Trajectory-Based Operations (TBO) Conference

March 24, 2009

Meeting Summary

Next Generation Air Transportation System
Joint Planning and Development Office

Conference Agenda

8:00 a.m. **Opening Remarks/Meeting Objectives**
8:15 a.m. **TBO Morning Session**

TBO Baseline – Jay Merkle, FAA/JPDO
TBO Avionics Systems – Stephen Van Trees, FAA
TBO Solution Set – Rowena Mendez, FAA
TBO Concepts – Michele Merkle, FAA
Net-Centric Operations – Col. Doug Wreath DoD/JPDO
Relationship of Research Transition Teams to TBO – Paul Abramson, PDA Associates

10:15 a.m. **Break**
10:30 a.m. **Resume Morning Session**

Role of Trajectory in Decision Support – Debby Kirkman, MITRE
Air Navigation Services Working Group Air Traffic Management Concept of Operations – Rose Ashford, NASA
Aircraft Trajectory Considerations in the Present and Future – Dave Nakamura, Boeing

12:00 p.m. **Lunch**
1:00 p.m. **TBO Afternoon Discussion Session**

Group Discussion: A Common TBO Vision

2:30 p.m. **Break**
2:45 p.m. **Resume Afternoon Session**

Group Discussion: Next Steps of TBO-Related Work with JPDO Working Group Members

5:30 p.m. **Meeting Adjourn**

Opening Remarks – Robert Pearce, NASA/JPDO

The Joint Planning and Development Office (JPDO) Deputy Director Robert Pearce opened the conference by welcoming attendees and outlining the agenda. He briefed the purpose of the conference and the expectations of reaching a common TBO vision amongst the attendees at the conference.

Presentations from the conference can be found at http://www.jpdo.gov/library.asp, under "Meetings and Conferences."

TBO Baseline Briefing – Jay Merkle, FAA/JPDO

Jay Merkle, JPDO Chief Architect, provided an overview of the context and background regarding the JPDO's work on TBO, as well as an introduction to the TBO framework in the NextGen Integrated Work Plan (IWP) and the Avionics Roadmap. Specifically, Jay provided a summary of the Operational Improvement (OI) groupings in the IWP that are relevant to TBO, including Surface Management, Automation, Merging and Spacing, Airspace Management, and Trajectory Management. In addition, he elaborated on the definition of mid-term OIs (through 2018) and far-term OIs (2019 and beyond).

For the ATM OIs, the JPDO's primary focus is on the far-term OIs. The FAA NextGen Implementation and Integration Office and the JPDO are working on federation of the Enterprise Architecture (EA) to align the far-term ATM OIs with the National Airspace System's (NAS) OIs. This involves consolidating certain IWP OIs. The non-ATM OIs (such as those concerning safety, security, surveillance, etc.) are coordinated between the JPDO and the appropriate Partner Agency(-ies).

The following notes highlight key discussion points:

Slide 2 The intent of the conference is to understand the near- and mid-term TBO activities so that the JPDO Working Groups can focus on the far-term goals. Near- and mid-term TBO tasks will be completed by the FAA NextGen Implementation and Integration Office. The JPDO tasks will assume that the FAA NextGen Implementation and Integration Office will meet their near- and mid-term deliverables.

During a discussion on the need for a common TBO vocabulary, Jay stated that the JPDO Interagency Architecture and Engineering Division (IAED) has made some progress with definitions and nomenclature describing TBO. Source materials include the IWP, NextGen Implementation Plan, and the JPDO EA. The results are available in the Glossary of the JPDO Joint Planning Environment (JPE) at http://jpe.jpdo.gov/ee/ .

Slide 3 The TBO baseline details the connection of OIs for 2018-2025.

Slide 4 In the IWP, OI-0370 represents the end-state progression of TBO in 2025. All aircraft operating in high density airspace are managed by Four-Dimensional Trajectory (4DT) in en route climb, cruise, descent, and airport surface phases of the flight.

Mark Andrews, Weather Working Group Government Co-Chair, asked if the term "high density airspace" is defined, and, if so, what percentage of airspace is categorized as high density airspace. Jay said that high density airspace has not yet been defined. An example of high density airspace includes metropolitan areas with complex airspace procedures due to multiple airports and large volumes of air traffic. New York and the Dallas Metro areas serve as two key examples. In addition, some high altitude areas (for example, the routing between areas such as Chicago and New York) may also be considered high density airspace.

Slide 5 The evolution from assisted to automated negotiation focuses on three specific functions: Trajectory Management, Separation Management, and Negotiation. Yuri Gawdiak, JPDO Interagency Portfolio and System Analysis Division Director, is modeling costs and benefits between OIs. There is potential for substantial increases in cost in the evolution from assisted to automated negotiation functions. Accordingly, the additional benefits of automated negotiation over assisted negotiation need to be comprehensively assessed.

