Initial Investigation of Operational Concept Elements for NASA's NextGen-Airportal Project Research

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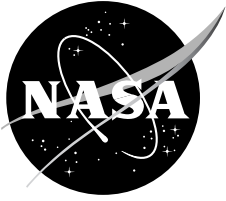
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GLOSSARY/ACRONYMS/ABBREVIATIONS

4D	Fourth Dimension
AAR	Airport Arrival Rate
ADR	Airport Departure Rate
ADS-B	Automatic Dependent Surveillance-Broadcast
AOC	Airline Operations Center
ATC	Air Traffic Control
ATIM	Airportal Transition and Integration Management
ATM	Air Traffic Management
ATM/ATC	Air Traffic Management/Air Traffic Control
ATSP	Air Traffic Service Provider
CADOM	Coordinated Arrival/Departure Operations Management
CD&R	Conflict Detection and Resolution
CDM	Collaborative Decision-Making
ConOps	Concept of Operations
CSPR	Closely-Spaced Parallel Runways
DAC	Dynamic Airspace Configuration
ETA	Expected Time of Arrival
EVO	Equivalent Visual Operations
JPDO	Joint Planning and Development Office
NAS	National Airspace System
NextGen	Next Generation
PBS	Performance-Based Services
PRT	Personal Rapid Transit
RFA	Research Focus area
RNAV	Area Navigation
RNP	Required Navigation Performance
SA	Separation Assurance
SATS	Small Aircraft Transportation Systems
SDO	Super Density Operations
SESO	Safe and Efficient Surface Operations
SLDAST	System-Level Design, Analysis and Simulation Tools
SUA	Special Use Airspace
SWIM	System-wide Information Management
TFM	Traffic Flow Management
TPSU	Trajectory Prediction, Synthesis, and Uncertainty
TRACON	Terminal Radar Approach Control

EXECUTIVE SUMMARY

These concepts have been developed for NASA's Next Generation Air Transportation System (NextGen)-Airportal Project under the Airspace Systems Program. The NextGen-Airportal Project supports NextGen by providing key research results to enable integrated solutions for safe, efficient, and high-capacity airports.

The NextGen-Airportal Project is organized into three research focus areas: Safe and Efficient Surface Operations (SESO), Coordinated Arrival/Departure Operations Management (CADOM), and Airportal Transition and Integration Management (ATIM). The content in this document was derived from an examination of constraints and problems at airports for accommodating future increases in air traffic, and from an examination of capabilities envisioned for NextGen. The concepts are organized around categories of constraints and problems and therefore do not precisely match the research focus areas. However, the categories generally reflect the research focus areas.

The concepts provide a framework for defining and coordinating research activities that are and will be conducted by the NextGen-Airportal Project. The concepts will help the research activities function as an integrated set focused on future needs for airport operations and will aid in aligning the research activities with NextGen key capabilities. The concepts are presented as concept elements with more detailed sub-elements under each concept element. The concept elements and cross-cutting attributes of the concept elements are:

Surface
- Runway Management
- Taxi Route Planning
- Surface Super Density Operations
- Surface Weather and Environmental Planning

Terminal Airspace
- Precise Spacing and Separation Assurance
- Dynamic Airspace Management
- Adapting Operations to Conditions
- Metroplex Operations

Coordination and Integration of Concept Elements
- Coordination and Integration among Airport Surface Operations
- Coordination and Integration among Terminal Airspace Operations
- Coordination and Integration among Airport Surface and Terminal Airspace Operations
- Coordination and Integration among Metroplex Operations

Small Airports

Advanced Concepts Elements
- Adaptive Metroplex Operations
- Advanced Airport Design Tools

Crosscutting Attributes of Concept Elements
- Human Factors
- Safety
- Environment
- System Failure

For each concept element, the following topics are discussed: constraints and problems being addressed, benefit descriptions, required technology and infrastructure, and an initial list of potential research topics. Concept content will be updated and more detail added as the research progresses. The concepts are focused on enhancing airportal capacity and efficiency in a timeframe 20 to 25 years in the future, which is similar to NextGen's timeframe.

INITIAL INVESTIGATION OF OPERATIONAL CONCEPT ELEMENTS FOR NASA'S NEXTGEN-AIRPORTAL PROJECT RESEARCH

Jonathan Lee,[1] Gary Lohr,[2] James L. Poage,[3] and Leonard Tobias[4]

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1   INTRODUCTION

These concepts have been developed for NASA's Next Generation Air Transportation System (NextGen) - Airportal Project under the Airspace Systems Program. The program conducts Air Traffic Management (ATM) research in support of the NextGen being developed by the Joint Planning and Development Office (JPDO). The NextGen-Airportal Project supports NextGen by providing key research results to enable integrated solutions for safe, efficient, and high-capacity airports.

The major goal of the NextGen-Airportal Project is to enable capacity improvements in the terminal and airport domains to achieve the NextGen target of a two- to three-fold capacity increase for the National Airspace System (NAS). This goal will be pursued with consideration for safety implications, mitigation of environmental impacts, system efficiency and flexibility, and user preferences (i.e., preferences of the aircraft operator). Since every airport is a unique environment and demand is not expected to increase equally at each airport, the project will develop and evaluate a suite of capacity-increasing concepts and the system analysis capability to aid tailoring solutions to specific needs.

The NextGen-Airportal Project is organized into three research focus areas: Safe and Efficient Surface Operations (SESO), Coordinated Arrival/Departure Operations Management (CADOM), and Airportal Transition and Integration Management (ATIM). The content in these concepts was derived from an examination of constraints and problems at airports for accommodating future increases in air traffic and from an examination of capabilities in NextGen. The concepts are organized around categories of constraints and problems and therefore do not precisely match the research focus areas. However, the categories generally reflect the research focus areas.

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1.1 Purpose of the Airportal Concept

The concepts provide a framework for defining and coordinating research activities that are and will be conducted by the NextGen-Airportal Project. The concepts will help the research activities function as an integrated set focused on future needs for airport operations and will aid in aligning the research activities with NextGen key capabilities. This content will aid the project in identifying research issues, determining specific research activities for the issues, and forming the "right mix" of research activities. The concepts will also support analysis of benefits, examining human-automation interactions and other human factor issues, safety impacts, and environmental implications. In fact, analyses of these topics are the subject of companion documents currently being prepared.

The concepts are also intended to provide a basis for exchanging ideas and coordinating research with the Airspace Project and the JPDO. Both the Airportal and Airspace Projects involve the terminal airspace, and thus there is overlap between the projects. Roles for the two projects regarding the terminal airspace will be coordinated as the two projects plan their research activities.

This document discusses Airportal operational concept elements. It is not a "Concept of Operations," which typically describes such topics as roles and responsibilities of participants in operations, how Air Traffic Management/Air Traffic Control (ATM/ATC) services will be provided, and how aircraft will fly gate-to-gate. Since the Airportal concepts are intended to provide a framework for defining and coordinating the project's research activities, they do not present a detailed statement of specifics about how future concept elements for airport operations will be performed.

The Airportal concepts might be viewed as performance-level concepts in that they present elements of airport operations, but not the details on how this performance will be realized. The concepts describe constraints and problems for meeting future airport demand, concept elements for operations to overcome these problems, high-level benefits of these operational improvements, and research topics to develop the operational improvements. The research topics are presented as suggestions; the actual research activities to be conducted are planned by the SESO, CADOM, and ATIM research focus areas. While roles and responsibilities of humans and automaton are not described in the concept, there is a discussion of potential research issues for human-automation interactions.

1.2 Scope of the Airportal Concepts

The concepts are focused on enhancing airport capacity and efficiency in a timeframe 20 to 25 years in the future, which is similar to NextGen's timeframe. While the NextGen Concept of Operations (ConOps) has considerable detail on airspace operations, it has few details on airport operations. Thus, this document goes beyond the information presented about airport operations in the ConOps. The content of these concepts are not limited by current research activities of the NextGen-Airportal Project.

Several topics related to airport operations are beyond the scope of this concept and are therefore not addressed. These include changing the size of aircraft to handle future passenger demand, changing

schedules to spread out demand, other changes in business models of aircraft operators, and transition planning and mixed equipage of aircraft during transition. Aircraft are assumed to have the equipage needed to operate under the future concept elements described. Security is also not addressed, since this is not a NASA role.

1.3 Approach to Develop Airportal Concept

The concept elements presented in these concepts were identified by discussions with managers of the NextGen-Airportal Project, by reviewing NextGen concept documents and briefings (e.g., *Concept of Operations for the Next Generation Air Transportation System*, 2007), by reviewing journal papers on surface and terminal airspace (listed in the Bibliography), by reviewing concepts developed by others (e.g., *Virtual Airspace Modeling and Simulation System-Wide Concept*, 2006 and RTCA Free Flight Steering Committee, 2002), and by drawing upon the experience of the four concept authors.[5]

The writing of these concept elements involved interactions with the NextGen-Airportal Project's Principal Investigator, Project Scientist, Project Manager, and Associate Principal Investigators. There was also coordination with the Airspace Project to ensure that the directions of the Airportal and Airspace Projects are compatible.

1.4 Organization of This Document

Before presenting the concept elements to improve airport capacity, Section 2.0 discusses the future setting in which the improvements will operate. This examination is presented to help ensure that the concept elements are robust enough to meet future airport needs.

Sections 3.0, 4.0, and 5.0 present concept elements for surface, terminal airspace, and coordination and integration areas. In addition to describing concept elements, the sections discuss the constraints and problems being addressed, benefit descriptions, required technology and infrastructure, and an initial list of potential research topics. Section 6.0 discusses concept elements for small city and rural airports since these airports are likely to have more air traffic with an increase in point-to-point flights.

Section 7.0 describes advanced concepts elements that are likely to apply farther in the future. One is adaptive metroplex operations, where an aircraft's arrival airport (within a metroplex) can be changed dynamically prior to, or during, a flight. Another is planning tools to design airport layouts

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[5] The range of experience of the authors includes: development of ATM and ATC decision aids (e.g., NASA projects of Center-TRACON Automation System (CTAS), Virtual Airspace Modeling and Simulation (VAMS), and Advanced Air Transportation Technologies(AATT)); experience as an air traffic controller; experience working on Federal Aviation Administration (FAA) projects (e.g., Safe Flight 21 and FAA R&D program); and experience in optimization methods.

that take advantage of the elements to be developed by the NextGen-Airportal Project. Section 8.0 discusses topics that cut across the various concept elements presented in Sections 3.0 through 7.0, such as human factors, safety, and environmental issues. Section 9.0 discusses further development of the Airportal concepts.

Appendix A maps the Airportal concept elements into the Airportal and Airspace Project research focus areas. Appendix B summarizes the Airportal concepts in one multipage table. The table has three columns presenting the concept elements and summaries of the constraints or problems addressed by each element, the sub-elements of each element, and potential research topics for each element. This table assembles the concept elements and sub-elements in one easy-to-use display.

A bibliography of documents examined to identify airport capacity enhancing ideas is included. The papers include documentation of other air transportation concepts, studies of airport operations, and descriptions of techniques developed by various authors for enhancing particular aspects of airport operations.

2   FUTURE SETTING FOR AIRPORT CAPACITY IMPROVEMENTS

The future air traffic demand that will require increased capacity at the nation's airports is more than just an increase in total aircraft. There are many attributes of future air traffic that will affect how successfully the NextGen-Airportal Project will provide increased capacity. Such attributes include aircraft fleet mix (i.e., mix of jumbo jets, large jets, medium jets, regional jets, business jets, very light jets, and general aviation aircraft); scheduling of aircraft using particular airports (e.g., extent of peak period traffic); origin-destination traffic patterns; extent of hub operations; extent of point-to-point services; and extent of service to small airports. No set of future capacity-improving concept elements will provide the capacity to meet unlimited future air traffic demand. The ability of the future air transportation system to satisfy the needs for passenger and cargo transit will depend on both the attributes of capacity provided and the attributes of demand.

Attributes of air traffic demand for airport services in 20 to 25 years are unknown. To overcome this lack of future knowledge and to help ensure that the NextGen-Airportal Project research activities will be effective regardless of the attributes of future demand, it would be helpful for the capacity improvements to be robust enough to work in a variety of future demand scenarios. This section provides a brief discussion of the attributes of future demand and the concept elements presented in this document to deal with a range of demand scenarios.

2.1   Air Traffic Demand Attributes for Airport Services

Many designs and analyses of air transportation concepts assume that the distribution of persons to aircraft sizes, the distribution of aircraft sizes to airports, and the scheduling of aircraft to airports will remain fixed. Under these assumptions, the future demand is determined by increasing the total number of flights while keeping unchanged the distribution of aircraft size, distribution of aircraft to particular airports, and proportion of aircraft using airports by time of day. However, these distributions of demand attributes will change in the future due to changes in aircraft operator's

business models or to responses to future airport services. Noted below are some attributes in demand that may change in the future and will be considered in designing airport capacity enhancements.

Possible attributes of future airport demand include:

- Aircraft size mix – The future is expected to bring more heavy jets and very light jets, as well as changes in the use of other aircraft types. Changes in aircraft size mix affect the ability of overall airport capacity to meet demand because of the number of aircraft that may want to use a specific airport at peak times, sequencing landing aircraft to account for wake, and distribution of flights among major and small airports.

- Scheduling aircraft at peak periods – Aircraft operators may shift flights away from peak periods to gain efficiency in their operations. Future congestion pricing, in whatever form, may also shift flights.

- Hub and Point-to-Point operations – Changes in the number of future flights operated in a hubbing mode or in point-to-point will change the demand at particular airports and may shift flights from major hub airports to smaller airports. Such changes will influence the potential for metroplex operations and the need to provide more services at smaller airports.

- Changes in the number of air carriers – There may be continued consolidation in the number of air carriers that could decrease the number of flights, or there may be additional carriers with new business models (e.g., low-cost carriers, carriers focused on providing first class or business class service, or on-demand air taxi service with very light jets) that will increase the number of flights as well as change the demand for service at particular airports.

- Air carrier demand changes in poor weather – Collaborative Decision-Making (CDM) is changing the demand for airport services in poor weather by air carriers notifying ATC of cancelled flights or changes in flight plans. There may be other future changes in demand scheduling during poor weather that may affect airport demand.

2.2   Airport Capacity Attributes

The possible attributes of future demand for airport service, which are listed in Section 2.1, and the extent to which they are uncertain, need be addressed in the formulation of the Airportal concepts. This document deals with these demand attributes in a variety of ways, for example: concept elements to increase capacity at major airports (although it needs to be noted that there are limits in the ability to increase capacity at existing major airports to handle future demand); runway balancing and sequence improvements to tackle changes in fleet mix; provision for Closely-Spaced Parallel Runways (CSPR) to increase airport capacity; virtual and automated towers to enable small airports to handle more demand for point-to-point flights; equivalent visual operations (EVO) to maintain system capacity in poor weather; and metroplexes to handle increased demand at metropolitan areas.

2.3 Sources of Airport Capacity

Future capacity to provide for aircraft arrivals and departures will arise from the utilization of more airports, and from increased operations at existing hub airports, which can be expressed as

Total Capacity = [Utilize more airports] + [Better utilize existing hub airports].

Better utilization of existing hub airports is provided by increasing their base capacity and by mitigating weather impacts on capacity, thus

Total Capacity = [Utilize more airports] + [(Increased base capacity at existing hub airports)
+ (Mitigate weather impact on capacity)].

In addition to identifying constraints and problems for meeting future demand for airport services, these views of sources of increased airport capacity were also examined in identifying airport capacity concept elements. Examples of capacity enhancements resulting from utilizing more airports include the use of virtual or automated towers at small airports to increase the level of traffic they can support, and metroplexes of multiple airports that make better use of nonhub airports in a metropolitan area. Examples of increasing base capacity at existing hub airports include runway balancing and scheduling, CSPR operations, reducing runway occupancy time, improving taxi routing, and reducing wake constraints. Finally, examples of mitigating weather impacts on capacity include EVO, runway and taxi configuration management, and adjustment of surface operations for wet or snowy runway conditions.

