# Strategic Planning for Aircrew Readiness: How MS&T must be balanced with live-fly experiences to support future mission goals

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## ABSTRACT

Aircrew readiness needs are changing rapidly yet historical technology and training practices cannot support these requirements. Specifically, the USAF's family of simulators have not kept pace with the necessity to integrate platforms for training resulting in stove-piped, limited training experiences and reduced readiness. Specific issues include a lack of congruence with current platform capabilities, inaccurate simulated threats and experiences, and a lack of access to high-end integrated simulation environments. Accordingly, the USAF conducted a study of graduate level pilots across 12 airframes to inform resourcing and advanced training gaps with a focus on "Night One" readiness.

Specifically, objective and subjective training and readiness data were collected to determine if current training and technology adequately support readiness across airmen in high-end platforms. Findings suggest there are several existing gaps that warrant immediate attention including: a) live-fly ranges do not meet 5th Generation, Electronic Warfare (EW), or integrated and contested training requirements, b) synthetic training venues lack sufficient fidelity, are overly scripted, and lack integration with multiple platforms resulting in negative training, c) high-fidelity synthetic training venues do not have the capacity to meet requirements and are cost prohibitive, d) distributed training networks do not support 5th Generation or EW training due to latency, and e) a multi-platform simulated environment that supports training for the contested high-end fight has not been developed. More plainly stated, "the Air Force's projected force structure in 2030 is not capable of fighting and winning against this array of potential adversary capabilities (USAF Air Superiority Flight Plan, 2016)." Based on these data and the demand signal to modernize, key recommendations from the Strategic Aircrew Training Investment Strategy study regarding how to balance the need for live-fly experiences with the requirement to conduct high-end training and test in simulators are provided.

## ABOUT THE AUTHORS

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## INTRODUCTION

The National Defense Strategy (2022) requires a high degree of mission readiness by USAF personnel facing a rapidly evolving volatile, uncertain, chaotic, and ambiguous (VUCA) environment where Night One scenarios are more likely to be novel rather than planned or rehearsed. In complement, the USAF Air Superiority 2030 Flight Plan (2016) highlights the need for an emphasis on human readiness focused on time to train, training effectiveness, skill decay, resilience, cognitive model development, and application to the operational environment. In response, several modernization strategies and initiatives have been designed and funded to require technological interoperability, data access and analysis, the ability to rapidly evolve and expand the use of new technologies, and personalized data-driven training interventions and pathways (DoD Digital Modernization Strategy, 2019; DoD Data Strategy, 2020; Modernizing Learning, 2019). Yet, despite the guidance and support these strategic planning and operational documents provide, it remains necessary to drill down further to define actionable tactical level requirements, specifications, and standards – and in this case, specifically tied to synthetic versus live fly recommendations. These clarified elements then need to be stratified by need and timing to drive planning and resourcing requirements.

Accordingly, the Joint TACAIR Synthetic Training (JTST) Analysis of Alternatives (AoA, 2020) was conducted to determine training environment options that could meet the needs of the future force. Findings include the recognition that advanced live fly training and range practice cannot be conducted for a number of platforms due to security and pragmatic limitations. However, synthetic training options are also hindered. Specifically, current synthetic environments are not interoperable at necessary levels of fidelity and are “deficient at representing electromagnetic, U.S., and adversary capabilities, which results in negative training for operators at advanced levels.” The Operational Training Infrastructure (OTI) for Combat Air Forces (CAF) Intelligence Capabilities-Based Assessment (CBA) also noted that fidelity and future conflict realism cannot be met adequately in current synthetic environments. Multi-level security issues and the increasing demand for advanced operator training mean that current venues for high level integrated training cannot adequately deliver needed experiences. More specifically, “Realistic, advanced, live-fly training is not possible due to range size constraints, adversary collection capability of electromagnetic operations, and limited threat replication capability (AoA, 2020).”

