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A New Framework and Logic Model for Using Live, Virtual, and Constructive Training in the United States Air Force

KEY FINDINGS

- As capabilities for live, virtual, and constructive (LVC) training advance, decisions about which training tools are most appropriate for which aircrew training activities become more complex.
- Current U.S. Air Force policy bases decisions about the use of live or virtual equipment for continuation training on the mission level only (for each mission design series). However, identifying the underlying task and skill requirements can support more efficient and effective decisionmaking about appropriate use of training technologies. The Air Force Research Laboratory's Mission Essential Competencies provide a valuable foundation for distilling missions into tasks and skills.
- Decisions about using LVC for training have been binary in nature—that is, either “live” or “virtual.” Understanding the attributes of the myriad virtual technologies and tools can allow for a more effective match between skill requirements and training technologies.
- A common framework for parsing missions into tasks and skills and for associating those tasks and skills with appropriate training technologies could help (1) identify training needs and areas of investment and (2) facilitate the adoption of common training solutions and reduce redundant efforts and investments.
- There is no single “optimal” mix of LVC components. The appropriate use of LVC depends on a range of contextual factors.
- The U.S. Air Force needs a comprehensive, ongoing, strategic program of research on appropriate uses of LVC for continuation training to include development of valid and reliable measures of aircrew performance, systematic experimentation, and ongoing data collection from the field.

Continuation training (CT) for aircrews is critical to building and maintaining military readiness for the U.S. Air Force (USAF), especially with respect to complex, cognitive, collective tasks for mission training (as opposed to training in basic flight skills). Despite the importance of CT, there are many challenges to obtaining the necessary amount of training to ensure readiness, such as availability of equipment and financial resources. Various combinations of live, virtual, and constructive (LVC) training capabilities can help address these challenges. In fact, LVC is an essential element of the 2017 Operational Training Infrastructure 2035 Flight Plan, which addresses the infrastructure needed to train aircrews to achieve and sustain full spectrum readiness (Department of the Air Force, 2017). However, determining how to leverage LVC most effectively is a complex endeavor, requiring alignment of appropriate combinations of the

LVC components with the intended training goals. This work considers the complete LVC construct as well as various combinations of the underlying LVC components.

While prior research has addressed the use of LVC for training, it has focused largely on live or virtual technologies, without distinguishing among different types of virtual training capabilities. It has also focused only on the association between mission characteristics and live or virtual training rather than considering underlying task and skill requirements. Different missions can require the same tasks and skills, and focusing on the match between underlying tasks and skills with training technologies may be more effective for ensuring that appropriate specific training capabilities align with training needs (see Figure 1). Moreover, most prior work has not considered how a range of contextual factors, such as access to facilities and security concerns, can enable or limit use of training technologies.

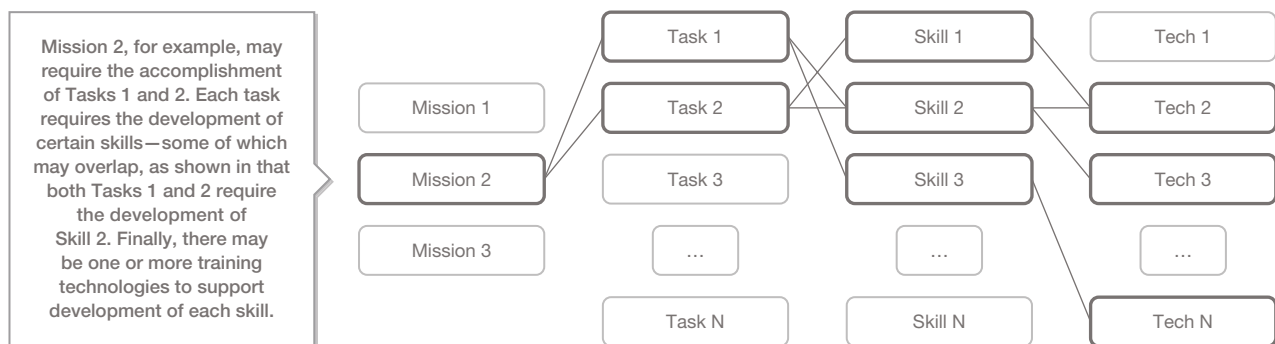
The USAF asked RAND Project AIR FORCE (PAF) to study the optimal mix of LVC components for aircrew CT with a focus on complex, cognitive, collective tasks. This document provides a summary of the project's final report (Marler et al., 2023). The analysis and products resulting from this work can help policymakers, research professionals, instructional designers, trainers, and acquisition specialists acquire, manage, and leverage LVC training capabilities more effectively.

