code, confirm it meets style and other requirements, collaborate with other members of the programming team, and automatically build, test, and document their progress. This allows teams of programmers to do iterative development with frequent feedback from users. (p. 1)

The DoD Chief Information Officer (2019) defines a *software factory* as

> A software assembly plant that contains multiple pipelines, which are equipped with a set of tools, process workflows, scripts, and environments, to produce a set of software deployable artifacts with minimal human intervention. It automates the activities in the develop, build, test, release and deliver phases. (p. 15)

A visual representation of a software factory is shown in Figure 1.

At the time of this study, there was no formal DAF definition or process for being designated an official software factory. However, the Air Force's Chief Software Officer (CSO) maintained a list of what his office considered to be DAF software factories, which included organizations or teams using agile development, security, and operations (DevSecOps) methodologies to deliver capabilities to warfighters.[1] In general, these factories develop and maintain a variety of software applications, from those focused on mobile-business (e.g., BESPIN's Airmen Against Drunk Driving application) to those that support command and control (C2) for different weapon systems (e.g., applications that track flight status).

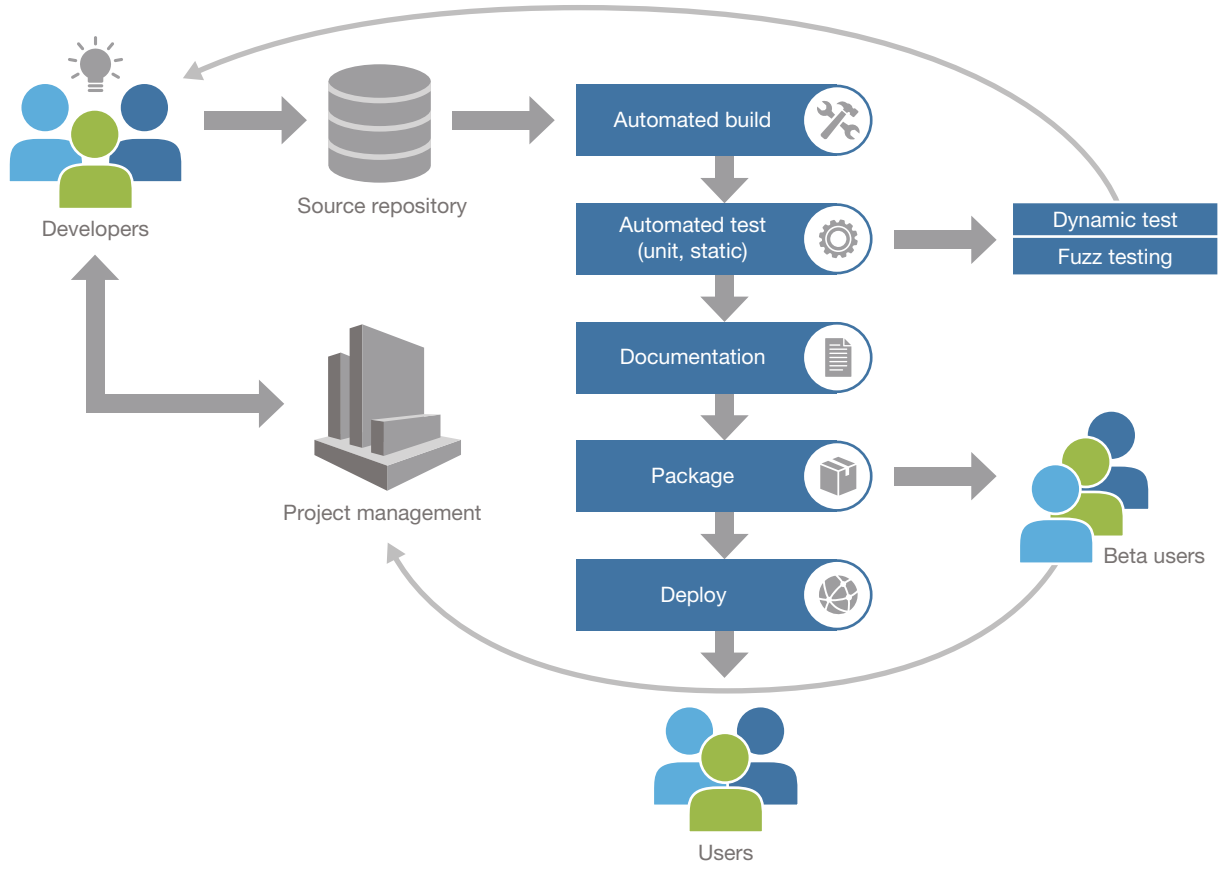
Because our goal was to better understand DAF digital talent needs through a case study of software factories, we focused our review of software factories on organizations that provide innovative organic software development with DAF oversight. Therefore, we did not include program offices or organizations that rely solely on contractors to develop or sustain software, even if they fit the definitions for a *software factory* described previously (e.g., Rogue Blue Software has government personnel in charge of integration but relies on contractors for software development).[2] We also do not include efforts that are joint in nature (e.g., N2X Pathfinder supports North American Aerospace Defense Command and U.S. Northern Command).

In identifying software factories for inclusion in our review, we first looked at those organizations specifically recognized as software factories by the Air Force CSO (Assistant Secretary of Acquisition, undated b).[3] We then identified additional organizations for inclusion through discussions with rep-

Abbreviations

ACC	Air Combat Command
AFB	Air Force Base
AFMC	Air Force Materiel Command
AFRC	Air Force Reserve Command
AFSC	Air Force Sustainment Center
AMC	Air Mobility Command
AOC	Air Operations Command
ARC	Air Reserve Component
BES	Business and Enterprise Systems
BESPIN	Business Enterprise Systems Product Innovation
C2	command and control
CSO	Chief Software Officer
DAF	U.S. Department of the Air Force
DevSecOps	development, security, and operations
DoD	U.S. Department of Defense
EDDGE	Extreme Digital Development Group Enterprise
FY	fiscal year
NDAA	National Defense Authorization Act
OPM	Office of Personnel Management
PACAF	Pacific Air Forces
PEO	Program Executive Office
POM	program objective memorandum
ShOC	Shadow of Operations
SWEG	software engineering group
TDY	temporary duty
USSF	U.S. Space Force

FIGURE 1
Visual Representation of a Software Factory



SOURCE: Adapted from Defense Science Board, 2018.

resentatives from those software factories and Air Force headquarters representatives involved in DAF digital talent efforts. We also interviewed representatives from other innovation-focused organizations in the DAF, including AFWERX, CyberWorx, and ARCWERX, who collaborate with the software factories, to better understand broader DAF efforts related to developing digital capabilities and facilitating innovation. However, we do not include these organizations in our review, given their difference in focus. Because there is no formal DAF process for designating an organization as a software factory, it is possible that there were other relevant organizations that are not included within this review. Additionally, it was beyond the scope of this effort to account for all organic software development activities that might be taking place within the DAF. We acknowledge that there may be additional pockets of organic software development that are not included in our review.

