Certification Challenges for Autonomous Flight Control Systems

David Homan
Air Force Research Laboratory Control Systems Development Branch

Introduction

As the Air Force works toward developing unmanned air vehicles (UAVs) to augment or replace manned systems, a need exists for levels of on-board intelligence and autonomy. This new functionality creates a daunting new concern, how can we trust the decisions these lethal weapon systems will make? At least part of the fallback safety mechanism has always relied on human intervention. Future Air Force systems are being planned to operate with minimal human oversight. In this case, new paradigms will be needed for airworthiness certification of these systems to provide the necessary assurance and confidence that all flight critical safety requirements have been met, while using a timely and affordable certification process. Computer systems have already replaced many of the menial human tasks, such as throttle control, automatic lights, and pinpoint targeting systems. Control systems to execute higher order and more complicated functions, such as autopilots and unstable flight modes, are considered mature technologies. However, future Air Force systems are being designed to include autonomous features, such as: automated mission planning, target selection and mission re-planning; multi-vehicle cooperative control; battle damage reconfigurable control; integrated active control with diagnostic and prognostic health systems; aerial refueling; and operation in and around airports. As the control system scope increases, the inherent difficulty in testing skyrockets.

Autonomous control is a revolutionary leap in technology. Such control replaces decision-making that requires years of training for pilots, or in the case of UAVs, remotely located operators. In piloted systems, we as designers take advantage of the human ability to deal with uncertainty, to be able to make decisions with incomplete or ambiguous information, and to provide the “outer-loop” control input that manages any contingency while maintaining stability and control. The machine itself remains completely deterministic. Future UAV systems will be designed to make their own common sense decisions and judgments. In order to trust decisions made by an autonomous system, it is envisioned new methods for control software verification and validation will be required for airworthiness certification of the control software.

System Complexity Drives Certification Challenges

As we progress down the autonomy continuum, more human decisions are made by the UAV control system. The problem then becomes trust in the machine. Can we assure the decisions made by the UAV will produce the desired output? Do we have confidence the UAVs will perform as designed, and will not become a threat to anything other than the intended target? The challenges surrounding certification of autonomous control systems are directly associated with the new capabilities required to enable CAO system attributes.

Some key technology issues surrounding UAV autonomy include: a mixed-criticality systems architecture, adaptive and learning systems with multi-modal functionality, mixed initiative and authority management and interaction (human-autonomy or autonomy-autonomy); multi-entity systems capability for functions that encompass multiple platforms, and sensor fusion integration that delivers sensor-derived information at high confidence levels. For autonomous control systems to meet these capabilities, software will experience a significant growth in the number of lines of code, with some estimation to be 500,000 to 1,000,000 lines. Current validation and verification processes will become obsolete to certify these systems based upon the sizable costs in time and resources needed to certify the software, and managing the complexity of these systems designs.

S&T Push for the Future

The aerospace community, both military and civilian, has recognized the impending challenges of certifying autonomous control systems, and has expressed needs for advances in verification and validation processes, techniques and tools to overcome these challenges. Under the DoD Fixed Wing Vehicle (FWV) Initiative in fiscal year 2004, AFRL is pursuing the Navy, Army, DARPA, NASA and the military-based aerospace industry to join together for the cooperative development of advances in flight critical systems software certification. The objectives of this activity are to establish a comprehensive research and development (R&D) portfolio, identify technology investments and stakeholders to execute research initiatives, promote establishment of government-academia-industry research teams to perform the research, and to associate technology transition and insertion opportunities in air vehicle platforms across the services.

In July 2004, a flight critical systems certification workshop convened at Wright Patterson AFB, Ohio with the FWV members. Participants included Air Force, Navy, Army, DARPA, NASA, NSF, and industry. The industry representatives were lead by the three major airframe manufacturers: Boeing, Lockheed Martin, and Northrop Grumman. The workshop provided an open forum for its participants to identify technology gaps in current certification process and to determine the appropriate technical investment areas (i.e. new methods, V&V tools and techniques) to enable safe and affordable systems certification of future capabilities. The workshop participants also confirmed the need to establish technical relationships and teams for evolutionary development of certification technology, and the importance for DOD agencies to coordinate research investments to meet collective certification needs.

Conclusion

There are many technical challenges associated with certification of intelligent and autonomous control systems. Advanced UAV capabilities being developed today will challenge certification techniques far beyond their current capacities. New V&V technologies are needed to enable timely and efficient certification of the intelligent and autonomous UAV control systems still in their infancy. V&V tools are needed to achieve the necessary degree of rigor that will ensure safety and mitigate risks associated with implementing autonomous control. A lack of research investment in certification technologies will have a significant impact on levels of autonomous control approaches that can be properly flight certified, and could lead to limiting capability for future autonomous systems. In addition, these advances in certification must also be repeatable, to ensure that modifications to the control system cannot directly or regressively compromise airworthiness. The aerospace community has acknowledged a consolidated R&D effort will be required to adequately address certification challenges, and to share the investment burden in order to realize technological change in the certification process.