Abbreviations

AF/A3T	Air Force Headquarters, Office of Training and Readiness
AFAMS	Air Force Agency for Modeling and Simulation
AFRL	Air Force Research Laboratory
CT	continuation training
LIMFAC	limiting factors
LVC	live, virtual, and constructive
MAJCOM	major command
MDS	mission design series
MEC	Mission Essential Competency
OCA	offensive counter air
PAF	RAND Project AIR FORCE
R&D	research and development
RAP	Ready Aircrew Program
RTM	Ready Aircrew Program Tasking Memorandum
SME	subject-matter expert
USAF	U.S. Air Force

We conducted this study using several underlying assumptions and findings from prior research (e.g., Ausink et al., 2018; Straus et al., 2019). First, we contend that there is no single “best” combination of LVC components; instead, the appropriate use of LVC depends on the specific training goals, which vary based on such factors as missions, mission design series (MDS), aircrew experience, and technical capabilities. In addition, whereas policy about use of training technologies currently is based largely on the mission, aligning training tools with the underlying

FIGURE 1
Interactive Network of Missions, Tasks, Skills, and Training Technologies



task and skill requirements can promote efficiency by identifying appropriate uses of tools across missions and MDSs.

Second, determining the mix of LVC components to train skills is just one component of a broader problem formulation. Appropriate uses of LVC can depend on contextual factors beyond skills and technologies, such as access to equipment, facilities, and personnel; operational security requirements; and aircrew safety. Although the USAF has completed a variety of studies concerning mixes of LVC components, it lacks a comprehensive, strategic plan for related research that accounts for the range of factors relevant to determining appropriate uses of LVC for training. It also lacks robust measures needed to evaluate LVC effectiveness, relying instead on number of sorties rather than quality of performance to assess crew proficiency.

Approach: There Are Two Main Analytic Tasks

We performed two main tasks to fill these gaps. First, to understand how various components of the LVC construct align with specific training goals, we built on prior research to **develop a systematic framework mapping specific training needs (missions, tasks, and skills) to training technologies**. Based on this analysis, we built a new prototype software tool that shows how training technologies align with training needs. While the software tool was developed as an initial prototype, the underlying approach is scalable across MDSs and USAF major commands (MAJCOMs). To determine the match between skills and training tools, we developed a taxonomy that categorizes skills and technologies based on **required and supported user interactions**, respectively.

Second, we **developed a logic model to provide context for LVC and the proposed framework**. This model illustrates the range of factors that influence which technologies are feasible to use for training. It also supports development of a program of research for assessing the effectiveness of the training technologies for task requirements.

Used in combination, these two products can ultimately provide a variety of benefits:

- guide research on the appropriate uses of LVC for a range of training technologies, missions, and MDSs
- produce efficiencies in training development and planning
- produce information to guide acquisition of resources
- identify necessary changes to training policy.

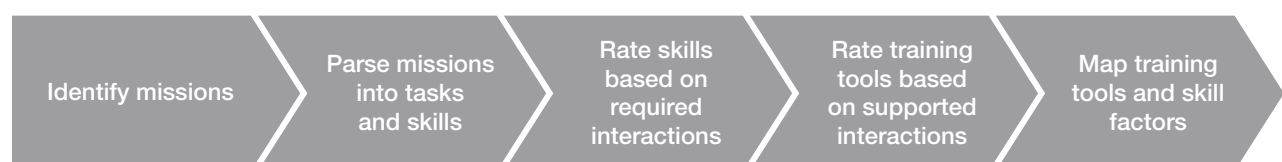
A New Framework and Mapping Tool to Align Training Needs and Capabilities

In this section, we present a step-by-step description of how we developed our framework. We then provide an overview of an interactive software prototype that allows users to access the framework in support of decisionmaking.

