NASA Controller Managed Spacing (CMS)-Air Traffic Technology Demonstration-1 (ATD-1)
Study 4 (CA-4) December 10-13th, 2012

12/28/2012

Danny Vincent
Michael Prichard
Chuck McAleavy
Jessica Ciotti
I. Introduction

This paper describes the simulation design, and preliminary results and recommendations from a human in-the-loop simulation of controller advisory tools known as ATD-1 tools. ATD-1 combines advanced arrival scheduling, controller decision support tools, and aircraft avionics to enable efficient arrival operations in high-density terminal airspace. These three technologies are known as Flight Deck Interval Management (FIM), Traffic Management Advisor with Terminal Metering (TMA-TM) and Controller Managed Spacing (CMS). The objectives of the simulation were to:

- Adapt Multi-Aircraft Control System (MACS) to simulate Phoenix (PHX) airspace in order to test and ensure the high fidelity automated tools provide accurate and reliable information to the TRACON controllers
- Define an initial baseline capability of automated tools that will be used to build enhancements over time
- Refine the controller/pilot ATD-1 procedures, phraseology and training
- Ensure the high fidelity tools meet the operational need, requirements, goals and objectives of the ATD-1 Concept of Operations

The preliminary results and recommendations are derived from comments and feedback from participants during the simulation as well as from observation, and future results will include controller feedback from questionnaires and objective data such as throughput.

II. ATD-1 Automated Advisory Tools

ATD-1 tools assist Terminal Radar Approach Control (TRACON) controllers in delivering aircraft as close as possible to the merge points or runway threshold at the scheduled time of arrival (STA) to achieve maximum throughput on capacity-constrained runways. The ATD-1 tools provide information such as speed advisories, early or late indications, scheduling information and spatial targets. (Shown in Figure 1). The ATD-1 tools evaluated during this simulation were:

- Timelines
  - Provide a graphical depiction of the relationship between the estimated time of arrival (ETA) and the STA. If the ETA is ahead of the STA, the aircraft requires delay. If the STA is ahead of the ETA, the aircraft needs to be advanced
  - Enable the controller to assess the aircraft’s schedule conformance by comparing its ETA to its STA
  - Available to both the feeder and final positions
  - Displayed for each merge point or runway threshold
- Early/Late Indicators
  - Represent the numerical difference between the ETA and STA to the next merge point or to the runway threshold as displayed on the timeline
o Generated when a single speed advisory cannot be calculated to resolve schedule conformance with a 10 knot (kt) discrimination and the difference between the ETA and STA is greater than or equal to five seconds
o Displayed as minutes and seconds if the difference between the ETA and STA is less than two minutes. If the difference between the ETA and STA is greater than two minutes, the minutes are displayed as whole numbers
o Available to both the feeder and final positions
o Located on the third line of the flight data block (FDB)

- **Slot Markers**
  o Are spatial circular targets on the display to indicate where an aircraft should be at that time if it were to fly the adapted route through the forecasted wind field, meet all published speed and altitude restrictions, and arrive at its STA on time to the merge point or to the runway threshold
  o Dwelling on a FDB or a callsign on the timeline will highlight the corresponding aircraft’s slot marker
  o Display the slot speed or current indicated airspeed (IAS) next to the slot marker and the current aircraft’s IAS next to the sector symbol
  o Represents 15 seconds of flying time in diameter, and increases/decreases in diameter with the charted speed
  o Available to both the feeder and final positions

- **Speed Advisories**
  o Displayed as air speeds when an aircraft’s ETA exceeds five seconds from its STA and only if the predicted speed will resolve the difference between the ETA and STA, otherwise, the early/late indicator will be displayed
  o Available to both the feeder and final positions
  o Located on the third line of the FDB

