Looking Forward To NextGen*

Robert Pearce
National Aeronautics and Space Administration
Deputy Director, NextGen Joint Planning and Development Office (JPDO)

Yuri Gawdiak
National Aeronautics and Space Administration
Director, Systems Modeling and Analysis, NextGen JPDO

Jay Merkle
Federal Aviation Administration
Chief Architect, NextGen JPDO

Peggy Gervasi
Federal Aviation Administration
Director, Policy, NextGen JPDO

P. Douglas Arbuckle
National Aeronautics and Space Administration
Special Assistant, NextGen JPDO

Dr. Edgar Waggoner
National Aeronautics and Space Administration
Director, Enterprise Architecture & Engineering, NextGen JPDO

Diana Takata
Federal Aviation Administration
Deputy Director, Portfolio Management, NextGen JPDO

Introduction

The Next Generation Air Transportation System (NextGen) is a Congressionally-mandated (Vision 100 – Century of Aviation Reauthorization Act, December 2003) multi-agency and public-private initiative to transform the air transportation system to meet the Nation's future needs. NextGen is intended to simultaneously address multiple objectives, including increased capacity, improved efficiency, better safety and security, and reduced environmental impact. In addition to developing and deploying hardware and software, NextGen addresses the roles and responsibilities of the organizations and people that operate and use the system and the policies and processes that govern its operation. NextGen is a transformation of the total system. The inherent complexity of such an endeavor requires that it is implemented in an evolutionary fashion to successively build out integrated capabilities, while managing risk and allowing inevitable course corrections. An effort of this magnitude, with requirements for mega-collaboration, also requires a new kind of governance, not that of central planning and management, but something we refer to as "co-evolutionary" management. This is a theme that is fundamental to this article and to realizing NextGen.

The Joint Planning and Development Office (JPDO) was formed as a part of the "Vision 100" legislation to "create and carryout a National plan" for NextGen. Within the first year, the JPDO completed the top-level National plan to set specific objectives and strategies. Since then we have been developing and have now baselined the more detailed NextGen plan that is meant to guide the transformation. As the JPDO looks forward, we will continue to build and evolve the NextGen plan. However, we are shifting our primary emphasis to supporting the member agencies in carrying out the plan. Therefore, it is a good time to take a step back and consider the context for furthering the plan and the implementation.

A Total Systems Perspective of NextGen

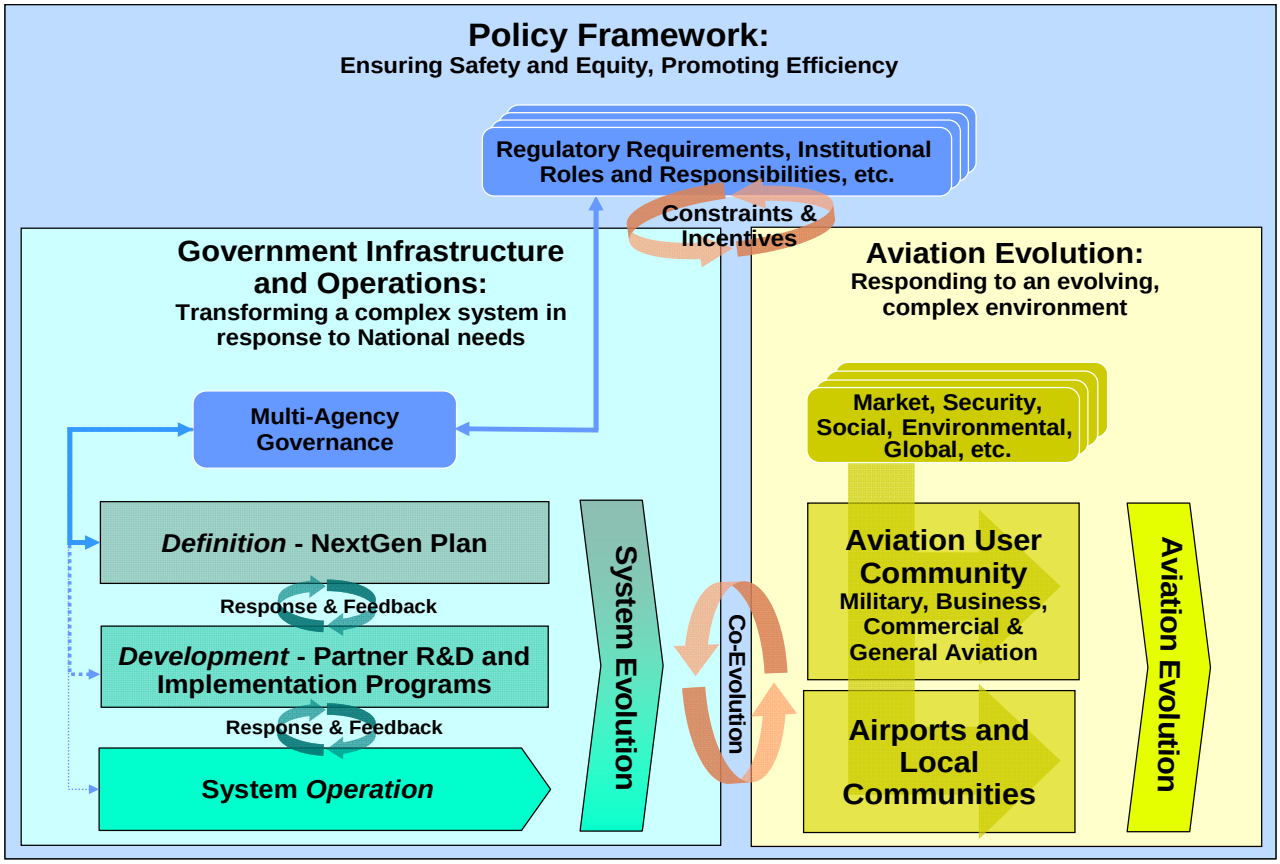
As we look forward, it is important to place NextGen in the proper context. Figure 1 provides a systems perspective of NextGen. It draws attention to three key areas that we will expand upon.