How We Developed Our Framework

Development of our framework entailed the following steps, as illustrated in Figure 2: (1) identifying missions for analysis, (2) parsing missions for specific MDSs (mission-MDS pairs) into underlying tasks and skills, (3) rating skills based on required aircrew interactions, (4) rating training tools according to how users interact with them, and (5) mapping training tools to skill factors.

FIGURE 2
Overview of Framework



The process is detailed as follows:

1. **Identifying missions.** We consulted with subject-matter experts (SMEs) to identify missions for each MAJCOM that involved cognitively demanding, collective tasks. This guided the selection of example mission-MDS pairs to illustrate how parsing missions into tasks and skills can help identify appropriate training tools. Missions used in our analysis included offensive counter air (OCA), defensive counter air, and close air support. Example MDSs used in conjunction with these missions include the F-16 Block 40, F-16 Block 50/52, and B-2 Spirit.
2. **Parsing mission-MDS pairs into tasks and skills.** We used the Air Force Research Laboratory's (AFRL's) Mission Essential Competencies (MECs) to parse missions into underlying tasks and skills (Bennett et al., 2017, p. 48). MECs are currently used primarily with Air Combat Command, but the method for developing MECs can be applied more widely across Air Force MAJCOMs and MDSs. We note, however, that different groups of SMEs have developed the MECs for each MDS, which sometimes results in different terminology for the same concepts. Developing a common language or taxonomy for similar missions, tasks, and skills could facilitate easier application of MECs across MDSs.
3. **Rating skills based on required interactions.** SMEs rated the skills using criteria adapted from an ICF International framework (ICF International, 2013).¹ For example, an SME rated "multirole tactical flow priorities," which is a skill that consists of "[making] real-time decisions on transition and execution of tactical flow priorities" (Department of the Air Force, 2014), as complex, cognitively demanding, and teamwork-intensive.

This in turn qualified this skill for evaluation using Table 1. The SME then rated this skill as being associated with the following required interactions per Table 1: production/service, two-way interactions, high degree of synchronicity, moderate level of built-in feedback and certainty, visual and audio cues, moderate number of team members (6–15), and potentially requiring both environmental and geographic context-specific information. SMEs rated the skills along three dimensions: complexity (rated from 1 to 5), cognitively demanding (yes or no), and teamwork intensity (low, medium, or high). SMEs then rated the resulting skills—those that are complex, cognitive, and collective²—using the skill factors summarized in Table 1. The skill factors were then rated (shown in the second column of Table 1) in terms of types of required interactions in which aircrews engage with other team members or equipment to complete their tasks. These *required interactions* were then aligned with the *supported interactions* (interactions that a particular technology or tool may facilitate) associated with each training tool, resulting in a map of training goals (skills) to training tools.

4. **Rating training tools according to supported interactions.** SMEs rated training tools based largely on the types of interactions that the tools support:³ types and range of movement, type of collaboration (e.g., one way or two-way, pairwise or multi-way), number of participants, contextual effects relevant to interactions (e.g., environment, geography, cyber or electronic warfare), synchronicity of communication (synchronous, asynchronous), primary sensory aspect supported (e.g., visual, auditory, haptic), and the extent to which an interaction faithfully represents a real interaction in a real environment.

¹ We did not use the ICF International tool in its entirety, because (1) it produces only a binary live/virtual recommendation that does not account for the myriad of virtual technologies that vary in attributes and capabilities and (2) some of the ICF International factors are not well suited for analyzing complex, cognitive, collective tasks.

² That is, skills rated as a 3 or higher on complexity, as cognitively demanding, and of medium or high teamwork intensity.

³ The types of interaction were derived from a review of the state of the art as well as a review of different approaches to categorizing training-simulation technologies.