### III. FAA Automation to be Fielded for ATD-1 Advisory Tools

FIM/Required Time of Arrival (RTA) and Ground Based Interval Management (GIM) are part of the Federal Aviation Administration’s (FAA) work to not only reduce or eliminate the use of Miles in Trail (MIT) en-route, but to reduce controller intervention during an aircraft’s Optimum Profile Descent (OPD). These automated tools coupled with the ATD-1 automated tools will assist controllers in ultimately delivering aircraft as close as possible to their STAs at the runway to achieve maximum throughput. These FAA automated tools could provide such information as speed advisories, required time of arrival to fixes, and the identification of spacing capable aircraft. (Shown in Figure 2). The FAA automated tools evaluated during this simulation were:
- **GIM**
  - Issuing the advised GIM speed to an aircraft ensures that the aircraft arrives at its STA on time to the MF
  - GIM speed advisories are no longer displayed when aircraft are in FIM or RTA mode
  - GIM speed advisory indication is displayed as an “I” on top of the FDB on the DSR

- **FIM/RTA**
  - Aircraft must be on the assigned route to engage in FIM operations
  - RTA is issued to the final approach fix (FAF)
  - Spacing capable aircraft will adjust their speed to follow a lead aircraft to ensure the spacing capable aircraft arrives at its STA on time to the FAF
  - Aircraft that are FIM/RTA capable display an “@” sign on top of the FDB on the DSR and on the third line of the FDB on STARS
  - Lead aircraft do not have to be FIM equipped

![Diagram of GIM and FIM/RTA indications](image)

Figure 1. ATD-1 STARS Controller Advisory Tools
IV. Existing Operational Tools Used During the Simulation

- Spacing Cones
  - Give visual indication of the required minimum wake vortex separation between aircraft
  - Displayed as a cone and extends forward from the aircraft target
  - Can be enabled or disabled for all aircraft or for one specific aircraft
    - The ability to enable the spacing cones for all aircraft is only available in the lab environment at this time

- J-Rings
  - Are indicators in the form of a circle around the aircraft target that assist in assessing the spacing between aircraft
  - The radius of a J-Ring is determined by the controller. For example, he or she can choose a 3 or 5 nautical mile (nm) radius

- Meter List
  - An ARTCC tool that provides an aircraft’s STA and early/late times to the MF
  - "**" denotes aircraft that are frozen
V. Simulation Overview

This simulation was conducted to assess the accuracy and reliability of the ATD-1 tools for merging, sequencing and spacing of aircraft in forecasted wind conditions on Area Navigation (RNAV) routes. This simulation also helped to refine the procedures, Interval Management (IM) phraseology and overall training for both the controllers and pilots. The following sections describe the simulation in more detail.

Note: In addition to the ASTOR and MACS aircraft a ‘CAB’ aircraft was also flown in each of the simulation runs. The ‘CAB’ aircraft data was derived from the B747-400, FAA –certified “Level D” simulator being flown at the Crew-Vehicle Systems Research Facility (CVSRF). The main purpose of the ‘CAB’ aircraft was to gather both analytical and human factors data on the use of ATD-1 tools in the flight deck environment.

VI. Simulation Run Description

This simulation took place over four days and was composed of nineteen data collection runs. The training runs were conducted the week prior, over three days. Each data run lasted approximately 60 minutes followed by a break. After the first data collection run, the controllers did not fill out the questionnaire due to technical difficulties. After the second data collection run, controllers were given a one page questionnaire regarding the accuracy and stability of the tools. Once the technical issues were resolved, controllers were able to take the questionnaires.

The data compiled from the controller input to the questionnaires will help to refine the ATD-1 tools by continuing to improve their accuracy and fidelity, and enhancing their accompanying procedures and phraseology as the research and development of these ATD-1 tools continues. Forecasted winds were incorporated into the simulation to determine the effects of the wind on the ATD-1 tools. For all jet routes, the stream class MIT values were set to 6 nm and the freeze horizons were set to 160nm. Table 1 depicts the wind condition, tool condition, CAB call sign, final approach fix matrix buffer, minimum wake vortex, the number of runs and the day each run was conducted.