First, at the highest level, policy creates the overall framework for the transformation. Policy seeks to ensure sufficient levels of safety and the equitable use of the national airspace resource, but should also encourage the efficient use of air transportation to meet national needs. Policy choices can have a major impact on the extent and pace of transformation by creating constraints and incentives to change. These are often very tough choices that are difficult to make due to competing interests among diverse stakeholders and the inability to fully assess the costs and benefits or even to fully predict outcomes. The ability to explore such choices with appropriate degrees of fidelity is clearly critical to a robust and substantial transformation.

Second, the aviation system evolves. The socio-politico-economic environment that aviation serves drives the evolution. Examples of key drivers include: market changes based on shifting demographics and changing economic and social needs for transportation; changes in the major inputs to aviation, such as energy and labor; and competitive challenges, such as substitution of advanced communications technologies (e.g., teleconferencing) for long-distance travel. Air transportation has no choice but to respond to these and other drivers if it is to serve our national needs. And, as evidenced by the challenging energy, environmental and market conditions faced by the airlines, the changes are complex, inter-related and cannot be fully accounted for in advance. The further complication is that government infrastructure and operations (e.g., CNS/ATM) must be robust to these complex evolutionary changes. The transition to NextGen, therefore, can be thought of as a "co-evolution" of aviation users, airports and federal infrastructure and operations. In this context, thinking of NextGen as simply a major acquisition with fixed requirements derived from forecasted needs is a profound mistake.

Finally, the system development process must also be compatible with an environment characterized by variable needs. So, while we often think of system definition, development and operation as distinct sequential phases, in the case of very large scale and complex systems such as NextGen, these phases are overlapping and recursive. This is driven not only by evolving needs but also by other important factors. For example, because of the number of interfaces and the level of integration that is anticipated there will be emergent system behaviors and operational innovation. Also, because NextGen will be a human-centric system, individual, organizational, and cultural learning and feedback must be accounted for. Therefore, approaches to improving the quality and timeliness of feedback between definition, development and operational activities are of paramount importance.

Figure 1. NextGen System Perspective



The environment and the systems are very complex. These complexities will surface in unanticipated ways and will need to be addressed. Problems with these attributes (i.e., like those being addressed by NextGen) have been termed "wicked problems"[1]. According to Mitre's Enterprise Systems Engineering Profiler, NextGen is on the "messy frontier" because the effort must manage the risks of multiple stakeholders, program boundaries, and users.[2] Words like "wicked" and "messy" don't suggest linear, step-by-step solutions, easy agreements, or unchanging plans. Nevertheless, we believe that NextGen can be successfully developed if we recognize the "messiness" in advance and address it systematically with thoughtful, innovative approaches that engage the stakeholder community.

So, at the top most level, the NextGen transformation process is a guidance process –- we must guide the definition, development and operation through a complex environment over the long-term. There must be robust feedback loops and sufficient maneuvering room to adjust the plan accordingly. We will need to accommodate variation. Therefore, we should plan in advance to work to a cost, schedule and performance design space that will provide the management flexibility that will be required to achieve success.

Moreover, the system context graphic also shows that we must manage the relationships between policy, co-evolution, and system definition, development and operation. Ideally, policy enables optimal co-evolution while ensuring safety, equity and efficiency; a co-evolution management process allows for recursions and variation in system development to ensure the system best serves National needs while keeping overall cost, schedule and performance within some pre-determined design space; and, the system development process provides the consistent data and demonstration necessary to support high-confidence policy and management decision-making while delivering a robust system.

Policy – Major Lever in Transformation

We begin by proposing a policy framework: the essential function of government in the air transportation system is to ensure safety and equity and promote efficiency. *Safety* is well understood in the aviation industry but for our purposes should be defined more broadly to include impacts to health and well-being from both environmental degradation and security threats. *Equity* captures government's role in balancing the needs of different groups who want to use or are affected by the air transportation system. *Efficiency* captures the objective of maximizing the utility of the air transportation resource. These are the fundamentals that we must be able to measure and seek to improve as we define, develop and transition to NextGen.