TABLE 1
Criteria Used to Rate Complex, Cognitive, Collective Aircrew Skills

Skill Factor	Description (Required Interaction)
Teamwork domain	• Project development: skills involved in mission planning– and debriefing-type activities • Action/negotiation: skills involved in communication and assessment among aircrews, where the output is a decision or recommendation • Production/service: skills involved in the physical manipulation of aircraft or other assets
Teamwork type ^a	• One-way interactions: interactions where communication is sent but not received by individual aircrew • Two-way interactions: interactions where communications are both sent and received by aircrew
Synchronous activity	Importance of synchronous action, where individual aircrews must take actions in close temporal proximity to one another. Rated as low, medium, or high.
Task certainty	Degree of built-in feedback on successful exercise of skill—that is, the extent to which an aircrew member knows that he or she has correctly exercised a skill. Rated as low, medium, or high.
Sensory aspect ^b	Which senses are primarily involved in the exercise of the skill? Raters choose among visual, audio, and/or touch/pressure.
Number of participants ^b	Bins for number of participants. These categories are chosen so as to capture the ability of current training technologies to support collective training among many participants simultaneously. Raters choose among 2–5, 6–15, and 16+.
Context-sensitive information ^a	• Geographic effects: exercise of the skill requires scenario-relevant terrain, e.g., mountainous terrain or buildings • Environmental effects: exercise of the skill requires special environmental effects, e.g., adverse weather, fog, rain

SOURCE: ICF International, 2013, pp. 13–17, and RAND analysis. Unless noted otherwise, skill factors are from the ICF International report.

^a Denotes skill factors modified from ICF International. Teamwork type is an adaption of ICF International's interactional/fidelity factor, and context-sensitive information is an adaption of the special environment factor.

^b Denotes skill factors from RAND's analysis.

5. Mapping training tools to skill factors.

We matched skill factors to training tools by cross-walking interactions that the *skills require* with interactions that the *tools support*. The cross-walk provides recommendations for tools that might be appropriate for training each skill (associated with particular skill factors) as shown in Table 2,⁴ which lists the criteria for matching training technologies to skills based on skill factors from Table 1. For example, as shown in the first two rows of Table 2, if a skill involves the skill factor “sensory aspect,” with a rating of “visual” (see Table 1), and the skill factor “number of participants” is rated as involving 2–5 or 6–15 participants, then, based on alignment with supported interactions for each type of tool,

candidate tools would include head-mounted and heads-up displays.

A New Interactive Tool Enables Users to Apply the Framework

Using the process outlined above, we developed an interactive, online software application that displays the connections among missions, tasks, skills, and training tools. Users can interactively explore connections between “nodes” (missions, tasks, skills, and training technologies) in a network, as shown in Figure 3.

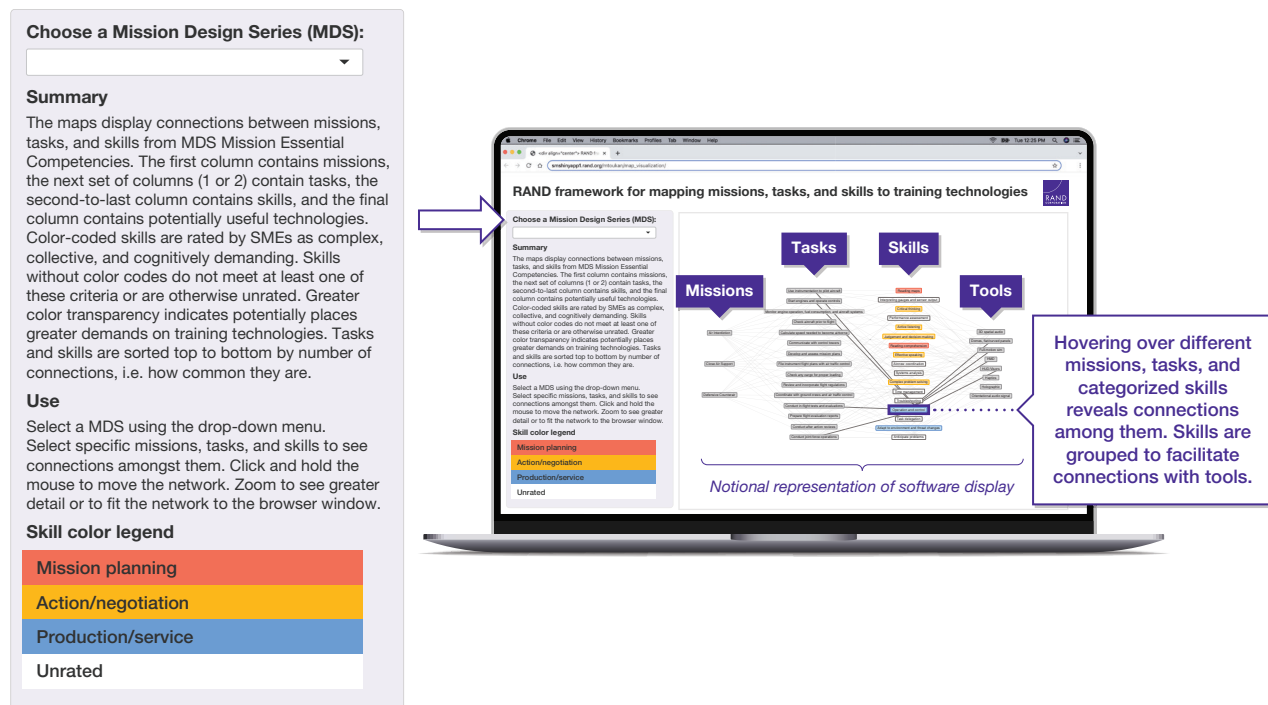
This tool is not necessarily intended as prescriptive for training design. Rather, it is intended as a training aid that can outline options and adapt and scale as new training tools and technologies emerge. Expert judgement, training device availability, and other constraints outlined in the logic model, discussed next, would also affect how to select which technologies to assess. This tool could also

