USAF Scientific Advisory Board
FY 2020 Study

Air Force Communications in the Future Operating Environment

Terms of Reference

Background

Air Force operations require a robust communications architecture for essentially all mission functions, including passing tactical data between heterogeneous airborne platforms, collecting and disseminating high bandwidth data from distributed surface, air and space-based sensors, and supporting joint all-domain command and control (JADC2) operations. Current Air Force communications capabilities are challenged in performing these functions in relatively permissive environments, and will be even further challenged in highly contested environments. While Air Force communications developments have lagged behind modern mission needs, there have been significant recent commercial and government investments to improve large data volume communications efficiency, including directional datalinks, cognitive radios and increased distributed communications capacity via proliferated low-earth-orbit (LEO) constellations. Substantial commercial investments in 5G may also offer improved communications capability in some environments with modest AF investment. However, Air Force missions may impose unique data quality, latency, resiliency, reliability and security constraints that will influence decisions on the viability of particular waveforms, communications architectures, and associated infrastructure. Additionally, cyber and other non-kinetic threats must be considered in developing and implementing the underlying technology and systems. The Air Force will benefit from a clearer understanding of the potential benefits and vulnerabilities of various communications architectures for maximizing operations across the spectrum of future missions.

Charter

The study will:

- Characterize aspects of the future operating environment that will challenge AF communications, and assess communication attributes required to satisfy needs for AF missions, including ISR, strike, and JADC2; address factors such as bandwidth, latency, link ranges, cybersecurity, and resiliency.
- Assess the ability of current AF communications and network technologies to support these future mission needs in permissive to highly contested environments, and identify key capability gaps.
- Identify and characterize emerging communications technologies, including 5G, proliferated LEO constellations, and mesh networks, as well as capabilities being developed and fielded by other services. Assess the extent to which key aspects of these capabilities can address the above gaps.
- Identify potential vulnerabilities and interoperability challenges for candidate approaches, including cyber, adversary denial, jamming, or spoofing, LPI/LPD concerns, multi-level security, system and spectrum availability, user equipment, and compatibility with legacy systems.
- Recommend approaches to assess promising communications capabilities, including data collections, modeling, simulation and analysis, multi-domain experiments and operational demonstrations.
- Recommend a strategy for phased implementation of promising communications technologies by leveraging commercial and government development, to include transitions from current state. Identify longer-term S&T efforts and investments that may address any remaining limitations.

Study Product

Briefing to SAF/OS & AF/CC in July 2020. Publish report in December 2020.

USAF Scientific Advisory Board
FY 2020 Quick Look Study

Future Air Force Vanguard Selection and Management Processes

Terms of Reference

Background

An effective Air Force science and technology (S&T) enterprise is essential to enable warfighting capabilities to meet the objectives of the National Defense Strategy. In April 2019 the Air Force released its new 2030 Science and Technology Strategy. As part of this strategy, the Air Force will allocate at least 20% of its S&T budget to a transformational component intended to drive future force design. This component will include a set of research projects called Vanguard programs, which will seek to advance emerging weapon systems and warfighter concepts via prototyping and experimentation, with a goal of transitioning to an Air Force Program of Record. The initial set of Vanguard programs are *(i)* Golden Horde (collaborative networked autonomy for smart munitions, including Small Diameter Bomb I and Miniature Air Launched Decoy); *(ii)* Navigation Technology Satellite-3; and *(iii)* Skyborg (manned-unmanned teaming for fighter aircraft). While an initial process was in place to determine the candidate Vanguards, going forward the Air Force intends to implement a more formalized selection and management process to maximize the likelihood of successful Vanguard program execution and transition to Programs of Record. The Air Force will thus benefit from an independent study that assesses a wide range of options for how Vanguard selection and management might be structured and recommends options that are most likely to meet the objectives of the Vanguard concept.

Charter

This "quick look" study will:

- Survey key Air Force stakeholders relevant to the Vanguard concept, including AFWIC, AFMC, AFRL, SAF/AQ, AF/ST and MAJCOMs, to determine overall goals, constraints, and key mission drivers for Vanguard programs.
- Survey government and commercial entities to understand their processes for selecting, executing, tracking, and transitioning or terminating complex prototyping programs.
- Identify distinguishing elements of these processes that enable successful prototyping, and recommend best practices that may be suited for current and future Vanguard programs.
- Using one or two initial Vanguard programs as case studies, compare the recommended best practices with the process and assessment criteria used in their selection, including operational suitability, technical maturity, integration readiness, and other factors.
- Recommend metrics, analyses and processes to inform the selection and subsequent management of future Vanguard programs to maximize the potential for rapidly developing and transitioning "game changing technologies" to Programs of Record.

Study Products

Briefing to SAF/OS and AF/CC in May 2020. Publish report in August 2020.

SAF/PA Release: 2020-0115

USAF Scientific Advisory Board
FY 2020 Study

Understanding and Avoiding Unintended Behaviors in Autonomous Systems

Terms of Reference

Background

The Air Force is in the early stages of a transformation to far greater use of autonomous systems, including unmanned aircraft and other systems and processes in which autonomous reasoning and control can provide benefits. Yet experience in the commercial world has demonstrated failures and unintended behaviors in such autonomous systems, including airport luggage handling and self-driving cars. Such systems are capable of self-awareness and adaptability, including the ability to adjust current operations to maximize capability. This may involve numerous inputs from on- and off-board sensors, the system's ability to make interdependent decisions based on fusion of the input data, and its ability to adapt in deterministic or stochastic ways. As the number of inputs and system adaptations increase, it becomes increasingly difficult to fully understand the range of behaviors that can result. In effect, these become near infinite state systems for which the range of actual system behavior can be unknowable, and the intended range of system performance may be imprecise. Adversary efforts to degrade a system's performance through cyber techniques (e.g., insertion of artifacts into the input data or attacks on the decision processes themselves) may cause additional unintended behaviors. Establishing certifiable trust in such highly adaptable autonomous systems is essential for enabling their use. While some existing approaches may be useful for decreasing the likelihood of unintended behaviors in autonomous systems, the current ability to prevent such behaviors is limited. The Air Force will benefit from a study that assesses the state of the art for understanding and avoiding unintended behaviors in highly adaptable autonomous systems.

Charter

The study will:

- Survey past cases of faults and unintended behaviors in autonomous systems, including but not limited to autonomous vehicles, in commercial-world and national defense applications.
- Define major classes of unintended behaviors and cyber vulnerabilities in autonomous systems, and assess their origins in software design, operating environment, system use, and resulting consequences, including how these depend on the level of autonomy.
- Review current theoretical frameworks that allow probabilistic or deterministic assessments of software logic errors in high-dimensional or near-infinite state software systems.
- Evaluate software architectures that can enable improved detectability of logic errors, and software design approaches that support improved software verification and validation.
- Assess current and foreseeable approaches, beyond simple run-time limiters, for detecting, alerting and avoiding unintended behaviors, and for increasing fault tolerance.
- Recommend promising areas of science and technology that may lead to improved software design, failure recognition, and fault tolerance in highly adaptable autonomous systems for the Air Force. Evaluate the robustness of these improvements to adversary countermeasures.

Study Products

Briefing to SAF/OS and AF/CC in July 2020. Publish report in December 2020.

SAF/PA Release: 2019-0822