DRAFT

Los Angeles Arrival Enhancement Project
Real-Time Simulation Test Report

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1. INTRODUCTION

1.1 Los Angeles Arrival Enhancement Project

In an effort to improve the safety and efficiency of air traffic management at Los Angeles International Airport (LAX), the Federal Aviation Administration (FAA) proposed to modify certain jet arrival routes, air traffic control sectors, and air traffic control (ATC) coordination procedures. The Los Angeles Arrival Enhancement Project (LAAEP) proposes a change in the location of one arrival route to LAX from the east and reassignment of airspace and coordination of procedures between the Los Angeles Air Route Traffic Control Center (ARTCC) and the Southern California (SOCAL) Terminal Radar Approach Control (TRACON) (FAA, 1997).

LAX has two final approach courses, one heading for the north airport complex (Runways 24L/R) and one heading for the south airport complex (Runways 25L/R). The current westbound arrival configuration to LAX consists of three main flows of aircraft that are funneled into one stream by Los Angeles Center (ZLA). The traffic is then worked primarily by one TRACON controller who provides sequencing to the southern approach course. Another TRACON controller handles inbound arrivals from the north and west, sequencing them to the northern final approach course (FAA, 1997).

Aircraft arrivals from the east typically create a much greater volume of traffic on the southern arrival course than the northern course with the current routes and procedures. This traffic configuration results in an imbalance in controller workload, and, at times, significant aircraft delays and thus increased user costs.

The LAAEP proposes a plan to improve the efficient use of airspace, reduce air traffic delays, balance controller workload, and improve coordination among controllers by reassigning a portion of airspace from the Los Angeles ARTCC to the TRACON, where closer aircraft separation standards are allowed. This new portion of airspace was named the BASIN sector, and it belongs to the SOCAL TRACON. In addition, the plan proposes a triple traffic flow further east than present, which eventually merges into a dual stream for final approach. Appendixes G and H include diagrams of the new BASIN sector and the proposed arrival stream configuration, respectively.

1.2 Real-Time Simulation Overview

The Western Pacific Region (AWP-500) selected the FAA's William J. Hughes Technical Center in Atlantic City, NJ, as a test bed to simulate the proposed LAAEP procedures. The Technical Center laboratories contain fully operational ATC displays in both terminal and en route environments that interface with each other to provide a high-fidelity environment for ATC experimentation.

The LAAEP simulation was conducted January 12-15, 1998. The goal of the simulation was to provide a realistic environment for LAAEP representatives and controllers to exercise, observe, and evaluate the proposed LA Center and TRACON airspace and procedural changes. It is important to note that a valid experimental design was forgone to allow a more exploratory type of evaluation of the procedure. No baseline study was conducted from which to draw comparisons between procedures. But, rather, different combinations of traffic levels and special events, such as aircraft in holding, runway closings, mile-in-trail (MIT) changes, visual flight rule (VFR) approaches, different sequencing strategies, were experienced and evaluated for effectiveness. The ultimate goal of the test was to first determine if the proposed changes were workable, and then, if consensus was reached as to the workability, make recommendations for a training program for all other controllers at ZLA and the SOCAL TRACON.

By simulating three terminal sectors, including one new sector, and four en route sectors concurrently, controllers could realistically control aircraft from the boundaries of the high-altitude sectors to the Los Angeles International Airport. Controllers from both the en route and terminal facilities worked together to test and make recommendations on the LAAEP proposed procedures.

2. EXPERIMENTAL APPARATUS

2.1 Target Generation Facility

The Target Generation Facility (TGF) is an advanced simulation system designed to support testing of current and future ATC hardware/software and procedures. The TGF generates realistic digital radar messages for aircraft targets in a simulated airspace environment. The simulation system can be adapted to mimic actual National Airspace System (NAS) and Automated Radar Terminal System (ARTS) characteristics including radar and environmental characteristics for a specific en route or terminal facility (TGF web site, 1998). The TGF enables testing of ATC equipment and procedures without live aircraft. Computer-scripted traffic scenarios provide ATC systems with realistic radar returns for simulated aircraft based on facility-supplied or originally created flight plans.

For the LAAEP simulation, the TGF was partitioned into three subsystems: simulation pilot, target generation, and development and support. Simulation Pilot Operators used simulation pilot workstations (SPWs), or computer workstations, to fly the simulated aircraft and commanded them in accordance with ATC instructions. The pilots performed their roles in a separate laboratory from the air traffic controllers. The SPWs contained a communication system that provided an audio interface with the Center and TRACON controllers. Controller-pilot voice communications were processed through an AMECOM voice communications system.

The target generation (TG) subsystem consisted of a TG chassis that performed all modeling within the TGF and correlated dynamic data, such as aircraft state vectors and radar performance, with known flight plan and adaptation data (TGF web site, 1998). Dynamic data within the simulation was updated every second, even though the aircraft were *seen* on the terminal radar scopes every 4.8 seconds and the en route scopes every 12 seconds. This ensured the simulation's fidelity and provided a realistic picture in both the en route and terminal applications (TGF web site, 1998).

The development and support subsystem provided the pre-exercise activity of traffic scenario development and the post-exercise activity of data reduction. Scenario development involved the process of storing environmental data and flight sample data into a database and previewing the database for use as the scenario in the simulation exercise (TGF web site, 1998). Data reduction following the simulation involved compiling aircraft data, simulation pilot command keyboard entries, and flight plans for analysis.

2.2 Terminal Radar Approach Control (TRACON) Laboratories

SOCAL provided the Technical Center TRACON Laboratory with a software adaptation of the fielded configuration of the DOWNE and STADIUM sectors. The adaptation was the latest operational copy (A.306) of ARTS IIIA dual systems. Technical Center laboratory personnel, however, modified the COAST video map and software to add an experimental BASIN sector. Three radar scopes displaying DOWNE, STADIUM, and BASIN sectors were simulated throughout the test. The frequencies for each terminal sector were the following: DOWNE = 124.9, STADIUM = 128.5, BASIN = 128.225.

2.3 Air Route Traffic Control Center (ARTCC) Laboratory

The Technical Center ARTCC Laboratory was driven by A4E1.3 Host software and the charting release was supplied by LA Center. Airspace modifications were configured practically identical to the field. Since there were subtle differences in the hardware at the Technical Center, software adjustments were made so that the systems would accept radar targets from the TGF. This allowed controllers to control aircraft. Some airspace adaptation was necessary since the simulation required resectorization for a portion of the en route airspace to the terminal airspace.

Four sectors were displayed throughout the simulation: two high sectors (37 and 39) and two low (19 and 20). The frequencies for each en route sector were the following: 37 = 133.55, 39 = 133.2, 19 = 126.35, 20 = 133.4. An inboard, unmanned, Ghost sector was set up to initiate traffic that fed into the traffic scenarios. A manned, outboard, Ghost sector received ATC handoffs outside the scope of the experiment. The Ghost stations gave the simulation realistic merit.

3. SIMULATION PARTICIPANTS

3.1 Test Director

The test director of the LAAEP simulation was an Air Traffic Control Specialist from the ATC Simulation and Support Branch (ACT-510). He was responsible for the training of the Simulation Pilot Operators, the installation of communications, the integration of the laboratories, and the monitoring of computer support. Additionally, the test director ensured that the proper scenarios were run and was responsible for the initiation and termination of the scenarios. The test director ensured that any problems encountered during a simulation were fixed to the satisfaction of the customers.

3.2 Full Performance Level Air Traffic Controllers

Six en route controllers from the Los Angeles ARTCC and four terminal controllers from the SOCAL TRACON participated in the simulation. All controllers had Full Performance Level (FPL) experience. Tables 1 and 2 show the controllers' average number of years of ATC experience at Los Angeles and other facilities.

Table 1. Terminal Controller Experience

	Mean	Standard Deviation	Maximum	Minimum
LA FPL (years)	9.1	3.5	12.0	4.0
Other FPL (years)	5.9	3.6	11.1	3.0

Table 2. En Route Controller Experience

	Mean	Standard Dev.	Maximum	Minimum
LA FPL (years)	7.8	4.2	14.3	5.7
Other FPL (years)	1.5	2.5	3.0	0.0

During the simulation, controllers from ZLA rotated through four sector positions in the en route laboratory. Controllers from SOCAL rotated through two sector positions (SOCAL TRACON) and one new sector position (BASIN) in the terminal laboratory.