Software Factory Oversight and Funding

Software factories are distributed across DAF commands. However, as of FY 2020, many of the DAF software factories were located under AFMC. Figure 2 provides a graphic overview of the current reporting structure for the software factories (green boxes) within AFMC.

With the existence of more-established software factories such as Kessel Run and a desire for innovation, other organizations across the DAF also have efforts to establish their own software factories (see Figure 3). This includes the Air Force Reserve Command (AFRC) with Corsair Ranch and Conjure, which was established under Air Mobility Command (AMC) in summer 2020. At the time of this study, Space CAMP was also in the process of transitioning

from the Air Force Research Laboratory to the U.S. Space Force (USSF).

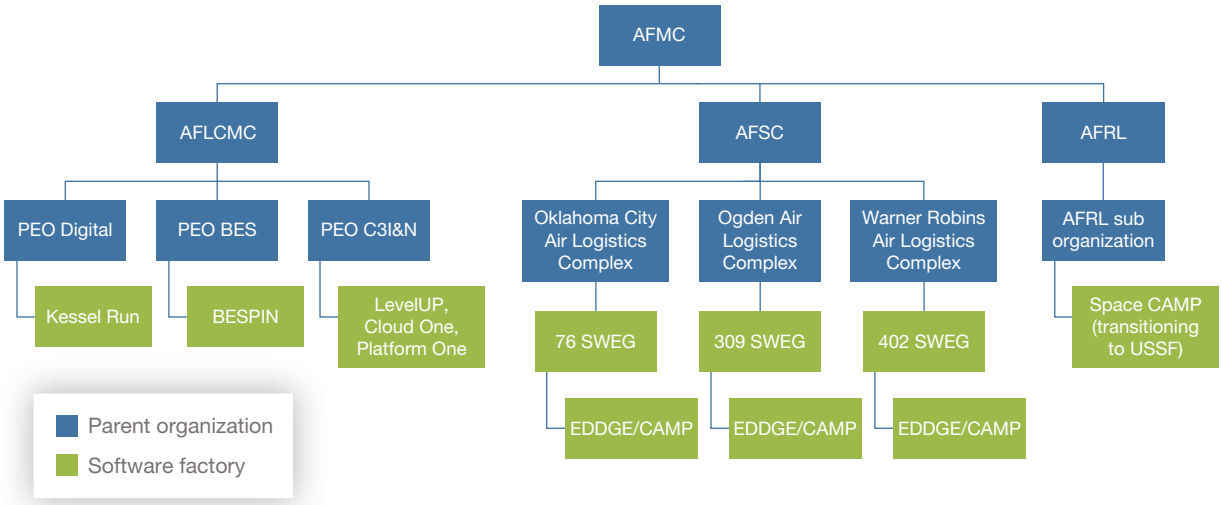
With a focus on innovation, funding for many of the software factories appears to be ad hoc. Parent or owning organizations provide some initial funds and billets for the factories to start up, but primary funding is provided by various customers or program elements that use the factories' software development capabilities. Therefore, with a few exceptions, as of FY 2020, the software factories themselves are not included as line items in the DAF's planned budget. For example, Kessel Run identified at least five different program elements that provide funding to support its operations. Similarly, although BESPIN receives some funds from the PEO BES, most of its funds come from innovation funding from various customers. Platform One, Space CAMP, and TRON also indicated that the majority of their funding was customer-based. Cloud One's platform is centrally funded, but the majority of funds it receives for migrating a system to the cloud are provided by customers. At least within AFMC, there are efforts to include some factories in future funding—specifically, program objective memorandum (POM) cycles (i.e., Kessel Run, BESPIN, LevelUP/Platform One)—to (1) ensure that software factories are permanently funded into the future so that their infrastructure could be leveraged by others and (2) address manpower gaps.

In a few cases, software factories do have direct funding from their program element or direct-oversight organization. For example, the innovation directorate software factory is housed within ShOC and indicated having POM'd funding through the United States Air Force Warfare Center Joint All-domain Command and Control Battlelab. Kobayashi Maru is also currently using established POM'd Joint Space Operational Center Mission System (JMS) program element funding. However, because that funding source was designed for the JMS program element, representatives indicated that it does not fully reflect the current manpower needs for the new Kobayashi Maru program. Finally, Corsair Ranch currently receives its funding directly from the Air National Guard–Air Force Reserve Test Center, but the money was yearly, discretionary funding during the study time frame.

In contrast to the other software factories, the SWEGs and their CAMP and EDDGE teams operate under a working capital fund. With this model, their operations and personnel are funded through customer-generated revenue, which makes it easier for them to scale up and down as needed.[4]

FIGURE 2

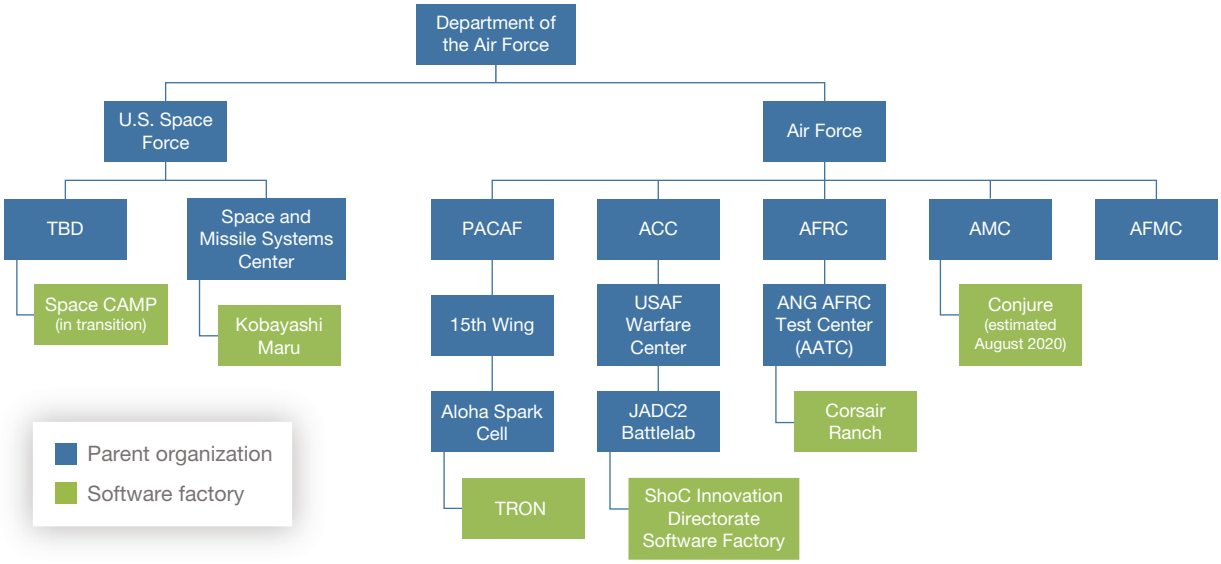
Air Force Materiel Command Software Factories



NOTE: AFLCMC = Air Force Life Cycle Management Center; AFRL = Air Force Research Laboratory; AFSC = Air Force Sustainment Center; BES = Business and Enterprise Systems; C3I&N = Command, Control, Communications, Intelligence, and Networks; PEO = Program Executive Office.