NextGen is rife with transformational challenges that have policy implications. We recounted some of the big ones in a 2007 ATCA speech:

Culture/Roles Transition

NextGen generally and high density operations in particular will rely increasingly on automation. This will naturally change the roles of air traffic controllers, pilots and dispatchers. Similar changes in the past have encountered understandable resistance from those affected and have slowed down – but ultimately did not stop – the necessary changes.

Infrastructure Upgrades

NextGen will require the installation of communication, navigation, and surveillance infrastructure on the ground. Should the government or the private sector undertake these installations? Sometimes, involving the private sector can result in quicker action because access to capital is more predictable, and budget stability is key to adhering to program baselines. However, many feel that these are inherently governmental facilities that should be owned and operated by the government. Even if it is decided that the government should own and operate the facilities, there will still be a policy question as to whether the facilities might be owned by local governments such as the local authority that owns and operates the airport.

NextGen Facilities

In order to fully realize the benefits of NextGen, it may be necessary to close, consolidate or realign some of the Centers, TRACONs, and other air traffic control facilities. Failure to do so would not necessarily prevent the implementation of NextGen technologies, but it would make the overall program much more difficult and expensive to implement. Consolidation efforts in the past by government agencies have often run into resistance from the employees and the communities affected and their representatives in Congress.

Interoperability/Equipage

NextGen will require integrated standards, interoperability, multi-agency and global deployment coordination, and targeted system equipage policies to support the required adoption of avionics.

---

[1] Conklin, Jeff; Wicked Problems & Social Complexity, Chapter 1 of Dialogue Mapping: Building Shared Understanding of Wicked Problems, Wiley, October 2006.

[2] Stevens, Renee; *Engineering Enterprise Systems: Challenges and Prospects*; Mitre paper 06-0342.

Operational incentives can be employed wherever possible, but inevitably some users will have no operational incentive to equip. If there is sufficient system-wide benefit to early universal equipage, the government must decide when to abandon voluntary equipage and mandates in favor of economic incentives.

Rules of the Road

In the high-density environments, there likely will be situations where more than one aircraft will seek to occupy the same airspace. NextGen high-density operations will probably be much more highly automated such that computer algorithms will be relied on to make these judgments. These algorithms could use the same first-come-first-serve approach as human controllers tend to use now. However, developing and adopting other prioritization regimes that embody all of the values of the NextGen ConOps might achieve a more optimal result.

Past experience suggests that coming to a decision on even one of these issues can take 10 years or longer. In that time, the technical work progresses, much money is spent on analysis, opposition, and infighting, and meanwhile technology continues to advance, which results in changing requirements. A decision is ultimately made to implement a change – sometimes after a Presidential Commission or Congressional direction – but the anticipated benefits have been dramatically reduced by the time it took to make the decision. Looking back, often the decision seems inevitable and we ask ourselves, "Why did it take so long?" In fact, recent preliminary analysis by the JPDO has demonstrated that such "pacing" decisions represent by far the largest schedule risk to accomplishing NextGen.

In planning for NextGen, however, where technology, operations, and the socio-economic environment will co-evolve over time, the approach to policy-making must reflect the long-term and inherently uncertain nature of the NextGen challenge. Simply put, we must change the definition of policy leadership from one where stakeholders look to government to decide, to one where leaders direct disciplined attention to the issues, orchestrate conflicting points of view and mobilize the stakeholders themselves to resolve the conflicts. We would argue that this is in fact what has happened in the past, but not explicitly and not according to a set timetable. We propose that this process be made explicit and its progress monitored. The process should include activities (symposia, simulations, demonstrations, pilot programs) designed specifically to tease apart the technical from the political challenges, test potential solutions, ensure policy fundamentals of safety, equity and efficiency are preserved or strengthened, and ultimately bring the stakeholders to a new position where shared values lead to common solutions. Progress monitoring would include periodic assessment of indicators of maturity and interventions when progress lags. A key to successfully developing the best NextGen policy solutions is to not over-constrain the process by taking potential controversial solutions "off the table" in advance. This requires objective processes and measures that all stakeholders can agree to in advance.

Stakeholders are the sources of government's authority, and changing the stakeholders' hearts and minds will be necessary if we are to achieve NextGen in a reasonable timeframe. Some believe that we need a "burning platform" in order to resolve difficult policy issues. We disagree – solutions that are developed in response to a crisis are rarely if ever good ones.

Managing NextGen in a Co-Evolutionary Environment

NextGen is a not a single program and cannot be managed that way. It is a phased, long term, multi-program, multi-agency, public-private strategic overhaul of the Air Transportation System. These characteristics are necessities not out of preference, but because of scope, resources, and the ability for market and infrastructure to incorporate and adapt. These characteristics are also a critical risk mitigation approach for deployment. However, this deployment strategy significantly increases management risk because the implementation has, and will continue, to be affected by: market changes, administration changes, organizational evolutions, and technology advancements that can easily modify values, priorities, and schedules.

