Appendix H-6
LAX SPECIFIC PLAN AMENDMENT STUDY REPORT

Los Angeles International Airport
North Airfield Safety Study

May 2010

.

Los Angeles International Airport North Airfield Safety Study

Final Report

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Executive Summary

The North Airfield Safety Study was undertaken by an Academic Panel comprised of the six professors listed above, with very substantial participation by colleagues at NASA-Ames. The primary aim of the study was *to estimate as specifically as possible the level of future safety of several alternate configurations of the LAX North Airfield*. An auxiliary goal was *to provide useful information about the capacity implications of the various configurations*, in light of projections about LAX traffic levels in 2020.

A central component of the study was a human-in-the-loop simulation exercise, conducted during August 2009 at the NASA-Ames FutureFlight Central facility in Mountain View, California. But the study also relied heavily on empirical evidence about runway safety and capacity, based on historical experience at LAX and elsewhere. The Panel took careful note of the changes completed in 2008 on the LAX South Airfield, which moved the two parallel runways 100 feet further apart and created a centerline taxiway between the runways.

As is explained in the report, the Panel concluded that the North Airfield of LAX is extremely safe under the current configuration. Changes to the configuration could create even greater safety, but they would be expected to reduce only slightly the overall risk that LAX air travelers face in the journeys. (That overall risk level is itself minuscule because air travel is exceedingly safe.) Considerations of *capacity* appear to make some alterations to the North Airfield less attractive, and others—particularly the option of moving Runway 24R 340 feet North—significantly more so. But the Panel believes that it would be difficult to argue for reconfiguring the North Airfield *on safety grounds alone.*

The Alternative Configurations

The study focused on five possible configurations of the North Airfield, including two variants of the existing layout:

(1A) *The existing configuration*, in which runways 24L and 24R are separated by 700 feet, with no centerline taxiway between them.

(1B) *The existing configuration*, but with changes to the taxiways leading from runway 24R so that planes landing on 24R would cross runway 24L closer to its west end.

(2) *The 100-North Option*, which would create on the North Airfield essentially a mirror image of the new arrangement on the South Airfield. Runway 24R would be moved North by 100 feet, and a centerline taxiway placed between runways 24L and 24R.

(3) *The 340-North Option*, which would move runway 24R 340 feet to the North and create a centerline taxiway between runways 24L and 24R.

(4) *The 340-South Option*, which would move runway 24L 340 feet to the South and create a centerline taxiway between runways 24L and 24R. This option would entail the demolition of existing terminals 1-3 and the construction of a new "linear" terminal.

(5) *The Three-Runway Option*, which would replace runways 24L and 24R with a single runway 24 and would handle most of the airport's Group V aircraft (e.g, 777class) and Group VI aircraft (e.g. Airbus 380 class), with other flight operations concentrated on the South Airfield.

The Available Data

The Panel was fortunate to have a wealth of information generated by the simulations at NASA-Ames. Experienced controllers worked simulated traffic at LAX--on both the North and South Airfields--expected during busy hours based on 2020 forecasts prepared by Ricondo Associates with modifications by the Panel. Three visibility conditions were simulated: Daytime Visual, Daytime Instrument, and Night Visual. Across the simulation hours, the number of operations by Group VI aircraft—the grouping with the largest planes, namely, the Airbus 380-800 and the Boeing 747-8—varied from two to six. Some of the landings were performed by actual pilots in a

Boeing 747-400 flight simulator, while other aircraft were landed by "pseudo-pilots" using a computer-based interface.

Several types of information and data were collected in the simulations. After the sessions, intensive oral and written interviews were conducted with both pilots and controllers. Moreover, some "anomalies" were introduced into the simulation to provide an alternate perspective on how well the controllers were coping with heavy and diverse traffic. For example, some pseudo-pilots were asked deliberately to read back controller instructions incorrectly, to see whether the controller noticed and corrected the error. In addition, data were available about the number and duration of transmitted messages between pilots and controllers. This information offers some insight about controller workload.

The Panel also thought it important to scrutinize information from several other sources, including:

- FAA projections about the national risk of fatal runway collisions in 2020
- FAA assessments about the accident-reduction potential of new technologies, such as the ASDE-X radar and Runway Status Lights
- The history of runway incursions on both the South and North Airfields of LAX
- The runway incursion history at other US airports besides LAX
- Worldwide historical data about casualty patterns in fatal runway collisions
- Worldwide historical data about runway *excursions*, in which a single aircraft deviates sharply and suddenly from its intended path
- Data about easterly arrivals at LAX, which were not included in the NASA simulation

Findings about Safety

The Baseline Case

After much analysis, the Panel unanimously concluded that the existing North Airfield will be *extremely safe* even under traffic levels projected for 2020. More specifically:

> **The Panel estimates that, at 2020 traffic levels, fatal runway collisions on the existing North Airfield would occur on average approximately once every 200 years.**

The Panel's reasoning is explained in detail in the report, but a quick synopsis would be:

- Various FAA studies imply that, at 2020 traffic levels, *fatal runway collisions* would occur at *some* towered US airport once every eight years.
- This estimate assumes high effectiveness for new technologies like AMASS (Airport Movement Area Safety System) ASDE-X radar and Runway Status Lights. (LAX South is one of the very few US airports that have all three technologies.) Thus far, the FAA's prediction has been justified by events: major runway incursions in the US dropped 80% between Fiscal 2000 and Fiscal 2009 (from 67 to 12). Furthermore, there have been no fatal runway collisions anywhere in the US since March 2000, and the accident on 2/2/91 at the LAX North Airfield—nineteen years ago – was the *last* collision at a towered US airport that caused deaths to scheduled airline passengers.
- To be conservative, the Panel estimated that fatal runway collisions would occur at 2020 traffic levels once every four years rather than every eight. In effect, the Panel was assuming twice the level of collision risk estimated by FAA.
- But if a fatal runway collision occurred at 2020 traffic levels at one of the US towered airports, what is the chance it would take place on the LAX North

Airfield rather than elsewhere? The Panel made eight different estimates of this probability, based on:

  - The runway incursion history at LAX-North relative to that for the entire US
  - The LAX-North share of squared traffic levels in the US, a key metric because FAA airport surface risk models assume that risk varies in proportion to the square of traffic levels.
  - Safety levels at other US airports that pilots in the NASA-Ames simulation considered equally safe with LAX-North (the "peer airports"). These peer airports included Atlanta, San Francisco, Miami, and New York-JFK.

- The eight estimates of the chance that a fatal runway collision that took place in the US would occur at LAX-North ranged from a low of 1 in 140 to a high of 1 in 60. To be conservative, however, the Panel estimated to be 1 in 50 (2%) the probability that the venue would be LAX-North. In other words, the Panel used a risk estimate for LAX-North that was *higher* than any that arose under its diverse estimation methods.
- The Panel explored whether the growing frequency of Group VI aircraft on the North Airfield might pose incremental collision risk, and concluded that it would not. A major reason for this conclusion is that Group V aircraft (the largest planes for which there is historical data) have not been involved in incursions at LAX to a disproportionate extent.
- The Panel then combined its numerical risk estimates. If:
  - fatal runway collisions occurred once every four years at some towered US airport and
  - 1 in 50 of these collisions took place at LAX-North

Then it follows that fatal runway collisions at LAX-North collisions would occur every 4x50=200 years.

Using the “one in every 200 years estimate,” plus estimates about the casualties in a fatal runway collision at LAX North, and data about LAX passenger traffic around 2020, the Panel reached a further approximation:

At 2020 traffic levels, the Panel estimates that fatal runway collisions at LAX-North would claim approximately five lives per decade. Because of the margin of error associated with this estimate, a range estimate for the actual rate extends from a low of one death per decade to a high of eight deaths per decade. **Given that roughly 750 million passengers would use LAX each decade at 2020 traffic levels, the figure “five death per decade” works out to one death per 150 million passengers.**

The statistic “one in 150 million” is obviously small in absolute terms. It is also extremely small relative to other accident risks that US residents face: an American baby born today, for example, has approximately a 1 in 100 chance of eventually dying in an auto accident. Moreover, the risk is small even relative to the exceedingly low risks of passenger air travel: the death risk per flight for US air travelers is approximately 1 in 10 million, which is *fifteen times* the risk that the LAX-North runways would present in the baseline case.

The Interim Improvements to the North Airfield (IRSIP)

The Panel explored evidence about whether IRSIP would improve North Airfield safety by requiring planes landing on Runway 24R heading towards terminals to cross Runway 24L further down the runway. The Panel estimates that the plan could increase from 33% to 51% the chance that a departing aircraft on 24L would already be airborne at the point where a landing plane blundered onto the takeoff runway. But the probability that a landing plane blunders onto 24L might not decrease significantly if the new runway exits proposed in IRSIP induce the high runway incursion rates associated with taxiways Zulu and AA. Indeed, for planes that now use Taxiway Yankee, the data suggest that the risk of incursion might well go up. Thus, it is possible that closing Taxiway Yankee would do more harm than good, and the matter warrants further study.

Moving Runway 24R 100 Feet North

Because such a proposal would essentially replicate on the North Airfield what has already been done on the South Airfield, the Panel put considerable weight on evidence about whether incursions have dropped on the South since its reconfiguration. While only about 18 months of data are at hand about safety under the new arrangements, they suggest that the changes have reduced incursion risk on the South by about **40%**. The apparent reason for the improvement is the new centerline taxiway, which causes landing planes to slow down before crossing the takeoff runway and which gives controllers greater flexibility in deciding when planes landing on Runway 25L should cross Runway 25R.

The Panel also considered a good deal of other evidence about the effectiveness of a 100-North configuration. From the NASA-Ames simulation, there were data about anomalies and radio communications between tower and pilot, as well as survey reactions from pilots and controllers. There were incursions data from airports other than LAX that have configurations similar to 100-North, and there were indications that Runway Status Lights might be especially effective when accompanied by a centerline taxiway. Some of this evidence suggested that the benefits of 100-North would exceed the 40% suggested by South Airfield data, while other evidence suggested a benefit less than 40%. The Panel concluded that, on balance:

> **40% is a reasonable estimate of the reduction in the risk of a fatal runway collision on the North Airfield if the existing runways were replaced by a 100-North configuration.**

Moving Runway 24R 340 Feet North

The Panel considered various data about this option, which has the distinguishing feature that its centerline taxiway is far enough from the active runways that Group VI aircraft need not require special treatment. The reconfiguration would also allow landing pilots crossing Runway 24L to get a better view than otherwise of departing traffic.

After various analyses, the Panel concluded that 340-North reduces collision risk relative to 100-North, but not by an enormous factor (perhaps 25%). Much of the benefit of introducing a centerline taxiway would already be achieved with the 100-North configuration. The Panel estimates that:

> **55% is a reasonable estimate of the reduction in the risk of a fatal runway collision on the North Airfield if the existing runways were replaced by a 340-North configuration.**

Moving Runway 24L 340 Feet South

Operationally, this arrangement is similar to 340-North. But the Panel concluded that the safety benefits would be slightly smaller, largely because the NASA simulations suggest that ground arrangements associated with revamping the terminals could get more complex and demanding for controllers. The Panel estimates that:

> **50% is a reasonable estimate of the reduction in the risk of a fatal runway collision on the North Airfield if the existing runways were replaced by a 340' South configuration.**

Moving to a Three-Runway Airport

If there were only one runway on the North Airfield, then planes landing there would have no takeoff runways to cross en route to terminals. On the other hand, the North Airfield would be perpetually involved in *mixed operations*, in which landings and takeoffs occur on the same runway. (Mixed operations on the North Airfield would occur even under other configurations, but to a much lesser extent.) Results from the NASA simulations and data about other US airports that extensively conduct mixed operations suggest that a three-runway configuration would largely achieve the safety benefits for which its proponents hope. The Panel estimates that:

> **50% is a reasonable estimate of the reduction in the risk of a fatal runway collision if the existing North Airfield were replaced by a single Runway 24 under a three-runway configuration for LAX.**

Capacity Assessment

The Panel was asked whether the limitations of airport capacity under individual configurations of the North Airfield would "unduly impact" the ability of LAX to handle the volume and mix of air traffic projected for 2020. Here the experiments at NASA-Ames provided quantitative data about how many departures that could be achieved under peak traffic conditions, as well as taxi-in and taxi-out times. Across the simulation hours, there were variations in weather and visibility conditions and in the number of Group VI aircraft, allowing a clearer picture of the sensitivity of capacity findings to the background assumptions.

The Panel concluded that the baseline, 100-North, and 340' South configurations could handle even peak traffic without "unduly" suffering stress and delay.

In the 340-North configuration, however, there was conspicuous improvement in capacity over the baseline and 100-North cases. The Panel estimates an annual cost savings of $15 million because of the reduction in taxiing times and runway blocking operations. The gain in departure capacity would be modest (perhaps four additional operations per hour), but it would open the door to reduced arrival delays. (The study did not estimate this size of this benefit.) Besides a capacity gain, having a centerline taxiway allows greater flexibility in handling aircraft and, in particular, Group VI aircraft.

The capacity results for the three-runway configuration were less encouraging: the reduction in departures observed at NASA could have adverse direct and indirect consequences. Given that mixed operations would occur on the North Airfield (i.e., landings and takeoffs on the same runway), arranging for departures in the face of frequent arrivals would be challenging. It is also true that the temporary shutdown of a runway can cause considerably more disruption when there are only three runways rather than four. The Panel fears, therefore, that the capacity limitations in the three-runway case *would* be unduly constraining in peak conditions, which would prevail for nine hours of the day under the 2020 forecast.

Caveats

The Panel has never been under any illusion that it could provide exact results rather than plausible approximations. Among the reasons for caution are:

- The 2020 forecasts about traffic levels at LAX, and about the fraction of traffic involving Group VI aircraft, are subject to considerable uncertainty.
- The experiments at NASA-Ames were extremely sophisticated and well conducted, but they can only approximate what might happen under various configurations of the North Airfield.
- Data about historical experience are valuable, but there are issues in generalizing from other airports to LAX, and from past patterns to those that might prevail in the future under new arrangements. Moreover, many of the data are subject to the high random variability associated with rare events, a circumstance that poses real challenges for statistical estimation.

One might remember, however, the adage that the perfect is the enemy of the good. The Panel believes that the thrust of its conclusions is accurate, and that the experiment at NASA-Ames and the review of historical and other data serve to point in the right general direction if not at the exact angle.

Main Conclusions

The Panel is unanimous on all of the following points:

- *For projected 2020 traffic levels and traffic mix, the LAX North Airfield is extremely safe under the current configuration.*

  The Panel estimates that, at 2020 traffic levels, fatal runway collisions would occur on the North Airfield at an expected rate of one every 200 years, and that such fatal collisions would cause approximately one death for every 150 million LAX passengers. That level of risk is low even relative to the exceptional safety of US passenger aviation.
- *All the proposals to create new configurations on the North Airfield would reduce by a substantial percentage the risk of a runway collision.*

  More specifically, the evidence from the NASA-Ames simulation and numerous kinds of historical data suggest that:

  - Moving Runway 24R 100 feet North and creating a centerline taxiway could reduce collision risk on the North by about 40% relative to the baseline.
  - Moving Runway 24R 340 feet North and creating a centerline taxiway could reduce collision risk on the North by about 55% relative to the baseline.
  - Moving Runway 24L 340 feet South and creating a centerline taxiway could reduce collision risk on the North by about 50% relative to the baseline.
  - Creating a single Runway 24 to replace 24L and 24R could reduce collision risk by about 50% relative to the baseline.
- *However, because the baseline level of collision risk is so low, reducing that risk by a substantial percentage is of limited practical importance.*

Aviation at LAX is exceedingly safe. Of the 750 million passengers who would use LAX per decade at 2020 traffic levels, only about 80 might be expected to perish in air disasters in the baseline case. Of these 80 deaths, five might occur in runway collisions. Reconfiguration of the North runways might be expected to reduce total deaths to about 78.

- *In terms of capacity, changes in the configuration could have major effects.*
    - Moving to a three-runway configuration could cause huge difficulties, even under visual flight conditions.
    - Moving to the 340'-North configuration, on the other hand, might significantly reduce airport congestion during peak hours and could provide appreciable capacity benefits.
- *A serious case could be made for building 340-North based on its capacity benefits, and it **would** improve safety.*

  But it would be more useful to consider the safety benefits the "icing on the cake" rather than the cake itself.
- *However, the North Airfield Safety Study was, as the name implies, primarily about safety. All things considered, the Panel cannot construct a compelling argument **on safety grounds alone** for reconfiguring the North Airfield.*

1. INTRODUCTION

In April, 2008, Los Angeles World Airports (LAWA) and the North Airfield Safety Advisory Committee (NORSAC) agreed to create an Academic Panel, which would conduct the North Airfield Safety Study with very substantial assistance from colleagues at NASA-Ames. The panel consists of six professors from various universities and various disciplines in Science and Engineering, but who have in common a longstanding interest in issues about aviation safety and efficiency. The Panel members are:

Arnold Barnett (Chair)	MIT Sloan School of Management PhD in Mathematics
Michael Ball	University of Maryland Smith School of Business PhD in Operations Research
George Donohue	George Mason University Department of Systems Engineering and Operations Research PhD in Mechanical and Aerospace Engineering
Mark Hansen	University of California, Berkeley, Department of Civil and Environmental Engineering PhD in Civil Engineering
Amedeo Odoni	MIT Department of Aeronautics and Astronautics Department of Civil and Environmental Engineering PhD in Operations Research
Antonio Trani	Virginia Polytechnic Institute and State University Department of Civil and Environmental Engineering PhD in Civil Engineering

Over the past eighteen months, the Panel has considered a host of issues related to safety and capacity of the LAX North Airfield, under a variety of configurations that could be adopted in the future. A central aspect of its work was an experiment at NASA-Ames in August 2009, in which pilots and controllers took part in sophisticated simulations of what might happen on the North Airfield in a busy hour in 2020, assuming several different geometries for the runways and taxiways. The Panel also considered information about past runway incursions and accidents at LAX and elsewhere, about the effectiveness of new technologies meant to enhance runway safety, and about the characteristics of LAX operations now and in the past. The Panel recognized from the beginning that it was engaged in an exercise in approximation, which might advance the discussion beyond a clash of conjectures about safety and capacity but fall short of exact predictions on either topic.

The main findings of the investigation are discussed in detail in this report. As we will describe, the Panel believes that:

- Even at projected 2020 traffic levels, the North Airfield would be extremely safe under the existing runway configuration.
- Nearly all the changes to the configuration that the Panel considered would be expected to improve safety, and to reduce runway collision risk by an appreciable proportion.
- However, because the baseline level of risk is so low, even reducing it by a significant fraction is of limited practical importance.
- Capacity might increase and congestion substantially diminish on the North Airfield under certain changes of runway layout.

In consequence of these assessments, the Panel believes that a case for changing the North Airfield might arise from capacity considerations, but that the case for doing so for safety reasons *alone* is not compelling. A modest improvement in safety might be "the icing on the cake" of a reconfiguration undertaken for other reasons, but it would probably not be the cake itself.

We begin our work in the next chapter, where we summarize what the Panel was and was not asked to do. Then in Chapter 3 we specify the six configurations of the North Airfield that were studied (including two variants of the baseline). In Chapter 4, we offer an overview of the experiment at NASA-Ames; in the following section, we list the other kinds of information that the Panel studied. Estimates about the safety of operations at 2020 traffic levels start in Chapter 6 and continue through Chapter 12, while Chapter 13 offers a detailed overview of findings about capacity. Finally, Chapters 14 through 17 offer caveats, answers to some specific questions posed to the Panel, some general observations and suggestions about North Airfield safety, and an overview, summary, and conclusions. An Addendum presents nine commentaries about the preliminary draft of this study, along with the Panel's responses to them. Many specific details about the investigation and much background information are presented in the appendices.

2. THE CHARGE TO THE PANEL

The Panel proceeded with certain understandings about what was expected of it. Here we articulate those understandings.

2.1. Safety First

The very fact that the endeavor was called the North Airfield Safety Study (as opposed to (say) the North Airfield Safety and Capacity Study) seemed to us to say a great deal about its priorities. We inferred that, above all, LAWA/NORSAC wanted to know whether certain configurations of the North Airfield could not guarantee at 2020 traffic levels an acceptably-high level of passenger safety. LAWA/NORSAC also wanted to know whether other configurations could do better at meeting high safety standards.

But we also understood that we were not being asked for vague or platitudinous assessments. It would not be enough to say that "X seems safer than Y"; we were asked to quantify "how much safer is X than Y?" as well as to specify "how safe was Y in the first place?" We therefore strived for – and obtained – quantitative estimates of passenger mortality risk in various LAX-North runway configurations. We also brought supplementary information to bear to offer perspective on the risk estimates and make clearer what the statistics meant

- About absolute risk to LAX passengers
- About relative risk compared to other safety hazards that face Los Angeles residents
- About runway risk relative to other mortality risks that air travelers face

2.2. Capacity Too

But we were also asked to consider capacity issues about the North Airfield. We were charged with investigating whether the constraints associated with individual runway configurations might "unduly impact" the ability of LAX to handle the levels of traffic that were projected for 2020. We considered two aspects of capacity that are related but not identical:

(i) Will the airport be able to accommodate the number of landings and takeoffs that would be sought at a peak hour, under various plausible assumptions about the fleet mix (e.g., about the fraction of operations involving aircraft design group VI aircraft)?

(ii) Will the operations that do occur take place expeditiously, or might there be a high degree of queuing and other forms of congestion? (For example, even if flight Z takes off as desired in the peak hour, did it do so rapidly or did it spend twenty minutes in taxi-out time before takeoff?)

Using information from the NASA Ames simulation and from other sources, we strived for specific answers to these questions for every configuration that we considered.

2.3. The Nine Questions

At the outset, we were given a set of nine questions that it was hoped we would answer the study:

(1) What are the causes of past and ongoing runway incursions and surface incidents on the LAX North Airfield?

(2) Are these incursions indicative of a current unacceptable level of risk by the FAA safety standards?

(3) What role does the existing airline fleet of aircraft serving LAX play in the risk of runway incursions?

(4) What roles do airfield marking, lighting, and signage play in the risk of runway incursions at LAX?

(5) What role does human error play in the risk of runway incursions? What role does air traffic control staffing play in the risk of runway incursions?

(6) What other factors play a role in the risk of runway incursions?

(7) Why has the South Airfield historically been subject to substantially more runway incursions than the North Airfield?

(8) Is there a relationship between the LAX North Airfield and South Airfield operations and the risk of incursions at the airport in general? If so, is this relationship a safety issue or problem?

(9) Will the planned airline fleet of aircraft have an impact on the LAX North Airfield operations? If so, is this a safety issue or problem?

In the body of our report, we address most of these questions directly or indirectly. But we devote a section (Section 15) to offering succinct summaries of our responses to the nine questions.

What the Panel Was Not Asked

We understood from the beginning that our assignment was not open-ended. We were not asked to consider the environmental implications of operating the North Airfield under different configurations, or the potential consequences on communities that border LAX. Nor were we asked to discuss how desires for a “balanced airfield” between North and South affect the attractiveness of particular configurations. And we were not expected to estimate the dollar cost of reconfiguring the North Airfield in various ways.

3. ALTERNATE CONFIGURATIONS FOR THE NORTH AIRFIELD

This section presents a brief overview of alternative configurations considered in this study. Overall, six alternatives or configurations were studied and modeled using the NASA Ames Research Center FutureFlight Central (FFC) and a series of external computer models and analyses performed by the Academic Panel. NORSAC provided four configurations for analysis: 1) Baseline, 2) moving runway 24L 340 South (340-South) with a center taxiway and a linear terminal configuration in the North airfield, 3) moving runway 24R 100 feet North (100-North) with a center taxiway, and 4) moving runway 24R North (340-North) with a center taxiway. Further description from NORSAC indicated the desirability to study all Group VI aircraft (ADG VI) operations in the South (called Baseline-S in this report). This effectively produced five alternatives. The Academic Panel also considered other options early on, including an End-Around Taxiway design (EAT) with a 52-foot depressed end-around taxiway for runway 24R. This would have allowed ADG VI operations around the depressed taxiway without affecting departure operations on runway 24L. The idea was not investigated further. The Academic Panel considered a sixth alternative for the airport, which was suggested at one of the earlier meetings with NORSAC. This alternative replaces the North Airfield's two runways with a single runway with well-designed supporting infrastructure, such as high-speed runway exits and parallel taxiways allowing expeditious service on the single runway for both departures and arrivals.

3.1. Baseline

The baseline configuration is the existing configuration of the North Airfield with minor upgrades in terms of runway status lights. The Baseline alternative is shown graphically in Figure 3-1. Runway 24R is the primary arrival runway with a runway length of 8,925 feet and 150 feet in width. The runway has 50 foot stabilized shoulders to accommodate ADG VI aircraft for both landings and departures. Due to its length, Runway 24R would not be expected to support ADG VI departure operations. Runway 24L would remain at 10,285 feet long and 150 feet wide. Shoulders are 50 feet wide allowing unrestricted ADG VI operations according to a modification of standards approved by the Federal Aviation Administration (FAA). Figure 3-1 shows the locations of runway status lights in the North Airfield. Taxiways Echo-8 (E8) and Victor (V) leading to runway 24L would be protected with runway-entrance lights (RELs) if runway 24L is unsafe for entry or crossing. The Runway 24L threshold has Takeoff-Hold Lights (THLs) as indicated by the long red line starting at Runway 24L threshold in Figure 3-1. Runway exits Yankee (Y), Zulu (Z) and Alpha-Alpha (AA) have runway-entrance lights (RELs) to signal aircraft if runway 24L is unsafe for entry or crossing. On the South airfield runways 25R and 25L remain unmodified at 12,091 x 150 feet and 11,095 x 200 feet, respectively. Runway 25L is compliant with ADG VI criteria in terms of the runway width and length. The South airfield has a 75-foot center taxiway located 400 feet from both runways 25L and 25R. The separation of the center taxiway is compliant with ADG V only under visibility conditions at or above 3/4 mile according to FAA design standards (FAA, 2010). The center taxiway separation does not meet FAA design standards to handle ADG VI independently. The current FAA criteria for ADG VI requires 500 feet separation between runway centerline and parallel taxiways for runways with approaches down to ½ mile plus adjustment to clear the runway Obstacle Free Zone (OFZ) surface. If the approach minima are lower than ½ mile, the FAA requires 550 feet plus correction for OFZ surface clearance.

ADG VI landings in the South require special attention by the ATC local controllers. Once an ADG VI aircraft is on the center taxiway, it blocks departures on 25R until the aircraft has crossed runway 25R and cleared the runway Obstacle Free Area (OFA). The South offers an extra challenge for ATC ground controllers because the distance between taxiway Bravo (B) and runway 25R does not allow simultaneous taxiing of ADG VI on Bravo and a departure on 25R. The distance between runway 25L and taxiway Bravo is 350 feet. Current work by LAWA on taxiway Charlie (C) should address some of these operational limitations. During the FFC simulations the Academic Panel asked NASA to locate runway-entrance lights (RELs) on the South at taxiway locations Mike (M), Papa (P), Tango (T), and Uniform (U) leading from center taxiway Hotel (H) to runway 25R. Similarly, FFC simulations had runway-entrance lights (RELs) located at taxiways Foxtrot (F) and Bravo (B) leading to runway 25R from the North. Finally, the Baseline scenario has Takeoff-Hold Lights (THLs) on runway 25R.

The Baseline configuration has a total 153 gates in ten different terminal complexes. Figure 3-2 illustrates the gate configuration provided by LAWA simulating the gate configuration expected in the year 2020. The appendix lists the gate compatibility with various aircraft and provides the gate naming nomenclature used in the study. Terminals 1-8 exist today. The West-side of the Tom Bradley International Terminal (TBIT) and the Midfield Terminal (MID) are new additions to the airport assumed to be in place in year 2020.

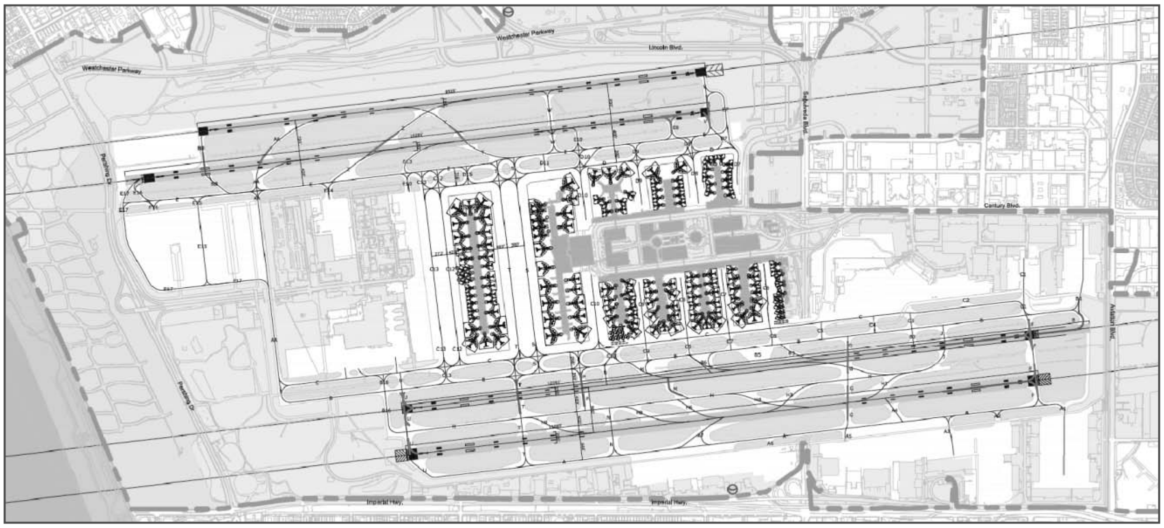


Figure 3-1: Los Angeles International Airport Baseline Alternative. Source: LAWA and HNTB (2009).

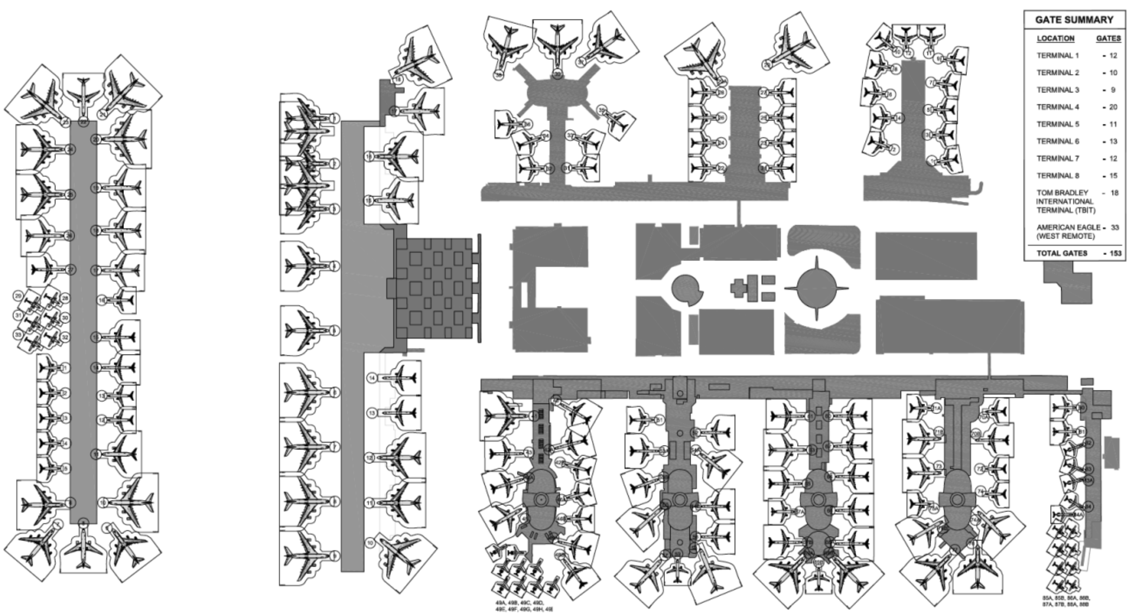


Figure 3-2: Los Angeles International Airport Gate Layout for Alternatives Baseline, 340-North, 100-North, and 3R (source: LAWA, 2009).

3.2. Baseline with Interim Runway Safety Improvement Project (IRSIP)

This configuration is an adaptation of the Baseline alternative. The Academic Panel was asked to look at this alternative late in July 2009 when the FFC experiments were ready to start. This configuration was not modeled in NASA's FutureFlight Central due to time constraints. The analysis presented in Section 7 of the report uses analytical techniques to examine the potential safety benefit of this alternative.

The basic idea of IRSIP is to move taxiway Zulu further downstream on runway 24R and create a new high-speed exit called AA1. The old Zulu and Yankee runway exits will be closed creating three similar high-speed runway exits on runway 24R. The change attempts to move possible runway incursions further downstream to the last one-third of runway 24L. Figure 3-3 illustrates the new layout of IRSIP.

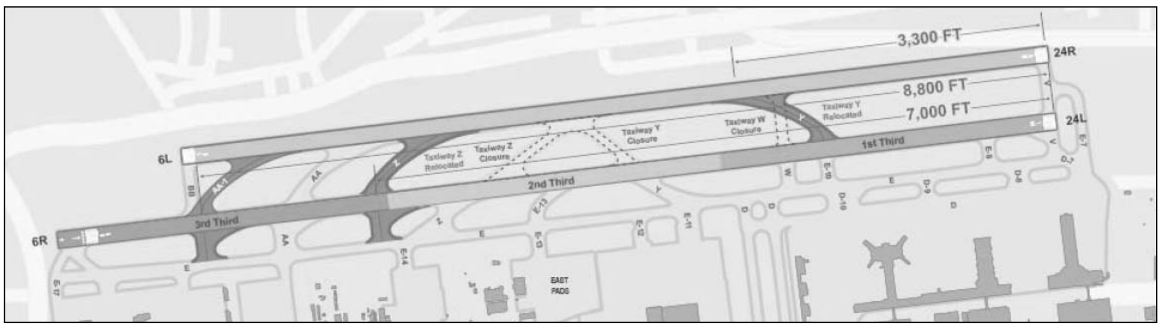


Figure 3-3: Proposed Interim Runway Safety Improvements in the North Airfield.
Source: LAWA and HNTB (2009).

3.3. Runway 24R Moved 100 feet North with Centerline Taxiway (100-North)

This configuration duplicates the current conditions of the South airfield in the North. Runway 24R is moved 100 feet to the North allowing a placement of a new center taxiway between runways 24R and 24L as shown in Figure 3-4. The layout shown in the figure predates the time when NASA and the Academic Panel became involved in this study. As originally proposed, runway 06L-24R would have a total of five runway exit locations for landings to the West. Runway exits Kilo-3 (K3) and Kilo-4 (K4) are high-speed exit locations leading to center taxiway Kilo (K). Runway exits Bravo-Bravo (BB), Charlie-Charlie (CC) and Delta-Delta (DD) are three right-angle runway exits further downstream on runway 24R. Runway 24R would be extended to 10,286 feet to protect landings from the East. A displaced threshold is provided for landings to the East on runway 06L. The length of the displaced threshold on 06L is approximately 850 feet long. Three runway exits are provided for East arrivals to runway 06L-24R. The study did not simulate East flow arrivals as they represent only 5% of the total operations at LAX.

Runway 24L is extended to a total of 11,563 feet long (see Figure 3-4). The first 1,250 feet of threshold 24L constitute a displaced threshold but are usable for departures. A new taxiway (Echo-7) is built as an extension to existing taxiway Echo. Echo-7 provides access to threshold 24L for departures. Both North runways retain their 150-foot width and 50-foot shoulders allowing ADG VI operations. Runway 24L has an 850-foot displaced threshold on runway end 06R. This provides protection for approaches from the East. A full center taxiway Kilo is present in this scenario. Kilo has a total of eight perpendicular taxiways to cross runway 24L. For the purpose of the FFC simulation, the location and placement of runway status lights in the 100-North configuration at crossing taxiways W, Y, Z, AA, and BB. These locations were selected based on our prediction models for runway exit use with landings on runway 24R. In FFC simulations runway exits CC and DD were never used. The South airfield follows the same configuration described in Section 3.1 for the Baseline alternative.

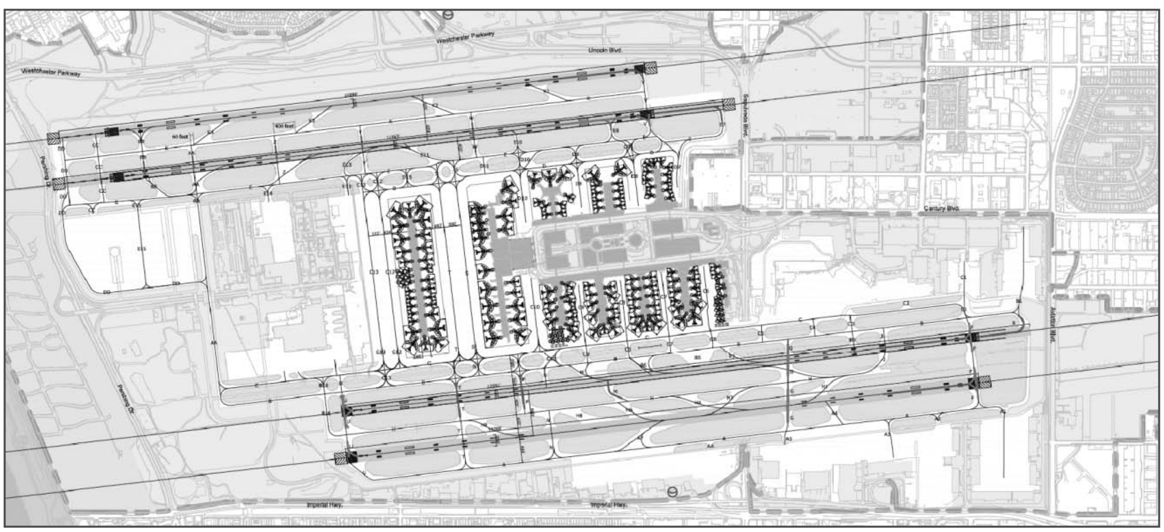


Figure 3-4: Los Angeles International Airport Alternative 100-North. Source: LAWA and HNTB (2009).

Operationally, 100-North would mirror operations of the South airfield today with a few exceptions. Three operational issues in the 100-North are: 1) the staggered thresholds 24L and 24R require ATC wake vortex separations between arrivals and departures; 2) the distance between inboard runway 24L and parallel taxiway Echo (i.e., 400 feet) provides more flexibility to ATC ground controllers compared to the South airfield; and 3) a restriction on the number of

ADG VI aircraft in the first 3,000 feet of taxiway Echo if an inboard arrival is to be processed. The handling of ADG-VI on the centerline taxiway has similar restrictions as those described for the South in Section 13.1.

The 100-North configuration has a total of 153 gates in ten different terminal complexes. Figure 3-2 illustrates the gate configuration provided by LAWA for operations in the year 2020. The gate configuration is similar to that of the Baseline alternatives described in Section 3.1.

3.4. Runway 24R Moved 340 feet North with Centerline Taxiway (340-North)

This configuration moves Runway 24R 340 feet to the North allowing a placement of a new center taxiway between runways 24R and 24L 520 feet from either runway. The layout of 340-North is shown in Figure 3-5. The layout shown in the figure predates the time when NASA and the Academic Panel became involved in this study. As originally proposed by the HNTB and LAWA, runway 06L-24R would have a total of five runway exit locations for landings to the West. Runway exits Kilo-3 (K3) and Kilo-4 (K4) are high-speed exit locations leading to center taxiway Kilo (K). Runway exits Bravo-Bravo (BB), Charlie-Charlie (CC) and Delta-Delta (DD) are three right-angle runway exits further downstream on runway 24R. Runway 24R would be extended to 10,286 feet to protect landings from the East. A displaced threshold is provided for landings to the East on runway 06L. The length of the displaced threshold on 06L is approximately 850 feet long. Strangely for this configuration, only two runway exits are provided for East arrivals to runway 06L-24R. The study did not simulate East flow arrivals as they represent only 5% of the total operations at LAX.

Runway 24L is extended to a total of 11,563 feet long (see Figure 3-5). Similar to 100-North, the first 1,250 feet of runway 24L constitute a displaced threshold but are usable for departures. A new taxiway (Echo-7) is built as an extension to existing taxiway Echo. Echo-7 provides access to threshold 24L for departures. Both North runways have 150-foot widths and 50-foot shoulders allowing ADG VI operations. Runway 24L has an 850-foot displaced threshold on runway end 06R. This provides protection for approaches from the East. A partial center taxiway Kilo is present in this scenario. This inconsistency compared to 100-North has no effect on the outcome of FFC simulations because only West-flow arrivals were modeled. Kilo has a total of nine perpendicular taxiways to cross runway 24L. For the purpose of the FFC simulation, the locations and placements of runway status lights in the 100-North configuration are crossing taxiways W, Y, Z, AA, and BB. These locations were selected based on our prediction models for runway exit use with landings on runway 24R. The South airfield follows the same configuration described in Section 3.1 for the Baseline alternative.

Operationally, 340-North allows ADG VI aircraft to taxi on the center taxiway (Kilo) without affecting departure operations on the inboard runway (24L) 99.55% of the time at LAX (FAA ASPM records, 2009). According to the current FAA airport design criteria, ADG VI aircraft require 500-foot separation between runway centerline and parallel taxiways for runways with approaches of no less than ½ mile plus adjustment to clear the runway Obstacle Free Zone (OFZ) surface (FAA, 2010). The OFZ adjustment for an Airbus A380-800 with a critical tail height of 80 feet is around 20 extra feet beyond the 500 feet minimum thus requiring a total of 520 feet between runway and parallel taxiway centerline to satisfy the FAA design criteria. This alternative and 340-South (see Section 3.5) are the only alternatives that meet the FAA standard for ADG VI aircraft.

The 340-North configuration has a total of 153 gates in ten different terminal complexes. Figure 3-2 illustrates the gate configuration provided by LAWA for operations in the year 2020. The gate configuration is similar to that of the Baseline alternatives described in Section 3.1.

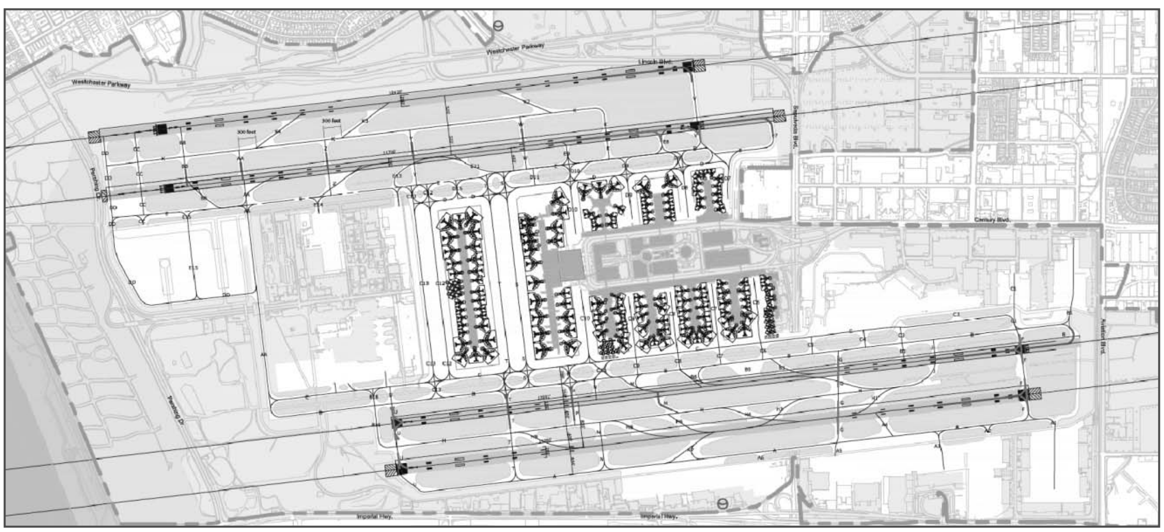


Figure 3-5: Los Angeles International Airport Alternative 340-North. Source: LAWA and HNTB (2009).

3.5. Runway 24L Moved 340 feet South with Centerline Taxiway (340-South)

This configuration moves Runway 24L 340 feet to the South and adds a new center taxiway between runways 24R and 24L that is 520 feet equidistant from both runways. The layout of 340-South shown in Figure 3-6, predates the time when NASA and the Academic Panel became involved in this study. As originally proposed by the HNTB and LAWA, runway 06L-

24R would have a total five runway exit locations for landings to the West. Runway exits Kilo-3 (K3) and Kilo-4 (K4) are high-speed exit locations leading to center taxiway Kilo (K). Runway exits Bravo-Bravo (BB), Charlie-Charlie (CC) and Delta-Delta (DD) are three right-angle runway exits further downstream on runway 24R. Runway 24R would be extended to 10,286 feet to protect landings from the East. A displaced threshold is provided for landings to the East on runway 06L. The length of the displaced threshold on 06L is approximately 850 feet long. In this configuration, only two runway exits are provided for East arrivals to runway 06L-24R. The study did not simulate East flow arrivals as they represent only 5% of the total operations at LAX.

Runway 24L is extended to a total of 11,563 feet (see Figure 3-6) similar to 100-North and 340-North. The first 1,250 feet of runway 24L constitute a displaced threshold usable for departures only. A new taxiway (Echo-7) is built as an extension to existing taxiway Echo. Echo-7 provides access to threshold 24L for departures. Both North runways have 150-foot widths and 50-foot shoulders allowing ADG VI operations. Runway 24L has an 850-foot displaced threshold on runway end 06R. This provides protection for approaches from the East. A partial center taxiway Kilo is present in this scenario. This inconsistency compared with 100-North has no effect on the outcome of FFC simulations because only West-flow arrivals were studied. Kilo has a total of eight perpendicular taxiways to cross runway 24L. For the purpose of the FFC simulation, the location and placement of runway status lights in the 100-North configuration are crossing taxiways W, Y, Z, AA, and BB. These locations were selected based on our prediction models for runway exit use with landings on runway 24R. The South airfield follows the same configuration described in Section 3.1 for the Baseline alternative.