⁴ We selected these tools that SMEs rated based on a review of the state of the art of simulation-based training technologies.

TABLE 2
Criteria for Matching Skills to Training Tools

Candidate Training Tool	Required Interaction for Each Relevant Skill Factor
Head-mounted displays	<i>Number of participants:</i> 2–5 or 6–15 individuals <i>Sensory aspect:</i> Includes visual
Heads-up displays and visors	<i>Number of participants:</i> 2–5 or 6–15 individuals <i>Sensory aspect:</i> Includes visual
Domes, flat/curved panels	<i>Sensory aspect:</i> Includes visual
Full-motion simulators	<i>Teamwork domain:</i> Action/negotiation or production/service <i>Number of participants:</i> 2–5 or 6–15 individuals <i>Sensory aspect:</i> includes visual or touch/pressure
Holographic	<i>Teamwork domain:</i> Project development <i>Task certainty:</i> Low or medium <i>Sensory aspect:</i> Includes visual
3D spatial audio	<i>Teamwork domain:</i> Action/negotiation or production/service <i>Task certainty:</i> Low or medium <i>Number of participants:</i> 2–5 or 6–15 individuals <i>Sensory aspect:</i> Includes audio
Orientalational audio signal	<i>Teamwork domain:</i> Action/negotiation or production/service <i>Sensory aspect:</i> Includes audio
Haptics	<i>Teamwork domain:</i> Action/negotiation or production/service <i>Number of participants:</i> 2–5 individuals <i>Sensory aspect:</i> Includes touch/pressure

FIGURE 3
Partial Screen Shot of Interactive Mapping Tool for F-16 Block 40



NOTE: The first column shows missions (i.e., "air interdiction, OCA-AO"). The second column shows mission tasks (i.e., "conduct joint force operations"). The third column shows skills associated with this task. The last column shows appropriate tools for one of the skills, "operation and control." Skill color indicates skill type, and the level of transparency in the color codes represents the potential demands that the skills require of the training technologies.

point to training technologies that might not otherwise receive consideration, and it could highlight potentially useful investments in emerging training technologies.

Deploying the Tool: Multiple Stakeholders Can Benefit

Potential users for the proposed tool include (1) MAJCOM operations staff (with input from unit commanders) developing Ready Aircrew Program (RAP) Tasking Memoranda (RTM) (Air Force Instruction 16-1007, 2019; Walsh, Taylor, and Ausink, 2019), (2) weapons officers creating and implementing operation group training plans, and (3) acquisition specialists in the research and development (R&D) community. With respect to training, the proposed mapping would not necessarily determine exactly which training tool or approach should be used. However, it could serve as a training aid to supplement SME and training-planner judgement. With respect to acquisition, it could help determine which training technologies merit additional R&D and what types of tools should be purchased.

