NEXT GENERATION AIR TRANSPORTATION SYSTEM

JOINT PLANNING AND DEVELOPMENT OFFICE

FLIGHT PRIORITIZATION DEEP DIVE: *FINAL REPORT*

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This report is a description of a study performed by Crown Consulting, Inc., under contract to the JPDO.

The findings, conclusions, and recommendations presented in this report are those of the study team and do not represent the official position of the JPDO.

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EXECUTIVE SUMMARY

INTRODUCTION

Even with the increased capacity and operating flexibility of NextGen, there will be situations and environments in which operators will compete for the same volume of airspace and airport facilities. Some may assume that contention for the same airspace in the future will be dealt with in a fashion similar to the methods in use today (e.g., controllers making tactical decisions to separate aircraft). However, under NextGen, trajectories or routes will be negotiated and contracted in advance with much greater accuracy and computers will be able to decongest the trajectories in advance. This means that, rather than controllers making tactical decisions on how to separate aircraft, computer algorithms will decide, within safety parameters, who goes first and who will have to wait, slow down, or take a different route. These Flight Prioritization (FP) rules in NextGen automation systems should be developed in a thoughtful way, considering what is best for aviation users and the National Airspace System (NAS).

NextGen Four-Dimensional Trajectory (4DT) management, more capable communications, and net-enabled system-wide information sharing will provide the capability for flights operating in congested environments to be prioritized in ways that increase overall capacity and efficiency in the system, while at the same time providing more predictability, flexibility, and collaboration for operators. However, in order to achieve the maximum benefits of these capabilities, prioritization rules must be conceived, developed, and converted into algorithms (e.g., the "equity algorithm"[1]) to be applied by the NextGen 4DT automation platforms. These parameters must be derived in collaboration with users and other stakeholders, both for traffic flow and trajectory management. Under these conditions, the common situational awareness and advanced lead times that benefit stakeholders under NextGen can provide innovative options for resolution of competing needs in airspace, airports, or any constrained area of required

[1] Trajectory-Based Operations (TBO) Operational Scenarios for 2025, *Version 1.9.1. TBO Study Team Draft, September 15, 2010,*

system service. Furthermore, even under nominal conditions, there is the expectation that a set of ground rules should be established to allow for strategic and near-term planning of flights in a transparent way. The increased planning horizon and a larger set of options for dealing with constraints will, thus, increase efficiency.

All FP rules are based upon projections of contention and, therefore, they operate in advance of the physical loss of separation. When a loss of separation is imminent, safety rules are invoked and take precedence. If contention can be projected further in advance, more time and, therefore, more options will be available for resolution. However, accurately predicting trajectories far in advance to determine contention for resources is complex due to inaccuracies and uncertainties associated with flight trajectory projections, weather and other factors.

STUDY OBJECTIVES AND APPROACH

The study objectives were as follows:

- Survey and document state of the art of FP mechanisms
- Define technical basis for developing and evaluating prioritization rules by establishing a set of metrics, weights, and criteria based on the NextGen National Plan, NextGen concepts and architectures, and knowledge of state of the art
- Provide understanding of the decision making process as it affects FP policy decisions
- Provide recommendations for moving forward

The Study Group consisted of six recognized aviation, air traffic technology and policy experts:

- *Richard Golaszewski*, Executive Vice President, GRA, Inc.
- *Shahab Hasan*, Program Director for Investment and Cost Analysis, LMI
- *Michael Ball*, Orkand Corporation Professor of Management Science, Robert H. Smith School of Business at the University of Maryland

- *David Schaffer*, Principal, David E. Schaffer, LLC
- *Frank Frisbie*, independent aviation consultant
- *William Cotton*, President, Cotton Aviation Enterprises, Inc.

The Study Group was supported by a Study Team consisting of:

- **Program Manager:** *Jim Cistone*, Crown Consulting, Inc.
- **Study Director:** *Peter Kostiuk*, Robust Analytics
- **JPDO Liaisons:** *Suzette Matthews* and *Jesse Lambert*, JPDO
- **Executive Support:** *Jenifer Lonon*, JPDO

The study followed a well organized process to develop NextGen metrics, logically identify and elaborate on feasible alternatives, analyze and rank those alternatives, and pose preliminary conclusions and recommendations. The steps of this process are described in the following sections.

LITERATURE REVIEW

The team initiated the inquiry with a review of aviation laws and related legislative reports, executive orders, FAA regulations, policy statements, and internal procedures. To better understand the NextGen foundational context and current planning requirements, the team reviewed the Vision 100 legislation (Pub. L. 108-176; 49 USC §40103), the NextGen Concept of Operations, Enterprise Architecture (EA), and Integrated Work Plan (IWP), all of which are incorporated into the JPDO Joint Planning Environment (JPE). Other material analyzed during the literature review included NextGen planning scenarios developed by the Interagency Portfolio Systems and Analysis (IPSA) Division, products of JPDO working groups and Study Teams, scholarly journals and other compendiums of air traffic technology research results, briefings and speeches of aviation subject matter experts in technical meetings and conferences, aviation trade press and other general news sources. From this literature review, the Study Team catalogued existing and proposed FP concepts for analysis.

DETERMINATION OF METRICS AND VALUES

Drawing on the referenced material, the Study Team selected and defined a set of high-level metrics/values to evaluate FP concepts. Some of these metrics/values specifically aim to assess the objectives of FP. Other metrics/values are directed toward evaluating the potential impact of FP concepts on other NextGen objectives. The list of metrics is as follows:

- ATS Performance & Efficiency
- Fairness
- Transparency
- Respects operator preferences
- Flexibility
- Predictability
- Environmental Impact
- Societal Values
- Service Quality
- Resilience
- Economic Efficiency
- Incentive Compatibility
- Scope
- Implementation Risk

WORKSHOP DELIBERATION

Following the literature review, assessment of the NextGen operating environment and metrics development, the Study Team conducted a series of workshops for the purpose of having aviation subject matter experts (SMEs) validate, revise, and expand the list of FP concepts developed by the Study Team. SMEs also provided input related to the description of the NextGen operating environment and proposed metrics. The workshops were organized as presented in *Figure E-1*:

Figure E-1: Workshop Schedule

Workshop # 1: Background, Current System, Future Concepts	
November 10, 2009	Understanding the NextGen operating environment as it relates to FP
November 11, 2009	Understanding current slot allocation methods, issues and applicability to the FP context
November 12, December 8, 2009	Review of current TFM and CDM concepts and research for applicability to NextGen FP
Workshop # 2: SME views on FP	
April 20, 2010	Airport Operations
April 26, 2010	Business Operations
April 27, 2010	Flight Operations
April 28, 2010	FP Research Topics
Workshop #3: Presentation of Study Results	
September 9, 2010	Presentation of Findings and Conclusions

STUDY ANALYSIS AND FINDINGS

The following sections describe the analysis, findings and results of the study. The analysis process followed a sequence of steps:

1. Identify potential FP concepts
2. Obtain feedback and suggestions from industry experts
3. Refine the concepts
4. Evaluate each concept on a stand-alone basis
5. Conduct gap analysis
6. Define the potential solution space
7. Define research needs

POST-WORKSHOP ANALYSIS

Workshop-derived information was captured in meeting minutes, which were synthesized and analyzed in Study Team deliberative meetings. Following Workshop #1 in November 2009, the Study Team used descriptions of the NextGen 2025 operational environment and information about Collaborative Decision Making (CDM) and Traffic Flow Management (TFM) as it currently operates to develop a preliminary list of FP concepts. This list was evaluated and revised from December 2009 to April 2010, and then presented to SMEs during Workshop #2. Feedback from Workshop #2 permitted

deeper refinement of the prioritization concepts list, which was then evaluated against the developed set of metrics. The potential FP concepts identified are listed below:

- **First-Projected, First-Served (FPFS)** is a transformation of the First-Come, First-Served (FCFS) concept, in which priority is established by being the first flight projected to arrive at a point along a 4DT, a takeoff or landing slot, or another constrained resource. FPFS establishes the sequence of flights on the basis of their projected arrival time at a constrained resource, without regard to other values or objectives.
- **Priority-by-Schedule (PBS)** is a concept in which priority is determined by the schedule. For scheduled operators, the published schedule forms the basis for prioritization during the initial 4DT negotiation phase. For all other operators, prioritization could be based on the ETA established in their initially negotiated 4DT. In both cases, all subsequent prioritization will be based on the operators' times embodied in the contracted 4DT. Intra-operator swapping of ETAs would be allowed under this concept.
- **First-Filed, First-Served (FFFS)** describes a concept in which a flight's priority would be established by the order in which the request (e.g., a 4DT flight plan, or a request to modify the plan, etc.) was submitted to the FAA. When a request is made, resource availability would be assessed and the request approved provided the resource had not already been previously reserved. The reservation would be firm, unless overridden by a safety concern.
- **Transitional Preference** is defined for the purpose of this study as giving an operating priority to the aircraft with more advanced equipage, whether or not that equipment enables improved system performance in that environment. To implement this concept, it might be necessary for FAA to define a level of NextGen equipage that would qualify an operator for this preferential treatment.

- **Best-Performing, Best-Served[2] (BPBS)** is a construct under which priority is based on having a capability that enables your aircraft to perform in an environment that allows enhanced operations. This concept might apply in airspace or ground environments segregated for aircraft with minimum equipage, or might be used to prioritize aircraft in mixed equipage environments (e.g., sophisticated operators get in first, and less capable aircraft are accommodated later, or when the contention subsides.) Under this concept, highly performing aircraft generate additional system capacity and improved NAS performance and those aircraft receive priority.
- **Market-Based Prioritization Mechanisms** are defined to mean markets where money is exchanged for access to resources on either a primary or secondary market. Three such concepts were explored: auctions, advance contract, and congestion pricing.
- **Priority Points** is a concept by which the Air Navigation Service Provider (ANSP) allocates points among aircraft operators that are used to indicate to the ANSP the relative value of a particular flight in situations of constrained operating resources. The ANSP would make an initial allocation of points among operators in accordance with objective criteria (e.g., some multiple of the number of operations conducted during the previous year). Operators would then bid their points in contention with other operators to win priority in any environment in which they are contending for the same resource. Operators might also be authorized to trade or sell accumulated points on a secondary market.
- **Minimize NAS Delays** involves identifying those flights that contribute most to flight delays and placing them later in the sequence, thereby improving the timeliness of a greatest number of operations overall.

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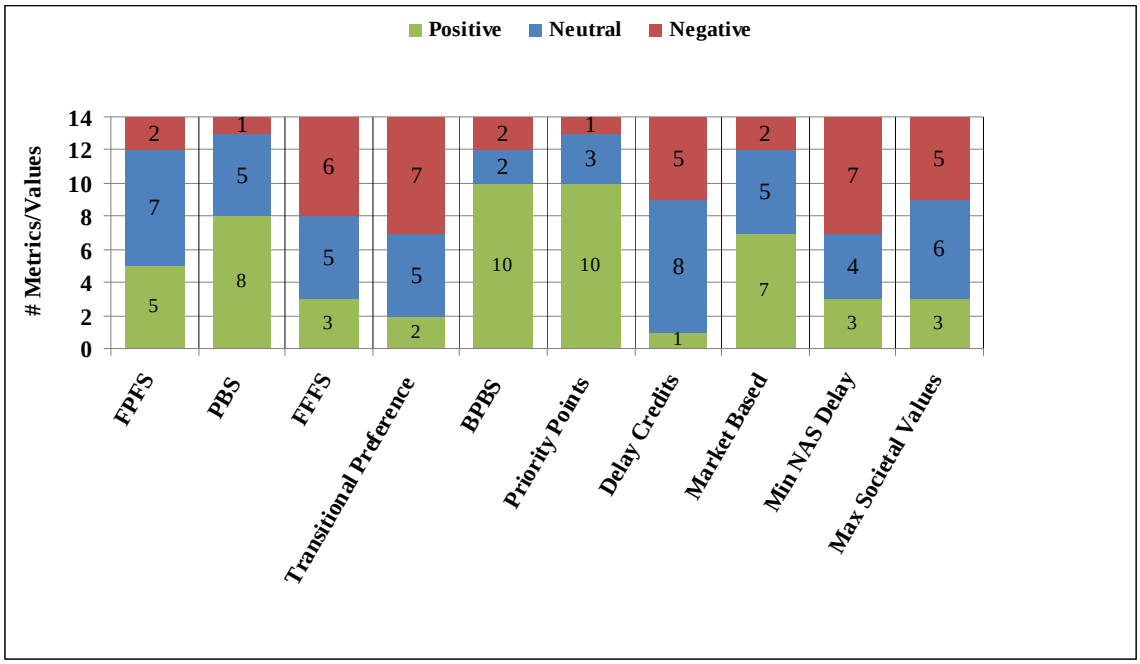
[2] There are three classes of BPBS: (1) *Non-Interfering Service Improvement*, where benefits accrue to equipped aircraft and there is no disadvantage to non-equipped operations; (2) *Operational-Positive Preference*, where non-equipped aircraft are disadvantaged by giving preference to equipped aircraft only when there will be net system benefits operationally to NAS users (either through capacity enhancement, or through benefits to equipped outweighing dis-benefits to non-equipped, or both); and (3) *Societal-Positive Preference*, where non-equipped aircraft are disadvantaged to obtain a societal benefit (such as reduced emissions) or "tip the scale", even though there is a stand-alone, net operational dis-benefit to NAS users.

- **Delay Credit Prioritization** is intended to raise the priority of a current operation to compensate for delays experienced earlier. This could mean upgrading the priority of a flight during a subsequent resource contention event because it was the loser in a previous one. Alternatively, delays could be recorded and tallied over time, so that operators could invoke priority in future operations on the basis of banked delay credits. Operators might be permitted to sell or trade delay credits to other operators for money or other items of value.
- **Prioritization Based on Societal Values** involves giving preference to or penalizing flights to the extent that their characteristics advance or detract from recognized societal goals, objectives, or values established in a policy-making context. These goals and values could include minimizing environmental impact, serving the largest number of passengers (or delaying the fewest), serving the market at the lowest possible fares, ensuring a strong competitive environment, providing access to all classes of operators, or minimizing the cost to taxpayers of building, maintaining and operating the air transportation infrastructure, fostering economic growth, and providing for the national defense and homeland security.

The Study Group then performed a qualitative assessment of each alternative autonomously against each metric/value with three possible attributes for each metric: positive, neutral, or negative. The assessment exercise was performed collaboratively among the full Study Group until consensus was achieved. *Figure E-2* is an array of the concepts that depicts the results of the analysis and allows them to be compared qualitatively.

Figure E-2: Metrics/Values Frequencies for FP Concepts



Among the concepts evaluated, four ranked highly enough to deserve further development and analysis since they were assessed as at least 50% positive on a standalone basis:

- PBS
- BPBS
- Priority Points
- Market-Based Prioritization Mechanisms

Although upon initial analysis four FP concepts appear most promising, those concepts that received lower assessments should not be overlooked because they have the potential to enrich other concepts in a variety of combinations. FPFS is one such concept. The need to be able to conduct FP across all flight phases and in different types of airspace imposes a substantial burden that might better be overcome by integrating multiple concepts into a solution that functions across the NAS. Moreover, no single concept was assessed positively against all values and metrics. Therefore, no single concept would be adequate to address all NextGen FP objectives.

GUIDING PRINCIPLES

The Study Team recognized that certain principles should guide development and implementation of any FP mechanism:

- Flight safety shall always be the first consideration in a FP regime.
- FP should optimize use of NAS resources.
- FP should attempt to achieve fairness among aircraft operators.
- A FP concept should allow aircraft operators to optimize the use of resources under their control and to clearly express their preferences and priorities in response to system constraints.
- FP processes should be transparent, rule-based, and predictable.
- Business decisions and priorities should remain the responsibility and concern of the individual aircraft operator whenever feasible.
- All operators, including non-scheduled, should be given equal opportunity to participate in NextGen FP.
- FP mechanisms should be amenable to incorporation of societal goals and values.
- Whatever FP methods are ultimately adopted, they should complement – and not substitute for – the augmentation of needed airport and airspace capacity.
- The application of FP in far-term should be conducive to adaptation as the dynamics of the NAS change across time and space.
- The development of a far-term FP solution should be developed in close collaboration between FP developers and those responsible for other NextGen systems.

CONCLUSIONS

The three workshops and further supporting analysis generated a substantial volume of data and insight into the broad range of FP issues. The conclusions of the study are as follows:

- PBS, Priority Points, BPBS and Market-Based Prioritization Mechanisms demonstrated significant promise and potential value and should receive more investigation and can benefit from focused research.
- Other than alternatives that involve the sale by FAA of prioritizations for money, FAA already has sufficient legislative authority to implement any of the FP concepts discussed in this report.

RECOMMENDATIONS

The following recommendations follow from the study analysis, finding, and conclusions:

- FP offers significant value in far-term NextGen and, therefore, FP research should be vigorously pursued. A work plan for maturing FP for NextGen implementation should be developed including the following tasks:
  1. Mature the individual concepts
  2. Develop a concept of operations for system-wide FP in far-term NextGen
  3. Perform technical feasibility assessments and cost/benefit analysis
  4. Design an integrated system-wide FP solution
  5. Mature FP requirements for NextGen automation and communications systems planning
- Useful concepts and technology generated through this research should be considered for early deployment.
- The policy implementation pathway should involve stakeholder engagement and collaboration.
- As soon as practicable, far-term NextGen developers should codify FP requirements when designing the TBO automation suite and Flight Object.

RESEARCH TOPICS

Following from the Recommendations are a set of research topics associated with developing and implementing NextGen FP:

- **PBS:** Research is required, supported by simulation, to develop a detailed mature concept of operations for schedule-based prioritization for gate-to-gate trajectory operations. This research should identify how the flexibility of non-scheduled operators is incorporated.
- **Priority Points:** Research is required, supported by simulation, to develop a detailed mature concept of operations for a Priority Points system under far-term NextGen, including criteria for allocation and use of points among operators in gate-to-gate operations. Additional analysis also would be required for identification and weighing of societal values, and NAS capacity, efficiency and performance factors that might be incorporated into the points computations.
- **BPBS:** In order to judge the utility of BPBS within far-term NextGen, a more comprehensive definition is required.
- **Market-Based Prioritization Mechanisms:** Specific, limited opportunities should be identified for demonstrating the performance of market-based approaches to FP in far-term NextGen. Additionally, policy research is required to identify whether additional implementation authority would be needed for implementation of market-based FP approaches in which FAA sells priority for money.
- **FPFS:** Research is needed to investigate how, where, and when FPFS reverts to FCFS.
- **Modeling of Innovative FP Concepts:** Modeling and simulation capabilities should be employed to evaluate system-wide impacts of FP concepts, anticipating how independent users would behave and interact if any of the FP concepts were implemented in their markets.
- **FP and the Flight Object:** Research is needed to specify the FP requirements that would be built into the far-term NextGen Flight Object, such that it can accommodate real-time prioritization of flights by the aircraft operator and use of that information by ATC automation in aircraft sequencing throughout execution of the 4DT.
- **FP and ANSP Automation/Communications:** Research is required to quantify the significant demands that FP may place on planned far-term NextGen

automation and communication systems. Any limitations on those systems should be fed back to FP research.

- **Non-scheduled Operations:** Policy research is required to determine the best way to accommodate non-scheduled operators in FP.
- **FP and the TBO Planning Horizon:** Research is required to specify characteristics of the planning horizon, including accuracy level of the trajectory, needed for FP. These requirements should be evaluated against far-term NextGen technical requirements.
- **Collaboration and Interactions among Operators**: Research is needed into the benefits and legal constraints of information sharing among operators. Current Ration-by-Schedule (RBS) practices include some level of such interaction but this is done without direct negotiation between the participants.
- **Relationships between Governance and FP systems:** Although the FP Study Team does not propose any changes to existing governance models, research is warranted to determine how FP options assessed in this study would function under alternative governance mechanisms. It is important to understand which FP options are robust and could function under any governance system and which FP options may require changes if the governance of the ATM system were to change.

1. INTRODUCTION

Even with the increased capacity and operating flexibility of NextGen, there will be situations and environments in which operators will compete for the same volume of airspace and airport facilities. Rush hour at congested airports and hazardous weather events are examples of situations in which demand for a specific operating resource may exceed what is available. Unmanaged excess demand can degrade system efficiency and cause delays that ripple through the entire air transportation system.

Some may assume that contention for the same airspace in the future will be dealt with in a fashion similar to the methods in use today (e.g., controllers making tactical decisions to separate aircraft). However, under NextGen trajectories or routes will be filed in advance with much greater accuracy and computers will be able to deconflict the trajectories in advance. This means that, rather than controllers making tactical decisions on how to safely separate aircraft, computer algorithms will decide who goes first and who will have to wait, slow down, or take a different route. These Flight Prioritization (FP) rules in the NextGen computer algorithm should be developed in a thoughtful way, considering what is best for aviation users and the NAS.

The good news is that, with NextGen Four-Dimensional Trajectory (4DT) management, more capable communications and net-enabled system-wide information sharing will provide the capability for flights operating in congested environments to be prioritized in ways that increase overall capacity and efficiency in the system, while at the same time providing more predictability and flexibility for operators. However, in order to achieve the maximum benefits of these capabilities, prioritization rules, mechanisms, and regimes must be captured, developed, and converted into algorithms to be applied by the NextGen 4DT automation. These parameters must be derived in collaboration with users and other stakeholders, both for traffic flow and trajectory management. Under these conditions, the common situational awareness and advanced lead times that benefit stakeholders under NextGen can provide innovative options for resolution of competing needs in airspace, airports, or any constrained area of required system service. Furthermore, even

under nominal conditions, there is the expectation that a set of ground rules should be established to allow for strategic and near-term planning of flights in a transparent way. The increased planning horizon and a larger set of options for dealing with constraints will, thus, increase efficiency.

All FP rules are based upon projections of contention and, therefore, they operate in advance of the physical loss of separation. When a loss of separation is imminent, safety rules are invoked and take precedence. If contention can be projected further in advance, more time will be available for resolution. However, accurately predicting trajectories far in advance to determine contention for resources is difficult due inaccuracies and uncertainties associated with flight trajectory projections.

This study is intended to develop, explore, and document historic and proposed FP rules, mechanisms, and regimes; develop a catalog of options that might be feasible and helpful for NextGen automation planning; and define a decisional pathway to establishing effective rules, mechanisms and regimes for prioritization of flights under various conditions that can be used by NextGen architects and system designers.

1.1. STUDY OBJECTIVES

- Survey and document state of the art of FP mechanisms
- Define technical basis for developing and evaluating prioritization rules by establishing a set of metrics, weights, and criteria based on the NextGen National Plan, NextGen concepts and architectures, and knowledge of state of the art
- Provide understanding of the decision-making process as it affects FP policy decisions
- Provide recommendations for moving forward

1.2. DEFINITIONS

For the purpose of this Study, the following definition of FP terms is used:

- **Tool/Method:** *Means, methodology or mechanism by which a FP concept/philosophy is implemented.* In end-state NextGen, this is likely to be an algorithm or set of algorithms resident in NAS Automation platforms.
- **Concept:** *Theoretical alternatives that are the basis for FP implementation.* A concept defines the rules for prioritizing flights.
- **Governance:** The *framework of rules and practices* by which a government agency, board of directors, or other governing body ensures accountability, fairness, and transparency in an enterprise's relationship with its all stakeholders (e.g., financiers, customers, management, employees, government, and the community).[3]
- **Scheduled/Non-scheduled Operations:** For the purpose of this report, *scheduled operations are those that operate in accordance with a published schedule; all other operations are categorized as non-scheduled.* No further distinction among categories of operators and operations is made or intended in this report.

[3] Adapted from http://www.businessdictionary.com/definition/corporate-governance.html

2. STUDY APPROACH

Figure 1 displays the general process of the FP Deep Dive study described in this report:

Figure 1. Study Approach

Develop and Analyze Concepts	Solicit Expert Opinion	Write Final Report
1. Define Metrics 2. Understand far-term NextGen opportunities 3. Identify and describe candidate concepts 4. Evaluate concepts vis-à-vis defined metrics	1. Conduct workshops 2. Conduct technical interchange meetings (TIMs) 3. Conduct in-depth technical discussions with FAA and industry experts	1. Document sources of metrics 2. Document results of literature research and SME/stakeholder input 3. Analyze candidate concepts 4. Produce recommendations 5. Provide policy way forward 6. Identify impacts of the JPDO Enterprise Architecture and Integrated Work Plan

2.1. STUDY TEAM COMPOSITION

The FP Deep Dive study was conducted by a JPDO-selected Study Group of six members, supported by a Program Manager, Study Director, and JPDO-provided support staff. Please refer to *Appendix D* for biographies of the Study Team members.

- ***Study Group:*** The Study Group consisted of six recognized aviation and air traffic technology and policy experts, who brought a balanced and representative range of expertise and perspectives from across the aviation community. Members were selected based on their ability to provide an objective, "honest broker" viewpoint, independent of any one constituency or industry.
- ***Program Manager:*** *Jim Cistone* was Program Manager for this task, responsible for management of overall Study Team activity, cost, and schedule, as well as for technical guidance of most aspects of the study.

- ***Study Director:*** *Peter Kostiuk* was study director for this task, responsible for lead technical analysis and development of study recommendations.
- ***Joint Planning and Development Office (JPDO) Support:*** *Suzette Matthews* and *Jesse Lambert* were liaisons to the Director of the JPDO Strategic Interagency Initiatives (SII) Division, who sponsored this study. Ms. Matthews and Mr. Lambert provided clarification and guidance throughout the study process, ensuring alignment with JPDO requirements in relation to the study. Additionally, *Jenifer Lonon* provided significant logistical and note-taking support.

2.2. STUDY PROCESS

The Study Team investigated many facets of the FP problem as described herein and developed this report of its findings, conclusions, and recommendations based on that evidence.

2.2.1. LITERATURE REVIEW

The team initiated inquiry with a review of aviation laws and related legislative reports, executive orders, FAA regulations, policy statements, and internal procedures. To better understand the NextGen foundational context and current planning requirements, the team reviewed the Vision 100 legislation (Pub. L. 108-176; 49 USC §40103), the NextGen Concept of Operations (ConOps), Enterprise Architecture (EA), and Integrated Work Plan (IWP), all of which are incorporated into the JPDO Joint Planning Environment (JPE). Other material analyzed during the literature review included NextGen planning scenarios developed by the Interagency Portfolio Systems and Analysis (IPSA) Division, products of JPDO working groups and Study Teams, scholarly journals and other compendiums of air traffic technology research results, briefings and speeches of aviation subject matter experts in technical meetings and conferences, aviation trade press and other general news sources. From this literature and concept analysis, the Study Team catalogued existing and proposed FP mechanisms, regimes, and concepts for analysis. The team also formulated an initial understanding of the far-term

NextGen operating environment, in which any FP concept would have to function. From the aforementioned literature analysis and workshop discussions, the Study Team derived a set of high-level metrics to evaluate existing and proposed FP concepts.

2.2.2. WORKSHOP DELIBERATION

Following the literature review, assessment of the NextGen operating environment and metrics development, the Study Team conducted a series of workshops for the purpose of having aviation subject matter experts (SMEs) validate, revise, and expand the list of FP concepts developed by the Study Team. SMEs also provided input related to the description of the NextGen operating environment and proposed metrics. SME attendees for each workshop are listed in Appendix A. The workshops were organized as follows:

Figure 2. Workshop Schedule

Workshop # 1: Background, Current System, Future Concepts	
November 10, 2009	Understanding the NextGen operating environment as it relates to FP
November 11, 2009	Understanding current slot allocation methods, issues and applicability to the FP context
November 12, December 8, 2009	Review of current TFM and CDM concepts and research for applicability to NextGen FP
Workshop # 2: SME views on FP	
April 20, 2010	Airport Operations
April 26, 2010	Business Operations
April 27, 2010	Flight Operations
April 28, 2010	FP Research Topics
Workshop #3: Presentation of Study Results	
September 9, 2010	Presentation of Findings and Conclusions

Workshop #1 was designed to provide the Study Team with a baseline to define the technical context of future FP operations in the 2025 timeframe.

- **Day 1** focused on NextGen concepts, and discussions were led by key NextGen planners and implementation organizations.

- **Day 2** explored the history and theory of slot auctions to better understand administrative congestion management practices.
- **Day 3** reviewed current Traffic Flow Management (TFM) and Collaborative Decision Making (CDM) practices, as well as new tools and procedures currently under development for near-term use.

Workshop #2 assessed the needs and views of operators with respect to FP and examined FP-related research discovered during the literature review. To prepare for the workshop the Study Team used knowledge developed through the literature review and discussions with outside experts to define candidate concepts. The Study Team also developed a document describing candidate FP concepts, and the expected role of FP in the far-term NextGen environment, provided to operator SMEs. Participants were asked to review the document before the meeting and come prepared to answer the following questions:

1. How would the move to trajectory-based operations and changes in FP rules, such as those discussed in this paper, impact your domain of interest in the US air transportation system?
2. Do you see any potential problems associated with the concepts discussed? For example, do any of them incentivize flight operators to behave in ways that might be considered undesirable? Are there certain unintended consequences on important NAS constituencies, such as airport operators, passengers, etc.?
3. How would each of the concepts affect high-level system values such as efficiency, equity, operator flexibility, access, environmental impact, and competition? What other values should be included in assessments of prioritization concepts?
4. What other FP concepts are there?
5. How would your stakeholder group measure success or failure for the FP mechanism?

