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STEVENS INSTITUTE of TECHNOLOGY THE INNOVATION UNIVERSITY

Stevens Institute of Technology
&
Systems Engineering Research Center (SERC)

Modeling and Analysis Framework for Risk-Informed Decision Making for FAA NextGen

Presented to: INCOSE 2013

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Outline

- Part 1:
  - —What is the Federal Aviation Administration's (FAA) NextGen
  - —Who are the stakeholders?
- Part 2: Problem
  - —Using FAA NextGen System of Systems (SoS) Terminology
- Part 3: Objective, approach, & expected analysis outputs
- Part 4: Sample results
- Conclusions
- Acknowledgment

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Risk-Informed Decision-Making: Leveraging What People Know in Changing Contexts

- Improving **collaboration** across SoS and disciplines
  - —NextGen is a complex SoS and rolling out capabilities is challenging due to:
    - Many factors
    - Complex interdependencies
    - Diverse set of stakeholders
- Developing a modeling and analysis framework to enable a **probabilistic process for risk-informed decision-making**
  - —Helps stakeholders understand cost, schedule, benefits, and risk tradeoffs
  - —Approach improves the accuracy of schedule and cost predictions
- Bayesian networks combine quantitative with qualitative expert judgment to capture and leverage causal relationships about **"Peoples' internal knowledge that is not captured externally or formally"**

Part 1:

What is NextGen and who are the Stakeholders?

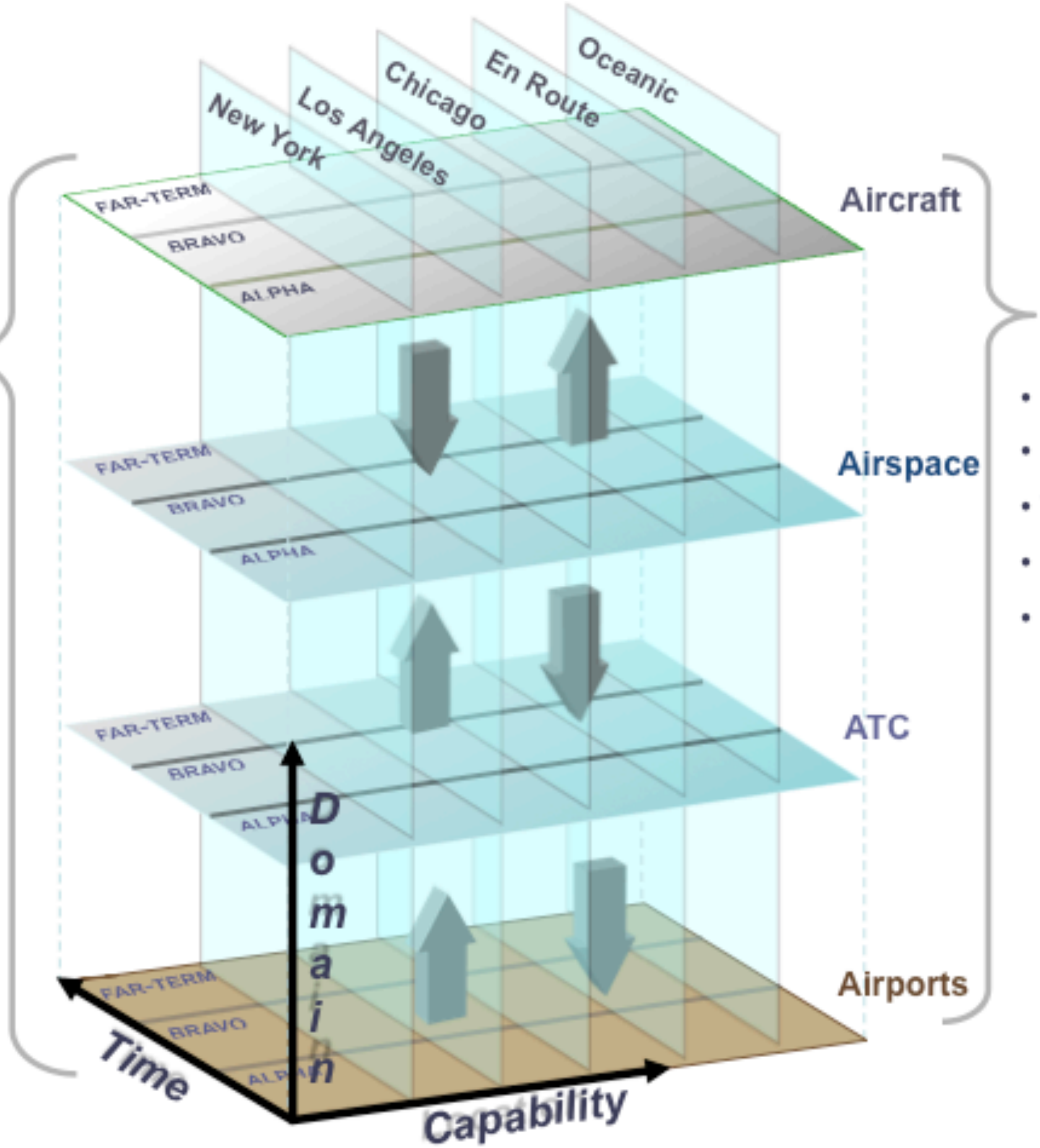
What is the FAA NextGen?

Image credit: NextGen Far-Term (2025), To-Be Enterprise-Level Architecture High-level Operational Concept Graphic (OV-1) Version 1.0, January 29, 2010

NextGen Vision of Integrated Framework of SoS Operations

Cross-Cutting Factors

- Environmental
- Safety
- Information Security
- Economic
- International
- Regulation



Enablers

- People
- Procedures
- Technology
- Data/Information
- Policy

Image credit: Ron Stroup,
Chief Systems Engineer for Air-Ground Integration

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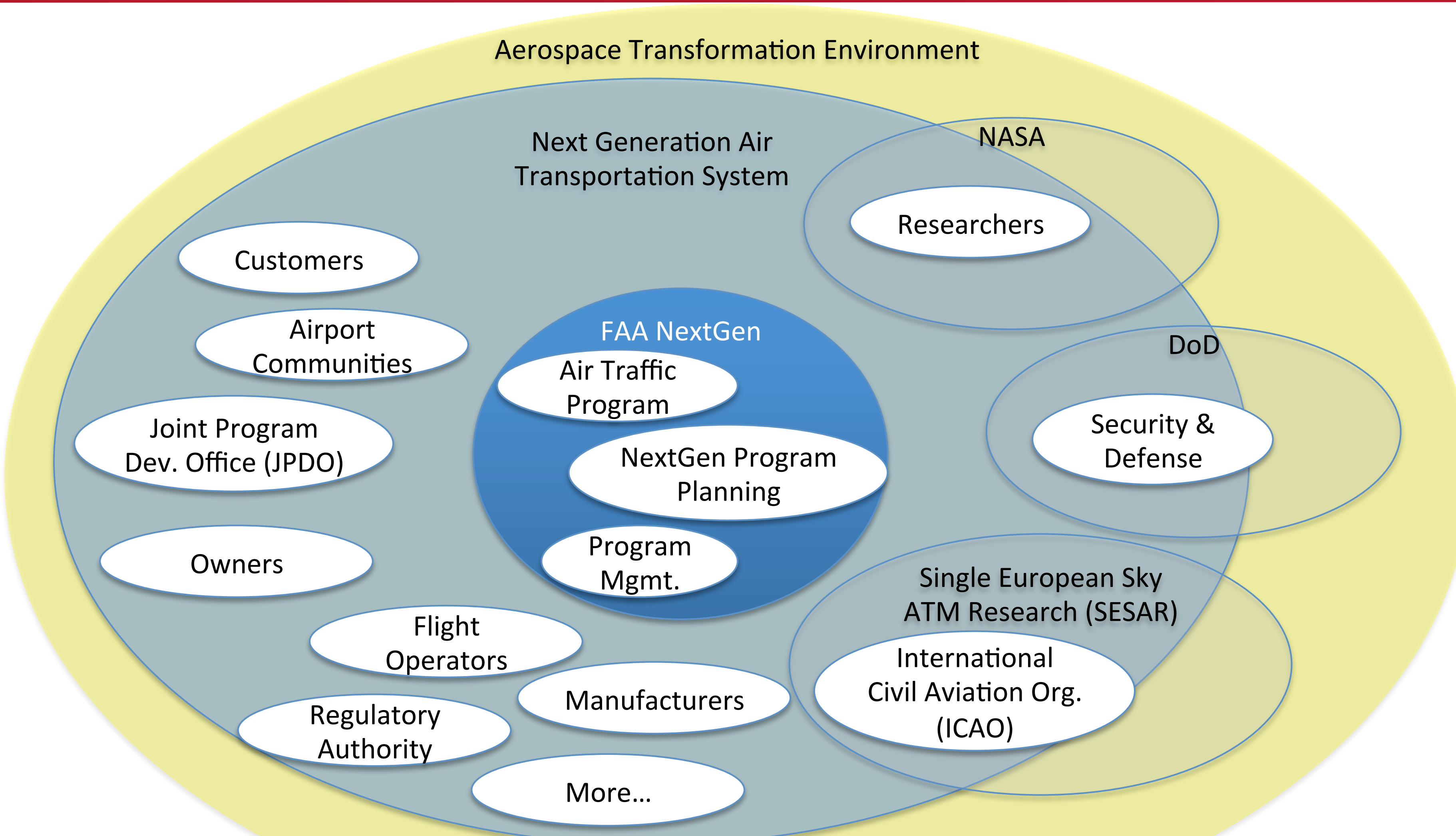
NextGen Has a Diverse Set of Stakeholders that Contribute to and Impact Decisions