Section 3.0 begins the presentation of concept elements and more detailed sub-elements for increasing airport capacity. The term "concept element" is used to indicate a specific means for improving airport capacity, and the term "concept sub-element" is used for a more detailed breakdown of how airport capacity can be improved under a particular concept element. An example is the four concept elements for improving surface capacity: runway management, taxi route planning, surface Super Density Operations (SDO), and surface weather and environmental planning. Several concept sub-elements are presented for the runway management concept element: optimized runway and taxiway configuration change, dynamic allocation of runways, and more efficient departure sequences and schedules.

3   SURFACE CONCEPT ELEMENTS

Surface concept elements are presented for runway management, taxi route planning, surface SDO, and surface weather and environmental planning. Increasing runway capacity is a goal of NextGen as indicated by the statement, "The movement of aircraft … on the airport surface requires new logistics, management, and technology in order to enable the efficiencies required with NextGen." from the Concept of Operations for the Next Generation Air Transportation System, Version 2.0, June 2007.

3.1 Runway Management

Runway management addresses which runways are used for arrivals, departures, and mixed operations, and which runway will be used by a particular aircraft. It also addresses changing runway and taxiway configurations to meet wind and demand conditions.

3.1.1 Constraint/problem for runway management

The airport ground infrastructure is fixed since the runways and taxiways are constructed of concrete and cannot be changed in any short timeframe. Thus, the Air Traffic Management (ATM) aspect of runways and taxiways is to determine which ones to use given wind, traffic demand, and environmental considerations. A particular runway configuration is usually selected to maximize capacity for given wind conditions. Environmentally friendly configurations (i.e., configurations that reduce noise) are selected when possible. Taxiway configurations are selected to fit the runways being used and gate locations. Any change in runway configuration includes changing the taxi routes of departing aircraft and the arrival routes in terminal airspace of arriving aircraft. Redirecting aircraft arriving and departing at the runways being changed may result in a long transition period with accompanying delays depending on the amount and location of surface traffic, the preparation time available prior to the change, and the surface taxiway layout. Currently, controllers have few tools to support configuration management and must react as conditions change.

3.1.2 Description of runway management

Airport runway management is a complex issue. Runway configuration needs to be changed based on wind, demand, and noise considerations; departures and arrivals on specific runways need to be handled based on their relative demand and terminal airspace route availability. Future airport operations will have advanced tools to manage runway operations more effectively. There are human factor issues for new runway management operations as was stated in Section 1.4. Human factor issues cut across most all of the concept elements to be presented and are discussed in Section 8.0 on crosscutting issues.

The concept elements for runway management will include:

- *Optimized runway and taxiway configuration change*

  Runway and taxiway configurations will be optimized for capacity based on weather (primarily wind), arrival and departure demands, dynamic wake separation criteria, environmental constraints, and other Traffic Flow Management (TFM) considerations. Transition of arrival and departure operations to a changed runway and taxiway configuration will be planned to minimize disruptions to capacity. The precise factors that influence optimizing runway configurations will be determined and incorporated into configuration planning tools.

- *Dynamic allocation of runways (for a given configuration)*

  The allocation of arrival and departure slots to runways, often called *runway balancing*, will be based dynamically on predicted demand to maximize overall airport capacity. Other factors will be considered, such as weather (wind direction in particular), airline preference, noise restrictions, and controller workload. Runway assignments will be accomplished in an

effective manner compared with today's operation where there are considerable inefficiencies associated with such assignments.

- *More efficient departure sequences and schedules*

  Departure sequences and schedules will be generated based on current predictions of available time of a departure slot at the runway and with more accurate wake data. The departure queues at multiple runways will be balanced to maximize capacity and minimize delay. Arrival sequences and schedules will be generated by the Terminal Radar Approach Control (TRACON) facility, but will be tightly coordinated with the surface to maximize runway usage based on arrival/departure demand. Reordering sequences of aircraft will be conducted to respond to user preferences when possible without harming capacity.

3.1.3 Benefits from runway management

Benefits of the above concept elements are to:

- Maximize airport surface capacity

  – Benefit arises from identifying and using the most efficient runway configuration to gain the maximum arrival and departure capacity
  – Benefit arises from assigning runways to arriving and departing aircraft in an integrated manner that maximizes the capacity of the runways
  – Benefit arises from sequencing aircraft to minimize the impacts of wake on separation and, hence, capacity

- Minimize transient delays during runway configuration change

  – Benefit arises from generating an optimum plan for changing the runway configuration and shifting aircraft to the new runway configuration

- Increase runway throughput by optimal allocation of departure slots

  – Benefit arises from allocating departure slots to take advantage of any windows in arrival streams.

3.1.4 Required technology and infrastructure for runway management

The technology listed in these sub-sections on required technology is what is assumed to be needed for each concept element. As the research progresses and results become available, the technology requirements may be modified.

The following technology and infrastructure items are assumed to be provided for the concept elements. Benefits include:

- Information sharing between airport facilities and airspace facilities controlling operations of terminal/en route/System Command Center (e.g., demand information)

- Information sharing between airport, pilot, and airline operations center (AOC) on time aircraft available for pushback

- Enhanced weather prediction information

3.1.5 Potential research topics for runway management

Some potential research topics for the sub-elements listed in this subsection are suggested below. The list is not definitive; it is included to aid in identifying research needs. Crosscutting research issues for human factors, safety, and environment are described in Section 8.0.

- Develop algorithm(s) to determine optimum runway configuration and provide efficient transition to change configuration

- Develop algorithms to allocate runways to departures and arrivals and to schedule time for departing aircraft to arrive at departure runways. Parameters on which to base this optimization include predicted arrival/departure demand, weather forecast, and fleet mix.

- Develop algorithms to sequence and schedule aircraft to use runways, including responding to user preferences

- Study how to include fairness in tradeoff with capacity maximization in managing runway allocation and changes.

3.2 Taxi Route Planning

Taxi route planning addresses planning the 4D taxi route for departing and arriving aircraft (the term 4D refers to the three spatial dimensions in airspace plus the time dimension). On the surface, there are only two spatial dimensions. It has become common usage to use the term 4D on the surface as well as in the air. This permits only one term to be used to indicate a precise trajectory specified in both spatial and time dimensions.

3.2.1 Constraints and problems for taxi route planning

As airport traffic increases, taxiing aircraft are subject to increased delays, and this adds to overall gate-to-gate time. There are several aspects of taxi movements that constrain surface capacity, including: taxi routes that take longer than if taxi routes are planned together; aircraft waiting for clearances for taxi route segments; queuing to cross active runways; departure queues; getting arriving aircraft off the runway quickly; and aircraft pushing back from the gate that block other aircraft.

3.2.2 Description of taxi route planning

There is a need to develop more effective algorithms for taxi route planning. This is analogous to airborne path planning, but there are striking differences. For instance, surface path variations are limited by the airport taxiway structure, and by greater uncertainties in key parameters (e.g., pushback time, time to cross an active runway, and stopping for taxi segment clearances).

- *Plan efficient taxi routes under specific airport constraints*

  The primary purpose of taxi route planning is to generate the route that will deliver aircraft to their assigned runways or gates at specified times, with minimum time spent taxiing. However, each airport has unique physical layouts and constraints that often severely limit the control actions that can be taken. For example, at Logan Airport in Boston, some gates are next to taxiways, and pushing back from the gate can effectively block the movement of other aircraft. Techniques are needed to coordinate pushback and other operations in the gate vicinity for more efficient management.

- *Increase density of surface operations*

  Precision taxi route planning, combined with precision surveillance and navigation aids, will support increasing the density of taxiing aircraft, and will increase the surface capacity of airports. It is noted that increased density of surface operations requires analysis to compare its benefits to those of other options, such as holding aircraft at gates and surface infrastructure design.

- *Minimize queuing and provide clearances for longer taxiing segments*

  Taxi route planning will minimize queuing at runway crossing points and at the departure runway, which shortens taxi time and, in turn, reduces fuel consumption and emissions. Crossing active runways with little or no queuing is a particularly difficult surface challenge, given the interaction between taxiing aircraft needing to cross the runway and aircraft arriving or departing on the runway being crossed. In addition to queue minimization, automated handoffs will eliminate stopping time of taxiing aircraft to accommodate handoffs between controllers. Clearances for longer taxi segments will reduce or eliminate stopping of taxiing aircraft to await a clearance for the next part of a taxi segment.

- *Provide for equipage differences, user preferences, and fairness*

  Differences in equipage may impact a departure runway (e.g., due to runway length, or noise concerns) and therefore also selection of the taxi route. Taxi planning algorithms will maximize airport capacity while, to the extent possible, responding to user preferences and maintaining fairness to all users. As such, negotiation between users and air traffic service provider regarding 4D taxi routes will be part of taxi route planning.

- *Integrate ground vehicle movement into surface traffic flow*

  Ground support vehicles will be considered in taxi route planning. As the density of aircraft on taxiways increases, these support vehicles still need to be accommodated.

- *Execute and adhere to precise taxi routes*

  Executing and monitoring adherence to a 4D taxi route plan, by both the flight deck and air traffic service provider, will be increasingly important due to the tighter separation between taxiing aircraft and the coordination with other parts of the ATM system. Executing 4D taxi routes can be aided by developing onboard displays that will assist with pilot compliance, or even by onboard automation controlling the aircraft to follow the 4D taxi route. Automation will support controllers and pilots in monitoring adherence to taxi routes and in responding to deviations from assigned taxi routes.

3.2.3 Benefits from taxi route planning

Benefits of the above concept elements are:

- To increase surface capacity via planning of more efficient taxi routes and precise execution of these 4D taxi routes

- Benefit arises from planning taxi routes for aircraft as an integrated whole to take the least time; from planning taxi routes to accommodate constraints of the airport layout; and from aircraft precisely executing the planned taxi routes.

- Reduced queuing when crossing runways and at departure runways

  - Benefit arises from an aircraft arriving at a runway to be crossed at the precise time such that it does not need to stop and wait in a queue.

  - Benefit arises from an aircraft arriving at the departure runway at the precise time such that it does not need to stop and wait in a queue but can roll onto the runway and depart.

- To increase surface capacity via increased density of taxiing aircraft

  - Benefit arises from planning and aircraft executing 4D taxi routes and from more precise surface surveillance of aircraft position. Such precise routes allow for more aircraft moving on the aircraft surface at any time.

- Safe surface operations via enhanced planning and collision avoidance algorithms

- Reduced fuel consumption and emissions by minimizing delays in surface movements

- More user preferences honored

  - Benefit arises from automated taxi route planning being able to handle more information about taxi routes and more complex taxi route planning. Thus, more "use requested preferences for taxi routes" can be honored, which provides a benefit to the aircraft operators.

3.2.4 Required technology and infrastructure for taxi route planning

The following technology and infrastructure items are assumed to be provided for the concept elements. Benefits include:

- Information sharing between airport, terminal, and en route airspaces

- Information sharing between airport and pilot/AOC

- Data link to communicate 4D taxi route to aircraft and for negotiation

- Aircraft automation hardware to provide automation for aiding, or actually executing, 4D taxi routes.

3.2.5 Potential research topics for taxi route planning

Some potential research topics for the sub-elements listed in this subsection are presented below. The list is not definitive; it is included to aid in identifying research needs.

- Determine the most effective means of 4D control: tight conformance to a 4D schedule or control at selected points along the planned route

- Reduce uncertainties in pushback time

- Determine the controllability provided by taxiways/holding areas

- Cross active runways with little or no queuing

- Automation of clearances/handoffs on the surface to reduce need for stopping while taxiing

- Incorporate user preferences and negotiating for taxi routes

- Onboard automation and display to aid pilot in following a 4D taxi route or to control the aircraft to follow a 4D taxi route

- Procedures for negotiating 4D taxi routes

- Efficient taxi route operations in the presence of large uncertainties

- Understand tradeoffs in optimal vs. robust operations

- Fairness issues in managing taxiway operations

- Roles and responsibilities of the pilot and controllers and their automation tools to plan, coordinate, negotiate, and monitor surface operations in an integrated manner

- Investigate the relationship of surface layout changes (e.g., new/extended runway, new taxiway/holding area) to increase surface capacity and flexibility.

3.3   Surface Super Density Operations (SDO)

Surface SDO will accommodate arrivals and departures during periods of peak demand through such sub-elements as reduced arrival and departure separation, EVO, and operations on CSPR. Many of these concept elements are a combination of surface and terminal airspace operations.

3.3.1   Constraints and problems for surface SDO

During peak periods, airport capacity is often not sufficient to support the demand. The increased density of traffic using runways and taxiways increases controller workload. It becomes more complex to handle operations such as intersecting or converging runways, taxiing aircraft crossing active runways, and aircraft landing on CSPR. The noise impact of dense operations and of closely-spaced arrivals may be unacceptable to local communities. Runway incursions become a bigger concern as the number of aircraft using an airport increases. A paper by Barnett et. al. suggests that the potential for runway incursion accidents increases with the square of the number of aircraft using an airport.

3.3.2   Description of surface SDO

There is a need for a greater capacity increase on the airport surface during periods of peak demand.

- *Reduced runway incursions and taxiway conflicts*

  As today's traffic increases at hub and other airports, runway incursions are a significant concern. Part of the problem will be ameliorated in the future by the use of sensor systems to enhance and monitor surface situations. However, the impact of SDO on the surface will be increased runway and taxiway operations. Enhanced planning and conflict detection algorithms will help enable these operations without negatively impacting safety.

- *Precision runway/taxi operations*

  Surface operations will be conducted with increased density without creating gridlock. Surface operations will accommodate more arrivals and departures on runways due to reduced separation in the terminal airspace and other enhancements. Multiple aircraft will

simultaneously occupy a runway with an aircraft crossing an active runway as soon as possible after the arriving or departing aircraft using the runway has passed the crossing point.

- *Reduced runway occupancy time*

  SDO will depend upon a new generation of surface operations including reduced runway occupancy time and high-speed runway exits. Airport SDO related to the surface will get arriving aircraft off the runway quickly after landing and will handle multiple aircraft after touchdown on CSPR. It is noted that the implications of this sub-element for increasing surface capacity needs further analysis and understanding.

- *Equivalent visual operations (EVO)*

  Aircraft will operate on the surface in the same capacity as in visual conditions to the extent possible. Precision surveillance and navigation aids will permit maintaining capacity during poor visibility. Automation will be developed that enables the execution of 4D taxi routes in poor visibility.

- *Reduction of wake vortex impacts*

  Improved detection, prediction, and integration into terminal airspace and surface 4D trajectory planning will reduce the impact of wake vortex hazards on airport capacity.

- *Intersecting and converging runways*

  Improved planning for arrival and departure operations on intersecting and converging runways, along with precise 4D trajectories, will increase departure and arrival rates in a manner that ensures proper separation between aircraft and avoids runway incursions. Intersecting and converging runway operations will be coordinated with terminal airspace operations and with taxi operations.

- *Weather and environment*

  Automation will plan 4D taxi routes with adjustments as needed to maintain capacity during poor weather. For example, rain or snow on the runway may decrease available capacity, but the planning automation will minimize this capacity reduction. Better weather prediction and increased precision in surveillance and navigation will permit less disruption to airport operations during convective weather. This increased traffic activity will be within the bounds of acceptable noise and emissions levels.

3.3.3 Benefits from surface SDO

Benefits of the above concept elements include:

- Increased surface capacity allowing for increased arrival rates, increased traffic density on taxiways, reduced queues, reduced runway occupancy times, CSPR operations, and increased flexibility in planning surface operations
  - Benefit arises in a variety of ways:

- More precise taxi planning and conformance monitoring tools lead to more efficient operations
  - Appropriately sized gaps in runway use are created for efficient use by aircraft needing to cross the runways
  - Aircraft coordinate and plan for exiting runways as soon as possible, which allows for additional operations on the runway
  - Reducing wake vortex separation requirements
  - Increased precision planning for operations on crossing and converging runways.

- Increased capacity in poor visibility provides EVO
  - Benefit arises because limits to operations in poor visibility are removed and most operations can be conducted in the more efficient Visual Flight Rules (VFR) mode.

- Safe surface operations, including prevention of runway incursions, via enhanced planning and collision avoidance procedures
  - Benefit arises from precisely coordinated air/ground planning and more accurate conflict prediction and detection.