Operationally, 340-South has similar advantages with 340-North. This alternative allows ADG VI aircraft to taxi on the center taxiway (Kilo) without affecting departure operations on the inboard runway (24L) 99.55% of the time at LAX (FAA ASPM records, 2009). This alternative and 340-North (see Section 3.4) are the only alternatives that meet the FAA standard for ADG VI aircraft.

The 340-South configuration has a total of 153 gates in eight different terminal complexes. Terminals T1, T2 and T3 are replaced by a new linear terminal with 14 gates capable of handling ADG VI and ADG VI aircraft. Figure 3-7 shows the airport configuration for 340-South. This the only configuration studied with the linear terminal (LIN) in the North.

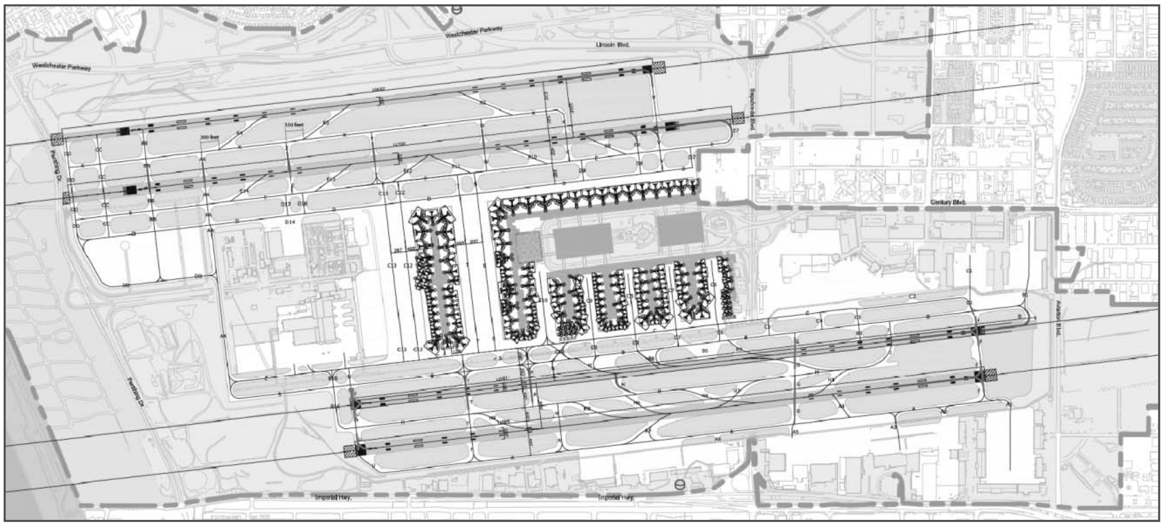


Figure 3-6: Los Angeles International Airport Alternative D (340' South). Source: LAWA and HNTB (2009).

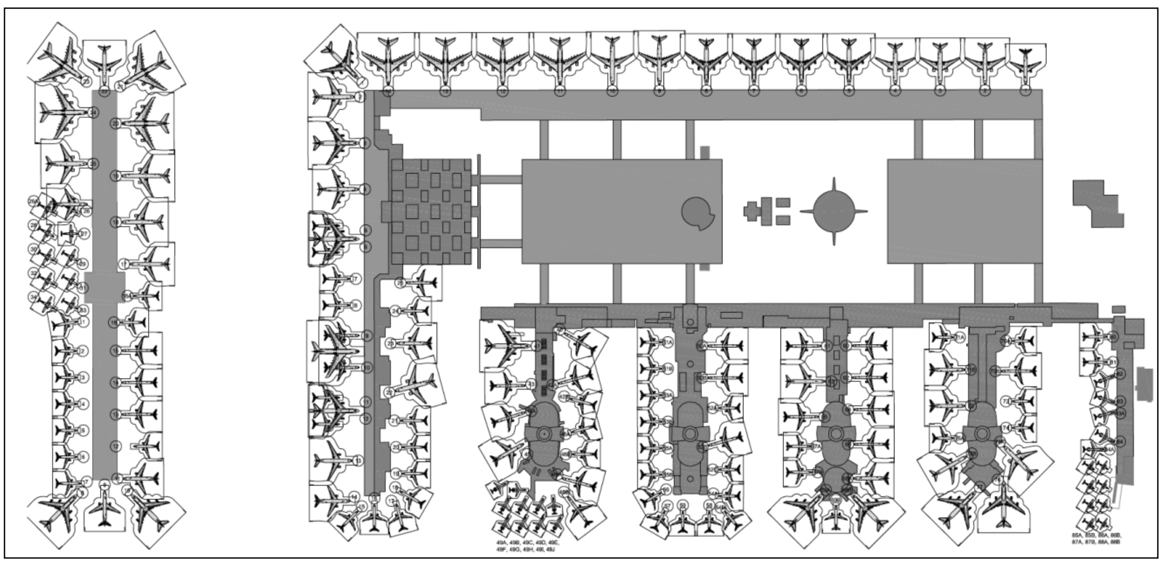


Figure 3-7: Los Angeles International Airport Gate Layout for Alternative Baseline, 340-South (source: LAWA, 2009).

3.6. Single Runway 24 on the North Airfield

This configuration keeps Runway 24R at its present location in the North. Runway 24L is converted to a parallel taxiway (700 feet separation from centerline of runway 24R to taxiway Kilo). Echo is retained as an additional parallel taxiway and is located 450 feet from taxiway Kilo. The layout of 3R is shown in Figure 3-8. The design of a single runway is optimized for the aircraft fleet mix expected at LAX in the year 2020. The Academic Panel used the Runway Exit Design Interactive Model (REDIM 3.0) (Trani et al, 2001) to locate three 30-degree, high-speed runway exits that will minimize runway occupancy time for arrivals. The design is to reduce Runway Occupancy Time (ROT) and thus maximize the gaps between arrivals allowing a maximum number of departures from a single runway. These runway exists are labeled Yankee, Zulu and AA but they bear little resemblance to their predecessors. These are high-speed runway exits with a 1,400-foot spiral to accommodate ADG VI aircraft up to 60-knot exit speeds. A detailed design of the high-speed runway exits is shown in Figure 3-9. Three right-angle runway exits are retained from the previous configurations at the end of runway 24R (taxiways BB, CC and DD). High-speed runway exits are 100 feet wide to improve their utilization at higher speeds.

Taxiways Kilo and Echo are ADG VI compliant with 100-foot width. Ten crossing taxiways provide quick access to the gates from Kilo or Echo. In this alternative, Runway 24R would be extended to 10,286 feet to protect landings from the East. A displaced threshold is provided for landings to the East on runway 06L. The length of the displaced threshold on 06L is approximately 850 feet long. In this configuration, four runway exits (2 high-speed and 2 right-angle) are provided for East arrivals to runway 06L-24R. Runway 24R is 200 feet wide and is fully compliant with ADG VI design criteria. Shoulders are 40 feet wide on each side.

The 3R configuration has a total of 153 gates in ten different terminal complexes. Figure 3-2 illustrates the gate configuration provided by LAWA for operations in the year 2020. The gate configuration is similar to that of the Baseline alternatives described in Section 3.1 of this report.

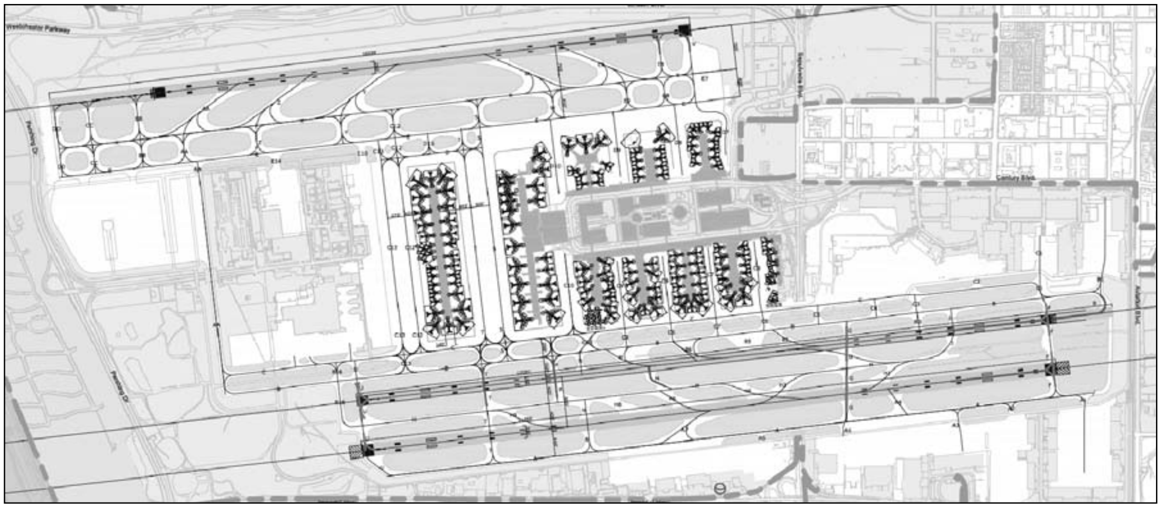


Figure 3-8: Los Angeles International Airport Alternative 3R. Source: Academic Panel Design, Drawing by HNTB (2009).

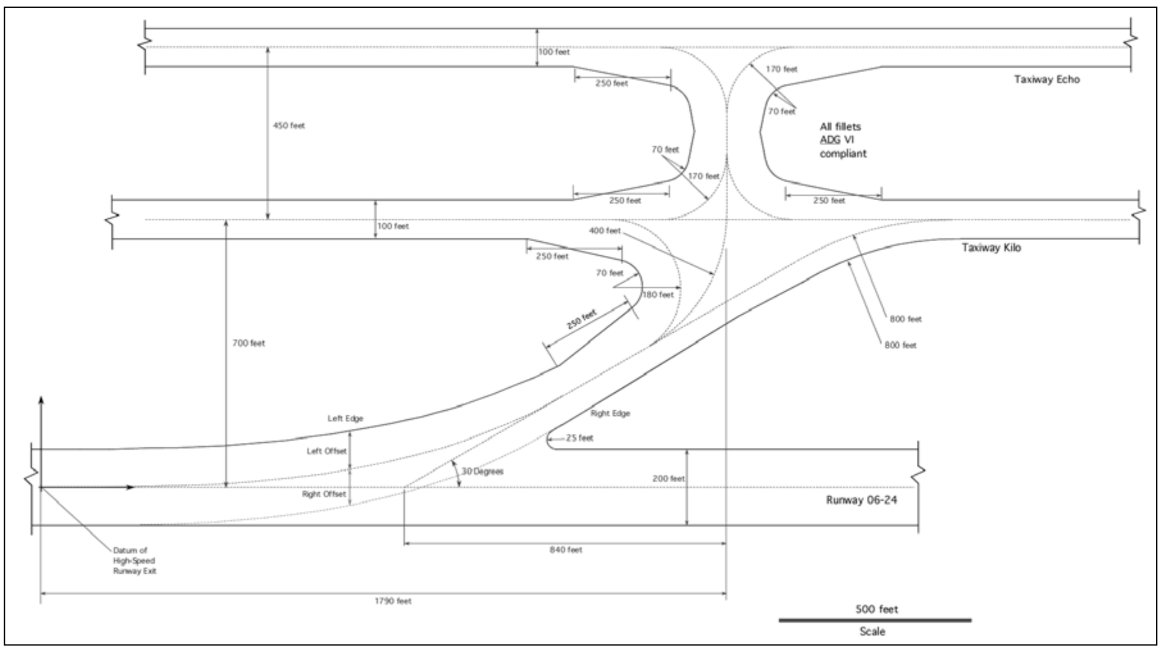


Figure 3-9: Detail Design for High-Speed Runway Exits for Alternative 3R. Source: Academic Panel.

4. EXPERIMENTS AT NASA AMES RESEARCH CENTER

4.1. Introduction

An important component of the North Airfield study consisted of a series of experiments conducted at FutureFlight Central (FFC), a simulation facility located at NASA Ames Research Center. This chapter describes the FFC facility and the experimental design methodology used by the Academic Panel and NASA to carry out the experiments. Section 4.2 provides background on FFC its capabilities. This sets the stage for the description of the design and conduct of the experiments undertaken for the present study.

4.2. NASA Ames Simulation Facility

The FutureFlight Central is a complex tower simulator housed at NASA's Ames Research Center. FutureFlight Central consists of a full 360-degree out-of-window view simulation facility that can simulate a control tower cab of any large airport in the U.S. (see Figure 4-1). The facility allows controllers and pilots to experience new airfield layouts, operating procedures, and technologies in order to assess their impacts on the safety and efficiency of airfield operations, as well as workload. The simulations employ a detailed and highly realistic 3-D airport visual model displayed on twelve projection screens, simulated radar displays similar to those used in the actual tower, 3-D models that closely replicate the appearance and performance of a wide range of aircraft types, and human pseudo-pilots who control these aircraft. Pseudo-pilots control several aircraft at once, using a plan view display. For this study the FFC was integrated with a NASA Ames Boeing 747-400 full motion simulator. The Boeing 747-400 simulator replicates all the functionality of a real aircraft (including a full motion based providing 3-degrees of freedom). The Boeing 747-400 simulator is certified at the highest level of realism (level D) and is housed at the nearby Crew-Vehicle Systems Research Facility, so that the same scenario can be experienced from the cockpit as well as the control tower.

As in a real control tower, the pilot and pseudo-pilot are given instructions by tower controllers, using a voice communication system that includes channels equivalent to the tower radio frequencies.

An extensive set of data is recorded throughout a simulation run. Detailed recordings of aircraft movements, radio communications and non-transmitted voice communication between controllers are made. In addition, simulation participants are typically debriefed at the end of each simulation run using a written questionnaire and an oral discussion. The Academic Panel designed both pilot and air traffic control surveys in consultation with NASA to evaluate various safety aspects of each simulation run.

4.3. Past LAX Studies performed at FutureFlight Central

Three previous studies concerning LAX were performed at FFC. The studies are termed Phase I, II, and III, and were performed between 2001 and 2003. The Phase I study (NASA, 2001a) was conducted in February, 2001. Its purpose was to evaluate possible remedies for runway incursions, from changes in airfield geometry to new control techniques and pilot procedures. Phase I was specifically aimed at assessing "whether the FFC simulation was sufficiently representative of LAX operations, such that FFC could be used to study the impact of the alternatives proposed in Phase II on operations at LAX." It was concluded that the FFC simulations were sufficiently realistic, based upon controllers' direct assessments of the degree of realism, their assessments of workload relative to that at LAX, and comparisons of throughput, taxi times, runway occupancy times, and communications activity between LAX and FFC.

Phase II (NASA, 2001b) was the first of the LAX studies that, like the current one, evaluated possible measures to improve safety. Alternatives included swapping arrival and departure runways, having two local controllers on the south side, and several variants that involved extending a taxiway (B16) to allow some or all departures on 25L to avoid crossing 25R. Assessment was based on controller subjective ratings of workload, efficiency, and runway incursion risk, as well as measured departure rates, taxi times, and frequency utilization. The simulations yielded two clear "winners," both involving the taxiway extension. These alternatives had the most favorable ratings with regard to efficiency and incursion risk, as well as the highest peak departure rates. The taxiway extension idea was not implemented, because FAA declined to grant permission for departures on 25R to proceed while aircraft crossed in front of it on B16.

Phase III, conducted in 2003, evaluated a new centerline taxiway on the South Airfield (NASA, 2003). The aim of this study, like several others conducted at FutureFlight Central, was to confirm the acceptability of a planned airfield change, in this case the centerline taxiway. Controller surveys revealed that the reconfiguration increased workload and reduced rated efficiency for the ground controller, while having the opposite effects for the local controller. Controller assessments of the impact of the center taxiway on the potential for runway incursions were also mixed, with ground controllers perceiving a slight increase in potential and local controllers a slight decrease. Departure throughput was unaffected except under IFR, where it decreased by 8%, while taxi times generally increased.

It is important to appreciate that these prior studies had different purposes than the one presented here. Phase I was a validation exercise. Phase II was intended to give preliminary assessments to several concepts, some of which would then be subject to extensive further review. Phase III was designed to confirm that a particular course of action that had already been virtually decided upon was acceptable. It is interesting to note that if the Phase III study had been the sole basis for deciding whether to build the centerline taxiway on the south, that option might well have been rejected. Given this background, it is understandable that, valuable as the FutureFlight Simulations were to the Academic Panel's work, it was also necessary to tap other sources of information to fulfill the aims of the study. This is the subject of Chapter 5.

Figure 4-1: NASA Ames Research Center FutureFlight Central. Source: A. A. Trani (2009).

4.4. FFC Experiments Performed for this Study

Description of ATC Controller Positions

A group of six LAX controllers each worked fourteen one-hour scenarios over a seven-day period. The complete schedule of the scenarios scheduled in FFC is shown in Appendix G of the report. The FFC simulations required staff on both North and South Airfields similar to the actual LAX tower. The following five positions were staffed by controllers during the simulation:

LC-1: Local Controller, South side (South Local)

LC-2: Local Controller, North side (North Local)

GC-1: Ground Controller, South side (South Ground)

GC-2: Ground Controller, North side (North Ground)

GC-3: Ground Controller, Mid-field (Mid-field Ground)

Due to the complexity of the future airport midfield terminal and the added gate positions behind the Tom Bradley International terminal, a dedicated ground control position was created in each simulation (GC-3). A local assistant controller was also present on the North side of the field. A tower supervisor was also present during all runs. The tower supervisor and the local assistant controller acted as a neutral party in the simulation and their performance was not evaluated in this study. The supervisor position was staffed by two experienced LAX air traffic controllers with many years of experience. The frequencies assigned to each position are shown in Table 4-1.

Table 4-1: LAX Tower Frequencies and ATC Control Positions Assigned in the FFC Experiment.

Position	Name	Frequency (Mhz)	Airfield Side
Ground Control	GC-1	121.75	South
Local Control	LC-1	120.95	South
Ground Control	GC-2	121.65	North
Local Control	LC-2	133.95	North
Ground Control	GC-3	126.25	Midfield

The FFC tower simulator setup showing the staffed air traffic positions is shown in Figure 4-2. A total of three sets of air traffic controllers participated in the study. All North controller positions involved former LAX tower controllers. Most of the South controllers were also former LAX although some had experience at other large hub airports in the country (Phoenix and San Francisco). The investigation focuses on the North controllers. In general, as it will be shown in Section 13.3 of the report, the North controllers performed better in terms of handling more traffic more efficiently than South controllers.

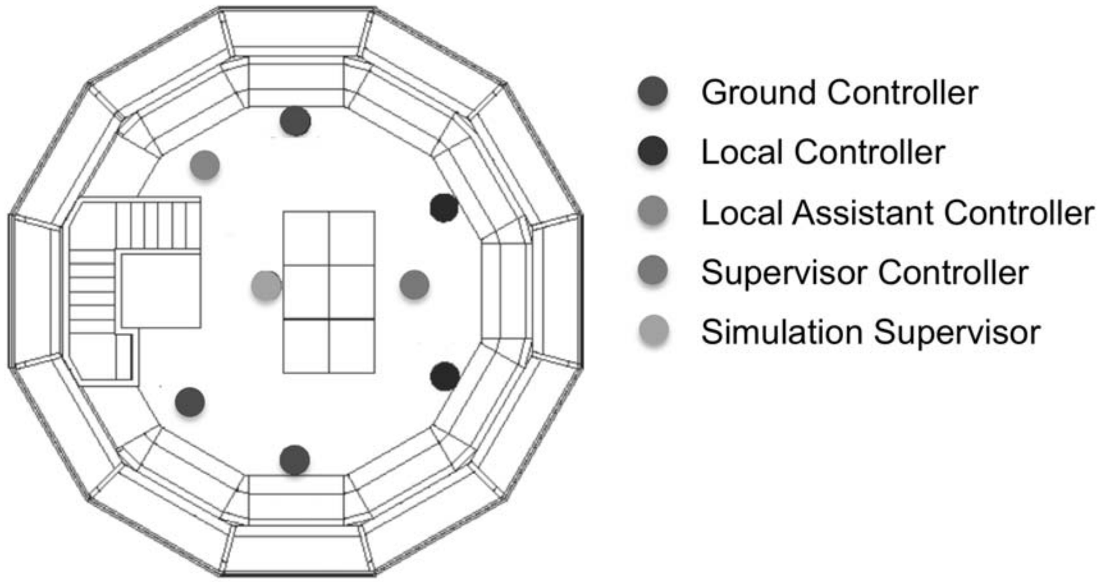


Figure 4-2: NASA Ames FutureFlight Central: Tower Cab Layout Used in the Experiments. Source: NASA Ames Research Center.

Description of the Boeing 747-400 Flight Simulator

The Boeing 747-400 flight simulator used in this study represents a state-of-the-art training simulator certified at the highest level of realism (level D). The simulator has a full-motion base allowing realistic replication of aircraft acceleration onset rates. The simulator has a Vital Multiview visual display system capable of displaying 180 degrees laterally and 40 degrees vertically (see Figure 4-3). The Boeing 747-400 simulator is housed at the nearby Crew-Vehicle Systems Research Facility at NASA Ames Research Center. For this experiment, a total of ten Boeing 747-400 or Boeing 777-200 test pilots participated in the evaluation of various airport configurations. The Boeing 747-400 requires a crew of two. In each flight a “neutral” pilot would accompany the test pilot to manage systems similar to a revenue flight. Pilots were asked to fly approaches to LAX airport joining the final approach sequence at 5,000 feet and 17 miles out of runway 24R and then fly a standard final approach procedure, land and taxi to a prescribed gate on the Midfield terminal.

Figure 4-3: NASA Ames Boeing 747-400 Flight Simulator. Source: NASA Ames Research Center Web Site.

4.5. Experimental Design

The Academic Panel, in extensive consultation with their NASA colleagues, designed a set of simulation runs that addressed the questions it was charged to answer. The design attempted to balance the various factors that had to be addressed with the limited number of runs that could be performed. Factors incorporated into the design included:

- *North airfield alternative.* All the alternatives were simulated except for the baseline with relocated exits, which was not originally a part of the study;
- *Visibility.* Three visibility conditions, Daytime Visual, Daytime Instrument, and Nighttime Visual, were included. Experiments with all three conditions were run for five of the six alternatives. The exception was Baseline with Design Group VI aircraft operations restricted to the South Airfield, which was not simulated in Nighttime conditions;
- *Design Group VI Operations.* Experiments with 2, 4, and 6 Design Group VI Operations were run;

- *Controller Team.* To obtain reliable results, it was necessary to have more than one controller team participate in the experiments. We had three teams. Team members were retired tower controllers with experience at major airports, including LAX, SFO, and DFW.

Given the number of factors and factor levels involved, it was not possible to simulate every combination. To do so for a *single* alternative would require 3 (visibility conditions) x 3 (design group VI traffic levels) x 3 (controller teams) =27 runs, while fewer than 60 total runs were available. To economize on runs, combinations were selected so as to avoid systematic correlation between any two factors. In practice, this meant than every team saw every alternative three times, under every visibility condition (with the exception for the Baseline South alternative already noted), and under every level of design group VI operations, but that for a given team and alternative the visibility condition was correlated with the number of group VI aircraft. These correlations varied across teams and alternatives so that across the entire set of runs they were eliminated. Table 4-2 identifies the specific runs conducted.

Table 4-2: Experimental Design Table.

Team	Alternative	Group VI Aircraft	Visibility
1	B	2	VMC
1	B	6	IMC
1	B	4	Night-VMC
1	B-South	6	VMC
1	B-South	4	IMC
1	D	4	VMC
1	D	2	IMC
1	D	6	Night-VMC
1	M	2	VMC
1	M	6	IMC
1	M	4	Night-VMC
1	N	6	VMC
1	N	4	IMC
1	N	2	Night-VMC
1	3R	4	VMC
1	3R	2	IMC
1	3R	6	Night-VMC
2	B	4	VMC
2	B	2	IMC

2	B	6	Night-VMC
2	B-South	2	VMC
2	B-South	6	IMC
2	D	6	VMC
2	D	4	IMC
2	D	2	Night-VMC
2	M	4	VMC
2	M	2	IMC
2	M	6	Night-VMC
2	N	2	VMC
2	N	6	IMC
2	N	4	Night-VMC
2	3R	6	VMC
2	3R	4	IMC
2	3R	2	Night-VMC
3	B	6	VMC
3	B	4	IMC
3	B	2	Night-VMC
3	B-South	4	VMC
3	B-South	2	IMC
3	D	2	VMC
3	D	6	IMC
3	D	4	Night-VMC
3	M	6	VMC
3	M	4	IMC
3	M	2	Night-VMC
3	N	4	VMC
3	N	2	IMC
3	N	6	Night-VMC
3	3R	2	VMC
3	3R	6	IMC
3	3R	4	Night-VMC

Anomalies were also included in the experiments. These were scripted “mistakes” by the pseudo pilots requiring an appropriate response from the controllers. The mistakes included failure to call in by a pilot on approach, incorrect read-backs of controller instructions, and busted hold lines. It was important that these anomalies, while scripted, be unpredictable to the controllers. To accomplish this, randomization was employed to, first, determine the numbers of different anomalies that would be scripted into each run, and, second, decide which specific flights would commit the mistakes. For busted hold-lines and some read-back errors, improvisation on the part of the pseudo-pilots was required, since the mistake could only be made in certain circumstances. (For example, a hold-line could not be busted if there were no instruction to hold.) The pseudo-pilots fulfilled this responsibility—an additional burden for a job that is quite difficult to begin with—admirably.

4.6. Demand Scenarios for FFC Experiments

The Academic Panel designed each one of the 54 detailed scenarios ran in the FFC simulation. These scenarios involve a full description of the following items: 1) aircraft assigned to each arrival stream, 2) aircraft injection times into the simulation (both arrivals and departures), 3) aircraft types and company liveries to reproduce a projected demand scenario, 4) gate assignment for both arrivals and departures and 5) Standard Instrument Departures (SIDs) for every flight departing LAX. The Academic Panel worked with LAX controllers Kurt Rammelsberg and Elliot Brand as well as with NASA Ames personnel, Betty Silva, Mike Madson, and Boris Rabin, to understand many technical aspects of the simulation and the LAX airport procedures before embarking in the demand generation task. The Academic Panel relied on Performance Data Analysis and Reporting System (PDARS) radar data to understand aircraft operational procedures in and out of the LAX airport. A sample departure track analysis performed by the Academic Panel for the South airfield is shown in Figure 4-4. The demand scenarios created by the Panel attempted to replicate current procedures flown at LAX with higher demand loads expected in the year 2020. The Academic Panel also examined the LAWA/Ricondo demand scenarios proposed for year 2020 at the airport (see Figure 4-5).

In creating demand sets for FFC simulations we struck a balance between arrival and departures for every scenario. For example, during a typical one-hour FFC simulation run, between 77 and 80 arrivals are scheduled for the one-hour period. According to Figure 4-5, LAWA expects 147 operations in the peak hour in the year 2020. Note that there are 9 hours during the design day with more than 127 operations per hour. Note that during the highest loads of the design day, the 2020 demand schedule calls for an almost equal number of arrivals and departures. This fact was maintained in the FFC simulations. The LAWA/Ricondo design day has a fleet mix fraction shown in Figure 4-6.

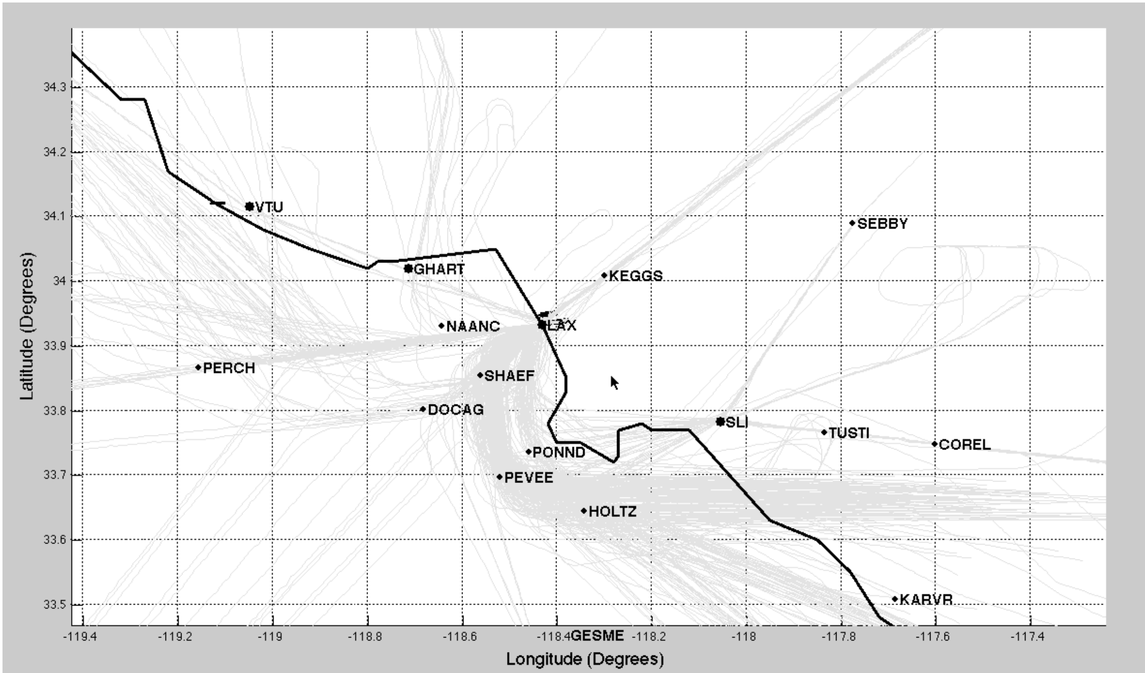


Figure 4-4: Typical South Airfield Departure Tracks. PDARS Data (2007).

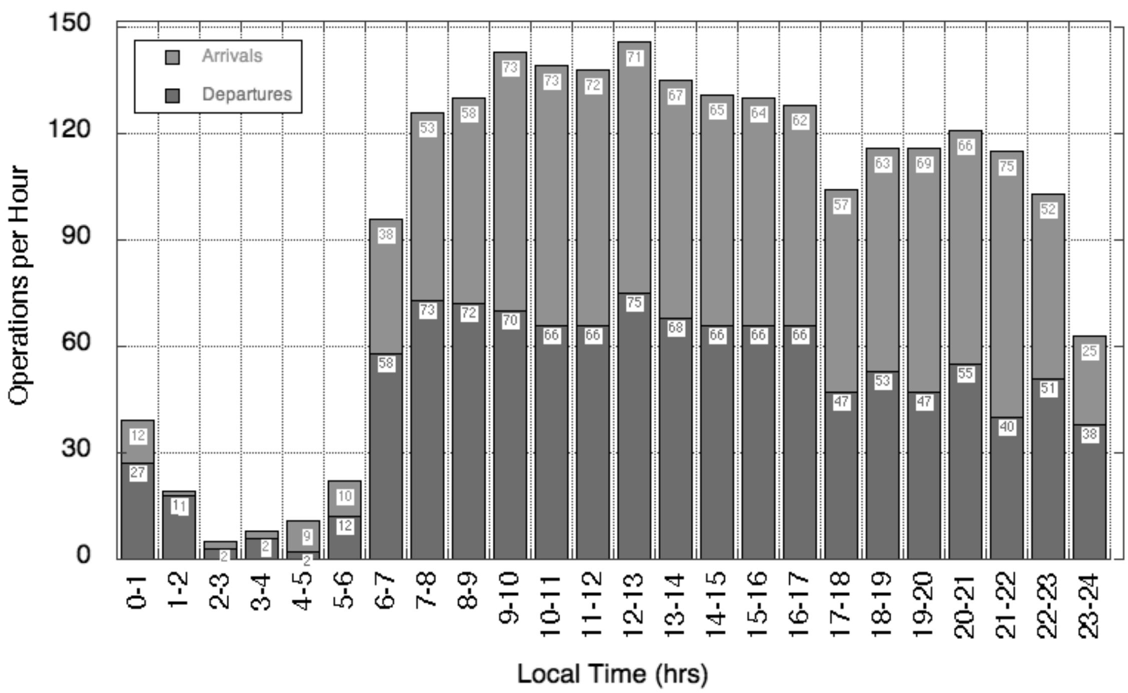


Figure 4-5: LAWA/Ricondo LAX Baseline Demand Scenario (2009).

The Panel used the baseline demand as an initial guideline. However, we deviated from the baseline demand to account for recent trends in fleet mix at both the National and local levels. For example, the LAWA/Ricondo demand included numerous flights by small aircraft prominently with Embraer 120 aircraft in 2020 (i.e., 11% of aircraft in the small wake class). The Panel judged that such aircraft will be mostly retired from the fleet and we substitute for larger turboprop aircraft (Aerospatiale ATR 72). The result of such substitution is an increase in the size of aircraft to larger wake classes with a corresponding reduction in arrival capacity at the airport. Similarly, we reason that many Boeing 757-200 aircraft will be retired in 2020 (a verifiable trend today in the US fleet) and thus substituted some Boeing 757-200 operations for Boeing 737-800 and Boeing 787-8 "Dreamliners".

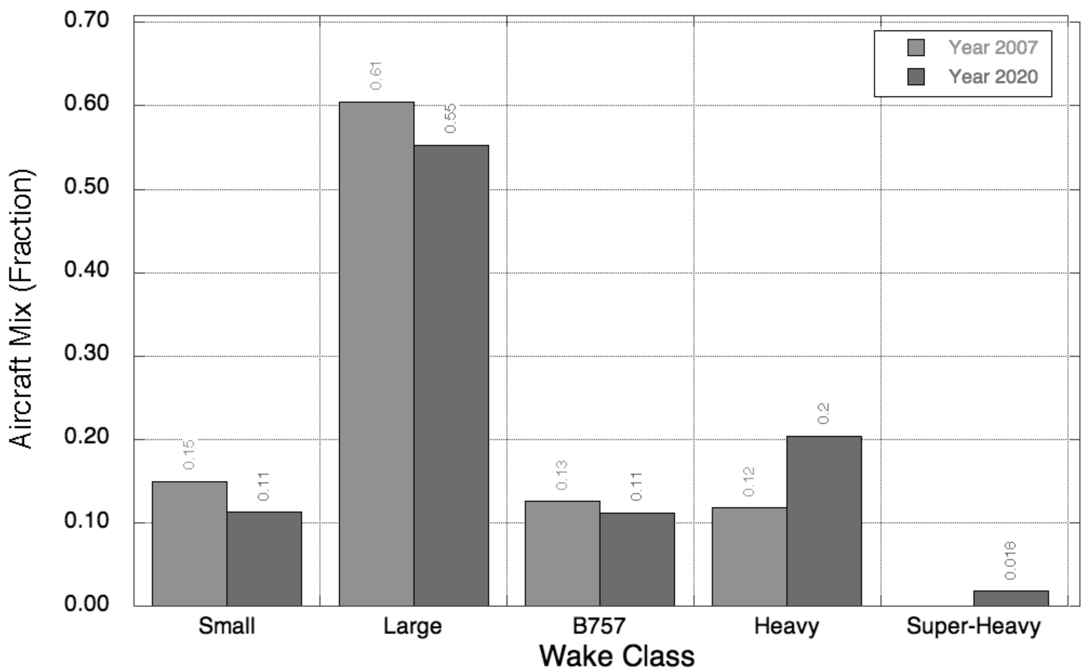


Figure 4-6: LAWA/Ricondo 2007 and 2020 Aircraft Wake Class Distribution.

Aircraft Performance Data

Whenever possible, the Academic Panel scrutinized FFC flight profile data to verify the realism of the simulator for aircraft arrivals. Using PDARS radar data the Panel determined average approach speed profiles in the sections of airspace where aircraft were "injected" 17 miles from runways 24R and 25L at 5,200 feet. Using such data, the Panel asked NASA to update the aircraft performance parameters for all aircraft modeled in the simulation. This provided added realism as every aircraft flew a unique approach profile similar to those observed in the field.

Air Traffic Separations Analysis to Generate FFC Arrival Data

The PDARS radar data was also used by the Panel to derive realistic aircraft in-trail separations. Using a full day of radar data, the Academic Panel derived cumulative density functions similar to that shown in Figure 4-7 to set aircraft-aircraft arrival separations at LAX during high-demand periods. These arrival separations were used to create arrival times for each aircraft arrival at the airspace injection points in the FFC simulation. We also developed a Monte Carlo simulation model to derive optimal procedures for the 3R configuration. This configuration is described in Sections 3 and 10 of the report.

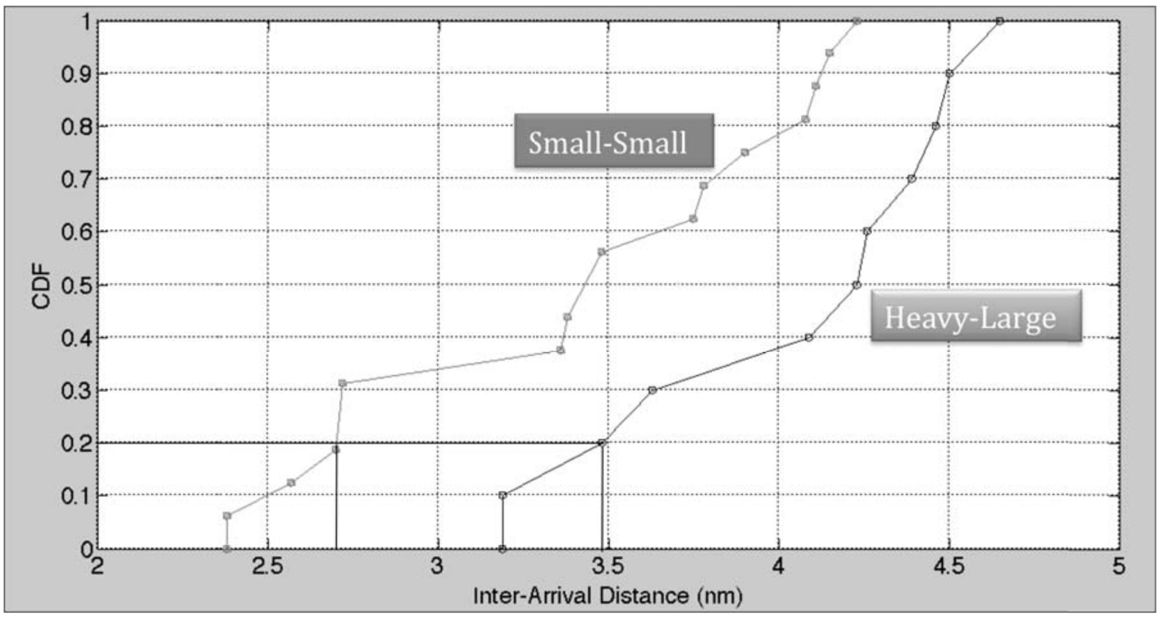


Figure 4-7: Cumulative Density Functions of Distance Between Successive Arrivals. PDARS Data. Academic Panel Analysis.

Methodology to Generate FFC Traffic Data

Using the information gathered in the field and from various sources as described above, we created 54 detailed scenarios representing 54 operational hours for the LAX airport in the year 2020. Section 4-5 explained the experimental design process used to set control variables in the simulation process. Control variables in the experiment were weather conditions (VMC, Night and IMC), number of design group VI aircraft (2,4 and 6), and 6 North airfield configurations. Figure 4-8 illustrates a flowchart to show the steps needed to generate each one of the 54 scenarios. First we extracted the baseline demand data from fast-time simulation studies done by Ricondo for LAWA. The demand follows the same profile as that shown in Figure 4-5. Since FFC simulations lasted one hour, we selected individual peak hour periods to emulate in the FFC simulation. Aircraft substitutions are made to this baseline demand based on fleet mix trend analysis performed by the Academic Panel. We then assign the number of ADG VI aircraft to the modified hourly schedule and calculate arrival times to the runway threshold. Using the observed separation criteria at the airport, we back track the runway arrival times to create injection times in the airspace for arrivals and gate push back times for departures. This process requires some heuristics to balance the use of gates across all terminal complexes. Random events are introduced according to probabilities sampled from real events as described in section 4-5. A few more checks are done after the steps in Figure 4-8 are completed to assign departure routes and still balance the use of gates at LAX.

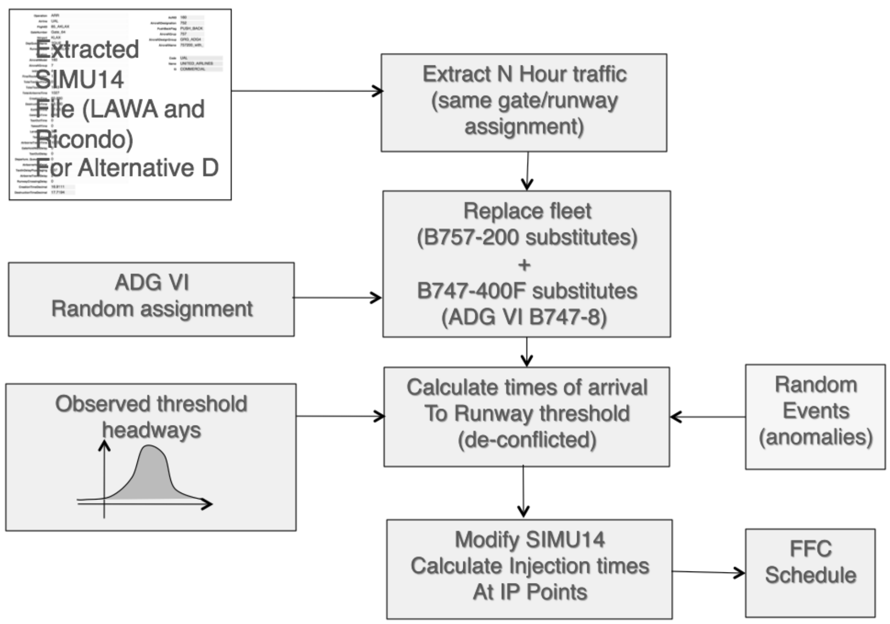


Figure 4-8: Methodology to Derive FFC Demand Schedule.

5. OTHER EVIDENCE CONSIDERED BY THE PANEL

The Panel supplemented the valuable information from the NASA simulations with other evidence that allows a fuller picture. The additional information utilized is described briefly in the following sections.

5.1. The Runway Incursion History at LAX

We studied incursions in recent years on both the North and South Airfields. We noted in particular:

- what happened
- where on the runways or taxiways the incursions occurred
- what kinds of aircraft (and other vehicles) were involved
- whether operations were in Easterly or Westerly flow
- the severity of the incursion (under the A, B, C, D classification scheme used by FAA, which we describe in Section 7).

5.2. The Runway Collision on the LAX North Airfield on 2/2/91

The collision on Runway 24-L between a landing US Air jet and a SkyWest commuter plane killed 34 people in the worst runway accident in US aviation history. We considered the circumstances of the event, and the effectiveness of measures taken to prevent a recurrence.

5.3. LAX Operations Data

We considered data on such subjects as:

- how traffic was distributed between the North and South Airfield
- how far down the runway departing aircraft of various kinds travelled before they became airborne
- which taxiways landing aircraft took to exit the arrival runway
- what proportion of operations took place in Easterly and Westerly flow
- what fractions of operations occurred under IMC and VMC

5.4. Runway Incursions at Other Towered US Airports

We considered US incursion records in detail, paying particular attention to other airports that offer information of special relevance to the LAX North Airfield. These airports included:

- Airports deemed similar to LAX by pilots who took part in the NASA simulation

- Airports that have centerline taxiways between parallel runways, with spacing similar to those proposed under some LAX-North reconfiguration scenarios

- Airports that participate frequently in mixed operations (i.e., involving landings and takeoffs on the same runway).

5.5. Worldwide Data about Fatal Runway Collisions

We considered the circumstances of such collisions, and the proportions of passengers killed on the various aircraft involved.

5.6. Worldwide Historical Data about Runway Excursions

Runway excursions are events in which planes deviate suddenly and sharply from their intended paths, for reasons unrelated to other aircraft or land vehicles. Such events could potentially lead to collisions with other aircraft. We explored data about the frequency and nature of such events, and considered whether they could appreciably affect the relative safety of different runway configurations.

5.7. Previous Studies about North Airfield Runway Safety

The information described above falls into the general category of data that the Panel gathered for the North Airfield Safety Study. But we also studied data collected and analyses performed by others in prior work.

5.8. Prior Collision-Risk Research

We understood that peer-reviewed research might offer data and analyses that could benefit the present work, and reviewed such research.

5.9. FAA Effectiveness Assessments for Relevant New Technologies

In recent years, the FAA has undertaken extensive analyses about the potential effectiveness of AMASS, ASDE-X radar, and Runway Status Lights. All three of these technologies are now in place on the LAX South Airfield, and they should soon be in place on the North Airfield. We sought and gained access to the FAA analyses, and carefully considered them in the present study.

5.10. Studies about the Interim Runway Safety Improvement Program for the North Airfield

We considered proposals to change/move exit taxiways from Runway 24R so that landing planes crossing Runway 24L en route to terminals would do so further west.

5.11. Prior Studies about Safety on the LAX North Airfield

Organizations such as the Washington Consulting Group have conducted safety studies about some possible configurations of the North Airfield, and we reviewed such studies.

6. SAFETY ANALYSIS: THE BASELINE CASE

Of fundamental importance to the Study is the question: assuming 2020 traffic levels and the associated traffic mix, what level of risk would prevail if the LAX North Airfield remained as it is now? This section offers an approximate answer to the question. The focus in on *fatal* runway collisions, and on two subsidiary questions:

- If 2020 traffic levels prevailed over a long period, what would be the baseline *frequency* of fatal runway collisions on the LAX North Airfield?
- When fatal accidents occur, what would be their expected *consequences* in lives lost?