During Workshop #2, the participants provided detailed comments on each of the concepts, including assessments of business impact, operational considerations, and feedback on each of the metrics. Over the four workshop sessions, the Study Team received comments from experts representing large airlines, on-demand operators, air cargo operators, General Aviation (GA) operators, government and academic researchers, the air traffic controllers union, and airport operators.

Prioritization alternatives developed by the Study Team were presented to SME panels organized by area of expertise. Comments on each alternative were recorded, and SMEs were asked to judge each alternative against the high-level metrics developed by the Study Team during the literature review stage.

- **Day 1** focused on Airport Operations, eliciting the needs and opinions of airport operation stakeholders and representatives from airport trade associations related to potential FP constructs.
- **Day 2**, Aircraft Business Operations involved airline marketing and finance stakeholders, as well as representatives from general and business aviation trade organizations. This session was focused on needs of those who set airline schedules or who determine the business rules for aircraft operation.
- **Day 3**, Aircraft Flight Operations day, involved flight operations personnel who are responsible for daily operations under company business rules and FAA regulations.
- **Day 4** was devoted to exploring promising research related to FP. The Study Team heard a series of presentations from active researchers whose research is relevant to FP. During that session, the Study Team welcomed the participation of a NATCA representative who contributed constructively to the deliberations.

Workshop #3 provided an opportunity to present Study Team results to SMEs who were invited to and/or attended Workshops #1 and #2. Written comments

were solicited in response to the briefing. SME input was considered and incorporated as necessary in the final version of this report.

2.2.3. POST-WORKSHOP ANALYSIS

Workshop-derived information was captured in meeting minutes, which were synthesized and analyzed in Study Team deliberative meetings. Following Workshop #1 in November 2009, the Study Team used descriptions of the NextGen 2025 operational environment and information about CDM and TFM as it currently operates to develop a preliminary list of FP concepts. This list was evaluated and revised from December 2009 to April 2010, and then presented to SMEs during Workshop #2. Feedback from Workshop #2 permitted deeper refinement of the prioritization concepts list, which was then evaluated against the developed set of metrics.

By invitation of the Port Authority of New York and New Jersey (PANYNJ), in June 2010, the Study Team visited John F. Kennedy International Airport (JFK) to view an innovative approach to constrained departure operations at the airport that was used during the Bay Runway reconstruction project. Observations from this visit provided insight to some of the prioritization alternatives under consideration.

Following Workshop #2 and the JFK airport visit, the Study Team spent the subsequent period analyzing accumulated information, and converging on the main conclusions and recommendations of this study. A draft report was submitted to the JPDO SII Division Director for review and comment August 31, 2010. The Study Team then revised the draft report, and submitted this *Final Report* to the JPDO on September 30, 2010. JPDO staff members were part of the Study Team, participated in report preparation, and will manage distribution of the report.

3. METRICS AND VALUES

The Study Team considered whether some objective and easily quantifiable metrics, such as passenger delay minutes or passenger throughput, could serve to distinguish among FP concepts. It was quickly realized that such quantifiable measures could not capture the values and policy objectives embodied in Vision 100 and the NextGen Integrated Plan. The Study Team therefore focused on high level objectives that could, through further research, be decomposed into more measurable effects. Sources or substantiation for each metric is incorporated in this analysis. Some metrics/values, in addition to a source in NextGen documentation, also have a strong stakeholder constituency that commends their use.

Drawing on the referenced material, the Study Team selected the following metrics/values to evaluate FP concepts. Some of these metrics/values specifically aim to assess the objectives of FP. Other metrics/values are directed toward evaluating the potential impact of FP concepts on other NextGen objectives.

- ***NAS Capacity, Efficiency and Economy:*** This metric is based on FAA's statutory responsibility to operate the NAS safely and efficiently (Vision 100, Pub. L. 108-176; 49 USC §40103), and on goals and objectives stated in the NextGen Integrated Plan. The FP concept was assessed positive if it has the potential to improve capacity, efficiency, and/or economy in the NAS; it was assessed neutral if would have no impact positive or negative on NAS operations even though it might have beneficial outcomes for aircraft operators; it was assessed negative if it would have the effect of reducing NAS capacity, efficiency, and/or economy, regardless of how beneficial it was for aircraft operators.
- ***Fairness:*** The FP concept was assessed as positive to the extent that it would treat all aircraft operators fairly, but not necessarily equally or similarly. Expert testimony of aircraft operator representatives indicated that dissimilar treatment of various classes of users would be considered fair as long as the differences were based on legitimate NAS objectives, and that operators were treated with

impartiality. A positive rating means that operators would perceive the FP concept as fair in its application; a neutral a means that the alternative would be perceived as fair by some operators but unfair by others, or have no impact on fairness; a negative assessment means that the FP would treat operators in ways that none would consider fair.

- ***Transparency:*** The FP concept was assessed as positive to the extent that the basis for prioritization and the regime's operations are disclosed, understandable, and visible to all stakeholders including the government and the traveling public. This metric is based on the January 21, 2009 Presidential Memorandum titled "Transparency and Open Government" (74 Fed. Reg. 4685, January 26, 2009). A positive assessment means that the FP concept would improve transparency over regimes and methods in operation today; a neutral assessment means that the FP concept would neither increase nor decrease transparency over what pertains today; and a negative assessment means that the FP concept would decrease the ability of operators and other stakeholders to understand the rules and procedures for how flights are prioritized.
- ***Honors Aircraft Operator Preferences:*** The FP concept was assessed as positive to the extent that it could honor an aircraft operator's articulated preferences. This metric is derived from expert testimony of aircraft operator representatives. A positive assessment means that the alternative would improve the ability of operators to execute their preferred options; a neutral assessment means that the FP concept would neither improve nor detract from options operators have today to execute their preferences, or its impacts were mixed in that the concept might improve the position of some classes of operators and decrease the influence of others; a negative rating means that the FP regime would reduce the ability of most operators to execute their operating preferences.
- ***Flexibility:*** The FP concept was assessed as positive to the extent that it allows the ANSP and aircraft operators to adapt quickly and with agility to changing circumstances with the greatest range of operating options. This metric is based on language from the NextGen Integrated Plan, was identified as an objective by expert aircraft operator representatives, and contributes to FAA's statutory

responsibility to advance safety and efficiency in the NAS. A positive assessment means that the FP concept improved the flexibility of either aircraft operators or the ANSP and did not negatively impact others, or it improved the flexibility of both; a neutral assessment means that the FP concept either did not impact flexibility at all, or had a mixed impact in that it improved things for either the ANSP or operators; a negative assessment means that the FP concept negatively impacted the flexibility of operators, the ANSP, or both.

- ***Predictability:*** The FP concept was assessed as positive to the extent that its application yields results that could be forecast with reliability, and thereby facilitates advance planning by aircraft operators, passengers and shippers. The predictability metric is based on language from the NextGen Integrated Plan, and was cited as a positive value by expert aircraft operator representatives. A positive assessment means that the FP concept improved predictability for all or some operators, and did not reduce predictability for any; a neutral assessment means that the alternative did not improve or decrease predictability for anyone, or its impact could improve predictability for some but not for others; a negative assessment means that the alternative would make things less predictable for just about everyone.
- ***Minimizes Aviation's Environmental Impact:*** The FP concept was assessed as positive to the extent that it enables the ANSP and aircraft operators to operate in a way that minimizes negative impacts to the environment, such as noxious emissions, noise, and climate changing effects. This metric is based on goals stated in Vision 100, Pub. Law 108-176, and the NextGen Integrated Plan. A FP concept received a positive assessment if it incorporated a method for advancing the goal of reducing environmental impacts (e.g., providing incentives for desired operator behavior); it was assessed neutrally if it made no improvement to, nor detracted from, the ability to advance environmental goals; it was assessed negatively if the FP concept would make it more difficult to address environmental goals.
- ***Societal Values:*** The FP concept was assessed as positive to the extent that its operations further societal goals and objectives, as determined by policy-makers.

Societal goals may be independent of aviation objectives. They may align with, be neutral, or, in some cases, be antithetical to aircraft operator and/or aviation sector objectives. Among such societal objectives are competition, best use of air transportation infrastructure (e.g., encouraging use of larger aircraft), reserving or encouraging service to small communities, contributing to trade and tourism, creating jobs, improving national and local economies, facilitating EMS, national defense, and homeland security. This metric is derived from Vision 100, Pub. L. 108-176 and the NextGen Integrated Plan. A FP concept received a positive assessment if it incorporated a method for advancing societal goals that would be established in a policy-making context; it was assessed neutrally if it made no improvement to, nor detracted from, the ability to advance societal goals; it was assessed negatively if the FP concept would make it more difficult to address societal goals. No specific attempt was made by the FP Study Team to identify what those societal goals would be during this assessment.

- ***Passenger/Shipper Service Quality:*** The FP concept was assessed as positive to the extent that it has the potential to improve the access of passengers and shippers to the widest range of service options at the lowest prices, and enable aircraft operators to provide services at the lowest cost and with greatest convenience, comfort and timeliness for consumers. This metric is based on language from the NextGen Integrated Plan, and is discussed extensively in "FAA Notice re: Delta/US Airways Petition for Waiver" (75 Fed. Reg. 7308, February 19, 2010). The FP concept was assessed positive if would have the effect of improving the ability of operators to provide good service to passengers and shippers; it was assessed neutrally if it would have no impact on the ability of operators to serve their customers, or if its impact could improve service for the customers of some operators but also negatively impact service provided by others; the alternative was assessed negatively if it would have impacts that would result in worse service for most customers.
- ***Resilience/Recoverability:*** The FP concept was assessed as positive to the extent that it has the potential to improve ability of the NAS to avoid, minimize the effects of or recover from disruptive events like large scale hazardous weather

events or unexpected facility disablement (e.g., ATC outages, airport/runway closures, etc.) This metric is derived from the FAA's statutory responsibility to operate the NAS safely and efficiently, from language from the NextGen Integrated Plan, and from FAA and expert airline representative testimony. A FP concept was assessed positive if it would improve the ability of the ANSP and aircraft operators to avoid or minimize, or to recover more quickly from the effects of disruptive events; it was assessed neutrally if it would have no impact on avoidance, minimization or recovery from disruptive events; it was assessed negatively if the alternative would make it more difficult, or increase the time it would take for the NAS and operators to recover from disruptive events.

- ***Economic (Allocative) Efficiency:*** The FP concept was assessed as positive to the extent it furthers the objective of putting NAS resources to their highest and best use. The economic efficiency metric is a requirement for government expenditures as stated in OMB Circular A-94. The FP concept got a positive assessment if it tended to maximize highest and best use; it was assessed neutrally if it would have no ability to improve the overall application of resources in the NAS; it was assessed negatively if it was likely to encourage inefficient or wasteful uses of NAS resources.
- ***Incentive Compatibility:*** The FP concept was assessed as positive to the extent its operation would encourage aircraft operators to behave in a way that promotes NextGen objectives. This metric emanates from the FAA's statutory responsibility to operate the NAS safely and efficiently, and from language from the NextGen Integrated Plan. The FP concept was assessed positively if it encouraged desired behavior by some or all operators and did not encourage others to behave in detrimental ways (e.g., providing incentives for operators to provide the ANSP with more planning information early or encourage operators to relinquish an operating priority earlier so that it could be used by someone else to greatest advantage); it was assessed neutrally if it was likely to have no influence on operator behavior; it was assessed negatively if it has the potential to encourage any category of aircraft operators to behave in ways antithetical to best operations of the NAS (e.g., hoarding operating priorities to achieve a competitive

advantage or withholding information that might improve NAS system planning and efficiency).

- ***Scope:*** The FP concept was assessed as positive to the extent that it could be applied geographically across the NAS, to all phases of flight, and to all operators. The scope metric is derived from Vision 100, Pub. L. 108-176 and the NextGen Integrated Plan. A positive assessment means the concept has wide applicability geographically, to all phases of flight, and to all operators; a neutral assessment indicates that the concept is useful in only some contexts, and/or would be applicable in only some classes of operations or operators; a negative assessment means that the concept is so narrowly applicable in terms of geography, operations and operators that it has little overall utility.
- ***Implementation Risk:*** The FP concept was assessed as positive to the extent that its implementation is associated with an acceptable level of technical, operational, financial, and/or policy risk. This metric is derived from responsibilities assigned to the JPDO by Vision 100, Pub. L. 108-176. A positive assessment means the FP concept has low implementation risk; a neutral rating means the alternative has medium or a reasonable level of risk; negative means the alternative is high risk.

For completeness, the Study Team assessed the merits of each FP concept against each of the preceding metrics/values. This construct provides a decisional framework for analysis by future policy-makers who might refine, change or delete the various metrics herein proposed, as well as assign numeric weights to each metric/value. Primary values for FP may include fairness, respect operator preferences, flexibility, transparency, and economic efficiency. Others, such as scope, risk, and incentive compatibility, describe concept characteristics that affect the ability of the FP concept to achieve its objectives. Finally, there are some metrics/values that must be considered because of possible detrimental system impacts.

The relative desirability of each alternative depends on its rating against each metric/value and the relative weight that a policymaker places on each of the metrics/values. Stakeholders also vary in the importance that they place on the different

metrics/values. Operators, for example, focus on operating in the way that best achieves their business objectives and, therefore, emphasize flexibility and predictability more highly than furthering societal goals such as reducing environmental impacts. *Figure 3* summarizes all metrics/values employed in this study:

Figure 3. FP Metrics/Values

Metric	Positive	Neutral	Negative
NAS Capacity, Efficiency and Economy	Has potential to improve capacity, efficiency and/or economy in the NAS	Has no impact positive or negative on NAS operations regardless of other benefits	Has the effect of reducing NAS capacity, efficiency and/or economy regardless of other benefits
Fairness	Operators would perceive alternative as fair in its application	Would be perceived as fair by some operators, but unfair by others, or no impact on fairness	Would treat operators in ways that none would consider fair
Transparency	Improves understanding of rules, procedures, and operation of how flights are prioritized	Neither increases or decreases understanding of rules, procedures, and operation of how flights are being prioritized	Decreases understanding of rules, procedures, and operation of how flights are being prioritized
Honors Aircraft Operator Preferences	Improves ability of operators to execute their preferred options	Neither improves nor detracts from options operators have today to execute their preferences	Reduces ability of most operators to execute their operating preferences
Flexibility	Improves flexibility of either aircraft operators or ANSP	Does not impact flexibility at all, or had mixed impact	Negatively impacts flexibility of operators, ANSP, or both
Predictability	Improves predictability for all or some operators, and would not make things less predictable for any	Does not improve or reduce predictability for anyone, or had mixed impact	Reduces predictability for most users and ANSP
Minimizes Aviation's Environmental Impact	Helps to reduce environmental impacts	Does not directly reduce environmental impact nor would it impede ability to advance environmental goals	Does not impede ability to address environmental goals
Societal Values	Helps further societal goals established in a policy-making context	Does not directly further societal goals, nor would it impede ability to advance them	Impedes ability to address societal goals
Passenger/Shipper Service Quality	Improves ability of operators to provide good service to most customers	Has no impact on operator service or might have mixed impact for some operators	Reduces ability of operators to provide good service for most customers

Resilience/Recoverability	Improves ability of operators to avoid or minimize, or to recover more quickly from the effects of disruptive events	Has no impact on avoidance, minimization or recovery from disruptive events	Impedes NAS and operator recovery from disruptive events
Economic (Allocative) Efficiency	Maximizes highest and best use of NAS resources	Has no ability to improve overall application of NAS resources	Is likely to encourage inefficient use of NAS resources
Incentive Compatibility	Encourages desired behavior by some or all operators and does not encourage others to behave in detrimental ways	Has no influence on operator behavior	Has potential to encourage any category of aircraft operators to behave in ways antithetical to best NAS operations
Scope	Widely applicable geographically, to all phases of flight, and to all operators	Useful in only some contexts, and/or would include only some classes of operations or operators	Narrowly applicable geographically and/or has little overall utility to all operations and operators
Implementation Risk	Low implementation risk	Medium or reasonable implementation risk	High implementation risk

4. TODAY'S STATE OF THE ART IN FP

Two widely used FP methods are integral to operational procedures and automation in today's NAS: First-Come, First Served (FCFS) and Ration-by-Schedule (RBS). This section discusses how these concepts are applied today and explores how they could be used in the NextGen NAS. This section also documents insight into FP derived from experience with FCFS and RBS.

4.1. FIRST-COME, FIRST-SERVED (FCFS) IN NAS OPERATIONS

First-Come, First-Served (FCFS) is a practice used in air traffic control that is older than the air traffic control system itself. It is common practice in US society to form a queue at a constrained public resource, whether at an airport runway or a lunch counter. The practice is ingrained in our culture. Since the early days of flying, before ATC, pilots used FCFS when lining up for takeoff and entering the traffic pattern for landing. This practice is still followed by pilots at non-towered airports, augmented by radio communications among the pilots using the Common Traffic Advisory Frequency (CTAF). When air traffic control was introduced, first at airports and later in the en route airspace, controllers naturally used the same practice. In fact, when performing the task of spatially ordering a sequence of aircraft to use a common resource, FCFS is the simplest solution for a controller. To set up any other sequence requires pulling an aircraft out of line and re-inserting it somewhere else, at a considerable increase in workload.

It should also be noted that FCFS is the only FP method formally accepted by FAA procedural rules.[4] The FAA Controllers' Handbook says that air traffic control services will be provided on a First-Come, First-Served basis, except for certain special operations that will be given priority or special handling. There are many circumstances in the application of air traffic control today in which controllers apply the FCFS rule. Most apparent are the takeoff and landing queues on and near

[4] FAA Controllers' Handbook, ATO Order JO 7110.65T, Section 2-1-4.

airports. FCFS is also used by ground controllers in creating the sub-queues of departing aircraft segregated by first departure fix. En route controllers use it when merging traffic from several directions into a common stream, as do flow planners trying to recover a group of diverted flights after a weather event. All would use the term FCFS to describe the process they use to establish their flight sequence.

Understanding the term requires knowing where, how and when it should be applied. The "where" may be the first call on a frequency or physical crossing of a sector boundary or en route waypoint. The "how" would be obtaining attention of the controller to provide a clearance or to trigger a handoff to another controller. In most cases, however, air traffic service is provided in FCFS by placement into a sequence of flights that will use the same airport or airspace resource. The location is usually a runway or an arrival or departure fix. In today's manually controlled sectors, the "when" is determined in the controller's mind as traffic enters and leaves a sector. Because aircraft arriving from different directions may have different speeds, a mental calculation of their respective arrival times at the merge point is used in setting the sequence. Thus, controller application of FCFS is based upon human projection of the order in which aircraft would arrive at a merge point. Subsequent control actions are then taken to create the desired spacing of aircraft within that sequence.

There are also many occasions in today's air traffic system in which FCFS is not followed in practice, in addition to those exceptions listed in the FAA Controllers' Handbook. These occurrences result from another ATC mandate to "provide the safe and expeditious movement of air traffic." The structure of the airspace established to control today's air traffic often dictates the use of procedures that violate FCFS in one respect while expediting the traffic overall. For example, if a weather situation has reduced the capacity over one departure fix, flights using other departure fixes may take off ahead of the restricted flights even though they were behind them in the original takeoff sequence for the runway. Similarly, a flight departing Des Moines that will be using J-80 westbound may be held on the ground awaiting a slot in the

overhead flow on J-80, while a flight that taxied out later and is not using J-80 is able to take off without delay. Many other local flow control and central flow control measures alter the sequence determined by initial estimates of arrival times at constrained resources. These alterations of sequence are done to make maximum use of total air traffic system resources, thus maximizing efficiency and minimizing total system delay. They are also artifacts of the existing structure of ATC which will not necessarily exist under NextGen.

While the FCFS rule today is predominantly applied near the constrained resource, both spatially and temporally, one major exception to this is the Ground Delay Program (GDP), designed to reduce arrival traffic flow rates by controlling takeoff times of individual flights that have not yet departed. Using CDM, more sophisticated rules for preserving fairness during GDPs have evolved over the last two decades. These are described fully in the next section. In this process, known today as RBS, the projections of "first-come" times at the destination airport are taken from the published flight schedules rather than extrapolation of speed or flight plan estimates.

While CDM represents important developments in FP, it is important to note that these methods are only used when specific Traffic Management Initiatives (TMIs) are put in place to cope with temporary reductions in capacity. By and large, airborne and surface operations are still governed by FCFS and usually applied by human controllers in a manual fashion. Still, the principle of establishing an initial flight sequence based upon an Estimated Time of Arrival (ETA) at a resource has already been extended into air traffic automation. The Converging Runway Display Aid (CRDA) has been a part of terminal automation software for nearly 20 years and embodies this principle. The Traffic Management Advisor (TMA), part of the Center Terminal Automation System (CTAS) software developed for FAA by NASA has been in use in en route centers for many years, incorporating FCFS into automation software used by controllers every day.

Thus, it is expected that in far-term NextGen, when the ANSP looks for instances of contention in their analysis of all 4DT plans, projections of contention will be determined by the initial 4DT sequence. Before departure, the fourth dimension (i.e., time) is generated as a part of the flight plan. Once in flight, the estimated times at points ahead are projected either by flight planning systems or on-board Flight Management Systems. Under far-term NextGen, the projected times used to determine "first-come" at constrained resources may be substantially different from manual projections of human controllers. For this reason, the Study Team uses the term First-Projected, First-Served (FPFS) to refer to the form of FCFS supported by more advanced, automated projections using Estimated Time of Arrival (ETA) at waypoints along the trajectory. FPFS is used throughout this report to refer to the evolutionary concept of FCFS in the far-term NextGen environment.

4.2. RATION-BY-SCHEDULE (RBS)

RBS is a fundamental component of the CDM capabilities introduced in the US in the mid-1990s. CDM activities grew out of a desire on the part of the scheduled airlines and the FAA to improve planning and control of GDPs. As mentioned under FCFS, GDPs are a specific Traffic Flow Management (TFM) technique employed by the ANSP to reduce demand at an arrival airport that is expected to have a temporary reduction in its acceptance rate. GDPs delay flights prior to their departure by an amount necessary to ensure the arrival rate will not exceed the acceptance rate at the constrained arrival airport.

The CDM effort began in the mid-1990s under the name FAA/Airline Data Exchange (FADE). The FAA and, more specifically, the Air Traffic Control System Command Center (ATCSCC) realized the need for more updated information on the status of flights currently delayed due to mechanical or other problems, or even cancelled unbeknownst to the ATCSCC. The FAA also recognized the value of timely information regarding airline intentions vis-à-vis flight cancellations and delays over the next few hours. At the same time, the airlines did not feel the allocation procedures used by the ATCSCC were always fair and efficient. In addition, each

airline wished to gain more control over how delays were allocated among its own flights and desired more transparency into the overall process. Thus, both the airlines and the FAA had specific, although different, objectives that motivated their participation in CDM.

A key component in the development of CDM was the introduction of RBS. It is instructive to review its essential features that led to acceptance by the CDM community. GDPs are motivated by a reduction in the airport acceptance rate, or arrival capacity, at a particular destination airport. The basic control implemented involves delaying flights on the ground at their origin airports. However, the problem is modeled by assigning each flight a revised arrival time or slot. Thus, if a flight's arrival is delayed 20 minutes, then this is converted into a 20 minute departure delay. Prior to the use of CDM procedures for GDP planning, the revised flight arrival times were assigned using the Grover Jack algorithm. To illustrate its operation, consider the following list of flights:

Figure 4. Original Schedule

FLT	SCHED	EST
AA205	1600	1600
AA34	1602	1602
UA10	1603	1603
US98	**1604**	**1614**
UA610	1605	1605
US105	1607	1607
CO205	**1608**	**1618**
US225	1610	1610
UA135	1611	1611
C045	1612	1612

The first column is a selection of hypothetical flights. The second column gives the scheduled arrival time (SCHED). The third column gives the estimated (i.e., earliest) arrival time (EST). Note that EST of two flights is 10 minutes later than SCHED. This might be due to internal airline problems such as mechanical delays or delayed inbound flights. Suppose that the normal airport acceptance rate is 40 arrivals per hour and that the rate has been reduced to 20 arrivals per hour under a GDP. This is

conceptualized by allowing one arrival every three minutes (i.e., an arrival "slot" is created every three minutes). The output of a GDP is the assignment of each flight to an arrival slot. Grover Jack prioritized flights based on their estimated arrival time. Thus, flights were ordered by increasing the value of EST and slots assigned in order, illustrated in our example below:

Figure 5. Grover Jack Adjustment Results

FLT	SCHED	EST	SLOT
AA205	1600	1600	1600
AA34	1602	1602	1603
UA10	1603	1603	1606
UA610	1605	1605	1609
US105	1607	1607	1612
US225	1610	1610	1615
UA135	1611	1611	1618
C045	1612	1612	1621
US98	**1604**	**1614**	**1625**
CO205	**1608**	**1618**	**1628**

It can easily be seen that the Grover Jack priority rule implicitly imposed a strong disincentive for airlines to provide updated estimates of flight arrival times. Specifically, the result of informing the FAA of the internal delays on US98 and CO205 is that these two flights are given lower positions on the priority lists and as a result they receive more delay. For example CO205, after suffering 10 minutes of delay due to internal causes (1608 to 1618), received an additional 10 minutes of FAA-assigned delay (1618 to 1628). The airlines referred to this phenomenon as the double penalty, and it initially represented a strong impediment to progress in the initial FADE discussions.

RBS evolved through the FADE/CDM discussions and experiments. Among other desirable features, it eliminated the double penalty. RBS involves a conceptually simple change to the prioritization rules: rather than ordering flights by estimated arrival time (EST), they are ordered by scheduled arrival time (SCHED). The result for our example is shown below:

Figure 6. RBS Schedule Adjustment Results

FLT	SCHED	EST	SLOT
AA205	1600	1600	1600
AA34	1602	1602	1603
UA10	1603	1603	1606
US98	**1604**	**1614**	**1609**
UA610	1605	1605	1612
US105	1607	1607	1615
CO205	**1608**	**1618**	**1618**
US225	1610	1610	1621
UA135	1611	1611	1625
C045	1612	1612	1628

Note that CO205 receives slot 1618, which implies that the only delay it incurs is its original internal delay. There is a problem, however, with US98. Its slot time is actually earlier than its EST, which implies that it will be unable to use its assigned slot. This problem can be solved by another important CDM feature, the substitution process. Once the initial RBS assignment is made, US can exchange the slot assignments for US98 and US105. Note that US105 has an EST earlier than the 1609 slot time, so it can use this slot and US98 can use the slot (1615) initially assigned to US105. The final result is given below:

Figure 7. Slot Exchange Adjustment Results

FLT	SCHED	EST	SLOT
AA205	1600	1600	1600
AA34	1602	1602	1603
UA10	1603	1603	1606
US105	**1607**	**1607**	**1609**
UA610	1605	1605	1612
US98	**1604**	**1614**	**1615**
CO205	**1608**	**1618**	**1618**
US225	1610	1610	1621
UA135	1611	1611	1625
C045	1612	1612	1628

The overall CDM process for the assignment of arrival slots GDPs can be summarized as follows:

1. Initial allocation of slots to flights using RBS
2. Internal airlines slot-to-flight reassignment using cancellation and substitution process
3. Cross-airline slot exchange using compression, slot credit substitution and adaptive compression.

Note that the simple substitution illustrated earlier is an example of the potentially very extensive process used by airlines, involving large numbers of substitutions, as well as strategic cancellation of certain flights. Specifically, when extreme delays force airlines to cancel some flights, they have the flexibility to choose which flights are cancelled and can combine flight cancellations with a string of substitutions to substantially reduce the delay on multiple flights. Also, note the additional capabilities provided in step 3. It provides certain processes that allow airlines to interchange slots they cannot use (e.g., because of internal delays) for slots they can use. While the preceding description might make the process seem somewhat static, in fact it is highly dynamic. Specifically, there is typically a dynamic interplay between steps 2 and 3 with elements from each being executed multiple times over the course of a GDP.

Recall that the initial motivation for FADE/CDM involved developing better, more updated information. This was accomplished and a key component of CDM now is timely information sharing of NAS status among the FAA and flight operators. This information exchange also includes the projected impact of weather on NAS capacity and other initiatives planned by the FAA. This allows both the FAA and the flight operators to make better decisions.

From these initial developments to support GDP planning, a CDM philosophy has emerged. Broadly speaking, it represents an application of the principles of

information sharing and distributed decision making to TFM. Specific goals include the following:

- Generating a better "knowledge base" by merging information provided by the airspace users with the data that are routinely collected by directly monitoring the airspace
- Creating common situational awareness by distributing the same information to both traffic managers and airspace users
- Creating tools and procedures that allow airspace users to respond directly to capacity/demand imbalances and to collaborate with traffic flow managers in the formulation of flow management actions.

Specific FP principles that have emerged are as follows:

- One must carefully consider the relationship between FP methods and user incentives. The switch from Grover Jack to RBS removed a disincentive to provide flight time status information. Any major change in FP can have a significant impact on flight operator incentives and behavior (both positive and negative). These should be examined and understood carefully before implementing such changes.
- RBS evolved from the CDM activities through an extensive set of human-in-the-loop experiments. It has now been in use for over ten years and has been enhanced in a variety of ways. It is safe to say that RBS is a de facto standard and a broadly accepted criterion for fair allocation in TFM.

