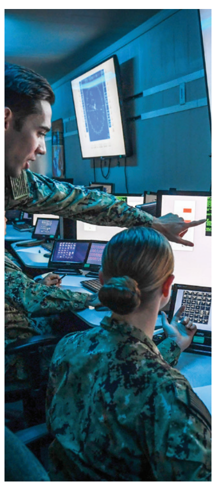
TIMOTHY MARLER, MATTHEW W. LEWIS, MARK TOUKAN,
RYAN HABERMAN, AJAY K. KOCHHAR, BRYCE DOWNING,
GRAHAM ANDREWS, RICK EDEN

Supporting Joint Warfighter Readiness

Opportunities and Incentives for Interservice and Intraservice Coordination with Training-Simulator Acquisition and Use






For more information on this publication, visit **www.rand.org/t/RRA159-1**.

Published by the RAND Corporation, Santa Monica, Calif.

Cover: Cover (left to right): U.S. Army; U.S. Air Force/Airman 1st Class Tiffany Price; U.S. Navy/ Petty Officer 2nd Class Joseph Millar; U.S. Navy/Mass Communication Specialist Apprentice Riley McDowell.

About This Report

This report documents research and analysis conducted as part of a project titled *Supporting Joint Warfighter Readiness: An Analysis of Gaps Between Joint Training Needs and Training-Simulator Capabilities*. The purposes of the project were to (1) investigate the gap between joint training needs that support readiness requirements across services and currently available and forthcoming technology in the training-simulator field and (2) recommend potential incentive structures for fostering cross-service collaboration for simulator acquisition and use.

The research reported here was completed in January 2021 and underwent security review with the sponsor and the Defense Office of Prepublication and Security Review before public release.

RAND National Security Research Division

This research was sponsored by the Office of the Under Secretary of Defense for Personnel and Readiness and conducted within the Forces and Resources Policy Center of the RAND National Security Research Division (NSRD), which operates the National Defense Research Institute (NDRI), a federally funded research and development center sponsored by the Office of the Secretary of Defense, the Joint Staff, the Unified Combatant Commands, the Navy, the Marine Corps, the defense agencies, and the defense intelligence enterprise.

For more information on the RAND Forces and Resources Policy Center, see www.rand.org/nsrd/frp or contact the director (contact information is provided on the webpage).

Contents

Figures and Tables

Figures

Tables

Summary

The Need for Joint Simulation-Based Training

Joint operations require joint training at all levels of warfare, and much of this must be simulation-based training (SBT) conducted on networked and distributed training systems that allow participants from multiple services to interoperate. The prospects for highly capable joint SBT systems appear favorable, because the commercial industry is rapidly advancing the state of the art for training simulators. Yet these efforts do not necessarily respond directly to warfighter needs. There is not a systematic and consistent alignment between the needs of the U.S. Department of Defense (DoD) and industry pursuits. Furthermore, coordination and interoperability among services are critical for supporting joint training, but these have long been challenges within DoD. As current and potential conflicts increasingly involve joint operations, joint training becomes increasingly important, and this brings current gaps into focus.

Research Objective and Approach

The objective of this study was to identify changes that DoD could make in its structures, processes, and incentives to improve the development of SBT requirements and the acquisition of interoperable training simulators that can support joint training at the operational and tactical levels of war.

To fulfill this objective, we analyzed the gap between DoD joint training needs and current and future SBT resources. The focus of this report is on operational and tactical SBT, particularly cross-service air and ground simulators. Information sources for the gap analysis included literature reviews (both military and academic literature), engagements with subject-matter experts in both DoD and industry, and case studies of current air and ground simulators.

This report is divided into four parts. The first part of the report focuses on the individual services and coordination within each service, the second part focuses on joint training needs and coordination among services, the third part focuses on industry and the state of the art that can presumably respond to these needs, and the fourth part summarizes our findings and recommendations.

We sought to answer the following questions:

- What are the differences among the services with respect to organizational structure and internal coordination?
- What are the differences among the services with respect to simulator requirements and acquisition processes?
- What are the joint training needs?
- What incentives are there for cross-service collaboration, interoperability, and industry support of interoperability?
- What technological capabilities are available to support cross-service simulator integration?

Findings and Recommendations

The Services Should Align Organizationally to Facilitate Coordination

The services are not organized optimally for coordinating the development and acquisition of training simulators—either internally, within a service, or externally, with other services—to ensure that they are interoperable and networked to support joint training. Both internal and external coordination would be facilitated by having additional centralization, whereby a single internal organization has visibility into

SBT efforts across the service. The same organization would also be positioned to provide a primary point of contact for external organizations, thus helping facilitate integration with their SBT efforts. The Office of the Secretary of Defense (OSD) should urge alignment of services' organizational structures involved in simulator development to help support interservice coordination. OSD should also incentivize each service to develop a coordinating organization or office with the same responsibilities and general structure.

The Services Should Coordinate Development of Simulation-Based Training Requirements

The services use different processes to develop requirements for SBT, including requirements for joint training. Decentralization of requirements gathering and coordination for specific SBT products is more likely to produce siloing of acquisitions such that best practices and lessons learned are not shared across acquisition efforts. The services' modeling and simulation (M&S) offices could provide a means for coordinating SBT expertise and requirements within and across services. These offices house significant expertise and often coordinate between themselves. However, they might need additional resources, in terms of funding or policy, to enact improvements in cross-service coordination. Each service should fund and require M&S offices to carry out coordination with respect to joint SBT technical information and capabilities. These offices could help develop plans for science and technology (S&T) development that supports integrated joint training. The Defense Modeling and Simulation Coordination Office (DMSCO) should have sufficient funding and policy levers to provide oversight to the service M&S offices with respect to coordination. DMSCO could help compare, coordinate, and align S&T plans. OSD should consider providing Title 10 authority to the Joint Staff Force Development Directorate (JS J7) for identifying, prioritizing, and feeding joint M&S requirements into the development process.

The Services Should Coordinate in the Acquisition of Simulation-Based Training Systems

The services manage the acquisition of SBT differently, and these differences can hinder coordination in the acquisition of SBT systems. Coordination is needed to overcome challenges in prioritizing interoperability, maintaining currency with fielded systems as they are upgraded, and meeting information-assurance standards. Case studies of air-ground simulators for each service illustrate these differences in SBT acquisition organizations and processes as well as common challenges, such as prioritizing interoperability, maintaining currency, and meeting information-assurance standards. Each service should ensure that efforts for acquiring and setting requirements for simulators fall under the same management, thus ensuring alignment and coordination. Service acquisition offices should acquire training simulators along with the weapon system as a matter of course and upgrade them to maintain currency.

Demand for Joint Training Can Be Unclear at Lower Levels

Challenges with coordination extend beyond the individual services and can stem from an unclear demand signal. With multiple disincentives and barriers in place, it is difficult to establish the true demand for joint SBT. Thus, the demand signal for joint SBT needs to be clarified to inform coordination and prioritize development of interoperable simulators.

The Joint Capabilities Integration and Development System (JCIDS) is the primary process through which joint acquisitions take place, including acquisition of joint training simulators. However, the JCIDS process can be cumbersome and can operate on long time horizons, imposing transactional costs that reduce incentives to pursue joint training-simulator solutions. These characteristics can stifle agile development of interoperable simulators that respond directly to joint training needs.

Each of the services is responsible for training joint Tier 3 and Tier 4 tasks outlined in the Universal Joint Task List (UJTL), and the Joint National Training Capability (JNTC) provides mechanisms for doing so. However, the lack of centralization for joint training within the services makes coordination of joint training at Tier 3 and Tier 4 challenging. This might suppress the true demand for joint SBT at these tiers.

JNTC should gather additional data that reflect demand for joint training on the Tier 3 and Tier 4 levels. In part to improve coordination, DoD has developed joint tactics, techniques, and procedures (TTP), has developed Joint Mission Essential Tasks (JMETs), and has established UJTL. However, since Joint Forces Command's (JFCOM's) disestablishment in 2011, the UJTL program has atrophied, and OSD should support the UJTL program (including joint TTP and JMETs) more thoroughly.

Office of the Secretary of Defense Organizations Should Facilitate Coordination Among the Services

There is little coordination among the services to develop interoperable simulators, but there are DoD organizations that could play larger roles in encouraging and facilitating cross-service coordination. OSD should appoint a single joint organization, possibly JS J7, to focus on simulator-development coordination and Tier 3 and Tier 4 simulator training. The proposed organization should oversee which capabilities should be codified by the Joint Requirements Oversight Council (JROC) and thus qualify for funding through joint streams. The DoD Senior Steering Group (SSG) for simulator interoperability can provide a venue for services, DoD agencies, OSD, and the Joint Staff to collaborate. The Joint Training Coordination Conferences can address simulator requirements.

The Deputy Assistant Secretary of Defense (DASD) for Force Education and Training (FE&T) could use its role as simulator interoperability SSG lead of the conceptual model working group to help services coordinate around common conceptual models. DASD(FE&T) could also use its position on the Defense Advanced Distributed Learning Advisory Committee to identify common, critical interoperability requirements. With oversight from DASD(FE&T), the Advanced Distributed Learning initiative could address simulator development.

DMSCO promotes coordination, interoperability, common standards, and M&S reuse. It potentially could serve a more robust function of tracking, coordinating, and directing M&S activities, but it has atrophied in size.

Joint Interoperability Test Command (JITC) tests DoD information technology systems for interoperability, but, under current policy, training simulators do not require interoperability testing because they do not use real-world data. A joint body that could test and certify simulator interoperability could be extremely helpful and could incentivize services to coordinate over simulator development to meet certification standards.

When JFCOM was dissolved in 2011, many of its key functions were transferred to JS J7, but some functions that may have served to facilitate joint collaboration have degraded over time or were lost in the transition. Most importantly, JFCOM had Title 10 authorities to formulate and conduct joint training, while the JS J7 currently does not. The current focus of JS J7 is on Tier 1 and Tier 2 training, while Tier 3 and Tier 4 currently do not have a joint-level body that serves to help services coordinate on identifying and developing simulator requirements and capabilities. JS J7's training-gap analysis forums no longer occur, and this is detrimental to coordination efforts.

The Office of the Secretary of Defense Should Incentivize Development of Cross-Service Simulation-Based Training

The services have relatively few incentives to collaborate in developing SBT or to pursue interoperability. As a result, service-specific training requirements take precedence over joint training. The Under Secretary of Defense for Personnel and Readiness (USD[P&R]) should prioritize funding for joint training requirements. OSD could take the lead in helping increase incentives for coordination. In particular, OSD could seek Title 10 authority for JS J7, thus providing leverage that previously resided with JFCOM. JS J7 could then be responsible for identifying, prioritizing, and feeding joint M&S requirements into the development process. In addition, OSD could incentivize services to develop joint simulators, either by taking steps to reduce problems with joint programs, such as multi-stream funding and uncoordinated governance (between services), or by setting aside funds specifically for interoperability.

JS J7 and JNTC control funds that might serve as an incentive, but these are modest. JROC designation of a simulator acquisition program as joint-interest would incentivize collaboration, but simulator programs rarely receive this designation. Negative incentives can also be included in the form of doctrine or policy requirements for specific functions to operate at the joint level and, by extension, require joint contracting. Joint training requirements need to be formally specified, and organizations and requirements for testing interoperability should be identified.

More-Efficient Communication Is Needed Between DoD and Industry

Industry continues to advance the state of the art in ways that are beneficial to joint training simulators. However, it is not clear that these overall lines of effort specifically align with DoD and warfighter needs. Thus, there is a need to constantly cross-walk industry research-and-development efforts with the demand signal from joint training efforts. Furthermore, given the rapid changes in technology and inevitable changes in warfare, such analysis should occur regularly. However, systematically characterizing such needs is a challenge. This can leave industry pursuing projects that perhaps require relatively little effort and are expected to generate profits but do not respond to specific user needs. This, in turn, can generate inefficiency.

Cross-service simulator integration is supported by a mix of (incompatible) standards for information exchange and federation techniques. Industry-developed simulation engines ("game" engines) offer rich tool sets for M&S that are proving to be beneficial to military M&S needs, including simulator design and development. However, fundamental differences between the entertainment industry and military needs prohibit DoD from leveraging all aspects of the success that the gaming industry has had with respect to scalable networked simulators. In particular, the diversity of hardware and software systems presents substantial challenges in ensuring system interoperability, especially compared with the success of the gaming industry. Furthermore, testing is insufficient to ensure adherence to data standards. The

Chairman of the Joint Chiefs of Staff should exercise Title 10 authority for technical standards more frequently in the context of training.

Enabling multiple levels of security is a persistent challenge for joint interoperation across simulators. The DoD Risk Management Framework requires the integration of cybersecurity into the system's design process. OSD should consider implementing joint-level processes to overcome difficulties in information assurance and security.

DoD also could restructure its relationship with industry partners by implementing a marketplace that supports and improves the communication between, and coordination of, DoD "buyers" and "sellers" of training simulators. Service M&S offices could help articulate a current demand signal for interoperability of simulations, both for current or near-term acquisitions and for future acquisitions, and could quickly screen contracts for inclusion of joint interoperability requirements. The marketplace also would include test beds or evaluation tools that can evaluate whether training simulators meet contractual interoperability requirements before they are delivered.

The Office of the Secretary of Defense, the Services, the Joint Staff, and Industry Have a Way Forward

Although substantial changes in organization or responsibilities might be impractical for near-term impact, there is a series of changes that DoD could make within services and across services. In general, these changes entail ensuring the existence of organizations with some level of centralized coordination. This can be especially helpful with respect to archiving information and data. Within each service and within the Joint Staff, there should be one organization that at least aggregates information concerning simulator capabilities, requirements, and acquisition. The first step does need not to be any significant change in funding or policy, but rather simple transparency of information and data. Ultimately, changes in policy and financial resources will be helpful as incentives for services to collaborate with one another.

Table S.1 summarizes the major recommendations of this study in the form of a roadmap for improved coordination.

Table S.1
Major Recommendations

Category and Organization	Recommendations
Management of the services	
OSD should . . .	• Incentivize all services to develop coordinating organizations with the same responsibilities and structure. • Urge services to align structures for simulator development to facilitate interservice coordination.
Each service should . . .	• Fund and require M&S offices to coordinate technical information and capabilities. • Develop a clear vision and plan with regard to S&T development that supports integrated joint training.
Management of the joint community	
OSD should . . .	• Increase the focus on joint coordination. • Appoint a single joint organization to focus on simulator-development coordination. • Explicitly fund interoperability. • Consider implementing joint-level processes for information assurance and security. • Have USD(P&R) prioritize funding for joint training requirements and help services coordinate common conceptual models.
The Joint Staff should . . .	• Support the UJTL program to support joint coordination. • Exercise its Title 10 authority for technical standards in the context of training. • Have JS J7 resume its training-gap analysis forums as a mechanism to support joint coordination. • Have JITC resume responsibility for testing simulator interoperability. • Have JNTC gather additional data concerning joint training exercises on Tiers 3 and 4.
Technology development	
DoD and industry should . . .	• Focus future acquisition programs not just on simulators but on supporting capabilities, including data standards, gaming technology, and security considerations. • Leverage methods from distributed systems, high-performance computing disciplines, and advanced networking concepts. • Establish technology readiness levels and standards for interoperability and joint simulator training exercises.

Table S.1—Continued

Category and Organization	Recommendations
Interfacing with industry	
DoD should . . .	• Ensure that financial incentives are large enough to overcome the opportunity cost of not implementing open standards and not relinquishing data rights. • Consider nonmonetary incentives for joint simulators. • Consider both positive and negative incentives with application to both government program offices and industry contractors.
OSD should . . .	• Take the lead in implementing an accessible and efficient marketplace to bring together industry and DoD.

Acknowledgments

We would like to thank the senior leaders at the Office of the Under Secretary of Defense for Personnel and Readiness and DASD(FE&T). In particular, our sponsor, Fred Drummond, and our action officer, Shep Barge, provided valuable oversight, guidance, and expert feedback throughout the course of our work.

We are grateful for input from industry representatives and from subject-matter experts from the Joint Staff and each of the services.

At the RAND Corporation, we thank John Winkler, director of the Forces and Resources Policy Center, for his support and guidance. John Ausink, our dedicated reviewer, also provided valuable insight. Finally, we are indebted to Craig Bond and Paul Steinberg for initial edits and feedback on the structure and content of the report.

Abbreviations

ACC	Air Combat Command
ADL	Advanced Distributed Learning
AETC	Air Education and Training Command
AFAMS	Air Force Agency for Modeling and Simulation
AFI	Air Force Instruction
AFLCMC	Air Force Life Cycle Management Center
AJST	Army Joint Support Team
AMC	Air Mobility Command
AMSO	Army Modeling and Simulation Office
ANG	Air National Guard
AoA	Analysis of Alternatives
AR	Army Regulation
ARCIC	Army Capabilities Integration Center
ASA	Assistant Secretary of the Army
ASN(RDA)	Assistant Secretary of the Navy for Research, Development, and Acquisition
ATO	authorization to operate

AVCATT	Aviation Combined Arms Tactical Trainer
CAVE	Combined Arms Virtual Environment
CBA	capabilities-based analysis
CCMD	combatant command
CCMDR	combatant commander
CCTT	Close Combat Tactical Trainer
CD&I	Combat Development and Integration
CDB	Common Database
CDD	Capabilities Development Directorate
CE2T2	Combatant Commander Exercise Engagement and Training Transformation
CFT	cross-functional team
CIO	Chief Information Officer
CJCS	Chairman of the Joint Chiefs of Staff
CJCSI	Chairman of the Joint Chiefs of Staff Instruction
CJCSM	Chairman of the Joint Chiefs of Staff Manual
CMC	Commandant of the Marine Corps
CNO	Chief of Naval Operations
CNSSI	Committee on National Security Systems Instruction
CoE	Centers of Excellence
CSA	combat support agency
DASD(FE&T)	Deputy Assistant Secretary of Defense for Force Education and Training

DASD(FR)	Deputy Assistant Secretary of Defense for Force Readiness
DASD(RP&R)	Deputy Assistant Secretary of Defense for Readiness Programming and Resources
DC CD&I	Deputy Commandant for Combat Development and Integration
DCR	Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities, and Policy change request
DCS	Deputy Chief of Staff
DIS	Distributed Interactive Simulation
DMO	Distributed Mission Operations
DMSCO	Defense Modeling and Simulation Coordination Office
DoD	U.S. Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DOTMLPF-P	Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities, and Policy
DRRS	Defense Readiness Reporting System
FE&T	Force Education and Training
FOM	Federation Object Model
FPS	first-person shooter
GAO	U.S. Government Accountability Office
HLA	High-Level Architecture
IAMD	integrated air and missile defense

ICD	Initial Capabilities Document
I/ITSEC	Interservice/Industry Training, Simulation and Education Conference
IS-ICD	Information Systems Initial Capabilities Document
IT	information technology
JCIDS	Joint Capabilities Integration and Development System
JELC	Joint Event Life Cycle
JFCOM	Joint Forces Command
JFS ESC	Joint Fires Support Executive Steering Committee
JITC	Joint Interoperability Test Command
JLCCTC	Joint Land Component Constructive Training Capability
JMET	Joint Mission Essential Tasks
JMETL	Joint Mission Essential Task List
JNTC	Joint National Training Capability
JROC	Joint Requirements Oversight Council
JSIMS	Joint Simulation System
JS J7	Joint Staff Force Development Directorate
JTAC	Joint Terminal Attack Controller
JTC TRS	Joint Terminal Control Training and Rehearsal System
JTIMS	Joint Training Information Management System

JTLS	Joint Theater Level Simulation
JTP	Joint Training Plan
JTRS	Joint Tactical Radio System
JTS	Joint Training System
LVC	live, virtual, and constructive
LVC-TE	live, virtual, and constructive training environment
M&S	modeling and simulation
MAGTF	Marine Air-Ground Task Force
MAJCOM	major command
MCI	Marine Corps Installations
MCMSO	Marine Corps Modeling and Simulation Office
MCTL	Military Critical Technologies List
MDD	Materiel Development Decision
MET	mission-essential task
METL	mission-essential task list
NARG	Naval Aviation Readiness Group
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NAWCTSD	Naval Air Warfare Center Training Systems Division
NGREA	National Guard and Reserve Equipment
NIST	National Institute of Standards and Technology

NMSO	Navy Modeling and Simulation Office
NTSP	Navy Training System Plan
NTTL	Navy Tactical Task List
OGC	Open Geospatial Consortium
OPLAN	operational plan
OPNAV	Office of the Chief of Naval Operations
OSD	Office of the Secretary of Defense
OUSD(P&R)	Office of the Under Secretary of Defense for Personnel and Readiness
PDU	protocol data unit
PEO	program executive office
PEO STRI	Program Executive Officer for Simulation, Training and Instrumentation
PM	program manager
PM TRASYS	Program Manager for Training Systems
R&D	research and development
RA	requirements authority
RDT&E	research, development, test, and evaluation
RFP	request for proposal
RMF	Risk Management Framework
RTT	Requirements Transition Team
S&T	science and technology
SAVT	supporting arms virtual trainer
SBT	simulation-based training

SECDEF	Secretary of Defense
SIMNET	Simulator Networking
SISO	Simulation Interoperability Standards Organization
SME	subject-matter expert
SOCOM	Special Operations Command
SP	Special Publication
SPO	Simulators Program Office
SSG	Senior Steering Group
STE	synthetic training environment
SYSCOM	system command
T&EO	training and evaluation outline
TADSS	training aids, devices, simulations, and simulators
TDL	tactical data link
TECOM	Training and Education Command
TEMP	test and evaluation master plan
TENA	Test and Training Enabling Architecture
TGAF	training gap analysis forum
TPT	Training Planning Team
TRADOC	Army Training and Doctrine Command
TSA	training support agency
TTP	tactics, techniques, and procedures
TYCOM	type command

UJTL	Universal Joint Task List
USAF	U.S. Air Force
USD(A&S)	Under Secretary of Defense for Acquisition and Sustainment
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics
USD(R&E)	Under Secretary of Defense for Research and Engineering
USD(P&R)	Under Secretary of Defense for Personnel and Readiness
USMC	U.S. Marine Corps
USN	U.S. Navy

CHAPTER ONE

Introduction

Problem and Motivation

Providing effective collective training is a central pillar of the U.S. Department of Defense's (DoD's) processes to ready joint forces "to compete, deter, and win" in conflicts with near-peer opponents.[1] Joint warfighters must be prepared to collaborate with other services, and, to train as they fight, they need networked distributed training systems and environments that allow them to train for inter-force operations and decisions. As early as 1997, there was a recognized need for a ". . . larger interoperability end state where service and joint integrated live, virtual, and constructive (LVC) training systems are routinely interconnected to support joint training and mission rehearsal events . . . ."[2] In fact, Hambleton and Lollar argue that the need for distributed systems is expanding beyond joint operations to coalition

---

1 DoD, *Summary of the 2018 National Defense Strategy of the United States of America: Sharpening the American Military's Competitive Edge*, Washington, D.C., 2018a, p. 1.

2 U.S. Air Force, *Operational Requirements Document for Distributed Mission Training*, Washington, D.C., CAF 009-93-I-A, October 8, 1997.

operations.[3] Nonetheless, the need for and value of joint, integrated virtual training are now well recognized.[4]

Concurrent with the growing need for virtual distributed training capabilities, the military simulation-and-training market is growing; it was estimated to be approximately $10.3 billion in 2016.[5] And this market includes substantial efforts to develop *new* training-simulator capabilities that leverage the increases in graphics capabilities, immersive environments, and virtual and augmented realities. The commercial sector is also pushing forward with such capabilities as more-efficient methods for data transfer within an LVC environment and new software systems for extracting, aggregating, analyzing, and communicating user-performance data to support training.

However, technology development is not always driven by training needs, especially for cross-service exercises. Development of training simulators often drives the users rather than the reverse, especially with respect to distributed training systems. In addition, DoD organizations might not necessarily have the resources to thoroughly study the technology that best responds to their specific training needs and thus supports readiness requirements. This, in turn, highlights a need for a gap analysis to compare training needs with current and future simulation-based training (SBT) resources, especially with regard to distributed training systems and cross-service integration.

This two-year project sought to investigate the gap between joint training needs that support readiness requirements across services and currently available and forthcoming technology in the training-

---

[3] Orris Hambleton and Grover Lollar, "USAF Coalition Distributed Mission Operations (DMO): Achieving Multinational Full Mission Training in Integrated LVC Environments," in *Proceedings of the 2008 Summer Computer Simulation Conference*, Vista, Calif.: Society for Modeling & Simulation International, 2008.

[4] U.S. Joint Forces Command, *Joint Live Virtual and Constructive (JLVC) Federation Integration Guide*, Version 3.1, Norfolk, Va., January 13, 2010.

[5] MarketsandMarkets, *Military Simulation and Training Market by Application (Airborne Simulation, Naval Simulation, Ground Simulation), Training Type (Live Training, Virtual Training, Constructive Training, Gaming Simulation Training), and Region—Global Forecast to 2021*, AS 1125, October 2016.

simulator field and to recommend potential incentive structures for fostering cross-service collaboration for simulator acquisition and use.

Background

Over the past 20 years, RAND Corporation project team members have attended the Interservice/Industry Training, Simulation and Education Conference (I/ITSEC)[6] to monitor the state of the art in applying technology to military training and to present research results. This is the annual conference and trade show of the National Defense Industrial Association and is advertised as "the world's largest modeling, simulation and training event."[7] Over those years, many paper presentations, visits to training provider booths on the trade show floor, and hallway discussions with military and industry representatives have revealed a discouraging, clear pattern: The military has sought joint interoperability of SBT systems, and that interoperability has not appeared.

During a General/Flag Officer Panel session at the 2016 I/ITSEC, there was discussion specifically about the growing perception among military leadership that technology development might not necessarily respond directly to the training needs of the services. To be sure, research and development (R&D) is often funded by customers who presumably understand their own needs. However, companies and organizations often can advance new technology with internal funds, somewhat independently of direct market demand or customer input, especially in the case of larger manufacturers. Hence, development of training simulators has been described as driving the users rather than the other way around. In addition, as we noted earlier, DoD organizations might not necessarily have the resources to thoroughly study what kind of technology best responds to their specific training needs.

---

6 Interservice/Industry Training, Simulation and Education Conference, homepage, undated a.

7 Interservice/Industry Training, Simulation and Education Conference, "About I/ITSEC," webpage, undated b.

This issue is especially pronounced with respect to distributed training systems (i.e., integrated simulators that exchange data in real time and work together) across services, given the inherent difficulty in coordinating and collaborating among large organizations. This highlights a need for a gap analysis, described in the previous section.

Of course, there have been and continue to be efforts to coordinate simulators. The Defense Modeling and Simulation Coordination Office (DMSCO)—now the Modeling and Simulation Enterprise[8]—and many technical efforts have sought to develop common standards and protocols that facilitate simulator interoperability. Specifically, DMSCO has evaluated potential LVC architecture roadmaps, including data formats, studying whether DoD should migrate to one format or another. The U.S. Air Force's (USAF's) Simulator Common Architecture Requirements and Standards program currently strives to coordinate and integrate legacy training systems. The U.S. Army's Program Executive Officer for Simulation, Training and Instrumentation (PEO STRI) continues to seek a synthetic training environment (STE) to support training across LVC simulations and simulators and legacy and next-generation systems. However, although efforts like these are ambitious and valuable, they fall short of addressing the gap between joint or cross-service training needs and technological capabilities with respect to distributed training systems.

This challenge is not just a matter of available technology. Much of the challenge in recognizing training needs and having industry respond appropriately can stem from organizational structures, mechanisms for coordination between services, and past acquisition of what have become legacy systems. Often, there can be a "sunk cost," whereby various organizations or services have committed resources to a specific approach or system, and coordination would require unavailable new investments. This points to a significant multidisciplinary problem that combines technical, cultural, and doctrinal aspects.

---

[8] Modeling and Simulation Enterprise, homepage, U.S. Department of Defense, last updated October 26, 2020.

Objectives

We sought to identify the root causes of the lack of joint interoperability for SBT by investigating the gap between joint training needs and currently available and forthcoming technology in the training-simulator field.

Specifically, we sought to document how each service

- is organized and internally coordinates and provides oversight of training simulators
- defines requirements, including joint requirements, and manages acquisition processes
- provides coordination with other services.

We then compared the results of these analyses to identify best practices by service as potential lessons for other services.

We also sought to identify ways to improve the coordination between DoD and industry to better support joint interoperability. This includes changes to the structure of the marketplace for joint SBT. Finally, we sought to analyze current and possible future incentives for cross-service collaboration, for interoperability, and for industry support of interoperability.

Scope

The domain of "interoperability of joint SBT" is broad, so appropriate scoping of the research was important. DoD's four training tiers are defined as follows:

> Tier 1 events are national level and CCMD [combatant command] strategic and operational training events; tier 2 are [Joint

> Task Force] training; tier 3 are functional and Service Component training; and tier 4 is individual organizational training.[9]

The specific focus of this work was defined as "cross-service air and ground simulators for Tier 3/4 training." These two tiers are described more specifically in Table 1.1.

Study Approach

To explore the relationships between services and their ability to support joint training needs, we took a four-part approach to the study. Part I focused on the individual services and the structure and collaboration *within* each service. Part II focused on the coordination *between* the services. Part III reviewed the state of the art in industry. Part IV summarized the primary themes and actions for DoD stakeholders. The different components of these parts are summarized in this section and are detailed in respective chapters.

Table 1.1
Definitions of Training Tiers 3 and 4

Training Tier	Levels	Focus
Tier 3	• Functional and service component level • Operational-level mission or mission environment	• Ability of systems, units, and/or forces to operate in an interagency, nongovernmental, or international environment
Tier 4	• Individual unit level • Tactical-level mission or mission environment	• Basic technical and operational capabilities in support of Joint Force Commanders

SOURCES: CJCSM 3500.03E, 2015; and Joint Staff J-7, Deputy Director Joint Training, *Joint Training Event Handbook 2017*, 2017.

---

[9] Chairman of the Joint Chiefs of Staff Manual (CJCSM) 3500.03E, *Joint Training Manual for the Armed Forces of the United States*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, April 20, 2015, p. B-8.

Part I. The Services: Organizational Structures, Requirements Processes, and Acquisition Processes

Part I involved three primary components, all drawing from discussions with subject-matter experts (SMEs) and review of policy documentation: consideration of organizational structures, requirements processes, and acquisition processes. In general, each component provided a different kind of comparative analysis, extracting differences between and lessons learned from the individual services (including the U.S. Marine Corps [USMC]).

First, we mapped out in detail the **organizational structure** of each service and the Joint Staff, and then we distilled the consequent organizational charts into illustrative frameworks that summarize how each individual service is structured with respect to requirements, acquisition, and sustainment processes. These illustrations provided a mechanism for conducting comparative analysis, extracting best practices, and identifying opportunities for improved coordination within each service.

Second, we studied **the process by which requirements are developed** for SBT within each service. This was done using a visual framework for each service that outlines the process and relevant underlying departments for setting training requirements and for setting simulator-development requirements. This analysis illustrates how and to what extent requirements are tied to joint training needs, depicting how training needs are incorporated in the requirements process.

Third, we studied each service's **acquisition process** for training simulators. This was done by identifying and illustrating each relevant organization and stakeholder in the context of the Joint Capabilities Integration and Development System (JCIDS) process. This framework provides another mechanism for comparative analysis and helps identify any steps during the simulator acquisition process that might be unique to the respective services.

Drawing on existing literature and discussions with SMEs, and to illustrate findings from the review of requirements processes and acquisition processes, we conducted a series of **case studies** regarding joint simulator capabilities for each service. These case studies reflect the advantages and disadvantages of each service's approach to managing the SBT requirements and acquisition processes.

Part II. Joint Operations: Training Needs, Coordination, and Incentives

Following a thorough analysis of, and comparison between, each service, we focused in Part II on joint operations and how the services coordinate and communicate with each other. First, we assessed **joint training needs** based on (1) discussion with the Joint Staff Force Development Directorate (JS J7), (2) available data describing joint training exercises, and (3) enumerations of the Universal Joint Task List (UJTL) and mission-essential tasks (METS).

The second component of Part II involved studying the **coordination between services, with respect to joint training**. This was done by reviewing organizations that could help provide coordination between the services, according to existing literature and policy documentation. We aligned and cross-walked the history of (1) organizations that provide joint coordination, (2) joint management policy for modeling and simulation (M&S), (3) joint training policy, and (4) joint training manuals.

Third, using the analysis of individual services and policy documentation for joint training, we itemized existing **incentives for collaboration** between services as well as incentives for collaboration between DoD and industry. This included identifying opportunities for each service to coordinate joint training efforts internally (within the service) and externally (with organizations outside the service, specifically JS J7).

Part III. The State of the Art

Finally, through a review of the R&D literature and discussions with industry representatives, we reviewed the **technical state of the art**. The focus was not on existing simulators, but rather on capabilities that support networking various simulators. This included the topics of interoperability, data standards, virtual gaming, and network security. This review focused on distributed training systems for aircraft and ground-vehicle systems, including LVC elements. It focused on commercially available products and on R&D efforts in the military and civilian sectors rather than on existing facilities in the military.

This assessment sets up a potential future comparison of industry capabilities with warfighter needs. Because of initial limits in resources, this final step was reserved for future work, while this report focuses on mechanisms and incentives for cross-service coordination.

Outline of This Report

Our report follows the parts just discussed. Like the study, the report is organized into four parts; these can be used as independent sources or collectively, as an analysis of collaboration for joint training.

Part I of the report focuses on the individual services, with the goal of documenting important similarities and differences in how they are organized and operate with respect to joint SBT. Part I covers the organization, requirements process, and acquisition process for each service. It begins with Chapter Two, which provides an in-depth analysis of how each service is organized and managed and of each service's potential for improvements with respect to providing oversight and acquisition of training simulations. Chapter Three contains a comparison across services of these processes and identifies potential best practices for developing training requirements for SBT. It goes on to address how well each service aligns the training requirements with the requirements for the simulators that will support those training requirements. The acquisition processes for each service are detailed in Chapter Four, which also identifies some best practices of specific services.

Part II of the report addresses the demands for joint training and how the services currently embrace efforts to coordinate joint SBT. Part II begins with Chapter Five, in which we analyze the joint training needs for interoperability of air and ground simulators for tactical-level training. Chapter Six follows with an exploration of the organizational and policy mechanisms that currently exist to foster coordination between the services and identifies potential opportunities for improvement. Part II closes with a review, in Chapter Seven, of the importance of incentives for all stakeholders for developing joint, interoperable SBT.

Part III provides the review of the state of the art, including a forward-looking view as to where the military and industry are currently heading and where these capabilities are believed to be heading. In Part IV, the report closes with a summary, the primary themes, and recommendations for DoD stakeholders.

PART I

The Services: Organizational Structures, Requirements Processes, and Acquisition Processes

CHAPTER TWO

Coordination Within Services: Organizational Structures

As an initial step toward studying how the services approach SBT, this chapter lays out the organizational structure for each service and for the Joint Staff. While subsequent chapters focus on processes, this chapter focuses on underlying organizational structures. Comparative analysis of these structures provides a few benefits. First, although the concept of depicting an organizational chart is not necessarily novel, such charts are not always readily available for specific areas (in this case, SBT) across DoD, especially given frequent changes in responsibilities and organizational structure. Secondly, the organizational charts that underlie the analysis in this chapter represent raw data in the form of a framework for tracking lines of communication and governance within each service. Given an overall layout, we identify organizations that focus on requirements, acquisition, and/or sustainment; these responsibilities can be depicted in simplified organizational structures that facilitate comparative analysis (between services). Finally, organizations with current or potential *internal* coordinating roles within a service can be identified, as can organizations with current or potential *external* coordinating roles. The latter entails communication and coordination with other services and with JS J7. This, in turn, provides a foundation for recommendations on how to improve coordination between services.

Consequently, this chapter first lays out relevant segments of the organization chart for each service. These charts are then summarized in a simplified form. Finally, the services are compared through this framework, and opportunities for improved coordination are identified.

The overarching questions that we pursue in this chapter are as follows:

- What are the differences between the services with respect to organizational structure and internal coordination (oversight of training simulators)?
- What are the best practices with respect to organization and management?
- What opportunities are there, with respect to organizational structure, to improve internal coordination and alignment between requirements and acquisition?

Approach

Our approach to understanding the structures of each service essentially involved three steps. First, we laid out the organizational charts, which essentially provided the raw data for understanding how each service was set up with respect to requirements, acquisition, and sustainment functions for simulators across USAF, the U.S. Army, USMC, and the U.S. Navy (USN). These charts are shown in Appendix A. Then, we developed a framework for simplifying this information, in the form of summary charts that facilitate comparative analysis. Finally, using the summary charts, policy documentation, and interviews with SMEs, we identified organizations within each service that could potentially help improve coordination within each service and across the services.

The summary charts primarily focus on the high-level offices or types of office and color-code them by their function. For example, the summary charts discuss the functions of program executive offices (PEO) in general within a service, as opposed to naming specific PEOs. In cases in which an office performs a central role with respect to simulator development, the charts highlight that office by name. When an office performs more than one function (e.g., both acquisition and sustainment), the color of that office is a gradient combination of the colors associated with acquisition and sustainment.

The organizational mapping is limited in scope to (1) offices that are directly responsible for the requirements for, acquisition of, or sustainment of simulators and (2) offices that exercise functions closely related to simulator development or sustainment, such as policymaking bodies or offices that lead the development of virtual environments. To build the organizational charts, we gathered the most-recent organizational charts provided by the services, consulted service and DoD policies and directives, and gathered additional data from SME interviews.

The intent of the organizational mapping was to identify unique or common features across the services that might affect the ability of services to develop interoperable simulators and more generally coordinate with one another. We also highlight offices that are involved with within-service and cross-service coordination related to simulator development or policy. We then discuss notable patterns and differences between services, which influence the development of simulators for joint air-ground training.

Results

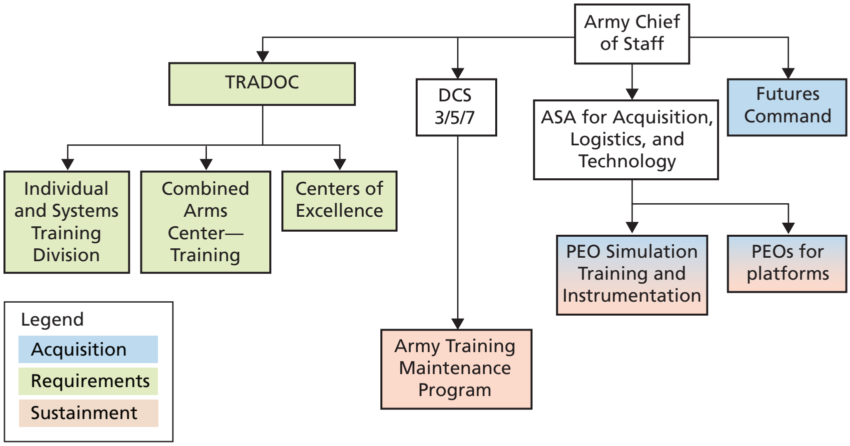
U.S. Army

Figure 2.1 displays the summary organizational chart for the Army.[1] The Army's PEO STRI is the materiel developer for nonsystem trainers, i.e., simulators that are not simulating a unique weapon system. PEOs usually develop a simulator alongside the weapon system, although they can turn to PEO STRI for assistance with system simulator development and are encouraged to coordinate with PEO STRI per Army Regulation (AR) 350-38 and AR 70-1.[2] System PEOs and

1 See Figure A.1 for the complete organizational chart.

2 AR 70-1, *Army Acquisition Policy*, Washington, D.C.: Headquarters, Department of the Army, June 16, 2017; and AR 350-38, *Policies and Management for Training Aids, Devices, Simulators, and Simulations*, Washington, D.C.: Headquarters, Department of the Army, February 2, 2018.

Figure 2.1
Simplified Organizational Chart for the U.S. Army



NOTE: ASA = Assistant Secretary of the Army; TRADOC = Army Training and Doctrine Command.

program managers (PMs) have the option to have PEO STRI execute all or some portion of the acquisition and can transfer a simulator to PEO STRI for sustainment. In practice, PEOs do most of the system simulator acquisition. Although system PEOs and PMs are required to coordinate with PEO STRI per these regulations, in practice, coordination is often lacking, per our interviews with SMEs throughout the Army acquisition community.

One consequence of this arrangement is that there is no central organization in the Army that is responsible for coordinating all simulator development or sustainment, or both. Because nonsystem training simulators are not tied to the development of a specific weapon system, there is often a concurrency gap between the nonsystem simulator and the systems on which they are based. This is the case, for example, with the Aviation Combined Arms Tactical Trainer (AVCATT), which simulates several rotary-wing aircraft. Note that system simulators do not connect to one another as often as (collective) nonsystem simulators do. This stands in contrast to USAF, for example, where there tends to be a greater focus on having system simulators interoperate more easily through Distributed Mission Operations (DMO) capabilities.

TRADOC generates training requirements, and TRADOC Capability Managers generate further system requirements for simulators. TRADOC proponents are responsible for the generation of training and system requirements for system and nonsystem training devices. Notably, there is no organization in the Army that generates *joint* training requirements for simulators. This is a recurring theme throughout the analysis of the service simulator-development communities; in practice, it is rare for simulators to include capabilities that facilitate joint training. Likewise, service policies that govern M&S infrequently assign responsibility to develop, identify, and track such requirements across the services.

U.S. Air Force

Simulators for USAF's weapon systems are delivered alongside the system and are part of the same contracting process. Aircraft simulators are often developed to connect with other simulators using DMO capabilities. Although simulator development in USAF is decentralized, most simulators are sustained by the Simulators Program Office (SPO), under the Agile Combat Support Directorate in the Air Force Materiel Command. Figure 2.2 displays the summary organizational chart for USAF.[3]

In USAF, major commands (MAJCOMs) serve as the dedicated lead commands of a weapon system and are responsible for acquiring the simulators for those systems. Lead commands are designated in Air Force Policy Directive 10-9; policy on training systems is established in Air Force Instruction (AFI) 36-2251.[4] Figure 2.2 displays the organization of Air Combat Command (ACC) and Air Mobility Command (AMC) as examples of how MAJCOMs are structured for simu-

---

3 See Figure A.2 for the complete organizational chart.

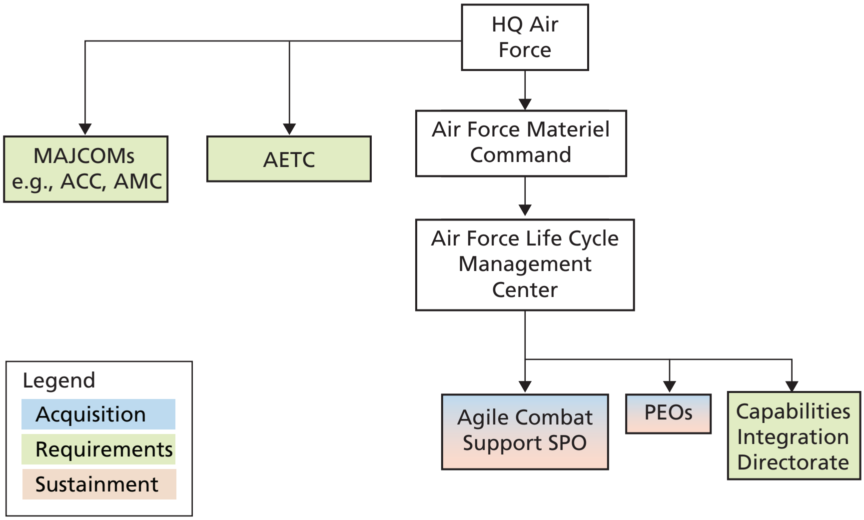
4 AFI 36-2251, *Management of Air Force Training Systems*, Washington, D.C.: Headquarters, Department of the Air Force, June 5, 2009; and Air Force Policy Directive 10-9, *Lead Command Designation and Responsibilities for Weapon Systems*, Washington, D.C.: Headquarters, Department of the Air Force, March 8, 2007.

lator development. Note that other MAJCOMs (e.g., Air Force Special Operations Command and Air Force Global Strike Command) are, in principle, responsible for the acquisition of simulators for the systems for which they are the designated lead command.

Air Education and Training Command (AETC) training managers work with lead commands to refine system requirements. MAJCOMs that are the end users of simulators—"using commands"—define command-specific system requirements (including training and DMO requirements) in cooperation with the lead command.[5] Unlike in the Army, where TRADOC serves as a centralized hub that formulates requirements for training systems, USAF is more decentralized.