6.1. Some Background Data

A starting point for the analysis is the article "Fatal US Runway Collisions over the Next Two Decades," which was commissioned by FAA and published in the peer-reviewed *Air Traffic Control Quarterly* (Barnett, Paull, and Iadeluca (2000); the paper appears as an Appendix to this report). The two decades in question were the years 2003-2022. Using US and worldwide data about runway incursions and accidents, and official projections of US traffic growth, the authors concluded that, for the two decades 2003-2022, *fifteen* was a mid-range estimate of the number of fatal runway collisions that would occur at the approximately 500 towered US airports. (A high estimate was 33 fatal collisions, while a low estimate was four.) Analysis of survival and casualty patterns in historical data led to the approximation that an average of 48 lives would be lost in each one. Fifteen events over twenty years works out to an average of one event every sixteen months. But under the assumption of steady traffic growth, the rate in 2020 would be higher than the average for 2003-2022, and would average approximately ***one fatal runway collision per year,*** at some towered US airport.

However, these estimates were based on technology and procedures in place in the 1990's at towered US airports. They did *not* consider the safety benefits of three major technologies that have since been introduced:

The **Airport Movement Area Safety System** (**AMASS**), which offers visual and aural warnings to tower controllers about many situations that potentially compromise safety.

Airport Surface Detection Equipment, Model X (ASDE-X), which detects potential runway conflicts using surface movement radar, multilateration sensors, aircraft transponders, and other indicators of the positions of both aircraft and ground vehicles.

Runway Status Lights (RWSL) , which turn red at the centerline of a runway or taxiway when it is unsafe to proceed because of other traffic movements. These lights use information from airport surveillance and surface detector radars, as well as multilateration information from the ASDE-X system.

All three of these technologies are now available on the LAX South Airfield, and all should be available on the North by 2020.

After intensive investigations, FAA has subsequently made estimates of the effectiveness of these three technologies in preventing a runway collision:

- **63.0%** for AMASS accompanied by ASDE-3 radar, a predecessor of ASDE-X radar
- **72.6%** for AMASS and ASDE-X
- **87.6%** for AMASS, ASDE-X, and RWSL

Source: FAA Surface Benefits Model, 2008

In other words, FAA believes that the combination of AMASS, ASDE-X, and runway status lights can cut by approximately **7/8** (87.6%) the risk of runway collisions that prevailed prior to their introduction.

6.2. A Two-Part Procedure for Estimating the Baseline Frequency of Runway Collisions at the LAX North Airfield

We consider two questions in sequence:

(i) Assuming 2020 traffic levels in the US as well as the use of AMASS, ASDE-X, and RWSL, what would be the expected frequency of fatal runway collisions at towered US airports as a group?

(ii) Given that a fatal runway collision occurred, what is the probability that it would happen at the LAX North Airfield rather than elsewhere?

The first of these questions is fairly easy to answer if we use the background data arising from FAA studies. One could say that the *original* frequency of fatal collisions for 2020 traffic levels would be approximately one per year, but the introduction of AMASS, ASDE-X, and

RWSL would reduce that risk by a factor of roughly eight. Thus, the revised frequency would be approximately *one in eight years*.

However, the Panel thought it important to assess whether the FAA effectiveness assessments for the new technologies have been borne out by actual airport experience. That review is the subject of the next section.

6.3. Some Trends in US Runway Incursions, 1999-2009

The International Civil Aviation Organization (ICAO) and the FAA define a runway incursion as:

"any occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle, or person on the protected area of a surface designated for the landing and take-off of aircraft."

In the late 1990's, FAA developed a classification system that created four categories of runway incursions at US airports:

Category A: "Separation decreases and participants take extreme action to narrowly avoid a collision, or the event results in a collision."

Category B: "Separation decreases and there is a significant potential for collision."

Category C: "Separation decreases but there is ample time and distance to avoid a potential collision."

Category D: "Little or no chance of collision but meets the definition of a runway incursion."

Source: FAA Runway Safety Report, June 2008

The Panel examined trends in US runway incursions over the period 1999-2009 to see whether the substantial drops in incursions that FAA expected because of new technologies had actually materialized. While ASDE-X and RWSL have only recently been introduced at US airports, AMASS was installed at 32 of the largest US airports over 2001-03. A FAA data analysis estimated that, subsequent to installation, Category A and B runway incursions at those airports declined by 59%, from an expected 24.3 to an actual 10 (Surface Benefits Model, 2008). That statistic is close to the 63% reduction that FAA projected prior to the installation. It is not clear that AMASS deserves full credit for the improvement: other airports that did not receive AMASS also showed a drop in incursions, perhaps because of better airport signage, training, and other measures. Whatever the exact reasons, the observed drop was large and statistically significant.

Indeed, an FAA fact sheet issued on 10/9/09 about *all* towered US airports stated that

“The number of serious runway incursions — classified as Categories A and B — dropped by more than 63 percent from fiscal year (FY) 2000 through fiscal year 2008.” And in FY 2009, A and B incursions dropped by factor of two compared to 2008, from 24 to 12. In all, A and B incursions fell from 67 in FY 2000 to 12 in FY 2009, a decline of **80%**. This last statistic includes the benefits of ASDE-X at roughly 15 US airports, which include several but not all of the very largest. Very few airports had RWSL by 2009; LAX has them on its South Airfield but not on the North. In other words, the observed decline was ***greater*** than that which FAA envisioned before RWSL’s and with only a partial implementation of ASDE-X.

These incursion statistics are encouraging. If the number of A and B incursions is a reasonable proxy for collision risk over a given year, then the data suggest that the combination of AMASS , ASDE-X and other measures has improved safety on the runways by roughly 80%, But the Panel considered a question: is it possible that “grade deflation” meant that some events that might have been classified as (say) Category B incursions towards the start of the 21st century were being classified as (say) Category C incursions several years later? The Panel does not take this possibility seriously because of another statistic, which is not subject to variations in judgment. The number of fatal runway collisions at towered US airports has been *zero* in recent years.

Zero. The Barnett, Paull, Iadeluca analysis for FAA (2000) anticipated approximately four fatal runway collisions at towered US airports over 2003-09. Traffic was lower during those years than had been projected before 9/11 but, even accounting for that shortfall, the absence of any fatal accidents reflects a statistically significant improvement in runway safety that cannot plausibly be dismissed as a coincidence. (There have been no fatal runway collisions at towered US airports since March 2000, when two GA planes collided at Sarasota, Florida. The runway collision at LAX in February 1991—*nineteen years ago*—was the last runway collision at a towered US airport which caused deaths to passengers on scheduled flights.) In short, the empirical evidence about both major incursions and fatal accidents strongly indicates that US runways were far safer around 2009 than they were in the 1990’s.

Developments in aviation beyond airport runways further increase the Panel’s confidence in the ability of technology and new procedures to achieve huge improvements in safety. For a long time, midair collisions involving scheduled aircraft occurred in the US on average every other year. (Southern Californians will recall the PSA collision at San Diego and the Aeromexico collision south of Los Angeles.) But *not one* scheduled flight in the US has been involved in a fatal midair collision in *more than twenty years*, in substantial part because of on-board collision avoidance systems. Similarly, thunderstorm-induced wind shear caused frequent disasters near airports in the 1970's and 1980's, including Pan Am at New Orleans and Pago-Pago, Eastern at JFK, Delta at Dallas/Fort Worth, and Ozark at St. Louis. Yet, with the advent of Doppler radar, on-board wind-shear detectors and wind-shear avoidance training, there have been no wind-shear related crashes on US scheduled flights in more than fifteen years (and the last event, in 1994, occurred at an airport that had not yet received Doppler radar). Aviation safety is a continuing story of mortal hazards that have been rendered harmless by a combination of new equipment and improved training, and the recent sharp reductions in dangerous runway incursions seem consistent with that history.

6.4. The Panel's Estimate of National Risk of Fatal Runway Collisions, 2020

Under these circumstances, the Panel estimated that US fatal runway collisions at towered airports in 2020 will not occur at a rate on one per year (per Barnett, Paull, Idaeluca), but rather at a substantially lower rate. We have noted that, if we use FAA benefit statistics about AMASS, ASDE-X, and RWSL—statistics that are consistent with actual experience so far—we would cut the risk by a factor of eight, to one fatal collision every eight years. To be conservative, however, we estimated a reduction by a factor of four rather than eight, meaning that we assume a national frequency of fatal runway collisions of *one every four years* at towered US airports. The upshot is that we are assuming roughly *twice t*he level of risk in 2020 than the FAA projections would imply.

Why this conservatism? Because RWSL have not been widely deployed, we do not have field experience to validate FAA assessments about their benefits. FAA estimated that AMASS/ASDE-X/RWSL would cut risk by about 88%, as compared to 73% for AMASS/ASDE-X alone. In other words, of the 27% of potential collisions that AMASS/ASDE-X would not in themselves avert (namely, 100% - 73%), roughly 15% would be prevented if RWSL were added to the mix (88% -73%). RWSL would therefore cut collisions by roughly *half* from the level that would prevail in its absence (i.e, by 15% out of 27%). The Panel is effectively assuming for now that, while AMASS/ASDE-X and other measures have achieved the major gains that were anticipated, it is possible that RWSL may not fully do so. *Let us be clear*: we have no reason to be skeptical of the benefits assessment about RWSL. But, to reduce the danger of overstating the safety of US runways in 2020, we use 75% rather than 88% as the estimated improvement in runway safety in 2020, as compared to a projection based on the 1990's.

In summary:

*The Panel assumes an expected frequency of fatal runway collisions in 2020 at the 504 towered US airports of **one every four years**. That statistic assumes that AMASS/ASDE-X/RWSL are present at the major airports at which risk is concentrated, and that traffic grows between now and 2020 in accordance with forecasts. (If the traffic forecasts prove too optimistic—as was certainly the case about growth over 2000-09—then risk in 2020 would be lower.)*

6.5. Baseline Runway Collision Risk at LAX-North as a Share of National Risk

To move from a national risk estimate to one for LAX-North, we considered the question: if a fatal runway collision does occur in 2020 at a towered US airport, what is the probability that it would do so on the LAX North Airfield? While there are 504 towered US airports (505 if LAX South is treated as distinct from LAX North), the chance would not be 1 in 505. Simply because LAX-North has far more than 1/505 of national air traffic, one would expect a higher probability than 1 in 505. But how much higher?

Because no estimation procedure in this context is manifestly correct, we made eight separate estimates of the risk to LAX-North, assuming that the runway configuration in 2020 is the same as the one in place now. The first two are based on the runway incursion history of LAX-North, as it relates to national history. Over the period 1999-2009[a], LAX-North experienced:

1.1% of the 181 Category-A incursions at towered US airports (2/181).
2.2% of the 231 Category-B incursions (5/231)
0.4% of the 942 Category-C incursions[b] (4/942)

Notes:

(a) We used the period 1999-2009 because the FAA classification system was not introduced until 1997, and we assumed a short start-up period before national consistency was fully established.

(b) The category-C data are from 1999-2007, because a shift to ICAO classification rules as of FY 2008 raised problems in aggregating data from 1999-2007 with those from 2008-09.

One could argue that, because LAX-North suffered 1.1% of the Category A incursions in recent years—1 in 90— it would have approximately a 1 in 90 chance under baseline conditions of suffering a fatal accident in 2020. That argument tacitly assumes that the level and mix of air traffic at LAX-North would bear the same relation in 2020 to the national level and mix as prevailed in the recent past. We discuss the"fleet mix" assumption in Section 6.7; to put it briefly, we are comfortable using 1 in 90 as one plausible estimate of LAX-North's share of national risk.

Another estimation rule acknowledges that Category B and C incursions—though not as dire as those in Category A—represent lapses that pose real collision risk. A second estimate of LAX-North's risk share is the *average* of its share of national Category A, Category B, and Category C incursions (i.e., of 1.1%, 2.2%, and 0.4%). That process yields a risk estimate of **1.2%,** very close to the number that arose for Category A incursions alone.

Two other estimates of LAX-North's risk share arise from its level of traffic rather than its share of incursions. Barnett, Paull, and Idaeluca (2000) offered both conceptual and empirical arguments that collision risk at an airport varied not with its level of operations but rather with the *square* of the level of operations (*the quadratic model*). The FAA continues to use the quadratic model in its risk assessments about airport surface safety. LAX-North's share of national risk based on the quadratic model[a] would be:

1.7% based on actual levels of operations in 2000[b]

1.3% based on projected levels in 2020[c]

Notes:

(a) We used the quadratic model to get the risk share for LAX as a whole, and then allocated risk between LAX-North and LAX-South based on their own squared traffic levels.

(b) We use 2000 data because 2000 was the year when operations at LAX reached their peak, so it yields a high estimate of the LAX traffic share.

(c) For 2020, we used Ricondo estimates of traffic levels at LAX, and TAF estimates for traffic at other airports.

These two traffic-based estimates--1.7% and 1.3%-join the two incursion-based risk estimates (1.1% and 1.2%) of the LAX-North risk share, yielding a total of four estimates. But more estimates can be obtained.

The Peer Airports

Other estimates of the risk share arose from the August experiment at NASA-Ames. Pilots in the Boeing 747 cockpit simulator who landed at LAX-North were asked about their perceptions, and in particular answered the following question in their post-flight surveys:

"How did the overall safety of this configuration compare to that at the other airports into which you fly?"

The pilots answered on a scale from 1 to 7, in which 1 meant "LAX much safer" and 7 meant "other airports much safer."

Those pilots who landed in the existing layout for LAX North (i.e., in the baseline case) gave an average rating of 3.65 on the 1-7 scale. This outcome implies that LAX-North was *about average* in risk in comparison with the other airports (actually, slightly better than average), and was highly consistent with what they said in interviews. This assessment offers another way of estimating the risk share of LAX-North, based not on LAX data but rather on safety information about other US airports. The basic idea is that, if LAX-North is deemed as safe as Atlanta and the risk level at Atlanta is estimated as X, then X is also an estimate of the risk at LAX-North.

We designate the airports that the pilots considered about as safe as LAX-North baseline the *peer airports*. All the pilots at NASA-Ames were 747-qualified, and conducted international flights. They came from the airlines American, United, Northwest/Delta, and Cathay Pacific. When asked what other airports they had in mind when the answered questions about LAX-North, they (collectively) responded:

Airport	*Airport*
Atlanta	Miami
Chicago-O'Hare	New York (JFK)
Dallas-Fort Worth	San Francisco
Denver	Washington (Dulles)
Detroit	

We worked out the risk level *per operation* for these nine airports taken together, and used that to approximate the risk level per operation at LAX-North. To estimate risk per operation at the peer airports, we used the same four statistics we used earlier with LAX-North data:

(i) rate of Category A incursions per operation
(ii) average rate of Category A, B, and C incursions per operation
(iii) squared traffic per operation in 2000
(iv) squared traffic per operation in 2020 (using TAF data)

Using these four metrics and the peer-airport data, we reached the following estimates for the LAX-North risk share:

0.8% (based on Category A incursions at peer airports)

0.7% (based on A, B, and C incursions)

1.7% (based on squared operations in 2000 at peer airports)

1.7% (based on projected squared operations in 2020)

It is striking that these estimates—which were not rooted in data from LAX-North---were nonetheless very close to those previously offered that were based on LAX data. Taken together, the different estimates are *mutually corroboratory*: the pilots considered baseline LAX-North about as safe as the airports they deemed its peers, and incursion histories and traffic level risk-estimates implied essentially the same conclusion.

6.6. An Estimate of the LAX-North Risk Share

In summary, we have come up with eight estimates of the chance that, if a fatal runway collision occurred in 2020 at a US towered airport, it would do so at LAX-North (assuming continuation of the present layout). These estimates were:

1.1% (Category A incursions, LAX-North)
1.2% (Category A,B, C incursions, LAX-North)
1.7% (Squared traffic share, 2000)
1.3% (Squared traffic share, 2020)
0.8% (Category A incursions, peer airports)
0.7% (Category A, B, and C incursions, peer airports)
1.7% (squared traffic per operation, 2000, peer airports)
1.7% (squared traffic per operation, 2020, peer airports)

The average of these eight numbers is 1.3%. However, to be conservative, we estimate as **2%--**1 in 50—the chance that a fatal runway incursion in 2020—if it occurs in the US would occur at LAX-North. This estimate is *higher* than all eight estimates we reached, and, once again, reflects our desire not to underestimate risk at LAX-North under baseline conditions.

To repeat:

We estimate as 2% the chance that, if a fatal runway collision occurs at a towered US airport at 2020 traffic levels, it would do so at LAX-North (assuming it retains its current layout).

6.7. Aircraft Design Group VI Aircraft

It could be objected that none of these estimates takes account of the fact that Group VI aircraft—initially the Airbus 380 and the Boeing 747-800—will serve LAX to a highly disproportionate extent among US airports. If Group VI operations are less safe than those for smaller aircraft, then calculations that ignore their role could be too optimistic.

We have considered this possibility, and reject it on three grounds:

(i) *LAX has always been served disproportionately by the largest aircraft.*

Thus, if large aircraft did pose excess risk of serious incursions, that circumstance would already be reflected in the incursions statistics about LAX.

(ii) *While LAX has more large aircraft than the average US airport, its fleet mix does not diverge sharply from that at other major US airports.*

The following table offers a synopsis of the situation:

Table 6-1: Peer Airports Considered in the Study.

Airport	***Passengers per Aircraft Movement (Year 2007)***
Atlanta (ATL)	90
Charlotte (CLT)	64
Chicago O'Hare (ORD)	82
Dallas Forth-Worth (DFW)	87
Denver (DEN)	81
Detroit (DTW)	77
Houston (IAH)	71
Los Angeles (LAX)	91
Miami (MIA)	87
Minneapolis/St. Paul (MSA)	78
New York (JFK)	108
New York / Newark (EWR)	82
Orlando	101
Phoenix (PHX)	78
San Francisco (SFO)	85
15-City Average	85

Source: A. Odoni, Table 12.1 in *The Global Airline Industry (2009)*

At 91, the average number of passengers per operation is only slightly higher than that at the 15 largest US airports (85), which handle a sizable fraction of US air traffic.

But perhaps most persuasive argument is the third:

(iii) *There is no evidence that Group VI aircraft will be more "incursion prone" than other planes.*

By that statement we mean that Group VI planes will be no more likely to suffer incursions than other aircraft. If an incursion does occur and leads to a collision, the *consequences* could well be greater with Group VI aircraft, as we discuss in Section 6.6

There is little experience as of now with Group VI aircraft at LAX or elsewhere, though nothing to date indicates higher incursion rates for these planes. But LAX has a long history of handling large numbers of both "heavy" planes and Group V aircraft. The table below reflects LAX runway incursion data, and shows that large planes have been involved in incursions in proportions very close to their share of LAX traffic:

Table 6-2: *Large-Aircraft Involvement in LAX Runway Incursions, 2002-2008.*

Type of Plane	*Percentage Share of Aircraft Involved in Incursions*	*Percentage of LAX Flight Operations*
Heavy	19%	18%
Group V	7%	9%

Notes: By "percentage share of aircraft involved in incursions," we mean the fraction of those aircraft involved in incursions that were of the type listed. We do not distinguish between the plane that was the "intruder" in the incursion and the other aircraft.

Heavy aircraft include the Boeing 747, Boeing 767, Boeing 777, Airbus 330, Airbus 340, and McDonnell Douglas MD-11.

Group V aircraft include the Boeing 747, Boeing 777, and Airbus 340. Group V is a subset of "heavy."

In short, we see no reason to expect that Group VI aircraft will pose a higher level of incursion risk than other planes operating at LAX.

6.8. A Baseline Frequency Estimate for Fatal Collisions at LAX-North

At this stage, the overall risk estimate for LAX-North baseline follows quickly from what was said earlier.

(i) We estimated that, at 2020 traffic levels, a fatal runway collision would occur at a towered US airport approximately once every four years.

(ii) We estimated that 2% of such runway collisions—1 in 50--would occur at LAX-North under baseline conditions.

Taken together, these estimates imply that:

*At 2020 traffic levels, fatal runway collisions at LAX-North under the current airport layout would occur approximately once every 4 x 50 = **200** years.*

Of course, this statistic "once every 200 years" is an average, mid-range estimate. We are not asserting that such a collision could not occur on 1/1/2020; we are suggesting that the daily probabilities are so low that the average time until the first fatal collision would be 200 years.

We understand that this estimate might strike some readers as unreasonably low. We can only respond that it follows inexorably from the calculations that preceded it. And we stress that at two key points—in estimating the effectiveness of AMASS/ASDE-X/RWSL and in estimating the risk-share for LAX-North baseline---we used *higher risk estimates* than were suggested by the underlying data. Had we used the FAA estimate of 88% effectiveness for AMASS/ASDE-X/RWSL (rather than 75%), and had we assumed that LAX-North baseline had a 1.3% chance of being the venue of a fatal US runway collision (rather than 2%), we would have reached a risk estimate of once every 600 years.

We would also reiterate that there has not been a fatal runway collision at a towered US airport since early 2000. During the decade since that time, there have approximately 500 million safe operations at these airports. It is projected that LAX-North will have approximately 400,000 operations per year in 2020. Thus, towered US airports have collectively performed over *1000-years worth of LAX-North operations* since early 2000, and all in perfect safety. Against that backdrop, it is not outlandish to suggest that LAX-North can average as few as one fatal collision every 200 years, especially with technologies like ASDE-X and RWSL that were not widely available in the last decade.

6.9. The Consequences of a Fatal Runway Collision on LAX-North

While the frequency of fatal collisions in of great interest, it is necessary to estimate how many lives would be lost should a collision occur. Barnett, Paull, and Idealuca (2000) studied casualty patterns in worldwide fatal collisions, and estimated after extensive calculations that a fatal runway collision at a towered U.S. airport would on average cost 48 lives. The actual number killed could vary widely around that average: many fatal collisions involve only one or two deaths; at the other extreme, the 1977 collision at Tenerife in the Canary Islands cost 583 lives. The estimate of 48 deaths took account of a consistent pattern: when two planes of unequal size collided, the percentage killed is generally far higher on the smaller plane than on the larger one. In the 1991 collision at LAX, for example, the death rate was 100% on the small commuter plane but was 25% on the 737 jet that crashed into it.

It is certainly the case that planes at LAX on average carry more passengers and crew than those at a randomly-chosen US airport (though, as we have seen, only slightly more than at a busy US commercial airport). Group VI aircraft are projected to perform only a small percentage of LAX flights in 2020 (perhaps 3%), but they could carry up to 500 passengers apiece. Taking various factors into account, the Panel approximately *doubled* the overall casualty estimate in the 2000 study: roughly speaking, the assumption was that two planes that collided at LAX would on average hold 200 passengers in total, and that half of them would survive the fatal crash. The Panel estimated that:

*A fatal runway collision on the LAX North Airfield in 2020 would on average entail a death toll of **100**.*

6.10. Mortality Risk on the LAX North Airfield in 2020, Baseline Case

As described, the Panel reached the approximations that:

- On average, fatal runway collisions at LAX-North would occur on average once every 200 years, under 2020 traffic levels and the current runway layout.
- When fatal runway collisions occurred at LAX, they would on average take 100 lives.

Taken together, these assumptions imply an average loss of 100 lives every 200 years. That works out to *five lives lost per decade*. Because of random variability in the actual frequency of fatal collisions and in the death toll in each one, there is a statistical *margin of error* in this projection. Over a long period, the confidence interval for lives lost extends from a low of *one* death per decade and a high of *eight*. Outcomes near five are more likely to arise than outcomes at the edges of the confidence interval. The actual toll could obviously fall outside these limits, but the Panel believes that the probability that would happen is low.

To summarize:

*The Panel estimates that, if the current layout at LAX-North remains in place, runway collisions at 2020 traffic levels would cause an average toll of **five deaths per decade** there. This average arises because fatal collisions would occur on average once every 200 years, but would cause an average of 100 deaths when they do occur. The Panel assigns a **margin of error** to this estimate, and projects that the average death toll per decade could be as low as one and as high as eight. It believes, however, that five is a more likely outcome than these lower or upper bounds.*

6.11. Some Perspective on the Mortality Risk Estimate

Like everyone at LAWA or NORSAC, the Panel would prefer that the risk level be zero. But how might one interpret a statistic like "five deaths per decade in runway collisions?" We will discuss the issue further in the chapter on Summary and Conclusions, but offer a few thoughts now.

At 2020 traffic levels, LAX would handle approximately 75 million passengers per year. That works out to 750 million passengers per decade, meaning that the risk per passenger assuming five deaths per decade would be approximately *one per 150 million* (750 million ÷ 5). That number is small compared to the risks that citizens face every day. Based on recent statistics, for example, an American baby born now would have roughly a 1 in 100 chance of eventually dying in an auto accident. And Southern Californians know of the menace posed by the San Andreas Fault.

It is true that aviation is held to an extraordinarily high safety standard. Even by that standard, however, the risk associated with runway collisions is small. Accidents beyond the runways and terrorist acts are statistically more dangerous to passengers than runway collisions, as is illustrated by recent LAX experience. During the first decade of the 21^{st} century, Alaska Air 261 crashed into the Pacific while attempting an emergency landing at LAX, while, on 9/11/01, American #11, United #175, and American #77 never reached their destination of Los Angeles. There were no survivors on any of these flights. Overall, the death risk per flight on a US aircraft was *one in ten million* over 2000-09 (Barnett, 2009). At that rate, about 75 of the 750 million passengers who landed at or took-off from LAX would perish for reasons unrelated to runway hazards. Runway collisions on the North Airfield in baseline conditions, in other words, would account for approximately 1/16 of the extremely low level of mortality risk that US air travelers face (5 deaths out of 75 + 5 = 80 deaths).

To summarize, aviation hazards would cause approximately 80 deaths *per decade* at 2020 traffic levels among the 750 million passengers served each decade by the LAX runways. Five of these deaths would arise in runway collisions. (We emphasize that *this calculation assumes continuation of the present layout of the North Airfield.*) Even if changes to the North Airfield runway configuration reduced the number of deaths in runway collisions by (say) half, the expected number of deaths would only fall from 80 to approximately 78. We would summarize our conclusions about mortality risk *in the baseline case* as follows:

- The runway-collision risk to LAX air travelers would be extremely low in absolute terms, even at 2020 traffic levels.
- The risk would be very low relative to the other mortality risks that face residents of Los Angeles.
- The risk would be low even relative to overall mortality risk of passenger aviation, which is itself exceedingly low.

7. COLLISION-RISK ASSESSMENT: BASELINE WITH IRSIP

At the request of NORSAC the Academic Panel reviewed the Los Angeles Interim Runway Safety Improvement Project (IRSIP) (Feldman 2009a; Feldman 2009b). This program is a pro-active effort by LAWA to enhance the safety of the existing airport while maintaining operational efficiency pending the long-term decisions of the North Airfield configuration (LAWA, 2009a). The IRSIP improvements discussed here are rooted in the FAA Engineering Brief 75 (FAA, 2007) that states:

"… The preference is for aircraft to cross in the last third of the runway whenever possible, since within the middle third of the runway the arriving/ departing aircraft is usually on the ground and traveling at a high rate of speed."

The application of this guiding design principle to the North airfield has been studied by LAWA and its contractor HNTB in the last two quarters of 2009. The goal is to move runway exit Zulu further downrange from its present location, eliminate Yankee for West landings, and create a new high-speed runway exit called AA1 further downrange of the present AA. This new configuration for the North Airfield is shown in Figure 7-1. The idea is to locate runway exits on runway 24R so that all the junctions of these runway exits with runway 24L fall in the last third segment of the runway as stipulated in the FAA Engineering Briefing 75.

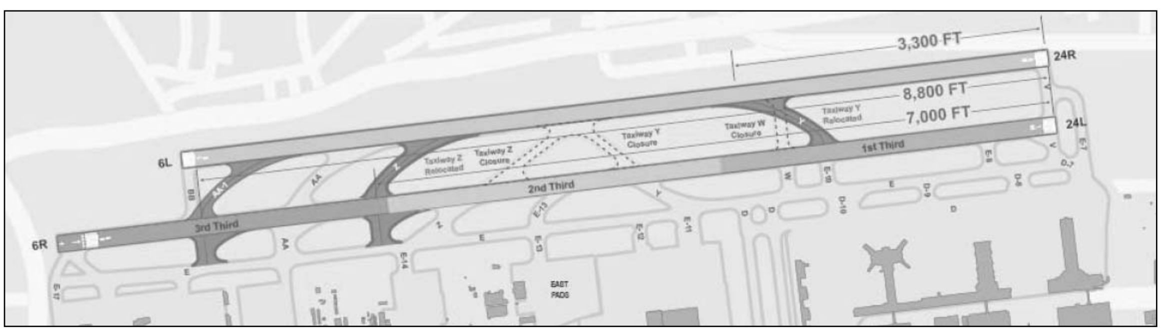


Figure 7-1: Proposed Interim Runway Safety Improvements in the North Airfield.
Source: LAWA and HNTB (2009).

The analysis presented in this Section is a simple analytical effort to estimate some of the safety implications of the new Baseline airport with changes stated in the IRSIP document. The Academic Panel and NASA were made aware of this idea in the third quarter of 2009. At the time, all FFC visuals had been prepared and the long lead-time of the simulation did not allow this scenario to be tested. Nevertheless, we gathered data about the airport operations that could be the starting point of a more detail analysis later on.

The WCG LAX study (2007) describes a matrix of 10 hazards identified for LAX. Feldman (2009a) describes hazards LAX001 and LAX002 as runway incursions caused by a blundering landing aircraft that crosses the hold bars on Yankee and Zulu while a departure takes place on runway 24L. The differentiation of the two hazards is related to the wake class of the departing aircraft on runway 24L. Two more runway incursion hazards are identified when the blunder occurs on taxiway AA or BB (called LAX003 and LAX004). Again, the wake class makes the difference between hazards LAX003 and LAX004. The WCG matrix is shown for completeness in Figure 7-2. Note that both LAX001 and LAX002 fall into the medium risk zone since the severity (or consequence) of a collision for a departing aircraft on 24L with another crossing Zulu or Yankee would occur at relatively high speeds thus causing a “hazardous” condition in the severity category. It is interesting to observe that hazards LAX003 and LAX004 are placed in the “minor” severity category and are as improbable to occur as LAX001 and LAX002 with probability of happening once every 1-100 years. One immediate question from the previous evaluations is whether or not the severity classification for these cases is objective, considering the historical trends observed at the airport.

Severity / Likelihood	No Safety Effect	Minor	Major	Hazardous	Catastrophic
	5	4	3	2	1
Frequent – A More than once per week					
Probable – B Once every month					
Remote – C Once every year			LAX 005 LAX 008 LAX 009		
Extremely Remote – D Once every 10-100 years		LAX 003 LAX 004 LAX 010	LAX 006	LAX 001 LAX 002 LAX 007	
Extremely Improbable – E Less than once every 100 years					*

Figure 7-2: LAX North Airfield Risk Matrix. Source: LAX WCF Safety Risk Management Panel (2007). Red = High Risk, Yellow = Medium Risk and Green = Low Risk.

For example, taxiways with historically distinct runway incursion rates are bundled together in the likelihood category (i.e., Yankee and Zulu). Figure 7-3 demonstrates that various runway exits in the North airfield have very distinct Runway Incursion Rates (RIR). The figure has been created using FAA runway incursion data for years 1999-2007 (ASIAS, 2010) and using the FAA Terminal Area Forecast (TAF) to account for operations at LAX over the time period of analysis. Following historical patterns at LAX, 42% of the landings at LAX are assigned to runway 24R. The number of operations at individual runway exits on runway 24R have been estimated using the Academic Panel's field observations (time-stamp method) and studying four hours of ASDE-X radar data. Table 7-1 summarizes the runway exit data collected by the Academic Panel. Figure 7-3 suggests that perhaps the hazard analysis suggested in Figure 7-2 should distinguish between exit locations that are more prone to runway incursions. Obviously Zulu is very prone to runway incursions, whereas Yankee is not. AA falls in-between but still displays a high runway incursion incidence compared to Yankee (one of the exits to be eliminated in the IRSIP program).

The IRSIP document states that if the relocation of the runway exits is carried out the overall risk level will be reduced for the North airfield so as to move LAX001 to the "major" severity category and LAX002 to the extremely improbable category (i.e., less than once in 100 years). The analysis presented in the WCG seems to be based on "qualitative" assessments and does not offer the analysis to justify moving some of the hazards from the medium risk to the low risk area. For example, the reduction of risk for LAAX002 would require that most heavy aircraft departing runway 24L would be airborne at the junction of 24L and the new Zulu (located 7,000 feet down the runway).

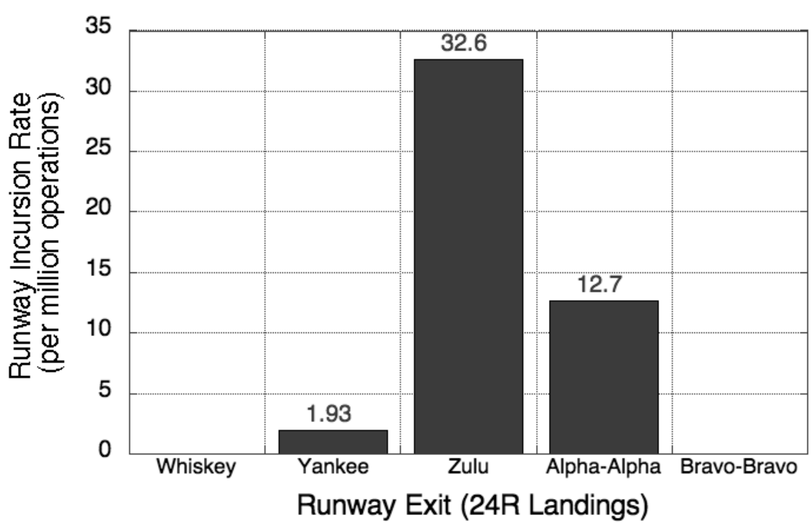


Figure 7-3: LAX North Airfield Runway Exit Incursion Rates.

Table 7-1: Summary of Runway Exit Utilization in the North Airfield. Numbers in the Table Represent the Percent of Aircraft Landing on Runway 24R Taking a Specific Runway Exit. Academic Panel Observations and Analysis.

	Runway Exit				
	W	Y	Z	AA	BB
All Operations (ASDE-X)	0	36	14	50	0
All Operations (Time-Stamp)	1	40	4	54	1
Final Values in Risk Analysis	**0**	**38**	**9**	**52**	**1**

7.1. Empirical Observations at LAX

Our empirical observations using video and ASDE-X suggest that 20% of the heavy fleet operating at LAX will be barely airborne at such distance. Figure 7-4 illustrates the cumulative density function of the airborne distance versus distance from departing threshold of runway 24L. Figure 7-4 also suggests that 53% of the non-heavy aircraft operating at LAX today would likely be just airborne at a point 7,000 feet down the runway. The distance **x** corresponds to the first instance in the ASDE-X video data when an aircraft transitions from the ground to the air mode.

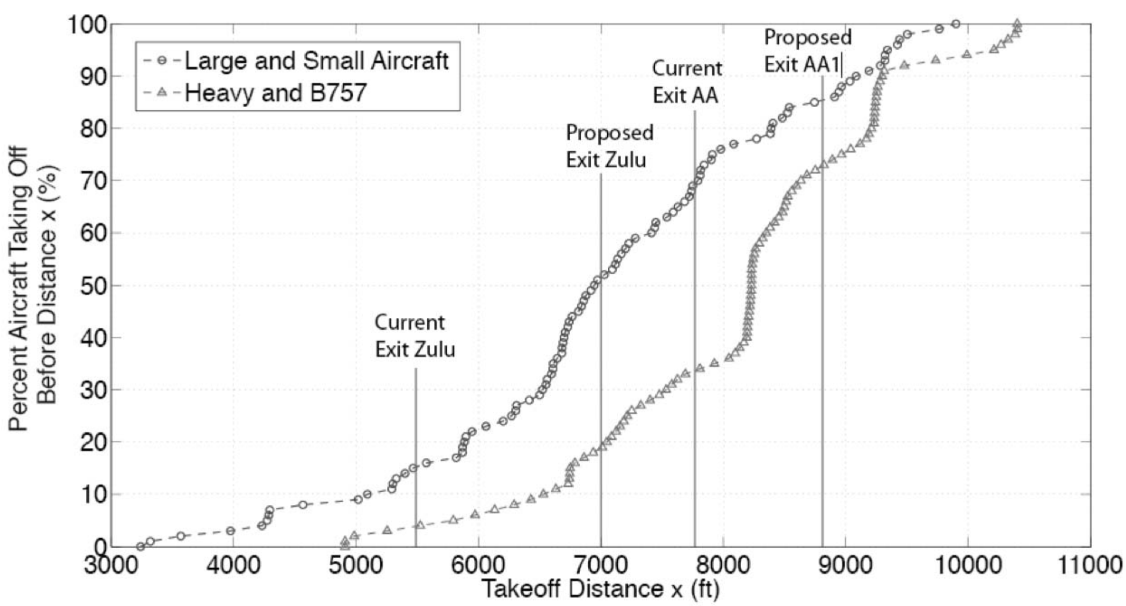


Figure 7-4: Cumulative Density Function of Aircraft Takeoff Distance x from Runway 24L Departing Threshold at LAX. Data Applies to all Runways at LAX.

Table 7-2 summarizes the mean and standard deviation of takeoff distances for two groups of aircraft defined in the IRSIP study (i.e., non-heavy and heavy). The heavy group has a mean takeoff distance of 8,080 feet. Large and small aircraft (all in one category) have average takeoff distances of 7,024 feet. The sample size is small but generally shows a trend that seems realistic. Today, most of the aircraft operating out of Los Angeles employ "flex" thrust settings at takeoff to reduce engine wear and prolong engine life. This effect lengthens the takeoff runway distances. The AP Panel observations using actual video of operations corroborates the takeoff distance numbers. For example, Figure 7-5 shows a Boeing 737-700 (non-heavy) departing runway 24L while an Airbus A380-800 holds on taxiway AA. The Boeing 737-700 rotates slightly ahead of the 7,000 feet mark but, according to our definition of takeoff distance the ASDE-X system will not "detect" the aircraft in the airborne phase until 50-100 feet above the ground. This is the distance reported in this study. Notice that the same distance is not likely to clear a tall tail of an ADG VI aircraft as shown in the picture. Nevertheless, for this analytical study, our definition of takeoff distance would probably equate to the ability to clear an imaginary 35-foot obstacle as stipulated by FAA takeoff distance requirements (FAR 25, 2010).

Table 7-2: Summary of Takeoff Distances Observed at LAX Using ASDE-X Radar Video Data.

Parameter	*Large and Small (non-heavy)*	*Heavy and B757 (report as heavy)*
Mean Takeoff Roll Distance (feet)	7,024	8,080
Standard Deviation Takeoff Toll Distance (feet)	1,485	1,235
Number of Data Points (takeoffs)	86	29

7.2. Estimation of Runway Exit Use Under IRSIP Scenario

To further understand the safety benefit of the relocations proposed in IRSIP we estimate the utilization of the new exits (new Zulu, AA and AA1). This is accomplished using the Runway Exit Design Interactive Model (REDIM 3.0) – a computer model developed at Virginia Tech for the FAA and NASA to that estimates the runway exit utilization considering individual aircraft kinematics (Trani et all, 1999). The input to the model to estimate the utilization of new exits is shown in Table 7-3. The aircraft fleet is representative of today's operations at LAX in the North airfield. The model predicts an expected value of runway occupancy time (ROT) of 56 seconds for all operations. ROT in the model is defined as the time span from threshold crossing to the clearance of the imaginary plane of the runway with either a wingtip or a tail-tip (if taking a right-angle turnoff).

Figure 7-5: Example of Operations in the North Airfield with Potential Runway Incursion Interactions (A.A. Trani).

Table 7-3: Aircraft Mix Used to Estimate Runway Exit Utilization for Landings of Runway 24R Under IRSIP Scenario.

Wake Class	Percent Fleet Mix (%)	Representative Aircraft (% of Fleet)
Small	5	EMB120 (5)
Large	77	Boeing 737-300 (27) Boeing 737-700 (20) Airbus A320 (20) EMB135 (10)
B757	6	Boeing 757-200 (6)
Heavy	11	Boeing 747-400 (6) Boeing 777-200 (5)
Super-heavy	1	Airbus A380 (1)

Table 7-4 summarizes the exit utilization with the Interim Improvements. The table shows that 71% of the Airbus A320 will use the New Zulu exit, 23% will use AA and the remaining 6% are likely to use AA1. The values shown in the table assumed 75% dry runway conditions and 25% wet to account for annual use with varying pavement conditions.

Table 7-4: Estimated Runway Exit Utilization for Landings on Runway 24R. Academic Panel Analysis Using the REDIM 3.0 Model. Numbers in Each Cell Represent the Percent of Aircraft Taking Each Runway Exit.

Runway Exit	New Zulu	AA	AA1	BB	Total
Aircraft					
A320	71	23	6	0	100
A380	0	56	41	3	100
B733	75	24	1	0	100
B738	73	26	1	0	100
B744	0	56	40	4	100
B757	65	34	2	0	100
B772	31	58	10	1	100
E120	100	0	0	0	100
E135	92	8	0	0	100

Table 7-5: Los Angeles International Airport Breakdown of Annual Runway Operations (source: LAWA EIS, 2008).

Runway	***Arrivals***	***Departures***
24R	134,111	7,206
24L	7,597	136,142
Total North	141,708	143,348
25R	20,908	143,533
25L	158,179	31,855
Total South	179,087	175,388
Total Airfield	320,795	318,736

Table 7-5 contains the typical breakdown of landings per runway for LAX (EIS, 2008). Using Tables 7-4 and 7-5 we estimate the expected number of operations at every new runway exit proposed by the Interim Improvement plan. Table 7-6 shows the results of this analysis. A few observations are important.

1) The new taxiway Zulu takes most of the landing traffic from Yankee, old Zulu and about 47% of the operations assigned to AA in the Baseline case.

2) The move from old Zulu to new Zulu is good news since this will improve the chance that an aircraft departing runway 24L would avoid a collision with a blundering aircraft entering 24L accidentally.

3) However, the traffic that moves from AA to new Zulu actually would increase the conditional probability of a collision given a blunder because more traffic will be crossing closer to the departure end 24L.

Table 7-6: Estimated Annual Runway Exit Use for Landings on Runway 24R. Numbers in Each Cell Represent the Number of Aircraft Landings Expected in Each Runway Exit.

	Runway Exit

	Yankee	Zulu	New Zulu	AA	AA1	BB
Exit Location (ft) From 24R threshold	4,560	4,600	6,200	7,000	7,800	8,670
Percent Use (%) Baseline	38	9	N/A	52	N/A	1
Annual Landings Baseline	50,962	12,070	N/A	69,738	N/A	1,341
Percent Use (%) IRSIP Scenario	N/A	N/A	68	27	5	0
Annual Landings IRSIP Scenario	N/A	N/A	90,632	36,155	6,893	429

N/A means runway exit is not available in that scenario.

Using the CDF distribution presented in Figure 4-7 we estimate the probability that an aircraft taking off on runway 24L will lift-off in various runway segments between runway exits. Table 7-7 presents the results of this calculation and we introduce labels 1-6 for all runway segments. The utilization of each runway exit is presented in Table 7-8. We introduce labels A through F to facilitate further calculations.

Table 7-7: Probability that the Aircraft Taking off on Runway 24L will Lift-off in a Runway Segment.

	1	***2***	***3***	***4***	***5***	***6***
	0-Yankee	Yankee – Zulu	Zulu – New Zulu	New Zulu – AA	AA – AA1	AA1 – BB
Non-Heavy	0	0.16	0.36	0.14	0.20	0.14
Heavy	0	0.04	0.14	0.15	0.40	0.27

Table 7-8: Probability that an Aircraft Landing on Runway 24L will use a given Exit.

	A	***B***	***C***	***D***	***E***	***F***

	Yankee	Zulu	New Zulu	AA	AA1	BB
Baseline	0.38	0.09	0	0.52	0	0.01
IRSIP	0	0	0.68	0.27	0.05	0

The next step is to perform a simple convolution calculation to estimate the percent of aircraft that taking off from runway 24L that would clear a blundering aircraft using a given exit. To illustrate the problem consider non-heavy aircraft taking off from runway 24L in the Baseline configuration. The percent of aircraft departing 24L and lifting off between Yankee and Zulu is known to be 16% (0.16 in column 2 of Table 7-7). According to Table 7-8, 38% of the arrivals on runway 24R use runway exit Yankee in the Baseline case. The contribution of these landing aircraft to the overall probability of aircraft departing on 24L and lifting off in segment Yankee-Zulu is then the product (0.16)(0.38) = 0.0608. This is shown in Table 7-9. This process is repeated for all combinations of values contained in Tables 7-7 and 7-8. The results are shown in Tables 7-9 through 7-12. Tables 7-9 and 7-10 show the results for the Baseline airfield. Tables 7-11-and 7-12 show the results for the IRSIP configuration. The numbers in red indicate the percentages of aircraft taking off that will be airborne and thus avoid a collision if the blundering aircraft enters runway 24L accidentally. Table 7-13 summarizes the percent of aircraft of each type that will be able to overfly a runway incursion. The table indicates that under Baseline case 33% of the aircraft departing runway 24L will be able to overfly an incursion.

Table 7-9: Convolution of Tables 7-7 and 7-8. **Baseline Scenario: Non-Heavy Takeoff**. Numbers in Red Indicate Percentages of Aircraft Airborne.