Table 1. ATD-1 Simulation Run Conditions

<table>
<thead>
<tr>
<th>Day</th>
<th>Run #</th>
<th>Forecasted Winds</th>
<th>Tools</th>
<th>CAB</th>
<th>FAF Matrix Buffer</th>
<th>Minimum Wake Vortex</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/10/12</td>
<td>1</td>
<td>111102 - 09Z/11Z</td>
<td>UAL338</td>
<td>.3</td>
<td>3nm</td>
<td></td>
</tr>
<tr>
<td>12/10/12</td>
<td>2</td>
<td>111102 - 09Z/11Z</td>
<td>UAL985</td>
<td>.3</td>
<td>3nm</td>
<td></td>
</tr>
<tr>
<td>12/10/12</td>
<td>3</td>
<td>111102 - 09Z/11Z</td>
<td>UPS437</td>
<td>.3</td>
<td>3nm</td>
<td></td>
</tr>
<tr>
<td>12/10/12</td>
<td>4</td>
<td>111102 - 09Z/11Z</td>
<td>UAL1505</td>
<td>.3</td>
<td>3nm</td>
<td></td>
</tr>
<tr>
<td>12/10/12</td>
<td>5</td>
<td>111102 - 11Z/09Z</td>
<td>UAL437</td>
<td>.3</td>
<td>3nm</td>
<td></td>
</tr>
<tr>
<td>12/11/12</td>
<td>6</td>
<td>111102 - 09Z/11Z</td>
<td>UAL742</td>
<td>.3</td>
<td>3nm</td>
<td></td>
</tr>
<tr>
<td>12/11/12</td>
<td>7</td>
<td>111102 - 11Z/09Z</td>
<td>Tools</td>
<td>UAL437</td>
<td>.3</td>
<td>3nm</td>
</tr>
<tr>
<td>12/11/12</td>
<td>8</td>
<td>111102 - 09Z/11Z</td>
<td>Tools</td>
<td>UAL985</td>
<td>.3</td>
<td>3nm</td>
</tr>
<tr>
<td>12/11/12</td>
<td>9</td>
<td>111102 - 11Z/09Z</td>
<td>Tools</td>
<td>UAL437</td>
<td>.3</td>
<td>3nm</td>
</tr>
<tr>
<td>12/11/12</td>
<td>10</td>
<td>111102 - 09Z/11Z</td>
<td>Tools</td>
<td>UAL985</td>
<td>.3</td>
<td>3nm</td>
</tr>
<tr>
<td>12/12/12</td>
<td>11</td>
<td>111102 - 09Z/11Z</td>
<td>Tools</td>
<td>CPA742</td>
<td>.3</td>
<td>3nm</td>
</tr>
<tr>
<td>12/12/12</td>
<td>12</td>
<td>111102 - 11Z/09Z</td>
<td>No CMS</td>
<td>CPA985</td>
<td>.3</td>
<td>3nm</td>
</tr>
</tbody>
</table>
VII. PHX Airspace

The simulation airspace, PHX arrivals in a West configuration, (modified from current operational airspace) contained four Air Route Traffic Control Center (ARTCC) sectors: Albuquerque (ZAB) Sector 39, ZAB Sector 42, ZAB Sector 43 and ZAB Sector 46, plus two TRACON Feeder positions, Quartz and Apache and two TRACON Final positions, Freeway and Verde. RNAV routes were modified to connect to the runway threshold and all aircraft had RNAV capabilities and were FMS equipped. FIM equipped aircraft only flew on the EAGUL-5 and KOOLY-4 routes. See Figure 3 for the PHX airspace overview. Altitude restrictions, route speeds, meter fixes, merge points, runways, and airspace sectors are labeled in Figure 4. PHX Airspace Routes and Restrictions. Note: ZAB Sector 42 included portions of ZLA airspace and ZAB Sector 43 and ZAB Sector 46 were made up of multiple sectors within these sectors.
Figure 3. PHX Airspace Overview

Figure 4. PHX Airspace Routes and Restrictions
VIII. Simulation Participants

There were a total of eight controllers that participated in this ATD-1 simulation; all are confederate controllers from TRACONs and ARTCCs across the National Airspace (NAS). Some of the controllers had previous experience as participants in NASA simulations, to include simulations for the ATD-1 tools.