FIGURE 3

Department of the Air Force Software Factories Beyond Air Force Materiel Command



NOTE: AATC = Air National Guard–Air Force Reserve Test Center; ACC = Air Combat Command; ANG = Air National Guard; JADC2 = Joint All-Domain Command and Control; PACAF = Pacific Air Forces; TBD = to be determined; USAF = U.S. Air Force. TRON is depicted as falling under PACAF, which is where it was originally established. At the time of this study, it considered itself to report to a variety of major commands (e.g., PACAF, AMC, ACC), although funded billets were through PACAF.

Establishment and Missions of Department of the Air Force Software Factories

We provide an overview of the software factories identified for inclusion in our review (listed in alphabetical order) in Table 1, including the date they were established, major command–level oversight, and their primary mission areas.

As Table 1 shows, with the exception of the SWEGs under the AFSC in AFMC, all of the software factories were established in 2017 or later. Software factories have emerged as part of DAF efforts to modernize software acquisition and development practices. In the 2018 report by the Defense Science Board, the board states that "problems associated with software development continue to plague major DoD acquisition programs. This results in long delays in fielding, significant cost overruns, and, in some cases, program cancellation" (p. 2). To modernize DoD software development, the Defense Science Board recommended using a software factory approach as the foundation of being able to provide continuous, iterative, and rapid software development and sustainment. Consistent with this approach, the 2018 U.S. Air Force *Acquisition Annual Report* states that

> [s]oftware must adapt in near real-time to ensure success in the fight. The focus of Agile Development Operations is to deliver valuable software on a frequent cadence of days or weeks, rather than months or years, with regular user feedback and engagement during the development process. This approach contrasts the status quo of monolithic software delivery, which most often results in non-intuitive and non-valuable software that is already obsolete by the time it arrives on the battlefield. (U.S. Air Force, undated, p. 91)

Kessel Run is perhaps the most well-known DAF software factory and reflects an initial pilot effort that was stood up in 2017 following a collaboration between the Defense Innovation Unit and the Air Operations Command (AOC) program office to modernize the AOC following contracting efforts that were over budget and behind schedule.[5] Following the example set by Kessel Run, other software factories were established with the idea of providing

TABLE 1
Software Factories and Their Primary Mission Areas

Software Factory	Year(s) Established	Major Commands	Primary Mission Areas[a]
BESPIN	2019[b]	AFMC	(1) Mobile/cloud app development in support of BES; (2) facilitation of citizen developers; (3) software development of Air Force enterprise mobile apps; (4) software development for Air Force urgent operational need
Conjure	2020	AMC	"[Deliver] user-centered software supporting Mobility Air Force warfighters to provide rapid global mobility to the Department of Defense"[c]
Corsair Ranch	2019	AFRC	Provide organic software capability to the Air Reserve Component (ARC)
Kessel Run	2017	AFMC	Deliver war-winning software that warfighters love; includes a focus on modernizing the Air Operations Center and maintenance software of F-35 and F-22
Kobayashi Maru	2018	USSF	Provide space domain awareness and battle management command and control for warfighters (i.e., Space C2 mission)
LevelUP	2020	AFMC	Deliver Unified Platform;[d] support all elements of the U.S. Cyber Command Joint Cyber Warfighting Architecture
ShOC Innovation Directorate Software Factory	2019	ACC	Link command and control tools throughout the joint and partner nation community using the ShOC integration environment
Software engineering groups	1980s	AFMC	Develop and sustain weapon system software
EDDGE teams[e]	2019; Tinker 2017		Provide innovative software solutions to Air Force warfighting systems
CAMP teams	2020		Focus on the continuous development and deployment of local SWEG mission applications to the warfighter using Platform One nodes
Space CAMP	2019	Transitioning to USSF	Pioneer a USSF ecosystem that accelerates dynamic solutions from discovery through deployment as a node of Platform One
TRON	2019	PACAF	Build a force-wide cadre of digitally enabled airmen through open, extensible, mission-obsessed software

SOURCE: Author interviews with representatives from the factories and materials provided by interviewees (with the exception of Conjure).

[a] Material in this column is derived from quotes or other materials provided by interviewees.

[b] BESPIN was created as a proof of concept in 2018 and then was established more officially in 2019.

[c] Mission statement is based on information provided on the CSO website (Assistant Secretary of Acquisition, undated b).

[d] Unified Platform was established in 2017.

[e] Tinker is an Air Force Base (AFB) located in Oklahoma. The Tinker EDDGE team was established in 2017. The other EDDGE teams were established in 2019.

similar cutting-edge organic software capability for specific DAF program offices and organizations. Most recently, Corsair Ranch was established to provide organic software development for the ARC, and the newly established software factory, Conjure, is described as providing innovative software development in support of AMC (Assistant Secretary of Acquisition, 2020). However, not all software factories were established to support specific program offices or organizations. In the case of TRON, it was stood up with funds from the Aloha Spark Cell Under the 15th Wing at PACAF with wing innovation funds. Spark Cells are an AFWERX effort that helps facilitate opt-in, grassroots innovation cells colocated with bases across the country.[6] Thus, TRON is an example of a software factory that arose from a more grassroots effort instead of from a clear strategic or program need.

In general, the software factories have a primary mission that is focused on supporting their owning or parent organization, but software factory representatives discussed taking on projects outside their primary mission area as well. For some of the software factories, their goal is to eventually be the go-to software factory for a particular capability. For example, a key part of BESPIN's mission is providing mobile and cloud app development in support of its oversight organization, PEO BES, which is within AFMC. However, BESPIN's goal is also to provide such services more broadly and be the primary resource for software development of mobile apps across the DAF enterprise. Although Kessel Run has various projects focused on modernizing the AOC, the organization described taking on a host of other software development efforts across the DAF as well. Thus, although many of the software factories are aligned with specific program offices or organizations, their customer base can have a broader span, including to DoD. In some cases, software factories may also work together on a particular development effort.

Organizations that have interrelated but distinct missions and customer bases compared with the other software factories are Cloud One and Platform One, which enable and support the software factories, and AFSC's SWEGs, which have been established for many decades. Next, we describe each of these organizations in more detail.

Software factories have a primary mission that is focused on supporting their parent organization but often take on projects outside this mission area.