	A	B	C	D	E	F
1	**0**	**0**	**0**	**0**	**0**	**0**
2	**0.0608**	**0.0144**	**0**	**0.0832**	**0**	**0.0016**
3	**0.1368**	**0.0324**	**0**	**0.1872**	**0**	**0.0036**
4	**0.0532**	**0.0126**	**0**	**0.0728**	**0**	**0.0014**
5	**0.076**	**0.018**	**0**	**0.104**	**0**	**0.0020**
6	**0.0532**	**0.0126**	**0**	**0.0728**	**0**	**0.0014**

Table 7-10: Convolution of Tables 7-7 and 7-8. **Baseline Scenario: Heavy Takeoff.** Numbers in Red Indicate Percentages of Aircraft Airborne.

	A	B	C	D	E	F
1	0	0	0	0	0	0
2	0.0152	0.0036	0	0.0208	0	0.0004
3	0.0532	0.0126	0	0.0728	0	0.0014
4	0.057	0.0135	0	0.078	0	0.0015
5	0.152	0.036	0	0.208	0	0.004
6	0.1026	0.0243	0	0.1404	0	0.0027

Table 7-11: Convolution of Tables 7-7 and 7-8. **IRSIP Scenario: Non-Heavy Takeoff**. Numbers in Red Indicate Percentages of Aircraft Airborne.

	A	B	C	D	E	F
1	0	0	0	0	0	0
2	0	0	0.1088	0.0432	0.008	0
3	0	0	0.2448	0.0972	0.018	0
4	0	0	0.0952	0.0378	0.007	0
5	0	0	0.136	0.054	0.01	0
6	0	0	0.0952	0.0378	0.007	0

Table 7-12: Convolution of Tables 7-7 and 7-8. **IRSIP Scenario: Heavy Takeoff.** Numbers in Red Indicate Percentages of Aircraft Airborne.

	A	B	C	D	E	F
1	0	0	0	0	0	0
2	0	0	0.0272	0.0108	0.002	0

3	0	0	**0.0952**	**0.0378**	**0.007**	**0**
4	0	0	0.102	**0.0405**	**0.0075**	**0**
5	0	0	0.272	0.108	**0.02**	**0**
6	0	0	0.1836	0.0729	0.0135	**0**

Table 7-13: Probability of Overflying Incursion Aircraft. North Airfield Operations.

	Baseline	***IRSIP***
Non-heavy take-off	0.37	0.57
Heavy take-off	0.19	0.25
80% Non-heavy, 20% Heavy	**0.33**	**0.51**

The IRSIP scenario indicates that 51% percent of the aircraft will overfly the blundering aircraft. This result implies that, "all other conditions being equal", the IRSIP scenario reduces the probability of collision given a runway incursion by 27% ((67-49)/67). However, this analysis assumes that the exposure to runway incursions will be the same in the Baseline and IRSIP. There is evidence that the risk of runway incursion is higher for certain types of runway exits in the North. For example, Figure 7-3 shows the large variability of runway incursion rates among runway exits in the North airfield. More careful analysis is needed to understand the causal link between runway exit geometry and runway incursion rates. For LAX North, common elements of runway exits Zulu and AA (with the highest RIR metric) are: 1) both are high-speed exits and 2) both have acute exit angles (albeit different geometries).

Figure 7-6 presents the RIR metric vs. runway exit angle for all four exits in the North airfield. The plot clearly indicates that while high-speed runway geometries are good to reduce ROT and thus improve saturation arrival capacity on Runway 24R, they also pose a problem in terms of runway incursions in the specific case of close-parallel runways (a well known problem for airports like Los Angeles). If the new exit types in the IRSIP study are similar to AA and, and if the runway incursion rate of AA is an indication of the things to come (6 times higher risk than Yankee), then having two new "good" runway exits further downrange with higher individual RIR risks, could erode the gains achieved by displacing the runway exits further downrange. This suggests that it is not certain that closing Taxiway Yankee will reduce collision risk but could rather increase it if historical trends are to be believed.

Consider the analysis presented in Table 7-7. The table illustrates the total risk calculation of Baseline vs. IRSIP if we assume the RIR metric for the new exits is half that of AA (i.e., 6.34 incursions per million landings). The table shows that cumulatively, the total risk of incursions per year for the Baseline is 1.38 incursions per year. The table also shows that the total risk for IRSIP would be 1.08 runway incursions per year. This produces a net gain for the IRSIP alternative of 22% in risk reduction compared to the Baseline. However, if the new exits Zulu and AA1 are as risk prone as AA (with RIR at 12.68 incursions per million landings), the analysis produces 1.38 runway incursions per year for the Baseline and 1.70 runway incursions per year for IRSIP. This means the probability of incursion for IRSIP would be higher than the Baseline case. Factoring in the probability of collision given an incursion for the IRSIP case, this would produce a net gain for IRSIP of 18.9%. This is the most likely scenario given the apparent relationship between runway exit angle and runway incursion rate.

This suggests that careful attention should be paid to the geometric design aspect of the new runway exits suggested for IRSIP to avoid high RIR rates as in the current Zulu. At the time of our report writing, the detailed geometric design standards for AA1 and New Zulu were not known.

This last point bring us to the paradox of high-speed runway exit design with two close parallel runways (e.g., LAX). This paradox applies to both Baseline and IRSIP. In general we would like to:

i) Design high-speed runway exits to reduce Runway Occupancy Time (ROT) – good for arrival acceptance rate or good for mixed runway operations, and

ii) Design high-speed runway exits that promote safety at the crossing junction with 24L

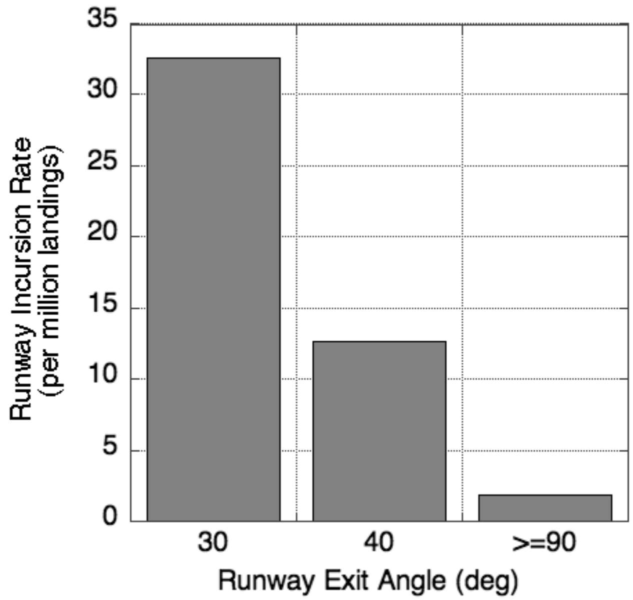


Figure 7-6: Runway Incursion Rate vs. Runway Exit Angle. Runway 24R Exits.

These two design criteria are difficult to reconcile without an invisible "barrier" that precludes pilots from blundering. The barrier could be a center taxiway or a combination of technologies (ground-based lights like RWSL, flight deck or ATC tower-based systems like ASDE-X) that prevents pilots from crossing hold bars accidentally. Both techniques are investigated in Section 8 of this report. Any airport designer will agree that building high-speed exits between two closely-spaced runways is not a good idea. Our analysis of taxiways Zulu and AA is that they do have slightly more than 1,150 feet of path length (at the centerline) to decelerate an aircraft between the point of curvature (entry point to the turnoff on the runway centerline) and the hold bars. If an aircraft enters either Zulu or AA at 60 knots (considered a very high speed for these exits), a very modest deceleration rate of -4.4 ft/s^2 would be needed to bring the aircraft to a full stop at the hold bar position. This assumes the pilot is attentive and willing to brake in the turn at a modest rate.

Table 7-14: Estimated Yearly Incursions and Risk of Baseline vs. IRSIP. Assume RIR for New Exits is Half the Historical Value of Runway Exit AA.

	Runway Exit						
	Yankee	Zulu	New Zulu	AA	AA1	BB	Total RI

Annual Landings Baseline	50,962	12,070	N/A	69,738	N/A	1,341	
Annual Landings IRSIP Scenario	N/A	N/A	90,632	36,155	6,893	429	
Runway Incursion Rate (per million) Baseline	1.98	32.56		12.68		0.00	
Incursions per Year	0.0983	0.3931		0.8843		0	1.3757
Runway Incursion Rate (per million) IRSIP			6.34	12.68	6.34		
Incursions per Year			0.5747	0.4584	0.0437	0	1.0769

N/A means runway exit is not available in that scenario.

The analysis so far does not consider the benefit IRSIP could have by providing pilots and controllers with more time to recognize and react to a runway incursion because the runway exits are located further downrange. This requires an estimation of the probability that the takeoff will be aborted and that the aborting aircraft stops short of a collision. This was not calculated in this study. The Academic Panel recommends more analysis for this configuration.

8. COLLISION-RISK ASSESSMENT: 100' NORTH

The significant change brought by the 100-North alternative is a centerline taxiway between runways 24L and 24R. We begin our analysis of the 100-North alternative with a general comparison between a runway complex with two closely-spaced parallel runways and a centerline taxiway (CeT case) and a complex having two closely-spaced parallel runways without such a taxiway (NCT case). There are a number of operational capabilities and performance changes provided by centerline taxiways. Some of these mainly impact the efficiency of airport operations and others mainly impact safety. Our focus here is safety. Probably the most prominent collision risk of an NCT runway complex, like the Baseline, involves an aircraft arriving on the outboard runway, taking a high-speed exit and then crossing the inboard runway, or breaching the hold bar, without clearance from the controller. Such an incident can involve a very high degree of risk, as the arriving aircraft could encounter an aircraft departing on the inboard runway. A number of such runway incursions have been observed on both the LAX North runway complex and the LAX South runway complex (prior to the construction of a centerline taxiway on the South). These runway incursions play an important role in our analysis and so we specifically identify them as Exit-No-Stop (ENS) incursions. It seems clear that an ENS incursion generally would be caused by a distracted or disoriented pilot or by a pilot exiting at too high a speed. Usually there is some degree of mis-communication between the pilot and controller as well.

Figure 8-1 illustrates the exit path of an aircraft arriving on the outboard runway with and without a centerline taxiway. One can see that, in the CeT case, the aircraft is forced to perform a combination of two rather sharp turns. This both reduces the likelihood of a pilot being distracted by requiring greater attentiveness, forces a greater degree situational awareness and, of course, forces a greater speed reduction. Thus, it seems evident that:

A centerline taxiway should reduce the risk of ENS incursions and moreover this is an objective of their design.

Of course, there are other operational advantages of a centerline taxiway. While these most directly would seem to provide efficiency advantages, they also can potentially improve safety. A major challenge in managing aircraft operations for airports with closely spaced parallel runways involves maintaining a high level of departure throughput in light of the need to allow arriving aircraft to cross the inboard (departure) runway. A further challenge can be posed by congestion in the terminal area, e.g. on a taxiway parallel to the runways. Such congestion might prevent the ability to cross aircraft at certain times and/or locations. As illustrated in Figure 8-2, the crossing of aircraft is facilitated by the ability to buffer aircraft. In the NCT case, the taxiway-exits between the two runways provide some buffering capability, while in the CeT case, the entire centerline taxiway provides a (much larger) buffer. Further, the centerline taxiway also provides the capability to move aircraft to different crossing locations, while in the NCT case, the arriving aircraft can only cross the inboard runway at the location of the taxiway-exit it used upon arrival. Thus,

A centerline taxiway:

- ***i) gives controllers the ability to move aircraft to the most appropriate crossing point,***
- ***ii) improves the controller ability to time crossings and***
- ***iii) offers more opportunity to cross multiple aircraft simultaneously.***

These capabilities can be used to improve the efficiency of ground operations. Moreover, by reducing the cases where a controller is forced to carry out a particular crossing operation, they have the potential to improve safety.

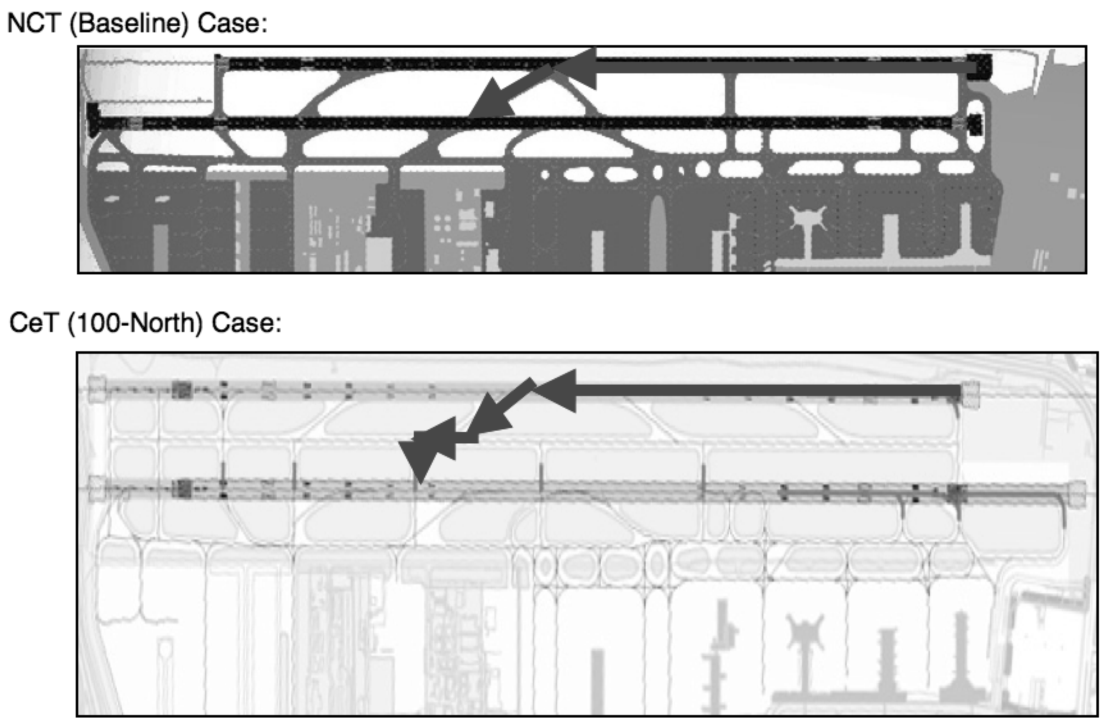


Figure 8-1: Comparison of Exit Path with and without Centerline Taxiway

Another related safety issue for the NCT case involves holding aircraft on the exit-taxiways. For larger aircraft, it can be the case that, if an aircraft holding on an exit-taxiway is incorrectly positioned, its tail could protrude into outboard runway safety zone. This obviously would pose a safety hazard. It can also be the case, that two aircraft could occupy the same exit-taxiway. Such an occurrence would result in an even greater risk that the protrusion of an aircraft tail into the outboard runway. Thus,

The centerline taxiway should nearly eliminate hazards involving aircraft tails protruding onto the outboard runway.

With this background we now proceed to assess the relative risk of the Baseline and 100-North cases. We start with an analysis of the results from the Sim (Section 8.1) and then proceed with an analysis of historical LAX incursion data (Section 8.2). Section 8.3. provides overall conclusions for the 100-North case.

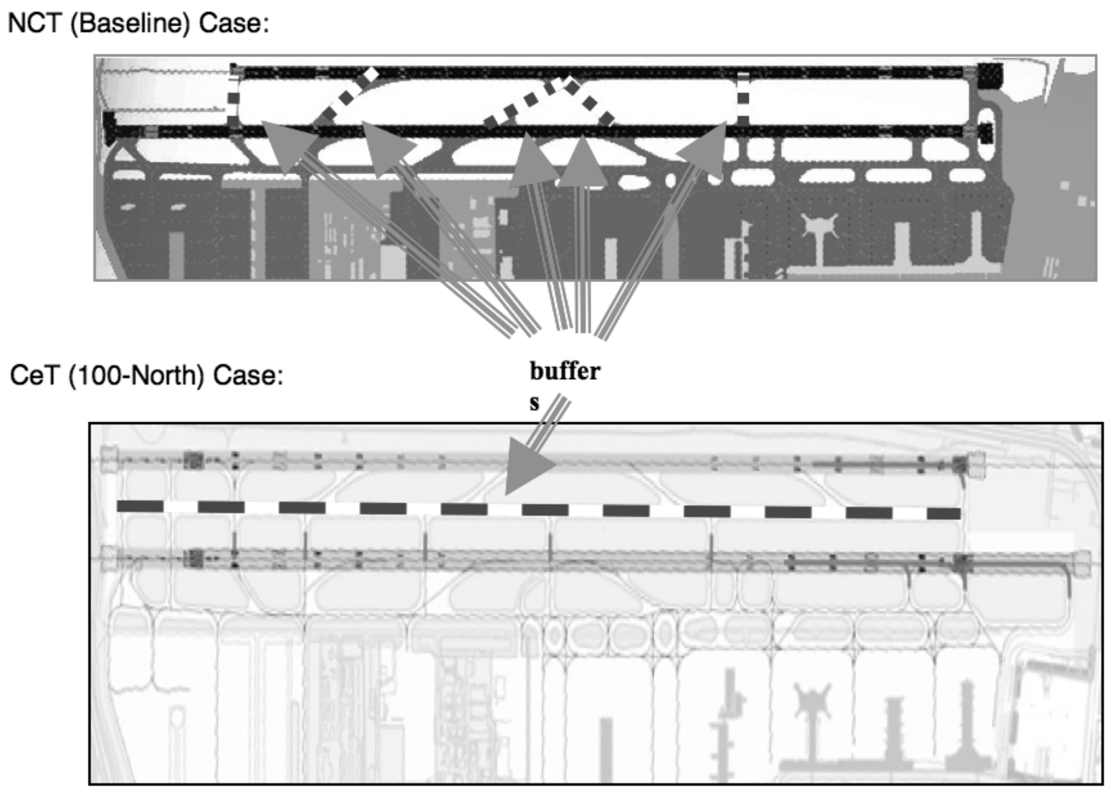


Figure 8-2: Comparison of Buffers with and without Centerline Taxiway.

8.1. Analysis of Simulation Results

We now review the Simulation results and present the insights they provide and the conclusions they support. First, it is very important to point out that the Simulation allowed the AP, the subject pilots, the subject controllers and other experts to observe the "actual" operation of the LAX North Runway complex after the 100-North modifications. This has been invaluable in providing the AP with insights into the basic functionality 100-North provides and how it differs from the Baseline and the other alternatives. In fact, the discussion provided at the beginning of this section was largely based on our own observations and discussion with experts while watching 100-North operations.

8.1.1 Controller Interviews

We start with an analysis of the controller interviews. A very prominent theme in the interviews was the near universal opinion that a centerline taxiway provides a significant positive impact on airport operations. Below we provide some specific excerpts from the interview notes that support this conclusion:

Group 1:

> *South easier to manage than North – tremendous improvement with center taxiway; Center taxiway is the only way to go: more flexibility in timing runway crossing (don't miss departure "holes"); can better respond to congestion on other taxiways.*

Group 2:

> *Centerline taxiway helps ground controllers and local controllers alike; today's operation is surgical (requires a lot of planning and limited holding capacity between runways in the North); the presence of a centerline taxiway allows more flexibility in handling traffic; a centerline taxiway is a "must" to improve the operation at this airport; any of the 100' or 340' is a vast improvement over today's configuration.*

Group 3:

> *Centerline taxiway is a tough mindset to change, i.e. it makes things much easier to operate; it makes lots of strategies "work"; don't have to be super-precise; generally things are not as efficient or safe without center taxiway; reduces risk of incursion.*

The 2^{nd} and 3^{rd} groups of controllers both rated 100-North and 340-N significantly above all other alternatives indicating that 340-N was noticeably better than 100N; the 1st group of controllers was not quite as explicit but implicitly seemed to have a similar opinion. The 3rd group of controllers explicitly used the analogy that if 340-N represented 100% improvement then 100-North attained 80% of that objective. Certain controllers indicated that the relative degree of incremental improvement of 340-N over 100-North depended on the number of Group VI aircraft in the fleet composition. Here it seemed clear that the criterion for rating one alternative better than another depended on a combination of improved safety, improved efficiency and better ability for the controllers to carry out their job function well.

8.1.2 Controller Surveys

We now consider the controller surveys. Questions 1 through 13 deal with effects generally related to operational efficiency and improvement in the controller job function. Question 15 explicitly deals with the risk of a runway incursion. To quantify the degree of difference in the risk level between 100-North and the Baseline as expressed by the subject controllers, we mapped the responses on Question 15 to a relative risk scale as follows. We assume that answers at the extreme ends of the scale—1 and 7 in the surveys conducted for our study—are associated with a large difference in relative risk, say 95% for 7 and 5% for 1. Relative risk values for intermediate points can then be calculated by interpolation. Two forms of interpolation may plausibly be employed. The first is linear. Assuming 95% and 5% for the endpoints, then a 1-point move along the scale is associated with a (95%-5%)/(7-1)=15% change in relative risk. The second form of interpolation is logarithmic. In this case, each 1-point movement has a constant multiplicative effect. Again assuming 95% and 5% for the endpoints, a 1-point increase multiplies the risk by $(95\%/5\%)^{1/(7-1)}$=1.63. There is a body of research on risk perception supporting the use of a logarithmic scale, e.g. see [Longo and Lurenco, 2007]

Table 8-1 gives the results of our analysis. We see that in the controllers' perception, 100-North provides an incursion risk reduction in the range of 19 to 29 per cent.

Table 8-1: Results of Controller Surveys for Incursion Risk.

Incursion Risk	*Linear Scale*	*Logarithmic Scale*
Baseline	0.57	0.27
100-N	0.46	0.19
100-N improvement %	19%	29%

Viewing the other relevant survey results (Questions 1 through 13), the results generally support the perceptions gained from the interviews. Overall the surveys indicated that the 100-North provided an improvement in operational performance when compared to the Baseline. The average percent improvement indicated by the surveys were in the mid-20% range.

8.1.3 Pilot Interviews

The pilot interviews were constructed so as to gain insight into the relative merits of the various alternatives. However, we also tried to use them to gain insight into the safety of LAX compared to other airports. A summary of the information provided is given below.

- *Pilots generally expressed the opinion that LAX (today) was about in the middle of other major airports from a safety perspective; in particular, there did not appear to be a reason to call it an unsafe airport (relatively speaking).*
- *There did seem to be almost universal agreement that a center taxiway would improve safety. At the same time, some pilots expressed a dislike for the centerline taxiway due to the requirement for additional aircraft maneuvering. At least in one case, we felt this was associated with a poor design of the taxiway exit system.*
- *Certain pilots pointed out that, under the Baseline alternative, the fact that some heavies (and, of course, super heavies) cannot hold between the runways (their tail would protrude into 24L) is a safety hazard. This is especially problematic since controllers must remember to give these aircraft special treatment.*

Multiple pilots pointed out the safety advantage of the ability of a pilot to look down the inboard runway prior to crossing it. One can build on this comment to view the decision to cross the inboard runway from a systems reliability standpoint. Specifically, the following three processes serve to provide redundancy in making this decision: i) controller clearance, ii) runway status lights, iii) pilot visual check of runway status. It was noted that the ability to see down the runway depends on the angle at which the aircraft approaches the runway. For larger aircraft, in the case of the Baseline and in the case of 100-North, the aircraft must approach the inboard runway at an acute angle that eliminates (or reduces) a clear line-of-sight down the runway. This issue will be analyzed later and, in fact, is the driver of a potential safety difference between 100-North and 340-North.

The pilots also provided useful feedback on the effectiveness of runway status lights (RWSL). Insights gained from these comments will be employed in the quantitative analysis performed in Section 1.2.

8.1.4 Pilot Surveys

A general review of the raw data resulting from the pilot surveys can at times seem to give counter-intuitive and even contradictory results. This in part may be due to the relatively small number of pilots involved and also to the fact that individual pilots did not see all of the alternatives. For these reasons we feel less weight should be placed on these surveys. We conducted tests to determine the statistical validity of the hypothesis that the pilot answers indicated a significant difference in the area covered by the question. Comparing 100-North to the Baseline, there was one safety-related question that passed the test: Question 3, which dealt with the safety of the runway-cross phase. That is, the hypothesis that the runway crossing phase is safer under 100-North than under the Baseline, as perceived by the pilots, can be supported by the data. We also calculated the metric described in the previous section for question 23 that asked pilots to compare the North runway alternative under consideration to other airports from a safety perspective. The results are given in Table 8-2.

Table 8-2: Summary of Pilot Survey Results.

	Basic Safety	***Crossing Safety***	***General Operations Performance***	***Comparative Confusion***	***Comparative Safety***
Baseline	0.070	0.208	0.426	0.335	0.621
100-North	0.101	0.127	0.414	0.330	0.582
% Improve	-46%	39%	3%	1%	6%

These results may seem a bit inconsistent and somewhat contradictory. We performed statistical tests and found that, of the questions referred to above, the only one that displayed a statistical significance in the responses was the Crossing Safety question. It should be pointed out that the Basic Safety questions largely treated issues not affected by the centerline taxiway. For this reason and since our statistical tests did not support the hypothesis that there was a difference between the Baseline and 100-North based on the responses, we do not place a great deal of significance in the seemingly large advantage for the Baseline indicated by the responses. Overall, we feel the surveys support the hypothesis that the centerline taxiway provides a significant safety advantage relative to runway crossing. Otherwise, they generally indicate little difference in performance.

8.1.5 FutureFlight Simulation Data

We consider three types of Simulation data: anomalies statistics, radio frequency usage and capacity and delay information. For all types of anomalies, 100-North was indistinguishable from the Baseline. Thus, two conclusions can be supported: i) that the 100-North alternative does not significantly affect controller error rates or ii) that this particular experiment was not able to identify such difference (for many possible reasons). A similar situation exists relative to the frequency usage data. Specifically, there were no significant differences between 100-North and the Baseline and, thus, the same two conclusions could be supported. Section 13 analyzes the capacity and delay data in detail so we will just touch on it here. The data indicated a slight advantage of 100-North over the Baseline. Specifically, given the same level of operations, under 100-North there should be slightly less surface delays and slightly shorter taxi times. To the degree that such a reduction in congestion would reduce workload and stress, it should have a positive impact on safety.

8.1.5 General Conclusions

There was certainly a near universal conclusion among controllers and pilots that a centerline taxiway improved airport operations, when compared to the Baseline. “Improved” in this case could be interpreted along multiple dimensions, one of which is safety. This conclusion came out both in the interviews and in the surveys. Using a method to convert the survey responses to improvement factors, the controllers’ collective opinion indicated a 21% reduction in collision risk and a 23% increase in a combined measure of operational performance. Applying these methods to pilot survey results, the pilots indicated a 35% increase in runway crossing safety, a 6% increase in comparative (to other airports) safety, a 46% *decrease* in general (landing and taxi-to-gate) safety and minimal change in operation performance. We must use these results with care as they are based on the subjective judgment of the subjects and the scales used are difficult to convert to actual risk values. Particular care must be applied to the pilot results due to the very small sample sizes. We will discuss this later when developing our overall conclusions. The Simulation data did not show a significant difference between 100-North and the Baseline except in the area of capacity and delay, which it indicated a slight advantage for 100-North.

8.2. Analysis of Historical Incursion Data

While the Simulation results provide strong evidence that a centerline taxiway improves airport operations and airport safety, it can be challenging to explicitly estimate changes in collision risk from the Simulation results. In this section we turn to analysis of historical incursion data. This analysis will allow us to both validate the Simulation results and also to generate quantitative estimates of the risk impact. The similarities between the current LAX North runway complex and the LAX South runway complex, before the new centerline taxiway was built, and also the similarity between the current South runway complex and the 100-North alternative allow for the very effective use of historical incursion data. The incursion data used in this Chapter was obtained by merging data from the LAX Incursion “Maps” provided on the LAWA web site with data downloaded from the FAA’s **Aviation Safety Information Analysis and Sharing (ASIAS) System**. The ASIAS database included all incursions that appeared on the LAWA web site plus a few additional ones. These additional incursions were minor and did not even receive the standard A, B, C or D classification. Generally, we ignored these in our analysis although for reasons related to computational convenience we used this larger set in our analysis of the frequency of appearance of large aircraft in incursions. Incursion statistics are calculated on a calendar year basis. Please note that FAA reports general provide incursion statistics on a fiscal year basis. Some of this (fiscal year) data is used elsewhere in this report (when this is done the basis year assumed is noted).

The principal risk that we focus on in evaluating runway alternatives is the risk of a collision due to a runway incursion. The runway geometry also impacts the risk of a collision resulting from an excursion. This risk is dealt with in Section 6. Runway geometry may also impact the risk of accident in the general vicinity of the airport. Such accidents are generally a second order effect of runway geometry and they will be discussed as appropriate after the main analysis.

We start by considering the relationship between the risk of a collision due to a runway incursion and the risk of a runway incursion.

Risk of fatal runway collision =

Prob[fatal collision resulting from runway incursion]

$$\text{Prob[fatal collision | runway incursion] * Prob[runway incursion]} \qquad (8.1)$$

The final term involves the product of the probability that a runway incursion occurs and the probably that a particular runway incursion results in a fatal collision. The importance of this equation is that the risk of a fatal runway collision can be reduced by either reducing the chance that a runway incursion occurs (equivalently the annual rate of runway incursions) or by reducing the chance that a runway incursion results in a fatal collision. When we consider the impact of various alternatives, these may impact one or both of the terms in the product.

The starting point for our incursion analysis is the identification of the ENS incursion as defined earlier. We estimate the risk reduction impact of a centerline taxiway by estimating the ability of a centerline taxiway to reduce the rate of ENS incursions. To do this, we employ historical data from the South to estimate the ENS incursion risk reduction of the centerline taxiway under 100-North. The justification for this approach is the similarity discussed earlier between the pre-centerline taxiway South airfield and the current North airfield and the post-centerline taxiway South airfield and the 100-North alternative. We are well aware that, in spite of these similarities, there are significant differences between the North and South airfields (and historically there have been significant differences in the incursions rates). However, we do not attempt to estimate absolute incursion rates on the North from the South but rather we apply ***an estimate of the rate reduction*** experienced on the South to the North under the 100-North option.

Based on an examination of the descriptions of all runway incursions that occurred at LAX between 1998 and 2007, we classified each incursion as being an ENS incursion or not. We note that some subjective judgment was required in some cases; however, the number of such cases was relatively small. The result of this analysis was:

Average number ENS incursions / yr on S: 3.6 (55%)

Average number ENS incursions / yr on N: 1.1 (55%)

Note that, somewhat remarkably, the percent of ENS incursions on the North and South were virtually identical. This analysis considered incursions of all severity levels (A through D). Since some estimates and analyses performed by us and others restrict attention to more severe incursions we did an additional analysis to estimate the incursion breakdown restricted to only A and B incursions and to only A, B and C incursions. These did not differ significantly from the above breakdown so we feel this estimate is quite reliable.

The key estimate that will drive our analysis is the reduction factor for ENS incursions on the South attributed to the centerline taxiway. We first consider estimating the pre-centerline ENS incursion rate. This taxiway was opened in June of 2008, with the early part of 2008 largely devoted to construction. Thus, we use as a cutoff point the end of 2007. While our analysis has generally employed data starting in 1998 or 1999, two significant changes occurred during the year 2001. The first was the introduction of ASDE-3 and AMASS and the second is a decrease in traffic. Since we wish to estimate the incremental impact of a centerline taxiway over and above ASDE-3 and AMASS and also, we wish to do so in roughly equivalent traffic conditions, a reasonable time frame would seem to be 2002 to 2007. Table 8-3 provides both the 1999-2007 rates and the 2002-2007 rates for AB, ABC and ABCD incursions.

Table 8-3: Pre-Centerline ENS Incursion Rates on LAX South.

Rate/year	*1999-2007*	*2002-2007*
AB	1	0.5
ABC	3	1
ABCD	3.6	3.2

We note that 02-07 rates do show a substantial drop from the 99-07 rates in all cases except ABCD. The relatively small change in the ABCD rate can perhaps be attributed to changes in the criteria for C and D incursions. The next major challenge is to estimate a post-centerline taxiway rate. From July of 2008 through December of 2009, there was a single incursion on the South that could be classified as an ENS incursion: the 10/25/2009 incident, which was classified as a category C incursion. One incursion over an 18-month period represents a .67 rate. Even though the data collection period (18 months) is short and the number of observations very small (1), the change in the ABCD rate from 3.2 or 3.6 to .67 is highly statistically significant. Thus, we can conclude with confidence that the centerline taxiway has significantly reduced the ENS incursion rate on the South. On the other hand, the specific estimate of the rate, .67, represents a point in a fairly wide confidence interval. Thus, we must use judgment and intuition in arriving at a reasonable ENS incursion rate reduction factor. For reasons discussed earlier we will restrict use for the pre-centerline rate, the 2002-2007 data. One could argue that the default should be to employ the ABCD rate since generally our analysis has focused on all incursions. On the other hand, FAA studies have tended to focus on serious incursions, e.g. AB, or possibly ABC. In our case, focusing only on AB would not produce meaningful results as such incursions are simply too infrequent. Focusing on ABC starts to alleviate this issue to a degree. At the same time, it seems clear that data concerning D incursions is certainly meaningful and one certainly should not ignore the very significant drop in ENS D incursions after the centerline taxiway introduction.

Table 8-4 lists the 2002-2007 pre-centerline taxiway rates, the post-centerline taxiway rates and the corresponding reduction factor.

As discussed above the "default" would be to use the ABCD analysis and the reduction factor of 79%. To acknowledge the much more modest reduction factor for ABC incursions one could take the approach of weighting the three categories (and reduction factors) evenly and taking the average reduction factor: (100 + 33 + 79)/3 = 71%. We should note that this approach implicitly gives higher weight to the more serious incursions. These two estimates are relatively close and for our analysis we take a compromise and use a reduction factor of 75%.

Table 8-4: ENS Incursion Rate Reduction on South Airfield.

Rate/Year	***Before Center Taxiway***	***After Center Taxiway***	***Reduction Factor***
AB	0.5	0	100%
ABC	1	0.67	33%
ABCD	3.2	0.67	79%

8.2.1 Risk Reduction without RWSL

We now proceed to calculate the risk reduction provided for the 100-North alternative. Because of certain subtleties in our analysis we use as a starting point the level of risk for a *modified Baseline that assumes the 2020 traffic levels, ASDE-X and AMASS but no RWSL*. We define this starting risk level as R:

starting risk = R

Allocating based on incursion distribution yields:

= non-ENS collision risk + ENS collision risk =

.45 * R + .55 * R

Applying a risk reduction (75% ➔ factor of 4 reduction) for ENS incursion risk:

.45 * R + .55/4 * R =

.45 * R + .14 * R =

.59 * R ➔ a risk reduction of ~ 40%

8.2.2 Analysis of Runway Status Lights

RWSL play an important and somewhat subtle role in our analysis. In the previous section we compute the incremental impact of 100-North relative to the Baseline without RWSL. From there, we will compute the impact of RWSL on the Baseline, the impact of RWSL on 100-North and then compare the two results. The reason for this approach is that our analysis shows that the incremental improvement provided by RWSL applied to 100-North is actually greater than the incremental improvement provided by RWSL applied to the Baseline.

FAA studies have estimated that runway status lights (RWSL) would decrease the collision risk by an additional factor of 50% over and above the impact of ASDE-X and AMASS. However, insights gained from the Simulation led us to examine this conclusion carefully and not to apply it in a uniform manner. Consider the following scenarios.

> ***A:*** *A pilot has stopped at the hold bar of the inboard runway and has observed a red runway entrance light (REL). The pilot then proceeds to cross runway (or "bust" the hold bar) even though REL is still red.*
>
> ***B:*** *A pilot is distracted or has exited the outboard runway at a high speed and failed to slow down; the pilot then proceeds to cross the inboard runway or bust hold bar even though REL is red.*

In case B, the fact that the pilot is distracted would seem to increase the likelihood that he/she would fail to take notice of the REL's; also, in case B, if the aircraft was exiting at an excessive speed, it is possible that the pilot would not have enough time to stop the plane short of the hold bar having observed the REL. ***Both of these explanations suggest that the effectiveness of REL's should be greater in scenario A than in scenario B.*** It is also the case, that, in the FAA analysis of ASDE-X, AMASS and RWSL, the experts were told to assume that the relevant technology "worked as it was supposed to" – this apparently was interpreted by the experts to mean that the pilot was alerted by the RWSL's and took whatever action he or she thought was most appropriate. ***This provides further justification to a more careful application of the FAA results.***

Consider now the comments from several Simulation pilots.

> ***Pilot 3:*** *"RWSL's are counter intuitive because they run along side the runway; not being able to stop is not the issue; it is saturation of tasks."*
>
> ***Pilot 4:*** *"[RWSL] Lights are easy to be missed; they don't stand out:*

- *have to train oneself to see them;*
- *it would be better it they were a bigger indicator."*

Pilot 5: *"In the Simulation the RWSL don't appear to be a high intensity system; they really should be brighter; they need to be a distraction."*

Pilot 6: *"With rain or low visibility it would be easy to accidentally cross both runways;*

- *RWSL may or may not stop pilots from crossing runways;*
- *[need] some sort of stop sign."*

Other comments provide a similar sentiment. On the other hand, it is certainly the case that pilots also had many positive things to say about RWSL's. Also, it seems clear (based on comments and our experience in the flight simulator cockpit) that the RWSL's were not as bright in the Simulation as they would be in real life. On balance, we feel the pilot feedback from the Simulation supports the hypothesis that the RWSL's are less effective at preventing the ENS incursions than at preventing other incursions. We do not have an analytic basis on which to derive a quantitative estimate so we "split the difference" and assume RWSL's are twice as effective once an aircraft has stopped:

RWSL risk reduction for ENS incursion: 33%

RWSL risk reduction if aircraft has stopped: 67%

RWSL general risk reduction: 50% (FAA estimate)

8.2.3 Risk Reduction with Runway Status Lights

We now continue with our prior analysis and include the impact of RWSL:

Starting risk = .45 * R + .14 * R

Apply risk reduction of 50% (factor of 2) for non-ENS incursion risk and risk reduction of 33% (factor of 2/3) for ENS incursion risk:

.45 / 2 * R + .14 * 2/3 * R =

.23 * R + .09 * R =

.32 * R ➔ total risk reduction for 100-North with RWSL ~ 70%

We now consider the impact of RWSL on the modified Baseline.

starting risk for modified Baseline = R =

Allocating based on incursion distribution yields:

$$.45 * R + .55 * R$$

Apply RWSL risk reduction factor of 50% to non-ENS incursion risk (multiply by 1/2) and RWSL risk reduction factor of 33% for ENS incursion risk (multiply by 2/3):

$$.45 / 2 * R + .55 * 2/3 * R =$$

$$.23 * R + .37 * R =$$

$$.6 * R \Rightarrow \text{a risk reduction of} \sim 40\%$$

To find the risk reduction of 100-North over the Baseline (with RWSL), we compare the 100-North Risk: (.32 * R) with the Baseline Risk (.6 * R) and reach the following conclusion.

Thus, the 100-North option reduces risk over the baseline by a factor of

(.60 - .32) R / (.6 R) = .47 → 47%

It is instructive to compare the incremental impact of RWSL in the two cases. RWSL reduces the risk of the modified Baseline by 40%. On the other hand, RWSL reduces the risk of 100-North (without RWSL) by a factor of (.59 - .32) * R / (.59 * R) = .46 or 46 %. Does it make sense that the impact of RWSL on 100-North should be greater than its impact on the (modified) Baseline? In fact, the reason for this difference is that the centerline taxiway is very effective at reducing the risk of ENS incursions, whereas, RWSL are less effective with ENS incursions and more effective with others. Thus, in a sense the combination of RWSL and a centerline taxiway is a pairing of two measures that are most effective in complementary areas leading to a more pronounced effect.

It is certainly true that we had to apply some judgment in carrying out this analysis. However, this rather significant risk reduction is certainly consistent with the controller and pilot input provided during the Sim. Further, it should be noted that this analysis only considered the impact of RWSL on the risk of ENS incursions. As discussed earlier there are other positive benefits to the centerline taxiway that should further reduce risk.

8.2.4 Impact of Fleet Mix Changes Including Group VI Aircraft

The Baseline risk estimate served as the starting point for our analysis. Since it has taken into account a growth in traffic (and the implied quadratic growth in risk) our analysis has allowed for a growth in traffic predicted by the year 2020. However, by relying on historical data, the analysis described in Section 8.2 implicitly assumed the current fleet mix. Of particular concern is an increase in the percentage of larger aircraft, most notably Group VI aircraft. We now investigate the degree to which fleet mix changes might impact our conclusions.

Recalling again equation (8.1), we can view this question in terms of whether larger aircraft might have a higher (or lower) risk of either being involved in a runway incursion or of having an incursion result in a collision. As data-driven starting point we examine the question of whether larger aircraft are more likely to be involved in runway incursions. Tables 8-5, 8-6 and 8-7 give relevant statistics.

Table 8-5: Fraction of Incursions Involving Heavy Aircraft.

Year	2002	2003	2004	2005	2006	2007	2008	Average
Heavy Incursion % North	0.67	0.20	0.25	0.14	0.00	0.08	0.17	0.17
Total Aircraft Involved in Incursions (North Airfield)	3	5	4	7	4	13	6	
Heavy Incursion % South	0.40	0.33	0.00	0.13	0.13	0.19	0.00	0.18
Total Aircraft Involved in Incursions (South Airfield)	15	21	12	15	15	27	4	

Table 8-6: Fraction of Incursion Involving Group V Aircraft.

Year	2002	2003	2004	2005	2006	2007	2008	Average
Group V Incursion (%) North Airfield	0.33	0.00	0.25	0.00	0.00	0.08	0.17	0.10
Total Aircraft Involved in Incursions (North Airfield)	3	5	4	7	4	13	6	
Group V Incursion (%) North Airfield	0.13	0.05	0.00	0.13	0.00	0.04	0.00	0.06
Total Aircraft Involved in Incursions (South Airfield)	15	21	12	15	15	27	4	

The first two tables provide the relative frequency with which heavies and Group V aircraft appear in runway incursions. We note that a typical runway incursion involves two aircraft, although some involve only one. We count an "appearance" as either being one of the two aircraft in a two-aircraft incursion or the single aircraft in a one-aircraft incursion (Thus, the totals given in these two tables are the total number of aircraft that were involved in incursions not the total number of incursions. We also note the set of incursions considered in this analysis was the larger set that appears in the ASIAS database). Table 8.7 provides statistics on the representation of heavies and Group VI aircraft in the LAX fleet. A comparison of the data in the first two tables with the data in the third reveals that the representation of these aircraft types in runway incursions is very close to representation in the general fleet mix. Thus, we conclude that it is neither more nor less likely that these very large aircraft will appear in a runway incursion.

Table 8-7: LAX Fleet Mix Characteristics.

Year	2002	2003	2004	2005	2006	2007	2008	AVE
Fleet % Heavy	0.21	0.19	0.19	0.18	0.17	0.17	0.17	0.18
Fleet % Group V	0.09	0.08	0.08	0.09	0.09	0.09	0.09	0.09

We now move on to the question of whether the larger aircraft have a higher (or lower) risk of collision given that they are involved in an incursion. Two effects seem to be worth considering in detail:

1. ***Larger aircraft have longer takeoff rolls, i.e. they become airborne further down the runway; as a result it is less likely that they would overfly an aircraft that breaches the runway downfield.***
2. ***Larger aircraft, simply due to their size, are more likely to collide with another aircraft when the two get in close proximity.***

Both of these effects are potentially significant. Effect 1) is analyzed in some detail for the IRSIP case (Section 7). It seems likely that increases in the per cent of very large aircraft in the fleet mix (including Group VI) will increase the collision risk estimate we have calculated.

However, we argue that this effect will apply equally to all alternatives assuming similar exit locations. Further the degree to which exits can be relocated (as is done with IRSIP) in such a way to influence the risk change, such changes can be applied to any of the options. We do not view the 100-North design used in the Sim as final and in fact we have proposed various recommendations some of which involve changes in exit placement (see Section 16).

> ***Thus, we conclude that while effect 1) may increase risk it will change risk in a similar way for the Baseline. Further, exit changes that mitigate this risk under the Baseline, e.g. IRSIP, could equally be applied under 100-North.***

One could argue that effect 2) is in fact the reason that FAA standards for runway displacement changes with aircraft size. Thus, it is certainly a very important consideration. However, it can also be argued that FAA requirements on both runway displacement and operational restrictions address this effect. In particular, under the 100-North alternative, Group VI aircraft cannot remain on the centerline taxiway while a departure takes place on the inboard runway (while under 340-North they can). There is, of course, a similar requirement for the Baseline. Thus, we conclude that effect 2) will most likely increase the collision risk under 100-North. However, it would induce a similar increase under the Baseline. Thus, we conclude that this effect does not change our relative risk reduction calculation.

8.3. Overall conclusion for 100-North Case

The analysis of the LAX incursion data has indicated risk reduction of close to 50% due to the substantial reduction in the frequency of ENS incursions. Viewing this part of the analysis in isolation, this reduction factor can be viewed as lower bound on the magnitude of the reduction since other positive impacts of the centerline taxiway were not considered. Considering the Sim results, interviews with the subject controllers and pilots as well as the results of surveys also indicate a significant positive impact of the centerline taxiway and the 100-North changes. Sim data was less conclusive showing only a small positive impact in the area of capacity and delays. Further, our conversion of the controller survey data into a collision risk reduction factors indicated a smaller impact than the historical data (e.g. between 19 and 29% vs 47 % for the controller data). The pilot data, considered less reliable showed an even lower reduction factor.

Balancing these various perspectives, we feel that the numerical estimates based on the historical analysis are more reliable than the numerical estimates from the surveys since the surveys themselves relied on human judgment. Further the Simulation results certainly do not contradict the historical analysis in any way. In fact, the Simulation results strongly support the essential conclusions, if not the exact numerical value. A second reason to support the higher risk reduction estimate based on historical data is that our analysis did not take into account the positive effects of the centerline taxiway over and above its impact on ENS incursions. .At the same time, the numerical results from the Simulation suggest a slight lower risk reduction. Thus, we feel it prudent to reduce the estimate based on historical data slightly. Therefore,

> ***We conclude that the 100-North alternative significantly reduces the risk of a fatal runway collision over the Baseline case and we estimate the magnitude of the risk reduction to be 40%***

9. COLLISION-RISK ASSESSMENT: 340’ NORTH

This section examines the collision risk associated with the alternative of moving runway 24R/6L 340’ north and placing a center taxiway between it and the neighboring 24L/6R. Hereafter we will refer to this as 340-North.