IX. Scenarios

The traffic scenarios varied depending on the run. For example, during the 5th data collection run, additional aircraft were added. Modifications were also made to where the CAB entered the scenario; although the CAB always landed on 26 runway, the route flown varied. The average arrival rates for any 15 minute period calculated to 84-88 scheduled aircraft (AAR).

X. Simulation Environment

The ATD-1 controller advisory tools were evaluated using the Multi-Aircraft Control System (MACS). The RTA/FIM aircraft were flown using the Aircraft Simulation for Traffic Operations (ASTOR) interface and the CVS RF B747-400 simulator. MACS was adapted to simulate PHX ARTCC and the P50 TRACON airspace and operations; specifically simulating the PHX arrivals in a West configuration landing on runway 26 and 25L. NASA also used research Traffic Management Advisor (TMA) version 3.12 of the FAA baseline. It was noted in the simulation that aircraft STA times were freezing based on an adapted mileage in MACS and not based on the parameters in TMA. One observer noted that this caused a frozen STA time to change when the aircraft froze in TMA. This also required a verbal notification to the controllers when the STA times were stable at the beginning of each simulation.

The air traffic lab layout consisted of four TRACON positions (two feeder positions and two final positions) and four ARTCC positions. The evaluation focused on the feeder and final controllers using the ATD-1 tools to deliver the aircraft as close as possible to the STA, at the merge points and runway threshold. The evaluation also focused on the ARTCC controllers using the FAA automated tools to deliver the aircraft as close as possible to the STA, at the meter fix. The feeder and final positions were also able to display timeline information associated with the merge points or runway threshold. Figure 5 depicts the ATC lab configuration.
XI. **Roles and Responsibilities of Controllers**

The ARTCC controller tasks were to clear the aircraft for OPD, issue the FIM/RTA clearance, issue GIM advised speeds and to absorb delay in order to meet the STA at the meter fix. The feeder controller tasks were to use the slot marker and speed advisories as tools to adjust an aircraft’s speed to meet its STA at the runway, to allow the FIM or RTA aircraft to fly the procedure without interference (unless to maintain safe separation), to assign arrival runways and to ensure proper spacing to the final controller. The final controller tasks were to clear the aircraft for the RNAV approach, to use the ATD-1 tools to issue speeds if appropriate, to use normal approach procedures, to issue final approach clearance, and to ensure adequate spacing on the final approach.

XII. **Simulation and Participant Guidelines**

The controllers were advised of the following simulation and participant guidelines:

Simulation Guidelines

- All aircraft have RNAV capability
- All aircraft are FMS equipped
- In ARTCC airspace, schedule times need to be frozen before clearances are issued
- The TBFM schedule uses wake vortex separation and an additional three tenths of a mile buffer at the FAF
- When the flight crew initiates FIM pairing, the aircraft will no longer be responsible for the RTA time to the FAF
- An aircraft on a FIM or RTA procedure has clearance to the FAF
- An aircraft on an OPD has clearance to the FAF
- IM spacing is available even if the aircraft is off the route, but the aircraft will not be able to be in paired mode until the aircraft returns to the route
- MACS aircraft cannot fly the altitude windows
- ASTOR aircraft can fly the altitude windows