3.3 Simulation Pilot Operators

The Simulation Pilot Operators provided the link between the air traffic controllers and the simulated aircraft in the LAAEP simulation. The pilots reported aircraft information such as position and status to the controllers through voice communications using standard ATC phraseology. By use of keyboard devices, pilots entered controller instructions. Depending upon the complexity level of the traffic scenarios, pilots were able to control up to 10 aircraft per computer terminal.

Two categories of simulation pilots were utilized in the LAAEP simulation: 13 federal Air Traffic Assistants in Simulation (ATAs) and 13 contracted certified, general aviation pilots. All individuals were trained to understand and interpret controller phraseology as well as understand the keyboard commands that had to be entered into the system to fly aircraft in accordance with ATC instructions.

3.4 Simulation Observers

Three simulation observers, with human factors, mathematics, and real-time simulation experience, participated in the LAAEP simulation. The observers documented simulation-related events, such as procedural modifications, hardware and/or software problems, and changes to daily and controller position schedules. The observers also recorded information as requested by controller participants for debrief discussion and review. In addition, the observers collected certain real-time air traffic-related data during simulation runs (a simulation *run* was defined as a 1-hour and 15-minute traffic scenario- or *up to* 1 hour and 15 minutes of controlled traffic). They also administered post-run questionnaires and post-simulation questionnaires to the controllers. The information documented by the simulation observers was particularly critical to interpreting LAAEP data, since frequent modifications were made *on the fly* to traffic scenarios and procedural strategies.

4. EXPERIMENTAL DESIGN

Before the simulation began, schedules were developed to randomize and counterbalance the variables in the test. For instance, the level of traffic in the traffic scenarios varied. To be experimentally valid, the number of times each scenario was scheduled was counterbalanced to ensure each scenario was shown the same number of times. In addition, controllers rotated through sector positions. The number of times each controller worked a particular sector had to be randomized and counterbalanced. On a broader scale, the total number of runs for the entire simulation was determined based on an evenly distributed showing of traffic scenarios and controller position assignments.

The schedules were followed to a degree during the actual simulation. Participating LAAEP representatives and controllers decided, however, that it was more important to make decisions as to which traffic scenarios and special events, such as holding aircraft and conducting VFR approaches, should be simulated on a run to run basis. That way, particular problems could be introduced to the scenarios in combination with a variety of conditions. LAAEP participants felt it was more important to stretch the capabilities of the resectorization and observe the effects than to statistically analyze data. The following sections explain how the traffic scenarios were originally developed and how they were actually simulated. The daily simulation schedule is also presented.

4.1 Traffic Scenarios

The aircraft targets displayed on the controller scopes during the simulation were generated from a sample of System Analysis Recorder (SAR) data from ZLA. The TGF received flight plans from the Center for a peak traffic level period and converted the flight data into TGF format. From the flight plan data, one master traffic sample was developed. From that sample, three traffic scenarios, with different levels of traffic, were developed. The master traffic sample was Scenario 4, described in Table 3 below. From that scenario, aircraft were selectively deleted to create Scenarios 3 and 1, also defined in Table 3. Originally, four scenarios were going to be generated, but due to time constraints, one scenario was not developed. Each traffic scenario was 1-hour and 15-minutes in length.

During the actual test, the MIT maintained by the Center corresponded directly to the original scenario description shown in Table 3. The TRACON, however, did not always conduct VFR approaches throughout an entire run. In addition, the TRACON sometimes ran visuals in Scenario 1 and sometimes did not run visuals in Scenario 3. Refer to Appendix A for an exact description of the traffic conditions simulated in each run.

Table 3. Original Scenario Description

Scenario	ARTCC	TRACON	Number aircraft	Airport acceptance rate
1	20 MIT	IFR	165	68
3	15 MIT	VFR + IFR	175	77
4	15 MIT	VFR	182	84

*MIT = Miles in trail

4.2 Daily Simulation Schedule

The LAAEP simulation was conducted from 4 PM to 12 AM over a 4-day period. Three 1-hour and 15-minute runs (or *up to* 1 hour and 15 minutes) were conducted the first two days, 4 runs on the third day, and 2 runs on the last day of the test, for a total of 12 runs. After each run, a short debrief session took place between controllers, LAAEP representatives, and Technical Center personnel to address simulation-related issues. Procedural issues and/or strategies were discussed among controllers and technical issues were addressed by TGF.

4.3 Procedure

ZLA and SOCAL controllers monitored and controlled aircraft in their respective facilities (i.e., ARTCC and TRACON laboratories) for the duration of each run. They rotated through working the sectors in their airspace so that they each experienced the proposed LAAEP airspace and procedural changes from all positions. Controllers used the standard ATC phraseology to command aircraft to make heading, speed, and altitude changes as they would in their actual facilities. Simulation pilots responded to controller instructions via specialized keyboards. Aircraft targets on the controllers' displays responded as well. Special events, such as the holding of aircraft and runway closings were simulated on an as needed basis, and controllers responded to those events.

At the end of each traffic scenario, controllers completed workload questionnaires based on their experiences throughout the run. Following the questionnaire sessions, informal debriefs were held.

5. DATA COLLECTION

5.1 Controller Questionnaires

Three types of questionnaires were developed for the LAAEP simulation. The purpose of the questionnaires was to first obtain background information on the participating controllers. Then, questionnaires were distributed after each run throughout the simulation to collect human factors data on controller workload and performance. Lastly, questionnaires were distributed at the conclusion of the simulation to collect short answer-type controller assessments of the LAAEP proposed plan. Examples of the questionnaires can be found in Appendix B.

5.1.1 Background Information Questionnaire

Prior to participating in any simulation scenarios, controllers were asked to complete Background Information Questionnaires. The purpose of the Background form was to collect information on controller experience at current and previous facilities. The form also asked the controllers to rate seven variables on the degree to which they contributed to the controller's perception of workload. This information was useful to understanding subsequent workload ratings on Post-Run Questionnaires.

5.1.2 Controller Post-Run Questionnaire

Controller Post-Run Questionnaires were distributed to the controllers after each simulation run to collect subjective workload and performance data. Controllers rated the workload they experienced with the new airspace procedures. They also compared that workload to the workload they typically experience at their actual facilities (with current operations). The Post-Run Questionnaire also asked controllers to rate their performance on the ability to maintain traffic flows and separation, and the need for coordination with the proposed procedures. In addition, controllers assessed the traffic complexity of each run. Lastly, controllers rated the realism of each simulated scenario as compared to actual air traffic control operations at their respective facilities.

5.1.3 Controller Post-Simulation Questionnaire

Controllers completed Controller Post-Simulation Questionnaires at the end of the simulation. The format of the questionnaire was short-answer to enable the controllers to express their opinions in various areas regarding the proposed procedures. Questions addressed the overall safety of the new procedures and whether or not any changes should be incorporated into the procedures. The distribution of workload across sectors was also addressed. Controllers were asked to compare the amount of vectoring, speed adjustments, interfacility and intrafacility coordination necessary with the simulated procedure as compared to actual current operations at their facilities. The Post-Simulation Questionnaire also asked the controller his opinion whether or not the simulated procedure could accommodate future air traffic growth.

5.2 Simulation Observer Records

The simulation observers noted specific events that occurred during each run of the simulation (e.g., runway closings, mile-in-trail restrictions, holding of aircraft, stacking-aircraft vertically separated- of aircraft) to enable a better understanding of questionnaire responses and quantitative data. Most runs differed to some extent from each other with respect to the scripting of special situations. The simulation observer records were critical to the proper reporting of the resultant data. A *Scenario Description by Run* table was compiled by the simulation observers and is contained in Appendix A. This table should be referred to when interpreting simulation data results.

5.3 Computer-Generated Data Files

The TGF, ARTS, and Host systems generated computer data continuously throughout the simulation in TGF, Continuous Data Recording (CDR), and SAR formats, respectively. The data were quantitative in nature and provided measures on numerous air traffic control variables including: aircraft tracks worked; heading, altitude, and speed commands; aircraft in holds; times spent in sectors; and conflict alerts. Computer-generated data were compiled and presented in this report to provide objective feedback on simulated LAAEP operations.