From an operational point of view 340-North has certain clear cut advantages over all others considered, including 100-North, which moves 24R/6L 100’ north. The major difference is that under 340-North design group VI aircraft can—with a few exceptions when visibility is low--occupy the center taxiway without disrupting operations on the north runways. This increases the capacity of the airport when there are group VI operations, as discussed in Chapter 13. It is also apparent that, from the viewpoint of residents and businesses in the areas north of LAX, 340-North has clear-cut disadvantages. LAWA and NORSAC have agreed that such concerns are outside the scope of this particular report.

The focus of this chapter is exclusively on collision risk. Should 340-North be built, how will this affect the probability of a collision between two aircraft? To get a handle on this question, the AP examined evidence from a variety of sources. First, we reviewed previous studies concerning the North Airfield in order to better understand the safety case for 340-North. Second, we considered results from the FFC simulations. Third, we examined the empirical record both at LAX and at other airports in order to ascertain whether the incidence of runway incursions is affected by the amount of separation between runways.

We first review the evidence from each of these sources as it pertains to the collision risk for 340-North. Then, in consideration of this evidence, we offer our summary estimate of the collision risk of 340-North relative to 100-North and the Baseline.

9.1. Prior Studies

The safety impacts of 340-North are addressed in three previous studies. In 2007, LAWA sponsored a safety risk assessment of this alternative. The work, performed by the Washington Consulting Group, employed a panel of six individuals with extensive knowledge of LAX operations, the existing and proposed airfield layouts, and safety risk management procedures. The panel identified a total of 10 hazards associated with operations on the North Airfield, and qualitatively assessed how the risks from the hazards would affected by replacing the Baseline with the 340-North configuration. The panel concluded that the 340-North would greatly reduce or eliminate risks from 24R arrivals crossing 24L without a clearance, reduce the risk from “go-arounds” forced by conflicts between arrivals and departures, and reduce the risk from heavy and super-heavy aircraft occupying taxiways that restrict operations of nearby runways. Of the six highest specific hazards judged by the panel to carry the highest risks, three are entirely eliminated, one is made less probably and much less severe, and two are made less probable. These findings are, in the words of the report, based on “the analysis of qualitative data obtained from subject matter experts,” not historical data from LAX.

The WCG study considers only the Baseline and 340-North, and does not attempt to quantify the reduction in collision risk that results from the latter. The results may, however, be used to make such an estimate, and also to assess how it might differ for 100-North.

To convert the WCG findings into an estimate of collision risk reduction, consider Figure 9-1 below, which reproduces Figure 8 of the WCG study. Figure x.1 is a risk matrix, a widely used construct in safety analysis. The rows correspond to the likelihood of occurrence of some hazard, while the columns correspond to the severity of the hazard. The entries in the table correspond to different hazards. For example, LAX 001 is the hazard of an arrival on 24R crossing 24L without a clearance on taxiway Yankee or Zulu, when there is a non-heavy aircraft departing. The likelihood of this hazard is viewed by the panel to be “Extremely Remote,” but the event is viewed as quite serious—“Hazardous” in the terminology of the matrix--should it occur.

It is common practice to quantify the degree of hazard as the product of two numbers, one associated with its row and the other with its column. For example, if Likelihood Category D is associated with the value 1/100 and Severity Category 2 is assigned the value 1/10, then the hazard score for LAX 001 is $\frac{1}{100}\cdot\frac{1}{10}=\frac{1}{1000}$. Assuming that all collision hazards are included in Figure 8, the total collision hazard is the sum of the hazard scores of each.

Figure 9-2, also taken from the WCG report, depicts how the risk matrix would change, in the judgment of the WCG panel, if 340-North were implemented. Some hazards are eliminated entirely, others made less likely, and others less severe. Using the same procedure as before, a total collision hazard could be calculated for this scenario. The ratio of the two scores is a measure of the degree of risk reduction if the Baseline configuration were replaced with 340-North.

Unfortunately, the WCG report does not specify the numerical values associated with the Likelihood and Severity categories. Normally, the variation is logarithmic, with adjacent categories differing by a constant multiplicative factor on the order to 10. For example, the

Likelihood Category A might be 100 times a year, B 10 times a year, C once a year, etcetera. If we assume this is the case, then it is possible to calculate the ratio of the two risk scores, even if we don't know the exact numerical values for the categories. If the multiplicative factor is indeed 10, the result obtained is about 0.06, implying that 340-North would reduce the risk of a collision by about 94%. The ratio is 0.03 if the multiplicative factor is 20, and 0.11 if it is 5. In sum, the WCG risk analysis suggests a reduction in collision risk of between 90 and 97 percent if 340-North is constructed.

While the WCG panel did not explicitly consider 100-North, it appears that most of their findings would apply to this option as well. The major exception is that 100-North would not address Hazard LAX 009—"increase in complexity associated with new mix of Design Group V/VI aircraft." Thus, referring to Figure 9.2, under 100-North the LAX 009 would remain in the Likelihood Category C cell instead of moving to the Likelihood Category D cell. Repeating the above calculation with this one change, and again, assuming a multiplicative factor of 10, we obtain a risk score ratio of 0.23, suggesting that 100-North would yield a risk reduction of 77% compared to the Baseline. Similarly, the ratio of the 100-North and 340-North risk scores is 0.25. In other words, by moving 24R 340' north instead of 100' north, we reduce collision risk 75%, according to these calculations.

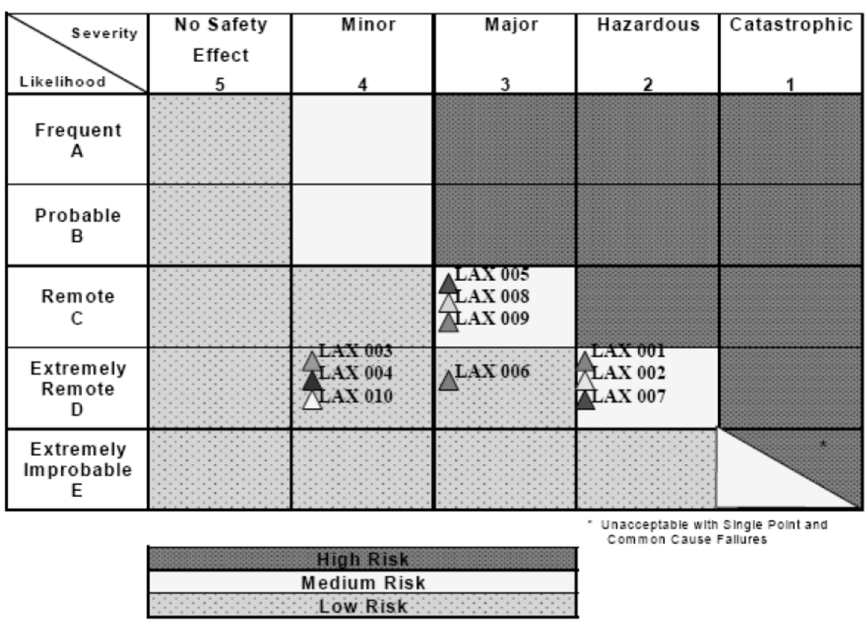


Figure 9-1: Risk Matrix for LAX North Airfield Baseline, According to WCG Panel.

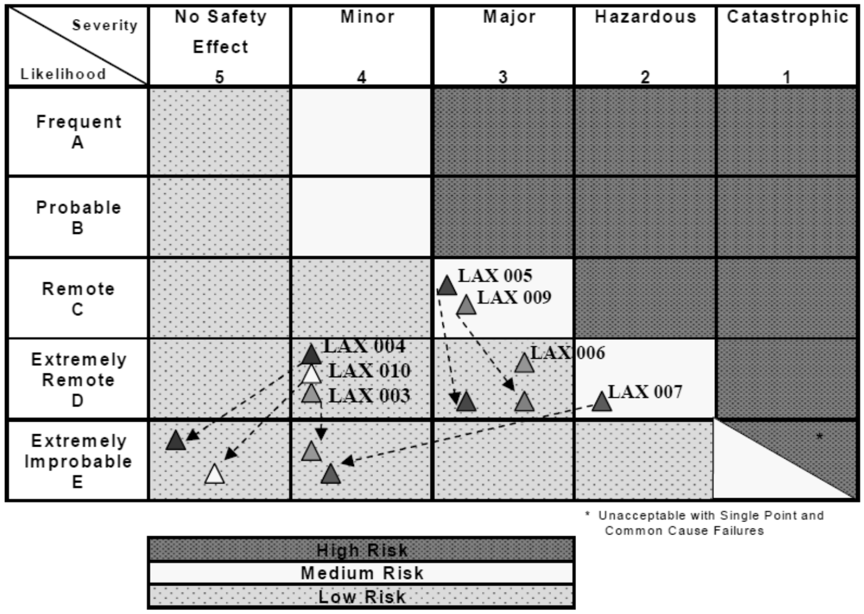


Figure 9-2: Change in Risk Matrix from Going from Baseine to 340-North, According to WCG Panel.

Two other studies from the same period also support the 340-North alternative. The "Special Peer Review" of the LAX North Airfield concluded that this was "the North Airfield alternative offering maximum safety, balance, and efficiency." This conclusion was based on a 3-day visit by the Peer Review Group, which included briefings from LAWA staff, a tour of the airfield and tower, and a review of historical background information and data. The group also had a favorable view of the 100-North alternative, preferring 340-North mainly because of its compatibility with group VI aircraft. Alternatives involving building a runway to the south were considered undesirable because of their impact on the terminal area, while the "present North Airfield configuration is prone to runway incursions." The second study, entitled, "Analysis of LAX North Airfield Alternatives" and prepared by the International Aviation Management Group concluded that 340-North has a "High" potential to mitigate runway incursions, while 100-North has a "Medium" potential. The basis for this difference is not clear, although it is stated that, in contrast to 340-North, 100-North "provides minimal increased separation between runways."

9.2. Results from FFC Simulations

Controller and Pilot Feedback

As elaborated in Chapter 8, controllers and pilots participating in the FFC simulations considered the center taxiway featured in 340-North—as well as 340-South and 100-North—to be a significant safety improvement. The taxiway would virtually eliminate runway incursions onto

24L of aircraft exiting 24R, either because of excessive aircraft speed or pilot inattentiveness (ENS incursions as defined in Chapter 8). The taxiway forces pilots to maneuver a longer, more complicated, path to from the 24R exit to the 24L crossing, so that the crossing is made in a more deliberate and controlled manner. Controllers also cited the greater holding capacity of the center taxiway as compared to the exits in the Baseline configuration. This reduces pressure to cross arriving aircraft in order to clear the exits for subsequent arrivals. It also eliminates the risk of an aircraft on the exit intruding into the obstacle free zone 24R.

While above advantages hold for Alternatives 340-South and 100-North as well as 340-North, controllers and pilots also perceived certain advantages of 340-North over the other two. Controllers noted that with 340-North, in contrast to 100-North, they did not have to remember special rules for super-heavy aircraft, or face the pressure to immediately cross them in order to allow a subsequent departure. Controllers also placed some value on the extra exit traversal time resulting from the additional separation between the runway and the center taxiway, which could be used for braking, tower-cockpit communication, and more deliberate decision making on how to route the aircraft to the gate. Some pilots believed that 340-North enabled them to orient their planes to be perpendicular with 24L at the crossing, affording them the ability to see down the runway for approaching aircraft.

Controller's quantitative survey responses suggested that 340-North reduced the difficulty of their tasks compared to the Baseline. On a seven-point scale, the overall difficulty of runs involving 340-North was rated 0.6 points easier than either Baseline alternative. Tasks with the greatest reduction in difficulty included "deciding how to best manage traffic" and "gathering or and applying the information needed to control aircraft." There were also sizable improvement in controller ratings of "potential for confusion" and controller assessment of "the relative likelihood of a runway incursion on North versus South."

The survey responses revealed considerable less difference in controller ratings for 340-North and 100-North. On most questions, the ratings were not significantly different, although 100-North came out slightly better. On the all-important question of the relative likelihood of runway incursion compared to the South, however, 340-North was judged to have the lower risk, by a margin of 0.6 points on a seven-point scale. Considering these results together, it appears that controllers saw little difference between 340-North and 100-North in terms of the overall difficultly and complexity of controlling traffic, but a significant difference in the ability to prevent incursions.

As described in Chapter 8, one approach to assessing collision risk is to assume that the numerical survey responses reflect controllers' perception of relative risk. Using the same assumptions and methods described in Chapter 8, we converted controllers' ratings of runway incursion risk into estimates of relative risk, using both linear and logarithmic interpolation. The results appear in Table 9-1. Based on the incursion risk question, the reduction in risk relative to the Baseline is estimated to be 34% using linear interpolation and 46% using logarithmic interpolation.

Table 9-1: Estimation of Relative Risk from Controller Rating of Incursion Risk.

	Risk Relative to Highest Risk Rating, Linear Interpolation	***Risk Relative to Highest Risk Rating, Logarithmic Interpolation***
Baseline	0.57	0.27
100-North	0.46	0.19
340-North	0.34	0.15
340-North improvement over Baseline%	34%	46%
340-North improvement over 100-North %	26%	21%

A similar analysis was performed on the pilot survey responses regarding airport safety. Following the logic described in Chapter 8, we extracted estimates of perceived risk from answers to the question in which pilots rate the safety at LAX compared to other major airports they have experienced. The results, shown in Table 9-2, suggest that pilots see less difference in safety among the alternatives then controllers do, but still favor 340-North over the Baseline and 100-North.

Anomalies

As explained in Chapter 4, the FutureFlight simulations included scripted "anomalies"—mistakes by pseudo-pilots. By observing how controllers responded to these anomalies, we hoped to gain additional insight about the complexity and safety of the different airfield alternatives. If controllers are very busy with other tasks, they may be less likely to notice an anomaly. This has a direct safety implication, since a correct controller response to a pilot error can prevent a mistake from turning into a catastrophe.

Table 9-2: Estimation of Relative Risk from Pilot Rating of Airport Safety.

	Risk Relative to Lowest Safety Rating, Linear Interpolation	***Risk Relative to Lowest Safety Rating, Logarithmic Interpolation***
Baseline	0.62	0.33
100-North	0.58	0.28
340-North	0.55	0.25
340-North improvement over Baseline %	12%	22%
340-North improvement over 100-North %	6%	10%

Table 9-3 compares the percentage of incorrect controller responses for the three types of anomalies included in the simulations under the Baseline, 100-North, and 340-North alternatives. These results are based on small samples, since care had to be taken to avoid making a simulation into a "chamber of horrors." As a result, none of the differences are statistically significant. They do, however, suggest that under 340-North controllers respond better to pilot errors. In particular, the average of the incorrect response rates for 340-North is about 25% lower than for the Baseline or 100-North, while the latter alternatives score about the same on this metric. This evidence conflicts somewhat with the slightly higher ratings controllers give to 100-North in the survey.

Let us assume that virtually every accident involves a pilot error and a failure of the controller to correctly respond to that error. 340-North and 100-North probably have about the same effect on the likelihood of pilot error. However, the anomaly results suggest that 340-North increases the probability that the controller responds correctly to such an error. This implies that the differences between the alternatives observed in Table 9-2 translate directly to a reduction in risk of a failure of a controller to avert a collision in the face of a pilot error, and hence into a similar reduction in collision risk. On this reading, the results suggest that 340-North has a collision risk 26% less than 100-North.

Table 9-3: Percentage of Anomalies with Incorrect Controller Response, by Category and Alternative.

	No Pilot Call In	***Readback Error***	***Busted Hold Line***	***Average***
Baseline	56%	32%	76%	55%
100-North	62%	43%	64%	56%
340-North	62%	15%	47%	42%
340-North improvement over Baseline %	-11%	51%	39%	24%
340-North improvement over 100-N %	-1%	64%	27%	26%

9.3. Empirical Evidence

In addition to results from previous studies and the FutureFlight Central simulations, there is empirical evidence regarding the incidence of runway incursions at US airports. As noted in Chapter 6, the FAA maintains a runway incursion database that includes all such events from October 1, 2001 to the present. As of this writing, the database includes some 8248 incursions.

We used these data to compare the incidence of runway incursions at LAX, airports whose geometry is similar to 340-North, and airports whose geometry is similar to 100-North. For Alternative 340-North airports, we selected those with parallel runways separated by more than 1000’ up to 1300’, and with centerline taxiways. Airports in this category include ATL, DFW, PIT, CLE, and STL. 100-North airports have parallel runway separations 1000’ or less, along with centerline taxiways. This category includes LAS, MIA, and MEM.

While the incursion data extend back to 2001, for analysis we considered incursions starting in 2004. By this time, ASDE-X and AMASS had been implemented at most airports. We divided the time since 2004 into two periods. The first extended through May of 2008, since in June of that year the south airfield centerline taxiway at LAX became operational. The second period runs from July 2008 to September of 2009.

We compared incursion rates for each airport category. Two different rates, a linear rate and a quadratic rate, were calculated. The linear rate is calculated as:

$$R_{L,C} = \frac{\sum_{t,a} I_{t,a}}{\sum_{t,a} O_{t,a}}$$

where $I_{t,a}$ is the number of incursions for airport *a* and month *t*, and $O_{t,a}$ is the total airport operations (arrivals plus departures) for airport *a* in month *t*. The quadratic rate is calculated as:

$$R_{Q,C} = \frac{\sum_{t,a} I_{t,a}}{\sum_{t,a} O_{t,a}^2}$$

In both of these equations, the summations are over all airports in a given category and months in the analysis period. The rational for the quadratic rate is the theory, explained in Chapter 6, that the incidence of runway incursions is proportional to the square of the airport traffic. In calculating these rates we did not consider incursions involving ground vehicles, since these are not likely to the affected by the geometric factors under consideration.

Table 9-4: Runway Incursions Rates, by Airport Category, 1/2004-5/2008.

	All Incursions		***ABC Incursions***		***AB Incursions***	
	Linear (10^{-6})	Quadratic (10^{-9})	Linear (10^{-6})	Quadratic (10^{-9})	Linear (10^{-6})	Quadratic (10^{-9})
LAX	14.1	0.255	3.77	0.0685	1.72	0.0311
Category 100-North Airports	8.70	0.215	2.63	0.0651	0.164	0.00407
Category 340-North Airports	8.73	0.162	3.01	0.0560	0.155	0.00287

The rate calculations for the first period are shown in Table 9-4. The results support the conclusion that LAX had higher incursion rates over this period that either the Category 100-North or 340-North airports. The linear rate difference is greater than the quadratic rate difference, reflecting the fact that LAX has more operations than most of the Category 100-North and 340-North airports. The difference is particularly great for the more severe (AB) incursions, for which even the quadratic rate differs by than an order of magnitude. (It should be noted that the AB rates are based on very small numbers of events—5, 1, and 2 for LAX, Category 100-North, and Category 340-North airports respectively.)

Comparing rates for 100-North and 340-North airports, we see that the linear results are mixed, but the quadratic rate is consistently lower for 340-North. This again reflects that the Category 340-North airports are somewhat busier. Considering the quadratic results only, the 340-North rate is lower than the 100-North rate by between 14 and 30 percent, depending on the severity level. Comparing the Category 340-North quadratic rates with those for LAX, the former are lower by 37, 18, and 91 percent for all incursions, ABC incursions, and AB incursions respectively.

In Chapter 6, it was suggested that a simple average is a reasonable way to combine the reductions for different categories of incursions in order to estimate the reduction in collision risk. The average appropriately gives more weight to individual incursions that are more severe incursions, since the percentage reduction for these is based on a smaller number of events. Applying this method, and considering the quadratic results only, we estimate than 340-North airports have a collision risk 48% less than LAX without center taxiways, and 23% less than 100-North airports.

The Baseline considered in study includes a center taxiway on the south of LAX, whereas the previous analysis is based on LAX without it. Table 9-5 compares the incursion rates for LAX and other airports before and after completion of the centerline taxiway on the south. The rates are based on all severity levels; since the definitions for these levels changed in 2008 severity-specific comparisons are not available. Interestingly, the LAX rates with the center taxiway on the south are less than the other airports in the 340-North and 100-North categories.

Table 9-5: Runway Incursion Rates, by Airport Category, Before and After South Airfield Improvements at LAX.

	LAX		***Alternative 100-North Airports***		***Alternative 340-North Airports***	
	Linear (10^{-6})	Quadratic (10^{-9})	Linear (10^{-6})	Quadratic (10^{-9})	Linear (10^{-6})	Quadratic (10^{-9})
1/2004-5/2008	14.1	0.255	8.70	0.215	8.73	0.162
7/2008-present	4.76	0.101	7.09	0.200	10.07	0.202

The dramatic reduction in runway incursions after the south centerline taxiway was built reflects that in the earlier period the majority of runway incursions occurred on the South. While based on sparse data, these results also raise some question about the potential for further improvement from adding a centerline taxiway on the north.

9.4. Summary of Collision Risk Estimates for 340-North

Table 9-6 summarizes the collision risk results for 340-North, in terms of estimated risk reduction versus the Baseline and 100-North alternatives. We will focus on the risk reduction versus 100-North. With a few exceptions, there is a fairly close bunching in the range of 20-30%. There are reasons to question each of the outlier estimates, aside from their extreme values.

Table 9-6: Summary of Risk Reduction Estimates, 340-North.

Basis for Estimate	*Risk Reduction Versus Baseline*	*Risk Reduction Versus 100-N*	*Comments*
WCG Study	94%	75%	Log-scaling or risk matrices.
Controller Survey Linear Interpolation	34%	26%	Linear scaling of controller assessment of runway incursion risk.
Controller Survey Log Interpolation	46%	21%	Log scaling of controller assessment of runway incursion risk.
Pilot Survey Linear Interpolation	12%	6%	Linear scaling of pilot assessment of LAX comparative safety.
Pilot Survey Log Interpolation	22%	10%	Log scaling of pilot assessment of LAX comparative safety.
Anomalies		26%	Risk of failing to correct pilot error.
Cross-sectional I	48%	23%	Cross-sectional comparison of quadratic incursion rates, 1/2004-5/2008. Baseline assumes no centerline taxiway on north of south.
Cross-sectional II	0%	0%	Cross-sectional comparison of quadratic incursion rates, 7/2007-9/2009.

The WCG estimate is based on very specific assumptions about how to quantify the risk matrix, as well as a matrix that is itself very coarse. The Cross-Section II estimate is based on very little data for LAX. The pilot estimates are based on just a handful of landings, and are confounded by the fact that different pilots experienced different alternatives. All things considered,

we estimate a 25% risk reduction for 340-North compared to 100-North.

Given that the estimated risk reduction of 100-North compared to the Baseline is 40%, we estimate 340-North to have a risk relative to the Baseline of (1-0.25)*(1-0.4)=.45. Thus,

we estimate a 55% reduction in risk for 340-North compared to the Baseline.

10. COLLISION-RISK ASSESSMENT: 340' SOUTH

This section examines the collision risk associated with the alternative of moving runway 24L/6R 340' south and placing a center taxiway between it and the neighboring 24R/6L. Hereafter we will refer to this as 340-South. Those familiar with recent history at LAX will also recognize it as the North Airfield component of Alternative D, which was approved by the Los Angeles City Council as the Master Plan for LAX in late 2004 and by FAA shortly thereafter. A series of lawsuits against LAWA and the City of Los Angeles led to a settlement in which it was agreed that they would re-evaluate North Airfield improvements called for in Alternative D. Indeed, this report is part of the re-evaluation.

From a collision risk point of view, 340-South has a great deal in common with 340-North. The processes of landing on 24R/6L, exiting, traversing the centerline taxiway, and finally crossing the 24L/6R will be essentially the same wherever these elements are located relative to the Central Terminal Area. The advantages of the centerline taxiway, greater separation between the runways, and compatibility with ADG VI aircraft will be realized under either 340-South or 340-North.

With this as the starting point, the aim of this chapter is to identify differences between 340-South and 340-North that may influence collision risk, and to estimate the change in risk that may result from them. We begin by reviewing past studies that qualitatively compare 340-South and 340-North. We then discuss results from the FutureFlight Central simulations, which for the alternative provide the major basis for risk quantification.

10.1. Prior Studies

340-South was not part of the original LAX Master Plan, released in 2001, which identified as a preferred alternative a plan similar to 340-North known at Alternative C. Called the "Enhanced Safety and Security Plan", it was shaped by public comments on the original plan and the 9/11 terrorist attacks. This description primarily reflected changes in the terminal designed to increase protection against terrorist attacks, and to "provide a facility that can continue to operate under the highest security levels with minimal impacts on the passenger processing experience." However, it was also noted that Alternative D, by increasing separation between runways and adding centerline taxiways, would reduce runway incursions. To our knowledge, the original analysis of Alternative D did not mention any difference with Alternative C from a runway safety standpoint.

The risk analysis performed by WCG does not explicitly consider 340-South. It appears that most of the hazards in the Baseline configuration found in that study to be mitigated by 340-North are mitigated by 340-South to an equal degree. The major difference is hazard LAX-008, which involves a Group V or VI aircraft on taxiway Echo impeding on the obstacle-free zone of runway 24L. While this hazard is eliminated by 340-North as a result of increased separation between the taxiway and runway, 340-South does not have this feature. Employing the method discussed in Section 1.2, the relative risk of 340-South compared to the Baseline is .26, the same as 100-N. The IAMG study concluded 340-North and 340-South both have "high" potential to mitigate runway incursions, but also noted that north airfield incursions on the east side of 24L "occur in part due to the close proximity of the ramp, taxiways, and runways in this area," and, referring to 340-South, "reducing the distance between the runway and the adjacent taxiway environment will do little to mitigate the potential of runway incursions, and may be a factor in aggravating this issue."

The Special Peer Review, in contrast to the other studies, is highly critical of 340-South, which it includes to be "clearly not feasible" because it would "require years of extensive and disruptive apron/gate and terminal demolition" while not allowing "balanced use of the airfield and terminal apron/gate complex." The Review does not, however, explicitly state that 340-South is inferior to 340-North from the standpoint of safety.

10.2. Results from FFC Simulations

Controller and Pilot Feedback

In general, controllers viewed 340-South as an awkward layout because of the need to move a lot of traffic between the gates on the South side of the airport and the North runway complex. In the words of one controller, 340-South would "create more problems on the South than you solve on the North." The operation put particular stress on the Ground Controller 1 position. With the Southwest gates moved to the south terminal, GC-1's area included the gate complexes for three busy airlines. Pilots did not have much qualitative feedback on 340-South, although one reported a problem with the sequence of maneuvers involved in turning onto the centerline taxiway, traversing it for a short distance, and then exiting it.

In the survey, controllers in general rated 340-South and 340-North quite similarly. There was not a single question for which the ratings difference between these alternatives was statistically significant. In 12 of 14 questions, however, 340-North had the higher average rating. On the question of incursion risk, controllers rated 340-South above 100-N by a statistically significant margin, as they did 340-North. While 340-North had a slightly higher rating than 340-South on this question, the difference is so small as to be negligible. Thus, for the estimates of relative collision risk based on this question, we will use the values obtained from 340-North (9-2).

Pilots, in contrast, tended to prefer 340-South, although again the differences for individual questions were not statistically significant. Pilots, on average, favored 340-South over 340-North on nine of 10 questions. The largest difference in rating was on “potential for confusion” on which pilots rated 340-North to have greater potential by 1.5 points on a scale of 7. The advantage of 340-South over 340-North on this question and most other questions could the fact that pilots were landing on the north airfield, where the ground controller is less busy under 340-South. This advantage did not, however, carry over into overall rating of safety compared to other airports, where advantage for 340-South over 340-North was just 0.3 points.

Anomalies

Examining controller responses to scripted anomalies, we find that, overall, the correct response rate for 340-South was higher than the Baseline and slightly lower than 340-North, as shown in Table 10-1. 340-South does is better than the Baseline and worse than 340-North on this metric. Following the logic of the analysis in 340-North, we estimate from these results that the probability of failing to avert a collision by failing to respond correctly to a pilot mistake increases by a factor of (1-.54)/(1-.58), an increase of 11%.

10.3. Other Evidence

The evidence from runway incursion incidence at other airports considered for 340-North is equally applicable to 340-South. The estimates of collision risk drawn from that cross-sectional analysis are therefore equally valid for 340-North.

As shown in Chapter 13, voice communication activity for the midfield terminal ground controller is higher under 340-South than for any other alternative. This reflects the large amount of cross-field traffic that results from the 340-South gate configuration. The voice activity for the north field ground controller was concomitantly reduced. While higher workload is associated with increased collision risk, the risk implications of the workload redistribution associated with these results is not clear.

Table 10-1: Percentage of Anomalies with Correct Controller Response, by Category and Alternative.

	No Pilot Call In	Readback Error	Busted Hold Line	Average
Baseline	44%	68%	24%	45%
340-North	38%	85%	53%	58%
340-South	55%	40%	67%	54%
340-North improvement %	-14%	24%	127%	29%
340-South improvement %	26%	-42%	183%	20%

10.4. Summary of Collision Risk Estimates for 340-South

Table 10-2 summarizes our estimates of the difference in collision risk for 340-South versus 340-North. With the exception of the estimate based on the WCG risk analysis, they suggest little or no difference. While a case could be made that 340-South has the same collision risk as 340-North, observations from prior studied, controller interviews, as well as the estimates below suggest that there is 340-South is not quite as safe as 340-North. On the basis of these sources, our estimate is that 340-South **has a collision risk 10% greater than 340-North**. This implies that this alternative has a collision risk **50% less than the Baseline.**

Table 10-2: Summary of Estimates of Collision Risk Difference between 340-South and 340-North.

Basis for Estimate	Difference in Risk Versus 340-North	Comments
WCG Study	+75%	Log-scaling or risk matrices.
Controller Survey Linear Interpolation	No change	Linear scaling of controller assessment of runway incursion risk.
Controller Survey Log Interpolation	No change	Linear scaling of controller assessment of runway incursion risk.
Pilot Survey Linear Interpolation	No change	Linear scaling of pilot assessment of LAX comparative safety.
Pilot Survey Log Interpolation	No change	Log scaling of pilot assessment of LAX comparative safety.
Anomalies	+11%	Risk of failing to correct pilot error.
Cross-sectional I	No change	Cross-sectional comparison of quadratic incursion rates, 1/2004-5/2008. Baseline assumes no centerline taxiway on north of south.

11. COLLISION-RISK ASSESSMENT: THREE-RUNWAY AIRFIELD

We turn next to the three-runway alternative ("3R") in which the existing two-runway system of the North Airfield is replaced by a single Runway 24 that would handle most of the airport's Group V and VI aircraft. Smaller planes would be concentrated on the South Airfield. A preliminary design of this runway and associated taxiway system was described in Section 3.6 and is shown again in Figure 11-1. The availability of plentiful space in the North Airfield to accommodate a single runway would make it possible to develop a full-fledged supporting infrastructure (two parallel longitudinal taxiways, high-speed exits, right-angle exits) for a runway and taxiway complex designed to Group VI standards, as described in Section 3.6. The design outlined in that section, although carefully prepared, should be viewed as preliminary, as there may be possibilities for further improvements. It was prepared for the purposes of the FFC Simulation and implemented in the FFC environment.

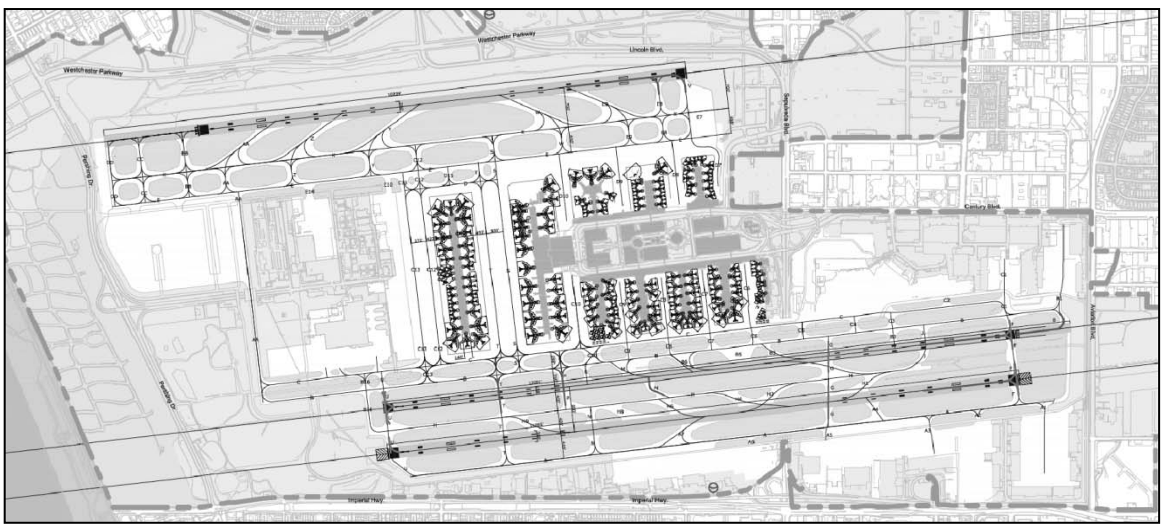


Figure 11-1: Los Angeles International Airport Alternative 3R (3 Runways). Source: LAWA and HNTB (2009).

The 3R alternative is different in a fundamental way from all others considered in this report. Whereas, in all other alternatives, one runway (24R/6L) is dedicated almost exclusively to arrivals and the other (24L/6R) to departures, in the case of 3R the single runway on the North Airfield would be used for "mixed" operations and would, in the long run, serve about as many arrivals as departures.

This chapter continues with a description of how Runway 24 would probably be operated under the 3R alternative (Section 11.2) followed by a short, qualitative discussion of the implications of this mode of operation for safety and ATC workload (Section 11.3). With this background, we then review the assessments of the 3R alternative by the controllers and pilots who participated in the FFC Simulation (Section 11.4), as well as some empirical evidence from other airports (Section 11.5). The chapter concludes (Section 11.6) by providing an overall risk estimate for 3R that combines all the above considerations.

11.1 . Airport Operations under the 3R Alternative

There are two different modes of operating a runway which serves arrivals and departures in about equal numbers. Mode 1 is to have alternating "strings" of arrivals and departures operating on the runway. During a period of heavy demand under this approach, ATC would have departing aircraft form a queue next to the threshold of the runway while a string of consecutive arriving aircraft land on the runway. When all the arrivals in the string have landed, the runway is turned over to take-offs and (all or some of) the waiting departures are served before the runway begins serving arrivals again. If, in the above scenario, a string of arrivals proves to be so long that the departures queue grows excessively, ATC may intervene to have some departing aircraft take off by interrupting the arrivals string and having arriving aircraft wait for a while in the air. The reverse may also happen if the departures string is too long. (Serving arrivals is typically, but not always, given priority over serving departures, for obvious reasons.) In summary, under Mode 1, sequences like AAAADDDDDAAADDDDAAAAAA… will be observed on the runway, where "A" denotes an arrival and "D" a departure.

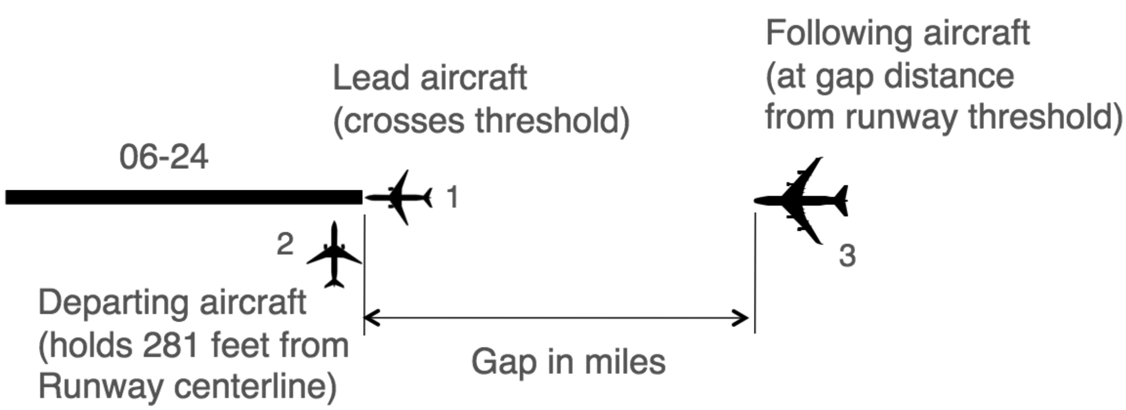


Figure 11-2: Inserting a takeoff between a pair of landings (source: Academic Panel). Numbers in the diagram show the sequence of operations on a single runway.

The second approach, Mode 2 (see Figure 11-2) is to sequence operations so that single arrivals and departures alternate, more or less, on the runway for an extended period of time. Sequences like ADADDADADAADA… might be observed under Mode 2. As far as airport capacity is concerned, Mode 2 is often superior by a significant margin. The reason is that the required ATC separations on final approach between certain pairs of consecutive landing aircraft are, in some cases, large enough to make it possible to insert a takeoff (and sometimes two takeoffs) between the two landings without having to increase the separation between the landing aircraft. This essentially means a "free" extra movement (a takeoff) between two landings in such cases. More commonly – and more important, from the practical point of view – it is typically true that a relatively small increase in the required separation between a pair of consecutive landing aircraft will provide a gap between the landings (Figure 11-2) which is sufficiently long to insert a takeoff or possibly two takeoffs. In summary, under Mode 2, it is sometimes possible to nearly double the landing capacity of a runway by "stretching" the separations between consecutive arriving aircraft as needed to insert a departure between them: with a small "sacrifice" in the number of arrivals served, the runway can serve as many departures as arrivals during any particular period of time.

For illustration purposes, we give here typical ranges for the capacities achievable under the two modes in good weather conditions at busy U.S. commercial airports with a 50%-50% mix of arrivals and departures: 50 – 58 movements per hour (e.g., 28 arrivals and 28 departures per hour) under Mode 2; and 42 – 48 movements per hour (e.g., 24 arrivals and 24 departures per hour) under Mode 1. In other words, Mode 2 may enjoy a capacity advantage of 10 – 30% over Mode 1 depending on local circumstances. This advantage is extremely important at busy airports, as it may result in very large differences in the air traffic delays experienced under the two approaches.

11.3. Qualitative Characteristics of the 3R Alternative

LAX is expected to be a congested airport in 2020 or later years under the demand scenarios posited to the Academic Panel (AP). It was therefore necessary for the AP to assume that the Mode 2 approach to runway operations sequencing would be adopted in operating the single runway (Runway 24) of the North Airfield under the 3R alternative. The AP thus designed the FFC Simulation of Alternative 3R in a way that encouraged ATC controllers to utilize this second operating mode, i.e., controllers generally handled traffic by "stretching" separations between consecutive landing aircraft in order to insert one or, sometimes, two departures between them. *The reader should therefore keep in mind that the assessments of risk and operability provided by FFC pilots and controllers and described below for Alternative 3R refer to Mode 2 of operations.*

This is important because it is reasonable to expect *a priori* that the comments and ratings concerning ***safety*** that were submitted by the FFC controllers and, possibly, the pilots would be influenced significantly by this mode of operating the North Airfield runway. Mode 2 requires considerable skill and concentration on the part of ATC controllers. For example, with reference to Figure 13 – 2, as soon as the leading arrival (Operation 1) touches down on the runway, the local controller must decide whether to clear the waiting departure (Operation 2) to enter the runway and take off prior to the landing of the trailing arrival (Operation 3). To make this decision the controller must answer mentally questions like: How long will the leading arrival (Operation 1) take to exit the runway, so that the take-off roll of the departing aircraft (Operation 2) may begin? How close to the runway will the airborne trailing arrival (Operation 3) be at the time when the take-off roll (Operation 2) will begin? At that point, will there be sufficient time for the departing aircraft (Operation 2) to become airborne (or, at least be more than 6000 feet away from the beginning of the take-off roll) before the trailing aircraft (Operation 3) will touch down on the runway? Note that the controller must *project* mentally that no unsafe conditions will arise throughout this process before issuing the clearance to the departing aircraft to enter the runway. And the situation must be monitored continuously, in case there is a need to advise the trailing arrival (Operation 3) to perform a go-around. Thus, the overall risk associated with operating the single runway on the North Airfield might be perceived as increasing.

Two other characteristics of operations with the 3R alternative may have a bearing on risk and on perceptions concerning risk. One is that, while Runway 24 on the North Airfield would be operated in mixed mode with a large fraction of Group IV, V, and VI aircraft in the fleet mix, the two runways on the South Airfield would continue to be operated as essentially all-departures (25R/7L) and all-arrivals (25L/7R) with a significantly "lighter" fleet mix. Thus, local controllers and TRACON controllers assigned to the North and South Airfields may require different types of training and may end up operating, in the long run, with two different mental "frameworks" regarding traffic control and sequencing. Among other consequences, this might reduce flexibility in ATC personnel assignments with, conceivably, some negative implications for safety.

Other potentially negative consequences from the safety viewpoint are that, with the 3R alternative, (i) the South Airfield would handle significantly more movements than the North and (ii) the airspace structure around LAX would have to be carefully re-designed to ensure maximum flexibility in assigning arriving and departing aircraft – irrespective of provenance or destination – to the appropriate airfield. For example, "Heavy" aircraft from/to the South would have to "cross-over" to/from the North Airfield.

Similarly, the ground movement of aircraft on the airport's surface may be complicated by the fact that most Heavy aircraft will be operating on the North Airfield and most other aircraft on the South.

Finally, reliance on a single runway on the North Airfield may pause a risk in situations where the runway has to be closed temporarily (e.g., due to a disabled aircraft) and no back-up runway is available, unlike the case for all other alternatives.

Weighing against all these potential negatives is a major safety benefit: the absence of an "outboard" runway (24R/6L for all other alternatives) removes the possibility of incursions by aircraft which have just landed and attempt to cross the "inboard" runway (24L/6R for all other alternatives). In short, the study of risk on the North Airfield under 3R need not consider runway collisions due to aircraft taxiing across an active runway. This risk has been a focus of much of the analysis in this report. However, the possibility of other types of incursions still remains and must be considered.

11.4. Qualitative and Quantitative Assessments of the 3R Alternative

With this background, we proceed to review qualitative and quantitative assessments of 3R by controllers and pilots participating in the FFC Simulations.

In the case of *controllers*, the comments submitted were in line with what was expected (see previous section). We summarize below separately the comments from the three groups of controllers to underline the considerable uniformity of the views expressed:

Group 1:

- Ground control is much easier (on the North Airfield) under 3R, but overall this is a poor configuration; the local controller must constantly perform "squeeze play" (to interweave arrivals and departures); there is also potential for more go-arounds by aircraft landing on Runway 24; operations on the South Airfield would also become more difficult.

Group 2:

- The interweaving of arrivals and departures on Runway 24 was deemed "inherently" unsafe by LAX- trained controllers, who did not like mixed operations; go-arounds will be a problem for aircraft landing on Runway 24; good co-ordination of traffic from/to the

South will be necessary; when it comes down to it, the Baseline alternative is preferable to 3R

Group 3:

- Ground control on the North Field will be easy, but local control (landings and takeoffs on runway) will be like “hitting holes” which will become tighter and tighter as traffic increases; there is potential for many go-arounds; cannot plan ahead for more than a few minutes because you always have to deal with ongoing operations; there are no runway crossing problems, but arrivals and departures on the same runway may cause bigger problems; the possibility of having to close the runway due to an unforeseen event makes this a bad option.

In interpreting the above comments, a potential consideration is that LAX controllers do not generally have much experience with mixed operations on a single runway under conditions of heavy demand. This may have shaded, to a certain extent, the opinions expressed about 3R.

The quantitative scores that the controllers assigned to the various alternatives did not quite reflect the negative tenor of the opinions they voiced during their group debriefing sessions, as outlined in the above paragraphs. Specifically, as Table 11-1 indicates, Alternative 3R was assigned the lowest “risk value” by the controllers, ranking first among alternatives with a “risk reduction” potential of 52% compared to the Baseline alternative. The method used to compute the relative risk values was described in Section 8.1.2.

The apparent inconsistency between the oral comments and the risk reduction scores assigned to 3R may have several possible explanations. For example, “group dynamics” may have played a role during the debriefing sessions with some individuals with strong views regarding the various alternatives possibly dominating the discussion. Or, it is possible that, when it came to assigning a “grade” to 3R, the safety benefits resulting from the removal of runway crossing conflicts outweighed concerns about the risks involved in interweaving arrivals and departures on Runway 24.

Table 11-1: Relative risk values and risk reduction relative to Baseline of the various alternatives according to controllers participating in the FFC Simulations.

Alternative	*Relative Risk Value*	*Risk Reduction Relative to "Baseline" Alternative*
Baseline	0.567	0%
100-N	0.461	21%
340-N	0.377	37%
340-S	0.393	34%
3R	0.297	52%

Pilot comments seem to make no reference to risk associated with interweaving arrivals and departures during mixed operations on Runway 24. Instead, perhaps due to experience with a broad range of airport operations, pilots seemed to treat such mixed operations as routine and commonplace. In fact, there were very few comments explicitly addressing the 3R alternative.

Table 11-2: Relative risk values and risk reduction relative to Baseline of the various alternatives, according to pilots in FFC Simulation; responses corrected for potential bias (see Chapter 8).

Alternative	*Relative Risk Value*	*Risk Reduction Relative to "Baseline" Alternative*
Baseline	0.624	0%
100-N	0.581	7%
340-N	0.548	12%
340-S	0.472	24%
3R	0.489	22%

One pilot stated that the 3R alternative on the North Airfield is “very easy” as there is no runway to cross and taxiing to/from a gate is simple. Another pilot mentioned that 3R is much safer than San Francisco, Narita, and Chicago O’Hare. (The criteria on which this comparison was based are not clear.) The same pilot indicated that he preferred 100-N (and presumably 340-N) to 3R because of the higher capacity of the former.

