

Transforming the Air Traffic Management System – Why is it so Hard?

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Outline

- The Equity Concept
- Introduction to NextGen
- System Complexity and its Implications
- Trajectory-Based Operations
 - The TBO Concept
 - An Example: In-Trail Procedures
 - Another Example: Performance-Based Navigation
- Unmanned Aircraft Systems Integration

The Equity Concept

Chocolate Cake Problem: How can I distribute this cake equitably among each of the students sitting in this room?



Reference: <http://www2.edc.org/womensequity/edequity/hypermail/1432.html>

Means of Cake Distribution

- We could all get equal sized pieces of cake. But if some people don't want any cake that will make the pieces for everyone else artificially small.
- I could give everyone a fork and have you fight for your share. That could cause a mess and someone could be injured in the process.
- Perhaps we could each have an equal chance at getting a piece of cake by using a lottery system with the winner receiving the whole cake. That would mean most of you would be out of luck and someone is stuck with a whole cake.
- People could testify to their need for a piece of cake, and the most convincing get a piece. How will I decide who is most convincing?

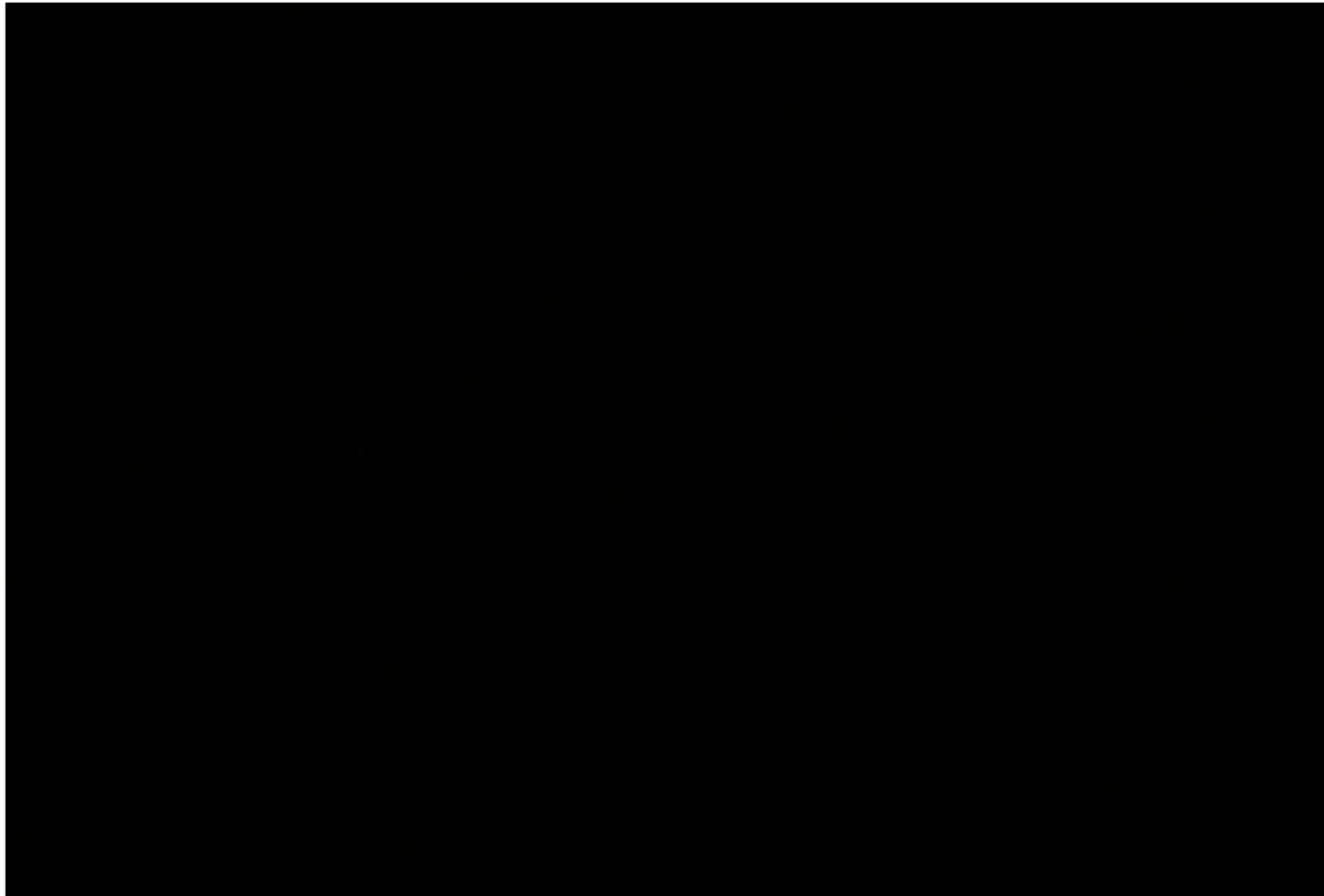
Aviation Stakeholders



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NextGen Turns 10!



NextGen Turns 10!



Partners in the Next Generation Air Transportation System

Joint Planning and Development Office



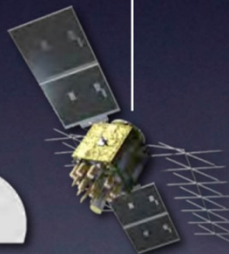
Multi-Agency
Leadership



Advanced
Aviation
Operations
& Safety



Intelligent
Weather
Solutions



Advanced
Operations
& Security



Enhanced
Layered
Security



Aeronautics
Research
& Technology



National Policy

Integration and Collaboration

The JPDO Collaborative Methodology

- Stakeholder engagement
- Define roles and responsibilities for strategy execution
- Establishment of compatible standards, policies and procedures
- Monitor and report on multi-agency progress through Senior Policy Committee

Results are National approaches to complex NextGen related issues and reduced duplicative efforts leading to cost savings.



How do we Accomplish our Goals?

- The JPDO fosters a collaborative approach
 - Provides a “future” focus
 - Maintains a “big picture” perspective
 - Conducts a variety of analyses to address priorities
- The assessments include:
 - Program management and integration
 - Cost, benefit and risk assessment
 - Policy analysis
 - Interagency data exchange definition
 - Public/private partnership – NextGen Institute
 - Maintaining and supporting the National integrated plan

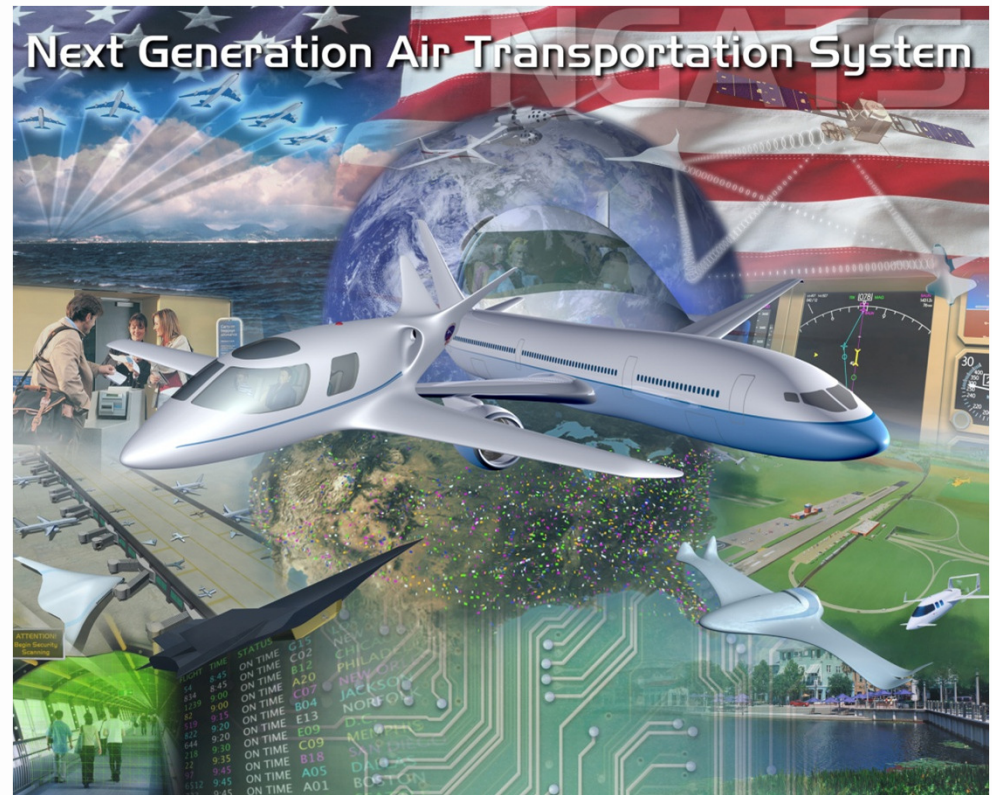
2025 Concept

Operating Principles

- “It’s about the users...”
- System-wide transformation
- Prognostic approach to safety assessment
- Globally harmonized
- Environmentally compatible to enable continued growth