"Wicked" problems are **bewilderingly complex and have far-reaching implications for large numbers of very different stakeholder groups, each with competing interests**. [Rittel 1972]

Inspired by: Assessment Of The Faa Nextgen Acquisition Process & Development Of A Progress Metric Framework For Portfolio Management, Patrice Kone, 2012

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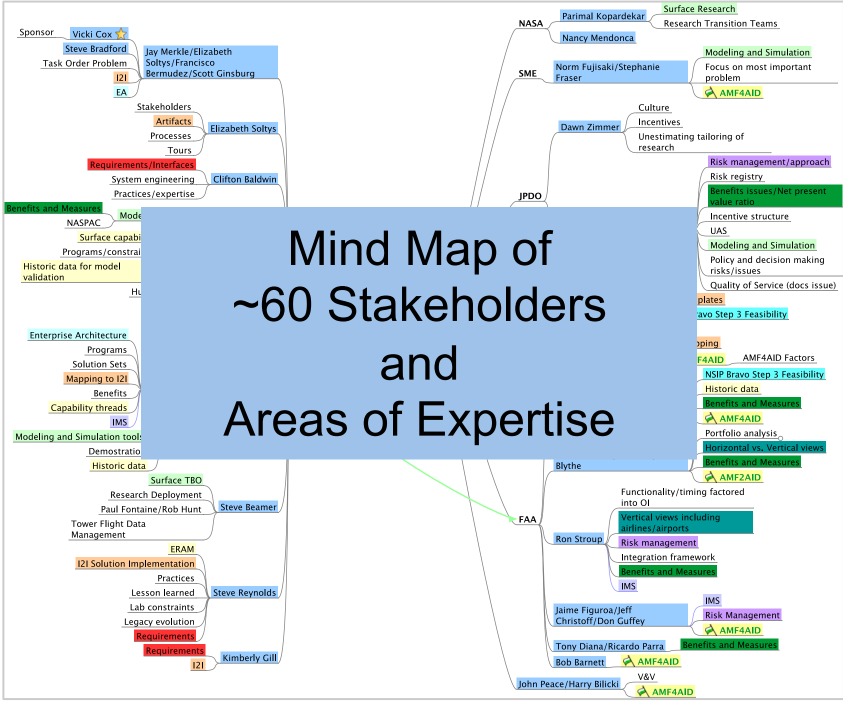
We Talked to Many Stakeholders about Various Aspects of the System of System (SoS)

- We started with FAA's Assistant Administrator for NextGen, Vicki Cox (our research sponsor)
- After talking with more than 60 success-critical stakeholders, who were very open about the challenges, we found out that:
  - —All component dependencies are not systematically identified
  - —All interface dependencies are not formally tracked (e.g., using databases)
  - —Tradeoff impacts difficult to assess
  - —People can only roughly estimate impact of interdependencies between component functionality
  - —Difficulty continually challenges those responsible for planning, developing, and deploying capabilities



Part 2:

Problem statement using FAA NextGen SoS Terminology

FAA NextGen Rolls Out Capabilities to SoS

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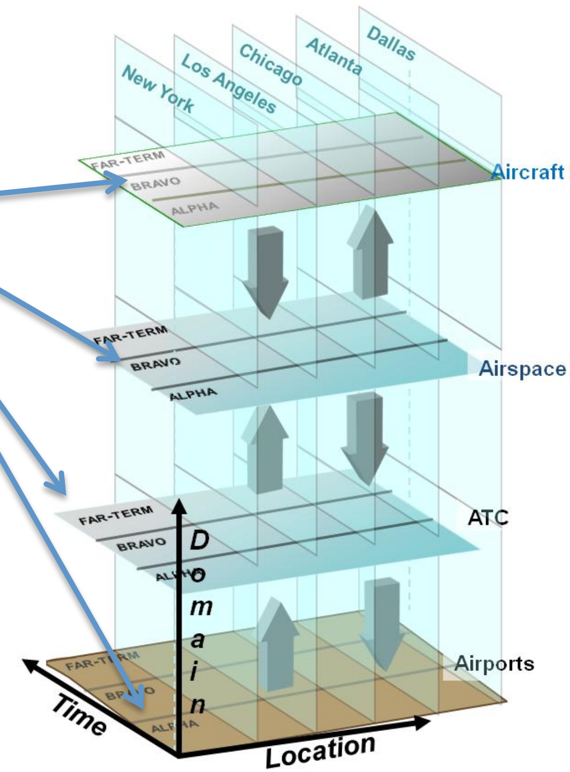
- Capabilities cut across programs, domains, and time

Solution Sets
Trajectory Based Operations (TBO)
High Density Arrivals/Departures (HD)
Flexible Terminals and Airports (FLEX)
Collaborative ATM (CATM)
Reduce Weather Impact (RWI)
System Network Facilities (FAC)
Safety, Security and Environment (SSE)

Capabilities

Transformational Programs
Automatic Dependent Surveillance Broadcast (ADS-B)
System Wide Information Management (SWIM)
Data Communications
NextGen Network Enabled Weather (NNEW)
NAS Voice Switch (NVS)
Collaborative Air Traffic Management Technologies (CATM-T)