5.4 Audio and Video Recordings

Audio and video recordings were made over the course of the simulation at the request of LAAEP management and controllers. The purpose of the video recordings was to provide LAX representatives with a means of showing simulation events and procedures to interested parties and to allow for post-hoc analyses of simulation events. Audio was recorded on the videotapes. In addition, backup audio for all sectors and all twelve runs was recorded on a DENRO Digital Voice Recording System (DVRS).

6. ASSESSMENT METHODOLOGY

Participating Center and TRACON controllers were the evaluators of the proposed LAAEP procedures in this simulation. They drew upon their expertise and understanding of the nature of daily operations and the full range of traffic contingencies to evaluate the workability of the procedures. Controllers introduced a variety of situations and/or potential problems into the traffic scenarios. They then assessed the workability of such circumstances. By simulating *worst-case* conditions, the limitations of the new arrival streams and new terminal sector could be tested, training recommendations devised, and conclusions drawn regarding the safety of the proposed procedures.

7. SIMULATION RESULTS

At the discretion of the customer, a proper experimental design was forgone to allow the maximum amount of exposure to different traffic situations for each controller. In addition, no baseline study was conducted to allow a valid statistical comparison between current operations and planned operations. Given this situation, only a limited amount of reporting can be done. Data were examined to see if trends could be identified to help understand the effects of the proposed procedural changes.

7.1 Controller Questionnaire Analyses

The feedback obtained from the controller questionnaires, particularly from the Post-Simulation Questionnaires, was crucial to assessing the workability of the LAAEP procedures. Controllers put forth a great deal of effort to express their workload assessments and opinions regarding their participation in the simulated LAAEP scenarios.

7.1.1 Background Questionnaire

Controllers were asked to rate seven factors that contributed to workload levels in their current ATC environment. A rating of 1 indicated a very low contribution and 8 represented a very high contribution. On the average, both terminal and en route controllers rated *aircraft performance characteristics/aircraft mix* as the biggest contributing factor to controller workload. Tables 4 and 5 show all of the average ratings for each facility.

Table 4. Terminal Workload Contributing Factors[a]

	Mean	Standard Deviation	Maximum	Minimum
Route Structure	6.3	1.0	7.0	5.0
Airspace Configuration	6.5	0.6	7.0	6.0
Interfacility Coordination	5.5	1.0	6.0	4.0
Intrafacility Coordination	6.0	0.8	7.0	5.0
Aircraft Mix	7.0	1.4	8.0	5.0
Weather	6.0	1.8	8.0	4.0
Facility Procedures	6.0	1.8	8.0	4.0

[a] In addition, 2 controllers reported Traffic Management Unit (*TMU) Flow* and gave it a rating of 8.

Table 5. En Route Workload Contributing Factors[a]

	Mean	Standard Deviation	Maximum	Minimum
Route Structure	5.0	1.5	7.0	3.0
Airspace Configuration	5.0	1.1	6.0	3.0
Interfacility Coordination	5.2	1.2	7.0	4.0
Intrafacility Coordination	5.2	1.5	7.0	3.0
Aircraft Mix	6.3	0.5	7.0	6.0
Weather	5.5	2.4	8.0	2.0
Facility Procedures	5.2	1.5	7.0	3.0

[a] In addition, 1 controller listed *sequence order* and rated it as 5, another controller listed *destination* and rated it as 5, and a different controller listed *management practices* and rated it as 7.

7.1.2 Post-Run Questionnaire

7.1.2.1 Workload Ratings

The average workload for each run was examined to help identify the effects of various airspace and procedural changes as well as events simulated during this study on the air traffic controllers. Some trends can be found if these values are correlated to the traffic description shown in Appendix A. The following sections discuss the average workload ratings across sectors for each run (labeled with the scenario). Appendix C contains all controller workload-related comments recorded on the Post-Run Questionnaires.

7.1.2.1.1 En Route Controller Responses

Trends in en route post-run data suggest that with the proper training and exposure, controllers should be able to work with the proposed changes. However, the effects of special situations should be reviewed closely and compared to current operations.

Figure 1 depicts the average workload rating for each run. In addition, each bar is labeled to indicate which scenario was being run.

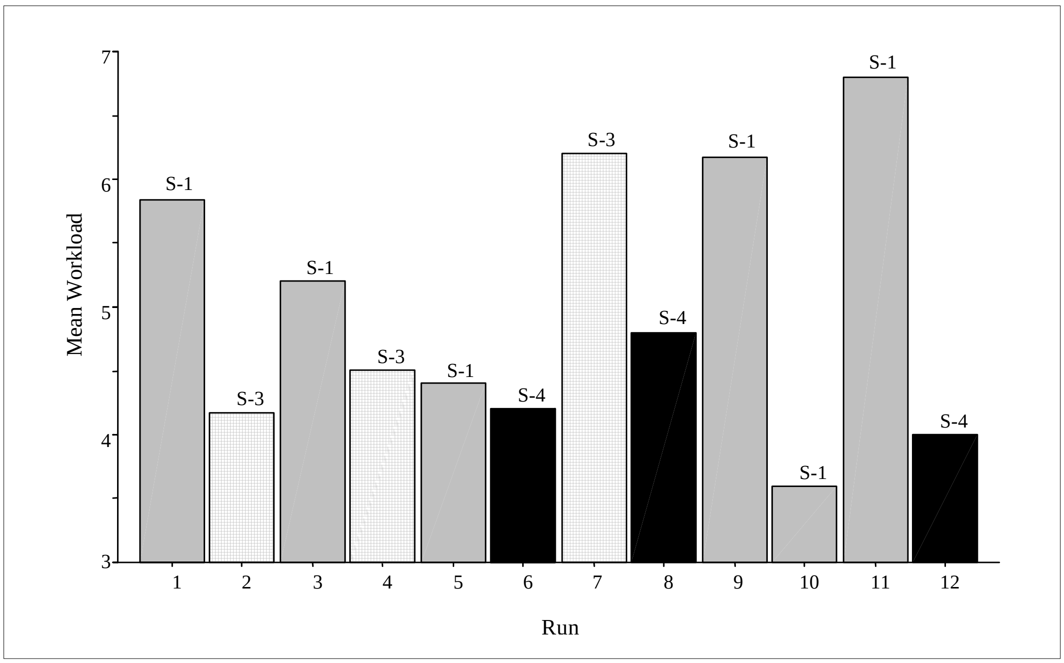

Figure 1. En Route Average Workload by Run

Scenario 1 showed a steady decline in the average workload for Runs 1, 3, 5, and 10. This behavior was expected because of the repetition of the same problem. However, the average workload sharply increased during Runs 9 and 11 which had special events, such as runway closings and holding of aircraft.

The graph shows that the average workload for the first two runs with Scenario 3 (Runs 2 and 4) have similar ratings. It should be noted that Run 2 only lasted approximately 49 minutes as opposed to the other run which lasted an hour. This could explain the unexpected lower rating in Run 2. During Run 7, an increase in the average controller workload rating is noted. This was the first run with Scenario 3 that incorporated major traffic changes (refer to Appendix A) indicating that the proposed changes may have different effects depending on the traffic.

The same type of trend can be observed for Scenario 4. By Run 6, a steady decrease in the average workload was still observed. However, when Run 6 was compared to Run 8, an increase in workload is noted. Again this was the first time Scenario 4 was run with the new traffic changes. Run 8 has a lower average workload rating than Run 7 because it is the second run with the new traffic changes. During Run 12 an even lower average workload was noted for Scenario 4. This can probably be attributed to the repeated traffic, run time, and increased acceptance rate from the TRACON.

Figure 2 depicts the average controller workload and complexity ratings by sector. Controllers commented on the Post-Run and Post-Simulation Questionnaires that with the proposed changes; the workload in sectors 19 and 20 was lower than sectors 37 and 39, and that sector 19 had less workload and was less complex than sector 20. Controller comments are supported by trends in the data.