This tool must be **sustained and expanded** to inform future acquisitions and training operations. Given its position as providing training oversight, Air Force Headquarters Office of Training and Readiness (AF/A3T) could manage implementation, coordination, and sustainment of the mapping tool. However, given the dependence of this mapping tool on specific missions and MDSs, each MAJCOM A3T office would need to provide data to AF/A3T to update the framework and refine the tool as new technologies, missions, and MDSs surface. In addition, use of this mapping tool and the logic model discussed below could be codified in policy documentation, helping to inform RTM, as well as operations group training plans.⁵

⁵ An operations group training plan is specific to a wing and focuses on training gaps within the wing that need to be addressed. This training plan is unique to each squadron, and the level of detail is up to the discretion of the operations group.

Determining the appropriate use of LVC for training depends on a variety of factors beyond just skills and technologies.

Our Logic Model Contextualizes LVC and Guides Research

Our data collection revealed that determining the appropriate use of LVC for training depends on a variety of factors beyond characteristics of skill requirements and capabilities of technologies to train on those requirements. For example, the appropriate mix of technologies is likely to depend on the skill level of trainees and time available for training. Furthermore, other contextual factors affect the feasibility of using particular training technologies. For example, live flight might be the best way to train particular skills from a pedagogical perspective, but opportunities for live sorties might be limited because of air space, equipment availability, or security concerns.

We developed a logic model depicting the range of factors that influence selection and testing of LVC.⁶ The model serves two purposes:

- By specifying the range of contextual factors affecting use of training technologies, the model can serve as a **roadmap for a strategic program of research** on appropriate mixes of LVC, and it can serve as a mechanism to coor-

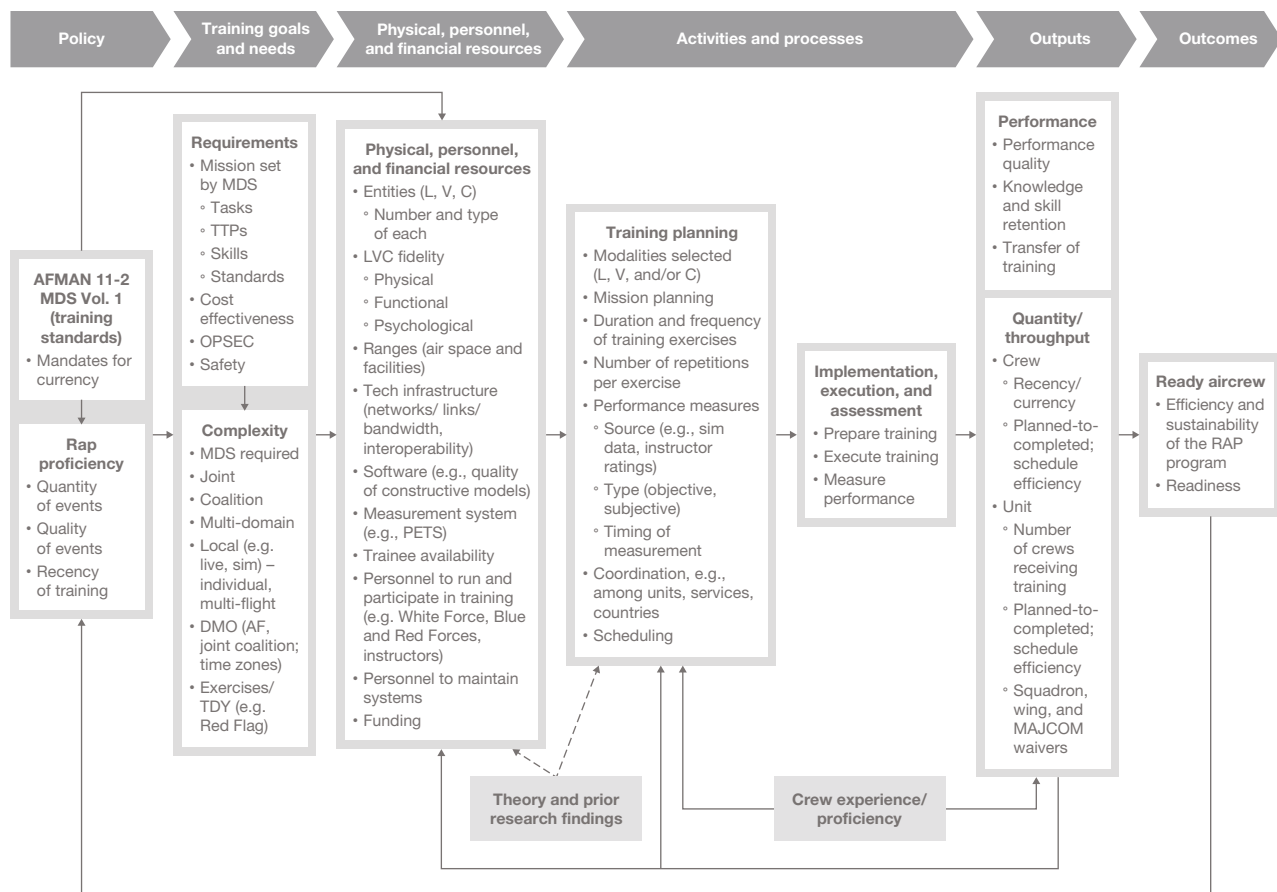
⁶ Logic models provide a graphical depiction of constructs in a program or system and relationships among those constructs. Constructs often included in logic models are inputs, such as resources available to operate a program; processes, such as carrying out program activities; outputs resulting from these activities and processes, such as short-term performance and stakeholder responses; and longer-term outcomes or impacts, such as organizational readiness or other aspects of performance.