Example Capability Mapping to Programs and Decision Points

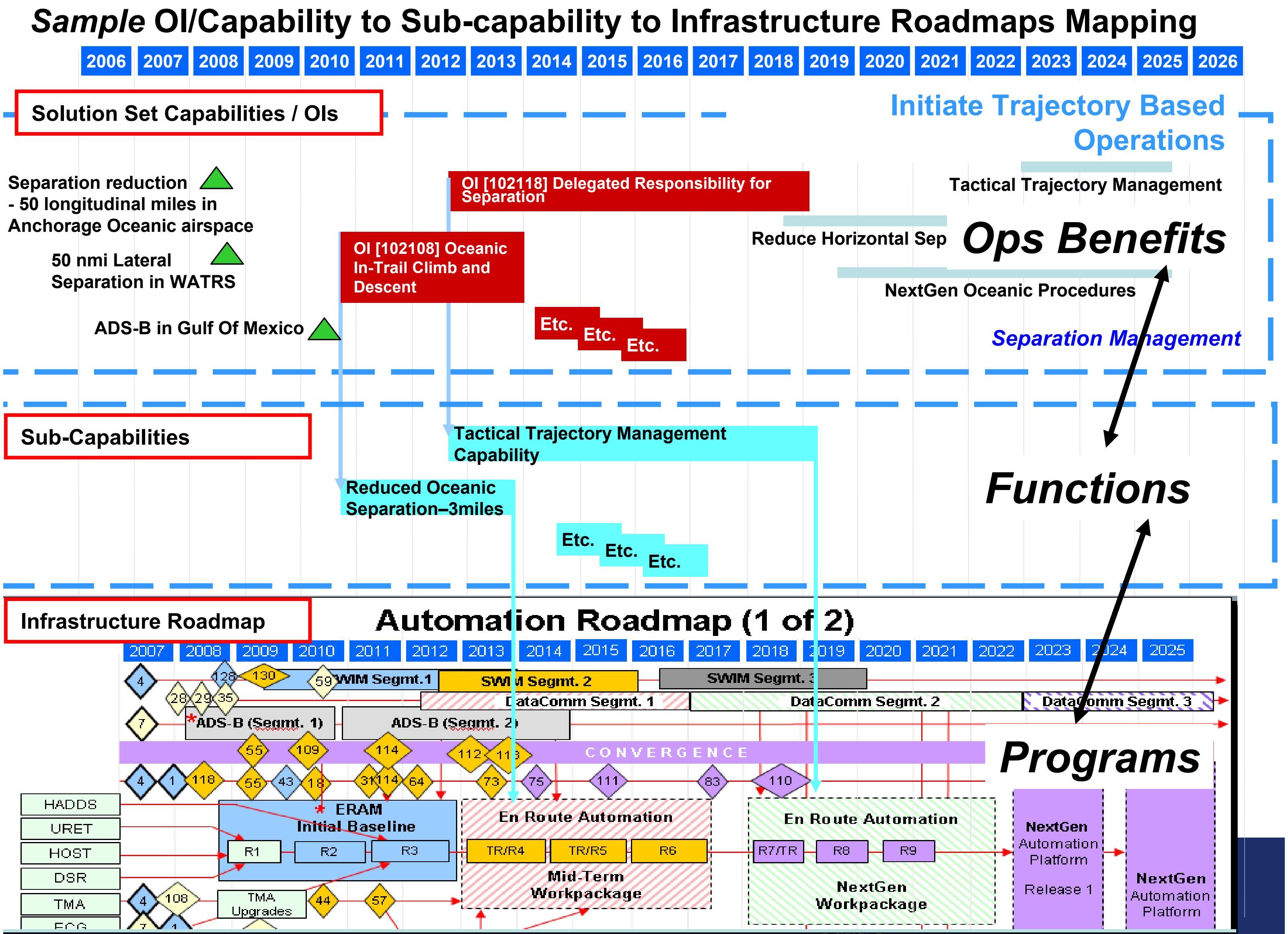
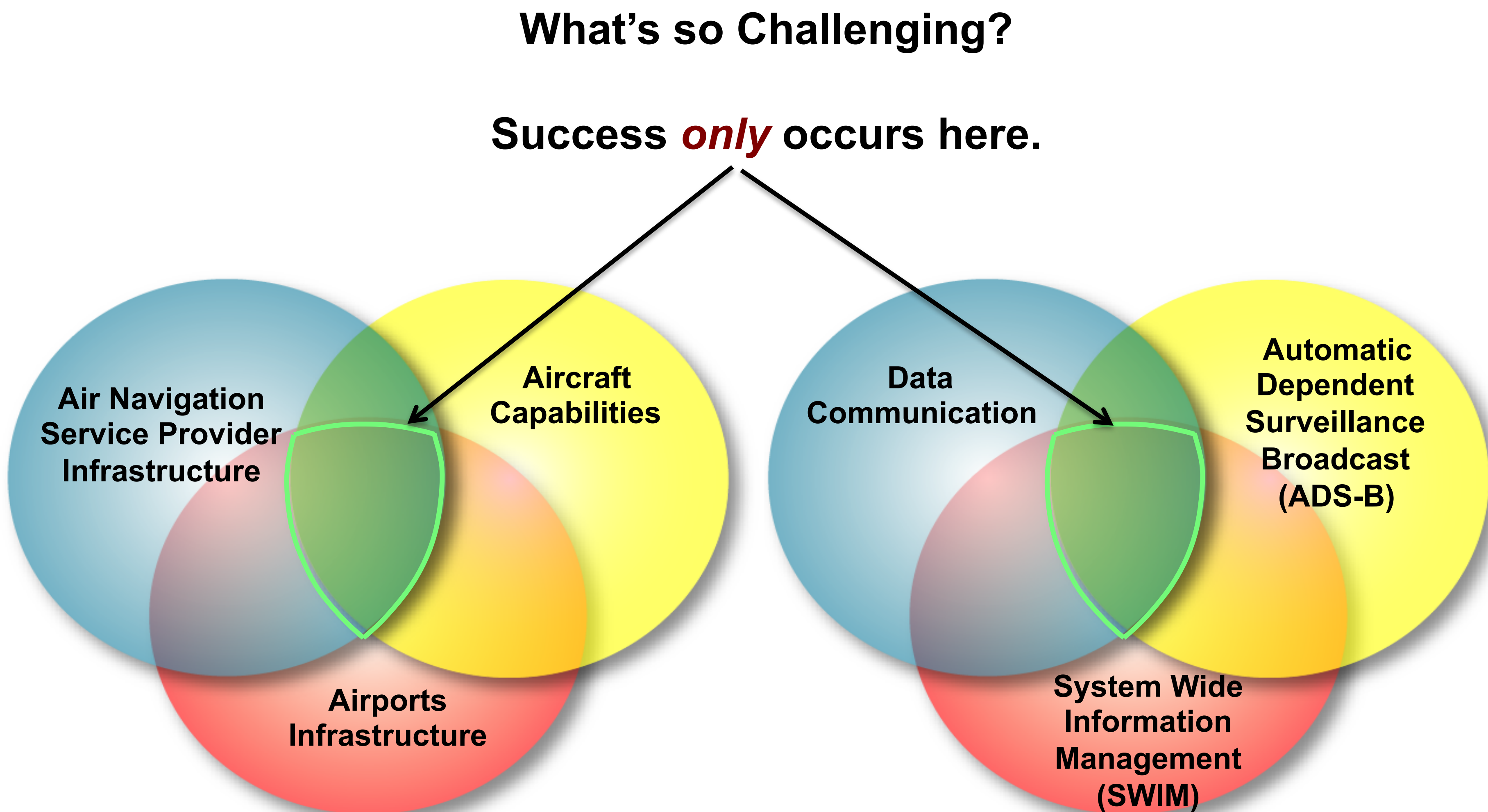


Image credit: FAA NAS Enterprise Architecture Federal Aviation Administration, Jesse Wijntjes / NAS Chief Architect April 28, 2010

To Realize Benefits the Transformation Requires Integration Across Domains



Example of Program Dependencies for Capability

Inspired by Ron Stroup,
Chief Systems Engineer for Air-Ground Integration

Part 3:

Objective,
Approach,
Expected Analysis Outputs
&
Analysis and Modeling Framework

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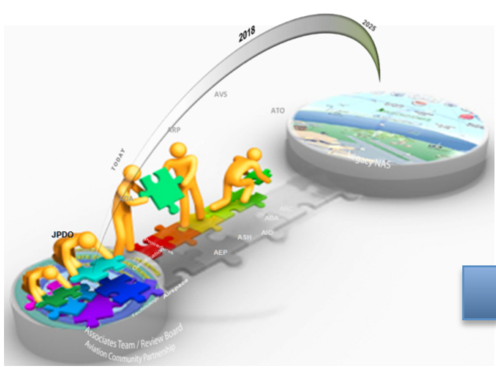
Objective Statement from Kickoff Meeting

- **Develop a modeling and analysis framework** to enable a **process for managing decision-making** that occurs when capabilities must be integrated, deployed and acquired asynchronously
  - —Analysis and Modeling Framework for Asynchronous Integration and Deployment (AMF4AID)
  - —**Predictive Model for Estimating Cost, Schedule, Benefits, with Visualizations of Probabilistic Risk to aid in decision making**



Which capability?