In order to minimize these management risks, NextGen requires what we would term a "co-evolutionary management approach" that includes: a participative process and inclusive governance; a flexible, iterative plan to guide the process, an architecture with unprecedented levels of robustness; and, instantiating strategic reassessment points.

Participative process and inclusive governance

First and foremost, we need to establish and maintain a participatory process that allows all stakeholders an active voice in the transformation. According to Yaneer Bar-Yam, one of the nation's leading experts in complex systems - "What do people do today when they don't understand "the system"? They try to assign responsibility to someone to fix the problem, to oversee "the system", to coordinate and control what is happening. It is time we recognized that "the system" is how we work together. When we don't work together effectively putting someone in charge by its very nature often makes things worse, rather than better, because no one person can understand "the system" well enough to be responsible.

We need to learn how to improve the way we work together, to improve "the system" without putting someone in charge, in order to make things work."[3] This was not intended to imply that clear lines of authority and accountability are not required; however, consolidating authority can not be a substitute for "improving the way we work together".

While not the only approach, it is instructive to examine the JPDO within this context. The JPDO is built on a foundation of democratic/participatory decision-making. Nine Working Groups of both federal and private sector participants work side-by-side to provide subject matter expertise across the total scope of NextGen. JPDO staff provides the Planning, Enterprise Architecting, Portfolio Management, and Modeling and Simulation disciplines to integrate the NextGen Plan and assess its impacts.

The Working Groups were initially charged with defining the future operational state of the Nation's air transportation system (Vision) that when realized would meet NextGen goals and objectives. The second step in the process was to articulate the pathway to get from where we presently are to the future Vision. Hence, they were not constrained in defining the future state by systems, processes, procedures, relationships, etc. inherent in the present. Thus, the "design space" was opened up to far more novel and innovative thinking than would have been allowed with the traditional approach of planning a series of marginal improvements to the current system.

A very open and inclusive process ensured that not only the Working Groups, but all stakeholders have an opportunity to participate. For example during the development of the NextGen Concept of Operations (ConOps) an extensive vetting of the various versions of the ConOps yielded over 4500 comments on various aspects of the document. These were about equally divided between industry (55%) and government (45%). Of the received comments well over 3000 of the comments were included directly or with some change into the ConOps. Hence, the stakeholder community had a powerful influence on the content of the ConOps.

The power of a collective vision is a compelling force. However, the legislature that established the JPDO also established a Senior Policy Committee chaired by the Secretary and composed of the Deputy Secretaries or Administrators of the partner Department and Agencies. The SPC (and the JPDO Board that was established at the Senior Executive level just below the SPC) has implementation authority. Therefore, there is a governance process that can turn the plan into action.

In addition to the Federal governance process, the NextGen Institute's Management Council provides a forum for the private sector to come together across the full private stakeholder community to provide critical input into JPDO processes and products.

This is not to say that the JPDO model is not without flaws. Given the limited authority and resources and the largely "pro-bono" participation model for the Working Groups, the pace has been limited. Moreover, given the unique approach that has been developed, we are also learning and adjusting based on feedback on the JPDO planning products which has also limited progress at times.

Nevertheless, the JPDO model is starting to bear fruit with recent inter-agency agreements for: adopting a common safety management standard; developing and integrating a 4D weather "cube" capability into system automation and operations; and, developing a net-centric information sharing architecture.

A Flexible and Iterative Plan

The NextGen plan guides the transformation of the air transportation system. The term guide is important. It would be unrealistic and counter-productive to build a definitive implementation plan for long-term capabilities that are predicated on research results and concept exploration. Given the complexities discussed in the previous sections, we believe that the NextGen Plan must be a flexible, evolutionary instrument that projects the vision, the range of alternatives, and the general evolution of the capabilities. The idea of a plan as a guide and not a programmatic baseline is an unfamiliar concept. It must be recognized that if it is to serve as an effective guide then it cannot stand alone. There must be a closed-loop process for utilizing the NextGen Plan to align programs to NextGen needs and then capturing feedback and making adjustments to the NextGen Plan based on program results and operational impacts.

The NextGen Plan that JPDO has developed is comprised of three main components, a Concept of Operations, an Enterprise Architecture, and an Integrated Work Plan. The NextGen plan uses these three documents in unison to capture how the need, plan and implementation are changing. One of the greatest values of this approach is that it creates, in unison with the participative process, an environment in which the debate that defines public/private partnership flourishes.

The Concept of Operations describes a vision of future capabilities and their interrelationships in a prose form. The NextGen Concept of Operations differs from traditional concepts because it describes a range of possible future capabilities. The capabilities describe the design space that sets the research and policy agendas. The community chose the set of capabilities based of their potential to achieve the NextGen goals.