Participant Guidelines

- ATD-1 tools should be utilized in the TRACON airspace during runs with a tool-condition
- ATD-1 speed advisories given within TRACON airspace, should be used unless unrealistic
- FAA automated tools should be utilized in ARTCC airspace during each run
- ARTCC controllers are to pre-condition aircraft to 2 minutes or less or to their best ability
- To the extent possible, keep FIM/RTA aircraft on its assigned route
- FIM operations can be suspended or resumed (not cancelled)

XIII. Data Collection

From each control position, keyboard inputs into the system, schedule information, aircraft information, and responses to the post-run questionnaire were recorded. Voice-to-voice communication between pilots and controllers were also recorded. During the data runs, trainers and observers captured the time of the run, position observed, type of run, any issues, and resolutions. No formal debriefs were held after the data collection runs, but on the last day of the simulation the final debrief occurred. Throughout the simulation, the participants provided feedback on how well the tools worked, any issues found, the IM phraseology, and procedures. The Researchers, SMEs and other observers were on hand to address the participant questions or describe any system changes made to a specific run.

All data is currently being analyzed. Additional results based on the controller surveys and system recordings will be provided in the upcoming weeks. Refer to section XV Results.

XIV. Training

A training briefing package was created and distributed to the controllers prior to the simulation. Training was divided up into three parts. The first part discussed the background and motivation to conduct this simulation. A screen shot and a description of each of the ATD-1 tools and FAA automated tools were also included in the package. The second part of the training included dividing the ARTCC and TRACON controllers into two groups. During this time the Researchers or SMEs explained the IM
The scenarios were simplistic in order to direct controller focus on the tools; therefore they did not reflect true traffic situations. As the simulations continue, increasing complexity and including a more realistic complement of traffic situations (e.g., Add to the scenarios: three to four turbo prop aircraft over the EAGUL-5 arrival flow, departures, and VFR traffic) will provide a more realistic view of current actual operations. There was also an inconsistency between ASTOR and MACS altitudes which required controllers to use two different arrival charts. It is also recommended that a consistent group of current FAA air traffic controller SMEs be used to reduce the time spent training and allow for a greater number of simulation runs that would concentrate on defining the requirements needed to support an operational demonstration of ATD-1.

XV. Roles and Responsibilities of Trainers and Observers
Trainers instructed the controllers on airspace, operations, IM phraseology, ATD-1 tools and FAA automated tools and answered any questions posed by the controllers. The trainers and observers documented controller feedback and observations, both positive and negative. See Section XI Data Collection for additional information regarding the responsibilities of the trainers and observers.

XVI. Results
As described in Section XII Data Collection, each control position, keyboard inputs into the system, schedule information, aircraft information, and responses to the post-run questionnaire, were recorded. Voice-to-voice communication between pilots and controllers was also recorded.

All data is currently being analyzed. Additional results based on the controller surveys and system recordings will be provided in the upcoming weeks.

XVII. Observations/Discussions
Below describes the ATD-1 tools, the FAA Automated Tools, and the aircraft behavior, as observed during the data collection runs. Controller feedback as well as recommendations for future simulations is also included in this section.

A. Early/Late Indicators
During this simulation the Early/Late indicators were shown as “+3 or -3” instead of using “E=3 or L =3,” for example. If the aircraft was on time, 00:00 would be displayed, if the aircraft was within 10 seconds of being early, +00:00 would be displayed and if the aircraft was within 10 late seconds of being late, -00:00 would be displayed.
B. Slot Markers
Of all the ATD-1 tools, slot markers appear to be the most utilized by TRACON controllers. It seemed that the visual indication of the schedule provided the controller all that was necessary once they were familiar with slot markers adapted performance. The slot marker and CAS speeds seemed to be useful at first and may be beneficial to changing conditions but after time the controllers did not seem to rely on the information or were conditioned to their performance. Slot markers appear to be essential for feeder controllers in a mixed equipage environment so that aircraft remain on PBN approaches. The TRACON controllers commented that aircraft wanted to accelerate after resuming RTA or FIM clearances even if they were in the slot marker and flying the RNAV adapted speeds.