Slide 6 Several groupings of Air Traffic Management (ATM)-related OIs contribute to the TBO end-state in 2025. Merging and spacing OIs will be completed in the mid-term.

Slide 8 Surface automation has an integration point with Trajectory Management in 2018. The Near-Zero Visibility Surface Operations will come online and be integrated into TBO in 2025.

Slide 9 There are three Airspace Management OIs in the far-term: National Airspace System (NAS) Wide Sector Demand Prediction and Resource Planning, Dynamic Airspace Reclassification, and Flow Corridors. These OIs are primarily related to dynamic airspace planning and management. The functionality and intent of the Resource Planning OI (OI-0361) may be consolidated into related OIs for clarity and consistency. Jay will keep the JPDO community up-to-date on to the status of this activity.

Slide 10 In 2024, automation will support the end-state gate-to-gate TBO with automated negotiation of 4DTs between properly equipped aircraft and ground automation for Separation Management. The Automation-Assisted Trajectory Negotiation (OI-0360) is under consideration to appear in the NAS Architecture 6 (NAS 6).

Slide 11 Debby Kirkman asked if there are any OIs that relate to Separation Management connected to TBO. Jay stated that some OIs have merged, while others have become enablers.

Slide 13 As a foundation for long-term evolution of the system, the NextGen Implementation Plan provides a summary of mid-term TBO capabilities through 2018.

Slide 14 The Avionics Roadmap provides a conceptual framework for TBO, as it relates to 4DT integration with avionics capabilities.

A participant asked whether the NextGen Implementation Plan will move the NextGen target date. Jay replied, "Yes, the NextGen Implementation Plan is a 10-year moving plan." It has not been determined whether the far-term definition (2019 and beyond) will stay as is or if it will shift, including a shift beyond 2025.

Slide 15 The NAS Enterprise Architecture (NASEA) Infrastructure Roadmaps depict planned improvements through 2018. Substantial work is ongoing to align the NAS 6 with the JPDO EA, through federation of the EA. An EA user toolkit is also under development, and will serve as a good reference point. NAS 6 EA reference materials can be found online at http://nas-architecture.faa.gov/nas/, while the JPDO EA is at www.jpdo.gov and http://jpe.jpdo.gov/ee/.

TBO Avionics Systems – Stephen Van Trees, FAA

Steve Van Trees, Aircraft Working Group Government Co-Chair (Acting), gave a briefing on the NextGen Avionics Roadmap and its vision of the TBO Conceptual Framework, including mixed capability TBO to form an inclusive basis throughout the NAS. All aircraft will have 4DTs, which will be negotiated prior to flight with ATM tools setting required performance (clearances will be used to modify trajectories). The integration of Trajectory and Separation Management with a trajectory window was discussed, to allow the aircraft operator some flexibility. Trajectory data and negotiation concepts in the Avionics Roadmap were also discussed. Currently, the Aircraft Working Group is working to integrate their concepts into the JPDO Joint Planning Environment (JPE).

The following notes highlight key discussion points:

Slide 2 Looking at Reference Business Trajectory (RBT) within the Single European Sky ATM Research (SESAR) program, steps are being taken to stay consistent with SESAR work currently under development. The Aircraft Working Group is tracking the activities of the Avionics Roadmap and NextGen Concept of Operations (ConOps), and comparing the activities of each to the work being completed under the SESAR program.

Slide 3 The aircraft-centric capabilities detailed in the Avionics Roadmap are currently being integrated into the FAA's NextGen Implementation Plans.

Slide 6 The TBO framework has mixed capabilities that form an inclusionary basis everywhere in the NAS. Steve elaborated on how the framework must refer to every aircraft currently being managed by the FAA today.

Mark Andrews suggested the need for guiding rule assumptions for TBO, citing that the frameworks between activities include different things. Steve stated that the Aircraft Working Group will include all aircraft in their planning.

Framing the discussion and citing the problem regarding a need for a common terminology, and definition of TBO, Rose Ashford referenced a question that needs to be addressed. "Does TBO refer to management by trajectory or high density operations where datalink is likely to be required?"

Debby Kirkman noted that different levels of 4DT should specify the difference in timing and accuracy. She explained the need to address questions such as, "What is the size of the window? Does size vary with the estimated time of arrival or timing precision?" These questions demonstrate the varying levels or spectrum of TBO capabilities that are envisioned, and need to be incorporated into a refined TBO concept.

Slide 9 In phases of trajectory operations, Steve looked at the four phases: pre-negotiation, negotiation, agreement, and execution.

Jim Wetherly, Air Navigation Services (ANS) Working Group Government Co-Chair, asked about the switch from the pre-negotiation phase to the negotiation phase. Steve suggested looking at the two phases as pre-flight and in-flight. He explained that the work of the ANS Working Group is the pre-negotiation phase, while the work of the Aircraft Working Group is the negotiation phase.

