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Simultaneous Offset Instrument Approaches at Newark International Airport:

An Airspace Feasibility Study

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16. Abstract

A real-time human-in-the-loop study of simultaneous offset instrument approaches (SOIA) was conducted at the William J. Hughes Technical Center in Atlantic City, NJ, August 14 through 17, 2000. The purpose of the study was to assess the operational feasibility of Air Traffic Control to support dual feed operations to Newark International Airport (EWR) with a straight-in approach to Runway 4R and an offset localizer directional aid with glideslope approach to Runway 4L *with no changes to the current EWR airspace configuration*. Five Certified Professional Controllers and one Operational Supervisor from the EWR sector of the New York Terminal Radar Approach Control participated in the study to evaluate the feasibility of conducting SOIA within the EWR airspace boundaries. They determined that, under the current airspace configuration, dual feed SOIA operations are not feasible. The reason is the lack of airspace south of the airport that is necessary to sequence, vector, and pair the aircraft for the final. If certain traffic flows could be flip-flopped within the EWR airspace, the procedure may be able to provide the benefits for which it was intended. A follow-on study should be conducted to investigate the effects of such proposed modifications.

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Executive Summary

A real-time, human-in-the-loop simulation team from the Federal Aviation Administration (FAA) performed an airspace study from August 14 through 17, 2000 to evaluate the feasibility of Simultaneous Offset Instrument Approaches (SOIA) at Newark International Airport. The purpose of the study was to assess the operational feasibility of ATC to support dual-feed operations to Newark International Airport (EWR) with a straight-in approach to Runway 4R and an offset localizer directional aid (LDA) with glideslope approach to Runway 4L *with no changes to the current EWR airspace configuration*.

SOIA procedures allow aircraft to fly dual approaches to runways spaced less than 2500 ft apart in marginal Instrument Flight Rules/Visual Flight Rules conditions. With SOIA, air traffic controllers strategically pair aircraft on adjacent approaches rather than setting them up to fly single stream approaches. This configuration can allow for increased throughput. The SOIA procedure requires the use of Precision Runway Monitor technology, which provides controllers enhanced monitoring and surveillance capabilities during closely spaced approaches.

Five Certified Professional Controllers and one Operational supervisor from the EWR sector (N90) of the New York Terminal Radar Approach Control (TRACON) participated in 11 test scenarios. The scenarios contained varying traffic volumes and were controlled by either one or two final controllers. The simulation team tested several different control strategies based on participant recommendations to evaluate the feasibility of conducting SOIA within the EWR airspace boundaries.

The participants determined that, under the current airspace configuration, dual-feed SOIA operations are not feasible. The reason is the lack of airspace south of the airport necessary to sequence, vector, and pair the aircraft for final approach. This was quite evident whenever heavy aircraft were present. The CPCs completed some aircraft pairings, but they noted that it required an excessive amount of coordination.

New York TRACON (N90)/EWR personnel recognized the potential benefits of the SOIA procedure, however, the present airspace is too limited and the present traffic flows, particularly the Yardley (ARD) and Robbinsville (RBV) flows, are not favorable for effectively running dual stream 'paired' arrivals. If the ARD and RBV flows could be flip-flopped, the procedure may be able to provide the benefits for which it was intended. A follow-on study should be conducted to investigate the effects of such proposed modifications.

1. Introduction

A real-time, human-in-the-loop (HITL) simulation team from the Federal Aviation Administration (FAA) performed an airspace study in August 2000 to evaluate the feasibility of Simultaneous Offset Instrument Approaches (SOIA) at Newark International Airport (N90[1]/EWR). The team consisted of researchers from the NAS Advanced Concepts Branch (ACT-540) and its support contract organization, Titan Systems. The team also included technical support from the NAS Simulation Branch (ACT-510) and pilot and controller subject matter experts. The team performed the test in the Precision Runway Monitor (PRM) Laboratory at the William J. Hughes Technical Center (WJHTC), in Atlantic City International Airport, NJ. Five Certified Professional Controllers (CPCs) and one Operational Supervisor (OS) from the EWR Terminal Radar Approach Control (TRACON) facility participated in the study. Because the CPCs and the OS were evaluators in the study, the group referred to as 'simulation team' in this report also includes their participation.

1.1 Simulation Objectives

The simulation team conducted the N90/EWR airspace study to determine if dual-arrival streams could be positioned to land on Runways 4R and 4L in marginal weather conditions (i.e., ceiling of 1500 ft or more and visibility of 4 nm or greater), within the present N90/EWR airspace and with the use of the present airspace feed points. To allow for this type of operation, participants assumed a procedure known as SOIA to be in place.

The specific objectives of the N90/EWR SOIA feasibility study were as follows:

a. Assess the operational capability of Air Traffic Control (ATC) to support dual-feed operations to a straight-in Instrument Landing System (ILS) approach to Runway 4R and an offset Localizer Directional Aid (LDA) with glideslope approach to 4L (i.e., SOIA) with no changes to the current configuration of N90/EWR airspace and with no changes to overflights, departures, or satellite operations, routes, or procedures.

b. (If answer to ‘a.’ is no): 1) Identify changes to N90/EWR airspace, routes, and/or procedures that would provide for a viable SOIA operation, and 2) Identify any potential impacts of those changes to airspace, routes, or procedures.

1.2 SOIA Procedure Overview

SOIA allows simultaneous approaches to be flown to runways spaced less than 2500 ft apart (i.e., closely spaced runways). Some airports do not conduct approaches to closely spaced runways but, rather, operate single stream traffic. Other airports conduct parallel visual approaches to closely spaced runways when the weather (i.e., ceiling and visibility) permits the aircraft approaching the adjacent runways to establish visual contact with one another in sufficient time to be issued visual approach clearances. Ceilings for such approaches are normally only

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[1]New York TRACON contains three segments, Newark International Airport, John F. Kennedy International Airport, and LaGuardia International Airport (LGA). N90 refers to the EWR segment.

available down to 4000-5000 ft above ground level (AGL). As the weather deteriorates, the airport must change to single flow arrival streams, which significantly reduces the potential capacity.

SOIA utilizes an ILS on one runway and an offset LDA with glideslope on an adjacent runway to allow simultaneous approaches to ceilings down to about 1500 ft and visibility of 3 to 4 miles. ATC monitors a standard 2000-ft wide No Transgression Zone (NTZ) for aircraft deviations between approach courses. The FAA requires the use of a PRM system to provide controllers with aircraft position data once every second. The NTZ extends from the point on final where vertical separation of 1000 ft is lost to the LDA Missed Approach Point (MAP). Outside of the MAP, the geometry of the approach courses permits the application of current FAA regulations for simultaneous approaches. The LDA MAP is located where the approach course separation is 3000 ft. Adjacent aircraft are "paired." A specified ceiling provides the pilot of the trailing aircraft at least 25 seconds after exiting the overcast to visually acquire the leading aircraft on the adjacent runway and receive a "maintain visual separation" clearance prior to reaching the MAP. Aircraft perform SOIA to runways spaced less than 2500 ft apart; therefore, controllers must apply all applicable wake turbulence criteria between aircraft on the same and adjacent finals. Figure 1 depicts the SOIA procedure.

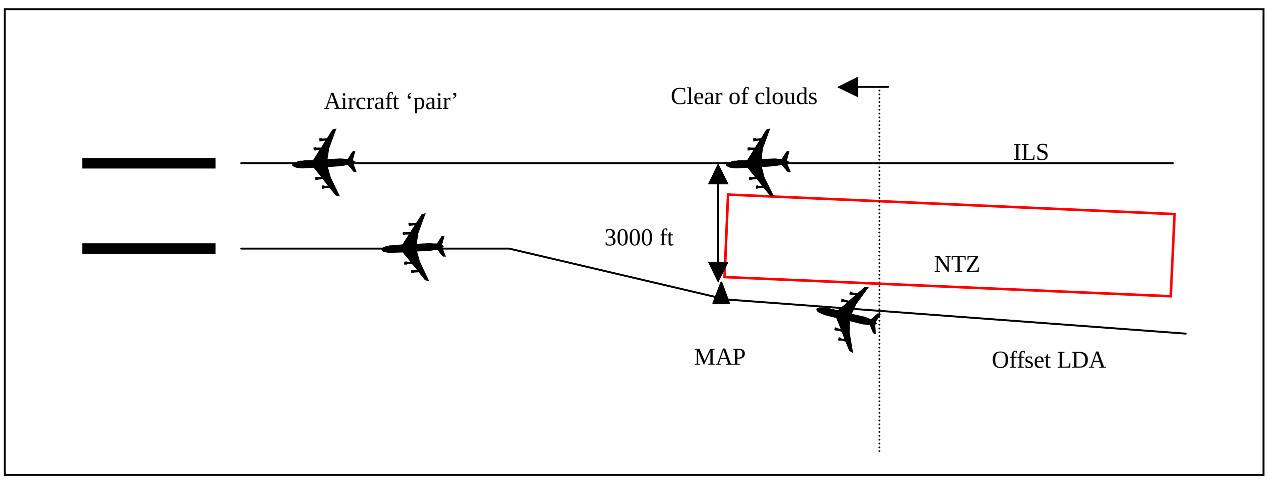


Figure 1. SOIA procedure.