From its beginning in the 1990s the CDM community has remained very active and has been the source of a wide range of TFM innovations in the US. The FAA, flight operators, and TFM experts are included in the community, augmented by members of the research and development community. While flight operator participation initially involved the major scheduled air carriers, over time participation has

expanded to a broad range of carriers, both small and large, including package carriers, business jets, and non-scheduled operators.

While non-scheduled operators have now been participating in the CDM community for several years, RBS does not naturally accommodate non-scheduled flights. Since RBS is based on schedules, if a flight does not have a scheduled arrival time, some replacement must be obtained to determine priority. Of course, as soon as a flight files a flight plan, it generates a projected arrival time. However, if this time is used to set a flight's priority, it generates a situation where the information provided close to the time of departure determines a flight's priority. This leads to a setting where the information provided and resources obtained are closely linked, leading to the potential for "gaming." Additionally, there is nothing to prevent the last minute overloading of an airport's arrival capacity with such requests, or the potential that many non-scheduled flights could receive priority over regularly scheduled flights from the major air carriers.

Two approaches have been developed for handling non-scheduled flights during GDPs: DAS (Delay Assignment) and General Aviation Airport Program (GAAP) program. Under a DAS-GDP, non-scheduled flights receive the average delay assigned to all scheduled flights. This approach works well in the case when there are a relatively small number of non-scheduled flights. However, it can lead to excess congestion and the need for program revisions when this number becomes moderate to large. Under a GAAP-GDP, slots are initially allocated to scheduled operators and non-scheduled operators are then allocated the remaining slots on a FCFS basis. A maximum delay is defined so that no unscheduled operators receive more than this value. This approach places a heavier burden (i.e., more delays) on non-scheduled operators and is a de facto prioritization system favoring scheduled over non-scheduled operations. It should be noted that scheduled flight operators also generate a small number of non-scheduled flights, which are treated in the manner described above. These approaches have worked reasonably well over the years, but there are some challenges associated with both. Thus, it is safe to say that challenges remain in

the application of RBS, and CDM methodology more generally, to non-scheduled flight operators.

Over the years there have been a variety of enhancements to initial GDP planning tools. These tools were also adapted to address en route problems. Specifically, tools and procedures were developed to implement airspace flow programs (AFPs). AFPs apply GDP-like capabilities to address en route congestion problems. In fact, this is done in a rather direct way. First, a volume of congested airspace called a flow constrained area (FCA) is identified. The purpose of the AFP is to restrict the flow through the FCA over a period of time. Time slots are defined at the boundary of the FCA and these are then allocated to flights in a GDP-like fashion. RBS is used as the FP method. To do this, scheduled arrival times are required at the boundary of the FCA. These are obtained by translating each flight's scheduled arrival time at its destination airport to the time it would be required to reach the FCA. A potential problem with this approach is that the flight demand on the FCA depends on which flights file their flight plans through the FCA. Thus, in this setting the flight plan information provided by the flight operators influences their use of the constrained resources, opening the potential for "gaming." In concept, an airline could file extra flight plans through the FCA in order to obtain earlier use of the resource. At this point it does not appear that such "gaming" has been a problem. Nonetheless, it should be noted that there are some challenges and potential pitfalls associated with the extension of RBS to the en route environment. (Note: In describing the potential for contention in en route airspace in this context and elsewhere in the report, the Study Team recognizes that far-term NextGen improvements are likely to make such situations rare *(Section 5)*.

4.3. TRENDS TOWARD TRAJECTORY FLEXIBILITY

Recently the TFM R&D community has been moving toward greater flexibility in the specification of user intent. This is probably most notably embodied in the development of Collaborative Trajectory Options Program (CTOP). CTOP allows flight operators to express a rich set of options for a flight together with preference

information applicable to those options. These options and preferences are embodied within the flight's trajectory option set (TOS). When a flight encounters a scarce resource, the flight's TOS would be queried at the time resources are allocated. The TOS might specify that a flight would prefer to fly its preferred flight plan as long as no more than 10 minutes of added delay need be taken (e.g., in the form of ground delay). However, if over 10 minutes were required, then the operator would prefer that flight to depart immediately on a specified alternate route. This is a simple example but the TOS allows for multiple options and more complex tradeoffs.

CTOP represents a trend away from static, single flight plan information toward a richer, more dynamic information set. That is, one can view the TOS as the replacement of a single flight plan with a range of alternative flight plans together with decision logic for choosing among the alternatives. CTOP developers, as well as flight operators, have expressed the opinion that this represents a future trend toward flexibility in expressing user intent. That is, rather than expressing the intent for a flight as a single flight plan, intent is expressed as a range of options. The Study Team notes a possible tension between this viewpoint and concepts stated in NextGen documentation, which are based on a 4DT. In any event, it is important that future FP methods be adaptable to this more flexible point of view.

4.4. LIMITATIONS OF CURRENT FP: SYSTEM EFFICIENCY VS. FLIGHT OPERATOR EFFICIENCY

A key philosophical component underlying CDM is the recognition that there can be a very large discrepancy between maximizing NAS efficiency (e.g., flight delay minimization or throughput maximization), and minimizing the costs incurred by individual flight operators. ANSP metrics and systems generally do not recognize that the cost of a 30 minute delay on flight A, and the cost of a 30 minute delay on flight B, could vary substantially. However, CDM processes allow flight operators to reallocate resources allocated to their own flights and, thereby, take into account such cost variations. For example, the cancellation and substitution process allows a particular flight operator to reallocate GDP slots among its own flights. Further, a

certain amount of cross-airline resource exchange is allowed through compression, slot credit substitution and adaptive compression. Nonetheless, evidence indicates there still may be substantial additional benefit possible through improvements in the ability of flight operators to optimize their internal cost functions. This can be illustrated through a simple example:

In *Figure 8* below, four flights are described. They are owned by two different flight operators (UA and AA). Suppose that some FP method (e.g., RBS) has ordered them as shown. Note that UA would want to exchange the position of UA1 and UA4, since UA4 is a high priority flight. Such an exchange would be possible under the cancellation and substitution process. However, suppose further that this exchange cannot be executed because the first slot is too early for UA4.

Figure 8. Initial RBS Allocation

Flights	Owner	Owner Priority	FP Order
UA1	UA	Low	1
AA2	AA	High	2
AA3	AA	Low	3
UA4	UA	High	4

Now suppose that it is feasible for AA2 to move up one slot and for UA4 to move up one slot. In fact, there is a cross-airline exchange of slots that can provide benefit to both UA and AA. It is illustrated in the following table.

Figure 9. Adjusted for Slot Exchange

Flights	Owner	Owner Priority	FP Order
AA2	AA	High	1
UA1	UA	Low	2
UA4	UA	High	3
AA3	AA	Low	4

Under this exchange, AA moves up its high priority flight, AA2, in exchange for moving down its low priority flight, AA3. Similarly, UA has moved up its high priority flight, UA4, in exchange for moving down its low priority flight, UA1. Note

that, if feasible, UA may also wish to exchange the positions of UA1 and UA4, through a normal substitution. Viewing this exchange in terms of slots owned by flight operators, we can see that AA traded the 2nd and 3rd slots to UA, and received in return the 1st and 4th slots. In this case, both flight operators are better off and can improve their internal costs. Exchanges of this type are not currently supported by existing CDM processes or FP methods.

This is a very simple example but it illustrates the potential to improve the ability of individual flight operators to optimize their internal cost functions. In the NAS metrics/values list, improvements in performance in this area fall in the category of Economic (Allocative) Efficiency. This is distinct from NAS Capacity, Efficiency, and Economy, which refers to more standard ANSP metrics, such as those related to flight delays. When discussing new FP methods we will indicate those which may produce improved performance as illustrated in this section.

5. FAR-TERM NEXTGEN OPERATING ENVIRONMENT

The deployment of NextGen over the next decades offers unique opportunities to improve the capacity and efficiency of the NAS. While there are many uncertainties about how important capabilities will be implemented, several key NextGen capabilities will affect the feasibility and benefits of FP policies. To set the context for this analysis, the Study Team met with NextGen engineers and architects to understand the likely evolution of NextGen capabilities for the far-term. For the purposes of this study, we assumed that the following capabilities and approaches would be deployed:[5]

- Safety remains the overriding, primary operational rule and is never subordinated to FP tradeoffs.
- Trajectory-Based Operations (TBO) are the basis for routine NAS operations, meaning that each flight has an associated 4DT that covers the entire flight.
- The ANSP automation platforms support strategic and tactical planning such that stakeholders can propose preferred flight profiles or 4DTs (including alternatives for the same flight) well in advance (e.g., published schedules) as well as up to, and including, the operation of the flight or flight segment. These proposals are evaluated and prioritized according to the predetermined FP rules and the outcomes are made known to the originators. Any affected stakeholders are kept apprised of changes. Computing power is sufficiently robust to allow for real-time point processing or auctioning in support of FP within the ATS automation.
- Automation has developed and been implemented across the NAS such that the role of air traffic controllers has evolved to that of air traffic flow managers, whose responsibilities are consistent with the NextGen precept of "manage by exception." The goal is that sector saturation based on human limitations (or "Red Sectors") is eliminated as an en route airspace constraint.

[5] These assumed NextGen capabilities are not intended to reflect official FAA plans or budgets. They are based on discussions with experts on the likely capabilities for far-term NextGen and are used solely to provide a technical context for evaluating possible FP policies and concepts.

- Mixed equipage of aircraft in the NAS persists, although most commercial aircraft (e.g., air carriers, freight carriers, on-demand carriers) and many GA operators employ all of NextGen-enabling avionics and crew training necessary to exploit NextGen capabilities (e.g., collaboration with the ANSP using data link messaging to facilitate prioritization aloft). Flight Object data sets can incorporate operator or ANSP FP preferences (e.g., NAS efficiency and/or societal values).
- Ubiquitous net-centric information sharing, and the necessary communications (data and voice) necessary for FP real time information sharing and exchange, are in service both on the ground and in the avionics.

5.1. THE VISION FOR OPTIMIZED TRAFFIC FLOW

NextGen Operational Improvements (OIs) are very comprehensive in addressing corrections to today's air traffic problems and planning for tomorrow's traffic so that the travel experience will be less disruptive. Trajectory management is being designed to give each operator the opportunity to optimize business objectives to the maximum extent possible, consistent with safety and the presence of many other flights. A simplistic analogy with highway traffic illustrates in two dimensions how NextGen air traffic could flow in the far-term future.

Imagine speeding along a six-lane superhighway with ample room to pass slower cars and to allow faster cars to pass you. Then you see a sign indicating that a toll plaza is ahead and that some of the tolling lanes are closed, causing all traffic to slow and all drivers to jockey for position as they attempt to negotiate this constraint with the least delay to their travels. Everyone is guessing which lane is going to move the quickest, merging right and left into other lanes and some drivers are even driving down the shoulder in an attempt to get to the head of the line. Now insert a "choreographing" system that polls all the traffic approaching the toll plaza and estimates when each car would get there to compile a handling sequence that is fair to all. Each driver is given another car to follow and all available tolling lanes are equally utilized. Recently, equipment was even installed at the toll plaza that automatically reads transponders in

cars that have bought them, enabling the toll to be charged while driving through on two special lanes at highway speeds. These drivers get to pass the constraint without delay and, thus, reduce the total demand on the manual lanes.

On another nearby freeway, High Occupancy Tolling (HOT) lanes have been built. Some of the traffic that chooses to pay the toll speeds along on these lanes while the rest of the freeway is congested at peak times of the day. Laws specify that vehicles carrying a specified minimum number of passengers and/or powered by environment-friendly technology (e.g., hybrids, plug-in electric, and hydrogen fuel-cell) may also use these lanes, perhaps with reduced tolls or toll-free, to reflect social policy goals.

These are visions of operations at resource contentions (i.e., the toll plaza, and the freeway lanes) where some sort of prioritization would have been invoked to choreograph the flow through the constrained resource. Now, replace the highway vehicles with airplanes approaching a constrained airport and add the vertical dimension. With FP as the choreographer, aircraft can approach and land at this area of contention safely, smoothly and more efficiently. Some flights with precision navigation and self-separation capability can use another runway that cannot be utilized otherwise, eliminating any delay for themselves and reducing it for all. At another airport, the landing slots at peak demand times of the day are auctioned to the highest bidders with others having to wait until the demand slacks off. Still another possibility is for priority to be given to airplanes using advanced clean energy propulsion technology.

5.2. EXAMPLE OF FP – A SIMPLE SCENARIO

The following scenario is a simple example of an environment in which FP would need to be invoked in the Far-Term NextGen environment. Its simplicity could be expanded to cover other scenarios. In the NextGen 2025 environment, the anticipated utilization of FP will be when demand for a particular resource causes contention for the resource, be it an arrival fix, a departure runway, or other air navigation resource.

There are ten aircraft approaching Chicago's O'Hare Airport (ORD) that are between one and two hours from the Final Approach Fix (FAF) for their assigned runway. All aircraft are on a direct trajectory to the FAF and all ten aircraft are anticipated to arrive at the fix within a two minute time window, at the same altitude. The arrival rate for this FAF crossing is one aircraft per minute, all other arrival runways are fully occupied, and there are open FAF crossings before and after the two minute window. Thus, the group of ten aircraft will need to be sequenced such that they arrive at the FAF in one minute intervals. FP will determine the sequence of these ten aircraft well in advance of any physical conflict.

5.3. FAR-TERM NEXTGEN FP

FP is the process by which aircraft are sequenced to use a resource that is under contention. When contention is projected, FP rules will decide "who goes first" by allowing one to proceed and directing others to move or wait.

5.3.1. WHO GOES FIRST?

If NextGen capacity improvements do not eliminate all resource contention, then FP will be invoked to determine how the flights will be sequenced. Increased shared situational awareness of the contention problem for all operators and the ANSP might result in voluntary flight trajectory modifications from one or more operators that eliminate the contention. If the resource contention is detected far enough in advance, operators could collaborate with the ANSP in developing the resolution. The 4D geometry of the contention situation and the number of aircraft in contention for the same resource can complicate, and possibly limit the range of resolutions.

In any case, the paradigm is operator negotiation with the ANSP to resolve contention, with the resulting decision executed by the ANSP. The operator's options are:

- "Take me out of the situation."

- "Keep me in the game, and here are the limits in altering my trajectory that I am willing to accept at this time."
- "Here is my priority for this flight operating through this point of contention for the ANSP to use when evaluating against other contenders."

Contention resolutions could be treated differently, depending on whether the flights in contention are operated by the same or different operators:

- **Relative Priority:** If the aircraft in contention are from the same operator, then that operator's prioritization relative to its aircraft would be respected by the ANSP.
- **Absolute Priority:** If the aircraft in contention are operated by different operators, FP priority rules between operators would be invoked by the ANSP.

5.3.2. HOW DOES A FLIGHT OPERATOR INDICATE PRIORITY TO AN ANSP?

The flight priority could be established and recorded in the Flight Object as a static value for later use in the resolution of any resource contention along the flight path. Alternatively, the FP system could allow the operator to change flight priority at will as a component of the real-time Flight Object. The FP system could then query the Flight Object for that flight's priority value only if and when a contention arises along the trajectory. Other priority ground rules and issues include:

- An operator can only set priorities relative to their own flight operations.
- These relative priorities can be viewed by the ANSP and judgments made between aircraft within the operator's fleet.
- An absolute priority scale is required to adjudicate contention when multiple or different operators are involved.

- There could be a mechanism for the ANSP to set a minimum priority for access to a resource based upon the demand.

6. FAR-TERM FP CONCEPTS

Through the literature search, the workshops, and internal discussions, the Study Team, developed a list of candidate FP concepts to be evaluated qualitatively against the metrics/values described in *Section 3*. This list is intended to include all of the plausible ideas discovered but is not intended to be comprehensive or exclusive to other ideas that may be suggested in the future.

In this section, FP concepts are described and evaluated. Each concept was evaluated as to whether it would have a positive, neutral, or negative effect on the metric/value. As most of the concepts are not yet fully developed, the Study Team approached each concept without postulating the details of how it might be implemented in far-term NextGen. This resulted in the Study Team evaluating each concept in its purest form, although potentially significant implementation issues pertaining to each concept were identified. For clarity of analysis, each concept was evaluated independently, even if some of the concepts could be combined to construct a comprehensive solution.

Major inputs to the evaluation process were elicited during Workshop 2 *(Section 2)*. Participants provided detailed comments on each of the concepts, including assessments of business impact, operational considerations, and feedback on each of the metrics/values. Over the four workshop sessions, the Study Team received comments from experts representing large airlines, on-demand operators, air cargo operators, GA operators, government and academic researchers, the air traffic controllers union, and airport operators *(Appendix A)*.

Subsequently, the Study Team convened several internal meetings to digest the information generated at the workshop, extract significant information from the responses, and conduct additional assessments. These discussions proved helpful in understanding the potential usefulness of the concepts in far-term NextGen. Simultaneously, the Study Team observed that the metrics/values were of unequal weight and that any metric/value is likely to be weighed differently by different stakeholders.

Nevertheless, comparative analysis yielded general insight into the potential utility of FP concepts. The Study Team also concluded that two additional metrics/values were useful in examining the concepts: Scope and Implementation Risk.

The following section describes the Study Team's assessment of each concept. Each evaluation includes a brief description of the concept, discusses its pros/cons, assesses the concept according to each metric/value, summarizes the analysis results, provides conclusions, and lists issues pertaining to that concept that should be to be researched or resolved.

6.1. FIRST-PROJECTED, FIRST-SERVED (FPFS)

Concept Description: First-Projected, First-Served (FPFS) is a transformation of the First-Come, First-Served (FCFS) concept, in which priority is established by being the first flight projected to arrive at a point along a 4DT, a takeoff or landing slot, or another constrained resource. FPFS establishes the sequence of flights on the basis of their projected arrival time at a constrained resource, without regard to other values or objectives. These projections of arrival times begin with the published schedule for the scheduled carriers, but are replaced with times from the pre-departure 4DT negotiation after flight plans have been filed. The 4DT times may be renegotiated as necessary due to changing flight conditions once en-route. For unscheduled operators, prioritization will be based on the ETAs contained in their initially negotiated 4DT. In both cases, all subsequent prioritization will be based on the operators' ETAs as embodied in the cleared 4DT.

Pros: FPFS comports with a basic sense of fairness and is consistent with a cultural norm that does not favor "line jumping." Currently, aircraft operators and air traffic service providers accept FCFS as the default prioritization rule in current operations because it is easy to understand, even in complex or congested traffic environments. In like manner, FPFS could maximize aircraft throughput at a constrained resource. It could provide a starting sequence in cases of resource contention by showing the unperturbed order in which flights would arrive. Any other prioritization scheme

could begin with FPFS order of arrival and make appropriate modifications to achieve other values.

Cons: FPFS does not necessarily maximize NAS-wide efficiency or result in the allocative efficiency of NAS resources. Additionally, FPFS does not by itself honor other values that might be applied to the order of flights to satisfy other objectives.

Analysis: FPFS has utility because it conveys the natural sequence of flights in the absence of other prioritization values, or the imposition of flow measures by the ANSP. It has NAS-wide scope because the 4DTs that contain the FPFS projected times contain the entire gate to gate trajectories. Further, each iteration updating the 4DTs potentially results in a new sequence at each constrained point, reflecting the most recent projections of FPFS.

Figure 10. FPFS Concept Evaluation

Metric	Evaluation	Comment
NAS Capacity, Efficiency and Economy	Neutral	Does not contribute directly to increasing efficiency and throughput, although it generally prevents wasting "slots"
Fairness	Positive	Perceived as fair through historical use; comports with basic notions of fairness
Transparency	Positive	Clear, understandable rules for determining projected times along track in software would be used by all parties
Honors Aircraft Operator Preferences	Neutral	Does not allow operators to express priority preferences
Flexibility	Neutral	Allows ANSP to move aircraft into position that are able to use that resource, but insensitive to operator preferences
Predictability	Neutral	Difficult to predict which aircraft will get priority, but next available aircraft will always be served
Minimizes Aviation's Environmental Impact	Neutral	Does not consider environmental impact
Societal Values	Negative	Does not provide mechanism for incorporating societal values
Passenger/Shipper Service Quality	Neutral	Limits ability of operators to reduce delays for higher priority flights; probably would "spread the pain" equally among flights
Resilience/Recoverability	Positive	Ensures continuous use of resources as long as flights are there to use them

Economic (Allocative) Efficiency	Neutral	Does not actively consider economic efficiency
Incentive Compatibility	Negative	Might encourage operational gaming in order to gain a competitive advantage
Scope	Positive	Applies across the trajectory
Implementation Risk	Positive	Predecessor form (FCFS) already in use

Conclusion: FPFS could accommodate conflict resolution and provide initial sequencing upon which other prioritization concepts can be exercised to reflect other values in the final sequence.

Issues to be Researched or Resolved: Research is needed to investigate how best to implement this dynamic sequencing tool. The accuracy of projected times at various time horizons, the averaging time intervals to use when determining flow rates at various times in the future and the treatment of different projected time accuracies (especially between airborne flights and those still on the ground) all need additional research. When best to apply other prioritization values to alter the FPFS sequence must also be determined so as to prevent gaps in the flow at the constrained resource.

6.2. PRIORITY-BY-SCHEDULE (PBS)

Concept Description: In the far-term NextGen timeframe, Priority-by-Schedule (PBS) is a concept in which the published schedule forms the basis for prioritization during the 4DT negotiation. For resolving potential contention in the en route airspace, a "scheduled time" for a waypoint would be computed by adjusting a scheduled arrival or departure time by an estimated flight time. Since PBS requires a published schedule, it does not apply to non-scheduled operators in a direct way. For en route airspace contentions, for non-scheduled operators the 4DT could be the basis for prioritization. Intra- and inter-operator swapping of ETAs would be allowed under this concept.

Pros: PBS should receive a high level of acceptance from operators based on two decades of experience with RBS within the CDM community. One of the major strengths of PBS is that it focuses on the schedule as a key performance driver. Delay

against schedule is one of the most important performance metrics used by operators, the FAA, and the traveling public to evaluate NAS performance. PBS has strong incentive compatibility properties in that it encourages accurate and timely provision of information and could provide a strong basis for future prioritization efforts.

Cons: While maximizing individual operators' freedom of choice, PBS does not provide a means for allocating scarce resources to high-value flights. PBS does not provide a means for mediating priorities among operators, nor does it allow them to exchange priorities among themselves. PBS does not easily incorporate other objectives such as passenger service, system throughput, societal values, and minimizing environmental impact.

Analysis: Schedule-based prioritization has demonstrated its ability to maximize the use of constrained NAS resources within the limits of current technology. PBS could provide operators flexibility and treats all operators fairly. Current participants consider schedule-based prioritization to be fair and equitable *(Section 2)*, which could reduce implementation risk. However, as the traffic balance shifts between scheduled and non-scheduled operators, there is uncertainty as to the limits of extensibility of this concept. This concept preserves the desirable attributes of the schedule but carries with it the associated rigidity.

Figure 11. PBS Concept Evaluation

Metric	Evaluation	Comment
NAS Capacity, Efficiency and Economy	Neutral	Uses available NAS capacity effectively but does not explicitly have mechanisms to increase capacity
Fairness	Positive	Should be perceived as fair by all operators
Transparency	Positive	Rules and algorithms will be explicit.
Honors Aircraft Operator Preferences	Positive	Allows operators to make the best use of their resources
Flexibility	Neutral	Provides substantial flexibility to an operator within its network of flights; inflexible for ANSP

Predictability	Positive	Provides high degree of predictability
Minimizes Aviation's Environmental Impact	Neutral	Does not consider environmental impact
Societal Values	Negative	Does not provide mechanism for incorporating societal values
Passenger/Shipper Service Quality	Positive	Promotes performance reliability, allowing all operators to deliver better customer service
Resilience/Recoverability	Neutral	Places ability to react to changing conditions in the hands of the operators
Economic (Allocative) Efficiency	Positive	Increases the probability of high-value use of scarce NAS resources
Incentive Compatibility	Positive	PBS encourages operators to honor their own schedules
Scope	Positive	Applies to all operators and across the trajectory
Implementation Risk	Neutral	Extension to include non-scheduled operators introduces moderate risk

Conclusion: The transition to TBO in the far-term highlights the need to address all constraints along the 4DT. After initial negotiation, the ETA should be the surrogate for the schedule. Prioritization on the basis of an ETA can incorporate all operators, including non-scheduled. With those modifications, PBS warrants further exploration.

Issues to be Researched or Resolved: Research is required, supported by simulation, to develop a detailed mature concept of operations for schedule-based prioritization for gate-to-gate trajectory operations.

6.3. FIRST-FILED, FIRST-SERVED (FFFS)

Concept Description: First-Filed, First-Served (FFFS) describes a concept in which a flight's priority would be established by the order in which the request (e.g., a 4DT flight plan, or a request to modify the plan, etc.) was submitted to the FAA. When a request is made, resource availability would be assessed and the request approved provided the resource had not already been previously reserved. The reservation would be firm, unless overridden by a safety concern.

A somewhat analogous situation occurs in today's environment during high demand special events such as the Super Bowl and the annual Oshkosh GA air show. To manage the excess demand for access to the destination airport, the FAA requires IFR operators to obtain an IFR reservation within a defined time window. IFR reservations are approved on a first-request basis and later requesters can be locked out of the airport during the peak period.

Pros: The FFFS concept would encourage operators to develop and submit their best estimated operational intent information as early as possible, thus facilitating overall NAS resource planning. This concept is consistent with the notion of a negotiated 4DT contract, a central feature of far-term NextGen.

Cons: A first-filed 4DT might discourage other operators from planning a competing 4DT even though the first operator might well change its plans, thereby causing unnecessary planning iterations early in the process. This disadvantage could be mitigated somewhat by setting an earliest point in time relative to departure in which a 4DT could be filed. FFFS also might allow operators to secure access to constrained resources by filing early, even if they have little intention of actually using that resource, thereby thwarting competitors' access to the resource. In some circumstances, such as when there is heightened uncertainty due to weather, the ANSP would want to discourage early filing by opening the filing window closer to the time a flight operates.

Analysis: Limited experience using FFFS to manage temporarily highly constrained airport slots has been viewed as fair by operators. However, there is no experience using this concept across the NAS on a routine basis. Theoretically, FFFS could improve predictability but at a significant cost in flexibility. A method would have to be devised to test early intent information for likelihood of actually operating at these times, while at the same time allowing the operator to adjust the plan in response to changing conditions or priorities.

Figure 12. FFFS Concept Evaluation

Metric	Evaluation	Comment
NAS Capacity, Efficiency and Economy	Neutral	Does not directly maximize efficiency and throughput
Fairness	Negative	Perceived as fair if all operators have equal opportunity to file; non-scheduled operators are disadvantaged; would be considered unfair if scheduled operators whose business models are based on far in advance planning were advantaged over on-demand operators or GA whose business models are based on operating agility
Transparency	Positive	Clear rule
Honors Aircraft Operator Preferences	Negative	Allows operators to establish some priority within their own operation; honors preferences of scheduled operators but on-demand and GA operators might find themselves often being relegated to lower choices
Flexibility	Negative	Limits potential ability to respond quickly to changing conditions
Predictability	Positive	Provides high predictability under stable conditions
Minimizes Aviation's Environmental Impact	Neutral	Does not consider environmental impact
Societal Values	Negative	Does not provide mechanism for incorporating societal values
Passenger/Shipper Service Quality	Neutral	Neutral; probably would improve airline service because it protects airlines' schedules; might make on-demand carrier service worse because they might be relegated to lower ranking operating choices
Resilience/Recoverability	Neutral	No identified impact
Economic (Allocative) Efficiency	Negative	Priority rule does not encourage high value use
Incentive Compatibility	Negative	Incentive to file early and secure scarce resources; poses risk of gaming schedules.
Scope	Positive	Feasible to apply gate-to-gate
Implementation Risk	Neutral	Low level of technical risk but likely to engender strong policy resistance

Conclusions: Operators viewed FFFS as inefficient in a NextGen context and offered too many examples of opportunities for deceptive and non-competitive

behavior. Those opportunities could possibly be overcome but at the expense of added complexity and loss of the collaboration and incentive for accurate information sharing that exists today. Providing access to non-scheduled operators was also considered to be more problematic for this prioritization concept because their planning takes place closer to flight time than does the planning of airlines.

Issues to be Researched or Resolved: If it were desired to carry FFFS forward, assessing the value of early intent information and developing a reliable and effective methodology for testing the veracity and reliability of that information would be critical to its viability. Also, a mechanism would have to be developed for continually updating and approving operator intent information so that available operating times (i.e., 4DTs) are not wasted. Additionally, this mechanism should incorporate an incentive or penalty imposed on operators who do not relinquish unused resources or update filings in a timely way.

6.4. TRANSITIONAL PREFERENCE

Concept Description: For the purpose of this study, Transitional Preference is defined as giving an operating priority to the aircraft with more advanced equipage, whether or not that equipment enables improved system performance in that environment. To implement this concept, it might be necessary for FAA to define a level of NextGen equipage that would qualify an operator for this preferential treatment.

Pros: Giving operating preference to "NextGen-Equipped" aircraft – a "preferred operator" card so to speak – would provide incentives for universal equipage, which would benefit the NAS on a system level.

Cons: In its pure form, this construct does not necessarily contribute to improved NAS operations in specific operational contexts. It could be wasteful overall in an economic sense, because operators might be encouraged to equip with technologies that are not useful in environments they frequent, just to get an overall advantage in

places they do operate. In the long run, the value to individual operators in qualifying for the "preferred operator card" diminishes over time as more and more operators equip.