Taken together, the national strategies define the near and longer-term threats facing the USAF while the AoA (2019) provides clarity regarding current training constraints that will hinder aircrew readiness to face those threats. This shortfall in training environments impacts readiness today, most specifically for future high-threat scenarios that we cannot replicate for training. Emerging threat systems outpace training systems in development indicating that this gap will widen. Therefore, to ensure consistent readiness, training, and preparation, investments are being considered to inform strategic decision making.

*“Aircrew must be routinely exposed to the risks and physical feedback/violence of the live air combat environment and develop confidence in the actual combat systems as well as a healthy respect for the real world*

*consequences of poor judgement or performance. Decision making under G loading is a fundamental principle in our training." (Combat Air Forces Live, Virtual, Constructive [Blended] Training, 2018)*

As peer and near-peer adversaries gain technological advantages that allow for a leveled capability, it will be the differences in human readiness that will decide the results. The outcomes of potential conflict events will be decided by readiness defined not by the number of hours spent flying and practicing but instead by optimizing the total Airman – physically, physiologically, and cognitively. By necessity, training will become personalized to the needs of each Airman depending on the skills needing to be gained and taught in environments based on the capabilities of the systems. As a result, the demand for high-end aircraft training is projected to expand 400% between the years 2020 – 2029 (AoA, 2020). When these realities are combined with increasing real-world networked Joint Force expectations to interoperate technology and training, significant changes will need to be made in collaboration with other DoD efforts to ensure the effectiveness and efficiency of training development. These factors support the need for a strategic investment plan that articulates the hierarchical training needs of the USAF across all platforms.

## METHOD

### Document Review

Over 150 documents were reviewed covering such diverse yet integrated topics as investigating challenges the USAF has faced in training for the past decade, issues with simulators and their continued use, costs associated with live-fly training and range usage, and the presentation of simulated threats, each of which inherently present obstacles to effective training execution. The types of documents reviewed include but are not limited to scientific research studies, military reviews, policy requirements, and strategic guidance.

### Interviews

Interviews of active duty officers were conducted to determine which operational issues are most problematic and need urgent attention for future systems and planning. Key areas of focus included determining the relative importance of live versus virtual training, and "high" versus "low" simulator presentation capabilities, understanding the RAP Tasking measurements as a basis for readiness determination, live flight limitations, and associated costs.

### Syllabi Review

Each platform syllabi was also reviewed including Mission Qualification Training (MQT), Instructor Pilot Upgrade (IPUG), and the Weapons Instructor Course (WIC). The requirements from the RAP Tasking Memorandum were also included. The first task was to determine the simple ratio of training events accomplished in Live Fly versus delivered via virtual means. Further delineation was determined between administrative events, "low-end threat" training (tactical training that does not fit into the high-end definition including such events as local area orientation simulators and flights, and instrument and mission emergency procedures evaluations, SERCO), and "high-end threat training" (Training conducted in a contested, congested electromagnetic (EM) environment against relevant and realistic peer/near-peer threats with joint/multi-domain assets as defined in tasked OPLANs; SATIP Gap Analysis and Syllabus Data Gathering, 2021). The simple ratios were reviewed for trends and recommendations summarized.

## FINDINGS

### Training Environments

There are four training environments relevant to aircrew readiness used by the USAF: classroom, live fly, range, and simulator. These broad "environments" have some overlap and are programmed to become hybrids; e.g. live-fly is frequently performed in a range environment, and ranges are working to develop greater abilities to inject simulated entities into live-fly training. In these instances, adversary replicators are used to represent threat systems. These replicators range in complexity from simple trainers to 4th and even 5th Generation fighter aircraft. Low-end adversaries such as the T-38 are beneficial to the extent that they provide some basic context in which to fight but are significantly problematic as well because they do not exhibit the same flight patterns or capabilities of the actual enemy aircraft. Threats to training are significant. More advanced adversaries such as F-16s and F-35s represent a significant improvement in training, but their cost and limited availability are a significant constraint. In addition to airborne adversaries, the USAF utilizes numerous ranges which host a variety of surface threat emitters and weapons systems. These ranges vary in complexity and scale, but for example, the Nevada Test and Training Range (NTTR) represents the most complex and capable range available to aircrew. NTTR and JPARC have been identified as the main focus ranges for investments (OTTI roadmap). Even so, the most advanced ranges lack the ability to simulate the most advanced threat capabilities and densities that are required. Furthermore, the cost and limited availability of ranges like the NTTR make them necessary yet insufficient to meet current and projected training requirements.