To allow for SOIA at EWR, the approach configuration would include the 4R ILS and a 3-degree offset LDA to 4L. Controllers would pair aircraft on the 4L LDA with aircraft on the 4R ILS. The 4L LDA aircraft would have to visually acquire the 4R ILS aircraft and receive a "maintain visual separation" clearance prior to reaching the 4L MAP. Pilots would fly the 4L approach from the MAP to the runway threshold in visual conditions.

The focus of this simulation was not just on the SOIA geometry, but also on the airspace surrounding the 4L and 4R finals. A key concern was the ability of the controllers to maneuver aircraft in that airspace to allow SOIA to take place. The simulation team evaluated the procedure from the N90/EWR airspace boundaries to the beginning of the NTZ (i.e., 12.8 miles from the airport).

2. Method

2.1 Experimental Apparatus

2.1.1 Facilities and Equipment

The simulation team conducted the study in the Simulation Display Laboratory (SDL) at the WJHTC. Participants controlled traffic on four high-resolution 20 x 20-inch Sony displays. The Target Generation Facility (TGF) provided the ATC environment, including the simulated radar sensors, airspace configuration, aircraft targets, and aircraft performance characteristics. Simulation pilots controlled the TGF-generated aircraft targets via specialized computers in the Simulation Pilot Laboratory. They commanded and controlled aircraft in accordance with controller instructions.

2.1.2 Simulated Airspace

The simulated traffic entered the EWR airspace from the primary north and west arrival fixes of SHAFF, NYACK, COATE, PENNS, and the south arrival fix of ROBBINSVILLE (RBV). Two radar controllers sequenced traffic from the west and north and either one or two controllers (depending on the particular scenario) vectored traffic to the 4L and 4R finals. In addition, to add realism to the study, overflight traffic bound for Teterboro Airport (TEB) and LaGuardia International Airport (LGA) entered the simulation from the south fix of YARDLEY (ARD).

Almost all traffic approaching RBV entered the simulation at 280 kts groundspeed, descending to 8000 ft Mean Sea Level (MSL). Two or three targets entered the simulation northeast or southeast of RBV at lower altitudes. CPCs normally vectored RBV traffic to intercept the 4R ILS, then descend to 4000 ft MSL. Currently at EWR, controllers typically vector RBV traffic westerly into headwinds, which reduces airspeeds for the 4R intercept. Because the simulation did not include wind effects, the CPCs vectored RBV traffic straight in to intercept 4R because aircraft speeds automatically decreased at the appropriate rates.

All other EWR traffic in the simulation entered the scenarios level at 8000 ft with 250 kts groundspeed and was sequenced to land on Runway 4L via the 4L LDA. Aircraft typically joined the 4L LDA level at 3000 ft MSL. Figure 2 depicts the simulated EWR traffic flows. NYACK and COATE are outside the range of the map, located further out in the north/northwest direction.

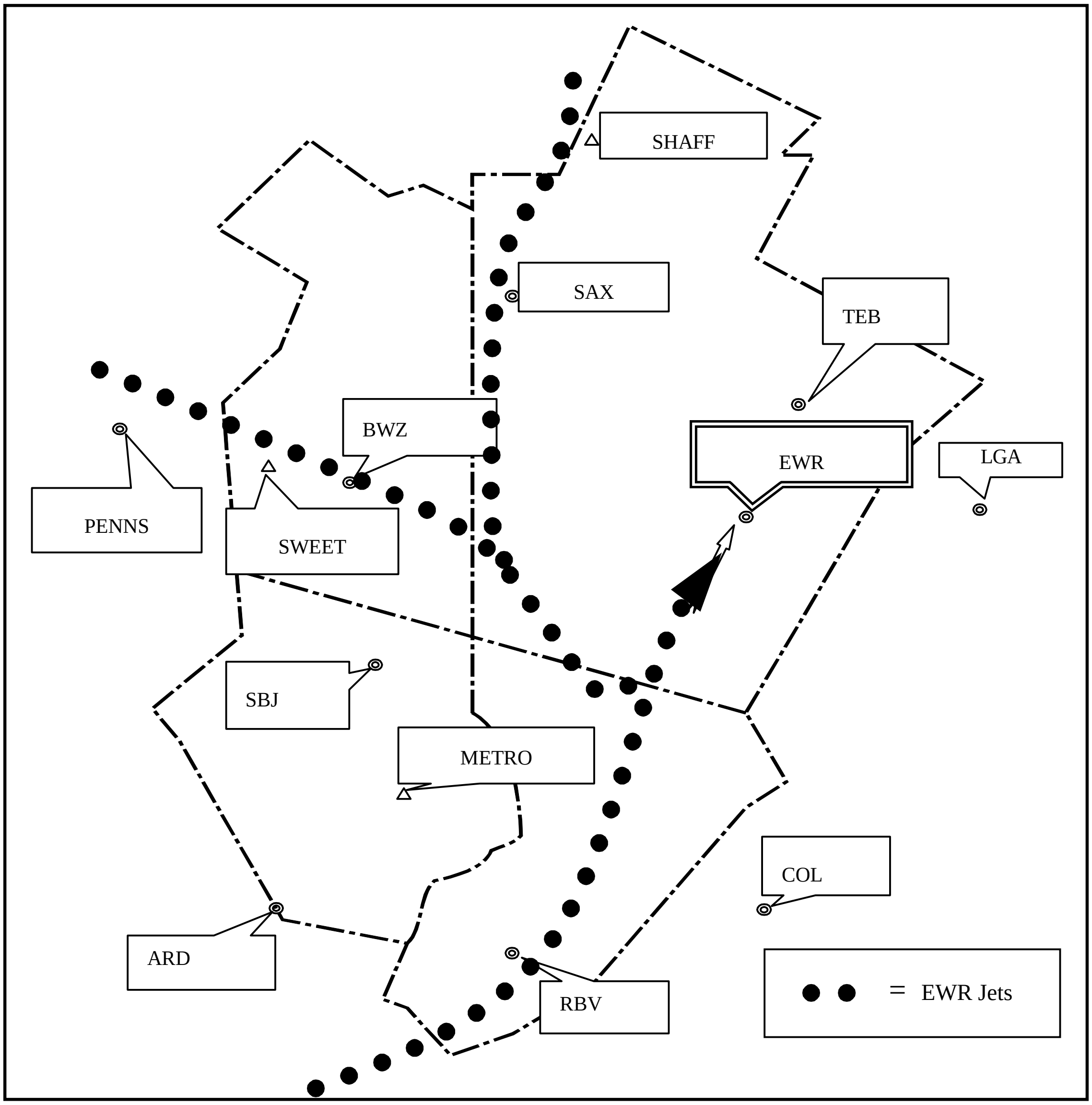


Figure 2. Simulated EWR arrival traffic flows.

The 4L LDA matched the location of the proposed SOIA LDA. The 4L LDA had a convergence angle of 3 degrees with the 4R ILS. At 3 nm from the airport, the distance between the 4L LDA and the 4R ILS was 3000 ft. The NTZ terminated at this point. The NTZ began at a point 12.8 nm from the airport. At this location, the distance between the ILS and LDA courses was about 6300 ft. The controllers' displays contained a single “x” mark on each final approach course to represent the beginning of the NTZ. A double “x” mark positioned 2 miles outside of the beginning of the NTZ served as a reference point for participants to establish aircraft on the final approach courses.

2.1.3 Controller Positions

The simulated controller positions included the following: North Feeder, Metro Feeder, 4R Final, and 4L Final. Every run included the North and Metro Feeders, and the 4R Final position. Only runs involving the split final SOIA operation included a 4L Final position (i.e., One 4R controller and one 4L controller).

2.2 Participants

2.2.1 Terminal Certified Professional Controllers

Five CPCs from the EWR New York TRACON participated in the study. Four CPCs were test participants only. One CPC was a simulation observer for most of the study but also acted as a controller in a few of the runs.

2.2.2 Orientation and Training

The participants had no prior experience with monitoring and controlling SOIA operations. They received a 1-hour orientation briefing on SOIA procedures prior to the test runs during which they had an opportunity to ask questions. In addition, each CPC participated in three hands-on training runs, which were each 1 hour in duration.

2.3 Procedure

For each run, the CPCs initially sequenced all RBV arrivals to Runway 4R. The North and Metro Feeder controllers vectored aircraft from all fixes except RBV. They fed the aircraft to either one 4R/4L final controller or two final controllers (i.e., one 4R controller and one 4L controller). The CPCs applied normal simultaneous approach sequencing to establish the two final arrival streams. They attempted to "pair" aircraft with a nominal 6 nm between the pairs initially, collapsing to 5 nm at the outer marker. Within the pairs, they had the ILS aircraft lead with the LDA aircraft in-trail by not more than 1.5 nm. The CPCs did not have to space aircraft exactly according to SOIA criteria because the PRM final monitor controllers would be responsible for that. This simulation did not include PRM controller positions. The CPCs, therefore, did not make adjustments to aircraft separation within the pairs after the aircraft were within the jurisdiction of the monitor controllers' airspace (i.e., past the beginning of the NTZ).