Bob Beard, ANS Working Group Industry Co-Chair, stated that there needs to be time distinction. It is important to know the precise phase of TBO when shifting from one to another. Steve agreed.

Jay Merkle added that the IWP and JPDO planning documents assume airborne System Wide Information Management (SWIM). However, there is no current FAA plan for airborne SWIM, so there is a gap in the concept. A participant compared FAA plans with SESAR plans, stating that SESAR SWIM is being built at a higher-level with ATM data over SWIM.

Debby Kirkman asked if the airborne SWIM capability is optional or a requirement. Does this require two datalinks? Jay responded by stating that the airborne SWIM capability is not a requirement. "You don't need airborne SWIM equipment, it's an enhancement. Without it, an Air Navigation

Service Provider (ANSP) can provide trajectory prior to flight and an aircraft can to fly the trajectory, but there is no in-flight assisted or automated trajectory negotiation."

Slide 10

Steve elaborated on the various types of trajectory data:

- Trajectory Objectives: Aircraft operator objectives (e.g., departure/arrival airports and times, expected routes/procedures).
- Intended Trajectory: The specific path (in 4D) an operator intends to follow.
- Actual Trajectory: The path an aircraft takes—only defined behind the aircraft.
- Window: A region (in any dimension) where the aircraft operator can place their intended trajectory and still be compliant with a trajectory clearance.
- Performance: The performance constraints around the intended trajectory (e.g., RNP type).

A participant asked about the difference between window and performance requirements. Mike Marsili, Global Harmonization Working Group Industry Co-Chair, replied, "A window requirement is a concept that details where the aircraft operator can place his/her intended trajectory. Performance requirements detail where you must stay relative to that trajectory."

Slide 12

Steve reviewed the implications for aircraft, including the use of current aircraft capabilities, and referenced that "full" 4D TBO will require new aircraft capabilities. Data communication is key to describing/inferring trajectory windows and to negotiating trajectories (including Flight Operations Center, or FOC, integration). The work completed is grounded in present day. There will be a gradual turnover in the fleet, for new capabilities

A participant asked if there is a need for broadcasting intent over Automatic Dependent Surveillance-Broadcast (ADS-B). Steve said, "Broadcasting intent is a key discussion point of the Avionics Roadmap. It is not included at this point, but leads to a good discussion for mid-term considerations."

Slide 13 - 14

In closing, Steve explained the key attributes for aircraft and the NAS, per the Avionics Roadmap.

A participant asked if vertical performance and cruise climb were addressed. Dave Nakamura responded, "Yes, to some extent. Cruise climb was not identified as a unique function requirement."

Joe Sherry, Weather Working Group member, asked about strategic versus tactical decision-making for integration of Weather Single Authoritative Source (SAS). Mark Andrews suggested that a 20-minute window could work. The aircraft has knowledge of what weather is in its proximity inside the 20-minute

window. Outside the 20-minute window, the ANSP knows more about the weather and can manage trajectories from a strategic flow perspective.

In addition, the actual time window still is not finalized and will change to meet safety concerns. The goal is to never put the pilot in the strategic decision-making mode or to pass along raw data that is not in decision ready form.

Passing weather information from aircraft to aircraft can be used for information such as turbulence. This is not currently addressed in the Avionics Roadmap, but it is not precluded either.

TBO Solution Set – Rowena Mendez, FAA

Rowena Mendez, FAA Solution Set Coordinator, briefed TBO activities, FY09 budget context, and projects from the ATO's perspective. FAA ATO is currently working on activities through the mid-term period (2018). The JPDO is working in the far-term period, and so the JPDO's work is dependent on the FAA's mid-term plans. Currently, the main focus of the TBO solution set is en route cruise, with future goals in the areas of gate-to-gate TBO, Separation Management, and Trajectory Management.

The following notes highlight key discussion points:

Slide 3 One of the goals for TBO is for Air Traffic Control to transition to traffic management by trajectory.

Aircraft will fly negotiated trajectories, and air traffic control will move to Trajectory Management. The roles of pilots/controllers will evolve to support the requirements.

Slide 6 A participant asked who is working Unmanned Aerial Systems (UAS). Rowena responded by stating that, "UAS efforts are under FAA Solution Set Coordinator, Paul Fontaine. UAS is another type of aircraft in the NAS that needs to be addressed, and are part of demo activities." The UAS 4DT-based demonstration includes installation of Flight Management System (FMS) into a UAS.

Slide 8 For FY09 TBO projects, Michele Merkle's team is focused on the pre-implementation phase and the concept of high altitude. Traffic Management Advisory (TMA) will be evolving for space metering.

Mark Andrews asked who bridges between pre-flight, terminal, and the en route phase, since the focus is on en route cruise. Jay Merkle answered by stating that activities are unified through the OIs. In addition, a solution set portfolio approach is being used. Using the OIs as a framework to move forward, there is a process of validating OIs to avoid missing key parts.