Expert airline representatives did not like this alternative. They were concerned about the possibility that operators would be forced into a race to equip with technology they did not need, just to avoid being bumped to a lower priority by more financially capable competitors. The result would be that operators would experience increased equipage costs without a corresponding benefit. Airline representatives thought that any priority derived from more advanced equipage should directly contribute to efficiency and capability in specific operating environments.

Analysis: Although the Transitional Preference alternative would encourage increased equipage, which in the long run would accelerate full implementation of NextGen and its benefits to the NAS overall, individual operators might be encouraged to equip with technologies that were not of direct benefit to their individual operations. Finally, the value of Transitional Preference to individual operators diminishes over time as more and more equip.

Figure 13. Transitional Preference Concept Evaluation

Metric	Evaluation	Comment
NAS Capacity, Efficiency and Economy	Positive	See analysis of Best-Performing, Best-Served (BPBS)
Fairness	Negative	Lack of direct link to improved operating opportunities perceived as unfair by operators
Transparency	Positive	Clear
Honors Aircraft Operator Preferences	Negative	Generates disconnect between operator investment decision and better service in the NAS
Flexibility	Negative	Does not increase operator ability to respond to changing conditions
Predictability	Neutral	Should not have a significant impact across the NAS.
Minimizes Aviation's	Neutral	Does not consider environmental impact

Environmental Impact		
Societal Values	Negative	Does not provide a mechanism to incorporate societal values
Passenger/Shipper Service Quality	Negative	Unnecessary expenditures could increase costs and fares
Resilience/Recoverability	Neutral	No identified impact
Economic (Allocative) Efficiency	Negative	Does not directly encourage high value use of constrained resources
Incentive Compatibility	Neutral	Encourages investment that ANSP desires but could result in gaming by operators as unintended consequence
Scope	Negative	Does not solve FP problem for similarly- or non-equipped aircraft, which will require other FP concepts for resolution
Implementation Risk	Neutral	No unusual technical hurdles but will require clear policy regarding qualifying levels of equipage, followed by careful oversight

Conclusion: The economic case for universal equipage for all aircraft in all airspace has not yet been made.

Issues to be Researched or Resolved: Further in-depth analysis is required to identify the combination of equipage and operational airspace that can be economically justified.

6.5. BEST-PERFORMING, BEST-SERVED (BPBS)[6]

Concept Description: For the purpose of this study, Best-Performing, Best-Served (BPBS) is a construct under which priority is based on having equipage that enables the aircraft to perform in an environment that allows enhanced operations. This concept might apply in airspace or ground environments segregated for aircraft with

[6] There are three classes of BPBS: (1) *Non-Interfering Service Improvement*, where benefits accrue to equipped aircraft and there is no disadvantage to non-equipped operations; (2) *Operational-Positive Preference*, where non-equipped aircraft are disadvantaged by giving preference to equipped aircraft only when there will be net system benefits operationally to NAS users (either through capacity enhancement, or through benefits to equipped outweighing dis-benefits to non-equipped, or both); and (3) *Societal-Positive Preference*, where non-equipped aircraft are disadvantaged to obtain a societal benefit (such as reduced emissions) or "tip the scale", even though there is a stand-alone, net operational dis-benefit to NAS users.

minimum equipage, or might be used to prioritize aircraft in mixed equipage environments (e.g., sophisticated operators go first, and less capable aircraft are accommodated later, or when the contention subsides.) Under this concept, highly performing aircraft generate additional system capacity and improved NAS performance, and it is those aircraft that receive priority.

Pros: BPBS serves the dual purpose of providing incentives to operators to equip with new technologies that provide a benefit to their own operations, while at the same time enhancing performance of the NAS. This construct, unlike the Transitional Preference, would not encourage non-useful equipage. Although in some contexts BPBS works to exclude some operators from access to some operating environments, it is being applied today in a variety of contexts and seems to be universally accepted as fair by all categories of aircraft operators. BPBS is consistent with the NextGen concept of Performance Based Operations (PBO), which is based on the notion that the NAS should support a range of aircraft performance levels and allow higher performing aircraft to take advantage of their performance capabilities. An underlying principle of the PBO concept is that aircraft operators should be encouraged to adopt capabilities that improve the performance and capacity of the NAS, and should reap the associated performance benefits.

Cons: BPBS can work to perpetuate segregated airspace and segregated operations, and might encourage a persistent class of under-equipped aircraft that will discourage or delay full implementation of TBO. In the long run, this could perpetuate sub-optimal operations into the NextGen NAS. Also, the benefits of BPBS must be demonstrated application-by-application if aircraft operators are to equip voluntarily.

Analysis: BPBS offers a significant contribution to system performance and efficiency by enabling high throughput operations for qualified aircraft. As the opportunity to participate is made available to all operators that meet the criteria, BPBS offers high transparency and perceived fairness. The long history of performance-qualifying operations (e.g., CAT II/III landings, RNP approaches)

supports the continued use of BPBS when operationally feasible. RTCA Task Force 5 has recommended the increased use of performance-based operations.

Figure 14. BPBS Concept Evaluation

Metric	Evaluation	Comment
NAS Capacity, Efficiency and Economy	Positive	Improves system performance by increasing capacity for qualifying operations
Fairness	Positive	Same opportunity available to all operators
Transparency	Positive	Clear qualifying rules
Honors Aircraft Operator Preferences	Positive	Operator equips based on its own return on investment
Flexibility	Positive	Should improve flexibility for qualifying flights
Predictability	Neutral	Should improve predictability for qualifying flights; less chance of being perturbed when bad events happen
Minimizes Aviation's Environmental Impact	Neutral	Does not consider environmental impact
Societal Values	Negative	Does not provide a mechanism to incorporate societal values
Passenger/Shipper Service Quality	Positive	Improves service quality for some operations
Resilience/Recoverability	Positive	Equipment should improve operations during disruptive weather events.
Economic (Allocative) Efficiency	Positive	Encourages economically efficient investments by operators
Incentive Compatibility	Positive	Encourages operators to equip with capacity enhancing technologies when in their economic self-interest
Scope	Negative	Limited to a relatively small fraction of NAS operations
Implementation Risk	Positive	Consistent with standard industry decision processes and criteria, long history of successful implementation.

Conclusion: BPBS improves NAS performance and efficiency by enabling high-throughput operations by technically qualified aircraft. Whereas, the opportunity to participate is in BPBS is made available to all operators with qualifying capability

and is logically linked to NAS benefits, BPBS is widely accepted by aircraft operators as fair. The precedent of BPBS in operations today (e.g., CAT II/III landings, RNP approaches) supports the application of BPBS in the NextGen NAS.

Issues to be Researched or Resolved: The positive cost/benefit of BPBS operations to the NextGen NAS overall, as opposed to local applications, should be confirmed. Refine the criteria for participation in BPBS and the effects of an application of BPBS on NAS performance, as well as the required precision and performance for each element.

6.6. MARKET-BASED PRIORITIZATION MECHANISMS

Concept Description: At its core, FP is about allocating a scarce resource. As such it is very natural to consider whether some kind of market mechanism would be appropriate. This would assure that the resource went to the party that valued it the most. In this section, market-based approaches involve true markets where real money is exchanged.

Market-Based Prioritization Mechanisms can be either:

- **Primary,** involving the sale of NAS access rights or priorities by the ANSP to the flight operators, where flight operators would pay the ANSP for the rights.
- **Secondary,** involving trading of access rights and priorities among the flight operators. Here, trading could involve the exchange of resources of value, possibly with a side monetary payment, or outright buying and selling. In a secondary market, flight operators would pay each other, and no money would go to the ANSP. Since the flight operators would need to "own" the resources before exchanging them, secondary markets require an initial allocation of resources by some method.

The Study Team considered several concepts for market-based alternatives:

- Prioritization by Auction
- Congestion Pricing
- Advanced Contract

6.6.1. Prioritization by Auction

Consistent with the definitions above, auctions can create primary, secondary, and/or hybrid markets:

- *Primary Market:* The pure form of a primary market would be prioritization by auction. That is, when contention for resources exists, priority would be assigned to the highest bidder. An auction could be conducted strategically during negotiation of 4DTs or in real time during flight, as contention for operating resources emerges. On the surface it might seem that an auction involving airborne flights would be impractical due to timing constraints. However, such an auction would, in most cases, be conducted using software-based "proxies" and parameters set by the participants. Thus, the outcome would be determined in near-real time. Auctions would be conducted through an "honest broker," a NASDAQ-like mechanism incorporated into the air traffic automation. The disposition of the proceeds would be of great concern to the aviation community and others. Proceeds could be remitted to the Airport and Airway Trust Fund, or they might be designated for specific uses based on how they were generated. Other possibilities exist.
- *Secondary Market:* A secondary market would provide flight operators the ability to exchange resources of value with possible side payments and also to buy and sell them. As with a primary market, an honest broker would be required to run the market. Such broker could be the ANSP; however, there is no reason why a private company could not perform this function.

- *Hybrid Primary / Secondary Market*: In such a case, the honest broker would run the market but, based on an agreed upon implicit initial allocation, the proceeds paid by the buyers would be directed to those who relinquished the priorities. In this case, the market would operate like a primary market but would effectively be a secondary market in the sense that the ANSP would not have cash inflow.

6.6.2. Congestion Pricing

Another type of primary market could be based on congestion pricing, somewhat similar to the HOT lanes used on toll roads where variable pricing for priority is used to manage congestion and delays. A congestion fee for FP would be levied on day of flight only if a resource (e.g., center airspace, terminal or departure point, or runway for arrival or departure) is contested. It may also be possible to include airport operations, such as taxi-in and taxi-out. This concept would work like a tolled lane where the fee changes to control congestion. The user decides whether to pay the fee or use the more crowded "free" route. It would be a simple and transparent process that focuses on the core problem – limiting congestion and delay for those willing to pay to avoid it. This concept assumes that there would be alternate lanes, fixes, routes.

6.6.3. Advance Contracts

Priority by advance contract means that an operator enters into a contract for priority with the ANSP well in advance of the flight operation. This contract provides the operator with a guaranteed level of service for the flight operation, thereby bounding delay from the departure gate to the arrival gate, in accordance with the limits, terms and conditions of the contract. The exact nature of this contract could take on any number of forms. The long-term ownership of an airport slot could serve as the basis for FP based on advance contract to the extent that it conveys specific day-to-day airport access rights to the owner. Differing levels of service for a trajectory could be purchased based upon the importance of the flight operation to the operator. More critical schedules for an operator would

be achievable through purchasing an advanced contract from the ANSP for that flight. There are many other possibilities. For example, the ANSP could sell exemptions into traffic management initiatives should they exist in far-term NextGen. The advanced contract could be limited to either departures, arrivals, or to part of the en route portion of the flight. The contract could provide for daily operation or for selected dates or days of the week.

The ANSP would sell the advance contracts to flight operators, representing a primary market. However, it is possible that these contracts also could be traded on a secondary market. The advance contract would allow operators to build certainty into their schedule based upon a highly predictable estimate of NAS access during times of constrained supply of NAS resources. Given the importance of schedules to airline service this concept would be of considerable value to scheduled carriers. That notwithstanding, non-scheduled operators could purchase advanced contracts to assure that a high level of service is afforded to their critical operations as well.

Pros: Planned NextGen net-centric information sharing capabilities offer the potential framework for implementing Market-Based Prioritization Mechanisms in FP. Market mechanisms are an objective and easily understood means for aircraft operators to signal the value of a particular operation to their business. In concept, a market mechanism could be used in any context, and the basic principles and processes for participating in a market are universally understood.

Markets encourage the best overall allocation of scarce resources throughout the aviation marketplace. Placing a monetary value on operating priority would encourage operators to use that priority for their highest value flights.

There is substantial precedent for federal government allocation of scarce resources through monetary auctions (e.g., for example the auction of radio spectrum and

mineral rights). Highway pricing is well established with toll roads; HOT lanes are being increasingly used to control congestion.

Cons: FAA's existing authority to auction air traffic operating resources such as 4DT reservations or FP preferences is not settled. However, it is well settled that FAA has the legal authority to authorize aircraft operators to trade or sell operating "slots" on the secondary market, provided the trading does not result in anti-competitive outcomes (*Section 7).*

During Workshop #2, airline representatives expressed reservations about market mechanisms. In particular, they cautioned against prioritization proceeds (from a primary market) becoming another "tax" on operators already struggling for profitability. This objection would not apply to a secondary market. Nonetheless, even secondary markets were not embraced by most represented aircraft operators. Overcoming industry skepticism would require strong evidence of the benefits of even a secondary market before the flight operators would be willing to accept this change.

Unlike the government's auctioning of mineral rights and frequency spectrum, the scarce NAS resources are temporary reductions in runway or airspace capacity. The degree and duration of the scarcity is often difficult to forecast, such as adverse weather conditions. Thus, the value of the auctioned slots could disappear with an early improvement in the weather, leaving the slot owners holding a resource contract that now has no value. To prevent this situation from occurring, those owning access rights to scarce resources would have an incentive to keep the restrictions in place until their paid advantage is realized, even though overall system efficiency would suffer.

While NextGen has strong information handling and communications requirements, the day-of-operations markets described would certainly represent an information technology and communications challenge. Auctioning or trading resources, possibly

involving airborne flights, among various flight operators would require the real-time execution of an iterative auction with multiple participating organizations, or a dynamic congestion fee system.

Analysis: Three separate Market-Based Prioritization Mechanisms were considered and described. Their evaluation against the identified metrics is relatively uniform, allowing a single evaluation to be provided.

Figure 15. Market-Based Prioritization Mechanisms Concept Evaluation

Metric	Evaluation	Comment
NAS Capacity, Efficiency and Economy	Neutral	Improve the utility of scarce resources; temporary and unpredictable nature of these resource constraints might lead to a negative evaluation
Fairness	Positive	Equal opportunity to participate for all operators
Transparency	Positive	Easy-to-understand and transparent if designed well
Honors Aircraft Operator Preferences	Positive	Operator preferences expressed through willingness to pay
Flexibility	Positive	Allows users to match resources to their needs
Predictability	Neutral	Depending on type of mechanism, predictability may vary
Minimizes Aviation's Environmental Impact	Neutral	Does not consider environmental impact
Societal Values	Negative	Does not provide mechanism for incorporating societal values
Passenger/Shipper Service Quality	Neutral	Operators could purchase resources necessary to provide most appropriate service quality; however, day-of-operations market could disrupt published schedule, potentially leading to poor service by those unwilling or unable to pay to provide high quality service.
Resilience/Recoverability	Neutral	Primary market does not appear to have any particular advantage; however, secondary market should improve system ability to respond to changing conditions.
Economic (Allocative) Efficiency	Positive	Accepted as best means for supplying scarce resources to willing and able buyers
Incentive Compatibility	Positive	Should properly align incentives if designed well

Scope	Positive	Can potentially be applied NAS-wide
Implementation Risk	Negative	Widespread industry resistance and may require legislative approval

Conclusions: Aircraft operators express caution about this alternative if it is structured to be a cost in addition to current user fees and taxes. This concern could be mitigated if limited to a secondary market. However, even in this case acceptance by aircraft operators remains a challenge. Research is underway to determine whether applying market mechanisms to 4DT negotiation and contracting would be feasible and beneficial in the NextGen NAS.[7] Demonstrating the benefits is critical to user acceptance. Well-defined, limited-demonstration projects would be useful.

Issues to be Researched or Resolved: To the extent it is determined that FAA does not now have authority to implement a primary auction of priorities, policy initiatives need to be considered.

6.7. PRIORITY POINTS

Concept Description: Priority Points is a concept by which the ANSP allocates points among aircraft operators that are used to indicate to the ANSP the relative value of a particular flight in situations of constrained operating resources. The ANSP would make an initial allocation of points among operators in accordance with objective criteria (e.g., some multiple of the number of operations conducted during the previous year). Operators would then bid their points in contention with other operators to win priority in any environment in which they are contending for the same resource. Operators might be also authorized to trade or sell accumulated points on a secondary market. NASA is currently researching the incorporation of user flight preferences in ATM, an approach that employs the use of points.[8]

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[7] George Mason University, GRA, Incorporated and Sensis, Market-Based and Auction Based Models and Algorithms for En Route Airspace Allocation and Configuration, research in process for NASA Ames Research Center

[8] Sheth, K. Incorporating User Flight Preferences in Air Traffic Management. NASA Ames Research Center. Presented at JPDO FP Workshop #2. 28 April 28 2010.

Pros: A Priority Points mechanism can be designed to include all operators and all operations NAS-wide. It allows operators to compute and communicate to the ANSP the value of various flights within their own operation without the government having visibility into their business decisions. The Priority Points mechanism is transparent, fair, and easily understood. It is consistent with the NextGen TBO operating concept and appears to be compatible with NextGen automation and communications planning. It adjudicates priorities between and among operators. Priority Points could be made to be bankable, tradable, or saleable on a secondary market. It can be used as a mechanism to incorporate NextGen NAS capacity, efficiency, and performance, as well as environmental and societal values into FP decision making.

Cons: The Priority Points concept is relatively immature with many unresolved issues. The ANSP and operators may require investments in additional information sharing and flight planning systems for dynamic uses of the points system for prioritization. The system depends on the process by which points are allocated to and expended by flight operators. This could become a politically sensitive, highly contentious issue.

Analysis: The strength of the Priority Points mechanism is that it provides operators a method to set their flight priorities and clearly communicate those preferences to the ANSP. The ANSP then converts the quantitative assessments and adjudicates resource contention.

As a prioritization concept with broad applicability across NAS operations, a Priority Points mechanism offers rich opportunities for accommodating user priorities and allocating scarce resources to highest value flights. A Priority Points system could also provide a mechanism to incorporate societal values into FP. Further, this allocation mechanism can be implemented in selected operations or airspace, allowing for the gradual introduction of the points mechanism while retaining other allocation approaches in parts of the system (e.g., slots). A Priority Points system could also accommodate trading in both primary and secondary markets if desired.

Workshop participants identified several advantages of the Priority Points concept. Direct expression of operator preferences was considered a clear advantage, especially if those preferences could be updated during the flight to reflect changing information and operator business priorities. The participants also expressed reservations about how the issues of allocation of points would be resolved.

Figure 16. Priority Points Concept Evaluation

Metric	Evaluation	Comment
NAS Capacity, Efficiency and Economy	Neutral	No direct impact on efficient use of NAS resources
Fairness	Positive	Fair system if initial points allocation is set properly
Transparency	Positive	Rules open and known to all operators
Honors Aircraft Operator Preferences	Positive	Provides direct quantitative expression of operator preferences
Flexibility	Positive	Enables operators to respond quickly to changing conditions
Predictability	Neutral	Operators can reflect changing priorities throughout trajectory; offsets gains in predictability
Minimizes Aviation's Environmental Impact	Positive	Provides direct mechanism to incorporate environmental factors into prioritization rules
Societal Values	Positive	Provides mechanism to incorporate social priorities in prioritization algorithms
Passenger/Shipper Service Quality	Neutral	Predictability for individual operators, possibly improving passenger/shipper service quality
Resilience/Recoverability	Positive	Allows users to reassign priorities following disruption
Economic (Allocative) Efficiency	Positive	Increases probability of high value use of scarce NAS resources
Incentive Compatibility	Positive	Encourages operators to accurately value scarce resources
Scope	Positive	Should readily apply NAS-wide, and gate-to-gate, and across all trajectories
Implementation Risk	Negative	Represents significant change in resource allocation method; technically less mature than some other concepts

Conclusions: Use of Priority Points allows operators to communicate their priorities directly and enables comparison of priorities across operators. Through the point allocation process, the point mechanism could provide a direct method to incorporate NextGen NAS capacity, efficiency, and performance, as well as environmental and societal values into FP, which may not otherwise be adequately included in the operator decision process. The Study Team was encouraged by the prospect that this concept, in conjunction with the far-term NextGen concept of the Flight Object, could support FP across the full trajectory in real time.

Issues to be Researched or Resolved: Research is required to develop a detailed operational concept and technical requirements for a Priority Points system under far-term NextGen, including criteria for allocation and use of points among scheduled and non-scheduled operators in gate-to-gate operations. Additional analysis and policy activity also would be required for identification and weighing of environmental and societal values, and NAS capacity, efficiency, and performance factors that might be incorporated into the Priority Points algorithms.

6.8. DELAY CREDITS

Concept Description: The concept of Delay Credit prioritization would be intended to raise the priority of a current operation to compensate for delays experienced earlier. This could mean upgrading the priority of a flight during a subsequent resource contention event because it was the loser in a previous one. Alternatively, delays could be recorded and tallied over time, so that operators could invoke priority in future operations on the basis of banked delay credits. Operators might be permitted to sell or trade delay credits to other operators for money or other items of value.

Pros: Delay Credits allocation might be viewed as fair and equitable because over time it would tend to share the pain of delays evenly among all aircraft operators. An operator who had borne the burden of a delay previously would get priority the next

time there was contention. This concept would ensure equity as operators that incur disproportionate delays can be compensated by reduced delays at a later time.

Cons: Aircraft operators pointed out that the most significant NAS delays result from factors beyond operator control, such as hazardous weather, or airport or airspace congestion. Users make choices on the markets they serve and if some are delay-prone this should not benefit them at the expense of operators who fly in areas with fewer delays. Moreover, it was agreed that operators should not benefit from credits awarded as a result of NAS-induced delays. Banking delay credits could potentially be unfair since airlines operate in substantially different environments and experience vastly different systemic delays.

According to industry participants in Workshop #2, accounting for these variations would be difficult and would require constant monitoring to prevent anti-competitive behavior and unfair advantages to some airlines. Aircraft operator representatives were concerned that operators frequenting the most delay-prone markets would bank delay credits and use them to the competitive disadvantage of other operators. They felt it would be very difficult to distinguish operator-induced delay from delay caused by other factors, and therefore thought this alternative would be very difficult to implement fairly. Most industry experts considered the possible pros of delay credit allocation to be insufficient to compensate for potential fairness problems.

Analysis: Fairness, the primary objective of the delay credit allocation, seems not to be a likely result of its implementation. In terms of other metrics such as transparency, flexibility, delay reduction, environmental impact, and predictability, the benefits of this approach are either unclear or neutral.

Figure 17. Delay Credits Concept Evaluation

Metric	Evaluation	Comment
NAS Capacity, Efficiency and Economy	Neutral	Does not directly encourage better system performance and the compensatory nature of the credit detracts from current operational efficiency.

Fairness	Neutral	Diversity of operator experience generates uneven baseline of delay
Transparency	Positive	Clear rules defining use of delay credits are easily achievable
Honors Aircraft Operator Preferences	Neutral	Operator with abundant credits gains priority over other operators
Flexibility	Neutral	Limits ability of low credit balance operators to adjust their preferences
Predictability	Negative	Uncertainty over how and when other operators will use their credits decreases predictability
Minimizes Aviation's Environmental Impact	Neutral	Does not consider environmental impact
Societal Values	Negative	Does not provide mechanism for incorporating societal values
Passenger/Shipper Service Quality	Neutral	Mixed potential results
Resilience/Recoverability	Neutral	Unclear potential effects
Economic (Allocative) Efficiency	Negative	Does not directly encourage high value use of scarce resources, potentially rewarding operators who contribute most to delay
Incentive Compatibility	Negative	Could offer opportunities for anti-competitive "gaming" behavior
Scope	Neutral	Applies to scheduled operators only; should be combined with other FP concepts
Implementation Risk	Negative	Delay metrics difficult to compute; expected significant disagreements about fairness of proper use and allocation

Conclusion: Delay experience could be one consideration in the award of Priority Points. However, there is lack of support for Delay Credits as a standalone FP concept on the grounds of possible unfairness.

Issues to be Researched or Resolved: Analysis should be conducted to determine whether NAS efficiency would be improved and delays reduced by giving priority to those flights that had been delayed in the past. If this approach were to be pursued, research is needed to get a better idea of how it might actually work in practice and whether the unfairness issues that some fear would materialize.

6.9. PRIORITIZATION TO MINIMIZE NAS DELAYS

Concept Description: Prioritizing flights to minimize NAS delay involves identifying those flights that contribute most to flight delays and placing them later in the sequence, thereby improving the timeliness of a greatest number of operations overall. This concept is being explored and developed by Sensis Corporation.[9]

Pros: This concept could potentially reduce total aircraft delays in the NAS.

Cons: There is potential that many of the operations having the greatest delay impact on the NAS will be airlines' greatest revenue generators, or those with most connection dependencies. If so, aircraft operators will resist having those flights moved lower in the queue, regardless of their downstream impact. Strong positive or negative incentives might be necessary to facilitate implementation of this alternative if benefits to the NAS are significant enough. The feasibility of this approach as applicable to the far-term NextGen NAS environment must be demonstrated as it raises difficult equity issues (e.g., if 30 flights are scheduled into a 15 minute interval, which flight caused the delay – the first or last one, or any of those in between?)

Analysis: The implementation challenges for this concept are likely to be significant as it relies on complex analysis of schedules and traffic flows. Even if technical certainty could be achieved, attributing delays to individual flights in a complex system would be contentious, and might lack transparency to operators. Operators would also experience less predictability and flexibility unless there were a set of flights that repeatedly caused delays. It would also be important to know the downstream operational impacts of delaying those high-impact flights. It is unlikely that the ANSP would have sufficient visibility into those operator and passenger service quality effects to make the optimal decision.

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[9] Hunter, G. Toward an Economic Model to Incentivize Efficient and Cooperative Traffic Flow. Sensis Corporation. Presented at International Congress of the Aeronautical Sciences, #26. 2008.

Figure 18. Prioritization to Minimize NAS Delays Concept Evaluation

Metric	Evaluation	Comment
NAS Capacity, Efficiency and Economy	Positive	Increases overall throughput by moving high-impact flights to time periods without congestion
Fairness	Negative	Diversity of operator experience generates uneven baseline of delay
Transparency	Negative	Heavy dependence on analysis requires high level of trust
Honors Aircraft Operator Preferences	Negative	Increases decision making by the FAA rather than the operators
Flexibility	Neutral	Will reduce operator flexibility without a negotiation process
Predictability	Neutral	Could improve predictability for many flights at the expense of high delays for other flights.
Minimizes Aviation's Environmental Impact	Positive	Reduces environmental impact by reducing total NAS delay
Societal Values	Negative	Does not provide mechanism for incorporating societal values
Passenger/Shipper Service Quality	Positive	Impacts are unclear
Resilience/Recoverability	Neutral	Impacts are unclear
Economic (Allocative) Efficiency	Neutral	If only considering aircraft delay, impacts on economic efficiency are unknown
Incentive Compatibility	Negative	May encourage deceptive reporting of operator intent
Scope	Positive	Unclear how it can be implemented in practical terms
Implementation Risk	Negative	Presents significant challenges to develop credible delay assignment analysis and receive operator acceptance

Conclusions: Prioritization to Minimize NAS delays has the potential to further the best utilization of NAS resources and reduce aircraft delays. The feasibility and applicability of this concept in the NextGen TBO environment must, however, be validated. It could be implemented by giving the offending flight the lower/lowest priority at each contention point along its routing or, in a Priority Points regime by reducing its points or by increasing points required for potentially delay-impacted operations.

Issues to be Researched or Resolved: The methodology for identifying delay-inducing flights would have to be developed and validated for applicability to the far-term NextGen environment. Further research should be conducted to determine how that information could be incorporated into the automated 4DT negotiation and approval process, along with a means for operators to communicate to the ANSP the value of such delay-inducing flights to their individual business operations for consideration in TFM decision making. It would also be useful to research the implications on passenger delay from a system that had minimized aircraft delays as its objective.

6.10. PRIORITIZATION BASED ON SOCIETAL VALUES

Concept Description: Prioritizing aircraft operations on the basis of societal values means giving preference to or penalizing flights to the extent that their characteristics advance or detract from recognized societal goals, objectives, or values established in a policy-making context. These goals and values could include minimizing environmental impact, serving the largest number of passengers (or delaying the fewest), serving the market at the lowest possible fares, ensuring a strong competitive environment, providing access to all classes of operators, or minimizing the cost to taxpayers of building, maintaining and operating the air traffic/air transportation infrastructure, fostering economic growth, and providing for the national defense and homeland security.

Pros: Prioritizing operations in accordance with recognized societal goals and values would be consistent with NextGen goals and objectives, and would further the public interest.

Cons: Aircraft operators resist using FP to further societal values because the outcome would compete with operator preference as a governing principle. This might work to constrain their flexibility, and create incentives that might be contrary to their business models, and/or increase their costs or impair their competitiveness, vis-à-vis each other or globally. Prioritizing flights on the basis of societal values

would not, except incidentally, improve NAS capacity, efficiency or performance. Incorporating societal values directly into FP algorithms presents significant policy challenges, although not technical implementation problems. Many societal values compete with each other, meaning that determination of their relative values could be a very contentious process. In addition, there are a range of things that society values and it may be necessary to understand the tradeoffs among them.

Analysis: Achieving societal goals has always been an important component of aviation policy. Maintaining access to small communities, protecting competition, environmental protection, and supporting new entrants have long been important goals for national policy. The difficult question for FP is whether those broad goals can be achieved effectively through prioritization policy or could better be supported by other means, such as mandates or explicit economic incentives. Pending that policy decision, there are some concepts that could enhance societal values while still helping to achieve primary aviation industry objectives. As a primary objective, maximizing societal values through prioritization rules could have a detrimental impact on industry economic performance.