During the runs, the CPCs applied normal wake turbulence separation to aircraft in-trail and to aircraft on adjacent finals. Within the aircraft pairs, however, they could reduce separation down to 0.5 nm when the pairs consisted of any aircraft type behind a small or any type of aircraft but a small behind a large. They could not, however, pair B757s and/or heavy aircraft. In addition, aircraft on the 4L LDA had to trail the 4R aircraft in all pairs unless wake-turbulence criteria required the 4L aircraft to lead.

** *The purpose of this study was to see if controllers could vector aircraft within the existing airspace boundaries and space aircraft arrivals to allow for SOIA. A follow-on study would be necessary to evaluate the feasibility of SOIA arrivals all the way to the runway thresholds. A follow-on evaluation would consider missed approaches, breakout angles, and other issues.*

2.3.1 Daily Schedule

The simulation team conducted the study Monday through Thursday, August 14-17, 2000, from 8:30 am - 4:30 pm. They dedicated the first day to controller orientation and training. The researchers first briefed the participants on the simulation objectives, described in detail the SOIA procedure, and then allotted time for a question and answer period. The participants then went into the SDL and spent a few minutes getting familiar with the displays and the overall test environment. They participated in three 1-hour training runs over the course of an afternoon. Following each training run, an informal discussion session transpired during which participants provided feedback on simulation- and procedural-related issues.

The data-collection runs commenced on the second day of the simulation and continued for the duration of the study. Participants completed 11 runs: 4 runs on 9/15, 4 runs on 9/16, and 3 runs on 9/17. A questionnaire period and a debrief session followed each run. The simulation team reserved a longer period for the final debrief, which took place after the last run on 9/17.

2.3.2 Traffic Scenarios

The simulation team developed 11 traffic scenarios for the study that consisted of two training scenarios and nine test scenarios.

2.3.2.1 Training Scenarios

The training scenarios contained 35 EWR arrivals for a 65-minute period (75% traffic volume as compared to present-day EWR operational statistics). The researchers modified aircraft call signs to create two different training scenarios. During the training scenarios, the CPCs gained experience with SOIA and had an opportunity to ask questions about the procedures.

2.3.2.2 Testing Scenarios

The researchers divided the test scenarios into three types: baseline, SOIA-1, and SOIA-2. The baseline scenario provided a basis for comparison for the proposed SOIA operations. In the baseline scenario, the CPCs worked traffic like they presently do at EWR, to Runway 4R. That is, they vectored all aircraft arrivals from the various fixes to 4R. Although departures were not simulated, the non-use of Runway 4L for arrivals signified departures were occurring on that runway. The CPCs occupied three positions during baseline runs: North Feeder, Metro Feeder, and 4R Final.

The baseline scenario consisted of 50 arrivals and 2 overflights for a 65-minute period. With 50 arrivals, the traffic represented 100% volume (based on present-day EWR operational statistics).

Of these arrivals, approximately 25 aircraft were jets sequenced over RBV. The remaining arrivals originated from all other fixes and less than 10 of these aircraft were turboprops. The researchers modified the aircraft call signs and types to create three different baseline scenarios.

The researchers developed the SOIA-1 scenario to see if SOIA could be run with one controller working arrivals to both Runways 4L and 4R. Thus, SOIA-1 involved three controller positions: North Feeder, Metro Feeder, and 4L/4R Final.

The SOIA-1 scenario consisted of 50 arrivals and 2 overflights for the 65-minute period (100% volume). It was identical to the baseline scenario with regards to volume and traffic mix. The only difference was the implementation of the SOIA procedure and thus the pairing of aircraft. The researchers modified the aircraft call signs and types to create three different SOIA-1 scenarios.

The SOIA-2 scenario added another controller position to see if SOIA could be run with one controller working Runway 4R and a separate controller working Runway 4L. Therefore, SOIA-2 scenarios involved four controller positions: North Feeder, Metro Feeder, 4R Final, and 4L Final.

The SOIA-2 scenario consisted of 73 arrivals and 2 overflights, or 150% traffic volume, for the 65-minute period. Of these arrivals, approximately 28 aircraft were jets sequenced over RBV. The remaining aircraft originated from all other fixes and less than 10 of these were turboprops. The researchers modified the aircraft call signs and types to create three different SOIA-2 scenarios.

** *As will be discussed in later sections, participants found that the 150% scenarios were extremely workload intensive. As a result, all three SOIA-2 (150%) scenarios were modified to create three 125% traffic-load scenarios. The researchers deleted the same number and types of aircraft (based on identical start times into the scenarios) in each SOIA-2 (150%) scenario to create three SOIA-2 (125%) scenarios.*

2.4 Data Collection

2.4.1 Questionnaires

Consent Form - Prior to the start of the study, researchers gave the participants Consent Forms to read and sign. The forms addressed the nature of the study and the expectations of the researchers. The participants provided signatures acknowledging their consent to participate in the study with the right to withdraw at any time. Appendix A contains a Participant Consent Form.

Background Questionnaires - Participants provided information related to their operational experience on Background Questionnaires. They completed these questionnaires prior to the training scenario. Appendix B includes a sample Background Questionnaire.

Post-Run Questionnaires - Participants completed Post-Run Questionnaires at the conclusion of each of the 11 test runs in which they rated their overall workload (physical and mental) during the run. The questionnaire asked them to rate the workload associated with monitoring, planning, vectoring, speed adjustments, and ground-to-air communications. It also asked the participants to rate the realism of the simulated traffic.

If the run involved SOIA operations, the participants indicated whether SOIA was feasible in the existing airspace without compromising airspace and/or procedural restrictions. They also described any difficulties they experienced with SOIA during the run. Finally, they indicated whether the SOIA procedure affected their workload. A Post-Run Questionnaire is contained in Appendix C.

Post-Simulation Questionnaires - Participants completed Post-Simulation Questionnaires at the end of the 4-day study. The questionnaire had a short-answer format. It asked participants questions related to the feasibility of conducting SOIA operations at EWR. If participants believed SOIA was not feasible, they stated what changes to airspace, decision support tools, sector staffing, and/or procedures would make it feasible. The questionnaire also asked the participants to describe the effect of SOIA on their workload.

With respect to the simulation conduct, the questionnaire asked the participants if they received adequate training on SOIA prior to the test runs. It also asked them to rate the realism of the traffic scenarios as compared to actual EWR traffic operations. A Post-Simulation Questionnaire is contained in Appendix D.

2.4.2 Workload Assessment Keyboard

During the traffic scenarios, participants provided real-time ratings of workload using a Workload Assessment Keyboard (WAK). The keypads contained numbers ranging from 1 to 7 that automatically illuminated and sounded tones at 5-minute intervals, prompting the participants for responses. A rating of 1 corresponded to the lowest workload rating and 7 corresponded to the highest workload rating. If the participant did not enter a rating within 20 seconds of the prompt, the keypad lights extinguished and a rating of "99" was automatically entered. That rating assumed the participant was too busy to enter a rating.

2.4.3 Debrief Sessions

The researchers conducted an informal debrief session at the end of each run in which they posed questions to the study participants and recorded their responses with a tape recorder. All participants were encouraged to offer their opinions on maneuvering aircraft in the airspace to allow for SOIA and its impact on capacity, safety, and controller workload. On the last day of the study, the researchers led an end-of-simulation debrief during which participants offered their final concluding remarks and recommendations on SOIA at EWR.

2.4.4 Simulation Observer Logs

The simulation observers recorded during-the-run events, such as airspace violations and procedural errors, on observer logs. They provided their opinions and observations regarding aircraft pairing, workload, and SOIA in general to be used in conjunction with other data to evaluate the study. An Observer During-the-Run Form is contained in Appendix E.

2.4.5 Researcher Documentation

The researchers recorded objective data during each run including the number of aircraft pairings, except for in the baseline scenario, and the number of arrivals to each runway (counted when aircraft passed the outer marker). Using this information, the researchers computed the arrival rates-per-hour.

2.4.6 Audio and Video Recordings

The researchers collected video and audio data for all simulation runs. The video data included two views of the EWR SOIA operation. Researchers used a scan converter to change the digitally formatted display information into video, and recorded it on S-VHS videotapes. The audio data included air-to-ground voice communications for all control positions. The researchers collected video and audio data to supplement the subjective and objective data, not to use for separate analyses.

2.5 Data Analysis

This simulation was an initial feasibility study. For an airport to be able to perform SOIA, it must have sufficient airspace geometry and traffic-flow patterns to allow aircraft to be positioned to do SOIA. Therefore, the first step in the evaluation process for EWR was to determine if SOIA was feasible within EWR's current airspace and with its current arrival flows.

To make those determinations, the sponsors of the study agreed that the simulated procedure should be assessed by the participating CPCs, OSs, and observer/subject matter experts. The simulation team collected objective data from other sources to supplement the subjective assessments (e.g., number of aircraft pairings and number of arrivals to each runway), but because of the participants' intrinsic familiarity with N90/EWR operations, their opinions of the procedure were considered the basis of this initial evaluation.