Cloud One

Cloud One works to ensure that key mission systems have a secure means of accessing cloud services. The team sets up an enterprise approach to the cloud that helps it centralize its funding and troubleshooting capabilities. Though Cloud One's focus is on supporting DAF requirements, it does accept customers from the sister services and combatant commands (e.g., U.S. Cyber Command) as capabilities allow. At the time of this study, efforts to move Cloud One to support multiple security levels were driving most of the staffing needs, and the Cloud One representative we spoke with anticipates growth over the next few years. This, coupled with Cloud One's position as a service for other software factories, makes it a critical piece in ongoing modernization efforts.

Platform One

Platform One (Colorado Springs, Colorado, and San Antonio, Texas) became DoD's preferred enterprise service provider in May 2020. Platform One, under the direction of the DAF CSO, is designed to help empower program offices and mission systems by providing technologies with Authority-to-Operate reciprocity across DoD.[7] Although the acquisition authority comes directly from the Air Force Lifecycle Management Center under AFMC, the technical oversight is provided by the DAF CSO. With more than 15 applications currently in production and more than 10,000 daily active users on the platform, Platform One is viewed as a core piece of the larger modernization efforts taking place across DoD; it is rapidly expanding and is investing in its capacity to support more customers. Additionally, with the recent rise in prominence of software factories, Platform One's ability to share its resources across the broader ecosystem will become increasingly critical.

Several of the other software factories listed in Table 1 are also considered to be nodes of Platform One. This includes Space CAMP and the CAMP teams underneath the SWEGs (see the next section for more detail). TRON considers itself both a customer and executor of Platform One.

Air Force Sustainment Center's Software Engineering Groups

Also included in our list of software factories are the SWEGs under AFMC's AFSC Software Enterprise. There are three separate SWEGs: the 76 SWEG at Tinker AFB, the 309 SWEG at Hill AFB, and the 402 SWEG at Robins AFB. The SWEGs are composed of roughly 4,500 civilian technical professionals focused on software sustainment and development for various DAF weapon systems and have been doing software sustainment for the DAF since the 1980s. Together, the SWEGs support more than 400 active software development efforts across 45 weapon systems and 13 PEOs. Although the larger SWEGs have been providing DAF software development and sustainment for many decades, they also recently established more-innovative software factory teams.[8]

In 2019, each SWEG established its own Platform One node: Ski CAMP (Ogden, Utah), Blue Sky (Warner-Robins AFB), and Thunder CAMP (Oklahoma City, Oklahoma). The SWEGs also have embedded personnel within Platform One in Colorado Springs, Colorado. As Platform One nodes, they help both new and legacy software development teams leverage Platform One services and provide consulting on adopting more-modern DevSecOps approaches to software development.

In addition to the CAMP Platform One nodes, each of the SWEGs also established its own EDDGE team, with the first EDDGE team established in 2017 at Tinker AFB. The EDDGE teams were established to focus on innovative software development at the SWEGs by helping solve complex problems for each SWEG and for other organizations that approach them for help, including DoD organizations or program offices. With a focus on innovation, the EDDGE teams try to partner with academia, industry, and research labs to employ cutting-edge software development methods.

Rebranding

We also note that, because traditional definitions of a *software factory* focus on the tools or processes used in software development instead of an organization or people, in some cases an existing organization or program has rebranded into a software factory with the adoption of more-agile software development capabilities. For example, Kobayashi Maru is a rebranded software development effort that converted from a software program using out-of-date software development methods to a new effort focused on providing continuous, iterative software development in support of the Space and Missile Systems Center. Within the larger Kobayashi Maru factory, personnel have also established a branch known as *Section 31*, which focuses on providing organic software development.

We also identified several projects focused on software development for a specific program or weapon system that were listed as separate software factories by the DAF CSO because of the practices that they use, but in which the people conducting the software development were part of a larger organization. For example, we learned that Mad Hatter is an effort within Kessel Run focused on addressing issues with the F-35, and Sonikube was an effort led by developers who are also part of Ski CAMP within the SWEGs and focused on modernizing legacy hardware for the F-16.[9] Therefore, for our purposes, we did not include these as separate entities in our review.

Current and Future Personnel Needs

A primary objective of our software factory case study was to better understand potential DAF needs for personnel with digital skills, such as software development. For each of the software factories included in our review, we asked for data on current authorized billets and assigned personnel (Table 2) and desired future personnel (Table 3).[10] Overall, we found that the software factories have some funded billets and assigned personnel, but they do not have all the billets and personnel that they feel they currently need or will need to meet future demands.[11]

Current Software Factory Personnel

As stated earlier, the goal of DAF software factories contained in our review is to provide innovative organic software development. To that end, the software factory representatives we spoke with described

TABLE 2

Current Software Factory Authorizations and Assigned Personnel

	Officer		Enlisted		Civilian		
Software Factory	Authorizations	Assigned	Authorizations	Assigned	Authorizations	Assigned	Contractors
BESPIN	16	16	56	56	23	23	251
Cloud One	5	5	0	0	10–15	7–10	10–15
Corsair Ranch[a]	2	2	0	6	0	0	7
Kessel Run	77	82	4	21	132	213	863
Kobayashi Maru	20–25	20–25	0	0	~5	~5	~200
LevelUP	4	9	0	0	44	22	101
Platform One	0	5	0	0	1	3	~200
ShOC Innovation Directorate Software Factory	24	9	28	6	18	0	4
Space CAMP	0	4	0	0	2	3	~30
SWEGs	N/A	N/A	N/A	N/A	N/A	~4,500	51 at Robins AFB
TRON	1	1	4	3	0	0	~20

NOTE: ~ = an estimate; N/A = not applicable. We were not able to include Conjure in this review because it was established at the end of the study. Kessel Run also reported having 250 civilian Direct Cite Authority billets that are not included in the table.

[a] Corsair Ranch military members are Guardsmen and Reservists.

trying to build project teams in which government personnel (military or civilian) are leading the team as product managers (i.e., providing oversight over product development teams and outcomes) and product designers (i.e., focusing on ensuring that the products meet user needs). Contractors—along with other military and civilian members—fill software engineering roles. The contractors are also able to provide software development expertise and skills that may not be readily found within the military or civilian workforces.

Military Personnel

As shown in Table 2, almost all software factories included in our review had some military authorizations and assigned personnel. The exceptions to this are the SWEGs under the AFSC and their EDDGE and CAMP teams; the SWEGs are managed as a working capital fund and employ civilian personnel. We were told that at any one time, however, they do have one to two active-duty personnel assigned at each location. Kessel Run and BESPIN, which are more established, have the largest number of military billets and personnel. Many of the other software factories were still in a start-up phase at the time of our study and had only a small number of funded billets and assigned personnel. Military officers are primarily from Cyber (17X), Engineering (62E), and Acquisition (63A) specialties, while enlisted members are primarily from Cyber (3D) specialties.

When looking at the total number of authorized billets compared with personnel, even for more-established software factories, such as Kessel Run, the organizations do not always have the number of funded billets that they indicated that they need to meet their workload, and in some cases, they have stacked multiple military members on single billets or have multiple personnel assigned on long-term temporary duty (TDY) assignments. In other cases, some software factories, such as ShOC Innovation Directorate Software Factory, have billets but were in the process of getting assigned personnel as the organization became more established.