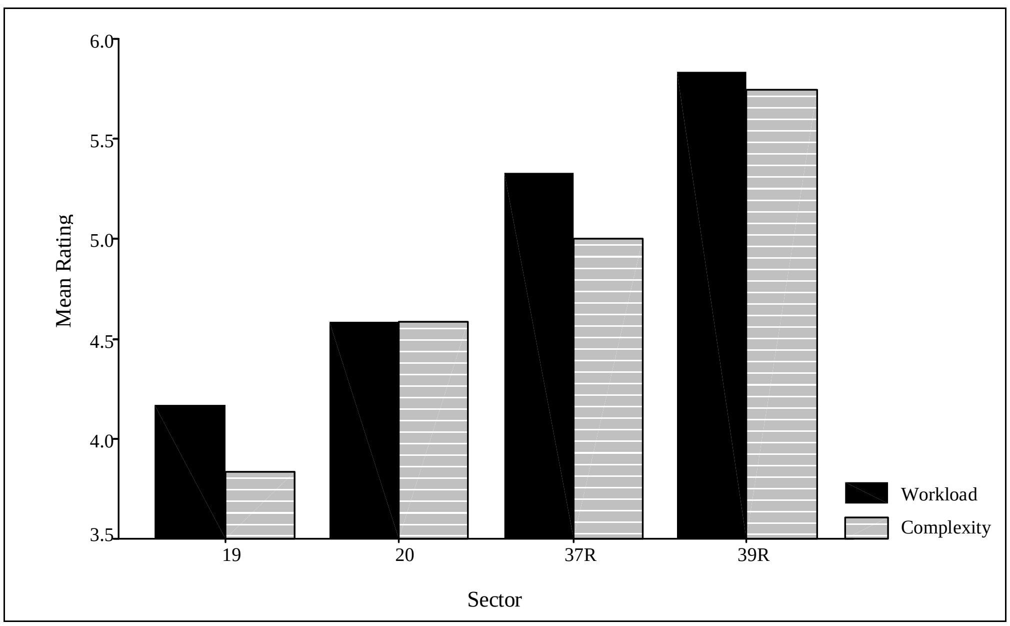

Figure 2. En Route Workload by Sector

7.1.2.1.2 Terminal Controller Responses

The BASIN sector did not actually exist in the field for the terminal controllers at the time of the simulation. However, the purpose of simulating a BASIN sector was to assess performance and workload in the newly-defined sector and to look at traffic feeds to the two approach sectors, DOWNE and STADIUM. The BASIN controller strategically positioned aircraft, easing the workload for the approach sectors. Trends in TRACON post-run data suggest that with the proper training and exposure, controllers should be able to acclimate to the new working conditions. However, procedures need to be clearly defined to ensure a safe and steady traffic flow.

Figure 3 depicts the average workload rating for each run. In addition, each bar is labeled to indicate which scenario was being run.

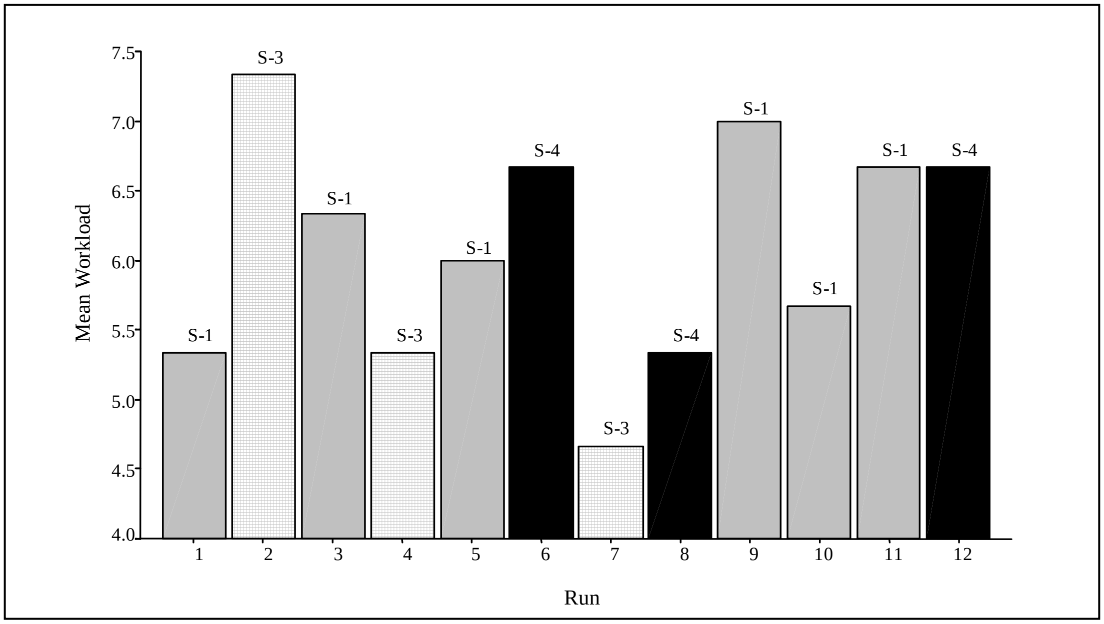

Figure 3. Terminal Average Workload by Run

Controllers reported lower average workload ratings as they gained more experience with Scenario 1. However, an increase in the average workload was noted during Scenarios 9 and 11. This can be explained by special events scripted into both runs. Controllers noted that in the field, hand-off controllers are available to assist during peak traffic and under special circumstances. During the simulation, however, they were not. Controllers also mentioned that taking aircraft out of holding patterns was *workload intensive*. It was difficult to pull aircraft out of holding and maintain standard in-trail separation.

The same trend was seen in Scenarios 3 and 4. Controller average workload steadily decreased with experience. An increase was seen in Run 12. The purpose of this run was to find the maximum approach capacity. To accomplish this, the Center flooded the TRACON with aircraft. Controllers stated that their labor intensified in BASIN when routing aircraft downwind and east of the SMO VORTAC. Workload increases can be attributed to the traffic flooding which required less separation (7 MIT), and more communication between the controllers and visual-approach aircraft.

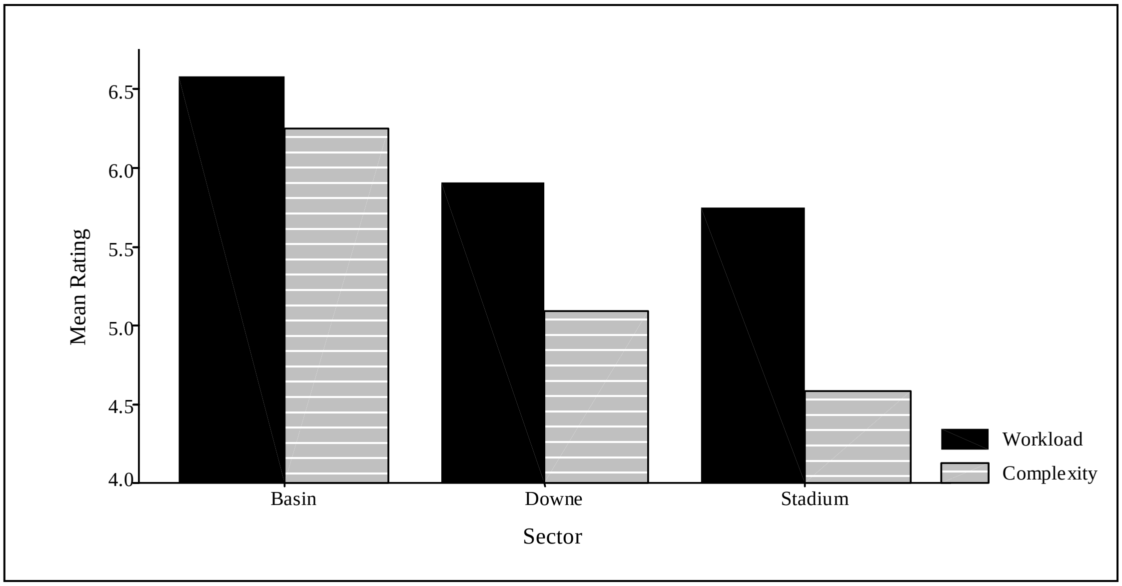

Figure 4. Terminal Workload by Sector

Figure 4 depicts the average controller workload and complexity ratings by sector. Controllers noted that offloading aircraft from DOWNE to STADIUM on Runway 24R was vital to managing traffic on Runway 24R. This process increased DOWNE's complexity and allowed for a more equitable distribution of traffic between DOWNE and STADIUM. In addition, using inboard runways with visual-approach traffic helped maintain a moderate level of complexity for the DOWNE sector. Controllers cautioned that aircraft offloading to Runway 24R is not a normal operation in the field.