As technology advances among both friendly forces and potential adversaries, training missions cannot be accurately practiced exclusively in live flight. Simulation-based training, at various task levels, fidelity levels, and frequencies must be increased. Specifically, a paradigm shift from using simulators to prepare for live fly (basic skills, EPs, etc.) to using live fly (basic Airmanship, G-loading, MDS-specific TTPs, etc.) needs to occur in order to prepare for high-end training in the simulators.

**Training Platforms**

One cannot adequately understand this disconnect between training needs and training opportunities without considering the relationships between training platforms and their limitations. Accordingly, 14 pilots and platform training commanders were interviewed to better understand the challenges currently facing instructors and trainees including fighters, C2, bombers, tankers, mobility, and remotely piloted aircraft. Table 1 provides a breakdown of key issues as well as general needs described throughout the interviews. Across the platforms, several primary points were noted. Namely, (1) there is a need to define readiness by the capabilities of the pilots regardless of the number of hours or sorties flown, (2) it is expected that the majority or entirety of high-end training will need to transition to the virtual environment, and (3) the need to practice unscripted, high-end, contested fight scenarios is a requirement that will necessitate a connected multi-platform virtual environment. Specific needs of each platform are provided below.

Table 1. Platform Review Summary

| Platform | Task | Specific Need | General Need |
|---|---|---|---|
| F-22 | Fighter | Ranges are not sufficient for high end integrated training due to OPSEC, size, and EW constraints | Sims not sufficient for high end integrated training due to fidelity, interoperability, and proprietary ownership issues<br>Basic airmanship skills are being compromised to accommodate requirements that exceed available time to train |
| F-35 | | The biggest issue is that this aircraft is intended to fight in very challenging threat environments – simulating that requires high end technology to replicate and it takes large air space to replicate tactics.<br>ET (Embedded training) lacks accuracy, realism, and can create negative training situations | Need integrated virtual fight space to practice realistic contested scenarios<br>Must be able to access joint technology/environment<br>Need to address cognitive overload expected during contested Night One |
| F-16 | | Maintenance Issues | Lacks whole picture (scenery, ripple effect of impact)<br>Need integrated practice – outgrown air-to-air practice |
| AWACS | C2 | Full mission planning exp - working only our one platform planning is like talking to oneself<br>Need to plan WITH other assets<br>Aircraft maintenance | Ability to talk to live fighters in a realistic system<br>Complex Battle Management Experience<br>Other people - Require other people to do their job. They are seldom written into other people's training plans.<br>Definition of readiness and clear objective metrics needed |
| B-2 | Bomber | Sims are too synthetically perfect/scripted – need unexpected elements (fog and friction)<br>Air space limitations make simulation and live fly a challenge – need to practice distributed operations | Biggest concern is the need to train together<br>Need a fully joint virtual environment to practice coordination |
| B-52 | | Sims not concurrent with plane<br>EW not the same in sim/live | Cannot integrate with other platforms<br>Can practice flying close but the art of refueling is not representative |
| MC-130J | SOF Tanker | Need to redefine "readiness" to reflect what the actual missions of the future will require and use that to drive training objectives and activities | Need to coordinate across the platforms and services (integrated training)<br>Need accurate assessments of readiness for the contested Night One reality |
| KC-135 | Tanker | Limited access to sims<br>Sims focus on basics<br>Sims are artificial and predictable | Need integrated training<br>Need to focus on high end fight<br>Need repeated exposure to unpredictable contested scenarios |

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| | | | Need sensors on board to support battlefield awareness |
| C-17 | Mobility | Lack SA in the aircraft, need supporting technology to improve battlefield awareness<br>Lack forward training planning for contested fight | Need to train to a contested battlespace<br>Need to train in an integrated simulation<br>Need supporting technology<br>Need to train against a peer enemy |
| RPA MQ-9 | Remote Piloted | Biggest issues are regulatory in nature (e.g., FAA rules) | Need dedicated training time before entering theater<br>Need integrated fight training experience |
| RQ-170, RQ-150 | | RPAs are poorly represented in sims | |