Challenges

Although there is a desire to have military members at the software factories, the software factories described several challenges in achieving this goal. The most critical challenge is the lack of a dedicated pipeline of military personnel with the technical skills that they need. At the time of this study, the DAF did not have dedicated officer core specialties in the area of software development, although there were initial efforts to begin developing talent in this area with the creation of the 16K duty specialty for software development officers in 2019. On the enlisted side, there is an existing computer systems programming (3D0X4) specialty and the recent development of the 8K duty specialty for software development specialist. However, there are a limited number of enlisted 3D0X4 billets across the DAF, and software factory representatives indicated during our discussions that development in this specialty was not on par with the skill sets needed. Specifically, we were told that members of this specialty have not been traditionally trained in the latest software development techniques, and in the past, members were often used for tasks such as maintaining websites or responding to helpdesk requests rather than more-advanced software development tasks.

As a result, software factory representatives described significant challenges in identifying military members with the required technical skills and described mostly finding military members through word-of-mouth, career field managers, or calls put out by wing leadership (e.g., mass emails to wing members about potential opportunities). In addition, because the software factories lack the number of military billets that they identified needing and are not part of any special assignment for development, they face additional challenges in getting military personnel assigned to the software factories; this has resulted in military members often being at the factories on short-term, six-month TDY orders instead of factories having assigned personnel filling funded billets. At the time of our study, Corsair Ranch, Kessel Run, Kobayashi Maru, Platform One, ShOC Innovation Directorate Software Factory, and Space CAMP all

TABLE 3

Desired Software Factory Personnel and Mix

Software Factory	Desired Personnel and Mix
BESPIN	• Increase of ~20 enlisted and nine officers • Parity between military and contractors; some civilian
Cloud One	• Potential increase of ten personnel (civilian/military)
Corsair Ranch	• In start-up phase; goal is to have close to 12 billets for ARC members • Parity between ARC and contractors
Kessel Run	• Add 487 positions: 105 officer, 175 enlisted, 207 civilian • Government-led teams (civilian or military) with contractors
Kobayashi Maru	• Scale up to 60 teams, with about two to four government personnel per team
LevelUP	• Add more than 200 military billets (~40 percent enlisted and 60 percent officers) • Government-led teams (civilian or military) with contractors
Platform One	• Goal of ~30 military, 40 civilian, and 20 contractors over next five years
ShOC Innovation Directorate Software Factory	• Current authorized billets may be sufficient once filled • ~Two-thirds military, one-third civilian; contractors to scale as needed
Space CAMP	• Expect to scale to ~100 personnel under USSF • Goal of mostly military personnel
TRON	• Increase of ~30–40 authorized government billets • Mix of military and civilian with goal of roughly 2:1 ratio of contractor to military

NOTE: ~ = an estimate. We were not able to include Conjure in this review because it was established at the end of the study. Information in the table reflects the manner in which interview participants provided responses to our question about desired and anticipated personnel. Because the responses varied in format, we could not provide a standardized set of information (e.g., total number of personnel desired and anticipated for each factory).

reported having at least some military personnel who were there on TDY orders. Furthermore, all software factories that used military members indicated that there was no planned or designated follow-on assignment for military personnel at a similar type of organization or performing in a similar type of position. Therefore, any training and development that resulted from their time at the software factory was not necessarily going to be used in a future assignment.[12]

Civilian Personnel

Almost all of the software factories included in our review also employed civilian personnel, except for some of the smaller factories that were still in a start-up phase (Corsair Ranch, TRON). Kessel Run also reported having 250 Direct Cite Authority billets for civilians, which, according to a representative from AFMC's office overseeing Manpower and Organization, is used when one organization (e.g., Air Combat Command) sends funds to another organization (e.g., AFMC) to pay for billets in the receiving organization.

As stated earlier, the SWEGs and their sub-teams are entirely civilian personnel, with roughly 4,500 civilian personnel total working across their three locations. As a working capital fund, the SWEGs are able to hire civilian personnel as funds allow and are not constrained by a specific number of authorized civilian billets. Although the advanced EDDGE and CAMP teams are in constant flux to be able to respond to needs across the DAF, at the time of this study, the EDDGE team at Tinker AFB had nearly 50 civilians, and the other two EDDGE teams had fewer than five civilian personnel. The CAMP teams also vary in size. The largest team, Blue Sky at Robins AFB, had close to 60 civilians at the time of this study, compared with smaller teams of 20 and 13 personnel at Thunder CAMP and Ski CAMP, respectively. With their ability to scale as needed, the SWEGs have also loaned civilian personnel to other software factories (e.g., Kessel Run reported 59 civilian personnel assigned on long-term TDY) to help meet their personnel demands for specific efforts.

For software factories with a mix of civilian and military members, representatives described civilians as filling similar roles to military members in terms of serving as product managers and product designers. Civilians also hold more-technical software development roles. In addition, civilians are viewed as providing key institutional knowledge for the organization because they will not need to rotate out to another position like military members. Civilians who provide technical talent to the factories tend to come from the engineering occupational series (i.e., 801: general engineering; 850: electrical engineering; 854: computer engineering; 855: electronics engineering) and from computer science (1550) and information technology management (2210) occupational series.[13]

Challenges

We also heard of ongoing challenges in attracting and retaining top civilian talent. In particular, software factory representatives stated that current DAF civilian compensation is not competitive with pay in the private sector. In addition, they stated that current Office of Personnel Management (OPM) classification and qualification standards can create obstacles to hiring civilians who have the technical skills needed but perhaps do not meet the exact degree requirements specified by OPM. As a result, software factory representatives described using the information technology management (2210) occupational series because it provided the greatest flexibility in terms of degree requirements; this series offers less compensation, however, so they described trade-offs in its use. The SWEGs described themselves as being the exception to using the 2210 occupational series to the same degree because the majority of their civilians are engineers or come from other sciences (e.g., physics); only roughly 5 percent fall under the 2210 occupational series. They indicated that the engineers and staff from other science disciplines bring the skill sets they need to deal with complex weapon systems.

To overcome these challenges, software factories reported recruiting and hiring talent through both traditional DAF assignment and hiring processes and alternative routes. For example, several of the factories reported that they use external marketing tools to recruit talent (e.g., LinkedIn, AngelList), including holding "Ask Me Anything" sessions through LinkedIn to better market the software factories. Several software factories also moved off-base and into more-modern facilities to try to mimic Silicon Valley.

Contractors

All of the software factories included in our review also used contractors to complete their work. For some software factories, such as BESPIN and Kessel Run, there has been a heavy reliance on contractors because the factories do not have the military and civilian talent that they desire. However, their goal is to shift away from such a reliance in the future. For example, as shown in Table 2, the majority of personnel at many of the larger factories, such as BESPIN, Kessel Run, and Kobayashi Maru, are contractors. However, unlike previous software acquisition models in which contractors delivered final products, software factory representatives described using contractors to provide specific technical expertise and fill software development roles on DAF product teams. The contractors also provide a means to quickly scale up efforts as needed.