3.3.4 Required technology and infrastructure for surface SDO

The following technology and infrastructure items are assumed to be provided for the concept elements. Benefits include:

- High-speed turnoffs from runways

- Coordination between airport and terminal/en route on arrival time at the runway

- Precision surveillance, navigation, and other sensors to support CSPR operations

- New CSPR

- Automated aircraft braking systems (to safely reach precoordinated runway exit)

- Technology to provide location information for aircraft, runways, taxiways, and other objects during poor visibility

- Limiting or restricting access to airport operations for aircraft not suitably equipped for the needed operations

- Surface surveillance to allow less separation between taxiing aircraft, and collision avoidance techniques.

3.3.5 Potential research topics for surface SDO

Some potential research topics for the sub-elements listed in this subsection are presented below. The list is not definitive; it is included to aid in identifying research needs.

- Conflict detection and resolution (CD&R) and other safety aspects in the closely-spaced environment of SDO, including during EVO

- Low altitude, runway, and taxiway collision avoidance

- Procedures, algorithms, automation, and equipage requirements for CSPR operations

- Procedures, algorithms, automation, and equipage requirements for precise taxi operations

- Procedures, algorithms, automation, and equipage requirements for planning and executing 4D taxi routes

- Reduction of impact of wake vortex

- Airborne and ground roles and responsibilities (conformance monitoring, conflict detection and resolution)

- Determine ground arrival capacity for major airports under SDO.

3.4 Surface Weather and Environmental Planning

A key objective of the NextGen-Airportal Project is to increase airport capacity. This objective must be achieved by mitigating the impact of weather and by understanding environmental constraints.

3.4.1 Constraints and problems for surface weather and environmental planning

Winds can cause arrivals and departures to be assigned to a less efficient set of runways. If changes in wind direction are poorly predicted, configuration changes may be required which can result in inefficient and lengthy transition periods. Surface movement can be slowed considerably by reduced visibility, or by wet or snowy surface conditions. As for the environment, if current operations are at or near environmental limits, increased capacity may not be possible without technological advances to reduce airframe and power plant noise and emissions output.

3.4.2 Description of surface weather and environmental planning

Weather can dramatically degrade the capacity of surface operations. If such capacity degradation occurs too frequently and with a great impact, aircraft operators will not be able to plan schedules to take advantage of capacity increases that occur only in good weather. Also, the public generally will not accept negative environmental impacts from increased airport capacity.

- *Weather*

  Automation to plan 4D taxi routes and airport surface configuration will account for weather-related phenomena, such as moving weather cells, low visibility operations, and wet or snowy runways. Surface operations will efficiently account for deicing operations when needed, either at the gate or at separate deicing stations. Scheduling of arrivals and departures will be adapted for the weather conditions. The NextGen-Airportal Project will not develop sensor technologies or predictors for weather; it will utilize these "enablers" to improve the efficiency of operations impacted by weather-related phenomena.

- *Environment*

  Airport planning will address the environmental issues of noise and emissions while planning capacity-increasing operations. Tools will be developed to monitor environmental impacts during surface operations and provide inputs to planning surface routes to mitigate negative impacts. Precision Required Navigation Performance (RNP) allows for more precise maneuvering to reduce noise/emissions.

3.4.3 Benefits for surface weather and environmental planning

Benefits of the above concept elements include:

- Reduced disruption in capacity during adverse weather conditions

  - Benefit arises because reduced visibility does not limit capacity. If changes in wind direction are predicted more reliably, runway and taxiway configuration modifications may be planned in a more effective manner.

- Reduced negative impacts on capacity operations during deicing

  - Benefit arises because deicing can be accomplished in a timely manner prior to departure so that the deicing process does not need to be repeated.

- Reduced negative impacts on noise and emissions from increased surface operations

  - Benefit arises by reducing the aircraft's "engine-on" time on the surface, applying noise sensitivity to runway usage and taxi route planning, and segregating noisier aircraft to less noise sensitive areas.

3.4.4 Required technology and infrastructure of surface weather and environmental planning

The following technology and infrastructure items are assumed to be provided for the concept elements. Benefits include:

- More accurate prediction of weather phenomena

- New quieter aircraft

- New reduced-emission power plants

- Data sharing/exchange for coordinated planning of nonvisual operations

- Environmental impact sensors for noise and emissions

- Better RNP technology for ground and flight deck.

3.4.5 Potential research topics of surface weather and environmental planning

Some potential research topics for the sub-elements listed in this subsection are presented below. The list is not definitive; it is included to aid in identifying research needs.

- Develop procedures to utilize improved weather predictions

- Incorporate environmental impacts into surface operation planning

- Develop human and automation roles for operations involving weather and environmental impacts.

4   TERMINAL CONCEPT ELEMENTS

Terminal concept elements are aimed at increasing capacity in the terminal airspace. Elements are presented for precise spacing and separation assurance, dynamic airspace management, adapting operations to conditions, and metroplex operations. The Airspace Management portion of the Airportal concepts supports several of the key capabilities under NextGen: Performance-Based Services, Trajectory-Based Operations, EVO, and SDO.

As was explained at the end of Section 2.0, the term "concept element" is used to indicate a specific means for improving airport capacity, and the term "concept sub-element" is used for a more detailed breakdown of how airport capacity can be improved under a concept element.

4.1   Precise Spacing and Separation Assurance

More precise surveillance data, adherence to 4D trajectories, and enhanced conflict detection and resolution will allow more precise spacing in the terminal airspace, which will, in turn, enable reduced separation standards and CSPR operations. Enhanced separation assurance will also support EVO.

4.1.1   Constraints and problems for precise spacing and separation assurance

The ability to reduce spacing and separation between traffic is currently limited. Surveillance capabilities are limited by accuracy and update rate. Likewise, flying accurate 4D trajectories is needed to permit improved spacing precision. Finally, improvement in conflict detection is needed for closer spacing between aircraft.

4.1.2   Description of precise spacing and separation assurance

The primary role of the ATC system is to separate aircraft. This is substantiated by the provision in the Air Traffic Control Handbook (FAA Order 7110.65), which establishes the priorities as the "safe, orderly, and expeditious" flow of air traffic. Reductions in separation standards are central to capacity gains. Improved surveillance capabilities, navigational accuracy, and improved communications capabilities can all serve to reduce basic separation standards. These standards could potentially be dynamic depending on conditions. The concept elements for separation assurance will include:

- *Precise spacing*

   The application of precise spacing, whether flight deck or ground based, will provide increased capacity. In many cases, precise spacing will enable reduced separation. Onboard displays and algorithms permit aircrews to achieve either time-based or distance-based separation and/or spacing to higher degrees of precision. Ground-based solutions to achieve precise spacing can also show benefits. Time-based separations can be particularly beneficial as they can allow for speed profiles typically flown in the terminal areas resulting in target spacing at the runway threshold.

- *Reduced wake vortex separation criteria*

  Detection and planning to reduce the separation which is currently required behind aircraft to avoid hazardous encounters with wake vortices will be part of a future system. Reduced wake vortex separation standards will help enable efficient CSPR operations. It will also be a significant step in moving towards EVO during weather conditions that currently require the use of instrument approaches. Finally, a better understanding of the wake vortex phenomenon will enable separation standards to better reflect the hazard.

- *Closely Spaced Parallel Runway (CSPR) operations*

  Separations for CSPR and converging runway operations can be reduced if navigation and separation assurance are provided with a greater degree of precision. The use of 4D trajectories can permit precise spacing of aircraft relative to adjacent parallel-runway traffic. This can position an aircraft aft of a collision risk and at the same time forward of a location where wake is a hazard. As aircraft operate in closer proximity with CSPRs, ground-based or flight-deck–based conformance monitoring and conflict detection needs to be explored. Algorithms and procedures for alerting and for avoidance maneuvers will also have to be developed to support these operations.

- *Scheduling and sequencing interactions with surface and en route*

  4D trajectories in the terminal airspace will be coordinated with the en route and surface domains. This will enable landing aircraft to reach arrival fixes and the runway threshold at desired times and departing aircraft to take-off and be integrated into the en route airspace at desired times.

- *Intersecting trajectories in airspace*

  Precise spacing and improved conflict detection and avoidance will allow new, and in some cases more complex, arrival and departure paths (4D trajectories) that can increase capacity when there are intersecting departure and/or arrival paths. There will also be the ability to dynamically change intersecting 4D trajectories depending on conditions.

4.1.3 Benefits from precise spacing and separation assurance

Benefits of the above concept elements include:

- Increased capacity for both arrival and departures due to reductions in spacing and wake separation criteria.

  – Benefit arises from more precise positional information, automation to provide guidance or spacing cues, and an improved wake detection and prediction capability.

- Increased runway capacity due to added flexibility for runway usage at airports with CSPR by accurately determining when wake vortices are not an issue; greater latitude in runway selection by more accurately determining when a wake separation penalty will not be incurred.

  – Benefit arises from the application of wake detection and prediction capabilities to reflect the true wake hazard, and to optimize runway configuration and assignments.

- Less fuel burn due to more efficient speed management with minimum throttle adjustment from time-based clearances issued at the terminal boundary.

  − Benefit arises from the use of automation in generating speed cues for aircraft, based on required spacing at the runway threshold.

- Possible decrease in controller workload due to flight-deck managed spacing or automation-assisted ground-based separation resulting in precision spacing.

  − Benefit arises from the generation of speed cues to the pilot from an onboard algorithm that reduces communications and controller conflict-detection tasks; ground based algorithms offer similar benefits.

4.1.4 Required technology and infrastructure for precise spacing and separation assurance

The following technology and infrastructure items are assumed to be provided for the concept elements. Benefits include:

- Automatic Dependent Surveillance – Broadcast (ADS-B) capability

- Area Navigation (RNAV) capability

- 4D Trajectory capability

- Advanced aircraft surveillance technology

- Data-link communications

4.1.5 Potential research topics for precise spacing and separation assurance

Some potential research questions to provide the sub-elements listed in this subsection are presented below. The list is not definitive; it is included to aid in identifying research needs. Crosscutting research issues for human factors, safety, and environment are described in Section 8.0.

- What separations can be achieved for CSPR operations with greater aircraft navigation and surveillance precision?

- What is the best solution for precision spacing: flight-deck managed, ground-based managed, or some combination of both?

- Regarding separation responsibility, what role is appropriate for the flight deck and for ATC?

- What alerting is needed to detect separation violations in an environment where standards are closer?

- What are the information requirements for groundside if airborne-managed separation is used?

- What are the information requirements for the flight deck if groundside separation is used?

- How precisely can wake information be provided? What levels of reduced separation, CSPR operation, and EVO can be attained by using the wake information that will be available?

- How to respond to off-nominal situations?

4.2 Dynamic Airspace Management

Dynamic airspace re-allocation will allocate airspace among preplanned alternative airspace structures. The re-allocation of airspace sectors to accommodate demand, weather, and runway constraints can enable the terminal airspace to provide more capacity for the particular constraints being experienced.

Airspace sector structures are currently redesigned infrequently, consequently the structures are slow to respond to changes in schedule or origin-destination air traffic that may result over a year or several years. More frequent updating of the alternative airspace structures available for reallocation would better accommodate long-term changes in traffic that uses an airport.

Both the dynamic re-allocation of terminal airspace structure among alternative structures and the occasional redesign of the underlying alternative structures are covered in this section.

4.2.1 Constraints and problems for dynamic airspace management

Inefficiencies in the flow of traffic occur as a result of generally static and inflexible airspace allocation. The current system does not provide, with few exceptions, the re-allocation of airspace to meet ever-changing demand. Hence, traffic is delayed while parcels of airspace go unutilized. Controllers, lacking tools or procedures that would facilitate quickly adapting to realigned or resectorized airspace, are not equipped to quickly reorient to adjustments of airspace boundaries.

A common complaint from pilots is that in some cases they are being separated from airspace. For example, an airport located in the middle of the country gets a heavy arrival push from the east coast, with few departures during one period, so a portion of the airspace is heavily utilized, while another is underutilized. Many of these aircraft depart for both east and west coast destinations with few arrivals during another period. Inflexible airspace limits the efficiency of these operations.

At many locations, segments of airspace are defined in letters of agreement that permit coordination among ATC facilities for use of that airspace on an ad hoc basis. An example where this type of airspace use might be required is during operations when an unusual direction of arrivals or departs is needed. Rather than coordinate use of adjacent airspace for each individual flight, use of a predefined area may be requested for a given period of time. This level of flexibility today must be predefined for a particular situation.

4.2.2 Description of dynamic airspace management

The Airportal concepts will accommodate flexible allocation of terminal airspace.

- *Dynamic terminal airspace sector allocation*

  Re-allocating airspace will maximize the airspace available for arrivals and departures depending on demand, weather, and other factors. This re-allocation can be in a consistent manner (e.g., daily basis, specific hours) where traffic flows are predictable, or on an "ad hoc" basis to respond to changes that are not periodic, such as weather.

- *Airspace sector redesign*

  The alterative airspace structures to be re-allocated in the above bullet will likely have been previously designed. More frequent redesign of the alternative airspace sectors to be dynamically reallocated will provide a more timely adjustment to changes in demand that occur over the course of a year or more.

4.2.3 Benefits from dynamic airspace management
Benefits of the above concept elements include:

- More efficient use of airspace and, hence, more airspace capacity resulting in delay reductions
  - Benefit arises from re-allocation of airspace to meet dynamic needs of traffic demand under weather and other constraints.
- Fuel savings for users
  - Benefit arises from shorter flight paths based on availability of airspace that might otherwise not be used due to coordination or other issues.

4.2.4 Required technology and infrastructure for dynamic airspace management
The following items are required technology and infrastructure that are assumed to be provided:

- Automation tools that predict sector loading
- Mechanisms for alerting affected entities to new airspace boundaries

4.2.5 Potential research topics ford airspace management
Some potential research questions are listed below. The list is not definitive; it is included to aid in identifying research needs.

- How can airspace be reallocated to meet demand and be done in a way that increases efficiency of operators?
- What time horizon is required for all affected entities to adjust to new boundaries?
- How to dynamically implement transitions to new airspace configurations so that the transitions are efficiently achieved without confusion or uncertainty for air traffic service providers or pilots?
- Is there additional workload from more aircraft in sectors, and is it manageable?
- How to design the new airspace structures to be dynamically allocated? Is new modeling capability required?
- What are the interactions of terminal airspace with en route airspace to maximize the benefit of changes made in terminal airspace?

4.3 Adapting Operations to Conditions

The Airportal concepts will contain automation to manage a variety of changes to operations. Some adjustments will be for changing conditions, such as runway configurations, weather, and demand. Others will be for off-nominal conditions, such as missed approaches and emergency operations.

4.3.1 Constraints and problems for adapting operations to conditions

There are a myriad of situations that can be categorized as changes in the flow of air traffic operations, either among alternative operational modes (e.g., change between automated ground-based separation assurance and self-separation) or to react to off-nominal conditions. These situations require strategies and procedures that minimize impact on the overall operation while achieving specific objectives. There are many challenges in dealing with these situations based on competing interests: e.g. airline: economics; air traffic service provider: localized and systemic flow efficiency; public; noise; and others. Landing aircraft that have missed approaches will have more impacts on future capacity due to denser traffic utilizing airports.

4.3.2 Description of adapting operations to conditions

Concept elements for adapting to conditions, whether to changes among alternative operation modes or reacting to off-nominal condition, are provided below.

- *Respond to runway changes*

  In the case of a runway change, the goal is to reroute arrival traffic through airspace to accommodate the new configuration in the least disruptive manner.

- *Reduction of wake vortex impacts*

  Improved detection and prediction of the wake hazard, complemented by enhanced 4D trajectory planning, will reduce the impact of wake vortex hazards on airport capacity.

- *React to weather deviations/reroutes*

  More precise 4D trajectories, utilizing improved weather forecasts, will be available to fly around weather. The EVO sub-element explained in Section 3.3.2 for surface operations will extend into the terminal airspace as necessary. The dynamic allocation of terminal airspace described in Section 4.2 also supports the terminal airspace in maintaining capacity during adverse weather.

- *Environment*

  Further precision in flying 4D trajectories will allow flying more curved arrival and departure paths to avoid noise sensitive areas and to fly routes that reduce emissions. The ability to change routes often will allow modification to routes in response to changing conditions (e.g., weather and demand) that affect noise profiles and emissions dispersions. Improved sensors to monitor environmental impacts during operations will provide input to route planning to reduce negative impacts.