**Specific Summary Points:**
Beyond highlights, interviewees revealed insights that clarify the demand for advancing aircrew readiness. Specifically, adversaries are bringing on new capabilities every six months and the exponential trend line is expected to continue which has increasingly exacerbated the need to train to high-end threats and to set up for them quickly and consistently. Thus, for the first time in a generation, we are now training warriors not for a planned Night One fight but instead, for a novel situation. However, because no integrated multi-platform simulated training environment currently exists, the ability to train to a novel night one is hindered. For example, for F-35 pilots, Embedded Training (ET) is one of the most pressing concerns. It is a synthetic training system that simulates threats in the air and while it has a low cost, it has an inaccurate kill responses and threat targeting and is different per location. Accordingly, cognitive overload was noted as a significant and debilitating issue. "When you're combining your threats on the ground (real) and ET (sim), you have to use extra brain power when you're flying because you have to wonder if when I killed it – will it die (real) or continue in error (ET)?" (Interviewed F-35 Pilot).

Additionally, instructors consistently reported the need for more access to connected simulators that help trainees develop decision making skills under high stress situations. Yet, simulators were reported as extremely helpful when full simulation capabilities are present. Specifically, they help trainees understand the "why" behind decisions. However, they are too synthetically perfect, scripted, and ultimately unrealistic. Fidelity and concurrence with the aircraft are also issues. At times, the simulator hardware and software are two generations behind currently fielded aircraft systems. For example, weapons and navigation interfaces with the aircraft are not replicated accurately in the B-52 simulator. This results in negative training, or missed training opportunities altogether.

**Synthetic Environments**

The USAF has training environments in various stages of development (from fully deployed for training to early stages of design), each with different levels of fidelity, capability, and focus for training or testing. Each of them is or will be ready for use at different dates and require different levels of financial and expert resources. None of the systems are aligned with modernized performance objectives feeding into organization-wide accessible learning architectures. The following highlights key systems and their features (Table 2).

**Virtual Test and Training Center – Nellis (VTTC-N)**
The VTTC is a government-owned, physical architecture with simulators at Nellis AFB, NV providing an isolated, closed-loop system in which to conduct testing, tactics development, and advanced training for USAF 4th and 5th Generation+ aircraft. It is currently operational and intended for High-End Advanced Testing, Tactics & Training (HEAT3) environment but does not adequately meet this requirement. It is conceptually capable of networking with other USAF/USN platforms via Distributed Mission Operations Network (DMON).

**Joint Simulation Environment (JSE)**
The JSE is a high-fidelity government-owned, non-proprietary modeling and simulation environment being used and further developed to test fifth-generation aircraft and systems, which will be accredited to supplement open-air testing. Its prototype is currently in use at Nellis AFB, NV, Edwards AFB, CA, Wright-Patterson AFB, OH, and Pax River NAS, MD. JSE 1.0 currently supports F-35 Blk 3F IOT&E while JSE 2.0 (JSE AF, JSE Next) is expected to reach minimal viable solution to support F-35 Block 4 & F-22 Capability Pipeline IOC in FY24 to enable "Fair Fight" simulations and graded outcomes. JSE 3.0 aims to fully support Multi-Domain Command and Control (C2) applications and Distributed Mission Operations, specifically for F-35 testing and evaluation (T&E). The facility at

Edwards is being built, and the facility at Nellis is still being planned. (email exchange with JSE PM at Edwards AFB).

**Distributed Mission Operations Network (DMON)**

The Combat Air Force (CAF) DMON has been in use since 1997. It provides readiness training to warfighters by networking geographically separated Mission Training Centers (MTC) and disparate training systems. Additionally, the CAF DMO program develops and maintains common standards that federated training platforms adhere to in order to exercise interoperability. The DMON is currently operational and a widely prolific network architecture provides integrated training for numerous platforms. However, legacy security and network architecture create latency challenges. Thus, capabilities are sufficient for many existing platforms but insufficient for advanced 5th Gen HEAT3 training.