Modeling Framework for Decision Making at Enterprise Levels

Quantitative | Qualitative | Hybrid

- **Cost, Schedule, & Benefit predictions**
- **Risk calculations**
- **Factor impacts on practices**
- **Support FAA Acquisition Management System (AMS)**

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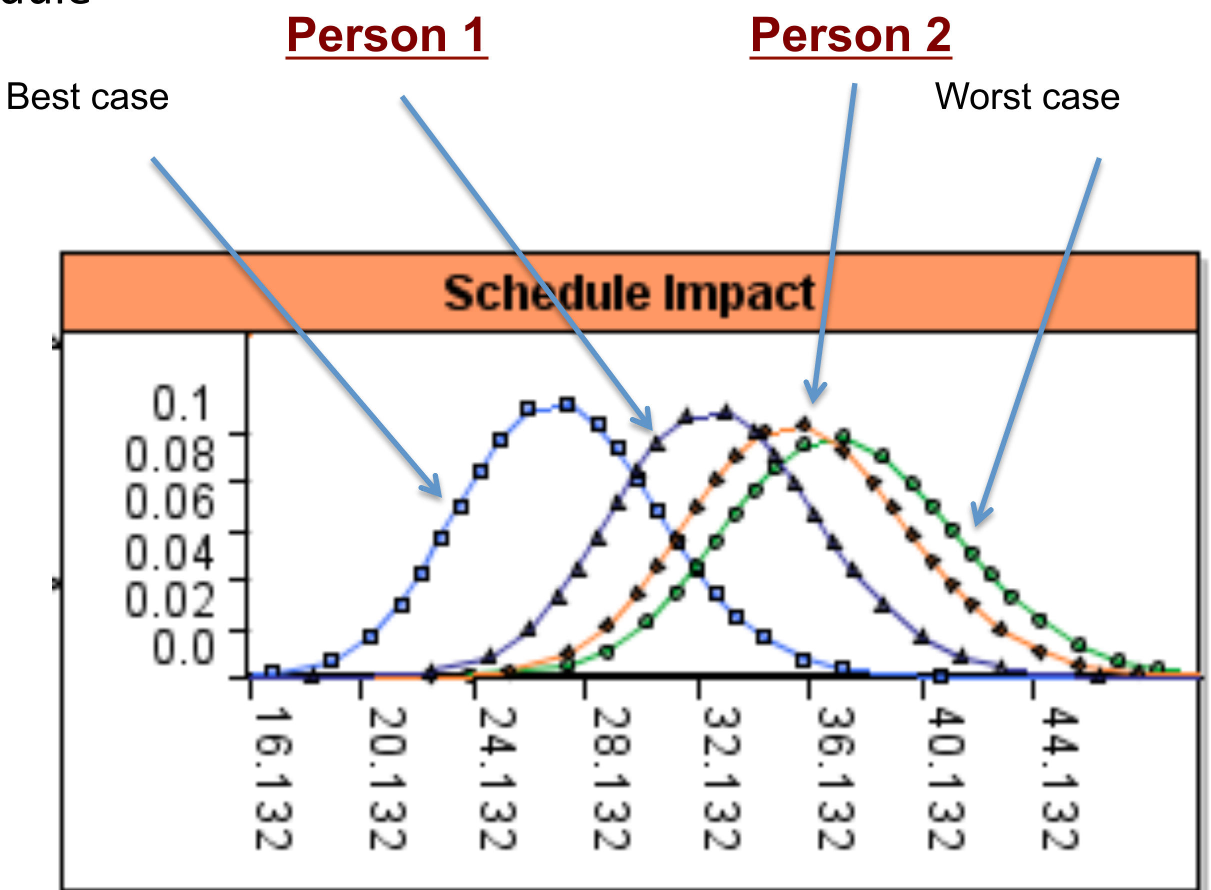
FAA Problem Statement Summary

- NextGen is being implemented through a time-phased series of Operational Improvements (OI), each of which is broken down into a series of OI Increments (aka Functions)
- Acquisition of each Function is defined in a "scenario" that has a predicted cost, schedule, benefit, and risk
- In practice, scenarios don't play out as originally planned
  - E.g., technologies mature more slowly than expected
- Scenarios often have multiple dependencies
  - It is often difficult to understand the relationships between scenarios
  - Even more difficult to understand implications of changing one or more scenarios
- This research will develop a model that helps decision makers better understand the relationships between scenarios and to better predict the effect of changing them
  - This should aid in their selection of the best series of scenarios to implement capabilities

Framework Predicts Risk using Bayesian Networks That Combine Quantitative and Qualitative Data

- Tooling for framework provides probabilistic representation of cost, schedule and benefit risks that enable stakeholders to make better decisions
  - Use as a collaboration tool to discuss different beliefs on risks related to cost or schedule



Part 4:

Sample Results

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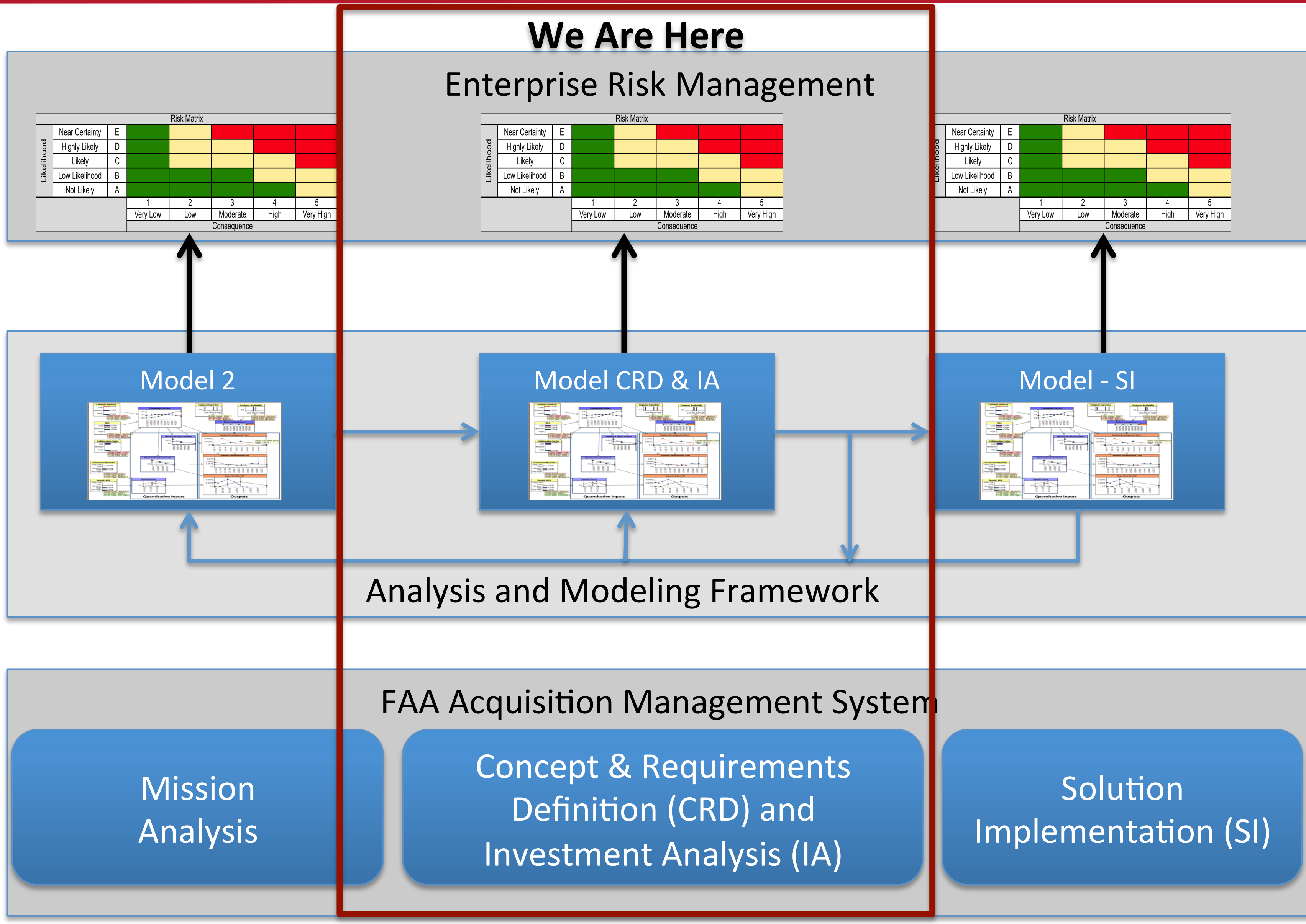
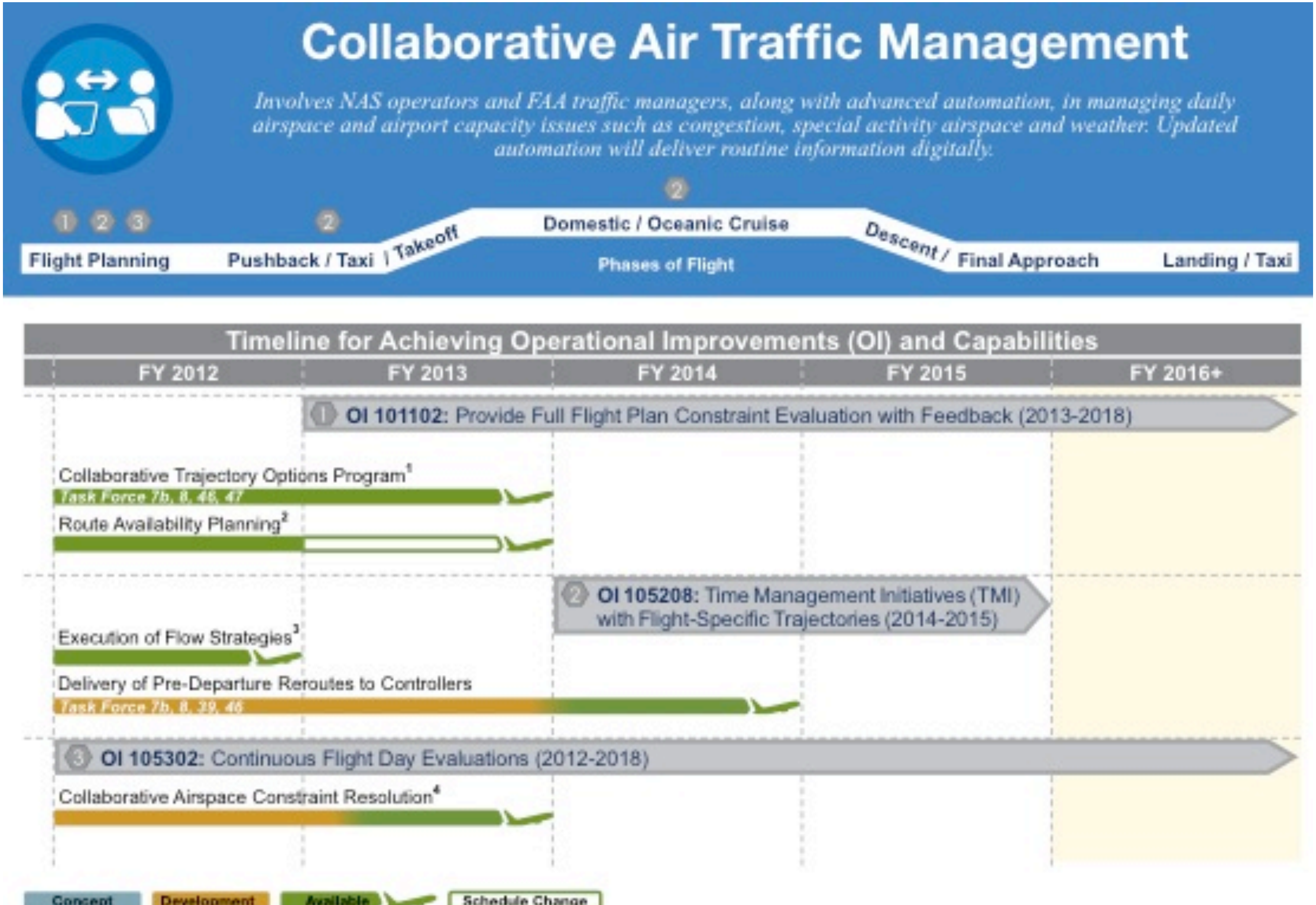
Model Aligns Primarily with CRD and Investment Analysis Aspects of AMS