Due to the exploratory nature of the study and small sample size, the researchers did not perform any inferential statistical analyses. However, they reported descriptive statistics such as means, standard deviations, and maximum/minimum values as appropriate.

In order to provide an opportunity for all participants to execute the SOIA procedure, the controllers rotated through each of the four simulated positions (i.e., Metro, Feeder, 4R, and 4L) across the different scenarios. This scheme provided SOIA familiarity to all controllers. However, it restricted the experimenters' ability to make comparisons across the scenarios because both participant controllers and scenarios changed simultaneously.

3. Results

3.1 Constraints and Limitations of the Study

Because the simulation team had rather short notice to prepare the SOIA test, they did not have sufficient time to develop data reduction software to capture some important pieces of data. As such, in examining the simulation results, one should consider the following data constraints and limitations of the study. Further studies should include these data for a more comprehensive analysis.

a. *No separation violation data*. The researchers did not have the means of objectively evaluating the separation adequacy between aircraft throughout the test scenarios. This would have been an important piece of objective data because it provides an understanding of the effect and adequacy of pairing and the ability to maintain aircraft separation during the pairing process.

b. *No departure spacing data*. Although controllers were briefed to build in gaps for departures, the researchers did not collect data to validate that they were able to provide such departure gaps and how often. This would have been useful data because if airports ever implement SOIA, controllers will have to build in room between aircraft pairs to allow for departures.

c. *No separation data within and between aircraft pairs*. The researchers did not collect data to allow for the analysis of separation requirements within and between aircraft pairs. These data would have shown if CPCs organized the pairs in a manner that satisfied all SOIA criteria, particularly the wake-vortex separation criteria.

3.2 Procedural Considerations

3.2.1 Aircraft Pairing

The SOIA procedure calls for the pairing of aircraft on adjacent localizers in order to gain the maximum capacity benefit. As with any operation, CPCs must apply proper wake-vortex separation at all times. With SOIA, CPCs must consider all wake separation restrictions with respect to what aircraft they can and cannot pair. The test participants indicated that the pairing of aircraft in this study involved considerable vectoring and monitoring, which contributed to increased workload, particularly during busy times. It should be noted, though, that the participants had no experience with SOIA procedures prior to this study and had a considerable amount of information to process with respect to SOIA restrictions. In addition, EWR controllers typically sequence aircraft in-trail with their current operations, therefore pairing aircraft required a different type of control strategy than that which they were accustomed. Participants indicated that with practice and training, the pairing process might become easier.

Table 1 provides a summary of the data related to the number of aircraft pairs and the number of arrivals resulting in each run. For purposes of the simulation, the researchers defined a pair as two aircraft on separate final approaches separated longitudinally by approximately 1.5 nm at the time they crossed the outer marker. The simulation observer recorded the number of pairs based

Table 1. Number of Arrivals and Aircraft Pairings by Run

Run	Scenario identifier	Scenario description	Split final (Y/N)	Duration of run	Number of arrivals (estimated hourly rate)	Number of heavy aircraft (including B757s)	Number of pairs	Number of pairs with 4R aircraft leading	Average time between pairs
1	7	Baseline (no SOIA)	N	0:50:31	39 (45)	7	N/A	N/A	N/A
2	2	SOIA-1	N	0:51:21	43 (49)	7	8	5	0:00:17
3	6	SOIA-2 (150%)	Y	0:56:10	53 (55)	13	15	7	0:00:18
4	3	SOIA-2 (150%)	Y	0:26:05	25 (55)	5	5	2	0:00:11
5	8	SOIA-1	N	0:48:50	39 (47)	12	12	7	0:00:27
6	5	SOIA-1	N	0:50:45	40 (47)	12	5	2	0:00:17
7	3	SOIA-2 (125%)	Y	0:44:10	43 (57)	11	12	7	0:00:18
8	9	SOIA-2 (125%)	Y	0:32:26	28 (50)	7	3	0	0:00:22
9	6	SOIA-2 (125%)	Y	0:50:59	47 (55)	12	8	4	0:00:11
10	8	SOIA-1	N	0:46:47	38 (48)	10	5	2	0:00:16
11		SOIA 2 (150%)	Y	0:52:00	65 (75)	No heavy aircraft	22	11	0:00:10

on what he/she saw on the radar display, not based on actual aircraft separation data. Also, some participants took the opportunity to pair aircraft more often than others. This must be taken into account when reviewing the number of aircraft pairs per run.

An examination of the baseline (i.e., arrivals to 4R only and no SOIA procedure) and SOIA-1 runs indicates that the arrival rate-per-hour was higher in all SOIA-1 runs (49, 47, 47, and 48) as compared with the baseline run (45). Although these results indicate some promise, one must treat them with caution because the simulation team only conducted one baseline run.

When the CPCs participated in the SOIA-2 (150%) scenarios, they remarked that the traffic load was too workload intensive (EWR arrival rate of 73 aircraft per 65-minute period). Therefore, after two presentations, the simulation team modified the scenarios to have 125% traffic volume. Although the CPCs did pair a considerable number of aircraft during the 150% scenarios, they did not always maintain minimum separation within and between the aircraft pairs. This could have been attributed to the very high traffic volume and the unfamiliarity with the pairing process. The SOIA-2 (150%) runs did not provide any meaningful insight into the ability to pair aircraft with respect to maintaining adequate separation throughout the procedure. The SOIA-2 (125%) scenario consisted of approximately 62 aircraft with the same distribution of aircraft over the fixes as the other scenarios.

For the last run of the simulation, the SOIA-2 (150%) scenario was revisited. This time, however, the CPCs assumed there were no heavy aircraft in the mix. This approach demonstrated that in the absence of heavy aircraft (thus fewer wake-vortex considerations), the CPCs did have an easier time setting up aircraft pairs. Again, the researchers did not objectively measure separation, but the CPCs did set up the greatest number of SOIA pairs during that final run. In addition, just before the last scenario on the last day of the study, the CPCs decided to run an SOIA scenario assuming no heavy aircraft in the traffic mix. The idea to run such a scenario evolved from observations the simulation team made over the course of the study. Had the researchers anticipated this scenario at the beginning of the study, they would have conducted a baseline scenario with no heavy aircraft to provide a comparison of SOIA with current operations. The resultant SOIA-no heavy aircraft-scenario data, must, therefore, be interpreted carefully.

The SOIA-2 (125%) run results indicated higher arrival rates per hour (57, 50, and 55) than the SOIA-1 and baseline runs. Again, though, it is important to note that the researchers could not determine if the aircraft pairing separation distances were appropriate. In addition, they did not assess the adequacy of gaps for departures.

3.2.2 Aircraft Mix

The results presented in Table 1 indicate that CPCs were able to pair aircraft in the SOIA scenarios. The highest number of pairings (22 pairs) occurred in one SOIA scenario where CPCs assumed there were no heavy aircraft in the traffic mix. This indicates that one of the considerations (possibly a difficulty) with pairing is the presence of heavy aircraft and the subsequent wake-turbulence separation criteria. For instance, heavies cannot be the leading aircraft in a pair. Also, two heavies cannot be paired together. Heavy aircraft can, however, be paired with large and small aircraft as long as the heavy is the trailing aircraft. Controller subjective comments reinforced the notion that they experienced difficulty in accommodating heavy aircraft and the corresponding separation minima in the pairing process.

3.2.3 Wake-Vortex Separation

CPCs applied standard wake-vortex separation to all aircraft. For aircraft that were paired, they applied additional wake restrictions. Specifically, any aircraft could follow a small aircraft. Any aircraft but a small could follow a large aircraft. As previously discussed, the SOIA procedure does not allow heavy aircraft to be paired, which presented a problem for controllers when heavy aircraft arrived from RBV. CPCs had limited time and limited airspace to orchestrate acceptable pairings with those aircraft.

3.2.4 Controller and Sector Positions

The simulation team explored two controller/sector assignment schemes. Under the first scheme, the 4R and 4L finals were split and the 4L controller performed the pairings. This required close coordination with the 4R controller who was feeding aircraft to Runway 4R. The coordination involved ensuring that the 4R final controller was aware of the aircraft pairs being arranged.

Under the second scheme, one controller handled both finals. This scheme seemed to reduce the necessary amount of coordination and eased the pairing process for some of the final controllers.

During the SOIA conditions, the straight-in RBV flow to Runway 4R dictated the sequencing for both runways. All sequencing decisions required considerable coordination between the 4R and 4L controllers (when running the split final configuration). Furthermore, any changes in controller "plans," such as switching runway assignments, were complicated by the fact that the runways were separated by only 900 ft and aircraft altitude changes were required. In the operational environment, this situation may also be a challenge for pilots who would need to make last minute Flight Management System (FMS) changes.

3.2.5 Training

Controllers indicated that training would be an important consideration if airports implemented SOIA procedures. Familiarity with the SOIA procedures may decrease workload as compared to workload experienced in this study.