- *Recovery from missed approaches*

  The degree to which missed approaches disrupt the system are a function of several factors: current traffic demand, available runways (can a departure runway be used?), current traffic loading in the terminal airspace, etc. As separation becomes more precise, strategies for landing missed approaches or reabsorbing them in an efficient manner into traffic streams will be able to mitigate impacts on capacity.

4.3.3 Benefits from adapting operations to conditions

Benefits of the above concept elements are:

- Reduce flight time and fuel usage while changing aircraft trajectories in reacting to changes in conditions
  - Benefit arises from increase in throughput and efficiency resulting from more effective responses to off-nominal conditions

4.3.4 Required technology and infrastructure for adapting operations to conditions

The following technology and infrastructure items are assumed to be provided for the concept elements. Benefits include:

- Aircraft-based or ground-based separation tools

- Improved weather predictions and information on current weather

- Sensors to monitor noise and air quality levels

- Automation to predict the delay required for a runway change, opening of a runway after a closure, etc.

4.3.5 Potential research topics for adapting operations to conditions

Some potential research topics are listed below. The list is not definitive; it is included to aid in identifying research needs.

- Algorithms to adjust terminal airspace routes for changes in runway configurations

- Adjusting to changing wake separation requirements in the terminal airspace

- Dynamic changes in terminal airspace routes to adjust to weather information provided by improved weather forecasts

- Planning precise and more varied (e.g., curved arrival and departure paths approaches) 4-D trajectories to avoid noise sensitive areas and to fly routes that reduce emissions. Use the data from environment sensors for planning trajectories

- What are the off-nominal situations, in addition to missed approaches, that should be addressed in developing automation aids for terminal operations? How should these off-nominal conditions be addressed? How should recovery transition from off-nominal conditions be addressed?

4.4 Metroplex Operations

Metroplexes utilize multiple airports in a metropolitan area to handle future increases in air traffic to that area, and have the potential to be a major factor in increasing capacity in the nation's air transportation system.

4.4.1 Constraints and problems for metroplex operations

At virtually all airports, there are constraining factors that limit capacity. Often there are nearby airports that might be used to increase overall capacity for a metropolitan area. Many airports are also constrained by operations arriving at, or departing from, surrounding airports. This can occur for several reasons, such as conflicting arrival/departure paths and shared arrival/departure fixes. Traffic increases at airports that currently experience high demand, as well as increases at airports with light traffic loading, will further exacerbate the aforementioned constraints and form new interdependencies. With these issues in mind, traffic flow management strategies that reflect these interdependencies and provide for operations at multiple airports in a metropolitan area will be required.

4.4.2 Description of metroplex operations

A metroplex, as defined in the Airportal concepts, is a network or group of airports with one or more interacting constraining characteristics. These constraining characteristics may be in the form of operational interdependencies or the inability of a particular airport(s) to meet traffic demand such that significant delays are incurred. As the issues with respect to "inter" and "intra" metroplex operations are numerous and varied, the approach to solutions will have to be multifaceted.

- *Precisely flown paths*

  The greater and more complex density of traffic traveling to and from the airports within a metroplex will be accommodated with the precisely flown flight paths. The precisely flown flight paths will permit traffic flows to handle a high density of traffic to multiple airports in a metroplex. It follows that these flight paths will be deconflicted through procedural or tactical means.

- *Flexible flight paths*

  Flexible flight paths, including curved paths, for approaches will increase the capacity of metroplex airspace. The current requirement for long straight-in segments for instrument approaches is inherently restrictive and poses constraints on airspace design. Flexible, curved paths allow for turns onto the final approach course closer to runway, permitting greater flexibility for use of the airspace. In dense metroplex operations, competition for airspace restricts many operations, including the implementation of instrument approaches. The use of curved approaches, which require less of a straight-in segment, could permit the implementation of approaches where they are currently not operationally feasible.

- *Increased TFM planning horizon*

  Optimized plan-ahead (i.e., surface rerouting) tools for the surface, coupled with advanced air traffic flow management between terminal and en route airspace, will ensure that delays for aircraft departing from, or arriving at, airports within the metroplex are absorbed on the

ground or outside the airspace-constrained metroplex area. This will enhance the capacity of the metroplex airspace, and will not increase workload for controllers and pilots involved with the metroplex airspace.

- *Route planning and execution under adverse weather*

  To the extent feasible, metroplex operations under adverse weather will be conducted as EVO. Such operations will account for different airports being impacted by weather to different degrees at different times. There will be tools for the planning of routes under adverse weather and for aircraft to execute the routes under adverse weather.

- *Increased capacity at uncontrolled airports*

  Uncontrolled airports (no control tower) within a metroplex, many of which are currently underutilized, will experience increased traffic activity as larger airports become capacity constrained. Absent the ability to provide on-site ATC services, alternative solutions will be required that will increase capacity. Potential solutions for this problem include self-separation (e.g., small aircraft transportation systems (SATS) environment) or the implementation of virtual or automated towers. This topic of increasing capacity at uncontrolled airports is addressed in Section 6.0, and will not be covered further in Section 4.0.

4.4.3 Benefits from metroplex operations
Benefits of the above concept elements are:

- Overall improvement in throughput for airports within the metroplex
  - Benefit arises from coordinated operations reflecting a systemic strategy; better overall management of airport configurations and traffic flows.
- More efficient trajectories for aircraft within metroplex result in saved time and reduced fuel burn
  - Benefit arises from design of airspace and traffic flows that accommodate efficient flight paths.
- Greater capacity, time savings, and less fuel use due to efficiency for aircraft operations through improved scheduling and planning
  - Benefit arises from a systemic approach to using Metroplex resources that considers overall NAS efficiency.
- Greater capacity, time savings, and less fuel use through improved flexibility in airspace usage
  - Benefit arises from more flexibility to adjust airspace to meet demand, weather, and other conditions.

4.4.4 Required technology and infrastructure for metroplex operations
The following technology and infrastructure items are assumed to be provided for the concept elements. Benefits include:

- Improved navigational and surveillance capabilities

- Improved communication capabilities

- Navigation aids, surveillance equipment, and virtual tower capabilities at currently uncontrolled airports to enable increased capacity with ATC automation tools

- Airports in the metroplex with adequate infrastructure, such as runway length and pavement condition, passenger and baggage processing facilities, and aircraft servicing facilities.

4.4.5 Potential research topics for metroplex operations

Some potential research questions for the sub-elements listed in this subsection are presented below. The list is not definitive; it is included to aid in identifying research needs.

- How to plan arrival and departure routes for multiple airports in a metroplex?

- How close can arrival and departure paths be located for separation purposes?

- How can arrival and departure paths in a metroplex be dynamically changed to account for changes in weather and in constraints at particular airports?

- How can airspace be designed and dynamically changed to account for changes in weather and in constraints at particular airports?

- How can metroplex operations be planned and executed under adverse weather?

- What information should be shared among air traffic service providers at airports, terminal airspace, and en route airspace?

5   COORDINATION AND INTEGRATION OF CONCEPT ELEMENTS

Section 3 addressed Airportal concept elements on the surface and Section 4 addressed terminal airspace. This section presents concept elements for integrating among the surface concept elements, among the terminal concept elements, and across the surface and terminal concept elements. Coordinated operations within and among these concept elements is expected to yield additional airport capacity benefits by minimizing unused arrival and departure slots and increasing the overall density of traffic possible in airports.

The concept elements addressed in this section relate to several NextGen key capabilities: Performance-based Services, Weather Assimilated into Decision-making, Broad-area Precision Navigation, Aircraft Trajectory-based Operations, EVO, and SDO.

Integrated operations among surface concept elements will be presented first in Section 5.1. Integrated operations among terminal concept elements will be addressed in Section 5.2, followed by integration among surface and terminal operations in Section 5.3, and coordination and integration among metroplex operations in Section 5.4.

Many of the research topics identified in Section 5 cut across the various concept elements for coordination and integration. To accommodate this and not be redundant, research topics specific to a particular coordination and integration concept element are presented in that section while research topics that apply to multiple concept elements are presented in Subsection 5.5.

5.1 Coordination and Integration among Airport Surface Operations

Integrated operations within the airport surface are addressed in this section.

5.1.1 Constraints and problems for coordination and integration among airport surface operations

Many potential constraints and conflicts can arise on the airport surface from the different surface concept elements and sub-elements interacting with each other, such as runway assignments interacting with scheduling and sequencing on each runway, taxi route planning interacting with runway availability, and gate/runway assignments for multiple aircraft causing interactions among surface operations for these aircraft. These constraints and conflicts, if not managed, can cause inefficiency and delay.

5.1.2 Description of coordination and integration among airport surface operations

The airport surface coordination and integration concept element addresses interactions among the different planning processes from the surface concept elements and provides the optimal 4D taxi trajectory for each arrival and departure flight. There are four primary airport surface elements to be integrated, which were described in Section 3: (1) runway management, (2) taxi route planning, (3) surface SDO, and (4) weather and environmental planning.

The airport surface coordination and integration concept element will consider inputs from terminal airspace and AOC, although planning functions do not fully integrate these domains until the sub-elements described in Section 5.3 are developed. The inputs include the flight plan, runway preference, gate assignment, aircraft position, type, equipage, and other ground traffic. These inputs will be used as constraints during the planning process. The concept elements for surface integration include:

- *Surface Flow Constraint*

  Based on the current weather, weather forecast, and time of day, the surface flow constraint sub-element will calculate the separation requirements while satisfying the safety and environmental constraints. These constraints will feed into the surface SDO concept element and the runway management concept element. The surface SDO concept element, based on the separation requirement, aircraft type, aircraft weight, and equipage, will calculate the minimal runway occupancy time as well as the maximum taxi speed for each aircraft. These flow constraints will be inputs to the following Surface Flow Management sub-element. It is noted that the impacts of runway occupancy time and taxi speed on surface capacity need further analysis and understanding.

- *Surface Flow Management*

  The surface flow management sub-element will integrate runway configuration planning and runway allocation based on taxi route capacities, runway capacities, runway preference, separation requirement, minimal runway occupancy time, gate assignment, flight plan, current aircraft positions, and capacity limitations.

- *Surface Trajectory Planning*

  The surface trajectory-planning sub-element will calculate the optimal taxi route based on the assigned runway, minimal runway occupancy time, maximal taxi speed, assigned gate, and other ground traffic. The airport surface coordination and integration element will iterate between the runway configuration management and the taxi route planning sub-elements to obtain the optimal 4D trajectory for each aircraft arriving or departing the airport, as well as the trajectories of ground vehicles.

- *Surface Tactical Control*

  The airport surface tactical control sub-element will actively monitor conformance of each aircraft to its planned taxi route as well as for off-nominal operations. If an aircraft is out of conformance during taxiing or has passed its pushback time, alternative plans would be generated to cope with the discrepancy between planned and actual trajectories in a manner that minimizes impacts on other taxiing aircraft. Surface tactical control will also detect and initiate action for runway incursions and taxi conflicts.

5.1.3 Benefits from coordination and integration among airport surface operations

Benefits of the above concept elements include:

- Increase system throughput and reduce delay on airport surface

  – Benefit arises from better coordination of various airport surface planning processes that may otherwise impose conflicting constraints and result in reduced throughput and increased delay. This includes better coordination of minimizing delays in crossing runways while taxiing, better aircraft surface routing, better aircraft control (e.g., less difference between planned and actual trajectory), and better planning (runway balancing).

- Maintain airport throughput in reduced visual conditions

  – Benefit arises from the use of better surveillance and navigation technologies (not constrained by weather on runway or taxiways) and better flow management.

- Increase controller productivity

  – Benefit arises from the use of automation tools.

- Reduce aircraft fuel burn on the surface

  – Benefit arises from more efficient taxi routing and runway crossing resulting from better planning (runway assignment), prediction, and aircraft trajectory execution on airport surface (e.g., less difference between planned and actual trajectory).

5.1.4 Required technology and infrastructure for coordination and integration among airport surface operations

The following technology and infrastructure items are assumed to be provided for the concept elements. Benefits include:

- Better communication tools, including digital data link

- Better surveillance and navigation technologies

- Improved weather prediction

- 4D trajectory technology on ground and on aircraft

- Better information sharing (i.e., system-wide information management (SWIM)).

5.1.5 Potential research topics for coordination and integration among airport surface operations

The beginning of Section 5.0 mentioned that many issues related to integrating surface and terminal airspace concept elements are similar and will be presented in Section 5.5. Also issues related to human factors, safety, and environment will be discussed in Section 8.0.

One research question specific to coordination among the surface concept elements is:

- How to obtain better prediction of pushback time? In the context of probabilistic information, how to better characterize the pushback time for coordination and integration purpose?

5.2 Coordination and Integration among Terminal Airspace Operations

Integrated operations within terminal airspace are addressed in this section.

5.2.1 Constraints and problems for coordination and integration among terminal airspace operations

In the future, more aircraft will transition through terminal airspace, there will be CSPR operations, and wake vortex separation will be more critical. Separation assurance, terminal airspace management, arrival and departure path planning, and handling non-normal operations will all interact in the terminal airspace to affect capacity. Optimizing each of these concept elements will help increase capacity, but also coordinating and integrating these concept elements will provide further capacity enhancements.

5.2.2 Description of coordination and integration among terminal airspace operations

The terminal airspace coordination and integration element manages the different planning processes from the concept elements within the terminal airspace to provide the optimal 4D trajectory for each arrival and departure flight. There are four primary terminal airspace elements, described in Section 4.0, to be integrated: (1) separation assurance, (2) airspace management, (3) off-nominal operations, and (4) metroplex operations. The first three are addressed in this subsection, and metroplex operations are addressed in Section 5.4.

The terminal airspace coordination and integration element will consider inputs and constraints from user preferences, en route airspace, and airport surface, although planning functions do not fully integrate these domains until the sub-elements described in Section 5.3 are developed. The inputs include the flight plan, runway preference, aircraft position, type, equipage, current aircraft weight, airport arrival rate (AAR), and airport departure rate (ADR). These inputs will be used as constraints during the planning process.

- *Terminal Airspace Flow Constraint.*

  Based on the current weather, weather forecast, and time of day, separation requirements will be calculated while satisfying the safety and environmental constraints. These separation requirements will feed into the SDO sub-element and the terminal airspace management sub-element. Separation requirements will be also determined for CSPR operations. These separations requirements will be inputs to the following Terminal Airspace Flow Management sub-element.

- *Terminal Airspace Flow Management.*

  This terminal airspace flow management sub-element will coordinate terminal airspace configuration management with other elements of terminal airspace operations to insure the airspace structure will accommodate the traffic demand with minimal delay. Furthermore, any changes in airspace configuration will be coordinated with overall airspace operations to provide a smooth transition.

- *Terminal Airspace Trajectory Planning.*

  This concept sub-element will calculate the optimal 4D airspace arrival route for single or multiple runways, or CSPR. This trajectory calculation will include the arrival aircraft converging into the arrival stream prior to landing. This concept sub-element will factor in weather, environmental, equipage, runway configuration, and other constraints. In addition, the optimal point for each arrival aircraft to efficiently merge into the arrival stream will be calculated. For departure aircraft, this sub-element will determine the optimal 4D airspace departure route, and optimal turn-off point to merge with en route traffic. The terminal trajectory planning sub-element will calculate the optimal arrival or departure sequence for aircraft to minimize separation and hence maximize capacity, based on the current separation standard, current aircraft position, aircraft type, weight, equipage, and weather condition, as well as satisfying environmental constraints and en route sector capacity limits.

- *Terminal Airspace Tactical Control*

  The terminal airspace tactical control sub-element will monitor conformance of each aircraft to its planned 4D trajectory. If an aircraft is out of conformance, actions will be generated to cope with the discrepancy between planned and actual trajectories in a manner that minimizes impacts on other aircraft. This sub-element will also resolve off-nominal situations and coordinate to obtain the terminal resources needed to resolve such situations. If there is a conflict among any processes within the terminal airspace, the terminal airspace tactical control sub-element will formulate a resolution for the conflict.