[3] Bar-Yam, Yaneer; Making Things Work, Solving Complex Problems in a Complex World; New England Center for Complex Systems; Knowledge Press, 2004

The results of implementation, research, policy and performance analysis will explore the trades in the capability design space. The concept range will be focused as industry and agencies make design choices. Innovations in burgeoning technologies, like commercial space, will also contribute new concepts. The concept will never be fully complete or validated until the capability is implemented. If we are to achieve capabilities in a timely fashion, this process of exploration and focusing must be efficient and structured.

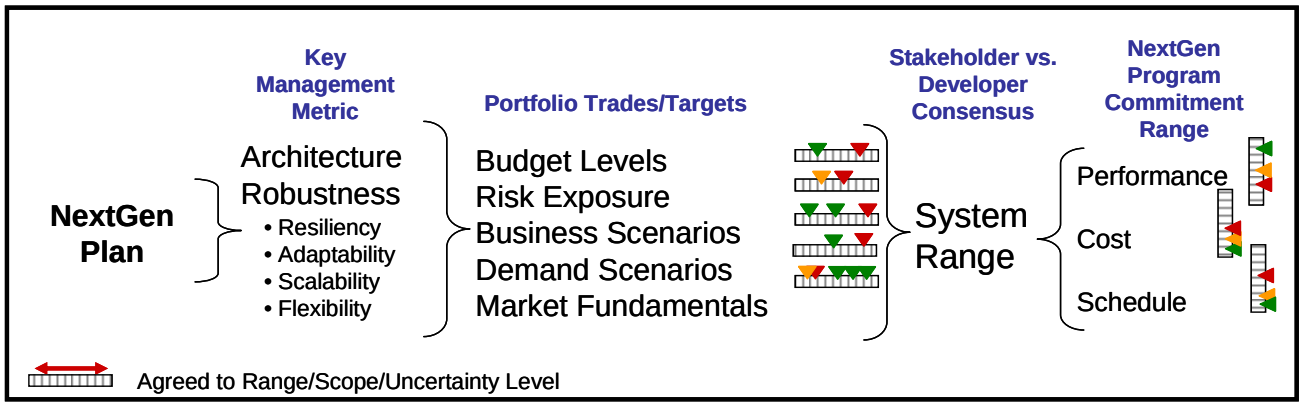
The NextGen Enterprise Architecture (EA) is similar to and differs from the traditional 5-7 year high confidence planning framework. The NextGen EA is similar because it provides the common lexicon and a structured method for organizing performance, technical, cost and risk data. Analysts and senior decision makers to understand, integrate, and assess the health of the NextGen Plan can use these data. The NextGen EA is characterized as an "enterprise of enterprises" architecture. The NextGen EA federates the EA's of partner agencies, thus providing the only framework where the whole plan is seen. The EA methodology is derived from the capital planning process. However, it is not common to find an EA built to guide research or to close a design space forecasted over 15 years into the future. However, this is a critical feature that must be incorporated into the NextGen EA. The NextGen EA, therefore, defines the structure to guide the work planning of both capital and research investments. The EA will evolve and be refined annually to update the information and provide the framework for reflecting the most current understanding of partner agency and industry plans.

The Integrated Work Plan (IWP) appears the most like a baseline program plan while the most different in how the components are used. The IWP, like a baseline program plan, contains activities over time with dependencies. However, the activities of the IWP are the operational improvements that project the evolution of NextGen capabilities. Enablers for the operational improvements that represent the key technology, policy or procedures are also captured. The IWP is not a populated work breakdown structure for NextGen. Rather, it is an interactive reference database to be used by stakeholders and decision makers to assess and validate agency and program strategies. It provides the strategic requirements, the critical dependencies and tracks the progress of the multi-agency efforts.

The IWP is used to guide and track agency commitments. The IWP must include and account for a range of agency commitments. For example, a near-term baselined program represents a high level of confidence in an agency commitment. Political and strategic commitments also imply high levels of confidence. Budgeted activities convey some confidence. The confidence decreases with the number of budget years projected. Activities without an agency budget or plan commitment represent the least amount of confidence. The IWP includes all these activities. Integrating these elements across all the partner agencies creates a complex network, but also creates a powerful tool for assessing and prioritizing alignment and gaps in investment.

The efficacy of the IWP was demonstrated this summer. We utilized the IWP in cooperation with the partner agencies to perform a detailed gap analysis. The gap analysis revealed a number of gaps that were then valued based on available data on benefits, costs, and risks. Such a detailed gap analysis across the entire scope of NextGen would not have been possible without the IWP. While the IWP is still a work in progress (and always will be), it created an objective basis for coming to agreement with the agencies on where there is good alignment, where there are clear gaps, and where there is disagreement or confusion on operational improvements.

Figure 2. Strategic Re-Assessment



The JPDO has documented this process and the results of this year's analysis, including lessons learned so that we can improve the process for subsequent years.

There are also two additional elements that we have not yet instantiated in the JPDO process, but that are compatible with the structure and approach we have taken. The first is ***architectural robustness:*** robustness is the quality of being able to withstand stresses, pressures, or changes in procedure or circumstances. For NextGen robustness is further broken down into additional characteristics:

Resiliency – the ability to handle off-nominal conditions efficiently.