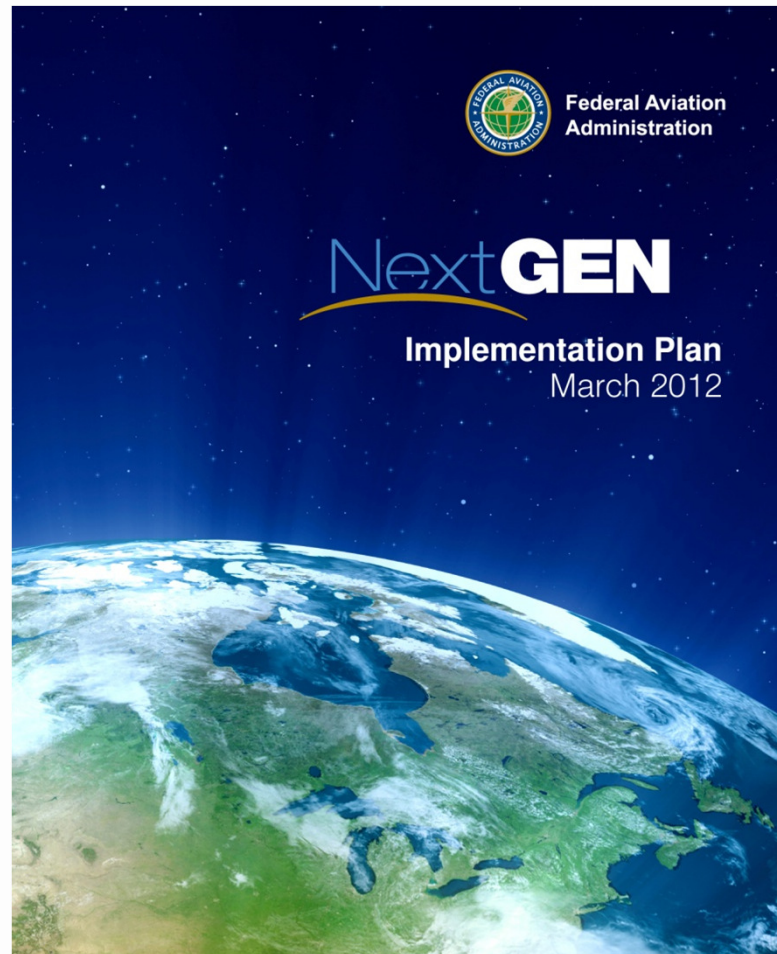
Key Capabilities

- Net-Enabled Information Access
- Performance-Based Services
- Weather-Assimilated Decision Making
- Layered, Adaptive Security
- Position, Navigation and Timing Services
- Trajectory-Based Aircraft Operations
- “Equivalent Visual” Operations
- “Super Density” Operations