ordinate study efforts across MAJCOMs. Constructs in the model can guide specific studies on appropriate mixes of LVC components to validate suppositions from the mapping tool. The model also points to experimental design factors to consider when testing the effectiveness of various mixes of LVC components.

- The model can also **support training operations**. For example, consideration of available resources and requirements could point to the need to use virtual and constructive technologies, even when live flight is more appropriate from a pedagogical perspective. Results of experiments on appropriate mixes of LVC components may guide decisions regarding acquisition of training technologies or other resources. The model can also be used for program evaluation.

The logic model is shown in Figure 4. The model consists of six constructs: policy; training goals and needs; resources (physical, personnel, and financial) that can enable or impose limiting factors (LIMFACS) on the feasibility of training; activities and processes; outputs; and outcomes. Arrows show the relationships between constructs or elements of the constructs, including direct effects, indirect effects, and feedback loops. Although the model can be used to support operations and program evaluation, we focus on using it to guide an ongoing program of research on appropriate mixes of LVC capabilities.

FIGURE 4
Logic Model to Guide Research on the Use of LVC



One Approach to Using the Model Is Input-Driven

One approach for using the model to guide selection of the mix of LVC components for research is *input-driven*. This involves considering how current policy or known LIMFACs affect which technologies are feasible to use for training. For example, units might determine that pilots are having difficulty with tactical execution in weather on the F-16. One important skill for this task is “effectiveness of A-G tactics.” The interactive tool indicates that a number of technologies, including domes, flat/curved panels, head-mounted displays, and heads-up displays/visors, may be appropriate for this skill. The logic model can then be used to identify other elements to include in study designs. Experiments could (1) compare some mix of these tools with the current approach (full-motion simulator) to introduce weather effects, (2) assess how many practice sessions crews need to achieve proficiency using these tools, and/or (3) compare a subset of these tools in terms of learning, cost, and availability. Planning and executing the study involves other elements of Activities and Processes (in Figure 4), such as determining the number of participants needed, creating training scenarios, determining the number and length of training trails, identifying appropriate measures of proficiency,⁷ and so forth.

A Second Approach Is Technology-Driven

Alternatively, a *technology-driven* approach starts with testing technologies not currently approved for CT. For example, the USAF could conduct research to test the mapping tool’s recommendations about the match between aircrew skills and training technologies (e.g., domes or head-mounted displays compared with full-motion simulators or live training for performance on reacting to air-to-air threats).

⁷ For example, RAP tracks proficiency in terms of productivity measures, such as flying the required number of sorties, the quantity of events, quality of events, and recency of training. However, RAP does not track the quality of aircrew performance or sorties. Assessing appropriate use of LVC requires measures of actual proficiency or performance.