Adaptability – the ability to handle different configurations of fleet mixes, business drivers, and market fundamentals (population, location, commodity price changes, policy decisions, etc.)

Scalability – the ability to be efficient and profitable at different demand levels.

All three of these sub-definitions rely on **Flexibility** as a key ingredient in enabling the required performance.

The concept of robustness needs to be further developed in the context of NextGen and utilized as a central metric in assessing the architecture and in working through solution set trade-offs.

Finally, we need the instantiation of strategic decisions (i.e., architecture, investment, and implementation) with ***re-assessment points*** to accommodate the realities of long-term, phased, strategic deployments. First, we need to accommodate reprioritizations that differ significantly from the original baseline return-on-investment parameters based on market, security or other changing conditions. Second, system evolution dynamics will play out over time as systems will not be deployed exactly as originally planned. Third, operational changes may significantly change system operations and performance with unintended consequences. And, finally, business strategies may shift deployment priorities and system requirements. Figure 2 illustrates relationships among key parameters at a re-assessment point.

Moreover, NASA research[4] had led to the realization that long term systems like the Shuttle, Space Station, and NextGen will evolve significantly during their operations phases in both design and performance. Even though incremental changes go through standard configuration management processes the overall system architecture periodically needs a Critical Design Review (CDR) type effort to re-assess the complex evolving end-to-end performance.

The JPDO has created a structure that is an ideal mechanism for the long-term deployment lifecycle management of the NextGen communities and partners. Governance and communication channels and liaisons are in place. Course correction CDR type meetings are natural evolutions out of the IWP and the portfolio and systems analysis capabilities are already in place to integrate partner and stakeholder economic and business models to help drive strategic re-assessments.

This structure and co-evolutionary management practice is essential to ensure that our investments enable capabilities that drive performance, and result in benefits and value to the nation. Used in this way the architecture and plan are more than guides for the technical issues but are practical and essential tools for policy-making and investment decision-making.

Key Concepts for System Development

Finally, we believe that there are a few strategic system thrusts within the context of system development that would provide the basis for an efficient, evolutionary transition to NextGen.

Defining the integrated, enabling CNS infrastructure

The success of NextGen depends on robust feedback between the NextGen Plan and agency program planning and implementation. While this process is being worked across the board, we feel one of the critical areas that needs to be highlighted is an Integrated Communications, Navigation and Surveillance (ICNS) set of capabilities rather than the discrete development and deployment of singular technologies (e.g. ADS-B, Data Communications, etc.). ICNS involves complex multi-agency relationships around large-scale, safety-critical systems. This can lead to long timeframes for the resolution of issues. At the same time, there is a need for greater clarity in the near-term because large investments are being planned and executed today (e.g., ADS-B and Datacom) that reflect uncertainty in the target design space for ICNS. Moreover, these current efforts are being driven by historical organizational constructs (i.e., separate offices for communications, navigation, and surveillance systems) that do not reflect the true integrated nature of future CNS systems.

[4] Engineering for Complex Systems Program was instantiated to understand the dynamics of large complex mission development and operations and to develop tools and methods to improve overall organizational performance

NextGen aims to achieve more flexibility, responsiveness and agility compared with our current Air Traffic Management system through use of:

[C] ubiquitous data communications to enable full information sharing between/among all authorized users (air-ground or air-air)

[N] accurate, robust and universal Positioning, Navigation and Timing (PNT) Services

[S] correlated cooperative and non-cooperative surveillance data to create a user-defined operational picture

These CNS elements are much more interrelated and dependent upon one another than today's system. NextGen Communication services will rely on a mix of terrestrial and space-based commercial networks, with some aircraft-to-aircraft direct links, providing both addressable and broadcast message capabilities. Air-ground and air-air applications will rely on core network services to make information available, securable and usable in real time according to defined "communities of interest". NextGen PNT services will be mostly space-based and will inherently support Required Navigation Performance (RNP) operations and applications of Automatic Dependent Surveillance – Broadcast (ADS-B). NextGen Surveillance services will detect, identify, and monitor the movements of all operating vehicles. Cooperative surveillance involves each vehicle broadcasting its ID, location and flight/ground path intent. Non-Cooperative surveillance will use sensor data to independently verify an air vehicle's location and track as provided by cooperative surveillance. This integrated surveillance approach will enable security/defense authorities to focus on air vehicle operations detected by non-cooperative means, while air traffic service will use non-cooperative surveillance information to mitigate failure modes in cooperative surveillance. All of the above services must improve operational efficiency both at an individual aircraft level and for the entire airspace system, as well as allow aircraft separation standards to be safely reduced (improving system capacity). Furthermore, transition to a more space-based or commercial service approaches will allow significant US Government cost savings from decommissioning of a significant amount of legacy ground-based CNS infrastructure.

NextGen integrated CNS will be used to distribute decision-making appropriately during normal operations and abnormal events -- improving the speed, efficiency and quality of decisions. In this future, we envision multiple "control loops" existing in parallel or as needed to suit the task(s) at hand. This is expected to yield higher performance in ATM/aircraft system operations at the cost of a more complex system design.