Version 2.0 (13 June, 2007) at:
<http://www.jpdo.gov>

FAA's NextGen Implementation Plan

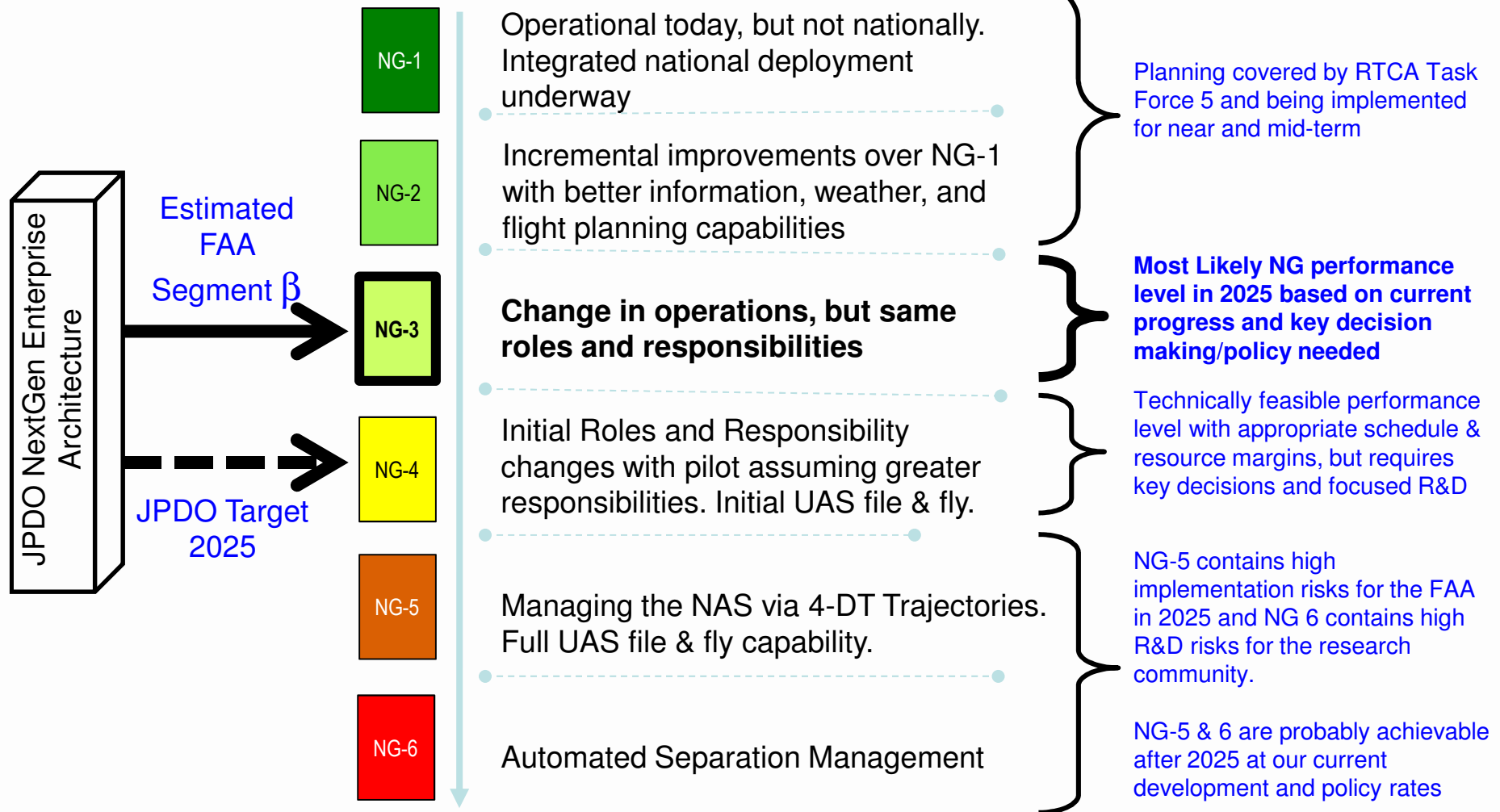


For more information see: <http://www.faa.gov/nextgen>



Executable NextGen Architectures

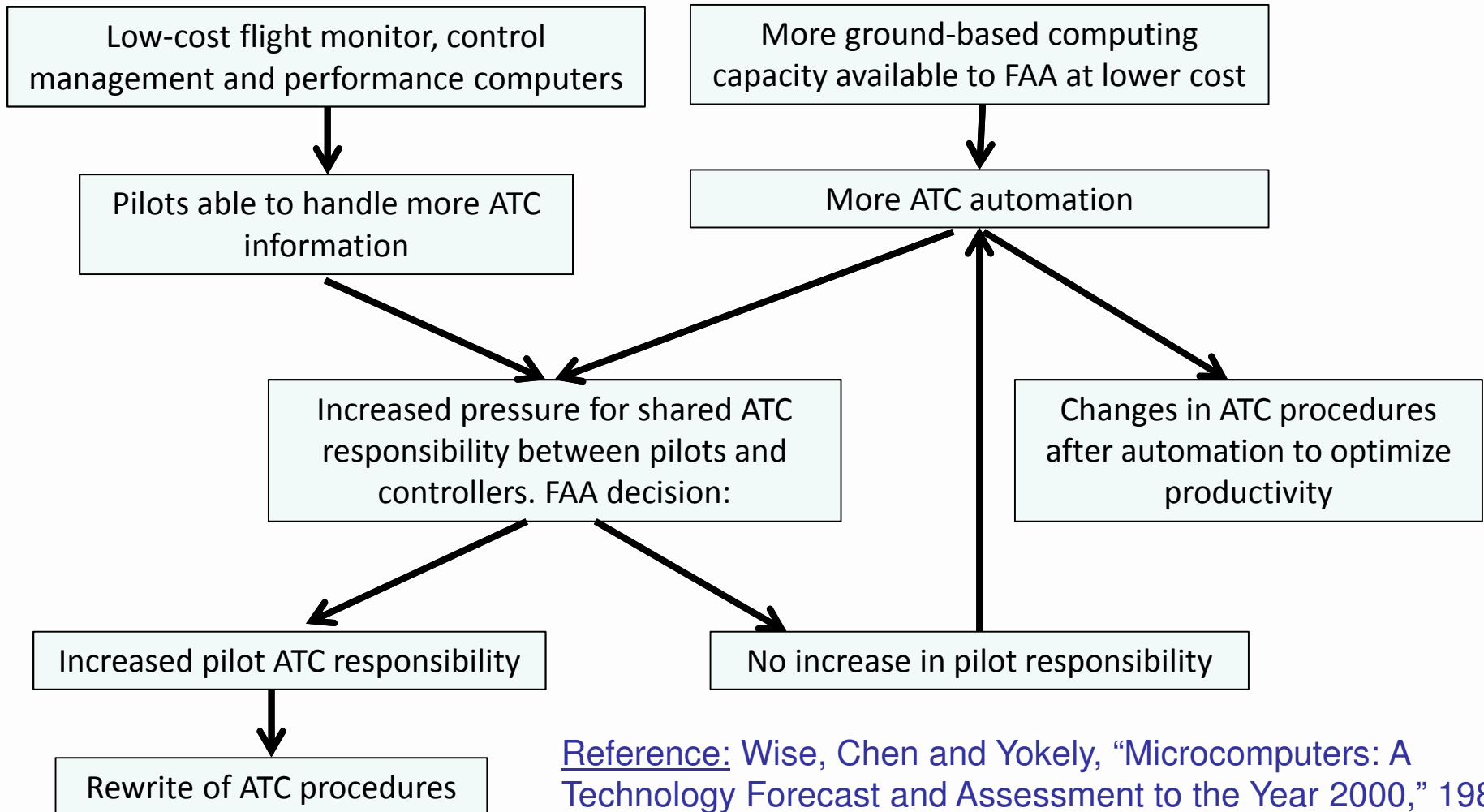
Lowest Performance, Automation & Risk



Highest Performance, Automation & Risk



Microcomputer Technology Trends



Reference: Wise, Chen and Yokely, "Microcomputers: A Technology Forecast and Assessment to the Year 2000," 1980



Outline

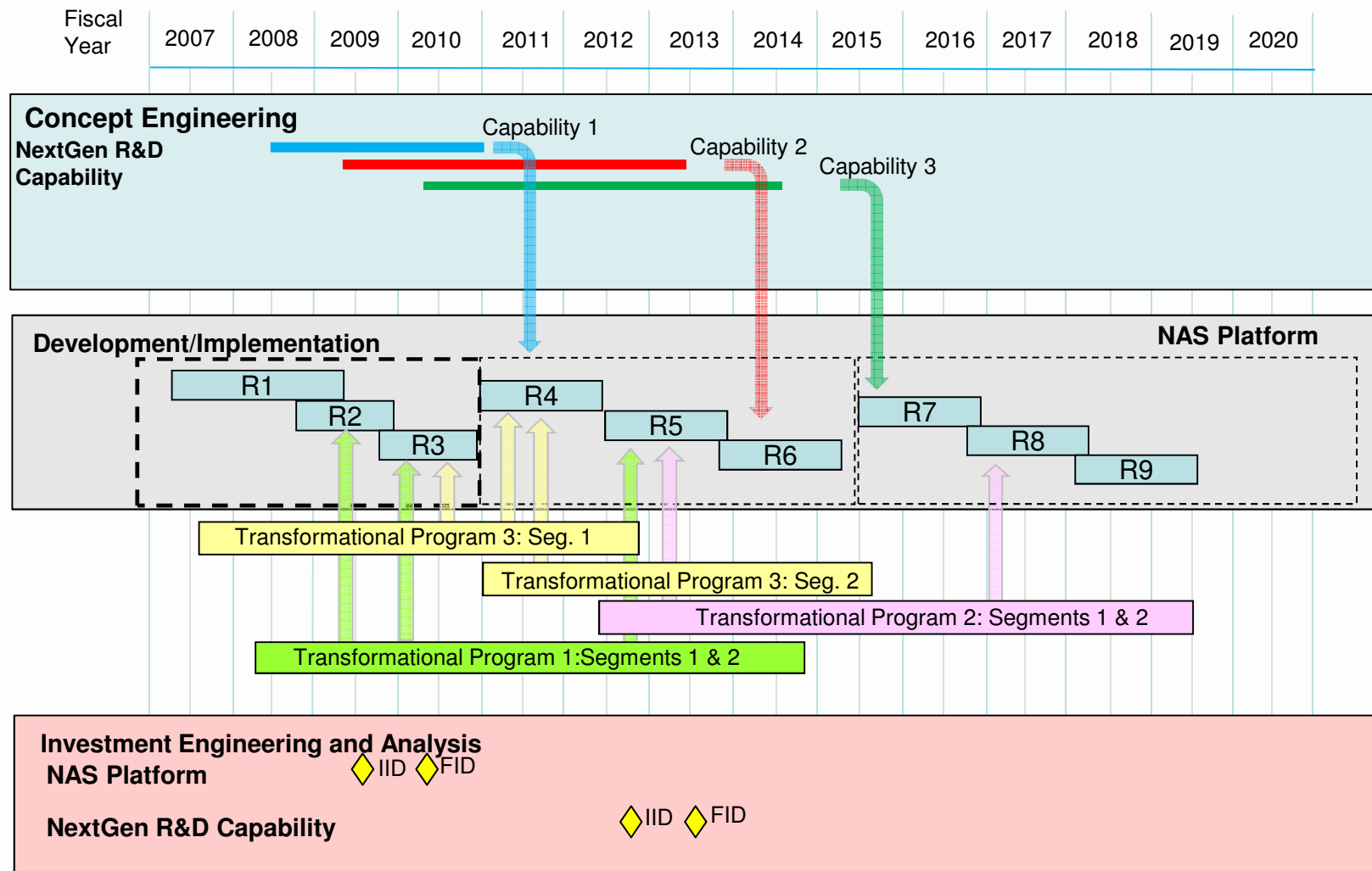
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Definition