3.3 Airspace Considerations

Under current operations at EWR, controllers primarily use Runway 4R for arrivals and Runway 4L for departures. The airspace configuration and corresponding procedures require traffic from Washington Air Route Traffic Control Center (ARTCC) to cross over RBV at 10,000 ft. This flow must maintain separation with crossing traffic from the west, which is at 7,000 ft on approach to LGA. The RBV flow must reduce airspeed and descend for a Runway 4R approach. Tailwinds from the south, however, generally prevent a straight-in final. EWR controllers typically vector RBV traffic to the west in order to allow aircraft to make proper speed and altitude adjustments before sequencing them with the Metro flow. Controllers must separate the traffic flow from Boston ARTCC from TEB arrivals and EWR departures on Runway 22L. Then, the aircraft descend and are sequenced with arrivals from the south.

Because this study was an initial examination of the feasibility of the dual-feed SOIA concept, the simulation team did not incorporate all routine airspace operations and procedures. For example, the participants were feeder and final controllers, not departure controllers. To compensate for the lack of departure control positions, the CPCs built in the necessary spacing requirements to assume that departures occurred on Runway 4L in-between aircraft arrivals. Departing aircraft, however, did not actually appear on the displays. The simulation team recognized that the presence of visible departures, along with other operations and key personnel (e.g., missed approaches and tower controllers), would need to be included in later feasibility studies.

To allow for SOIA operations, the CPCs had to implement certain changes to the way traffic flowed within the current airspace configuration. This is not surprising, considering the SOIA procedure called for dual, precisely-paired arrivals in an airspace accustomed to in-trail arrival traffic only. In the SOIA scenarios, the 4R controller vectored aircraft straight in to the 4R final from RBV. Due to simulation limitations, with respect to aircraft performance and the lack of simulated tail winds, the 4R controller was usually able to simultaneously slow and descend the RBV arrivals without using vectors. Since the RBV flow was generally straight in, this impacted the controllers' pairing options. The steady RBV 4R arrival stream and the reduced airspace for vectoring to the west generally established the 4R aircraft on final. The controller had to pair from the west using the sequence of the RBV arrivals. He had limited flexibility due to traffic to the west that he had to vector more south than usual. Those aircraft had to be established on the ILS prior to the beginning of the NTZ for SOIA. Unless the CPCs were able to sequence single aircraft (i.e., aircraft not paired) above this zone, it pushed the vectoring airspace further south.

A few times, CPCs reported violating another sector's airspace in an effort to vector aircraft and establish pairs. They also expressed concern that under normal wind conditions, and the normal space that aircraft over RBV would need to slow and descend, the reduced amount of airspace available for vectoring would dramatically increase the difficulty of the procedure. The participants remarked that if the RBV and ARD arrival flows were transposed, traffic flows from Washington and Boston ARTCC could be merged and sequenced in the feeder sectors prior to hand-off to the final control positions. This would allow for more time and airspace for planning. In addition, LGA arrivals would be further south and would be less of a crossing consideration for EWR traffic.

Controller feedback from the simulation questionnaires and debriefs indicated that *with the current airspace and traffic flow patterns,* the SOIA procedure holds no promise or, at best, has a very limited application. The airspace is too restricted with the current arrival flows and with the need to vector the north traffic flow further down the runway to establish traffic on the LDA outside of the NTZ. The simulated SOIA procedures pushed the traffic flow further south and transferred the sequencing responsibilities to the 4R and 4L controllers instead of with the feeder positions.

However, SOIA operations may be feasible with some procedural changes, airspace changes, and traffic flow redesign. For instance, if the traffic flows were modified such that RBV would feed aircraft to LGA and ARD would feed aircraft to EWR, the SOIA procedure might be viable. The result of such a redesign would allow controllers to pair aircraft earlier, possibly as early as within Metro airspace, making the SOIA procedure manageable.

3.4 Controller Workload

3.4.1 Post-Run Questionnaire

The Post-Run Questionnaire asked the CPCs to provide ratings on a 1-7 scale (1 = very low, 4 = moderate, and 7 = very high) for overall workload for each run, and more specifically, workload associated with monitoring, planning, vectoring, speed adjustments, and ground-to-air communications. The descriptive statistics (e.g., mean, standard deviation, maximum and minimum) resulting from these ratings are provided in the Appendix F.

These results must be treated with caution because of the limited sample size. Furthermore, each scenario had a different sample size (e.g., the simulation team conducted a baseline only once, whereas, they performed SOIA-2 (125%) three times). The researchers did not perform inferential statistical tests on the data due to the limited sample size. It is, therefore, difficult to state if the mean differences were statistically significant (and therefore truly different) or not.

The general trend of the questionnaire data indicated a higher workload with SOIA-2 (125%) and SOIA-2 (150%) scenarios for all controller positions (i.e., Metro feeder, North feeder, 4R Final, and 4L Final). This could be due to the increased traffic levels (higher arrival rates) and limited airspace in which to work, SOIA's pairing process, and/or the lack of proficiency with the SOIA procedure.

3.4.2 Workload Assessment Keypad Ratings

The WAK rating averages indicated that the 4R final and 4L final positions experienced considerably more workload than the Metro feeder and North feeder positions. Although the researchers did not perform inferential tests to detect statistical differences, graphs of the data (provided in Appendix G) indicate such a trend.

The researchers examined the ratings of scenarios that involved SOIA procedures to see if they resulted in higher workload ratings as compared to the baseline scenario. The figures in Appendix G indicate that the SOIA scenarios resulted in consistently higher workload ratings, particularly for the final controllers, as compared to the baseline scenario. Once again, these results cannot be stated conclusively because of the sample size restrictions (unequal and limited).

4. Discussion

4.1 Benefits of SOIA

The arrival rates appeared to be higher when SOIA operations were in effect. However, because the researchers did not determine the number of separation violations, they cannot empirically validate this observation. A few CPCs indicated that when they were able to pair aircraft, they were able to shorten the flying distances for the aircraft on approach to Runway 4L. This is so because those aircraft that were not going to be part of a pair could be turned onto the 4L final sooner and at a shorter distance to the runway.

4.2 Recommendations for Further Evaluation

This first real-time HITL simulation of SOIA highlighted a number of issues that require further investigation. These include EWR airspace and traffic flow redesign alternatives and subsequent impacts on SOIA operations, the effect of SOIA traffic mixes on controller workload, the number of and specific controller positions required to execute SOIA to 4R and 4L, the role of departures, the impact of SOIA on breakout procedures and missed approaches, and the need for controller training. Further research should investigate the impact of such issues.

4.2.1 Airspace Considerations

Debriefing comments and questionnaire responses from participants indicated that the SOIA procedure might hold some promise if the EWR airspace and traffic flows are modified. A follow-on study should consider the implications of redesigned airspace and traffic flows (most significantly, switching the ARD and RBV flows).

4.2.2 Aircraft Mix Considerations

Participant feedback clearly indicated a concern over the presence of heavy aircraft and their impact on the controllers' ability to pair and sequence aircraft efficiently on the final and with enough airspace to maneuver them. Strategies to incorporate heavies into the procedure more effectively should be explored.

4.2.3 Controller/Sector Positions

Whether SOIA requires one 4R/4L final controller position or a split final (i.e., one 4R controller and one 4L controller) needs to be further explored. This is so because participant opinions differed and there was no unanimous preference for one option over the other.

4.2.4 Breakouts and Missed Approaches

Regardless of any proposed airspace changes at EWR that could potentially enable an SOIA operation, how the aircraft will execute breakouts or missed approaches when separation is compromised must be addressed. Any procedural changes would have to be devised within the NY TRACON and include the John F. Kennedy and LGA areas.

4.2.5 Other Considerations

Simulation limitations affected traffic realism. The simulated aircraft performed to optimal capabilities with quick turns and descent rates, which is not always the case in the operational environment. In addition, because winds were not factored into the simulation, the study did not accurately represent some of the typical tailwinds experienced at EWR. All controllers indicated that the training runs before the study were adequate. Concerning the traffic scenario adequacy, both feeder positions indicated that they had very little to do during all runs and indicated low workloads.

This preliminary feasibility investigation did not examine the decision aid needs of controllers. A follow-on study could identify areas where support tools would be beneficial to controllers to facilitate the SOIA procedure (e.g., ghosting targets to facilitate aircraft pairing).

5. Conclusions

The subjective feedback from participating controllers indicated that *the SOIA procedure is not feasible within the current EWR airspace configuration*. The participants recognized the potential benefits of SOIA operations, however, the present airspace and traffic flows, particularly the ARD and RBV flows, are not favorable for effectively running dual stream 'paired' arrivals. If the ARD and RBV flows could be flip-flopped, the procedure may be able to provide the benefits for which it was intended. A follow-on study should be conducted to investigate the effects of such proposed modifications.

Appendix A

Consent Form

EWR PRM SOIA STUDY

PARTICIPANT CONSENT FORM

I, ______________________________, understand that the Federal Aviation Administration's (FAA's) Air Traffic Procedures (ATP-100) organization and the William J. Hughes Technical Center's (WJHTC's) NAS Advanced Concepts Branch (ACT-540) sponsor and direct this study, entitled *Simultaneous Offset Instrument Approaches (SOIA) at EWR.*

I. <u>Nature and Purpose</u>

I agree to volunteer as a participant in the study cited above. I understand the purpose of *SOIA at EWR* is to determine whether or not SOIA can be conducted within the existing airspace configuration at EWR. If the procedure is determined to not be feasible within the existing airspace, I will make recommendations/suggestions with respect to airspace, procedural, and/or route changes that would enable a successful SOIA operation. I will also identify potential impacts of such changes on EWR and the surrounding airspace.