Simulators are transitioned to SPO for sustainment. SPO does acquire some simulators (e.g., the Predator Mission Aircrew Training System and the Joint Terminal Control Training and Rehearsal

Figure 2.2
Simplified Organizational Chart for the U.S. Air Force



[5] A3O-AT, the Operational Training Division, is responsible for setting MAJCOM reporting requirements on DMO capabilities (AFI 16-1007, *Management of Air Force Operational Training Systems*, Washington, D.C.: Headquarters, Department of the Air Force, October 1, 2019).

System [JTC TRS]). The SPO is also designated as a focal point for simulator development throughout USAF. The latest instruction available, from 2009, indicates that the Training Systems Product Group, which includes the SPO, should serve as the within-service coordinating body to provide expertise and assist in refining simulator system requirements.[6]

U.S. Navy

Figure 2.3 displays the summary organizational chart for simulator development in USN.[7] Naval Air Warfare Center Training Systems Division (NAWCTSD) is the most prominent focal point for simulator acquisition in the service, as shown in Figure A.3. The Surface Training Systems office in Naval Sea Systems Command (NAVSEA) also develops air-ground simulators, although it does not engage in the same degree of internal and external interfacing that NAWCTSD does (e.g., the latter's membership in Team Orlando, a collaborative alliance of U.S. military organizations working in modeling, simulation, and training, which is discussed in more detail in Chapter Six).

In USN, the Office of the Chief of Naval Operations (OPNAV) sponsors the Deputy Chief of Naval Operations to work with USN type commands (TYCOMs) to formulate early estimates of training and system requirements in a Navy Training System Plan (NTSP). The system PM leads the NTSP development. The NTSP is then transferred to a training support agency (TSA) to lead the acquisition and further refine requirements with NTSP stakeholders. NTSPs are updated and validated continually throughout the acquisition process.[8] USN policy does not specify which agencies can serve as TSAs. This is consistent with the process described in interviews by which a system

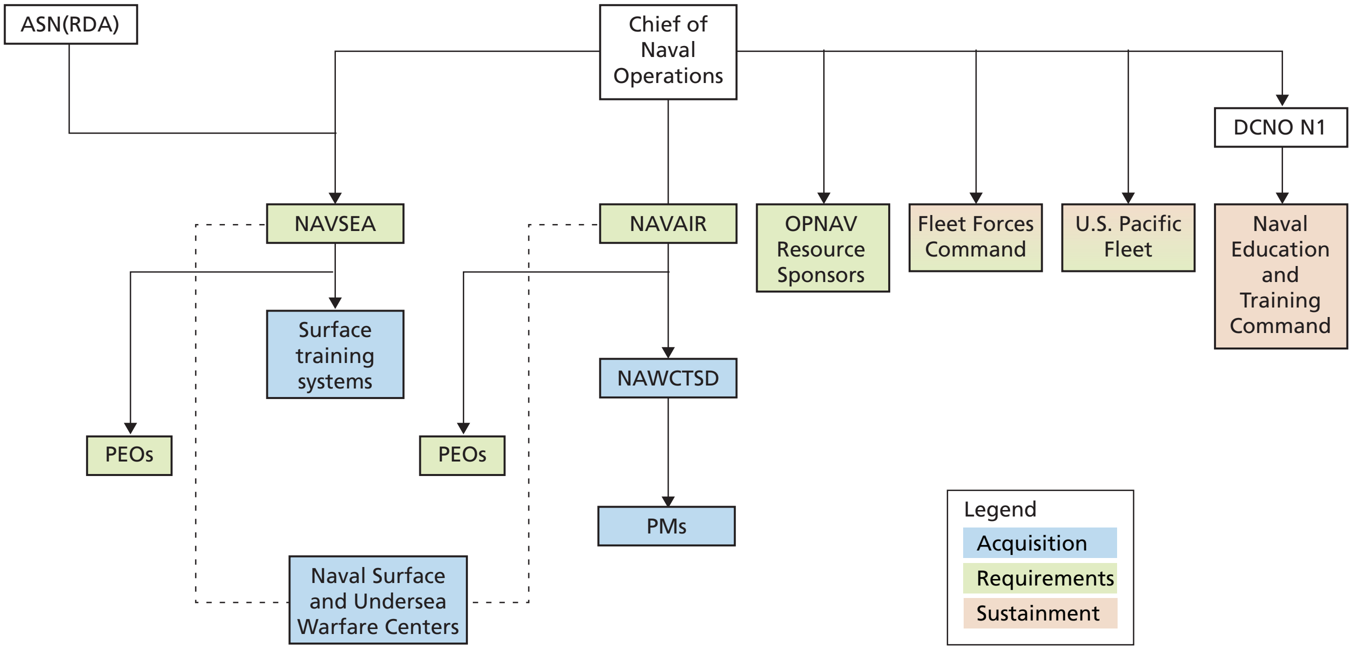
---

6 The Training Systems Product Group is currently composed of the SPO (Air Force Life Cycle Management Center Simulators Division) and the Warfighter Readiness Research Division in the 711th Human Performance Wing at the Air Force Research Laboratory, Wright-Patterson Air Force Base.

7 See Figure A.3 for the full organizational chart.

8 OPNAV Instruction 1500.76C establishes policy for the development of training systems (OPNAV Instruction 1500.76C, *Naval Training Systems Requirements, Acquisition, and Management*, Washington, D.C.: Headquarters, Department of the Navy, August 14, 2013).

Figure 2.3
Simplified Organizational Chart for the U.S. Navy



NOTE: ASN(RDA) = Assistant Secretary of the Navy for Research, Development, and Acquisition; DCNO = Deputy Chief of Naval Operations; NAVAIR = Naval Air Systems Command.

command (SYSCOM) training-system office might "shop around" simulator development to different offices and warfare centers. PMs in USN SYSCOMs develop system requirements for simulators.

Once developed, a simulator is transitioned to a training agency, which assumes responsibility for sustainment. Any organization that uses the simulator and serves as the training agency can be responsible for sustainment. Resource sponsors—offices responsible for guiding an acquisition program through the stages of planning, programming, budgeting, and execution—are required to identify the relevant training-system offices to serve integrating roles in the trainer development process. These include the Surface Training Systems office under NAVSEA and NAWCTSD in NAVAIR. Note that these offices can also serve as TSAs to develop the system. The overall process in the service is relatively flexible, and few roles are strictly performed by dedicated organizations. However, the processes necessary for this flexibility can potentially stifle coordination.

U.S. Marine Corps

Figure 2.4 displays the summary organizational chart for USMC.[9] Acquisition in USMC is less complicated and more streamlined than in the other services. The Program Manager for Training Systems (PM TRASYS) under Marine Corps Systems Command serves as the focal point for acquisition activities, while requirements come from the Marine Air-Ground Task Force (MAGTF) Training Directorate and Training and Education Command (TECOM). Per the *MARCORSYSCOM Acquisition Guidebook*, the PM is responsible for sustainment.[10]

The relationship between SYSCOM and PM TRASYS is further outlined by the USMC Requirements Transition Process (RTP).[11] The RTP outlines how a requirements originator transfers approved requirements to Commander, SYSCOM with the help of a Require-

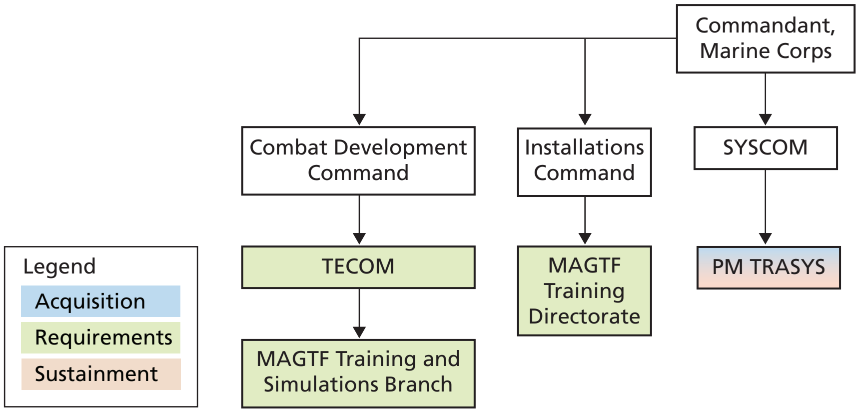
---

9 See Figure A.4 for the full organizational chart.

10 USMC System Command, *MARCORSYSCOM Acquisition Guidebook*, Headquarters Marine Corps, October 30, 2020.

11 USMC System Command, 2020.

Figure 2.4
Simplified Organizational Chart for the U.S. Marine Corps



ments Transition Team. The commander then assigns a PM and determines the acquisition strategy.

Joint Staff

The Joint Staff does relatively little work with simulator acquisition.[12] What acquisition it does is limited to constructive capabilities (e.g., joint theater-level simulations) that are used by services to participate in battle-staff exercises. Thus, we did not create a summary organizational chart. However, the Joint Staff plays an important role in helping coordinate the individual services, so we outline its organization briefly in this section as a foundation for discussions in latter chapters. The organizations shown in Figure A.5 perform coordinating and policy guidance functions. Notably, there are no offices responsible for the creation of joint training requirements.

DMSCO is the primary focal point for services' M&S policy, planning, and guidance; its roles in this regard are explained in detail in Chapter Six. However, DMSCO does not coordinate simulator devel-

[12] Because the Joint Staff has little direct engagement in the simulator-development process, we omit a simplified organizational chart. A full organizational chart mapping the responsibilities of various Joint Staff and DoD offices is available in Figure A.5.

opment. Although J7 coordinates the Joint National Training Capability (JNTC), it does not coordinate services' joint training requirements or simulator acquisition programs.

Opportunities for Coordination

Our review of individual organizational charts and our interviews with SMEs show that there is little cross-service coordination over simulator development in practice. Our review of organizational responsibilities and service and DoD policies further supports this finding; to the extent that responsibilities to coordinate across services are specified, they are specified at a high level. Nonetheless, certain organizations within each service are better positioned to adopt new or enhanced coordinating functions, either because of their existing functions with respect to simulator development or because these organizations are already outward-facing to some extent. In Appendix A, organizations in each service are labeled as having either an internally or externally facing coordinating role.

We discuss such offices in this section, and Table 2.1 summarizes these offices by service. The table lists those offices that have some measure of external coordination assigned by policy, along with offices that are well situated to take on greater external coordinating roles but currently do not have such responsibilities. The latter set is indicated by asterisks. Note that all of the offices in the table have some role to play with some aspect of internal coordination of simulator or M&S tool development within their respective service. However, some offices play more-central internal coordinating roles than others. Specifically, these offices include Agile Combat Support, SPO, NAWTSCD, PM TRASYS, PEO STRI, and each service's M&S office. These are underlined in Table 2.1.

U.S. Army

The Army Modeling and Simulation Office (AMSO) has the clearest responsibilities for coordinating with other services, including the Office of the Secretary of Defense (OSD) and the Joint Staff, on M&S policy. AMSO has a liaison to PEO STRI but not to other services' simulator acquisition offices.

Table 2.1
Cross-Service Coordinating Offices, by Service

Service	Offices
USAF	• **Air Force Agency for Modeling and Simulation** • **SPO (Agile Combat Support)*** • MAJCOMs
U.S. Army	• **Army Modeling and Simulation Office** • Centers of Excellence (CoE) • TRADOC Capability Managers* • National Simulation Center • Army Training and Support Center • **PEO STRI***
USMC	• Marine Corps Systems Command • **PM TRASYS*** • TECOM • Combat Development and Integration
USN	• **NAWCTSD*** • U.S. Fleet Forces Command • **NMSO**

NOTES: NMSO = Navy Modeling and Simulation Office. Bold offices play a more central internal coordinating role.
* Indicates offices that do not have external coordinating responsibilities for simulator development that are specified by policy, although these offices might engage in some degree of external coordination in practice.

Army CoE commanders are responsible for identifying joint programs and ensuring that Army requirements are included in joint training systems, per AR 350-38. Although this regulation calls out joint programs, of which there are relatively few, it specifies that CoEs are responsible for cross-service coordination. Therefore, they are the only offices in the Army's training-system acquisition policy that have that explicit responsibility spelled out in policy according to RAND's review of Army policy. This might position them for an augmented role in cross-service coordination.

It is notable how high up these external coordinating organizations are. The responsibilities for coordination that are explicitly spelled out in policy are quite thin; there is little detail regarding which sister-service offices should be involved in coordination or formal requirements on the manner, frequency, or documented output of cross-service coordination. More generally, our interviews across services did not reveal any consistent, structured coordination over simulator development that occurs in practice, either in the Army or in the other services.

Army policy suggests other offices that might play a role in cross-service coordination. Army regulations specify that training-system integrators—including TRADOC Capability Managers, the National Simulation Center, and Army Training Support Center—must review all requirements documents for integration into existing training systems. Although the policy does not call out other services' systems or requirements documents, these offices are responsible for reviewing requirements documents in JCIDS and working with training developers on requirements. This suite of responsibilities potentially situates them to feed information on existing programs and capabilities across other services that might promote collaboration.

PEO STRI is the Army's only dedicated simulator-development organization and is supposed to consult on simulator development elsewhere in the service, so it is well positioned to coordinate with other services. The Army also has an office, the Army Joint Support Team (AJST), that is dedicated to interfacing with USAF over joint air-ground integration. This office, or this type of arrangement, could be leveraged as part of efforts to identify joint training needs that inform air-ground simulator development.[13]

U.S. Air Force

USAF does not have a central organization that is responsible for ensuring within-service coordination on simulator development, and the lack of such an organization was noted multiple times in our interviews. The Air Force Agency for Modeling and Simulation (AFAMS)

---

[13] TRADOC Regulation 350-50-3 describes the AJST as follows:

> The AJST is the TRADOC and Combined Arms Center (CAC) lead for joint air-ground operations, education, and training, including both the mission command processes and the joint command and control processes associated with joint air operations (e.g., close air support, air interdiction, airspace control, joint targeting, common operational picture, and integrated air and missile defense). (TRADOC Regulation 350-50-3, *Mission Command Training Program*, Fort Eustis, Va.: Headquarters, U.S. Army Training and Doctrine Command, April 19, 2018, p. 11)

has an operations division that is responsible for USAF's Operational Training Infrastructure Line of Effort concerned with joint M&S interoperability. This is in addition to AFAMS's interface with different DoD M&S forums. A USAF official noted that, beyond the lack of any incentive in USAF to collaborate with other services, there is scarcely any incentive for collaboration within the service itself.

The SPO in Agile Combat Support is responsible for consulting with MAJCOMs as they formulate requirements. In its capacity as a member of the Training Systems Product Group, it is also responsible for convening summits "to share lessons-learned across MAJCOMs; and to facilitate discussions on potential cross-program synergies and DMO opportunities, advocacy issues and future technology needs."[14] However, from our interviews, it is unclear how often this occurs in practice. In this capacity, the SPO coordinates and integrates simulator acquisition activities across USAF. It is potentially situated to perform this function with other services as well.

The MAJCOMs are responsible for coordinating with their "joint/service counterparts" for JNTC, specifically with respect to M&S tools to support JNTC.[15] This indicates that the offices within each MAJCOM that engage in JNTC coordination might be well situated to serve as a coordinating channel for cross-service simulator development and coordination.

U.S. Navy

As USN's primary office for simulator acquisition and as its central member on Team Orlando, NAWCTSD is a strong candidate for leading cross-service coordination. U.S. Fleet Forces Command has responsibilities for coordinating joint exercises; oversees USN's contributions to JNTC; and develops USN's Continuous Training Environment, USN's STE. Therefore, it is also situated to perform some external coordinating functions.

---

[14] AFI 36-2251, 2009, p. 6.

[15] AFI 10-251, *Air Force Participation in Joint Training Transformation Initiative (JTTI) and Joint National Training Capability (JNTC) Events*, Washington, D.C.: Headquarters, Department of the Air Force, June 15, 2015, p. 6.

NMSO acts as the action arm for USN's M&S Governance Board. As such, it coordinates M&S issues with the joint community. The governance board has representatives from across USN and is chaired by ASN(RDA). As the action arm of the governance board, NMSO has coordinating responsibilities with the joint community.

U.S. Marine Corps

As USMC's centralized office for simulator development, PM TRASYS is a natural candidate for coordination with other services. Figures 2.4 and A.4 (in Appendix A) highlight TECOM as an office that could perform cross-service coordination on simulator development, because it plays a central role in developing the USMC capability for simulator interoperability, the live, virtual, and constructive training environment (LVC-TE). TECOM has primary responsibilities for identifying training gaps in terms of the STE and determining interoperability requirements for training at all levels. In this role, TECOM and its capabilities division are a centralized source of information on interoperability needs and capabilities for the rest of USMC.

The Deputy Commandant for Combat Development and Integration (DC CD&I) is responsible for policy and guidance for integrating virtual training across USMC, and coordination across other services could potentially include this office.[16] SYSCOM also coordinates training-system development with NAVAIR. It might be appropriate for SYSCOM to broaden its scope of coordination to other services as well. In the past, DC CD&I served as the USMC M&S lead and was responsible for serving as the USMC representative at DoD, joint, and USN M&S forums.[17] However, this order was canceled in 2019. The most recent instruction assigns coordination responsibilities to USN and USMC M&S Executives.[18] The M&S Executive is still responsible

---

16 Marine Corps Order (MCO) 3710.6A, *Marine Corps Aviation Training System (ATS)*, Washington, D.C.: Headquarters, Department of the Navy, September 30, 2011.

17 MCO 5200.28A, *Marine Corps Modeling and Simulation (M&S) Management*, Washington, D.C.: Headquarters, Department of the Navy, July 15, 2014.

18 Secretary of the Navy Instruction 5200.46, *Department of the Navy Modeling, Simulation, Verification, Validation, and Accreditation Management*, Washington, D.C.: Headquarters, Department of the Navy, March 7, 2019.

for oversight of the Marine Corps Modeling and Simulation Office (MCMSO), which suggests that this responsibility is still with CD&I.

This latest instruction assigns coordination responsibilities to a USN M&S Advisory Group. If this instruction is, in fact, chartered,[19] it would include U.S. Fleet Forces Command stakeholders, the Deputy Chief of Naval Operations, a variety of OPNAV stakeholder, and CD&I. The Advisory Group would be responsible for coordinating M&S issues between USN and USMC and between joint bodies and other services. MCMSO represents USMC in DoD and joint-level M&S forums on policy, planning, and guidance. It also interfaces with the USN M&S office, and it is responsible for assisting USN in "maintaining asset visibility and interoperability with the other Services."[20]

Conclusion

To lay the foundation for further analysis, we have depicted and compared the organizational structure for each service and for the Joint Staff. In addition, we have identified opportunities for each service to improve internal coordination and alignment between requirements and acquisition. In doing so, we present a novel framework for comparing which organizations have responsibilities for training requirements, acquisition, and sustainment. This framework also helps identify which organizations are properly positioned both to coordinate SBT internally and to represent the service to the broader SBT community.

We find that each service has opportunities for improving coordination internally and for integrating with the broader community more effectively. However, currently, these responsibilities tend to be ad hoc and segmented. While findings for each service were discussed

---

[19] The authors found no evidence that it has been chartered. The 2019 order itself (Secretary of the Navy Instruction 5200.46, 2019) discusses the Advisory Group's responsibilities as applicable only in the event that it is chartered. That is, the order itself does not address the group as something that already exists.

[20] Secretary of the Navy Instruction 5200.46, 2019, p. 7.

in detail throughout the chapter, what follows are primary overarching findings concerning the SBT enterprise:

- **Services are structured differently with respect to requirements, acquisition, and sustainment of simulators.** To be sure, each service has unique needs and must structure itself accordingly. However, having some degree of centralization, whereby a single internal organization has visibility into SBT efforts across the service, is necessary for internal coordination. In addition, having a primary point of contact for external organizations helps facilitate integration with those external organizations.
- **The degree of centralization within each service varies.** USAF has a centralized agency that inherits oversight of new simulators for sustainment. The Army's PEO STRI is the centralized simulation office, but it develops only nonsystem simulations. It does not have responsibility for continued sustainment. USMC is the only agency with one simulation office for both acquisitions and sustainment. USN's structure tends to be the most fragmented, with many different options for where a simulator is acquired and sustained.
- **Simulators are acquired along with the weapon system in USAF and the Army as a matter of course.** This can help support initial concurrency between the simulator and the actual system. However, upgrades to simulators in the Army are not coordinated with upgrades to weapon systems.
- **Differences in the functions that main simulator offices play within each service might have implications for coordination.** For example, PEO STRI (in the Army) and the Agile Combat Support SPO (in USAF) are both responsible for nonsystem simulator acquisition. Alternatively, USN's simulation offices focus on system-simulator acquisition. Thus, coordination could be easier and more natural between the Army and USAF with respect to simulator development. More generally, if the main simulator offices across services have different functions with respect to acquisition, they are likely to have different types of information,

authorities, and responsibilities that might make coordination between them more difficult.

- **There are few organizations that focus on cross-service (external) coordination with JS J7 and other services.** Within each service, there are certainly organizations that communicate outside the service. However, there are few centralized organizations responsible for aggregating information and simulator-system status across a service and then interfacing externally with JS J7 or other services.

CHAPTER THREE

Requirements Processes

DoD's acquisition process relies on defining and then gathering requirements for the targeted acquisition. In this chapter, we review how each service first gathers training requirements for SBT and then maps those training requirements to requirements for SBT that will support the defined training requirements. We also identify differences between the services in these processes and supporting M&S organizations. How well each service aligns training requirements with simulation requirements is addressed based on interviews with SMEs across services. Drawing on a review of the differences identified, we highlight what appear to be best practices for requirement-development processes and identify opportunities for improvement.

Approach

To understand how training requirements connect to simulation requirements, we first conducted a literature review of each service's M&S and training requirements doctrine. We looked for examples of how training requirements are documented and formally sent through the training and M&S organizations. The documents that we reviewed are listed in Table B.1, in Appendix B.

We were also interested in mapping the requirements process outlined from the literature review with the organizations involved in each step of the process. We mapped each service's specific organization with its respective roles and responsibilities in the requirements process. To do so, we gathered data from the literature and held discussions with

SMEs across the services. We presented preliminary findings during the discussions to understand and fully map out the training requirements process for each organization and service component.

Results

U.S. Army

The Army requirements process, shown in Figure 3.1, stems from mission requirements defined through mission-essential tasks (METs). These are then used to define simulator requirements. METs are based on tactical mission requirements and are designated at the individual and collective levels. METs are combined for a given unit to form a unit's training and evaluation outline (T&EO), which is used as a training rubric at training exercises. The requirements for live and synthetic training are built on a combination of METs, the mission-essential task list (METL), and T&EOs.

TRADOC works to define the METs, which then populate a unit's T&EO. Simulation organizations coordinate the simulator requirements with TRADOC through METs and unit T&EOs to produce training that matches the training requirements. The Army requirements process, which is coordinated and centralized within TRADOC, is more streamlined than those in the other services. Training requirements and the simulation requirements are under the same command. Coordination exists between the Capabilities Development Directorate (CDD), under the Army Capabilities Integration Center (ARCIC), and the CoE. Requirements working groups are able to coordinate requirements to TRADOC Capability Managers.

U.S. Air Force

Simulator requirements for USAF flight simulators are inherently based on flight requirements. As shown in Figure 3.2, these begin with the most basic level, which concerns generic flight requirements, and extend to more-specific requirements pertaining to specific aircraft, units, and missions. Associated with each aircraft is a specific ready aircrew program (RAP) task list as a training directive. RAP task lists

Figure 3.1
U.S. Army Requirements Processes and Related Organizations

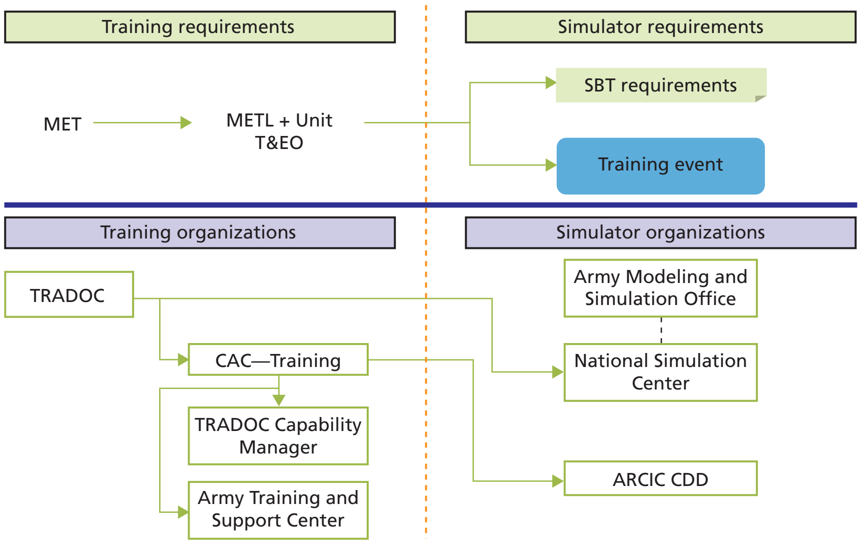
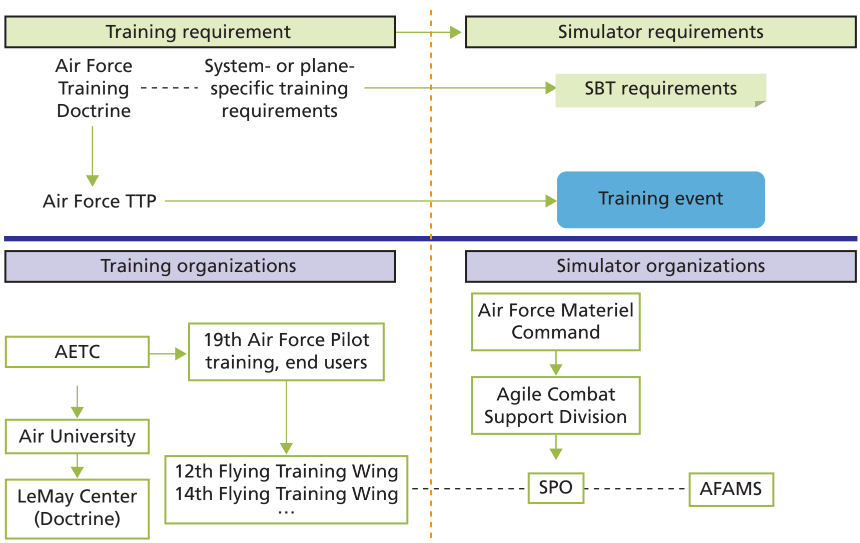


Figure 3.2
U.S. Air Force Requirements Processes and Related Organizations



itemize the tasks a pilot should train on. The complexity of the types of requirements increases as the complexity of the task increases.

Operators in each of the MAJCOMs generate the requirements. The specific platform and mission-specific requirements come directly from MAJCOM A3/5. The USAF acquisitions office acquires new platforms based on those requirements. When those platforms are being built, the simulator is attached to that respective program, and the simulator requirements are developed based on the training requirements for the system itself. The platform and the corresponding simulator are acquired in conjunction with one another. The USAF requirements process is more decentralized than those of the other service components. Training requirements are varied among different stakeholders. An end user in one MAJCOM might have a different mission-specific requirement than a similar end user in another.

U.S. Navy

Figure 3.3 shows the USN processes and organizations for gathering and coordinating requirements. Note that USN requirements focus only on aircraft and naval simulators—USMC deals with all ground simulators. Within USN, NAVSEA deals with capability requirements; NAVSEA also validates those requirements to ensure that they are a priority; and, once a prioritized list is complete, the requirements are transitioned to OPNAV, which funds the requirements. NAVAIR is the acquisition organization.

According to interviews with NAWCTSD, USN has no central authority for managing enterprise or cross-platform training requirements. Naval requirements come from U.S. Fleet Forces Command. The USN TYCOMs under U.S. Fleet Forces Command generate requirements based on naval aviation requirements group meetings. Requirements are then passed to either OPNAV or NAVSEA, where they are validated. OPNAV funds the requirements. NAVAIR executes requirements for air systems. NAVSEA processes surface and submarine fleet requirements. NAWCTSD then helps derive SBT requirements from NAVAIR.

A USN TYCOM coordinates the Man, Train, and Equip (MT&E) functions for specific communities within USN. For example, the Commander, Naval Air Forces exercises administrative control over aviation forces, and the Commander, Naval Surface Forces does the same for the surface warfare community.

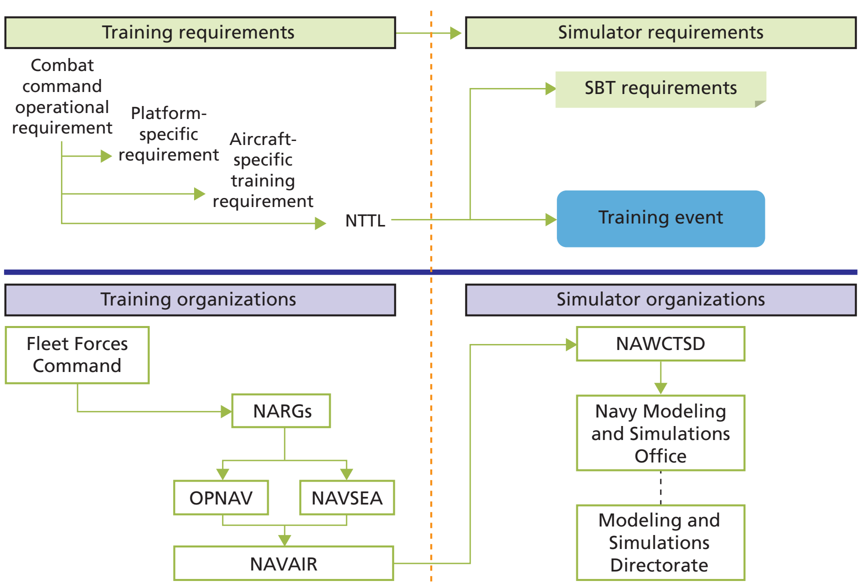
The Navy Tactical Task List (NTTL) is the comprehensive list of naval tasks and is doctrine-based and designed to support current and future METLs. The Universal Naval Task List is a list of USN-specific tasks that includes the NTTL and the Military Critical Technologies List (MCTL).

The requirements-generation process is similar to USAF aviation requirements. The fleet identifies requirements by platform for a given CCMD's priorities; Naval Aviation Readiness Groups (NARGs) vet requirements and prioritize to training gaps; and the top issues are briefed at the platform NARG level.

U.S. Marine Corps

The USMC processes and organizations for gathering and coordinating requirements are shown in Figure 3.4. The operating force identifies

Figure 3.3
U.S. Navy Requirements Processes and Related Organizations

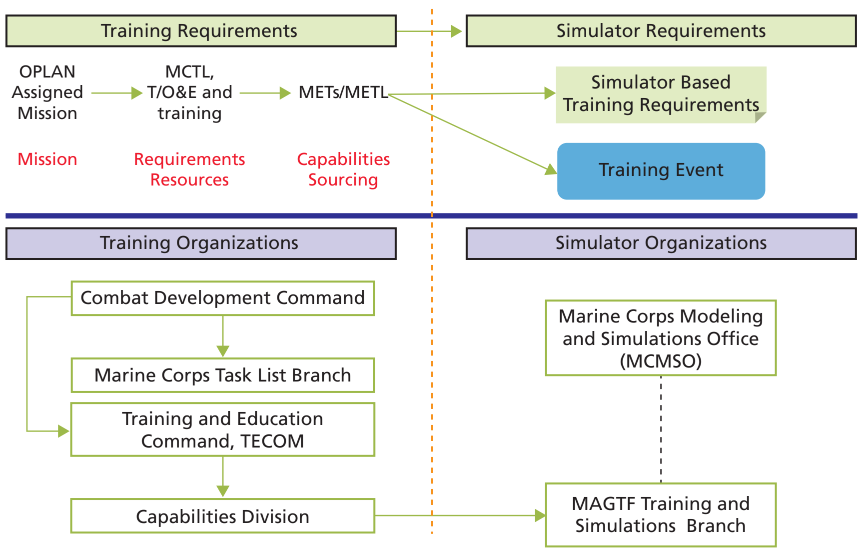


training needs either at training events or on missions. Those training needs are passed on to the Commandant of the Marine Corps (CMC), who approves requirements. The requirements authority (RA) builds those requirements and refines them for the CMC and then provides them to the commander of Marine Corps Systems Command after they are validated. Those requirements are then assigned or directed to a PEO as appropriated and are executed through the acquisition process and all relevant stakeholders.

Operational plan (OPLAN) missions define the sorts of tasks that need to be performed by marines. These are then defined as METs and unit T&EOs, similar to the Army. The USMC TECOM defines these requirements and coordinates with simulations organizations so that simulators meet training needs.

The USMC training requirements process is similar to the Army's, but it has better-defined participants. Those requirements are identified at the warfighter level and passed to the RA for definition. The

Figure 3.4
U.S. Marine Corps Requirements Processes and Related Organizations



RA is named,[1] and the commander of Marine Corps Systems Command validates and funds requirements.

Operational forces identify needs and training requirements; these are then passed to the RA, who defines and builds requirements. The RA then provides validated requirements packages to the commander of Marine Corps Systems Command.

Marine Corps Systems Command accepts validated and funded requirements, assigns a PM, and executes the acquisition process, which includes the RA and all relevant stakeholders. The commander of Combat Development Command is dual-hatted with the development and integration command. USN works on the aviation training requirements with USMC, and, as noted earlier, only USMC focuses on the ground-based training simulation.

Conclusion

To understand how training requirements are connected to simulation requirements, we conducted a literature review of services' relevant doctrine and carried out interviews with SMEs from each service. We also developed a framework for analyzing how simulator requirements align with training requirements and how the various requirements processes map onto the specific roles and responsibilities for specific organizations in each service.

This review of requirements processes and supporting organizations identified several significant differences between services. The first main difference concerns the coordination roles for requirements. The process for gathering and managing requirements is centralized in the Army and USMC and more decentralized in USAF and USN. For example, as shown in Figures 3.1 and 3.2, the Army centralizes the requirements process in one organization, TRADOC, whereas USAF distributes the process among the MAJCOMs. SME interviews suggest that decentralization of requirements gathering and coordination for specific SBT products is more likely to produce siloing of

---

1 The RA is typically the DC CD&I.

acquisitions—that is, best practices and lessons learned are not shared across acquisition efforts.

Also of interest was that the level of collaboration and coordination between USN and USMC could provide valuable lessons for other services. In an explicit effort to build and leverage specific expertise relevant to training domains, USN coordinates the aviation requirements and simulators, while USMC does so for ground ones. However, there is similarity in the processes and structures for transitioning requirements between USN and USMC; USMC did not invent its own.

In other services, the operational requirements are often determined by a different organization than the training-simulator system requirements. This can make the communication and coordination difficult and insufficient. In these cases, there is risk of procuring training systems that do not directly respond to training needs. The service M&S offices can provide a common thread across all of the services and even within the services. These offices already house significant expertise and often coordinate between themselves. However, they do not necessarily have resources in terms of funding or policy control to enact improvements in cross-service coordination.

Of final note in the review of requirements processes for SBT are two missing elements that could improve the training effectiveness of the systems. The first is not including a detailed review and set of specifications for the level of detail needed in the simulation for effective training. For example, what are the levels of physical, audio, or psychological fidelity needed in the simulation?[2] The second missing element is defining measures of training effectiveness and requiring assessments of system effectiveness based on these measures. If these two elements are not captured as requirements, they cannot be included in the later acquisition process.

---

[2] For more detail on the importance of physical and psychological fidelity to training effectiveness, see Susan G. Straus, Matthew W. Lewis, Kathryn Connor, Rick Eden, Matthew E. Boyer, Timothy Marler, Christopher M. Carson, Geoffrey E. Grimm, and Heather Smigowski, *Collective Simulation-Based Training in the U.S. Army: User Interface Fidelity, Costs, and Training Effectiveness*, Santa Monica, Calif.: RAND Corporation, RR-2250-A, 2019.

CHAPTER FOUR

Acquisition Processes

Having studied the organizational structures of the services in Chapter Two and the simulator requirements processes in Chapter Three, we now turn to the acquisition process. Specifically, we ask what the differences are between the services with respect to simulator acquisition processes. We analyze the key similarities and differences in how simulator requirements are gathered and how acquisition processes are carried out across the services in an effort to identify best practices.

Approach

Our approach involved two steps. First, we mapped out the acquisition process for each service. In doing so, we again introduced a new framework for comparing processes in the services. Then, we conducted case studies of how the services acquired "air-ground" SBT to illustrate the differences in SBT acquisition organizations and processes, as well as common challenges, such as prioritizing interoperability, maintaining currency, and meeting information-assurance standards.

Results: Mapping the Acquisition Process

For each service, we mapped out the acquisition process by identifying the organizations responsible for determining requirements and transitioning them to the acquisition system; the acquisition process through production and deployment; and operations and support of the simulator. We consulted service policies to identify the offices responsible at each phase of this process. With the acquisition processes mapped out using the framework in Appendix C, we focused on comparisons of the management structure. There are other dimensions along which we might compare acquisition processes—e.g., contract structures or workforce characteristics—but a comparison of management structures aligns most closely with the report's focus on practices of and incentives for collaboration across services.[1] Therefore, we focus largely on organizational responsibilities and policies that govern ownership of different points in the acquisition process.

The mapping process revealed important differences between services in how SBT is acquired. The **Army**'s acquisition is centered in PEO STRI and PEOs, with some acquisition executed in Army Futures Command. Although the weapon-platform user generally leads acquisition, the user has the option of having PEO STRI lead the acquisition. TRADOC CoEs are largely responsible for training-device requirements. Sustainment is largely in the PEOs, with some contracted support under the Army Training Maintenance Program. PEO STRI can also inherit simulators from other PEOs for sustainment. Of all of the services, the Army has the most-extensive formalized involvement of its training command (TRADOC) in setting requirements for the acquisition process.

Within **USAF**, the bulk of the acquisition is done in the PEOs. The SPO inherits simulators for sustainment and also does some acquisition for nonsystem simulators. The PEOs also perform some sustainment. Requirements come largely from the MAJCOMs and AETC, while the Capabilities Integration Directorate under the Life Cycle Management Center assists the MAJCOMs with requirements definition. Requirements definition in USAF is not as centralized as in the Army, but sustainment is more centralized. As USAF's main simulator

---

1 For other dimensions of comparison for service acquisition practices, see Rene G. Rendon, Uday M. Apte, and Aruna Apte, "Services Acquisition in the DoD: A Comparison of Management Practices in the Army, Navy, and Air Force," *Defense Acquisition Research Journal*, Vol. 19, No. 1, January 2012.

office, the SPO plays a more centralized role in inheriting simulators as compared with the Army.

USN has the least centralized acquisition structure of the services. A variety of organizations can serve as "training support agencies," which acquire simulators. These organizations include NAWCTSD, NAVSEA's Surface Training Systems division, and naval warfare centers. NAWCTSD also has offices that deal with some surface and undersea training systems. Likewise, requirements come from a variety of places, including PEOs, SYSCOMs (e.g., NAVAIR and NAVSEA), and the Navy Pacific Fleet and Fleet Forces Command. OPNAV resource sponsors lead the formulation of requirements, which the resource sponsors hand off to acquisition leads.

Sustainment is done by what USN calls "training agencies," which are any organizations that use a simulator. Overall, USN has the most fragmented organizational structure and flexible set of processes for the development of simulators. As an illustration of this, one SME involved in naval simulator acquisition described a process by which simulator development is, in essence, "competed" out to different offices throughout USN.

USMC is the most centralized of the services, and it tends to focus on ground systems. (The F-35C is an exception.) Acquisition is squarely centered in Marine Corps Systems Command, under which PM TRASYS executes simulator development. PM TRASYS also performs sustainment. Requirements come from TECOM and the training directorate under Installations Command.

The centralization of acquisition in USMC stands in stark contrast to the fragmentation in USN and illustrates the variety of managerial structures and processes in place across services. The complexity and variety of structures across services might make coordination across services more difficult.

Results: Case Studies Illustrating Why Interservice Differences Are a Problem

We use case studies of air-ground simulators acquired by each service to illustrate the differences in SBT acquisition organizations and processes, as well as common challenges, such as prioritizing interoperability, maintaining currency, and meeting information-assurance standards. Air-ground simulators were chosen because they provide a case in which each service must include the requirements of other branches. Each of the air-ground systems reviewed should have been developed as a joint system that included ground and air simulations to interact in support of the training needs of the service members.

To select cases, we identified programs that were most similar between services. We selected Joint Terminal Attack Controller (JTAC) simulators as quintessential air-ground simulators for comparison across services. JTAC trainers simulate ground forces coordinating with and directing combat aircraft for close air support. We were unable to secure much information on the Army's JTAC trainers. For the Army, we selected the AVCATT.[2] It is an air-ground simulator that struggled in its development and can provide broader lessons for collective training. For the remaining services, we selected the same class of simulator to facilitate comparison. Comparing like-to-like tasks holds other factors constant to some degree. It is thus easier to identify where practices between services diverge in developing a similar type of simulator.

In the following sections, we first review how the Army acquired AVCATT for collective training of Army helicopter aircrews who have to interact with ground elements. We then review JTAC simulators developed by USAF, USN, and USMC to train service members to coordinate with and direct combat aircraft for close air support of ground units.

---

2 For more details on the AVCATT, see Straus et al., 2019.

Army Acquisition of AVCATT

The AVCATT is the Army's collective trainer for helicopter aircrews and is acquired by PEO STRI as a nonsystem simulator. The simulator is reconfigurable to train to a variety of different helicopters. The AVCATT has a reputation as a troubled acquisition.[3] One of the primary issues has been concurrency—that is, the simulator's capabilities being out of sync with the version of the platform that it is intended to simulate. As the platforms that the AVCATT simulated became increasingly digital, government data rights hindered concurrency of the AVCATT. PEO STRI ended up having to reverse engineer the operational flight program for the helicopters being simulated because it did not own the data rights. The contract for the AVCATT did not account for the costs of maintaining concurrency. It was too expensive for the government to own the data rights and to simultaneously do the necessary reverse engineering. The result was nonconcurrent training and underutilization of the AVCATT.

Although the AVCATT is, in theory, interoperable with any simulator that uses the Distributed Interactive Simulation (DIS) standard and operates through the Army's Synthetic Environment Core capability, interoperability with other simulators has been rare in practice. Technical and coordination problems have also hampered interoperability. The visual resolution that a helicopter aircrew might find relevant for operations is potentially different from the resolution required by a combat vehicle or a dismounted soldier.

The AVCATT case suggests that interoperability is relevant only if a simulator meets training requirements for its parent platform in the first place. AVCATT's issues with concurrency and interoperability with other simulators within the Army made it a great challenge to fulfill the Army's service-specific training requirements, much less pursue integration and interoperability across services.

---

3 See Wade Becnel, "AVCATT: Understanding the Challenges of Unintended Consequences," *Army Aviation*, Vol. 66, No. 7, July 31, 2017.

U.S. Air Force, Navy, and Marine Corps Acquisition of JTAC

JTAC simulators are used by USAF, USN, and USMC to train service members to coordinate with and direct combat aircraft for close air support. USAF, USN, and USMC independently developed different JTAC simulators, largely without coordination. The Air National Guard (ANG) even developed its own version to avoid the constraints of the JCIDS process under which USAF PEOs must operate.

U.S. Air Force

USAF's immersive dome JTAC trainer, the JTC TRS, was developed in fits and starts, with multiple early iterations failing to produce a solution. As USAF was struggling with different contracts for a JTAC trainer, the ANG developed its own solution under the National Guard and Reserve Equipment (NGREA) account. Because ANG was using NGREA funds, it was able to pursue a streamlined acquisition process that was not subject to the same strictures of the JCIDS process under which USAF PEOs must operate. The program embedded ANG JTACs as SMEs with industry to develop the system, producing a solution that effectively met USAF training requirements for JTACs. ANG's solution was ultimately adopted by USAF.

This unique arrangement suggests some benefits to a streamlined, single-office acquisition process but also some risks. The ANG acted as a prototype developer of sorts for the larger USAF. The inclusion of USAF JTACs working alongside industry also seemed to yield more-effective requirements than were formulated in USAF's prior efforts. However, ANG does not have its own contracting agency and must allocate 80 percent of NGREA funds within a year. Thus, there is risk in contracting and sustainment.

Within USAF, the JTC TRS has had success interoperating with other systems. Simulators in USAF are often delivered with DMO capability. Nonetheless, there do remain some challenges with interoperability in USAF, most notably stemming from issues with network security. The process of receiving authorization to operate (ATO) to link classified systems across USAF and joint networks is lengthy and costly, and SMEs noted an unwillingness among the services to accept the risk posed by connecting simulators. This was an issue that every service noted in our conversations about JTAC simulator development. USAF and other SMEs specifically noted that the lack of higher-level guidance on information assurance stands in the way of simulator interoperability.