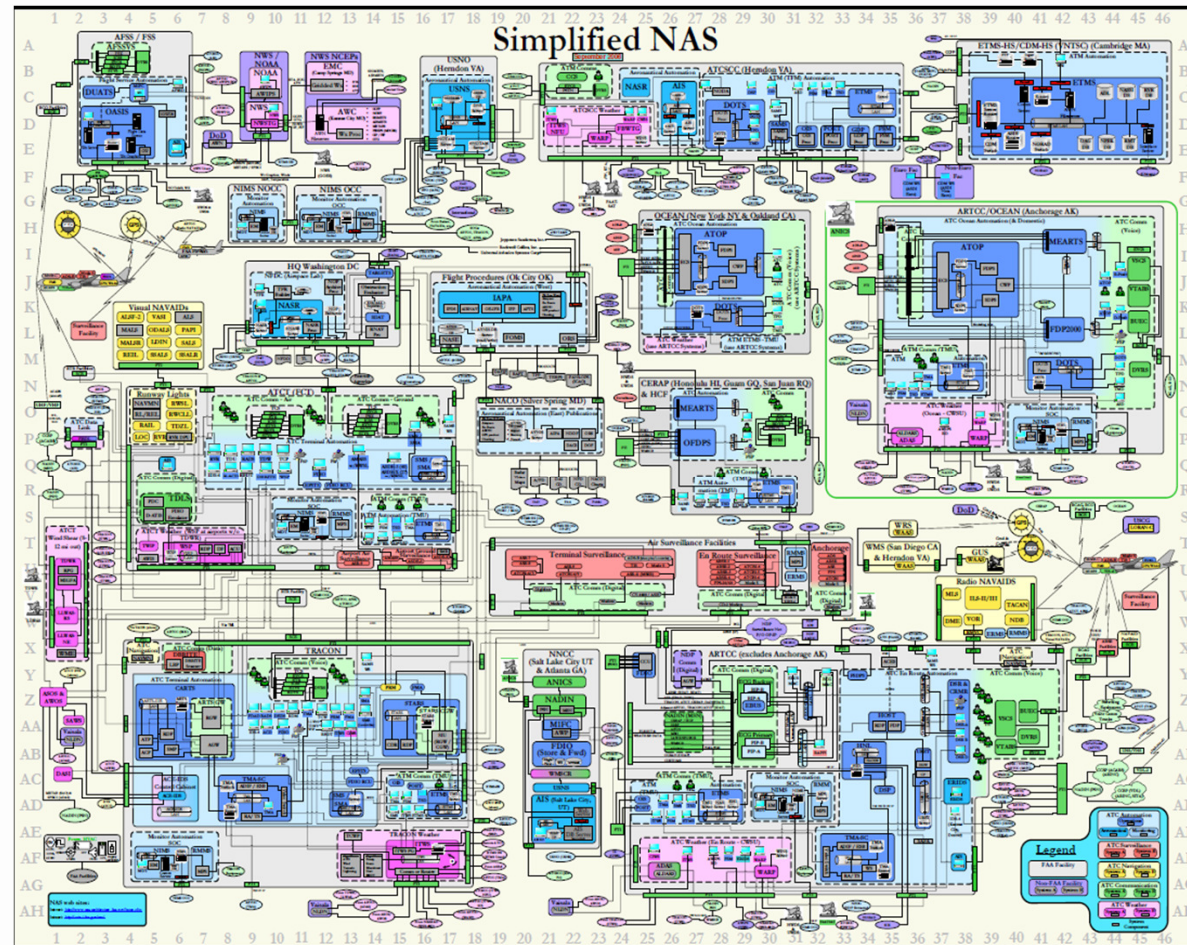
Wikipedia defines a complex system as:

“a system composed of interconnected parts that as a whole exhibit one or more properties (behavior among the possible properties) not obvious from the properties of the individual parts.”

Notional System Integration



Complex Differs From Complicated



Resilience to Different Futures

- This complex system must be resilient to many perturbations and failures
 - Transformation to NextGen will span more than 20 years
 - Aircraft that fly in the system have 20-30 year life spans
- A real life example: the DARPA internet in the 1980s

F-22 Raptor



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Evolution of ATC/ATM

Past

Procedural
Separation



Estimate
current and
future aircraft
positions

Present

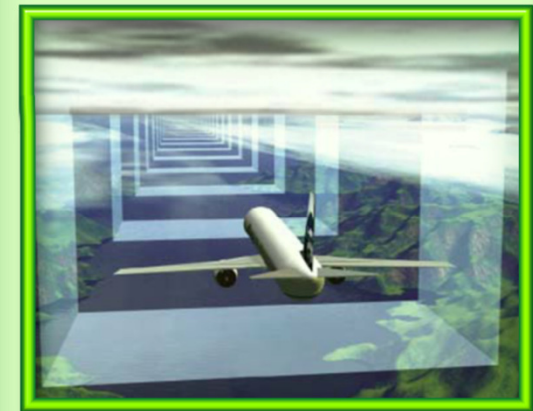
Radar
Separation



Know current and
estimate future
aircraft position

Future

4-D Trajectory
Separation



Know
current and
know future
positions

TBO Concept Overview

- TBO represents a real paradigm shift in how we do air traffic management
- A generation beyond what FAA and RTCA call Trajectory Operations and “TBO” as used by SESAR
- The underpinnings of TBO are:
 - Trajectory planning
 - Trajectory negotiation
 - Execution of negotiated 4D trajectory from gate to gate
 - Trajectory replanning and re-negotiation to deal with new ATM system constraints or changes in user desires
- Today’s sectors and route structure may disappear

TBO Concept Overview (cont'd)

- Pilots, controllers, FAA flow managers, and Operations Centers may see their roles change.
- They will interact with each other and with their respective automation systems in new ways.
- A 2012 JPDO study examined how future roles for Operations Centers are critical to improving aviation safety.
 - TBO will allow operations centers to negotiate a flight's trajectory before it takes off, helping operators meet the response to expected increases in demand.
 - It will also allow operators to negotiate optimal flight paths for individual flights based on optimization of their entire network.



TBO Concept Overview (cont'd)

- TBO requires a truly net-centric system.
 - Timely, common information will be available to all (humans and machines) to help them make their decisions.
 - While any change in the approach to separation represents a cultural shift, the increased collaboration through net-centricity to improve common situational awareness will increase predictability and reduce variability.
- This concept is about choices, negotiations, and precise navigation.
- BUT -- there are still a lot of unknowns in TBO that present a fertile area for research

Some TBO Research Questions

- How resilient is the plan when the system is interrupted by weather, airport acceptance rates change, or unexpected aircraft enter the zone?
- Should aircraft separation be ground-based? If not, what is the best role for the pilot and cockpit automation?
- When does a trajectory need re-negotiated? How often and for what cause?
- How is the prioritization done when scarce resources must be allocated? (Remember how hard it was to distribute the chocolate cake!)

ADS-B In-Trail Procedures

Enabling Climbs, Saving Fuel

From Concept to Flight

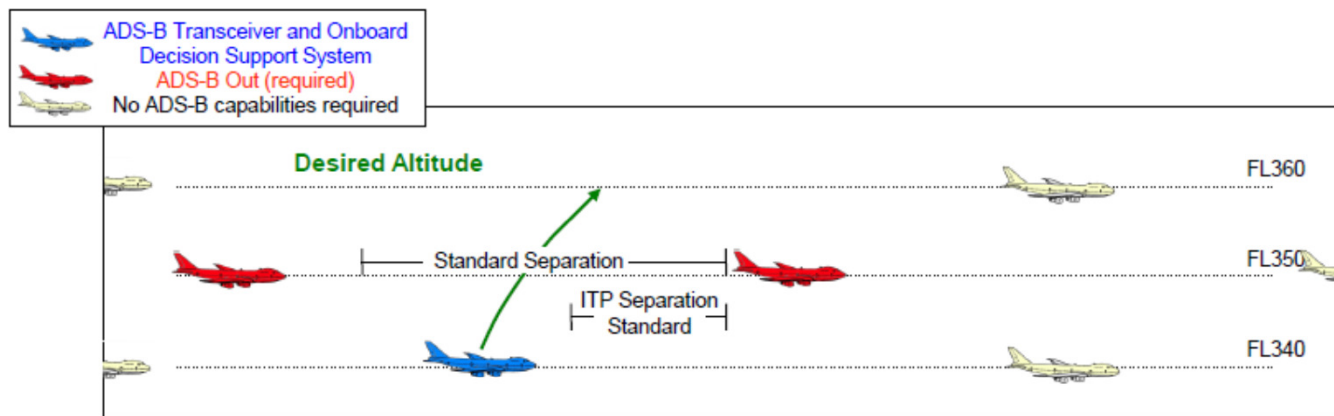
AIAA Aviation Technology,
Integration, and Operations Conference
Indianapolis, Indiana
September 17-19, 2012

Kenneth M. Jones
NASA Langley Research Center



Enabling Altitude Changes

Motivation for ADS-B In-Trail Procedures



NEED → **CHALLENGE** = **OPPORTUNITIES**

→ Altitude Changes required for better fuel economy, winds, and ride quality

→ The combination of locally dense traffic and large separation minima limits altitude changes

