NASA SBIR 2022 Phase I Solicitation

A3.03 Future Aviation Systems Safety

Lead Center: ARC

Participating Center(s): LaRC

Scope Title
Future Aviation Systems Safety

Scope Description
Public benefits derived from continued growth in the transport of passengers and cargo are dependent on the improvement of the intrinsic safety attributes of the Nation’s and the world’s current and future air transportation system. Recent developments to address increasing demand for access to the airspace include: increased use of automation and autonomy to enhance system capabilities; airspace systems with tightly coupled air and ground functionality; cloud computing-based technologies used to perform functions or services; other widely distributed functions across ground, air, and space environments; increasingly integrated aircraft systems; and novel vehicle capabilities for both traditional and advanced air mobility (AAM) operations such as Unmanned Aircraft Systems (UAS) and Urban Air Mobility (UAM). These revolutionary changes are leading to greater system complexity, and current methods of ensuring that airspace and vehicle designs meet desired safety levels will likely not scale to these levels of complexity (Aeronautics R&D Plan, p. 30). The Airspace Operations and Safety Program (AOSP) is addressing this challenge with a major area of focus on In-Time System-Wide Safety Assurance (ISSA).

Understanding and predicting systemwide safety concerns of the airspace system and the vehicles flying in it, as envisioned in future aviation systems, is paramount. Thus, a proactive approach to managing system safety requires that once a new system, technology, procedure, or training is introduced, that operators have: (1) the ability to monitor the system continuously and to extract and fuse information from diverse data sources to identify emergent anomalous behaviors through health monitoring of systemwide functions and (2) the ability to reliably predict probabilities of the occurrence of hazardous events and of their safety risks. Specifically, AOSP’s System-Wide Safety (SWS) Project is developing an In-Time Aviation Safety Management System (IASMS), a scalable and distributed system approach to address aviation safety needs. Based on ISSA building blocks, IASMS services, functions, and capabilities (SFCs) are architecturally structured to “Monitor—Assess—Mitigate” operational safety risks. For definition, services are systems that produce safety-relevant information, functions produce safety-relevant outputs or data needed to compute safety-relevant metrics, and capabilities provide safety-relevant benefits that may leverage services and functions. IASMS SFCs are envisioned to include increasingly automated and autonomous functionality to adapt and scale to the increasing complexity of aviation operations, necessitating new approaches to assure autonomous functionality. Therefore, proposals focused on assurance of autonomy for operational systems will also be considered for award. Additionally, due to the increasingly digital transformation of the airspace system and nature of the IASMS, one research area of high interest is methods for monitoring, assessing, and mitigating cybersecurity vulnerabilities and attacks. Innovative approaches and methods are sought that monitor/assess/mitigate vulnerabilities before they can be exploited by malicious actors. Proposed innovations are sought that can be easily incorporated into the IASMS. Proposals that lack a technology/function that can be integrated into the concept of an IASMS will be declined.
Specifically, this subtopic seeks the following types of proposals, whose technologies can be integrated into IASMS:

- Proposals to address the safety-critical risks identified in beyond visual-line-of-sight (BVLOS) operations in small and large UAS, including but not limited to risks such as:
  - Flight outside of approved airspace.
  - Unsafe proximity to people/property.
  - Critical system failure (including loss of command and control (C2) link, loss or degraded Global Positioning System (GPS), loss of power, and engine failure).
  - Loss-of-control (i.e., outside the envelope or flight control system failure).
  - Any potential cybersecurity or cyber-physical attack affecting any or all operations within the UAS airspace system.

- Proposals supporting the research and development of ISSA objectives: 
  - To detect and identify systemwide safety anomalies, precursors, and margins.
  - To develop the safety-data-focused architecture, data exchange model, and data collection mechanisms.
  - To enable simulations to investigate flight risk in attitude and energy aircraft state awareness.

