A1.09  Vehicle Sensor Systems to Enable Situational Awareness

Lead Center: GRC

Participating Center(s): AFRC, ARC, LaRC

Scope Title:

Technologies to Enable Situational Awareness for Autonomous as well as Increasingly Autonomous Air Vehicles

Scope Description:

Achieving a vision for a safer and more efficient National Airspace System (NAS) with increasing traffic and the introduction of new vehicle types and unpiloted vehicles requires increasingly intelligent vehicle systems able to respond to complex and changing environments in a resilient and trustworthy manner. Future air vehicles, especially autonomous vehicles and those that support Advanced Air Mobility (AAM), must operate with a high degree of awareness of their own well-being, and possess the integrated intelligence to efficiently conduct operations while providing warning of off-nominal states. A vehicle's capability to independently assure safety may be the only recourse in some situations, and for piloted vehicles addresses the recurring issue of inappropriate crew response. Internal to the vehicle, predictive maintenance reduces maintenance cost and vehicle down time through improved vehicle availability and throughput. Understanding the vehicle state also has impact on vehicle performance, efficiency, and environmental impact. External to the vehicle, vehicle awareness of the environment and ability to detect potential hazards in the surrounding airspace is crucial to the overall safety of the NAS and a vehicle’s ability to meet flight objectives.

This subtopic seeks technologies to enable intelligent vehicle systems, including subsystem and avoidance technologies, with an internal and external situational awareness to assure safety; optimize mission completion, efficiency and performance in nominal conditions; and respond to off-nominal conditions. The emphasis is on piloted vehicles augmented with autonomous capabilities, as well as increasingly autonomous unmanned air vehicles (including AAM). This subtopic includes vertical lift vehicles in general, but excludes sensor systems specifically designed for monitoring powertrain health; such proposals should propose to A1.06. Vertical Lift Technology and Urban Air Mobility. Situational awareness of new or alternate vehicle configurations, including distributed and hybrid electric propulsion, are also of interest. Areas of interest include:

- Sensing and perception technologies that provide the ability of the vehicle to detect and extract internal and external vehicle information.
- Information fusion technologies to integrate information from multiple, disparate sources and evaluate that information to determine health and operational state.
Onboard hardware and software systems that are modular, scalable, redundant, high reliability, and secure with minimal vehicle impact.

Diagnostic technologies that provide critical markers trending to unsafe state.

Networked sensors and algorithms to provide necessary vehicle full-field state information ranging from the component level to the subsystem and system level.

Integrated systems technologies that enable the diagnosis of multiple hazards, while effectively dealing with uncertainties and unexpected conditions.

Approaches that enable improved in-flight vehicle state safety awareness with adaptive methods to achieve improved efficiency, performance, and reduced environmental impact.

Methods that significantly enhance the fidelity and relevance of information provided to ground systems by the vehicle in-flight for use in on-demand maintenance.

Perception software capabilities including multispectrum sensor fusion, real-time perception system assurance software, and wake detection.

Low-SWaP-C (size, weight, power, and cost) detection hardware that can detect objects at far distances, e.g., 1,500 ft to 3 nmi, including visual cameras, infrared (IR) cameras, event cameras, gated camera, Lidar, radar, and sonic hardware.

Highly reliable vehicle navigation technologies (position, orientation, and rotational and translational velocities) robust against Global Positioning System (GPS) denial/failures and responsive to the external environment.

**Expected TRL or TRL Range at completion of the Project:** 3 to 6

**Primary Technology Taxonomy:**

Level 1: TX 10 Autonomous Systems

Level 2: TX 10.1 Situational and Self Awareness

**Desired Deliverables of Phase I and Phase II:**

- Prototype
- Hardware
- Software

**Desired Deliverables Description:**

Phase I deliverables should include, but are not limited to:

- A final report clearly stating the technology challenge addressed, the state of the technology before the work was begun, the state of technology after the work was completed, the innovations that were made during the work period, the remaining barriers in the technology challenge, a plan to overcome the remaining barriers, and a plan to infuse the technology developments into applications.
- A technology demonstration that clearly shows the benefits of the technology developed.
- A written plan to continue the technology development and/or to infuse the technology. This may be part of the final report.
• Resulting products can include hardware, software, demonstrations, reports, products, components, and integrated systems