Example From NextGen Implementation Plan



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Use Pull Down Menu to Select Value (Low, Med, High) that is most applicable

- Quantitative data not shown here or needed to assign factor values
- What point in time – before FID (IARD, IIA)?

Factors (by Category)

			Candiate Factors																					
Operational Improvement and Increments for Portfolios		Dependencies	Requirement goodness				Dependency criteria			Interface impact			Operational Readiness			Risk Impact			Emergence impacts			Technical Logistical Readiness		
	Starting Point Timeframe		Requirement maturity and stability	Sequence Diagram Completeness	Function Rqmts Completeness	Operational Rqmts Completeness	Interdependencies	Legacy Dependencies	Integration Impact	Asynchronicity	Interface Complexity	Number Of Interfaces	Training Impacts	Policy Impacts	Standards Impacts	Safety Security Risk	Supportability Risk	Concept Maturity Risk	Technology Readiness Risk	Political Readiness	Research Completeness	Airline Readiness	Airport Readiness	Implementation Readiness
Collaborative Air Traffic Management Portfolio (DP 19 WP2, 199 - WP3)	Pick																							
Traffic Management Initiatives with Flight-Specific Trajectories (105208)																								
105208-11 Execution of Flow Strategies		4	Med	w	Med	Low	Med	Low	Low	Med	Low	Low	High	Med	High	Med	Med	Med	Med	Med	Low	Low	Low	Low
105208-12 Delivery of Pre-Departure Reroutes to Controllers		4	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick
Continuous Flight Day Evaluation (105302)		0																						
105302-12 Enhanced Congestion Prediction		2	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick
105302-11 Collaborative Airspace Constraint Resolution (CACR)		3					Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick
Provide Full Flight Plan Constraint Evaluation with Feedback (101102)		0																						
101102-11 Collaborative Trajectory Options Program (CTOP)		5	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick
101102-12 Route Availability Planning		2	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick
Improved Surface Operations Portfolio	Pick	0																						
Provide Full Surface Situation Information (102406)		0																						
102406-11 Situational Awareness and Alerting of Ground Vehicles		4	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick	Pick

Rank Factor (3)
Pick
Low
✓ Med
High

Operational Improvement Increment (OII)

Menu for selecting factors value (L, M, H)

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Collection Spreadsheet has Factor Guidelines on Factors-Meaning Definition Worksheet

Factor Category	Factors	General: These factors should apply to most Operational Improvements that are Pre-implementation.	Ranking Levels
Requirement goodness	Requirement maturity and stability	- If there is near 90-95% confidence that the requirements are unlikely to change and that they are well defined and understood by the stakeholders (developer, PM, operators), then High (H), - if there is some possibility that they will change then Medium (M), - otherwise Low (L).	H - Best M - Medium L - Worst (negative impact)
	Sequence Diagram Completeness	The I2I process and EA require Sequence Diagrams to be used to characterize operational interactions and requirements. - If there is near 90-95% confidence that the Sequence Diagram are unlikely to change and that they are well defined and understood by the stakeholders (developer, PM, operators), then High (H), - if there is some possibility that they will change then Medium (M), - otherwise Low (L).	H - Best M - Medium L - Worst (negative impact)
	Function Rqmts Completeness	- If there is near 90-95% confidence that the Functional Requirements are unlikely to change and that they are well defined and understood by the stakeholders (developer, PM, operators), then High (H), - if there is some possibility that they will change then Medium (M), - otherwise Low (L).	H - Best M - Medium L - Worst (negative impact)
	Operational Rqmts Completeness	- If there is near 90-95% confidence that the Functional Requirements are unlikely to change and that they are well defined and understood by the stakeholders (developer, PM, operators), then High (H), - if there is some possibility that they will change then Medium (M), - otherwise Low (L). If Sequence Diagrams are used and they are complete, it is likely that the Operational Requirements will align with the same factor rating.	H - Best M - Medium L - Worst (negative impact)
Dependency criteria	Interdependencies	- If there are a large number of interdependencies (for example as reflected in the Increment-to-System Mapping sections of NSIP 5.0), - if there are a lot of internal system interdependencies, then High (H), - if the capability has only a few interdependencies the Low (L), - otherwise Medium (M).	L - Best M - Medium H - Worst (negative impact)
	Legacy Dependencies	- If there are a large number (relative, but could be > 3) of Legacy Dependencies (and/legacy components) then High (H), - if the capability has no interdependencies the Low (L), - otherwise Medium (M) If there are Legacy systems for which the new OII is to replace, and the current capabilities of the Legacy system are not well documented (e.g., only know in the code, or if there are a lot of variants that related to different airports), then consider making the rating High (H) or Medium (M), otherwise Low (L).	L - Best M - Medium H - Worst (negative impact)
	Integration Impact	- If the number of dependencies associated with the previous two factors is Low, then most likely Low (L), - if integration across other systems involves other organization, collaboration operators, changes in policies, safety, tools and technology, then High (H), - otherwise Medium (M).	L - Best M - Medium H - Worst (negative impact)