**Common Synthetic Training Environment (CSTE)**

The CSTE was a concept that envisioned the development of a government-owned digital environment that provides operationally and tactically relevant training representations of combat with a peer/near-peer adversary for operational training, including HEAT3. CSTE would utilize a common environment and simulation with various models and physical simulator devices to maximize efficiency for continual advances in technology and rapidly evolving operational demands. It was primarily designed for training with capability to expand to test. CSTE would provide a low-latency, complex EMOE, data-centric, networked training environment with the ability to evolve platforms and modules. This program was set to begin initial development in 2022 but the USAF has refocused efforts on building out JSE to include training.

**Joint Integrated Training Center (JITC)**

The JITC is a concept that seeks to leverage eventual synthetic environment advancements in a VTTC-style center that is jointly operable. It will support a training capability that will provide joint, tactical-air-focused, composite strike package high-end training in a synthetic environment that represents complex Great Power Competition Scenarios. The U.S. Air Force Warfare Center (USAFWC) proposes establishing the JITC facility within the campus of related synthetic test and training capabilities at Nellis AFB. The synthetic environment implemented in the JITC will largely determine its effectiveness for training. It will be capable of large-force mission rehearsal in a HEAT3 complex EMOE. The training audience will be limited however, as aircrew will be required to travel to Nellis AFB for training. In the future, it could be possible to integrate the JITC with other distributed simulators that share the synthetic environment and architecture.

**Simulator Common Architecture Requirements Standards**

SCARS is not an environment or synthetic solution, per se. It provides the standards for modular architecture for simulators supporting interoperability. SCARS conducts cybersecurity compliance and monitoring and maintains the library for terrain and model updates. CAE is the prime contractor for SCARS and leads an industry team to help the USAF develop a common architecture to integrate and standardize aircraft training simulators. Approximately 2,400 simulators at 300 locations are to be updated with the new common architecture.

Table 2: Synthetic Environments Comparison

| Synthetic Environment | FOC | Interoperable | Integrated Platforms | EMOE | Proprietary | Distributed | Able to integrate future technology | Cost to FOC | Platforms Served | Description | Issues |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DMON | Current | Yes | Yes | No | Yes | Yes | No | \$50M + \$40M | | networks geographically separated Mission Training Centers (MTC) and disparate training systems | Dissimilar views across simulators, Issues for foreign partners, MLS, latency, lacks space/cyber |
| VTTC | Current | No | No | No | No | No | No | \$500M | 4th and 5th Gen | complex, multi-domain, peer-adversary scenarios for | Isolated, closed loop system |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | integrated warfighter training, tactics development, and capability test | |
| JSE | FY24 | Yes | Yes | Yes | No | No | Limited | | F-35, F-22 | high-fidelity gov-owned, M&S environment to test fifth-plus generation aircraft and systems | High fidelity, Limited platforms |
| CSTE | FY27 | Yes | Yes | Yes | No | Yes | Yes | $440M | All USAF, Joint | Peer/near-peer adversary, High-end advanced testing, tactics, & training | Conceptual, does not currently exist |
| JITC | FY30 | Yes | Yes | Yes | No | Yes | TBD | $270M | F-35,22; EA-18,G; F-15E,16; EC-130H | Training events specific to employment of tactical air platforms | Only a signed memo |

Note: Virtual Test and Training Center (VTTC), Joint Synthetic Environment (JSE), Common Synthetic Training Environment (CSTE), Joint Integrated Training Center (JITC), Distributed Mission Operations Network (DMON). Reference: Rated Aircrew Strategic Training Plan, Operational Test and Training Infrastructure (OTTI), 2021. USAF A3T

## JTST Analysis of Alternatives Findings

Given the multiple options of synthetic training environments, an extensive review of these simulation tracks was conducted to inform investment planning (AoA, 2019). Several recommendations surfaced. Specifically, simply continuing with current baseline and incremental planned improvements will not meet training requirements. The Joint Force is unable to train like they would fight now and, in the future, given the current roadmap. Improvements to fidelity are required to drive positive training transfer. Current networks and simulations do not support 5th Gen/EW platforms. This includes developing the JITC for increased fidelity and to support joint, high-end EW-5th generation training; the JSE/Fighter-in-a-box (FIAB) Architecture Framework as a solution for local "4-ship" or less home station training; and JDC-SE as a solution for data-centric distributed training, data analytics, and shared services.