In the BASIN sector, traffic complexity seemed to be a leading factor for higher workload, possibly because fixed procedures were not in place at the time of the simulation. Controllers attempted to combat the in-trail compression before handing aircraft off to the DOWNE and STADIUM sectors. Also contributing to traffic complexity was high traffic volume, transitioning holding aircraft, instrument flight rule (IFR) conditions, and interfacility coordination. Controllers also mentioned that in the BASIN sector, visual-approach traffic ran smooth. This might have been because DOWNE transferred some aircraft to STADIUM and freed Runway 25L for more aircraft.

7.1.2.2 Traffic Realism Ratings

7.1.2.2.1 En Route Controller Responses

Figure 5 displays the average realism rating given by the en route controllers for each run. Examination of the figure indicates that changes made to the scenarios during run time seemed to increase the realism. If this chart is correlated with Appendix A, some trends become more obvious. Runs 1, 3, 5, 9, 10, and 11 all had Scenario 1 traffic. Runs 1 and 2 were the exact same scenario, hence had very similar ratings. Run 5 had four overflights added which resulted in a slight increase in the realism. By Runs 9, 10, and 11, additional changes were made and the average increased even more. The same type of trends can be noted for Scenarios 3 and 4.

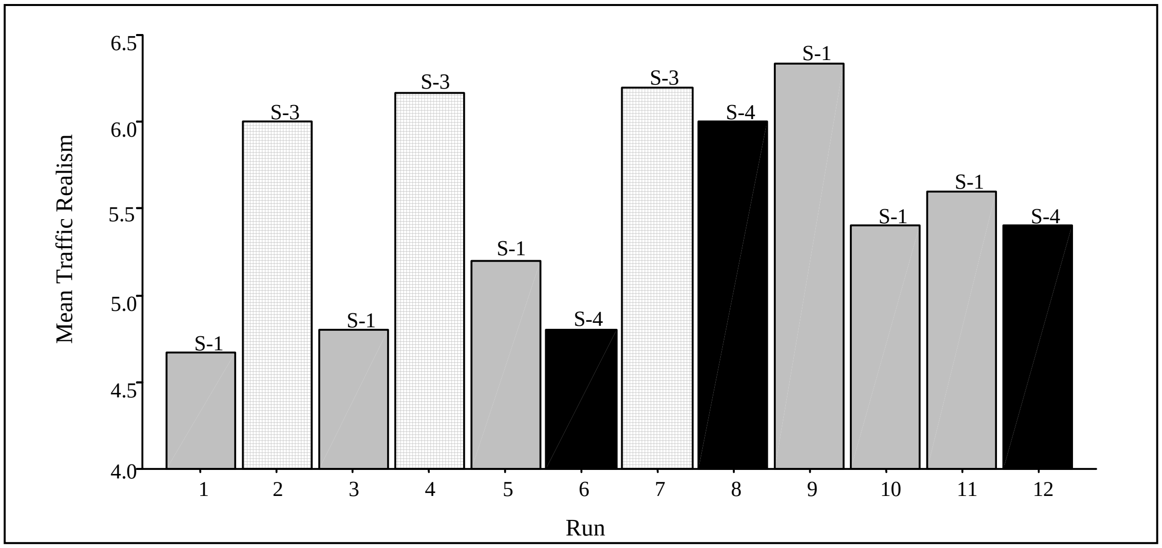

Figure 5. En Route Mean Ratings for Realism

7.1.2.2.2 Terminal Controller Responses

Figure 6 displays the average realism rating given by the terminal controllers for each run. Controllers felt that they could not rate the realism of the BASIN sector because it did not exist in the field at the time of the simulation. Therefore, BASIN ratings are not included in the data.

Factors that contributed to realism ratings were faster-than-normal speeds and visual-approach aircraft maintaining less separation when approaching the final. Researchers collaborated with controllers to find unrealistic aircraft characteristics. Following some corrections, realism ratings increased. Controllers rated Runs 9 and 12 as being the most realistic during the simulation. It seemed that controllers felt scripted events and IFR traffic most accurately represented field activities.

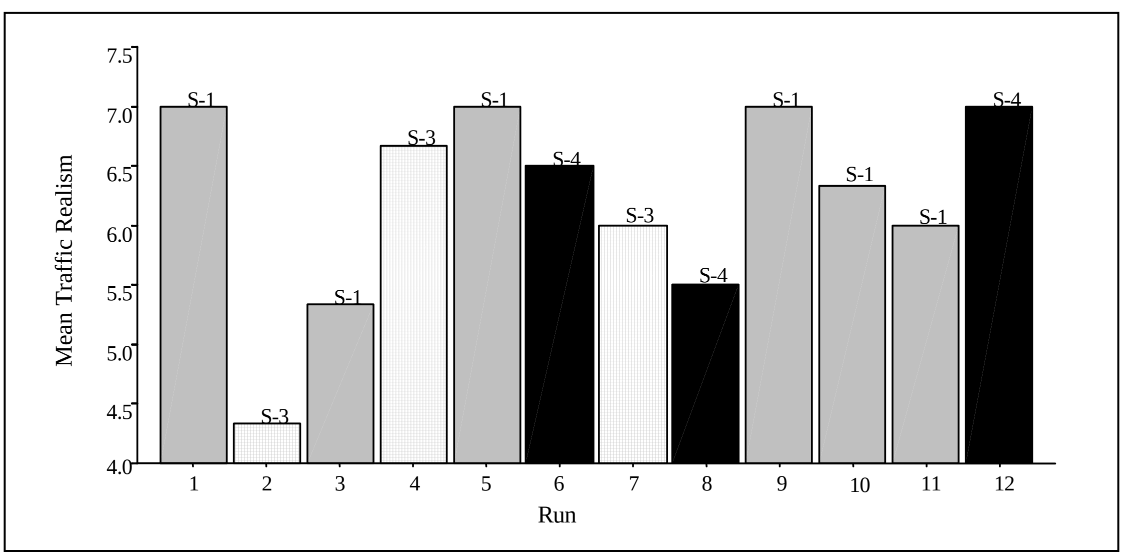

Figure 6. Terminal Mean Ratings for Realism

7.1.3 Controller Post-Simulation Questionnaires

The following questions were answered by all participating controllers at the end of the simulation. Because the feedback received was detailed and particularly informative with regard to training recommendations and controller strategies, responses were not summarized in the following section, but presented in their entirety. The en route controller responses to questions are given first for each question, followed by the terminal controller responses.

*Q1. Can the **proposed** Los Angeles arrival routes and procedures be safely controlled in an actual operational environment?*

EN ROUTE CONTROLLERS	
Response	**Comments**
Yes	Sectors 39 and 37 should be just as safe as they are today. The increased miles in trail will cause more vectoring, however. I see a problem at sector 19 with KONZL and BANDS being too close, which will require constant monitoring. Sector 20's workload has increased. J65 traffic and PSP arrivals and departures are your conflict traffic.
Yes	None given.
Yes	With definite changes in the proposed training plan, it will work. The current plans for training at both SCI and ZLA are inadequate and will cause the system to fail. It is also very dependent on TMU, if they do not protect the controllers the system will fail. This will effect not only the efficiency but also the safety margin to the point that an accident will be imminent.
Yes	This will be a much better system to run traffic if the union's requested procedures are fulfilled.
Yes	Only with proper preparation of personnel, numerous changes in airspace and procedures, and we will need more TMU support and much more input with the command center to explain our needs.
Yes	With traffic management and saturation control, this will work safely. Training must be adequate.
TERMINAL CONTROLLERS	
Response	**Comments**
Yes	However, revised procedures, developed by our workgroup, must be implemented.
Yes	Using terminal rules allows the final to become compressed earlier. We must use the new devised (stacked) procedures for this to work effectively.
Yes	Provided we develop sound procedures for offloading to runway 24. Traffic management and the arrival coordinator must take a proactive role to make this sector work efficiently.
Yes	With the correct miles in trail flow from ZLA sectors, the BASIN sector does work.