II. <u>Participant Responsibilities</u>

The study will emulate operational air traffic conditions in the Terminal Radar Approach Control (TRACON) environment at EWR. I will monitor and control aircraft arrivals to EWR as I would in the field. I will provide workload ratings when prompted and complete questionnaires after each scenario and at the completion of the simulation.

III. <u>Discomforts and Risks</u>

There are no expected discomforts or risks associated with this experiment.

IV. <u>Participant Assurances</u>

I understand that my participation in this study is completely voluntary. I understand that if new findings develop during the course of this research that may relate to my decision to continue to participation, I will be informed. I understand that I can withdraw from the study at any time without penalty or loss of benefits to which I may be entitled. I also understand that the researcher of this study may terminate my participation if he/she feels this to be in my best interest.

I understand that records of this study are strictly confidential, and that I will not be identifiable by name or description in any reports or publications about this study. Video and audio recordings are for use within the WJHTC only. Any of the materials that may identify me as a participant cannot be used for purposes other than internal to the WJHTC without my written permission.

I have read this consent document. I understand its contents, and I freely consent to participate in this study under the conditions described. I have received a copy of this consent form.

Research Participant: ___________________________Date: ____________

Appendix B

Background Questionnaire

Simultaneous Offset Instrument Approaches (SOIA) at EWR

August 14-17, 2000

Background Information Form

Role (circle one): Controller Observer Participant ID: _______________

1. How many years of experience do you have as an Air Traffic Control Specialist (include FAA and military experience)? ___________________ years

2. How long have you worked as a TRACON controller? ___________________ years

3. List the TRACON facilities in which you have worked.

   ____

4. How long have you worked at EWR? ___________________ years

5. Do you have any experience monitoring simultaneous approach operations? If yes, how many years of experience and at what facilities?

   ___________________ years

   Facilities: ____

6. If you are not an EWR controller, please indicate your current job title, place of employment, and years of experience in that position.

   Title: ____

   Place: ____

   _________________ years

This form is to be completed by all SOIA controller and observer participants. This form requests general background information. Your name will not be listed or appear in any reports to ensure anonymity and to encourage unbiased reporting. Findings will be reported generically (e.g., Controller or Observer A, B, C, etc.).

Thank you for your participation! ☺

Appendix C

Controller Post-Run Questionnaire

Simultaneous Offset Instrument Approaches (SOIA) at EWR
August 14-17, 2000
Controller Post-Run Questionnaire

Run Number:	____________	**Scenario:**	TC Use Only:
Participant ID:	____________	**Position:**	____________
Date:	____________		

1. **Rate your *overall workload* level (physical and mental) during this run.**

1	2	3	4	5	6	7
Very Low			Moderate			Very High

2. **Rate the workload for each the following factors associated with *maintaining aircraft separation* during this run*:***

   a) **Monitoring**

1	2	3	4	5	6	7
Very Low			Moderate			Very High

   b) **Planning**

1	2	3	4	5	6	7
Very Low			Moderate			Very High

   c) **Vectoring**

1	2	3	4	5	6	7
Very Low			Moderate			Very High

   d) **Speed Adjustments**

1	2	3	4	5	6	7
Very Low			Moderate			Very High

Comments/Additional factors contributing to workload: ____________________

____

over →

3. Rate the workload associated with *ground-to-air communications* during this run.

1	2	3	4	5	6	7
Very Low			Moderate			Very High

Comments:

4. Rate the *realism of the traffic* in this run.

1	2	3	4	5	6	7
Very Unrealistic			Moderate			Very Realistic

Comments:

5. Did this run involve the SOIA procedure? YES NO

If NO, stop here. If YES, continue with the following questions.

6. Was the SOIA procedure feasible in your airspace without compromising airspace and/or procedural restrictions during this run? YES NO

If your answer is NO, please explain how, if at all, it could be feasible.

7. What difficulties, if any, did you experience in using the SOIA procedure in this run?

Comments:

8. How was your workload affected, if at all, by the SOIA procedure in this run?

Comments:

Appendix D

Controller Post-Simulation Questionnaire

Simultaneous Offset Instrument Approaches (SOIA) at EWR
August 14-17, 2000
Controller and Observer Post-Simulation Questionnaire

Participant ID: ____________________ **Date:** ______________________

1. Is the SOIA procedure, as simulated, feasible at EWR? YES NO
   If NO, please explain.

____
____
____
____
____
____

2. If the SOIA procedure is not feasible, what changes do you recommend in airspace, decision support tools, sector staffing, and/or procedures to make it feasible?

____
____
____
____
____
____

3. Describe the effect of the SOIA procedure on controller workload.

____
____
____
____
____
____

→ over

4. Did you receive adequate training on the SOIA procedure prior to the test runs?
   YES NO If NO, please explain.

5. How realistic were the simulation traffic scenarios as compared to actual EWR traffic?

1	2	3	4	5	6	7
Very Unrealistic			Moderately Realistic			Very Realistic

If your response is any other than 7, please explain.

6. Please provide any additional comments and/or observations related to the SOIA procedure, its feasibility, the simulation realism, or any other issue.

Comments:

Thank you for your participation! ☺

Appendix E

Observer During-the-Run Form

Simultaneous Offset Instrument Approaches (SOIA) at EWR
August 14-17, 2000
Observer During-the-Run Form

Scenario: _______ **Position** ________ **Run #** _____ **Observer ID** _______

Please record airspace violations, procedural errors, separation violations, and any other observations (good and bad), related to, for e.g., aircraft pairing, missed approaches, communications, workload, simulation problems, etc. Please use multiple pages, if needed.

Sim Time	Aircraft ID(s)	Description of *Airspace Violation* (location and reason)
Sim Time	**Aircraft ID(s)**	**Description of *Procedural Error* (location and reason)**

Sim Time	Aircraft ID(s)	Description of *Separation Violation* (location and reason)
Sim Time	**Aircraft ID(s)**	**Description of *Other Observation***

Appendix F

Post-Run Questionnaire Responses

**For all questions, 1 to 7 = lowest to highest workload*

Q1. Rate your overall workload level (physical and mental) during this run.

	NORTH FEEDER	**METRO FEEDER**	**4R FINAL**	**4L FINAL**
B *N*=1	1	1	4	*N/a*
S-1 *N*=4	*M*=1.50 *SD*=1.00 *Min*=1 *Max*=3	*M*=1.00 *SD*=0 *Min*/*Max*=1	*M*=2.5 *SD*=1.29 *Min*=1 *Max*=4	*N/a*
S-2(125%) *N*=2	*M*=2.00 *SD*=1.41 *Min*=1 *Max*=3	*M*=1.00 *SD*=0 *Min*/*Max*=1	*M*=5.00 *SD*=0 *Min*/*Max*=5	*M*=4.00 *SD*=1.41 *Min*=3 *Max*=5
S-2 (150%) *N*=3	*M*=2.33 *SD*=1.53 *Min*=1 *Max*=4	*M*=1.67 *SD*=1.15 *Min*=1 *Max*=3	*M*=5.00 *SD*=1.00 *Min*=4 *Max*=6	*M*=5.00 *SD*=3.46 *Min*=1 *Max*=7
150% No heavy aircraft *N*=1	5	1	4	4

Q2. Rate the workload for each of the following factors associated with maintaining aircraft separation during this run:
***A) Monitoring*.**

	NORTH FEEDER	**METRO FEEDER**	**4R FINAL**	**4L FINAL**
B *N*=1	1	1	3	*N/a*
S-1 *N*=4	*M*=1.5 *SD*=1 *Min*=1 *Max*=3	*M*=1 *SD*=0 *Min*/*Max* =1	*M*=2.5 *SD*=0.96 *Min*=1 *Max*=3	*N/a*
S-2(125%) *N*=2	*M*=1.50 *SD*=0.71 *Min*=1 *Max*=2	*M*=1.00 *SD*=0 *Min*/*Max*=1	*M*=5.00 *SD*=0 *Min*/*Max*=5	*M*=4.00 *SD*=1.41 *Min*=3 *Max*=5
S-2 (150%) *N*=3	*M*=3.33 *SD*=3.21 *Min*=1 *Max*=7	*M*=2.00 SD1.00 *Min*=1 *Max*=3	*M*=5.33 *SD*=1.15 *Min*=4 *Max*=6	*M*=5.00 *SD*=2.46 *Min*=1 *Max*=7
150% No heavy aircraft *N*=1	5	1	5	5

B) Planning.