## Lightweight Simulator Systems

In addition to the high-end, integrated training environments, significant development has occurred in the lightweight simulator space that is yielding promising training outcomes at a substantially reduced cost. A recent review of defense training companies at Interservice/Industry Training, Simulation and Education Conference (I/ITSEC) yielded 150 companies involved in developing modeling and simulation training platforms that can support flight and related USAF training. This technology is mature and most are immediately deployable. It is also expected that as a connected, interoperable high-end virtual environment is created that the lightweight simulation technologies will be able to automatically "plug in" to the full-scale environment allowing a fluid transition and connection with legacy and developing products, platforms, and environments.

The primary benefit of these technologies is that they target training to focus on decision making under stress, a widely studied cognitive training focus across all military branches. Specifically, through part-task training, practice, and assessment, the mind can focus on elements of the fight and improve overall performance substantially. Key technologies include desktop and mobile models and simulations, augmented reality (AR), virtual reality (VR), and mixed reality (MR). Desktop and mobile devices can be used at a very low cost to provide access to decision making vignettes that can be personalized based on data analysis. The training benefit of these focus primarily on increasing speed and practice in making decisions based on a variety of scenario variables. AR provides real time, in scenario training, explanations, directions, and support that can substantially increase comprehension and connections to other elements as well as decrease time to proficiency. VR can improve visual and conceptual understanding of environments, human elements, and situational awareness by providing a virtual representation of the real world. MR makes possible learning to exist in a mix of real and virtual worlds which allows the brain to benefit from both platform elements. Combined, these lightweight simulator options can be connected to create an efficient and effective learning pathway for pilots at a low cost.

**Specific Training and Procurement Considerations**

To optimize readiness, it is necessary to invest in comprehensive planning that maximizes the usage of each technology available and defines how best to use it. Alternatively, one-off purchases or investments can lead to individual apparatus that train one element but fail to connect that learning to the greater readiness goals. During interviews, this issue was widely named as the biggest hindrance to readiness achievement. Each simulator and other technologies are purchased separately, through different vendors, without standardized requirements for connecting the use of these apparatus, the data that comes from them, or the appropriate learning pathway needed to achieve mastery. The most direct path to the desired readiness goal is to apply learning engineering principles to the people, processes, and tools involved. Interviews, research, studies, and gap analyses yielded a substantial list of concerns (Table 4). These challenges fall into six distinct categories: Pragmatic issues, fidelity, human limitations and needs, intangible threats, security issues, and cost (see table 4 for a summary). These issues combine to highlight four primary capability gaps: 1) EMOE, 2) MLS, 3) Interoperability, and 4) Representation (AoA, 2020).

Table 4: Consolidated Current Issues

| | |
|---|---|
| Pragmatic issues | 5th gen aircraft; range size; time vs performance measures to achieve RAP requirements (policy); time and cost to access proprietary weapons systems data for currency updates; inadequate ability to plan, brief, execute, and debrief in distributed training; cumbersome and unresponsive software update processes |
| Fidelity | EW; OPSEC restrictions; a lack of integration and threat replication; unrealistic/inconsistent EMOE; Non-concurrence between simulators and weapons systems/aircraft |
| Human limitations | Readiness for novel environments and the contested fight; cognitive overload; cognitive agility; optimized teams; technological enhancements |
| Intangible threats | Eligibility/interest/expectation; pace of change; Chinese investments in technology and research; civil population misinformation attacks |
| Security | Multi-level security; distributed operations |
| Cost | Contractor-owed; location-static rentals; TDYs are not always supported but are necessary for readiness achievement |

Note: Data collected from AoA, 2020 and interviews

Accordingly, research, development, and training goals will be geared toward developing for the high-end contested environment and by 2027 is expected to include a substantial variety of simulation technologies for training that increasingly will be used in addition to live-fly. Ultimately the goal is to accommodate the pace of change, evolving threats, and human optimization expectations (see Table 5 for a summary of goals by year).