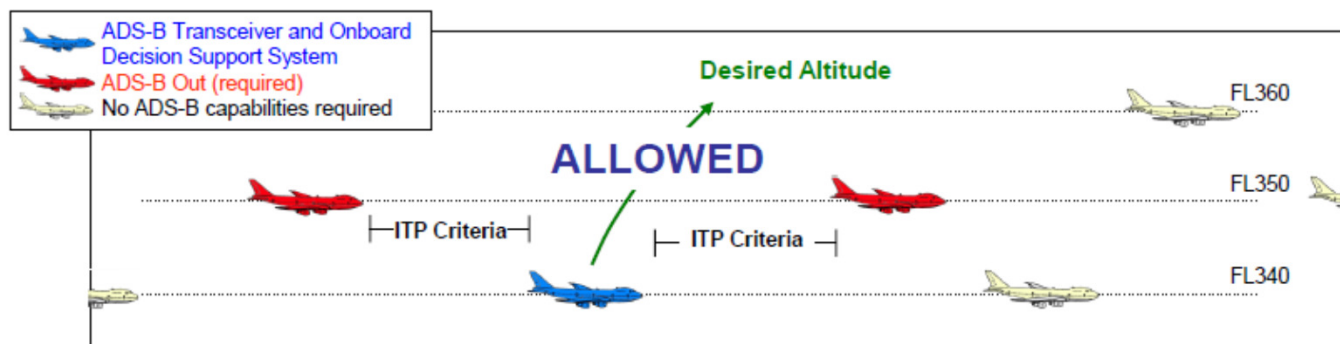
→ Use airborne ADS-B applications to enable altitude changes otherwise blocked by conventional operations

Steps to Execute

ADS-B In-Trail Procedures Sequence



ADS-B ITP Climbing



Pilot Responsibility

Step 1: Pilot verifies ITP criteria

- ☒ ITP distance is greater than 15 NM
- ☒ Ground speed difference < 20 kts if 15 NM - 20 NM from reference aircraft or <30 kts if greater than 20 NM

Step 2: Pilot requests ITP climb from ATC

Step 5: Pilot revalidates ITP criteria

Step 6: Executes maneuver

Controller Responsibility

Step 3: Controller verifies:

- ☒ Altitude requested is available
- ☒ Closing Mach number difference between aircraft requesting ITP and reference aircraft ≤ 0.06

Step 4: Controller grants ITP climb

Why do this Procedure?

- This is a straightforward procedure that enables aircraft to **save fuel** by flying at optimal altitudes and speed.
 - The certainty that less fuel will be used allows airlines to increase payload on an aircraft. Thus, the **airlines benefit**.
 - It also moves ADS-B In ahead with an application that gives those who choose to equip immediate benefits. The **FAA also benefits** with more ADS-B adopters.
- Given a simple algorithm that saves fuel and has benefits for airlines and air traffic control, why has implementation taken years?

From Lab to Revenue Demonstration

ADS-B In-Trail Procedures Maturity (~2008)

- **Concept Development (2004)**
- **Evaluation (2005-2007)**
 - **2005 - 2007** Batch simulations to evaluate ITP climb opportunities and efficiency gains
 - **2006** Experimental HITL evaluation of ITP and cockpit decision support tools: pilot perspective
 - **2007** Experimental HITL evaluation of ITP operations: controller perspective
- **Standards**
 - RTCA DO-312: ITP system level avionics standard (2008)
 - ICAO Separation and Airspace Safety Panel (SASP): ADS-B ITP Circular (panel approved ITP separation standard, 2009)
- **Next step – move from simulation to revenue service**
- **Transfer technology to the FAA**
 - FAA SBS had the mission and resources to implement this in revenue service



ITP Prototype Display (2006)
in NASA LaRC's Air Traffic Operations Lab

Working toward Flight Approvals

ADS-B In-Trail Procedures

Operational Evaluation Partnership Agreements

- **Partnership**

- FAA and United Airlines agreement signed in April 2009
 - Additional partners include Honeywell and Goodrich

- **Scope**

- Retrofit 12 UAL 747-400 aircraft with certified ITP systems
- Gather data on use of systems in SOPAC for a year starting in 2011

- **Outcomes**

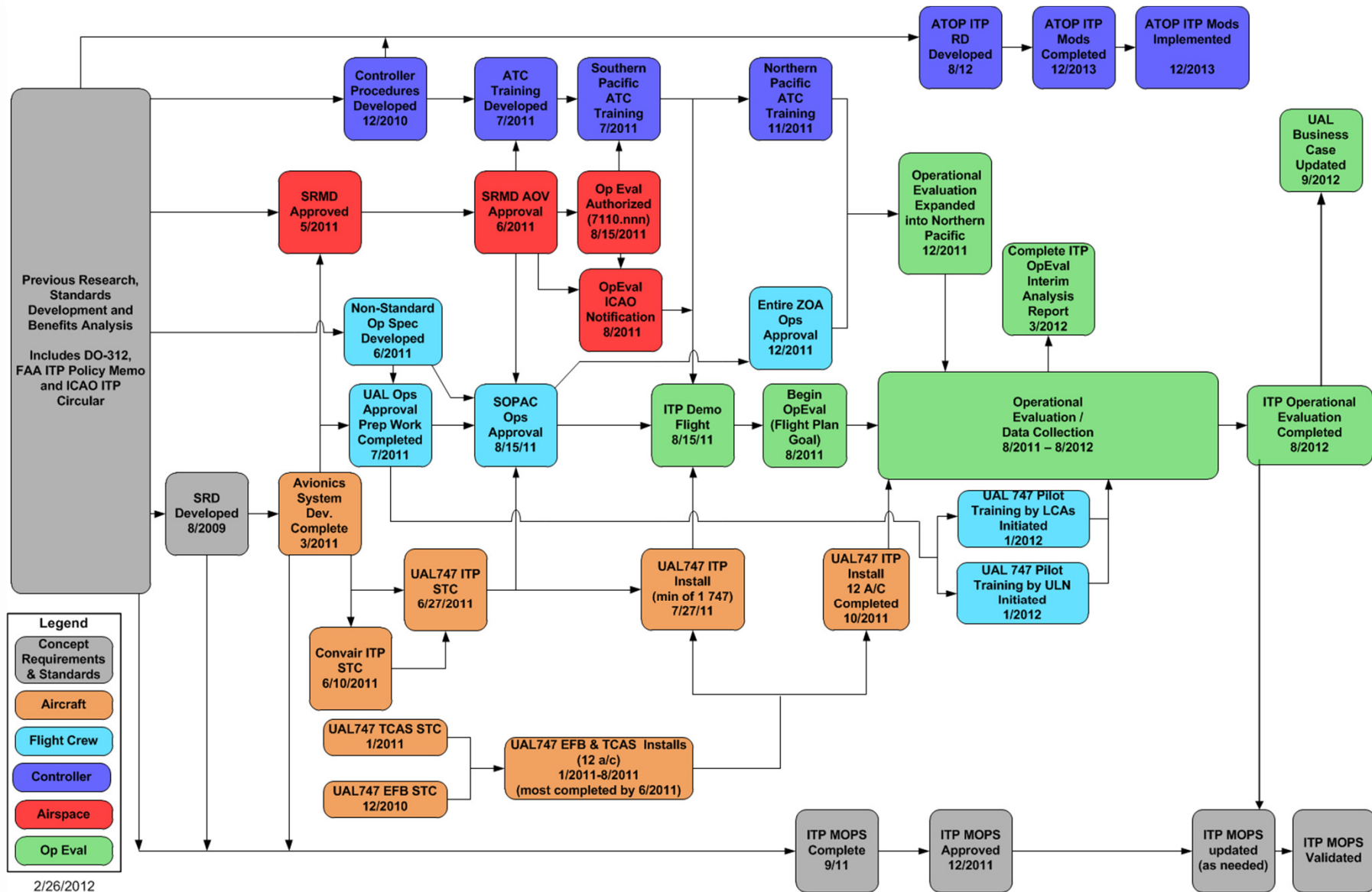
- Validate economic benefits of ADS-B ITP
- Validate operational performance of ADS-B ITP