TBO Concepts – Michele Merkle, FAA

Michele Merkle, FAA Manager of Air Traffic Services (ATS) Concept Development and Validation Group, briefed on the development of the Mid-Term (2018) NAS ConOps, which will describe the NAS in the 2018 timeframe. Operations and ATC services in all phases of flight will be described, including the use of Data Communications (DataComm) Segment 2, Surface Operations, NextGen Towers, High Altitude use by TBO aircraft, Multi-Sector Planner, and Integrated Arrival and Departure Management for achieving planned TBO performance levels in 2018. The Mid-Term ConOps is planned for publication in approximately six months.

The following notes highlight key discussion points:

Slide 4 The End-to-End Mid-Term NAS ConOps is a complete architectural level description of the NAS in the 2018 timeframe. It describes operations and ATC services in all phases of flight.

Michele explained how her team is working to integrate OIs, enable capabilities, and identify gaps. The intent is to provide as much flexibility as possible to manage resources.

Slide 7 DataComm Segment 2 covers all phases of flight, including issuance of clearances. Research includes a series of simulations to address several issues, for example: (1) Is there a loss of situational awareness with datalink, since there would be no party line datalink (e.g., sharing of turbulence reports that occur via voice communication today)?; (2) What is the best format for datalink in the cockpit, such as a Heads Up Display (HUD), etc. in tactical terminal airspace?; and (3) With mixed equipage, can controllers effectively manage some aircraft via datalink while others remain on legacy voice radios?

Slide 11 During the general implementation phase, there are three stages of configuration for the Staffed NextGen Tower (SNT). These stages include the following:

- Supplemental Configuration: Will include a controller in the tower with use of tools that are certified for separation.
- Flexible Configuration: Will include a remote controller providing separation services, with another controller in the tower as a safety precaution.

- Full SNT Configuration: Will include only remote controllers to provide ATC services.

Slide 13 - 14 The High Altitude Concept includes a blending of principles for Ultra High

Altitude Airspace with TBO, as the airspace will be exclusive to aircraft that are TBO capable (and are Area Navigation (RNAV) capable and DataComm equipped). This concept was designed to more effectively respond to daily events (e.g., weather or Special Use Airspace activation), as well as seasonal changes in traffic demand. DataComm is a key technology in airspace moving towards Trajectory Management.

A participant asked, "What are the traffic management improvements?" Michele stated that increased throughput, user-preferred routing, taking full advantage of aircraft avionics, and delegated separation are all key improvements.

Slide 16 Multi-Sector Planner is a step towards Trajectory Management and Flow Contingency Management (FCM) in the mid-term period, by using 4DT intent data to bridge the gap between strategic, traffic management initiatives, and tactical operations at the sector level.

Slide 19 In the Big Airspace Concept, the focus is on transition airspace where an aircraft climbs and descends. This is managed as one service in one facility, 120 miles from the airport up to FL290. There is limited dynamic sectorization in this concept.

Currently, determining automation requirements is key in the implementation phase.

Steve Brown, Weather Working Group Industry Co-Chair, commented that current attempts to overcome problems that occur at a boundary area seem to move boundary issues to occur at a new location. This in turn does not resolve the boundary issue.

Citing that there will always be a boundary, Michele commented that the goal is to move the boundary issues to a less tactical environment (i.e., closer to en route).

Slide 20 Significant congestion exists today in the arrival and departure streams of medium to large airports. The Three-Dimensional (3D) Path Arrival Management (PAM) Concept is an initial intervention in advance of NextGen 4DT operations to address this problem by creating an efficient and predictable method to deliver aircraft from the top of descent to a metering fix, prior to arrival. 3D PAM leverages ground automation which calculates a

trajectory that is then communicated to the aircraft.

Slide 24 Michele will continue to report the results of her group's efforts to the JPDO. In addition, she will work with Jay Merkle to determine how to best coordinate and brief the Working Groups.

Net-Centric Operations – Col. Doug Wreath, DoD/JPDO

Col. Doug Wreath, Net-Centric Operations (NCO) Government Co-Chair, presented a briefing on "net-centricity" and how it will be applied in NextGen to net-enable desired operational outcomes for the planned OIs, including as oceanic separation and flexible routing initiatives. Doug explained that he is both the JPDO NCO Division Director and the NCO WG Government Co-Chair.

The following notes highlight key discussion points:

Slide 2 Doug stated that NCO is an enabler. The purpose of NCO is to apply network methods and technologies in an effort to improve or transform operations and/or processes.

Slide 3 The NCO Division is recruiting net-savvy individuals who would like to participate in the net-centric effort. Any relevant resources that can assist the NCO Working Group can be approved through Charlie Bergman, NextGen Institute Executive Director.