USAF's development of a JTAC dome simulator reveals lessons for the difficulties that services have in coordinating on a common, interoperable solution to facilitate joint training. The Joint Fires Support Executive Steering Committee (JFS ESC) was stood up in 2004 as a joint-level body under the Joint Requirements Oversight Council (JROC) to address joint fires support issues across the services and multinational partners. Although the JROC designated the JTC TRS as the single joint program of record, these joint bodies have not had sufficient influence to force the services to adopt it. Even where the need for coordination was so great as to necessitate a joint-level coordinating body, services still largely went their own way.

U.S. Navy

While USAF experienced delays in developing a JTAC trainer that USN might have adopted, USN developed its own system, the Combined Arms Virtual Environment (CAVE). The CAVE is built using the JTC TRS software baseline. This system illustrates the flexibility and fragmentation of USN's simulator acquisition system. The requirements for the trainer were transitioned to the Naval Undersea Warfare Center for acquisition. Notably, the simulator office in NAVAIR did not develop this system, as would seem a natural fit for a close air support training system.

Here, too, information assurance has proven to be an issue with simulator interoperability. A USN official noted that the CAVE cannot yet connect to USN's Continuous Training Environment because it has not fulfilled cybersecurity requirements. The bureaucratic drag and costs associated with cyber accreditation have impeded the CAVE's ability to interoperate. Naval SMEs noted that the devolution of cybersecurity accreditation to lower-level offices in USN was meant to speed up the process but ended up being yet more cumbersome. They also noted that issues with the interoperability of the parent platforms themselves are reflected in issues with the associated simulators, including the CAVE. With regard to collaboration with other services, one official reported not having seen any joint training requirements or joint input in the CAVE's development.

The length of the acquisition process also proved challenging for the development of the CAVE. Turnover in leadership meant that new officials might question execution plans and that stakeholders wanted to change performance specifications midstream. New sets of eyes can bring needed perspective to projects but can also lead to some inefficiencies in execution.

U.S. Marine Corps

USMC decided to use a modified version of the USN CAVE as its JTAC dome training device after surveying the range of solutions across the services. The supporting arms virtual trainer (SAVT) does not interoperate with other simulators as a matter of course, although one system at Marine Corps Air Station Yuma has been modified to interoperate with a select number of aircraft simulators.

Although the goal of the SAVT is to interoperate with a range of USMC simulators, interoperability requirements for specific systems have taken a back seat as USMC has been evaluating interoperability requirements for the service at large. The SAVT illustrates how the relatively small size of USMC drives it to look to other services' programs but also how interoperability takes a back seat as USMC prioritizes other requirements in light of limited resources. Interoperability is resource intensive and is, therefore, on hold. The one SAVT system at Yuma is one of the only simulators to have been linked to other systems outside Large-Scale Exercise (LSE) 14, illustrating how rare it is for USMC simulators to be linked together.[4]

Interviews suggested a number of potential issues with requirements for the SAVT and for JTAC trainers more broadly. Threshold requirements are often the same as the objective requirements, which does not enable growth or modification of the system. There was also some concern that accreditation of JTAC trainers by the services them-

4 For information on LSE-14, see Barron Mills, *Live, Virtual, and Constructive-Training Environment: A Vision and Strategy for the Marine Corps*, Monterey, Calif.: Naval Postgraduate School, September 2014.

selves might not produce credible results. However, joint-level policy specifies that accreditation be done by the JFS ESC.[5] This illustrates that, even in a rare instance in which joint-level policy guides services toward a focal point for development of air-ground simulators, that policy is not always followed.

To summarize, the USAF JTAC simulators have had success interoperating with other systems, but there are issues with network security. The process of receiving ATO to link classified systems across USAF and joint networks is lengthy and costly, and SMEs noted an unwillingness among the services to accept the risk posed by connecting simulators. The USN JTAC simulator has also faced challenges with information, and it cannot yet interoperate with the USN Continuous Training Environment because it has not fulfilled cybersecurity requirements. USMC uses a modified version of the USN simulator, and it also does not interoperate with other simulators.

Conclusion

To identify differences between services and identify potential best practices in acquisition processes for simulations and modeling systems, we mapped the acquisition processes and organizations for each service and compared their management structures, contract structures, and workforce characteristics. We then used case studies for each service to illustrate these acquisition processes.

Overall, we found that the organizations of the different services and their acquisition processes were marked by only limited attempts to coordinate with requirements development. As a result, development efforts were replicated, and dollars were spent developing simulations that are not interoperable.

In addition, acquisition processes vary dramatically across the services in terms of complexity and managerial structure. The Army

---

5 Chairman of the Joint Chiefs of Staff Instruction (CJCSI) 5127.01A, *Joint Fire Support Executive Steering Committee Governance and Management*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, December 14, 2018.

and USMC have relatively centralized coordination of acquisition.[6] Centralization can lead to more-integrated efforts, helping ensure that SBT appropriately incorporates interoperability into requirements. There was also evidence that more-decentralized processes could be the source of siloed acquisition within branches. The close collaboration between USN and USMC provides a model for processes and structures for transitioning requirements into an acquisition.

As noted in Chapter Three with regard to the requirements processes, the existence and placement of M&S offices can provide a common thread across services for acquisition.

While specific findings are discussed with the case studies, overarching findings from the studies are as follows:

- **Joint "coordinating bodies" can help coordinate acquisition processes.** For example, JFS ESC helped services find and adopt systems and components that met requirements when individual service efforts faltered.
- **Existing coordinating organizations do not have sufficient mechanisms to incentivize services.** JFS ESC does not have significant policy levers or funding, nor does it have appropriate incentives to get services to collaborate, even in an area in which collaboration is key. In general, collaboration was driven by necessity after multiple independent efforts by individual services struggled.
- **The JROC project designation of "joint-interest" provides an effective mechanism for incentivizing service collaboration, but it is rarely used.**
- **Information-assurance and security protocol is one of the biggest obstacles to interoperability.** Many SMEs noted the absence of top-down guidance and joint-level focal points for information-assurance policy coordination. Every SME mentioned information assurance as a problem for interoperability,

6 See Appendix C for further information on the major acquisition stakeholders and processes across each service.

and the four Joint Fires SMEs agreed that it is the "biggest problem."

- **Resource constraints can result in interoperability being a relatively low priority.** For example, USMC put interoperability of its simulators on hold while waiting for the LVC-TE program to mature.
- **The length of the acquisition process can create obstacles for collaboration.** Leadership turnover can mean questioning execution plans, and delays in acquisition can stifle the ability to leverage the latest capabilities provided by industry.

PART II

Joint Operations: Training Needs, Coordination, and Incentives

CHAPTER FIVE

Joint Training Needs

While the previous chapters focused on how each individual service operates with respect to training-simulator requirements and acquisition, this chapter begins the discussion of how the services operate in a joint capacity. Specifically, we summarize the joint training needs that motivate joint training operations. This, in turn, leads to Chapter Six, which focuses on the coordination between the services in response to these needs. When studying any aspect of training, especially any new tool or system being developed (such as a simulator), it is critical to consider the end user and the training need. When considering tactical operations, there is much focus on training needs within each service. However, the training needs for the joint community and the coordination between services are more elusive.

To provide background and context, we first summarize the different levels of training in the military. We then study training needs based on (1) feedback from SMEs within JS J7, (2) assessment of current training exercises, and (3) assessment of UJTL. Finally, we review published plans and directions for each service with respect to joint simulator-based training. These goals provide a complement to training needs with respect to future simulator development. The primary question that we address in this chapter is, What are the joint training needs with respect to interoperability of air and ground simulators for Tier 3 and Tier 4 training?

Training Tiers

Because of the complexity of the military's structure and operations, training is segmented into different levels, called *training tiers*, which are summarized in Table 5.1. Tier 1 exercises are organized at the CCMD level. They focus on integrating the efforts of various agencies within the U.S. government, nongovernmental organizations, and international partners in strategic- or operational-level mission environments.

Tier 2 exercises are organized at the Joint Task Force level. They focus on preparing national and international organizations to better unify their efforts for a particular operational-level mission or mission environment (but are not whole-of-government efforts).

Tier 3 exercises are organized at the functional or service component level. They focus on training the ability of systems or units

Table 5.1
Training Tiers

Tier	Description
Tier 1	• National forces and CCMD-level organizations • Strategic- or operational-level mission or mission environment • Focuses on integrating the efforts of various agencies, nongovernmental organizations, and international partners
Tier 2	• Joint Task Force level • Operational-level mission or mission environment • Focuses on preparing national or international organizations to unify their efforts for a specific mission or mission environment
Tier 3	• Functional or service component level • Operational-level mission or mission environment • Focuses on the ability of systems, units, or forces to operate in an interagency, nongovernmental, or international environment
Tier 4	• Individual unit level • Tactical-level mission or mission environment • Focuses on basic technical and operational capabilities in support of Joint Force Commanders

SOURCES: CJCSI 3500.01H, *Joint Training Policy for the Armed Forces of the United States*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, April 25, 2014; and CJCSM 3500.03E, 2015.

to operate with other services, government agencies, nongovernmental organizations, or international partners for a particular operational-level mission or mission environment. Although Tiers 2 and 3 seem similar, the primary difference is that Tier 2 exercises focus on training an organization's ability to integrate, while Tier 3 exercises focus on training the ability of individuals.

Tier 4 exercises are organized at the individual unit level. They focus on training the ability of individuals and units to perform basic technical and operational capabilities in support of Joint Force Commanders. This report is concerned primarily with Tier 3 and Tier 4 training.

Training Process

The joint training process and the process for updating simulators are itemized in Appendix D. This includes JNTC, which essentially provides simulator capabilities that are used within the Joint Training System (JTS). As part of JTS, any gaps in simulator capabilities are identified and then addressed via the JCIDS acquisition process.

A key aspect of simulator development, let alone coordinated development across services, is the ability to systematically ensure that new simulator capabilities respond to training needs. Although JTS provides a process for identifying such capability gaps and JCIDS provides a systematic process for addressing them, the JCIDS process can be inefficient. This, in turn, can stifle agile development of interoperable simulators that respond directly to joint training needs. In addition, the complexity and potential inefficiency of JCIDS can impose additional transaction costs on developers, and this can reduce the incentives to pursue joint training-simulator solutions.

Approach

To understand the needs for SBT coordination between services, it was necessary to assess the demand signal at the joint level. To do this, we conducted a literature review of policies related to joint training; interviewed stakeholders at the Joint Staff level; analyzed available unclassified joint training exercise program data from the Combatant Commander Exercise Engagement and Training Transformation (CE2T2) enterprise; and compiled and analyzed UJTL data.

In addition, we reviewed documentation describing plans for each service with respect to future SBT goals and development. This provided a target for each service that can generally be compared with overarching joint training needs.

Results

General Training Needs

At the joint level, the most predominant demand signal for joint training stems from Tier 1 and Tier 2 training events. These are the national-level exercises at the CCMD level and above. Stakeholders noted that, at the Tier 3 and Tier 4 levels, the demand for joint training was lower, as were the resourcing and capacity for joint SBT. Furthermore, it was suggested that there are minimal formal requirements for joint SBT at the Tier 4 level.

However, there were a few capability areas that were exceptions to this trend. Integrated air and missile defense (IAMD) and specific Special Operations Command (SOCOM) mission sets do, in fact, have a larger requirement for Tier 3 and Tier 4 joint SBT. These mission sets are generally unique and could be areas in which standing up more joint SBT could be worthwhile.

A contributing factor to the lack of demand for joint training at the lower tiers is the lack of coordination across the tiers. Furthermore, some SMEs noted that there is a common semantic challenge when determining what is considered "joint." An effort to bridge this particular gap has been the development of joint tactics, techniques, and procedures (TTP) and Joint Mission Essential Tasks (JMETs). This development began around 2002 with the establishment of UJTL. UJTL is managed at the JS J7 and is updated as new requirements evolve. Defining joint TTP is critical, in part because all of the services might perform any given task a bit differently. Joint TTP establish a common framework for performing tasks at a level that incorporates more than one service. These aim to establish communication, increase interoperability, and reduce incidents of fratricide, among others. However, a challenge with TTP has been that the program for joint TTP and JMETs has been greatly reduced in terms of staff. The UJTL program was previously housed at Joint Forces Command (JFCOM) but has atrophied since JFCOM's disestablishment in 2011. The UJTL program is an area in which establishment of joint concepts could grow further as the demands for interoperability and joint training increase.

In discussions with stakeholders at different services' training and education departments, and from a review of their literature, we found several service-specific challenges with respect to joint training. Many SMEs noted that there simply is not much appetite or incentive for joint collaboration. Some of this lack of interest is due to intricacies related to the funding attached to the JROC and whether the requirements for a system being acquired jointly were codified. Requirements codified through the JROC are able to receive funding through joint streams versus service-specific funding. If a requirement was not a joint requirement or in the JROC, services did not have the incentive to spend their own dollars to train to it.

For USAF, in particular, stakeholders noted that their requirements come from MAJCOMs. They stated that they sometimes face difficulty in managing the competing requirements between CCMDs to maintain intraservice interoperability, much less interoperability with other service branches.

USMC stakeholders echoed that there needs to be a forcing function, such as the requirement being codified by the JROC, to implement joint training from higher echelons. USMC has certain LVC-TE and SAVT requirements established with USN, but they do not interface with many other organizations at the joint level.

Army stakeholders also noted that the Army has difficulty spending its own money on something unless there is an official joint program of record for the requirement or program. The Army uses the Joint Land Component Constructive Training Capability Bridge (or JLB) to connect its training simulators with other services' simulations, but the stakeholders noted that the other services sometimes have issues if they do not have the proper technological requirements on their end.

Joint Training Exercises

We looked at the frequency of joint training exercises as a second indicator for joint training needs. Joint training exercises bring together more than one service with the intention of demonstrating joint functional area capabilities. These exercises are conducted at the CCMD level through the CE2T2 program and JNTC (see Appendix D). JNTC provides mechanisms for services to train in the joint context at the Tier 3 and Tier 4 levels. However, each of the services is ultimately responsible for training joint Tier 3 and Tier 4 tasks outlined in UJTL. That is, higher-level training needs are handed down to the services by CCMDs, and the services are then responsible for planning Tier 3 and Tier 4 training internally, in an effort to support CCMDs. This, of course, makes coordinating between services on the Tier 3 and Tier 4 levels challenging. Stakeholders mentioned that capturing the demand signal for joint Tier 3 and Tier 4 training is difficult; there is a lack of centralization for joint training at those levels, making it difficult to capture the demand.

One potential avenue for future research to capture that demand signal lies with Defense Readiness Reporting System (DRRS) data captured from joint exercises. After a given exercise, data are recorded in DRRS and tied to UJTL functional areas and levels of war. These data might demonstrate the frequency and level at which units are training to tasks at the Tier 3 and Tier 4 levels.

UJTL Data Analysis

We analyzed the tasks outlined in UJTL to get a better understanding of the types of training requirements outlined for all of the services. UJTL is the “what” that is to be performed in a joint training exercise. It is broad and open for interpretation so that each service can tailor it to its own language. UJTL does not explain the “how” of the task, or by what means it should be accomplished; that is up to the respective services. The UJTL tasks are organized by functional category and level of war so that the services may then link their own training tasks with them.

The functional categories, which involve joint capability areas, are as follows:

- Deployment and Redeployment
- Intelligence
- Employment of Forces
- Sustainment
- Command and Control
- Mobilization/Force Protection
- Force Development/Readiness
- Multinational/Interagency
- CBRNE [Chemical, Biological, Radiological, Nuclear, and Explosives] Deterrence/Counter CBRNE.

The levels of war align with the training tiers. In Table 5.2, the levels of war are categorized and linked to the training tiers to which they correspond. We used these levels to determine the number of tasks associated with each training tier.

Table 5.3 lists the number of tasks associated with each level of war and training tier. Most of the tasks described in UJTL lie at the Tier 1 through Tier 3 levels. At the Tier 4 level, there were far fewer tasks coded in UJTL. At 114 total tasks, tactical-level Tier 4 training

Table 5.2
UJTL Levels of War and Training Tiers

Level of War	Training Tier
Strategic	
Strategic National (prefix *SN*)	Tier 1–2 training events
Strategic Theater (prefix *ST*)	Tier 1–2 training events
Operational (prefix *OP*)	Tier 3 training events
Tactical (prefix *TA*)	Tier 4 training events

SOURCE: Joint Chiefs of Staff, “Universal Joint Task List,” database, January 15, 2020.

Table 5.3
Total Tasks per Joint Training Tier and Level of War

Joint Training Tier	Level of War	Prefix	Number of Tasks	Percentage of Total Tasks
1	Strategic National	SN	482	35
2	Strategic Theater	ST	386	28
3	Operational	OP	400	29
4	Tactical	TA	114	8

SOURCE: Joint Chiefs of Staff, 2020.

tasks account for only 8 percent of the total tasks codified in UJTL. This corresponds to what some stakeholders described as being a minimal demand for Tier 4 training at the joint level. Tasks at the Tier 3 level, however, are more numerous.

Future Development for the Services

To understand the services' visions of joint simulator-based training, we reviewed documents and briefings from the past decade that discuss future goals for training strategy and infrastructure. This review sheds light on both the demand signal from the services for future integrated simulator development and the goals for the services with respect to SBT capabilities. Most of the documentation that we reviewed points toward joint simulator interoperability as a medium- to long-term goal. The medium term for documentation from the mid-2010s is essentially the present (2020). The goal of cross-service simulator interoperability has long been in the services' sights.

Within **USAF**, an AFAMS brief from 2018 indicates that joint LVC integration is planned for the third increment of the capability, around 2022 or 2023, and joint interoperability of simulators is one of 13 lines of effort in the USAF 2035 Operational Training Infrastructure Flight Plan.[1] The ANG also aims to have its simulators networked to USAF Distributed Training Centers, other services, and other coalition and interagency systems in the future.[2]

USN does not have a recent M&S vision statement, but some sense of USN's direction can be gleaned from other documents. The Air Defense Strike Group Facility at Naval Air Station Fallon aims to integrate with joint partners. This was spelled out in 2016, but it is unclear whether that has happened yet.[3] In 2017, an official from NAWCTSD noted, "As we start to field the next generation of simulators, in the documents that we provide to industry, they all include requirements to be able to connect across the networks."[4] USN has also recently participated in large-scale USAF exercises (e.g., Northern Edge) and indicates a desire to integrate USN simulators into more USAF exercises in the future.

Like USN, the **Army** also lacks a recent M&S vision statement. The 2017 *U.S. Army Learning Concept for Training and Education*, developed by TRADOC, does not mention joint or other services in the context of integrated simulator capabilities; rather, the focus is on the Army and the depth of soldier training experiences.[5] However, the 2018 Army vision statement by the chief of staff of the Army sounds a note that is oriented more toward future development of joint simulator capabilities. The statement notes the need for "leverage of combined arms maneuver with the Joint Force, allies, and partners," and notes that the "training will require rapid expansion of our synthetic

1 Robert Epstein, "Air Force Agency for Modeling and Simulation," briefing slides, Headquarters U.S. Air Force, July 2018.

2 ANG, *The Air National Guard LVC Flight Plan*, Joint Base Andrews, Md., 2015.

3 Department of the Navy, *Naval Aviation Vision 2016–2025*, Washington, D.C., January 2016.

4 Interservice/Industry Training, Simulation and Education Conference, "Navy Works Toward LVC Future," *I/ITSEC 2017 Official Daily News Digest*, November 28, 2017, p. 6.

5 TRADOC Pamphlet 525-8-2, *The U.S. Army Learning Concept for Training and Education, 2020–2040*, Fort Eustis, Va.: Headquarters, U.S. Army Training and Doctrine Command, April 2017.

training environments and deeper distribution of simulations capabilities down to the company level."[6]

The **USMC** 2015 *Marine Corps Ground Training Simulations Implementation Plan* envisioned the USMC LVC-TE to have joint interoperability by 2020.[7] As noted in the case studies described earlier, USMC has put interoperability within the service itself on hold as it determines its own common interoperability requirement. More-recent policy, from 2019, states that "M&S shall be interoperable and support composable systems of systems environments to the greatest extent practical."[8] However, the most-recent Commandant's Planning Guidance suggests a move away from large-scale, connected simulation exercises. The guidance states, "we need less of the grand 'simulations' solution connecting a variety of individual cockpit or rifleman-level sims into the flow of larger exercises than a modernized command and control system that integrates advanced wargaming functions for both training and planning."[9]

Conclusion

Moving from the material in Chapters Two through Four, which focused on individual services, this chapter has provided a review of *joint* training. We have reviewed JTS, JNTC, and JCIDS, all through the lens of processes for supporting cross-service simulator use and development. In addition, we have tried to document the demand signal for Tier 3 and Tier 4 joint training through interviews with SMEs, assessment of recent or currently planned training exercises,

---

[6] To read the vision statement, see Mark A. Milley and Mark T. Esper, "The Army Vision," Department of the Army, 2018, p. 2.

[7] USMC, *Marine Corps Ground Training Simulations Implementation Plan*, Washington, D.C.: Department of the Navy, June 2017.

[8] Secretary of the Navy Instruction 5200.46, 2019, p. 3.

[9] David H. Berger, 38th Commandant of the Marine Corps, *Commandant's Planning Guidance*, Washington, D.C.: Headquarters, Department of the Navy, 2019, p. 19.

and UJTL. Finally, we have reviewed published plans for each service with respect to joint simulator-based training development.

In trying to assess the joint training needs with respect to interoperability of air and ground simulators, a key finding echoed by joint training SMEs is that the demand for Tier 3 and Tier 4 SBT is difficult to capture accurately. It might, in fact, exist, but it is not measured effectively. In general, documentation and SMEs note the need for joint training, even at a tactical level, as well as simulator interoperability across the services. However, data that support these needs can be sparse. Thus, it would be helpful to evaluate data in DRRS that are related to UJTL functional areas and levels of war. These data might provide insight concerning the frequency with which units train to tasks at the Tier 3 and Tier 4 levels. IAMD and some specific SOCOM mission sets, however, do reflect a clear demand for joint SBT at the Tier 3 and Tier 4 levels. These mission sets are generally unique and could be areas in which standing up more joint SBT could be worthwhile.

More-specific findings are as follows:

- **Although JTS provides a process for identifying joint training capability gaps, and JCIDS provides a systematic process for addressing these gaps, the JCIDS process can be cumbersome and can operate on long time horizons.** This, in turn, can stifle agile development of interoperable simulators that respond directly to joint training needs.
- **The UJTL program could help support joint concepts.** However, the UJTL program was previously housed at JFCOM and has atrophied since JFCOM's disestablishment in 2011.
- **JCIDS, although not a main deterrent to the acquisition of joint simulators, can impose additional transaction costs that likely reduce the incentives to pursue joint training-simulator solutions.** Nonetheless, acquiring preexisting simulators (likely those already purchased by other services) and then submitting a separate contract to modify them is likely the most efficient currently existing process to obtain joint simulators. Alternate paths

through JCIDS already exist to aid in the acquisition of preexisting capabilities and information technology (IT) solutions.

- **The individual services are ultimately responsible for training to Tier 3 and Tier 4 tasks that are more operational and tactical, and, although this allows services to respond to local and specific training needs, it fosters a lack of coordination between services.** Higher-level training needs are handed down to the services by CCMDs, and the services are then responsible for planning Tier 3 and Tier 4 training internally, in an effort to support CCMDs. The consequent lack of centralization for joint training at this level can contribute to the difficulty in determining or quantifying demand.
- **Each service needs a clear vision and plan with regard to science and technology (S&T) development that supports integrated joint training.** This could provide a basic mechanism for ensuring that the services have a coordinated vision with respect to simulator interoperability. Much of the documentation for these plans is outdated. Nonetheless, it generally suggests that cross-service simulator interoperability has long been a goal for the services. This pervasive goal of simulator interoperability with minimal detailed documentation of the joint training need risks yielding ineffective acquisition programs.

CHAPTER SIX

Coordination Between Services

While the first part of this report looked at organizations within each service that could help coordinate simulator development, this chapter looks at higher-level organizations across DoD that could help support coordination. Chapter Two identified organizations within each service that could provide an external interface with the broader training community. Such organizations would presumably have aggregated data and expertise regarding the service. However, it must be clear which external DoD organization, or organizations, the services should interface with to pursue integrated joint training goals. We will show that these necessary DoD organizations exist in many respects, but, over time, they have lost the ability to create incentives (via policy, funding, or transparency of information), which are discussed in more detail in Chapter Seven. The overall finding is that there is little coordination between services, and policy-assigned coordinating roles at the joint level have grown weaker over time, especially after the dissolution of JFCOM.

In this chapter, we examine organizations at each level, present a timeline of relevant policies and policy changes governing M&S coordination among the Joint Staff and services, and then discuss gaps in coordination. First, we itemize the various DoD organizations that could potentially help support coordination between services within the training community. For each organization, we summarize its purpose and then note how, with minimal changes, it could further foster coordination. After itemizing the relevant organizations, we describe the history of joint and DoD organizations and policies. This provides a framework with which to study the various policies and governing bodies that have affected or could affect training-simulator development for joint operations. The overarching questions that we pursue in this chapter are as follows:

- What organizational and policy mechanisms exist to foster coordination between services?
- What opportunities are there for improvement?

Potential Coordinating Organizations

In this section, we examine the types of coordinating bodies and the nature of coordination at the service and joint levels. Although there is little coordination between services, the following existing organizations could play larger roles in encouraging and facilitating cross-service coordination over simulator development. We note these potential roles in this section.

OSD DASD(FE&T)

Within OSD, the overarching organization that involves training simulation is the Office of the Under Secretary of Defense for Personnel and Readiness (OUSD[P&R]). Under this organization are three related subordinates responsible for training and readiness: The Deputy Assistant Secretary of Defense (DASD) for Force Education and Training (FE&T), the DASD for Readiness Programming and Resources (RP&R), and the DASD for Force Readiness (FR). DASD(FE&T) oversees the development of policies and plans for military training and education and is thus most relevant to training-simulator coordination. Responsibilities include service and joint training policy, cyber training policy, joint professional military education, training capability modernization, and enabling access to the land, air, and sea live training domains.

The DoD Senior Steering Group (SSG) is a steering group for simulator interoperability. It was started by a SOCOM request, because SOCOM lacked the needed interoperability to train with the different services in time for operational requirements. The DoD SSG was then organized to address this need. However, SMEs have noted that the charter for the steering group was broad and opportunities existed for the group to continue tackling simulator interoperability beyond the first SOCOM issue. Participants of the steering group come from each service and from the Joint Staff, DoD agencies, and OSD. Representatives for each service include members at the O-6 and Senior Executive Service ranks to provide senior-level input. The steering group has a broad charter and can address a variety of issues at the joint level, thus providing a venue for services, DoD agencies, OSD, and the Joint Staff to collaborate. Most relevant to simulator interoperability and coordination, conceptual modeling has been identified by the SSG as a priority with an effort to address incompatibilities in underlying assumptions used to build models. OUSD(P&R) is the lead for the SSG conceptual model working group.

DASD(RP&R) serves as the principal staff assistant and adviser to the Assistant Secretary of Defense (Readiness) on all matters pertaining to (1) the DoD Planning, Programming, Budgeting, and Execution System; (2) total force readiness resource oversight management; and (3) staff oversight for approximately $350 billion per year, supporting more than 2 million civilian personnel.

DASD(FR) is the focal point within OSD for the near-term strategic and operational readiness of the armed services, and thus develops and oversees policies and programs to ensure that the U.S. military is ready to perform missions assigned by the President and the Secretary of Defense. In this capacity, DASD(FR) also serves as a principal staff adviser on global force management and reserve component mobilization and is responsible for DoD's quarterly readiness reporting to Congress.

Advanced Distributed Learning Initiative

With oversight from DASD(FE&T), the Advanced Distributed Learning (ADL) Initiative brings together the services with other federal agencies to coordinate on distributed learning policy and technologies. It is composed of members across DoD and from partner nations, industry, and academia. Although the initiative does not explicitly address simulators as a technology separate from the broader category of distributed learning, its goal of furthering software standards for interoperability and reducing duplicative efforts across the government could be tailored to address simulator development as appropriate.

The ADL Initiative began in the early 1990s to support the National Guard in building prototype electronic classrooms and learning networks to increase personnel access to learning opportunities. There was a growing proliferation of learning management systems and digital instructional platforms at the time, and, by the mid-1990s, DoD realized that it needed a more comprehensive, coordinated approach.

The 1996 Quadrennial Defense Review directed a DoD-wide strategy for modernizing technology-based education and training, and this spawned the original ADL Initiative. After DoD and other federal agencies had each developed their own ADL-like initiatives, the White House's Office of Science and Technology Policy (OSTP) led an effort to unify the systems into a federal government–wide program and approach to distance learning. By 1999, the ADL Initiative was largely defined, and its rationale and vision continue today.

The Defense ADL Advisory Committee helps support cross-service collaboration and is composed of members across the joint training enterprise. Joint Staff–level representation comes from JS J7 Joint Knowledge Online personnel and the DoD Chief Learning Officer. Across the services, representatives from the training commands are involved, including TRADOC, Naval Education and Training Command, AETC, USMC TECOM, and the National Guard Bureau.

JNTC

As noted in Chapter Five, JNTC is a joint training program administered by JS J7. JNTC supports and accredits service-administered joint training events. There are semiannual Joint Training Coordination Conferences in which the services, JS J7, and SOCOM meet to discuss joint training issues and requirements for their training events.[1] This

---

1 CJCSM 3511.01, *Joint Training Resources for the Armed Forces of the United States*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, May 26, 2015.

venue, and JNTC more broadly, do not deal explicitly with simulator requirements. Nonetheless, the discussions that take place through JNTC and the semiannual conferences could be captured as indicators of critical capability needs and fed into service simulator development.

DMSCO

DMSCO is DoD's focal point office for M&S policy coordination. Its role is to promote policy coordination, interoperability, common standards, and M&S reuse. Among other activities, DMSCO publishes a catalog of M&S used throughout the services (although contributions to this catalog are voluntary) and serves as DoD's lead on standardization, including representation in different standards organizations. It also can oversee M&S projects at the direction of the Under Secretary of Defense for Research and Engineering (USD[R&E]).[2] Although DMSCO cannot effectively compel (via policy or funding) action by the services, it could potentially serve a more robust function of tracking, coordinating, and directing M&S activities.

Team Orlando

As a collaborative alliance of U.S. military organizations working in modeling, simulation, and training,[3] Team Orlando is the closest thing to a coordinating body among the service simulator acquisition offices. However, it has no direct policy influence. It acts primarily as a broad collaborative body to foster communication and collaboration among its members and within the M&S community. It is a consortium of service organizations that are involved in M&S. Its principal focus is on supporting requirements for M&S, ADL, training systems, and human performance. However, there is no central funding for this organization.

Team Orlando is governed by two boards: the Executive Board of Directors for strategic vision and guidance and the Board of Directors

---

2 DoD Instruction (DoDI) 5000.70, *Management of DoD Modeling and Simulation (M&S) Activities*, Washington, D.C.: U.S. Department of Defense, May 10, 2012, Incorporating Change 3, October 15, 2018.

3 Team Orlando, homepage, undated.

for execution. The Executive Board of Directors consists of the commanders of the principal commands from the four services and two advisers. It meets annually to guide and approve plans, decisions, and actions of the Board of Directors. Members of the Executive Board of Directors include PEO STRI; Commanding Officer, NAWCTSD; PM TRASYS; Commander, Marine Corps Systems Command; and AFAMS. The Board of Directors consists of senior leaders from the service commands and other federal agencies.

Team Orlando aims to identify areas of common need across the services and encourage partnerships between the services to develop capabilities to meet common requirements. Team Orlando includes the Joint Training Integration and Evaluation Center, a forum that brings together deputies from the service simulator acquisition offices to share information on ongoing development efforts. The center also convenes quarterly forums that focus on different topics, including a recent focus on LVC capabilities.

A summary of Team Orlando's collaborative achievements includes the establishment of forums, LVC capabilities and initiatives, and activities to synchronize standards and training assessments.[4] The summary does not mention collaboration on specific simulator programs, although the forum brings together PMs in a fashion that could be conducive to greater coordination around simulator development. JS J7 is notably absent from Team Orlando, and a presence by JS J7 might help inform and guide joint-level coordination and awareness of requirements that are common among the services.

JITC

Joint Interoperability Test Command (JITC) is a body that tests DoD IT systems for interoperability. As it stands, there is no dedicated joint body that systematically ensures that simulators are interoperable according to their own interoperability requirements, to the extent such requirements are included in system-development documents.

---

[4] Jennifer J. Vogel-Walcutt, William E. Cole, Timothy M. Hill, Walter Yates, Robert Epstein, Diana Teel, and Katie Flinn, *Team Orlando: Community of Progress*, paper presented at Interservice/Industry Training, Simulation and Education Conference (I/ITSEC), 2018.

Specifically, although a request for proposal (RFP) might include requirements for interoperability, there is no organization tasked with objectively ensuring that such requirements are met, especially as they might pertain to systems in various services. A joint body that could test and certify interoperability would incentivize services to coordinate on simulator development to meet certification standards.

Under old policy, JITC was, in theory, responsible for testing simulator interoperability.[5] This policy was canceled, and policies governing IT interoperability testing are now included in the JCIDS manual.[6] The most recent policy does not call out simulators for interoperability testing, and, in fact, other DoD policy on IT interoperability specifies that simulators *do not* require interoperability testing so long as a simulator "only stores, processes, or exchanges simulated (i.e., not real-world) data."[7] Services might have less incentive to collaborate on simulator development without the prospect of being held to requirements for joint interoperability. Joint interoperability requirements are not always part of a simulator's system requirements (discussed in Chapter Seven). As a further disincentive for getting interoperability requirements right, there is no joint body that actually tests the interoperability of the services' simulators as JITC does for other DoD IT capabilities.

---

5 Per CJCSI 6212.01E, JITC "certifies stimulator/simulator and training systems and may certify them in the same manner as operational systems. These systems must have J-6 I&S Certification first before the JITC joint interoperability test certification. JITC does not certify that these systems provide an accurate model of any particular environment" (CJCSI 6212.01E, *Interoperability and Supportability of Information Technology and National Security Systems*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, December 15, 2008, p. F-18).

6 CJCSI 5123.01H, *Charter of the Joint Requirements Oversight Council (JROC) and Implementation of the Joint Capabilities Integration and Development System (JCIDS)*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, August 31, 2018.

7 DoDI 8330.01, *Interoperability of Information Technology (IT), Including National Security Systems (NSS)*, Washington, D.C.: U.S. Department of Defense, May 21, 2014, Incorporating Change 2, December 11, 2019, p. 2.

Joint Forces Command and JS J7

JFCOM was formed in 1999 out of what was previously Atlantic Command and was tasked with acting as the coordinator of joint training, among many other functions. Upon JFCOM's dissolution in 2011, many of its key functions were transferred to JS J7. These included administering JNTC (see the earlier discussion on JNTC) and developing capabilities to facilitate battle staff–level joint training with constructive capabilities, such as the Joint Theater Level Simulation.[8] JFCOM was dissolved as part of a cost-cutting effort ($1 billion budget) and, ostensibly, because military forces had succeeded in becoming "joint" since JFCOM's creation.[9]

As we discuss in the next section, some functions that might have served to facilitate joint collaboration were degraded over time or lost in the transition to the Joint Staff. For example, JFCOM initially was responsible for "identifying, gathering, and integrating all joint training M&S requirements."[10] This included assisting CCMDs in developing joint training requirements. It is notable that, even under a regime in which JFCOM held formal responsibilities to formulate joint requirements, it had limited influence at the JROC, Defense Acquisition Board, and advisory board responsible for reviewing the costliest acquisition programs.[11]

In addition to JFCOM's more formal role in developing joint M&S requirements, as compared with the role that JS J7 would subsequently play, JFCOM had Title 10 authorities to formulate and con-

---

[8] See Don Weter and Larry Hose, "Joint Theater Level Simulation," briefing slides, Washington, D.C.: Joint Staff J7, September 2016.

[9] Mark R. Hirschinger, *The Disestablishment of U.S. Joint Forces Command: A Step Backward in "Jointness,"* thesis, Norfolk, Va.: National Defense University, Joint Forces Staff College, June 16, 2011; and Jason Ukman, "U.S. Joint Forces Command Formally Dissolved," *Washington Post*, August 4, 2011.

[10] CJCSI 3500.01B, *Joint Training Policy for the Armed Forces of the United States*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, December 31, 1999, p. D-4.

[11] See the testimony of Andrew Krepinevich in U.S. House of Representatives, "Improving the Readiness of U.S. Forces Through Military Jointness," hearing before the U.S. House of Representatives Committee on Armed Services Subcommittee on Readiness on March 31, 2011, Washington, D.C.: U.S. Government Printing Office, 2011.

duct joint training,[12] while the JS J7 currently does not, thus giving the latter less ability to influence joint training.[13] Furthermore, JFCOM was granted limited acquisition authority by Congress in 2004. This was an authority that JFCOM infrequently used to acquire equipment that would meet urgent joint warfighting needs; however, as of 2007, this authority had not been used to acquire any simulators or simulation capabilities.[14] In the 2010 National Defense Authorization Act, the Joint Staff received $285 million to support services in developing simulators for joint training.[15] In contrast, the JS J7 has more-limited funds available to distribute to support joint training events, such as the transportation of personnel and equipment.[16]

The current focus of JS J7 is on Tier 1 and Tier 2 training, while Tiers 3 and 4 do not currently have a joint-level body that serves to help services coordinate on identifying and developing simulator requirements and capabilities.[17] Under JFCOM, the Joint Staff had a peripheral presence in Team Orlando with the Joint Development Integration Facility, which aimed to spur collaboration on technologies and infrastructure for the joint training environment. However, the Joint Staff no longer has a significant presence in the Orlando community, which might make the goal of supporting service M&S coordination more difficult to achieve.

---

[12] Title 10 of the U.S. Code provides the legal basis for the roles and responsibilities of each of the services and DoD.

[13] Specifically, JFCOM was responsible for "conducting joint training and assessing interoperability of assigned USJFCOM combatant command forces that will operate as part of joint/combined task forces" (CJCSI 3500.01B, 1999, p. D-4).

[14] U.S. Government Accountability Office (GAO), *Defense Acquisitions: Status and Challenges of Joint Forces Command's Limited Acquisition Authority*, Washington, D.C.: GAO-07-546, April 2007. This report notes that JFCOM's use of this authority was limited, in part because no funds were directly allocated to its use.

[15] National Training and Simulation Association, *Joint Training: Training 2015*, Arlington, Va., November 2010, p. 25.

[16] See CJCSM 3511.01A, *Joint Training Resources for the Armed Forces of the United States*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, August 30, 2019.

[17] Interview with Joint Staff officials.

Timeline of Organizations and Policy

The previous section covered coordinating organizations at the service and joint levels. The summary of JFCOM's coordinating activities highlights that joint policy has changed over time with respect to high-level governance and coordinating responsibilities for DoD simulator development. Thus, using information from SME interviews and a review of policy literature, in Figure 6.1, we present a timeline of joint- and DoD-level policies and organizations that affect simulator development. Each color represents a series of policy documents. That is, documents with the same color address the same general topic.

One key insight from tracing the evolution of policy and organizations is that joint oversight and support for identifying joint training requirements for simulators have become less clearly assigned and have received less support over time. Responsibilities to identify, prioritize, and feed joint M&S requirements into the development process have gradually disappeared from joint policy and guidance. Specifically, JFCOM's responsibility to identify joint M&S requirements was not transferred to JS J7. Similarly, Joint Staff J8's responsibility to produce a joint M&S plan and a prioritized list of requirements was also dropped from policy, as was its responsibility to produce a joint M&S plan to feed into the funding cycle.[18]

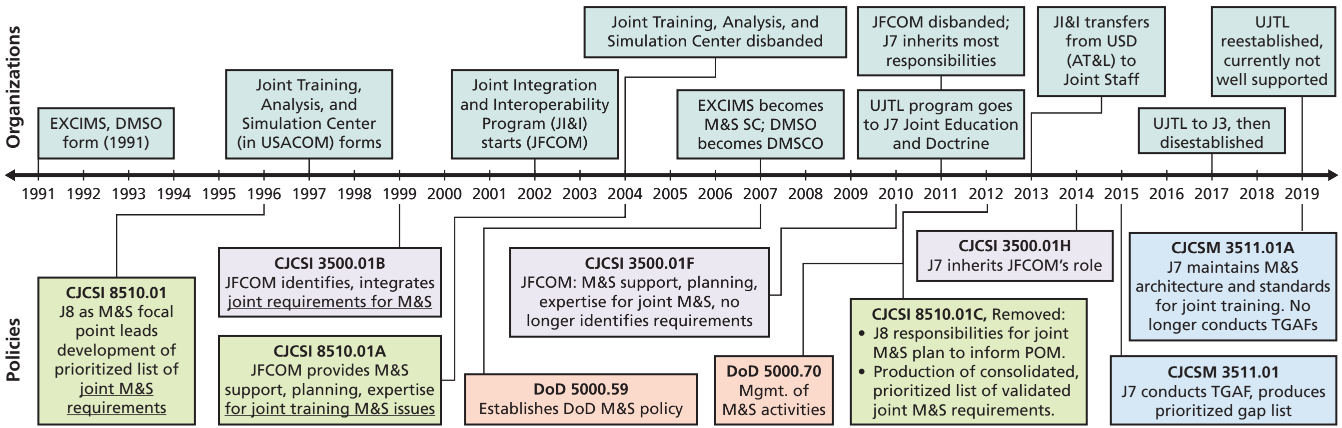
Even relative to JFCOM's previous responsibilities, JS J7's responsibilities with respect to joint M&S have also been reduced over time. In 2015, JS J7 was responsible for convening a training gap analysis forum (TGAF) that produced a prioritized list of capability gaps. By 2019, the responsibility to convene TGAFs no longer appeared in joint policy.[19] The UJTL program, which identifies common tasks across the joint force to serve as a foundation for training, experimentation, and capability development, has gradually lost funding. By 2019, the program had only one individual devoted to its maintenance on a part-

---

18 In Figure 6.1, see CJCSI 8510.01C, *Management of Modeling and Simulation*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, August 17, 2012; compare with previous iterations of the policy.

19 Compare CJCSM 3511.01, 2015; and CJCSM 3511.01A, 2019.

Figure 6.1
Timeline of Joint and DoD Organizations and Policies



SOURCES: CJCSI 3500.01B, 1999; CJCSI 3500.01F, *Joint Training Policy and Guidance for the Armed Forces of the United States*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, November 19, 2010; CJCSI 3500.01H, 2014; CJCSM 3511.01, 2015; CJCSM 3511.01A, 2019; CJCSI 8510.01, *Joint Modeling and Simulation Management*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, April 24, 1996; CJCSI 8510.01A, *Joint Modeling and Simulation Management*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, January 26, 2004; CJCSI 8510.01C, 2012; Department of Defense Directive (DoDD) 5000.59, *DoD Modeling and Simulation (M&S) Management*, Washington, D.C.: U.S. Department of Defense, August 8, 2007; Incorporating Change 1, October 15, 2018; and DoDI 5000.70, 2018.
NOTE: DMSO = Defense Modeling and Simulation Office; EXCIMS = Executive Council for Modeling and Simulation; M&S SC = modeling and simulation steering committee; POM = Program Objective Memorandum; USACOM = U.S. Atlantic Command; USD(AT&L) = Under Secretary of Defense for Acquisition, Technology, and Logistics.

time basis, and over a third of the tasks on the list were out of date. This trend reflects the broader overall trend of less joint-level involvement in the identification of joint M&S requirements to inform capability development.

Conclusion

This chapter has reviewed the organizations and policies available to help coordinate the SBT efforts across the services, in an effort to respond to the joint training needs discussed in Chapter Five. It has itemized the organizations that are currently in place (with the exception of JFCOM) and that could help improve cross-service coordination and system interoperability. In addition, it has traced the history of relevant policies and organizations to identify where gaps in policy may have originated and to extract lessons learned from past policies. In fact, the structure of large organizations like the DoD training enterprise can change organically over time, and individual components might react to local issues with insufficient consideration of the overall enterprise. Aligning changes in organizations with changes in policies can help mitigate such issues.