Q2. *Should any **changes** be incorporated into the proposed procedures?*

EN ROUTE CONTROLLERS	
Response	**Comments**
No	We have discussed all possible changes.
No	None given.
Yes	LAX arrivals need to be vertically separated above SNA, LGB, ONT, etc., arrivals routed over PSP on a static basis.
Yes	None given.
Yes	We need to move some airspace around and develop some new holding fixes and procedures.
Yes	BASIN's ability to move airplanes to 24 and Stadium's sector. Compression stacking for sectors 19 and 20 to give to Basin.
TERMINAL CONTROLLERS	
Response	**Comments**
None given	Too early to tell - but stacks of aircraft to BASIN help ZLA.
Yes	AR1, AR2, AR3, AR4, CI2 duties must be redefined. The specifics will be fully explained, in writing, by the Union's Los Angeles Area Representative.
Yes	24 offloading must be addressed.
Yes	BASIN handoff to DOWNE and STADIUM. Visual separation between these aircraft is best. On days with lower visibility, five miles or more staggered will be required (& match speed).

Q3. *Did you change your usual **control and work strategies** in any way in order to work the traffic in this simulation? If yes, what did you do differently?*

EN ROUTE CONTROLLERS	
Response	**Comments**
Yes	In order to get 15 – 20 MIT you must start sooner and use more drastic vectors. Direct KONZL from south of PKE gets too close to sector 40's J212 traffic. Stacking an occasional aircraft did away with compression.
Yes	I started spacing the aircraft sooner and descended them sooner in high altitude. In low, when vectoring was required, I used harder vectors for shorter periods of time.
Yes	My vectors were drastically sharper for less duration. I also descended all the different airport arrivals much sooner on the average.
Yes	None given.
Yes	I changed where I would move aircraft toward KONZL at sector 39. Holding was used more often and I moved numerous en route overflights to accommodate the new arrival procedures.
Yes	Used harder turns to get spacing faster. Holding aircraft sooner in low acceptance rate times.

TERMINAL CONTROLLERS	
Response	**Comments**
No	Speeds are faster so vectors happen slower however, the same strategies work.
Yes	We used procedures between AR1 and AR2 to safely separate aircraft on 24R and 25L. All aircraft on 24R worked by AR2. All aircraft on 25L worked by AR1.
Yes	I used slightly different phraseology so the simulation pilot could keep up. Otherwise, I just need to get used to the new timing requirement.
Yes	I had to lead turns on STADIUM to run the downwind visual pattern.

Q4. *Was the* ***distribution of workload across sectors*** *you controlled during this simulation the* ***same as*** *the distribution of workload with current operations at your facility? If no, please explain.*

EN ROUTE CONTROLLERS	
Response	**Comments**
No	Sector 19 was not as difficult because you've taken away over ½ of its traffic. The airspace is so small that it is more difficult to vector now. Sector 20's workload has increased due to working aircraft other than LAX arrivals. Sectors 37 and 39 remain about the same.
No	I think this distributes the workload better. Sector 19 and 20 are more evenly matched in their workload and complexity.
No	Sectors 37, 39, and 20 worked harder and sector 19 worked less.
No	Workload is shared between sectors 19 and 20 as they are currently configured. The new sectors placed a higher workload on sector 20. If sector 20 is in holding, the new configuration could be a problem.
No	Sector 20's workload is increased yet sector 19's workload was reduced to a great extent. Sector 37 and 39s' workload is different yet within acceptable levels.
None given	None given.
TERMINAL CONTROLLERS	
Response	**Comments**
No	Procedures we developed and used during the simulation resulted in equal workload for AR1 and AR2. This balance is not the true makeup of workload at AR1 and AR2. The demand of airplanes is in AR1's airspace.
No	This was much better. It distributed the load to each complex and controllers equitably.
No	This simulation demonstrated that we can balance the workload between STADIUM & DOWNE. It made DOWNE's job much easier. STADIUM's workload increased, but it was still very manageable.
No	BASIN can get busy, but can't compare this sector since it is new. DOWNE has less workload with this simulation. STADIUM's workload picks up and seems more balanced with DOWNE. (This is good).

Q5. *Was there an* ***equitable distribution of workload between sectors*** *you controlled during this simulation? If no, what sectors produced uneven workload levels?*

EN ROUTE CONTROLLERS	
Response	**Comments**
No	Today sector 19 is more complex than sector 20. With the new proposal, sector 20 will be more complex than sector 19.
No	Sectors 37 and 39 worked harder than 19 and 20.
No	19 and 20 were not even. Sector 20 was much busier.
None given	None given.
Sometimes	When SCT was taking stacks the workload was balanced very well. When 39 and 37 had to provide a solid 20 miles in trail, they were much busier than 19 and 20.
Yes	19 and 20's traffic is more manageable.
TERMINAL CONTROLLERS	
Response	**Comments**
No	The feeder, BASIN, does a lot of work. If a handoff could be staffed during the simulation, BASIN is very manageable.
Yes	Due to the use of our procedures the workload was close to equal at AR1 and AR2. The reduced workload at AR1 was shifted to AR4. However, AR4's workload was not unmanageable.
Yes	We attained the goal of equal distribution by offloading aircraft to the 24 complex at LAX.
Yes	This simulation demonstrated that we can balance the workload between STADIUM & DOWNE. It made DOWNE's job much easier. STADIUM's workload increased, but it was still very manageable.

Q6. *(a) Did the simulated procedure change the* ***amount of vectoring*** *needed as compared to current operations at your facility? If yes, please explain. (b) Per aircraft?*

EN ROUTE CONTROLLERS	
Response	**Comments**
None given	None given.
(a) Yes, (b) No	As stated before more vectoring is needed for 15-20 MIT. But if we can stack aircraft it should relieve vectoring almost completely.
(a) Yes, (b) Yes	The spacing required by each high altitude sector necessitates more vectors to get it done in a timely manner. Note: when SCT takes stacks, the amount of vectoring is reduced.
(a) Yes, (b) Yes	To gain the increased spacing my vectors were larger for shorter duration. This was complicated further by having less airspace in sectors 19 and 20.
(a) Yes, (b) Yes	It caused more vectoring in the high altitude sectors except when the occasional stacks on LAX arrivals were utilized.
(a) Yes, (b) Yes	Vectors were needed early during low rate acceptance period. During high acceptance rate, no vectoring or little vectoring was needed.

	TERMINAL CONTROLLERS
Response	**Comments**
(a) Yes, (b) None given	BASIN did a lot of vectoring to keep flow/separation for handoff to DOWNE and STADIUM. Vectoring for STADIUM/DOWNE had very little change.
(a) Yes, (b) Yes	Since our new procedures at AR4 result in the sequence to 24R and 25L being determined by the AR4 controller, instead of by the AR1 controller or CI2, AR1 and AR2 have minimal need to vector internal aircraft. Our procedures for AR4, by placing aircraft on 24R and 25L, result in less vectoring. If the AR4 controller does not have the authority to choose which aircraft are placed on 24R then vectoring will be increased. If a third party, such as TMC, CI2, or supervisor, directs the AR4 controller to move aircraft to 24R, as CI2 currently does with AR1, then increased vectoring will result. Runway changes must be done as far from the airport as possible.
(a) Yes, (b) Yes	It reduced the vectoring needed because the BASIN sector balanced the arrival flow, which allowed AR1 & AR2 to fine-tune the final.
(a) Yes- Stadium, (b) No- Downe	STADIUM had to vector a bit more due to increase in straight in runway 24 traffic. Having BASIN put the aircraft on 24 reduced the vectoring DOWNE had to do.

Q7. *(a) Did the simulated procedure change the* ***amount of speed adjustments*** *needed as compared to current operations at your facility? If yes, please explain. (b) Per aircraft?*

	EN ROUTE CONTROLLERS
Response	**Comments**
(a) No, (b) No	None given.
(a) No, (b) No	You still have to control a sequence of a string of aircraft and the techniques and amount of adjustments needed seemed to be the same.
(a) No, (b) No	None given.
None given	None given.
(a) Yes, (b) No	More speed adjustments because of longer in trail requirements. But again stacking aircraft will help.
(a) Yes, (b) Yes	To create and maintain the increased flow I issued more drastic speeds. I am not sure if I issued more total speeds.

Terminal Controllers	
Response	**Comments**
(a) No, (b) No	None given.
(a) Yes, (b) Yes	Speed adjustment workload increased in BASIN sector. This is normal for a feeder sector.
(a) Yes, (b) Yes	None given.
(a) Yes, (b) Yes	Yes. A/C came to us faster and needed 1 - 2 more speed adjustments to get them slowed and into sequence.

Q8. Did the simulated procedure change the ***amount of interfacility and/or intrafacility coordination*** *needed as compared to current operations at your facility? If yes, please explain.*

En Route Controllers	
Response	**Comments**
No	None given.
No	None given.
None given	None given.
Yes	Since sectors 37 and 39 run independent flows, there is less coordination required between the two. There is also less coordination with TMU.
Yes	Intrafacility coordination was reduced in reference to the LAX flow. Interfacility coordination did not change.
Yes	Sectors 39 and 37 could use less coordination due to not needing to flow each other's LAX traffic. 39 and 40 are going to have more point outs to take care of. Sectors 19 and 20 are going to have an increase in coordination.
Terminal Controllers	
Response	**Comments**
No	None given.
Yes	Interfacility was reduced. Intrafacility was slightly increased because of direct coordination between AR1 and AR2.
Yes	But not excessive.
Yes	ZLA called to APREQ altitude between A/C. Not much change in amount of coordination for runway assignments.

*Q9. In your opinion, will the simulated procedure **accommodate future air traffic growth**? Airline/user requests? Please explain.*

EN ROUTE CONTROLLERS	
Response	**Comments**
Don't know	I think it will help overall especially in the TRACON. Unless LAX improves its capacity it is not really going to make much difference. We are just setting up procedures to hold aircraft and begin to have controllers and pilots used to holding in the airspace. We will be able to contain it better.
No	We are at capacity now. This procedure will not change that; an increase will not be able to be accommodated.
None given	None given.
Yes	I think it is an improvement and will handle more aircraft because BASIN sector can accept aircraft, sequence, and then hand off to DOWNE or STADIUM. Sector 20 now can not do this.
Yes	If the procedures developed while here are incorporated with the proposed changes, throughput will increase and airport acceptance should also increase.
Yes, No	Yes, I will think it will accommodate future growth to some degree because it allows us to put more airplanes through the Center's sectors. No, it does not accommodate pilot requests in that they like to stay high as long as they can and they will need to start down earlier.
TERMINAL CONTROLLERS	
Response	**Comments**
Yes	If our procedures were implemented it is possible to realize a more efficient flow of aircraft from the East. Any increase in traffic will remain to be seen.
Yes	We may be able to take more aircraft using all four runways during visual separation.
Yes	It will drastically increase airport efficiency.
Yes	It will help to fill the airport at times when all A/C come from the East.

7.2 Simulation Observer Documentation

The simulation observers compiled the table in Appendix A to use as a reference for interpreting questionnaire and computer-generated data. In addition, every fifteen minutes within a simulation run in the TRACON area, the observers counted the number of aircraft at each controller sector position. This traffic count provided snapshots of the distribution of workload and the efficient use of airspace across terminal sectors. It also provided the controllers with preliminary information regarding the role of the BASIN sector feeding traffic into the DOWNE and STADIUM sectors. Table 6 shows the 15-minute interval aircraft counts per run per terminal sector.

Table 6. TRACON Sector Aircraft Counts per Fifteen-Minute Intervals*

Run	Traffic Level	15-minutes			30-minutes			45-minutes			60-minutes		
		B	D	S	B	D	S	B	D	S	B	D	S
1	1	5	7	6	2	10	5	4	5	5	3	13	3
2	3	5	9	7	4	10	6	4	5	7	-	-	-
3	1	3	5	9	2	6	7	6	3	7	7	7	8
4	3	6	9	6	4	6	6	5	6	7	4	9	6
5	1	7	7	8	6	6	8	5	7	8	-	-	-
6	4	6	10	7	5	8	5	5	6	10	-	-	-
7	3	5	8	7	4	7	8	7	5	7	5	9	9
8	4	6	10	9	7	9	6	4	6	10	-	8	8
9	1	5	8	7	5	8	8	4	5	9	5	12	8
10	1	6	9	6	5	6	7	6	6	5	-	-	-
11	1	8	2	2	7	4	3	5	8	9	9	4	8
12	4	6	8	8	6	8	8	-	-	-	-	-	-

* B = BASIN, D = DOWNE, S = STADIUM

At most 15-minute snapshots, the BASIN sector had control of a slightly smaller number of aircraft than DOWNE and STADIUM. During Run 11, however, that was not the case. The higher BASIN numbers in Run 11 were most likely due to the holding of aircraft in the first 20 minutes of the run.

The snapshot counts for the DOWNE and STADIUM sectors appear to be rather evenly distributed over all runs. The total DOWNE counts were higher than STADIUM, but this makes sense when correlated to the *Scenario Description by Run* table in Appendix A. DOWNE put more aircraft in hold than STADIUM over the course of the simulation. Taking that into consideration, the allocation of aircraft by BASIN into the DOWNE and STADIUM sectors appeared to be well-distributed.

7.3 Computer-Generated Data Analyses

The TGF, ARTS, and Host facilities generate a large quantity of data in TGF, CDR, and SAR formats, respectively. Such data provides measures of airspace and/or airport capacity. In addition, some of the data, such as air traffic volume data, heading, speed, and altitude data entries, and aircraft mean sector flight times can provide information about the complexity of a particular airspace or sector. Other data, such as the number and duration of aircraft holds and the number of conflict alerts within a certain period of time can provide information on the level of controller workload.

At the request of the LAAEP participating controllers, the above mentioned variable measures were compiled and investigated with the LAAEP simulation data. Because no baseline study was conducted and because simulation runs varied in special events, no statistical inferences could be drawn from the data. However, raw data is presented and discussed. Those individuals knowledgeable of Los Angeles Center and TRACON operations should be able to compare the quantitative data from the simulation to current operations at their facilities.

7.3.1 Air Traffic Volume

Air traffic volume data were compiled by sector for each run of the simulation. The total number of aircraft tracks worked, which included arrivals, departures, and overflights, was determined. In addition, the total number of LAX arrivals solely was computed.

7.3.1.1 Number of Aircraft Tracks Worked

Table 7 depicts the total number of aircraft worked per sector per run of the simulation. Data were not available for the DOWNE sector for Runs 1-6 due to a software problem. Although between-sector numbers can be examined for each run, not a great deal can be inferred, because run lengths varied. Table 8, however, shows throughput data for the first 45 minutes of each run. Run 12 was only 39 minutes in length, so one would expect the numbers presented to be slightly higher for a 45-minute period. The counts should still be compared with caution, due to different events that transpired in each run (refer to Appendix A).

On the average, despite traffic level and special event differences, Sector 39 controlled the most aircraft per run. Questionnaire responses from the Center controllers support this observation.

Table 7. Total Number of Aircraft Worked Per Sector for Entire Run

Run	Run Length	Traffic Scenario	39	37	20	19	BASIN	STADIUM	DOWNE
1	67m, 11s	1	58	39	31	34	37	20	n/a
2	46m, 27s	3	43	26	25	24	33	21	n/a
3	71m, 6s	1	55	40	31	31	41	31	n/a
4	64m, 2s	3	57	41	32	31	46	33	n/a
5	56m, 39s	1	53	41	29	30	35	26	n/a
6	51m, 31s	4	48	43	32	29	40	36	n/a
7	61m, 16s	3	55	44	34	34	45	48	48
8	51m, 29s	4	49	42	32	30	39	48	43
9	60m, 6s	1	50	42	32	29	39	46	43
10	49m, 37s	1	51	37	30	27	33	33	43
11	62m, 43s	1	51	42	31	28	30	39	31
12	39m, 9s	4	39	34	25	24	30	39	32

Table 8. Total Number of Aircraft Worked Per Sector for 45 Minutes*

Run	Run Length	Traffic Scenario	39	37	20	19	BASIN	STADIUM	DOWNE
1	45m	1	43	31	20	22	26	14	n/a
2	45m	3	41	35	24	24	31	21	n/a
3	45m	1	42	33	22	19	27	19	n/a
4	45m	3	43	35	24	24	33	26	n/a
5	45m	1	42	34	20	23	29	19	n/a
6	45m	4	42	36	24	23	35	31	n/a
7	45m	3	43	36	28	26	34	36	35
8	45m	4	44	36	29	26	36	43	36
9	45m	1	40	31	23	21	24	25	32
10	45m	1	39	34	28	24	30	29	30
11	45m	1	40	33	21	18	22	27	26
12	39m, 9s	4	39	34	25	24	30	39	32

* Run 12 was 39m, 9s in length. Figures would be slightly higher for 45 minutes.

