

Sensing Requirements for Unmanned Air Vehicles

Engineers develop requirements and metrics to ensure integration of future autonomous unmanned aircraft into manned airspace.

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Engineers from the Air Vehicles Directorate transferred unmanned air vehicle (UAV) sensing system requirements for airspace operations to civilian UAV users and developers. These requirements represent design goals on which to base future sensing subsystem designs, filling an omission in UAV technology planning. Directorate engineers are continuing to develop the technologies that will enable future UAVs to coexist with manned aircraft in both military and civilian airspace. Incorporating these requirements will ensure that engineers design future UAVs to detect possible conflicts, such as midair collisions or runway incursions, and take action to avoid them.

Present UAVs cannot detect manned aircraft and conflict situations and, therefore, they cannot share airspace with manned aircraft. To overcome this obstacle, UAVs need to sense the presence of other aircraft in their operating environment (see figure on next page). In other words, UAVs need to at least replicate a human pilot's ability to see and avoid problems before they will be accepted into the national air space (NAS). Since some aircraft do not have air traffic transponders, UAVs must use onboard sensors to detect aircraft and coordinate that information with available transponder information. With this level of capability, UAVs and operators will have the situational awareness of the airspace around the vehicle to ensure safety at the same level as manned aircraft.

With this goal in mind, directorate engineers worked with Northrop Grumman Corporation (NGC) engineers to establish, iterate, and finalize sensing system performance requirements for the broad range of future Air Force missions. During this collaborative process, directorate engineers noted that many mission elements were similar to civilian airspace operations tasks, and that the requirements they were developing were directly applicable to civilian UAV technology. They also found no report that defined and expressed these requirements for nonmilitary use. To help fill this void, directorate engineers coordinated their research results with the American Institute for Aeronautics and Astronautics UAV airspace operations' focal point, North Atlantic Treaty Organization's Standards Committees, the National Aeronautics and Space Administration, and industry organizations working the same topics from the civilian side. Incorporation of the directorate's technology into civilian requirements' definitions and standards will directly impact airspace operations' sensing systems for current and future UAVs.

The coordinated effort of directorate and NGC engineers that resulted in the sensing system requirements represents the first stage of work on the Autonomous Flight Control Sensing Technology (AFCST) program. This program's long-term goal is to develop the upfront portion of the UAV virtual pilot capability. During this first phase, NGC engineers analyzed midair and near-midair collision data, along with runway incursion data, to generate lessons learned. Then, the NGC engineers combined the lessons learned from aircraft mishap data with sensing performance specifications and good engineering judgment to establish conventions for operating aircraft in the NAS. Next, they examined

airspace tasks for operation in NAS and grouped them into deconfliction, collision avoidance, autonomous landing, and ground operations. The UAV functional requirements resulting from this effort are shown in the table.

As shown in the table, the threshold values represent the near-term requirements (year 2007), while objective values are far-term requirements (year 2013). Engineers consider the forward vision threshold values equivalent to or slightly better than human performance. Federal Aviation Administration data indicates the dominant cause for mid-air collision is when an aircraft is overtaken by a faster aircraft because a pilot's position in the cockpit limits rear visibility. In the UAV, rear visibility is not restricted because designers can locate sensors anywhere on the aircraft. Objective values contain UAV rear vision capability to improve safety in this scenario.

Directorate and NGC engineers are currently working on the second phase of AFCST—the preliminary design of the sensor hardware architecture. The AFCST design strategy for all UAV situational awareness functions is to minimize hardware and software quantity and maximize use of multifunction sensors and common image processing software components. Most of the design efforts are completed satisfactorily. NGC engineers are continuing detailed sensor reliability analyses, capturing the individual and combined effects of sensor field-of-view coverage, sensor failure rates, and exposure rates.

During the final stage of the AFCST program, engineers will run simulations emphasizing landing and collision avoidance-tasks with demanding sensing and processing requirements. The engineers will develop landing and see-and-avoid strategies of operation as well as a detailed software architecture design. The simulations should determine if the preferred electrooptic/ infrared and radar sensors meet the specifications identified in the first phase of the AFCST program and the number of false alarms and false negatives that will be encountered. The engineers will also compare various image-processing solutions to determine the most reliable. The ideal system design will be free of nuisance faults caused by system error and will include software designed to minimize such faults. Reliability analysis studies will eventually combine software reliabilities with hardware reliabilities to meet the overall UAV system reliability.

In the near future, directorate and NGC engineers plan to publish the results of the detailed sensor reliability analysis. Program managers are also planning a follow-on hardware-in-the-loop simulation effort to address and demonstrate the integrated system design. In this realistic simulation, engineers will study concepts such as the integration of AFCST sensors with instrument flight rules avionics for see-and-avoid maneuvers, landing, and automated traffic collision avoidance. Real-time simulation will stress the detailed sensor architecture design, allowing the engineers to assess its adequacy and determine its readiness for technology transition to flight test. These efforts will ensure the safe incorporation of UAVs into the NAS.

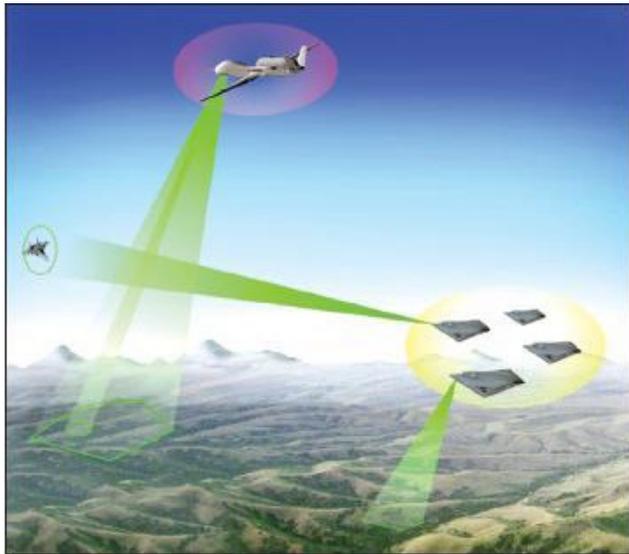


Figure. UAV senses presence of other aircraft

AIRSPACE OPERATIONS SENSING REQUIREMENTS FOR UAVs		
Functional Requirements	Threshold Values	Objective Values
Field of View	Azimuth: 60° Elevation: 30°	4 π steradians
Field of Regard	Azimuth: +/-100° Elevation: +30°, -90°	4 π steradians
Ranging	0.5 ft CEP* @ 100 ft 700 ft CEP* @ 6 nm	0.25 ft CEP* @ 100 ft 770 ft CEP* @ 13.2 nm
Imaging	Varies from 30 ft to 3 nm	Varies from 30 ft to 13.2 nm
Data Rate	30 Hz	60 Hz
Weather Capability	Visual Meteorological Capability	Visual and Instrument Meteorological Capability
Criticality	Safety Critical	Safety Critical
Emission Constraints	Various Federal Aviation Administration Limitations	Various Federal Aviation Administration Limitations
*CEP = circular error probability		

Table. Near- and far-term UAV sensing requirement

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