In general, we find that there is, in fact, minimal coordination between services. Few organizational and policy mechanisms exist to foster coordination between services. This issue magnified with the dissolution of JFCOM, when Title 10 authorities to formulate and conduct joint training at the Tier 3 and Tier 4 levels were transferred to the individual services. However, there are a few organizations that can help improve coordination; there are opportunities for improvement. The roles of these organizations should be coordinated and considered holistically rather than independently. Although individual services certainly must attend to specific, local training needs, these higher-level organizations can help balance those local needs with centralized coordination. Specific findings are as follows:

- **There are no joint-level organizations focused on simulator-development coordination and Tier 3 and Tier 4 simulator**

training. JS J7's focus is generally on Tier 1 and Tier 2 training, and constructive capabilities in particular.

- **There are few offices with responsibility for joint coordination.** To be sure, many organizations do provide informal cross-service coordination. For example, offices that deal with JNTC specifically are likely to have information about joint training needs that involve simulators or simulations. Offices that coordinate JNTC events have insight into gaps between what they would like to do with M&S tools and what is feasible. However, few organizations have substantial coordination roles spelled out in policy. There are few instances in which responsibilities to identify joint programs are spelled out in an organization's responsibilities. Those offices that do have some coordination responsibilities tend to be higher level, and coordination is less likely to occur.
- **Coordinating joint requirements has been deemphasized over time.** Responsibilities to identify, prioritize, and feed joint M&S requirements into the development process have gradually disappeared from joint policy and guidance. Specifically, JFCOM's responsibilities with respect to identification of joint M&S requirements did not transfer to J7. Joint Staff J8's responsibility to produce a joint M&S plan and prioritized list of requirements also went away.
- **Although many JFCOM functions did transfer to JS J7, JS J7 now plays a less robust role with coordination.** Some functions were essentially dropped, especially concerning identifying joint requirements. JFCOM had Title 10 authority, but JS J7 does not.
- **JS J7's training gap analysis forums no longer occur, and this is detrimental to coordination efforts.**
- **There are opportunities for improving coordination and collaboration:**
  - JS J7 is notably absent from Team Orlando forums, and its inclusion would be helpful.
  - In large part because of the transfer of Title 10 authority, the Joint Staff is not able to hold the services accountable for coordination, and relevant policy should be updated to rectify

this absent policy lever. However, the Chairman of the Joint Chiefs of Staff (CJCS) does have Title 10 authority for technical standards,[20] and JS J7 is tasked with "establish[ing] technical standards required for the development and acquisition of joint training systems."[21] Exercising these authorities more frequently in the context of training systems might be helpful.

– Joint training requirements need to be formally specified to incentivize funding solutions and allow for testing.
– Additional funds are needed to incentivize coordination (e.g., CE2T2 research, development, test, and evaluation [RDT&E] funds are minimal compared with service simulator budgets).

---

[20] Per CJCSI 3500-01J, *Joint Training Policy for the Armed Forces of the United States*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, January 13, 2020:

> Title 10, U.S. Code, chapter 5, section 153 prescribes, subject to the authority, direction, and control of the President and the Secretary of Defense [SECDEF], that the CJCS will be responsible for 'formulating policies and technical standards, and executing actions for the joint training of the Armed Forces.' This instruction contains policy from the CJCS to the CCMDs, Services, NGB [National Guard Bureau], CSAs [combat support agencies], [Joint Staff], and other joint organizations for planning, conducting, and assessing joint training (reference d).

[21] Kevin D. Scott, Patrick E. Matlock, Scott F. Smith, Timothy C. Kuehhas, William F. Mullen III, Robert Karmazin, and Walter E. Fountain, *Joint Training Technical Interoperability Strategy*, Suffolk, Va.: Joint Staff J7, August 1, 2018, p. 8.

CHAPTER SEVEN

Incentives to Develop Interoperable Simulation-Based Training

Generally, organizations must be strongly incentivized to prioritize investments in capabilities that benefit other organizations, as is the case for interoperability of training simulators. Even if different organizations have structures and aligned processes that facilitate collaboration, they must be motivated to collaborate. Earlier RAND research has highlighted the complexities of how stakeholders view incentives for creating content that is reusable by other stakeholders, both within and between service branches.[1] Any attempt to improve the development of interoperable SBT systems must improve actions to increase incentives both for services and for industry partners. The goals of for-profit companies, by definition, are to be commercially successful and to maximize their profits. These goals can conflict with the goal of building content that is interoperable with the systems of competitors.

Thus, in this chapter, we itemize the incentives and disincentives for each service to collaborate with external organizations. Then, through a detailed analysis of existing contracting processes, we study incentives for collaboration between DoD and industry. The overarching question that we pursue in this chapter is, What incentives are there for cross-service collaboration, for interoperability, and for industry support of interoperability?

---

1 Michael G. Shanley, Matthew W. Lewis, Susan G. Straus, Jeff Rothenberg, and Lindsay Daugherty, *The Prospects for Increasing the Reuse of Digital Training Content*, Santa Monica, Calif.: RAND Corporation, MG-732-OSD, 2009.

Collaboration Between the Services: The Services Lack Sufficient Incentives to Collaborate on Simulation-Based Training

There are relatively few incentives for cross-service collaboration in developing SBT, and these must be weighed against the disincentives. The balance of incentives is largely in favor of services going it alone—or largely alone—in developing simulator capabilities. Table 7.1 summarizes incentives and disincentives specific to each service and generally across the services, derived primarily from discussions with SMEs and from review of policy literature.

U.S. Air Force Incentives and Disincentives

USAF has some incentive to collaborate across the services generally because it plays a support role in many missions. There is, thus, a general incentive to collaborate given its role in many joint operations. Specifically, USAF has an incentive to collaborate with USN given the incentive to harmonize between the two services' fixed-wing air components.

However, the diffuse nature of requirements determination and acquisition of simulators across USAF might act to disincentivize collaboration. Although sustainment of SBT is the most centralized in USAF, as compared with the other services, the up-front activities of developing requirements and acquisition are not; it is precisely in the early stages of simulator development that collaboration might matter most for ensuring interoperability and visibility of acquisition across the services.

U.S. Army Incentives and Disincentives

As the largest service, the Army has strong disincentives to collaborate with other services on simulator development. Each service rationally hopes that the standards and tools that it has developed will become more widely adopted by other services; for the Army, this might be especially true, given the scale of resources devoted to developing its systems and the costs that might be associated with the wholesale adoption or transition to different M&S tools and standards.

Table 7.1
Incentives for Services to Collaborate on Simulation-Based Training Are Outweighed by Disincentives

Service	Incentives	Disincentives
USAF	• Harmonize with USN's air component • Support role for many missions	• Requirements and acquisition processes diffuse across USAF
Army		• As the largest service, there's additional reason to want to control simulator development
USMC	• As a smaller service, it has a lot to gain from collaborations, potentially secure resources	
USN	• Harmonize with USAF	• No central authority for enterprise training requirements • Short PM tenure—solve immediate problems
General (all services)	• Pots of money, e.g., CE2T2 program budget review requests • Scenario-driven events can spur cross-service collaboration • JROC designation of platform as joint-interest—quite rare • JNTC funds	• Services want their program or baseline to become program of record • Funding is scarce relative to requirements that need to be funded—interoperability requirements come last. • Money goes to training capacity • J7 would be a clear driver of collaboration, but does not dictate • J7 more focused on command-post, not tactical training • ATO difficulties, no joint body to accredit • PEOs do not want responsibility for delivery reliance for other platforms

U.S. Marine Corps Incentives and Disincentives

The Army stands in contrast to USMC, which has perhaps the strongest incentive among the services to find opportunities for collaboration. With fewer resources, USMC stands to gain from adopting solutions developed by the larger services. This can be seen in the case studies, in which USMC surveyed the JTAC simulators that other services had developed before settling on using the USN system as its baseline. Similarly, USMC recently conducted an Analysis of Alternatives (AoA) comparing other services' interoperability requirements.

U.S. Navy Incentives and Disincentives

As noted earlier, USN has incentive to collaborate with USAF to harmonize its air components. Nevertheless, the structure of the USN development process might make deeper collaboration with other services more challenging. Of all of the services, USN has the most fragmented acquisition process for simulators. The lack of centralization might make it difficult to consolidate information on planned and ongoing efforts. Similarly, it might be more difficult to establish persistent links across services when there are many offices involved in simulator development. In our discussions with USN acquisition personnel, it was also noted that the short tenure of project and program managers might disincentivize collaboration because PMs will prioritize immediate problems.

General Incentives for Service Collaboration

As shown in Table 7.1, there are a few general incentives for cross-service collaboration. Overall, these are insufficient to overcome the disincentives to coordinate development of SBT systems.

JS J7 is the office with the clearest responsibilities over joint SBT capabilities. JS J7 does not have the substantive focus that would drive collaboration; it concentrates largely on simulations—not simulators—and on battle-staff and command and control training. It does control modest funds that might serve as an incentive. For example, JS J7 controls funds under the CE2T2 program through Program Budget Review Requests.[2] However, these funds pale in comparison with the size of some simulator programs' budgets and are not large enough to systematically shift the incentives of the services toward collaboration.

---

2 CJCSM 3511.01A, 2019.

Funds under JNTC also might potentially spur collaboration, but these funds are used for the training events, including personnel and equipment transportation, not the development of new capabilities. Furthermore, the demand for funding of JNTC events regularly outstrips the availability of funds.[3]

The JROC designation of a simulator acquisition program as being joint-interest could also incentivize service collaboration on SBT, because a program that is designated as joint-interest can receive funding through joint streams. Requirements for programs that are designated as joint-interest are subject to validation by the JROC and review by others.[4] Programs above certain cost thresholds receive automatic designations as joint-interest, as do other programs on a case-by-case basis, if they have a sufficiently large impact on joint warfighting. However, through our interviews, we learned that it is extremely rare for a simulator program to receive this designation. Although the JCIDS process technically does contain potential incentives for joint collaboration—the JROC can say "no" to a program if it does not account for such things as interoperability requirements with other programs or systems—this option for JROC does not currently seem to function as an incentive.

General Disincentives for Service Collaboration

As shown in Table 7.1, there are also strong general disincentives for services to coordinate on developing interoperable SBT systems. Limited funding is one general disincentive to collaboration on SBT. Services commonly perceive that many of their immediate training requirements do not have sufficient funding. Parochial concerns for meeting service-specific requirements will win out when funding is scarce. At the margin, additional funds often go to increasing training capacity rather than developing additional training capabilities, including joint simulator interoperability.

---

[3] Joint Staff, *Fiscal Year (FY) 2020 President's Budget Operation and Maintenance, Defense-Wide*, Washington, D.C.: U.S. Department of Defense, March 2019.

[4] See CJCSI 5123.01H, 2018, for details on the JCIDS process.

A second general disincentive is the lack of a robust joint-level process that could provide collaborating services with validated lists of joint requirements that they could use to inform simulator development. Services particularly need clearly determined requirements for joint training at the Tier 3 and Tier 4 levels, where simulators are most often used and would need to interoperate. The services' specific training priorities and the lack of a robust joint training requirements process mean that interoperability requirements, to the extent that they are included in requirements documents for simulators, are not given priority. A number of SMEs with whom we spoke noted that interoperability requirements are often given waivers in the process of document review by the requirements oversight councils at the joint and service levels.

Risk-related factors also disincentivize collaboration on SBT. For instance, cybersecurity issues pose time, cost, and risk barriers to the services' developing interoperable simulators. Setting up a simulator in one service to talk with a simulator from another service might take many months or even years, which serve to reduce the overall demand for such training capabilities. Issues of cybersecurity were one of the most-consistent themes in our discussions with service personnel across the requirements, acquisition, and training communities.

Collaboration Between DoD and Industry: DoD Lacks Sufficient Incentives to Overcome Industry Disincentives to Develop Interoperable Simulation-Based Training

DoD can incentivize contractors to participate in the development of interoperable systems by using contractual "carrots," such as additional units, and contractual "sticks," such as RFP requirements. However, the power of these incentives is limited and might be insufficient to overcome industry disincentives.

Incentives in Contracting

DoD regulations allow for contracting officers to include a variety of incentives in the contracts they negotiate. Notably, there are two axes that are traditionally used in incentive-based contract negotiation:

- fixed price versus cost plus
- award versus incentive.

The fixed-price versus cost-plus axis shows the difference between initially stipulating a price for the contract that the government will pay regardless of the eventual cost of the system (fixed price) and stipulating a percentage of the total cost that the government will pay upon completion of the contract (cost plus). The primary difference in effect between these two approaches is which side will assume the risk of cost overruns and gain the benefit from reduced costs—the contractor in fixed price, and the government in cost plus.

The award versus incentive axis differs in scope. Awards are generally for more-subjective and nonmonetary aspects of the contract (e.g., contractor responsiveness, meeting target milestone dates). Incentives generally take the form of a sliding scale of final deliverable costs, where savings are distributed between the contractor and the government according to the share ratio. In short, incentives generally refer to a sliding scale of rewards determined by a formula for higher levels of performance or cost savings, while awards are generally for passing some threshold, either quantitative or qualitative, beyond the minimum expectations of the contract.

DoD provides guidance for determining when each incentive-based contract type is appropriate:[5]

- **Cost-plus contracts are generally used for unproven or experimental products** so that DoD assumes the tail risk of cost overruns to incentivize potentially risk-adverse contractors. These types of contracts can be of particular importance to smaller con-

[5] GAO, *Defense Contracting: DoD Needs Better Information on Incentive Outcomes*, Washington, D.C., GAO-17-291, July 2017.

tractors who, because of their size, cannot spread cost overruns across multiple contracts, whereas DoD has a greater ability to absorb these costs.
- **Fixed-price contracts are recommended for projects that do not involve significant research hurdles or the use of novel technologies.** This is because, when the risk of cost fluctuations is low, the value that the contractor derives from passing off this risk goes down, making the cost-plus model a less appealing incentive.[6]
- **Award-fee contracts generally are used when DoD wishes to incentivize certain aspects of contractor performance** (e.g., contractor responsiveness, meeting milestone deadlines) **that do not directly relate to the end specifications of the product.**
- **Incentive fees revolve around ensuring that both the contractor and the government have an incentive to keep prices low.** Therefore, incentive fees should be used in situations in which this is not the case, such as in conjunction with cost-plus contracts that reduce the contractor's incentive to control costs or in fixed-price contracts that reduce the government's incentive to control costs.

Although selecting the appropriate contract type can help incentivize preferable results from contractors, problems can arise for several reasons:[7]

- **Lax standards:** Lax standards for award-incentive contracts have previously resulted in contractors whose products did not achieve satisfactory performance metrics still receiving award payments.

---

6 Firm fixed-price contracts—i.e., fixed-price contracts without incentive or award pricing—are also potential contract models, but these are not considered incentive-based contracts. Similarly, cost-reimbursement contracts cannot be used for acquiring commercial products, which might include some types of simulators.

7 GAO, 2017; and David M. Walker, "DoD Acquisitions: Contracting for Better Outcomes," testimony presented before the U.S. House of Representatives Committee on Appropriations Subcommittee on Defense on September 7, 2006, Washington, D.C.: U.S. Government Accountability Office, GAO-06-800T, September 7, 2006.

This can subvert the intention of award-incentive contracts by causing contractors to focus more on meeting the subjective performance standards laid out in the contract than on producing a product that actually fulfills the needs that it was intended to fulfill.

- **Rollover awards:** Rollover awards, which are awards that are tied to a specific performance period but can sometimes be rolled over into the subsequent period, can cause similar problems. On a similar note, correlated incentives can cause over- or under-incentivization of specific goals. For instance, completing a project under budget and completing it ahead of schedule (cost and schedule) are often correlated with one another, and, if both of these outcomes are incentivized, the cost of paying out these awards is likely to be greater than what might be necessary. The reverse can also be true for negatively correlated incentives, such as end performance and cost or performance and schedule.[8]
- **Data collection and interpretation:** Another unrelated problem that has historically plagued incentive contracts is the lack of data collection for the end results of incentive contracts. Unfortunately, even when data collection occurs, it often skews toward including larger, more-costly projects rather than a representative sample of all DoD contracts. However, some strides have been made to rectify this problem—specifically, the creation of several repositories, such as the Contract Business Analysis Repository and the Cost Assessment Data Enterprise, and processes, such as the post-award peer review and Contract Performance Assessment Reporting System—that allow for greater retention and defusal of lessons learned. However, post- and pre-award review are required only for contracts with an estimated value of $1 billion or more, so these are unlikely to apply to the acquisition of joint simulators.[9]

---

8 Walker, 2006.

9 Shay D. Assad, "Peer Reviews of Contracts for Supplies and Services," memorandum, Washington, D.C.: Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, September 29, 2008; Cost Assessment Data Enterprise, homepage, undated;

Incentivization Is Harder in Joint Contracting

Contracting within a specifically joint context has additional complications. Not only does joint contracting suffer from all of the same problems as non-joint contracting, but it also inherits all of the problems that come with working within a joint context. These include relatively intractable problems, such as interservice cultural complications and ballooned requirements specifications, but also more-approachable problems, such as multi-stream funding organization and joint program governance. However, one of the largest problems with joint contracting is simply encouraging both the government and industry to participate in the contracts. The services can be positively incentivized to go joint by taking steps to reduce or to eliminate the general problems with joint programs, such as those mentioned earlier, or they can be incentivized via funds set aside specifically for joint programs. Negative incentives also can be included, in the form of doctrine or policy requirements for specific functions to operate at the joint level and, by extension, to require joint contracting. For contractors, similar sets of incentives exist in which the "carrots" are additional units and potential contract incentives and the "sticks" are RFP requirements.

Conclusion

In this chapter, we itemized the incentives and disincentives for coordination across services with regard to simulator development. We then analyzed incentives for collaboration between DoD and industry through the lens of contracting processes.

A main finding is that the balance of incentives across services points away from collaboration and toward narrow, project-specific development interests, even within services. The services tend to want to see their programs prevail, and joint-level stakeholders have few options for preventing these relatively narrow, project-specific interests

---

CPARS, homepage, undated; Defense Contract Management Agency, *Contract Business Analysis Repository (CBAR) 1.7.3*, web tool, 2015; GAO, 2017; and OSD, "OSD Level Peer Reviews: Best Practices, Lessons Learned, and Recommendations," December 20, 2013.

from being the primary influence on specific contracts. Disincentives tend to outweigh incentives at the joint level.

Even in the face of such disincentives, existing incentive options for DoD contracting officers are limited. The practice of granting waivers to requirements for interoperability is an area for future analyses to determine which training systems should be interoperable.

Specific findings regarding service incentives to collaborate on development of interoperable SBT systems include the following:

- **USAF and USN have incentives to align given USN's air component,** and USAF specifically plays a support role across a wide variety of missions, giving it an incentive to collaborate.
- **USAF and USN have fairly diffuse structures for developing simulators, which might impede joint collaboration.**
- **USMC benefits from other services' larger sizes** and commensurately larger budgets for developing simulators.
- As the largest service, **the Army might have an incentive and supporting resources to pursue its own solutions.**

Additional findings regarding general incentives include the following:

- **Some positive incentives for collaboration exist, but they are minimal.** They include relatively small amounts of funding, scenario-driven joint events, and the (somewhat rare) designation of a program as "joint-interest" by the JROC.
- **Service PEOs generally want to avoid responsibility for developing capabilities that are needed by other platforms.** Scarce funding tends to support service priorities, and joint interoperability requirements are often given a waiver. There is a lack of high-level guidance that could shift the services' calculus toward accepting risk associated with networking simulators.
- **JS J7 lacks the authorities to encourage the services to identify joint training requirements** for simulators and develop systems that meet those requirements.
- **There are no joint-level processes in place to overcome serious difficulties in information assurance and security.**

PART III

The State of the Art

CHAPTER EIGHT

Current Capabilities Supporting Networking Simulators and Interoperability

While Parts I and II of this report focused on organizations and processes involved in acquiring and using training simulators, this chapter focuses on the currently available technical capabilities that support simulator interoperability. Current R&D surrounding training simulators and simulation is extensive, so the intent with this chapter is to highlight aspects that are specifically relevant to networked simulators and interoperability. Through a review of the R&D literature and discussions with industry representatives, we reviewed the technical state of the art. The first step in this process involved parsing the current R&D efforts in terms of what technologies helped support and were pervasive across the training-simulator enterprise. Specifically, we focused on capabilities that support networking various simulators. This includes the following topics:

- interoperability
- data standards
- virtual gaming
- network security.

In general, this chapter focuses on commercially available products and on R&D efforts in the military and civilian sectors rather than on existing facilities in the military.

This assessment begins to lay out a roadmap for R&D efforts in DoD and industry that support joint training-simulator needs. Given that the services do not currently have a coordinated set of R&D plans (see Chapter Six), this chapter provides initial input for such directions.

The overarching questions that we pursue in this chapter are as follows:

- What technological capabilities are available to support cross-service simulator integration?
- What are the technical challenges with respect to simulator interoperability?

Interoperability

What Does *Interoperability* Mean?

Interoperability concerns the exchange and use of information, as well as the capabilities to do so.[1] Joint simulator-based training is distributed by nature, and interoperability is particularly important in this context. With multiple players or warfighting agents simultaneously engaged in a training exercise, simulators might interoperate across sites at different geographic locations. Different types of participating simulators also might be distributed within a training center (a single facility) or more broadly, over networks that extend geographically across multiple training centers operated by different services. Consequently, interoperability is particularly important. However, it is inherently complex. Thus, before we summarize the development

---

[1] IEEE, "Systems and Software Engineering—Vocabulary," ISO/IEC/IEEE 24765, 2nd ed., September 2017. The ISO/IEC/IEEE 24765 2017-09 standard further notes that "Interoperability is used in place of compatibility in order to avoid possible ambiguity with replaceability" (IEEE, 2017). The *Department of Defense Modeling and Simulation Body of Knowledge (BOK)* defines the concept of *interoperability* as "the ability of a model or simulation to provide services to, and accept services from, other models and simulations, and to use the services so exchanged to enable them to operate effectively together" (DoD, *Department of Defense Modeling and Simulation Body of Knowledge (BOK)*, Washington, D.C., June 2008, p. 13). Composability and interoperability are closely related concepts. For a discussion, see Paul K. Davis and Robert H. Anderson, *Improving the Composability of Department of Defense Models and Simulations*, Santa Monica, Calif.: RAND Corporation, MG-101-OSD, 2004.

trends in government and industry, and then the primary challenges with respect to SBT, we first decompose interoperability in terms of (1) the technical capabilities needed to support it and (2) the aspects that contribute to its complexity (why it is so difficult to achieve from a technical perspective).

Broadly, technical capabilities that support interoperability address three main areas:[2]

- a common software architecture
- an ability to meaningfully communicate
- a common operating context.

Software architectures organize the operation of component simulation software systems by defining the purpose and function of each, along with the interfaces and rules applied for interoperation, from a computing standpoint. **Meaningful communication** requires a common language and a common communication mechanism for semantically meaningful interpretations of the information being exchanged between systems. A **shared, common operating context** (means of interoperation) is established within the architecture by maintaining a common understanding of (1) environmental information (e.g., terrain and weather conditions), (2) the progression of time, and (3) the technical procedures applied by simulations as training events unfold.

These three broad technical areas can be broken down further to describe **several distinct technical areas that are used in concert to produce a total environment in support of joint training** (Table 8.1). Each of these technical areas also characterizes distinct challenges for simulator interoperability. Facilities with the technical operational infrastructure to host or support simulator training environments must be available.[3] Authorized, secure network segments

---

[2] S. Sandberg and K. Lessmann, "LVC Simulation Interoperability 101," Interservice/Industry Training, Simulation and Education Conference (I/ITSEC), November 2018.

[3] USAF, USN, and the Army each have significant efforts underway to advance the technological infrastructure in support of expectation of future training needs. Examples include

Table 8.1
Technical Areas for Joint Training-Simulator Interoperability

Technical Area	Description
Operational infrastructure	Facilities supporting or providing suitable host environments for training simulators and related computing services
Secured networking	Authorized network pathways between interoperating training environments; cybersecurity protocols; multiple levels of security
Standards for data formats	Structure and content for exchanged data (message format and content)
Standards for communication methods	Architectural methods for managing the flow of information; mechanisms for the transport of exchanged information
Latency requirements	Tolerance for delays associated with communication and simulator capabilities
Terrain and environmental data	Authoritative, multi-resolution, and uniformly detailed environmental information
Realism of operating conditions	Authenticity of environmental conditions and effects; completeness of scenario representation; semantically uniform presentation of events; causally plausible occurrence of events
Time progression	Framework for the synchronous advancement of simulator clocks as joint training progresses

SOURCES: The categorization presented in this table has been inferred from SME interviews and literature concerning interoperable military simulation systems. See, for example, Duncan C. Miller, "SIMNET and Beyond: A History of the Development of Distributed Simulation," I/ITSEC, 2015; and Andreas Tolk, John Fowler, Guodong Shao, and Enver Yücesan, *Advances in Modeling and Simulation: Seminal Research from 50 Years of Winter Simulation Conferences*, Cham, Switzerland: Springer, 2017.

following the established policy and guidelines must be in place. Well-defined standards for data structures, information-sharing, and mechanisms for exchanging data must be commonly implemented for coherent interoperation across the simulators and the functional training roles being represented. The architecture for communication must be computationally efficient to minimize time delays caused by latency

USAF's Advanced Battle Management System, USN's Tactical Combat Training System, and the Army's Synthetic Training Environment.

arising from the coordination and communication of simulators or simulations themselves. Finally, to ensure authenticity of the training experience, the representation of the simulated environment must be sufficiently detailed and consistently represented across simulators as combat operations take place, and the corresponding events must be plausible, without any compromise of their realism with respect to the key elements of the real-world experience being practiced.

Several complexities of interoperability that affect the use of joint training simulators stem from the need for synchronization, differences in the quality of environmental information, and the diversity of simulators themselves.

With regard to **synchronization**, simulation for distributed joint training is inherently time-sensitive, with warfighting actions hinging on synchronous interactions and environmental representations for a consistent view of the battlespace across simulators. A synchronous, coherent picture is also a necessity to execute operational-level training tasks for cross-service collaboration. Time-management techniques are applied to guide the progression of simulated time to enable a coherent training context. This helps ensure the time consistency of warfighting perspectives across networked simulators for authentic and accurate warfighting conditions and any subsequent situational decisions to be made during training, as events progress and new conditions emerge.

The **quality of the environment** can depend on multiple factors: the fidelity of the environmental details, the environmental effects, and the virtualized experience. Although fidelity is a critical consideration, it does not necessarily result in better training.[4] Fidelity tends to benefit training in proportion to the importance of the element being simulated to the understanding of the task at hand. Air and ground simulators can also have unique requirements for effective training based on the specific type of weapon platform. Technical design differences in how the environment is represented by a simulator, the granularity with which simulated entities are tracked, and limitations in the technical capacity of a simulator to interoperate can all lead to unique technical requirements that are dependent on the weapon platform or

---

4 Straus et al., 2019.

task and require additional software or hardware components to enable interoperation, because of significant hardware or software differences.

With regard to **simulator diversity**, the development of flexible and commonly defined protocols for exchanging messages between simulators, and the development of common standards for correctly interpreting the data being sent and received, have been goals for over 40 years (a brief history of standards is presented in Appendix E). Because joint training exercises cut across warfighting domains and activities, a variety of interoperating modes must be supported by protocols and data standards.

Modern simulators designed for joint training are challenged to consider all of these technical areas in conjunction with the capabilities of virtual and constructive components that they are providing directly through simulation. Furthermore, when a simulator is used in training, it necessarily relies on the operational training infrastructure to which it integrates, and, therefore, its value in a training exercise depends inherently on the training capabilities enabled and supported by that infrastructure.

Why Does Interoperability Matter in the Joint Training Environment?

Given the detailed discussion of what interoperability entails, this section discusses why interoperability is relevant to joint training exercises. Within the context of a *joint* training exercise, several factors contribute to the technical approach for interoperability:

- selection of a training tier, participants, and simulators
- ability to share and realistically portray environment data at every player cell[5]
  - choice of federation method that enables interaction between participant simulators or simulations

[5] The CJCS DoD Terminology Program defines a *cell* as "a subordinate organization formed around a specific process, capability, or activity within a designated larger organization of a headquarters" (CJCS, *DoD Dictionary of Military and Associated Terms*, Washington, D.C., January 2021, p. 30; and Joint Publication 3-33, *Joint Task Force Headquarters*, Washington, D.C.: Joint Chiefs of Staff, January 31, 2018, p. xiii).

- format and detail of data exchanged during interoperation between systems
  - communication protocol (or protocols) used to exchange data
- standard to synchronize time between simulators.

In this context, a federation provides an overarching framework or model to facilitate the timely communication of events and actions to a distributed group of players (and software systems).[6] In general, a *federation* is a system for integrating and aligning different software systems (called *federates*). A *federation method* is an approach for integrating software systems. Thus, a federation is a key concept that currently defines how joint training exercises are implemented in practice today. Simulators and simulations are viewed as federates when connected through a federation. **How data are shared between simulation users** depends on the underlying software federation.

The **training tier selection** and participating services determine the types of simulators and simulations that will be used for a particular training event. A realistic portrayal of operating environments within the simulators (e.g., one that takes into account the actions of other players on the battlefield) then provides an accurate context for joint training. A training tier relevant to the training goals is selected as part of the execution process for a joint training exercise. The selected training tier determines the granularity of information to be exchanged between simulators (independent of a simulator's ability to change the granularity of data being sent) and influences the security considerations surrounding exchanged data. The data exchanged during the training exercise might further require translation, aggregation, or disaggregation to enable interoperation between simulators with capabilities that operate at differing levels of granularity, in real time, to maintain a consistent picture of events.

A consistent approach to **formatting and exchanging data** using a common protocol ensures a consistent semantic interpretation of data

---

[6] International Standard ISO/IEC/IEEE 24765 defines *federation* as a "community of domains," where a *domain* is a "set of objects, each of which is related by a characterizing relationship to a controlling object" (IEEE, 2017, p. 3).

at a level of detail required for simulator operation. Generally, a formally standardized protocol for communication, such as IEEE 1278, for DIS, or IEEE 1516, for High-Level Architecture (HLA), is used for distributed simulation with joint training.[7] The real-time simulation of mission events requires that each player cell interact with other cells at the appropriate time (each *cell* being a grouping of participants directly contributing to the training exercise). Furthermore, the events resulting from player cell interactions must logically correspond with the actual courses of actions that are taken during the training exercise. If they do not, if there is no correspondence between cell interactions and the consequences of those interactions, then the events perceived by each player diverge from reality, and the effectiveness of the training exercise can be undermined. The accuracy of real-time feeds, such as to support a common operating picture, is also degraded in the absence of alignment between cell interactions and appropriate consequences.

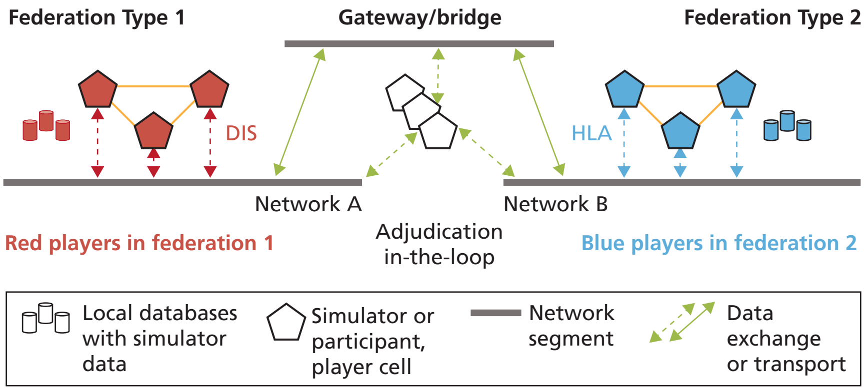
Not only is it necessary to provide mechanisms that directly support simulator interoperability; it is also necessary to capture technical, real-time, and event-specific data during training exercises to isolate and resolve technical issues that occur. This information is then taken into account in after-action meetings. Figure 8.1 provides a simplified illustration of the interoperating technical components that might be involved in a joint training exercise.

As illustrated, interoperability is constituted by a suite of interrelated, technically distinct capabilities.

Simulators can physically reside at different centers, on different networks, and can participate in a joint training exercise using different communication methods and data formats. Joining such simulator networks together can require additional, critical **nonsimulator software systems** for interoperability. An example of a nonsimulator software system is a gateway or a bridge. Gateways or bridges are critical pieces of the architecture for interoperation, directly enabling com-

[7] IEEE, "IEEE Standard for Modeling and Simulation (M&S) High Level Architecture (HLA)—Framework and Rules," IEEE 1516-2010, August 18, 2010; and IEEE, "IEEE Standard for Distributed Interactive Simulation—Application Protocols," IEEE 1278.1-2012, December 19, 2012.

Figure 8.1
Joint Training Simulators Can Interoperate via a Gateway Supported by Human-in-the-Loop Adjudication



NOTE: This figure is a simplified view of the potential range of interoperating components used in joint training exercises (for illustration).

munications when interoperating simulators reside in different federations and differences in communication methods exist. They are often incorporated to support establishing a shared view of events and environments through data translation software, but they can also introduce system-specific dependencies that enable and limit interoperability at the same time.[8]

When integration of simulators with live assets is to be incorporated during a training exercise (such as an aircraft receiving synthetically driven or generated inputs during flight), tactical networks and systems are critical to interoperation, in that they provide access to an operational weapon platform via a **standardized tactical data link** (TDL).[9] Table 8.2 outlines some of the existing and in-development

---

[8] Sandberg and Lessmann, 2018.

[9] Myron Hura, Gary McLeod, Eric Larson, James Schneider, Daniel Gonzales, Dan Norton, Jody Jacobs, Kevin O'Connell, William Little, Richard Mesic, and Lewis Jamison, *Interoperability: A Continuing Challenge in Coalition Air Operations*, Santa Monica, Calif.: RAND Corporation, MR-1235-AF, 2000.

Table 8.2
Tactical Data Links

Tactical Data Links	What Do TDLs Provide?
Existing • Link 16—connects various TDLs to create a multi-TDL network • Link 11—used primarily to exchange radar data • Situational Awareness Data Link—used to communicate between Close Air Support platforms (F-16, A-10) • Adaptable Toolkit for Open Messaging Systems—used in the ballistic missile defense ecosystem	• Interoperability between platforms for specific missions and domains • Connecting various existing networks via the Media and Transport levels of the Open Systems Interconnection stack (Physical, Data Link, Network) • Operation in denied environments via jam resistance • Common standards—in particular, mission threads, and then connection of these threads via meta standards, such as Link-16
In development • System of Systems Integration Technology and Experimentation/Stitches—connects various message standards for use in a multi-TDL network • Link 22—an updated Link 11 focusing on improving information throughput and Link 16 integration	• Variable interoperability between platforms that can be mission or domain agnostic • Connecting existing networks via the Host and Network levels of the OSI stack (Application, Presentation, Session, Transport) • Operation in denied environments via more-dynamic routing • Integration of existing standards without having to modify these older standards

TDLs, along with what they currently provide and how they are evolving.

Additionally, TDLs can be oriented for use with specific platforms and offer varying amounts of bandwidth, which might affect their capacity for joint training exercises.[10] Tactical networks presently offer a variety of connectivity options for communication, concerning bandwidth and formats for exchanged data across a heterogenous array of weapon platforms. However, they do so to varying extents of interoperation with respect to joint training requirements, and a uni-

[10] CJCSI 6610.01E, *Tactical Data Link Standardization and Interoperability*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, April 10, 2014.

fied approach for standardized, flexible interoperation is still under research.[11]

Industry and Government Trends

Given the importance of interoperability, it receives significant attention with respect to R&D. Industry and government development efforts with respect to interoperability are occurring in several technical areas that might eventually provide opportunities that are beneficial to joint training simulators. Significant research and commercial activities focus primarily on the following topics:

- virtual and augmented reality systems
- open standards and engineering methods for modeling system designs
- cloud-based computing methods and infrastructure for training environments
- flexible software system designs that leverage gaming platforms for multi-participant simulator training
- M&S methods for cybersecurity capabilities and threats
- applications of artificial intelligence for constructive simulations and adaptive training
- low-earth orbit satellite constellations for tactical networking.

These areas are described as trends in Table 8.3 and are paired with their potential benefits and potential challenges to joint training.

There are few focus areas of R&D that are particularly active and relevant to SBT. The first concerns the "live" aspect of LVC techniques. This includes extending the real environment with synthetic information ("constructive" elements), using augmented displays (e.g.,

[11] See, for example, the Simulation Interoperability Standards Organization (SISO) Tactical Digital Information Link (TADIL) Technical Advice and Lexicon for Enabling Simulations (TALES) Product Development and Study Group efforts to support "a family of SISO tactical datalink simulation standard products with a common and consistent structure, look, and feel, including support for both the IEEE Std 1278.1 (DIS) simulation protocol and the IEEE Std 1516 (HLA) simulation protocol" (SISO, "TADIL TALES PDG & PSG," webpage, undated e).

Table 8.3
Industry Trends: Capabilities for Joint Training

Technical Capability	Potential Benefits to Joint Training	Potential Challenges to Joint Training
Virtual, augmented, mixed-reality systems[a]	• There is a greater range of training scenarios • Training is more-frequent, and training efficiency is improved • Player interactions are live and simulator-based • Teaming for cross-service, collaborative training • Improved safety of training experience • Scenarios that cannot be trained in a live setting	• Rapidly evolving tools with limited portability to current training systems • Increased data and computing needs • Haptic elements are not yet well developed • Realism of the training experience
Open standards for geospatial information and software components; engineering modeling methods for simulation system designs[b]	• Greater commonality among training technologies and methods across DoD services • Model-based systems engineering for systems design and long-term evolution, adoption, and sustainability of simulator standards and technology • Uniform representation of reference data for simulation platforms	• DoD requirements for training might exceed the capability of open standards to support training, requiring close coordination with standards bodies • Difficult to incorporate on a large scale
Cloud-based computing infrastructure services for training environments[c]	• Competitive SBT as a service (on demand) • Scalable training resources • Consistent and coherent environmental representation • Flexible, extensible virtual training capabilities	• Highly centralized methods that are not presently conducive to distributed joint training over large geographic distances • Availability of standard frameworks that are suitable across services and training tiers • Existing training simulators might not be compatible with new infrastructure • Shared nature of cloud computing poses unique data security challenges

Table 8.3—Continued

Technical Capability	Potential Benefits to Joint Training	Potential Challenges to Joint Training
Simulation frameworks, gaming platforms and engines[d]	• Flexible architectures for software systems and scalable methods • Support for multiple data formats	• Proprietary versus standard and open-source systems • Might require extensive customization to fully realize DoD requirements for entities, data formats, and system performance
Cybersecurity M&S[e]	• Development of cyber training ranges • Potential to introduce cyber-effects into networked simulators • Emulates real-world scenarios and incorporates artificial intelligence methods • Expands information and intelligence aspect of training	• Rapidly evolving baseline of technology • Might require workforce roles with multidisciplinary skills and experience with scenario design to realize benefits • Might require accurate models of relevant cyber infrastructure to develop scenarios
Artificial intelligence[f]	• Potential for adaptive training, tailored to each user • Improved simulation of human behavior • Can explore effects of future military capabilities and threats, operating environments, and battlefield conditions • Real-time data-intensive analysis • Potential for real-time semantic analysis of communications	• Underdeveloped methods in an expanding area of research • Objective, quantitative measures supporting accuracy in performance assessment

Table 8.3—Continued

Technical Capability	Potential Benefits to Joint Training	Potential Challenges to Joint Training
Low Earth orbit satellite constellations[g]	• Higher bandwidth, lower-latency tactical networks for distributed training	• Presently in early stages of development (a rapidly evolving technology)

NOTES:

[a] See, for example, Alexa Culbert, "23rd Flying Training Squadron Revolutionizes Pilot Training," U.S. Air Force, November 7, 2019; Dan Hawkins, "AETC Partners with Multiple MAJCOMs to Create Virtual Aircraft Maintenance Hangers," U.S. Air Force, February 25, 2020; Stephen Losey, "The Air Force Is Revolutionizing the Way Airmen Learn to Be Aviators," *Air Force Times*, September 30, 2018b; and Tory Patterson, "Dyess AFB Airmen Revolutionize C-130 Maintenance," U.S. Air Force, June 9, 2020.

[b] Mark Blackburn, *Transforming Systems Engineering Through Model-Centric Engineering*, Hoboken, N.J.: Stevens Institute of Technology, Systems Engineering Research Center, A013 Final Technical Report SERC-2019-TR-005, April 30, 2019; and Open Geospatial Consortium (OGC), "CDB," webpage, undated.

[c] For information about Air Force Space Command's "Unified Data Library," see Theresa Hitchens, "Crider: SSA Data 'Library' Will Open to Allies," *Breaking Defense*, May 3, 2019. See also John Dvorak, Roy Scrudder, Kevin Gupton, and Kevin Hellman, "Enabling Joint Synthetic Training Interoperability Through Joint Federated Common Data Services," Cyber Security and Information Systems Information Analysis Center, January 9, 2020.

[d] Brian Chell, Steven Hoffenson, Douglas Ray, Roger D. Jones, and Mark R. Blackburn, "Optimizing for Mission Success Using a Stochastic Gaming Simulation," Cyber Security and Information Systems Information Analysis Center, January 9, 2020; and "Embracing Gaming Technology to Create Enhanced Synthetic Training Environments to Train Warfighters," Modern Integrated Warfare, May 11, 2018.

[e] Dan Lohrmann, "Cyber Range: Who, What, When, Where, How and Why?" Government Technology, March 10, 2018.

[f] Alicia Datzman, "Joint All-Domain Command and Control Operational Success Requires Investment in Multi-Domain Test and Training," Modern Integrated Warfare, November 25, 2019; and Amy Dideriksen, Joseph Williams, Thomas Schnell, and Gianna Avdic-McIntire, *The Value of Cognitive Workload in Machine Learning Predictive Analytics*, Interservice/Industry Training, Simulation and Education Conference (I/ITSEC), 2019.

[g] Gary Sheftick, "Army Looks to Leverage 'Low Earth Orbit' Satellites," Army News Service, March 9, 2020.

using augmented-reality techniques), and injecting synthetic entities into instrumentation during the course of live training.[12]

The second focus is to improve real-time feedback available to command staff for a holistic common operating picture that coincides with a shift toward a joint all-domain command and control or multidomain command and control.[13]

Virtual-reality efforts are focused on the *realistic* representation of a simulated environment suited for training that could not or should not happen in physical space for technical, logistical, security, or physics reasons, among others.[14] Chief among these recent efforts is the development of reusable terrain data for simulator training environments across domains.

Finally, trends for constructive content (simulated or synthetically generated) are focused on improving the behavior and dynamics of introduced elements and leveraging artificial intelligence strategies to evolve their sophistication to further the effectiveness of training. Trends could range from the inclusion of future threats to techniques for adaptive training, to improve trainee performance, especially when it might otherwise be cost prohibitive or unrealistic to provide the training solely through live training.

To supplement our review of R&D literature, we discussed trends and challenges with industry and government SMEs. A few themes emerged concerning simulator technology, security, and organizational processes and opportunities, which are summarized as follows.

---

[12] For information about the Army's Integrated Visual Augmentation System, see Sydney J. Freedberg, Jr., "Army Targeting Goggles, VR Training May Use JEDI Cloud," *Breaking Defense*, January 24, 2020. See also Gina Marie Giardina, "SLATE Demo Highlights Live, Virtual, Constructive Environment for Pilot Training," U.S. Air Force, October 10, 2018.

[13] See, for example, Datzman, 2019; and Theresa Hitchens, "First Multi Domain C2 Exercise Planned: 'ABMS Onramp,'" *Breaking Defense*, December 6, 2018.

[14] Realistic in both the visual appearance of the environment and entities that are present and the accuracy of the conditions being represented during training with respect to actual and current real-world conditions.

Simulator Technology

Although simulator technology is actively employed for a variety of training domains—such as full motion simulation for aircraft training, artillery safety training, artillery firing, JTAC trainers, ground vehicles, and infantry training—simulations are rarely networked across weapon systems or organizational boundaries. Connected and modular software systems are common in advanced commercial gaming solutions, and aspects of these capabilities that are applicable to DoD training are discussed later. Active areas of development emphasize virtualization capabilities (including augmented reality, haptic interfaces, and virtual environments for training within a greater range of threat environments relative to physical counterparts), cloud-based principles for data storage and analysis of large volumes of resulting simulation training data, and simulator interoperability within individual services. A haptic interface is essentially a system that allows a user to interact with a computer through sensations and movements.