When it came to the quantitative assessment of the alternatives, pilots collectively rated 3R as the second best alternative, behind 340-S, with a “risk reduction” potential of 22% compared to the Baseline alternative (Table 11-2).

11.5. Empirical Evidence

The AP also sought empirical evidence about the safety associated with the mixed-use runway operation on the North Airfield by looking at other commercial airports operating with a single runway. Unfortunately, of the 35 busiest airports in the United States, only one, San Diego (SAN), operates with only one runway. For this reason, this investigation was extended to: (a) three other, less important airports, South West Florida International (RSW), Bangor (BGR) and Harrisburg (MDT) that operate with a single runway handling a significant number of movements annually and (b) two major airports, Charlotte (CLT) and Washington Reagan (DCA), which have multiple runways but are known to operate their principal runways in mixed mode, with arrivals and departures often interweaved in the manner described in Section 11.2.

Table 11-3: Runway Incursions Rates, for LAX and for airports with extensive use of mixed operations on the same runway, 1/1/2004-5/1/2008.

	All Incursions		***ABC Incursions***		***AB Incursions***	
	Linear (10^{-6})	Quadratic (10^{-9})	Linear (10^{-6})	Quadratic (10^{-9})	Linear (10^{-6})	Quadratic (10^{-9})
LAX	14.1	0.255	3.77	0.0473	1.72	0.0311
Comparison Airports	5.3	0.176	1.43	0.0473	0.4	0.0135

We performed an analysis of incursions at these six airports (SAN, RSW, BGR, MDT, CLT, and DCA) similar to the one described in Chapter 9 (cf. Table 9.1). As in Chapter 9, the focus was on the period January 1, 2004 to May 1, 2008. Table 11-3 compares the rate of "all incursions", "ABC incursions" and "AB incursions" (landings and takeoffs) at the six airports combined with the corresponding rates per LAX. The comparison, as in Chapter 9, is performed for both a linear model and a quadratic model. For the linear model, it can be seen that the rates for the six comparison airports are equal to 38%, 38%, and 23%, respectively, of the rates for LAX. The average of these three estimates is 33%, implying a roughly two-thirds reduction in the rate of incursions.

For the quadratic model, the rate reductions are smaller than for the linear one, reflecting the fact that LAX has far more operations than all the comparison airports with the exception of CLT. The rates are equal to 69%, 69% and 43%, respectively, of the rates for LAX, with the average of 60% implying a roughly 40% reduction in the rate of incursions.

A review of the ASN Aviation Safety Database also indicated that there have been no fatal accidents at any of the six comparison airports during the 1990s or the 21st century (or earlier for that matter) that could be construed as related in any way to the use of their runways for mixed operations.

11.6. Estimation of Risk Reduction

Finally, we proceed to calculate the risk reduction provided by the 3R alternative, following the approach already described in Sections 8.2.1 and 8.2.3 of this report. Little explanation will be offered, as all the steps duplicated those in the referenced sections.

Consider as a starting point the level of risk for a *modified Baseline that assumes the 2020 traffic levels, ASDE-X and AMASS but no RWSL*. We define this starting risk level as RISK.

The absence of an outboard runway means that "ENS collision risk" has been removed in the case of the 3R alternative. Based on the data analysis of Chapter 8, we then have that the remaining collision risk ("non-ENS collision risk") for the 3R alternative is given by:

non-ENS collision risk = .45 * RISK

It was also argued in Section 8.2.3 that RWSL would further reduce by 50% the non-ENS incursion risk, leading to the reduced risk of:

.45 / 2 * RISK = .23 * RISK

As in the earlier analysis this must be compared to the reduced risk of the Baseline with RWSL: .6 * RISK. The risk reduction relative to this level is:

$$(.6 - .23)\ \text{RISK} / (.6\ \text{RISK}) = .62 \rightarrow 62\%.$$

Thus, the analysis produces a risk reduction estimate for 3R of 62%.

We feel it is likely that operating with a mixture of arrivals and departures should increase the likelihood of certain "non-ENS incursions". Specifically, there may be a greater likelihood of a "threshold incursion", where an aircraft goes into position and holds without clearance. Thus, while this estimate should provide some indication of risk reduction, it may overestimate the reduction.

11.7. Overall Assessment

In conclusion, and with the exception of the subjective opinions expressed by some of the FFC controllers, the combination of evidence from the FFC Simulations, empirical data and probabilistic analysis points to a significant reduction of risk under the 3R alternative.

- The FFC controllers' evaluations indicate a 52% reduction:
- The FFC pilots' evaluations indicate a 22% reduction:
- Empirical evidence from other airports suggests a 67% reduction according to the linear model and a 40% reduction according to the more standard quadratic model; and
- The empirically based model and analysis of Chapter 8 indicates a 62% reduction.

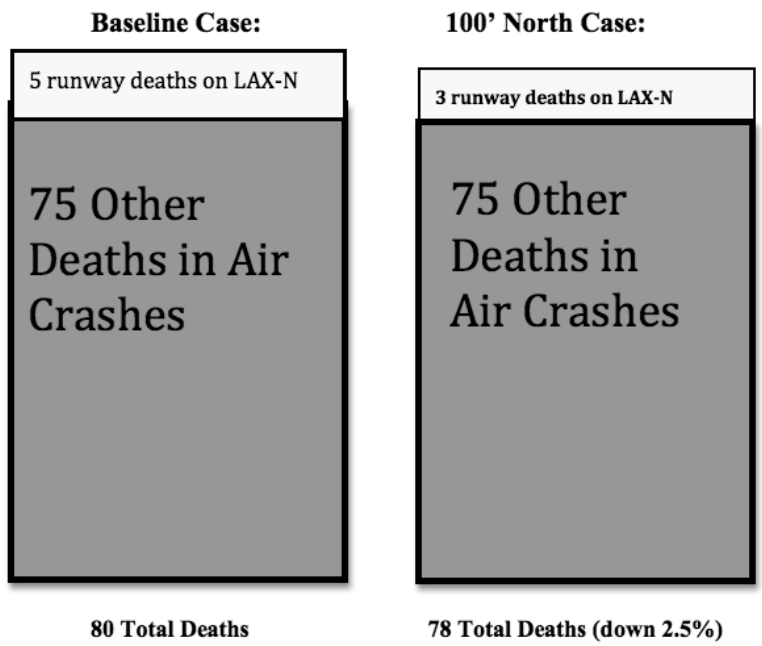
On the basis of this fairly consistent information, it is reasonable to use 50% as our estimate of the risk reduction (relative to the Baseline) that can be obtained through the 3R alternative.

12. COMPARATIVE SUMMARY OF SAFETY ASSESSMENTS

Given the large and bewildering array of safety numbers about that the reader has encountered in previous sections, it is worth pausing to stress what the key statistics are and what they imply about risk to LAX air travelers. The main estimates are:

- In the Baseline case for the North Airfield, fatal runway collisions would occur at 2020 traffic levels on average once every 200 years. They would cause an average of *five deaths per decade,* which works out to approximately one death per 150 million LAX passengers.
- Compared to the Baseline case, the risk of a fatal runway collision would drop approximately 40% if the existing North Airfield were replaced by the 100’ North configuration with a centerline taxiway. Thus, instead of five lives lost per decade, the estimated number would drop to *three*.
- Compared to the Baseline case, the risk of a fatal runway collision would drop approximately 50% if the existing North Airfield were replaced by the 340’ North configuration with a centerline taxiway. Thus, instead of five lives lost per decade, the estimated number would drop to an average of 2.5. *(Compared to 100’ North, deaths per decade would drop from three to 2.5.)*
- Compared to the Baseline case, the risk of a fatal runway collision would drop approximately 40% if the existing North Airfield were replaced by the 340’ South configuration with a centerline taxiway. Thus, instead of five lives lost per decade, the estimated number would drop to three.
- Compared to the Baseline case, the risk of a fatal runway collision would drop approximately 50% if the existing North Airfield were replaced by a single runway 24 in a three-runway airport. Thus, instead of five lives lost per decade, the estimated number would drop to 2.5.

But some perspective is provided if we note that, under risk levels in the first decade in the 21^{st} century, US air travelers face a 1 in 10 million chance of perishing on each flight because of aviation crises beyond the runways (e.g., a mechanical failure that causes total loss of control, as occurred on Alaska Air 261 near LAX). Assuming that risks remain at that level in the next decade or so, the roughly 750 million passengers who pass through LAX per decade would suffer 750 million x 1 in 10 million = 75 deaths. The overall situation is suggested in Figure 12-1.



Other Cases:

340’ North	**77.5 Total Deaths (on average)**
Three-Runway	**77.5 Total Deaths**
340’ South	**78 Total Deaths**

Figure 12-1: Mortality Risk Summary at 2020 LAX Traffic Levels.

These numbers imply that reconfiguring the North Airfield could save perhaps *one life every four years*, and could reduce passenger death risk per flight to about 97% of its level under the Baseline case. The question is whether the sums spent in the reconstruction might save many more lives if used in other ways.

13. CAPACITY AND WORKLOAD ASSESSMENTS FOR THE VARIOUS CASES

This section describes a capacity assessment for the Los Angeles International Airport derived from FFC simulation data and complemented using analytical and simulation studies. This section is organized into five parts: 1) throughput analysis results of FFC, 2) taxi-in and taxi-out analyses for all alternatives, 3) FFC voice communication analysis, 4) runway capacity modeling and 5) conclusions of capacity analysis.

13.1. FFC Throughput Analysis

The experiment at the NASA Ames FutureFlight Central provided an opportunity to estimate airport system throughputs in a complex man-in-the-loop simulation. The mean arrival rate of aircraft into each one of the 6 alternatives investigated is presented in Figure 13-1. The results are presented for all three weather conditions studied in the FFC simulation facility. The results of the graph illustrate the arrival rates designed by the AP Panel and programmed in the in FFC logic by NASA to present a relatively high demand condition. The aim was to present ATC local controllers with a fast pace of arrivals during each one-hour experiment.

Visual Meteorological Condition (VMC) arrival rates presented in Figure 13-1 are approximately the same for all five alternatives with 4 runways. In the design of the FFC experiments, the Academic Panel employed current ATC separation rules to schedule between 75-77 arrivals per hour during the one-hour simulation time period. The range denotes that in some FFC runs, more super-heavy aircraft were introduced and thus fewer arrivals could be scheduled in the one-hour period. The three-runway alternative (3R) could handle fewer arrivals in the North compared to the Baseline alternative. With a single runway in the North, the nominal aircraft separation between successive arrivals was set at 5.5 nautical miles for VMC conditions and 5.9 nautical miles for IMC conditions. This is typical spacing used in mixed operations (i.e., arrivals and departures on the same runway) at other airports in the United States. Nighttime arrival rates are similar to VMC rates because the same aircraft separation rules apply at night in VMC conditions. As a point of comparison, the LAWA design day for year 2020 had high-demand hourly arrival rates ranging from 73 to77 per hour for the top three peak hours of operation.

The Instrument Meteorological Condition (IMC) arrival rates were designed to be 21% lower than the VMC conditions using known ATC separation rules and the Academic Panel analysis of Los Angeles International Airport terminal radar data (PDARS data). 3R simulations produced a 16% reduction in arrival rates for the three-runway alternative (3R).

The arrival rates designed in the FutureFlight Simulations represent realistic upper bound values of what Southern California (SoCal) air traffic controllers could deliver to LAX under saturation conditions. According to personal communication between the Academic Panel and LAX tower controllers, the upper limit of arrival traffic per hour from SoCal controllers is around 80 aircraft per hour in two arrival streams.

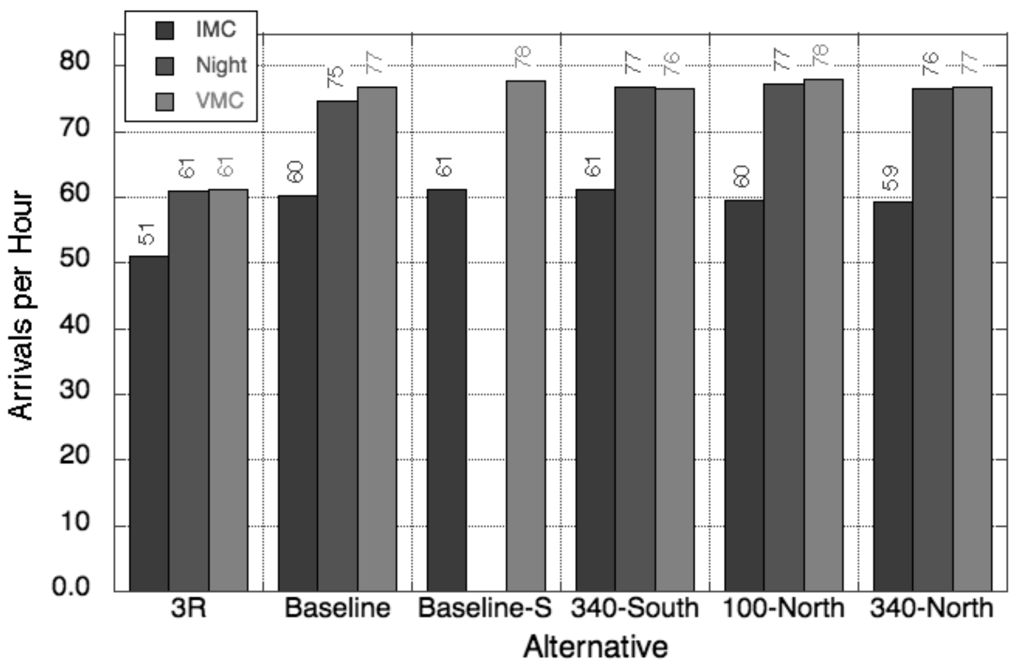


Figure 13-1: Mean Arrival Rates per Hour Observed for All Six Alternatives Studied.

A measure of the departure throughput capacity of the airport is presented in Figure 13-2. Departure rates observed in the FFC simulations were slightly higher than expected. The numbers shown in Figure 13-2 nevertheless offer a qualitative assessment of the various alternatives tested. In general, it was observed that ATC controllers used similar departure separation rules for IMC and VMC conditions. This would result in nearly similar departure rates under VMC/Night and IMC conditions. However, the departure rates for VMC and Nighttime conditions are affected by four inboard arrivals per hour per complex scheduled in the simulation under VMC/Night conditions. This fact reduces the departure rate for VMC and Nighttime conditions as shown in

Figure 13-2. All VMC and Nighttime FFC simulations were designed with four inboard arrivals per hour per complex to balance the arrival and departure flows to the airport. The Academic Panel studied in detail the LAWA commissioned fast-time simulations for Alternative 340-South and they included 7-8 arrivals to inboard runways per hour for the complete airfield (4 per complex). No inboard arrivals were designed into the IMC runs following standard practice at LAX. The behavior of ATC in sequencing departure traffic under IMC conditions was considered aggressive by the Academic Panel but perhaps understandable given the large number of departures scheduled during each FFC simulation run. In Section 13.4 we estimate measures of runway capacity correcting for this behavior.

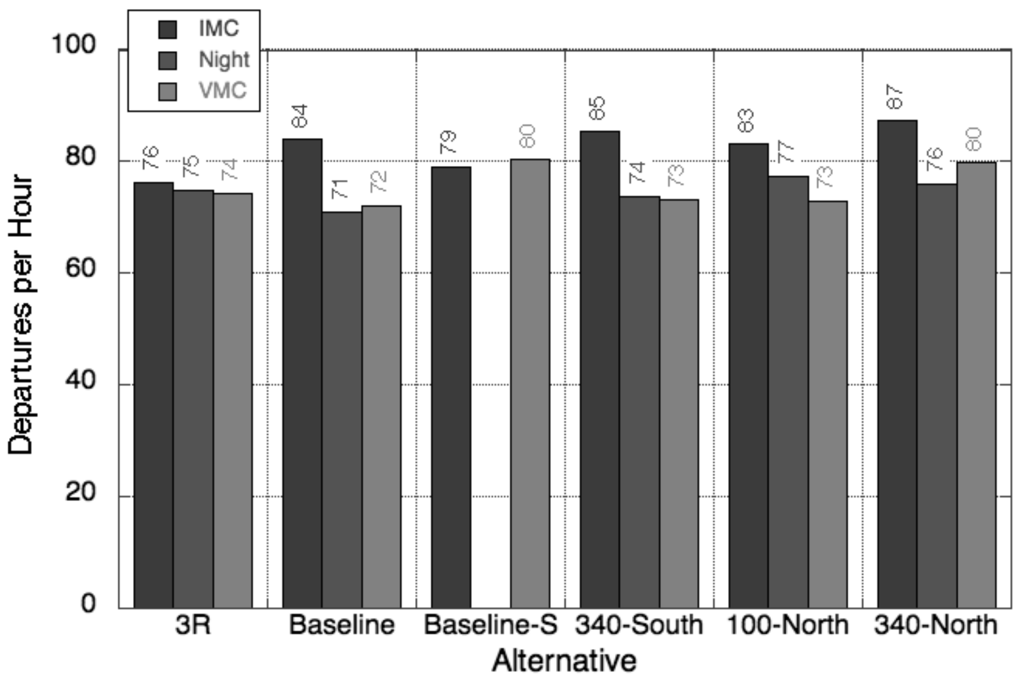


Figure 13-2: Mean Departure Rates per Hour Observed for All Six Alternatives Studied.

An assessment of the throughput arrival rates expected in the North field is presented in Figure 13-3. By design, the arrival rates to the North complex for all 5 alternatives are very similar representing saturation arrival conditions. The three-runway alternative has significantly lower arrival rates (22-23 per hour) allowing departures to occur between successive arrivals. The gap between successive arrivals for the three-runway alternative was optimized using a Monte Carlo simulation performed by the Academic Panel using several parameters observed at LAX using limited ASDE-X data collected for this study.

Departure rates observed in the FFC simulations follow similar trends to those observed for the complete airfield. Departure rates in VMC and Nighttime conditions are affected by four inboard arrivals per hour scheduled in each simulation run. Using the numeric averages of three weather conditions simulated for five of the alternatives we observe some trends shown in Figure 13-5. Alternative 3R is in a class by itself with the lowest departure rates. This was expected since the gaps between successive arrivals were designed to accommodate one departure per gap. The FFC simulations proved that controllers could release two departures per gap in some instances making the results for 3R better than expected. In the Academic Panel's opinion, local controllers were pushing very hard to release departure operations in the North airfield and some adjustment is warranted to estimate realistic departure saturation rates for the three-runway alternative. This will be covered in Section 13.4. Alternatives 340-South, 100-Northorth and Baseline are clustered in a second group as shown in Figure 13-5. This second group produces an average of 42 departures per hour. Alternative 340-North is in a class by itself with close to 46 departures per hour. This result was expected because in alternative 340-North all aircraft, including design Group VI aircraft, are allowed to taxi in the center taxiway without affecting the departures on the inboard runway (i.e., runway 24L).

Alternative 340-South shares similar runway separation with 340-North. However, this alternative could not achieve the same departure rates as 340-North and it proved to be challenging to air traffic controllers. The linear terminal in alternative 340-South creates a large imbalance of gates in the North airfield requiring significantly longer aircraft taxiing to the North to balance the South and North departure flows. This produced similar departure rate performance with the Baseline and alternative 100-North.

A comparison of the number of operations in the South and the North Airfields is shown Figure 13-6. The results indicate that the North airfield was more efficient in handling departures than the South. This was expected since the air traffic controllers in the North were all former LAX controllers and were more familiar with specific LAX airfield procedures. The results for Baseline-S should be interpreted with care. Our observations show that in many instances ATC controllers in the South handled aircraft design Group VI just like aircraft design Group V contributing to the high departure rates observed for the Baseline-S alternative. It is our assessment that under real world circumstances, the South airfield should experience departure saturation rates more inline with alternatives Baseline and 100-North.

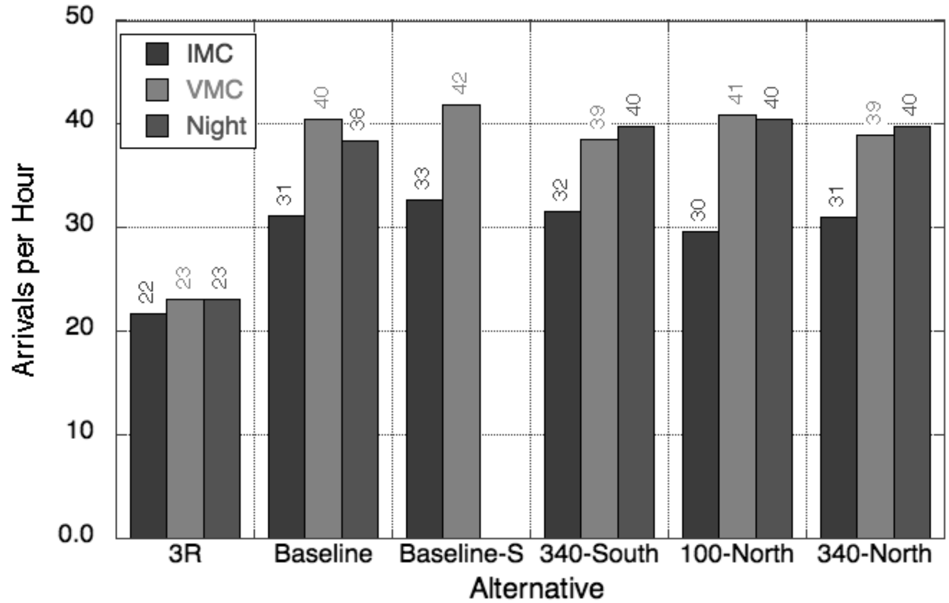


Figure 13-3: Mean Arrival Rates per Hour Observed in the North Airfield.

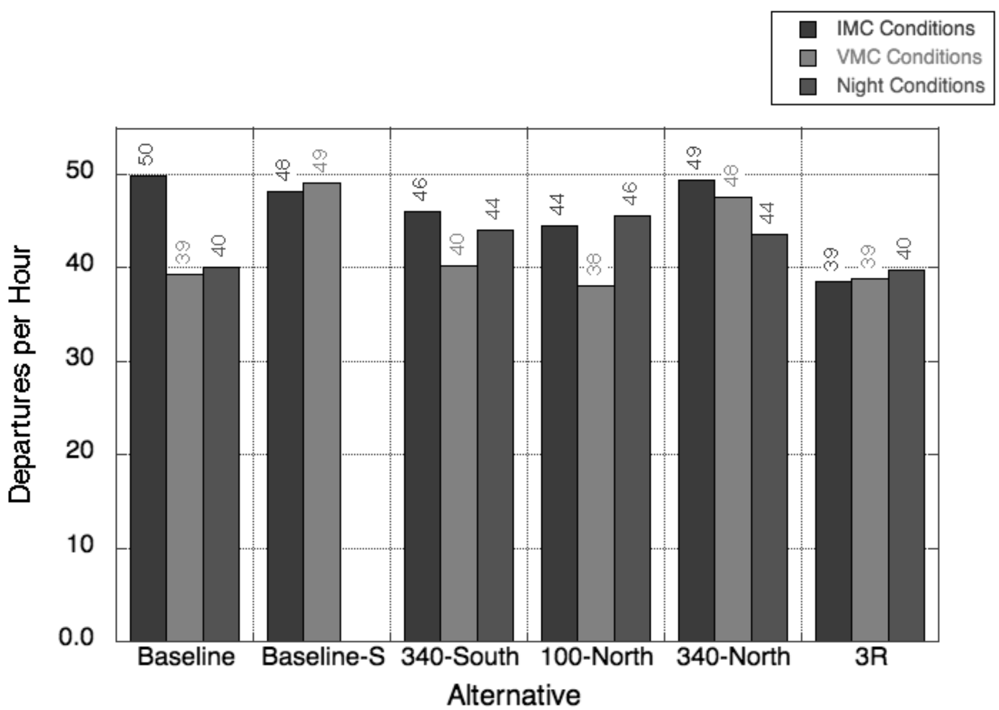


Figure 13-4: Mean Departure Rates per Hour Observed in the North Airfield.

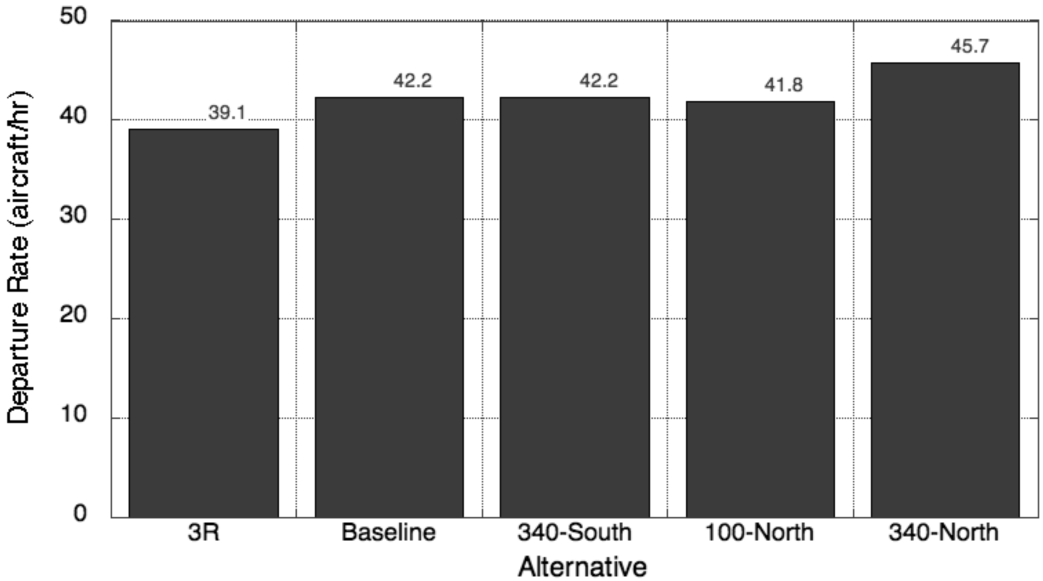


Figure 13-5: Average Departure Rates per Hour Observed in the North Airfield. Five Alternatives with all Three Weather Conditions Simulated in FFC.

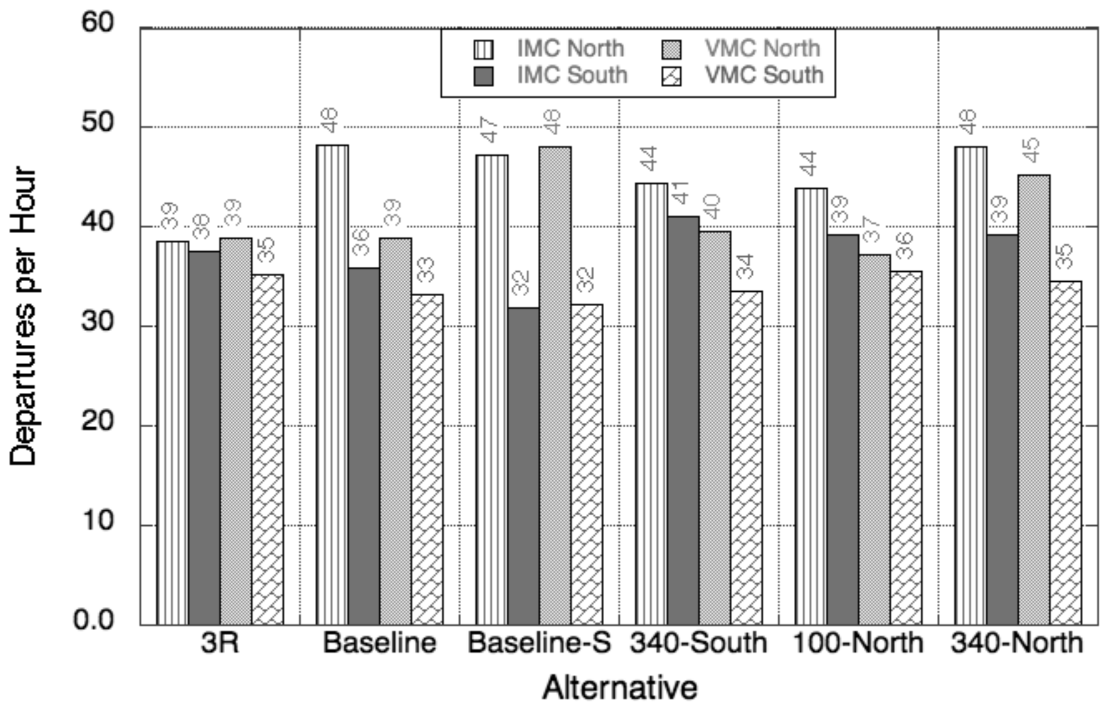


Figure 13-6: Mean Departure Rates per Hour Observed in the North Airfield Under Various Weather Scenarios.

13.2. Taxi-in and Taxi-Out Analysis

While this study concentrates on safety of the Los Angeles International Airport, airport operations should be efficient to handle traffic on runway, taxiways and in apron areas near gates. This section describes the taxi-in and taxi-out results of the FutureFlight Central simulations.

Taxi-In Times

Taxi-in times measure the time interval between the aircraft touchdown condition and the time when the same aircraft reaches its gate. Table 13-1 presents a summary of the taxi-in time results obtained in the FFC simulations. Figure 13-7 shows the mean taxi-in times observed in the FFC simulations for six airport alternatives. The y-axis represents taxi-in time per arrival in seconds. Statistical analysis of the data for 52 FFC runs shows that there are significant differences in taxi-in times for each alternative (at 95% confidence level). 340-South performs last in terms of taxi-in times with a mean taxi-in time of 708 seconds per arrival. The best alternative in terms of taxi-in times is 340-North with a mean taxi-in time of 612 seconds per operation followed closely by 100-North (630 seconds per operation). While runway 24R in 340-North is located further from the gates, the taxiing times are better than 100-N because of improved ground flows observed in the simulations. In other words, alternative 100-North produced more frequent aircraft stops on the ground for arriving aircraft compared to alternative 340-N. The ground stops for arriving aircraft are affected by both arrival and departing traffic flows in the airfield. Since 340-North has the best departure saturation capacity of all alternatives (i.e., fewer departure queues), this produced fewer bottlenecks on the ground network thus reducing taxi times in the airfield for both arrivals and departures in 340-North compared to other alternatives. This provides evidence that 340-N is a more efficient configuration to handle ground traffic. The poor performance of 340-South is attributed to the large imbalance in the number of gates in the North (i.e., linear terminal) compared to the South complex. The results for alternative Baseline-S include two weather conditions (VMC and IMC). The five remaining alternatives include all three weather conditions (VMC, Night and IMC). Comparisons between Baseline-S and other alternatives should be done with reservations since Baseline-S had no nighttime runs. Analysis of track data from FFC simulations reveals that alternative 340-South had the longest average travel distance in the field of all alternatives tested. This comes to no surprise, since many aircraft arrivals processed on the North airfield taxied long distances to the more numerous South airfield gates.

Taxi-Out Times

Taxi-out times measure the time interval between the aircraft push back condition at the gate and the time when a departure is processed on the runway (i.e., aircraft becomes airborne). Taxi-out times statistics are gathered for flights that reach the airborne phase. A summary of taxi-out times is shown in Table 13-2. Figure 13-8 shows the mean taxi-out times (i.e. taxi times for departures) observed in the FFC simulations. The y-axis represents taxi-out times per departure in seconds. Statistical analysis of the data for 52 FFC runs shows that there are significant differences in taxi-out times for some alternatives. 3R performs last in terms of taxi-out times with a mean taxi-out time of 1,309 seconds per departure. The best alternatives in terms of taxi-out times are 340-North and 340-South with mean taxi-out times of 1,198 and 1,208 seconds per departure, respectively. As would have been expected, 3R performs last with an average of 1,309 seconds of taxi-out time per operation. During the FFC runs for 3R, the North field taxiway "Echo" became very congested. Under 3R the North complex did not have the ability to handle the same amount of traffic as others.

Table 13-1: Taxi-In Time Analysis. FutureFlight Central Simulation Analysis Results.

Alternative	***Mean Taxi-In Time (s) Overall***	***Mean Taxi-In Time (s) IMC***	***Mean Taxi-In Time (s) Night***	***Mean Taxi-In Time (s) VMC***
3R	627	613	617	650
Baseline	645	606	713	633
Baseline-S	609	599	N/A[1]	619
340-South	708	640	697	789
100-North	630	584	624	684
340-North	612	601	636	600

[1] No Night condition was simulated in FFC for Baseline-S. Thus comparisons with others should be viewed with care.

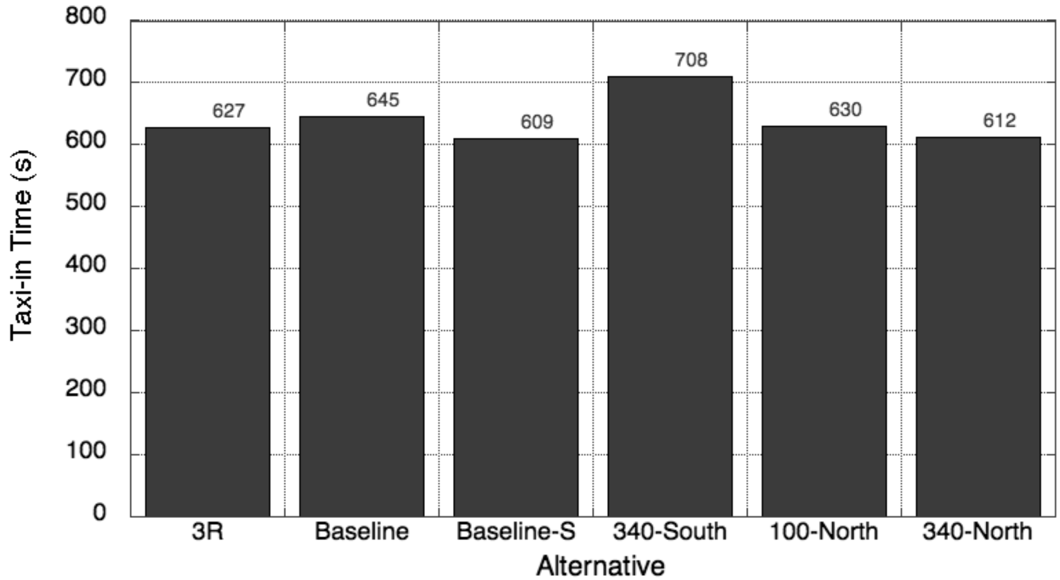


Figure 13-7: Taxi-In Times per Operation Observed for all Six Alternatives Studied.

Table 13-2: Taxi-Out Time Analysis. FutureFlight Central Simulation Results.

Alternative	*Mean Taxi-Out Time (seconds) Overall*	*Mean Taxi-Out Time (seconds) IMC*	*Mean Taxi-Out Time (seconds) Night*	*Mean Taxi-Out Time (seconds) VMC*
3R	1,309	1,356	1,306	1,266
Baseline	1,267	1,218	1,271	1,312
Baseline-S	1,236	1,255	N/A	1,217
340-South	1,208	1,132	1,195	1,292
100-North	1,257	1,239	1,259	1,272
340-North	1,198	1,201	1,197	1,198

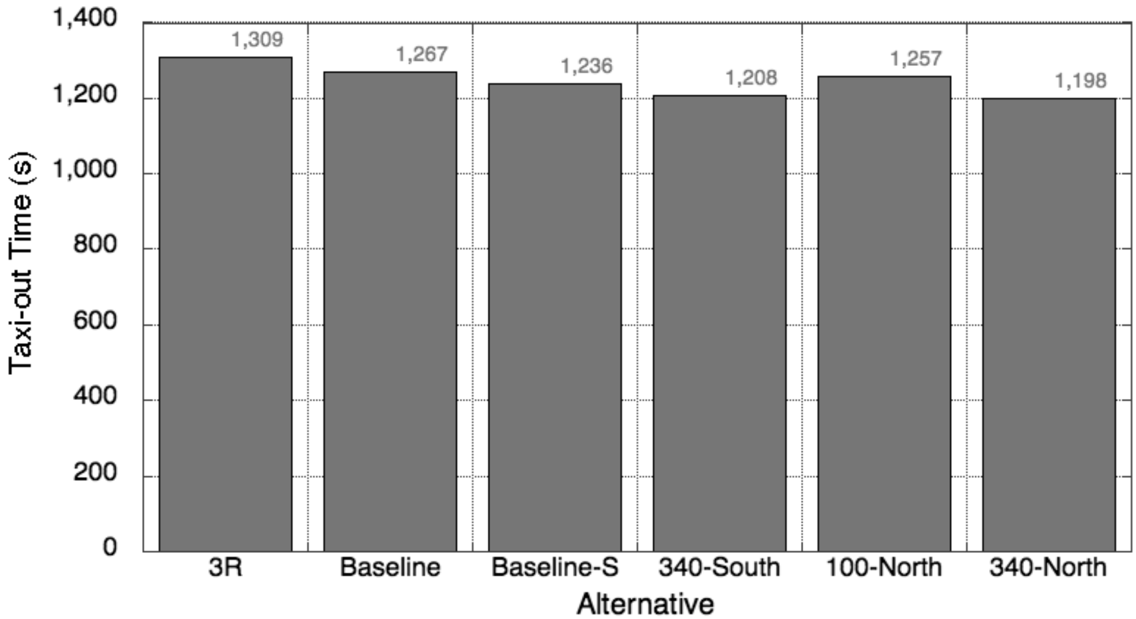


Figure 13-8: Taxi-Out Times per Operation Observed for Six Airport Alternatives.

In order to understand the implications of the FFC results, a simple economic analysis was conducted to understand the long-term impacts of added taxi-in and taxi-out times for various airport alternatives. The analysis considers periods of demand at the airport with conditions above a minimum threshold of demand to justify the use of FFC taxi-out and taxi in results. During the FFC simulations, the range of demand values tested varied from a low 127 operations per hour (for 3R) to a high of 163 operations per hour. Examination of the expected demand function over a 24-hr period at LAX (see Figure 4-3) provides insight of the range of the operations expected at the airport in the future. Using a low threshold of 127 operations per hour, we estimate 9 one-hour periods in the year 2020 with demand values above that minimum threshold. A total of 1,220 operations are impacted and considered in the analysis of delays based on FFC taxi-in and taxi-out times. Note that this approach assumes the contribution of delays in the remaining hours of operation during the day is zero. However, this is compensated because not all 9 one-hours selected are operated at the highest demand load simulated in FFC.

The results of the first-order cost analysis are presented in Table 13-3. The table presents the estimated annual operating cost savings ($2010) between the Baseline and all other alternatives (see column 2). The same table presents the operating cost with reference to alternative 340-North. 340-North was the alternative with the lowest operating cost per year of all six simulated in FFC. The results show that the Baseline would have an added cost of ground operations of 20.5 million dollars compared to alternative 340-North. Similarly, alternative 340-

North could save 10.9 million dollars per year compared to alternative 100-North. It is important to realize that part of the savings account for fuel burn savings that impact emisisons. The Academic Panel has not evaluated the environmental impact of these operations.

Table 13-3: First-Order Estimation of Annual Delay Savings for Six LAX Alternatives. Aircraft Operating Cost $3,250 per hour ($2010). 1,220 Daily Flight Operations Impacted and Considered in the Analysis.

Alternative	*Total Savings vs. Baseline ($2010) 2020 Demand*	*Total Savings vs. 340-North ($2010) 2020 Demand*
3R	-7,750,167	-20,482,583
Baseline	0	-12,732,417
Baseline-S	5,720,361	-7,012,056
340-South	10,887,139	-1,845,278
100-North	1,845,278	-10,887,139
340-North	12,732,417	0

13.3. FutureFlight Central Voice Communication Analysis

Voice communication results obtained for every FFC alternative are presented in this section. We compare four voice communication metrics for each alternative: 1) transmissions per hour, 2) average length of transmissions, 3) average airtime distributions and 4) transmission efficiency (number of transmissions per aircraft per hour). These metrics have been used in past studies (references) to estimate measures of workload that could potentially affect safety.

Frequency Transmissions Analysis

We first study the results for Local Controller 2 Position (i.e.,North Controller). The results of ATC frequency passages per hour are shown in Figure 13-9. There were statistically significant differences observed in the number of transmissions per hour among several of the alternatives. 3R had the lowest transmission rate**.** This is explained due to a lower number of operations in the North airfield. A second group formed by Baseline-S, 340-North, 100-North, and Baseline had the highest transmission rates (In that order). Alternative 340-South was in the middle.

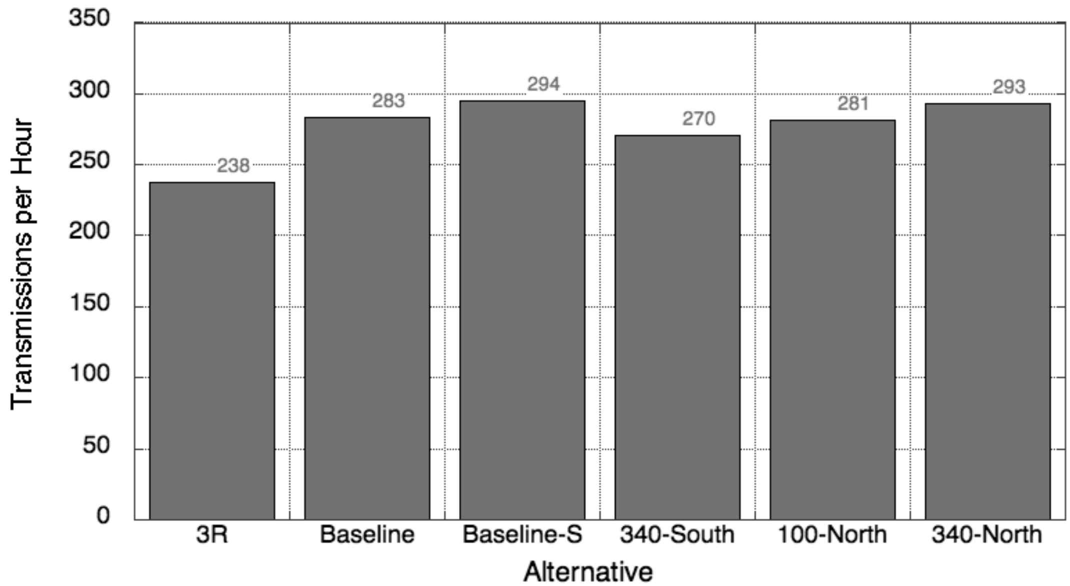


Figure 13-9: North Airfield Local Controller (LC2) Transmissions per Hour.

The transmission rates observed for 340-North and 100-North alternatives are not significantly different than the Baseline at the 95% confidence level. Transmission efficiency rates are shown in Table 13-4. The transmission efficiency ratings (transmissions per operation) for 340-North and 100-North are comparable to those of the Baseline alternative. This would suggest that all alternatives with a center taxiway do not have a significant disadvantage with respect to workload compared to the Baseline alternative.

Table 13-4: Transmission Efficiency for LC2 Transmissions for Six Alternatives.

Alternative	*North Airfield Operations per Hour*	*LC2 Transmissions per Hour*	*LC2 Transmissions per Operation*
3R	61.68	238	3.86
Baseline	78.67	283	3.60
Baseline-S	84.89	294	3.46
340-South	78.42	270	3.44
100-North	79.29	281	3.54
340-North	82.26	293	3.56

The results for the North Ground Controller (GC2) are examined next. There were statistically significant differences observed in the number of transmissions per hour for the GC2 position for some of the six alternatives studied (see Figure 13-10). 340-South had the lowest transmission rate**.** This can be explained due to the limited number of gates on the North airfield.

A second group formed by Baseline, 100-North, 340-North, and Baseline-S had the highest transmission rates (In that order). 3R was in the middle. The transmission efficiency observed for 340-North and 100-North alternatives are not significantly different compared to the Baseline alternative at the 95% confidence level (see Figure 13-11).

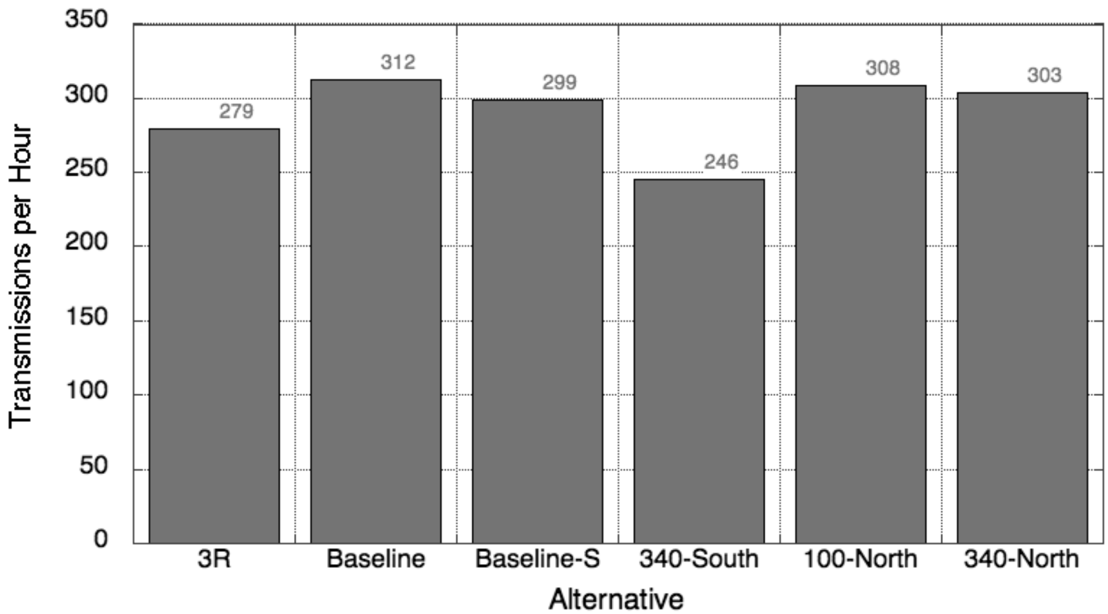


Figure 13-10: North Airfield Ground Controller (GC2) Transmissions per Hour.