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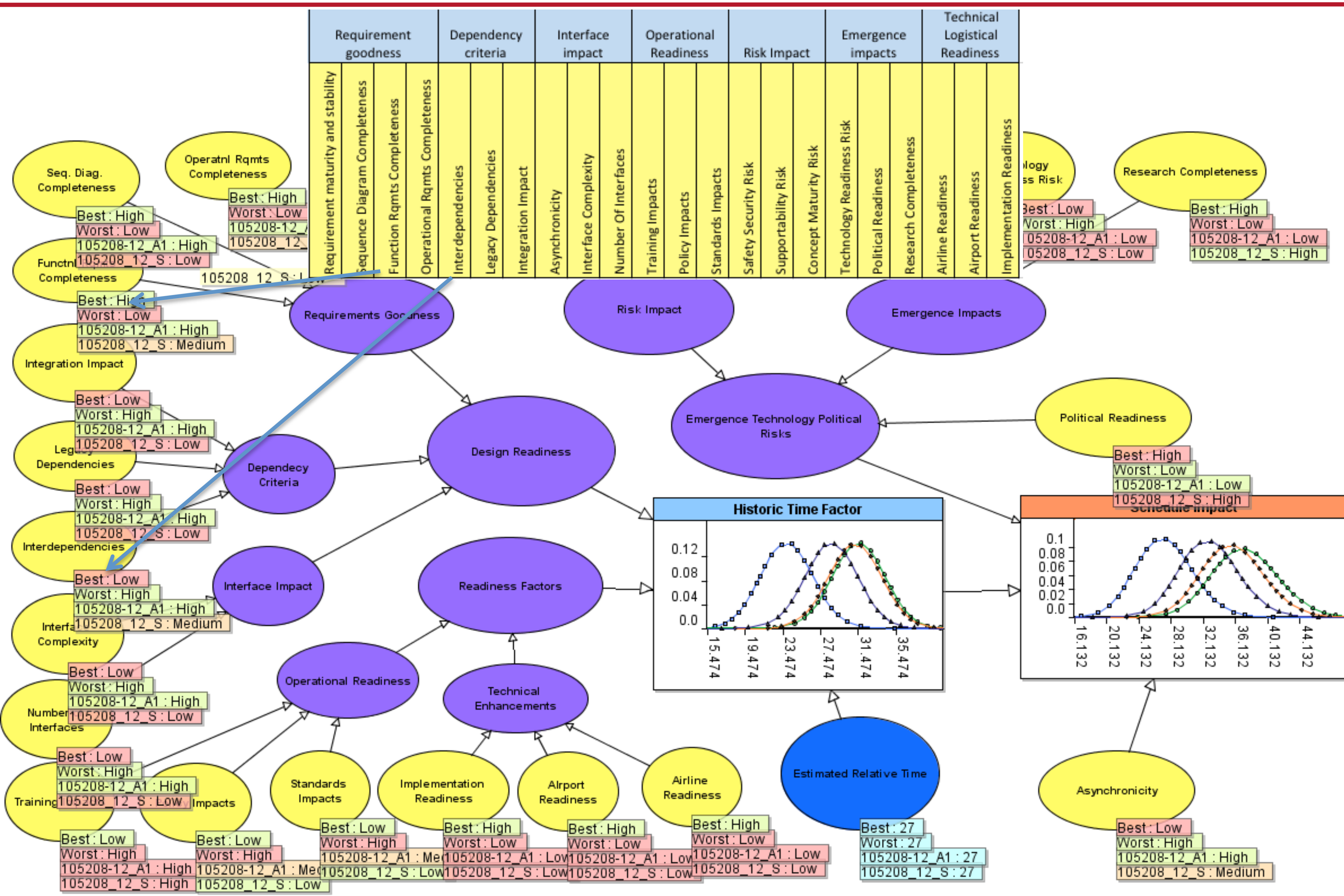
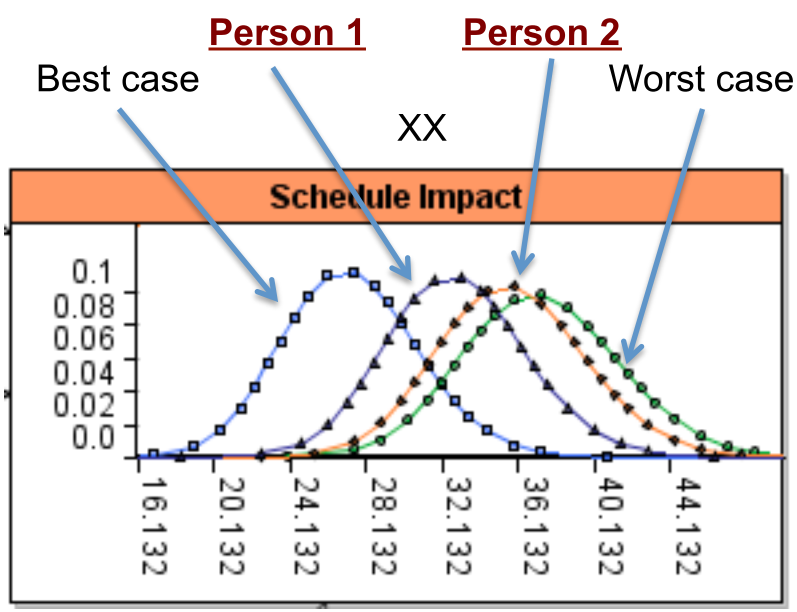
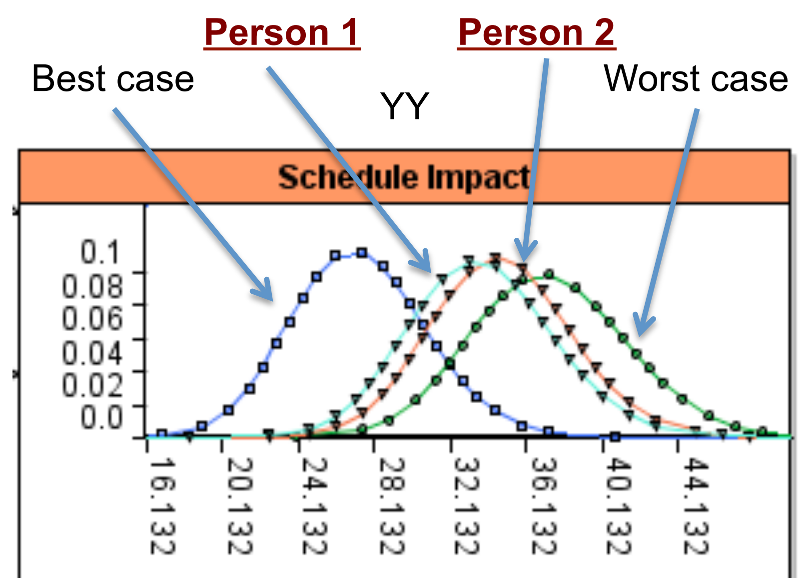
Qualitative Factors Map to Nodes in Model