- Proposals supporting safety prognostic decision support tools, automation, techniques, strategies, and protocols:
  - To support real-time safety assurance (including in-time monitoring of safety requirements).
  - That consider operational context, as well as operator state, traits, and intent.
  - For integrated prevention, mitigation, and recovery plans with information uncertainty and system dynamics in a UAS and trajectory-based operations (TBO) environment.
  - To enable transition from a dedicated pilot in command or operator for each aircraft (as required per current regulations) to single-pilot operations.
  - To enable efficient management of multiple unmanned and AAM aircraft in civil operations.
  - To assure safety of air traffic applications through verification and validation (V&V) tools and techniques used during certification and throughout the product lifecycle.

- Proposals supporting assurance of highly automated and increasingly autonomous systems that support safety-critical functions. Specific focus includes:
  - Identification and development of new technologies that enable increasingly autonomous air safety services. Each new technology should be accompanied by examples of the services it enables.
  - Technologies that overcome the limitations of current V&V capabilities with respect to new increasingly autonomous systems. For example, new testing techniques sufficient for deploying machine learning (ML)-enabled systems.
  - Determination of where current certification standards (such as DO-178C) fail to address assurance needs for these technologies or fail to consider V&V results associated with the new technologies.
  - Development of use cases demonstrating novel certification approaches, such as Overarching Properties or safety cases, that enable the certification of increasingly autonomous systems.
  - Development of use cases demonstrating the assurance of cyber-physical-human systems that accommodate shifting roles and responsibilities between humans and automation.

- Cybersecurity resiliency requiring availability and integrity of critical functions including:
  - Rapid detection of incidents to enable remediation.
  - Automatic remediation actions to restore sufficient network or application services to support mission essential functions.
  - Information resilience for shared airspace status.
  - Reliable delivery and authentication of important messages.
  - Security management systems, security management frameworks, or information security management systems.
  - Resilient voice, data, and precision navigation and timing.

- Proposals that develop, apply, and assure IASMS services, functions, and/or capabilities to emergency response missions using aerospace vehicle operations. Operations may include but are not limited to: wildfire fighting, hurricane disaster relief and recovery, search and rescue, medical courier, and security operations.
  - SFCs should address one or more hazards highlighted in previous sections or identified through hazard analysis. Proposers are encouraged to leverage prior NASA work in this area.
Expected TRL or TRL Range at completion of the Project:

1 to 3

Primary Technology Taxonomy:
Level 1: TX 16 Air Traffic Management and Range Tracking Systems
Level 2: TX 16.1 Safe All Vehicle Access

Desired Deliverables of Phase I and Phase II:

- Research
- Analysis
- Prototype
- Software

Desired Deliverables Description:

Technologies that can advance the goals of safe air transportation operations that can be incorporated into existing and future NASA concepts.

Desired deliverables for Phase I include development of multiple concepts/approaches, tradeoffs analyses, and proof-of-concept demonstrations.

Desired deliverables for Phase II include development of functional prototypes, integration of prototypes into existing and future NASA concepts, and demonstration of the prototype in a realistic environment.

State of the Art and Critical Gaps:

State of the art: Recent developments to address increasing air transportation demand are leading to greater system complexity, including airspace systems with tightly coupled air and ground functions as well as widely distributed and integrated aircraft systems. Current methods of ensuring that designs meet desired safety levels will likely not scale to these levels of complexity (Aeronautics R&D Plan, p. 30). AOSP is addressing this challenge with a major area of focus on ISSA.

Critical gaps: A proactive approach to managing system safety requires: (1) the ability to monitor the system continuously and to extract and fuse information from diverse data sources to identify emergent anomalous behaviors after new technologies, procedures, and training are introduced and (2) the ability to reliably predict probabilities of the occurrence of hazardous events and of their safety risks. Also, with the addition of UAM/AAM concepts, and increasing development of UAS Traffic Management (UTM), the safety research needs to expand to include these various missions and vehicles.

Relevance / Science Traceability:

Successful technologies in this subtopic will advance the safety of the air transportation system. The AOSP safety effort focuses on proactively managing safety through continuous monitoring and extracting relevant information from diverse data sources and identifying anomalous behaviors to help predict hazardous events and evaluate safety risk. This subtopic contributes technologies towards those objectives.

References:
