Final Report of the NextGen Advisory Committee in Response to a Tasking from The Federal Aviation Administration

October 2016
Appendix A: Organizations Participating in the Performance Based Navigation (PBN) Time, Speed Spacing Task Group

Appendix B Tasking Letter
Background/Introduction

In December 2015, the Federal Aviation Administration (FAA) tasked the NextGen Advisory Committee (NAC) with developing a 15-year roadmap for Performance Based Navigation (PBN) and Traffic Flow Management (TFM). The NAC has been instrumental in working with the FAA to address these and other complexities inherent in moving to greater use of (PBN) procedures.

The request included reviewing the FAA’s current plans for traffic flow management scheduling, sequencing and spacing tools and developing a 15-year deployment strategy that complements the FAA’s National Airspace System (NAS) Navigation Strategy 2016 that was approved by the PBN Operations Aviation Rulemaking Committee PARC).\(^1\) The FAA request stated that, “The goal of the PBN strategy is to combine the flight efficiency of visual meteorological conditions with the predictability and stability of instrument operations. Operators have implemented a number of capabilities that enable them to fly predictable paths, laterally and vertically, enhancing the ability for air traffic management (ATM1) automation to predict the flow of traffic at airspace constraints, such as runway capacity.”

The FAA’s PBN strategy outlines near-term (2020), mid-term (2025) and far-term (2030) initiatives in the following focus areas:

- Implement PBN throughout the NAS with the right procedures to meet capacity, efficiency, and throughput needs;
- Provide navigation structure where beneficial, and flexibility where possible;
- Continue transition from distance-based to time-based and speed-based air traffic management;
- Deliver resilient navigation services;
- Modernize the FAA navigation service delivery;
- Enable lower visibility access to airports and airspace; and
- Innovate and continuously improve.

The strategy for the time, speed and spacing assignment will address what types of tools are appropriate in various operating conditions, what tools should be identified as high priority, and how the various capabilities can be integrated into efficient traffic flow management. There is also the need to determine the role of cockpit-based and ground-based Traffic Flow Management Systems/tools.

The efforts of the Task Group are complimentary to the NextGen Implementation Working Group (NIWG) which is considering the pre-2020 implications of PBN implementation. The NIWG is focused on prioritization of activities for the next three years.

Executive Summary

A transition to a time-based system is necessary to enable higher percentages of PBN operations with the goal of keeping aircraft on an optimal path. Managing the flows requires leveraging existing and future tools for the controllers and aircraft, and it also requires a large cultural change.

The FAA’s NextGen Segment Implementation Plan (NSIP) states that, “the overarching objectives for the future remain the same — maximizing airspace capacity with more sophisticated and seamlessly integrated information about the future position of aircraft at a given time — while maintaining the

\(^1\) Letter from Michael Whitaker (FAA Deputy Administrator) to Margaret Jenny (RTCA President) dated December 2, 2015.
The NAC has emphasized the need for NextGen to result in achieving visual meteorological conditions (VMC) performance in instrument meteorological conditions (IMC). Decision support tools are critical in the timing and evolution of this transition dependent on the technological capabilities that will enable functionality, particularly the expanding set of metering tools and applications, being operational in air traffic control facilities across the NAS.

The implementation must be integrated, fielding any single technology that has not been considered as part of an integrated system may sub-optimize the system. The system has air and ground components as well as human contribution, and accelerating any one technology in isolation may have unintended consequences.

The goal of the Task Group effort is to “keep the aircraft on the PBN procedure from EnRoute to the runway while maintaining or increasing throughput”. To meet that goal there are candidate capabilities that need to be considered based on a set of criteria. These criteria include, but are not limited to, the following:

- Current state of the capability (maturity, life cycle)
- Necessary investment
- Investment timing
- Benefits - Key Performance Indicators (KPI) – such as – efficiency, throughput, predictability

The strategic roadmap embraces the following concepts:

- Near Term (2020)
  - Focuses on policy, procedures and training to enable initial PBN capabilities and using existing tools and systems for a better integrated system
  - Infusing time-based metering into the culture

- Mid Term (2021-2025)
  - Focuses on continued deployment of available NextGen capabilities consistent with meeting the goal of PBN Time, Speed, and Spacing in an integrated manner
  - Begins the process of integrating aircraft trajectory data with ground systems

- Far Term (2026-2030)
  - Further enhances, increasing resilience of ground based tools
  - Integrates the stand-alone capabilities described in the mid-term
  - Leverages Flight Deck Interval Management (IM) demonstration for potential full NAS implementation
  - Based on experiences from Near and Mid-Term, begins implementing advanced Data Comm capabilities defined by RTCA Special Committee 214, Standards for Air Traffic Data Communication Services

One of the most critical aspects for this successful transition is a comprehensive and collaborative change management plan for all operationally responsible parties. The concept of change management encompasses all those disciplines involved in the operation of aircraft and the ATC system. While the
current system provides safe, efficient, and reliable processes to control and manage aircraft, the ability to evolve the NAS is dependent on all stakeholders embracing change and acknowledging the potential benefits of those changes.

Flight Operators, as well as the FAA must constantly refine a change management plan that responds to an ever-changing environment, systems and work force. As collaborative stakeholders in the NAS, we are all compelled to adapt to the evolution that goes along with improved technology and procedures. Inclusive of that evolution is the concurrent adaptation of tools and applications--in this case, time-based methodologies that support those technological and procedural improvements. The results of that collaboration will be a measurably successful transition that allows for optimization in a PBN-based system.

The solution space is large. In order to ensure that the goals are met, a performance-based approach has been taken to evaluate the strategic alternatives. First, an understanding of the end-to-end system requirements will be identified. Then the performance will be allocated to the different solution domains. These allocations may evolve over time as new capabilities are made available. This is not a “clean sheet” design space, so a combined top down and bottom up approach will be taken. This ensures that investments already made are considered in the timing of the solution space.

As the FAA moves forward with the implementation of decision support tools and other time, speed, spacing capabilities there is the need to evaluate the benefits and evaluate alternatives--when appropriate. There needs to be sufficient flexibility in making adjustments to programs and projects based on assessments of performance. There may be times when the FAA and industry determine that the best path forward may be to change or even eliminate a project based on changes in operations, technology and other factors that determine the value of the capabilities.

**Methodology**

The Time, Speed, Spacing Task Group (Appendix A) is comprised of representatives from a cross-section of stakeholder groups who have been engaged in planning and implementing various aspects of NextGen capabilities. This includes operators, airports, pilots, controllers, automation providers, technical advisors and a diverse set of FAA Subject Matter Experts who have provided leadership in NextGen planning, pilot and demonstration programs, and PBN implementations.

The Task Group took the following steps in creating the recommendations:

1. Determined and reached consensus agreements on the scope of the task that guided the process of deliberations and subsequent outcome of Task Group recommendations. This included a set of assumptions and guiding principles.

2. Reviewed a library of reports and abstracts related to the complex aspects of time, speed and spacing that covered FAA, NASA and industry business case/needs assumptions as well as R&D efforts.

3. Developed a baseline, high level understanding of FAA plans for the three planning time frames, and reached a general consensus of the prioritization for the ground and aircraft based initiatives. This included a “Demo Day” held at The MITRE Corporations facilities that featured a series of briefings, lab demonstration and open discussions with individuals experienced in FAA infrastructure and PBN implementation efforts.
4. Captured the proposed solution alternatives and the ranking criteria. There is a recognition that priorities may change over time as systems and solutions evolve. Elements that may be necessary for access to early benefits may be discontinued in the future. Additionally, overall performance and allocation of performance to different system components may evolve as improved information sharing is enabled.

To complete this step, there were candidate capabilities that needed to be considered based on a set of criteria. These criteria include, but are not limited to, the following:

- Current state of the capability (maturity, life cycle)
- Necessary investment
- Investment timing
- Benefits - Key Performance Indicators (KPI) – such as – efficiency, throughput, predictability

5. Developed recommendations.

Key observations and findings from each step of the work of the Task Group are identified in the following sections of this Report.

**Assumptions & Guiding Principles**

The overall purpose of the PBN Time, Speed, Spacing work group is to develop strategies for time, speed, and spacing assignment and should address what types of tools are appropriate in various operating conditions, what tools should be prioritized, and how the various capabilities can be integrated into efficient traffic flow management. These will deliver operational capabilities that will provide a timing infrastructure to truly enable PBN. The assumptions and guiding principles adopted by the Task Group to meet this goal are summarized below:

- The Task Group’s set of recommendations will be as transparent and as objective as possible, clearly laying out the methodology that the group employed to reach consensus on the specific recommendations.
- Implementation timelines are deliverables in the 5 to 15-year time frame.
- In order to understand the strategic need to identify the candidate solutions, each of the components needs to be considered. These components are all interdependent and include:
  - The air traffic automation (including both command and control automation and flow management tools, and the operator)
  - The airborne capabilities (including on-board decision support tools)
  - The human component of each

- The human component of candidate solutions is especially important. As performance is allocated to the different automation and human elements, complexities arise. The performance assessment will include technical and human components. As timing becomes a key performance attribute, care must be taken to ensure that there is a balance in how the timing is allocated to the automation and to the human. An over-allocation of time to the human will drive cost into the solution space. An under-allocation of time to the human component may impact overall system safety.
• Near-term Technology and concept of operations plans must be sufficiently mature to support the recommendations. New tools to improve system flow or terminal spacing and sequencing will be introduced through the planning period.
• There are FAA programs (enablers) currently underway that are fundamental to PBN. The PBN Strategy depends on the development and application of expanded and more mature scheduling, sequencing and pacing tools and automation.
• Mixed equipage will remain— it is an on-going process and a reality that must continually be addressed.
• Delivery of capabilities should maximize the use of existing aircraft equipage when possible, with no broad-based fleet upgrades required recognizing that the FAA’s PBN Strategy anticipates a progressively more capable fleet of aircraft able to fly more precise PBN procedures as outlined in the Strategy. The PBN Strategy should also leverage the purchase of new generation aircraft and the equipage modernization consistent with the PBN Strategy roadmap. Automation is expected to evolve over the planning period. Lessons learned as PBN operations increase and improve may re-allocate performance attributes to the different domains.
• The mixed equipage fleet has broad attributes with a continuously evolving “mixed fleet” of capabilities. Even the most modern A350 or B787, with all of their PBN capabilities may not have considered all of the future needs. Legacy aircraft will continue operating in the airspace and will bring a variety of tools and capabilities that need to be integrated into the solution space.
• Performance-based requirements will be used to manage the allocation of performance and balance complexity to benefits.
• The business case justification for NextGen equipage will be strengthened by the near-term delivery of capabilities. Aircraft operators continue to invest in updated aircraft/equipage based on a positive ROI and anticipate the removal of barriers to gain their return on investment in these new capabilities.
• The timing reference or desired point of timing is the approach end of the runway.
• Timing to the runway threshold must be accurate to +/- 10 seconds in order maintain or enhance current throughput rates.
• International Harmonization - Airborne equipment requirements should be compatible with the technology and dates of the ICAO Aviation System Block Upgrade plan. Where appropriate, the recommendation should be consistent with SESAR and other ATC modernization plans for aircraft equipage.
• Projects should be carefully scoped to balance complexity and benefits. "Scope creep" should be minimized.

Transitioning to a Time-Based System

The tasking from the FAA and the NAC is to provide a strategic roadmap for greater use of PBN procedures through time, speed and aircraft spacing. While it is tempting to focus on specific solutions, we need to focus on developing a vision of how we would prefer the future to evolve. That said, investment decisions have already been made on several of the candidate solutions and, for others, investment decisions are in process. These elements, along with airborne avionics investment decisions made in the past, will be considered as part of the evolving infrastructure.

An overarching principle is the endorsement of transition to time referenced airspace. The timing of this transition is dependent on the necessary metering tools being operational in the EnRoute, TRACON and
Terminal facilities. Also critical is the change management/cultural issues for controllers, pilots, dispatchers and others involved in the operation of aircraft and the ATC system.

There is consensus desire from industry to utilize time-based spacing systems in order to achieve the routine use of PBN, allowing them to capitalize on investments made to equip fleets. The efficiency gains of a time-based system, versus the traditional spatial system are well documented. However, the time, speed, spacing strategies must include controller and pilot understanding and acceptance to fully realize those benefits. The FAA has taken positive steps to address the barriers that have prevented moving the NAS to a time-based system, but additional emphasis is needed to truly change the entrenched habits and culture embedded in today’s operation.

Individual ATC facilities tend to focus on resolving local problems and, at times, fail to see or consider the “bigger picture” system when applying solutions to those problems. Often facilities fall back to “tried and true” methods of spacing using miles-in-trail rather than a more system-oriented time-based approach due to some combination of a lack of understanding of the purpose or value of time-based system, a lack of confidence in the tools, or a lack of shared vision and common goals in managing the effectiveness of the NAS. Today this is evidenced in the fact that there are varying degrees of use and acceptance of the available time-based tools. There are a few locations in the NAS where time-based tools are being fully applied as intended (e.g. Many facilities that utilize TBFM have morphed its intended use to fit their own version of how the tool should be used and determined what level of use is acceptable). These local decisions to either reject or repurpose TBFM are well intentioned and often made in an effort to improve the operation in the facility’s area of influence. However, these facilities fail to understand the implications these local “work-a-rounds” have on the overall success of the tools and the toll they take on realizing system-wide benefits.

The agency must focus on taking the necessary steps to standardize time-based and operational policies that drive NAS benefits. We understand this task is outside the norm of routine delivery of new capabilities and moves into an area of change management. The FAA must incorporate a change management function as part of the implementation strategy and make it a priority to reduce the risk for both industry and the agency in delivering the promises of NextGen.

To be clear, subject matter experts, including the DOT Inspector General, US General Accountability Office and the MITRE Corporation, have pointed out that there are critical dependencies underpinning a successful cultural change. They include a finely “tuned” and operationally managed automation system that will lead controllers to have a high level of confidence in the output provided and that supports the ability of aircraft to accurately comply. Training for controllers that includes the vision, philosophy and objectives of the enhancements must be included in the rollout to new facilities. At facilities where the tools have already been deployed, yet are not being utilized properly, intensive education efforts must be made that stress the benefits to the NAS. The agency has efforts underway to address system concerns and should continue to focus on time-based automation as a critical component of the NAS.

With the goal of moving to the routine use of time to manage the NAS, we must consider the following difficult principles that if not adhered to would lead to failure from industry’s perspective:

- Add predictability without penalty to either industry or ATC. A predictable schedule should not compromise throughput.
- A system based on time must not adversely affect performance. Schedule integrity must be maintained.
• The use of time-based tools must meet the original objectives: PBN use while maintaining or improving throughput.
• Layered implementations provide an incremental path that assists in the successful transition.
• Ground-based decision support tools must be developed and implementation accelerated to achieve the benefits.
• A collaborative development and implementation process with all stakeholders is critical to ensure cooperation and understanding.
• The system cannot be so rigid that the aircraft or airport efficiency is adversely impacted.
• To ensure maximum benefits, metrics developed by the NAC (including the industry-FAA work of the Joint Analysis Team) and recommended to the FAA must be jointly monitored to verify intended results are achieved. In instances where performance doesn’t match intended results these can guide potential corrections to the plan.

With agreement on the need to move to a time-based culture, success will be anchored by leadership continuing to reinforce the change and setting expectations for achievement of the common vision and goals.

**Recommendation:** The agency adopts change management principles as part of their implementation process to gain the acceptance and culture change to realize the benefits of time-based enhancements.

The following sections describe the capabilities and associated changes to aircraft, ATC automation, TFM automation, ATC decision support tools, TFM decision support tools, pilot tools as well as changes to Comm, Nav and Surveillance components for each of the three time frames. Each increment addresses costs and benefits to the extent possible.

**Candidate Systems**
The FAA has provided a notional graphic representing a collection of strategic elements and candidate systems to be considered for these operations.
Within this graphic representation both strategic elements and candidate solutions are considered. For reference, the strategic thread would include:

- Departure Scheduling
- Arrival Metering
- Extended Metering
- Coupled Scheduling
- Terminal Metering

The candidate solution components fall into the airborne and ground components. These include:

- Airborne
  - Time of Arrival Control
  - Flight Deck Interval Management (IM) EnRoute and Terminal operations
- Ground Based
  - Speed Advisories
Near-term 2016-2020

Time Based Flow Management (TBFM) (foundational scheduling function)

Time Based Flow Management (TBFM) is an existing system that develops the schedule that is communicated to the various capabilities and tools identified in the near, mid and far time frames. It is the core tool that provides spacing and sequencing information and must be able to bear the weight of being a foundational element for NAS scheduling, sequencing and spacing moving forward. Accuracy and stability are critical to timing success. Conversely, instability or poor performance can create uncertainty and loss of workforce confidence in movement to a time-based NAS.

Advancements in the TBFM system have increased the reliability and accuracy of time-based operations where applied. Improved algorithms, surveillance data and ingestion of high definition wind modeling has improved the trajectory accuracy of TBFM and are, in most cases, producing reliable scheduled times.

The NAC recommends continued TBFM system improvements to ensure a strong foundation to build upon for future capabilities that will address the sequencing and spacing necessary for routine use of PBN in all domains. Particular attention and emphasis should be placed on site adaptation and issue resolution. Although improvements in TBFM trajectory modeling have occurred, excellence in site adaptation is crucial to producing desired results.

Additionally, the FAA should expand and standardize the use of TBFM in the NAS to meet the goals contained in operational use policy that covers EnRoute, TRACON and Tower airspace. Providing quality change management processes, including early training of the workforce, is a key aspect of continued implementation of TBFM. The FAA must have a commitment to have resources necessary for staffing, training and support and sustain this significant change.

Alternative use of CRDA (Flow Merging and Spacing)

Converging Runway Display Aid (CRDA) is an existing automation tool designed to assist controllers with spacing arrivals on the final straight approach segment to converging runways. By utilizing the foundational design principles of CRDA, the tool can be extended to provide its familiar visualization of the relative distance of aircraft to a merge point from converging streams anywhere in the terminal area, including PBN and non-PBN approaches. The opportunity to extend CRDA should be pursued, especially given the higher cost and longer time frame of other solutions that involve system-of-systems development and integration. An Extended CRDA capability would be integrated within the Standard Terminal Automation Replacement System (STARS), independent from other systems, and would be available at all sites, independent of Terminal Sequencing and Spacing (TSAS) deployment. Merging and Spacing Tools may also be used in harmony with time-based tools such as TSAS. A relevant example is the existing spacing tool for Automated Terminal Proximity Alert (ATPA). The utility of ATPA is not diminished by TSAS, nor is the utility of TSAS diminished by ATPA. The same is true for the extension of CRDA relative to use of TSAS. The overall goal should be to provide a suite of controller decision support tools that can be utilized depending on facility traffic volumes, airspace and airport configuration,
system deployment/integration, and the needs of different operational positions (e.g. feeder position versus final).

The NAC recommends that alternate use of CRDA should be evaluated and pursued given the extended period of time before the more complete solutions that are currently in development are available. It must be emphasized that the use of existing tools is only seen as a means to provide partial capability during the transition period.

Ground-based Interval Management – Spacing (GIM-S)

GIM-S is an EnRoute tool, resident in the TBFM and ERAM systems, that extends the time-based solution to 400-500 miles from the arrival airport and provides EnRoute controllers speed queues to keep aircraft on the appropriate time schedule. Timing accuracy at the meter fix is expected to be within 30 seconds of target. This level of fidelity will deliver to the terminal controller a workable solution that will enhance the use of PBN procedures closer to the airport.

GIM-S is available now for deployment in the NAS and is use at PHX, DEN and SEA. Adaptation work at these key sites to improve performance underway. The NAC endorses implementing GIMS-S at the nine Terminal Sequencing and Spacing sites prior to 2020.

Due to the technical, change management and cultural complexities of deploying this evolutionary tool, the NAC endorses this measured approach. As with all TBFM measures, a robust issue resolution process at the 9 sites should allow for expansion of GIM-S to operationally viable TBFM airports in 2020-time frame.

Terminal Sequencing and Spacing (TSAS)

GIM-S, extended metering and speed advisories, will allow EnRoute controllers to deliver aircraft to the Terminal controller within 30 seconds of their scheduled target time. TSAS extends the timing solution into the terminal airspace and, for the first time, links the timing mission to the terminal controller. The terminal controller is presented timing queues that will allow a high percentage of flights to remain on the PBN approach procedures by applying only speed adjustments. This high fidelity and synchronized, timing will additionally allow for greater throughput by reducing the inter-arrival buffer or gap.

It is important to consider that TSAS is a decision support tool, not a separation tool. Similar to GIM-S, cultural and technical complexities in deployment will exist. Currently, terminal controllers have no experience with time-based sequencing, so this evolutionary change will require excellence in change management.

The NAC endorses this rollout plan, but also recommends completing deployment of TSAS at all NSG1 airports and remaining NSG2 hub airports in the mid-term.

Required Time of Arrival (RTA)

Next generation Flight Management Computers will have a Time-of-arrival-control (TOAC) function to execute a Required Time of Arrival (RTA) instruction and many aircraft have the ability to conduct some of the TOAC functions in specific phases of flight. However, additional research is necessary to evaluate the variability in existing functionality and the operational implication of the differences. Like the
previously recommended tools, an RTA target could be derived from TBFM which controllers would issue to aircraft via voice. This flight deck resource could be used to assist in conditioning traffic flows and potentially reducing controller workloads.

The NAC recommends that the FAA continue its assessment of RTA through additional research and flight demonstrations to evaluate if the existing fleet capabilities can provide a significant operational benefit.

**Flight Deck Interval Management (IM): IM EnRoute and Terminal Operations**

Flight Deck Interval Management (IM) uses ADS-B IN traffic information to provide speed cues to pilots to manage inter-arrival spacing. The goal of IM is to reduce the variation in inter-arrival spacing, thus enabling more capacity. The more direct control loop enabled by calculation of speed by IM avionics results in a significant reduction in the standard deviation of the inter-arrival rate. This leads to more available capacity, compared to current operations with ATC vectoring and speed assignments. Since IM arrivals end with instrument approach procedures, there is no need to conduct visual approaches to achieve maximum capacity. Maintaining higher arrival rates, similar to VMC arrival rates, will be possible with IM during periods of lower ceiling and visibilities, down to Category 1 approach minimums.

Implementation of IM would require a change in the way traffic is managed. Pilots will have a new task of following speed guidance from avionics to support a spacing task, rather than receiving speed instructions from ATC. Pilots will not be responsible for separation; their only responsibility will be to follow speed guidance from the avionics. Controllers are responsible for separation, however to achieve increased capacity, they may need to apply smaller buffers to the minimum separation standard than those applied today. In the future, it may be possible to reduce current separation standards for IM operations, further increasing capacity.

The FAA and industry need to layout time line for collective process and how that relates to ADS-B In ARC. The potential efficiencies enabled by IM are the same as those recognized by the ADS-B In ARC in 2012 and the recommendations of the ARC to pursue IM and IM with wake mitigation are still valid today. With awareness of atmospheric meteorological conditions, IM systems may be able to monitor for potential increases in the probability of a wake vortex encounter, leading to an IM with wake mitigation capability.

The ADS-B In ARC recognized that the equipage costs and benefits needed further definition. The policies associated with separation standards and ATC and pilot roles and responsibilities as they relate to separation also need to be researched. Many years of research and several HITLs have been conducted on IM capabilities. Previous research has repeatedly demonstrated that the variability (standard deviation) in inter-arrival spacing for IM operations is significantly reduced when compared other concepts. In early 2017, NASA will be conducting a flight demonstration of IM using air transport category aircraft. In 2018 and 2019, several more HITLs will occur to further define procedures, validate avionics and ground automation requirements, and to evaluate the integration of the airborne and ground-based ATC systems. If the flight demonstration and HITLS shows a standard deviation in the inter-arrival rate similar to that predicted through analysis and simulation, the FAA may have a good
business case to continue the development of IM. Likewise, airlines may have a good business case to invest in IM capable ADS-B In avionics.

Therefore, after the demonstration is complete and prior to the FAA’s final investment decision, the NAC recommends that an FAA-industry review of the results, including the cost and benefits, should be conducted to determine the final status of future recommendation on IM development and implementation.

**Mid-term 2021-2025**

**Time Based Flow Management (TBFM) and Shared Trajectory Information**

The airspace in the next decade must begin its transition to a highly integrated system – Air and Ground components and their associated human participants will need to share information to be most effective. For ground systems such as TBFM to model projected route optimums discounts, the real time data captured and used by airborne systems must be used to optimize the complete system.

The Flight Management System has been designed to perform both path management and to optimize the performance according to a variety of attributes including fuel consumption, minimized cost and time profiles. In today’s systems, this information sharing is described in a variety of air-ground messages, primarily used by the aircraft operator.

Coupling these capabilities to the TBFM tools and other evolving ground automation provides an increased situational awareness to allow airspace planners and managers to ensure that individual aircraft trajectories are optimized according to the business interests of the airspace user. These enhanced “degrees of precision” ensure that airspace managers have optimized situational awareness and can better accommodate aircraft with lesser or failed capabilities.

Therefore, the NAC recommends that the FAA begin the process of integrating aircraft trajectory data with ground systems in the midterm.

**Evolution of Tools in the Mid-Term**

The benefit case for TSAS for some National Service Group 2 airports may not exist. There is however, a need to enable use of PBN at airports, therefore, some type of merging and spacing tool may be necessary. Various tools may be appropriate including CRDA and a yet to be fully defined “light” version of TSAS.

**Alternative use of CRDA (Flow Merging and Spacing)**

Although CRDA may not be appropriate at all locations (or as a long term solution) because it has significant limits, it should be considered based on a site specific analysis.

**Ground-based Interval Management – Spacing (GIM-S)/Path Stretch**

GIM-S with Path Stretch allows the aircraft to be metered when a speed solution alone does not exist. When necessary, a path stretch clearance Stretch would be issued and completed in level flight prior to top of descent. Today, controllers complete this task via high workload vectoring.
GIM-S with Path Stretch extends the time-based solution to 400-500 miles from the arrival airport, giving controllers speed advisories and a de-conflicted off course path to fly (if necessary) to meet TBFM’s schedule for sequence allowing OPD’s to be flown and more accurately delivering flights to the TRACON.

The FAA plans for Path Stretch include initial operating capability (IOC) at TSAS sites beginning in 2022. The NAC endorses this GIM-S with path stretch timeline. Deployment of GIM-S with path stretch at all TBFM airports, where appropriate, should occur near the end of mid-term time horizon.

EnRoute DataComm will be deployed at all CONUS EnRoute Centers prior to 2022. Included in the Data Comm services are controller initiated reroutes. Due the potential complexity of path stretch clearances, CPDLC delivery to the flight deck would greatly reduce workload. Safety is increased by the transmitting a fully loadable clearance directly to the flight deck.

Therefore, the NAC recommends integrating Data Comm capability into the initial requirements for GIM-S with Path Stretch.

Terminal Sequencing and Spacing (TSAS)

The NAC recommends deployment of TSAS at all NSG1 airports and remaining NSG2 hub airports. TBFM may need to expand to added additional airports that are high value to industry.

Required Time of Arrival (RTA)

The focus during this time frame is the implementation of this capability. The NAC recommends that the use of RTA be available as a supplement to other timing tools during this time frame recognizing that there is a need for a communication mechanism that reconciles between flight crews, dispatchers and controllers.

Flight Deck Interval Management (IM): IM EnRoute and Terminal Operations

A review of the near term activities, including the NASA flight test and HITL events, will provide guidance on whether mid-term efforts are warranted. These flight trials and HITLs must include industry and ATC stakeholders. Assuming a positive benefits case exits, phased development in the 2023 to 2028 should occur. Accordingly, the FAA should consider a funding mechanism to incentivize equipage that has proved successful in the Data Comm integrated services contract.

Far-term 2026-2030

Time Based Flow Management (TBFM) and Aircraft Integration

The airspace in the far term should transition to a highly integrated system – Air and Ground components and their associated human participants need to share information to be most effective. Ground systems that model projected routes do not currently account for the real time data captured and used by airborne systems in their attempts to optimize the system. The result is that projected benefits of system evolution are not realized and aircraft equipment investment returns never mature.

Integration of flight management system trajectory information, data that has been designed to perform both path management and to optimize the performance to achieve fuel consumption, cost and time objectives, will be essential to fully optimize the air traffic control system.
This data rich information exchange will be enabled by new message sets described by the work performed by RTCA SC-214. These messages should be integrated into the EnRoute TBFM tools to provide discrete information exchanges between airspace managers and aircraft systems. These same messages can be exchanged in ground/ground formats between airline planners and airspace capacity and contingency planners.

Coupling these capabilities to the TBFM tools and other evolving ground automation provides an increased situational awareness to allow airspace planners and managers to ensure that individual aircraft trajectories are optimized according to aircraft performance, environmental factors and the business interests of the airspace user. These enhanced “degrees of precision” ensure that airspace managers have optimized situational awareness and can better accommodate aircraft with lesser or failed capabilities.

The use of this information should ensure that multiple systems do not rely on different sources of data. In the Collaborative Decision Making model, the intent is to make the same information available to all decision makers at the same time. This optimizes decision making to ensure that everyone has access to the same data. All part of the information management goal of how the airspace will evolve.

Therefore, the NAC recommends that based on experiences from Near and Mid-Term, the FAA begin implementing advanced Data Comm capabilities defined by SC214. The FAA should continue with the development of improvements to the timeliness and accuracy of environmental information provided to the aircraft, particularly for the descent phase of flight, such that existing aircraft RTA capabilities can reach their full potential.

**Flight Deck Interval Management (IM): IM EnRoute and Terminal Operations**

Provided that gateways recommended in the near and midterm meet expectations, arrival and approach applications should be launched. These applications may allow for IM operations to independent and dependent runways (including parallel and converging and crossing runways). Cruise applications to support same route or merging routes should be available. Implementation of IM needs to be integrated with ground time-based systems such that IM capability improves the benefits provided by ground-based tools.

**Culture Change to a Time-Based NAS**

The broad deployment of Performance Based Navigation (PBN), which has resulted in repeatable paths to/from airports, has enabled the foundation upon which a shift towards a Time-based Scheduling and Management paradigm throughout the National Airspace System (NAS) must be pursued. The repeatability of PBN procedures allows for increased predictability which is a key component for

---

2 SC-214, Standards for Air Traffic Data Communication Services, established March 22, 2007, is developing Safety and Performance Requirements (SPR) and Interoperability Requirements (INTEROPS) documents for the Air Traffic Services (ATS) supported by data communications to be implemented in the United States by the NextGen Data Communications Program in defined environments through 2025 and in Europe as part of the Single European Sky ATM Research (SESAR) operational improvements. Data communications will introduce services that allow evolution from the current workload-intensive, voice-based air traffic control concepts, to collaborative, management-by-exception operations. Advanced data links between ground and airborne systems are envisioned to increase capacity, allowing greater user access and more efficient flight routing.
sustaining a time-based system which consists of both scheduling and making in-flight adjustments to deliver to that schedule (i.e., management). Time-based scheduling has shown to be more efficient means over use of distance-based spacing goals. More robust solutions for management of arrival flows are needed to more accurately and efficiently meet a time-based schedule. The ultimate goal is to fully utilize the PBN procedures that are developed in a way that does not adversely impact throughput at the most critical sites and Metroplex environments of the NAS.

While there are various practices and techniques (e.g., vectoring, holding) currently used today by national and local air traffic to help manage and space flows, there is a general lack of understanding about what a NAS Time-based Scheduling and Management system means from the perspectives of both Air traffic and System adaptors. This lack of understanding (in regards to a shared vision, set of common goals, and sustainability plan) has contributed to challenges experienced at some field sites when applying more robust tools/automation to meet the schedule, which results in a lack of confidence for managing traffic flows and causing gaps in the effectiveness of the NAS.

Positive steps in the areas of policy and training have been recently taken by the FAA to address transitioning to a NAS Time-Based Scheduling and Management paradigm, which is dependent upon multiple systems (such as Time-Based Flow Management system (TBFM) and Traffic Flow Management System (TFMS), ERAM, and STARS) as well as multiple actors. The following include some updates for clarifying use of the TBFM system today so that it is conducive for transitioning the NAS to a Time-Based Scheduling and Management paradigm.

Policy & Procedures

- The following changes to the Federal Aviation Administration Order JO 7110.65W, Air Traffic Control, and the Briefing Guide:
Training

- Traffic Management Coordinator (TMC) and Air Traffic Controller (ATC) training for TBFM has been developed in both the classroom and the eLearning Management System (eLMS). This training has only been developed in the last two years. All operational personnel completed the 90 minute eLMS training by December 2015. It is estimated that it will take three years for all TMCs to go through the seven-day classroom-based course in Oklahoma City.

For well over a decade, the role of proactively managing arrival flows has resided primarily in the EnRoute environment while the terminal airspace has continued to be managed very tactically and reactively. With broader availability of PBN procedures, Terminal (Tower and TRACON) facilities have had to take a more collaborative role in flow management. A flight’s schedule in TBFM consists of scheduled times of arrival (STAs) at defined reference points (e.g. meter fixes, merge points, runway thresholds) based on either the flight plan (in EnRoute) or along a fixed nominal route (in terminal). The alignment of the path expected to be taken to these defined reference points relative to the path the flight actually takes is a key component to the TBFM system’s ability to accurately calculate an estimated time of arrival value (ETA) upon which to generate a meaningful arrival schedule.

PBN procedures are being developed and implemented so an aircraft can fly a lateral and vertical profile that normally terminates in close proximity to the destination airport and in some cases at the runway.
threshold. Lateral and vertical constraints are defined by the PBN procedures to accomplish several things (e.g., comply with airspace restrictions). What was once a normal interaction between controllers and pilots (i.e., vectoring flights to approach) performed on a tactical basis is now being defined by the PBN procedures, thereby minimizing the degree of tactical control required. PBN procedures typically define the following three types of constraints:

- **Vertical constraints**
  - Intended to keep aircraft on a similar vertical profile throughout the entire procedure and aid in minimizing speed disparities
  - Allow air traffic to de-conflict procedures from other procedures and airspace

- **Lateral constraints**
  - Procedures today specify most direct routing for lateral efficiency. Conventional procedures typically had bends or “dog legs” defined, which were sometimes a result of the location of ground-based navigation aids as well as the desire to build in an opportunity to make sequencing and spacing adjustments or absorb delay; if no sequencing or spacing was required, flights are often given a short-cut.

- **Speed constraints**
  - Ensure aircraft are maintaining compatible speeds throughout the entire procedure
  - Allow for the appropriate energy management of the aircraft which is now repeatable and predictable for both pilots and controllers

Three of the most effective techniques ATC have for sequencing and spacing aircraft are the abilities to assign vectors, speeds, and altitudes. With the development of PBN and the desire to remain on the procedure, this limits ATC options in utilizing those techniques. While these options remain available to ATC, the desire to keep aircraft on the procedure can directly conflict with the need for more tactical control if flows are not managed.

Unpublished speed adjustments while on the profile could affect the FMS’s ability to keep the aircraft on the procedure. With that being said, traffic management now requires a robust approach at managing flows to any given airport prior to Top of Decent (TOD). TOD normally starts from a minimum of 100 miles from the destination airport. When developing efficient PBN procedures, one must consider criteria standards, de-confliction from other procedures, environmental impacts, airframes (i.e., aerodynamic performance), FMS, and aircraft operator business models. This has proven to be difficult at times and requires stakeholders to work closely together to ensure a safe and efficient end product.

PBN deployment into busy TRACONS has caused individual facilities rely on “outside help” for managing arrival flows, which they didn’t have previously. This may mean reaching two to three Area Route Traffic Control Centers (ARTCC) upstream from the arrival facility. Previous methods for managing flows were normally contained within the arrival ARTCC and rarely requested flow management support from upstream facilities. Often, individual ATC facilities tend to focus on resolving arrival flow management issues as “local” problems to be addressed vs. a “big picture” system when applying solutions to those problems.
The habits and culture that are embedded in the NAS today are working. Managing flows in and out of airports on a tactical versus time basis or a combination of the two has been due to “lack of faith” or understanding of the contributions available from the Decision Support Tools (DST). Often facilities depend upon the “tried and true” methods of in-trail spacing using either DST individually or a combination thereof. Some of the tools TMCs use are miles-in-trail, holding, or other components of TBFM rather than a more systematic-oriented time-based approach. ATC and TMC lose confidence in tools already deployed because the tools never delivered what they were told they would, and tool adaptation is not updated to coincide with airspace or procedural changes, thus failing to deliver accurate timing solutions. These barriers have prevented the NAS from moving to a time-based system, but additional emphasis is needed to truly change the entrenched habits and culture embedded in today’s operation. It seems that systems get developed and then put in with the promise they will do “X”. Testing in the lab shows that they can do “X”, but when deployed in operational settings you can’t get “X” out of the systems. The opinion from the majority of ATC facilities is that systems are developed, deployed and then success is declared, which creates the appearance of lack of follow through. The measure of success should be the use of a set of metrics that, when evaluated clearly, show systems provided the required output desired to some level of exactness. If systems do not meet these set objectives, then work must be done to meet those objectives before success is declared.

Today this is evidenced in the fact that there are varying degrees of use and acceptance of the available time-based tools. There are a few locations in the NAS where the tool is being fully applied as intended. However, many facilities that use TBFM have morphed its intended use to fit the operation. How the tool should be used and what level of use is acceptable is determined at the local level. These local decisions to either reject or repurpose TBFM are often well intentioned, and often made in an effort to improve the operation in the facility’s area of influence. Without a clear communicated national vision or guidance to that vision, facilities that adapt the use of TBFM never fully understand the implications of a local “work-a-round” and the overall success of the tools. The issue extends beyond the local level because there is a lack of consistent staff to maintain and update these tools. The FAA must hold Program Offices accountable for the systems they deploy and understand that technically these tools need a higher degree of maintenance than is currently being provided. As more complex procedures and systems are deployed, the commitment to monitoring and maintaining them must be a part of the path to success.

The FAA must focus on taking the necessary steps to standardize the use of the tools for overall system benefit and for the NextGen vision of PBN. The culture of each local facility deciding whether a particular tool is beneficial to their particular local operation and having the option to reject using it, or only using portions of it, must change to fully realize the benefits to the overall system. This task is outside the normal delivery of new capabilities and moves into an area of change management. The FAA must incorporate a clear vision and a change management function as part of the implementation strategy. This should be a high priority in order to reduce the risk for both the FAA and industry in not delivering NextGen as promised.

This approach will require starting further out in order to increase utilization during the departure, EnRoute and arrival phase of flight. There is a recognized need from ATC to utilize time-based spacing systems in order to achieve the routine use of PBN. The efficiency gains of a temporal system versus the traditional spatial system are well documented. However, the time, speed, spacing strategies must have the goal of achieving controller and pilot understanding and acceptance to fully realize those benefits.
There are dependencies underpinning a successful cultural change that cannot be ignored and have been pointed out by Subject Matter Experts (SMEs). They include a finely “tuned” and “operationally managed automation system”, that will lead controllers to having a high level of confidence in the output provided and will support the ability of aircraft to accurately comply. Training for ATC that includes the vision, philosophy and objectives of the enhancements must be included. At facilities where the tools have already been deployed but are not being used properly, intensive education efforts must be made that stress the benefits to the NAS. There are efforts underway to address system concerns and there must be a continued focus on the automation as a critical component of the NAS, with the support necessary to maintain it as such.

Metrics must be jointly developed and monitored to verify intended results are achieved. With agreement on the need to move to a time-based culture, success will be anchored by leadership of both the FAA and Industry who must to continue to reinforce the change and set the expectation for achievement of the common vision and goals.

**Recommendation:** The agency adopts change management principles as part of their implementation process to gain the acceptance and culture change to realize the benefits of time-based enhancements.

**Findings and Recommendations**

The FAA has taken positive steps toward implementing time-based flow management capabilities. The findings and recommendations herein should be considered for enhancements and additions to the FAA’s plans associated with PBN implementation.

**Findings**

- While the FAA has increased efforts associated with Time Based Flow Management implementation and use, overarching / system culture change is needed.
- While the FAA has a leading role to play in implementing ground based decision support tools, time, speed and spacing is highly dependent on aircraft FMS capability and as such requires all stakeholders to fulfill their respective roles and responsibilities in a collaborative and coordinated manner throughout the entire 15-year roadmap.
- Increasingly integrated air to ground capabilities requires alignment between FAA investments and aircraft investments for cost avoidance and adequately timed and optimized benefits.

**Recommendations**

The NAC recommends that the FAA:

1. Create an agency-wide vision for changing to a time-based system and develop and implement a plan to communicate the vision.
2. Incorporate the roadmap outlined throughout this document for 2016-2020; 2021-2025; and 2026-2030 for decision support tools and aircraft capabilities.
3. Adopt change management principles as part of their implementation process to gain the acceptance and culture change to realize the benefits of time-based enhancements.

Recommendations related to specific capabilities:

1. Continue TBFM system improvements to ensure a strong foundation to build upon for future capabilities that will address the sequencing and spacing necessary for routine use PBN in all domains. Particular attention and emphasis should be placed on site adaptation
and issue resolution. Although improvements in TBFM trajectory modeling have occurred, excellence in site adaptation is crucial to producing desired results.

2. Expand and standardize the use of TBFM in the NAS to meet the goals contained in operational use policy that covers EnRoute, TRACON and Tower airspace. Providing quality change management processes, including early training of the workforce is a key aspect of continued implementation of TBFM. The FAA must have a commitment to have resources necessary for staffing, training and support to sustain this significant change.

3. Evaluate alternate use of CRDA given the extended period of time before the more complete solutions that are currently in development are available. It must be emphasized that the use of existing tools is only seen as a means to provide partial capability during the transition period.

4. The NAC endorses implementing GIMS-S at the nine Terminal Sequencing and Spacing sites prior to 2020.

5. Implement the TSAS rollout plan in the near-term time frame at 9 sites, and complete TSAS at NSG 1 Airports and NSG 2 hub airports in the mid-term timeframe.

6. The FAA continue its assessment of RTA through additional research and flight demonstrations to evaluate if the existing fleet capabilities can provide a significant operational benefit. After the NASA IM demonstration is complete and prior to the FAA’s final investment decision, an FAA-industry review of the results, including the cost and benefits, should be conducted to determine the final status of future recommendation on IM development and implementation.

7. The FAA plans for Path Stretch include initial operating capability (IOC) at TSAS sites beginning in 2022. The NAC endorses this GIM-S with path stretch timeline. Deployment of GIM-S with path stretch at all TBFM airports, where appropriate, should occur near the end of mid-term time horizon.

8. Begin the process of integrating aircraft trajectory data with ground systems in the midterm.

9. Consider CRDA as a mid-term solution for flow merging and spacing based on site-specific analyses.

10. Integrate Data Comm capability into the initial requirements for GIM-S with Path Stretch.

11. Make the use of RTA available as a supplement to other timing tools during this time frame recognizing that there is a need for a communication mechanism that reconciles between flight crews, dispatchers and controllers.

12. FAA should consider a funding mechanism for FIM to incentivize equipage that has proved successful in the Data Comm Integrated Services Contract.

13. Based on experiences from the Near and Mid-Term, the FAA begin implementing advanced Data Comm capabilities defined by SC214.

14. Continue with the development of improvements to the timeliness and accuracy of environmental information provided to the aircraft, particularly for the descent phase of flight, such that existing aircraft RTA capabilities can reach their full potential.
Appendix A: Organizations Participating in the Performance Based Navigation (PBN) Time, Speed Spacing Task Group

Air Line Pilots Association
Airbus
Alaska Airlines
American Airlines, Inc.
City of Houston, Texas
Delta Air Lines, Inc.
Federal Aviation Administration

**Dan Allen**  FedEx Express  **Group Chair**
GE Aviation
Harris Corporation
HMMH (DP)
Honeywell International, Inc.
JetBlue Airways
Landrum-Brown
Leidos
Metron Aviation, Inc.
National Air Traffic Controllers Association
National Business Aviation Association
Professional Aviation Safety Specialists
Raytheon
Regulus Group
Rockwell Collins, Inc.
RTCA, Inc.

**Steve Fulton**  Sandel Avionics, Inc.  **Group Chair**
SESAR Joint Undertaking
Southwest Airlines
Tetra Tech
The Boeing Company
The MITRE Corporation
U.S. Air Force
United Airlines, Inc.
Appendix B Tasking Letter
December 2, 2015

Ms. Margaret Jenny  
President, RTCA, Inc.  
1150 18th Street, NW.  
Washington, DC  20036

Dear Ms. Jenny:

The NextGen Advisory Committee (NAC) has been instrumental in working with the Federal Aviation Administration (FAA) to address the complexities inherent in moving to greater use of performance-based navigation (PBN) procedures. To further this work, the FAA is seeking the NAC’s assistance in the development of a PBN strategy that builds improvements to the National Airspace System (NAS) capacity through time, speed, and aircraft spacing without compromising safety.

The goal of the PBN strategy is to combine the flight efficiency of visual meteorological conditions with the predictability and stability of instrument operations. Operators have implemented a number of capabilities that enable them to fly predictable paths, laterally and vertically, enhancing the ability for air traffic management (ATM) automation to predict the flow of traffic at airspace constraints, such as runway capacity. Using PBN capabilities when traffic demand is high will depend on effective time, speed, and spacing management to maintain and eventually improve NAS capacity, efficiency, and throughput. The strategy for these ATM capabilities must be aligned to a broader navigation strategy.

The PBN strategy outlines near-(2020), mid-(2025) and far-term (2030) initiatives in the following focus areas:

- Implement PBN throughout the NAS with the right procedures to meet capacity, efficiency, and throughput needs;
- Provide navigation structure where beneficial, and flexibility where possible;
- Shift to time- and speed-based air traffic management;
- Deliver resilient navigation services;
- Modernize the FAA navigation service delivery;
- Enable lower visibility access; and
- Innovate and continuously improve.
These initiatives are possible because the navigation capabilities of aircraft have continued to improve, with a variety of capabilities spanning terminal and en route operations, including RNAV, RNP, advanced RNP, and several types of instrument approach operations (LNAV, LNAV/VNAV, LPV, RNP AR).

The most significant challenge to implementation is the need to integrate the path of a single flight with all of the other flights before and after it. The full use of PBN can only occur when the predictable and efficient path of each aircraft provides safe separation to the preceding and succeeding aircraft. Air traffic controllers are currently able to achieve a safe separation at maximum capacity by adjusting flight paths and speeds close to the final approach. The clear goal is to achieve a similar, or even improved, level of utilization during PBN operations.

Overcoming this challenge requires us to improve air traffic management through speed, spacing, and time control. These improvements require the development, deployment, and use of decision support tools for controllers and pilots. Some decision support tools have already been developed to manage demand and capacity and are being adapted for PBN. The FAA is also deploying ground-based interval management. Merging and spacing tools must be developed to support the PBN operational environment and to manage the differences in aircraft performance. Ultimately a combination of tools will be needed to allow reliable flight path planning prior to top-of-descent and to maintain spacing throughout the arrival.

The PBN Strategy depends on the development and application of expanded and more mature scheduling, sequencing, and spacing tools and automation. Example enhancements include:

- Procedure-specified speeds;
- Terminal spacing and sequencing;
- Improved trajectory modeling through PBN and data communications;
- Common winds aloft through uplink of winds;
- Path stretching to absorb larger delays (simple capability using voice communications, or more sophisticated capability using data link communications);
- Flight deck interval management where the controller can assign a time-based spacing objective; and
- Use of a controlled time of arrival at or prior to the top of descent to improve the ordering of traffic

Specifically, the FAA requests that the NAC review the plans for these and related capabilities and develop a 15-year strategy for their deployment that would complement the FAA’s NAS navigation strategy. The FAA requests draft findings from this work at the February NAC meeting, followed by a final report no later than the June NAC meeting. The strategy for time, speed and spacing assignment should address what types of tools are appropriate in various operating conditions, what tools should be prioritized, and how the various capabilities can be integrated into efficient traffic flow management.
The FAA will make subject matter expertise available to the NAC upon request. If I can be of further assistance, please contact me or Mr. Bruce DeCleene, Manager, Flight Technologies and Procedures Division, at (202) 267-8790.

Sincerely,

[Signature]

Michael
Whitaker Deputy Administrator

cc: Edward Bolton, Assistant Administrator, NextGen
John Hickey, Deputy Associate Administrator, Aviation Safety
Teri Bristol, Chief Operating Officer, Air Traffic Organization
Rick Swayze, Assistant Administrator for Policy, International Affairs and Environment
Eduardo Angeles, Associate Administrator, Airports