Collaborative Air Traffic Management Portfolio Example

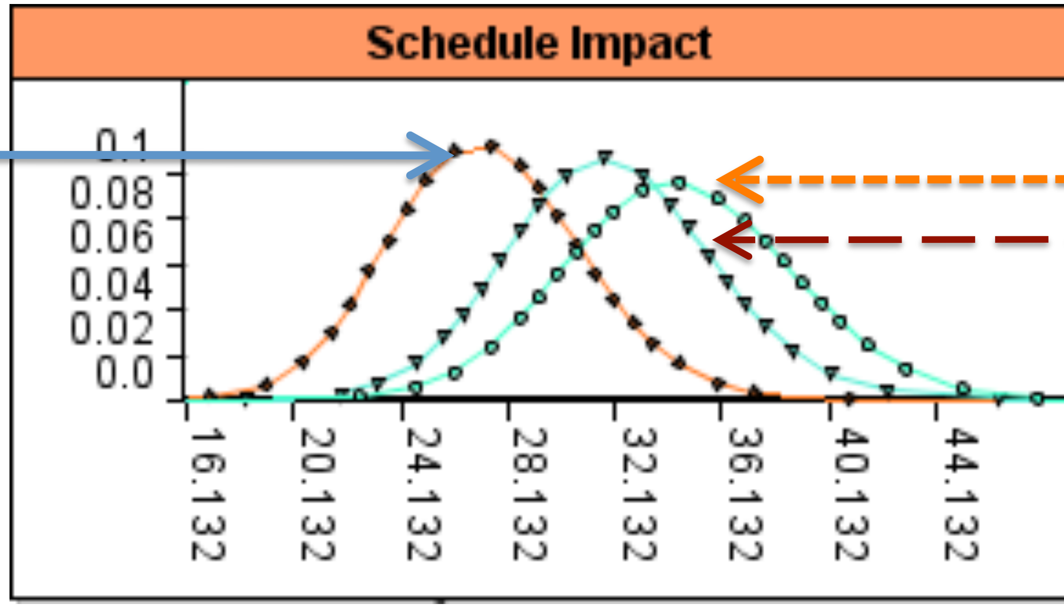
- Two subject matter experts who regularly attend portfolio management reviews provided factor inputs to a number of OIIs
- What does the information show:
  - Difference in beliefs for XX suggest potential schedule difference of more than 3 months
  - Estimate for YY is close – stakeholder beliefs align





Improved Surface Portfolio Example

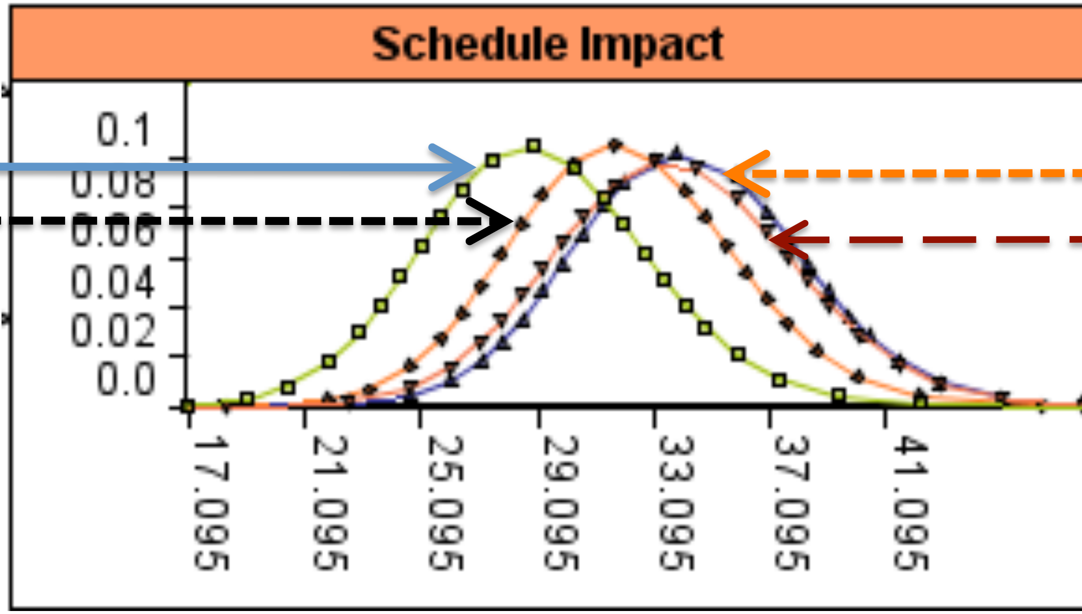
- Three SME inputs illustrate difference in schedule of ~7 months based on different beliefs in factors



Operational Improvement Increments	Mean
Situational Awareness and Alerting of Ground Vehicles	27.4
	32.0
	34.6

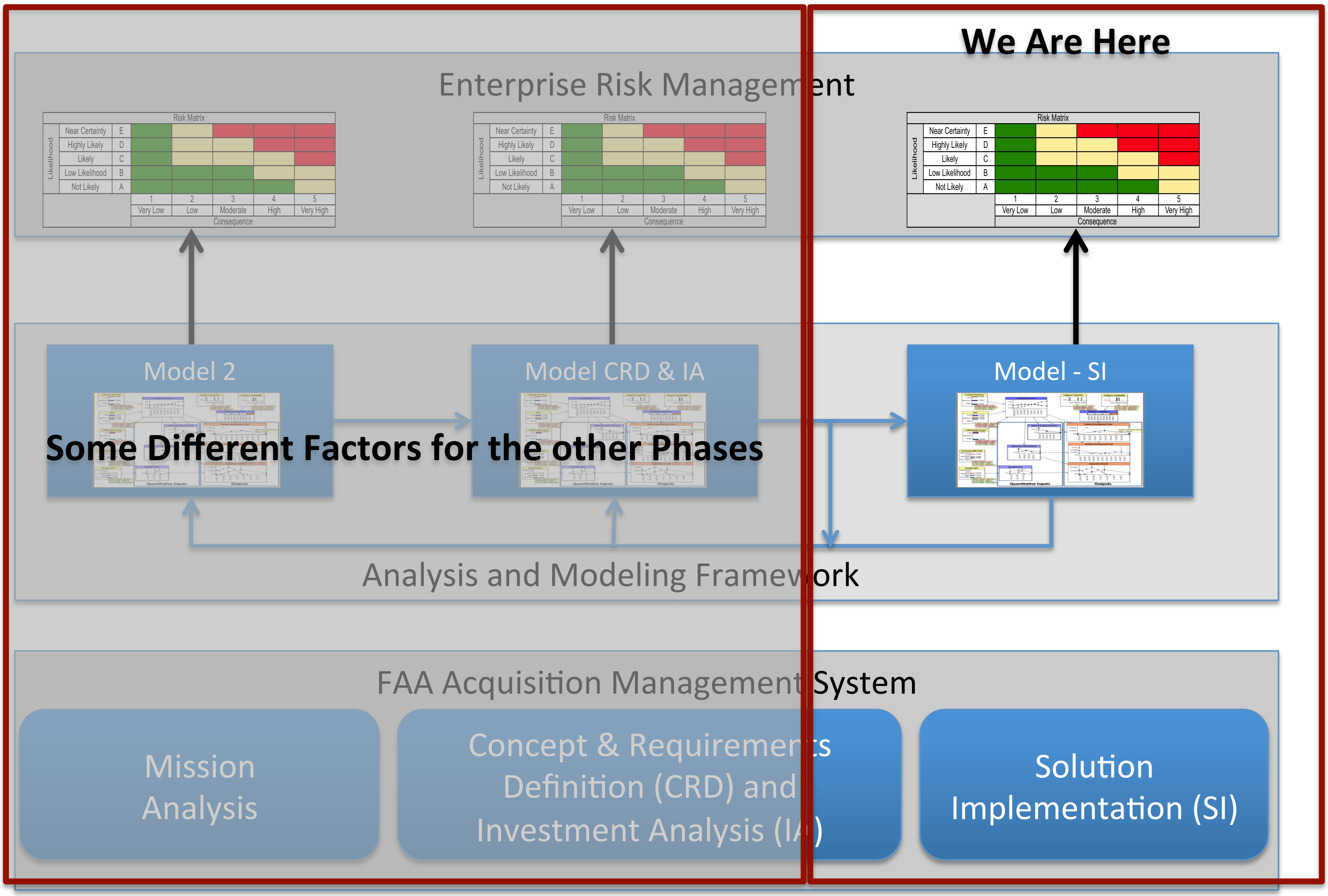
Time-Based Flow Management Portfolio Example