Table 13-5: Transmission Efficiency for GC2 Transmissions for Six Alternatives.

Alternative	*North Airfield Operations per Hour*	*GC2 Transmissions per Hour*	*GC2 Transmissions per Operation*
3R	61.68	279	4.53
Baseline	78.67	312	3.97
Baseline-S	84.89	299	3.52
340-South	78.42	246	3.13
100-North	79.29	308	3.89
340-North	82.26	303	3.69

The last set of transmission results apply to a midfield ground controller position called GC3. This is a new ground control position created to deal with the added complexity of a new midfield terminal and additional gates on the West side of the Tom Bradley International Terminal.

Statistically significant differences were observed among several of the alternatives in terms of the number of transmissions per hour for the GC3 position (see Figure 13-11). 340-South had the highest transmission rate**.** This result can be attributed to the large number of crossings between North and South fields observed during the FFC simulations due to the limited number of gates on the North. This alternative created significantly more workload for GC3. A second group formed by 3R, Baseline, Baseline-S, 100-North, and 340-North had lower transmission rates (in that order).

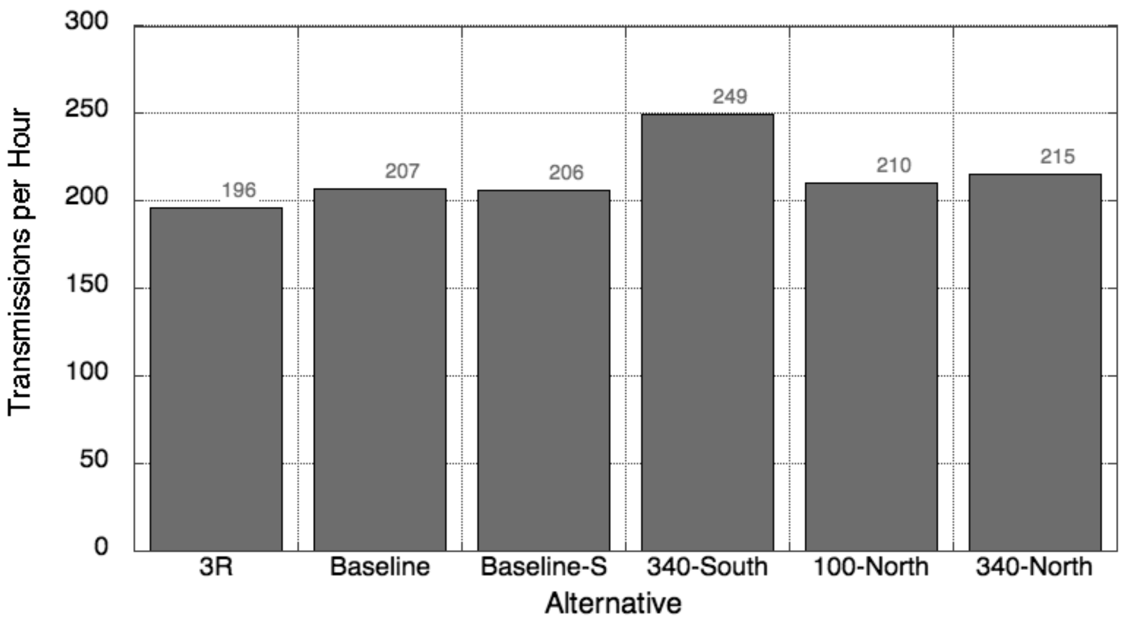


Figure 13-11: Midfield Ground Controller (GC3) Transmissions per Hour.

The transmission rates observed for 340-North and 100-North alternatives are not significantly different than the Baseline at the 95% confidence level. Transmission rates have been known to correlate with controller workload.

The results obtained in these simulations were compared to those obtained by NASA Ames in a previous FFC simulation study of the Los Angeles International Airport (NASA, 2003). The previous study analyzed the South Airfield to understand workload measures with a center taxiway in the South. In a previous NASA FFC study, the tower simulator was staffed by two controllers on each side (GC1, LC1 and GC2, LC2) with no GC3 controller (NASA, 2003).

The transmission rates for GC1 and LC1 controllers (South-side controllers) in the previous study were 300 and 309 transmissions (i.e., passages) per hour, respectively. The average transmissions per hour for GC2 in our study for alternatives 100-North and 340-North were 308 and 303 transmissions per hour for GC2. The average transmissions per hour for LC2 in our study for alternatives 100-North and 340-North were 291 and 293 transmissions per hour for GC2. While many variables can affect the transmission rates, the transmissions rates observed in this study seem comparable with the previous center taxiway study performed by NASA. Our discussion with Air Traffic Controllers suggests that the workload for the South Field has been acceptable. Consequently, the results of the North Airfield Study suggest both ground and local controllers should be able to cope with the workloads expected in the North field with alternatives 100-North and 340-North. Alternative 340-South would probably result in higher workload for the mid-field controller (GC3) compared to today's ground controllers.

Airtime Frequency Analysis

Airtime frequency use is another important variable to estimate precursor measures of ATC controller workload. Starting with Ground Controller position #2 (i.e., North Controller), there are statistically significant differences in the airtime distributions for some of the alternatives at the 95% confidence level (see Figure 13-12). In the FFC simulations, 340-South had the lowest airtime frequency use. This was expected due to the small number of gates in the North airfield complex compared to the Baseline alternative. A second group formed by Baseline-S, 100-North, Baseline, and 340-North had higher airtimes (in that order) than 340-South. Based on our own analysis, none of the airtimes seemed excessive. The airtime observed for 340-North and 100-North alternatives are not significantly different than the Baseline alternative at the 95% confidence level.

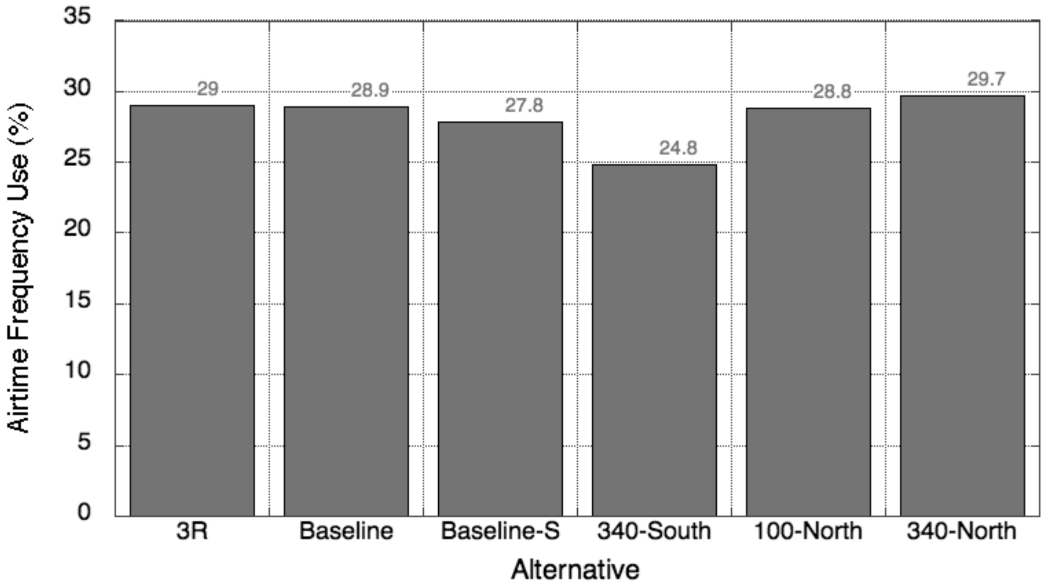


Figure 13-12: North Airfield Ground Controller (GC2) Airtime Frequency Use.

Figure 13-13 shows the percent of time of frequency use for local controller # 2 (North Controller). The results for LC2 (local controller position 2 – North Airfield) show that statistically, no appreciable differences observed in the airtime distribution at the 95% confidence level. 3R had slightly lower airtime demands. This was expected due to lower demand on the North Airtime frequency demand varied from 23.1% to 26.9% for all 6 alternatives tested.

These values are comparable to those observed in a previous NASA center taxiway study (i.e., 26.3%) for South LC1 controllers. The airtimes for LC2 seem to be within acceptable controller workload thresholds. The airtimes observed for center taxiway alternatives (340-South, 100-North and 340-North) are not significantly different than the Baseline alternative at the 95% confidence level.

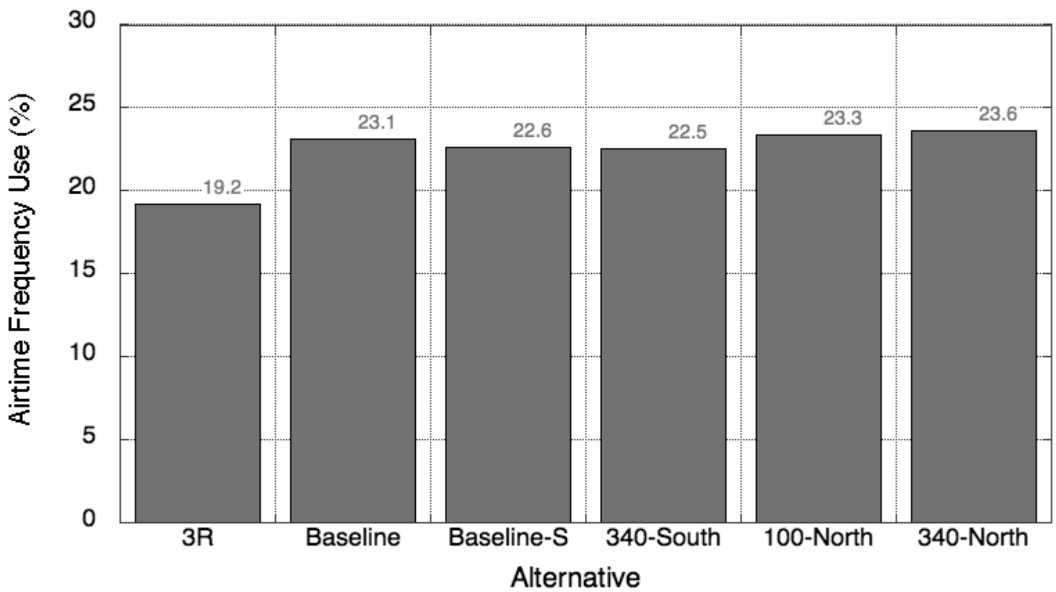


Figure 13-13: North Airfield Local Controller (LC2) Airtime Frequency Use.

The final airtime analysis corresponds to position GC3 or the ground controller in charge of midfield terminal traffic. The airtime percent use of the frequency for GC3 is shown in Figure 13-14. The results show statistically significant differences observed in the number of transmissions per hour for the GC3 position at the 95% confidence level. 340-South had the most demanding airtime requirement. This was attributed to the limited number of gates on the North creating substantially more crossover traffic and thus more workload for GC3. A second group formed by 340-North, Baseline, Baseline-S, 100-North, and 3R (in that order) had airtime distributions that were very similar.

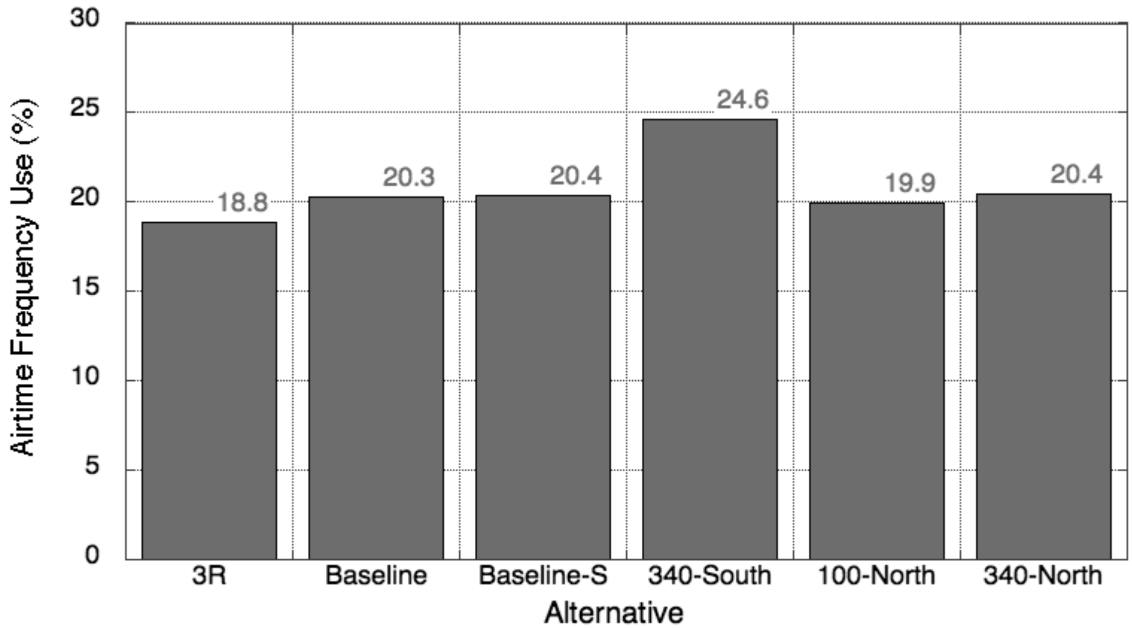


Figure 13-14: Northfield Ground Controller (GC3) Airtime Frequency Use.

The airtime results illustrated in Figure 13-14 show that 24% of the GC3 controller was busy in alternative 340-North and 26% of the time for alternative 100-North. These percentages are lower than the airtimes observed for South Airfield ground controllers (GC1) in a previous NASA study (NASA, 2003). The airtime results should provide confidence that a GC3 position can be staffed as simulated in this North Airfield FFC study. This position will be critical in future operations at Los Angeles International Airport due to the complexity of the midfield terminal and the limited visibility available from the existing ATC Control Tower as shown in Figure 13-15 and Figure 13-16.

Figure 13-15: Visibility from LAX ATC Control Tower to Midfield Terminals. FFC Simulation (A.A. Trani).

Figure 13-16: Current Visibility from LAX ATC Control Tower to the Tom Bradley Terminal (A.A. Trani).

Average Transmission Length Analysis

The third voice communication metric obtained from the FFC simulations was the average transmission length. For the Local Controller position in the North Airfield (LC2) no appreciable differences were observed in the average transmission length among all alternatives. The results are shown in Figure 13-17. Transmission lengths varied from 3.17 to 3.54 seconds. The values observed in this study are comparable to those observed in a previous NASA taxiway study (NASA, 2003) for South LC1 controllers. The transmission lengths for LC2 seem to be acceptable and in line with a previous South Airfield NASA study. The average transmission lengths observed for all center taxiway alternatives are not significantly different than the Baseline alternative at the 95% confidence level.

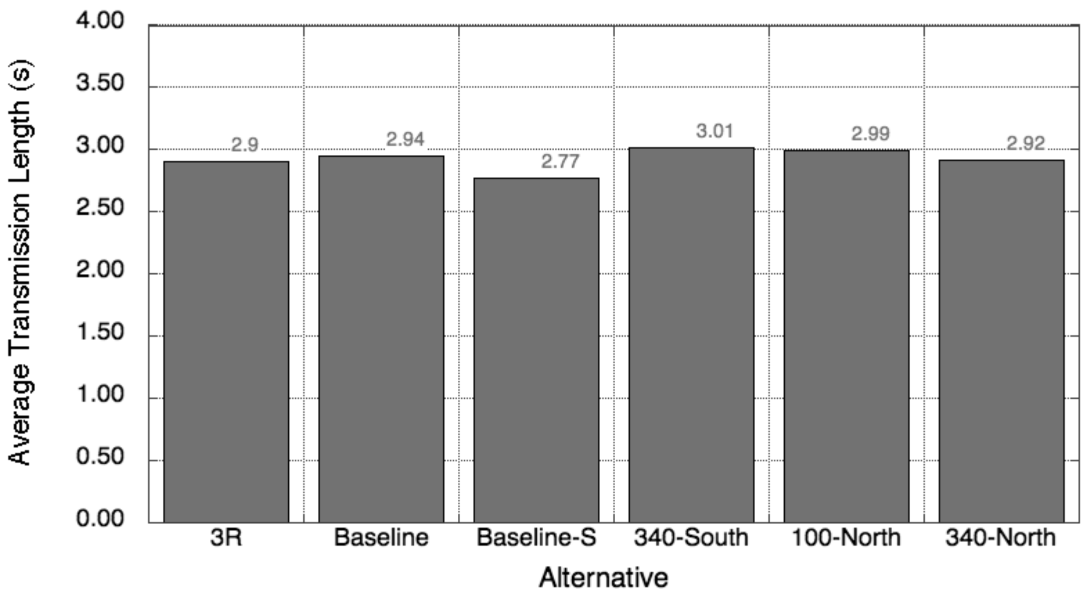


Figure 13-17: North Airfield Local Controller (LC2) Average Transmission Length.

For the Ground Controller position in the North Airfield (GC2) no appreciable differences were observed in the average transmission lengths among all alternatives. The results are shown in Figure 13-17. The average transmission lengths observed for all center taxiway alternatives are not significantly different than the Baseline alternatives (Baseline or Baseline-S) at the 95% confidence level. Transmission lengths for the GC2 position varied from 3.40 to 3.81 seconds. These values are comparable to those observed in a previous NASA center taxiway study (NASA, 2003) for South GC1 controllers.

Finally, the Ground Controller position in the Midfield (GC3) had similar average transmission lengths among all alternatives. The average transmission lengths observed for all center taxiway alternatives are not significantly different than the Baseline alternative at the 95% confidence level. The results are shown in Figure 13-18. Transmission lengths for GC3 position varied from 3.73 to 3.84 seconds.

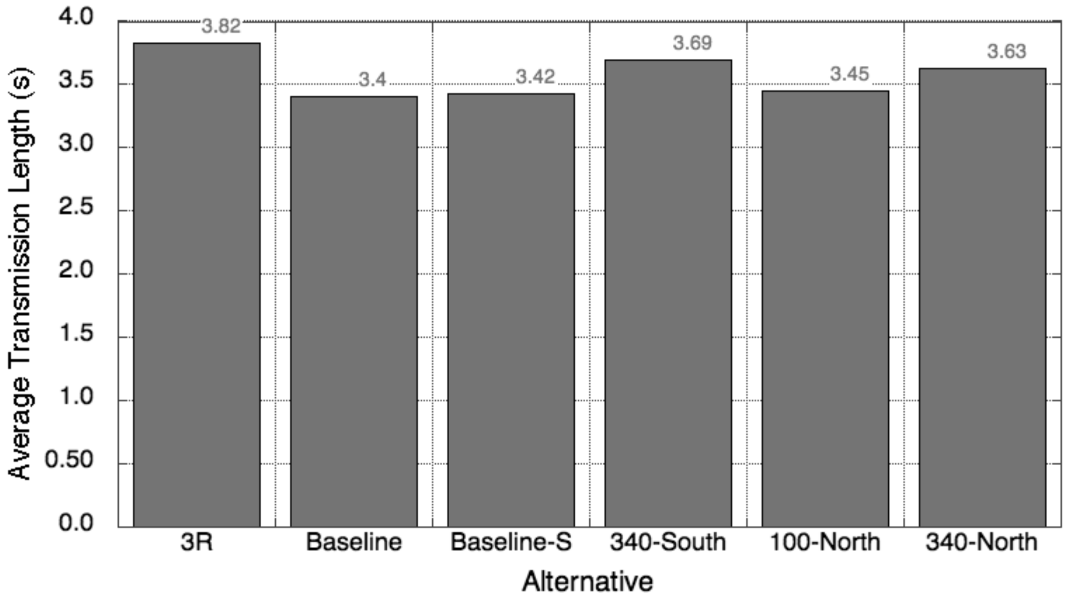


Figure 13-18: North Airfield Ground Controller (GC2) Average Transmission Length.

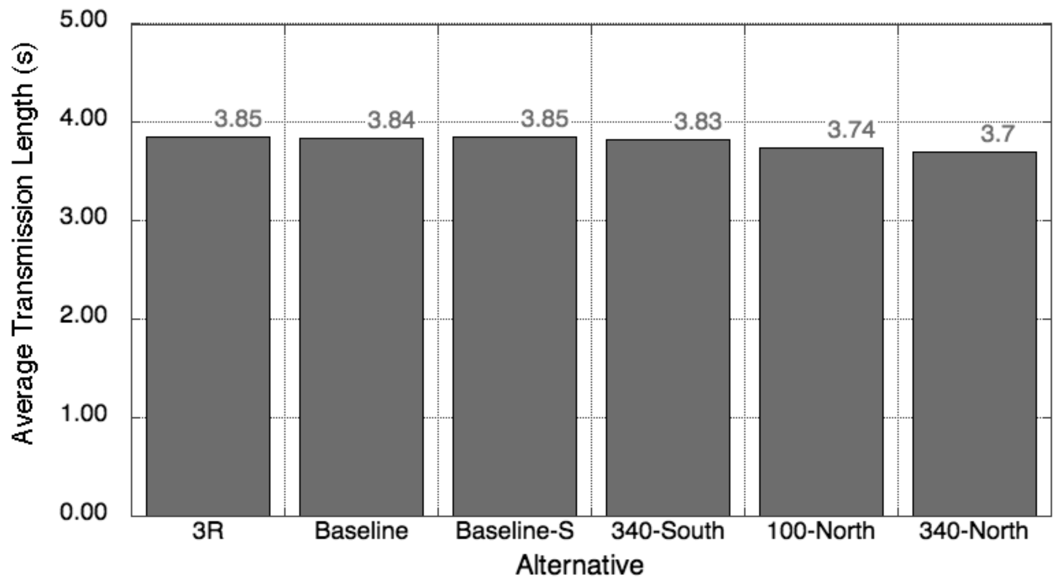


Figure 13-19: Midfield Ground Controller (GC3) Average Transmission Length.

Summary of Voice Communication Analyses

Three precursor workload metrics were studied using FFC output data: transmissions per hour (transmission rate), average transmission length, and airtime distribution. For all three metrics and 3 North controller positions, alternatives 340-North and 100-North demonstrated similar precursor workload parameters than the Baseline alternative. The 340-South alternative was particularly demanding in transmission rate and airtime for the GC3 controller position. This could indicate that if alternative 340' South were to be adopted, it would likely result in the highest workload conditions for the Ground Controller in charge of the midfield. All three metrics for the North Airfield local and ground controllers were very similar in absolute terms to those measured in the previous NASA study (NASA, 2003)

13.4. Runway Operations Analysis Model

Section 13.1 presented the throughput analysis of the airport in terms of actual observations in the FFC simulations. As noted before, air traffic controllers were pushing very hard to service many departures from inboard runways and in some cases it was observed that, for some configurations more than others, the separation minima was either below the FAA standards or close to it. In real life, air traffic controllers would act more conservatively and thus adjustments to the throughput values obtained in Section 13.1 are warranted. This section provides an independent evaluation of runway capacity to understand the impacts of various alternatives in the future of LAX operations.

Discrete-Event Simulation Model of North Airfield Interactions

To evaluate in some detail the impact of ADG VI aircraft operations in the North airfield, a discrete event simulation model of the runway operations was created. The model, created in the ExtendSim modeling language, consists of blocks connected to model the interactions between arrivals on runway 24R and departures on runway 24L. The model includes an interaction block to delay departures on 24L while ADG VI aircraft are operated on the center taxiway under alternative 100-North. The diagram of the model is shown in Figure 13-20. The model runs the complete LAWA 2020 demand schedule for one day of operations with the percent of ADG VI aircraft varied parametrically between 1 to 3% simulating various futures of operations at LAX. To model 100-North operations the model blocks departure operations on 24L while a design Group VI aircraft occupies the center taxiway and performs a crossing of runway 24L in 2.8 minutes. This is the expected travel time of a super-heavy using runway exits K3, K4 and BB in 100-North. The travel time has been estimated using the Academic Panel observations at the airport for Qantas Airbus A380-800 operations and considers the FAA Modification of Standard (MOS) prescribed limit of 15 miles per hour taxiing speed on 75-foot taxiways. The analysis for 340-North includes a ½ minute blocking time for departures on 24L while the ADG VI aircraft crosses runway 24L at low speeds observed in the field. This time was added because the time gaps between successive departures will lack sufficient time to allow a super-heavy aircraft crossing the departure runway and clear the runway Object Free Area (OFA) or Runway 24L.

To obtain stable results, we ran 100 repetitions of the model simulating 100 independent days of operation. A sample output of the model is shown in Figure 13-21. The results of the discrete-event simulation model are shown in Table 13-6 for Visual Meteorological Conditions (VMC). The table summarizes the values of incremental departure delays per operation at the airport over a 24-hour period. The values of delay in the table represent the departure delays that would be added if the runway is blocked because a Group VI aircraft maneuvers in the center taxiway. Other delays at the gate or taxiways are not factored in here because we are attempting to understand the effect of runway blocking for departures only. In general, other sources of delay on taxiways will add to the analysis presented here.

The results of the simulation show reductions of 0.20 to 0.54 minutes per departure operation for alternative 340-North compared to 100-North. These results are average numbers accumulated over a complete day of operations for every departure in the North airfield.

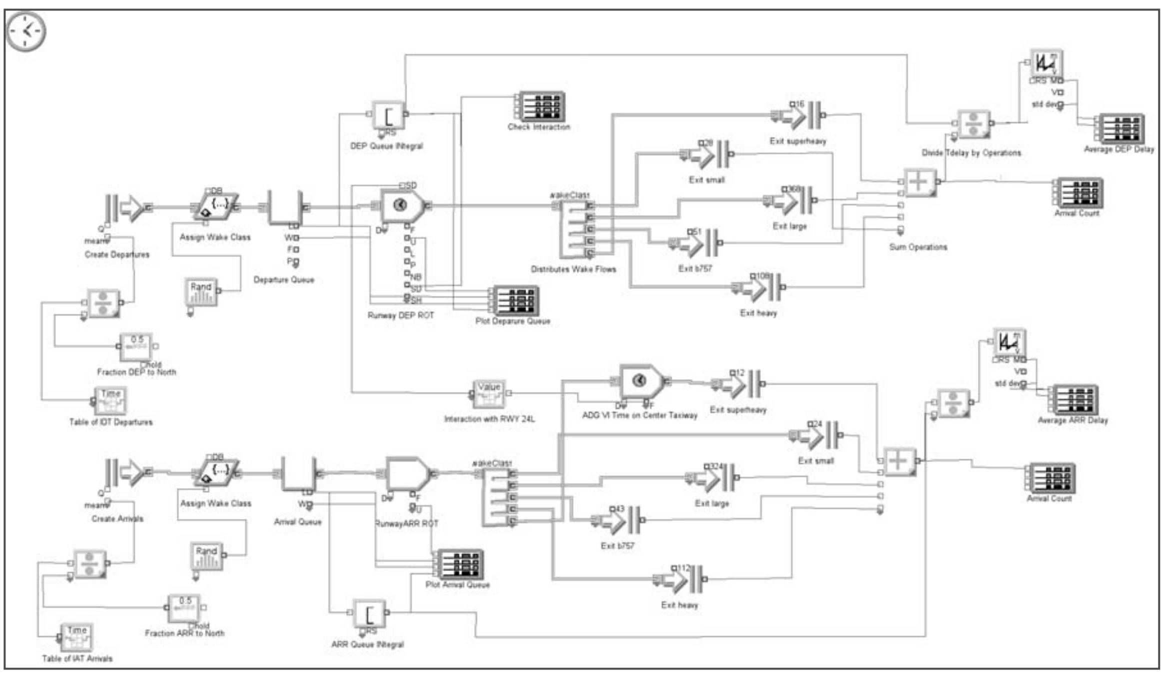


Figure 13-20: Block Diagram of Discrete-Event Simulation of the North Airfield to Measure Departure Delay Impacts in the North Airfield.

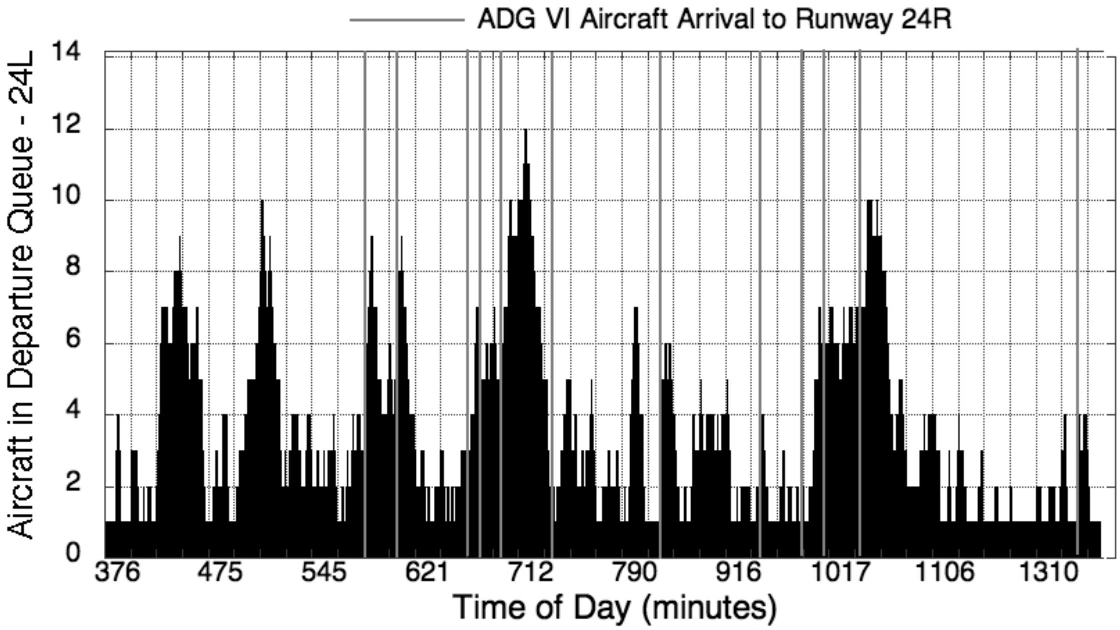


Figure 13-21: Departure Queue Output of the Discrete-Event Simulation of the North Airfield. IMC Scenario with LAWA 2020 Demand Profile. 100-North Alternative with 2% ADG VI Aircraft in the Fleet Mix.

Table 13-6: Incremental Departure Delays per Operation (LAWA 2020 Demand: 2284 operations per day). ADG VI Fleet Varies from 1-3%. VMC Operating Conditions. Tally of 100 Discrete Event Simulations Representing 100 Days of Activity at the Airport.

	% ADG VI in Fleet Mix		
Alternative	1%	2%	3%
100-North	1.81	2.21	2.37
340-North	1.61	1.74	1.83
Improvement 340-North vs 100-North	0.20 min/operation	0.47 min/operation	0.54 min/operation

The situation in Instrument Meteorological Conditions (IMC) is presented in Table 13-7. The table shows incremental delays ranging between 0.62 and 0.99 minutes per departure operation. To put in perspective the results shown in Tables 13-6 and 13-7, it is necessary to consider a mixed scenario that accounts for both VMC and IMC conditions. According to FAA Aviation System Performance Metric database (FAA, 2009) LAX is operated 24% of the time as equivalent IMC conditions. The remaining 76% of the time the airport is operated in equivalent VMC conditions.

Table 13-7: Incremental Departure Delays per Operation (LAWA 2020 Demand: 2284 operations per day). IMC Operating Conditions. ADG VI Fleet Varies from 1-3%. Tally of 100 Discrete Event Simulations Representing 100 Days of Activity at the Airport.

	% ADG VI in Fleet Mix		
Alternative	1%	2%	3%
100-North	3.11	3.58	4.11
340-North	2.49	2.90	3.12
Improvement 340-North vs 100-North	0.62 min/operation	0.68 min/operation	0.99 min/operation

Using this breakdown in the analysis we estimate the annual cost of departure delays due to improvements in operations with 340-North. In this analysis we use 2% of the fleet mix in the year 2020 to be ADG VI aircraft. According to the LAWA demand estimate, in 2020 there could be 525 departures per day that will be affected by any improvement in the North (assuming 46% departures in the North airfield). The cumulative added delay using a 76/24 split of VMC/IMC conditions yields 273 aircraft-minutes of added delay per day if 100-North is implemented instead of 340-North. This translates into $5.4 million dollars per year saved using an operating cost of $3,250 per hour using conservative numbers ($2010). This number only considers the added delay due to runway blocking effects of runway 24L for departures due to ADG VI operations in the North airfield.

Using the taxi-in and taxi-out times presented in Section 13.2 (see Table 13-2) we make a first-order estimate of the taxi-out times for each operation discounting the stopped times at the runway departure queue. The results are summarized in

Table 13-8. The difference in taxiing times between 340-North and 100-North is 57 seconds discounting all stopped delays. This delay is due to increased taxiing distance effects of one alternative versus another one (i.e., extra routing to overcome traffic). Using this number as first-order cost estimation, another 499 aircraft-minutes (8.3 aircraft-hours) of delay per day would be added to the 100-North alternative compared to 340-North. This translates into $9.9 million dollars in the year 2020. The total delay savings accounting for loss of departure capacity and taxiing effects is estimated to be $15.3 million per year in 2020. In summary, the second cost analysis presented here provides a first-order estimate of added delay costs of 100-North versus 340-North.

Table 13-8: Estimated Taxi-Out Times without Stopped Delay.

Alternative	*Average Taxi-Out Time (seconds)*	*Mean Taxi-Out Time Without Stopped Delay (seconds)*	*Average Stopped Delay per Departure (seconds)*
100-North	1,257	1,186	71
340-North	1,198	1,129	69
Improvement 340-North vs. 100-North		57 seconds (0.95 minutes)	

Table 13-9: Estimated Delay Cost 100-North vs. 340-North. 340-North is used as the Reference Condition. $3,250 per Hour.

Alternative	*Departure Delays due to Runway Blocking Effect ($2010 Millions)*	*Added Taxiing Delays (zero Stopped Delay) ($2010 Millions)*	*Total Added Cost ($2010 Millions)*
100-North	5.4	9.9	15.3
340-North	0	0	0

13.5. Conclusions of Capacity and Operational Analysis

Comparing the two economic analyses presented in Sections 13.2 and 13.4 it is clear that alternative 340-North offers operational efficiency advantages and cost benefits over all other alternatives. If 340-North is compared with 100-North, the cost savings presented in Section 13.2 using FFC estimates alone produce $10.9 million dollars per year. The estimation using both FFC data and the discrete simulation model yield $15.3 million in cost savings per year. The conclusion of this analysis is that there are tangible advantages for 340-North from a capacity and operational efficiency viewpoint. There are other delay effects that are likely to appear if the analysis is carried in more detail. For example, arrival delays resulting from a smaller capacity in the airfield have not been factored in the FFC or in the discrete-event model. These arrival delays would likely add costs to the operation for each alternative with lower saturation capacities. This would be critical for alternatives like 3R that have the lowest acceptance rate of all. The reader should realize that once an airport is operated at the "knee" of the delay curve (like it is proposed in the year 2020) over extended periods of time during the day, small reductions in the capacity function of the airport result in large changes in delays (i.e., non-linear behavior). The following final conclusions can be made about the alternatives studied:

i) We conclude that the **340-North alternative offers superior operational efficiency and capacity of the airport over all others including the Baseline and 100-North cases**. We estimate the magnitude of the cost savings to be 15.3 million dollars per year compared to 100-North just on ground taxi and runway blocking operations. The effect of a modest gain in departure capacity for 340-North would yield operational benefits to better cope with the expected demand in the year 2020. These benefits would produce reduced arrival delays that our study has not estimated.

ii) Besides capacity, the **operational benefits** of having a centerline taxiway, **340-North provides an added benefit of holding capacity** to deal with unexpected conditions. The **Baseline configuration is limited in terms of holding capacity** for arrivals queueing at taxiways AA, Zulu and Yankee today. Our analysis of future runway operations using the IRSIP configuration will place higher demands on the new location for Zulu and under periods of heavy arrival conditions, could produce unwanted queues at new Zulu and AA.

iii) **The 340-North configuration could also improve the situational awareness of pilots crossing runway 24L by providing better viewing angles from the flight deck**. While it is difficult to state that "poor" viewing angles or runway exit angles are the main cause of high runway incursion rates in AA and Zulu, it is clear that proper geometric design of taxiway-runway junctions provides another safety net to avoid runway incursions. The 340-North configuration provides the best alternative to design good high-speed geometries and at the same time, taxiway-runway junction to the inboard runway.

iv) **The three-runway alterative (3R) would not provide adequate capacity** for conditions expected in 2020 or similar to the LAWA 2020 demand profile. For 9 hours of each day the capacity of 3R would fall short of the capacity needed to maintain the airport delays at a reasonable level. Moreover, 3R does not offer backup ability in case a runway is closed. Runways are closed at airports for maintenance duties and for operational reasons.

v) The Baseline configuration provides reasonable capacity in the short term. However, based on two first-order cost analysis presented in this Section the **Baseline configuration is inferior to 340-North for a 2020 demand scenario**. The Baseline alternative with IRSIP offers limited queueing capacity between runways 24R and 24L. The provision of high-speed exits for the Baseline condition requires careful attention to detail to avoid inducing pilots to take runway exits at such high speeds as to cause blunders.

14. CAVEATS IN THE ANALYSIS

The North Airfield Safety Study is necessarily an exercise in approximation, an attempt to amass and work with clues rather than to reach exact truths. Some of key caveats related to our analysis are listed below.

The 2020 forecasts about traffic levels at LAX, and the fraction of traffic involving Group VI aircraft, are subject to considerable uncertainty.

This point needs little elaboration, given the extent to which recent demand patterns have deviated from forecasts made a decade ago. Because commercial US air traffic in 2009 was far below what was anticipated, one might wonder whether growth will resume sufficiently so that 2020 forecasts emerge as accurate. And Boeing and Airbus have long disagreed on whether Group VI planes like the Airbus 380 will be crucial to future international passenger travel, or whether instead point-to-point services on smaller aircraft will gain growing prominence. One way to interpret the forecasts is as representation of future demand levels at *some* point in the future, perhaps not 2020 but (say) 2030. Because decisions about the North Airfield concern its future over many decades, too literal a focus on 2020 might be misplaced.

The experiments at NASA-Ames were extremely sophisticated and well conducted, but they can only approximate what might happen under various configurations of the North Airfield.

Aviation is forever changing, and even assumptions in the simulation that were sensible when they were made might not reflect what might happen in the future. To pick but one example, aircraft are now taking off with *reduced thrust*, which means that they travel farther down the runway before becoming airborne than they did in recent years. That procedure limits wear-and-tear on the engines and is popular with airlines, but it means that the probability a plane will be in the air within a certain time and at a certain distance down the runway may be less than the simulation assumed. That circumstance affects the evaluation of the "built-in" safety of moving crossing points down the runway, and it also has implications about airport capacity. The Panel tried to make adjustments for such factors, but they arise in too many ways for such adjustments to be complete and exact.

Likewise, we gained a great deal from the oral and written surveys of both pilots and controllers in the simulation. But, sometimes, what was said in the oral sessions diverged (in tone at least) from what was written. Such differences are to be expected when people are questioned after intense simulated sessions in heavy air traffic; it is not obvious how best to reconcile any such diversions. The Panel used judgment in synthesizing the information, but its judgments are far from infallible.

Historical experience is valuable, but the data are subject to random variability that poses major challenges for statistical estimation.

This point is illustrated if we consider how the changes on the South Airfield have reduced runway incursions when planes landing on runway 25-L cross runway 25-R en route to the terminals. There have been no such A and B incursions on the South since the reconfiguration was completed in 2007. That is good news but, given that such incursions were rare on the South in the several preceding years, it is too early to come up with an estimate of the incursion rate reduction with a high degree of accuracy. Many of the numbers we estimated in the analysis are subject to the volatility associated with rare events, and they are subject to margins of error that are potentially large and hard to quantify.

A Final Perspective

It should be obvious from our report that ***we generally took a conservative approach to estimating risk***: if we erred, we did so on the side of overestimating risk. Further, where there was a degree of uncertainty in estimating a risk reduction parameter, ***we generally took of the approach of obtaining multiple estimates using diverse techniques and then taking a "consensus" estimate.***

While the Panel admits that its estimates have degree of uncertainty associated with them, it believes that ***the thrust of its conclusions is basically accurate.*** Thus, it believes that the experiment at NASA-Ames and the review of historical and other data serve to point in the right direction, even if there remains considerable uncertainty about the exact angle.

15. ANSWERS TO THE NINE QUESTIONS

15.1. What are the causes of past and ongoing runway incursions and surface incidents on the LAX North Airfield? Simulate/recreate circumstances and conditions to assess and identify all primary and contributing factors.

We have reviewed and classified incursions on the North and found the following.

55% of the incursions are of the exit-no-stop (ENS) type. They have been discussed at other parts of the report. They involve an aircraft arriving on the outboard runway and erroneously crossing the inboard runway or breaching the hold bar at the inboard runway without stopping. They are usually caused by a distracted or disoriented pilot or a pilot that takes a runway exit at very high speed. In many cases, some form of miscommunication between the pilot and controller is a contributing factor. In a few cases, they are caused by a controller incorrectly giving a clearance.

15% of the incursions are "threshold" incursions. These involve an aircraft entering a runway at or near the threshold without clearance. In many cases, these incursions result in a go-around for an airborne arriving aircraft. These are caused by some miscommunication between the pilot and controller.

15% of the incursion are "takeoff without clearance" incursions. These involve an aircraft starting its takeoff role without clearance. These are caused by some miscommunication between the pilot and controller.

The remaining incursions could involve ***i) service vehicles, ii) an aircraft arriving on the outboard runway and entering the inboard runway without clearance after a stop or iii) an aircraft entering the active inboard runway from taxiway E.***

We did not have the resources to simulate these incursions as requested.

15.2. Are these incursions indicative of a current unacceptable level of risk by the FAA safety standards?

As indicated in our Baseline analysis, the incursion (and collision) risk on the North Runway Complex are in line with national averages. Moreover, by objective standards, the fatality risk is extremely low so ***we conclude it is not unacceptable.***

15.3. What role does the existing airline fleet of aircraft serving LAX play in the risk of runway incursions?

We have found no reason to believe that the existing LAX fleet mix has a significant impact on the risk of runway incursions at LAX when compared to national averages. An analysis of historical incursion files indicated that the representation of larger aircraft (Group V, heavies) in incursions was very close to their representation within the fleet. Thus, there is no reason to believe that larger aircraft are more or less likely to be involved in an incursion. However, the risk that an incursion causes a collision may increase with aircraft size (see discussion in this report). We feel that the differential risk does not vary substantially among the alternatives considered, given the differential operational restrictions imposed by the FAA..

15.4. What roles do airfield marking, lighting, and signage play in the risk of runway incursions at LAX?

As discussed in the report’s Baseline risk assessment, there has been a substantial decrease in incursion risk nationally over the past eight years. Much of this decrease is most likely due to the introduction of ASDE-X and AMASS. However, in that time period, there has been a concerted effort by the FAA and airport operators to improve marking, lighting and signage and, in fact, as a group, even airports that did not receive ASDE-X and AMASS have experienced a risk reduction. This provides evidence that such measures do reduce the risk of runway incursions. The FAA has specifically estimated that RWSL should decrease runway collision risk by 50%. Thus, it certainly would appear that these mechanisms, as a group, have a noticeable positive impact on risk.

15.5. What role does human error play in the risk of runway incursions? What role does traffic controllerstaffing play in the risk of runway incursions?

A review of incursion reports reveals that human error plays the major role in virtually all runway incursions. Further, pilot error is much more frequently the cause than controller error, although controllers often have an opportunity to correct pilot errors before they lead to incursions. We observed in the FFC Simulation on multiple occasions that the Local Assist Controller (an optional position) was critical in identifying a hazardous condition and averting an operational error. Thus, if increased staffing levels increase the percent of time that a Local Assist Controller is available, staffing level increases should increase safety. We have been unable to quantify this effect, however.

15.6. What other factors play a role in the risk of runway incursions?

While it is true that human error is virtually always the cause of a runway incursion, many other factors can play a role in reducing (or increasing) incursion risk.

Weather conditions, especially those causing poor visibility, can increase the likelihood that a pilot becomes disoriented and erroneously enters an active taxiway. As discussed earlier collision risk grows quadratically with ***traffic levels***. As discussed in other parts of the report runway ***exit geometry*** can influence the likelihood of incursions. The IRSIP analysis shows that ***exit placement*** can change the likelihood that a departing aircraft is able to fly over an aircraft that has entered an active runway. ***Fleet mix*** may potentially influence collision risk as discussed under an earlier question and elsewhere in this report. Finally, ***technology***, e.g. ASDE-X, AMASS and RWSL, ***signage*** and ***runway complex architecture***, which are analyzed extensively elsewhere in the report, clearly impact incursion risk.

15.7. Why has the South Airfield historically been subject to substantially more runway incursions than the North Airfield?

Prior to the introduction of the centerline taxiway on the South, the rate of incursions on the South airfield was substantially greater than on the North. If one goes back to 1998 the difference in rates was about three to one; if one starts with 2002, the rate was closer to two to one. We have identified three factors that could contribute to this difference.

Exit locations and relative gate locations: The old South Complex had multiple high-speed exits (J, K, M) that led across the inboard runway directly to heavily used gate complexes. This configuration could potentially have led pilots to focus on getting to a gate quickly and possibly ignore the fact that they were crossing the (possibly active) inboard runway. By contrast the North Complex exits, with the exception of Y, tend to lead aircraft away from busy gate areas. While taxiway Y on the North does directly face a busy gate area, it has experienced a single incursion since 1998. A likely reason for this low incursion rate is that it requires an acute turn forcing aircraft to slow down and it allows pilots a clear line of vision toward the inboard runway threshold.