Figure 19. Prioritization Based on Societal Values Concept Evaluation

Metric	Evaluation	Comment
NAS Capacity, Efficiency and Economy	Neutral	Should set minimum performance target to reduce impact on system performance
Fairness	Negative	
Transparency	Neutral	Shift of decision making from operators/ANSP to political realm will reduce transparency
Honors Aircraft Operator Preferences	Negative	Will reduce operator ability to meet business objectives
Flexibility	Negative	Adding additional objectives and constraints will restrict operator flexibility
Predictability	Neutral	Impact depends on the stability of the social values priority and the details of the implementation process
Minimizes Aviation's Environmental Impact	Positive	Provides a mechanism to incorporate environmental goals into prioritization process

Societal Values	Positive	Provides mechanism for direct incorporation of social values
Passenger/Shipper Service Quality	Neutral	Could have beneficial impact if service quality were explicitly emphasized
Resilience/Recoverability	Neutral	Adding more objectives and constraints could reduce system resilience
Economic (Allocative) Efficiency	Negative	Tradeoff of economic efficiency for other societal values
Incentive Compatibility	Neutral	Encourages operators to behave in ways valued by society; but unclear whether there will be gaming or unintended consequences
Scope	Positive	Can be applied NAS-wide and to all classes of aircraft
Implementation Risk	Negative	Widespread industry resistance and numerous analytical and public policy challenges

Conclusion: Most of the prioritization concepts discussed in this report operate through the business processes of the aircraft operators as expressed to the FAA. To incorporate other societal values – particularly those that are non-economic and do not directly affect operator return on investment (ROI), except through mandates or other government constraints – requires explicit intervention by the FAA in the prioritization rules. Because these societal values are important and may not typically be included in stakeholder decisions, a mechanism should be developed to incorporate these values into prioritization.

Emphasizing societal values does not provide a useful organizing principle for prioritization as it does not provide adequate guidance to the FAA in constructing the software algorithms and information exchange mechanisms that will implement prioritization in the far-term. For example, rules reconciling multiple societal objectives would have to be established and converted into an algorithm for programming into the NextGen automation. A more productive approach would require that any future prioritization mechanism enable the inclusion of societal values into the priority algorithms and allow policymakers to promote clearly defined societal goals that would not otherwise be viable without government intervention.

Issues to be Researched or Resolved: Societal values should be identified that cannot be satisfied through the normal competitive operations of industry stakeholders. Once those values are defined and performance targets quantified, a study of the alternatives available to achieve those targets, including prioritization rules, should be conducted to determine whether, to what extent, and how societal values could be incorporated into FP systems. There are some societal values such as avoiding noise sensitive areas or distributing traffic to different areas for noise problems that are amenable to rules-based programs and could fit into FP systems.

6.11. OTHER CONCEPTS AND CONSIDERATIONS

The Study Team investigated other ideas that could play a role in FP. Most of these ideas were not considered by the Study Team to be amenable to stand-alone implementation, but might if desired be incorporated into another FP mechanism.

6.11.1. Operator Dominance

At many airports a single aircraft operator performs the majority of flights. Providing some FP preference to predominant operators in a market may be fair as it recognizes the investments such an operator has made in developing a particular market, and encourages operators to contribute toward financing airport infrastructure through long-term lease arrangements. On the other hand, perpetuating such dominance through FP might increase a dominant operator's market power, allowing it to raise prices and/or discourage competition[10].

6.11.2. Information Quality and Operator Incentives

Flight prioritization in NextGen relies on accurate and timely sharing of information on NAS status, schedules, aircraft mechanical issues, and other factors relevant to predicting and managing delay-causing events. Industry experts at the workshops emphasized the importance to NAS efficiency of accurate information and some suggested that operators could be incentivized to

[10] FAA Notice re: Delta/US Airways Petition for Waiver, 75 Fed. Reg. 7308. 19 February 2010.

improve the quality and timeliness of information they share. One operator suggested that operators should receive FP credit depending how closely the initial 4DT information it files corresponds to the flight profile it actually operates. Today's CDM tracks how well advance schedule data provided by the operators matches actual operation and while there is no formal enforcement mechanism, the FAA does provide feedback to the operators. Among CDM participants, the perception of fairness and equity are important to participants. If FP is to be used as an incentive for better information sharing, it will be important to guard against "gaming" the system.

6.11.3. Ration-by-Distance (RBD)

As described in *Section 4*, today's TFM uses a RBS-based system to allocate arrival times during GDPs. The RBS algorithm is modified by a Ration-by-Distance (RBD) algorithm that exempts long-haul flights from the delay program. The reason for exempting long-haul flights is to account for the uncertainty of weather forecasts and route uncertainties. This is an example of how a well-designed prioritization process can balance competing objectives and generate improved NAS performance.

6.12. SYNTHESIS OF CONCEPTS

The preceding analysis of individual FP concepts provides insight into potential building blocks for a far-term NextGen FP system. The next step in the analysis process uses the conclusions of the concept evaluations to address the following:

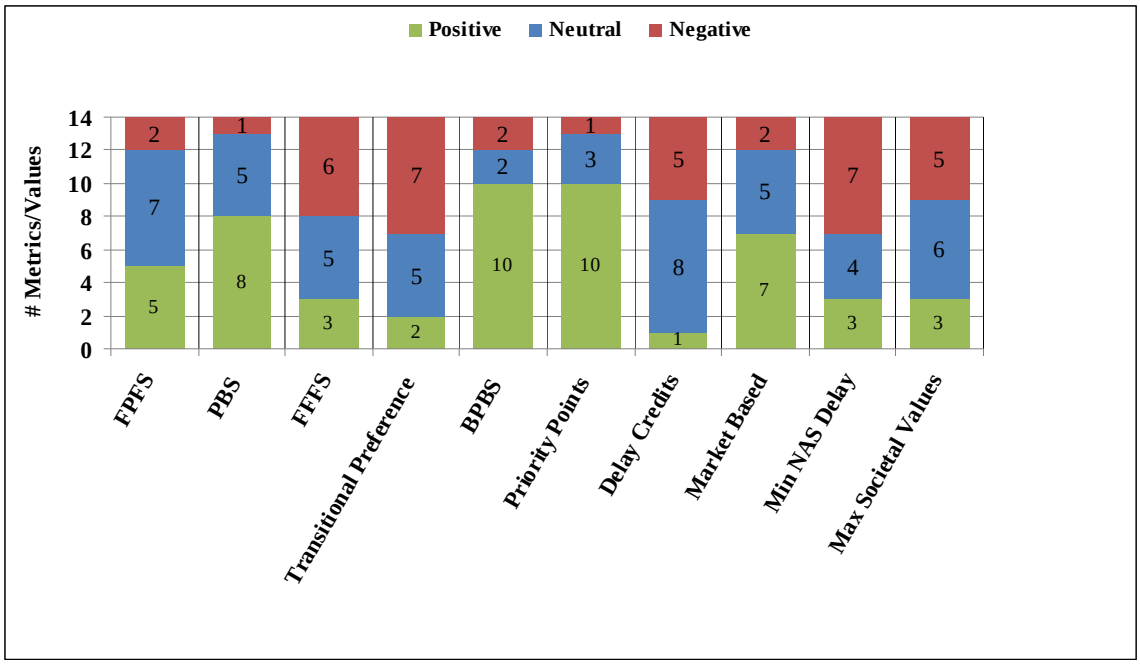
- FP concepts that offer the potential to make significant contributions to a system-wide solution
- An integrated set of concepts provide a complete far-term FP solution if no single concept can satisfy all of the metrics/values
- Additional technical work that must be performed to select and develop the FP solution
- How governance models might affect FP concepts

6.12.1. PROMISING FP CONCEPTS

Figure 20 below arrays the concepts for qualitative comparison. Among the concepts evaluated, four ranked highly enough to deserve further development and analysis because they were assessed as at least 50% positive on a standalone basis:

- PBS
- BPBS
- Priority Points
- Market-Based Prioritization Mechanisms

Figure 20. Metrics/Values Frequencies for FP Concepts



Priority-by-Schedule (PBS) received high marks on most of the operator-focused metrics and its reliance on the schedule supports a central tenet of passenger/shipper service quality. Maintaining schedule integrity is a primary objective of many operators. The schedule drives most of an airline's operating costs including the efficient use of aircraft and crews, access to maintenance

facilities when needed, and regulatory compliance. Moreover, the public places high value on schedule predictability. The schedule will continue to be the initial driver of scheduled carrier trajectory negotiation.

Best-Performing, Best-Served (BPBS) provides numerous benefits with few drawbacks. To the extent that dedicated high-performing operations can be developed and implemented through appropriate procedures, BPBS can deliver significant benefits. However, BPBS applies only in limited and well-defined environments. Because of the need to preserve operating environments for less well equipped aircraft, BPBS cannot serve as a NAS-wide prioritization mechanism. Even within a BPBS operation, there may be a need to apply other prioritization rules to flights competing for the same resource within that environment. However, BPBS can be deployed in specific NAS environments without the need to develop a system-wide FP solution.

Priority Points offers the opportunity to introduce user-preferred and market-based resource allocation into FP while avoiding legal and institutional challenges of financial market mechanisms. As a prioritization concept with broad applicability across NAS operations, a Priority Points mechanism offers rich opportunities for accommodating user priorities and allocating scarce resources to high value flights. This allocation mechanism can also be implemented in selected operations or airspace, allowing for the gradual introduction of the points mechanism while retaining other allocation approaches in parts of the system (e.g., slots) for selected applications. A points system could also accommodate trading in both primary and secondary markets if desired.

Additionally, the Points framework could be used to incorporate societal values into the prioritization. For purposes of this study it was not necessary to speculate whether or what these societal values will be in the future. The FP approach only needs to be compatible with the introduction and adjustment of these values. For example, additional points could be allocated to operators based on the efficiency

or size of their aircraft to reduce environmental impacts or reduce airport congestion. This is not to say that there will be no contention over the amount of points assigned by the ANSP for any of these purposes, or the numbers to be spent in various constrained scenarios.

Market-Based Prioritization Mechanisms offer the best opportunity to achieve the many objectives of NextGen while providing operator and ANSP flexibility and improved economic performance for the air transportation industry. However, many operators resist the application of market-based approaches to aviation, largely out of reluctance to pay directly for resources that are now being supported indirectly through taxes and fees paid into the Aviation Trust Fund. Operators are skeptical that payments would be used for the benefit of aviation and view user fees and other direct charges as additional taxes. Further, some operators resist market-based mechanisms that involve payment of money because they may be in financial distress and they are fearful of the involvement of financial analysts in day-to-day airline operations. Non-scheduled also have concerns about increased costs. Nonetheless, there are many varieties of market-based FP resource allocation mechanisms that do not involve a cash outlay, including trading of prioritization benefits on a secondary market, as well as "zero-sum games" in which operators who relinquish priority net a benefit paid by those who value or need the priority more.

The transition to TBO will facilitate the application of market-based mechanisms to FP. As the FAA and operators negotiate trajectories FAA will be able to identify all constraints along the entire length of a proposed trajectory. Operators can assess the value to their own operations of competing for limited resources as opposed to seeking less congested operating environments. Today's TFM is unable to address multiple constraints along a flight path, and even Concept CTOP only allows operators to express preferences among a fixed set of alternatives. With the enhanced information exchange and automated trajectory negotiation enabled by far-term NextGen, it will be possible for operators to

improve their knowledge of congestion in the NAS, refine their practical options, and effect the best mix of competitive and non-competitive resources for their business model.

Overall, the value of market-based FP is that it directly promotes allocative efficiency. Consistent with the FAA mandate to support the efficient movement of aircraft, market allocation maximizes the use of NextGen investment. The potential benefits of applying market solutions to FP support the argument that the FAA should, at a minimum, investigate ways to overcome industry concerns.

6.12.2. INTEGRATING CONCEPTS FOR A SYSTEM-WIDE SOLUTION

Although upon initial analysis four FP concepts appear most promising, those concepts that received lower assessments should not be overlooked because they have the potential to enrich other concepts in a variety of combinations. FPFS is one such concept. The need to be able to conduct FP across all flight phases and in different types of airspace imposes a substantial burden that might better be overcome by integrating multiple concepts into a solution that functions across the NAS. Moreover, no single concept was assessed positively against all values and metrics. Therefore, no single concept would be adequate to address all NextGen FP needs.

The ideal combination of concepts requires an understanding of the degree to which the concepts may complement each other. *Figure 21* shows the results of a preliminary assessment of the compatibility of the candidate concepts.

Figure 21. Compatibility of Different FP Alternatives

FP Concepts	FPFS	PBS	FFFS	Transitional Preference	BPBS	Priority Points	Delay Credits	Market-Based	Minimize NAS Delays	Maximize Societal Values
FPFS										
PBS										
FFFS										
Transitional Preference										
BPBS										
Priority Points										
Delay Credits										
Market-Based										
Minimize NAS Delays										
Maximize Societal Values										
Consistent: Could be applied together										
Conflict: Must choose one or other										

6.12.3. ADDITIONAL TECHNICAL WORK

A work plan for maturing FP for NextGen implementation might be sequenced as follows:

1. Mature the individual concepts
2. Develop a concept of operations for system-wide FP in far-term NextGen
3. Perform technical feasibility assessments and cost/benefit analysis
4. Design an integrated system-wide FP solution
5. Mature FP requirements for NextGen automation and communications systems planning

Uncertainties related to how NextGen will be implemented present additional challenges to developing the far-term NextGen prioritization policy. FP will be implemented through NextGen automation and information exchange platforms. Technical limitations of the NextGen systems could influence the range of feasible FP options. In turn, FP is likely to place additional requirements on those same platforms.

6.12.4. GOVERNANCE

When looking at FP in the far-term the impact of changes in governance models should be considered. Within each of the ATM governance structures, the system could be further characterized as such:

1. **Corporate / Fee-for-Service System:** Private corporation operates ATM system on fee-for-service basis with government safety, and perhaps economic, oversight (e.g., UK NATS).
2. **User-Owned Co-Op:** Users own system and there is a system operator; government retains safety regulation and perhaps economic regulation; generally operated on fee for service cost recovery basis.
3. **Government-Provided Service:** Government agency funds, operates and makes decisions (e.g., FAA); duties could be split among branches of government and within agency; FAA ATM currently funded via indirect user taxes and General Fund.

These should not be taken as pure governance models as some countries blend models. For example, in the US, the FAA operates, maintains and develops the ATM system and controls important areas, such as how much capacity to develop. However, it also allows CDM to operate more like a user-governed club in deciding the rules under which operators can respond to some capacity shortfalls. Fee-for-service can operate under all the governance models. Important considerations include safety oversight (how independent) and the need to control for monopoly when system operates as a fee for service entity.

Figure 22 shows how each FP concept examined in this section would fit under the three governance approaches identified above. It shows that most of the FP concepts could be implemented under each of the governance systems. However, there are cases where the basic principle behind a FP concept is inconsistent with a specific governance model. For example, a FP system based on Delay Credits would not function well under a corporate governance model that awards priority

to those users who value it most. In many cases the FP concept could be adapted into a governance model if agreed to.

Figure 22. FP Concepts vs. Governance Options

FP Concepts	Corporate / Fee-for-Service	User-Owned Co-Op	Government-Provided Service
FPFS	Y	Y	Y
PBS	N	Y	?
FFFS	Y	Y	Y
Transitional Preference	N	Y	Y
BPBS	N	Y	Y
Priority Points	Y	Y	Y
Delay Credits	N	?	Y
Market-Based	Y	Y	?
Min NAS Delay	N	Y	Y
Max Societal Values	N	N	Y
Y: Governance model supports concept			
N: Governance model does not support concept			
?: Effect of governance on concept uncertain			

Governance is important because it affects incentives for system operators and users, and incentives ultimately determine how organizations perform. It is important to understand which FP options are robust and could function under any governance system and which FP options may require changes if the governance of the ATM system were to change. Even so, the analysis of this study is largely predicated on the continuation of the existing FAA Command and Control governance model.

7. POLICY ISSUES AND IMPLEMENTATION PATHWAYS

The Study Team surveyed and performed a preliminary analysis of potential alternative procedures to implement NextGen FP rules and mechanisms.

7.1. LEGISLATIVE AUTHORITY

Other than alternatives that involve the sale by FAA of prioritizations for money which is not resolved, FAA already has sufficient legislative authority to implement any of the FP concepts discussed in this report. Pursuant to 49 USC Section 40103(b), the FAA has authority to develop plans and policies, and prescribe regulations with the objective of ensuring safe and efficient use of the airspace. This section states:

1. The Administrator of the Federal Aviation Administration shall develop plans and policy for the use of the navigable airspace and assign by regulation or order the use of the airspace necessary to ensure the safety of aircraft and the efficient use of airspace. The Administrator may modify or revoke an assignment when required in the public interest.
2. The Administrator shall prescribe air traffic regulations on the flight of aircraft (including regulations on safe altitudes) for —
    a. Navigating, protecting, and identifying aircraft;
    b. Protecting individuals and property on the ground;
    c. Using the navigable airspace efficiently; and
    d. Preventing collision between aircraft, between aircraft and land or water vehicles, and between aircraft and airborne objects.

To the extent that the FAA decides that a FP concept involving the sale of priority for money would be beneficial, a question may arise as to whether such a mechanism would be within FAA's existing legal authority. However, such mechanisms are in use today on a limited basis. For example, there has been a rule

in place for many years that allows airlines to buy and sell slots among themselves in a secondary market.[11] A court recently upheld a FAA decision to permit airports to vary their landing fees to reduce congestion.[12] On the other hand, an agency proposal to itself auction slots for money on the basis of its property management authority[13] was withdrawn in the face of airline opposition.

The Government Accountability Office (GAO) has issued an opinion that FAA lacks the authority to auction landing slots for money.[14] But the GAO explicitly stated in the same report that it was not making any finding as to whether FAA has authority to implement other market-based mechanisms. And the court that upheld variable airport landing fees commended the FAA for considering innovative ways to deal with airport congestion.[15] However, legislation might be required for implementation of a FP concept that involved FAA selling priority for money, by auction or other mechanism.

7.2. IMPLEMENTATION BY INTERNAL AIR TRAFFIC POLICIES AND PROCEDURES

Currently, FAA FP policies and procedures are implemented through internal FAA documents. As a general matter, FAA Traffic Management Initiatives are implemented by FAA ATO Policy Order JO 7210.3.W, Facility Operation and Administration, Part 5, Chapter 17.[16] When implementing a Ground Delay Program, FAA assigns[17] delays to airline flights in 15 minute increments on the basis of pre-GDP schedules.[18] An airline may then substitute flights to meet FAA-assigned

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[11] 14 CFR 93.221
[12] Air Transport Association of America, Inc. v. US Department of Transportation, 08-1293, (D.C. Cir. 2010)
[13] FAA proposed the auction on the basis of its property management authority because of legal ambiguity about whether it has the authority to conduct such an auction as a regulatory matter.
[14] Letter from Gary L. Kepplinger, General Counsel, United States Government Accountability Office to Members of Congress, September 30, 2008 (B-316796).
[15] "As the airspace is used ever more intensively, it is unsurprising that the Department would update its approach to landing fees in an effort to relieve airport congestion. So long as it complies with the applicable statutes, its creativity should be welcomed on its merits, not spurned for its novelty."
[16] http://www.faa.gov/documentLibrary/media/Order/FAC.pdf.
[17] FAA Order JO 7210.3.W, Section 17-9-4.
[18] *See CDM Requirements Document*, V.2, Section 4, http://cdm.fly.faa.gov/whatscdm/cdmdocs.html.

arrival times, in accordance with CDM agreements FAA has in place with the airlines.[19]

The baseline prioritization rule "First-Come, First-Serve" is embodied in FAA Controllers' Handbook, ATO Order JO 7110.65T, Section 2-1-4.[20] Implementing a new FP scheme through similar Policy Orders or Handbook changes would be the easiest and most expeditious way to proceed as the schedule for this process would be within the agency's discretion and would not require a long public notice and comment period.

There are two existing forums from which FAA could derive operator and stakeholder views and community coordination for FP technical implementation. The first is RTCA[21], a not-for-profit federal advisory committee (FACA) that develops consensus-based recommendations regarding CNS and CNS/ATM system issues. Although to date RTCA has performed those activities through its Air Traffic Management Advisory Committee (ATMAC), in light of the broad scope of NextGen FAA has requested that RTCA disband the ATMAC and in its place form a new advisory group with a broader aviation community membership, including industry participants who speak for the interests of safety, airport, environment, and global harmonization, as well as air traffic.[22]

Another potential source of operator views and FP implementation coordination is the Air Transport Association (ATA) CDM Working Group.[23] The CDM Working Group CDM is a joint government/industry initiative aimed at improving air traffic

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[19] *See CDM MOA*, March 1, 2009, http://cdm.fly.faa.gov/whatscdm/cdmdocs.html. Procedures for how an operator gains access to the CDM process are stated in the Standard Operating Procedures for Adding CDM Participants, http://cdm.fly.faa.gov/whatscdm/cdmdocs.html.
[20] http://www.faa.gov/documentLibrary/media/Order/ATC.pdf.
[21] http://www.rtca.org/aboutrtca.asp
[22] *See* FAA's guidance statement on "FAA-Aviation Community Engagement Strategy for Implementing NextGen": http://www.faa.gov/about/initiatives/nextgen/accomplishments/collaboration/media/NextGen%20Engagement%20Proposal%205-28-10.pdf.
[23] http://cdm.fly.faa.gov/whatscdm.html

management through increased information exchange among various parties in the aviation community and improving automated decision support tools. Its activities include: (1) scheduling data exchange between CDM-member airlines and the FAA for the purpose of better strategic traffic management during ground delay programs; (2) development and application of better ATM decision support tools; and (3) stakeholder sub-teams that provide advice to FAA on how to improve traffic management.

Although a wide and diverse community of stakeholders participate in the CDM Working Group sub teams, oversight and direction of the group's activities resides with the CDM Stakeholders Group (CSG) consisting of the Air Transport Association (ATA), National Business Aviation Association (NBAA), Regional Airline Association (RAA), and the Federal Aviation Administration (FAA). For the purposes of providing viewpoints and implementation coordination of NAS-wide NextGen FP, FAA might consider requesting that the CDM Working Group expand the membership of its governing CSG to be more inclusive of all operator categories, and that the CSG's deliberations and decision making be more transparent, much in the way FAA is asking RTCA to modify its ATMAC.

7.3. Implementation by Rulemaking

If the prioritization alternative to be adopted is deemed to be a "rule" within the definition of the Administrative Procedures Act ("…the whole or a part of an agency statement of general or particular applicability and future effect designed to implement, interpret, or prescribe law or policy or describing the organization, procedure, or practice requirements of an agency"),[24] rulemaking[25] or negotiated rulemaking[26] must be used as the implementing vehicle. Rulemaking or negotiated rulemaking might include reference of the proposed prioritization alternative(s) to the Aviation Rulemaking Advisory Committee (ARAC), or convening of another

[24] 5 USC. 551
[25] 5USC. 553; http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&rgn=div6&view=text&node=14:1.0.1.2.3.1&idno=14
[26] 5 USC. 563

aviation rulemaking committee (ARC) specifically to address FP. Rulemaking always includes one or more notices of proposed rule phases, publication of a final rule, and--depending on how controversial the action is--can be followed by a court appeal.[27] Using rulemaking to implement a FP concept could add one to three or more years for implementation, depending on the complexity and controversy of the alternative chosen.

While internal procedures may be the easier and quicker approach, rulemaking could be required in this case. Determining whether an agency's action is a rule requiring public notice and comment is a difficult issue and has been subject to much litigation. It is clear that an agency action can be considered by the courts to be a rule even if the agency did not classify it as such. Generally, an action will be held to be a rule if it is a departure from prior policy and is of general and proscriptive applicability.[28] It would certainly seem that that would apply in this case if a prioritization scheme was adopted that is different from the approach followed by the FAA today. However, the FAA has sometimes found expedited methods to implement its policies such as those described above to implement air traffic control procedures. So it may be possible to follow the same approach here. Or it may be possible to implement as an FAA internal process or procedure the less controversial aspects of one or more of the alternatives after input from a consensus making body such as RTCA, and then introduce the more controversial aspects incrementally through a formal ARC and/or rulemaking process. In the end, the extent to which rulemaking will be required might depend on how controversial the priority scheme to be adopted is and whether it is significantly different from the approach being followed today.

7.4. Technical Implementation Pathway

Recognizing that NextGen technical planning is already being translated into design requirements and, in some cases moving into implementation, there is urgency to

[27] 49 USC. 46110; 5 USC. 702
[28] Lubbers, *A Guide to Federal Agency Rulemaking*, 4th Ed., American Bar Association, pp 50-53, (2006).

choose and define the FP requirements so that they can be integrated with the other program elements to optimize the result. The automation platforms that will be the foundation for far-term NextGen are the primary locus for the needed integration. For example, if ERAM and TAMR are the en route and terminal automation platforms they will need to incorporate the algorithms that enable the prioritization in their respective flight domains. If far-term NextGen architecture is to be centered on a Common Automation Platform (CAP), that platform would require the same capabilities as ERAM and TAMR. In a similar fashion, the flight planning and flow control automation will require the functionality to deal with the trajectory probes, stakeholder negotiation, transparency other requirements derived from the FP selected. If it is decided that FP will extend across the entire trajectory and that user preference and/or ANSP preference (e.g., societal values) will be dynamically represented in any prioritization situation along the route, the Data Link and SWIM programs will also need to be reviewed to insure that the communications pathways, latency and other requirements are consistent with those that derive from the FP concept. In particular, current FAA planning regarding the possible roles of the Flight Object, as briefed in Workshop #1, appears to offer a valuable means for in-flight FP implementation and that work should remain cognizant of FP as it moves forward as well.

The Study Team's conclusions and recommendations provide flexibility to support any of the societal values that the ANSP decides to implement on whatever time scale it chooses after introduction of the Flight Object. This is accomplished by the insertion of a numerical weight into the designated portion of the Flight Object associated with a specific flight. In this way, the FP is biased in favor of those societal objectives. For example, the ANSP could decide that a flight with more passengers should enjoy some priority over one with fewer passengers. In this case, preferential "points" are included in the optimization algorithm, along with the other factors relevant to the decisions at issue. Again, adoption of this approach, while greatly facilitated by the promised automation capability, could be employed earlier using the CDM tools of the time. Thus, the Study Team did not preempt policy-

makers by attempting to quantify the priority/penalty associated with each attribute; rather the FP process includes “place holders” for metrics (e.g., points) that can be inserted into the prioritization algorithms in resolving contention.

8. GUIDING PRINCIPLES

The Study Team recognized that certain principles should guide development and implementation of any FP mechanism:

- Flight safety must always be the first consideration in a FP regime.
- FP should optimize use of NAS resources.
- FP should attempt to achieve fairness among aircraft operators.
- A FP concept should allow aircraft operators to optimize the use of resources under their control and to clearly express their preferences and priorities in response to system constraints.
- FP processes should be transparent, rule-based, and predictable.
- Business decisions and priorities should remain the responsibility and concern of the individual aircraft operator whenever feasible.
- All operators, including non-scheduled, should be given equal opportunity to participate in NextGen FP.
- FP mechanisms should be amenable to incorporation of societal goals and values.
- Whatever FP methods are ultimately adopted, they should complement – and not substitute for – the augmentation of needed airport and airspace capacity.
- The application of FP in far-term should be conducive to adaptation as the dynamics of the NAS change across time and space.
- The development of a far-term FP solution should depend upon close collaboration between FP developers and those responsible for other NextGen systems.

9. CONCLUSIONS AND RECOMMENDATIONS

9.1. CONCLUSIONS

The three workshops and further supporting analysis generated a substantial volume of data and insight into the broad range of FP issues. The conclusions of the study are:

- PBS, Priority Points, BPBS and Market-Based Prioritization Mechanisms demonstrated significant promise and potential value and should receive more investigation and can benefit from focused research.
- Other than alternatives that involve the sale by FAA of prioritizations for money, FAA already has sufficient legislative authority to implement any of the FP concepts discussed in this report.

9.2. RECOMMENDATIONS

- FP offers significant value in far-term NextGen and, therefore, FP research should be vigorously pursued as follows:
    1. Mature the individual concepts
    2. Develop a concept of operations for system-wide FP in far-term NextGen
    3. Perform technical feasibility assessments and cost/benefit analysis
    4. Design an integrated system-wide FP solution
    5. Mature FP requirements for NextGen automation and communications systems planning
- Useful concepts and technology generated through this research should be considered for early deployment.
- The policy implementation pathway should involve stakeholder engagement and collaboration.
- As soon as practicable, far-term NextGen developers should codify FP requirements when designing the TBO automation suite and Flight Object.

