**REDAC strategic research topics**

Zellweger – 21 July, 2014

The following is my list, from a NASOPS perspective, of the top emerging issues (things the FAA should get ahead of) and future opportunities (future areas where R&D could benefit the FAA). There is a certain amount of overlap across the topics – but I think that, because of the complex nature of NextGen, this is unavoidable. I have borrowed heavily from existing documents, especially in the write-ups of TBO and of Increasingly Autonomous Systems. In the former case, many of the words come from a JPDO draft report on TBO simulation needs and in the latter from the recent NRC report on Increasingly Autonomous Aviation Systems.

*Trajectory Based Operations (TBO)*

TBO is a generation beyond the initial trajectory operations that are being implemented today. It represents a real paradigm shift in how we do ATM. The TBO concept expands the value of flight planning to more closely accommodate user desired business trajectories and relies on automation to perform separation and traffic flow management, based on a combination of the current and future position of each aircraft. The underpinnings of TBO are trajectory planning and re-planning, system optimization, and negotiation of 4-dimensional trajectories (4DTs) to deal with changing ATM system constraints, alterations in user needs and desires, and a full range of system behaviors and environmental conditions. The 4DT will be executed from gate to gate. TBO should be designed to accommodate UAS operations, both in low altitude airspace and airspace that UAS will share with commercial aircraft operators.

- With the advent of Area Navigation/Required Navigation Performance (RNAV/RNP), an enhanced surveillance system (Automatic Dependent Surveillance Broadcast, ADS-B), and digital communications, it is highly likely that today’s sectors and route structure will be replaced by a more flexible, adaptive structure that supports the new TBO paradigm.

- Pilots, UAS operators, controllers, flow managers, and airline and flight operation centers (AOC/FOC) will likely see a change in their roles and responsibilities. They will interact with each other and with automation in new ways. The increased complexity , tighter coupling of system elements, and dependency on automation can lead to instances of unintended interactions which may lead to performance degradation or safety violations of the system being developed unless carefully accounted for in the design. As systems become more tightly coupled, unintended interactions become more pronounced. Mechanisms for dealing with failure of all sorts must be designed to be compatible with these new roles.

- TBO is a net-centric system of systems (SoS), where all SoS agents (both computers and people) have access to common information for decision making. The information shared across functions will be used to globally optimize traffic flow and locally optimize individual gate-to-gate trajectories. This net-centricity will lead to new SoS behaviors that must be examined for their impact on total system performance and safety under all types of conditions.

- TBO will require a system architecture and functional design that assures resilience. This will require computers and people (on the ground and in the air) to detect symptoms of potential degraded performance or safety issues. The system must be designed to have mitigations where people and machines can take appropriate steps to continue safe operations to deal with system anomalies and situations where TBO has lost some of its functionality.

The FAA R&D portfolio should develop the TBO concept and address the issues described above. It should also develop a strategy to transition form today’s NAS to TBO, including definition of incremental functional improvements. The research must address associated policy, standards, and certification issues.

*Separation concepts*

Today, aircraft separation in controlled airspace is a human responsibility, carried out on the ground with some decision support tool assistance. It has been postulated that this may not be the most efficient method of aircraft separation. There are already instances, such as the oceanic in trail procedures, where separation responsibility is delegated from the controller to the cockpit on a case by case basis.

One can think of aircraft separation as a two dimensional concept space – **by whom** the separation function is carried out and **where** it is accomplished. Separation **can be done by** humans or automation or some combination of the two and separation **can be carried out on** the ground or in the air or, again, some combination of the two.



In order to transition from today’s ATM system to NextGen for 2025 and beyond, research to find the “sweet spots” in this concept space is needed. Where the sweet spots are will vary for different types of airspace (approach/surface/departure/en-route) and will also vary over time, as NextGen evolves.

A research program to explore the separation concept space should include: a clear identification of the pros and cons of putting separation a specific place in this concept space; determination of the possible ways that people and machines will interact during both normal and off-nominal conditions; cockpit and ground system automation support; ground automation and cockpit equipage requirements; mixed equipage issues; safety and resilience analyses and simulations; and a transition strategy for moving to new ways of separating aircraft.

*Increasingly autonomous systems*

“Technological advances in computer processing, sensors, networking, and other areas are

facilitating the development and operation of increasingly autonomous (IA) systems and vehicles for a

wide variety of applications on the ground, in space, at sea, and in the air. IA systems have the potential to improve safety and reliability, reduce costs, and enable new missions. However, deploying IA systems is not without risk. In particular, failure to implement IA systems in a careful and deliberate manner could potentially reduce safety and/or reliability and increase life-cycle costs. These factors are especially critical to civil aviation given the very high standards for safety and reliability and the risk to public safety that occurs whenever the performance of new civil aviation technologies or systems fall short of expectations.” (2014 NRC Report Autonomy Research for Civil Aviation: Toward a New Era of

Flight p. vii – prepublication copy)

The NRC report identified a number of barriers to implementation and R&D priorities for IA systems (listed below). These provide an excellent basis for an FAA IA research thrust.

*Technology barriers:*

Communications and Data Acquisition; Cyber-Physical Security; Diversity of Aircraft; Human-Machine Integration; Decision-Making by Adaptive/Nondeterministic Systems; Sensing, Perception, and Cognition; System Complexity and Resilience; Verification and Validation.

*Regulation and Certification barriers*:

Airspace Access for Unmanned Aircraft; Certification Process; Equivalent Level of Safety; Trust in Adaptive/Nondeterministic Systems.

*Additional Barriers*:

Legal Issues; Social Issues.

*Research priorities*:

Behavior of Adaptive/Nondeterministic Systems; Operation without Continuous Human Oversight; Modeling and Simulation; Verification, Validation, and Certification; Nontraditional Methodologies and Technologies; Roles of Personnel and Systems; Safety and Efficiency; Stakeholder Trust.

*V&V of complex socio-technical systems and of adaptive/non-deterministic systems*

NextGen is a socio-technical system of systems (SoS) - more complex than current NAS:

- It is increasingly autonomous;

- It has more interaction of different system components that cut across domains, systems, and organizations and functions that are more distributed across these (for example, ATM functions will be distributed across ground and airborne systems);

- Its system architecture is not as “inherently resilient” as today’s NAS;

Today Comm - Nav – Surv are “independent”

Today controllers provide resilience – they are able to deal with most failures

- There will be new, different roles and responsibilities for humans and computers and changes in air/ground functional allocation;

- The environment in which 2025 functions will be used is still uncertain;

- Finally, transition involves many more steps, which often occur more frequently than changes in the past.

These NextGen socio-technical characteristics have a number Implications for V&V around which FAA should develop a new R&D thrust:

- More validation methods for the early part of lifecycle;

- Methods to validate the complete SoS in addition to validation of new function individually (methods for V&V when many components are integrated into a complex environment are lacking);

- Methods to validate that a function will continue to behave correctly as NextGen evolves;

- Validation that takes the uncertainty of the future environment into account;

- Validation to address emergent behavior of new functions;

- Ways to understand assess system of system resilience;

- V&V methods for agent-based, non-deterministic software;

- Safety validation methods that include people and multiple stakeholders in addition to traditional safety assessment (there is little experience with validation of systems with complex air/ground and human/machine interaction);

- Validation of complexity of interactions where traditional safety analysis assumptions of independence events are no longer valid;

- V&V methods to deal with system changes that are so large that traditional methods of incremental safety analysis will not work (requires setting Target Level of Safety - difficult because we don’t know how safe today’s system is!)