Simulator Challenges

Full, "end-to-end" integration of LVC capabilities remains an open challenge for industry, with requirements being unclear or underspecified, as does the ability to rapidly update and share terrain information presented during a simulation across participants. For shared simulation environments, a unified terrain model is needed. There is also a perceived need to expand currently limited training, such as call for fires, to other infantry, vehicles, and drone pilots. For classified weapon simulation, enabling multiple levels of security is a persistent challenge for joint interoperation across simulators.

Simulator Standards

Although HLA and DIS are well understood, without testing, current standards are not clear enough to ensure successful simulation integration. Although users might agree on a standard (such as HLA or DIS), differences in details within a specific data protocol can still present challenges to interoperability. That is, although two users might agree to use HLA, their specific instances might still be different enough that their systems cannot effectively exchange data. The mismatch between standards and simulator requirements between services is a key challenge. Thus, testing is necessary to ensure that specific instances and uses of these data standards align. Radar behavior and electronic warfare jamming, for example, are difficult to simulate and will need standardization. There is a sentiment that DoD standards are often made without a full understanding of the implications and potential cost of implementation.

Simulator Vendors

Companies receive funding individually and pay close attention to costs. They often reconfigure and resell similar software several times for different services and weapons, and they depend on the income from this practice to keep prices low. Because the initial costs for early R&D are paid out of pocket, many design decisions are effectively locked in. Rarely are there direct incentives for vendors to make simulators that are interoperable.

Simulators and Military Processes

The CCMDs have an expansive vision for training capabilities, but the services guard their budgets carefully. Where services coordinate on standards, the resulting requirements are not clear enough. Federal Acquisition Regulation rules are too strict, and ATO processes are not well-enough governed. Limitations in joint funding for development constrains services in their ability to satisfy expectations for joint training requirements, with industry pursuing available funding. Funding to incentivize joint interoperability is limited, so services might pursue local needs independently with minimal interoperability. Where not centrally required, interoperability is seen as a secondary effort. Because funding is platform-specific and platforms compete for funding and run on different schedules, incentives for interoperability can be undermined. In some cases, interoperability becomes impossible, because platforms have neither opportunity nor incentive to coordinate development of shared features.

Simulators and Opportunities

Untethered simulation (i.e., having simulation capabilities integrated on or travel alongside an actual weapon system) presents an opportunity to simulate advanced or classified capabilities in the field, where it is possible for simulator hardware to reside onboard. With respect to cross-service and joint training, aircraft and artillery tactical coordination could be expanded to include USAF and USN aircraft, Army rotorcraft, drone pilots, sensors and radars, JTACs, and special forces. Presently, coordination is limited to USAF and USN pilots and JTACs. Although multiple nations buy hardware from the United States, train to fight with the United States, and depend on U.S. coordination for their national defense plans, a corresponding approach to include them in SBT might be insufficiently developed. In at least one case, weapons sold to partners cannot be trained to their full potential without simulation, but the needed simulation software is not export-approved. Considering training tools, there might be an opportunity to reduce existing training loads and allow expanded skills (such as basic call for fires) in more roles. Mobile or remote virtual reality–based training devices can be used to streamline existing basic-task training while expanding simplified versions of useful skills to more people.

Most Challenging Areas for Simulation-Based Training

Despite the considerable R&D efforts discussed in the preceding section, significant challenges remain. Although none of the areas discussed in the preceding section are trivial or comprehensively addressed from a joint perspective, the corresponding areas that are most challenging for joint simulator training today are as follows:

- large-scale, multidomain distributed training systems
- support for both joint and service training goals
- networks and security
  - network authorizations
  - multiple levels of security
- realistic, uniform representation of terrain data and environmental effects
- standards for interoperation and capabilities for federation.

In conjunction with Table 8.1, this list begins to lay out a roadmap that shows where additional R&D work should focus.

Large-scale multidomain and distributed mission training will require a high degree of integration and interoperation between a large number of diverse, networked weapon platforms and command cells. A *command cell* is a richly heterogeneous mix of simulator systems, data sources, and security requirements. This is an active area of work with progress being made, but execution on a large scale remains a significant challenge.[15]

Currently, with respect to joint missions, the **alignment between training goals** defined for joint missions and service-level force readiness is not always clear. In fact, the training goals for each are developed independently. As a result, a natural tension arises between training tiers focused on operational readiness within a service and training tiers focused on coordinated training missions for joint force readiness. Each service defines its own training requirements and does so independently of joint training missions. This presents a challenge for joint simulator training when simulators are not able to integrate sufficiently for joint training exercises across services (e.g., for coordinated air-ground operations) or when trying to assess the effectiveness of joint training missions themselves.

The integration of simulators also depends strongly on accessibility and authorization to use **networks** for cross-service training, the ability to exchange information at appropriate classification levels, and the capabilities to federate or otherwise organize the interoperation over a heterogeneous set of distributed simulators. Joint training exercises cannot be executed without appropriate capabilities for networked integration and security. Although we focus on technical aspects of interoperability, international agreements and political motives play an influential role.[16]

The realistic exchange and representation of **terrain data and environmental effects** are computationally challenging to accomplish

---

15 For example, see Lockheed Martin, "Lockheed Martin Delivers F-35 Distributed Mission Training Capability: F-35 Simulators Connect for the First Time with Other USAF Aircraft at Nellis AFB," news release, July 1, 2020.

16 Jennifer Hlad, "Getting Serious About Interoperability," *Air Force Magazine*, March 1, 2020; and Eric V. Larson, *Interoperability of Coalition Air Forces: Lessons Learned from U.S. Operations with NATO Allies*, Santa Monica, Calif.: RAND Corporation, RB-117-AF, 2004.

in real time, on a large scale, and in a distributed setting. Numerous changes to the design of operational computing infrastructure are in progress that modernize infrastructure services in support of more-robust and more-flexible access to data sources, computing capabilities, and distributed joint training capabilities.[17] However, these capabilities are not yet available. When they are, there will be the additional challenge of interoperating with existing simulators that are already deployed and used in training today.

Implicit challenges that are not frequently referenced in discussions or literature is the *extent* to which systems are capable of interoperation, as well as **standards for interoperation**. When we began this section, we introduced *interoperability* as concerning "the exchange and use of information, as well as the capabilities to do so." This definition is consistent with International Standard ISO/IEC/IEEE 24765 vocabulary for interoperability, which also describes interoperability as the degree to which systems can interoperate—an aspect of interoperability that current DoD policy does not address sufficiently and for which there is no generally applicable guidance across services. This topic has been addressed, conceptually, through work by Diallo and others, where Levels of Conceptual Interoperability are defined analogously to Technology Readiness Levels to structure interoperability into distinct levels gauging the completeness of the capability.[18] At present, the Army is evaluating its ability to interoperate, within the service and with international partners, and revising its guidance with respect to a conceptualization for interoperation that also characterizes the degree to which systems are understood to be interoperable.[19]

---

[17] See, for example, Dvorak et al., 2020.

[18] Saikou Y. Diallo, Heber Herencia-Zapana, Jose J. Padilla, and Andreas Tolk, "Understanding Interoperability," *EAIA '11: Proceedings of the 2011 Emerging M&S Applications in Industry and Academia Symposium*, April 2011, pp. 84–91; and Saikou Y. Diallo, Andreas Tolk, Jason Graff, and Anthony Barraco, "Using the Levels of Conceptual Interoperability Model and Model-Based Data Engineering to Develop a Modular Interoperability Framework," in S. Jain, R. R. Creasey, J. Himmelspach, K. P. White, and M. Fu, eds., *Proceedings of the 2011 Winter Simulation Conference*, Phoenix, Ariz.: IEEE, 2011, pp. 2571–2581.

[19] See AR 34-1, *Interoperability*, Washington, D.C.: Headquarters, Department of the Army, April 9, 2020.

We examine the topics of standards, security, and how training environments are evolving in subsequent sections.

Data Standards

Data standards essentially represent the communication language between simulators, so interoperability depends critically on standards. Thus, this section reviews the role of standards for DoD joint training simulation systems. Key aspects of DIS, HLA, and Test and Training Enabling Architecture (TENA) are provided in Table 8.4, and a brief history of the emergence of these standards is provided in Appendix E.

An important takeaway from the history detailed in Appendix E is that *multiple* relevant standards and systems have been and are being developed and implemented today. And, aside from the initial development of Simulator Networking (SIMNET), the development of standards has, in practice, evolved organically over time and in a manner that ultimately shows that no single solution has yet satisfied requirements for comprehensive joint training.

Furthermore, different standards bodies develop standards relevant to interoperability by focusing on different technical aspects of interoperability, each of which is necessary to enable joint interopera-

Table 8.4
A Comparison of the Distributed Interactive Simulation, High-Level Architecture, and TENA Communication Frameworks Used for DoD Joint Training-Simulator Interoperability

Communication Method	Properties
DIS	• Fully specified methods • Less flexibility to implement • Real-time focus, fixed-object model
HLA	• Greater flexibility in the data distribution model • Presents greater range of integration challenges • Adds a coordinating run time, often vendor-specific
TENA	• Provides full architectural basis for interoperation, improves on HLA and DIS • Not a published standard • Provides reusable components

tion across simulators and across services. Consequently, the standards that are produced result in competing or overlapping methods, representing substantial trade-offs for system design and implementation (see Table 8.4).

For joint training exercises, the adoption of standards is presumed to promote or establish a reliable, operational baseline across different simulator platforms, provide common and actionable guidance for the implementation of simulator systems,[20] and reflect relevant training goals across different groups of stakeholders, from strategic to tactical training levels. However, despite the promise of standardization, the historical timeline shows achieving these goals in practice to be a difficult, open challenge, even from a technology-focused perspective.

Multiple standards groups and organizations are presently developing standards relevant to joint training simulators,[21] and there is a high degree of international interest and participation in development. Thus, standards development might be led by M&S experts drawn from a global community and individuals representing other defense organizations, such as the North Atlantic Treaty Organization, with similar challenges.[22] As a result, standards activities are not necessarily limited to goals or timelines for U.S.-specific national security readiness or training. Standards might take years to be proposed, developed, and fielded for adoption.

The standards activities themselves are simultaneously cross-sector, from an industry perspective, and cross-domain, from a mili-

---

[20] See, for example, SISO, *Standard for Commercial Off-the-Shelf (COTS) Simulation Package Interoperability (CSPI) Reference Models*, SISO-STD-006-2010, Orlando, Fla., March 9, 2010; and SISO, *Standard for Guidance, Rationale, and Interoperability Modalities (GRIM) for the Real-Time Platform Reference Federation Object Model (RPR FOM)*, Version 2.0, SISO-STD-001-2015, Orlando, Fla., August 10, 2015a.

[21] Although the formation of standards organizations and the adoption of standards are not the focus of this study, it is worth noting that members of standards committees might be sponsored by a mix of private- and public-sector organizations, and in a voluntary capacity. Similarly, different organizations might support different formal processes for the creation and evolution of standards, with influence potentially being shaped by predefined rules regarding membership status and the level of contribution permitted toward a standard.

[22] Stew Magnuson, "NATO Nations Strive to Standardize Training Systems," *National Defense*, July 1, 2019.

tary perspective. Areas with the greatest activity that are relevant to joint training presently concern the representation of environmental terrain data and greater support for real-time processing.[23] Both the Simulation Interoperability Standards Organization (SISO) and the Open Geospatial Consortium (OGC) are actively developing products to support open, standards-based interoperability for the exchange of environmental terrain and geospatial data.[24] Environmental effects caused by weather are another area of work, but these are also recognized as being challenging to represent with the appropriate fidelity in real time for distributed participants.[25] Activities relevant to joint interoperation of simulators are highlighted in Appendix F, with main lines of effort covering environmental data, communication standards, standards for command and control systems, training exercise management methods, and certification and compliance.

Policies for standards for interoperability are especially critical and are evolving. However, they are doing so independently of one another.[26] Standards organizations might be supported indirectly with representation from the DoD M&S roles, but the responsibilities for standards activities (development, support, and sustainment) rest with, and occur within, the broader community of industry participants nationally and internationally. Each organization is also organized dif-

---

23 See, for example, SISO, *Standard for Common Image Generator Interface (CIGI)*, Version 4.0, SISO-STD-013-2014, Orlando, Fla., August 22, 2014; and SISO, *Standard for Real-Time Platform Reference Federation Object Model (RPR FOM)*, Version 2.0, SISO-STD-001.1-2015, Orlando, Fla., August 10, 2015b.

24 See OGC, undated; and SISO, "RIEDP PDG—Reuse and Interoperation of Environmental Data and Processes," webpage, undated d.

25 The OGC is also developing standards for the real-time retrieval of environmental conditions from centralized, authoritative sources; see GitHub, "Opengeospatial/EDR-API-Sprint," webpage, last updated April 29, 2020.

26 Refer to Figures 6.1 and E.1, and Table 8.5, for a comparison of policy and standard timelines. For standards evolution, see OGC's ongoing efforts for the Common Database (CDB) standard for geospatial data (OGC, undated). See also Blackburn, 2019; and IEEE/SISO's standards development for "HLA Evolved," DIS 7, and DIS version 8 (SISO, "DIS/RPR FOM Product Support Group," webpage, undated a; SISO, "Distributed Interactive Simulation Version 8 (DIS V8) PDG," webpage, undated b; and SISO, "IEEE Standards Maintained by SISO SAC," webpage, undated c).

ferently, according to the participating community's interests. There is no single driving, coordinating force to promote adoption or development activities. There is no clear mechanism for consensus of joint M&S interoperability needs.

Policy evolution also reflects a timeline that is distinct from standards activities regarding cross-service interoperation (Figures 6.1 and E.1). Although there is a clear, persistent overlapping interest for joint M&S interoperability (spanning decades), policy documents are subject to vary substantially in content and scope with leadership changes (Figures 6.1 and E.1). The consequence is that future policy might conflict with ongoing service-level programs that implemented earlier policies. Standards that emerged or resulted through development within DoD programs might themselves outlive the DoD organizations that had the authority or direct ability to support their evolution and use, but they might continue to be *critical* for the execution of DoD or joint M&S training activities at a program level; this is the case with HLA and DIS.[27] Furthermore, regionally relevant and service-specific training systems used to satisfy Title 10 requirements might require or foster unique alternative standards and methods for joint interoperation in practice.[28] Therefore, there is a risk to DoD programs that stems from a lack of participation in the evolution and quality of the standards-development process.

Virtual Gaming

Lessons Learned from Gaming Technology and Infrastructure

The gaming industry has achieved great success with what are effectively highly networked and integrated simulators. This capability raises the question of what lessons DoD could learn from the gaming industry. Why not do what the gaming industry does, when it comes

---

[27] Both HLA and DIS are now international standards that are presently maintained by an international community, and both are actively used for distributed joint training simulators.

[28] For example, forces situated regionally within a theater might require unique training systems that are capable of interoperating with coalition forces.

to easily linking simulators globally with many different users for a relatively low cost?

To be sure, an active focus of DoD efforts with respect to distributed joint training is the incorporation of gaming engines and infrastructure for next-generation M&S for training. The gaming industry is seen as being at the forefront of realistic, distributed, and real-time online wargaming, and DoD is actively pursuing the use of games for training. In fact, USAF, USN, and the Army all have programs centered on leveraging the technology behind games for training.[29] Their efforts also extend to leveraging popular interest in competitive online gaming (electronic sports, or esports) for outreach and as part of a broader recruitment process.[30] Such efforts are also paralleled by U.S. allies, which might further incentivize programmatic development of game-based technologies.[31] However, using games for training is not the same as duplicating the scale of distributed operations seen in the gaming industry across the DoD training-simulator enterprise. Many networked games run with user and simulated entity counts an order of magnitude beyond what DoD does.

---

[29] Alion, "Game-Based Training," webpage, undated; Bohemia Interactive Simulations, "Remotely Piloted Aircraft and Air Operations Center Training," webpage, undated b; Damon Durall, "Synthetic Training Environment and the Digital Revolution in the Army," U.S. Army, October 3, 2018; Mariana Iriarte, "Gaming Tech: Shaping the Reality of Military Training," Military Embedded Systems, September 28, 2017; Stephen Losey, "Virtual Skies: Air Force Hopes 'Fun' Tech Transforms Pilot Learning," *Air Force Times*, January 16, 2018a; and John Schutte, "Researchers Use Gaming Technology for Interactive Military Training," Air Force Materiel Command, December 3, 2008.

[30] Air Force Gaming [@AirForceGaming], Twitter account, joined November 2019; and Peter Suciu, "USAF Gets Its Game On: Air Force Esports Team Recruiting for 2020 Evolution Championship Series," ClearanceJobs, April 28, 2020.

[31] "BISim Announces First Military & Defense Industry VBS4 Customers," Business Wire, December 2, 2019; Bohemia Interactive Simulations, "Forward Air Controller (FAC) Training: French Air Force, French & German Ground Operation School, French Procurement Agency (DGA), Airbus Defence & Space," webpage, undated a; and "NSC to Deliver Virtual Training Equipment for British Troops," Army Technology, last updated January 25, 2017.

Why Do Multiplayer Games Work Well?

Three factors contribute to the unique success of multiplayer games, and, although these factors do not yet apply to military applications, they could potentially provide insight for future integrated-simulator development:

- **Hardware design:** Large-scale, multiplayer games use data centers built for the purpose of supporting a high volume of users connecting over a network.
- **Software and game design:** Games are designed to provide computationally optimized experiences for a large number of participating players, with the flexibility to tune the fidelity of the experience based on the number of participants.
- **Business model:** Gaming vendors benefit from ecosystems of game developers enabled to develop content for games in many locations, as opposed to a singular effort by specific developers striving to make the canonical best experience, potentially at a higher cost; value is placed on a game platform's capabilities to enable state-of-the-art games, independently of content or design of a particular game.

With regard to **hardware design**, the gaming world does not usually connect two systems that do not share both hardware and software. In some cases, similar hardware—such as today's modern console systems, which have moved to using PC components—now allows *cross-play*, which is when players using different types of hardware console systems play together.[32] We could find no examples of different software being connected in a meaningful manner, and the hardware had to be very similar before connections were attempted. With military applications, however, most simulators, especially those used for cross-service integration, do not share hardware or software.

A critical aspect of gaming and hardware pertains to latency. *Latency* is the time lag encountered in delivering news of one's action to

---

[32] An example of a game with cross-play is Minecraft, which still has a unified software base but on differing (similar) hardware (Tom Warren [@tomwarren], "Nintendo and Microsoft Team Up to Promote Cross-Play, While Sony Remains Silent," *The Verge*, June 21, 2018).

other game players around the world. It is determined largely by physics and is the delay incurred between player actions arising from the network and the computational cost of simulation. For example, connecting players in Asia with players in North America requires crossing a distance of approximately 10,000 km. Even with two machines directly connected by optical fiber, there is an unavoidable delay of 100 to 200 ms. Latency is a fundamental challenge that is largely independent of the choice of gaming hardware today, and acceptable tolerances for in-game latency, in addition to software-system redesigns, remain concerns for connecting distributed simulation servers built on different hardware. Too much latency makes synchronizing the simulation state in real time impossible. A delay of more than 100 ms becomes very noticeable to the user when projectiles arrive a tenth of a second later than expected. Correspondingly, in-game tactics that involve manipulating the lag between users can be exploited to create advantages that would not exist in the real world. For example, when a room is being breached, if the room's defenders do not see the attackers for the first two tenths of a second, this gives the attackers a significant first-mover advantage in the ensuing battle. Therefore, connecting high-fidelity multiplayer games over distances that span more than one continent is not recommended, because it can lead to optimal tactics that would be foolhardy in the real world.[33]

With regard to **software design**, game developers often sacrifice software performance to support more users and thus increase scale and profitability. Table 8.5 itemizes gaming concepts that are key to allowing more players onto a system than it might handle normally. These are a mix of techniques, from farming out some of the work to additional servers to simplifying the simulation in places that users might not notice—for example, hiding faraway enemies that are unlikely or

---

[33] For examples of game play being limited to the same data center, see Spencer Havens [@spencerhavens], "PS4 and Xbox One Get Crossplay by Accident," blog post, Greenlight Games, September 19, 2017; Cal Jeffrey, "Cross-Platform Multiplayer Will Not Be Coming to PlayStation 4 Any Time Soon," TechSpot, June 15, 2017; and Square Enix, "World Visit System," play guide, last updated August 11, 2020. For a review of the significance of latency for gaming using data centers in game play, see Kevin Deierling, "In Modern Datacenters, the Latency Tail Wags the Network Dog," *Next Platform*, March 27, 2018.

Table 8.5
Techniques for Improving Game Bandwidth

Problem	Solution	Function
Too many users connecting at once	Load balancing	Spreads connection loads over many servers
Too many users interacting at once	Simplified collision physics	Simpler approximations for bullet hit detection
Many players operating in one place	Dynamic server meshing	Busier parts of the game run on more servers
Loading screens between servers	Container streaming	Quietly loads each player onto nearby servers too
Network congested with position updates	Network bind culling	Hides faraway or invisible entities from clients

unable to shoot at the player, even if they would have been visible in the real world. This can free up additional capacity to manage more users. Although effective, these techniques are not available to military applications because of the diversity of hardware and software.

One of the most significant advantages that the game industry has over DoD with respect to distributed simulators is its **business model**. Game developers often exercise *vendor lock*, a term that "describes the situation in which customers depend on a single manufacturer or supplier for some product . . . and cannot shift to another vendor . . . ."[34] This can be countered by fostering business models in which the vendor benefits from networking its simulator. This entails minimizing or eliminating benefits from vendor lock, standardizing legal agreements for simulator use across services, and defining how businesses interact with DoD so that delivering a specific simulator does not give the vendor better access to DoD than someone else who connects through their own system.

---

[34] Virginia L. Wydler, *Gaining Leverage over Vendor Lock to Improve Acquisition Performance and Cost Efficiencies*, McLean, Va.: MITRE Corporation, April 1, 2014, p. 3.

Adaptability and Scalability

Particularly appealing for military purposes in the gaming industry is the integration of tens of thousands of unique hardware systems through software standards into low-latency, high-performance simulated worlds. Similarly appealing is the development pace of the gaming industry, which allows it agility to integrate and experiment at a much more rapid pace than traditional military process allows. This appeal is combined with the proliferation of advanced, realistic physics-based simulation methods boasting high visual fidelity and developed using a rich array of modular software components. In addition, the gaming industry is self-supported by a mature workforce that is continuously innovating and moving simulation capabilities forward in a competitive process.[35] The availability of such tools and methods can streamline training activities and boost the overall effectiveness of learning, with the implication of a better-prepared force.

The vast number of users commonly seen in online gaming shows one capability that the military does not have (and requires) for large-scale joint training. The ability to have tens of thousands of people involved in a joint exercise would be a sea change in military training scale. Some games have daily peak user counts well above 30,000 simultaneous users. Not all games are "first-person shooters" (FPSs), and some have more in common with military communications systems than military simulators. The capacity to put hundreds of thousands of people onto a single simultaneous communication network is also of military value. To illustrate the limits of this technology, Table 8.6 presents a selection of reported records for the number of game participants, all but one of these records validated by Guinness observers. Each row represents a company trying to reach the absolute maximum number of users possible on its current hardware, at its current detail level. The *detail level*, which is summarized in the last column in terms

---

[35] Although the perception might be that industry capabilities are maturing and advancing smoothly, this is not without cost or struggle. See Riad Chikhani, "The History of Gaming: An Evolving Community," TechCrunch, October 31, 2015; Jeff Desjardins, "How Video Games Became a $100 Billion Industry," *Business Insider*, January 12, 2017; History.com editors, "Video Game History," webpage, History.com, last updated June 10, 2019; and Marshall Honorof, "Google Stadia Review," Tom's Guide, May 22, 2020.

of a comparable military abstraction level, indicates how thoroughly the world is simulated (e.g., whether bullets travel in an arc or a straight line). At the tactical level and below, individual users have positions tracked down to a millimeter, and projectiles are simulated as they are fired. A full-fidelity simulation adds such complexities as wind, aerodynamics, weather, temperature, and a host of other details that reduce the game's ability to handle more players. Because detail (e.g., visual fidelity) can be reduced to support more players, Table 8.6 shows the maximum number of people that can be supported at a given fidelity level.

Two details not immediately clear in this table are hardware and simultaneity. The computational power of hardware does have an effect, but many of the listed game platforms are already running on ideal or nearly ideal commercially available hardware; only the first and next-to-last items are not running the best-available hardware. An order-of-magnitude improvement with a hardware upgrade is unlikely in most cases.

Simultaneity describes the amount of interaction between the number of players involved. For example, if 20 players are online, but they are split into two rooms containing ten players each, then players in one room are not able to shoot at players in the other room. This reduces the amount of information sent about events in the other room and the players in it, resulting in the ability to accommodate additional players in the game. *Simultaneous* implies that any player could interact with any other player, at any time.

Data Centers

Each of the records noted in Table 8.6 depends on a data-center server design, and this can provide some insight for potential DoD development with respect to SBT. Training hundreds or thousands of simultaneous users, or more, will likely require data-center technology to achieve training goals. Data centers are an essential technical aspect of today's gaming infrastructure that enable highly distributed, large-scale gaming. They are at the center of a competitive space of firms

Table 8.6
Gaming Records for Number of Players

Upper Limits	Simultaneous?	Number of Players Reported	Platform	Military Simulation–Equivalent Level of Fidelity
Most participants in an online videogame—*Twitch Plays* Pokémon	No	1.1 million	Web browser/data center	Communications only, extremely low fidelity
Most players in one server—*World of Tanks*	No	190,541	PC/data center	Strategic, low fidelity
Most clients in a simultaneous battle (3,852 players)—*Hadean tech demo*	Yes	14,274	PC/data center	Strategic, low fidelity
Most players simultaneously involved in a multiplayer battle—*Eve Online*	Yes	6,142	PC/data center	Mixed strategic/tactical, medium fidelity
Most players in a simultaneous FPS battle [PC]—*PlanetSide 2*	Yes	1,158	PC/data center	Tactical, medium fidelity
Most players in a simultaneous FPS battle [Console]—*MAG*	Yes	256	PlayStation 3 console/ data center	Tactical, medium fidelity
Most planes in a simultaneous flight simulation—*War Thunder*	Yes	303	PC/data center	High fidelity

SOURCES: Guinness World Records, "Most Players Online in a Console FPS," record, January 2010; Guinness World Records, "Most Players Online Simultaneously on One MMO Server," record, January 21, 2013a; Guinness World Records, "Most Planes in a Flight Simulation Game," record, January 22, 2013b; Guinness World Records, "Most Users to Input a Command to Play a Live Streamed Videogame," record, March 1, 2014; David Stubbings, "EVE Online Gamers Set New Record for Taking Part in a Huge Video Game Battle," Guinness World Records, April 18, 2018; and Matthew Thorpe-Coles, "Over 14,000 Ships Flew to Battle in Eve: Aether Wars This Monday," PCGamesN, last updated April 5, 2020.

entering the gaming industry (*Wired* has termed this "an infrastructure arms race"[36]). Data centers can provide the following capabilities:

- high-performance computing clusters, where hundreds of servers with dedicated storage are networked
- redundancy to avoid critical failures in use
- cloud-computing methods and virtualization capabilities to support rapid development and large-scale events.

A data center takes the place of a server in a multiplayer-focused game. By separating the different game components that a single server would have into groups of machines, all connected by extremely high-speed network connections, a data center allows vastly higher performance than a single machine can provide. Today, data centers (small or large, regional or local) are built with high-performance computing and cloud-computing principles in mind. In essence, data centers and cloud-computing strategies are applied to compose gaming services from groups of dedicated computers, each playing specialized roles; high-performance gaming applications leverage cloud-computing strategies within data centers to support high-fidelity, distributed gaming on a large scale. The centralization of computing services enables simultaneous interaction among many participants. Because game vendors have full control over the entire range of game experiences, they are further able to standardize the gaming environment provided to all participant players, which unlocks further performance increases.

This centralization of services is also reflected in the software architecture of gaming infrastructures. The gaming infrastructures that are finding success today and drawing attention for potential application within DoD services are engineered to enable highly structured, scalable computing environments that are built on reusable, interacting component services. Cloud-based gaming services separate into "layers" with different tiers for M&S (where the game "engine" resides, along with relevant software tools and applications), authorita-

[36] Cecilia O'Anastasio, "An Infrastructure Arms Race Is Fueling the Future of Gaming," *Wired*, June 29, 2020.

tive sources for data (environmental, in-game effects, player state information), development and testing tools, user authentication services, game analytics and reporting services, and web access.

Cross-Play

An emerging trend for the cloud gaming industry is to make it easier for developers to develop their own content by providing more game-development tools—for example, to enable developers to directly use centralized, preexisting cloud infrastructure services for networking, persistence, and shared in-game services. The expected benefit is to reduce costs, speed the game-development life cycle, and natively improve the scalability and reusability of code for individual game designers or startups that might not have the resources or means to compete with larger developers. These tools are also expected to enable cross-platform game play—also known as *cross-play*.[37]

Cross-play is a natural interest for simulation technologists, because it parallels the linking of dissimilar hardware with similar software, as must be done for simulators originally made to run alone. However, when games link dissimilar hardware together, they do so only with identical software (even then, technical issues stemming from cross-play persist). Furthermore, in most cases of cross-play, players using different gaming hardware are *already* connected in one data center, separated only logically, not physically. For example, users of the popular competitive sports game *Rocket League*, running on two different hardware platforms (Xbox and Nintendo Switch), were actually connecting to the same data center when playing. They were simply instructed (via instruction from the gaming interface) to ignore users not from their own platform. When *Rocket League* enabled cross-hardware-play, the game system simply instructed the two systems to stop ignoring each other. Simulator systems, however, are not likely to have this standardization to benefit from, owing to the variety of inde-

---

[37] Kareem Choudhry, "Achieve More with Microsoft Game Stack," *Game Stack Blog*, March 14, 2019; Coherence, "About," webpage, undated; Microsoft, "Azure for Gaming," webpage, undated; and Stadia, "About," webpage, undated.

pendently prepared vendor platforms. Cross-play also relies predominantly on a common software code base for the game itself.

Security Considerations

Security considerations constitute a significant challenge to networking simulators. In order for the integrity of DoD technology infrastructure to be ensured, each simulator must be evaluated for cybersecurity risks and authorized for use, and the corresponding risks must be identified, documented, and mitigated as appropriate. Following this, prior to a simulator's inclusion in a joint training exercise, authorizations must be obtained to ensure that (1) information being exchanged is secure and (2) use of the network for interoperation does not introduce vulnerabilities or otherwise increase the threat to systems accessible over the network. A large number of policy documents and instructions potentially apply, reflecting the scope and effort that might be required to assess a system's use for joint training: As of April 2020, approximately 200 cybersecurity-related policies and issuances detail and organize cybersecurity for the DoD Information Network.[38] DoDI 8500.01, *Cybersecurity*; and DoDI 8510.01, *Risk Management Framework (RMF) for DoD Information Technology (IT)*, both of which we will briefly overview, capture essential, overarching policy for cybersecurity of DoD information systems.[39]

What Policies Are Ensuring That Data Are Secure?

DoDI 8500.01 and DoDI 8510.01 describe the policies, procedures, roles, and responsibilities for assessing and establishing secure use of DoD information systems. Together, these documents cover a broad

---

[38] A chart is actively updated by the DoD Chief Information Officer (CIO); see Department of Defense Information Analysis Centers, Defense Technical Information Center, DoD Cybersecurity Chart, last updated November 30, 2020.

[39] DoDI 8500.01, *Cybersecurity*, Washington, D.C.: U.S. Department of Defense, March 14, 2014, Incorporating Change 1, October 7, 2019; and DoDI 8510.01, *Risk Management Framework (RMF) for DoD Information Technology (IT)*, March 12, 2014, Incorporating Change 3, December 29, 2020.

scope that includes software implementation, information exchange, and continuous monitoring. Multiple organizations are involved in defining a comprehensive base of standards, and the individual roles and responsible parties are well defined within a coherent, enterprise-wide view of cybersecurity. This includes a governance structure for all levels of an organization and contractors. Responsibilities are defined at the programmatic, planning, and developmental levels, as well as for acquisition and operational activities. Table 8.7 presents an overview of the policies and standards to ensure that data are secure.

Table 8.7
Overview of Policies and Standards Relevant to Cybersecurity of Joint Training-Simulator Systems

Document Type	Documentation
NIST standards, public/general standards	RMF • Relevant to DoD policies for national security systems • NIST SP 800-37, rev. 2 (2018) Protecting unclassified, nonfederal information systems and organizations • NIST SP 800-171, rev. 2 (2021) • NIST SP 800-172 (2021) • Enhanced for critical programs and high-value assets
DoD policy and standards	DoD CIO guidance • DoDI 8500.01, *Cybersecurity* (2019) • DoDI 8510.01, *Risk Management Framework (RMF) for DoD Information Technology (IT)* (2020) • Committee on National Security Systems (2014) • Committee on National Security Systems Instruction (CNSSI) No. 1253, *Security Categorization and Control Selection for National Security Systems* (2014) • Many documents concerning specific aspects of cybersecurity • Federal Information Processing Standards • Cybersecurity Management Maturity Model • NIST SP 800 series publications

Table 8.7—Continued

Document Type	Documentation
Nonpolicy cybersecurity methods, tools, and practices	Multiple Independent Levels of Security (MILS) • Exchange of data at different levels of classification • Cross-domain access • Distributed environments Simulation—communication infrastructure • Defense Information Systems Agency Joint Communication Simulation System • Continuous monitoring and reporting tools • Encryption techniques • Data isolation • Network isolation • Network infrastructure, transport security • Authentication and authorization

SOURCES: CNSSI No. 1253, *Security Categorization and Control Selection for National Security Systems*, Ft. Meade, Md.: Committee on National Security Systems, March 27, 2014; DoDI 8500.01, 2019; DoDI 8510.01, 2020; Ronald S. Ross, *Risk Management Framework for Information Systems and Organizations: A System Life Cycle Approach for Security and Privacy*, Gaithersburg, Md.: National Institute of Standards and Technology, U.S. Department of Commerce, NIST SP 800-37, rev. 2, December 2018; Ron Ross, Victoria Pillitteri, Kelley Dempsey, Mark Riddle, and Gary Guissanie, *Protecting Controlled Unclassified Information in Nonfederal Systems and Organizations*, Gaithersburg, Md.: National Institute of Standards and Technology, U.S. Department of Commerce, NIST SP 800-171, rev. 2, February 2020; and Ron Ross, Victoria Pillitteri, Gary Guissanie, Ryan Wagner, Richard Graubart, and Deborah Bodeau, *Enhanced Security Requirements for Protecting Controlled Unclassified Information: A Supplement to NIST Special Publication 800-171*, Gaithersburg, Md.: National Institute of Standards and Technology, U.S. Department of Commerce, NIST SP 800-172, February 2021.
NOTE: NIST = National Institute of Standards and Technology; SP = Special Publication.

Risk Management Framework for Securing Networked Simulators

DoDI 8510.01 mandates the use of the RMF, defined in NIST SP 800-37,[40] for the authorization process used for development, testing, and operational activities that applies to DoD systems, such as networked simulators. The RMF establishes a cohesive risk management approach, from the mission or business-process level to the operational level. An organization's approach to risk management is codeveloped between an organizationally relevant governance structure and the business processes associated with its enterprise information architecture.

---

40 DoDI 8510.01, 2020; Ross, 2018.

The RMF emphasizes its association with acquisition processes and system engineering methods through integration of cybersecurity into the systems design process:

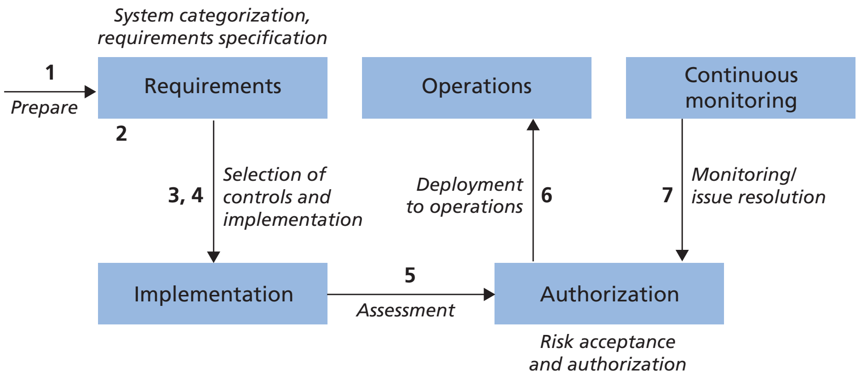
> The risk management framework (RMF) brings a risk-based approach to the implementation of cybersecurity. Transition to the RMF leverages existing acquisition and systems engineering personnel, processes, and the artifacts developed as part of existing systems security engineering (SSE) activities. Unlike a compliance-based checklist approach, the RMF supports integration of cybersecurity in the systems design process, resulting in a more trustworthy system that can dependably operate in the face of a capable cyber adversary.[41]

At each stage of the design, development, test, and evaluation parts of the evaluation process, the RMF specifies how risk assessment is to be performed. This includes detailed adherence to all applicable DoD standards for cybersecurity requirements, controls, procedures, and processes. As described by NIST, the seven steps of the RMF are (1) Prepare, (2) Categorize, (3) Select, (4) Implement, (5) Assess, (6) Authorize, and (7) Monitor. These are diagrammed in Figure 8.2 as actions guiding the systems engineering process. During the requirements stage, the simulator system is categorized and its cybersecurity requirements are specified, after which development and testing are performed. Risks that emerge during development and testing are evaluated and mitigated at the team level first, and subsequently at the program level or organizationally if mitigation is not available and an assessment of risk is required. When all risks are accepted, the system receives ATO and is deployed for operational use. The appropriate network authorizations and data security requirements have also been addressed during the risk assessment and acceptance step. In order for the cybersecurity of the simulator to be maintained, the system must

---

[41] DoD, *DoD Program Manager's Guidebook for Integrating the Cybersecurity Risk Management Framework (RMF) into the System Acquisition Lifecycle*, Version 1.0, Washington, D.C.: Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, September 2015, p. iii.

Figure 8.2
The Risk Management Framework Process for Systems Engineering and Evaluation



SOURCE: Authors' analysis of data from Ross, 2018.

be continuously monitored and receive reauthorization should a cybersecurity issue manifest. The relationship between steps in the RMF and phases of the acquisition timeline is outlined in Appendix G.[42]

Conclusion

This chapter has provided an overview of the state of the art with respect to simulator interoperability and networking training simula-

[42] The DoD *Cybersecurity Test and Evaluation Guidebook* does not explicitly include Prepare as Step 1, resulting in six steps (DoD, *Cybersecurity Test and Evaluation Guidebook*, Version 2.0, Change 1, Washington, D.C.: Office of Prepublication and Security Review, February 10, 2020). Several complementary paradigms for secure network architectures are also applied in practice. These also fit into the RMF being outlined in this section (e.g., via the process of evaluating organizational mission risks). Such paradigms are essential to establishing an environment that accommodates the total range of potential information, network, and cybersecurity issues. As starting points, see Scott Rose, Oliver Borchert, Stu Mitchell, and Sean Connelly, *Zero Trust Architecture*, Gaithersburg, Md.: National Institute of Standards and Technology, U.S. Department of Commerce, Draft NIST SP 800-207, September 23, 2019; and Carnegie Mellon University Software Engineering Institute's series of articles on Network Situational Awareness (Software Engineering Institute, "Subject: Network Situational Awareness," webpage, Carnegie Mellon University, undated).

tors for joint training; this overview included data standards, virtual gaming, and network security. The topics discussed in this chapter provide a starting point for aligning future industry developments with warfighter needs with respect to joint simulator use.

With regard to currently available capabilities, cross-service simulator integration is presently supported by a mix of (incompatible) standards for information exchange (such as DIS, HLA, and TENA) and federation techniques. Industry-developed simulation engines ("game" engines) offer rich tool sets for M&S that are proving to be beneficial to military M&S needs, including simulator design and development. However, fundamental differences between the entertainment industry and military needs prohibit DoD from leveraging all aspects of the success that the gaming industry has had with respect to scalable networked simulators.

New standards enabling the standardization of environmental data that are used by simulators for cross-service training are also in progress, as are larger-scale evolutions of DoD training environments with capabilities for supporting new modes of simulator integration based on new simulation frameworks, using game engines and virtualization on a larger scale. These methods will implicitly leverage cloud-computing principles.

During our review of the state of the art, we noted that the following areas relevant to simulator interoperability have active R&D:

- standards adoption
  - open versus domain-specific standards
  - multinational interoperation
- platforms
  - command and control simulation
  - cloud-based simulation platforms
  - soldier-based systems
- real-time interoperability
  - cross-service capabilities with greater collaboration
  - scalable architectures for simulation training environments

– open, modular frameworks for simulation based on gaming engines
– improved networking methods.

It is not clear that these overall lines of effort specifically align with DoD and warfighter needs. Thus, there is a need to constantly cross-walk industry R&D efforts with the demand signal from joint training efforts. Furthermore, given the rapid changes in technology and inevitable changes in warfare, such analysis should occur regularly. However, as noted in Chapter Five, systematically characterizing such needs is a challenge. This can leave industry pursuing projects that perhaps require relatively little effort and are expected to generate profits but do not respond to specific user needs. This, in turn, can generate inefficiency.

Additional primary findings are noted as follows:

- **Policies for joint M&S and standards for interoperability are evolving.** However, they are doing so independently of one another. There is no single driving, coordinating force to promote adoption or development activities, and there is no clear mechanism for consensus of joint M&S interoperability needs.
- **Lack of standardization remains a barrier to achieving interoperability.** No single data standard solution has satisfied requirements for comprehensive joint training. Multiple relevant standards and systems have been and are being developed and implemented today, and the development of standards has evolved organically over time.
- **Testing is insufficient to ensure adherence to data standards.** Definitions for data standards are not clear enough to successfully integrate simulations. Although users might agree on a standard (such as HLA or DIS), differences in details within a specific data protocol can still present challenges to interoperability. The mismatch between standards and simulator requirements between services is a key challenge.

- **The diversity of hardware and software systems presents substantial challenges in ensuring system interoperability**, especially compared with the success of the gaming industry.
- **Information assurance remains challenging.** Enabling multiple levels of security is a persistent challenge for joint interoperation across simulators. Approximately 200 cybersecurity-related policies and issuances detail and organize cybersecurity for the DoD Information Network.

PART IV

Conclusion

CHAPTER NINE

Summary, Primary Themes, and Actions for DoD Stakeholders

Summary

Coordination and interoperability between services have long been challenges within DoD. As current and potential conflicts increasingly involve joint operations, joint training becomes increasingly important, and this brings current gaps into focus. Within the scope of joint Tier 3 and Tier 4 training with respect to air- and ground-based simulators, we have taken a comprehensive look at how the services are organized and how they operate.

We sought to answer the following questions:

- What are the differences between the services with respect to organizational structure and internal coordination?
- What are the differences between the services with respect to simulator requirements and acquisition processes?
- What are the joint training needs?
- What incentives are there for cross-service collaboration, for interoperability, and for industry support of interoperability?
- What technological capabilities are available to support cross-service simulator integration?

In response to these questions, we presented new frameworks for assessing the organizations, the acquisition processes, and the requirements-setting processes for the services. We then explored the demand for joint training, using SME interviews, data for current training exercises, and data for current joint tasks. After the foundational analysis of individual services and the training needs, we looked at the organizations that could help provide joint coordination and the extent to which their mandates are themselves coordinated. However, even with organizations in place to foster collaboration, there must be incentives for services to pursue joint solutions, and there must be incentives for industry to respond accordingly. Thus, we reviewed incentive structures in both respects. Finally, we provided an extensive review of the state of the art of capabilities required for system interoperability and integration. This review lays the groundwork for cross-walking industry developments with warfighter needs.

While specific findings were noted with each chapter, pervasive themes and primary findings are discussed in the following section, and these are followed by a series of recommendations. Although some recommendations are necessarily broad, the focus and intended impact revolve around the training-simulation community.

Primary Findings

As with the governance of any large organization, a primary challenge with training management is balancing centralized coordination with decentralized training needs. With respect to Tier 3 and Tier 4 training, current joint coordination is minimal, and so is the accountability for cross-service collaboration. This stems, in large part, from the process whereby CCMDs hand down higher-level training needs to the services, and the services then plan their Tier 3 and Tier 4 training internally, in an effort to support CCMDs. Although services must retain autonomy in *how* they address higher-level training needs, there must be increased coordination between the services. Although the services must be free to tend to their specific training needs at the tactical level, acquisition that supports these training needs must be coordinated at a joint level. In addition, incentives must be balanced between both "carrots" and "sticks," enticing both the services and industry to pursue coordinated, interoperable solutions.