Desired or Anticipated Personnel Demands

With some exceptions, representatives from across the software factories indicated a gap in their authorized military and civilian billets and current or anticipated personnel needs (Table 3).

Software factories also described wanting a mix of military, civilian, and contractor personnel, but with a goal of having approximate parity between government personnel (military or civilian) and contractors. As discussed previously, unlike prior models in which contractors delivered a product, the software factories would like to provide organic software development involving government-led teams, with contractors providing specific skill sets to augment organic DAF software development.

Table 3 provides an overview of the desired number of personnel and the mix of military, civilians, and contractors for each software factory. These numbers represent estimates by each software factory and are not based on an official DAF manpower requirements study. However, at the time of this research, AFMC was in the early phases of conducting its own manpower requirements evaluation for Kessel Run.

Although SWEGs are not included in the table, SWEG representatives described interest in employing military members who could bring insight into how the software might be used in an operational setting if there were sufficient numbers of military members with the needed technical skills.

> Software factories want a mix of military, civilian, and contractor personnel.

Summary of Personnel Challenges

Our research highlighted the following personnel challenges:

- Software factories have some funded billets and assigned personnel but reported not having enough billets and personnel to meet what they consider their current or future needs. AFMC is beginning manpower studies to further establish the actual personnel requirements.
- Although there is a desire to have military members at the software factories, the factories reported challenges in acquiring more military members because of the absence of a dedicated pipeline of military personnel with the necessary technical skills.
- Training and development of military members that occurs at software factories is not currently used in future assignments.
- Attracting and retaining top civilian talent can be difficult because of less competitive compensation and rigid degree requirements.

Professional Development Practices at Software Factories

As a way to address the need for more-technical skills among military members and to help onboard civilian personnel, all of the software factories in our case study offered professional development to

staff in some form, although not in a standardized or formal program. Training and development can be a combination of on-the-job training, technical boot camps, and conferences, among other options. However, none of the factory representatives that we interviewed indicated that there are set training requirements, aside from what is required by DoD for acquisition positions (if relevant). BESPIN indicated working on more-standardized means to train and develop personnel and was involved in developing Digital University, an online learning environment designed to help the DAF develop a digital workforce.[14] BESPIN also described interest in standing up a mentoring program that it conceived in partnership with AFWERX. The program is called Drudonna and would create a Mentoring Hub at AFWERX. Personnel who have aptitude and interest in applying mobile or web-application skills in the field would go through a 12-month mentorship program. It is important to note that Drudonna is envisioned as an enabler of personnel upskilling, not as a program limited to those who go to BESPIN on assignment.

Software Factory Coordination

As part of our discussions with the software factory representatives, we attempted to better understand the extent to which the various DAF software factories were connected or coordinated any of their efforts. Overall, representatives indicated that there are close and frequent connections between some software factories (some even reported talking daily), but those connections tend to be at the individual level and are based on preexisting informal relationships among personnel. For example, individuals who were at Kessel Run then went on to establish Section 31 under Kobayashi Maru and maintained relationships with personnel at Kessel Run. Similarly, three individuals from Kessel Run established Space CAMP.

The software factories have also worked together in a community of practice capacity to help attract and develop Air Force talent. For example, BESPIN, Kessel Run, LevelUP, Platform One, Corsair Ranch, Space CAMP, and TRON collaborate to advocate for personnel to learn how to code. By working with Cyberspace career field managers, these organizations developed a 2020 summer Digital Airmen Internship program. The goal of the internship program was to help build a long-term pipeline of military members who can then be tracked for future assignment opportunities. As already noted, one of the challenges that the software factories described related to military personnel is that there is no current, deliberate career management in the area of software development that meets their needs; this includes no direct follow-on assignments for military members who do a tour at a software factory. As a result, most military members at the software factories were there through word of mouth. The internship program was an attempt to create more of a pipeline for future assignments.

Other than formal coordination when working for the same program office or on the same project, it appeared that there was no formal oversight or coordination across all DAF software factories at the time of this study. This has the potential to lead to silos and duplication of effort or capabilities and potential competition for customers. Recognizing the need for coordination and information sharing, we were told that AFMC PEO-level representatives have developed a collaboration forum that tries to meet periodically—but this forum pertained only to AFMC at the time of this study. Similarly, there is coordination of the SWEGs given their organizational structure under the AFSC. Thus, although the software factories indicate working closely together, there was no forcing function to ensure coordination.

Conclusion and Considerations for the Future

The software factories included in our case study continue to evolve and grow, and more factories are being established in the DAF. Many of the software factories described a need for more government (military and/or civilian) technical talent, yet they were challenged in obtaining billets and personnel with the technical skills that they need.

Addressing the Development and Utilization of Military Members

In particular, planned utilization of military members as technical experts at these factories (and elsewhere in the DAF) will require deliberate development and

career management. Although the DAF does not have dedicated core specialties to create a career path for these personnel, at the time of this study, there was movement in that direction in the cyber community for software development and computer programming. DAF interest in developing dedicated career specialties or paths for personnel (military and civilian) dovetails with calls from Congress and DoD-sponsored experts (e.g., Defense Innovation Board) for DoD to have career paths for digital talent.[15] We recommend that the DAF continue working toward dedicated career specialties or paths if it wants to sustain a digital workforce with the organic technical talent desired by the software factories.

As a sign that the DAF may be headed in this direction, we learned that the Deputy Chief of Staff for Manpower, Personnel and Services was working on creating a prefix for all software factories' military officers and enlisted personnel so that they rotate only among software factories. Dedicated specialties or career paths will also need to include key developmental opportunities, such as those at DAF software factories. These career paths will also require continued opportunities for assignments that are more technical in nature because technical skills could be perishable if not used on a consistent basis, or they might become obsolete as technologies and techniques change.[16] This need for sustaining technical skills may be more challenging on the military side than the civilian side given the requirement for officers (in particular) to have broader leadership roles as they reach higher ranks. The DAF may need to either establish technical core specialties or use a technical career track model for officers within the cyber community. A technical career track model has been considered for DAF pilots and requires planning to ensure that the broader community can be sustained while supporting a technical track (Robbert et al., 2018).

Software factories could also have a greater role in digital talent development. They were not established with the mission to develop digital talent; they were established to develop software, which is likely the reason that software factories do not have a standard approach for developing their new staff. However, assessments of military members' digital knowledge and skills could further support talent development through the software factories. For example, assessments could be used to help identify a pool of personnel who would have the knowledge and skills necessary for software factory positions; the assessments could also be used to determine how well the factories are developing digital skills among those personnel, identifying what specific skills are being developed and at which factories. The results of the assessments taken while personnel are at the factories could help the DAF in two ways. First, assessment results could help the DAF determine follow-on assignments for those personnel. Second, the assessments could be used to help shape professional development standards at the software factories if analysis shows that certain types or levels of professional development offered by the factories (e.g., technical boot camps versus on-the-job training) are more effective and efficient than others.[17]

Planned utilization of military members as technical experts at factories will require deliberate development.