C. Speed Advisories
Speed advisories were seldom used by controllers in the ARTCC and TRACON positions. Through observation and controller feedback, they often seemed uncomfortable issuing speeds that they were not use to or if the speed was below what is published in FAA Order 7110.65. They also voiced concern over the constantly changing speed advisories. Several times an advisory was given to speed up an aircraft followed by one to slow the aircraft. Controllers also lost confidence in the advisories when the speed advisory had an opposite effect on the achieve point scheduled time. For example, controllers reported situations where aircraft would speed up after being pre-conditioned and engaging in RTA or FIM even if there was still delay to be absorbed. The controllers did seem very comfortable with the use of the speed advisory interface.

D. FIM/RTA Aircraft Operating at Higher Speeds
The challenge for ATD-1 is the ability to operate in a mixed equipage environment. In the simulation, aircraft executing FIM and RTA clearances operated at a higher speed than those executing OPD/RNAV arrivals. Although the desired time at the FAF was met by the FIM and RTA aircraft, the deceleration to achieve the arrival time appeared to be more significant in the later phase of the flight. These overtake situations carried over into the feeder positions where controllers suspended FIM aircraft in order to maintain spacing. This deceleration often times caused overtake situations in the ARTCC and Terminal environment. ATRCC controllers also commented that the aircraft on FIM/RTA clearances were typically 20-40 seconds early at the MF. The TRACON controllers commented that aircraft wanted to accelerate after resuming RTA or FIM clearances even if they were in the slot marker and flying the RNAV adapted speeds.

There was considerable discussion on how to mitigate the issue of FIM and RTA aircraft flying different speeds. Pre-conditioning the aircraft to within one minute rather than within two minutes appeared to reduce the amount of the over-take. Moving the scheduling point further upstream from the FAF may prove to be the best compromise. From an ARTCC perspective, the scheduling point would work better in a mixed environment if it was the MF. Since the ARTCC control point is the MF, you would not have the overtake between the equipped and non-equipped aircraft if they had to meet at the same scheduling point. The Feeder controllers suggested that the scheduling point be moved to the Feeder/Final boundary. By moving the scheduling point further out, the uncertainty of behavior in the TRACON and aircraft separation at the MF should improve.
E. Pre-Conditioning Aircraft

Even though aircraft on RTA and FIM clearances were fully capable of executing the desired spacing after being pre-conditioned, there was a notable difference between pre-conditioning aircraft to one minute versus two minutes. When per-conditioning to two minutes or less, the TRACON had more delay to absorb and there were more overtake situations. In the ARTCC environment, controllers expressed little difference in workload between conditioning to one or two minutes.

F. RTA and FIM Clearance Separation

Controllers and pilots expressed the desire to separate the FIM and RTA clearance. They noted three reasons for this decision, too much frequency time being used at once, greater chance of communication error, and the RTA clearance is more urgent than the FIM clearance. One pilot said that if he flew into ORD the frequency congestion would seldom allow a clearance of this length. Controllers also stated they did not see a savings by combining the two clearances.

G. Compression on Final

Throughout each of the simulation runs there were several occasions where minimum separation was lost as aircraft approached the runway threshold. It appeared that the overarching reason for the loss of separation was due to compression caused by the significant reduction in flying speeds from the turn-on point to the runway threshold. Observation of the tower position indicated that there was an increase in these incidences when aircraft were following B747 and B757 aircraft, which in most cases represented ASTOR aircraft. There are four possible factors that could have contributed to this issue; difference in runway threshold speeds, pairing and RTA calculations were only done to the FAF, difference in winds between ASTOR and MACS aircraft, and possible too high of turn on speeds for aircraft in adaptation.