10. FUTURE RESEARCH ISSUES

Following from the Recommendations are a set of research topics associated with developing and implementing NextGen FP:

- **PBS:** Research is required, supported by simulation, to develop a detailed mature concept of operations for schedule-based prioritization for gate-to-gate trajectory operations. This research should identify how the flexibility of non-scheduled operators is incorporated.
- **Priority Points:** Research is required, supported by simulation, to develop a detailed mature concept of operations for a Priority Points system under far-term NextGen, including criteria for allocation and use of points among operators in gate-to-gate operations. Additional analysis also would be required for identification and weighing of societal values, and NAS capacity, efficiency and performance factors that might be incorporated into the points computations.
- **BPBS:** In order to judge the utility of BPBS within far-term NextGen, a more comprehensive definition is required.
- **Market-Based Prioritization Mechanisms:** Specific, limited opportunities should be identified for demonstrating the performance of market-based approaches to FP in far-term NextGen. Additionally, policy research is required to identify whether additional implementation authority would be needed for implementation of market-based FP approaches in which FAA sells priority for money.
- **FPFS:** Research is needed to investigate how, where, and when FPFS reverts to FCFS.
- **Modeling of Innovative FP Concepts:** Modeling and simulation capabilities should be employed to evaluate system-wide impacts of FP concepts, anticipating how independent users would behave and interact if any of the FP concepts were implemented in their markets.

- **FP and the Flight Object:** Research is needed to specify the FP requirements that would be built into the far-term NextGen Flight Object, such that it can accommodate real-time prioritization of flights by the aircraft operator and use of that information by ATC automation in aircraft sequencing throughout execution of the 4DT.
- **FP and ANSP Automation/Communications:** Research is required to quantify the significant demands that FP may place on planned far-term NextGen automation and communication systems. Any limitations on those systems should be fed back to FP research.
- **Non-scheduled Operations:** Policy research is required to determine the best way to accommodate non-scheduled operators in FP.
- **FP and the TBO Planning Horizon:** Research is required to specify characteristics of the planning horizon, including accuracy level of the trajectory, needed for FP. These requirements should be evaluated against far-term NextGen technical requirements.
- **Collaboration and Interactions among Operators**: Research is needed into the benefits and legal constraints of information sharing among operators. Current RBS practices include some level of such interaction but this is done without direct negotiation between the participants.
- **Relationships between Governance and FP systems:** Although the FP Study Team does not propose any changes to existing governance models, research is warranted to determine how FP options assessed in this study would function under alternative governance mechanisms. It is important to understand which FP options are robust and could function under any governance system and which FP options may require changes if the governance of the ATM system were to change.

11. IMPACT ON NEXTGEN INTEGRATED WORK PLAN (IWP)

The application or deployment of any FP concept in far-term NextGen is interdependent upon the introduction of the 4DT that is an integral part of the NAS transformation. The implementation of FP depends upon the precision of the 4DT trajectory at any point along the trajectory where some congestion or potential conflict is predicted. Less precise 4DT estimations (i.e., occupying a large volume of airspace) would increase the potential for conflict and the corresponding requirement to institute FP, whereas more precise 4DT estimations would decrease the necessity to invoke FP. Since FP is triggered by competition for NAS resources or airspace as identified by the 4DT trajectory probe, R&D activities for both must be carefully integrated.

Appendix I provides an initial assessment of the impacts of FP on NextGen plans captured in the IWP. The principal FP-related Policy Issue (PI), "High Density Operations – Flight Prioritization" *(PI-0077)*, is associated with many data elements that could be closely impacted by FP concepts, including R&D activities (R, D), Enablers (EN), and Operational Improvements (OI). Initial review indicates that the following research activities are most likely to be impacted by FP developments:

- "Applied Research on 4DT Use in Clearances and Flight Plans" *(R-0140)*
- "Applied Research on Automated Air and Ground Separation Management Alternatives" *(R-0530)*
- "Applied Research for Required Aircraft 4DT Intent Data" *(R-0820)*
- "Applied Research on an Automated Capacity Management Capability" *(R-1130)*

In sum, upon assessment of the full range of potential interactions, it is clear that successful introduction of FP into NextGen will require extensive coordination, involving research planned in the near-term and technological implementation over the far-term. FP concepts and derived technical requirements must be addressed systemically, incorporated into NextGen automation platforms and associated algorithms.

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APPENDIX B: TERMS OF REFERENCE

1. Introduction and Overview

Even with the increased capacity and operating flexibility of NextGen, there will be situations and environments in which operators will compete for the same volume of airspace and airport facilities. Unmanaged excess demand can degrade system efficiency and cause delays that ripple through the entire air transportation system.

Under these conditions, the common situational awareness and advanced lead time that benefit stakeholders under NextGen can provide innovative options for resolution of competing needs in airspace, airports or any area of required system service. The increased planning horizon and a larger set of options for dealing with constraints increase operational efficiency and system capacity. Trajectory negotiations between operators and the Air Traffic Service Provider will occur from the longer-ranged strategic time horizons down to the shorter tactical timeframes. These negotiations will be executed through computer-to-computer interaction, especially in the tactical environment. The computers for the operators and those for the ATSP will interact based upon their shared view of the current and projected air traffic situation, and each set of computers will be capable of representing the position of the operator or ATSP in the negotiations. Undoubtedly, the aircraft operators' computers will be programmed to execute business rules of the operator, including airlines and GA. Likewise the ATSP's computer will be programmed to execute rules of engagement that tend to represent the public good. Lower end GA operators may contract for these services through private vendors or representative organizations like AOPA.

As constraints appear that result in trajectory conflicts, the operator has the ability to choose from available options, and negotiate trajectory modifications as appropriate. Under strategic timeframes, the ATSP will adjudicate any conflicts and respond to the negotiating party with possible alternatives that are available. As the negotiations proceed down into the tactical timeframe the numbers of options are likely to become significantly less, and when the ATSP determines that negotiations must stop the ATSP

has the right to amend the trajectory in the way it determines best and the aircraft operator will abide by that decision. However, operators who understand that unclosed negotiation sessions may be terminated by the ATSP will seek to close the negotiations as soon as possible on the terms that favor them the most.

Under these conditions, rule sets will be required for all phases of flight, including strategic negotiations, tactical negotiations, and ultimately when the ATSP declares termination of negotiations. In fact, rules will be required for all parties involved to the negotiations, based upon their individual business objectives. The nature of these rules is the basis of this study.

The purpose of this study is to:

1. develop, explore and document historic and proposed flight prioritization rules, mechanisms and regimes
2. develop a catalog of options that might be feasible and helpful for NextGen, and
3. Define a decisional pathway to establishing effective rules, mechanisms and regimes for prioritization of flights under various conditions that can be used by aviation policy decision makers, NextGen architects and aviation system designers.

2. Background

Flight Prioritization results from the need to make a decision on airspace and airport resources when there is more than one operator requesting use of the resource at a particular time. The actual time that this "conflict" is determined may be hours, days, or months in advance of the actual conflict time, in which case having better situational awareness and an advanced planning horizon will provide more opportunities to solve the conflict. However, as conflict detection time approaches the actual conflict time, a resolution becomes more time-critical, and ultimately direction from the ATSP may be required to avoid the conflict. In either case, rules of engagement are required, and these

rules will require policy analysis and decisions for implementation. Flight Prioritization is illustrated through the following example scenario.

The year is 2025, and NextGen is fully implemented, including 4DT automation, fully capable communications, and net-enabled system wide information sharing.

Through a process involving collaboration and consensus among government, aircraft operators and other stakeholders including airports, the following rank-ordered battery of flight prioritization rules/mechanisms have been developed and are being applied by the 4DT automation: (1) military and homeland security aircraft on critical missions, law enforcement, and EMS aircraft first; (2) prioritization according to overall system efficiency (this group having its own set of criteria such as passenger count, connecting versus point to point values, slot controlled versus low demand destination airport, more versus less operationally capable aircraft, etc.) (3) NextGen equipped aircraft go before non-equipped and (4) where conflicting aircraft have the same values in higher ranked regimes, priority between them is determined through market mechanisms.

The following five aircraft are competing for the same resource (i.e. airspace, arrival slot): Two fully loaded B757s operated by different commercial airlines, one half-loaded B757, a military jet on a critical mission, a NextGen capable biz jet, and a single engine GA aircraft. Prioritization-relevant characteristics of the operations are accessible by the 4DT automation in each operator's flight planning and real time system operations data. In what order to they go?

Depending on the specifics of aircraft capabilities, the automation might present options to the operators that prefer the military jet first; then the NextGen biz jet (which gets value points for equipage, and might be fast enough to overtake the commercial aircraft without slowing them down); then the two fully-loaded B757s, which have the same "system efficiency" values are asked to bid for priority via a real-time market mechanism; next, the half-loaded B757 which has a lower "system efficiency" value; and finally, the GA aircraft. Prioritization is transparent to each aircraft operator; each is

presented with the prioritized option, along with other options that may or may not conflict with other flight plans and therefore may or may not also be prioritized. The goals of this example prioritization regime are to give the operator maximum flexibility, to prioritize only when necessary and only to the extent necessary, and to use market mechanisms only to resolve conflicts between similarly-valued operators.

Potential alternatives that may be studied include:

- *Market-based solutions*, employing congestion pricing, auction mechanisms, whereby a value or price can be established for the level of priority the user wants and is willing to pay for.
    - *NASDAQ approach*, a market-based solution, whereby increased demand and/or reduced availability or resources raises the "stock" price; this auction is managed in near-real time; hence the name "NASDAQ" approach.
    - *A zero-sum* market based approach, in which operators willing to relinquish a priority position receive a "credit" to someone who values it more and is willing to pay more; with "credits" being bankable for a priority position later in the same flight or another flight.
- *System-values-based algorithm*, with priority assigned on the basis of operating characteristics of a particular flight that contribute positively to overall NAS system performance.
- *Societal values-based algorithm, with priority assigned in furtherance of societal goals, for example military/homeland security/EMS operations, small community air service, low-fare operations/high capacity operations, etc.*
- *Slot allocation committees and other ad hoc measures* for strategic planning at high density airports where predictability is the overwhelming value.
- *Collaborative planning*, allowing flight operators to alter their operational plan in view of the constraining situation and their business rules, thereby optimizing their business operation; capture of CDM values being employed successfully today will provide insight into community-accepted notions of "equity."

- *Incentives* to influence resolution of tradeoffs among stakeholders; for example, "prioritization credits" that can be applied at other times for stakeholders forgoing certain privileges in times of congestion.
- *Determination of equity, and a mechanism to provide equity for flights.*
- *Or some combination of any or all of the above.*

Equally important with development of various prioritization options is development of feasible alternative decisional pathways to prioritization value determinations. Possible alternatives include blue ribbon commissions, collaborative forums and workshops, advisory and rulemaking committees, standards setting bodies such as RTCA, and formal rulemakings. Decisional pathways will be suggested for each of the prioritization options and will probably differ depending on the type of regime or mechanism.

3. Objectives

The objectives of this study are to:

- *Survey and document the state of the art of flight prioritization mechanisms.*
  A considerable body of work exists on certain aspects of flight prioritization, and there is some guidance in the National Plan regarding market-based mechanisms to be utilized in NextGen. Experience in other transportation modes such as surface vehicle high occupancy tolling, and with respect to market allocation of other government resources such as frequency spectrum allocations will be explored and documented if relevant.
- *Define a technical basis for developing and evaluating prioritization rules by establishing a set of metrics, weights, and criteria based on the National Plan, NextGen concepts and architectures, and knowledge of the state of the art.*
  The NextGen documents provide a high-level set of requirements that can be elaborated in adequate detail as to enable the formulation and assessment of policies and rules regarding flight prioritization. Models of operations under these documents will be analyzed and a set of metrics, weights, and criteria will be established to use in analyzing potential rule sets. Metrics could address such values as predictability,

equity, transparency, efficiency, enforceability, among others. The weights given to these metrics will be a key determinant of which rules best apply. For example, if predictability is a driving metric, a prioritization rule might allocate slots in advance of being invoked, and the effects would be known in advance. However, this predictability would be at the expense of flexibility to adjust to nuances of the particular situation, so that a more dynamic allocation of resources could enhance flexibility. Thus, the analysis of potential rules must consider the tradeoffs among metrics and decision criteria, and their effects on the desired operation. It is envisioned that this step will include a workshop and brainstorming activity to explore innovative prioritization concepts that might be enabled by NextGen concepts for information sharing and collaborative decision making and that these concepts will be added to the set of prioritization mechanisms.

- *Provide an understanding of the decision making process as it affects flight prioritization policy decisions.*

  This understanding can be encapsulated as the answers to a series of questions such as the following. Who makes the decision, and what is the process by which this decision is reached and implemented? Who are the affected stakeholders and what are their likely positions? What level of satisfaction is each stakeholder likely to accept, and how predictable is their behavior? What are the major political constraints and barriers, and how do they influence the decision? The answers to these and other questions will enable the formulation of acceptable solutions that are realistic from both technical and political points of view.

- *Provide recommendations for moving forward.*

  It is highly likely that multiple alternatives will be discovered, and that no single rule will suffice for all conditions. This study will document the alternatives, report the results of the analysis, and make recommendations for actions, including further study, if warranted. It is critically important for this study to define a way forward. Results of the study effort and shortcomings of knowledge will be analyzed relative to what will be required to establish a definitive approach to flight prioritization. This study activity will define gaps to be filled, and based on these gaps a set of necessary research activities and/or policy decisions will be defined so as to determine a clear

way forward. Needed research tasks will be defined in sufficient detail that the JPDO will be able to provide direction and measure future progress by the research organizations on a schedule consistent with NextGen requirements. Undoubtedly, a mechanism to engage stakeholders, formulation of policy, socialization of the alternatives, and development of algorithms for automation will ultimately be required. The recommendations should include next steps toward achieving acceptance of the policy decisions that will ultimately be required.

The results of the study are expected to respond to the following questions:

1. What are the key issues and state of the art relevant to flight prioritization concepts for future air traffic management and control?
2. Are there any new thoughts or approaches to prioritization that might be enabled by NextGen concepts and capabilities?
3. What metrics and criteria should be applied in selecting approaches to particular prioritization alternatives?
4. Based on what is known today, what decisions can be made about flight prioritization alternatives and, if multiple solutions are to be considered, what is the way forward to narrow the solution set?
5. Which issues require further analysis, experimentation, exploration of policy decisions, or other forms of maturation to support a decision, and what is the value of the information to be gained from such research?
6. What steps are recommended to reach decisions on these issues and implement effective prioritization strategies?

4. Approach

Following below is description of the approach to this study.

The Flight Prioritization Deep Dive study will be conducted by a specially appointed independent Study Group of 7 members with a diverse range of expertise and perspectives, under the leadership of an appointed Study Director. The members will be

selected to represent appropriate areas of expertise and a balance of perspectives on flight prioritization. Members will also be selected based on their independence from the results of any decisions or recommendations that may emerge from the study.

Roles and Team Membership

The team members for this review shall include:

Program Manager: Jim Cistone

The Program Manager is responsible for the day to day execution of the study task. He directs the team from a management sense and is responsible for the cost, schedule and technical aspects of the study.

Study Director: Peter Kostiuk

The study director is a technical expert in this field and will direct and guide the technical aspects of this study.

Project Analyst: Crown & JPDO SII Staff

The project Analyst is responsible for cataloging the information and performing the analysis of this information with respect to defined criteria under the guidance of the Study Director, Program Manager, and Subject Matter Experts.

JPDO SII: Suzette Matthews

The JPDO SII Team provides a liaison to remain cognizant of all study team activities, to address study issues that arise and to provide technical clarification on behalf of the JPDO, as necessary.

The Study Group:

The Study Group will consist of seven (7) experts who are recognized experts familiar with all aspects of this study. They are not actively working in the research and development scope of this study, but are cognizant of much of the operational domain. They are capable of understanding and evaluating the research topic for this study. The candidate list includes:

1. Richard Golaszewski, GRA
2. Shahab Hasan, LMI
3. Michael Ball, University of Maryland

4. David Schaffer, WPG
5. Frank Frisbie, Apptis Corporation
6. William Cotton, Cotton Aviation Enterprises, Inc

Study Process

The Study Group will investigate the many facets of the flight prioritization problem as described herein and will develop a report of its findings, conclusions, and recommendations based on the available evidence. Upon completion, the report will be transmitted to the JPDO.

In reaching conclusions and recommendations, the study group will hear invited presentations from experts familiar with the study area, and the Study Group will evaluate published and unpublished research from the relevant domain literature as part of an educational process designed to enable the Study Group to reach its conclusions. The Study Group may conduct brainstorming sessions to develop or mature candidate flight prioritization rules or metrics for analysis.
The Study Group will gather all pertinent information regarding alternative approaches for flight prioritization. A set of metrics, weights, and criteria will be developed based on the National Plan, the NextGen Concept of Operations, and the NextGen Enterprise Architecture, to be used in the analysis and evaluation of each of the alternatives.

A series of Study Group meetings will be conducted to gather essential information. It is anticipated that the Study Group will nominally meet for three days every other month to hear invited presentations knowledgeable individuals from the air transportation community, who will be invited to present their research results, conclusions, and views for inclusion in the analysis. The Study Group will have the ability to probe deeper into the presented information through interaction with the presenter and follow-up as appropriate. Approximately three invited sessions will be scheduled.

The Study Group will analyze the gathered facts and information in light of the established criteria and reach conclusions based on their analysis. As the investigation

proceeds, approximately two, three-day sessions every other month will be scheduled for the Study Group and staff to meet for analysis of the results, brainstorming, and formulation of the report. The JPDO staff will participate in preparation of the draft report and will manage the distribution of the report for review, editing and comment. This report will document the entire process, including the information inventory, criteria, analysis methodology, and results, including conclusions and recommendations. The final draft report will be submitted to JPDO for their review and comment.

The final report will indicate the disposition of significant comments received from the JPDO review of the draft report.

5. Period of Performance and Scope of Effort

The period of performance for the study effort will be 12 months, and the overall project will extend to 15 months to include final report preparation, review and JPDO support.

6. References

Examples of applicable documents to be considered include:

- *Ripple Delay and its Mitigation*, Cistone, James H.; Rome, James A.; Rose, Simon D.; Lee, Ronald W.; Bell, George F.; Leber, William S.; *Air Traffic Control Quarterly*, Vol. 9(2) 59-98 (2001).
- *A General Approach to Equity in Traffic Flow Management and its Application to Mitigating Exemption Bias in Ground Delay Programs*, Vossen, Thomas; Ball, Michael; Hoffman, Robert; Wambsganss, Michael, NEXTOR paper (2003).
- National Plan for the Next Generation Air Transportation System
- NextGen Concept of Operations
- NextGen Enterprise Architecture
- Publications on Collaborative Decision Making in Air Transportation.

7. List of Potential Policy Issues

This list is an initial, but not all-inclusive, list of potential Policy Issues that will be included in this study is provided below:

A list of potential policy issues that will be included in this study includes, but is not limited to:

1. The very fact that there are 4D-T negotiations taking place is a large policy issue. It opens the door for traffic management schemes that are other than First-Come, First-Served.
2. In order to negotiate, the aircraft operators will need to have significant automation capability to:
    a. Seek, obtain and process the past, present, and predicted airspace situation information, as it pertains to their operation(s).
    b. Seek, obtain and process their business rules and associated internal information sources such that they have complete situational awareness of their own operation.
    c. Utilizing the information from a) and b) above, analyze the information and determine the "best" 4-DT for their operation.
    d. Develop a set of rules of engagement for determining c) above, and for maintaining an "optimum" operation as the situation changes.
3. Given 2, the door is opened up for one operator to hire a world renowned algorithm developer and create a system that gives them a great advantage over other operators. This is capitalism at work, but not all operators are commercial carriers and the possibility of great inequities is significant.
4. What are the rules of engagement for negotiations? What governs the negotiations on either side? What is fair and equitable?
5. Exactly what is negotiated? The 4-DT or access? If the projected demand for RY 13 at LGA at 5PM EST Thursday reaches capacity on Monday at 10 AM EST, then how are future arrival 4-DTs for 5 PM @ LGA addressed? Does that imply that all whose 4-DTs are already "in" the system are good to go or that 4-DTs

entered after 10 AM on Monday can bump earlier 4-DTs? If “bumping happens”, then what is the prioritization for “bumping”?

6. Should the ATSP develop and provide a basic set of automation tools to counter any potential domination as discussed in 2) and 3) above? If so, then how do these tools get distributed in a fair and equitable manner? And the operators are still free to buy more tools to better game their operation.
7. Is the mechanism for negotiation something like NASDAQ? If so, does it apply to the full 4-DT or just elements of the 4-DT where there is contention for resources? In the latter case, how will that be managed?
    a. Will this kind of market-based approach force continued negotiations right up until “the sale is closed”?
    b. If the sale is closed, can it be reopened again if a higher priority need arises?
8. If b), then what policy determines “higher priority” and how do we deal with the closed sale that gets bumped? If we take a performance-based approach, then the equity will be that every operator has the opportunity to equip to achieve the required performance. That is much different than all can access equity. Today we have equity, for example, where aircraft A and aircraft B want to land at PHL, then they get to land in a First-Come, First-Served order, but they both get to land. Under RTSP, priority may be given to the aircraft that meets the performance requirement, say aircraft A, and access could be denied to aircraft B if it doesn't meet performance requirements, or aircraft B could be granted access at another time. So, access is no longer equal under RTSP. Having said that, all operators have the equal opportunity to equip their aircraft and train their crew and meet all of the RTSP requirements, so there is "equity" in equal opportunity to access, but not in equal access anymore.
9. What is the time of entry policy?
    a. If I file a 4-DT 6-months in advance, and it is approved as filed, then is it frozen?
    b. Am I guaranteed that filed 4-DT, or does the contract remain open until the negotiation freeze time?

   c. What will stop everyone from waiting until the last minute to file?
   d. What benefit is it for filing early? What guarantee do I have?

10. What constitutes priority? If there is a projected airspace resource constraint, how is it determined, and how are requests prioritized for that airspace resource?
11. Is maximizing throughput in the system is a value that trumps user preference in the negotiation phase?
12. What policy forms the basis for the rules of engagement governing the ATSP decisions after negotiations are frozen?
    a. Does equity of access rule?
    b. Does Required Total System Performance (RTSP) supplant equity, where equity is invoked by the opportunity for every operator to meet RTSP?
    c. Is there a general rule for "what is best for the Nation"?

APPENDIX C: STUDY PLAN

1. Introduction and Overview

Even with the increased capacity and operating flexibility of NextGen, there will be situations and environments in which operators will compete for the same volume of airspace and airport facilities. Rush hour at congested airports, hazardous weather events, examples of situations in which demand for a specific operating resource may exceed what's available. Unmanaged excess demand can degrade system efficiency and cause delays that ripple through the entire air transportation system.

Under these conditions, the common situational awareness and advanced lead time that benefit stakeholders under NextGen can provide innovative options for resolution of competing needs in airspace, airports or any area of required system service. Furthermore, even under nominal conditions, there is the expectation that a set of ground rules, arrived at by collaboration with the stakeholder community, should be established to allow for the both the strategic and near term planning of flights in a transparent way. The increased planning horizon and a larger set of options for dealing with constraints increase efficiency.

The good news is that NextGen 4D trajectory management, better communications vehicles, and net-enabled system wide information sharing will provide the capability for flights operating in congested environments to be rationalized and prioritized in ways that increase overall capacity and efficiency in the system, while at the same time providing more predictability and flexibility for operators. To achieve maximum benefits of these capabilities however, prioritization rules, mechanisms, and regimes (derived in collaboration with users and other stakeholders), both for strategic ATM and tactical trajectory management, must be captured, developed, and converted into algorithms to be applied by the NextGen 4DT automation. The purpose of this study is to develop explore and document historic and proposed flight prioritization rules, mechanisms and regimes, develop a catalog of options that might be feasible and helpful for NextGen, and

define a decisional pathway to establishing effective rules, mechanisms and regimes for prioritization of flights under various conditions that can be used by NextGen architects and system designers.

2. Objectives

The objectives of this study are to:

- *Survey and document the state of the art of flight prioritization mechanisms.*
  A considerable body of work exists on certain aspects of flight prioritization, and there is some guidance in the National Plan regarding market-based mechanisms to be utilized in NextGen. Experience in other transportation modes such as surface vehicle high occupancy tolling, and with respect to market allocation of other government resources such as frequency spectrum allocations will be explored and documented if relevant.
- *Define a technical basis for developing and evaluating prioritization rules by establishing a set of metrics, weights, and criteria based on the National Plan, NextGen concepts and architectures, and knowledge of the state of the art.*
  The NextGen documents provide a high-level set of requirements that can be elaborated in adequate detail as to enable the formulation and assessment of policies and rules regarding flight prioritization. Models of operations under these documents will be analyzed and a set of metrics, weights, and criteria will be established to use in analyzing potential rule sets. Metrics could address such values as predictability, equity, transparency, efficiency, enforceability, among others. The weights given to these metrics will be a key determinant of which rules best apply. For example, if predictability is a driving metric, a prioritization rule might allocate slots in advance of being invoked, and the effects would be known in advance. However, this predictability would be at the expense of flexibility to adjust to nuances of the particular situation, so that a more dynamic allocation of resources could enhance flexibility. Thus, the analysis of potential rules must consider the tradeoffs among metrics and decision criteria, and their effects on the desired operation. It is envisioned that this step will include a workshop and brainstorming activity to

explore innovative prioritization concepts that might be enabled by NextGen concepts for information sharing and collaborative decision making and that these concepts will be added to the set of prioritization mechanisms.

- *Provide an understanding of the decision making process as it affects flight prioritization policy decisions.*

  This understanding can be encapsulated as the answers to a series of questions such as the following. Who makes the decision, and what is the process by which this decision is reached and implemented? Who are the affected stakeholders and what are their likely positions? What level of satisfaction is each stakeholder likely to accept, and how predictable is their behavior? What are the major political constraints and barriers, and how do they influence the decision? The answers to these and other questions will enable the formulation of acceptable solutions that are realistic from both technical and political points of view.

- *Provide recommendations for moving forward.*

  It is highly likely that multiple alternatives will be discovered, and that no single rule will suffice for all conditions. This study will document the alternatives, report the results of the analysis, and make recommendations for actions, including further study, if warranted. It is critically important for this study to define a way forward. Results of the study effort and shortcomings of knowledge will be analyzed relative to what will be required to establish a definitive approach to flight prioritization. This study activity will define gaps to be filled and, based on these gaps, a set of necessary research activities and/or policy decisions will be defined so as to determine a clear way forward. Needed research tasks will be defined in sufficient detail that the JPDO will be able to provide direction and measure future progress by the research organizations on a schedule consistent with NextGen requirements. Undoubtedly, a mechanism to engage stakeholders, formulation of policy, socialization of the alternatives, and development of algorithms for automation will ultimately be required. The recommendations should include next steps toward achieving acceptance of the policy decisions that will ultimately be required.

The results of the study are expected to respond to the following questions:

1. What are the key issues and state of the art relevant to flight prioritization concepts for future air traffic management and control?
2. Are there any new thoughts or approaches to prioritization that might be enabled by NextGen concepts and capabilities?
3. What metrics and criteria should be applied in selecting approaches to particular prioritization alternatives?
4. Based on what is known today, what decisions can be made about flight prioritization alternatives and, if multiple solutions are to be considered, what is the way forward to narrow the solution set??
5. Which issues require further analysis, experimentation, exploration of policy decisions, or other forms of maturation to support a decision, and what is the value of the information to be gained from such research?
6. What steps are recommended to reach decisions on these issues and implement effective prioritization strategies?

3. Approach

Following below is description of the approach to this study.

The Flight Prioritization Deep Dive study will be conducted by a specially appointed independent study group of 6 members with a diverse range of expertise and perspectives, under the leadership of an appointed Study Director. The members were selected to represent appropriate areas of expertise and a balance of perspectives on flight prioritization. Members were also selected based on their independence from the results of any decisions or recommendations that may emerge from the study. The Study Group is presented below.

1. Richard Golaszewski, *GRA, Inc.*
2. Shahab Hasan, *LMI*
3. Michael Ball, *University of Maryland*
4. David Schaffer, *David E. Schaffer Associates, LLC*

5. Frank Frisbie, independent aviation consultant,
6. William Cotton, *Cotton Aviation Enterprises, Inc*

4. Study Process

The study group will investigate the many facets of the flight prioritization problem as described herein and will develop a report of its findings, conclusions, and recommendations based on the available evidence. Upon completion, the report will be transmitted to the JPDO.

In reaching conclusions and recommendations, the study group will hear invited presentations from Subject Matter Experts (SMEs) familiar with the study area, and the Study Group will evaluate published and unpublished research from the relevant domain literature as part of an educational process designed to enable the study group to reach its conclusions. The study group may conduct brainstorming sessions to develop or mature candidate flight prioritization rules or metrics for analysis.

The study group will gather all pertinent information regarding alternative approaches for flight prioritization. A set of metrics, weights, and criteria will be developed based on the National Plan, the NextGen Concept of Operations, and the NextGen Enterprise Architecture, to be used in the analysis and evaluation of each of the alternatives.

A series of study group meetings will be conducted to gather essential information. It is anticipated that the Study Group will nominally meet for three days every other month to hear invited presentations knowledgeable individuals from the air transportation community, who will be invited to present their research results, conclusions, and views for inclusion in the analysis. The study group will have the ability to probe deeper into the presented information through interaction with the presenter and follow-up as appropriate. Approximately three invited sessions will be scheduled.

The study group will analyze the gathered facts and information in light of the established criteria and reach conclusions based on their analysis. As the investigation proceeds,

approximately two, three-day sessions every other month will be scheduled for the study group and staff to meet for analysis of the results, brainstorming, and formulation of the report. The Study Group will review and report on which enablers, policy decisions, OIs, R&D, etc. will be affected by the recommendations, how they would be affected, and what actions would be required, including identifying gaps, such as enablers, policy decisions...R&D, etc., that will be needed but are not now in the JPDO plans as described in the Joint Planning Environment. The Study Group review will be included in the report.