	NORTH FEEDER	**METRO FEEDER**	**4R FINAL**	**4L FINAL**
B *N*=1	1	1	4	*N/a*
S-1 *N*=4	*M*=1.5 *SD*=1 *Min*=1 *Max*=3	*M*=1 *SD*=0 *Min*/*Max*=1	*M*=2.5 *SD*=1 *Min*=1 *Max*=3	*N/a*
S-2(125%) *N*=2	*M*=2.00 *SD*=1.41	*M*=1.00 *SD*=0	*M*=6.00 *SD*=1.41	*M*=4.50 *SD*=2.12

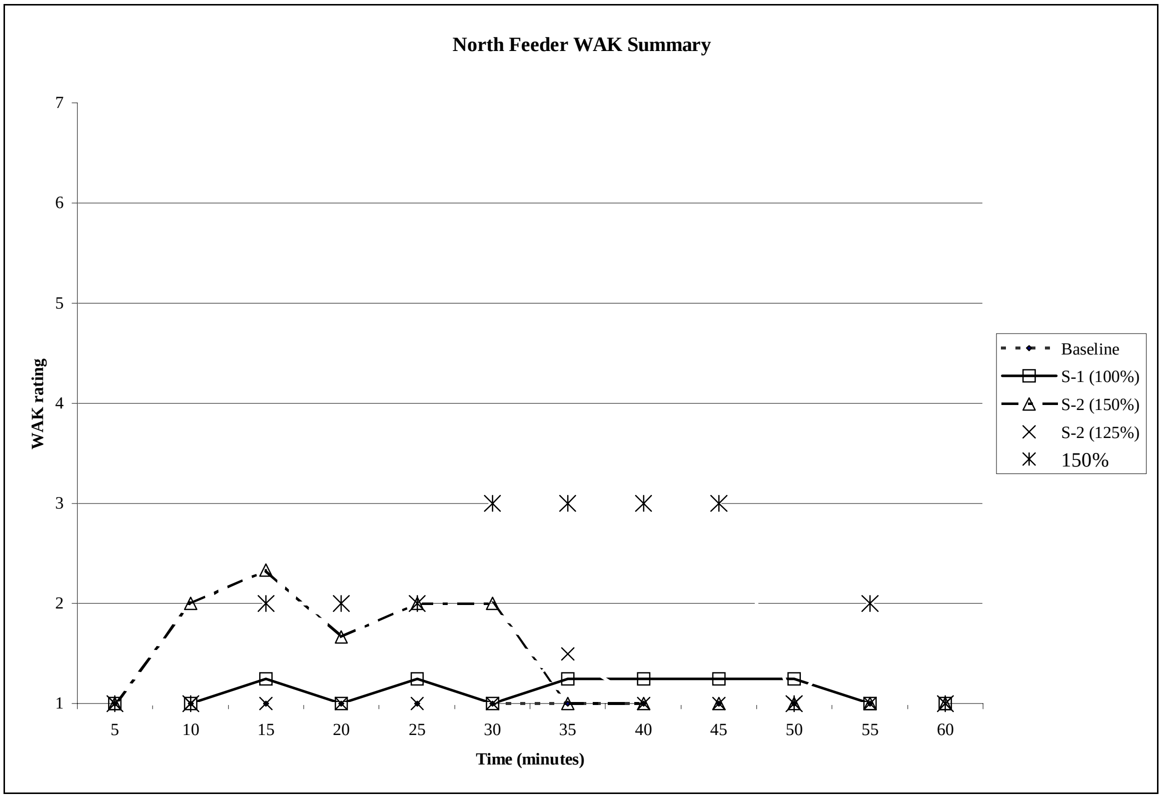
	Min=1 *Max*=3	*Min*/*Max*=1	*Min*=5 *Max*=7	*Min*=3 *Max*=6
S-2 (150%) *N*=3	*M*=3.33 *SD*=3.21 *Min*=1 *Max*=7	*M*=2.00 *SD*=1.00 *Min*=1 *Max*=3	*M*=5.00 *SD*=1.41 *Min*=4 *Max*=6	*M*=5.00 *SD*=2.65 *Min*=2 *Max*=7
150% No heavy aircraft *N*=1	5	1	5	5
C) Vectoring.				
	NORTH FEEDER	**METRO FEEDER**	**4R FINAL**	**4L FINAL**
B *N*=1	1	1	4	*N/a*
S-1 *N*=4	*M*=1.5 *SD*=1 *Min*=1 *Max*=3	*M*=1 *SD*=0 *Min*/*Max* = 1	*M*=2.5 *SD*=1.73 *Min*=1 *Max*=3	*N/a*
S-2(125%) *N*=2	*M*=2.50 *SD*=2.12 *Min*=1 *Max*=4	*M*=1.00 *SD*=0 *Min*/*Max*=1	*M*=5.00 *SD*=0 *Min*/*Max*=5	*M*=3.50 *SD*=2.12 *Min*=2 *Max*=5
S-2 (150%) *N*=3	*M*=4.00 *SD*=3.00 *Min*=2 *Max*=7	*M*=1.67 *SD*=0.58 *Min*=2 *Max*=7	*M*=5.00 *SD*=2.65 *Min*=1 *Max*=2	*M*=5.33 *SD*=2.89 *Min*=1 *Max*=7
150% No heavy aircraft *N*=1	5	1	5	5
D) Speed Adjustments.				
	NORTH FEEDER	**METRO FEEDER**	**4R FINAL**	**4L FINAL**
B *N*=1	1	1	4	*N/a*
S-1 *N*=4	*M*=1.5 *SD*=1 *Min*=1 *Max*=3	*M*=1 *SD*=0 *Min*/*Max*=1	*M*=2.25 *SD*=0.96 *Min*=1 *Max*=3	*N/a*
S-2(125%) *N*=2	*M*=1.00 *SD*=0 *Min*/*Max*=1	*M*=1.00 *SD*=0 *Min*/*Max*=1	*M*=5.00 *SD*=1.41 *Min*=4 *Max*=6	*M*=3.50 *SD*=2.12 *Min*=2 *Max*=5
S-2 (150%) *N*=3	*M*=3.33 *SD*=3.21 *Min*=1 *Max*=7	*M*=1.67 *SD*=0.58 *Min*=1 *Max*=2	*M*=4.67 *SD*=2.08 *Min*=3 *Max*=7	*M*=4.00 *SD*=3.00 *Min*=1 *Max*=7
150% No heavy aircraft *N*=1	5	1	5	5

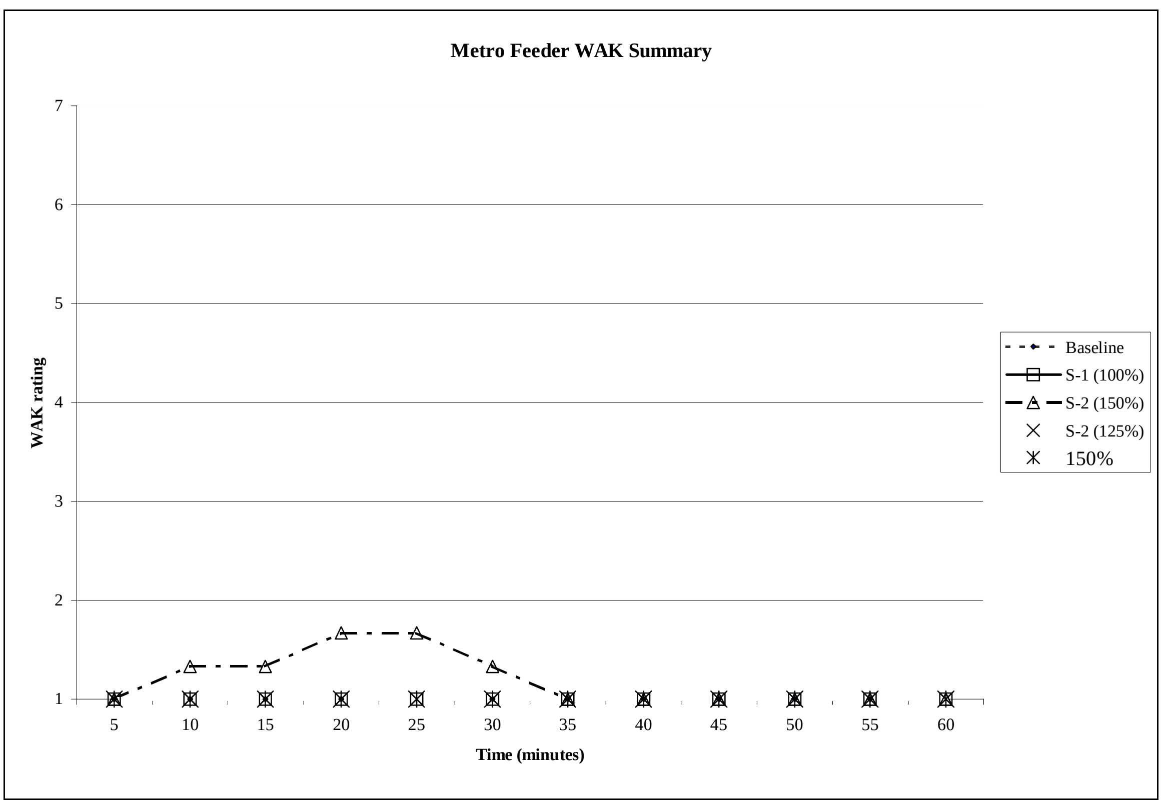
Q3. Rate the workload associated with ground-to-air communications during this run.				
	NORTH FEEDER	**METRO FEEDER**	**4R FINAL**	**4L FINAL**
B *N*=1	1	1	2	*N/a*
S-1 *N*=4	*M*=1.5 *SD*=1 *Min*=1 *Max*=3	*M*=1 *SD*=0 *Min*/*Max*=1	*M*=2.75 *SD*=1.26 *Min*=1 *Max*=4	*N/a*
S-2(125%) *N*=2	*M*=1.50 *SD*=0.71 *Min*=1 *Max*=2	*M*=1.00 *SD*=0 *Min*/*Max*=1	*M*=6.50 *SD*=0.71 *Min*=6 *Max*=7	*M*=3.50 *SD*=0.71 *Min*=3 *Max*=4
S-2 (150%) *N*=3	*M*=3.33 *SD*=3.21 *Min*=1 *Max*=7	*M*=1.67 *SD*=0.58 *Min*=1 *Max*=2	*M*=4.67 *SD*=1.54 *Min*=4 *Max*=6	*M*=4.67 *SD*=3.21 *Min*=1 *Max*=7
150% No heavy aircraft *N*=1	4	1	4	6