5.2.3 Benefits from coordination and integration among terminal airspace operations

Benefits of the above concept elements are:

- Increase throughput and reduce delay in terminal airspace
  - Benefit arises from better coordination of various terminal airspace planning processes that may otherwise impose conflicting constraints and result in reduced throughput and increased delay. Examples of coordinated terminal planning processes are precise 4D

trajectories using reduced separation standards, better aircraft sequencing (e.g., a small before a heavy vs. a heavy in front of a small), and better aircraft control (e.g., less difference between planned and actual trajectory) in the terminal airspace.

- Maintain terminal throughput in reduced visual condition

    - Benefit arises from the use of better surveillance and navigation technologies (not constrained by weather over corner posts) and better flow management (e.g., dynamic corner posts and terminal airspace routes that are not impacted by weather).

- Increase controller productivity

    - Benefit arises from the use of advanced automation tools.

- Reduce aircraft fuel burn

    - Benefit arises from more efficient terminal routing and less *path stretching* resulting from better planning, prediction, and better aircraft trajectory execution during the transition between en route and terminal airspaces.

5.2.4 Required technology and infrastructure for coordination and integration among terminal airspace operations

The following technology and infrastructure items are assumed to be provided for the concept elements to give benefits:

- Better communication tools, including digital data link

- Better surveillance and navigation technologies

- Improved weather prediction

- 4-D trajectory technology on ground and on aircraft

- Better information sharing (i.e., SWIM).

5.2.5 Potential research topics for coordination and integration among terminal airspace operations

A potential research question for the sub-elements listed in this subsection is presented below.

- How to obtain better-than-expected time of arrival (ETA) at arrival fixes for the planning purposes? In the context of probabilistic information, how to better characterize the ETA at the arrival fixes for coordination and integration purposes?

5.3 Coordination and Integration among Airport Surface and Terminal Airspace Operations

After discussing integrated operations within the surface domain and within the terminal airspace domain in Sections 5.1 and 5.2 respectively, this section addresses integration between surface and terminal airspace domains.

5.3.1 Constraints and problems for coordination and integration among airport surface and terminal airspace operations

Airport surface and terminal airspace have different operational characteristics and limitations. An aircraft flying through the two domains encounters different constraints and requirements. Optimizing traffic capacity in each domain separately does not imply that overall capacity is maximized.

5.3.2 Description of coordination and integration among airport surface and terminal airspace operations

The airport surface and terminal integration and coordination concept element integrates the planning for airport and terminal operations. It also incorporates constraints from en route airspace and the System Command Center into joint surface and terminal airspace planning. The result of the integrated planning is an optimal 4D trajectory through terminal airspace and surface taxiing for each arrival and departure flight.

The integrated airport and terminal coordination and integration concept element will consider user preferences and inputs from en route airspace and the AOC. Inputs include the flight plan, runway preference, gate assignment, aircraft position, type, equipage, current aircraft weight, other ground traffic, en route sector capacity, and the Airspace Flow Program imposed by the System Command Center. Collaborative decision-making procedures will enable effective use of this data. These inputs will be used as limitations during the planning process.

- *Integrated Flow Constraint*

    The integrated flow constraint sub-element will coordinate constraints, particularly separation requirements, from terminal airspace and surface taxi with surface and terminal airspace weather and environmental planning, SDO, and terminal separation assurance. The constraints will be inputs to the following Integrated Flow Management.

- *Integrated Flow Management*

    Based on the separation standards, the integrated flow management sub-element will iterate between runway management and airspace management sub-elements so that overall traffic flow in and out of the airports maximizes capacity.

- *Integrated Trajectory Planning*

    A 4D trajectory through terminal airspace and surface taxi for each aircraft will be derived by iterating between the taxi route planning function and terminal airspace route planning function. The trajectories will maximize capacity for the overall airport and will provide maximum efficiency for an aircraft in and out of the airport.

- *Integrated Tactical Control*

    The integrated tactical control sub-element will actively monitor conformance of each aircraft through both terminal airspace and airport surface. If an aircraft is out of conformance, this sub-element will coordinate response to the discrepancy between planned and actual trajectories.

5.3.3 Benefits from coordination and integration among airport surface and terminal airspace operations

Benefits of the above concept elements are:

- Increase system throughput and reduce delay in airport operations

  – Benefit arises from better coordination of terminal and airport planning processes that may otherwise impose conflicting constraints and result in reduced throughput and increased delay. Examples of processes coordinated are terminal airspace and airport surface route planning, better utilization of resources, minimizing delays in crossing runways, and better aircraft trajectory execution.

- Maintain airport system throughput in reduced visual conditions

  – Benefit arises from the use of better surveillance and navigation technologies (not constrained by weather on runway, taxiways, or terminal) and better flow management.

- Increase controller productivity

  – Benefit arises from the use of automation tools.

- Reduce aircraft fuel burn

  – Benefit arises from more efficient routing and coordination in terminal airspace and airport surface resulting from better planning, prediction, and aircraft control integrated for terminal airspace and surface.

5.3.4 Required technology and infrastructure for coordination and integration among airport surface and terminal airspace operations

The following technology and infrastructure items are assumed to be provided for the concept elements. Benefits include:

- Better communication tools, including digital data link

- Better surveillance and navigation technologies

- Improved weather prediction

- 4D trajectory technology on ground and on aircraft

- Better information sharing (i.e., SWIM).

5.3.5 Potential research topics for coordination and integration among airport surface and terminal airspace operations

A potential research question for the sub-elements listed in this subsection is presented below.

- How to obtain better prediction of pushback time and ETA at arrival fix? In the context of probabilistic information, how to better characterize the pushback time and ETA at arrival fixes for coordination and integration purpose?

5.4 Coordination and Integration among Metroplex Operations

Sections 5.1, 5.2, and 5.3 discussed integrated operations within and among the surface and terminal airspace concept elements. This section presents integration and coordination activities for metroplex operations. Metroplex operations are more complicated than those for a single airport since all the issues discussed in Sections 5.1 through 5.3 are involved, plus the integration and coordination required among multiple airports.

5.4.1 Constraints and problems for coordination and integration among metroplex operations

Metroplex operations include the same constraints as the integrated airport and terminal operations. In addition, there are aircraft flying into and out of the metroplex airports instead of just the single airport, and there are overlapping operations among the airports in the metroplex to utilize the shared terminal airspace. Coordinating all the terminal airspace arrivals and departures with the availability of capacity at the individual airports will be complex.

5.4.2 Description of coordination and integration among metroplex operations

The metroplex coordination and integration element directs the different planning processes among a network of airports and with their combined terminal airspace, while incorporating constraints from en route airspace and the System Command Center. The metroplex coordination and integration element provides the optimal 4D trajectory for each arrival and departure flight based on the constraints imposed by each airport and its terminal planning elements.

The metroplex coordination and integration element will consider user preferences, and inputs from en route airspace and AOC. Inputs include the flight plan, runway preference, gate assignment, aircraft position, type, equipage, current aircraft weight, other ground traffic, en route sector capacity, and the Airspace Flow Program imposed by System Command Center. These inputs will be used as limitations during the planning process.

The metroplex coordination and integration element is similar to the integrated airport and terminal coordination and integration element. The major enhancement is inclusion of the interactions between streams of flights into and out of several airports instead of a single airport, as well as coordination of runway management among the airports in the metroplex accounting for demand and weather conditions at the individual airports.

- *Metroplex Flow Constraint*
  The metroplex flow constraint sub-element will coordinate the flow constraints associated with overall metroplex airspace and the runways at the metroplex airports, and align them as an aircraft flies through shared terminal airspace.

- *Metroplex Flow Management*

  The metroplex flow management sub-element will coordinate the metroplex airspace configuration management and runway configuration management at the metroplex's airports to coordinate the overall flow of the metroplex.

- *Metroplex Trajectory Planning*

  The metroplex trajectory planning sub-element plans terminal airspace arrival and departure 4D trajectories that account for demand at each airport, each airport's runway capacities, weather in the metroplex terminal airspace and at each airport, and other constraints. It also plans, to the extent practical, the taxi routes at each airport so that they are coordinated with that airport's arrivals and departures. The terminal airspace trajectories may be in close proximity to each other. The trajectories will be implemented in a manner that will ensure safe separation in normal and off-nominal operations, and will accommodate recovery from off-nominal operations.

- *Metroplex Tactical Control*

  The metroplex tactical control sub-element will actively monitor conformance of each aircraft in the metroplex to its planned trajectory. If an aircraft is out of conformance, this sub-element will coordinate an action to cope with the discrepancy between planned and actual trajectories while accounting for the existing traffic in the metroplex.

5.4.3 Benefits from coordination and integration among metroplex operations

Benefits of the above concept elements are:

- Increase system throughput and reduced delay

  - Benefit arises from better coordination of terminal and airport planning processes among airports in the metroplex that may otherwise impose conflicting constraints and result in reduced throughput and increased delay. Examples of coordinated processes are planning terminal and airport routes, better utilization of resources (e.g., decreased runway occupancy time), minimizing delays in runway crossing, minimize interactions between flights to or from different airports in close proximity, and better aircraft trajectory execution.

- Maintain metroplex system throughput in reduced visual condition

  - Benefit arises from the use of better surveillance technologies (not constrained by weather on runway, taxiways, or terminal) and better flow management.

- Increase controller productivity

  - Benefit arises from the use of automation tools.

- Reduce aircraft fuel burn

  - Benefit arises from more efficient routing and coordination in terminal and airports resulting from better planning, prediction, and aircraft trajectory execution.

5.4.4 Required technology and infrastructure for coordination and integration among metroplex operations

The following technology and infrastructure items are assumed to be provided for the concept elements. Benefits include:

- Better communication tools, including digital data link

- Better surveillance and navigation technologies

- Improved weather prediction

- 4D trajectory technology on ground and on aircraft

- Better information sharing (i.e., SWIM).

5.4.5 Potential research topics for coordination and integration among metroplex operations

Some potential research questions to provide the sub-elements listed in this subsection are presented below. The list is not definitive; it is included to aid in identifying research needs.

- How to efficiently and safely recover from off-nominal situations in the NextGen metroplex airspace?

- How do system operators effectively monitor the conformance of multiple aircraft for multiple airports?

5.5 Overarching Research Topics for Integration and Coordination

As was mentioned previously, many issues related to integrating automation within and among surface and terminal airspace operations are similar. Therefore many research questions on coordination and integration are listed once in this subsection. The list is not definitive; it is included to aid in identifying research needs.

- Understand the dynamics of the interactions among surface, terminal airspace, en route airspace, and metroplex operations.
    - What is the impact of a new trajectory due to the renegotiation of the 4D trajectory?
    - How, and how often, can 4D trajectories be negotiated and renegotiated?

- Many objectives are possible for coordinating and integrating airport operations. For example, is the objective to maximize the throughput of the system, to be equitable to all users in the system, or to maximize the throughput while subject to some equity constraints? The objective will give direction on how the coordination and integration will be done. Some issues regarding objectives are:
    - How would a particular objective impact aircraft with different equipage levels?
    - What is the trade-off for using different objectives?
    - What type of user preference requests can be accommodated by the coordination and integration function and how?
    - What is the optimal time horizon of each planning function?
    - What are the different ways to coordinate competing objectives (e.g., between the local and national level)?

- Even with a well-defined objective, there could be several possible actions to achieve the desired result. Which ones should be considered feasible in the coordination and planning process? For example, can a coordination and integration automation aid suggest the slowdown of an aircraft by ten minutes from its predicted arrival time so as to optimize the

surface traffic? Should the actions be bounded to ensure system stability? What is the set of feasible actions?

- There are multiple parties operating in, or interfacing with, the airport (e.g., en route centers, TRACON, airports, and AOC). Each party may have different goals and objectives. Since there may be several actions to achieve the same desired results, what is the process to enable negotiation among the different parties to arrive at the optimal action?

- Many control actions are likely to be feasible, and the reality of how to construct or identify the best action set, with limited computational power and limited time, is a research area. Each aircraft goes through several different operations and each operation has several possible control actions. The total number of possible control action sets grows exponentially as a function of the number of aircraft. How can the best combination of control actions be constructed for each aircraft?

- Off-nominal events will always occur and not everything will happen as anticipated. In a coordinated and integrated system, many operations are coupled together. If an off-nominal event forces an operation to deviate from the plan and schedule, the event may also force other operations to deviate from their plans and schedules. A research issue is how to coordinate and integrate airport operations when an off-nominal event occurs so that there will be minimal impact to other operations

- The coordination and planning process is likely to be dynamic when dealing with off-nominal events. During off-nominal events, it is necessary to consider the different possible control action sets in real-time. A fast and accurate model is necessary to evaluate the control action. Currently, such a model for the airport surface and terminal airspace is lacking, and thus could be a research issue for the NextGen-Airportal Project.

- Current operations are planned based on deterministic input information (e.g., aircraft pushback time at 9:36 a.m.). The information often turns out to be inaccurate and highly dynamic. In the future, input information may be presented as a probability distribution. Future operations can then be planned based on probability distributions of input data (e.g., using a probability density function that describes the likelihood of when an aircraft may pushback over a period of time). Research is needed on how to effectively present and utilize the probabilistic input information. This research topic can be generalized to decision-making under uncertainty.

- There is a need to optimize the parts that make up surface operations to provide maximum capacity practical while addressing safety and environment considerations. There is a similar need to optimize across the components of terminal airspace operations and across surface and terminal operations. An investigation of possible optimization techniques for different parts of surface and terminal airspace operations, how to combine these different surface and airspace local optimizations into integrated, global optimized operations, and how to deal with uncertainty in these optimizations are subjects for research.

- There could be multiple stakeholders in the coordination and integration process with different, or even competing, interests. Procedures and rules may be necessary to establish effective and equitable collaborative-decision processes for different types of negotiations.

Research is needed on the proper decision-making and negotiation procedures and their impacts.

    − What are the most effective ways to negotiate or renegotiate 4D trajectories?

- Airport operations are integrated and coordinated. Failures in either avionics or systems used by the Air Traffic Service Provider (ATSP) are possible. Graceful failure of the future system is a desired characteristic. What is considered graceful failure? What are the different ways to achieve a graceful failure? What are the tradeoffs of the different ways to achieve a graceful failure?

6   SMALL AIRPORTS

Sections 3.0 through 5.0 have dealt primarily with large airports and metroplexes. Some of the airports in the metroplexes may be smaller airports. Future air transportation is also likely to bring more point-to-point service to airports in small cities removed from major metropolitan areas or airports in rural areas. These small airports may not have towers to ensure safe operations as usage increases, or to provide service during poor visibility. Commercial aircraft serving these small airports may include commercial jets, regional jets, commuter piston-driven aircraft, and very light jets (air taxi service). In addition, general aviation and business aircraft will likely be users of smaller airports, as may cargo aircraft of various sizes. There also needs to be the means to ensure safety and service in poor weather.

It is noted that the concept elements discussed in this section on smaller airports are applicable to regional and small airports that are part of a metroplex and to such airports removed from metroplexes.

For lower-demand airports, staffed or automated virtual towers may be implemented, enabling services equivalent to those provided by traditional towers at more airports than is affordable today and/or for extended hours of service.

6.1   Constraints and Problems for Small Airports

Small airports without towers will have trouble handling an increase in traffic or traffic in poor visibility. This will inhibit an increase in direct point-to-point routes to such small airports and the use of such small airports in metroplexes.

6.2   Description of Small Airports

Aircraft will be able to arrive and depart from small airports safely and in weather conditions that will replicate the types of weather for which major airports will have EVO. There are a variety of ways in which services can be provided at small airports to provide safe operations in adverse weather conditions. Some possible examples are listed below. These need to be investigated to determine those that are best suited to various types of small airports.

- Airports that serve a large enough air traffic base will have tower-provided ATC services with some sub-elements listed in Sections 2.0 through 5.0, as appropriate.

- ATC services for arriving and departing aircraft can be provided by a staffed virtual tower, whereby tower-type services are supplied by remotely-located human controllers supported with advanced airport sensors and supporting airport automation at the small airport.

- Automated ATC services, in what might be called an automated virtual tower, could be provided to a nontowered airport and its surrounding airspace for traffic flying into and out of the airport. Aircraft utilizing such an automated virtual tower airport would likely need a minimum equipage level, such as 2-way digital radio and a Mode C transponder. It is possible for automated ground-based separation assurance to be used for properly equipped aircraft.