- **ASPIRE Agreement Partners**

- Air Services Australia
- Airways Corp. New Zealand



In-Trail Procedures Key Activities



2/26/2012



Evaluation Equipment

- Equipment was kept as simple as possible
- Avionics were not modified
 - Electronic flight bag developed by Honeywell
 - Certification was difficult since this was new
- FAA's oceanic system (ATOP) was not modified
 - Controllers used an operational checklist

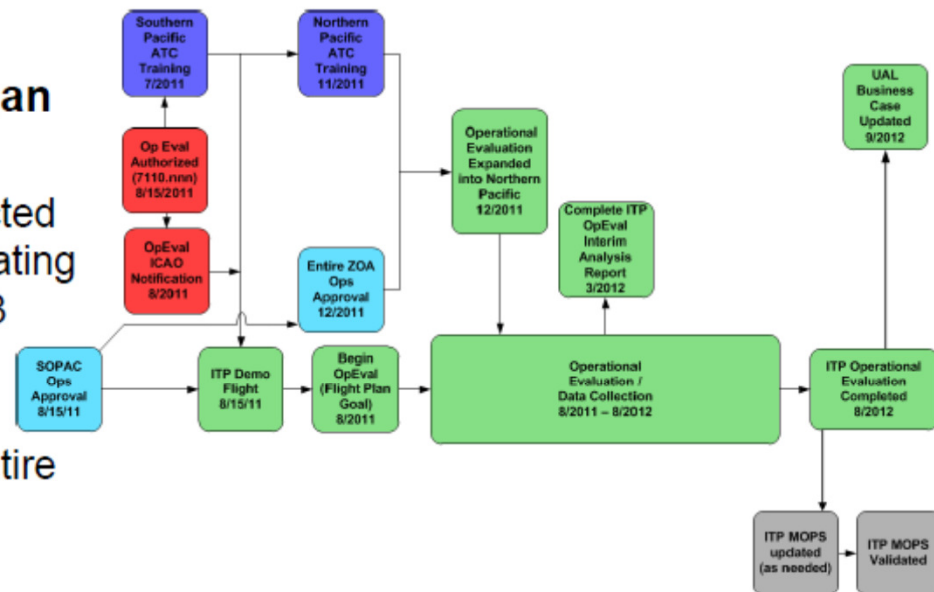


Data Collection to Validate Safety, Operational Performance and Economic Benefit

Operational Evaluation

- **Operational Evaluation began on August 15, 2011**

- Demonstration flight conducted using two United 747s operating in revenue service; UAL 863 and UAL 869 had qualified aircraft and flight crews
- Expanded to encompass entire ZOA FIR December 2011



- **Op Eval will take place for at least a two year period**

- Data will be collected and analyzed
- Data used to validate safety assumptions and will gather data on operational performance and economic benefits

Stakeholders who Needed to Agree

- Air Navigation Service Providers: FAA and Air Services Australia
- Standards organizations: ICAO and RTCA
- Manufacturers: Honeywell
- Airlines: United
- Controllers
- Pilots

Another Example: Performance-Based Navigation

- Researcher – it's a straightforward math model and simulation flights.
- System engineering – it's testing and integrating the math model within complicated software infrastructure.
- Controllers -- it's all about predictability.
 - How do you deal with different performance of different aircraft and equipage in the same airspace. Integration into busy airspace is even harder.
- Airport operator -- it depends on the community view.
 - Particular airports or metroplex areas must be considered to select locations for implementation. Are they highly engaged with the community?
 - How receptive will the community be to the precise tracks which coalesce all the noise in a certain place?
- Flight operators -- it's all about the business case.
 - Does the idea have economic benefit?
 - That case differs for general aviation, business and commercial carriers.
 - The benefit of the procedure is mostly external to the FAA but these operators have different views.

Another Example: Performance-Based Navigation

- In some cases, significant equipage is required to give users the benefits.
 - This leads to the equipage “chicken and egg” problem. When should I equip?
 - Early adopters sometimes don’t get the best return on investments.
- The FAA investment needs a different benefit than the operators.
 - For example, greener skies reduces complexity, hence mistakes or workload for controllers.
- There are also trades to be made.
 - Fewer track miles versus getting from the surface to altitude quicker?
 - System view or certain aircraft view only?
 - So you have to decide "which benefits"?
- Weather is always the wildcard.
- Politics and environment have a role too.

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New Frontiers for Aviation

- UAS challenge the airspace system with new flight paradigms:
 - Small, medium, and large aircraft
 - Varying performance
- Pilot and controller roles must be considered for the widely mixed fleet:
 - Remote pilots and autonomous aircraft
 - Training, qualification, and safety standards



NextGen Then and Now: From VLJ to Quadrocopter



JPDO analyzed whether the NAS was scalable to meet traffic patterns of Very Light Jets (VLJ) such as this Eclipse 500

http://en.wikipedia.org/wiki/Very_light_jet

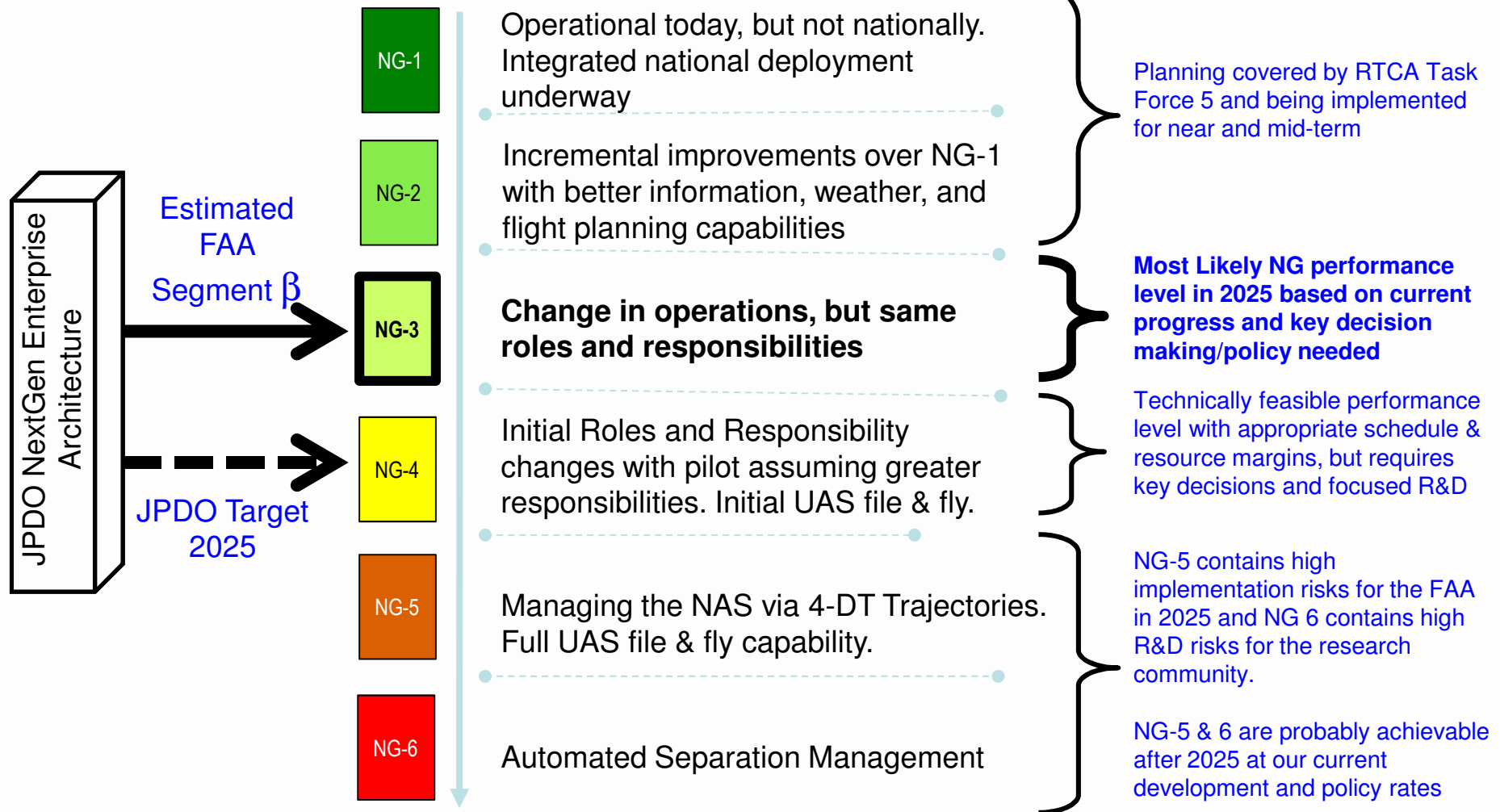


“Flying Robots Deliver Tacos to your Location. Our unmanned delivery agents are fast and work tirelessly.”