Opportunities for improved coordination are identified throughout the report, but the need for interoperability among training simulators across services for Tier 3 and Tier 4 exercises is much less clear. In fact, with few exceptions, there are minimal formal requirements for joint SBT at the Tier 4 level. Consequently, with unclear joint training needs, services may pursue goals independently, with minimal coordination, and the consequent signal to industry as to how it might support joint collaboration can be unclear. Larger services, which might have larger budgets, might have more autonomy with respect to simulator acquisition and are thus more difficult to incentivize. In addition, the perception of sunk costs and frictions associated with the adoption of other services' solutions can impede collaboration.

In addition to uncertain training needs, minimal coordination, and minimal accountability, there is limited transparency with respect to training-simulator capabilities and acquisition plans. Resources for data and information in this regard are not as centralized as they could be in each service and at the joint level. Mechanisms and organizations should be in place to provide relatively easy-to-access data regarding current simulator capabilities, current usage (regarding training exercises), and planned development.

Recommendations

In response to these findings, there are many steps that can be taken, with relatively little effort, to improve coordination. DASD(FE&T) can support some of these recommendations, but many recommendations apply beyond DASD(FE&T) to the broader training-simulation community and, in some cases, to higher levels of command.

Although substantial changes in organization or responsibilities might be impractical for near-term impact, there is a series of changes that DoD could make within and across services. In general, these changes entail ensuring the existence of organizations with some level of centralized coordination. This can be especially helpful with respect to archiving information and data. Within each service and within the Joint Staff, there should be one organization that at least aggregates information concerning simulator capabilities, requirements, and acquisition. The first step does not need to be any significant change in funding or policy, but rather simple transparency and frequent dissemination of information and data. Ultimately, of course, changes in policy and financial resources will be helpful as incentives for services to collaborate with one another.

Viewing the problem of coordinating the services conceptually through the lens of optimization with multiple objectives can be helpful. Each service operates with specific objectives. This inherently results in a multi-objective problem, whereby each service strives to pursue its own objective but might share some joint resources. With each service acting as a separate decisionmaker, so to speak, such multi-objective optimization problems take on the form of game theory.[1] There are many different solutions, and the best that one can do is to achieve what is called a *Pareto optimal solution*, whereby one cannot make a change (from a solution point) without detriment to at least one objective. However, to *ensure* that one achieves such an optimal solution, the decisionmakers must share information efficiently. Otherwise, although the results might seem adequate, it will still be possible to improve at least one decisionmaker's objective with no detriment to the others. Thus, transparency of joint training needs, resources, and plans is critical.

In addition to aligning organizations and sharing information, there are opportunities for improving coordination during the acquisition process. Service acquisition offices should acquire and upgrade training simulators in coordination with their respective weapon systems as a matter of course. This can help support concurrency between the simulator and the actual system. In addition, in support of acquisition processes, there is a need to establish and maintain uniform specifications for the technical capabilities required for joint training. Centralized organizations within the services should define and own

---

1 Tim Marler and Jasbir S. Arora, *Multi-Objective Optimization: Concepts and Methods for Engineering*, Saarbrucken, Germany: VDM Verlag, 2009.

the system requirements and related processes required to enable joint training goals.

Additional specific recommendations are itemized as follows with respect to potential improvement in the respective services, and then with respect to the joint training enterprise. Given the complexity of this problem and the number of organizations involved, there are many recommendations for improvement. These recommendations are grouped in Table 9.1 with respect to changes to the services, the joint enterprise, technology development, and industry. Subheadings are provided to indicate whether actions could apply to OSD, the individual services, or the Joint Staff. Note that some recommendations involve significant organizational changes and thus require high-level oversight within OSD. Although we recognize that these changes will not be easy and could take a substantial amount of time, they are nonetheless noted as opportunities for improvement. Alternatively, there are opportunities for DASD(FE&T) to support or advocate for some recommendations in the near term, and these are noted toward the end of this chapter, in Table 9.2.

Management of the Services

Action Items for the Office of the Secretary of Defense

Action items for OSD are as follows:

1. **Services should have coordinated structures: OSD (with SECDEF-level oversight) should incentivize each service to develop a coordinating organization or office with the same responsibilities and general structure across the services and with a focus on training simulation.** This organization within each service would (1) help coordinate acquisition internally within the service, (2) ensure that operational requirements are transitioned effectively to system requirements, and (3) interface externally with JS J7. The services already have organizations in existence that could play this role, as illustrated in Chapter Two, but responsibilities can be dispersed, so a single, centralized organization should be identified for each

Table 9.1
Summary of Recommendations

Category and Organization	Recommendations
Management of the services	
OSD should . . .	• Incentivize all services to develop coordinating organizations with the same responsibilities and structure. • Urge services to align structures for simulator development to facilitate interservice coordination.
Each service should . . .	• Fund and require M&S offices to coordinate technical information and capabilities. • Develop a clear vision/plan with regard to S&T development that supports integrated joint training.
Management of the joint community	
OSD should . . .	• Increase the focus on joint coordination. • Appoint a single joint organization to focus on simulator-development coordination. • Explicitly fund interoperability. • Consider implementing joint-level processes for information assurance and security. • Have USD(P&R) prioritize funding for joint training requirements and help services coordinate common conceptual models.
The Joint Staff should . . .	• Support the UJTL program to support joint coordination. • Exercise their Title 10 authority for technical standards in the context of training. • Have JS J7 resume its training-gap analysis forums as a mechanism to support joint coordination. • Have JITC resume responsibility for testing simulator interoperability. • Have JNTC gather additional data concerning joint training exercises on Tiers 3 and 4.
Technology development	
DoD and industry should . . .	• Focus future acquisition programs not just on simulators but on supporting capabilities, including data standards, gaming technology, and security considerations. • Leverage methods from distributed systems, high-performance computing disciplines, and advanced networking concepts. • Establish technology readiness levels and standards for interoperability and joint simulator training exercises.

Table 9.1—Continued

Category and Organization	Recommendations
Interfacing with industry	
DoD should . . .	• Ensure that financial incentives are large enough to overcome the opportunity cost of not implementing open standards and not relinquishing data rights. • Consider nonmonetary incentives for joint simulators. • Consider both positive and negative incentives with application to both government program offices and industry contractors.
OSD should . . .	• Take the lead in implementing an accessible and efficient marketplace to bring together industry and DoD.

service. This incentive could take the form of policy directives or support funding.

a. **USD(R&E) should urge alignment of the services' organizational structures** involved in simulator development to help support interservice coordination. As itemized in Chapter Two, different services can have very different organizational structures, and this can hamper communication between services. It can be unclear who, or what organization, is the appropriate contact outside one's own service. USN and USMC collectively provide a positive example of this kind of alignment.

Action Items for Individual Services

Action items for the individual services are as follows:

2. **M&S offices and DMSCO need more leverage: Each service should fund and require M&S offices to carry out coordination with respect to technical information and capabilities.** Specifically, AFAMS, AMSO, and NMSO should aggregate and disseminate information regarding existing training simulators and their capabilities. These offices already house significant expertise and often coordinate between themselves. However, they do not necessarily have resources, in terms of funding

or policy control, to enact improvements in cross-service coordination.

a. **DASD(FE&T) should advocate for DMSCO providing oversight to the service M&S offices** with respect to coordination. In theory, DMSCO is set up to do exactly this, but its funding and policy levers have been reduced significantly over time, even as its role remains critical.

3. **Each service needs a clear vision or plan with regard to S&T development that supports integrated joint training.** This could provide a basic mechanism for ensuring that the services have a common vision with respect to simulator interoperability. Respective M&S offices could help develop such plans, and, if afforded appropriate policy levers, DMSCO could help compare, coordinate, and align these plans.

Management of the Joint Community

Action Items for the Office of the Secretary of Defense

Action items for OSD are as follows:

4. **OSD (with SECDEF-level oversight) should increase the focus on joint coordination.** Although there might be many organizations that provide informal cross-service coordination, few have substantial coordination roles that are dictated by policy. When responsibilities are noted in formal policy, wording can be vague. Those offices with overarching coordinating roles tend to be relatively high in the command structure and thus focus on higher-level directions rather than on more-tactical efforts involving training simulators.

   a. **SECDEF should seek Title 10 authority for JS J7, thus providing leverage that previously resided with JFCOM.** JS J7 could then be responsible for identifying, prioritizing, and feeding joint M&S requirements into the development process.

   b. **SECDEF should appoint a single joint organization, possibly JS J7, to focus on coordinating the simulator-development process and on Tier 3 and Tier 4 simula-**

tor training. Currently, JS J7 generally focuses on Tier 1 and Tier 2 training, particularly constructive capabilities, with some funding put toward development. Higher-level training needs are handed down to the services by CCMDs, and the services are then responsible for planning Tier 3 and Tier 4 training internally, with minimal coordination. Although the services must be free to tend to their specific training needs at the tactical level, acquisition that supports these training needs must be coordinated at the joint level. This appointed organization would not necessarily fund all training-simulator development but would help ensure that acquisition is coordinated and aligned across services at the Tier 3 and Tier 4 levels.

5. **The Under Secretary of Defense for Acquisition and Sustainment (USD [A&S]) should explicitly help fund interoperability: Joint training requirements need to be formally specified** to incentivize funding solutions and allow for testing. Additional funds are needed to incentivize coordination (e.g., CE2T2 RDT&E funds are minimal compared with service simulator budgets). These funds need not fully support simulator development. Rather, they should complement development efforts by focusing on technical aspects for interoperability (e.g., implementing technical capabilities for using or supporting a specified common data protocol).
6. **OSD should consider implementing joint-level processes to overcome difficulties in information assurance and security.** Some of these difficulties stem from variation in security standards across services. Reciprocal agreements are needed between services, by which meeting the standards of one service would necessarily satisfy the standards of another service.
    a. **USD(P&R) should prioritize funding for joint training requirements.** Currently, joint training requirements are not necessarily informing simulator development. The presence of such requirements could drive collaboration.
    b. **USD(P&R) could use its role as simulator interoperability SSG lead of the conceptual-modeling working group**

to help services coordinate around common conceptual models. The lack of common models is a friction point that impedes collaboration.

Action Items for the Joint Staff

Action items for the Joint Staff are as follows:

7. **JS J7 (with support from OSD) should reinforce the importance of the UJTL program (including joint TTP and JMETs)** by continuing to fund the program and distributing related data more broadly across the joint SBT community to support joint coordination. Since JFCOM's disestablishment in 2011, the UJTL program has atrophied.
8. **CJCS should exercise Title 10 authority for technical standards more frequently** in the context of training. Developing and implementing common standards is a significant challenge with respect to supporting interoperability and, by extension, joint coordination. CJCS has responsibility for "formulating policies and technical standards, and executing actions, for the joint training of the armed forces,"[2] and could help ensure that developers adhere to common standards.
9. **JS J7 should resume its training gap analysis forums as a mechanism to support joint coordination.**
10. **JITC should again be responsible for testing simulator interoperability.** As it stands, there is no dedicated joint body that systematically ensures that simulators are interoperable according to their own interoperability requirements, to the extent that such requirements are included in system-development documents. A joint body that could test and certify interoperability would hold services to requirements and thus incentivize services to coordinate over simulator development to meet certification standards.
11. **JNTC should gather additional data concerning joint training exercises on the Tier 3 and Tier 4 levels.** Although there

---

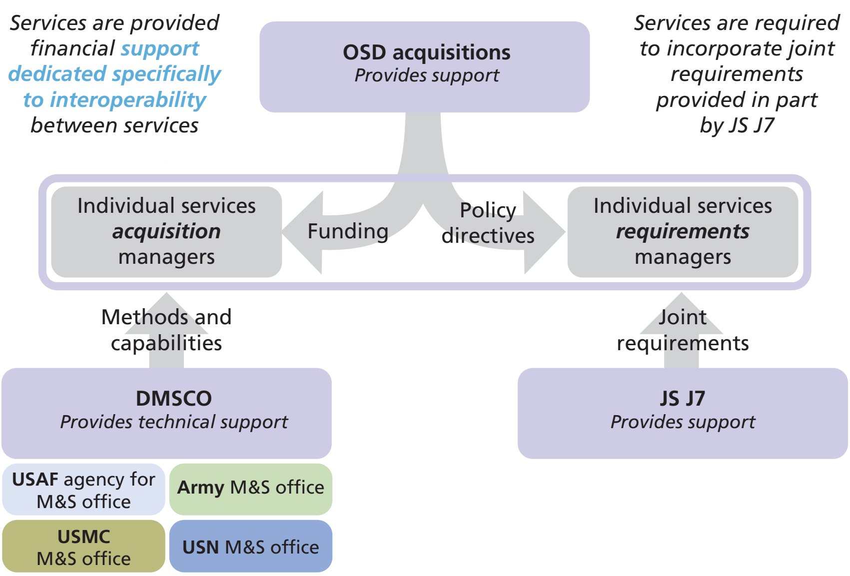
2 CJCSI 3500.01J, 2020, p. 1.

are easily accessed data concerning Tier 1 and Tier 2 training exercises, data concerning Tiers 3 and 4 are less accessible and are not necessarily gathered on a regular basis. Consequently, it can be difficult to quantify demand for simulator integration that supports joint exercises on a more tactical level.

Overview of Suggested Roles and Responsibilities

Figure 9.1 provides an overview of suggested responsibilities with regard to enhanced management of the joint community. In general, this structure does not veer far from current practices but nonetheless makes explicit relative roles that can balance centralized coordination with decentralized training needs. The primary influence for spurring coordination must come from a relatively high level because of the need to coordinate high-ranking commanders. Given that the primary intent has to do with acquisition of interoperable systems, USD(A&S) should drive the culture for interoperability. With regard to negative incentives (the "stick"), USD(A&S) would develop and dis-

Figure 9.1
Suggested Division of Responsibilities for Coordination



tribute policy directives to requirements offices in the services (detailed in Chapter Four), noting the necessity to include interoperability in training-simulator requirements documentation. With its view of the joint community, JS J7 would support these directives with data, information, and expertise regarding the details of what these requirements should include.

Concurrently, to provide a positive incentive (the "carrot"), USD(A&S) should provide funding to the acquisition offices within the services (detailed in Chapter Five) that is dedicated strictly to addressing the imposed requirements. With support from the individual M&S offices across the services, DMSCO would support this effort with expertise and information concerning available capabilities, simulator systems, networks, data standards, and more. As noted earlier, JITC would be responsible for verifying that new systems are, in fact, interoperable.

Technology Development

Although the most-impactful steps for improving collaboration concern incentives, policy, and management, there are also areas of technology development that could help support improved collaboration and interoperability. Although thoroughly cross-walking the state of the art with joint training needs is reserved for future work, the following broad recommendations are provided to both DoD acquisition and industry in general, to help support interoperability:

12. **USD(A&S) should focus future acquisition programs** not just on simulators but **on supporting capabilities**, including data standards, gaming technology, and security considerations. USD(A&S) should establish, expand, or leverage existing competitive acquisition processes to define, solicit, innovate, and develop solutions specifically for distributed joint training engineering problems. This could also include workforce development, training, and education initiatives.
    a. **USD(A&S) should leverage methods from distributed systems and high-performance computing disciplines.** It should view cross-service, collective simulator training

as a highly distributed network of heterogeneous computing resources. When collective simulator training is viewed through this lens, there is significant precedent to draw from with respect to currently available supporting capabilities.

b. **USD(A&S) should leverage advanced networking concepts** to reduce latency and improve communication goals or develop new networks from first principles for the joint training problem space.

13. **DASD(FE&T) should advocate for establishment of technology readiness levels and standards for interoperability and joint simulator training exercises.** These should be specified in system technical requirements during acquisitions and in contracts. Some work has been done in the Army to address interoperability readiness on a high level,[3] and additional work is needed with regard to actual simulators.

Interfacing with Industry

Contractual incentives were discussed in detail in Chapter Seven as a primary interface between DoD and industry. What follows are additional considerations for DoD in general to strengthen the link between industry efforts and DoD needs:

14. **DoD should pay developers enough to make it worth the while: Financial incentives need to be large enough to overcome the opportunity cost of not implementing open standards and relinquishing data rights.** Although this could be significantly more than the material and labor cost of implementing the feature, especially given the autonomy that services have when addressing Tier 3 and Tier 4 training needs, it could help foster interoperability and reduce overall DoD costs in the long term.

a. **DoD should consider nonmonetary incentives for joint simulators.** Some monetary incentives can have nonmon-

---

[3] Aaron Hill, Richard Kurasiewicz, and Craig Hayes, "The Army Interoperability Measurement System: AIMS," *News from the Front*, April 8, 2020.

etary disincentives, such as increased bureaucratic restrictions. Some existing nonmonetary incentives (notably the joint Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities, and Policy [DOTMLPF-P] change request [DCR] in the JCIDS process) incentivize selling similar or identical simulators to multiple services.

b. Any attempt to improve the development of interoperable SBT systems must **consider both positive and negative incentives with application to both government program offices and industry contractors.**

Marketplace for DoD-Industry Coordination

Regarding coordination between DoD and industry,

15. **OSD (with input from DASD[FE&T]) should take the lead in implementing an accessible and efficient marketplace and process to bring together industry and DoD.** As discussed throughout the report, transparency and communication are critical for coordination. With respect to aligning industry developments with DoD needs, a key recommendation involves improved communication and collaboration between the services who need simulators (the "buyers") and the builders, providers, and maintainers of the simulators (the "sellers"). To facilitate this improved communication, we recommend creating a new marketplace, the details of which are as follows.

Currently, there is limited consistent and organized communication between the DoD community as "buyers" and the industry community as "sellers." Each simulator buyer is acting as an individual, seeking to optimize its own outcomes, independent of possible benefits to other buyers. Buyers, within and across services, are generally not organized, integrated, or incentivized to acquire SBT that is jointly interoperable.

A robust marketplace connects buyers and sellers by providing access to information for all, making the market more efficient, which aligns with our overall recommendation concerning the necessary increase in transparency. Buyers get greater choice in what they seek to buy, and sellers get a variety of customers to sell to. The Army's Technology Integration Facility, in Orlando, Florida, provides a step in this direction,[4] but there is a need for a more broadly accessible marketplace. Various conferences provide opportunities for communication, but they are by no means comprehensive in this role.

It is of note that integrated data across branches do not exist on total number of contracts for SBT and simulation-based services and on total number of providers of those systems and services. However, it is clear from attending trade shows and having discussions with both buyers and sellers at these events that the current DoD SBT marketplace consists of many different buyers and sellers of different sizes and capabilities. It is also clear from these discussions that buyers generally only access a subset of the sellers based on the limited contacts known by the buyers. Furthermore, sellers do not have open access to buyers until a contract is put up for bid, and, by that time, the buyer and seller, often working based on an existing relationship, have defined the requirements. Without organization, integration, and incentives, each buyer will continue to maximize the value of its acquisition for the targeted service-specific or even platform-specific training audience.

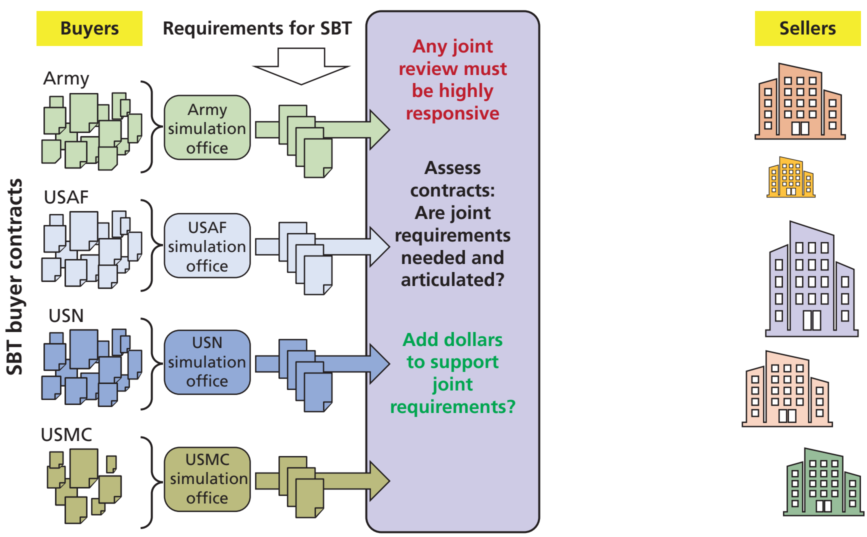
Adding the role of aggregating and integrating the disparate simulator needs of each service to the services' M&S could provide a better-articulated statement of current demand signal for interoperability of simulations, both for current or near-term acquisitions and for future acquisitions. M&S offices could provide these informed demand signals for interoperability to other services as well as to the sellers of systems. Such a communication of current and future demands could take place annually at a major event, such as I/ITSEC. It is probable that such communication of current and future demand signals for interoperability is being communicated between branches via informal channels between M&S offices and between specific customers and specific sellers. However, such informal communications cannot fulfill the information needs of the full market of buyers and sellers to ensure

[4] "Army Team Seeks Collaboration to Develop Current, Future Training Solutions," *SeriousPlayWire*, 2020; and Sean Kimmons, "Army Looks to Better Attract Gaming Industry for Training Simulations," Army News Service, July 14, 2020.

a robust market. For M&S offices to play this role would require minimal additional resources but could have significant impact.

Better understanding of the current and future demands for interoperability informs the joint simulator marketplace, but it does not ensure that contracts from services will be appropriately screened for incorporating interoperability.[5] Figure 9.2 provides a graphical representation for how M&S offices confirm the need for interoperability as a requirement. Then, a joint OSD-level entity could screen contracts to ensure that the designation of requiring or not requiring joint interoperability and the associated cost-effectiveness of such an investment are sound. If the joint entity agrees with the initial assessments, and if joint interoperability is, in fact, warranted, then the joint entity can determine whether extra, joint dollars should be added to help

Figure 9.2
A Joint Entity Assesses Needs for Joint Interoperability and Potentially Provides Funds to Support It

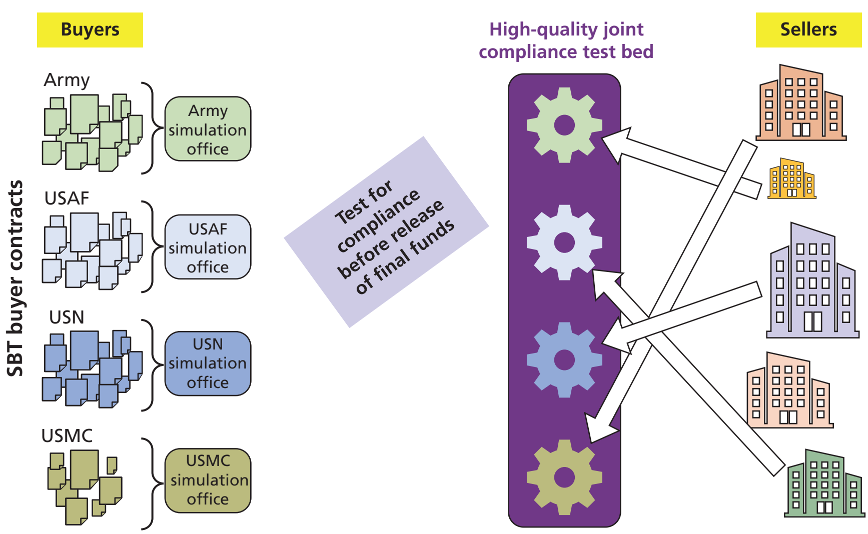


5 Note, again, that not all simulators require interoperability and only those that do require these capabilities should be reviewed and assessed for the cost-effectiveness of adding such features to the contract.

support development of the aspects of interoperability, as suggested in Figure 9.1. Such a joint review process must be resourced appropriately to provide rapid and responsive reviews and avoid significantly slowing the overall acquisition process.

Once a buyer has provided its simulator requirements, sellers have responded, and a contract has been awarded, development work begins on the simulator. A key aspect of evaluating the products delivered by the seller is testing to ensure that the aspects of joint interoperability that were required in the contract are provided by the seller. In the current market, there are few, if any, "test beds" or evaluation tools to ensure that, for example, simulator code appropriately includes specific requirements for access by simulations in a joint federation of models. Such evaluation systems and tools are critical to ensure that sellers meet requirements. Both the developers and the users should test often and test early, not just after development is complete. Figure 9.3 shows a role for a set of evaluation tools, or test beds, for testing compliance with joint interoperability requirements. Sellers would access this unbiased test bed, test their products, and provide results to the buyer to

Figure 9.3
Requirements Specified in Contracts Must Have Unbiased Evaluation Tools



ensure compliance with joint interoperability requirements. Ideally, they could use such testing capabilities independently, perhaps even before offering their capabilities or product to the government. As suggested earlier, JITC could oversee this aspect of the market. Only after all compliance checks had been passed would funds for the acquisition be released to the seller.

Opportunities for USD(P&R) and DASD(FE&T)

Some of the recommendations listed earlier can be addressed in some capacity using current DASD(FE&T) policy levers, which are grouped in terms of policy development, policy oversight, resource direction, and resource influence. Although some recommendations provide longer-term goals, those listed in Table 9.2 represent actions that USD(P&R) and DASD(FE&T) can pursue, support, or advocate for in the near term. Note that although the M&S Steering Committee is not necessarily as active as it used to be, it provides a necessary forum for executing some of the recommendations in this report.

Future Work

Although this report lays out recommendations for DoD to improve interservice and intraservice coordination, it also provides a platform from which to derive a roadmap for the training-simulator industrial community. Should the opportunity to expand the scope of our study arise, there is a need to cross-walk anticipated technology growth and anticipated training needs, resulting in a gap analysis to support future industry plans. As noted, lack of clarity of needs and coordination of capabilities (and transparency of such information) within DoD can be a significant roadblock for improved coordination. Such clarifications also must be communicated to industry, such that their efforts align with DoD needs rather than respond to internal (within-industry vendors') developmental opportunities. Any unmet needs (gaps) should be compared with currently available or future simulator or simulation technologies.

Table 9.2
Policy Levers for DASD(FE&T) and Viable Near-Term Recommendations

Study Recommendation	Lever	Description	Relevant Action	Sources	DASD(FE&T) Role
13	Policy development	Writing new policy for DoD	Develop and write DoD policy outlining USD(P&R) and/or DASD(FE&T) role(s) in training aspects of M&S	"USD(P&R) shall represent the DoD Training Community on the M&S [Steering Committee]" (DoD 5000.59, p. 3)	Advocate for development of new policy for establishing technology readiness
15					Support OSD in the development of training-simulator "marketplace"
2	Policy oversight	How services approach issues	Oversee and provide policy for individual military training programs for the total force	USD(P&R) has a key role in military training policy (DoDD 1322.18); SSG for simulator interoperability	Advocate to USD(R&E) for DMSCO oversight to the service M&S offices
6					Help services coordinate around common conceptual models, identify common interoperability requirements
None	Resource direction	Spending and directing funding	Provide financial incentives	USD(R&E) is the M&S Coordination Agent and the M&S Executive Agent (DoDD 5000.59; doctrine still reflects USD[AT&L] prior reorganization)	No direct role: DASD(FE&T) does not currently have financial resources to incentivize
1	Resource influence	Roles in significant groups and councils	Provide direct input into service training commands' leadership and policy	DASD(FE&T) oversees director for ADL and the Defense ADL Advisory Committee (a body of services' training commands and Joint Staff stakeholders)	Advocate for financial incentives for services to formalize their coordinating centralized organization
14					Advocate for financial incentives for industry use of open standards

SOURCE: DoDD 1322.18, *Military Training*, Washington, D.C.: U.S. Department of Defense, January 13, 2009, Incorporating Change 1, February 23, 2017; and DoDD 5000.59, 2018.

APPENDIX A

Organizational Charts for the Services and the Joint Staff

The following material represents raw data in the form of a framework for tracking lines of communication and governance within each service. Figures A.1 through A.5 provide detailed organizational charts for each service and for the Joint Staff. Key abbreviations for these figures are defined as follows:

- ALSA = Air Land Sea Application
- AWACS = Airborne Warning and Control System
- CCTT = Close Combat Tactical Trainer
- CFT = cross-functional team
- CNO = Chief of Naval Operations
- DASN = Deputy Assistant Secretary of the Navy
- DCS = Deputy Chief of Staff
- Dir. = Directorate
- FMS = foreign military sales
- HPW = Human Performance Wing
- ITE = integrated training environment
- JLCCTC = Joint Land Component Constructive Training Capability
- JTLS = Joint Theater Level Simulation
- JTS = Joint Tactics Squadron
- LVC-IA = live virtual, constructive integrating architecture
- MCSTE = Marine Corps Synthetic Training Environment
- MTS = Mobility Training Squadron

- PD = product director
- PdM = product manager
- PDSS = postdeployment system software
- prog. = program
- SAF/AQR = Associate Deputy Assistant Secretary of the Air Force for Science, Technology, and Engineering
- Sim. = simulator
- TCM = TRADOC Capability Manager.

Organizations are identified that focus on requirements, acquisition, and/or sustainment of training simulators. Organizations with current or potential coordinating roles *within* the service are also identified, as are organizations with current or potential *external* coordinating roles. The latter entails communication and coordination with other services and with JS J7. The figures indicate internal or external coordinating functions based on responsibilities specified in policy. Bodies that engage in cross-service coordination in practice but not in policy are indicated as internal coordinating bodies.

Figure A.1
Organizational Chart for the U.S. Army

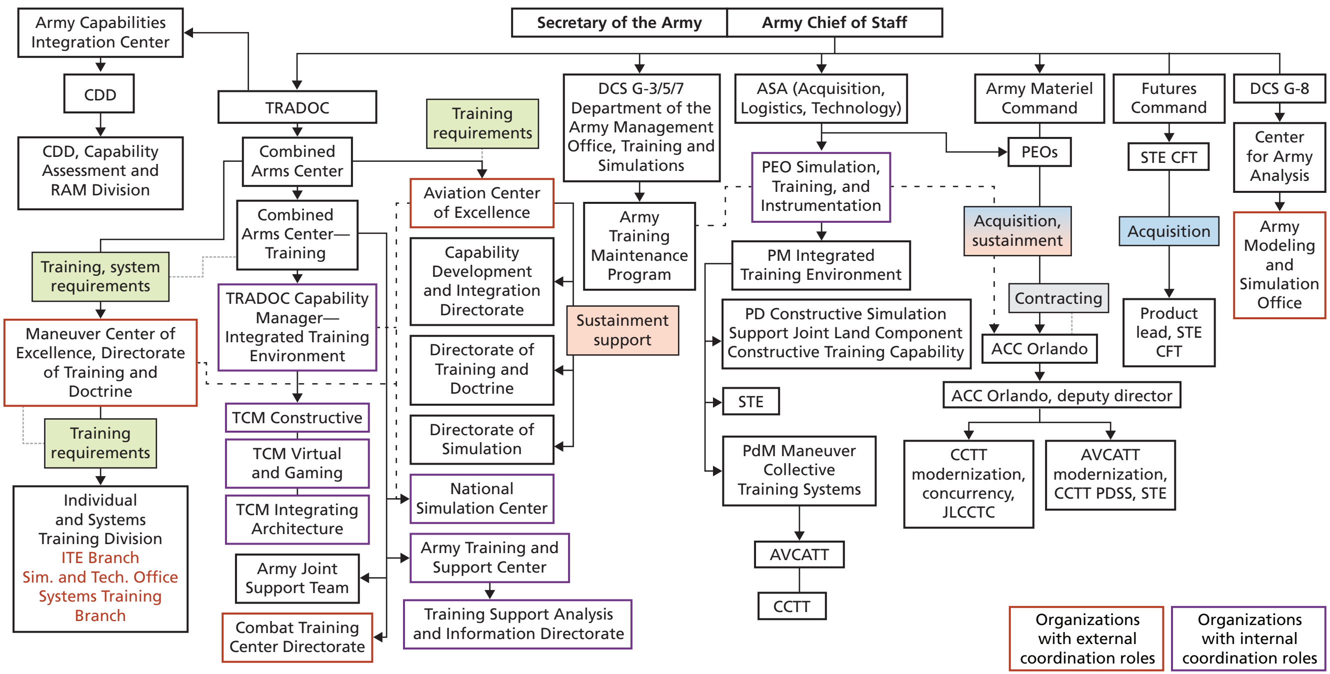


Figure A.2
Organizational Chart for the U.S. Air Force

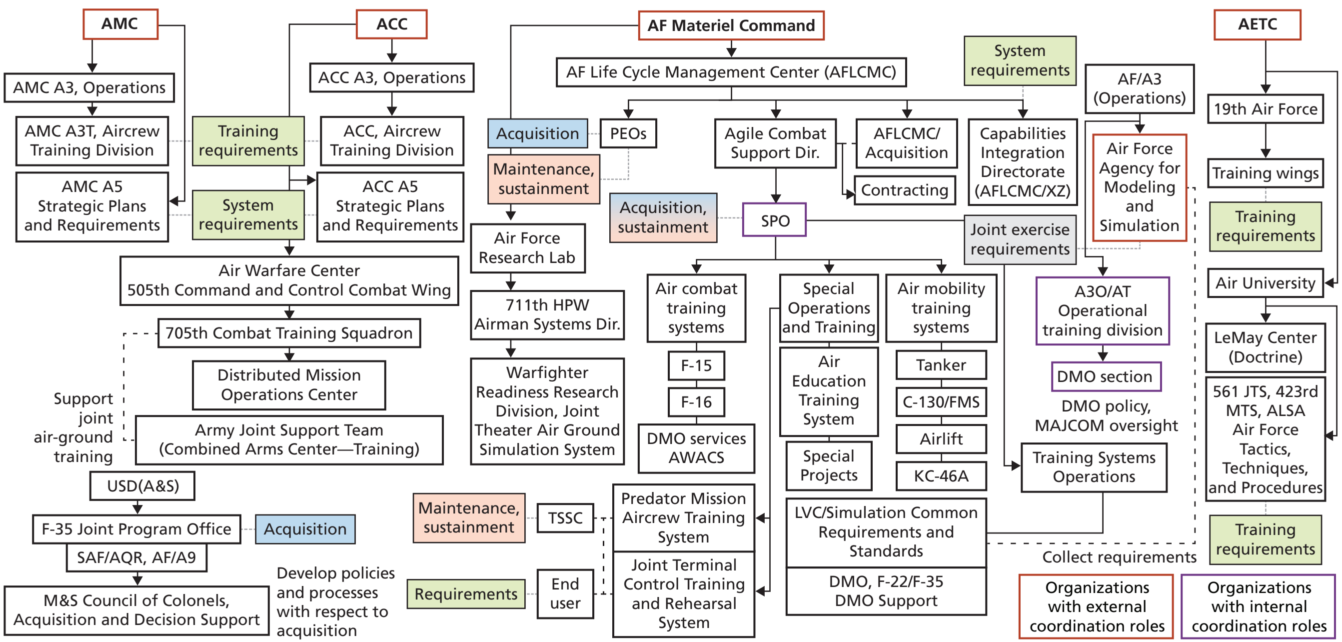


Figure A.3
Organizational Chart for the U.S. Navy

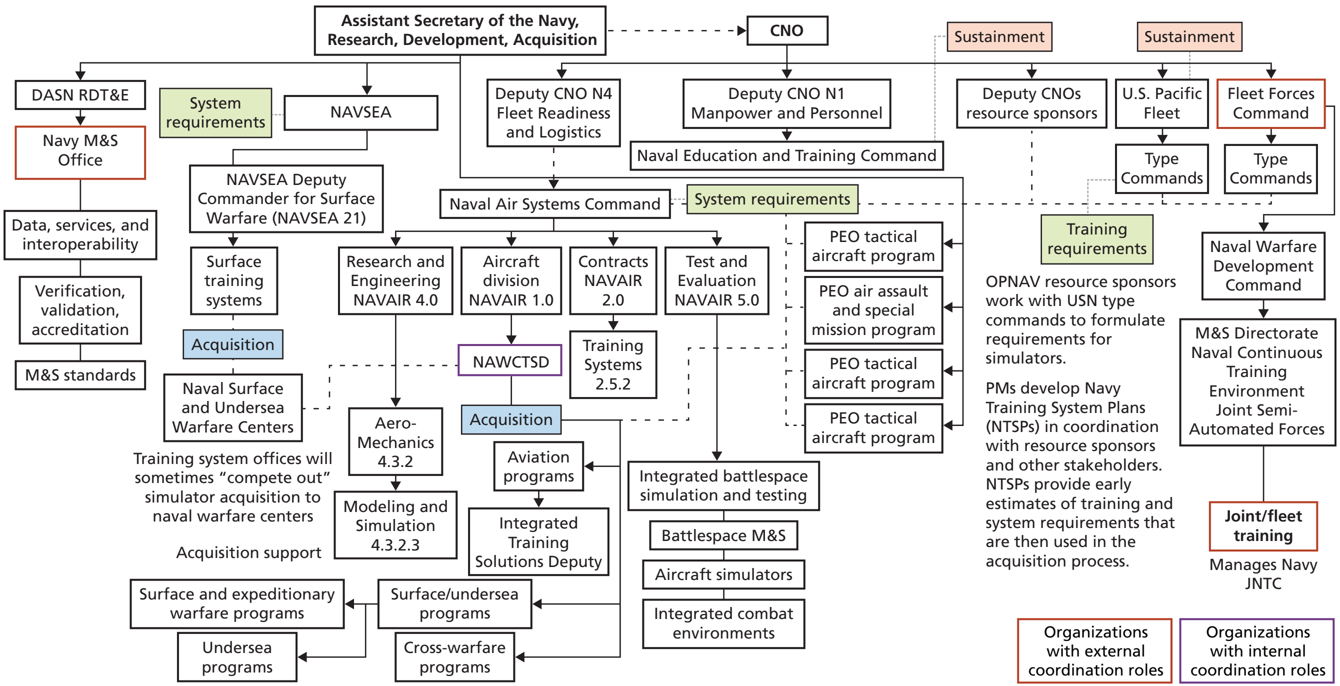


Figure A.4
Organizational Chart for the U.S. Marine Corps

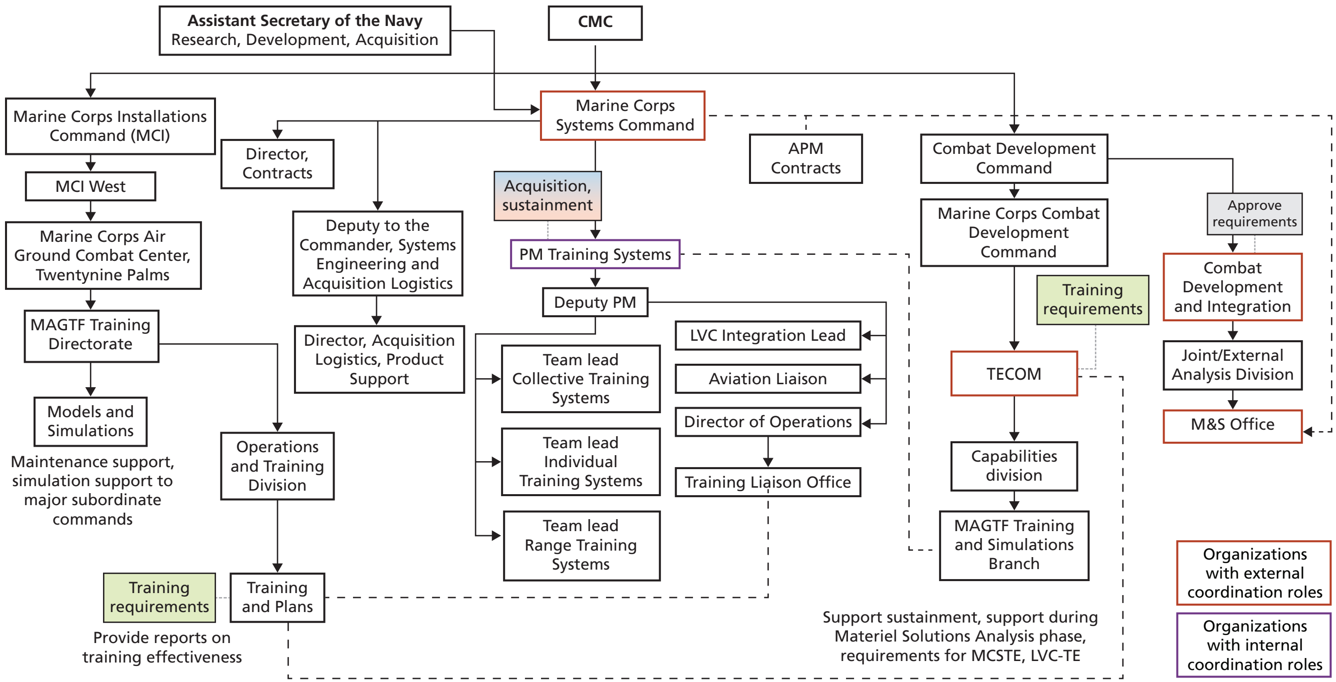
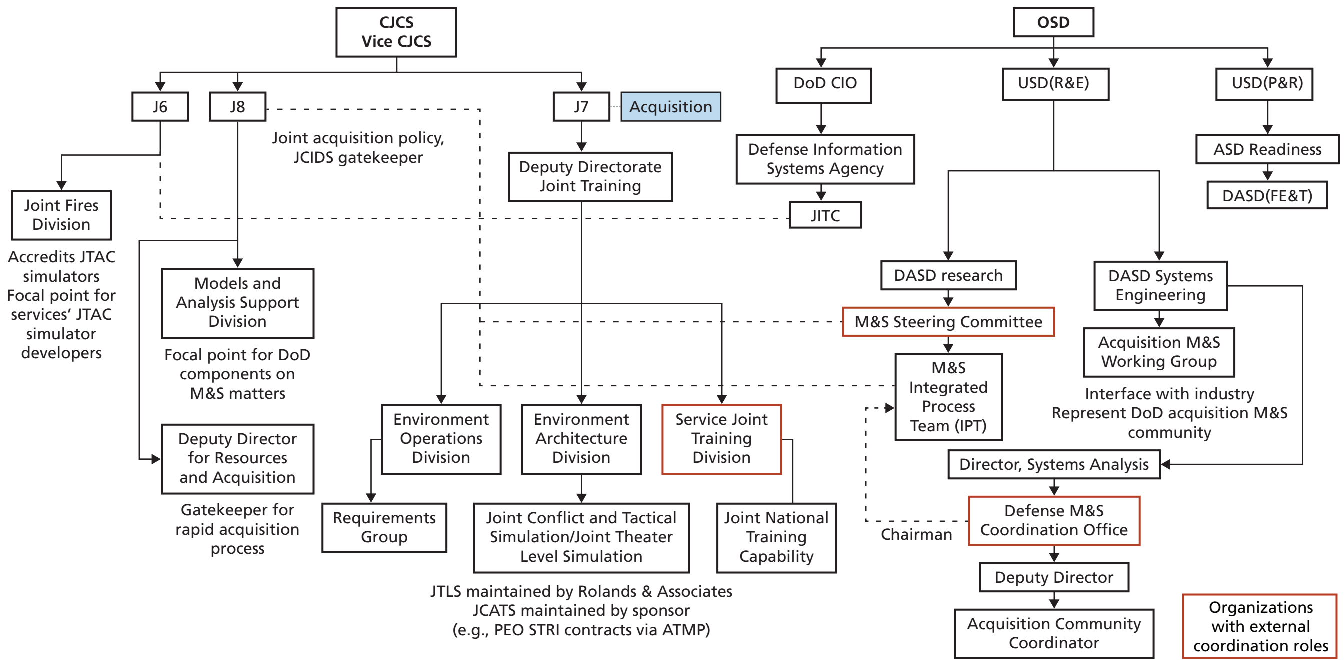


Figure A.5
Organizational Chart for the Joint Staff and DoD



APPENDIX B

Documents Reviewed to Map Requirements Processes for Each Service

We conducted a literature review of each service's M&S and training requirements doctrine. The documents that we reviewed are listed in Table B.1. Green shading is used for Army documents, light blue for USAF documents, red for USN or USMC documents, dark blue for OSD documents, and purple for RAND documents.