Slide 4 The NCO Division is currently using the Weather Working Group as the initial community of interest, and will be using lessons learned from them in future efforts.

Slide 6 Future NCO Division activities include a May 7, 2009 delivery of the Integrated Surveillance ConOps.

Relationship of Research Transition Team to TBO – Paul Abramson, PDA Associates

Paul Abramson, PDA Associates, provided an overview of the Research Transition Teams (RTT) as they relate to TBO. The RTT are made up of members from the FAA, NASA, and JPDO. The goal of these teams is to ensure that research and development (R&D) needed for NextGen implementation is identified, conducted, and effectively transitioned to the implementing agency. Currently, there are RTTs covering various aspects of Trajectory Management, Capacity Management, and Flow Contingency Management—many of which are integral to the mid-term ConOps work, such as Integrated Arrival/Departure/Surface, and Multi-Sector Planner. The RTT for Separation Management has not yet been established.

The following notes highlight key discussion points:

Slide 3 The RTT framework consists of the following areas: Convening Authority (Jaiwon Shin, NASA and Victoria Cox, FAA); Coordinating Committee; and the RTT.

Slide 4 Anticipated products of the RTT include: (1) agreed-upon descriptions of far-term concepts, as well as the mid-term foundations needed to achieve the far-term concepts; (2) research required to achieve far-term concepts; (3) expected research products; and (4) insertion of research products into FAA's acquisition decision-making.

A participant asked about predefined airspace activation. Paul answered by stating that NASA research on mid-term airspace reconfiguration and flow corridors are ongoing efforts. The scope of the work is done, and the RTT are currently addressing tradeoff analysis; cost and benefits will be looked at later. The participant asked if a framework exists by which to make a decision. Paul answered, "Yes, the FAA framework."

Jim Wetherly commented that maturity assessment will be a relevant discussion topic. Another participant commented that dynamic airspace configuration is important to DoD.

Role of Trajectory in Decision Support – Debby Kirkman, MITRE

Debby Kirkman, ANS Working Group member, provided an overview of the role of the trajectory in decision support to air traffic controllers, including current practices, mid-term needs, and potential challenges and key issues. Today, people serve as the primary trajectory predictors, using automation tools as aids. Decision support tools will need to evolve to provide predictable flight paths in the mid-term to controllers, as part of the transition to strategic management of traffic.

The following notes highlight key discussion points:

Slide 4 Today, terminal automation displays help humans to predict trajectories, as there are no algorithms to strategically predict trajectories.

Slide 5 Trajectory Prediction also plays a role in FAA En Route Automation. Trajectory Modeling is currently used in en route decision-support systems for prediction of potential separation loss (i.e., User Request Evaluation Tool (URET)) and for traffic synchronization to a metering fix (i.e., TMA). Accurate trajectory predictions are needed to provide reliable decision support, but there are many factors that can affect the quality of trajectory prediction, such as the automation's internal models of aircraft characteristics and wind data.

Slide 7 If the controller does not have time to update the assigned trajectory in the system, the automation may predict reroutes to return an aircraft to the former trajectory—adding uncertainties into the system, and reducing predictability.

Slide 10 Traffic Flow Management (TFM) analysis tools use trajectory prediction models to identify when intervention is likely to be needed to maintain safe levels of traffic for airspace and airports (e.g., Flow Evaluation Area).

Factors affecting predictability of demand include knowledge of aircraft departure times, uncertainties in weather forecasting, and future real-time decisions across multiple decision-makers.

Slide 11 Oceanic operations today are primarily based on strategic Trajectory Management. For example, conflict probe evaluates trajectory changes and proposed trajectory changes for aircraft-aircraft and aircraft-airspace contention.

Slide 12 There are a number of mid-term needs for decision-support capabilities and Trajectory Management. Active human engagement is essential so that controllers can manage at a strategic level, while also quickly managing off-nominal occurrences. Predictable flight paths are a fundamental underlying assumption for effective decision-support evolution, as well.

Slide 14 There are a number of mid-term principles related to Trajectory Management. "Closed Loop" trajectories are the norm. If a change is made, the change will include a way back to the flight path. Not every change will be a Closed Loop.

Slide 15 Consistency is also a key mid-term principle to Trajectory Management. Specifically, information needs to flow consistently between aircraft, ANSP, and the FOC.

Slide 19 Mid-term Trajectory Management concepts will provide enhanced information exchange and trajectory consistency to decision support systems.

Slide 20 Debby stated that Trajectory Management has a number of challenges and issues:

- Mixed capability operations: To what extent can ANSP personnel manage operations and differentiated services when aircraft have different Trajectory Management capabilities?
- How are equipage objectives achieved when benefits depend on a significant percentage of aircraft equipage?
- What are the ground system requirements for internally representing trajectories?
- How do human roles evolve as decision support systems evolve to manage increased density and complexity?