- Another option for nontowered airports is for aircraft to operate in a self-separating mode. It may be possible to develop equipment for such self-separation operations to help ensure safe operations under many weather conditions.

6.3   Benefits from Small Airports

Benefits of the above possible concept elements for improving capacity at small airports are:

- Provide safe operations at small city and rural airports
  - Benefit arises from alternative ways to provide services to ensure separation between arriving and departing aircraft as usage of the small airport increases.
- Provide operations in many adverse weather conditions at small city and rural airports
  - Benefit arises from alternative ways to provide services during poor visibility to ensure separation between arriving and departing aircraft and to ensure aircraft land on and take off at safe locations on the runway.

6.4   Required Technology and Infrastructure for Small Airports

The following technology and infrastructure items are assumed to be provided for the concept elements. Benefits include:

- Equipment (e.g., sensors, communications, hardware, etc.) to provide virtual towers, whether staffed or automated.

- Aircraft-based equipage for operations with staffed virtual towers, automated virtual towers, or self-separation at nontowered airports.

- Ground transportation and terminal facilities to serve passengers at small city and rural airports.

6.5 Potential Research Topics for Small Airports

Some potential research topics for the sub-elements listed in this subsection are presented below. The list is not definitive; it is included to aid in identifying research needs. Crosscutting research issues for human factors, safety, and environment are described in Section 8.0.

- Identification and development of any algorithms and procedures for operations at airports in small cities and rural areas, whether staffed virtual tower, automated virtual tower, or self-separation airports.

- Controller interface issues for managing operations remotely for multiple airports

- Impact of traffic growth at small city and rural airports on hub airport traffic demand and operations. Will there be a change in city-pair service that affects hub airports?

7   ADVANCED CONCEPT ELEMENTS

Section 7.0 describes concept elements that are likely to apply further in the future than those described in Sections 2.0 through 6.0. One is adaptive metroplex operations where an aircraft's arrival airport within a metroplex can be changed dynamically prior to, or during, the flight. Another is a set of planning tools to design airport layouts that take advantage of the technology discussed in this document. Adaptive metroplex operations will not likely occur until options for improving operations at traditional metroplexes are exhausted. The airport design tools would be useful for new airports and for major reconfigurations or additions to existing airports.

7.1 Adaptive Metroplex Operations

Metroplexes comprised of multiple airports are described in Section 5.4. In this case, scheduled flights used the same airports within the metroplex for each flight. Section 7.1 describes a metroplex as a set of integrated airports that operate in some sense as a very large airport. The biggest difference with the adaptive metroplex is that aircraft arriving at the adaptive metroplex are not prescheduled to arrive at a specific airport. Rather, aircraft are dynamically assigned, either before take-off from the originating airport, or during flight, to an arrival airport within the metroplex. This flexibility maximizes the capacity of the metroplex as a whole. If one airport has restricted capacity due to weather (e.g., a passing thunderstorm), aircraft can be assigned dynamically to land at another airport in the metroplex.

There are numerous hurdles for such an adaptive metroplex to be acceptable to aircraft operators, pilots and passengers. One hurdle to overcome is local transportation of passengers to and from whichever airport within the metroplex their flight might depart from or arrive at. Such a local transportation network might include a central gathering terminal from which passengers are dispersed to, or gathered from, their departing and arriving airports, and rapid transportation between airports for passengers transferring between aircraft. Airlines would need aircraft turnaround and maintenance services. Baggage and gate services for passengers would be needed. These and other

aspects are discussed further below as concept elements for the adaptive metroplex. The concept of adaptive metroplex goes beyond what is currently being considered by NextGen.

7.1.1 Constraints and problems for adaptive metroplex operations

The use of metroplexes with flights assigned to specific airports, as discussed in Section 4.4, is likely to provide sufficient airport capacity for some time to come. However, given the difficulty in building new airports, and in adding runways to existing airports, even metroplexes using existing airports may reach capacity as air travel demand reaches three times that of today. Also, when the demand at a metroplex nears the available capacity, the metroplex becomes susceptible to congestion and delays when weather or demand patterns cause a perturbation in the available capacity. Thus, some way of handling the large demand and weather perturbations would be useful. The concept described in this section, adaptive metroplex, can provide flexible metroplex operations to support a higher capacity and to handle perturbations of weather and demand.

7.1.2 Description of adaptive metroplex operations

Section 5.4.2 describes several concept elements related to flight operations for a metroplex. The flight-operation elements that also apply to the adaptive metroplex are precisely flown paths, flexible flight paths, increased TFM planning horizon, increased capacity at uncontrolled airports, route planning and execution under adverse weather, and airport clustering strategies.

The additional concept sub-elements that apply to the adaptive metroplex are described in this subsection.

- *Scheduling aircraft to airports*

  Aircraft will be assigned dynamically to the airport within an adaptive metroplex at which they will land, either before takeoff or during the flight. This decision will be made based on the availability of airports within the adaptive metroplex, and the preference of the aircraft operator. The preference of the aircraft operator might be to always land at the same airport. However, for adaptive metroplex to be feasible, there needs to be flexibility to land at another airport if the desired airport is not available. The aircraft operators' preferences in the adaptive metroplex concept are assumed to be for a particular airport given circumstances unique to the moment. There will be automation aids to do the scheduling of aircraft to airports. There will be a minimum time before landing after which there cannot be a change in the arrival airport within the adaptive metroplex.

- *Ground transportation network*

  A local ground metroplex transportation network will transport passengers to and from their arrival/departure airport as needed. Part of this concept sub-element might include one or more central gathering stations where passengers can park, check their baggage, and wait until their departure airport is announced. Then they will use the local ground metroplex transportation network to travel to their departure airport. Arriving passengers will pick up any luggage and leave their arriving airport or will travel to a central gathering station to pick up their luggage, meet relatives or friends, retrieve their car from parking, or take other means of transportation to their final local destination. These central gathering stations could be colocated at airports, city centers, or other locations as appropriate. A metropolitan area could contain more than one central gathering station.

The local ground metroplex transportation network might be a rapid rail system, a network of rapid, dedicated buses, an airborne-based system, such as helicopters or vertical take-off aircraft, a new technology such as Personal Rapid Transit (PRT), or a combination of any or all of these systems.

- *Aircraft servicing*

  Currently airlines service their own aircraft. Since the number and type of an airline's aircraft at any particular airport in the adaptive metroplex may vary from day-to-day, other concepts for servicing aircraft will likely be needed from those used today. Aircraft servicing might be provided by a common company for all aircraft using a particular airport.

- *Baggage and terminal passenger services*

  As with aircraft, baggage and passenger services within the terminal at any airport would likely be provided by a common company. Concepts for transferring baggage to a central gathering station, to a connecting flight at the same or different airport, or arranging for pick-up by passengers at that airport, would be needed. Similarly, means to plan passenger transfers, and to communicate to each passenger what they are expected to do, would be needed.

- *Very advanced concepts for adaptive metroplexes*

  The above concept elements, while a departure from today's airline operations, can be viewed as an extension of current practices. These may be concept sub-elements that are very different from today that bear investigation. One example is that the airline dynamically assigns an aircraft to a particular origin/destination flight based on the airport within the metroplex where the aircraft will land before its next flight. Thus, it would be known only shortly before a flight what aircraft, and possibly what crew, would be assigned to a particular flight. Another example is that an airline might use an aircraft owned by another airline for one of its flights. This is a variation of the run-through of railroad locomotives used by today's railroads. The locomotive supplied by a particular railroad at the origin of a train's journey will stay with the train and be operated by a crew of another railroad when the train enters that railroad's tracks. Such an operation would be more complicated for airlines since airlines have different cockpit setups and flight procedures. There would need to be more standardization of cockpits and airline operations than today. These aspects are illustrations of ideas to explore.

7.1.3 Benefits from adaptive metroplex operations

Benefits of the above concept elements are:

- Maximize capacity provided by airports in a metropolitan area by reacting to weather and demand variations
  - Benefit arises from flexibility of directing an arriving aircraft to an airport that can handle the flight when another airport originally planned as the destination is unavailable.

- Maximize flexibility in airspace usage depending on weather and demand
  - Benefit arises from flexibility of directing an arriving aircraft to use available airspace, when some airspace might be restricted due to weather, since the aircraft can land at an airport that has airspace available to it.

7.1.4 Required technology and infrastructure for adaptive metroplex operations

The following technology and infrastructure items are assumed to be provided for the concept elements. Benefits include:

- Local ground metroplex transportation network to transport passengers among airports and central gathering stations
- Central gathering stations for passengers to enter and exit the adaptive metroplex to begin or end air journeys
- Common aircraft servicing facilities at airports in the adaptive metroplex
- Baggage handling and transfer facilities.

7.1.5 Potential research topics for adaptive metroplex operations

Some potential research questions for the sub-elements listed in this subsection are presented below. The list is not definitive; it is included to aid in identifying research needs. Crosscutting research issues for human factors, safety, and environment are described in Section 8.0.

- What are incentives and requirements for a successful adaptive metroplex operation? This includes examining incentives from the viewpoint of all stakeholders, such as air carrier operators, passengers, airport operators, local government agencies, etc.
- How will final airport destinations be decided and how will negotiations be conducted?
- How will changes in airport destinations be implemented and flight routes changed?
- How will arrival routes and departures for multiple airports in a metroplex be planned?
- How close can arrival and departure paths be located for separation purposes?
- How can arrival and departure paths in a metroplex be dynamically changed to account for changes in weather and in constraints at particular airports?
- How can metroplex operations be planned and executed under adverse weather?
- What information should be shared among AOCs, flight deck, and air traffic service providers at airports, terminal airspace, en route airspace, and flow control facilities?

7.2 Advanced Airport Design Tools

For many of the proposed concept elements to succeed, a greater flexibility and maneuvering capability is needed than currently exists at major hub airports. Taxi planning, in particular, benefits from establishing 4D paths based on a set of optimization criteria, and is not merely first-come, first-served scheduling. Implicit in these advanced operations is the ability to manipulate the order of departures and arrivals at the gate. This, in turn, requires a level of controllability that may not exist

at all airports. Does the airport have the needed taxiways to resequence the traffic? Does it have holding/staging areas where aircraft can be held awaiting their gate area departure, rather than occupying a gate needed for an arriving aircraft? Are there alternative taxi routes available, like perimeter taxiways, to avoid delays and congestion at runway crossings? These questions can be answered by airport designs that utilize the new concept elements described in this document.

7.2.1 Constraints and problems of advanced airport design tools

Airports in 20 to 25 years will operate with technologies derived from many of the concept elements in this document. New airports, and existing airports that have changes in their runways, taxiways, or other surface infrastructure, will be able to capture more capacity and efficiency benefits if the airports are designed to utilize concept elements appropriate to each airport's particular requirements and constraints.

7.2.2 Description of advanced airport design tools

The focus is the design of airports that will fully capitalize upon innovative taxi-route planning. The ground rules to conceive and develop tools are as follows: (1) a clean-sheet-of-paper design, and (2) the surface sensors and automation technologies are in place to enable a radar-like, highly automated environment, rather than out-the-window observation and manual control.

There is primarily one operational aspect to the Advanced Airport Design Tools concept element, which is:

- *New airports and existing airport changes designed by Advanced Airport Design Tools*

  Airports will be designed to take maximum advantage of new automation for airport operations on the surface and in terminal airspace. Examples of airport infrastructure that will be designed by such a tool include staging areas, perimeter taxiways, new taxiways, high-speed exits from runways, deicing facilities, runway layout, CSPR, noise and emissions, and even some innovative mechanisms for manipulation and control of surface traffic. The design tools will also account for human performance compatibility, and the appropriate roles of humans and automation in the operation of the resulting airport.

7.2.3 Benefits of advanced airport design tools

Benefits of the above concept elements are:

- Increased surface capacity through better design of airport surface layouts
  - Benefit arises from more surface capacity and more efficient taxi routing and movements that are due to improved design of taxiway, ramp areas, and runways to take advantage of the concept elements.

7.2.4 Required technology and infrastructure for advanced airport design tools

The following technology and infrastructure items are assumed to be provided for the concept elements. Benefits include:

- Technology to provide location information for aircraft on runways, taxiways, and for other objects during poor visibility
- Surface and terminal airspace surveillance to allow less separation between taxiing aircraft

- Improved weather predictions and information on current weather

- Better communication tools, including digital data link

- Sensors to monitor noise and air quality levels.

7.2.5 Potential research topics for advanced airport design tools

Some potential research questions for the sub-element listed in this subsection are presented below. The list is not definitive; it is included to aid in identifying research needs. Crosscutting research issues for human factors, safety, and environment are described in Section 8.0.

- What attributes of airports should be addressed in the design functions of the tool?

- What concept elements of future operations should be addressed in the design tool?

- How should the design tool operate and what form should the user interface take?

8   CROSSCUTTING ATTRIBUTES OF CONCEPT ELEMENTS

There are several research topics related to the operation of future concepts for airport operations that cut across the concept elements presented in Sections 2.0 through 7.0. These include human factors, safety, and environment. These aspects are discussed in Section 8.0.

8.1   Human Factors

The human-automation roles and interfaces under future airport operations raise several key human factors issues. This section gives a summary overview of the drivers of change for human-automation interactions and potential human factor issues.

8.1.1   Description of human factors

A study of the following attributes, and their implications, will support the allocation of roles in conducting airport tasks among humans and automation, and will support the design of the humans' tasks.

- *More Precision* – This refers to tighter tolerances for aviation operations, including the use of time-based metering to achieve assigned 4D trajectories (i.e., position in both space and time), reduced separation, and EVO. The precision would be enabled by new surveillance technology with increased accuracy, improved weather predictions, improved traffic displays, and other technological advances. Reducing separation and other tolerances will result in the ability of more aircraft to pass through a given airspace in a given time period and in more aircraft landing at an airport in a given time period.

  Human factors implications under more precision will arise from precise actions that need to be taken at precise times (both for safety and to achieve capacity benefits) and from there being less time to react to off-nominal situations.

- *More Information and Information Sharing* – This refers to the increased information to be available in the NAS, as well as the sharing of information among all users. More information would enable the more efficient operation of the NAS.

  Human factors implications under more information and information sharing will arise from more information to access, interpret, and judge whether to use.

- *More Automation* – This refers to the computer-based technology for planning and execution of ATM/ATC. More automation enables taking advantage of the greater precision, and of the availability of more information.

  Human factors implications under more automation will arise from extensive use of decision support tools and from automation roles ranging from automation that aids the human execution of tasks, to the automation of entire tasks.

- *Extended Horizon for Planning and Operations* – This refers to the planning of ATM/ATC operations over a larger geographic region, and longer time horizon, than today. The extended planning horizon would permit increased optimization, and hence greater efficiency and capacity.

  Human factors implications for the allocation of flight deck tasks to human and automation, under an extended horizon for planning and operations, will arise from humans and automation needing to be aware of conditions (e.g., weather, traffic levels, special use airspace (SUA)) over a larger geographic region and longer time horizon than today, and needing to remember to conduct actions farther into the future than today.

- *Collaborative Decision-Making (CDM)* – This refers to decisions made through negotiations among users and ATSPs. CDM will give users a greater role in ATM and provide more efficiency. More CDM implies more user requests, and negotiation between flight deck and ATSP about how to honor these requests.

  Human factors implications under CDM will arise from more user requests and more negotiations.

- *Flexibility* – This refers to dynamically changing ATM/ATC airspace configuration and operations in response to changing conditions, such as weather, demand, and security needs. Flexibility enables more efficient handling of changing conditions in the NAS, thus enabling greater capacity.

  Human factors implications for more airspace flexibility will arise from the flight deck operating in more, and in changing, modes of operation.