Though the above represents some of our thinking on NextGen Integrated CNS, it should be stated clearly that we do not have a clear picture of this capability or the architectural form(s) that it will take. What we do know is that integrated CNS capabilities are beginning to appear. ADS-B is perhaps the best example of this – navigation information is "broadcast" via a data communication mechanism to provide surveillance information (and to communicate additional information in some ADS-B implementations). However, ADS-B is a single capability designed to meet a limited set of operational needs; it is not a comprehensive Integrated CNS approach.

Right now there are existing (PNT) and emerging (Integrated Surveillance) inter-agency activities that cover key elements of this complex design space. However, up to this time, there has been too little effort around the overall ICNS design space. Work being performed by the JPDO's Aircraft Working Group has started to address this issue and recognizes the changing nature of CNS relative to its integration in the flight deck – "Avionics are migrating from discrete components to multi-function, flexible, integrated avionics platforms. With reusable processors and common sub-functions, such as determining the aircraft position to support both navigation and ADS-B Out, the traditional avionics categories of communication, navigation, and surveillance (CNS) are becoming less descriptive"[5].

We believe substantial priority should be placed on developing a more detailed target architecture for ICNS to help guide current modernization efforts, facilitate interagency cooperation and support avionics planning.

Developing facilities that integrate operations, training, test & evaluation

As discussed earlier, we need to plan in advance for overlap and recursion among the definition, development and operational phases of NextGen. We can guide the transformation, but we cannot fully plan it in advance. Therefore we need to create opportunities to better connect those phases and strengthen the feedback loops. In practical terms, this means getting the planners, researchers, developers and operators out of their stovepipes to get them working together.

Moreover, aviation has very strong cultures. The vitality of those cultures lies in their ability to meet the challenges of the future. If those cultures can see a viable future and they believe they have the ability and means to achieve it, then they will engage it. Transformation is about change and it is a developmental and learning process that all of the key cultures need to engage in.

[5] Avionics Roadmap, Draft JPDO Document, June 2008

One practical approach to address these factors is to co-locate operations, training, test and evaluation functions in the same facilities. This would mean building permanent training and research infrastructure at key operational facilities. Operational staff would be trained to participate in research and have this participation as a part of their regular duties, including human-in-the-loop simulation, shadow-mode operations, and operational trials. Standard safety sensitive processes would need to be developed for trial integration of new software and systems and experimental evaluation of performance. The approach would increase operational costs at some locations. However, the advantage would be the ability to reduce the cycle time between research and fielding a capability. Such an approach would also represent a real commitment to continuous, evolutionary change and would substantially strengthen the feedback loops between the definition, development and operational phases. The proof of concept for this approach is the North Texas Research Station (NTX) operated by NASA at the Fort Worth Center in support of the development of the CTAS suite of controller automation aides.

Designing and Executing Capability Campaigns

Finally, in order to fully achieve the integrated capabilities that are envisioned as a part of NextGen, many concepts, technologies, policies, and procedures will need to be developed and validated. This will involve many linked and often difficult decisions that cut across both the public and private sectors (for example, those that were highlighted in the policy section). However, we often treat specific developments within a capability as a "silo" and validate and build business cases for them individually. What is really required is to generate and collect information across silos such that we are validating and building business cases for the total capabilities (e.g., trajectory based operations capability versus data communications technology).

To this end, a key concept is the best practices developed by the DoD around campaigns of experimentation[6]. Using the capabilities as the focus, they would instruct us to design series of inter-related experiments that will systematically answer the required questions and provide a consistent database of information upon which to develop and validate individual concepts and technologies as well as the overall capability. Assumptions, metrics, measurements and analysis are treated consistently across the capability space. In this context, experiments not only span the capability space, but also increasing levels of maturation and fidelity as articulated in Figure 3[7]. We would therefore define a capability campaign as a deliberate, planned progression of modeling, simulation, experimentation and demonstration that: develops and validates the key NextGen capabilities; provides consistent development and validation data for sub-capability technologies and systems; and, supports key decision points (acquisition, policy, etc.) with targeted demonstrations.

We believe such a systematic, capability driven approach would accelerate progress, enable efficient use of resources and reinforce feedback loops among definition, development and operation. As previously discussed, difficult management and policy choices are often avoided, resulting in delays and lost opportunities. Demonstrations that are deliberately planned as part of the campaign of experimentation can support timely, high confidence decision-making. Finally, such an approach would also complement a strategy of developing integrated operational, training, and test & evaluation facilities. Such facilities would serve as a natural venue for certain types of experimentation.

The Research Transition Teams (RTTs) that have been recently established by JPDO, FAA and NASA are a start in this direction. RTTs are intended to better coordinate research to implementation across the agencies and will therefore begin to address coordination of the full set of experimentation that is required to realize specific capabilities. However, more needs to be done to provide top-down planning toward capability-driven, multi-agency capability campaigns. We believe such plans should be developed as a guide for R&D program planning and execution.