- What are the tradeoffs among costs, benefits, and risks for different levels of capability for both aircraft and ground systems?

Air Navigation Services Working Group Air Traffic Management ConOps – Rose Ashford, NASA and Mike Cramer, MITRE CAASD

Rose Ashford, ANS Working Group member, and Mike Cramer, Aircraft Working Group member, discussed the efforts of their Working Groups to achieve consensus on key TBO characteristics. Their vision of TBO integration into Capacity Management, Flow Contingency Management, Trajectory Management, and Separation Management capabilities was briefed to the group, including ANSP management of performance requirements to enable greater capacity during high demand periods. Normally, a mixed equipment environment can be managed by the ANSP, but as demand increases, lower performing aircraft may need to be excluded until demand declines.

The following notes highlight key discussion points:

Slide 3 Trajectory is "…a description of the movement of an aircraft, both in the air and on the ground, including position, time, and, at least via calculation, speed and acceleration." (ICAO Doc 9854)

There are three types of trajectories:
- Planning Trajectory (flight plan)
- FMS Computed Trajectory (continuous set of curves)
- Actual Trajectory (what the aircraft flies)

Each of the four trajectory dimensions is associated with a tolerance depending on aircraft performance.

Mark Andrews asked, in trying to predict future performance, do you allow for a trajectory to have different spacial dimensions? Does a tube get bigger if flying into different area? Mike Cramer answered by stating that there is a need to set required levels of performance for different trajectories.

Slide 5 Performance Mix is a "lever" to manage capacity in the system, as the ANSP can set minimum performance requirements, as needed, to increase capacity in response to demand.

Slide 6 Aircraft can perform TBO using either voice communications or datalink, depending on the aircraft, operation, and performance level.

Slide 8 In regards to TBO as it relates to ATM in the short-term, there is more flexibility to move things around and put resources where demand is rather than during long-term Capacity Management (CM), which is more strategic in focus.

Slide 9 Flow Contingency Management (FCM) applies when demand/capacity imbalances still exist after the CM process, often because of weather or in certain areas such as New York. Ultimately, FCM is more deterministic than CM, about one hour prior to flight.

Slide 10 Trajectory Management operates just before and during a flight. In addition, it optimizes individual trajectories; positions and schedules aircraft for super-density or other delegated separation procedures; accommodates aircraft operator preferences (as much as possible); includes managing complexity; and performs strategic conflict detection/resolution, where appropriate.

Slide 11 In regards to Separation Management, enhancements—including reduced separation minima—will be enabled by TBO. Aircraft can fly close together with Required Navigation Performance (RNP)-based trajectories and aircraft-based blunder protection, which would enable Closely-Spaced Parallel Operations and Flow Corridors.

Conference Breaks for Lunch

Aircraft Trajectory Considerations in the Present and Future – Dave Nakamura, Boeing

Dave Nakamura, Aircraft Working Group Industry Co-Chair, provided background information regarding TBO from a capability aircraft perspective, and identified areas that may represent gaps and issues which need to be addressed. Requirements are needed to define 4D trajectories and operating window tolerances, including vertical performance. Given the substantial time needed to retrofit the fleet, the avionics upgrades for TBO need to be bundled for installation during major maintenance checks, and piecemeal upgrades may slow the transition to NextGen considerably.

The following notes highlight key discussion points:

Slide 6 Area Navigation (RNAV) and RNP with vertical guidance via vertical navigation (VNAV) are primary capability enablers for TBO that are available in advanced aircraft/systems today. RNAV allows more flexibility.

Slide 9 Lateral trajectories can exist end-to-end, but vertically, there are some parts of the flight profile where a defined path (trajectory) does not exist. Profile paths are not always a fixed trajectory (e.g., aircraft are flying by rate of climb).

Slide 10 Thousands of aircraft systems contain a capability for calculating the aircraft trajectory considering performance, winds, requirements, etc. System functions and performance are relatively fixed, and somewhat different. Mixed aircraft equipage increases complexity.

Slide 11 Aircraft owners prefer equipage updates to be bundled to reduce cost.

Slide 13 TBO also affects information and data in ground and communication systems. Coordination needs to be done between ground standards and communication standards.

Slide 14 There is no current means for full flight path vertical performance integrity. Vertical Required Navigation Performance (VRNP) is currently only a term for discussion—there is no definition or work plan for it to date.

Slide 16 For the far-term, the Aircraft Trajectory changes are unknowns, such as unique 4D requirements, specific path definition including VRNP, 4D windows and tolerances, CNS functional bundling, etc.

Joe Sherry asked if tolerance will change with unpredicted conditions, such as weather. Dave answered by stating that the aircraft will attempt to achieve the tolerance requirements. If aircraft cannot meet tolerance, changes will need to be made to planned trajectory.

Also, Dave noted that TBO, under perfect conditions, will give improved predictability, not 100% predictability. The development cycle for Minimum Aviation System Performance Standards (MASPS) is 3-5 years.