7.3.1.2 Number Of Lax Arrivals

Since the total number of aircraft tracks worked included not only arrivals, but departures and overflights as well, the number of LAX arrivals only was computed. Appendix D contains a table of LAX arrival numbers by runway for the DOWNE and STADIUM approach control sectors. The majority of aircraft were cleared for the outboard runways, 24R and 25L.

The numbers presented in Appendix D correspond, as expected, to the 15-minute interval snapshot data. LAX arrivals, for the most part, were evenly distributed between the DOWNE and STADIUM sectors, down to the runway thresholds.

7.3.2 Heading, Speed, and Altitude Commands

The number of heading, altitude, and speed commands were computed for each run by sector. The first table in Appendix E displays the figures. For data analysis, heading commands not only included *Fly heading xxx* commands, but also *Direct xxx* commands in the en route airspace and *Intercept localizer* commands in the terminal airspace. Altitude commands not only included climb and descend commands, but also *Cross intersection xxx* commands.

As with the *Aircraft Tracks Worked* data, numbers are difficult to compare because of the varying run lengths. The second table in Appendix E shows the frequencies of heading, altitude, and speed commands for the first 45 minutes of each run- with the exception of Run 12, which was just over 39 minutes long. Appendix A should be referred to when examining the numbers. It should also be kept in mind that individual controller differences also may have accounted for some of the variation in the numbers.

7.3.3 Number and Duration of Aircraft Holds

Appendix F details the number and duration of aircraft holds by run and by sector during the simulation. Appendix A shows which runs had aircraft in holds, but the exact magnitude of those special-scripted events is detailed in Appendix F. Run 9 and especially Run 11 were high-workload runs as far as holding was concerned. Again, the workload questionnaire data support this observation of the quantitative data.

7.4 Audio and Video Data Compilation

The original plan for videotaping the LAAEP simulation involved recording each sector each run using microcameras mounted to quick-looked, unmanned displays. The resolution provided by the cameras, however, was not adequate enough to read the aircraft data tags on playback. Therefore, a digital scan converter was connected to the TGF's X-windows Plan View Display (XPVD) containing a map of all seven simulated sectors. For each run, an area of the map was enlarged (i.e., either BASIN, DOWNE and STADIUM, 19 and 20, or 37 and 39) and recorded on a videotape. Audio was also recorded; in stereo for the paired sectors. Table 9 lists the videotape compilation for the entire simulation.

Table 9. LAAEP Videotape Compilation

Run	Sector(s)	Traffic Sample	Special Events
1	37 & 39	1	20 MIT; holding in Sector 39
2	Downe	3	10 MIT; holding; IFR; 2 active runways
3	Basin	1	10 MIT; IFR; 2 active runways
4	19 & 20	3	15 MIT
5	Downe & Stadium	1	10 MIT; IFR; 2 active runways
6	37 & 39	4	15 MIT; No D side on 37; stacks over KONZL instead of in-trail
7	19 & 20	3	15 MIT; stacks over KONZL instead of in-trail
8	Basin	4	10 MIT; VFR; 4 active runways
9	19 & 20	1	20 MIT with 2 flows to 15 MIT and 1 flow 30 minutes into the problem; holding
10	Basin	1	10 MIT; IFR; 2 active runways; switched to VFR at 30:00 and to 4 active runways
11	37 & 39	1	20 MIT; holding
12	Downe & Stadium	4	7 MIT; VFR; 4 active runways

8. SUMMARY

The full impact of an ATC procedural change on the ATC system is seldom clear until the change is actually implemented, or, where technology allows, simulated. The scope of the LAAEP plan was such that adequate testing and evaluation could not be done in the facility DYSIM laboratories. LAAEP representatives therefore recruited testing support from the FAA's William J. Hughes Technical Center, in New Jersey. The Technical Center's ARTCC and TRACON laboratories provided the air traffic controllers with fully-operational ATC displays and interfacility interface capabilities.

Six FPL controllers from ZLA and four FPL controllers from the SOCAL TRACON participated in the real-time simulation. The controllers were not only test subjects, but also evaluators of the LAAEP arrival route modifications and airspace resectorization plans. Over a four-day period, controllers rotated through sector positions and experienced varying levels of traffic complexity. They intentionally scripted special events into the traffic scenarios, such as runway closings and the holding of aircraft, to test the limitations of the proposed procedures. Controllers worked together to resolve issues and make recommendations for a workable operation.

Data were collected from laboratory computer systems and from questionnaires. However, because simulation run events varied and no baseline data was collected prior to the test, a limited amount of statistical analyses could be done. Objective data relating to capacity, sector complexity, and workload were collected in TGF, SAR, and CDR formats. Specifically, throughput, controller action, and special event data were compiled and the raw figures presented. The numbers must be correlated with specific run events, detailed in Appendix A, to be interpreted.

Controller workload data was collected following each of twelve runs comprising the simulation. For the most part, workload did seem to decrease as simulation experience progressed. Special scenario events seemed to affect workload more than the number of aircraft involved in a scenario. This was demonstrated by the high workload ratings associated with Runs 9 and 11, which were Scenario 1 runs, with a considerable amount of holding.

For some of the Center controllers, increased mile-in-trail requirements resulted in higher perceived workload. Several controllers commented that stacking the aircraft in lieu of in-trail separation was the more effective strategy, which also reduced workload. In the terminal area, the new BASIN sector was perceived by most controllers to be busy, but workable. Some difficulty was experienced, however, in keeping the most efficient flow of aircraft in the absence of clearly defined procedures. Both the DOWNE and STADIUM sectors were considered very manageable by most controllers.

Since only a limited amount of data analysis could be done, controller feedback on the LAAEP plan proved to be an invaluable source of information. All ten controllers agreed the LAAEP proposed procedures could be safely conducted in an actual ATC environment. New procedures training was considered a crucial component, however.

The stacking strategy was recommended by several Center controllers to be part of the training. All controllers felt they had to change their *usual* work strategies to some degree to work the traffic with the modified airspace.

As far as the distribution of workload between sectors was concerned, several controllers felt Sector 19 was not as busy as pre-LAAEP due to a more shared workload between Sectors 19 and 20. Most TRACON controllers felt the LAAEP demonstrated a workable balance of traffic between the DOWNE and STADIUM sectors, with the help of the new BASIN sector.

The majority of controllers believed the simulated LAAEP procedures would accommodate future air traffic growth. One controller believed the procedures offered an overall significant improvement with the TRACON. Another controller stated that the Center was able to work a higher flow of traffic with the TRACON able to accept the flow with new procedures. *Efficiency* was a key simulation outcome mentioned by many controllers. In summary, the users- the ZLA and SOCAL controllers, supported the simulated LAAEP procedures.

9. CONCLUSIONS

This simulation tested the proposed LAAEP east arrival route modifications and new BASIN sector for workability, efficiency, and safety. Seven sectors, four en route and three terminal, were simulated concurrently. Participating controllers worked arrival traffic at varying degrees of complexity. Special events, such as runway closings, aircraft in holding, mile-in-trail restrictions, and various combinations of such events were simulated and evaluated by the controllers to assess the limitations of the LAAEP plan. All ten FPL controller participants from the LA Center and SOCAL TRACON facilities agreed the proposed procedures could be safely controlled in an actual operational environment. They collectively devised performance strategies and training recommendations for all LAX controllers to ultimately enable a successful operation.

Acronym List

ARTCC	Air Route Traffic Control Center
ARTS	Automated Radar Terminal System
ATA	Air Traffic Assistant
ATC	Air Traffic Control
CDR	Continuous Data Recording
DVRS	Digital Voice Recording System
FAA	Federal Aviation Administration
FPL	Full Performance Level
IFR	Instrument Flight Rules
LAAEP	Los Angeles Arrival Enhancement Project
LAX	Los Angeles International Airport
MIT	Miles in Trail
NAS	National Airspace System
SAR	System Analysis Recorder
SOCAL	Southern California
SPW	Simulation Pilot Workstation
TG	Target Generation
TGF	Target Generation Facility
TMU	Traffic Management Unit
TRACON	Terminal Radar Approach Control
VFR	Visual Flight Rules
XPVD	X-Windows Plan View Display
ZLA	Los Angeles Center

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