- Maximum difference more than 8 months for Operational Improvement

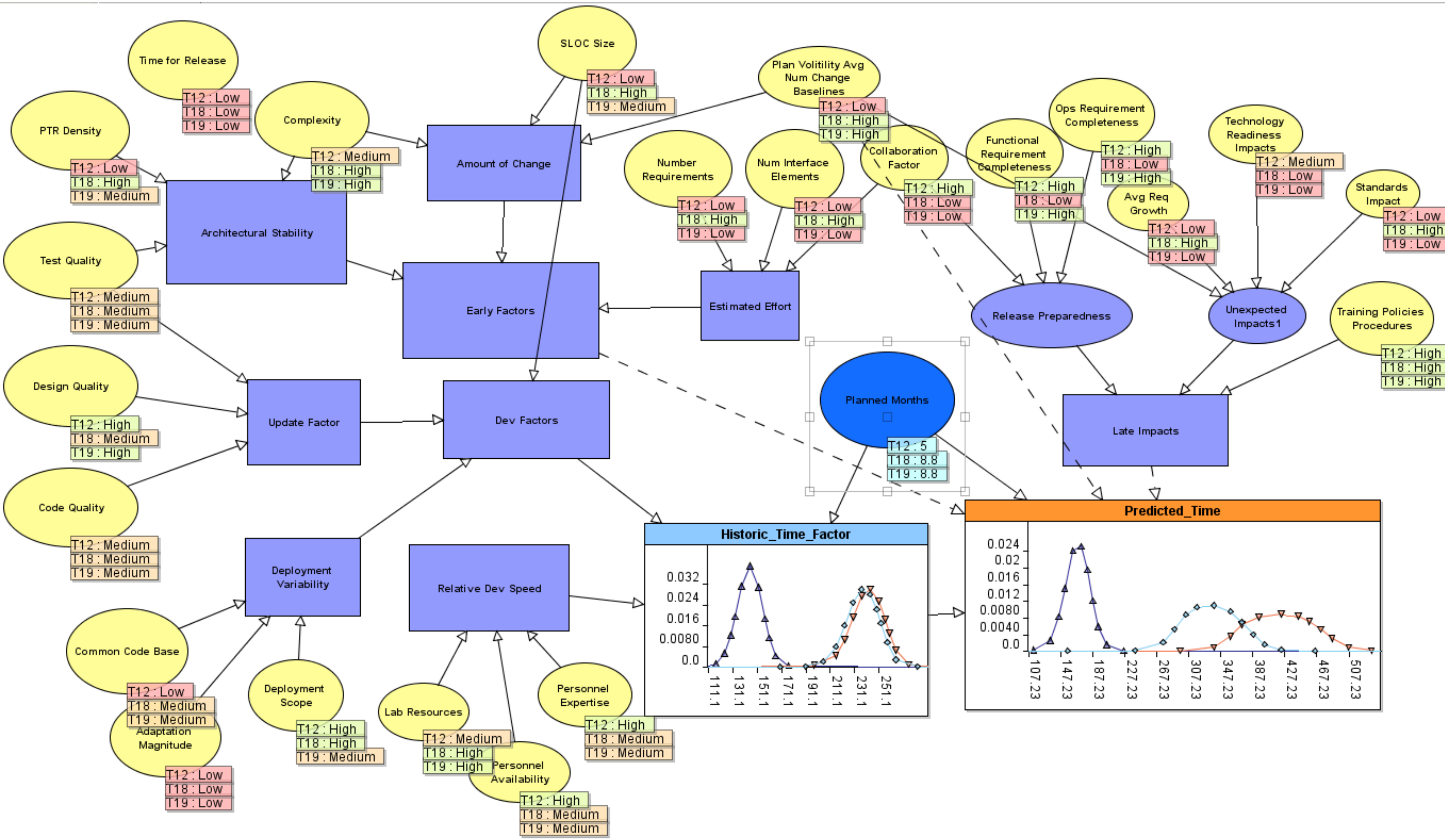


Operational Improvement Increments	Mean
Extended Metering	32.1
Arrival Interval Management Using Ground Automation	25.3
Use RNAV Route Data to Calculate Trajectories Used to Conduct TBM Operations	33.9
Integrated Departure/Arrival Capability	34.1

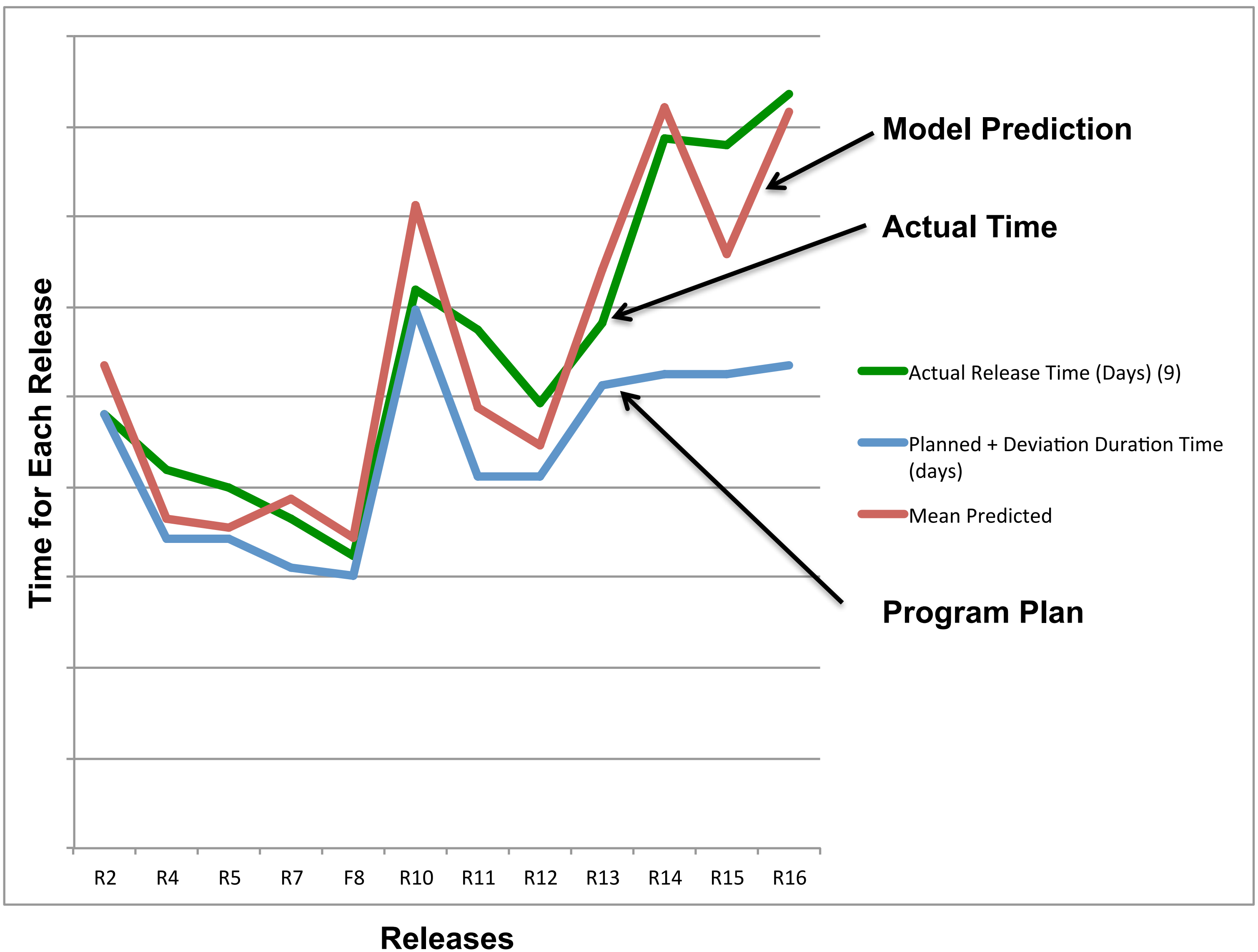
Model Aligns Primarily with CRD and Investment Analysis Aspects of AMS



Solution Implementation Phase Model



Comparison of Predicted, Actual, and Planned Schedule over Many Releases



Conclusions

- NextGen is a complex System of Systems and rolling out capabilities is challenging due to many factors and complex interdependencies and diverse set of stakeholders
- We are developing and refining a modeling and analysis framework to enable a **process for managing decision-making**
- Framework helps stakeholders understand cost, schedule, benefits, and risk tradeoffs
- Approach will improve the accuracy of schedule and cost predictions (and reduce the variance)
- Bayesian networks combine quantitative with qualitative expert judgment to capture and leverage causal relationships about **"Peoples' internal knowledge that is not captured externally or formally"**

Acknowledgment

- We wish to acknowledge the great support of the FAA sponsors and stakeholders, including stakeholders from NASA, JPDO and other industry partners that have been very helpful and open about the challenges of this complex problem.

- We also want to thank Dr. Bill Kaliardos and Cindy Adamskyj from the FAA who provided excellent comments that helped us improve this presentation especially for people not familiar with the FAA.

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Thank You

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