Slide 18 TBO will ultimately be defined by decisions on what future actions to pursue and the resolution of complex issues, including 4D requirements, operating window tolerances, path/trajectory definition, and the integration of climb gradients into trajectories. System performance standards and regulatory guidance is also needed. Ultimately, the avionics upgrades for TBO need to be bundled for C and D maintenance checks. Multiple updates are costly and inefficient to aircraft owners.

Slide 19 In closing, Dave presented a chart regarding forward fit and retrofit—fleet retrofits take 10 years or more to achieve a critical mass that provides benefits to the system.

Slide 20 Based on a second chart Dave presented during his final remarks, future predictions show substantial increases in growth for new airplanes.

A Common TBO Vision – Group Discussion – Moderator: Robert Pearce, NASA/JPDO

After the final presentation from Dave Nakamura, the participants reconvened for the afternoon session, led by Bob Pearce.

Mid- to Far-Term Transition and Boundary Issues

It was determined that there is a need for a list of assumptions to provide a better sense of what the mid- and far-term capabilities will be, and to illustrate different paths that can be taken. Boundary issues in transitioning from the mid-term to the far-term will also need to be identified. The mid-term ConOps will be published in six months, and may provide a starting point for assumptions.

A proposed approach is to define the far-term and compare it to the mid-term using boundary conditions to help define both ends. Alternatively, an evolutionary/revolutionary approach may work best to understand the issues that need to be resolved.

Cost and Benefit Calculations

As the discussion shifted to cost and benefit calculations, the group discussed the desire for a strategy to determine what needs to be achieved by the mid-term, and how the mid-term compares to the goals of the NextGen 2025 vision.

Mike Marsili commented that the cost and benefits of TBO will need to be calculated. He stated that on a predictable day, TBO is very accurate, but that on a less than predictable day, performance is better than today, but by how much?

A modeling capability will be used to understand evolution, provide a reference point for tradeoffs, and to create a framework for evaluation of planned TBO capabilities, including costs and benefits. It was determined that reference points foster logical discussion and allow clearer understandings of problems. OIs may need to be further refined to provide inputs to models.

The group also discussed the benefits of management by trajectory, which includes improvements to safety, security, and efficiency.

Tradeoffs

As the group discussed the specifics of the TBO concept, assumptions and tradeoffs became the focus. It was agreed that there is need for a common understanding of the relationships and tradeoffs related to increases in capacity and mixed equipage. There are currently multiple unknowns that require resolution.

Currently, aircraft can easily fly a two-dimensional path with little change; climb and descent paths are much less precise. Aircraft usually do not want to continuously control the fourth dimension (time).

Tradeoffs with environmental performance and security concerns will also need to be considered. High density/high complexity environments will be compared with levels of 4D trajectory performance. Further definition is also needed for ADS-B intent. As a tradeoff, aircraft /ADS-B intent (including FMS downlink) was discussed as part of the far-term.

For aircraft and ground systems, the tradeoffs among costs, benefits, and risks need to be identified for different levels of performance.

NCO

Participants changed gears and the discussion turned to NCO in NextGen. If NCO is to serve as an enabler, a basic set of assumptions and framework needs to be created in order to begin work. It was suggested that NCO look at tradeoffs from different perspectives. Because there is a long lead time for developing avionics, such as ATM automation and other NextGen systems and processes that will use NCO capabilities, choices need to be made early.

Terminology

Bob Pearce asked participants about their opinion of consistency related to TBO assumptions. The group agreed that concepts between TBO activities are similar; however, there is a substantial discrepancy in terminology. For example, participants expressed the need to define the difference between "window" and "performance" requirements, and to determine how the standards for a window could be defined. The JPDO EA will serve as a starting point for a common vocabulary, and as such will increase consistency between TBO activities. It was mentioned that SESAR terminology will also need to be coordinated with the terminology of NextGen.

TBO Spectrum/Performance Levels

The participants gradually moved the conversation to the topic area of the spectrum of TBO performance levels. It was agreed that a definition is needed for different TBO airspace types and aircraft equipment. In addition, identifying classes of operations along with key tradeoffs may help. When discussing the various TBO performance levels, the group determined that matching levels of performance to equipage may also need to be addressed.

Excluding lower-performing aircraft from certain airspace will contradict the NextGen principle of providing access to all. Further analysis is needed to address differentiated services.

Aircraft Equipage

As the discussion shifted to aircraft equipage, the creation of an aircraft-equipage timeline was suggested. The equipage timeline will aid airlines in bundling equipment upgrades. It was determined that avionics, ground equipage, and Surface Management upgrades will need to be done in unison to facilitate appropriate interaction.

The ANS Working Group believes that exploring the evolution of aircraft equipage is a critical item. It was suggested that TBO automation in the aircraft for separation management should be explored.