Table B.1
Documents Reviewed to Map Requirements Processes for Each Service

Document Number	Title	Publication Date
AR 5-11	*Management of Army Modeling and Simulation*	May 2014
AR 71-9	*Warfighting Capabilities Determination*	December 2009
AR 95-1	*Flight Regulations*	March 2018
AR 350-38	*Policies and Management for Training Aids, Devices, Simulators, and Simulations*	February 2018
DA PAM 5-11	*Verification, Validation, and Accreditation of Army Models and Simulations*	September 1999
TC 3-04.11	*Commander's Aviation Training and Standardization Program*	August 2016
AETCI 11-203	*Flying Training Simulator Instructor Programs*	November 2017
AFD-100930-038	*Air Force Modeling and Simulation Vision for the 21st Century*	July 2010
AFI 11-200	*Aircrew Training, Standardization/Evaluation, and General Operations Structure*	September 2018
AFI 11-2FTV1	*Flight Test Aircrew Training*	February 2017
AFI 36-2251	*Management of Air Force Training Systems*	June 2009
GTSIP	*Marine Corps Ground Training Simulations Implementation Plan*	June 2017
MCO 5200.28	*Marine Corps Modeling & Simulation Management*	April 2008
SECNAVINST 5200.38A	*Department of the Navy Modeling and Simulation Management*	February 2002
SECNAVINST 5200.46	*Department of the Navy Modeling, Simulation, Verification, Validation, and Accreditation Management*	March 2019
CJCS Guide 3501	*Joint Training System: A Guide for Senior Leaders*	May 2015
CJCSI 6212.01E	*Interoperability and Supportability of Information Technology and National Security Systems*	December 2008
CJCSI 6212.01F	*Net Ready Key Performance Parameter (NS KPP)*	March 2012

Table B.1—Continued

Document Number	Title	Publication Date
CJCSM 3500.03E	*Joint Training Manual for the Armed Forces of the United States*	April 2015
CJCSM 3511.01	*Joint Training Resources for the Armed Forces of the United States*	May 2015
DoDD 1322.18	*Military Training*	February 2017
DoDD 5000.59	*DoD Modeling and Simulation (M&S) Management*	October 2018
DoDD 5124.02	*Under Secretary of Defense for Personnel and Readiness (USD(P&R))*	June 2008
DoDD 5134.01	*Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L))*	December 2005
DoDI 1025.02	*National Security Education Program (NSEP) and NSEP Service Agreement*	January 2017
DoDI 1322.26	*Distributed Learning (DL)*	October 2017
DoDI 5000.70	*Management of DoD Modeling and Simulation (M&S) Activities*	October 2018
DoDI 8330.01	*Interoperability of Information Technology (IT), Including National Security Systems (NSS)*	May 2014
N/A	*Fidelity Requirements for Army Aviation Training Devices Issues and Answers*	2008
N/A	*Training System Device Certification and Qualification Process*	September 2013
N/A	*Report to Congress Restructuring the Department of Defense Acquisition, Technology and Logistics Organization and Chief Management Officer Organization*	August 2017
N/A	"CE2T2 Program Execution Plan FY19"	October 2018b
MG-442-OSD	*Implementing and Evaluating an Innovative Approach to Simulation Training Acquisitions*	2006
MG-765-NAVY	*An Examination of Options to Reduce Underway Training Days Through the Use of Simulation*	2008

Table B.1—Continued

Document Number	Title	Publication Date
MG-874-NAVY	*DDG-51 Engineering Training: How Simulators Can Help*	2009
PE-301-A/AF	*Shared Problems: The Lessons of AirLand Battle and the 31 Initiatives for Multi-Domain Battle*	2018
N/A	*Fifth-Generation Aircraft Operational Training Infrastructure: Practices, Gaps, and Proposed Solutions*	2018
RB-9166-OSD	*Acquiring Simulation Training: Evaluating and Implementing an Innovative Approach*	2006
RR-2250-A	*Collective Simulation-Based Training in the U.S. Army: User Interface Fidelity, Costs, and Training Effectiveness*	2019

NOTE: AETCI = Air Education and Training Command Instruction; DA PAM = Department of the Army Pamphlet; NA = not applicable; TC = Training Circular.

APPENDIX C

Acquisition Process and Stakeholders for the Services

Figures C.1–C.4 depict, in rough form, the organizations responsible for the major muscle movements of simulator acquisition by each service. The organizations with central responsibilities are arranged vertically by the stage of the acquisition process in which they are most involved. These steps are roughly aligned with the milestones in the JCIDS process. The pre-acquisition phase is when requirements are determined and transitioned to the acquisition office. System development takes place during the acquisition phase, after which the system enters the operations-and-sustainment phase.

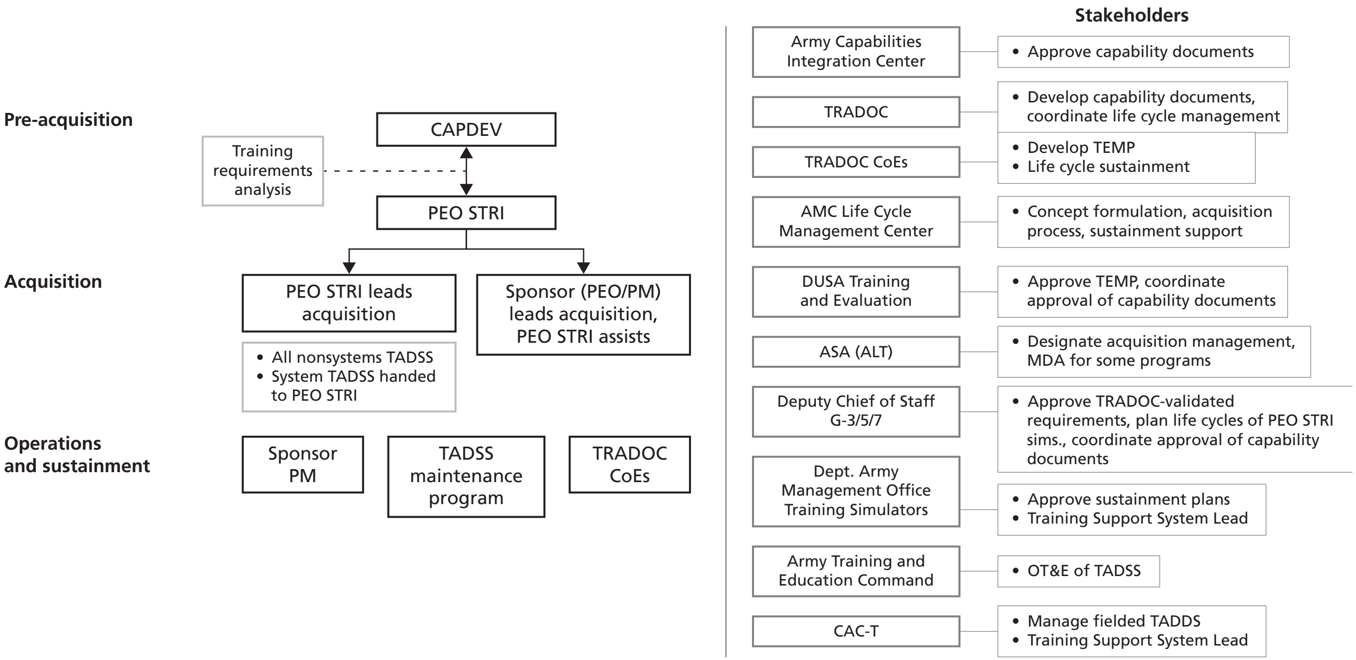
In the Army (Figure C.1), requirements are formed by a capability developer in consultation with PEO STRI in the pre-acquisition process. PEO STRI or the PEO developing the capability can lead the acquisition, after which various options are available for sustainment. Compared with the other services, the Army has the most-extensive formalized involvement of its training command (TRADOC CoEs and Capability Managers) in the setting of simulator requirements. There is also flexibility in where simulators are acquired—either in system PEOs or PEO-STRI.

Simulators in USAF (Figure C.2) are largely acquired by PEOs (lead commands), although the SPO in Agile Combat Support can acquire some system simulators. The PEOs tend to acquire simulators that are not specific to a platform (i.e., nonsystem simulators). Lead commands are supposed to work with the SPO to define requirements in a Training Systems Requirements Analysis. The SPO inherits simulators from PEOs for sustainment. USAF has the most structured process for the sustainment of simulators. With this process, the SPO inherits responsibility for most simulators after acquisition.

For USN, the simplicity of Figure C.3 belies the complexity and optionality of USN's simulator development. A variety of resource sponsors in OPNAV can work with TYCOMs to formulate requirements. Many organizations can serve as training support agencies, which acquire simulators, or training agencies, which inherit training systems for sustainment. Of the services, USN has the most fragmented set of organizations that participate in the acquisition of simulators. Although NAVAIR's Training System Division is the most centralized hub for simulator acquisition and coordination in USN, NAVSEA and the Surface and Undersea Warfare Centers can also do simulator acquisition. USN has, in essence, an internal process by which requirements for a simulator can be "competed" to different offices with the capacity to perform development.

USMC's transition from capability gap analysis through acquisition and sustainment is streamlined, funneling through SYSCOM (Figure C.4). USMC has a highly formalized process for transitioning requirements to the acquisition arm. Of the services, USMC has the most centralized process by far.

Figure C.1
Acquisition Timeline for the U.S. Army



NOTE: ALT = Acquisitions, Logistics, and Technology; CAPDEV = capability developer; DUSA = Deputy Under Secretary of the Army; OT&E = Operational Test and Evaluation; TADSS = training aids, devices, simulations, and simulators; TEMP = test and evaluation master plan.

Figure C.2
Acquisition Timeline for the U.S. Air Force

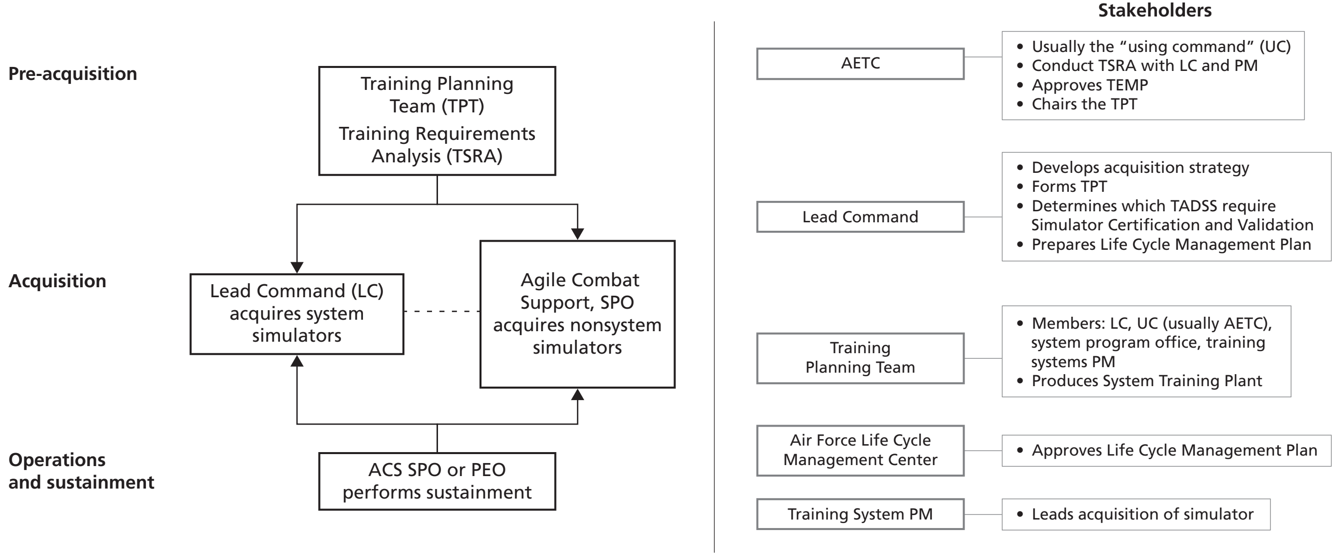


Figure C.3
Acquisition Timeline for the U.S. Navy

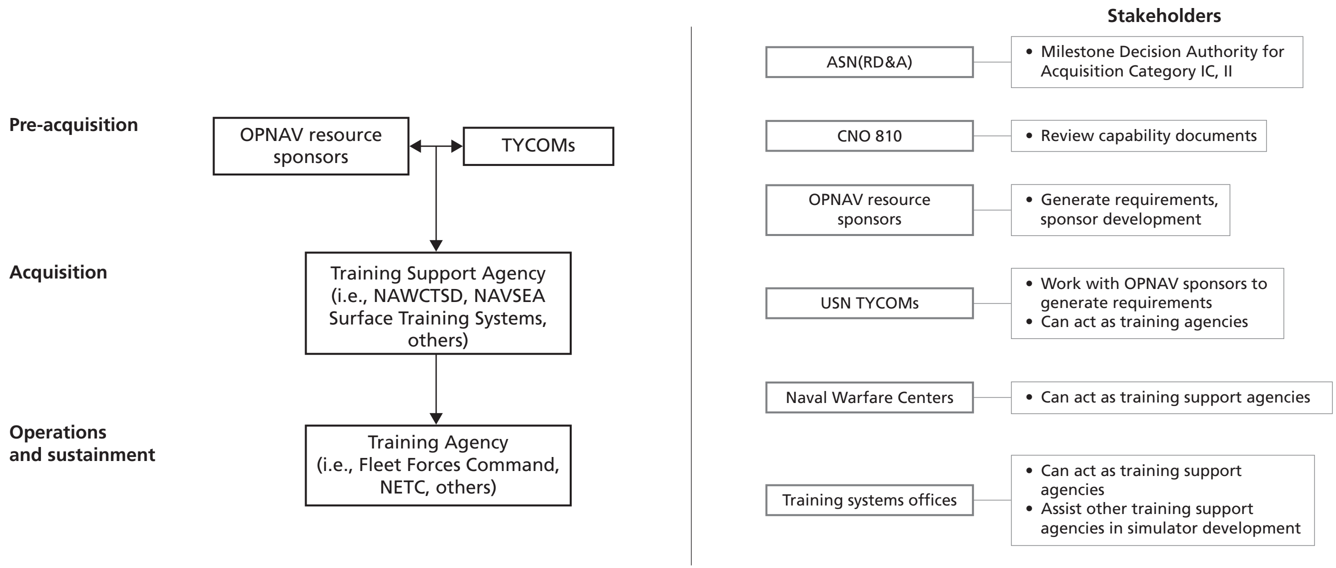
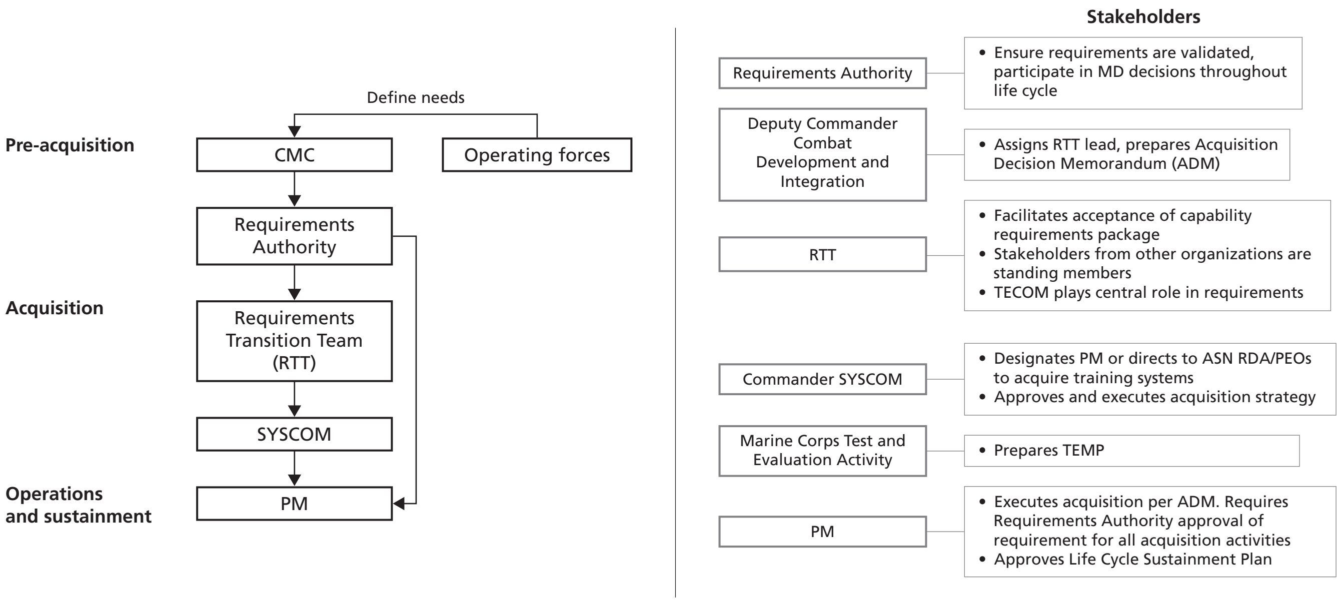


Figure C.4
Acquisition Timeline for the U.S. Marine Corps



APPENDIX D

Training Process

This appendix provides an overview of how joint training exercises are planned and executed through JTS; summarizes JNTC, which provides a system of joint training sites; and reviews JCIDS as it pertains to training simulators. This background ultimately provides a context for joint simulator use in that JNTC provides simulator capabilities that are used within JTS, and, as part of JTS, any gaps in simulator capabilities are identified and addressed via the JCIDS acquisition process.

Joint Training System

JTS is a four-phase process for planning, executing, and assessing joint training based on the requirements of CCMDs, campaign plans, and various other sources. Although each subsequent phase of the JTS process takes input from the previous phase, at any given point in time, multiple actions can be ongoing in different phases of the process. For example, the planning of future training events often takes place while other training events are taking place. The four phases of JTS are, in order, requirements, planning, execution, and assessment. These phases are summarized in Figure D.1.

The primary objectives of the **requirements phase** are to create a Joint Mission Essential Task List (JMETL) and to create the standards and conditions by which these tasks will be evaluated. This process starts by performing mission analysis directed by a combatant commander (CCMDR). From this mission analysis, a set of command METs will be selected from UJTL and organized into the command

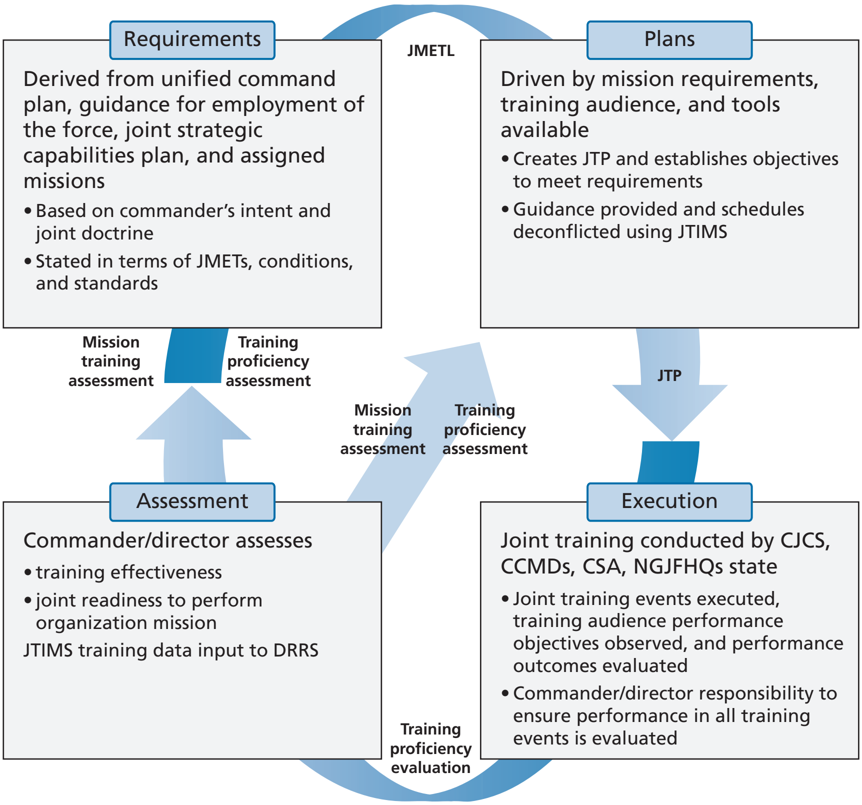
JMETL. After the initial list is created, the conditions and standards by which these tasks will be judged need to be decided. Each MET must also be allocated to different organizations to determine who is responsible for, and, by extension, who must train for, each individual task. Once these standards and distributions are decided, it might become apparent that various supporting tasks will be required to perform the METs at the required level. These supporting tasks also need to be listed and distributed. In addition to creating a JMETL, the requirements phase involves identifying joint force development–related projects, such as mature joint concepts and joint tests, for integration into joint training. Once this is completed, the finalized JMETL can be passed on to the planning phase of the JTS process.

The primary objective of the **planning phase** is to produce a Joint Training Plan (JTP) and associated component training plans.[1] JTP is a plan that documents the execution-level implementation of the joint training strategy for the training audience, and CCMDs update it annually. Component training plans are similar to JTP in that they document the execution level of the joint training strategy, but they differ in the fact that they are intended for service components rather than the CCMD as a whole. The planning phase starts with an assessment of the current capabilities of a CCMD with respect to the tasks and standards laid out by JMETL produced in the requirements phase. This assessment should reveal what capability gaps exist between the current capabilities of the CCMD and the standards laid out in JMETL. Once the gaps are identified, it must be determined who requires training to address these capability gaps and what the exact objectives of the training are. Then, the training design and scheduling process begins. This involves identifying the method of training, which typically includes some combination of academic and exercise components, and the individual training events themselves. For each training event, the estimated required resources, schedule, target audience, and tier are identified. Once all of these factors have been identified, they are recorded in the Joint Training Information Management System (JTIMS) and approved by the CCMDR. Although not

---

[1] CJCSI 3500.01H, 2014.

Figure D.1
Joint Training System



SOURCE: Adapted from CJCSM 3500.03E.
NOTE: NGJFHQ = National Guard's Joint Force Headquarters.

explicitly outlined by the JCIDS process, this phase also involves coordinating with different U.S. agencies, foreign partners, and nongovernmental organizations to ensure that the events involving them also meet their training needs and conform to their schedules. After JTP is approved, the CCMD moves on to the execution phase of the JTS process.

The primary purpose of the **execution phase** of JTS is to execute the training events laid out in JTP. This phase starts at the beginning of the fiscal year and ends when the final training event of the year is completed. The first step of this phase entails finalizing the resource allocations, schedule, and general planning of each individual training event. This is largely done through the Joint Event Life Cycle (JELC) process. JELC, a process internal to the execution phase, has five phases that each individual training event goes through: design, planning, preparation, execution, and evaluation.

JELC does not involve a strict ordering of what efforts must take place for a training event to occur. Rather, it is a set of guidelines for ensuring that planners have a comprehensive plan for executing events. Although JELC resides within the execution phase of JTS, each individual event has its own JELC timeline that can overlap with the other phases of JTS.

The *design phase* (of the JTS execution phase) is primarily concerned with determining the target training audience, training objectives, and mode or media of training for a specific training event. The training objectives, and often, by extension, the training audience, are determined by the guidance laid out in the requirements phase of JTS when JMETL is created and in the planning phase of JTS, when it is determined what organizations should be required to perform these tasks. The *mode* of a training event refers to the broad type of training, either academic or exercise based. The *media* of an event refers to the types of tools and expertise that will be required for the event, such as simulators or lectures. Once these determinations have been made, planners can proceed onto the planning phase of JELC.

The *planning phase* (of the JTS execution phase) is concerned with refining the concepts put forward in the design phase, drafting the exercise directive, and developing supporting plans for the mode and media of the event. This involves identifying the logistics requirements of the training event and any prescripted events that will need to take place during the training. Furthermore, the general structure of the training event is decided on and written down in a Joint Master Scenario Event List for use in the subsequent stages of the event. The exercise directive is basically an information packet for event participants. It includes exercise goals, objectives, and conduct. It also can have support or technical plans relating to the exercise. Once the general plans have been laid, planners can move onto the preparation phase of JELC.

The purposes of the *preparation phase* (of the JTS execution phase) are to update plans, prepare for the logistical requirements of the event, and have the event staff rehearse their roles. This phase involves executing all of the plans laid out in the previous phases that are not directly involved in the event itself. This can include a variety of tasks, such as booking space, finalizing travel plans, or finalizing presentations. This phase ends when the training event begins.

The *execution phase* (of the JTS execution phase) is concerned with completing the training event, but also with collecting data, feedback, and lessons learned. Once the event is concluded, the evaluation phase begins.

The *evaluation phase* (of the JTS execution phase) is concerned with condensing and analyzing the data and feedback from the execution phase. This generally begins with an after-action review to provide a first look at how well the training audiences achieved their training objectives. Beyond this, additional analysis can be done to determine exactly at what level of proficiency the training audience performed and whether that satisfies the requirements. If the task was not performed to the specified standard, a DOTMLPF-P category is identified as the reason for the shortfall and a potential way of mitigating the gap. Broader analysis is performed in the assessment phase of JTS.

The primary objective of the **assessment phase** of JTS is to determine which tasks are performed to the standards set for them in the requirements phase. This differs from the evaluation phase of the JELC in that, while the evaluation phase is concerned predominantly with gathering and evaluating information about the performance of individual units at individual tasks, the assessment phase is focused more on assessing the overall changes in capabilities that have resulted from the training, determining what changes might need to be made to meet these requirements if they were not fulfilled, and recording the overall lessons learned from the year's training events. Ultimately, each mission is rated trained, untrained, or partially trained, and the specifics of these ratings are used to inform what training exercises need to be planned to fill these training gaps.

The services factor into JTS in a few ways. First, the service component training plans are developed alongside JTP either for tasks that need to be performed exclusively within one service or for individual-level training. Second, the services often play an advisory role to CCMDRs throughout JTS. Third, individual task–level interoperability (such as air-to-air refueling between planes of different services) is a service component–level responsibility. Finally, there is necessarily an interplay between service-level training (which is exclusively the domain of individual services) and joint training (which is the responsibility of both individual services and CCMDs).

SBT specifically ties into the second and third phases of JTS. The second phase (the planning phase) is the phase in which the method, mode, and media of the training are selected, and SBT exists within the exercise method and the simulator mode. The third phase of JTS (the execution phase) is the phase in which the gaps found in the assessment portion can be used to justify DOTMLPF-P changes for the acquisition of additional training simulators as described in the JCIDS section of this report.

JNTC

JNTC is a system of simulator training sites built specifically to support JTS. It is a collection of interoperable sites meant to enhance the ability of CCMDRs and services to train within a joint context. It is administered by JS J7 and is meant to integrate into JTS by providing a standardized environment for planning, executing, and evaluating training events. JS J7 supports and accredits service-administered joint training events. In general, the simulator capabilities housed within JNTC support the training exercises executed via JTS. As part of JNTC and JTS, there are semiannual Joint Training Coordination Conferences in which the services, JS J7, and SOCOM meet to discuss joint training issues and requirements for their training events.[2]

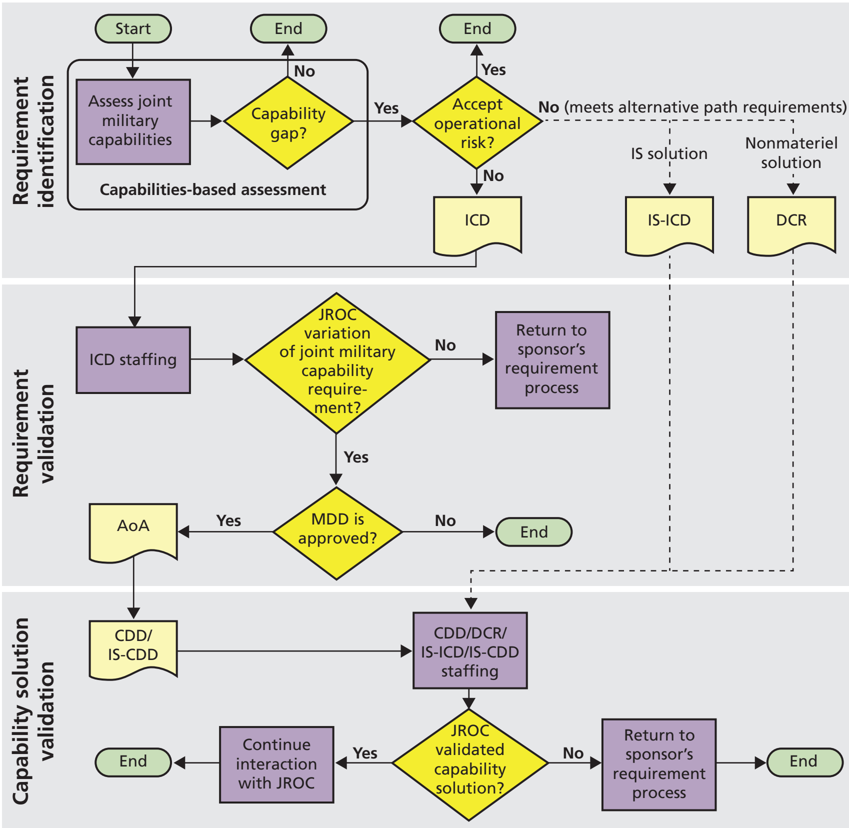
JCIDS

JCIDS is the primary process through which joint acquisitions take place and is illustrated in Figure D.2. The JCIDS process consists of

---

2 CJCSM 3511.01, 2015.

Figure D.2
JCIDS Process



SOURCE: Adapted from Joint Staff J-8, *Manual for the Operation of the Joint Capabilities Integration and Development System*, August 31, 2018.
NOTE: ICD = Initial Capabilities Document; IS-ICD = Information Systems Initial Capabilities Document; MDD = Materiel Development Decision.

three semi-distinct phases: requirements identification, requirements validation, and capability solution validation.

The primary purpose of the **requirements identification phase** is to identify what capability gaps exist within the joint force. The two primary methods of determining these gaps are a DCR and a capabilities-based analysis (CBA).

CBAs are one of the primary methods through which the JCIDS process is initiated. They can be based on a wide variety of experiences, including witnessed operational shortcomings (e.g., gaps identified as part of JTS), perceived future needs, examinations of functional areas or concepts, and needs pertaining to specific mission areas. CBAs consist of gathering background research, defining the problem space, choosing an analysis type, executing the analysis, reviewing the outcomes of the analysis, and obtaining gatekeeper approval to begin the Requirements Validation portion of the JCIDS process. Ultimately, the goals of any given CBA are to identify the gaps in joint capabilities and to determine which of these gaps require action.

The other primary method of beginning the JCIDS process is the production of a DCR. This method is less structured than a CBA because it can be produced from a variety of different sources, including JTS. Regardless, once the request is submitted, it must also be approved by a gatekeeper before it can pass into the Requirements Validation phase. In both cases, J8 normally serves as the gatekeeper.

Most joint simulator acquisition will have to start as a CBA rather than a DCR because the development of new materiel solutions cannot be performed through the latter. Despite this, should an existing simulator already be owned by one of the services, it could, in theory, be acquired and then modified by the rest of the joint force to work in a joint training environment.

The **requirements validation phase** begins when J8 determines that a CBA or a DCR identifies a capability gap, that the capability in question does not exist elsewhere in the joint force, and that the continued existence of the gap proves an unacceptable risk. The ultimate goals of the requirements validation phase are to determine, garner approval for, and perform an analysis of potential ways to fill the capability gap established in the previous phase. Once the capability gap has been established and has been shown to carry significant risk, a decision must be made on which document path through the requirements validation phase is most appropriate. This path determination is based predominantly on whether a materiel solution is necessary and whether an IT solution is necessary. The paths described in this report are not inclusive of all of the available paths in the JCIDS process, just the portion of paths in the deliberate portion of the requirements validation phase that can relate to training simulators.

The ICD path tends to be the most common, involving gaps that require some kind of materiel solution without a currently evident IT solution.

The IS-ICD path is a variant of the ICD path that exists for solutions that require IT solutions. Both the ICD and IS-ICD paths are initiated exclusively by CBAs. The difference between these two paths, beyond the IT solutions portion, is that the IS-ICD proceeds in an expedited manner through the approval process and requires a significantly less intensive AoA to proceed into the capability solution validation phase.

The joint DCR path is for filling capability gaps with nonmateriel solutions or solutions that do not require new materiel. Unlike ICDs and IS-ICDs, joint DCRs are generated by a DCR that can arise out of a variety of sources, including JTS.[3]

For the purpose of acquiring joint training simulators, the IS-ICD and the joint DCR paths are the most important. The IS-ICD path is a likely path for new simulators because most simulators only require novel software components and "off-the-shelf" hardware components. Specifically, the servers, on-site computers, and controllers needed for simulators are likely to be available for purchase without any additional development required. More importantly, the IS-ICD path expedites the approval and AoA portions of the process, since the range of potential alternatives is much smaller than their ICD counterparts. Joint DCRs are also well suited for acquiring simulators so long as the simulators already exist within another portion of the joint force. This allows for the distribution of one service's simulator to be used within other service components of the joint force.

Once an AoA has been completed, the chosen solution can proceed into the final step of the JCIDS process, the **capability solution validation phase**. The objectives of this phase are to finalize the chosen solution to the capability gap and to start the transition into the acquisition system. The only significant deviation from a non-joint

---

[3] Joint Staff J-8, 2018.

acquisition is the requirement that JROC validate the chosen solution before the overall acquisitions process can pass through milestone B, the step between pre-acquisition and acquisition.[4] Note that the AoA mentioned previously aligns with milestone A, which is the milestone between materiel solution analysis and technology maturation and risk reduction.

---

4 Joint Staff J-8, 2018.

APPENDIX E

History of Modeling and Simulation Standards

The existence and the use of data standards are critical for effective interoperability. As background, Figure E.1 shows a partial view of the history of simulation-related standards, emphasizing methods or systems that are in use today or those that represent a technical point of origin for the simulator-related systems. The figure traces key aspects of the technical lineage of simulators in use today.[1]

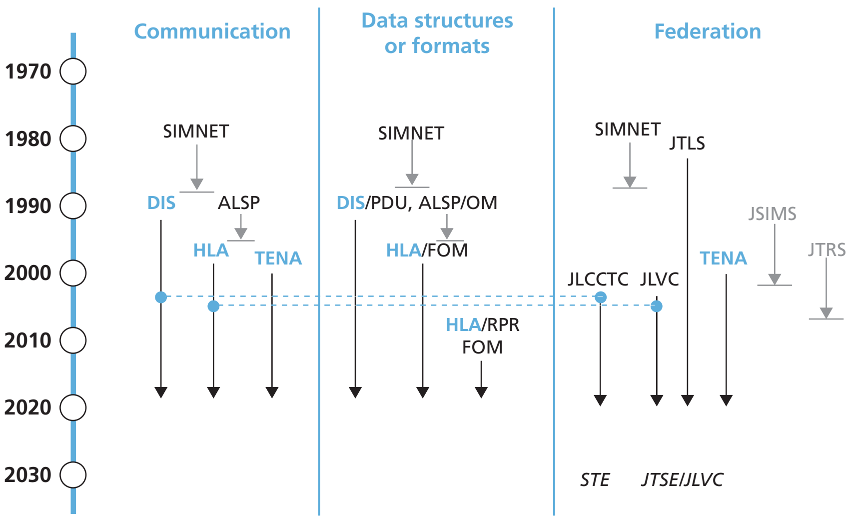
The three columns under the headings of "Communication," "Data structures or formats," and "federations" show how multiple standards have been defined and employed over time to achieve interoperability. Although distinct standards are in use today, the branching pattern for communication protocols and message data formats shows a single, common "ancestor" system originating or directly influencing each method: SIMNET. SIMNET was a DARPA initiative that formally explored, developed, and successfully demonstrated large-scale, real-time team training using tactical simulators over a wide area network.[2] After the SIMNET program ended, new and competing fed-

---

1 The timeline is derived from literature on M&S efforts for DoD training. See, for example, Miller, 2015; and Tolk et al., 2017. A more focused view of the historical relationship and evolution of DIS, HLA, and TENA can be found in Sandberg and Lessmann, 2018.

2 Duncan C. Miller and Jack A. Thorpe, "SIMNET: The Advent of Simulator Networking," *Proceedings of the IEEE*, Vol. 83, No. 8, August 1995; and Jack Thorpe, "Trends in Modeling, Simulation, & Gaming: Personal Observations About the Past Thirty Years and Speculation About the Next Ten," Interservice/Industry Training, Simulation and Education Conference (I/ITSEC) 2010, Paper No. IF1001, 2010. JSIMS and JTRS are examples of large DoD initiatives to define large-scale joint training systems. Both the Joint Simulation System (JSIMS) and the Joint Tactical Radio System (JTRS) have long, complex

Figure E.1
A History of Standards for Interoperable Military Simulation Systems



DIS
- Fully specified methods
- Less flexibility to implement
- Real-time focus, fixed-object model

HLA
- Greater flexibility in data distribution model
- Presents greater range of integration challenges
- Adds a coordinating run time, often vendor-specific

TENA
- Provides full architectural basis for interop, improved on HLA and DIS
- Not a published standard
- Provides reusable components

NOTE: ALSP = Aggregate Level Simulation Protocol; FOM = Federation Object Model; JLVC = Joint Live, Virtual, and Constructive; JTSE = Joint Training Synthetic Environment; OM = object model; PDU = protocol data unit; RPR = Real-Time Platform Reference.

eration methods emerged to support distinct mechanisms of interoperability, with each method based on conflicting standards for message exchange and data format.

---

histories that highlight the challenges for joint training. For more information on JSIMS, see Roxana Tiron, "Pentagon Cancels Program with 'Checkered' Past," *National Defense*, April 1, 2003. On JTRS, see Bob Brewin, "Pentagon Shutters Joint Tactical Radio System Program Office," Nextgov, August 1, 2012.

The three standards for distributed simulation available for defense modeling today are DIS, the HLA, and TENA.[3] The DIS standard focuses on highly specified data structures for real-time communication that details simulation state information being carried in messages, and also tend to be domain-specific.[4] The HLA standard introduces greater flexibility into the data distribution model to support a more heterogeneous mix of simulations. HLA adds a standardized interface with which simulations can interact in a normalized fashion by using an object model (a FOM) against which simulation systems can define and describe the data that would be sent to other simulations. Both DIS and HLA have continued to evolve over time; DIS has introduced greater flexibility,[5] and HLA has supported more specificity.[6]

---

[3] Each of these standards (DIS, HLA, and TENA) represents a family of standards but is commonly referred to in the singular form. HLA and DIS are IEEE Standards, for which SISO is the designated maintainer.

[4] In DIS, real-time communication relies on transport layer protocols (i.e., the User Datagram Protocol (UDP)) to exchange data carried by DIS-defined PDU messages and using either "broadcast" or "multicast" network transport methods.

[5] For details about DIS and the status of DIS 7 and DIS 8, see, for example, the SISO presentations by Mark McCall and Bob Murray (Mark McCall, "Distributed Interactive Simulation (DIS) 101," presentation slides, Simulation Interoperability Standards Organization, April 2020; and Bob Murray, "Distributed Interactive Simulation (DIS) 201," presentation slides, Simulation Interoperability Standards Organization, April 2020).

[6] For a detailed view of HLA and its evolution, see, for example, Katherine L. Morse, "HLA 101—Introduction to the High Level Architecture," Simulation Interoperability Standards Organization, April 2020.

APPENDIX F

Standards Activities Relevant to Joint Interoperability

Activities relevant to joint interoperation of simulators are highlighted in Table F.1, with main lines of effort covering environmental data, communication standards, standards for command and control systems, training exercise management methods, and certification and compliance.

Table F.1
A View of Current Standards Activities Relevant to Joint Interoperability of Simulators

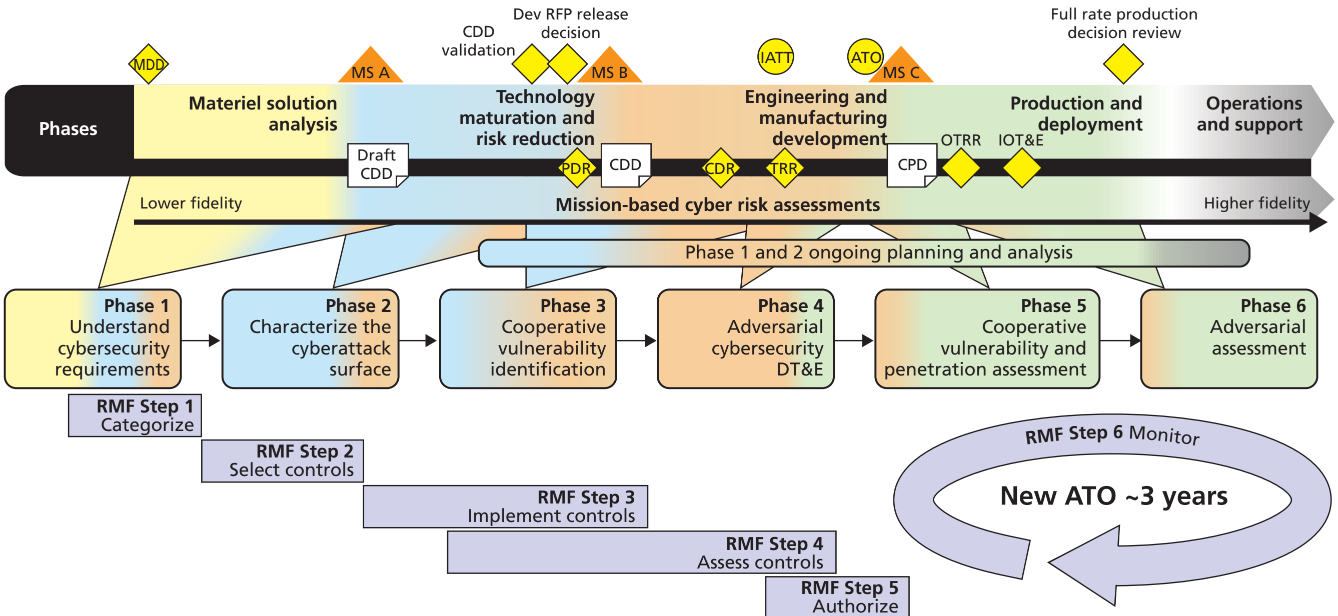
Standards Area	Activities
Environmental data	• OGC family of standards for geospatial information—CDB standard • SISO/International Standards Organization (ISO) Synthetic Environment Data Representation and Interchange Specification (SEDRIS) • 2014 SISO Common Image Generator Interface (CIGI) • SISO Reuse and Interoperation of Environmental Data and Processes (RIEDP) Product Development Group (PDG)
Communications standards	• HLA and DIS—SISO/IEEE family of standards that continue to evolve • IEEE 1516 HLA (HLA Evolved) • IEEE 1278.1 DIS (DIS 7 and 8) • Tactical networks • SISO standards for Link 16, Link 11, Automatic Identification System (AIS), Situational Awareness Data Link (SADL)
Command and control	• SISO Command and Control Systems—Simulation Systems Interoperation (C2SIM) • 2008 Mission Scenario Definition Language (MSDL) • 2014 Coalition Battle Management Language (CBML)
Management methods and practice	• IEEE 1278 Recommended Practice for Distributed Interactive Simulation—Exercise Management and Feedback
Certification and compliance	• 2007 IEEE Recommended Practice for Verification, Validation, and Accreditation of a Federation—An Overlay to the High-Level Architecture Federation Development and Execution Process (FEDEP) • 2018 Recommended Practice for Verification, Validation and Accreditation of a Distributed Simulation—An Overlay to the Distributed Simulation Engineering and Execution Process (DSEEP)

APPENDIX G

Alignment of the Risk Management Framework with the Acquisition Timeline

In Figure G.1, Phases 1 and 2 of the acquisition timeline determine cybersecurity requirements and characterize the cybersecurity attack surface, corresponding to RMF Steps 2 (categorize) and 3 (select) for system categorization, requirements, and selection of control measures. RMF Steps 4 (implement) through 6 (assess) overlap with one another and occur during Phases 3 through 5 for cooperative vulnerability identification, adversarial cybersecurity development, testing and evaluation, and assessment. The final step in both cases is for continuous monitoring, issue resolution, and authorization as applicable.

Figure G.1
The Risk Management Framework Steps Relative to the Test and Evaluation Phase of the Acquisition Process



SOURCE: Adapted from DoD, 2020.
NOTE: CDR = Critical Design Review; CPD = Capability Production Document; Dev = development; DT&E = Development, Test, and Evaluation; IATT = Interim Authorization to Test; IOT&E = Initial Operational Test and Evaluation; MS = milestone; OTTR = Operational Test Readiness Review; PDR = Preliminary Design Review; TRR = Test Readiness Review.

References

AETCI—*See* Air Education and Training Command Instruction.

AFI—*See* Air Force Instruction.

Air Education and Training Command Instruction 11-203, *Flying Training Simulator Instructor Programs*, Washington, D.C.: Headquarters, Department of the Air Force, November 2017.

Air Force Gaming [@AirForceGaming], Twitter account, joined November 2019. As of March 1, 2021:
https://twitter.com/airforcegaming

Air Force Instruction 10-251, *Air Force Participation in Joint Training Transformation Initiative (JTTI) and Joint National Training Capability (JNTC) Events*, Washington, D.C.: Headquarters, Department of the Air Force, June 15, 2015.