8.1.2 Potential research topics for human factors

Research topics for human factors that arise from the above discussion include:

- Workload for different operations to be conducted during airport operations, during transition between modes of operation, and the ability to carry out actions at precise times

- Understandability and clarity of tasks in any mode of operation

- Suitability and stability of tasks under different modes of operation and for emergency response actions under different modes of operation

- Robustness of human performance to contingencies

- Prospective memory issues, including remembering what to do in a particular mode of operation; remembering roles of automation, what the automation is doing now, and what it will probably do next; knowing who is responsible for overall safety; and remembering a response to an anomalous situation while in a different mode of operation

- Alertness to respond to new information and indicators

- Completeness and clarity of steps for transition between modes of operations

- Conveying of information, including the information display and what information to push and to pull

- What tasks to allocate, and how to allocate tasks between humans and automation in future airport operations when automation will have more functionality than today, and modes of operation will change more frequently than today

- When should task allocations between humans and automation change and how should the transition should be designed

- Transition from automation to humans to handle anomalies

- How to conduct training for new roles and responsibilities of humans.

8.2 Safety

It will be necessary to reduce the accident rate in the future as air traffic levels grow. Runway incursion accidents, in particular, have been a continual focus of the FAA.

8.2.1 Description of safety
While NASA's Aviation Safety Program is aimed directly at improvements to aviation safety, the NextGen-Airportal Project (within the Airspace Systems Program) shares a complimentary consideration to at least understand the safety implications of its research. This includes safety considerations of human-automation roles, resultant procedures from new concept elements, and technology performance including possible failures.

8.2.2 Potential research topics for safety
Safety implications of the concept sub-elements being developed by individual research activities may include:

- Impacts of new operations and procedures on safety

- Impacts of new automated planning and operations on performance of controllers and pilots related to safety

- Failure mode impacts on safety.

8.3   Environment

As the number of flight operations continues to increase, noise and emissions will become increasingly problematic. Unless environmental issues are addressed, higher-capacity operations may result in increased noise and emissions levels, which in turn may limit any potential capacity gains. The next generation of aircraft will be more environmentally friendly, but 20 years from now, the aircraft fleet at major hubs will still include a substantial number of today's aircraft. Hence, environmental concerns must be considered as a component of research activities.

8.3.1   Description of environment

Strategies must be developed to keep environmental impact at least within today's bounds (i.e., based on current traffic levels) even as the capacity increases. This means an average reduction in noise and emissions, keeping noise contained within the airport boundary, or the routing of traffic over areas away from populated areas. While increased capacity at airports is likely to bring increased noise and emission impacts, concept elements in this document have the potential to help mitigate these adverse environmental impacts. These concepts enable more flexibility for executing more noise-sensitive routes, such as funneling traffic over areas with low population density, routing older aircraft via less sensitive noise areas, using runway configurations with lower noise impact, and modifying routing based on changes in wind direction. Enabling aircraft to fly fuel-efficient routes will help to reduce emissions. Environmental constraints for noise and emissions can be integrated into the airport planning and operational processes through environmental advisory tools.

There are broader issues related to the environment that need to be addressed, and are identified by NextGen, including water quality, energy intensity, and global climate change. There are emerging topics of discussion at the international level concerning emissions trading schemes whereby operators can buy or sell emissions allowances. However, these issues are beyond the scope of this document.

8.3.2   Potential research topics for environment

Research topics for environment that arise from the above discussion include:

- Relationship of concept elements in this document to environmental impacts of noise and emissions.

- Understand the environmental impacts resulting from the amount of time aircraft operate on the surface under different 4D taxi trajectories, including taxi speed and acceleration, and from aircraft operating in the terminal airspace under different 4D terminal airspace trajectories, including engine acceleration for departure and power needs for descent. These include examining the types of trajectories that can reduce population exposure to noise and emissions, as well as reducing the noise and emissions generated from aircraft.

- Examine how to incorporate impacts on environment into the design of individual concept elements for airport capacity increases.

- Software tools that analyze environment impacts of airport operations under alternative concept elements.

- Understand how real-time noise and emissions information from sensors could be used by surface and terminal airspace trajectory planning tools to reduce environmental impacts.

8.4 System Failure

The previous presentations of concept elements have included responding to off-nominal situations, such as a missed approach, deviation from a flight trajectory, or deviation from a taxi route. More serious events that affect airport operations more extensively, and for a longer time period, might be considered to be system failures. System failure is defined as a significant difference between planned and realized operations. A system failure can be caused by human error, hardware/software failure, accident, disaster, or severe weather (significant weather disruptions are included as system failures since the system is unable to provide its intended services). As operations in the NAS become more precise and interdependent in the future, system failure can have a significant impact on the operations of the NAS. Ways to minimize the occurrence of a system failure, to mitigate the consequences of a failure, or to recover from a failure, is an important area of research.

8.4.1 Description of system failure

When a system failure occurs, there may be a significant impact on the NAS. With closer separation between aircraft in the future, there is less time to react to a failure in equipment, whether ground ATC service equipment or equipment on the aircraft. Major delays can arise in the NAS, disrupting many passengers, when a snowstorm moves unexpectedly slow across a major hub over a holiday weekend. With two or three times the aircraft flying in the future as today, and with the precision and interactions required in the future air transportation system, research is needed to minimize the occurrence and potential impact of a system failure.

Examples of general topics related to system failure include degradation failure to allow time for recovery; new equipment, software-based aids, and procedures robust enough to operate in a variety of conditions; and consideration of human-automation roles and interactions to prevent system failures and aid recovery should a system failure occur. There is a need to study where system failures might occur in future operations and what the consequences might be. This requires better understanding of the increasing complex NAS dynamics and interdependences between different components in the NAS.

8.4.2 Potential research topics for system failure

Research topics for system failure that arise from the above discussion include:

- Causes of system failures. In particular, examine interdependencies between different planning processes and NAS components.

- What does graceful failure mean in the future air transportation system? Are there any tradeoffs between the different ways to achieve graceful failure? What are the metrics that can measure a graceful failure? What are the implications of the use of different metrics?

- Design within new automation to detect conditions that are precursors to system failure

- Design within new automation to minimize the likelihood of system failures from human errors, such as verifying with the human user if they want to perform an action that the automation senses is questionable, or automation reminding the user of the current mode of operation and what tasks are to be performed

- Contingency planning

- Recovery from a system failure

- How would CDM work during a system failure? How can CDM minimize the impact of system failure?

- Equity among users during system failure.

9 FURTHER DEVELOPMENT AND EVOLUTION OF THE AIRPORTAL CONCEPT

Concept elements have been presented for the surface, terminal airspace, integrating and coordinating operations between the surface and terminal airspace and with the en route airspace, small airports, and advanced concepts. Changes, additions, and/or deletions to this initial set of concept elements are expected as research activities within and beyond the project yield results over time. The set of concept elements may evolve with both changes in the "integration" of research activities across Airportal and Airspace Project research focus areas and collaboration with the JPDO and community partners.

Moreover, as research progresses and knowledge is gained, the concept document is expected to evolve into more of a concept of operations including such topics as roles and responsibilities of participants and supporting automation/technologies, how services will be provided, and how aircraft would operate in the future system. In the meantime, this initial version provides a common framework and context for defining and coordinating research activities that are and will be conducted by the NextGen-Airportal Project.

APPENDIX A – MAPPING OF AIRPORTAL CONCEPT ELEMENTS

Mapping of Airportal Concept Elements to the Airportal and Airspace Project Research Focus Areas where Primary Contributions Reside (or would reside if funded)

NextGen-Airportal Research Focus Areas:
SESO: Safe and Efficient Surface Operations
CADOM: Coordinated Arrival and Departure Operations Management
ATIM: Airportal Transition and Integration Management

NextGen-Airspace Research Focus Areas:
TPSU: Trajectory Prediction, Synthesis, and uncertainty
PBS: Performance-Based Services
DAC: Dynamic Airspace Configuration
TFM: Traffic Flow Management
SA: Separation Assurance
SDO: Super Density Operations
SLDAST: System-Level Design, Analysis, and Simulation Tools

		Airportal Concept Elements	Related Airportal and Airspace Research Focus Areas
3.0 Surface Concept Elements	3.1	Runway Management	SESO, CADOM, TFM
	3.2	Taxi Route Planning	SESO
	3.3	Surface Super Density Operations	SESO
	3.4	Surface Weather and Environmental Planning	SESO
4.0 Terminal Concept Elements	4.1	Precise Spacing and Separation Assurance	CADOM, SDO
	4.2	Dynamic Airspace Management	DAC, SDO
	4.3	Adapting Operations to Conditions	CADOM, SDO
	4.4	Metroplex Operations	ATIM, SDO
5.0 Coordination and Integration of Concept Elements	5.1	Coordination and Integration among Airport Surface Operations	SESO
	5.2	Coordination and Integration among Terminal Airspace Operations	CADOM, SDO
	5.3	Coordination and Integration among Airport Surface and Terminal Airspace Operations	ATIM, SESO, CADOM, SDO
	5.4	Coordination and Integration among Metroplex Operations	ATIM, SDO, TFM
6.0 Small Airports	6.0	Small Airports	None[6] (SESO, CADOM, ATIM)
7.0 Advanced Concept Elements	7.1	Adaptive Metroplex Operations	ATIM
	7.2	Advanced Airport Design Tools	None (ATIM, SESO)

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[6] Currently, there is no Airportal or Airspace Research Focus Area (RFA) on this Airportal Concept Element. If this concept element is funded, the RFAs where the primary contribution would reside are listed in the parenthesis.

APPENDIX B – SUMMARY OF CONCEPT ELEMENTS AND SUB-ELEMENTS

Appendix B summarizes the concepts in one multipage table. The table has three columns. The first column lists the concept elements and summarizes the constraint or problem addressed by the concept element. The second column lists the sub-elements of the concept element. The third column summarizes the potential research topics for the concept elements.

TABLE B-1. SUMMARY OF CONCEPT ELEMENTS AND SUB-ELEMENTS

Concept Elements	Concept Sub-Elements	Potential Research Topics
3.0 Surface 3.1 Runway Management Adjusting runway and taxiway configuration for winds, traffic demand, and environmental considerations is slow, infrequent, and inefficient for enhancing capacity.	• Optimized runway and taxiway configuration change • Dynamic allocation of runways (for a given configuration) • More efficient departure sequences and schedules	• Develop algorithms to determine optimum runway configuration and provide efficient transition to change configuration • Develop algorithms to allocate runways to departures and arrivals and to schedule time for departing aircraft to arrive at departure runways • Develop algorithms to sequence and schedule aircraft to use runways, including responding to user preferences • Study how to include fairness in tradeoff with capacity maximization in managing runway allocation and changes.
3.2 Taxi Route Planning As airport traffic increases, taxiing is subject to increased delays, and this adds to overall gate-to-gate time. There are several aspects of taxi movements that constrain surface capacity, including taxi routes that are of longer time than if taxi routes are planned as a whole;	• Plan efficient taxi routes under specific airport constraints • Increase density of surface operations • Minimize queuing and provide clearances for longer taxi segments • Provide for equipage differences, user preferences, and fairness	• Determine the most effective means of 4D control • Reduce uncertainties in pushback time • Determine the controllability provided by taxiways/holding areas • Cross active runways with little or no queuing • Automation of clearances/handoffs on the surface to reduce need for stopping while taxiing

Concept Elements	Concept Sub-Elements	Potential Research Topics
aircraft waiting for clearances for taxi route segments; queuing to cross active runways and for departure runways; getting arriving aircraft off the runway quickly; and aircraft pushing back from gate blocking other aircraft.	• Integrate ground vehicle movement into surface traffic flow • Execute and adhere to precision taxi routes	• Incorporate user preferences and negotiating for taxi routes • Onboard automation and display to aid pilot in following a 4D taxi route or to control the aircraft to follow a 4D taxi route • Procedures for negotiating 4D taxi routes • Efficient taxi route operations in the presence of large uncertainties • Understand tradeoffs in optimal vs. robust operations • Fairness issues in managing taxiway operations • Roles and responsibilities of the pilot and controllers and their automation tools to plan, coordinate, negotiate, and monitor surface operations in an integrated manner • Investigate the relationship of surface layout changes (e.g., new/extended runway, new taxiway/holding area) to increase surface capacity and flexibility
3.3 Surface SDO During peak periods, airport capacity is often not sufficient to support the demand. Increased density of traffic using runways and taxiways increases workload. It becomes more complex to handle such operations as intersecting or converging runways, taxiing aircraft crossing active runways, and aircraft landing on CSPR. The noise impact of dense operations and of closely-spaced arrivals may be unacceptable to local communities. Runway incursions become a bigger concern as the number of aircraft using an airport increases.	• Reduced runway incursions and taxiway conflicts • Precision runway/taxi operations • Reduced runway occupancy time • EVO • Intersecting and converging runways • Weather and environment	• Safety CD&R in the closely-spaced environment of SDO, including during EVO • Low altitude, runway, and taxiway collision avoidance • Procedures, algorithms, automation, and equipage requirements for CSPR operations • Procedures, algorithms, automation, and equipage requirements for precise taxi operations • Procedures, algorithms, automation, and equipage requirements for planning and executing 4D taxi routes • Reduction of impact of wake vortex • Airborne and ground roles and responsibilities (conformance monitoring, CD&R) • Determine ground arrival capacity for major airports under super density operations

Concept Elements	Concept Sub-Elements	Potential Research Topics

<u>3.4 Surface Weather and Environmental Planning</u>
Winds can result in changing arrivals and departures to a less efficient set of runways. If changes in wind direction are poorly predicted, configuration changes may be required which can result in inefficient, lengthy transition periods. Surface movement can be slowed considerably by reduced visibility or wet/snowy surface conditions. As for the environment, if current operations are at or near environmental limits, increased capacity may not be possible.
	• Weather
	• Environment
		• Develop procedures to utilize improved weather predictions
		• Incorporate environmental impacts into surface operation planning:
		   - Directly as goals for increased surface capacity and reduced taxi times during adverse weather
		   - Indirectly as constraints, such as community noise limitations
		• Develop roles of human and automation for operations involving weather and environmental impacts

4.0 Terminal Concept Elements <u>4.1 Precise Spacing & Separation Assurance</u> Spacing and separation between traffic is currently a function of limitations in a number of areas. Surveillance capabilities are limited by accuracy and update rate; improvements in these areas will permit improvements to spacing precision. Likewise, improve-ment in flying more accurate 4D trajectories will also permit improved spacing precision. Finally, improvements in the ability to detect conflicts will allow consideration of closer spacing between aircraft.	• Precise spacing • Reduced wake vortex separation criteria • CSPR operations • Scheduling and sequencing interactions with surface and en route • Intersecting trajectories in airspace	• What separations can be achieved for CSPR operations with greater aircraft navigation and surveillance precision? • What is the best solution for precision spacing: flight deck managed spacing or ground-based spacing? • Regarding separation responsibility, what role is appropriate for the flight deck and for ATC? • What alerting is needed to detect separation violations in an environment where standards are closer? • What are the information requirements for groundside if airborne-managed separation is used? • What are the information requirements for the flight deck if groundside separation is used?