Phase II deliverables should include, but are not limited to:

• A final report clearly stating the technology challenge addressed, the state of the technology before the work was begun, the state of technology after the work was completed, the innovations that were made during the work period, and a plan to infuse the technology developments into applications.
• A technology demonstration that clearly shows the benefits of the technology developed.
• There should be evidence of efforts taken to infuse the technology into applications or a clear written plan for near term infusion of the technology. This may be part of the final report.
• Resulting products can include hardware, software, demonstrations, reports, products, components, and integrated systems.

State of the Art and Critical Gaps:

It is predominately left to pilots (not the vehicle) to interpret current state and infer future states based on experience and expertise. Commercial Aviation Software Team (CAST), Federal Aviation Administration (FAA), National Transportation Safety Board (NTSB), and the National Research Council (NRC) have called for research on systems that can predict the state of the aircraft, including the state of autonomous systems, to provide notifications of trending to unsafe states. In order for there to be trust in autonomy, vehicle situational awareness needs to be tailored for independent autonomous systems without human intervention. Significant new capabilities are needed to enable safe vehicle operation in the airspace independent of human intervention. Sensing systems as intended here not only include the sensing element itself, but may also include the supporting technologies necessary to provide a meaningful measurement. Such supporting include hardware (e.g., networking capability) but also software (e.g., sensor fusion).

There has been development in internal vehicle component health management technology with some adoption; integrated subsystem/vehicle system full-field health management is limited and do not presently enable a completely autonomous vehicle system. Further, measurement and monitoring technologies need to be adapted with the introduction of new vehicle types to provide information relevant to understanding the specific vehicle state. The objective is to provide sufficient, dependable information with limited vehicle impact to enable, e.g., time appropriate cognition and decision making. [For Unmanned Aircraft Systems (UAS) vehicles, proposals involving such cognition and decision making can be submitted to Subtopic A2.02. Unmanned Aircraft Systems (UAS) Technologies.]

Relevant to AAM, current exterior perception technologies are focused on specific domains that are not relevant to AAM. AAM applications fly faster and in a less cluttered environment than automobiles. Nominal operations are expected to be at speeds between 40 and 200 mph and altitudes below 5,000 ft over a range under a few hundred miles. They also fly at a lower altitude than commercial airlines, making them more susceptible to weather conditions, while resulting in a more obstacle-rich environment. Most perception systems and software are currently focused on the auto industry where required ranges are shorter and update rates need to be faster, or they are designed for extremely low SWaP unmanned aerial vehicles (UAVs) that do not have passenger carrying safety requirements. Known gaps include the following: maintaining an aviation-grade safety assurance of perception systems, reaching the required detection distances, detection of objects in low-contrast/degraded environments, and detection and knowledge of hyperlocal weather phenomena.

Relevance / Science Traceability:

This technology development is directly relevant to the NASA Aeronautics Research Mission Directorate (ARMD) Thrust 6 Autonomy Roadmap in order to allow more intelligent vehicle systems, and has strong relevance to NASA
autonomy activities. NASA also plans to have an increasing role in the expanding market of AAM. Autonomy applications will only be able to make decisions as good as the information and insight at hand. The approach is to mature technology through this subtopic for ongoing implementation into NASA missions and commercial applications. This subtopic will also help define the limits of commercially available technology to meet the needs of increasingly intelligent systems to operate autonomously and in new transportation paradigms.

Autonomy is also a core capability increasingly relevant across a range of NASA mission directorates. For Science Mission Directorate (SMD) and Space Technology Mission Directorate (STMD), autonomy is central to planetary exploration and Earth monitoring, enabling more capable missions that provide improved science without the burden of human intervention. For example, the capability of an autonomous probe to maintain operations in uncertain or unforeseen conditions without human intervention can be critical to the success of the mission. Vehicle situational awareness may be mandatory in remote missions where it is difficult for a human to be in the loop in a timely manner. Likewise, the safety of the astronauts in a manned mission may depend on appropriate vehicle response to rapidly changing conditions.

References:

2. https://www.nasa.gov/aam