Air Force Instruction 11-200, *Aircrew Training, Standardization/Evaluation, and General Operations Structure*, Washington, D.C.: Headquarters, Department of the Air Force, September 2018.

Air Force Instruction 11-2FTV1, *Flight Test Aircrew Training*, Washington, D.C.: Headquarters, Department of the Air Force, February 2017.

Air Force Instruction 16-1007, *Management of Air Force Operational Training Systems*, Washington, D.C.: Headquarters, Department of the Air Force, October 1, 2019.

Air Force Instruction 36-2251, *Management of Air Force Training Systems*, Washington, D.C.: Headquarters, Department of the Air Force, June 5, 2009.

Air Force Policy Directive 10-9, *Lead Command Designation and Responsibilities for Weapon Systems*, Washington, D.C.: Headquarters, Department of the Air Force, March 8, 2007.

Air National Guard, *The Air National Guard LVC Flight Plan*, Joint Base Andrews, Md., 2015. As of February 26, 2021:
https://www.ang.af.mil/Portals/77/documents/AFD-160329-033.pdf

Alion, "Game-Based Training," webpage, undated. As of February 26, 2021: https://www.alionscience.com/gamebasedtraining/

ANG—*See* Air National Guard.

AR—*See* Army Regulation.

Army Regulation 5-11, *Management of Army Modeling and Simulation*, Washington, D.C.: Headquarters, Department of the Army, May 2014.

Army Regulation 34-1, *Interoperability*, Washington, D.C.: Headquarters, Department of the Army, April 9, 2020.

Army Regulation 70-1, *Army Acquisition Policy*, Washington, D.C.: Headquarters, Department of the Army, June 16, 2017.

Army Regulation 71-9, *Warfighting Capabilities Determination*, Washington, D.C.: Headquarters, Department of the Army, December 2009.

Army Regulation 95-1, *Flight Regulations*, Washington, D.C.: Headquarters, Department of the Army, March 2018.

Army Regulation 350-38, *Policies and Management for Training Aids, Devices, Simulators, and Simulations*, Washington, D.C.: Headquarters, Department of the Army, February 2, 2018.

Army Training and Doctrine Command Pamphlet 525-8-2, *The U.S. Army Learning Concept for Training and Education, 2020–2040*, Fort Eustis, Va.: Headquarters, U.S. Army Training and Doctrine Command, April 2017.

Army Training and Doctrine Command Regulation 350-50-3, *Mission Command Training Program*, Fort Eustis, Va.: Headquarters, U.S. Army Training and Doctrine Command, April 19, 2018.

"Army Team Seeks Collaboration to Develop Current, Future Training Solutions," *SeriousPlayWire*, 2020. As of February 12, 2021: https://seriousplaywire.com/army-synthetic-training-environment/

Assad, Shay D., "Peer Reviews of Contracts for Supplies and Services," memorandum, Washington, D.C.: Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, September 29, 2008. As of May 7, 2021: https://www.acq.osd.mil/dpap/policy/policyvault/USA000820-08-DPAP.pdf

Ausink, John A., Anthony D. Rosello, Timothy Marler, Michael Vasseur, Brynn Tannehill, Dara Gold, Kelly Klima, and Laura Kupe, *Fifth-Generation Aircraft Operational Training Infrastructure: Practices, Gaps, and Proposed Solutions*, Santa Monica, Calif.: RAND Corporation, 2018, Not available to the general public.

Becnel, Wade, "AVCATT: Understanding the Challenges of Unintended Consequences," *Army Aviation*, Vol. 66, No. 7, July 31, 2017, pp. 37–38.

Berger, David H., 38th Commandant of the Marine Corps, *Commandant's Planning Guidance*, Washington, D.C.: Headquarters, Department of the Navy, 2019.

"BISim Announces First Military & Defense Industry VBS4 Customers," Business Wire, December 2, 2019. As of March 1, 2021:
https://www.businesswire.com/news/home/20191202005504/en/BISim-Announces-Military-Defense-Industry-VBS4-Customers

Blackburn, Mark, *Transforming Systems Engineering Through Model-Centric Engineering*, Hoboken, N.J.: Stevens Institute of Technology, Systems Engineering Research Center, A013 Final Technical Report SERC-2019-TR-005, April 30, 2019.

Bohemia Interactive Simulations, "Forward Air Controller (FAC) Training: French Air Force, French & German Ground Operation School, French Procurement Agency (DGA), Airbus Defence & Space," webpage, undated a. As of March 1, 2021:
https://bisimulations.com/company/customer-showcase/forward-air-controller-training

———, "Remotely Piloted Aircraft and Air Operations Center Training," webpage, undated b. As of February 26, 2021:
https://bisimulations.com/company/customer-showcase/remotely-piloted-aircraft-and-air-operations-center-training

Brewin, Bob, "Pentagon Shutters Joint Tactical Radio System Program Office," Nextgov, August 1, 2012. As of March 1, 2021:
https://www.nextgov.com/it-modernization/2012/08/pentagon-shutters-joint-tactical-radio-system-program-office/57173/

Chairman of the Joint Chiefs of Staff, *DoD Dictionary of Military and Associated Terms*, Washington, D.C., January 2021. As of April 20, 2021:
https://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/dictionary.pdf

Chairman of the Joint Chiefs of Staff Guide 3501, *Joint Training System: A Guide for Senior Leaders*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, May 5, 2015.

Chairman of the Joint Chiefs of Staff Instruction 3500.01B, *Joint Training Policy for the Armed Forces of the United States*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, December 31, 1999.

Chairman of the Joint Chiefs of Staff Instruction 3500.01F, *Joint Training Policy and Guidance for the Armed Forces of the United States*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, November 19, 2010.

Chairman of the Joint Chiefs of Staff Instruction 3500.01H, *Joint Training Policy for the Armed Forces of the United States*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, April 25, 2014. As of February 12, 2021: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.642.8458&rep=rep1&type=pdf

Chairman of the Joint Chiefs of Staff Instruction 3500.01J, *Joint Training Policy for the Armed Forces of the United States*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, January 13, 2020. As of February 12, 2021: https://www.jcs.mil/Portals/36/Documents/Doctrine/training/cjcsi3500_01j.pdf?ver=2020-01-21-111919-340

Chairman of the Joint Chiefs of Staff Instruction 5123.01H, *Charter of the Joint Requirements Oversight Council (JROC) and Implementation of the Joint Capabilities Integration and Development System (JCIDS)*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, August 31, 2018.

Chairman of the Joint Chiefs of Staff Instruction 5127.01A, *Joint Fire Support Executive Steering Committee Governance and Management*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, December 14, 2018. As of February 12, 2021: https://www.jcs.mil/Portals/36/Documents/Library/Instructions/CJCSI%205127.01A.pdf?ver=sFSDLi5zvKNH1kA-GsKQtA%3d%3d

Chairman of the Joint Chiefs of Staff Instruction 6212.01E, *Interoperability and Supportability of Information Technology and National Security Systems*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, December 15, 2008.

Chairman of the Joint Chiefs of Staff Instruction 6212.01F, *Net Ready Key Performance Parameter (NR KPP)*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, March 21, 2012. As of February 15, 2021: https://www.acqnotes.com/Attachments/CJCSI%206212.01F%20Net%20Ready%20Key%20Performance%20Parameter%20(NR%20KPP)%2012%20March%2012.pdf

Chairman of the Joint Chiefs of Staff Instruction 6610.01E, *Tactical Data Link Standardization and Interoperability*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, April 10, 2014.

Chairman of the Joint Chiefs of Staff Instruction 8510.01, *Joint Modeling and Simulation Management*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, April 24, 1996.

Chairman of the Joint Chiefs of Staff Instruction 8510.01A, *Joint Modeling and Simulation Management*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, January 26, 2004.

Chairman of the Joint Chiefs of Staff Instruction 8510.01C, *Management of Modeling and Simulation*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, August 17, 2012.

Chairman of the Joint Chiefs of Staff Manual 3500.03E, *Joint Training Manual for the Armed Forces of the United States*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, April 20, 2015. As of February 26, 2021:
https://www.jcs.mil/Portals/36/Documents/Library/Manuals/m350003.pdf

Chairman of the Joint Chiefs of Staff Manual 3511.01, *Joint Training Resources for the Armed Forces of the United States*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, May 26, 2015.

Chairman of the Joint Chiefs of Staff Manual 3511.01A, *Joint Training Resources for the Armed Forces of the United States*, Washington, D.C.: Office of the Chairman of the Joint Chiefs of Staff, August 30, 2019.

Chell, Brian, Steven Hoffenson, Douglas Ray, Roger D. Jones, and Mark R. Blackburn, "Optimizing for Mission Success Using a Stochastic Gaming Simulation," Cyber Security and Information Systems Information Analysis Center, January 9, 2020. As of February 12, 2021:
https://www.csiac.org/journal-article/optimizing-for-mission-success-using-a-stochastic-gaming-simulation/

Chikhani, Riad, "The History of Gaming: An Evolving Community," TechCrunch, October 31, 2015.

Choudhry, Kareem, "Achieve More with Microsoft Game Stack," *Game Stack Blog*, March 14, 2019. As of March 1, 2021:
https://developer.microsoft.com/en-us/games/blog/achieve-more-with-microsoft-game-stack/

CJCS—*See* Chairman of the Joint Chiefs of Staff.

CJCSI—*See* Chairman of the Joint Chiefs of Staff Instruction.

CJCSM—*See* Chairman of the Joint Chiefs of Staff Manual.

CNSSI—*See* Committee on National Security Systems Instruction.

Coherence, "About," webpage, undated. As of March 1, 2021:
https://www.coherence.io/about/

Committee on National Security Systems Instruction No. 1253, *Security Categorization and Control Selection for National Security Systems*, Ft. Meade, Md.: Committee on National Security Systems, March 27, 2014.

Cost Assessment Data Enterprise, homepage, undated. As of February 26, 2021:
https://cade.osd.mil/

CPARS, homepage, undated. As of February 26, 2021:
https://www.cpars.gov/index.htm

Culbert, Alexa, "23rd Flying Training Squadron Revolutionizes Pilot Training," U.S. Air Force, November 7, 2019.

DA PAM—*See* Department of the Army Pamphlet.

Datzman, Alicia, "Joint All-Domain Command and Control Operational Success Requires Investment in Multi-Domain Test and Training," Modern Integrated Warfare, November 25, 2019. As of February 26, 2021:
https://www.modernintegratedwarfare.com/military-training/training-effectiveness/joint-all-domain-command-and-control-operational-success-investment-multi-domain-test-training/

Davis, Paul K., and Robert H. Anderson, *Improving the Composability of Department of Defense Models and Simulations*, Santa Monica, Calif.: RAND Corporation, MG-101-OSD, 2004. As of February 12, 2021:
https://www.rand.org/pubs/monographs/MG101.html

Defense Contract Management Agency, *Contract Business Analysis Repository (CBAR) 1.7.3*, web tool, 2015. As of February 26, 2021:
https://www.dcma.mil/WBT/CBAR/

Deierling, Kevin, "In Modern Datacenters, the Latency Tail Wags the Network Dog," *Next Platform*, March 27, 2018. As of March 1, 2021:
https://www.nextplatform.com/2018/03/27/in-modern-datacenters-the-latency-tail-wags-the-network-dog/

Department of the Army Pamphlet 5-11, *Verification, Validation, and Accreditation of Army Models and Simulations*, Washington, D.C.: Headquarters, Department of the Army, September 1999.

Department of Defense Directive 1322.18, *Military Training*, Washington, D.C.: U.S. Department of Defense, January 13, 2009, Incorporating Change 1, February 23, 2017.

Department of Defense Directive 5000.59, *DoD Modeling and Simulation (M&S) Management*, Washington, D.C.: U.S. Department of Defense, August 8, 2007, Incorporating Change 1, October 15, 2018.

Department of Defense Directive 5124.02, *Under Secretary of Defense for Personnel and Readiness (USD(P&R))*, Washington, D.C.: U.S. Department of Defense, D.C., June 23, 2008.

Department of Defense Directive 5134.01, *Under Secretary of Defense for Acquisition, Technology, and Logistics*, Washington, D.C.: U.S. Department of Defense, December 9, 2005.

Department of Defense Information Analysis Centers, Defense Technical Information Center, DoD Cybersecurity Chart, last updated November 30, 2020. As of March 1, 2021:
https://dodiac.dtic.mil/dod-cybersecurity-policy-chart/

Department of Defense Instruction 1025.02, *National Security Education Program (NSEP) and NSEP Service Agreement*, Washington, D.C.: U.S. Department of Defense, January 3, 2017.

Department of Defense Instruction 1322.26, *Distributed Learning (DL)*, Washington, D.C.: U.S. Department of Defense, October 5, 2017.

Department of Defense Instruction 5000.70, *Management of DoD Modeling and Simulation (M&S) Activities*, Washington, D.C.: U.S. Department of Defense, May 10, 2012, Incorporating Change 3, October 15, 2018.

Department of Defense Instruction 8330.01, *Interoperability of Information Technology (IT), Including National Security Systems (NSS)*, Washington, D.C.: U.S. Department of Defense, May 21, 2014, Incorporating Change 2, December 11, 2019.

Department of Defense Instruction 8500.01, *Cybersecurity*, Washington, D.C.: U.S. Department of Defense, March 14, 2014, Incorporating Change 1, October 7, 2019.

Department of Defense Instruction 8510.01, *Risk Management Framework (RMF) for DoD Information Technology (IT)*, March 12, 2014, Incorporating Change 3, December 29, 2020.

Department of the Navy, *Naval Aviation Vision 2016–2025*, Washington, D.C., January 2016. As of February 26, 2021:
https://media.defense.gov/2020/May/18/2002302032/-1/-1/1/NAVAL_AVIATION_VISION.PDF

Desjardins, Jeff, "How Video Games Became a $100 Billion Industry," *Business Insider*, January 12, 2017.

Diallo, Saikou Y., Heber Herencia-Zapana, Jose J. Padilla, and Andreas Tolk, "Understanding Interoperability," *EAIA '11: Proceedings of the 2011 Emerging M&S Applications in Industry and Academia Symposium*, April 2011, pp. 84–91.

Diallo, Saikou Y., Andreas Tolk, Jason Graff, and Anthony Barraco, "Using the Levels of Conceptual Interoperability Model and Model-Based Data Engineering to Develop a Modular Interoperability Framework," in S. Jain, R. R. Creasey, J. Himmelspach, K. P. White, and M. Fu, eds., *Proceedings of the 2011 Winter Simulation Conference*, Phoenix, Ariz.: IEEE, 2011, pp. 2571–2581.

Dideriksen, Amy, Joseph Williams, Thomas Schnell, and Gianna Avdic-McIntire, *The Value of Cognitive Workload in Machine Learning Predictive Analytics*, Interservice/Industry Training, Simulation and Education Conference (I/ITSEC), 2019.

DoD—*See* U.S. Department of Defense.

DoDD—*See* Department of Defense Directive.

DoDI—*See* Department of Defense Instruction.

Durall, Damon, “Synthetic Training Environment and the Digital Revolution in the Army,” U.S. Army, October 3, 2018.

Dvorak, John, Roy Scrudder, Kevin Gupton, and Kevin Hellman, “Enabling Joint Synthetic Training Interoperability Through Joint Federated Common Data Services,” Cyber Security and Information Systems Information Analysis Center, January 9, 2020. As of February 12, 2021:
https://www.csiac.org/journal-article/enabling-joint-synthetic-training-interoperability-through-joint-federated-common-data-services/

“Embracing Gaming Technology to Create Enhanced Synthetic Training Environments to Train Warfighters,” Modern Integrated Warfare, May 11, 2018. As of February 26, 2021:
http://modernmilitarytraining.com/blended-training/embracing-gaming-technology-to-create-enhanced-synthetic-training-environments-to-train-warfighters/

Epstein, Robert, “Air Force Agency for Modeling and Simulation,” briefing slides, Headquarters U.S. Air Force, July 2018.

Everson, Matthew D., *Training System Device Certification and Qualification Process*, thesis, Monterey, Calif.: Naval Postgraduate School, September 2013. As of March 9, 2021:
https://apps.dtic.mil/dtic/tr/fulltext/u2/a589795.pdf

Freedberg, Sydney J., Jr., “Army Targeting Goggles, VR Training May Use JEDI Cloud,” *Breaking Defense*, January 24, 2020.

GAO—*See* U.S. Government Accountability Office.

Giardina, Gina Marie, “SLATE Demo Highlights Live, Virtual, Constructive Environment for Pilot Training,” U.S. Air Force, October 10, 2018. As of February 26, 2021:
https://www.af.mil/News/Article-Display/Article/1658324/slate-demo-highlights-live-virtual-constructive-environment-for-pilot-training/

GitHub, “Opengeospatial/EDR-API-Sprint,” webpage, last updated April 29, 2020. As of February 10, 2021:
https://github.com/opengeospatial/EDR-API-Sprint/blob/master/Final_Report_of_EDR_API_Sprint.md

Guinness World Records, “Most Players Online in a Console FPS,” record, January 2010. As of March 1, 2021:
https://www.guinnessworldrecords.com/world-records/most-players-online-in-a-console-fps/

———, “Most Players Online Simultaneously on One MMO Server,” record, January 21, 2013a. As of March 1, 2021:
https://www.guinnessworldrecords.com/world-records/most-players-online-simultaneously-on-one-mog-server

———, “Most Planes in a Flight Simulation Game,” record, January 22, 2013b. As of March 1, 2021:
https://www.guinnessworldrecords.com/world-records/most-planes-in-a-flight-simulation-game

———, “Most Users to Input a Command to Play a Live Streamed Videogame,” record, March 1, 2014. As of March 1, 2021:
https://www.guinnessworldrecords.com/world-records/most-participants-on-a-single-player-online-videogame

Hambleton, Orris, and Grover Lollar, “USAF Coalition Distributed Mission Operations (DMO): Achieving Multinational Full Mission Training in Integrated LVC Environments,” in *Proceedings of the 2008 Summer Computer Simulation Conference*, Vista, Calif.: Society for Modeling & Simulation International, 2008.

Havens, Spencer [@spencerhavens], “PS4 and Xbox One Get Crossplay by Accident,” blog post, Greenlight Games, September 19, 2017. As of March 1, 2021:
http://greenlightgames.co.uk/blog/ps4-and-xbox-one-get-crossplay-by-accident

Hawkins, Dan, “AETC Partners with Multiple MAJCOMs to Create Virtual Aircraft Maintenance Hangers,” U.S. Air Force, February 25, 2020.

Headquarters United States Air Force, *Air Force Modeling and Simulation Vision for the 21st Century*, Washington, D.C., AFD-100930-038, July 2010.

Hill, Aaron, Richard Kurasiewicz, and Craig Hayes, “The Army Interoperability Measurement System: AIMS,” *News from the Front*, April 8, 2020.

Hirschinger, Mark R., *The Disestablishment of U.S. Joint Forces Command: A Step Backward in “Jointness,”* thesis, Norfolk, Va.: National Defense University, Joint Forces Staff College, June 16, 2011. As of February 26, 2021:
https://apps.dtic.mil/dtic/tr/fulltext/u2/a545491.pdf

History.com editors, “Video Game History,” webpage, History.com, last updated June 10, 2019. As of March 1, 2021:
https://www.history.com/topics/inventions/history-of-video-games

Hitchens, Theresa, “First Multi Domain C2 Exercise Planned: ‘ABMS Onramp,’” *Breaking Defense*, December 6, 2018.

———, “Crider: SSA Data ‘Library’ Will Open to Allies,” *Breaking Defense*, May 3, 2019.

Hlad, Jennifer, “Getting Serious About Interoperability,” *Air Force Magazine*, March 1, 2020.

Honorof, Marshall, “Google Stadia Review,” Tom’s Guide, May 22, 2020. As of March 1, 2021:
https://www.tomsguide.com/reviews/google-stadia

Hura, Myron, Gary McLeod, Eric Larson, James Schneider, Daniel Gonzales, Dan Norton, Jody Jacobs, Kevin O'Connell, William Little, Richard Mesic, and Lewis Jamison, *Interoperability: A Continuing Challenge in Coalition Air Operations*, Santa Monica, Calif.: RAND Corporation, MR-1235-AF, 2000. As of February 12, 2021:
https://www.rand.org/pubs/monograph_reports/MR1235.html

IEEE, "IEEE Standard for Modeling and Simulation (M&S) High Level Architecture (HLA)—Framework and Rules," IEEE 1516-2010, August 18, 2010. As of February 12, 2021:
https://standards.ieee.org/standard/1516-2010.html

———, "IEEE Standard for Distributed Interactive Simulation—Application Protocols," IEEE 1278.1-2012, December 19, 2012. As of February 12, 2021:
https://standards.ieee.org/standard/1278_1-2012.html

———, "Systems and Software Engineering—Vocabulary," ISO/IEC/IEEE 24765, 2nd ed., September 2017.

I/ITSEC—*See* Interservice/Industry Training, Simulation and Education Conference.

Interservice/Industry Training, Simulation and Education Conference, homepage, undated a. As of May 7, 2021:
https://www.iitsec.org/

———, "About I/ITSEC," webpage, undated b. As of May 7, 2021:
https://www.iitsec.org/about-iitsec

———, "Navy Works Toward LVC Future," *I/ITSEC 2017 Official Daily News Digest*, November 28, 2017, pp. 1, 6. As of February 12, 2021:
https://www.iitsec.org/-/media/sites/iitsec/showdaily/2017-iitsec-day2.ashx?la=en

Iriarte, Mariana, "Gaming Tech: Shaping the Reality of Military Training," Military Embedded Systems, September 28, 2017.

Jeffrey, Cal, "Cross-Platform Multiplayer Will Not Be Coming to PlayStation 4 Any Time Soon," TechSpot, June 15, 2017. As of March 1, 2021:
https://www.techspot.com/news/69737-cross-platform-multiplayer-not-coming-playstation-4-anytime.html

Johnson, David E., *Shared Problems: The Lessons of AirLand Battle and the 31 Initiatives for Multi-Domain Battle*, Santa Monica, Calif.: RAND Corporation, PE-301-A/AF, 2018. As of March 10, 2021:
https://www.rand.org/pubs/perspectives/PE301.html

Joint Chiefs of Staff, "Universal Joint Task List," database, January 15, 2020. As of January 15, 2020:
https://www.jcs.mil/Doctrine/Joint-Training/UJTL/

Joint Publication 3-33, *Joint Task Force Headquarters*, Washington, D.C.: Joint Chiefs of Staff, January 31, 2018.

Joint Staff, *Fiscal Year (FY) 2020 President's Budget Operation and Maintenance, Defense-Wide*, Washington, D.C.: U.S. Department of Defense, March 2019. As of February 26, 2021:
https://comptroller.defense.gov/Portals/45/Documents/defbudget/fy2020/budget_justification/pdfs/01_Operation_and_Maintenance/O_M_VOL_1_PART_1/TJS_OP-5.pdf

Joint Staff J-7, Deputy Director Joint Training, *Joint Training Event Handbook 2017*, 2017.

Joint Staff J-8, *Manual for the Operation of the Joint Capabilities Integration and Development System*, August 31, 2018.

Kimmons, Sean, "Army Looks to Better Attract Gaming Industry for Training Simulations," Army News Service, July 14, 2020.

Larson, Eric V., *Interoperability of Coalition Air Forces: Lessons Learned from U.S. Operations with NATO Allies*, Santa Monica, Calif.: RAND Corporation, RB-117-AF, 2004. As of February 12, 2021:
https://www.rand.org/pubs/research_briefs/RB117.html

Lockheed Martin, "Lockheed Martin Delivers F-35 Distributed Mission Training Capability: F-35 Simulators Connect for the First Time with Other USAF Aircraft at Nellis AFB," news release, July 1, 2020. As of February 26, 2021:
https://news.lockheedmartin.com/2020-07-01-Lockheed-Martin-Delivers-F-35-Distributed-Mission-Training-Capability

Lohrmann, Dan, "Cyber Range: Who, What, When, Where, How and Why?" Government Technology, March 10, 2018. As of February 26, 2021:
https://www.govtech.com/blogs/lohrmann-on-cybersecurity/cyber-range-who-what-when-where-how-and-why.html

Losey, Stephen, "Virtual Skies: Air Force Hopes 'Fun' Tech Transforms Pilot Learning," *Air Force Times*, January 16, 2018a.

———, "The Air Force Is Revolutionizing the Way Airmen Learn to Be Aviators," *Air Force Times*, September 30, 2018b.

Magnuson, Stew, "NATO Nations Strive to Standardize Training Systems," *National Defense*, July 1, 2019.

Marine Corps Order 3710.6A, *Marine Corps Aviation Training System (ATS)*, Washington, D.C.: Headquarters, Department of the Navy, September 30, 2011.

Marine Corps Order 5200.28, *Marine Corps Modeling & Simulation Management*, Washington, D.C.: Headquarters, U.S. Marine Corps, Department of the Navy, April 3, 2008.

Marine Corps Order 5200.28A, *Marine Corps Modeling and Simulation (M&S) Management*, Washington, D.C.: Headquarters, Department of the Navy, July 15, 2014.

MarketsandMarkets, *Military Simulation and Training Market by Application (Airborne Simulation, Naval Simulation, Ground Simulation), Training Type (Live Training, Virtual Training, Constructive Training, Gaming Simulation Training), and Region—Global Forecast to 2021*, AS 1125, October 2016. As of February 12, 2021:
http://www.marketsandmarkets.com/Market-Reports/military-simulation-virtual-training-market-661.html

Marler, Tim, and Jasbir S. Arora, *Multi-Objective Optimization: Concepts and Methods for Engineering*, Saarbrucken, Germany: VDM Verlag, 2009.

McCall, Mark, "Distributed Interactive Simulation (DIS) 101," presentation slides, Simulation Interoperability Standards Organization, April 2020. As of March 1, 2021:
https://www.sisostds.org/DesktopModules/Bring2mind/DMX/API/Entries/Download?Command=Core_Download&EntryId=51307&PortalId=0&TabId=105

MCO—*See* Marine Corps Order.

Microsoft, "Azure for Gaming," webpage, undated. As of March 1, 2021:
https://docs.microsoft.com/en-us/gaming/azure/

Miller, Duncan C., "SIMNET and Beyond: A History of the Development of Distributed Simulation," I/ITSEC, 2015.

Miller, Duncan C., and Jack A. Thorpe, "SIMNET: The Advent of Simulator Networking," *Proceedings of the IEEE*, Vol. 83, No. 8, August 1995, pp. 1114–1123.

Milley, Mark A., and Mark T. Esper, "The Army Vision," Department of the Army, 2018. As of February 26, 2021:
https://partner-mco-archive.s3.amazonaws.com/client_files/1528309558.pdf

Mills, Barron, *Live, Virtual, and Constructive-Training Environment: A Vision and Strategy for the Marine Corps*, Monterey, Calif.: Naval Postgraduate School, September 2014.

Modeling and Simulation Enterprise, homepage, U.S. Department of Defense, last updated October 26, 2020. As of February 26, 2021:
https://www.msco.mil/

Morse, Katherine L., "HLA 101—Introduction to the High Level Architecture," Simulation Interoperability Standards Organization, April 2020. As of March 1, 2021:
https://www.sisostds.org/DesktopModules/Bring2mind/DMX/API/Entries/Download?Command=Core_Download&EntryId=51300&PortalId=0&TabId=105

Murray, Bob, "Distributed Interactive Simulation (DIS) 201," presentation slides, Simulation Interoperability Standards Organization, April 2020. As of March 1, 2021:
https://www.sisostds.org/DesktopModules/Bring2mind/DMX/API/Entries/Download?Command=Core_Download&EntryId=51308&PortalId=0&TabId=105

National Training and Simulation Association, *Joint Training: Training 2015*, Arlington, Va., November 2010.

"NSC to Deliver Virtual Training Equipment for British Troops," Army Technology, last updated January 25, 2017. As of March 1, 2021:
https://www.army-technology.com/news/newsnsc-to-deliver-virtual-training-equipment-for-british-troops-5724335/

O'Anastasio, Cecilia, "An Infrastructure Arms Race Is Fueling the Future of Gaming," *Wired*, June 29, 2020.

Office of the Chief of Naval Operations Instruction 1500.76C, *Naval Training Systems Requirements, Acquisition, and Management*, Washington, D.C.: Headquarters, Department of the Navy, August 14, 2013.

Office of the Secretary of Defense, "OSD Level Peer Reviews: Best Practices, Lessons Learned, and Recommendations," December 20, 2013. As of May 7, 2021:
https://www.acq.osd.mil/dpap/cpic/cp/docs/Recommendations_Best_Practices_as_of_20_Dec_2013.pdf

OGC—*See* Open Geospatial Consortium.

Open Geospatial Consortium, "CDB," webpage, undated. As of February 26, 2021:
https://www.ogc.org/standards/cdb

OPNAV—*See* Office of the Chief of Naval Operations.

OSD—*See* Office of the Secretary of Defense.

Patterson, Tory, "Dyess AFB Airmen Revolutionize C-130 Maintenance," U.S. Air Force, June 9, 2020.

Paul, Christopher, Harry J. Thie, Elaine Reardon, Deanna Weber Prine, and Laurence Smallman, *Acquiring Simulation Training: Evaluating and Implementing an Innovative Approach*, Santa Monica, Calif.: RAND Corporation, RB-9166-OSD, 2006a. As of July 8, 2021:
https://www.rand.org/pubs/research_briefs/RB9166.html

———, *Implementing and Evaluating an Innovative Approach to Simulation Training Acquisitions*, Santa Monica, Calif.: RAND Corporation, MG-442-OSD, 2006b. As of March 10, 2021:
https://www.rand.org/pubs/monographs/MG442.html

Rendon, Rene G., Uday M. Apte, and Aruna Apte, "Services Acquisition in the DoD: A Comparison of Management Practices in the Army, Navy, and Air Force," *Defense Acquisition Research Journal*, Vol. 19, No. 1, January 2012.

Rose, Scott, Oliver Borchert, Stu Mitchell, and Sean Connelly, *Zero Trust Architecture*, Gaithersburg, Md.: National Institute of Standards and Technology, U.S. Department of Commerce, Draft NIST SP 800-207, September 23, 2019. As of March 1, 2021:
https://csrc.nist.gov/publications/detail/sp/800-207/draft

Ross, Ron, Victoria Pillitteri, Kelley Dempsey, Mark Riddle, and Gary Guissanie, *Protecting Controlled Unclassified Information in Nonfederal Systems and Organizations*, Gaithersburg, Md.: National Institute of Standards and Technology, U.S. Department of Commerce, NIST SP 800-171, rev. 2, February 2020.

Ross, Ron, Victoria Pillitteri, Gary Guissanie, Ryan Wagner, Richard Graubart, and Deborah Bodeau, *Enhanced Security Requirements for Protecting Controlled Unclassified Information: A Supplement to NIST Special Publication 800-171*, Gaithersburg, Md.: National Institute of Standards and Technology, U.S. Department of Commerce, NIST SP 800-172, February 2021.

Ross, Ronald S., *Risk Management Framework for Information Systems and Organizations: A System Life Cycle Approach for Security and Privacy*, Gaithersburg, Md.: National Institute of Standards and Technology, U.S. Department of Commerce, NIST SP 800-37, rev. 2, December 2018.

Sandberg, S., and K. Lessmann, "LVC Simulation Interoperability 101," Interservice/Industry Training, Simulation and Education Conference (I/ITSEC), November 2018.

Schutte, John, "Researchers Use Gaming Technology for Interactive Military Training," Air Force Materiel Command, December 3, 2008.

Scott, Kevin D., Patrick E. Matlock, Scott F. Smith, Timothy C. Kuehhas, William F. Mullen III, Robert Karmazin, and Walter E. Fountain, *Joint Training Technical Interoperability Strategy*, Suffolk, Va.: Joint Staff J7, August 1, 2018. As of February 26, 2021:
https://apps.dtic.mil/sti/pdfs/AD1057364.pdf

Secretary of the Navy Instruction 5200.28B, *Dept of Navy M&S Management*, Washington, D.C.: Headquarters, Department of the Navy, April 2008.

Secretary of the Navy Instruction 5200.38A, *Department of the Navy Modeling and Simulation Management*, Washington, D.C.: Headquarters, Department of the Navy, February 2002.

Secretary of the Navy Instruction 5200.46, *Department of the Navy Modeling, Simulation, Verification, Validation, and Accreditation Management*, Washington, D.C.: Headquarters, Department of the Navy, March 7, 2019.

Shanley, Michael G., Matthew W. Lewis, Susan G. Straus, Jeff Rothenberg, and Lindsay Daugherty, *The Prospects for Increasing the Reuse of Digital Training Content*, Santa Monica, Calif.: RAND Corporation, MG-732-OSD, 2009. As of February 12, 2021:
https://www.rand.org/pubs/monographs/MG732/

Sheftick, Gary, "Army Looks to Leverage 'Low Earth Orbit' Satellites," Army News Service, March 9, 2020.

Simulation Interoperability Standards Organization, "DIS/RPR FOM Product Support Group," webpage, undated a. As of April 20, 2021:
https://www.sisostds.org/StandardsActivities/SupportGroups/DISRPRFOMPSG.aspx

———, "Distributed Interactive Simulation Version 8 (DIS V8) PDG," webpage, undated b. As of April 20, 2021:
https://www.sisostds.org/StandardsActivities/DevelopmentGroups/DISV8PDG.aspx

———, "IEEE Standards Maintained by SISO SAC," webpage, undated c. As of April 20, 2021:
https://www.sisostds.org/productspublications/standards/ieeestandards.aspx

———, "RIEDP PDG—Reuse and Interoperation of Environmental Data and Processes," webpage, undated d. As of April 20, 2021:
https://www.sisostds.org/StandardsActivities/DevelopmentGroups/RIEDPPDG-ReuseandInteroperationofEnvironmen.aspx

———, "TADIL TALES PDG & PSG," webpage, undated e. As of February 26, 2021:
https://www.sisostds.org/StandardsActivities/DevelopmentGroups/TADILTALESPDGPSG.aspx

———, *Standard for Commercial Off-the-Shelf (COTS) Simulation Package Interoperability (CSPI) Reference Models*, SISO-STD-006-2010, Orlando, Fla., March 9, 2010. As of February 26, 2021:
https://www.sisostds.org/ProductsPublications/Standards/SISOStandards.aspx

———, *Standard for Common Image Generator Interface (CIGI)*, Version 4.0, SISO-STD-013-2014, Orlando, Fla., August 22, 2014. As of February 26, 2021:
https://www.sisostds.org/ProductsPublications/Standards/SISOStandards.aspx

———, *Standard for Guidance, Rationale, and Interoperability Modalities (GRIM) for the Real-Time Platform Reference Federation Object Model (RPR FOM)*, Version 2.0, SISO-STD-001-2015, Orlando, Fla., August 10, 2015a. As of February 26, 2021:
https://www.sisostds.org/ProductsPublications/Standards/SISOStandards.aspx

———, *Standard for Real-Time Platform Reference Federation Object Model (RPR FOM)*, Version 2.0, SISO-STD-001.1-2015, Orlando, Fla., August 10, 2015b. As of February 26, 2021:
https://www.sisostds.org/ProductsPublications/Standards/SISOStandards.aspx

SISO—*See* Simulation Interoperability Standards Organization.

Software Engineering Institute, "Subject: Network Situational Awareness," webpage, Carnegie Mellon University, undated. As of February 12, 2021:
https://insights.sei.cmu.edu/sei_blog/network-situational-awareness/

Square Enix, "World Visit System," play guide, last updated August 11, 2020. As of March 1, 2021:
https://na.finalfantasyxiv.com/lodestone/playguide/contentsguide/worldvisit/

Stadia, "About," webpage, undated. As of March 1, 2021:
https://stadia.dev/intl/en_us/about/

Stewart, John E., D. M. Johnson, and W. R. Howse, *Fidelity Requirements for Army Aviation Training Devices: Issues and Answers*, Washington, D.C.: Defense Technical Information Center, 2008.

Straus, Susan G., Matthew W. Lewis, Kathryn Connor, Rick Eden, Matthew E. Boyer, Timothy Marler, Christopher M. Carson, Geoffrey E. Grimm, and Heather Smigowski, *Collective Simulation-Based Training in the U.S. Army: User Interface Fidelity, Costs, and Training Effectiveness*, Santa Monica, Calif.: RAND Corporation, RR-2250-A, 2019. As of February 12, 2021:
https://www.rand.org/pubs/research_reports/RR2250.html

Stubbings, David, "EVE Online Gamers Set New Record for Taking Part in a Huge Video Game Battle," Guinness World Records, April 18, 2018. As of March 1, 2021:
https://www.guinnessworldrecords.com/news/2018/4/eve-online-gamers-set-new-record-for-taking-part-in-a-huge-video-game-battle-522213

Suciu, Peter, "USAF Gets Its Game On: Air Force Esports Team Recruiting for 2020 Evolution Championship Series," ClearanceJobs, April 28, 2020. As of March 1, 2021:
https://news.clearancejobs.com/2020/04/28/usaf-gets-its-game-on-air-force-esports-team-recruiting-for-2020-evolution-championship-series/

Team Orlando, homepage, undated. As of February 26, 2021:
http://www.teamorlando.org/

Thorpe, Jack, "Trends in Modeling, Simulation, & Gaming: Personal Observations About the Past Thirty Years and Speculation About the Next Ten," Interservice/Industry Training, Simulation and Education Conference (I/ITSEC) 2010, Paper No. IF1001, 2010.

Thorpe-Coles, Matthew, "Over 14,000 Ships Flew to Battle in Eve: Aether Wars This Monday," PCGamesN, last updated April 5, 2020. As of February 12, 2021: https://www.pcgamesn.com/eve-online/eve-aether-wars-battle-size

Tiron, Roxana, "Pentagon Cancels Program with 'Checkered' Past," *National Defense*, April 1, 2003.

Tolk, Andreas, John Fowler, Guodong Shao, and Enver Yücesan, *Advances in Modeling and Simulation: Seminal Research from 50 Years of Winter Simulation Conferences*, Cham, Switzerland: Springer, 2017.

TRADOC—*See* Army Training and Doctrine Command.

Training Circular 3-04.11, *Commander's Aviation Training and Standardization Program*, Washington, D.C.: Headquarters, Department of the Army, August 2016.

Ukman, Jason, "U.S. Joint Forces Command Formally Dissolved," *Washington Post*, August 4, 2011.

U.S. Air Force, *Operational Requirements Document for Distributed Mission Training*, Washington, D.C., CAF 009-93-I-A, October 8, 1997.

U.S. Code, Title 10, Armed Forces. As of February 26, 2021: https://www.govinfo.gov/app/details/USCODE-2015-title10/

U.S. Department of Defense, *Department of Defense Modeling and Simulation Body of Knowledge (BOK)*, Washington, D.C., June 2008. As of February 26, 2021: https://acqnotes.com/acqnote/careerfields/modeling-and-simulation

U.S. Department of Defense, *DoD Program Manager's Guidebook for Integrating the Cybersecurity Risk Management Framework (RMF) into the System Acquisition Lifecycle*, Version 1.0, Washington, D.C.: Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, September 2015. As of March 1, 2021: https://www.dau.edu/tools/Lists/DAUTools/Attachments/37/DoD%20-%20Guidebook,%20Cybersecurity%20Risk%20Management%20Framework,%20v1.08,%20Sep%202015.pdf

U.S. Department of Defense, *Report to Congress Restructuring the Department of Defense Acquisition, Technology and Logistics Organization and Chief Management Officer Organization*, Washington, D.C., August 2017.

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., 2018a.

U.S. Department of Defense, "CE2T2 Program Execution Plan FY19," Washington, D.C., October 2018b.

U.S. Department of Defense, *Cybersecurity Test and Evaluation Guidebook*, Version 2.0, Change 1, Washington, D.C.: Office of Prepublication and Security Review, February 10, 2020. As of March 1, 2021: https://www.dau.edu/cop/test/DAU%20Sponsored%20Documents/Cybersecurity-Test-and-Evaluation-Guidebook-Version2-change-1.pdf

U.S. Government Accountability Office, *Defense Acquisitions: Status and Challenges of Joint Forces Command's Limited Acquisition Authority,* Washington, D.C.: GAO-07-546, April 2007.

———, *Defense Contracting: DoD Needs Better Information on Incentive Outcomes*, Washington, D.C., GAO-17-291, July 2017.

U.S. House of Representatives, "Improving the Readiness of U.S. Forces Through Military Jointness," hearing before the U.S. House of Representatives Committee on Armed Services Subcommittee on Readiness on March 31, 2011, Washington, D.C.: U.S. Government Printing Office, 2011.

U.S. Joint Forces Command, *Joint Live Virtual and Constructive (JLVC) Federation Integration Guide*, Version 3.1, Norfolk, Va., January 13, 2010.

U.S. Marine Corps, *Marine Corps Ground Training Simulations Implementation Plan*, Washington, D.C.: Department of the Navy, June 2017.

U.S. Marine Corps Systems Command, *MARCORSYSCOM Acquisition Guidebook*, Headquarters Marine Corps, October 30, 2020. As of April 20, 2021: https://www.marcorsyscom.marines.mil/Portals/105/HOMEMCSC/FY21-01%20MAG%20v1.0%2020201030.pdf?ver=qXiYXXTwtK32bWq6loT5IQ%3D%3D

USMC—*See* U.S. Marine Corps.

Vogel-Walcutt, Jennifer J., William E. Cole, Timothy M. Hill, Walter Yates, Robert Epstein, Diana Teel, and Katie Flinn, *Team Orlando: Community of Progress*, paper presented at Interservice/Industry Training, Simulation and Education Conference (I/ITSEC), 2018.

Walker, David M., "DoD Acquisitions: Contracting for Better Outcomes," testimony presented before the U.S. House of Representatives Committee on Appropriations Subcommittee on Defense on September 7, 2006, Washington, D.C.: U.S. Government Accountability Office, GAO-06-800T, September 7, 2006.

Warren, Tom [@tomwarren], "Nintendo and Microsoft Team Up to Promote Cross-Play, While Sony Remains Silent," *The Verge*, June 21, 2018.

Weter, Don, and Larry Hose, "Joint Theater Level Simulation," briefing slides, Washington, D.C.: Joint Staff J7, September 2016. As of February 26, 2021: https://www.rolands.com/jtls/j_iuc2017/JS-J7.pdf

Wydler, Virginia L., *Gaining Leverage over Vendor Lock to Improve Acquisition Performance and Cost Efficiencies*, McLean, Va.: MITRE Corporation, April 1, 2014. As of February 15, 2021:
https://www.mitre.org/sites/default/files/publications/gaining-leverage-over-vendor-lock-14-1262.pdf

Yardley, Roland J., James G. Kallimani, Laurence Smallman, and Clifford A. Grammich, *DDG-51 Engineering Training: How Simulators Can Help*, Santa Monica, Calif.: RAND Corporation, MG-874-NAVY, 2009. As of March 10, 2021:
https://www.rand.org/pubs/monographs/MG874.html

Yardley, Roland J., Harry J. Thie, Christopher Paul, Jerry M. Sollinger, and Alisa Rhee, *An Examination of Options to Reduce Underway Training Days Through the Use of Simulation*, Santa Monica, Calif.: RAND Corporation, MG-765-NAVY, 2008. As of March 10, 2021:
https://www.rand.org/pubs/monographs/MG765.html

RAND NATIONAL DEFENSE RESEARCH INSTITUTE

Given the military's continuing effort to "train as we fight," warfighters must be prepared to collaborate with other services. There is a need to ensure coordination and interoperability within and across the services with respect to simulation-based training. However, because of organic changes in policies and organizational structures, there are significant challenges for the services to coordinate within their own organizations and to collaborate with one another while working toward joint training needs.

Concurrent with the growing need for virtual distributed training capabilities, the military simulation-and-training market is growing, and this market includes substantial efforts to develop new training-simulator capabilities. However, technological development is not always driven by training needs, especially for cross-service exercises. Development of training simulators often drives the users rather than the reverse, especially with respect to distributed training systems.

With a focus on air and ground training simulators for Tier 3 and Tier 4 exercises—i.e., training at the service component (operational) and individual unit (tactical) levels—the authors of this report investigate the gap between joint training needs and currently available and forthcoming technology in the training-simulator field. They provide a broad analysis of the simulation-based training enterprise and the organizational structure, requirements processes, and acquisition processes for each service. They also analyze joint training needs, organizational and policy mechanisms for coordination between services, and incentives structures for cross-service simulator development.

www.rand.org

RR-A159-1