Attracting and Retaining Top Civilian Talent

Software factories also reported challenges in attracting and retaining top civilian talent because of less competitive compensation and rigid degree requirements. Over the past few years, Congress and others have called for reforms to civilian human resources systems to better attract, hire, and use digital talent in DoD and the DAF (e.g., Defense Innovation Board, 2019a). It was beyond the scope of the current project to directly examine issues with civilian recruitment and hiring, although the DAF should consider doing so to determine whether concerns about recruiting and hiring digital talent can be validated by evi-

dence (e.g., compensation analyses controlling for labor market characteristics). However, our understanding is that DoD is in the process of exploring whether there is a need for new occupational series for software engineering and data science, which may help address some of the challenges reported by the software factories.[18] The DAF should also continue exploring innovative ways to attract top civilian talent, including ways that the DAF might better use available hiring authorities and flexibilities.

We also offer two other options derived from our project findings that could help augment other reforms to acquiring civilian digital talent. First, because software factories are struggling with acquiring new billets that they indicate they need, one option to augment their current needs is to source DAF civilians from the SWEGs, which house thousands of civilians focused on software development. According to a senior SWEG representative, because the SWEGs use a working capital fund to hire civilian talent, SWEGs have flexibility in that they are not tied to civilian billets. This flexibility allows the SWEGs to readily provide civilian talent to other organizations, such as Kessel Run, because they do not face a zero-sum situation of sending billets from one organization to another. Other software factories and innovation centers that have available program funding could similarly work with the SWEGs to identify the technical talent that they need to augment their current workforce. If leveraged properly, this option to work with SWEGs could help meet short-term gaps for civilians at software factories.

The SWEGs also described leveraging partnerships with industry, including large defense contractors (e.g., Lockheed Martin), to upskill their engineers and other digital talent. Civilian engineers and computer scientists will be embedded with the industry partner to produce code side-by-side and to learn the weapon system software that the partner is developing. SWEG representatives also described partnering with academia to help engineers learn leading edge techniques (mainly via the SWEGs' EDDGE teams). Although partnerships with industry and academia are not limited to the SWEGs, their use in the SWEGs shows they can provide value to large, established DAF organizations that house civilian technical talent. The potential to engage in such learning experiences might also have the added benefit of making a civilian position within the DAF more attractive to private sector talent. However, unlike the first option to leverage existing SWEG talent at the software factories, the benefits of leveraging partnerships to develop talent could take months or years (i.e., this would be a longer-term approach to meeting needs).

Continued Information Sharing and Coordination

Finally, as factories become more established and grow, there may be a need for more oversight at the DAF level to facilitate information sharing and coordination. However, such oversight would need to be balanced with the factories' ability to continue to be flexible and innovative.

Summary

In conclusion, software factories have emerged as part of DAF efforts to modernize software acquisition and development practices. However, because the software factories are start-up organizations, initial funding appears to be ad hoc: The parent or owning organization provides initial funds and billets, but the majority of funding comes from customers that use the organizations' software development and platform capabilities. In trying to establish these software factories, representatives reported that, as of FY 2020, they had some funded billets and assigned personnel but did not have enough billets and personnel to meet what they consider their current or future needs. Furthermore, although there is a desire to have military members at the software factories, the factories reported challenges in acquiring military members because of the absence of a dedicated pipeline of military personnel with the necessary technical skills. Attracting and retaining top civilian talent was also reported as difficult because of less competitive compensation with the private sector. To fully use and leverage software factory capabilities, the DAF will need to address these challenges, including ensuring coordination among software factories as these software factories continue to grow and evolve.

Notes

[1] According to the DAF Chief Software Office website, *DevOps* "is a software engineering culture and practice that aims at unifying software development (Dev) and software operation (Ops). The main characteristic of the DevOps movement is to strongly advocate automation and monitoring at all steps of software construction, from integration, testing, releasing to deployment and infrastructure management." *DevSecOps* includes the use of "the cybersecurity stack built-in into the DevOps pipeline" (Assistant Secretary of Acquisition, Chief Software Office, undated a).

[2] Rogue Blue Software initially considered having government-led teams but decided that they would not be able to have enough government manpower to do that at scale.

[3] Two software factories included on this list at the time of our project but not included in our review are Rogue Blue Software and N2X Pathfinder because they did not fit our definition for the reasons we noted.

[4] More information on defense working capital funds can be found in Herrera, 2020.

[5] For more details on the development and success of Kessel Run, see Wallace, 2018.

[6] The more than 70 Spark Cells that are currently established can be viewed as smaller, nimble innovation teams that focus on specific challenges at the local level. AFWERX offers support to these groups by providing education and outreach (e.g., quarterly workshops) and helping to articulate the need, rationale, and capabilities for emerging Spark Cells. Therefore, AFWERX is not directly responsible for products and services, but its efforts in helping to stand up Spark Cells and link funding to promising products has directly led to new, innovative solutions. The Spark Cells themselves are not intended to be software factories, although personnel forming these Spark Cells might engage in software development, depending on their skill sets.

[7] Authority-to-operate reciprocity refers to agreement among two or more entities to "accept each other's security assessments in order to reuse information system resources and/or to accept each other's assessed security posture in order to share information" (Committee on National Security Systems, 2015, p. 100).

[8] In addition to the CAMP and EDDGE teams, the SWEGs also have two other teams that are doing more advanced DevSecOps: Xanatos Gambit under the 76 SWEG at Tinker AFB and PRC2 under the 309 SWEG at Hill AFB.

[9] Sonikube is a team within Ski CAMP that was involved in installing Kubernetes on legacy hardware in F-16s. Currently, they serve as a LevelUP node to help programs apply DevSecOps practices.

[10] Note that we were not able to obtain more-detailed personnel information regarding specific roles or positions. Therefore, the data provided in Tables 2 and 3 should be taken as a broad assessment of current and future personnel needs.

[11] In the course of our study, we learned that AFMC had done its own internal review of organic software coding needs. AFMC staff queried all AFMC centers and asked them to provide data on their current, funded manpower (organic and estimated contractor support), their projected future manpower requirements, and their future manpower disconnect. Using AFMC center inputs, AFMC estimated that about 6.6 thousand members were performing software coder duties (4.3 thousand organic and about 2.3 thousand contractors) and that there was a software coder manpower shortfall of about 800 billets. These estimates reflect the software factories included in our review and additional AFMC organic software coders outside the software factories. Note that no formal definition of *software coder* was provided as part of the query, so it is not clear how each center defined the manpower requirements included in its data.