Designing and planning these studies involve many of the same considerations for study design and execution described above. Results of these studies may point to needs for changes in such factor as policy (e.g., which technologies are approved for training) and resources (to acquire and deploy approved training technologies).

Conclusions and Recommendations

A central argument of this research is that there is no *single*, optimal mix of LVC components for training; instead, the optimal mix depends on a range of factors, as illustrated in Figure 4. That is, for any given set of parameters and conditions captured in the logic model, there can be a consequent appropriate, or even ideal, mix of LVC and training capabilities. Determining the optimal mixes, however, requires continuous data collection and research. PAF’s mapping tool and logic model can be used as a basis for these efforts.

Although there is no single optimal solution that applies to all conditions, the logic model can help formulate the problem of determining the appropriate mix of LVC components as an optimization problem. That is, the model can help identify decision variables (i.e., how much training should be live or what aspects of virtual training may be most appropriate), as well as constraints (i.e., cost limits) and objectives (i.e., performance metrics or aspects of readiness) that depend on the decision variables. With sufficient data collection over time, one can ultimately model how various objectives and constraints relate to the variables. One can then determine the value of the variables that optimizes the objective(s) while adhering to constraints. Just formulating this kind of problem, let alone solving it, could help facilitate more effective use of LVC.

Table 3 summarizes findings and recommendations and organizations best situated to address the recommendations, as discussed above and in the full study report (Marler et al., 2023).

TABLE 3
Conclusions and Recommendations

Conclusion	Recommendation	Responsibility ^a
There is a lack of standardized assessment and data for tasks, skills, and training capabilities, and there is insufficient alignment of training tools with needs.	Adopt and expand on the proposed mapping tool, including use of MECs.	USAF
The USAF relies on the number and type of sorties, rather than quality of performance, to determine aircrew proficiency.	Develop robust measures of aircrew performance to assess the relative value of different mixes of LVC and for use in operational settings.	USAF
There is no clear balance between centralized coordination of MAJCOMs and decentralized training needs.	Continue to provide centralized coordination across the MAJCOMs, track the availability of LVC training capabilities, and advocate for acquisition efforts where gaps exist.	AF/A3T and AFAMS
There is a lack of a strategic plan for research on mix of LVC components for CT.	Oversee the use of the mapping tool and logic model as a roadmap for continuous experimentation; oversee and support a corresponding program of research.	AF/A3T
Policy for CT makes a distinction between live and virtual but does not consider the range of available virtual technologies.	Use and help sustain the mapping framework to update CT (and RAP) by distinguishing among virtual technologies and developing an expanded portfolio of training tools.	MAJCOMs ^b
MECs provide a foundation from which to build a training framework, but they require expansion and refinement.	Transition sustainment of MECs from AFRL to MAJCOMs and adopt standard terminology to aid in application across missions and MDSs.	MAJCOMs

^a The USAF is the overarching organization in this context, responsible for actions that either require relatively high level governance or that have broad implications. Within the USAF, A3 (Operations) is the operational lead. AF/A3T was the sponsor for this study. It is responsible for policy, strategy, and oversight of training and readiness. The Air Force Agency of Modeling and Simulation (AFAMS) served as stakeholder and provided the action office for this study. AFAMS is responsible for leveraging modeling and simulation to support and facilitate operational training and readiness.

^b While MAJCOMs have the necessary expertise regarding their specific missions and MDSs needed to populate the framework, AF/A3T and/or AFAMS should be responsible for coordinating and sustain the actual software tool.

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About This Report

This document is a summary of prior report, *A New Framework and Logic Model for Use of Live, Virtual, and Constructive Training: Continuation Training for Complex, Collective Aircrew Tasks in the U.S. Air Force* (Marler et al., 2023). This research was commissioned by Major General James A. Jacobson and Mr. Steven Ruehl, Air Force Headquarters, Office of Training and Readiness (AF/A3T), and conducted within the Workforce, Development, and Health Program of RAND Project AIR FORCE as part of a fiscal year 2019 project “Enterprise View—Optimal Mix of Live, Virtual and Constructive Capabilities in Support of Training Across Warfighting Domains.”

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