Table 5: Training requirements by year

| | Environment Ratio LF:R:S | Environment Notes | Cognitive Enhancements | Instructor Interventions | Notes |
|---|---|---|---|---|---|
| Current | 40:30:30 | Fidelity, Integration Issues | None | Varies by Instructor | Sims used to replace live/range; Lack interoperability, EW, threat accuracy, mental model development support |
| 2027 | 50:10:40 | Sim expanded use for integration | Neuro-physiological data | Personalized training | Joint simulation exercises will be the norm; multi-platform environment required |

| | | | | | |
|---|---|---|---|---|---|
| 2035 | 30:10:60 | Sim primary training environment | Genetic pre-assessments; extensive real time sensor and internal data | Hybrid (Human + Tech) training; AI-instructors; Human facilitators | Readiness will require whole-airman optimization, resilience, and agility |

Note: LF=Live Fly; R=Range; S=Simulator. The ratios provided are intended to reflect estimations based on relative expected technology improvements and increasing OPSEC concerns. The reduced ratio of Live Fly training is not intended to imply reduced flying hours; rather, an increase in simulator training.

## RECOMMENDATIONS

The extent of technology changes that are now needed to train Airmen to continue to meet readiness requirements is growing exponentially (e.g., fast-paced technology advancements, extensive data streams, and continuously evolving cyber threats). As a result, short-term minimal interventions will be unlikely to support continued readiness at this pace and will be costly. Further, policy and national strategy mandates require holistic, connected solutions that support interoperability. This is why options which use an interoperable architecture and that will allow for rapid connectivity to update models, threat replication, and technology advancements, that will also support integrated high-end training for all platforms are being recommended. Thus, rather than focusing solely on platform-based specific issues being faced today, it is necessary to first understand the greater picture of technology capabilities and that are being coordinated across the entire department. It is no longer possible to skip this step due to policy requirements and what the low impact minor, targeted incremental solutions could provide. Finally, because ground, space, cyber, and civilian threats, both external as well as internal, affect all services, the total threat matrix can no longer focus solely on flight elements. Accordingly, recommendations include setting up a network of information and training to address current platform needs while anticipating future technology (e.g., sensors, artificial intelligence, and cybersecurity).

More specifically, the following recommendations are based on several criteria. First, these goals systematically address the capability gaps identified which need mitigation to achieve improved readiness to face a peer/near-peer competitor in 2027 and 2035. Second, these comply with the national strategies, DoD, and USAF policies referenced earlier which require learning system, data, digital, and cyber modernization. These recommendations may ultimately reduce some costs by targeting the use and upgrades of simulators and live ranges based on trainee needs and scientific findings that support optimized human cognition versus relying solely on human instructor capabilities. Finally, the second most important capability afforded by a modernized data and computing environment concept is that it dramatically simplifies the ability to continually evolve the live, virtual, constructive (LVC) ecosystem and training pipeline based on technology advancements. For these reasons, the following recommendations are made.

### I. Define readiness metrics by capabilities: Develop a Learning Engineering Design/Architecture

Current training syllabi and planning are based on current goals, technology constraints, and personal experience. To determine an optimized sequencing of content needing to be learned and in which environment it can be best trained, practiced, and assessed, a full unencumbered learning engineering design would need to be developed. Of particular concern and focus would be the human capabilities needed to react to future peer and near-peer adversaries. These additional human constraints and capabilities beyond traditional content include cognitive load management, cognitive agility, physiological control and measurement, and emotional reactivity. Based on the design, a learning architecture that would connect the RAP goals to training requirements would drive more efficient and effective readiness achievement.