The extent to which ANSP personnel can efficiently and safely manage operations and differentiated services in a mixed equipage environment (i.e., some aircraft using datalink with others using voice communications) needs to be evaluated.

The interface of individuals with decision-support systems will need to be analyzed, including the evolution of the interface to manage the increased density and complexity. How Airport Operations Center (AOCs)/Flight Operations Centers (FOCs) interact with the aircraft and ANS needs to be defined.

Ground automation requirements need to be determined for calculating estimated trajectories for aircraft that do not broadcast trajectory intent data.

The business case for initial aircraft equipage is challenging, since substantial benefits do not accrue until a significant percentage of the aircraft fleet is equipped.

Recommendations on Next Steps

Participants discussed the need to identify critical pieces for the development and transition to TBO, and the resources required to move forward. The following are next steps for the JPDO and Working Group members:

- The next steps on the work being performed by Rose Ashford and Mike Cramer's Concept Study Team need to be determined. JPDO is interested in continuing to work the far-term concepts; however, input is needed from the FAA's Mid-Term ConOps (which is not yet available) in order to proceed. Accordingly, work in this area should be defined keeping in mind the August publication of the FAA's Mid-Term ConOps.
- There was an identified need for the creation of a short list of high priority driving factors and tradeoff analysis for TBO. Ownership of this action was not assigned during this meeting, but could be considered for incorporation into future Working Group work plans.
- The JPDO will facilitate new work plan activities on the concepts, terminology, and tradeoffs for end-state TBO, to be coordinated with the Working Groups. The outcome of these efforts will provide the input needed for IAED to validate the far-term JPE elements, and for IPSA to analyze the tradeoffs involved with developing the spectrum of TBO capabilities.
- Flow back of information will be important to share concept development efforts between organizations working TBO issues and the JPDO Working Groups. Quarterly JPDO Working Group Co-Chairs meetings can serve as a forum to disseminate information to the Working Groups.

Meeting Adjourns 4:42 p.m. on March 24, 2009

Conference Roster

Last Name	First Name	Company/ Organization	Affiliation
Andrews	Mark	NOAA	Weather
Abramson	Paul	PDA Associates	Speaker/RTT
Ashford	Rose	NASA	ANS
Beard	Bob	CSC	ANS
Belk	John	Environment WG	EWG
Bergman	Charles	NextGen Institute	NextGen Institute
Bernier	David	TSA	Security
Bolczak	Katie	MITRE	Security
Brown	Steve	NBAA	Weather
Brown	Veronica	CS/JPDO	Support
Bruflat	Arne	BTC, Inc.	Security
Catapano	Sal	CS/JPDO	Support
Cramer	Mike	MITRE CAASD	Aircraft
Druckman	Paul	Morgan Franklin	Security
Duffy	Kent	BAH	Support
Galea	Claudia	Booz Allen Hamilton	AC/ANS Support
Johnson	Sally	NASA	ANS
Jones	Col. David	DoD	DoD
Keegan	Maureen	FAA/JPDO	JPDO
Kies	Jack	Metron Aviation	ANS
Kirkman	Debby	MITRE	ANS/Speaker
Leftwich	Robbie	BAH	Support
Lesser	Norma	FAA/JPDO	JPDO
Liu	Sandy	FAA -AEE	EWG
Lonon	Jenifer	CS/JPDO	Support
Makins	Nigel	EUROCONTROL	GHWG
Marsili	Mike	Lockheed Martin	GHWG
Mendez	Rowena	FAA	Speaker
Merkle	Jay	FAA/JPDO	JPDO
Merkle	Michele	FAA	Speaker
Miller	Mary Ellen	Raytheon	NCO
Morse	Glenn	Continental Airlines	Airports
Nakamura	Dave	Boeing	Aircraft/Speaker
Oswald	Chris	ACI-NA	Airports
Pearce	Robert	NASA/JPDO	JPDO
Polski	Paul	DHS	Security
Robinson	Claire	FAA/JPDO	JPDO
Ronn	Al	Northrup Grumman	Weather
Ryberg	Patsy	MITRE	ANS
Sherry	Joe	MITRE	Weather
Stobie	Jim	ENSCO	Weather
Storm	Al	DoD	ANS

Conference Roster (cont'd)

Last Name	First Name	Company/ Organization	Affiliation
Sweet	Dave	Boeing	NCO
Swenor	Patricia	BAH	ANS Support
Van Trees	Steve	FAA	Aircraft/Speaker
Waggoner	Ed	NASA/JPDO	JPDO
Wetherly	Jim	FAA	ANS
Wilson	James	CS/JPDO	Support
Windhoffer	Laszlo	FAA	EWG
Wing	David	NASA	NASA
Wreath	Douglas	DoD/JPDO	NCO/Speaker
Zellweger	Andres	JPDO	SII Support