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Research Challenges in Cyber-Physical Systems for the Next Generation Air Transportation System

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In June 2008, the Federal Aviation Administration (FAA) published its NextGen Implementation Plan (FAA, 2008). This plan is intended to drive key investment and policy decisions in the coming years as the FAA modernizes the United States' air transportation system. The plan is based on a vision laid out by the multi-agency Joint Planning and Development Office (JPDO, 2007) which collaboratively developed a vision and architecture for the Next Generation Air Transportation System (NextGen).

The NextGen plan addresses the need to accommodate increased passenger demand, improved passenger and cargo security, and reduced environmental impact, while maintaining or improving on overall levels of system safety and delay. It lays out a set of key capabilities, enabled in part by new technologies, that are needed to achieve the NextGen goals:

- Network-enabled information access,
- Performance-based operations and services,
- Weather assimilated into decision making,
- Layered, adaptive security,
- Position, navigation and timing services,
- Aircraft trajectory-based operations,
- Equivalent visual operations, and
- Super-density arrival/departure operations.

In order to meet NextGen's needed increases in system capacity, while maintaining or improving on current levels of safety, global aviation systems will increasingly rely on automation:

Reliable data communications links will provide critical coupling of air- and ground-based systems; en route controllers will rely on automation to identify flight path conflicts and propose automated resolutions; flight management systems will need to fly aircraft more precisely and predictably; and traffic flow management systems will explicitly incorporate probabilistic calculations in providing strategies for managing weather disruptions (Celio, 2007).

Cockpits will also be highly automated in the future, relying on technologies such as enhanced vision systems, cockpit displays of target information, enhanced traffic alert and collision avoidance systems, automatic dependent surveillance-broadcast, wake vortex sensing and other automated capabilities (Hollinger and Narkus-Kramer, 2006).

In addition remotely- and autonomously-piloted unmanned aircraft systems will need to be accommodated in the same airspace with human piloted aircraft (DeGarmo and Maroney, 2008).

While there is growing international consensus that the future of global aviation will be much more dependent on automated systems, there has not yet been enough research on the critical challenges that this trend will bring:

- Software assurance: how will we develop and test the software in these systems to meet demanding levels of reliability and safety?
- Certification: how will we certify these software-intensive systems as well as required periodic software updates?
- System Integration: how will we assure the overall reliability and safety of the integrated system-of-systems that results from the interactions of these numerous interconnected components?
- Human-Machine Integration: what are the human factors issues associated with this tight coupling of humans and automated systems?
- Failover and Backup: how can we assure safe, albeit degraded, levels of operation during automation failures, and how can we repair and recover system functionality following these events?

These are just some of the research challenges that we face in turning the NextGen vision into a reality. Solving them will take a combination of new thinking, new technologies, new techniques and hands-on research and evaluation.

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