Runway threshold speeds in TMA are calculated at 130 kts for all jets. During these simulations the B747 aircraft were operating with a threshold speed of 140 kts. To mitigate this difference, on the second data collection run on Thursday, an additional one tenth of a mile separation was added to the TMA runway matrix setting for all situations involving Heavy and B757 wake class of aircraft.

With aircraft crossing the FAF around 170 kts there was still a significant amount of compression between the FAF and the runway threshold because there is only a few miles to reach the threshold speed of 130 kts. The TMA system was configured for an IFR or THD matrix application, which should have corrected for this difference. Post data analysis should indicate whether or not this contributed to the compression issues near the runway threshold.

During the final data collection run it was suspected that there was a 20-knot difference in airspeed on final approach between the ASTOR and MACS aircraft caused by the calculated winds. This may prove to be the single most significant contributor to the compression problem especially since most of the issues appeared to be related to MACS aircraft operating behind ASTOR aircraft.

The adaptation for the turn-on speeds to final during these simulations was calculated at 210 kts. This is about 30 kts faster than today’s operational average. Although these speeds may be obtainable in VFR
conditions, during IFR conditions and turbulence it may be difficult to expect flight crews to operate to these speeds. It was noted that the tower controller was routinely issuing overtake advisories in the 40 knot range to aircraft on final approach.

**H. GIM Speed Advisories**

Controllers stated that that when an aircraft was given a speed that was the same as the GIM recommended speed, it would display as a GIM assigned speed. If the GIM advised speed was a MACH number then the associated indicated airspeed would appear in the FDB.

**I. Wind Files**

Although the same wind file was used for each simulation, the conversion for ASTOR, MACS, TMA, and the CAB aircraft occasionally created different results. There were a few data collection runs where there was a noticeable difference in behavior between aircraft as a result of different wind calculations used. For example, there were aircraft in trail at the same altitude, flying the same speeds that were showing a difference of 100kts in ground speed. This issue was significant enough that in some simulations the run needed to be restarted, but it may have also played a role in some of the more subtle issues noted such as compression on final, DCT behavior or overtake situations.

**J. Computer Human Interface (CHI)**

Currently the final FIM/RTA CHI has not been completed. While training the ARTCC controllers for the ATD-1 simulations it was clear that the two FIM/RTA prototyped symbols being used were confusing. Also, multiple inputs were required to maintain the status of the FIM/RTA clearances. The controllers desired a single identifier in the ARTCC FDB and in the TRACON three letters were used in the FDB. NASA engineers modified the CHI and reduced the number of keyboard entries to meet the controller requests and were able to implement the changes during the training runs. The controller feedback was extremely favorable.

**K. Recommendations for Future Simulations**

- Increase the traffic mix to include turboprop aircraft
- Include arrivals that depart within the TRACON
- Provide a TRACON tools only simulation
- Increase the number of configuration
- Include emergency or priority aircraft
- Provide first and second choice of runways
- Simulate a Go-Around
- Simulate a ripple or reschedule in the TRACON
- Include an RNP-AR or visual RNAV arrival route
- Include weather on at least one RNAV arrival route

**I. Conclusion**

The objectives of this ATD-1 simulation were to assess the accuracy and reliability of the ATD-1 tools using Phoenix Sky Harbor airspace and to enhance the procedures, phraseology and training.
As the research and development of these ATD-1 tools continues, unresolved issues will be addressed, modifications will be made, and the ability to discern in greater detail the effectiveness of the ATD-1 tools will become more apparent. Research does show a dependency on this type of technology to assist controllers with managing aircraft on PBN procedures while maintaining airport efficiency. Without these tools, controllers will have to intervene more to maintain proper sequencing and spacing between aircraft, which reduces any savings gain by the PBN procedure.

II. References


Callantine, T. “CA-3 Simulation Controller-Managed Spacing (CMS) for mixed Flight Deck Interval-Management (FIM and non-FIM Arrivals),” Moffett Field, CA, June 2012.