The JPDO staff will write the draft report and will distribute it to the Study Group for review, editing and comment. This report will document the entire process, including the information inventory, criteria, analysis methodology, and results, including conclusions and recommendations. The JPDO staff will edit the draft report as discussed with the Study Group and the draft and comment cycle shall repeat until closure is achieved. In the case of an impasse, the Study Director, in consultation with the JPDO SII Director, shall resolve the impasse and the report will be finalized and submitted to the JPDO for their review.

The final report will indicate the disposition of significant comments received from JPDO review of the draft report.

5. Period of Performance and Scope of Effort

The period of performance for the study activity will be 12 months, and the period for the entire project will be 15 months to allow time for report review and support to JPDO.

6. Study Plan

This section describes the plan for the study in terms of tasks to be performed, the end results and deliverables to be achieved, and the schedule of key dates.

6.1 Study Stages

The study is divided into four stages, as follows.

STAGE 1. Defining the Study – Completed 1/19/2009

Crown Consulting shall develop the specific "Terms of Reference" as well as a study plan, schedule, and cost for the execution of the study and a list of candidates to serve as the study group. The Terms of Reference will define and bound the scope of the study, and will serve as the basis for determining the expertise and the balance of perspectives to be represented on the study group. The Terms of Reference, study plan, schedule, and budget shall be reviewed and approved by the JPDO.

STAGE 2. Study Group Selection and Approval – End Date 2/28/2009

The study group will be nominated by the study director in consultation with the program manager and selected with approval of the JPDO. The study group will include experts with the specific expertise and experience needed to address the study's Terms of Reference. It is essential to evaluate the overall composition of the study group in terms of different experiences and perspectives, such that the relevant points of view are reasonably balanced. All study group members will be screened regarding possible conflicts of interest.

STAGE 3. Study Group Meetings, Information Gathering, Deliberations, and Analysis POP: October 1, 2009 – September 30, 2010

The study group will gather information through:

1. Meetings that seek presentations and information from invited participants. Participants will be selected based on their experience in flight prioritization concepts, general air transportation operations and economics, as well as the evaluation of such alternatives.
2. Reviews of the domain literature
3. Investigations by the study group members, support staff, and JPDO staff.

4. The draft final report will be developed by the study group and will document all aspects of the study, including information gathered, metrics developed, results of the analysis, and recommendations and conclusions. In addition, the study process will be fully documented.

The Stage 3 effort will proceed in four phases. Phases 1 and 2 take place concurrently, but they are directed at different products.

Phase 1 – NextGen Values/Metrics related for Flight Prioritization. This phase expands on the results of ongoing JPDO ISS activity. In this activity, we will explore what Next Gen objectives/goals/values would be advanced by a flight prioritization mechanism/regime (as opposed to "First-Come, First-Served"). This study phase addresses not only what aircraft operators consider NextGen values (business case objectives such as low cost, preservation of access to limited access facilities, more operating opportunities, flexibility, less delay, perception of equity), but also ANSP values (e.g. increased system capacity, low cost, efficiency, flexibility, increased safety, ease of administration, translatable and adaptable to automation, scalability), military operator and EMS values, passenger values (low cost air fares, less delay, more service in small communities, more direct service), and the public interest (e.g. user fee funding rather than general fund financing). For the NextGen values, we will do an assessment of the NextGen plan, values emanating from JPDO Working Group documents and the IWP, Congressional pronouncements (e.g. preambles of VISION 100 and reauthorization bills, and statements of prominent members of Congress), and Administration officials statements. User values will come from testimony and statements of airlines, trade associations (e.g. NBAA, AOPA), and our workshops. For user values, we will concentrate on having them explain their business

case objectives, especially their operational needs. For passenger values, we will examine passenger rights legislation, general press, and include business and travel agent representatives on our SME list.

Phase 2 – Existing constructs for Flight Prioritization. This is the process of fully exploring and documenting flight prioritization studies, proposed constructs, previous and ongoing demonstrations (e.g., George Donahue's auction experiment), CDM methodologies (e.g. compression, and how exactly Flow Control makes decisions about competing flights when CDM doesn't provide a solution). It will especially useful to capture any data about how those proposed or existing prioritization regimes/mechanisms impact traffic, congestion, delay, or cost. This involves a literature search by our team, SMEs from academic and research communities, interviews of officials that operate slot auctions and are the final decision makers in FAA flow control, and air traffic controllers about how they make prioritization decisions in real time in congested situations

Phase 3- Testing Existing and Proposed Prioritization Regimes and Mechanisms against values derived in Phase 1. In this phase, we perform an analysis of what we learned in Phase 1 against what was discovered in Phase 2. Then, in the final workshop, we call users/passengers/ANSP representatives and have they addressed our analysis to test our results and elicit more input. At this point we also call in noted aviation economists (e.g. Mike Levine) to provide comments/review the analysis and propose a way forward.

Phase 4- Conclusions and Propose a Way forward. In this final phase, we take all we've learned, decide whether any of the tested

regimes/mechanisms is a potential way forward, and if so, if it needs to be combined with some other alternative or modification; and propose a way forward.

STAGE 4. Final Report and JPDO Support: POP October 1, 2010 – December 31, 2010

After completion of the final report, it will be transmitted to the JPDO for final review and release. This stage will address JPDO comments, reissue a final report with comments, and provide applicable support to JPDO as required.

6.2 Tasks

The following specific tasks will be completed during each stage:

STAGE 1 (1-month): Completed 1/19/2009

1. Assign a staff team to the task. -
2. Develop terms of reference and a study plan, and obtain approval from JPDO.

STAGE 2 (1-month): End Date 2/28/2009

1. Nominate a Study Director and select a team of subject matter experts that will comprise the study group.
2. Seek JPDO approval for each nominee.

STAGE 3

1. Perform a literature search and conduct a series of fact-finding and data gathering meetings with invited personnel to develop a state-of-the-art baseline.
2. Develop a set of analysis metrics, weights, and criteria based on the National Plan and the NextGen Concept of Operations and Enterprise Architecture that will form the basis for the analysis. This activity will

examine existing JPDO and other studies and guidance documents as a source of criteria and related information.

3. Deliberate and analyze the gathered information and criteria to develop findings, conclusions, and recommendations.
4. Define a baseline set of prioritization alternatives.
5. Develop a set of research tasks and/or policy issues that are necessary to provide a way forward.
6. Develop and deliver a draft final study report.

STAGE 4

1. Support the JPDO process for review and approval of the draft report.
2. Modify the draft final report for final approval and release.

6.3 End Results and Deliverables

This effort will produce the following end deliverables:

1. Terms of Reference and study plan.
2. Final Nominee slate for the study group membership and study director.
3. A draft final report containing all aspects of the study for JPDO review.
4. A final report describing the process, information gathered results, conclusions and recommendations.
5. A presentation of the report contents and results for use by JPDO.

6.4 Schedule

The following table provides a task list and schedule. The table includes task start and end (if applicable), and task assignee: JPDO Staff includes Crown and JPDO, Study Group Members, and "ALL" which is both the JPDO Staff and the Study Group Members. SME Interview Meetings and Study Group Deliberation Meetings are 3-days each in duration.

		To date					Months										
			Oct-09	Nov-09	Dec-09	Jan-10	Feb-10	Mar-10	Apr-10	May-10	Jun-10	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10
TASK	PARTICIPANTS	2009	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Kick Off - Internal Team	All	12/29	9/28														
Action Meeting	JPDO Team	1/8															
Literature Search	JPDO Team	underway															
Select Study Group Members	JPDO Team	Completed															
Identify SMEs for Interview	JPDO Team	Started															
Line Up SMEs	JPDO Team	Start-1	Stop-1	Start-2	Stop-2	Start-3		Stop-3									
SME Workshop Meetings	Study Group			1			2			3							
Literature Analysis	JPDO Team	Started									End						
SME Workshop Analysis	JPDO Team			Start-1			Start-2			Start-3							
Develop analysis metrics, weights, criteria	JPDO Team	Started	Restart						End								
Study Group Deliberation Sessions	Study Group		1		2		3		4		5		6				
Deliberation Analysis and Report	JPDO Team										Draft		Draft Final	Final			
Baseline set of prioritization alternatives	All											Draft	Draft Final	Final			
Research tasks and/or policy issues	All											Start		End	Review		
Draft Report	JPDO Team												Start	End			
Review Report	Study Group												Start	End			
Incorporate Comments	JPDO Team												Start	End			
Draft Final Report	JPDO Team													X			
Final Review	Study Group													X			
Issue Report to JPDO	JPDO Team													X			
JPDO Review and Comments	JPDO													Start		End	
Incorporate JPDO comments	JPDO Team														Start		End
Support JPDO Activities	JPDO Team													Start			End
Monthly Progress Report	JPDO Team			X	X	X	X	X	X	X	X	X	X	X	X	X	X
Project Management Status Meetings	JPDO Team		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Program Reviews	JPDO Team			X			X			X			X		X		X

6.5 Progress/Compliance

The Government will require the following in order to monitor progress and ensure compliance:

- Monthly Progress Report
- Project Management Status Meetings – once per month or as required; consisting of the Crown PM, Study Director, and Government leadership team supplemented by others as required.
- Program Reviews – quarterly or as required.
- Report Outlines and Drafts – as noted in schedule.

6.6 Transmittal/Delivery/Accessibility

Hard copies of each deliverable and one electronic version shall be provided.

APPENDIX D: FP STUDY TEAM BIOGRAPHIES

Michael Ball is Orkand Corporation Professor of Management Science in the Robert H. Smith School of Business at the University of Maryland. He also holds a joint appointment within the Institute for Systems Research (ISR) in the Clark School of Engineering. He is co-director of NEXTOR, the National Center of Excellence for Aviation Operations and Director of Research for the Smith School. He is area editor for Transportation for Operations Research and associate editor for Transportation Science. In 2008, he was President of the INFORMS Transportation Science and Logistics Society. In 2004, he was named a Fellow of INFORMS. Dr. Ball received his PhD in Operations Research from Cornell University.

Jim Cistone has more than 30-years experience in aviation, including airspace modernization and air traffic management research and development. He has career experience ranging from software engineering to systems engineering and upward into strategic planning and development, program management and consulting with the FAA, JPDO and NASA on NextGen as a Senior Aviation Subject Matter Expert. He has been called an "out-of-the-box thinker" and "one of the top-ten systems engineers in the business." He is a member of AOPA and has been a licensed commercial pilot for over 30 years. Also a Certified Flight Instructor, an Advanced Ground Instructor, and a Representative of the FAA Safety TEAM (FAAST), he is currently pursuing his Instrument Instructor Ratings. Mr. Cistone is currently attending Embry-Riddle Aeronautical University as a Ph.D. in Aviation student.

Frank Frisbie is an independent aviation consultant. Mr. Frisbie is a former Senior Executive in both the FAA and the Department of Defense, a member of the Russian Academy of Navigation and Motion Control, a Registered Professional Engineer, a Panel Member on the National Research Council Decadal Survey of Civil Aeronautics, and past Chairman of the Air Traffic Control Association (ATCA). He is a frequent contributor to the ATCA Journal of Air Traffic Control, a regular speaker on ATM matters, and a Senior Member of AIAA.

Richard Golaszewski is Executive Vice President of GRA, Inc. Mr. Golaszewski has over thirty years of experience applying economic, financial, and statistical analysis to the air transportation industry for both private and public sector clients. He has developed in-depth analyses of restructuring air traffic control in Europe and the United States. Currently, he supports economic and cost studies of air traffic control services and the use of the ATM system as part of FAA Reauthorization. He was a member of the Aeronautics and Space Engineering Board for six years and is a member of AIAA's Public Policy Committee. He holds an MPA degree from the Wharton Graduate School and a BS in accounting from LaSalle University.

Shahab Hasan is Program Director for Investment and Cost Analysis at LMI, a not-for-profit government consulting company. He leads analyses of NASA's and FAA's aeronautics research, including cost-benefit assessments, safety risk analysis, and modeling and simulation. He has supported the JPDO since its inception, particularly with NextGen systems analysis, benefits assessment, and policy analysis. Prior to joining LMI, Mr. Hasan spent eight years at NASA Ames Research Center where he led benefits and safety assessments of NASA's ATM research and conducted conceptual aircraft design. He is the former chairperson of the AIAA Air Transportation System technical committee. Mr. Hasan received a B.S. in Aerospace Engineering and M.S. in Mechanical Engineering from Virginia Tech.

Peter Kostiuk, PhD is the President of Robust Analytics, a small business specializing in the analysis of the operational, economic, and safety impacts of investments in air traffic management technologies. He has been engaged in the development and evaluation of aviation R&D for over 20 years. Dr. Kostiuk supported the early planning efforts for NextGen and has been involved with the JPDO since its inception. He has an extensive background in the modeling and analysis of air transportation systems and pioneered many of the models and methods used to conduct cost-benefit analyses of NextGen programs. He received his Ph.D. in economics from the University of Chicago in 1986.

Prior to starting Robust Analytics in 2008, Dr. Kostiuk worked at LMI, the President's Council of Economic Advisers, and the Center for Naval Analyses.

David Schaffer is principal of David E. Schaffer, LLC. Mr. Schaffer is a recognized aviation attorney who has devoted over thirty years to aviation policy-making and oversight in a variety of capacities. He served six years as an attorney at the Civil Aeronautics Board and twenty years as counsel to the Aviation Subcommittee of the US House of Representatives, with the last 10 years as Chief of Staff to that Subcommittee. Since 2004, he has been an attorney and consultant in private practice and an advisor to the JPDO on policy issues.

William Cotton is President of Cotton Aviation Enterprises, Inc., an aviation and ATM consulting firm. While serving as Manager of Air Traffic and Flight Systems at United Airlines, he initiated the ATM concept of Free Flight and is still working with NASA in pursuit of those objectives. After receiving his M.S. in Aero and Astro Engineering from MIT, he has worked over forty years advancing ATC improvements and aviation operations. Over the past fifty years, he has piloted many types of airline and GA aircraft.

APPENDIX E: WORKSHOP PARTICIPANTS

Workshop #1 – November 10-12, 2009

- **Frank Berardino,** GRA, Incorporated
- **Steve Bradford,** Federal Aviation Administration (FAA)
- **Mike Brennan,** Metron Aviation
- **Rich Jehlen,** FAA
- **Diana Liang,** FAA
- **Mark Libby,** FAA
- **Jay Merkle,** Joint Planning and Development Office (JPDO)
- **Mike Sammartino,** FAA
- **Lance Sherry,** George Mason University
- **Tim Stull,** United Airlines
- **Steve VanTrees,** FAA and JPDO Aircraft Government Co-Chair
- **Craig Wanke,** FAA
- **Jim Wetherly,** FAA

Workshop #2 – April 20, 2010 and April 26-28, 2010

Session 1, April 20 – Airport Operations

- **Tom Brown,** TJB Aviation and JPDO Airports Government Co-Chair
- **Patty Clark,** Port Authority of New York and New Jersey
- **Flavio Leo,** Massachusetts Port Authority
- **Deborah McElroy,** Airports Council International – North America (ACI-NA)
- **Chris Oswald,** ACI-NA

Session 2, April 26 – Business, Scheduling, and Marketing

- **Montie Brewer,** Air Canada
- **Steve Brown,** National Business Aviation Association (NBAA)
- **William D. Hall,** Mosaic ATM
- **Doug Henneberry,** NetJets®

- **Steve Iverson,** American Airlines
- **Capt. Christian Kast,** United Parcel Service (UPS)
- **Randy Kenagy,** Aircraft Owners and Pilots Association
- **Kapil Sheth,** NASA Ames Research Center
- **Tim Stull,** United Airlines
- **Steve Vail,** FedEx

Session 3, April 27 – Flight Operations

- **Frank Alexander,** Air Transport Association (IATA) and JPDO Aircraft Industry Working Group Co-Chair
- **Roger Beatty,** Independent Consultant
- **Robert Deering,** American Airlines
- **William D. Hall,** Mosaic ATM
- **Capt. Christian Kast,** UPS
- **Ron Klenotic,** NetJets
- **Kirk Rummel,** Continental Airlines
- **Kapil Sheth,** NASA Ames Research Center
- **Phil Smith,** Ohio State University
- **Ernie Stellings,** NBAA
- **Tim Stull,** United Airlines
- **Steve Vail,** FedEx

Session 4, April 28 – Flight Prioritization Research

- **Mike Ball,** University of Maryland, Robert H. Smith School of Business
- **John-Paul Clarke,** Georgia Tech University
- **Bill Cotton,** Cotton Aviation Enterprises
- **George Hunter,** Sensis Corporation
- **Mark Klopfenstein,** Metron Aviation
- **Gary Lohr,** NASA Langley Research Center
- **Kapil Sheth,** NASA Ames Research Center

Workshop #3, September 9, 2010 – Flight Prioritization Research Findings

- **Lt. Col. Phil Basso,** United States Air Force (USAF)
- **Michael Brennan**, Metron Aviation
- **Steve Brown,** NBAA
- **Tom Browne**, TJB Aviation and Airports Working Group Industry Co-Chair
- **Patty Clark**, NJ/NY Port Authority
- **Doug Henneberry**, NetJets® Incorporated
- **Capt. Christian Kast,** UPS
- **Jesse Kallman,** FAA
- **Mark Klopfenstein**, Metron Aviation
- **Margaret Jenny,** RTCA, Incorporated
- **Kirk Rummel,** FAA
- **Lance Sherry**, George Mason University
- **Kapil Sheth,** NASA Ames Research Center
- **Ernie Stellings**, NBAA
- **Nicholas Tyshing,** FAA
- **Steven Van Trees**, Federal Aviation Administration and Aircraft Working Group Government Co-Chair
- **Steve Vail,** FedEx

APPENDIX F: FP RESEARCH LIBRARY

The FP Study Team created and maintains a document library on the NextGen JPDO KSN web site. The repository includes documents specific to the process of this study, background information related to FP concepts, as well as notes and presentations from FP Workshops.

To explore the FP Library, you must be a registered user of the JPDO KSN. Access the URL here:
https://ksn2.faa.gov/faa/jpdo/committees/fpdd/Aircraft%20WG%20Library/Forms/AllItems.aspx

APPENDIX G: FP IMPACTS ON THE NEXTGEN INTEGRATED WORK PLAN (IWP) [VERSION FY12 R1]

PI-0077: High Density Operations - Flight Prioritization				
Description: Policies should be developed to set a construct or regime for prioritizing flights in congested operating environments. Air Traffic Services congestion management guidelines should be developed for use in algorithm design. Will prioritization of operations be based on factors other than aircraft operating characteristics, such as aircraft capacity, operator mission? Will market or other ranking mechanism apply? Policy should be developed to determine the roles and responsibilities of various stakeholders in selecting among delay/gridlock mitigation options offered by the algorithms (e.g., which decisions should rest with the Air Navigation Service Providers [ANSP], airport operators, aircraft operators).				
Planned Initial Availability: 2014				
Data Element	**Name**	**Description**	**Planned Initial Availability**	**Comments and Proposals for New Elements**
CAPABILITIES				
N/A	Provide Collaborative Capacity Management	Collaborative capacity management provides the ability to dynamically balance anticipated/forecasted demand and utilization, and allocate NAS resources through proactive and collaborative strategic planning with enterprise stakeholders and automation (e.g., decision support systems), using airspace and airport design requirements, standards, and configuration conditions with the consideration of other air transportation system resources.	N/A	Needs to include requirements that enable stakeholder participation in FP decision making, supports transparency and shared situational awareness
N/A	Provide Collaborative Flow Contingency Management	Flow contingency management provides optimal, synchronized, and safe strategic flow initiatives and ensures the efficient management of major flows of traffic while minimizing the impact on other operations in collaboration with enterprise stakeholders, through real- or near-real-time resolutions informed by probabilistic decision making within established capacity management plans.	N/A	Needs to include requirements that enable stakeholder participation in FP decision making, supports transparency and shared situational awareness

N/A	Provide Efficient Trajectory Management	Efficient trajectory management provides the ability to assign trajectories that minimize the frequency and complexity of aircraft conflicts within the flow through the negotiation and adjustment of individual aircraft trajectories and/or sequences when required by resource constraints.	N/A	Needs to include implementation of FP algorithms
RESEARCH ACTIONS				
R-0040	Applied Research on Critical NextGen Aircraft Capabilities	Applied research on critical NextGen aircraft capabilities that will support the development of standards and certification procedures.	2009	Needs to address the implementation of FP to insure that points can be incorporated in Flight Object by crew or airline operations
R-0110	Applied Research on the Integration of Forecast and Observational Data	Applied research on the integration of forecast and observational data into a real-time single authoritative source of current weather information, which supports the initial development of the four dimensional (4D) weather information system.	2010	Needs to account for updates to the FP automation when weather changes contention scenarios downstream
R-0120	Applied Research on Low-Visibility and Surface Operation Technologies	Applied research on increased operator situational awareness for low-visibility terminal and airport surface operations to support an alternative selection for increasing surface movement efficiency.	2010	Needs to account for updates to the FP automation when weather or visibility changes contention scenarios downstream
R-0130	Applied Research on Automation-Assisted Collaboration Capabilities	Applied research on automation-assisted collaboration capabilities including the stakeholder's level of participation in the collaboration process.	2010	Needs to address pre-flight 4DT negotiation, compatible with FP, as well as in-flight adjustment with stakeholder involvement if that is part of the FP concept

R-0140	Applied Research on 4DT Use in Clearances and Flight Plans	Applied research on Four-Dimensional Trajectory (4DT) use in clearances and flight plans for further development and incorporation into future flight planning systems, Air Traffic Management (ATM) automation, and aircraft flight management systems (FMS). Research findings would support the development of specific data protocol and messaging structures capable of meeting the reliability, integrity and quality of service required.	2010	Needs to be closely coupled with FP concepts development, including possible use of the Flight Object to enable points to be used in FP; basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP
R-0340	Applied Research on 3D RNAV/RNP Procedures	Applied research on Three Dimensional (3D) Area Navigation/Required Navigation Performance (RNAV/RNP) procedures for aircraft operator implementation.	2011	Possible value in BPBS concept; need clear understanding of the operational benefits to enable implementation decisions
R-0350	Applied Research on Air and Ground-Based Runway Incursion Detection Technologies	Applied research on complementary air- and ground-based runway incursion prevention and detection systems.	2011	Not obvious how this contributes to FP
R-0370	Applied Research on Advanced Scheduling Concepts in Congested Terminal Airspace	Applied research on traffic spacing management for transition, arrival, and departure operations supporting high-throughput delivery of aircraft to the runway threshold and high-throughput departure operations, including capacity benefits and potential increased arrival/departure rates.	2012	Needs to incorporate potential role of FP concepts in these operations
R-0410	Applied Research on the Integration of Arrival/Departure and Surface Operations	Applied research on integrating arrival/departure flow management with surface operations.	2011	Needs to incorporate potential role of FP concepts in these operations

R-0500	Applied Research on Variable Separation Standards	Complete applied research on options for procedures, standard specifications, decision-support aids, and displays to support an alternative selection to enable variable separation standards based on performance levels in all airspace.	2012	Possible value in BPBS concept; need clear understanding of the operational benefits to enable implementation decisions; also need to insure that all procedures, specs, decision support aids and displays are compatible with implementation of FP
R-0510	Applied Research on Air and Ground Separation Management Architectures	Applied research on air and ground separation management architectures that can satisfy NextGen's increased capacity and safety requirements.	2012	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations

R-0530	Applied Research on Automated Air and Ground Separation Management Alternatives	Applied research on ground and airborne automated separation management options, which will guide the selection of technology and procedures development for Trajectory-Based Operations (TBO).	2012	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations
R-0540	Applied Research on Flexible Airspace Design Configurations	Applied research on flexible airspace design configurations, including corridors, to support an alternative selection of performance-based adaptable airspace structures.	2012	Possible value in BPBS concept; need clear understanding of the operational benefits to enable implementation decisions
R-0610	Applied Research on Safe Taxi Operations in Low Visibility Conditions	Applied research in safe taxi operations in low visibility conditions supporting options for the appropriate operator and air traffic management (ATM) roles.	2012	Tenuous connection to FP
R-0640	Applied Research on Metroplex Throughput Optimization	Applied research on optimizing performance-based trajectories in transition airspace through the metroplex environment.	2012	There is a basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4dt negotiation and execution as well as for identification of volumes requiring FP. This is a recurring need due to the dynamics of the flight environment and the large number of simultaneous operations.

R-0670	Applied Research on Applying "Control by Points" TMI	Applied research on the applicability of "control by points" Traffic Management Initiatives (TMI) to support the development options for flight operators to manage flights within the context of time-based control points.	2012	Need to include requirements specific to Points FP concept
R-0680	Applied Research on the Methodologies for Dynamically Allocating NAS Resources	Applied research on methodologies for the dynamic allocation of Air Navigation Service Providers (ANSP) and National Airspace System (NAS) resources including use of airspace for military and other national missions. This research will support changes to operational methodologies and support systems as well as policy decision such as PI-0007 'Rules of the Road' for how services and access, including prioritization of airspace use, will be equitably and dynamically distributed in a performance-based operation.	2012	Needs to address updates to FP projections created by airspace changes
R-0770	Applied Research on Dynamically Allocating National Airspace System (NAS) Demand	Complete applied research on dynamically allocating demand to facilities to support an alternative selection to increase productivity, maintain capacity, and manage workload.	2012	Tenuous connection to FP
R-0790	Applied Research for a National Surveillance Architecture	Applied research for a national surveillance architecture to meet the operational needs for NextGen, which includes air traffic management (ATM), defense, and security.	2012	Tenuous connection to FP

R-0820	Applied Research for Required Aircraft 4DT Intent Data	Applied research to define Four-Dimensional Trajectory (4DT) intent data output and associated precision requirements to support fixed and variable separation management and procedures in performance-based airspace.	2013	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations
R-0910	Applied Research on Optimizing Overlapping Runway Occupancies	Applied research to support alternative selection and policy decisions for overlapping aircraft runway occupancy during simultaneous runway operations.	2013	Tenuous connection to FP
R-0930	Applied Research on Low Visibility Independent Parallel and Converging Approach Procedures	Applied research on cockpit information requirements and procedures for independent parallel and converging runway approaches in low visibility conditions.	2013	Tenuous connection to FP
R-0960	Applied Research on 4D Trajectory Evaluation, Planning, Presentation and Negotiation	Applied research on operator and Air Navigation Service Providers (ANSP) capabilities for four-dimensional trajectory (4DT) evaluation, planning, presentation, and negotiation to support 4D flight planning and collaborative Air Traffic Management (ATM).	2013	Possible benefit to FP transparency and collaboration. Needs to incorporate means for operators to participate and execute collaborative FP including points concept
R-1050	Applied Research on Airspace Assignment Methods	Applied Research on airspace assignment methods for workforce operations in the NextGen environment.	2013	Tenuous connection to FP
R-1060	Applied Research on NextGen Team Size Optimization	Applied research to understand NextGen optimal team sizes and skill set compositions to support staff management and facility design.	2013	Tenuous connection to FP

R-1080	Applied Research on the Service Benefits and Costs for NextGen Aircraft Capabilities	Applied research on the service benefits and costs for NextGen aircraft capabilities. This research will include possible selections of incentive based programs or mandates for airborne capabilities in the 2020 timeframe.	2013	Benefits needed to support Transitional Preference and BPBS decision making and to provide insight into the underlying principle
R-1120	Applied Research on Automated Flight and Flow Evaluation and Resolution Capabilities	Applied research on collaborative automated flight and flow evaluation and resolution capabilities supporting flight operators and Air Navigation Service Providers (ANSP) negotiation objectives and trajectory preferences to balance priorities, including roles and responsibilities.	2014	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations
R-1130	Applied Research on an Automated Capacity Management Capability	Applied research on a capability to automate the detection, notification, coordination, and resolution of problems related to capacity management.	2014	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations
R-1190	Applied Research on Certification Methods, Requirements, and Standards for UAS	Applied research on safety certifications for control systems, sense and avoid capabilities, collision avoidance capabilities, and emergency procedures as they apply to Unmanned Aerial Systems (UAS).	2014	Needs to include consideration of how FP implementation is applied to UAS

R-1230	Applied Research on Weather and Wake Impacts for En Route Operations	Applied research to incorporate weather and wake impacts into reduced en route separation standards and overall en route operational procedures.	2015	Needs to address any impacts to FP implementation by identification of situations requiring FP
R-1240	Applied Research on Low Visibility Dependent Multiple Approach Procedures	Applied research on technologies and procedures supporting very closely spaced parallel runway procedures in low visibility.	2015	Needs to address any impacts to FP implementation by identification of situations requiring FP
R-1370	Applied Research on the Operational Concept for UAS in Trajectory-Based Airspace	Applied research on Unmanned Aircraft System's (UAS) operational and air-ground systems integration into trajectory-based airspaces to support alternative selection and regulation decisions on UAS access and transparency requirements.	2015	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations
R-1430	Applied Research on Human/Automation Roles in High-Density Surface Operations	Applied research on alternative aircraft/ground and human/automation roles and responsibilities to support an alternative selection for taxi instruction information and procedures enabling effective high-density surface operations via data messaging. Research will include the concept of communicating and executing taxi operations using data messaging.	2011	Controllers, pilots and aircraft operations personnel need to understand how FP implementation affects their specific operations so that they can collaborate on decision making
R-1460	Applied Research on Common Surface Automation Platform	Applied research for a common surface automation platform, networking and display systems to support cost-effective automated and integrated arrival/departure decision support systems and information technology infrastructure in the tower environment.	2014	Needs to incorporate FP algorithms