Concept Elements	Concept Sub-Elements	Potential Research Topics
		• How precise can information be provided as to whether a wake is present? What is the actual wake hazard as it applies to required separation, for example for reduced separation, CSPRs, and EVO? • How to conduct response to off-nominal situations?
4.2 Dynamic Airspace Management Inefficiencies in the flow of traffic occur as a result of airspace allocation, which is generally static and inflexible. The current system does not provide, with few exceptions, the re-allocation of airspace to meet ever-changing demand. Hence, traffic is delayed while parcels of airspace go unutilized. Controllers, absent tools or procedures that would facilitate quickly adapting to realigned or resectorized airspace, are not equipped to quickly reorient to adjustments to airspace boundaries.	• Dynamic terminal airspace sector allocation • Airspace sector redesign	• How can airspace be reallocated to meet demand and be done in a way that increases efficiency of operators? • What time horizon is required for all affected entities to adjust to new boundaries? • How to dynamically implement transitions to new airspace configurations so that the transitions are gracefully achieved, absent of any confusion or uncertainty for air traffic service providers or pilots. • Potentially more aircraft in sectors creates additional workload: is this manageable and what is the limit regarding number of aircraft? • How will the new airspaces to be dynamically allocated be designed? Is new modeling capability required? • What are the interactions of terminal airspace with en route airspace to maximize the benefit of changes made in terminal airspace?
4.3 Adapting Operations to Conditions There are a myriad of situations that can be categorized as changes in the flow of air traffic operations, either changes among alternative operational scenarios or changes to react to off-nominal conditions. These situations require	• Respond to runway changes • Reduction of wake vortex impacts • React to weather deviations/reroutes • Environment • Recovery from missed approaches	• Algorithms to adjust terminal airspace routes for changes in runway configurations • Adjusting to changing wake separation requirements in the terminal airspace • Dynamic changes in terminal airspace routes to adjust to weather information provided by improved weather

Concept Elements	Concept Sub-Elements	Potential Research Topics
strategies and procedures that minimize impact on the overall operation while achieving specific objectives. There are many challenges in dealing with these situations based on competing interests: e.g. airline: economics; air traffic service provider: localized and systemic flow efficiency; public: noise; and others. Landing aircraft that have missed approaches will have more impacts on future capacity due to denser traffic utilizing airports. Safety, as always, is the first consideration.		forecasts • Planning precise and more varied (e.g., curved arrival and departure paths approaches) 4D trajectories to avoid noise sensitive areas and to fly routes that reduce emissions • What are the off-nominal situations, in addition to missed approaches, that should be addressed in developing automation aids for terminal operations? How should these off-nominal conditions be addressed? How should recovery transition from off-nominal conditions be addressed?
4.4 Metroplex Operations At virtually all airports there are constraining factors that limit capacity to some degree. Often there are nearby airports, which might be used to increase overall capacity for a metropolitan area. Many airports are also constrained by operations arriving at, or departing from, surrounding airports. This can occur for several reasons, such as conflicting arrival/departure paths and shared arrival/departure fixes. Traffic increases at airports that currently experience high demand, as well as increases at airports with light traffic loading, will further exacerbate the aforementioned constraints and form new interdepend-encies. With these issues in mind, traffic	• Precisely flown paths • Flexible flight paths • Increased TFM planning horizon • Route planning and execution under adverse weather • Increased capacity at uncontrolled airports	• How to plan arrival routes and departures for multiple airports in a metroplex? • How close can arrival and departure paths be located for separation purposes? • How can arrival and departure paths in a metroplex be dynamically changed to account for changes in weather and in constraints at particular airports? • How can airspace be designed and dynamically changed to account for changes in weather and in constraints at particular airports? • How can metroplex operations be planned and executed under adverse weather? • What information should be shared among air traffic service providers at airports, terminal airspace, and en route airspace?

Concept Elements	Concept Sub-Elements	Potential Research Topics

flow management strategies that reflect these interdependencies and provide for operations at multiple airports in a metropolitan area will be required.
 	
5.0 Coordination and Integration of Concept Elements
 	
5.1 Coordination and Integration among Airport Surface Operations
Many potential constraints and conflicts can arise on the airport surface from the different surface concept elements and sub-elements interacting with each other, such as runway assignments interacting with scheduling and sequencing on each runway, taxi route planning interacting with runway availability, and gate/runway assignments for multiple aircraft causing interactions among surface operations for these aircraft. These constraints and conflicts, if not managed, can cause inefficiency and delay.
	• Surface Flow Constraint
	• Surface Flow Management
	• Surface Trajectory Planning
	• Surface Tactical Control
		Note: The issues are similar for integrating automation within and among surface and terminal airspace operations. Therefore research questions on coordination and integration (i.e., for Sections 5.1, 5.2, 5.3, and 5.4) are listed once below:
		• How to obtain better prediction of pushback time and/or ETA at arrival fix, as appropriate to the particular operation? In the context of probabilistic information, how to better characterize the pushback time and/or ETA at arrival fixes for coordination and integration purpose?
		• Understand the dynamics of the interactions among surface, terminal airspace, en route airspace, and metroplex operations.
		  ➢ What is the impact of new trajectory due to renegotiation of the 4D trajectory?
		  ➢ How, and how often, can 4D trajectories be negotiated and renegotiated.

5.2 Coordination and Integration among Terminal Airspace Operations In the future, more aircraft will transition through terminal airspace, there will be CSPR operations, and wake vortex	• Terminal Airspace Flow Constraint • Terminal Airspace Flow Management • Terminal Airspace Trajectory Planning • Terminal Airspace Tactical Control	• Many objectives are possible for coordinating and integrating airport operations. For example, is the objective to maximize the throughput of the system (to be equitable to all users in the system) or to maximize

Concept Elements	Concept Sub-Elements	Potential Research Topics
separation will be more critical. Separation assurance, terminal airspace management, arrival and departure path planning, and handling nonnormal operations will all interact in the terminal airspace to affect capacity. Optimizing each of these concept elements will help increase capacity, but also coordinating and integrating these concept elements will provide further capacity enhancements.		the throughput while subject to some equality constraints? Issues regarding objectives include: ➤ How would a particular objective function impact aircraft with different equipage levels? ➤ What are the tradeoffs for using different objective functions? ➤ What type of user preference requests can be accommodated by the coordination and integration function and how? ➤ What is the optimal time horizon of each planning function? ➤ What are the different ways to coordinate competing objectives, for example, between the local and national level?
5.3 Coordination and Integration among Airport Surface and Terminal Airspace Operations Airport surface and terminal airspace have different operational characteristics and limitations. An aircraft flying through the two domains encounters different constraints and requirements. Optimizing traffic capacity in each domain separately does not imply that overall capacity is maximized.	• Integrated Flow Constraint • Integrated Flow Management • Integrated Trajectory Planning • Integrated Tactical Control	• Which actions, given the objective function, should be considered feasible in the coordination and planning process? ➤ There are multiple parties operating in or interfacing with the airport (e.g., en route centers, TRACON, airports, and AOC). Each party may have different goals and objectives. What is the process for negotiation among the different parties to arrive at an action? • How to construct the best action set with limited computational power and limited time? Each aircraft goes through several different operations and each operation has several possible control actions. The total number of possible control action set grows exponentially as a function of the number of aircraft.
5.4 Coordination and Integration among Metroplex Operations Metroplex operations include the same constraints as the integrated airport and terminal operations. In addition, there are more aircraft flying into and out of the	• Metroplex Flow Constraint • Metroplex Flow Management • Metroplex Trajectory Planning • Metroplex Tactical Control	• How to coordinate and integrate airport operations so that when an off-nominal event occurs, there will be minimal impact to various operations? If an off-nominal event forces an operation to deviate from the plan and schedule, the event may also force other coupled operations to deviate from their plans and

Concept Elements	Concept Sub-Elements	Potential Research Topics
metroplex instead of a single airport. Moreover, there are overlapping operations among the airports in the metroplex to utilize the shared terminal airspace. Coordinating all the terminal airspace arrivals and departures with the availability of capacity at the individual airports will be complex.		schedules. • The coordination and planning process is likely to be dynamic with a quick solution needed when dealing with off-nominal events. A fast and accurate model is necessary to evaluate and help select a control action. • How to effectively present and utilize the probabilistic input information; this research topic can be generalized to decision-making under uncertainty. • Investigate optimization techniques for different parts of surface and terminal airspace operations; how to combine these different surface and airspace local optimizations into integrated, global optimized operations; and how to deal with uncertainty in these optimizations. • There are likely to be multiple stakeholders in coordination and integration across airport operations with different, or even competing, interests. Procedures and rules may be necessary to establish effective and equitable collaborative-decision processes for different types of negotiations. • Failures in either avionics or systems used by the ATSP are possible in airport operations that are integrated and coordinated. Graceful failure of the future system is a desired characteristic. What is considered graceful failure? What are the different ways to achieve a graceful failure? What are the tradeoffs of the different ways to achieve a graceful failure?

Concept Elements	Concept Sub-Elements	Potential Research Topics
6.0 Small Airports Small airports without towers will have trouble handling an increase in traffic or traffic in poor visibility. This will inhibit an increase in direct point-to-point routes to such small airports and the use of such small airports in metroplexes.	• Airports that serve a large enough air traffic base will have tower-provided ATC services with some sub-elements listed in Sections 2.0 through 5.0, as appropriate. • ATC services for arriving and departing aircraft can be provided by a staffed virtual tower • Automated ATC services, in what might be called an automated virtual tower • Another option for nontowered airports is for aircraft to operate in a self-separating mode.	• Identification and development of any algorithms and procedures for operations at airports in small cities and rural areas, whether staffed virtual tower, automated virtual tower, or self-separation airports • Controller interface issues for managing operations remotely for multiple airports • Impact of growth of traffic small city and rural airports on hub airport traffic demand and operations. Will there be a change in city-pair service that affects hub airports?
7.0 Advanced Concepts Elements 7.1 Adaptive Metroplex Operations The use of metroplexes with flights assigned to specific airports is likely to provide sufficient airport capacity for some time to come. But, with difficulty in building new airports and adding runways to existing airports, even metroplexes using existing airports may reach capacity as air travel demand reaches three times that of today. With the adaptive metroplex, arriving aircraft are not prescheduled to arrive at the same airport. Rather, the aircraft are dynamically scheduled, either before take off from the originating airport or	• Scheduling aircraft to airports • Ground transportation network • Aircraft servicing • Baggage and terminal passenger services • Very advanced concepts for adaptive metroplexes	• What are incentives and requirements for a successful adaptive metroplex operation? This includes examining incentives from the viewpoint of all stakeholders, such as air carrier operators, passengers, airport operators, local government agencies, etc. • How will final airport destinations be decided and how will negotiations be conducted? • How will changes in airport destinations be implemented and flight routes changed? • How to plan arrival routes and departures for multiple airports in a metroplex? • How close can arrival and departure paths be located for separation purposes? • How can arrival and departure paths in a metroplex be

Concept Elements	Concept Sub-Elements	Potential Research Topics
during flight, as to which airport in the metroplex the aircraft will land. This flexibility maximizes the capacity of the metroplex as a whole. If one airport has restricted capacity due to weather (e.g., a passing thunderstorm), aircraft can be assigned dynamically to land at another airport in the metroplex.		dynamically changed to account for changes in weather and in constraints at particular airports? • How can metroplex operations be planned and executed under adverse weather? • What information should be shared among AOCs, flight deck, and air traffic service providers at airports, terminal airspace, en route airspace, and flow control facilities?
7.2 Advanced Airport Design Tools Airports in 20 to 25 years will operate with operations derived from many of the concept elements in this Airportal concept. Any new airports constructed, and existing airports that have changes in their runways, taxiways, or other surface infrastructure, will be able to capture more capacity and efficiency benefits of the Airportal concept elements if the airports are designed to operate under the new concept elements.	• New airports and existing airport changes designed by Advanced Airport Design Tools	• What attributes of airports should be addressed in the design functions of the tool? • What concept elements of future operations should be addressed in the design tool? • How should the design tool operate and what form should the user interface take?
8.0 Crosscutting Attributes of Concept Elements There are several research topics that cut across the concept elements presented in Sections 2 through 7. These aspects are listed below.	Attributes from concept elements that will affect task allocations among humans and automation as well as the design of the humans' tasks:	• Workload for different operations to be conducted during airport operations, during transition between modes of operations, and the ability to carry out actions at precise times

Concept Elements	Concept Sub-Elements	Potential Research Topics
<u>8.1 Human Factors</u> The human-automation roles and interfaces under future airport operations raise several human factor issues.	• More precision • More information and information sharing • More automation • Extended horizon for planning and pperations • Collaborative Decision-Making (CDM) • Flexibility	• Understandability and clarity of tasks in any mode of operation • Suitability and stability of tasks under different modes of operation and for emergency response actions under different modes of operation • Robustness of human performance to contingencies • Prospective memory issues, including remembering what to do in a particular mode of operation; remembering roles of automation, what the automation is doing now, and what it will probably do next; knowing who is responsible for overall safety; and remembering a response to an anomalous situation while in a different mode of operation • Alertness to respond to new information and indicators • Completeness and clarity of steps for transition between modes of operations • Conveying of information (with the more information available) including display of information and what information to push and to pull • What tasks to allocate, and how to allocate tasks between humans and automation in future airport operations when automation will have more functionality than today, and modes of operation will change more frequently than today • When should task allocations between humans and automation change and how should the transition should be designed • Transition from automation to humans to handle anomalies • How to conduct training for new roles and responsibilities of humans.

Concept Elements	Concept Sub-Elements	Potential Research Topics
8.2 Safety It will be necessary to reduce the accident rate in the future as air traffic levels grow. While NASA's Aviation Safety Program is aimed directly at improvements to aviation safety, the NextGen-Airportal Project (within the Airspace Systems Program) shares a complimentary consideration to at least understand the safety implications of its research.	Potential sources of safety concerns include: • Human-automation roles • Procedures resulting from new concept elements • Technology performance and possible failures.	• Impacts of new operations and procedures on safety • Impacts of new automated planning and operations on performance of controllers and pilots related to safety • Failure mode impacts on safety
8.3 Environment As the number of flight operations continues to increase, noise and emissions will become increasingly problematic. Unless environmental issues are addressed, higher-capacity operations may result in increased noise and emissions levels, which in turn may limit any potential capacity gains.	Major environmental concerns are: • Noise • Emissions Broader environmental issues are: • Water quality • Energy intensity • Global climate change	• Relationship of concept elements in this Airportal concept to environmental impacts of noise and emissions • Understand the environment impacts resulting from amount of time aircraft operate on the surface under different 4D taxi trajectories, including taxiing speed and acceleration, and from aircraft operating in the terminal airspace under different 4D terminal airspace trajectories, including engine acceleration for departure and power needs for descent. These include examining what types of trajectories can reduce population exposure to noise and emissions, as well as reducing the noise and emissions generated from aircraft • Examine how to incorporate impacts on environment into the design of individual concept elements for airport capacity increases • Software tools that analyze environment impacts of airport operations under alternative concept elements

Concept Elements	Concept Sub-Elements	Potential Research Topics
		• Understanding of how real-time noise and emission information from sensors could be used by surface and terminal airspace trajectory planning tools to reduce environmental impacts
8.4 System Failure The previous presentations of concept elements have included responding to off-nominal situations, such as a missed approach, deviation from a flight trajectory, or deviation from a taxi route. More serious events that affect airport operations more extensively, and for a longer time period, might be considered to be system failures. System failure is defined as a significant difference between planned and realized operations. A system failure can be caused by human error, hardware/ software failure, accident, disaster, or severe weather. As operations in the NAS become more precise and interdependent in the future, system failure can have significant impact on the operations of the NAS.	Examples of general topics related to system failure include: • Graceful failure to allow time for recovery • New equipment, software-based aids, and procedures robust enough to operate in a variety of conditions • Consideration of human-automation roles and interactions to prevent system failures and aid recovery should a system failure occur	• Causes of system failures. In particular, examine interdependencies between different planning process and NAS elements • What does graceful failure mean in the future air transportation system? Are there any tradeoffs between the different ways to achieve graceful failure? What are the metrics that can measure a graceful failure? What are the implications of the use of different metrics? • Design within new automation to detect conditions that are precursors to system failure • Design within new automation to minimize likelihood of system failures from human errors, such as verifying with the human user if they want to perform an action that the automation senses is questionable, or automation reminding the user of the current mode of operations and what tasks are to be taken • Contingency planning • Recovery from a system failure • How would CDM work during a system failure? How can CDM minimize the impact of system failure? • Equity among users during system failure

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14. ABSTRACT
The NextGen-Airportal Project is organized into three research focus areas: Safe and Efficient Surface Operations, Coordinated Arrival/ Departure Operations Management, and Airportal Transition and Integration Management. The content in this document was derived from an examination of constraints and problems at airports for accommodating future increases in air traffic, and from an examination of capabilities envisioned for NextGen. The concepts are organized around categories of constraints and problems and therefore do not precisely match, but generally reflect, the research focus areas. The concepts provide a framework for defining and coordinating research activities that are, and will be, conducted by the NextGen-Airportal Project. The concepts will help the research activities function as an integrated set focused on future needs for airport operations and will aid aligning the research activities with NextGen key capabilities. The concepts are presented as concept elements with more detailed sub-elements under each concept element. For each concept element, the following topics are discussed: constraints and problems being addressed, benefit descriptions, required technology and infrastructure, and an initial list of potential research topics. Concept content will be updated and more detail added as the research progresses. The concepts are focused on enhancing airportal capacity and efficiency in a timeframe 20 to 25 years in the future, which is similar to NextGen's timeframe.

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