<http://www.tacocopter.com>

Executable NextGen Architectures

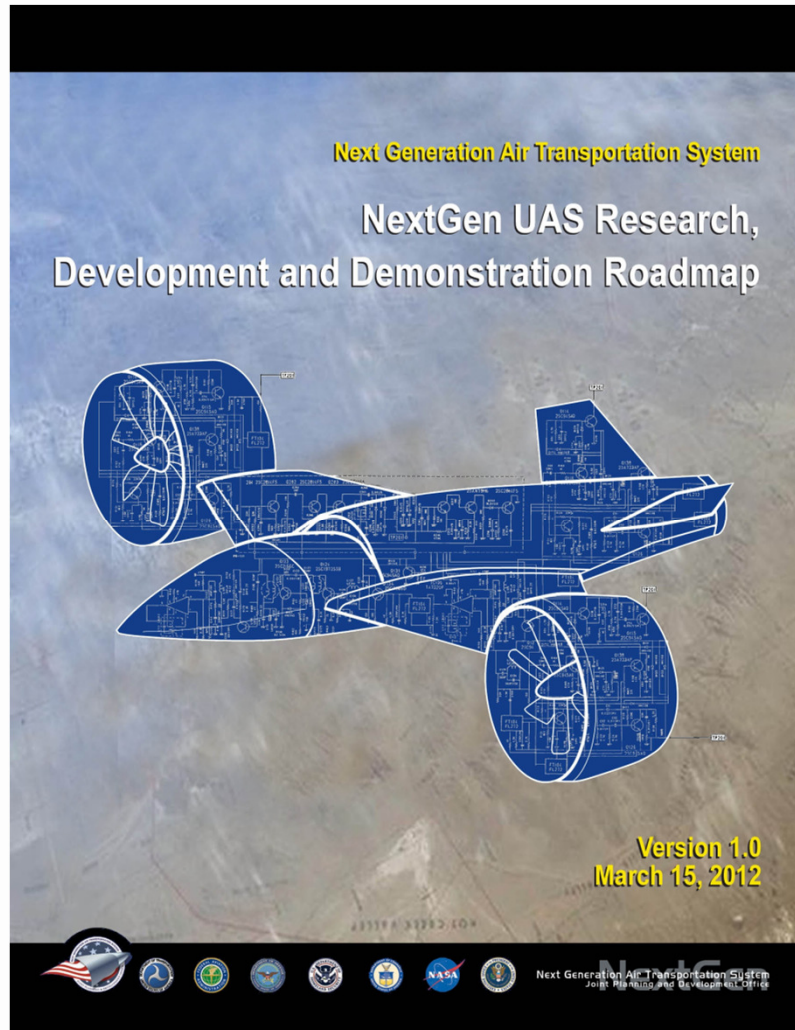
Lowest Performance, Automation & Risk



Highest Performance, Automation & Risk



UAS Research Roadmap



- Technical tracks
 - Communications
 - Airspace operations
 - Unmanned aircraft
 - Human systems integration
- Major challenges
 - Sense and avoid capability
 - Dedicated protected spectrum for control links
 - Unmanned aircraft and cockpit certification standards

Mapped Critical R&D Challenges, Needs & Goals

R&D Challenges	FAA Needs						
	Develop and validate UAS performance requirements for normal and abnormal operations	Resolve UAS and ATC interoperability issues during normal and abnormal operations	Provide robust failure modes and recovery operations	Validate NextGen concepts (e.g., "4D trajectory based") using UAS as testbed	Develop adequate safety case of UAS NAS integration	Develop required policies, standards and certification guidance material	Develop concepts for the wide-spread integration of UAS into the future NAS
3. Unmanned Aircraft							
3.1 State Awareness and Real Time Mission Management	X	X	X		X	X	
3.2 Airframe Certification			X		X	X	
3.3 Precise Location and Navigation	X				X		
3.4 UAS Avionics and Control Systems Certification	X		X		X	X	
4. Human Systems Integration							
4.1 Display of Traffic/Airspace Information	X			X	X	X	X
4.2 Effective Human-Automation Interaction	X	X	X	X	X	X	X
4.3 Pilot-Centric GCS	X			X	X	X	X
4.4 Definition of Roles and Responsibilities	X	X			X		X
4.5 Predictability and Contingency Management	X	X	X		X		
4.6 System-Level Issues		X			X		X
4.7 NextGen Airspace Users and Providers – Qualification and Training					X	X	
4.8 Support for Future/Enhance Capability of UAS					X		X

CHALLENGES	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2025	2030
3. Unmanned Aircraft												
3.1 State Awareness and Real-Time Mission Management				Δ Goal 1						Δ Goal 2		
3.2 Airframe Certification										Δ Goals 1 & 2		Δ Goal 3
3.3 Precise Location and Navigation										TBD		
3.4 UAS Avionics and Control Systems Certification								Δ Goal 1			Δ Goal 2	Δ Goal 3
4. Human Systems Integration												
4.1 Display of Traffic/Airspace Information								Δ Goal 1				
4.2 Effective Human-Automation Interaction				Δ Goal 1				Δ Goal 2				
4.3 Pilot-Centric GCS								Δ Goal 1				
4.4 Definition of Roles and Responsibilities								Δ Goal 1				
4.5 Predictability and Contingency Management								Δ Goal 1				
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4.8 Support for Future/Enhance Capability of UAS				Δ Goal 1								