R-1520	Applied Research on the Role of Human Forecasters and Automated Systems	Applied research on the role of human forecasters and operational expertise to augment the value of automatically generated Four-Dimensional (4D) weather grids.	2011	Not obvious how this contributes to FP
R-1600	Applied Research on Aircraft-Based CNS Technologies in Self-Separation Airspace	Applied research on the performance level requirements for aircraft-based Communication, Navigation, and Surveillance (CNS) technologies in self-separation operations.	2016	Needs to address BPBS benefits and identification of situations requiring FP
R-1620	Applied Research on Spacing Management in Congested En Route Airspace	Applied research on initial traffic spacing management alternatives in congested en route airspace to support an alternative selection on Trajectory Management, merging, spacing and metering.	2011	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations
R-1630	Applied Research on the Corridor-in-the-Sky Concept	Applied research on the Corridors-in-the-Sky (CITS) concept that identifies a number of corridor alternatives and operational considerations in a mixed equipage environment.	2012	Not obvious how this contributes to FP
DEVELOPMENT ACTIONS				

D-0830	Trajectory Negotiation Protocols for Air and Ground Information Architectures	Development of trajectory negotiation protocols supporting aircraft and ground information architectures.	2010	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations
D-0870	Mixed Equipage Trajectory-Based Routes and Advanced OPD Operations	Development of mixed equipage trajectory-based routes (e.g., Area Navigation/Required Navigation Performance [RNAV/RNP]) and advanced Optimized Profile Descent (OPD) operations to support flexible trajectory-based routing. OPDs are also known as Continuous Descent Arrivals (CDAs).	2013	Need quantification of benefits to better address BPPS concept for FPBPBS impacts
D-1200	Guidance for Trajectory-Based Procedures	Development of trajectory-based procedures to support a national policy decision on liabilities related to the shift in separation responsibility from air traffic service providers to flight operators as well as from humans to automation.	2015	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations
POLICY ISSUES (OTHER THAN PI-0077)				

PI-0001	Airline Operation Centers (AOC) Equipage Implementation Policy	Airline Operation Centers (AOCs) and other users of Four-Dimensional Trajectory (4DT) flight plans must utilize flight planning systems that provide the necessary 4DT data in a form acceptable by Air Navigation Service Providers (ANSP) automation systems. Policies should be developed to determine if operational incentives, economic incentives (e.g., tax credits) or mandates be employed to promote AOC equipage of NextGen technologies. Objective criteria should define when voluntary incentives are abandoned in favor of mandates.	2013	Needs to include requirements that enable stakeholder participation in FP decision making
PI-0014	Aircraft Equipage Implementation Policy	Policies have to be explored to determine if operational incentives, economic incentives (e.g., tax credits) or mandates should be employed to promote aircraft equipage of specific NextGen avionics technologies that will be necessary to achieve improved performance and safety in the National Airspace System (NAS). Objective criteria should define when voluntary incentives are abandoned in favor of mandates. Equipage strategies must reflect proper allocation of aircraft and Air Traffic Management (ATM) automation, with consideration of the tendency for Air Navigation Service Providers (ANSPs) and operators to favor investment solutions that divert costs to other stakeholders. Moreover, aircraft equipage policy must incorporate US and international regulatory/policy coordination, through the International Civil Aviation Organization (ICAO) and/or other bilateral/multilateral partnerships, to harmonize regulations/policies related to standards and compatibility requirements for avionics equipment, and to determine application of US air carrier equipage standards to foreign-based air carriers that enter US airspace. This should address foreign aircraft flying inside the NAS and domestic aircraft exiting the NAS.	2009	Benefits need to be assessed for possible use in BPBS concept

PI-0017	Communications Architecture Plan for Ground, Space, Airborne, and/or Performance-Based Architectures	Policies should be developed to define a strategy for communications services to ensure that performance and avionics standards will be in place when needed for ground-based, space-based, airborne-based, and/or performance-based architectures. This should include a decision on whether an "airborne internet" approach is used.	2009	Benefits need to be assessed for possible use in BPBS concept
PI-0092	Network-Enabled Aviation Safety Information Sharing Environment - Stakeholders	Various issues must be addressed by a safety information Community Of Interest (COI) to include access to or exclusion from privileged, proprietary or confidential information; privacy; non-punitive/non-reprisal error and incident reporting; and protection from third-party liability. These policies are needed because today competitive, liability, and privacy concerns discourage stakeholders in the private sector and state and local government from sharing helpful aviation safety information. Establishing such policies would enable community wide information to support migration from the current historic (accident) analysis to diagnostic and prognostic analyses that use system-wide safety information sources. New policy is needed to establish procedures for sharing aviation safety information among government agencies, state and local governments, and the private sector.	2013	Should address in-flight negotiation/implementation of FP
ENABLERS				

EN-0018	Trajectory Negotiation - Level 4 Automated 4DTs	Enhancements to the integrated suite of Air Navigation Service Providers (ANSP) automation tools that support the automated management of trajectories negotiation. These enhancements integrate auto-negotiation of ANSP and aircraft/operator four-dimensional trajectories (4DTs) with separation management. 4DTs are negotiated between flight crews/operators (including UAS operators) and the ANSP at a time varying from hours before departure to while the aircraft is airborne. ANSP systems perform separation management as trajectories are generated and negotiated. ANSP automation considers all real-time aircraft, airspace constraints, and aircraft capabilities for trajectory negotiation. The flight crew is responsible for final acceptance of negotiated trajectory for crewed aircraft. Explicit acceptance by a human controller is not necessarily required.	2020	Needs to specifically address FP preflight negotiation and implementation with stakeholders; needs to be able to continuously update contention volumes in a means such that all stakeholders, controllers, TMU personnel have information to enable shared situational awareness and informed decision making
OPERATIONAL IMPROVEMENTS				
EN-0032	Avionics - Airborne Self-Separation	Development, validation, and implementation of aircraft technologies and procedures, including those for wake turbulence separation, for airborne separation capability to meet requirements for all NextGen airborne separation applications (airborne self-separation airspace operations, including entry and exit, and delegated airborne separation operations in classic and Trajectory-Based Operations [TBO] airspace).	2022	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations

EN-0228	Avionics - Trajectory Negotiation and Automation	Navigation and automation systems are interfaced or integrated with data communications avionics enabling communication and negotiation between aircraft and the Air Navigation Service Provider (ANSP). While pilots and controllers continue to have final approval capabilities, the negotiation routes can be auto-loaded into navigation avionics and the ANSP. A digital clearance shall be data-linked from the ANSP to the flight crew and the flight crew would either accept/acknowledge, or amend and send back to the ANSP for approval or another round of amendments/approvals. The suggested amendments could be partially or fully automated, but the flight crew/controllers would still have the last rights of refusal. This reduces human errors and pilot/controller workload.	2020	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations
OI-0303	Traffic Management Initiatives with Flight Specific Trajectories	Individual flight-specific trajectory changes resulting from Traffic Management Initiatives (TMIs) will be disseminated to the appropriate Air Navigation Service Provider (ANSP) automation for tactical approval and execution. This capability will increase the agility of the National Airspace System (NAS) to adjust and respond to dynamically changing conditions such as bad weather, congestion, and system outages.	2014	Needs to include requirements that enable stakeholder participation in FP decision making, supports transparency and shared situational awareness

OI-0306	Provide Interactive Flight Planning from Anywhere	Flight planning activities are accomplished from the flight deck as readily as any location. Airborne and ground automation provide the capability to exchange flight planning information and negotiate flight trajectory contract amendments in near real-time. The key change is that the Air Navigation Service Provider's (ANSP) automation allows the user to enter the flight plan incrementally with feedback on conditions for each segment. Rather than testing full trajectories by submitting and waiting for full routes evaluations, the system will test each segment as entered and provide feedback. Through this process the user will work with the system to quickly reach a flight plan agreement. As before any subsequent change, constraint, preference, or intent triggers a full flight plan review with feedback to the filer. The filer can develop preferred trajectories that may include an identified constraint that the automation system maintains in case subsequent changes to conditions will allow its promotion to agreement. Automation thus maintains multiple flight plans for an individual flight.	2018	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations
OI-0319	Time-Based Metering into En Route Streams	This Operational Improvement (OI) provides increased departure throughput via manual time-based control of departing aircraft into an overhead stream using a decision support tool insuring that all available gaps in the En Route stream are filled. It also provides departure and en route time-based control for complex metropolitan airspace where there are multiple departure streams to sequence aircraft over a single en-route fix.	2008	Needs to address FP algorithm implementation

OI-0322	Low Visibility Surface Operations	Aircraft and ground vehicle movement on airports in low visibility conditions is guided by accurate location information and moving map displays. Aircraft and ground vehicles determine their position on an airport from Global Positioning System (GPS), Wide Area Augmentation System (WAAS), Local Area Augmentation System (LAAS), via ADS-B and Ground-Based Transceivers (GBT) systems with or without surface based surveillance. Location information of aircraft and vehicles on the airport surface is displayed on moving maps using Cockpit Display of Traffic Information (CDTI) or aided by Enhanced Flight Vision Systems (EFVS), Enhanced Vision Systems (EVS), Synthetic Visions Systems (SVS) or other types of advanced vision or virtual vision technology.	2018	Not obvious how this contributes to FP
OI-0326	Airborne Merging and Spacing - Single Runway	Arriving or departing aircraft to/from single runways are instructed to achieve and maintain a given spacing in time or distance from a designated lead aircraft as defined by an Air Navigation Service Provider (ANSP) clearance. Onboard displays and automation support the aircraft conducting the merging and spacing procedure to enable accurate adherence to the required spacing. Flight crews are responsible for maintaining safe and efficient spacing from the lead aircraft. Responsibility for separation from all other aircraft remains with the ANSP. Assigned spacing may include a gap to allow for an intervening departure between subsequent arrivals. Mixed-equipage operations are supported; a spacing-capable aircraft can perform airborne spacing behind a non-capable aircraft as long as it is transmitting cooperative surveillance information. This Operational Improvement (OI) includes multiple streams merging to a single runway and includes development of ANSP capability and procedures.	2014	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations

OI-0327	Full Surface Traffic Management with Conformance Monitoring	Efficiency and safety of surface traffic management is increased, with corresponding reduction in environmental impacts, through the use of improved surveillance, automation, on-board displays, and data link of taxi instructions. Equipped aircraft and ground vehicles provide surface traffic information in real-time to all parties of interest. A comprehensive view of aggregate traffic flows enables Air Navigation Service Provider (ANSP) to project demand; predict, plan, and manage surface movements; and balance runway assignments, facilitating more efficient surface movement and arrival and departure flows. Automation monitors conformance of surface operations and updates the estimated departure clearance times to renegotiate the 4DT. Surface optimization automation includes activities such as runway snow removal, aircraft de-icing, and runway configuration.	2018	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations

OI-0329	Airborne Merging and Spacing with OPD	Fuel consumption and noise on approaches are reduced while maintaining throughput in heavy traffic through Optimized Profile Descent (OPD) combined with airborne merging and spacing in moderate-to-heavy traffic. OPD is also known as Continuous Descent Arrival (CDA). This Operational Improvement (OI) requires airborne merging and spacing capability as well as airborne guidance to perform optimized OPD while staying within assigned lateral and vertical airspace corridor limits. This OI is complementary to OI-0325 which delivers the aircraft at top of descent with spacing to initiate a successful OPD. This OI improves individual aircraft fuel reduction through onboard energy guidance, and enables reduced spacing buffers and hence increased throughput from precision airborne spacing. Mixed equipage can be supported within a single arrival stream, with some aircraft self-spacing and other aircraft managed by Air Navigation Service Provider (ANSP). This OI requires an Implementation Decision to determine appropriate trajectory restrictions laterally, vertically, and in time, based on trade off between aircraft performance/efficiency versus optimal use of airspace, including weather and environmental constraints.	2015	Not obvious how this contributes to FP, although it may support BPBS understanding

OI-0330	Time-Based and Metered Routes with OPD	Time-based and metered Required Navigational Performance (RNP) routes are flown. Where practical, arrival routes support Optimized Profile Descent (OPD) operations under moderate to heavy traffic conditions, with ground-based automation providing conflict-free, time-based metering solutions over the entire OPD trajectory to the runway. OPD is also known as Continuous Descent Arrival, or CDA. This enables aircraft with minimal equipage to perform OPDs. This Operational Improvement (OI) requires an Implementation Decision to determine the most effective method for negotiating time-based route and an Implementation Decision to determine how restricted the trajectory will be laterally, vertically, and in time, based on trade off between aircraft performance/efficiency versus optimal use of airspace.	2016	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations

OI-0331	Improved Management of Arrival/Surface/Departure Flow Operations	This Operational Improvement (OI) integrates advanced Arrival/Departure flow management with advanced Surface operation functions to improve overall airport capacity and efficiency. Air Navigation Service Provider (ANSP) automation uses arrival and departure-scheduling tools and four dimensional trajectory (4DT) agreements to flow traffic at high-density airports. Automation incorporates Traffic Management Initiatives (TMIs), current conditions (e.g., weather), airport configuration, user provided gate assignments, requested runway, aircraft wake characteristics, and flight performance profiles. ANSP, flight planners, and airport operators monitor airport operational efficiency and make collaborative real-time adjustments to schedules and sequencing of aircraft to optimize throughput. Arrival and departure flows and surface operations are more effectively planned and managed through the integration of current flight plans as well as real-time airborne and surface trajectory information into Air Navigation Service Provider (ANSP) decision support automation tools. These decision support tools enable ANSP flow managers to work collaboratively with flight operators and with ANSP controllers to effectively manage high-capacity arrival and departure flows in the presence of various weather conditions. Automation provides optimal departure scheduling and staging and arrival sequencing based on aircraft wake and airborne performance characteristics.	2018	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations

OI-0333	Improved Parallel Runway Operations	The improvement will explore concepts to recover lost capacity through reduced separation standards, increased applications of dependent and independent operations, enabled operations in lower visibility conditions, and changes in separation responsibility between the ATC and the flight deck. This improvement will develop improved procedures that enable operations for closely spaced parallel runways (runways spaced less than 4300 feet laterally) in lower visibility conditions. This operational improvement promotes a coordinated implementation of policies, technologies, standards and procedures to meet the requirement for increased capacity while meeting safety, security, and environmental goals. Intermediate concepts for maintaining access to parallel runways continue to be explored (e.g., use of RNP approaches to define parallel approaches with adequate spacing; RNP transition to an ILS final approach course; RNP/LAAS/WAAS; Wake Program Office initiatives). Research will be initiated to support far-term capacity requirements. Research will be focused on finding ways to recover lost capacity due to IMC events by providing a monitoring capability that mimics or replaces visual separation. VMC-like capacity may be achieved by integrating new aircraft technologies such as ADS-B in, Precision navigation, data link and cockpit displays.	2016	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations

OI-0334	Independent Converging Approaches in IMC	This Operational Improvement (OI) enables maintaining Visual Meteorological Condition (VMC) arrival and departure rates in Instrument Meteorological Conditions (IMC) through use of onboard displays and alerting for independent converging runways. Using precision navigation, cooperative surveillance, and onboard algorithms and displays allows the reduction of lateral separation requirements for converging runway operations in IMC. Includes independent approaches to converging runways that are centerline distances greater than 2500 ft. The implementation of this OI is strongly dependent on when an airline decides this is important and steps forward to advocate for it.	2017	All displays need to incorporate FP functionality to facilitate transparency and shared situational awareness
OI-0335	Closely-Spaced Parallel Runway Operations in IMC	This Operational Improvement (OI) allows additional reduction of lateral spacing for arrivals to very closely spaced parallel runways at Operational Evolution Partnership (OEP) airports. This includes approaches with altitude offsets at suitable airports, and co-altitude approaches where necessary. This OI may result in more capacity than is achieved today, i.e., Visual Meteorological Condition (VMC) rates may increase. This OI applies to runways that are closer than 2500 ft centerline to centerline and converging runways. This enables new runways to be built much closer to existing runways, potentially reducing the cost for new runway construction. Avoidance of wake vortices is an important consideration. Determination of minimum parallel runway spacing for independent operations is dependent in part on wake turbulence avoidance.	2017	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations

OI-0338	Efficient Metroplex Merging and Spacing	Air navigation service provider (ANSP) automation and decision support tools incorporate aircraft wake characteristics and forecast wake transport conditions. Spacing buffers between streams approaching and departing multiple metroplex runways are reduced to allow efficient airborne merging and spacing, increasing greater traffic throughput and reduced ANSP workload in terminal areas. Arrival and departure flows are planned and executed based on a comprehensive view of real time airport operations. Automation provides optimal departure staging and arrival sequencing based on aircraft wake, wake conditions and airborne performance characteristics. Data communications provides required navigation performance routes to the flight deck. This OI includes development of ANSP capability and procedures and requires an Implementation Decision to determine what complex airborne merging and spacing operations will be required for effective use of high-density metroplex airspace, such as crossing streams, merging and diverging streams, etc.	2020	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations

OI-0340	Provide Surface Situation to Pilots, Service Providers and Vehicle Operators for Near-Zero-Visibility Surface Operations	Aircraft and surface vehicle positions are displayed to aircraft, vehicle operators, and air navigation service providers (ANSP) to provide situational awareness in restricted visibility conditions, increasing efficiency of surface movement. Surface movement is guided by technology such as moving map displays, enhanced vision sensors, synthetic vision systems, Ground Support Equipment and a Cooperative Surveillance System. Aircraft and surface vehicle position will be sensed and communicated utilizing systems such as Cockpit Display of Traffic Information (CDTI) and Automatic Dependent Surveillance-Broadcast (ADS-B). Efficient management of surface movement requires cooperative surveillance (i.e., ADS-B out) for all aircraft and ground vehicles present.	2025	All displays need to incorporate FP functionality to facilitate transparency and shared situational awareness.

OI-0348	Reduce Separation - High Density Terminal, Less Than 3-miles	Metroplex airspace capacity is increased through implementing separation procedures for conducting separation with less than 3-miles between high navigation precision arrival and departure routes. This Operational Improvement increases metroplex airspace capacity and supports super density airport operations. Enhanced surveillance and data processing provides faster update rates to allow reduced separation. Arrival/departure routes with lower Required Navigation Performance (RNP) values (e.g., RNP<1 nm) are defined with less than 3 miles lateral separation between routes, subject to wake vortex constraints, enabling the use of more routes in a given airspace. This may require airborne lateral separation between routes. Enhanced Required Surveillance Performance (RSP) is required, allowing more precise location so that separation can be further reduced. The specific level of RSP will determine to what degree separation can be less than 3 miles. This requires a Policy Decision to determine what RNP values to require based on performance benefit versus equipage requirements and operational considerations. Expected use: high density terminal and transition airspace.	2025	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations

OI-0351	Flexible Airspace Management	Air Navigation Service Provider (ANSP) automation supports reallocation of trajectory information, surveillance, communications, and display information to different positions or different facilities. The ANSP moves controller capacity to meet demand. Automation enhancements enable increased flexibility to change sector boundaries and airspace volume definitions in accordance with pre-defined configurations. The extent of flexibility has been limited due to limitations of automation, surveillance, and communication capabilities, such as primary and secondary radar coverage, availability of radio frequencies, and ground-communication lines. New automated tools will define and support the assessment of alternate configurations as well as re-mapping of information (e.g., flight and radar) to the appropriate positions.	2015	Needs to address FP algorithm implementation

OI-0355	Delegated Responsibility for Horizontal Separation (Lateral and Longitudinal): Terminal	Enhanced surveillance and new procedures enable the ANSP to delegate some responsibility for maintaining aircraft-to-aircraft separation to flight crews. Improved display avionics and broadcast positional data provide detailed traffic situational awareness to the flight deck. When authorized by the controller, pilots will implement delegated separation between equipped aircraft using established procedures to achieve more consistent and predictable aircraft spacing. This spacing will more accurately apply existing separation standards, in various meteorological conditions, while at the same time reducing controller workload. Broadcast surveillance sources and improved avionics capabilities provide ANSP and the flight deck with accurate position and trajectory data and therefore increased situational awareness. Aircraft that are equipped to receive the broadcasts and have the associated displays, avionics, and crew training will perform delegated separation when authorized by the controller. During specific meteorological conditions and/or air traffic procedures, delegated separation operations include the transfer of separation authority for a specific maneuver to achieve improved NAS capacity and flight efficiency. For example, during Instrument Meteorological Conditions (IMC), the additional situational awareness on the flight deck provided by displays of proximate traffic enable aircraft to accept some separation responsibility without adding a separation buffer to the 3 NM separation standard. During certain marginal conditions in the terminal area, this procedure enables aircraft to continue with the Visual Meteorological Conditions separation instead of decreasing capacity by switching to much lower capacity IFR operations. Aircraft performing delegated separation procedures are paired and separate themselves from one another by maintaining a given time or distance from a designated aircraft using cockpit-based tools. The use of this procedure will replace some of the ATC vectoring	2015	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations

OI-0360	Automation-Assisted Trajectory Negotiation and Conflict Resolution	Trajectory management is enhanced by automated assistance to negotiate pilot trajectory change requests with properly equipped aircraft operators to resolve conflicts. Four-Dimensional Trajectories (4DTs) are negotiated between the pilot/aircraft operator and the ANSP, using ground-based automation to provide trial planning using intent data, and conflict detection and resolution in en route trajectory-based operations. A trajectory change can be requested by an Unmanned Aircraft System (UAS) operator, or perhaps even Flight Operations Center (FOC) personnel. The trajectory change would then be relayed to the pilot/aircraft operator. The aircraft operator must acknowledge receipt and acceptance of the negotiated trajectory change. Decision support tools identify conflicts/complexity/density conditions and provide alternatives to the air navigation service provider (ANSP) to resolve the conditions. These alternatives include proposed trajectories, or intent data, that are exchanged with the operator via data communications, allowing solutions that are not subject to constraints imposed by voice. Human Air Navigation Service Providers (ANSPs), supported by automation, are responsible for separation management. This will enable higher density of operations thus higher capacity as well as decrease human errors in trajectory negotiation and data entry.	2021	Needs to specifically address FP preflight negotiation and implementation with stakeholders. In addition, needs to be able to continuously update contention volumes in a means such that all stakeholders, controllers, TMU personnel have information to enable shared situational awareness and informed decision making.

OI-0362	Self-Separation Airspace Operations	In self-separation airspace, capable aircraft, equipped with Automatic Dependent Surveillance-Broadcast (ADS- B) and onboard conflict detection and alerting, are responsible for separating themselves from one another, and the Air Navigation Service Provider (ANSP) provides no separation services, enabling preferred operator routing with increased ANSP productivity. Research will determine whether the ANSP will provide any traffic flow management services within self-separation airspace. Aircraft must meet equipage requirements to enter self-separation airspace, including transmission of trajectory intent information through cooperative surveillance. Transition into self-separation airspace includes an explicit hand-off and acceptance of separation responsibility by the aircraft. Transition into ANSP-managed airspace is facilitated through assigned waypoints with Controlled Time of Arrivals (CTAs), allowing the ANSP to sequence and schedule entry into congested airspace, and self-separating aircraft are responsible for meeting assigned CTAs. Self-separating aircraft execute standardized algorithms to detect and provide resolutions to conflicts. Right-of-way rules determine which aircraft should maneuver to maintain separation when a conflict is predicted. Contingency procedures ensure safe separation in the event of failures.	2022	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations

OI-0368	Flow Corridors - Level 2 Dynamic	High density En Route dynamic flow corridors accommodate aircraft that are capable of self-separation, equipped with Automatic Dependent Surveillance-Broadcast (ADS- B) and onboard conflict detection and alerting, traveling on similar wind-efficient routes or through airspace restricted by convective weather cells, Special Use Airspace (SUA), or overall congestion. Dynamic high density flow corridors are defined daily and shifted throughout the flight day to avoid severe weather regions and airspace restrictions (e.g., SUA) or take advantage of favorable winds. Dynamic corridor entry and exit points are also defined. This extends static flow corridor technology via dynamic airspace design capabilities to provide more En Route capacity to trajectory-based aircraft when the available airspace is restricted. Real-time information on corridor location, and logistics and procedures for dynamically relocating a corridor while it is in effect must be developed. If corridor use is to be widespread, techniques for merging, diverging, and crossing corridors may also be required.	2025	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations

OI-0369	Automated Negotiation/Separation Management	Trajectory management is enhanced by separation management automation that negotiates with properly equipped aircraft and adjusts individual aircraft Four-Dimensional Trajectories (4DTs) to provide efficient trajectories, manage complexity, and ensure separation assurance. Negotiating with aircraft and adjusting individual 4DT trajectories synchronizes or restricts access to airspace, tactically resolves conflicts among aircraft, and avoids weather, special use airspace, terrain, or other hazards. The ANSP Separation Management function is fully automated and manages separation by negotiating conflict-driven updates to the 4DT agreements with the aircraft. This evolution, required to maximize capacity and en route throughput, allows flexibility for higher density of operations thus higher capacity, as well as a decrease in human errors in trajectory negotiation and data entry. This Operational Improvement requires a Policy/Implementation Decision to determine appropriate roles/responsibilities allocated between humans/automation and air/ground.	2025	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations; Needs to specifically address FP preflight negotiation and implementation with stakeholders. In addition, needs to be able to continuously update contention volumes in a means such that all stakeholders, controllers, TMU personnel have information to enable shared situational awareness and informed decision making.

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OI-0370	Trajectory-Based Management - Gate-To-Gate	All aircraft operating in high density airspace are managed by Four Dimensional Trajectory (4DT) in En Route climb, cruise, descent, and airport surface phases of flight to dramatically reduce the uncertainty of an aircraft's future flight path in terms of predicted spatial position (latitude, longitude, and altitude) and times along points in its path. Integrating separation assurance and traffic management time constraints (e.g., runway times of arrival, gate times of arrival), this end state of 4DTbased capability calculates and negotiates 4DTs, allows tactical adjustment of individual aircraft trajectories within a flow, resolves conflicts, and performs conformance monitoring by Air Navigation Service Providers (ANSPs) to more efficiently manage complexity, ensure separation assurance, and enhance capacity and throughput of high density airspace to accommodate increased levels of demand. This will be enabled by the trajectory exchange through data communications, as well as many new surface automation and 3D (x, y, and time) trajectory operations.	2025	Basic need across NextGen, including for FP, that the geometry of any potential contention volume be well understood for both 4DT negotiation, as well as for identification of volumes requiring FP; recurring need due to the dynamics of the flight environment and the large number of simultaneous operations; Needs to address FP algorithm implementation

OI-0385	Full Collaborative Decision Making	Timely, effective, and informed decision making based on shared situational awareness is achieved through advanced communication and information sharing systems. Stakeholder decisions are supported through access to an information exchange environment and a transformed collaborative decision making process that allows wide access to information by all parties (whether airborne or on the ground), while recognizing privacy and security constraints. Decision-makers request information when needed, publish information as appropriate, and use subscription services to automatically receive desired information through the net-centric infrastructure service. Net-centricity ensures a robust, globally interconnected network environment in which information is shared in a timely and consistent manner among users, applications, and platforms during all phases of aviation transportation efforts. This information environment enables more timely access to information and increased situational awareness while providing consistency of information among decision-makers. A mixture of near-real-time and post-ops analysis from both the air navigation service provider and aircraft operators is shared. With nearly instant feedback on the system-wide implications of their plans, decision making can be allocated to the person in the best position to make safety and efficiency calls, including an increased level of decision making by the flight crew and flight operations centers. Decision-makers have access to options analysis Decision Support Tool (DST) which performs fast-time simulations to assess the NAS wide implications of any proposed changes in trajectory on other flight operations. Decision-makers have more information about relevant issues, decisions are made more quickly, required lead times for implementation are reduced, responses are more specific, and solutions are more flexible to change. To ensure locally developed solutions do not conflict, decision-makers are guided by NAS-wide objectives and test solutions to identify interference and conflicts with other initiatives.	2023	Needs to include requirements that enable stakeholder participation in FP decision making, supports transparency and shared situational awareness

OI-0408	Provide Full Flight Plan Constraint Evaluation with Feedback	Timely and accurate National Airspace System (NAS) information allows users to plan and fly routings that meet their objectives. Constraint information that impacts proposed flight routes is incorporated into Air Navigation Service Provider (ANSP) automation, and is available to users for their pre-departure flight planning. Constraint information is both temporal and volumetric. Constraint volumes can be "hard constraints" (no access to this volume for this time period), "conditional constraints" (flights are subject to access control), and "advisory constraints" (service reduction or significant weather). Flight trajectories are built from the filed flight plan and the trajectory is evaluated against the constraint volumes. Feedback is provided to the filer (not the flight deck) on the computed trajectory with a listing of constraints, the time period for the constraints, and the nature of access. A user can adjust the flight plan based on available information, and re-file as additional information is received, or can wait for a later time to make adjustments. Up to NAS departure time, as constraints change, expire, or are newly initiated, currently filed flight plans are retested. Update notifications are provided to filers if conditions along the trajectory change. In addition, the user can submit alternative flight plans.	2013	Needs to include requirements that enable stakeholder participation in FP decision making, supports transparency and shared situational awareness