[12] During summer 2020, several of the software factories developed a Digital Airmen Internship program with the goal of helping build a long-term pipeline of service members who can then be tracked for future assignment opportunities.

[13] Currently, there is no civilian occupational series focused specifically on software development or software engineering.

[14] Vendors such as Udemy, Udacity, and PluralSite will provide online courses that are meant to align with commercial best practices in such areas as software development, data science, artificial intelligence and machine learning, cloud engineering, cyber security, and user interface and user experience design (Digital University, 2020). According to the Digital University website (2020), the organization "leverages the same training model used by tech giants such as Google and Lyft" and is "free for all airmen and [civilians], and always will be."

[15] See Section 862 of the FY 2020 NDAA, which includes language directing DoD to establish career paths for software development and software acquisition personnel (Pub. L. 116-92, 2019). Also see the Defense Innovation Board reports, 2019a, *Software Is Never Done: Refactoring the Acquisition Code for Competitive Advantage*, and 2019b, *Campaign for an AI Ready Force*.

[16] Concerns about technical skill "perishability" often lack direct evidence to indicate which skills are subject to decay and under what conditions. Although we cite perishability as a potential risk, we note that formal evaluation would be needed to determine how much of a risk it truly presents.

[17] As an example of how this could work, personnel who have been at a factory for a set amount of time (e.g., a year) could take assessments of knowledge and skills relevant to the work role that they have at the factories and complete a questionnaire about the types and levels of training, education, and other developmental opportunities (e.g., mentoring) that they were provided during that time period. At a minimum, the DAF could correlate results from the questionnaire and digital skills assessments to see whether patterns emerge across personnel at different factories and in different roles. If there are patterns, this could help the DAF identify the relative utility of the types of training, education, and developmental opportunities offered.

[18] Even if DoD determines a need for new civilian occupational series, the ultimate decision is made by OPM, which takes into consideration the needs of other federal departments and agencies as well.

Bibliography

Assistant Secretary of Acquisition, Chief Software Office, "DevOps," webpage, undated a. As of September 28, 2020: https://software.af.mil/training/devops/

———, "Software Factories," webpage, undated b. As of September 28, 2020: https://software.af.mil/software-factories

———, "Conjure," webpage, September 1, 2020. As of September 28, 2020: https://software.af.mil/softwarefactory/conjure/

Committee on National Security Systems, *Committee on National Security Systems (CNSS) Glossary*, CNSSI No. 4009, April 6, 2015.

Defense Innovation Board, *Software Is Never Done: Refactoring the Acquisition Code for Competitive Advantage*, Washington, D.C., May 3, 2019a.

———, *Campaign for an AI Ready Force*, Washington, D.C., October 2019b.

———, *Appointing a Department of Defense Chief Digital Engineering Recruitment and Management Officer*, Washington, D.C., March 5, 2020a.

———, "Public Meetings," webpage, quarterly public meeting, virtual, September 15, 2020b. As of September 15, 2020: https://innovation.defense.gov/Meetings/

Defense Science Board, Office of the Under Secretary of Defense for Research and Engineering, *Design and Acquisition of Software for Defense Systems*, Washington, D.C.: U.S. Department of Defense, February 2018.

Department of Defense Instruction 1400.25, Volume 250, *DoD Civilian Personnel Management System: Civilian Strategic Human Capital Planning (SHCP)*, Washington, D.C.: U.S. Department of Defense, June 7, 2016.

Digital University, homepage, 2020. As of November 16, 2020: https://digitalu.af.mil/

DoD—*See* U.S. Department of Defense.

Herrera, G. James, "Defense Primer: Defense Working Capital Funds," Washington, D.C.: Congressional Research Service, IF11233, version 4, July 17, 2020.

Kennedy, Kevin, and Lauren Knausenberger, "Digital Talent," internal Air Force presentation, March 17, 2020, Not available to the general public.

McIntosh, Molly F., Patricia K. Tong, Hannah Acheson-Field, Noah Johnson, Norah Griffin, and Joshua Russell-Fritch, *Monetary and Nonmonetary Compensation for High-Value U.S. Department of Defense Civilian Skill Sets*, Santa Monica, Calif.: RAND Corporation, RR-A385-1, 2020. As of November 16, 2020: https://www.rand.org/pubs/research_reports/RRA385-1.html

NDAA—*See* Public Law 116-92.

Public Law 116-92, National Defense Authorization Act for Fiscal Year 2020, Sec. 862, Software Development and Software Acquisition Training and Management Programs, January 3, 2019. As of September 8, 2020: https://www.congress.gov/116/bills/s1790/BILLS-116s1790enr.pdf

Robbert, Albert A., Michael G. Mattock, Beth J. Asch, John S. Crown, James Hosek, and Tara L. Terry, *Supplemental Career Paths for Air Force Pilots: A Warrant Officer Component or an Aviation Technical Track?* Santa Monica, Calif.: RAND Corporation, RR-2617-AF, 2018. As of September 8, 2020: https://www.rand.org/pubs/research_reports/RR2617.html

U.S. Air Force, *Acquisition Annual Report, Fiscal Year 2018: Cost-Effective Modernization*, Washington, D.C., undated. As of September 8, 2020: https://www.af.mil/Portals/1/documents/5/FY18_AQReport.pdf

U.S. Department of Defense, *Summary of the 2018 National Defense Strategy of the United States of America: Sharpening the American Military's Competitive Edge*, Washington, D.C., 2018.

———, *Summary of the 2018 Department of Defense Artificial Intelligence Strategy: Harnessing AI to Advance Our Security and Prosperity*, Washington, D.C., 2019a.

———, *DoD Digital Modernization Strategy: DoD Information Resource Management Strategic Plan FY19–23*, Washington, D.C., July 12, 2019b.

U.S. Department of Defense Chief Information Officer, *DoD Enterprise DevSecOps Reference Design*, Version 1.0, Washington, D.C.: U.S. Department of Defense, August 12, 2019.

Wallace, Mark, "The U.S. Air Force Learned to Code—and Saved the Pentagon Millions," *Fast Company*, July 5, 2018.

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About This Report

To help meet congressional requirements in the fiscal year (FY) 2020 National Defense Authorization Act, which directs the U.S. Department of Defense "to promote and maintain digital expertise and software development as core competencies of civilian and military workforces of the Department, and as a capability to support the National Defense Strategy," the U.S. Department of the Air Force (DAF) established a Digital Talent Taskforce in FY 2020 to help define DAF digital talent needs, including developing requirements and competencies for digital talent. In support of the taskforce's efforts, RAND Project AIR FORCE was asked to conduct a case study to identify digital talent needs in the area of software development by exploring DAF software factories that use modern and agile software development practices. As of FY 2020, DAF software factories were newer organizations that were quickly growing in number and size, such that they present a challenge for workforce planning. According to this review, most DAF software factories were still in their start-up phases as of FY 2020, with additional software factories continuing to emerge across the DAF.

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