[6] Alberts, David S. and Richard Hayes; Campaigns of Experimentation, Pathways to Innovation and Transformation, CCRP Publication Series, 2005

[7] Graphic adapted from Alberts, David; Code of Best Practice: Experimentation; CCRP Publication Series; 2002

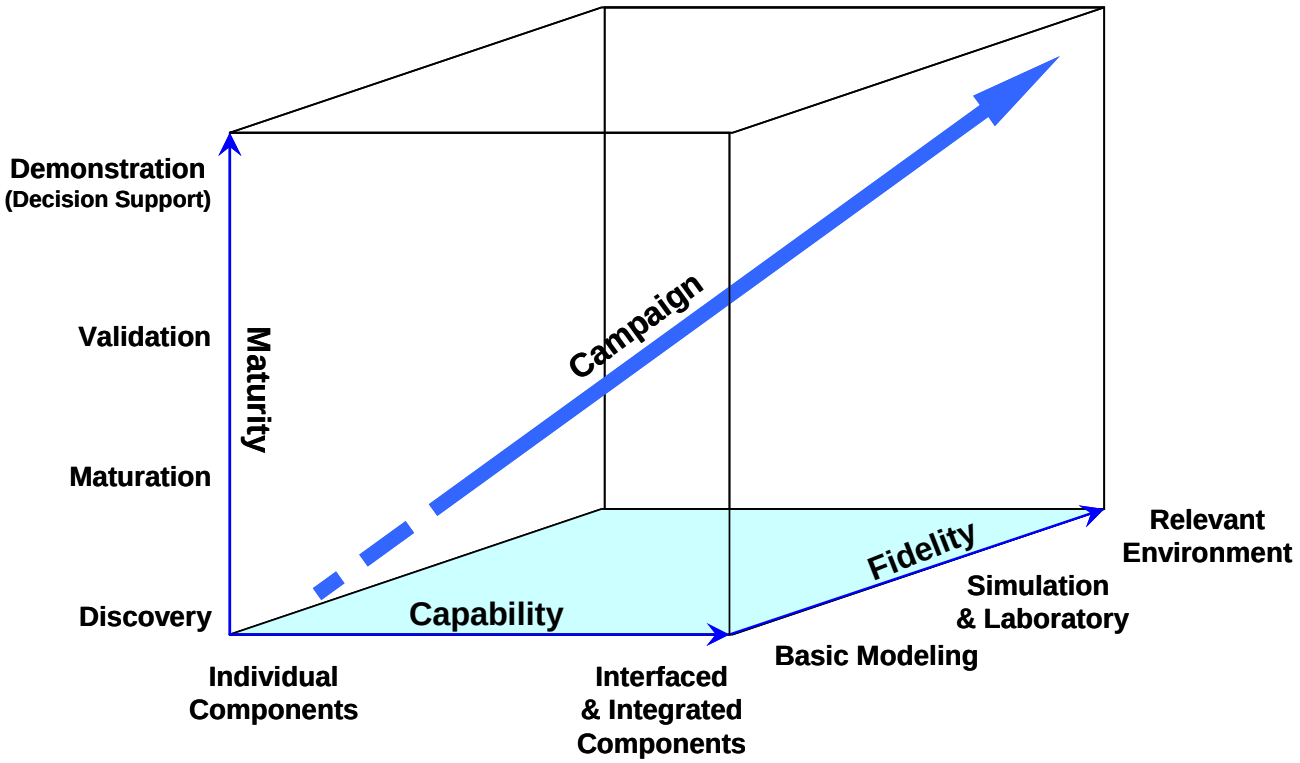


Figure 3. Capability Campaign

Conclusion

NextGen is truly a grand challenge. And it is one we need to take on and achieve if we are to have an air transportation system that supports our nation. But it is going to be a challenging road and there is no organizational, programmatic or budgetary panacea. The complexity of this enterprise leads to the reality that there will be no valid point estimates, there will be variation in needs over time and place, there will be unanticipated challenges, there will be recursion in our processes of definition, development and operation, and that architectural robustness and operational innovation will be required.

But we also believe that if we consider these factors now and continuously as part of the transformation process, then we can anticipate and adapt as the need arises. We also think that the approaches we have described can address the complexity of NextGen in a disciplined manner with good results.

Also, it is important to note that none of this is a substitute for well executed traditional program management and systems engineering. Rather, they are complements and need to be worked in tandem.

The summary of this article is not that the JPDO is the best approach or that it has been an unqualified success. The JPDO has stumbled at times in executing its mission, but as parts of the system ourselves, it is a learning process that has and will continue to require changes to how we get our part of the job completed. The JPDO is only one part of this complex system of change. Perfect execution by the JPDO would not result in NextGen. The summary is that it is only when all parts of the system are working together toward the vision that we will collectively achieve NextGen.

---

* This article represents the views and assessments of the authors, and, as such, does not intend to represent an official view of the Joint Planning and Development Office.