### II. Prioritize both Integrated Flight Opportunities and Basic Airmanship Flight Practice

Integrated high-end flight success is predicated on the internalization of basic airmanship skills. If these skills are not reduced to automatic action, the brain will be overloaded, and the Airman will be forced to choose to either a) focus on conducting basic actions to avoid potential safety issues or b) focus on a situation that requires complex decision making at the risk of accidents occurring. To date, the changes being made that minimize live fly practices have been difficult to measure because accident/safety of flight reports are a lagging indicator of training deficiencies. Basic airmanship must continue to be a high priority to complement high-end integrated training practices. Likewise, integrated flight opportunities are necessary to promote readiness for Night One. It is no longer the case that any one platform will fight alone or even that the USAF will fight alone. Rather, emphasis must be placed on learning nuances of operating while connected to and interoperating with other platforms. The operator has to learn both the relevant decision-oriented content and the processes of retrieving, compiling, and applying information to maximize effectiveness and efficiency. Of note, every platform interviewed and reviewed for this report stated that training together in a joint environment to practice against a novel peer adversary in a high-end fight was the most important augmentation to training that is needed.

### III. Transition to Virtual: Support and Expand Current Training Opportunities while Investing in Distributed Interoperable Modularized Training Technology

There is always a need to balance cost and investment constraints to maintain current efforts while simultaneously aiming to support future readiness. It is more difficult in situations when major modernization efforts are needed that will sunset key elements that at one point were substantial investments. Nonetheless, the expectation today and in the future is that the battlespace will be highly contested and as such, military branches and programs will not enter any fight without involvement from other branches (Title 10; NDS, 2018; USAF 2030). To comply with these expectations and ensure that Airmen are ready to meet the additional expectations required to be effective in this joint, high-end, contested, peer and near-peer environment, integrated training is mandatory. However, this is not achievable through current range or simulation capabilities (AoA, 2020) leaving curriculum designers, scenario developers, and instructors in a challenging predicament. Based on interviews, it is clear that the officers and contractors representing these groups are providing the best training possible given the current constraints. However, substantial research in the areas of artificial intelligence, cognitive and physiological real-time assessment, interoperability specifications and standards, instructional design, and human performance optimization have not only been conducted over the past two decades but have demonstrated significant success in improving readiness elements across military personnel. When combined, the expectation is that a multiplying effect will occur that will accelerate time to achieve readiness as well as heighten the cognitive, physiological, and physical agility of future Airmen. It is not possible for operational instructors and scenario developers to be individually aware of these advancements. Moreover, it is not possible for them to implement any one of these capabilities on their own. Rather, it is necessary to collaborate with multiple communities who are individually and collectively working toward a connected virtual distributed platform. Many current efforts are aimed at becoming compliant with the Digital, Data, and Learning Modernization strategic plans across all branches. This living ecosystem concept is the intended next step in supporting joint, integrated training.

### IV. Plan for Human Performance Optimization Technology Integration

Substantial research in human performance optimization has been conducted over the past two decades resulting in a deep understanding of the human body, brain, and emotions and how all these can be measured through sensors, analyzed by artificial intelligence algorithms, and then used to drive training decisions. Capabilities in this space range from basic research (e.g., DARPA brain initiative) to applied laboratory research (USAF's DNA assessments to drive training decisions) to COTS Neurophysiological headsets and sensors that are at TRL 8. Pilot Training Next is tying these initial products and findings to the USAF training pipeline and while the program is in its initial stages and will require additional adjustments, the use of sensors to monitor real-time human internal processes is enduring because the majority of research in these areas are being funded by adversarial nations. Consequently, it will be mandatory for the U.S. to also engage this apparatus to maximize human capabilities. Once technology is near-equivalent across nations, it will be the human-in-the-loop that will make the difference (Air Superiority 2030 Flight Plan, 2016).

## SUMMARY

Aircrew readiness requires modern approaches to address national security priorities across air, space, and cyber realms; this is a widely agreed upon notion. Research presented suggests that the path to achieve Air Readiness need not be laboriously complicated. Based on the current states of training and simulation infrastructures, researchers identified four concise actions that would advance efforts toward better Air Crew Readiness: Defining readiness metrics, prioritizing flight opportunities and basic flight practice, transitioning to more virtual tools across use purposes, and develop human optimization practices based on data.

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