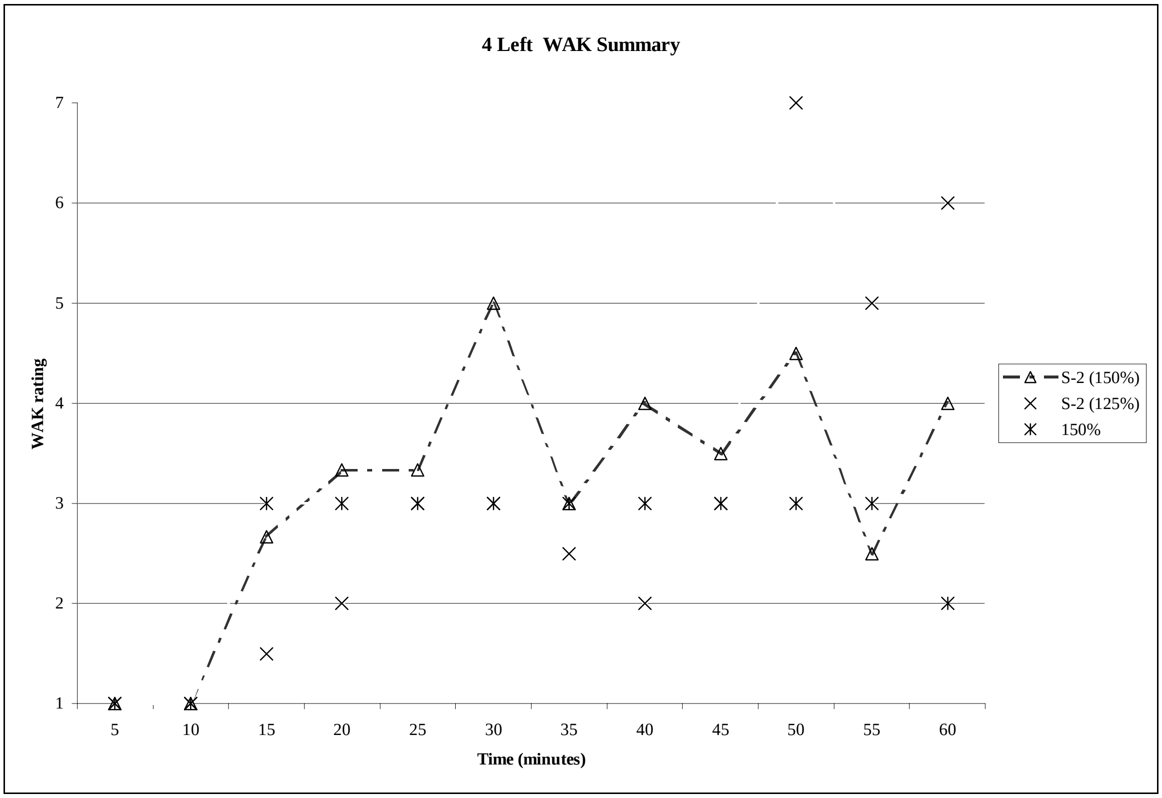
Q4. Rate the realism of the traffic in this run.				
	NORTH FEEDER	**METRO FEEDER**	**4R FINAL**	**4L FINAL**
B *N*=1	4	1	2	*N/a*
S-1 *N*=4	*M*=2.25 *SD*=1.5 *Min*=1 *Max*=4	*M*=2.5 *SD*=2.38 *Min*=1 *Max*=6	*M*=4.25 *SD*=1.71 *Min*=2 *Max*=6	*N/a*
S-2(125%) *N*=2	*M*=350 *SD*=0.71 *Min*=3 *Max*=4	*M*=2.00 *SD*=1.41 *Min*=1 *Max*=3	*M*=5.00 *SD*=0 *Min*/*Max*=5	*M*=5.00 *SD*=0 *Min*/*Max*=5
S-2 (150%) *N*=3	*M*=3.33 *SD*=2.08 *Min*=1 *Max*=5	*M*=2.00 *SD*=1.00 *Min*=1 *Max*=3	*M*=4.00 *SD*=1.73 *Min*=2 *Max*=5	*M*=2.00 *SD*=1.73 *Min*=1 *Max*=4
150% No heavy aircraft *N*=1	3	1	4	4

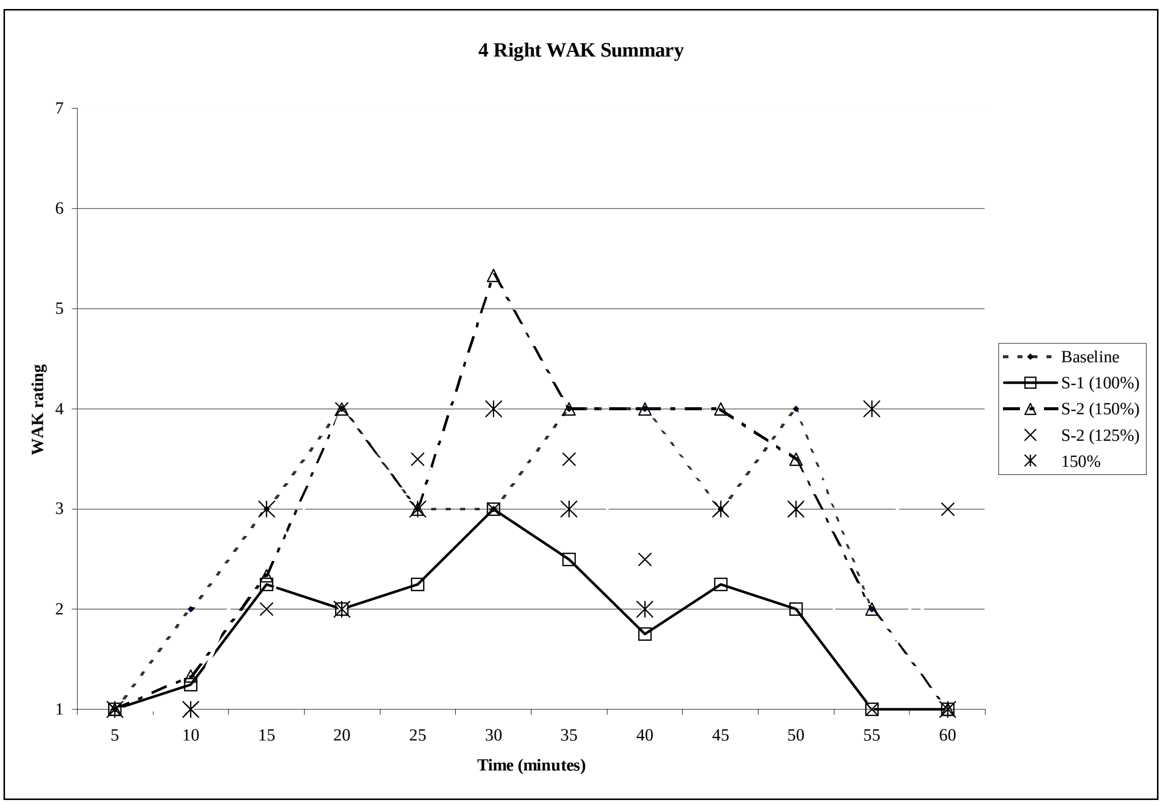
Appendix G

WAK Mean Interval Workload Ratings


North Feeder WAK Summary
WAK rating
7
6
5
4
3
2
1
5
10
15
20
25
30
35
40
45
50
55
60
Time (minutes)
Baseline
S-1 (100%)
S-2 (150%)
S-2 (125%)
150%


Metro Feeder WAK Summary
WAK rating
7
6
5
4
3
2
1
5
10
15
20
25
30
35
40
45
50
55
60
Time (minutes)
Baseline
S-1 (100%)
S-2 (150%)
S-2 (125%)
150%


4 Left WAK Summary
WAK rating
Time (minutes)
S-2 (150%)
S-2 (125%)
150%


4 Right WAK Summary
WAK rating
Time (minutes)
Baseline
S-1 (100%)
S-2 (150%)
S-2 (125%)
150%