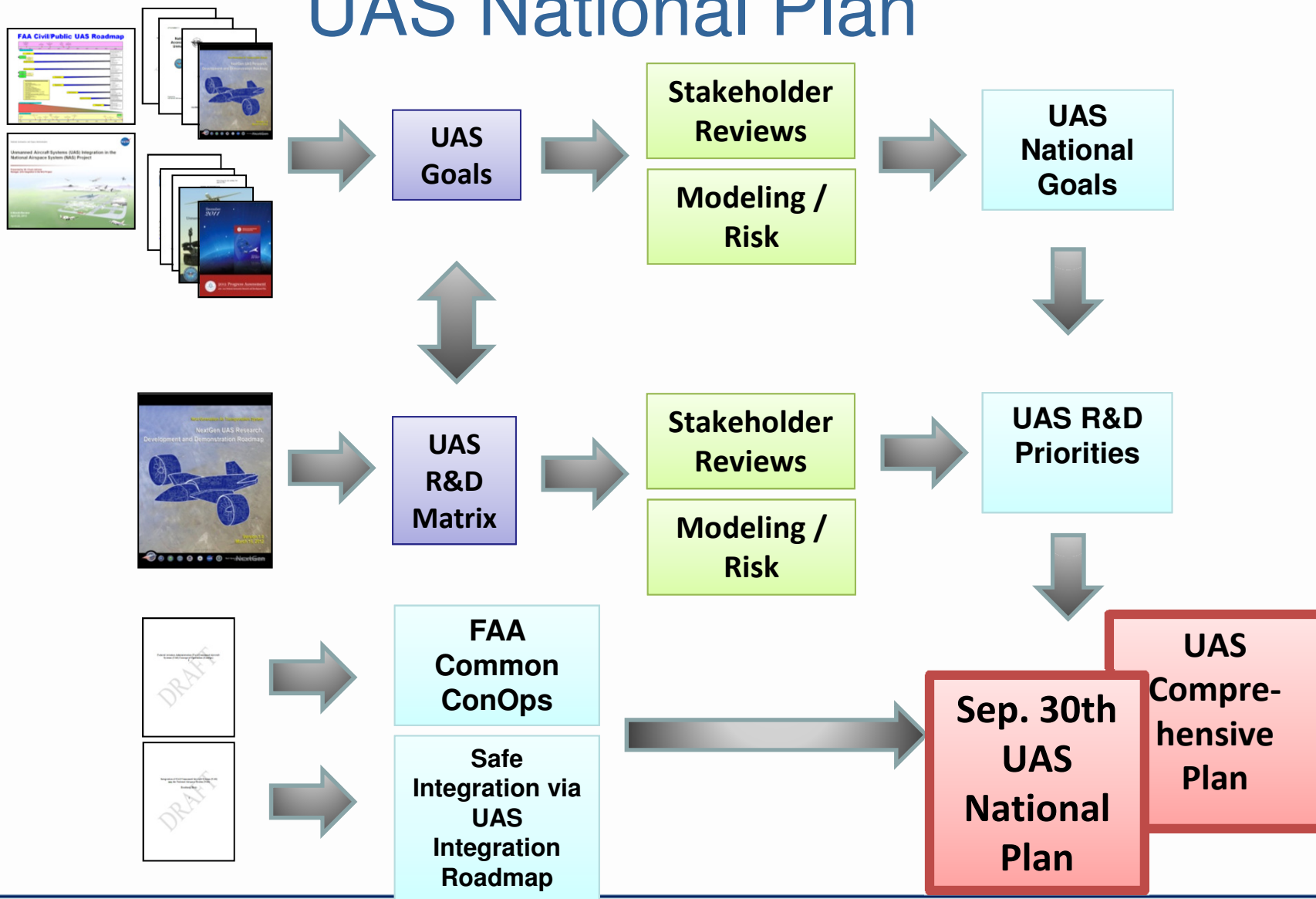
CHALLENGES	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2025	2030
1. Communications												
1.1 Impact of UAS Operations on NAS Communication Systems		Δ Goal 1 TBD				Δ Goal 2 TBD						
1.2 Ensure Availability of UAS Control Frequency Spectrum		Δ Goal 1 TBD				Δ Goal 2 TBD						
1.3 Develop and Validate UAS Control Communication System Performance Requirements				Δ Goals 1 & 2 TBD		Δ Goal 2 TBD						
1.4 Ensure Security of Safety Critical Communications with UAS		Δ Goal 1 TBD			Δ Goal 2 TBD							
1.5 Design and Develop UAS Control Datalink for Allocated UAS Frequency Spectrum Bands												
2. Airspace Operations												
2.1 Develop Integrated Separation Concepts		Δ Goals 1 & 2			Δ Goal 3							
2.2 Develop Airspace Integration Safety Case/Assessment		Δ Goals 1 & 2		Δ Goal 3 (2014+)								
2.3 Develop Sense and Avoid (SAA) Sensors and Fusion	Δ Goal 1	Δ Goal 2	Δ Goal 2									
2.4 Develop Separation Algorithms	Δ Goal 1	Δ Goal 2			Δ Goal 3							
2.5 Assess Availability/Quality of Surveillance Data		Δ Goals 1 & 2			Δ Goal 3			Δ Goal 4				
2.6 Develop Safe and Efficient Terminal Airspace/Surface Operations		Δ Goal 1		Δ Goal 2				Δ Goal 3				

- Critical R&D Challenges mapped to FAA needs
- Planned UAS R&D coverage assessment for NAS integration goals
 - Human Systems Integration and Unmanned Aircraft need better coverage

Assessment of Level of Coverage Key:	
Coverage to be determined (TBD)	TBD
Strong or sufficient coverage	
Fair coverage	
Poor coverage or partial coverage	

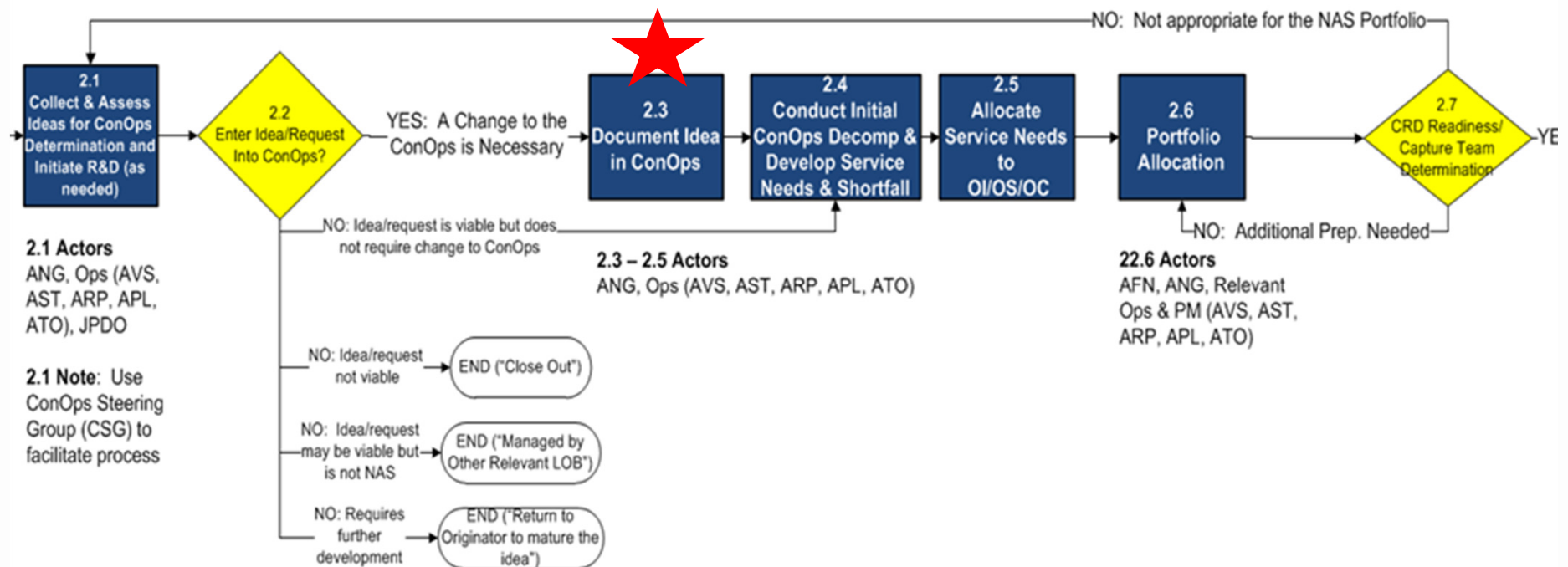


UAS National Plan



Next Steps: Idea to In-Service Implementation (i2i) Process

Some UAS capabilities are in early stages of FAA's i2i process that manages solution trades for the NextGen portfolio in the most cost effective way



Stakeholders for UAS Integration

What might be the issues that stakeholders will consider for UAS integration?

- Researchers?
- FAA?
- Standards Organizations?
- Air Traffic Control?
- Manufacturers?
- Airlines or General Aviation?
- Others?

UAS Stakeholders

A high-level view of UAS Stakeholders and their associated roles/functions, which are categorized by the seven bins listed in the Key

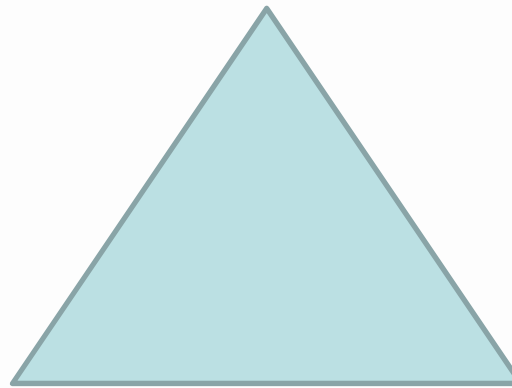


- ◇ — Policy/Regulatory
- ★ — Research and Development
- △ — Operators
- ◻ — Operations
- ➡ — Strategic
- — NAS Community & Public Advocacy
- ✚ — Manufacturers

Balancing Competing Factors

Safe Integration

*...new airframe certification...flight
prioritization...pilot certification...lost
link...autonomy...lower cost operations...*



Security

*...policy to protect against
intentional or unintentional
disruptions...cybersecurity...*

Privacy

*...the public perception (often
not fact based)...“prying eyes” of
UAS...local and Federal law...*

Summary

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