Presence of facilities and a taxiway on non-terminal side of runway complex: A very significant difference between the North and South runway complexes is that the South Complex has cargo and general aviation facilities on the South (non-terminal) side of the runway complex. In addition, there is also a parallel taxiway (A) to the South of the parallel runways. No such equivalent facilities exist on the North. An examination of incursion files reveals that several incursions on the South involved aircraft traveling to or from those facilities and/or taxiway A.

Traffic differences: The South Runway complex has historically had slightly higher traffic levels than the North. While the difference is relatively small, considering the quadratic growth in incursion risk with traffic, it could account for a noticeable (but small) difference in incursion rates.

15.8. Is there a relationship between the LAX North Airfield and South Airfield operations and the risk of incursions at the airport in general? If so, is this relationship a safety issue or problem?

The principle that says collision risk grows quadratically with traffic levels implies that risk is minimized by balancing traffic between the two runway complexes. It appears that the slight imbalance in traffic distribution between the North and South has caused a slight increase in collision risk. It is also certainly the case that congestion in the terminal area, and on taxiways B and E, can add challenges to the crossing of arriving aircraft over the inboard runway. This certainly can be detrimental to incursion (and collision) risk.

15.9. Will the planned airline fleet of aircraft have an impact on the LAX North Airfield operations? If so, is this a safety issue or problem?

It is certainly the case that a growth in the percentage of larger aircraft, especially Group VI, will impact operations on the North Airfield. Under the Baseline and 100-North alternatives, Group VI aircraft will require special handling. We investigated the extent to which larger aircraft are more likely to be involved in runway incursions and found the representation of Group V aircraft and heavy aircraft match their representation in the fleet, indicating larger aircraft do not have a higher incursion risk than others. It is also possible that incursions involving larger aircraft may be more likely to lead to collisions. While arguments for this are plausible, given the special operational procedures required for various alternatives, we feel that any risk differential among North Airfield alternatives relative to changes in the fleet mix is small.

16. GEOMETRIC DESIGN ISSUES

This section describes relevant aspects of airport geometric design considered in the safety analyses presented in Sections 6-12. This section ends with general airport design recommendations compiled during the conduct of the study.

16.1. Geometric Design Considerations and Aircraft Maneuvering for Centerline Taxiway Alternatives

The Academic Panel studied the geometric design implications of various alternatives and their impact in aircraft maneuvering and visibility while crossing an active runway. This discussion is important in the context of the high variability observed in the runway incursion rates of the North airfield runway exits (see Chapter 7). The ability of an aircraft to maneuver efficiently in the taxiway is of paramount importance in the design of any runway-taxiway configuration. Runway exit geometry could be linked to runway incursion rates as shown in Section 7 of the report. To understand the maneuvering capabilities of large aircraft in various airport configurations we used aircraft manufacturer data (Boeing, 2010; Airbus, 2008) to verify visibility angles and critical sight distances for various configurations in the North airfield. Table 16-1 lists relevant dimensions of the critical aircraft operating at Los Angeles International Airport. The table contains data estimated by the AP Panel for a stretch version of the Airbus A380 (called A380-900). Note that some vehicles are critical than others in one dimension. For example, the Airbus A340-600 has the longest wheelbase whereas the Airbus A380-800 has the tallest tail.

Figure 16-1 contains the definitions of two critical parameters examined in this analysis: 1) turning angle at the hold line and 2) critical sight distance from the reference eye position in the flight deck. Both parameters are important to verify if a departing aircraft is taking off from a runway to be crossed. While technologies such as runway status lights and ASDE-X and AMASS at LAX warn pilots and air traffic controllers of a potential runway incursion blunder, human visual inspection becomes the last condition to avoid a runway incursion.

Table 16-1: Critical Dimensions of Aircraft Operating or Expected to Operate at Los Angeles International Airport. Sources: Boeing Commercial Co. and Airbus Documents for Airport Design.

Aircraft	Overall Length (ft)	Overall Height (ft)	Wheelbase (feet)	Wheeltrack (feet)
A340-600	228.9	58.8	112.1	35.1
A380-800	238.1	80.1	104.6	40.9
B747-400	231.8	64.0	84.0	36.1
B777-300	239.8	61.5	102.0	36.0
B747-8	250.2	71.0[2]	97.4	36.1
A380-900	258.0	80.1	112.0	40.9

Figure 16-1 clearly indicates that in ideal conditions, pilots should have good visibility angles (i.e., total visual angle) to recognize a potential threat departing in an inboard runway. Similarly, distance (ds) is critical for pilots to be able to see potential traffic at long distance on the runway. The critical sight visibility distance (**ds**) is measured from the datum position of the pilot's seat. Pilots have limited movement in their seat (assuming their shoulder belts are unbuckled). This implies that pilots can achieve wider visual angles if unbuckled and move forward and close to the side windows. The critical sight distances represent the maximum distance (in the horizontal plane) that a pilot can see seated in the datum position of its seat (without doing any unusual movements).

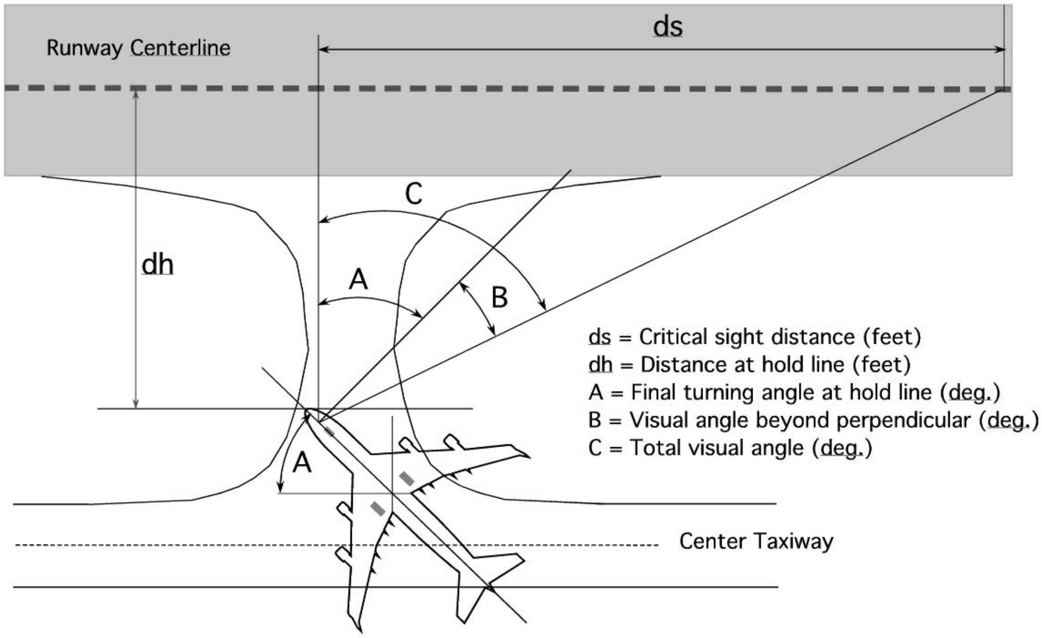


Figure 16-1: General Aircraft Maneuvering Envelope, Visibility Angles and Critical Sight Distance.

Baseline Configuration

The Baseline configuration at LAX offers a wide array of visual angles and critical sight distances at four runway exits used in West-flow operations. Table 16-2 lists the angles for each runway exit on Runway 24R. Table 16-2 indicates that visibility and critical distance (ds) are limited if an aircraft holds between Runways Runway 24L and 24R. The critical sight distances calculated by the Academic Panel are around 500 feet for Zulu and around 700 feet for Alpha-Alpha. Incidentally, Zulu and AA have the highest runway incursion rates (34.2 and 12.6 incursions per million landings, respectively) of all runway exits in the North. Figure 7-3 shows the runway incursion rates for individual runway exits.

As LAWA embarks in building new high-speed runway exits in the North airfield as part of the Interim Plan, it is important to pay special attention to the geometric design aspects (i.e., design exit speed, centerline geometry, runway exit width, etc.) of the junction between Runway 24L and the new exits. Noteworthy in Table 16-2 is taxiway Yankee. Yankee has had one incursion in 12 years. This suggests that careful attention should be paid to the geometric design aspect of the new runway exits suggested for IRSIP to avoid high RIR rates as in the current taxiway Zulu.

Table 16-2: Turning and Visibility Angle Analysis for the Baseline Alternative. Academic Panel Analysis Using Boeing Commercial Co. and Airbus Documents for Airport Design.

Runway Exit	***Final Turning Angle and Hold Line (deg.) A***	***Visual Angle Beyond Perpendicular (deg.) B***	***Total Visibility Angle (deg.) C***	***Critical Sight Distance - ds (feet)***
Yankee	135	44*	189**	Unlimited***
Zulu	30	31**	61	507
Alpha-Alpha	37	31**	68	696
Bravo-Bravo	89	35	134	Unlimited***

* Critical aircraft is Boeing 737-700
** Critical aircraft is Airbus A380-800
Estimated by Academic Panel using Boeing and Airbus airport design documents
*** Unlimited in CAVU (Clear Air Visibility Unlimited) conditions

Configurations with Center Taxiways

The configurations with center taxiways provide operational advantages over the Baseline configuration in the North airfield. These advantages been stated in Sections 8, 9 and 10 of the report. Of special interest in the geometric design analysis is the estimation of turning angles at the hold line and the critical distance (ds). Table 16-3 shows a comparison of the turning angles for configurations 100-North and 340-North/340-South. The angular difference between configurations 340-North and 340-South and 100-North averages 32 degrees. The impact of this difference in terms of critical sight distance is demonstrated later in this section. A scale drawing of the turning maneuvering envelopes for the Airbus A380-800 are shown in Figures 16-2 and 16-3 for configurations 100-North and 340-North/340-South, respectively.

Figure 16-2 illustrates an Airbus A380-800 making a turn from a center taxiway located 400 feet from the runway centerline. The diagram clearly indicates that visibility is restricted because the aircraft turns 38 degrees before stopping at the hold bar. The diagram shows the hold bar to be located 281 feet from the runway centerline. The turning angles improve for Boeing 777-300ER and Boeing 747-400 but not by much (3-5 degrees).

Table 16-3: Final Turning Angles at Hold Line Locations for Two LAX Centerline Taxiway Alternatives. Academic Panel Analysis Using Boeing Commercial Co. and Airbus Documents for Airport Design.

Aircraft	*100-North Turning Angle (deg.)*	*340-North/340-South Turning Angle (deg.)*	*Angular Difference (340-North/South – 100-North) (deg.)*
A340-600	39	72	33
A380-800	38	68	30
B747-400	42	73	31
B777-300	40	74	34

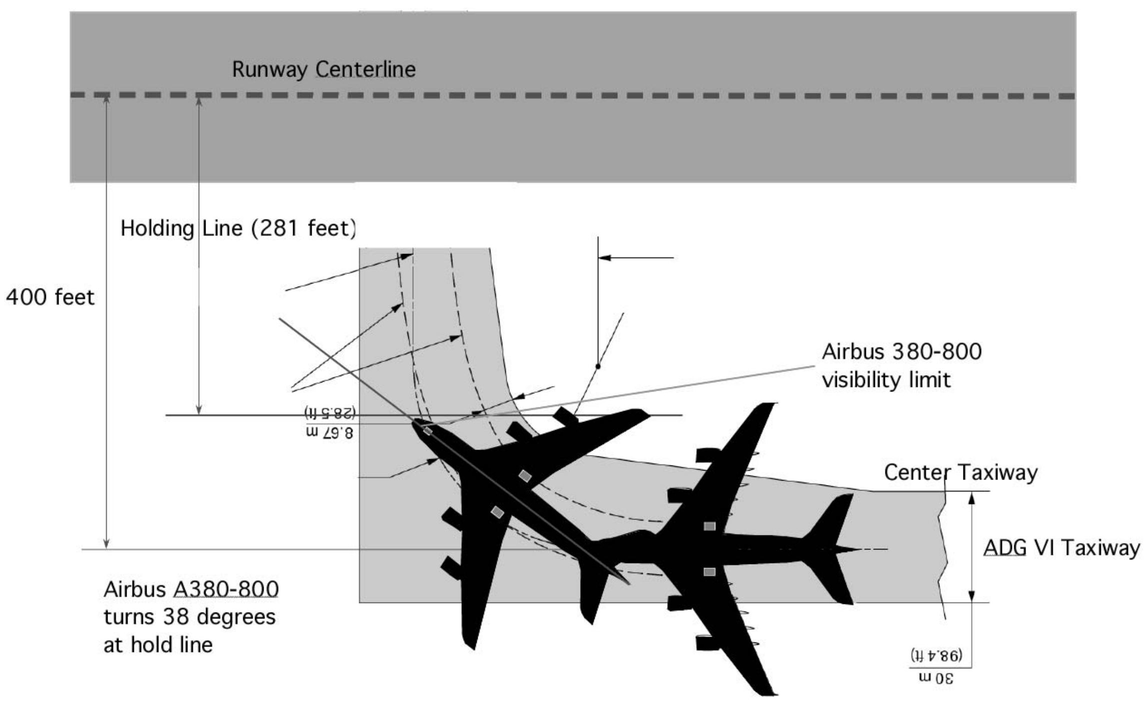


Figure 16-2: Airbus A380-800 Maneuvering Envelopes: 100-North Alternative Source: Airbus Document for Airport Planning with Adaptations by Academic Panel (2009).

Figure 16-3 illustrates an Airbus A380-800 making a turn from a center taxiway located 520 feet from the runway centerline for configuration 340-North. The diagram clearly indicates that visibility is greatly improved because the aircraft turns 68 degrees before stopping at the hold bar. The new visual angle should allow pilots to be more alert of the traffic on an inboard runway.

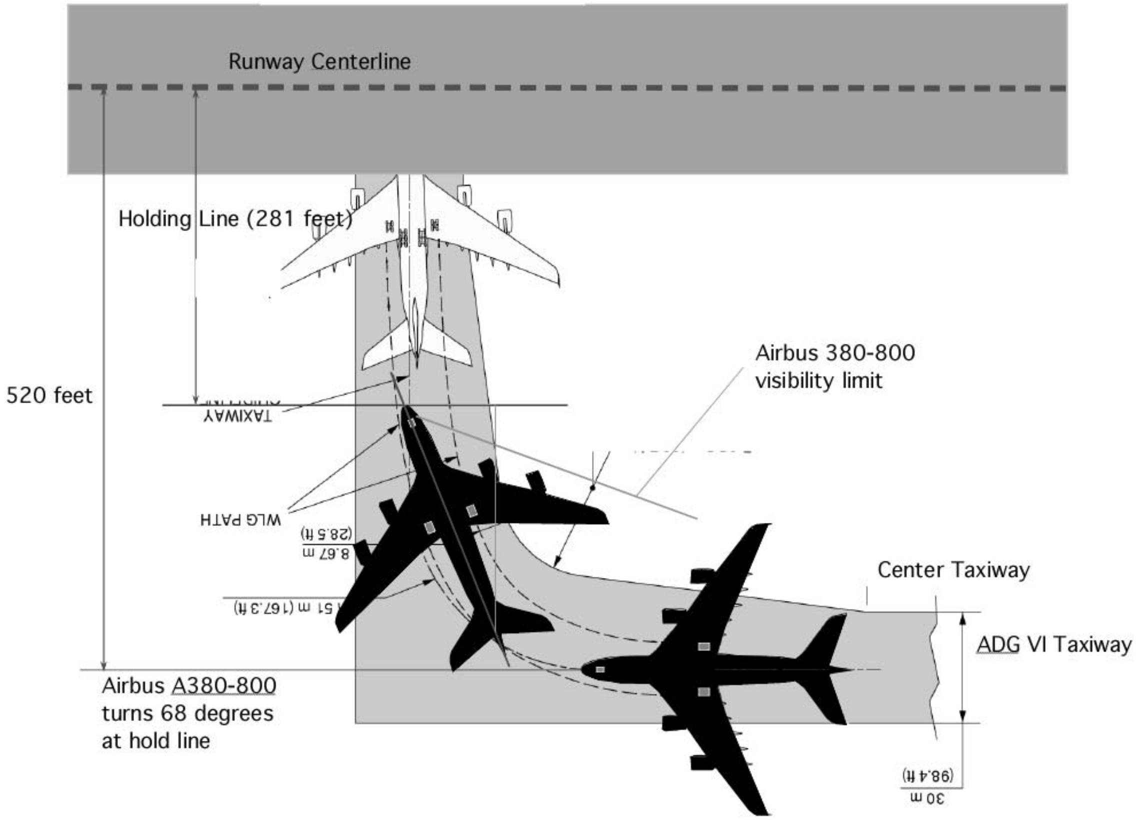


Figure 16-3: Airbus A380-800 Maneuvering Envelopes: 340-North or 340-South Alternatives. Source: Airbus Document for Airport Planning with Adaptations by Academic Panel (2009).

Alternatives 340-North and 340-South clearly offer pilots better visibility conditions to monitor runway activity and provides them with improved situational awareness to cross an active runway. The pilot's visibility from super-heavy aircraft (i.e., Airbus A380) is limited to 121 degrees (31 degrees beyond the perpendicular). The Boeing 747-400 aircraft has the highest visibility angle of all the critical aircraft studied (145 degrees). For the Boeing 747-400 aircraft, even negotiating right angle taxiways from the centerline taxiway in the 100-North alternative, the aircraft has an unlimited critical sight distance due to its large horizontal field of view.

Pilots can still achieve higher visual angles if they unbuckle and move closer to the lateral windows for all the alternatives. However, the provision of adequate visibility is of paramount importance in airport geometric design. This might well serve as the last line of defense against runway incursions – when other primary and secondary systems such as ASDE-X, AMASS, and Runway Status Lights fail to provide ample warning of the impending incursion.

Tables 16-3 and 16-4 present the critical angles and critical sight distances estimated for all four critical aircraft flying into LAX. According to our calculations, the Airbus A380-800 has the smallest visibility angle and the shortest critical sight distance (~700 feet). Tables 16-3 and 16-4 demonstrate the critical sight distance visibility gains moving from 100-North to 340-North or 340-South. For both 340-North and 340-South, the pilot's of very large aircraft, including ADG VI aircraft, would have unrestricted view of the departures on the inboard runway (see Table 16-4). In this case, any visibility restriction would be due to environmental effects (i.e., weather) and not due to geometric design limits.

Table 16-4: Turning and Visibility Angle Analysis for 100-North Alternative. Academic Panel Analysis Using Boeing Commercial Co. and Airbus Documents for Airport Design.

Aircraft	***Final Turning Angle at Hold Line (deg.) A***	***Visual Angle Beyond Perpendicular (deg.) B***	***Total Visibility Angle (deg.) C***	***Critical Sight Distance (feet) ds***
A340-600	39	45	84*	2677
A380-800	38	31	69	732
B747-400	42	55	97	Unlimited**
B777-300	40	35	75	1049

* Estimated by Academic Panel

** Unlimited in CAVU (Clear Air Visibility Unlimited) conditions.

Table 16-5: Turning and Visibility Angle Analysis for 340-North Alternative. Analysis by Academic Panel.

Aircraft	*Final Turning Angle at Hold Line (deg.)* A	*Visual Angle Beyond Perpendicular (deg.)* B	*Total Visibility Angle (deg.)* C	*Critical Sight Distance (feet)* ds
A340-600	72	45	117*	Unlimited**
A380-800	68	31	99	Unlimited
B747-400	73	55	128	Unlimited
B777-300	74	35	109	Unlimited

* Estimated by Academic Panel

** Unlimited in CAVU (Clear Air Visibility Unlimited) conditions.

16.2. General Design Issues Identified for the North Field

During this study several recommendations emerged from comments made by air traffic controllers, pilots and the Academic Panel's own observations. The following list is a series of recommendations that will be expanded in the final version of the report:

1) For all center taxiway configurations, provide a full parallel taxiway Kilo to Runways 24R and 24L,
2) The single-lane design of Taxiway Echo-7 should be revised allowing air traffic controllers more flexibility in departure sequencing,
3) The stagger of thresholds 24R and 24L in the center taxiway configurations requires air traffic controller's careful management of wake vortex, separations. This adds workload and reduced departure separation capacity.
4) The runway exits for airfield configurations with a center taxiway should be optimized in the same way as 3R,
5) Three high speed runway exits are recommended for all center taxiway configurations and West-flow arrivals,

6) Two optimal high-speed runway exits should be provided for East-flow arrivals

7) Runway safety areas need to be protected for all runway ends,

8) Careful design work is needed for crossing taxiways in all center taxiway configurations. The crossing taxiways were placeholders and not optimized in relation with the high-speed runway exits provided on Runway 24R, and

9) Careful attention should be paid to the geometric design aspect of the new runway exits suggested for IRSIP to avoid high RIR rates as in the current taxiway Zulu.

17. SUMMARY AND CONCLUSIONS

The primary aim of the North Airfield Safety Study was to estimate, as specifically as possible, the level of future safety of several alternate configurations of the LAX North Airfield. An auxiliary goal was to provide useful information about the capacity implications of the various configurations, in light of projections about LAX traffic levels in 2020.

A central component of the study was a human-in-the-loop simulation exercise, conducted during August 2009 at the NASA-Ames FutureFlight Central (FFC) facility in Mountain View, California. But the study also relied heavily on empirical evidence about runway safety and capacity, based on historical experience at LAX and elsewhere. The Academic Panel (AP) took careful note of the changes completed in 2008 on the LAX South Airfield, which moved the two parallel runways 100 feet further apart and created a centerline taxiway between the runways.

The principal conclusions of the study can be summarized as follows:

The North Airfield of LAX is extremely safe under the current configuration. Changes to the configuration could create even greater safety, but they would be expected to reduce only slightly the overall risk that LAX air travelers face in their journeys. (That overall risk level is itself minuscule because air travel is exceedingly safe.) Considerations of capacity appear to make some alterations to the North Airfield less attractive, and others – particularly the option of moving Runway 24-R 340 feet North – significantly more so. But the AP believes that it would be difficult to argue for reconfiguring the North Airfield ***on safety grounds alone*****.**

17.2. The Alternative Configurations

The study focused on five possible configurations of the North Airfield, including two variants of the existing layout:

(1A) Baseline: The existing configuration, in which runways 24L and 24R are separated by 700 feet, with no centerline taxiway between them.

(1B) Baseline with Interim Runway Safety Improvement Project (IRSIP): The existing configuration, but with changes to the taxiways leading from runway 24R so that planes landing on 24R would cross runway 24L closer to its west end.

(2) 100-North: The "100-North" alternative would create on the North Airfield essentially a mirror image of the new arrangement on the South Airfield. Runway 24R would be

moved North by 100 feet, and a centerline taxiway placed between runways 24L and 24R.

(3) 340-North: The "340-North" alternative would move runway 24R 340 feet to the North and create a centerline taxiway between runways 24L and 24R.

(4) 340-South: The "340-South" alternative would move runway 24L 340 feet to the South and create a centerline taxiway between runways 24L and 24R. This option would entail the demolition of existing Terminals 1-3 and the construction of a new "linear" terminal facing the North Airfield.

(5) 3R: The "3R" alternative would reduce the total number of runways at LAX to three by replacing runways 24L and 24R with a single Runway 24, which would handle most of the airport's Group V and VI aircraft, while smaller planes were concentrated on the South Airfield.

17.3. The FFC Simulation and the Available Data

The Panel was fortunate to have a wealth of information generated by the real-time simulations at NASA-Ames. Actual controllers oversaw simulated landings and takeoffs at LAX (on both the North and South Airfields), during busy hours based on 2020 traffic forecasts prepared by Ricondo Associates. Three visibility conditions were explored in different hours: Daytime Visual, Daytime Instrument, and Night Visual. Across the simulation hours, the number of Group VI aircraft – the grouping with the largest existing airplanes, namely, the Airbus 380 and the Boeing 747-8 – varied from two to six, in order to capture a range of possibilities about the extent of their presence at LAX. Some of the landings were performed by actual pilots in Boeing 747-400 flight simulator, while other aircraft were landed by "pseudo-pilots" using a computer-based interface.

Several types of information were derived directly or indirectly from the simulation. After the sessions, intensive oral and written interviews were conducted with both pilots and controllers. Moreover, some "anomalies" were introduced into the simulation to provide a perspective on how well the controllers were coping with heavy and diverse traffic. For example, some pseudo-pilots were asked deliberately to read back controller instructions incorrectly, to see whether the controller noticed and reacted to the error. In addition, data were available about the frequency and duration of transmitted messages between pilots and controllers. This information offers some insight about controller workload.

At the same time, the Panel considered information from many other sources, including:

- FAA projections about the national risk of fatal runway collisions in 2020
- FAA assessments about the accident-reduction potential of new technologies, such as the ASDE-X radar and Runway Status Lights (RWSL)
- The history of runway incursions on both the South and North Airfields of LAX
- The runway incursion history at other US airports besides LAX
- Worldwide historical data about casualty patterns in fatal runway collisions
- Worldwide historical data about runway excursions, in which a single aircraft deviates sharply and suddenly from its intended path
- Data about easterly arrivals at LAX, which were not included in the NASA simulation

17.4. Findings about Safety

The main findings of the study concerning the safety characteristics of the various alternatives will be summarized next. Detailed descriptions of the analysis for each of the alternatives are provided in Chapters 6–11.

17.4.1. The Baseline Case

After much analysis, the AP unanimously concluded that the existing North Airfield will be extremely safe even under traffic levels projected for 2020. More specifically:

The AP estimates that, at 2020 traffic levels, fatal runway collisions on the existing North Airfield would occur on average approximately once every 200 years.

A quick synopsis of the reasoning is as follows:

1. Various FAA studies imply that, at 2020 traffic levels, fatal runway collisions would occur at *some* towered US airport once every eight years.

2. This estimate assumes high effectiveness for new technologies like AMASS (Airport Movement Area Safety System) ASDE-X radar and Runway Status Lights. (LAX South is one of the very few US airports that have all three technologies.) Thus far, the FAA's optimism has been justified by events: major runway incursions in the US dropped 80% between Fiscal 2000 and Fiscal 2009 (from 67 to 12). Furthermore, there have been no fatal runway collisions anywhere in the US since March 2000, and the accident on 2/2/91 at the LAX North Airfield –

nineteen years ago – was the last collision at a towered US airport that caused deaths to scheduled airline passengers.

3. To be conservative, the AP estimated that fatal runway collisions would occur at 2020 traffic levels once every four years, rather than every eight. In effect, the AP was assuming twice the level of collision risk estimated by FAA.

4. But if a fatal runway collision occurred at 2020 traffic levels at one of the US towered airports, what is the chance it would take place on the LAX North Airfield rather than elsewhere? The AP made eight different estimates of this probability, based on:

- The runway incursion history at LAX-North relative to that for the entire US
- The LAX-North share of squared traffic levels in the US, a metric that figures prominently in FAA risk models
- Safety levels at other US airports that pilots in the NASA-Ames simulation considered equally safe with LAX-North (the "peer airports"). These peer airports included Atlanta, San Francisco, Miami, and New York-JFK.

5. The eight estimates of the chance that a fatal runway collision that took place in the US would occur at LAX-North ranged from a low of 1 in 140 to a high of 1 in 60. To be conservative, however, the AP estimated as 1 in 50 (2%) the probability that the venue would be LAX-North. In other words, the AP used a risk estimate for LAX-North that was higher than any that arose under its diverse estimation methods.

The Panel also explored whether the growing frequency of Group VI aircraft on the North Airfield might pose incremental collision risk, and concluded that it would not. A major reason for this conclusion is that Group V aircraft (the largest planes for which historical data exist) have not been involved in incursions at LAX to a disproportionate extent.

The Panel then combined its numerical risk estimates:

- if fatal runway collisions occurred once every four years at some towered US airport and 1 in 50 of these collisions took place at LAX-North, it then follows that fatal runway collisions at LAX-North would occur every 4x50=200 years.

Using the "one in every 200 years estimate," plus estimates about the casualties in a fatal runway collision at LAX North, as well as data about LAX passenger traffic around 2020, the AP reached a further approximation:

At 2020 traffic levels, the Panel estimates that fatal runway collisions at LAX-North would claim approximately five lives per decade.

Because of the margin of error associated with this estimate, a range estimate for the actual rate extends from a low of one death per decade to a high of eight deaths per decade.

Given that roughly 750 million passengers would use LAX each decade at 2020 traffic levels, the figure "five deaths per decade" works out to one death per 150 million passengers.

The statistic "one in 150 million" is obviously small in absolute terms. It is also extremely small relative to other accident risks that Los Angeles residents and others face: for example, an American baby born today has approximately a 1 in 100 chance of eventually dying in an automobile accident. Moreover, the risk is small even relative to the exceedingly low risks of passenger air travel: the death risk per flight for US air travelers is approximately 1 in 10 million, which is fifteen times the risk that the LAX-North runways would present in the Baseline case.

17.4.2. The Interim Improvements to the North Airfield (IRSIP)

The AP explored evidence about whether IRSIP would improve North Airfield safety by requiring planes landing on Runway 24R and heading towards terminals to cross Runway 24L further down the runway. The AP estimates that the plan (IRSIP) could increase the chance that a departing aircraft on 24L would already be airborne if a landing plane blunders onto the takeoff runway (from approximately 33% to approximately 51%). But the probability that a landing plane blunders onto 24L in the first place might not decrease significantly if the new runway exits proposed in IRSIP induce the high runway incursion rates associated with taxiways Zulu and AA. Indeed, for planes that now use Taxiway Yankee, the data suggest that the risk of incursion might well go up. Thus, it is possible that closing Taxiway Yankee would do more harm than good, and the matter warrants further study.

17.4.3. Moving Runway 24R 100 Feet North (100-N)

Because such a proposal would essentially replicate on the North Airfield what has already been done on the South Airfield, the AP put considerable weight on evidence about whether incursions have dropped on the South since its reconfiguration. While only about 18 months of data are at hand about safety under the new arrangements, they suggest that the changes have reduced incursion risk on the South by about 40%. The apparent reason for the improvement is the new centerline taxiway, which causes landing planes to slow down before crossing the takeoff runway and which gives controllers greater flexibility in deciding when and where planes landing on Runway 25-L should cross Runway 25-R.

The AP also considered a good deal of other evidence about the effectiveness of the 100-N configuration. Data were available from the FFC simulations about anomalies and radio communications between tower and pilot, as well as survey reactions from pilots and controllers. Incursions data from airports other than LAX that have configurations similar to 100-N were also studied. This review indicated that Runway Status Lights might be especially effective when accompanied by a centerline taxiway. Some of this evidence suggested that the benefits of 100-N would exceed the 40% suggested by South Airfield data, while other evidence suggested a benefit smaller than 40%. The AP concluded that, on balance:

40% is a reasonable estimate of the reduction in the risk of a fatal runway collision if the existing North Airfield were replaced by a 100-N configuration.

17.4.4. Moving Runway 24R 340 Feet North (340-N)

The AP considered various data about this option, which has the distinguishing feature that its centerline taxiway is far enough from the active runways that Group VI aircraft need not require special treatment. The reconfiguration would also allow some landing pilots crossing 24R to get a better view than otherwise of departing traffic.

The AP concluded that 340-N reduces collision risk relative to 100-N, but not by an enormous factor (perhaps 25%). Much of the benefit of introducing a centerline taxiway would already be achieved with the 100-N configuration. The AP believes that:

55% is a reasonable estimate of the reduction in the risk of a fatal runway collision if the existing North Airfield were replaced by a 340-N configuration.

17.4.5. Moving Runway 24L 340 Feet South (340-S)

Operationally, this arrangement is similar to 340-N. But the AP concluded that the safety benefits would be slightly smaller, largely because the FFC simulations suggest that ground arrangements associated with revamping the terminals could get more complex and demanding for controllers. The Academic Panel believes that:

50% is a reasonable estimate of the reduction in the risk of a fatal runway collision if the existing North Airfield were replaced by a 340-S configuration.

17.4.6. Moving to a Three-Runway Airport (3R)

If there were only one runway on the North Airfield, then aircraft landing there would not have to cross a takeoff runway en route to terminals. On the other hand, the North Airfield would be continuously involved in mixed operations, in which landings and takeoffs occur on the same runway. (Mixed operations on the North Airfield would occur even under the other configurations, but to a much lesser extent.) Results from the FFC simulations and data about other US airports that extensively conduct mixed operations suggest that a three-runway configuration would largely achieve the safety benefits for which its proponents hope. The AP believes that:

50% is a reasonable estimate of the reduction in the risk of a fatal runway collision if the existing North Airfield were replaced by a single Runway 24 under a three-runway configuration for LAX.

17.5. Capacity Assessment

The AP was asked whether any limitations of airport capacity under individual configurations of the North Airfield would “unduly impact” the ability of LAX to handle the volume and mix of air traffic projected for 2020. Here the experiments and NASA-Ames provided illuminating data about how many departures could be achieved under peak traffic conditions, as well as taxi-in and taxi-out times for, respectively, arriving and departing aircraft. Across the simulation hours, there were variations in weather and visibility conditions and in the number of Group VI aircraft, allowing a clearer picture of the sensitivity of capacity findings to the background assumptions.

The AP concluded that the baseline, 100-N, and 340-S configurations could handle even peak traffic without “unduly” suffering stress and delay. It is noteworthy that, in 2000, when daily operations at LAX were only about 5% below the level projected for 2020, the airport fared quite well.

In the 340-N configuration, however, there was conspicuous improvement in capacity over the baseline and 100-N cases. The AP estimates an annual cost savings of $15 million just because of the reduction in taxiing times and runway blocking operations. The gain in departure capacity would be modest (perhaps four additional operations per hour), but it would open the door to reduced arrival delays. (The study did not estimate the size of this benefit.) In addition to the capacity gain, having a centerline taxiway allows greater flexibility in handling aircraft, a benefit that is especially helpful in unexpected conditions. Furthermore, pilots who land on

Runway 24R in 340-N would often have a better view of departing traffic on Runway 24L before crossing that runway.

The capacity results for the three-runway configuration were less encouraging: the reduction in arrivals and departures observed at FFC could have adverse direct and indirect consequences. Given that mixed operations would occur on the North Airfield (i.e., landings and takeoffs on the same runway), arranging for departures in the face of frequent arrivals would be challenging. It is also true that unexpected conditions – such as the temporary shutdown of a runway – can cause considerably more disruption when there are only three runways rather than four. The AP fears, therefore, that the capacity limitations in the three-runway case would be unduly constraining in peak conditions, which would prevail for nine hours of the day under the 2020 forecast.

17.6. Caveats

The various estimates summarized above and presented in more detail elsewhere in this report should be interpreted as plausible approximations, rather than exact results. Among the reasons for caution are:

- The 2020 forecasts about traffic levels at LAX, and about the fraction of traffic involving Group VI aircraft, are subject to considerable uncertainty.
- The experiments at FFC were sophisticated and well conducted, but they can only provide an approximate indication of what might happen under various configurations of the North Airfield.
- Data about historical experience are valuable, but there are issues in generalizing from other airports to LAX, and from past patterns to those that might prevail in the future under new arrangements; moreover, many of the data are subject to the high random variability associated with rare events, a circumstance that poses real challenges for statistical estimation.

17.7. Main Conclusions

The AP is unanimous on all of the following points:

For projected 2020 traffic levels and traffic mix, the LAX North Airfield is extremely safe under the current configuration.

The AP estimates that, at 2020 traffic levels, fatal runway collisions would occur on the North Airfield at an expected rate of one every 200 years, and that such fatal collisions would cause approximately one death for every 150 million LAX passengers. That level of risk is low even relative to the exceptional safety of US passenger aviation.

All the proposals to create new configurations on the North Airfield would reduce by a substantial percentage the risk of a runway collision.

More specifically, the evidence from the NASA-Ames simulation and numerous kinds of historical data suggest that:

Moving Runway 24R 100 feet North and creating a centerline taxiway could reduce collision risk on the North by about 40% relative to the baseline.

Moving Runway 24R 340 feet North and creating a centerline taxiway could reduce collision risk on the North by about 55% relative to the baseline.

Moving Runway 24L 340 feet South and creating a centerline taxiway could reduce collision risk on the North by about 50% relative to the baseline.

Creating a single Runway 24 to replace 24L and 24R could reduce collision risk by about 50% relative to the baseline.

However, because the baseline level of collision risk is so low, reducing that risk by a substantial percentage will have a limited practical effect.

Aviation at LAX is exceedingly safe. Of the 750 million passengers who would use the LAX North Airfield per decade at 2020 traffic levels, only about 80 might be expected to perish in air disasters from all causes in the Baseline case. Of these 80 deaths, five might occur in runway collisions on the North Airfield. Reconfiguration of the North runways might be expected to reduce total deaths to about 78.

In terms of capacity, changes in the configuration could have major effects.

Moving to a three-runway configuration could cause major difficulties, in terms of flight schedule reliability and congestion, even under visual flight conditions.

Moving to the 340-N configuration, on the other hand, might significantly reduce airport congestion during peak hours and could provide appreciable capacity benefits.

Indeed, a serious case could be made for building 340-N based on its capacity benefits. This would also improve safety. But these safety benefits would essentially be a “side benefit”, not the principal one.

However, the North Airfield Safety Study was, as the name implies, primarily about safety. All things considered, the Panel cannot construct a compelling argument for reconfiguring the North Airfield on safety grounds alone.

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Los Angeles International Airport North Airfield Safety Study

Addendum to Final Report

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May 14, 2010

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1. CRITIQUES OF THE NORTH AIRFIELD SAFETY STUDY AND RESPONSES TO THEM

After the preliminary version of the North Airfield Safety Study was released on February 19, 2010, eight letters were written about it. These letters were dispatched by:

Air Line Pilots Association
Alliance for a Regional Solution to Airport Congestion (ARSAC)
City of El Segundo
Cities of Inglewood and Culver City
Federal Aviation Administration
LAX Airline Airport Affairs Committee
LAX-TEC
Los Angeles International Airport Advisory Committee

In addition, the *Los Angeles Times* wrote an editorial about the study titled "Redefining Safety at LAX," which appeared on February 23, 2010.

In this addendum, we present these nine commentaries in the entirety. We then offer the Panel's reaction to the letters; when the Panel decided not to change its report despite comments in the letters, we generally explain why. We did make some changes to the report in response to the letters, including correcting some errors that eluded us in preparing the report but did not escape careful readers.

Our treatment of the individual letters/critiques varies a bit. The Panel prepared a detailed response to the FAA critique, believing that doing so was important to the credibility of the study. That response appears here in its entirety. So does the Panel's response to the *Los Angeles Times* editorial. For other letters, we prepared brief chapter-by-chapter discussions about points that were raised, identifying the sources of individual comments. Many comments concentrated on our baseline risk estimates for the North Airfield under its existing configuration at 2020 traffic levels.

The Panel decided not to attempt a detailed response to the letter from ARSAC. Many of the requests in that letter go beyond the scope of the Panel's responsibilities; to the extent that others fall within those responsibilities, we have tried to answer them in the report.

We are grateful for the efforts that the letter-writers made to assist us in improving the report. The discussion about North Airfield safety is richer and clearer because of these letters and also, we hope, because of the responses that they provoked.

2. RESPONSE TO FAA COMMENTS

April 21, 2010

Ms. Gina Marie Lindsey
Executive Director,
Los Angeles World Airports
Los Angeles, CA 90045

Dear Gina Marie:

The FAA has done an outstanding job of advancing aviation safety in the United States. For that reason, we—the authors of the LAX North Airfield Safety Study—take extremely seriously the concerns raised by FAA about the analysis we presented in February 2010. We wanted to report to you in detail what we concluded after reviewing FAA's comments, so that you can make your own judgment about the cogency of our study.

The FAA's concerns center on our risk estimates in the baseline case, under which the north runways at LAX would remain where they are. We estimated that, at traffic levels projected for 2020, fatal collisions would occur on the North Airfield on average once every 200 years, and would cause the deaths of one of every 150 million LAX passengers. *After reviewing the FAA critique of our study, we see no reason to amend our estimates.* We disagree with the assessment that our work suffered from "several critical flaws in the study's assumptions, methodology and conclusions" We continue to believe that our analysis was logical, accurate, and conservative.

We reach these conclusions for five primary reasons:

- The North Airfield Safety Study relied heavily on work performed by FAA. We used FAA effectiveness studies about new runway technologies, FAA models for the distribution of runway risk across US airports, FAA data about the time and place of runway incursions, and FAA severity classifications for individual incursions. Despite its negative tone, the critique does not identify *any* instances in which we applied FAA methodologies inappropriately or cited FAA data erroneously.

- Data analyses in the critique that are said to contradict our findings also contradict the FAA's own methods and findings related to runway safety.
- Incursion data and other evidence suggest that the existing North Airfield at LAX is just as safe as the South Airfield with its new centerline taxiway.
- Since completion of the centerline taxi on LAX-South in mid-2008, both LAX- North and LAX-South match or outperform the incursion records of Atlanta, Chicago O'Hare, and Dallas-Fort Worth, three airports cited in the FAA critique as safer than LAX.
- Many comments in the critique are not relevant to assessing the *absolute* level of safety on LAX North Airfield, a quantity we were specifically asked to estimate.

We amplify on these comments below, but postpone detailed responses to many individual FAA comments to an Appendix.

The Baseline Risk Estimate

We reached our baseline risk estimate by considering in turn three questions:

- At 2020 traffic levels, what will be the average frequency of fatal runway collisions at towered US airports as a group?
- Given that a fatal runway collision occurred under 2020 traffic levels at a towered US airport, what is the probability that it would occur at LAX North Airfield rather than elsewhere?
- Given a fatal runway collision on the LAX North Airfield, what number of deaths might be expected?

As we understand the FAA critique that accompanied Administrator Babbitt's letter, the FAA did not disagree with our procedures for answering the first and third of these questions. More specifically:

The critique took no issue with our estimate of the national frequency of fatal runway collisions at 2020 traffic levels.

Our national risk assessment started with the study "Fatal Runway Collisions Over the Next Two Decades," which was performed under contract with FAA and was presented to the FAA Administrator. It was published in the *Air Traffic Control Quarterly* in 2000 after a peer-review process, and estimated risk based on technologies and procedures used in the 1990's. The critique does not criticize this national-level study or suggest that we misquoted its findings.

We went on to note three major technological innovations that arose in the first decade of the 21st century: AMASS, ASDE-X, and Runway Status Lights. We cited *FAA's own safety analyses*, which estimated that, taken together, these three technologies would reduce runway collision risk by 88%. Again, FAA does not suggest that we misrepresented these studies.

We cited recent evidence that suggests that these technologies and changes in procedures have indeed improved aviation safety. Over the last ten years, category A and B runway incursions have declined by 80% at towered US airports. We pointed out that the last fatal runway incursion at a towered US airport occurred in March 2000 and that, in the ten years since that time, there has not been a fatal collision in over 500 million landings and takeoffs. FAA does not challenge the accuracy of these statistics.

Taking these factors together, we estimated that, at 2020 traffic levels, fatal runway collisions at towered US airports would occur on average every four years. That estimate was conservative, and applied nothing more than simple arithmetic to the information we cited above.

Nor does the critique take issue with our estimate of the consequences of a fatal collision on the LAX North Airfield.

We estimated that a fatal runway collision at LAX-North would cause 100 deaths. That number is *fourteen times* the average of seven deaths in US runway collisions in the last forty years, and about three times as high as the greatest death toll in an actual US runway collision (which arose at LAX in February 1991). This high statistic reflects our full awareness of a point raised in the FAA critique: if a fatal runway collision occurred at LAX-North, it would have a higher chance of involving large passenger planes than a collision at many other airports. (The critique suggests a factor-of-seven correction for this tendency (14% vs 2%), but we applied a larger factor-of-fourteen adjustment.) Our strategy was to incorporate aircraft size into the projected *consequence* of a fatal collision at LAX-North, rather than in the estimated probability of such a collision.

The critique does question some (though not all) aspects of our procedure for estimating the chance that a US runway collision would occur at LAX-North rather than elsewhere. But we consider its arguments unconvincing.

In the second stage of our analysis, we estimated the probability that a fatal US runway collision at 2020 traffic levels would occur on the LAX North Airfield rather than at another one of the roughly 500 other towered US airports. There is no definitive way to make such an estimate, so we proceeded in *eight* different ways.

Several of these approaches used *the FAA's quadratic traffic model* of runway risk, which posits (based on empirical evidence) that major runway incursions at towered US airports occur in proportion to the square of their numbers of operations. We worked with quadratic traffic shares in 2000-the recent year in which LAX's proportion of national traffic was greatest—as well as projected shares in 2020. FAA's critique does not take issue with our use of this key FAA model for distributing risk across airports; nor does it suggest that we used the model inappropriately.

Still other estimates arose from the simulation at NASA Ames. Actual Boeing -747 pilots landed in cockpit simulators in the baseline configuration at LAX North under 2020 traffic levels (and with Group VI aircraft like the Airbus 380 in the traffic mix). These pilots were asked directly to compare the safety of their landings at LAX-North baseline with the landings these pilots now perform in the same visibility conditions at other US airports. On a scale from 1 to 7, in which 1 meant "LAX-North much safer" to "LAX-North much less safe," the pilots gave LAX North an average rating of 3.65. In effect, they judged LAX-North slightly safer than the other airports as a group. Questioning revealed that these other airports included Atlanta, JFK, Dallas-Fort Worth, and San Francisco. The critique does not suggest that these pilots gave inaccurate assessments, or that it was improper to use these assessments in estimating risk at LAX-North.

But the critique does raise questions about our interpretation of recent incursion data at LAX and elsewhere. For *some* of our LAX-North risk estimates, we explored the possibility that recent incursion patterns serve as "barometers" for runway collision risk. The critique does not object to this approach; on the contrary, it uses it extensively. There was, however, a major difference between our approach and that in the critique. We made use of the FAA severity classification for every runway incursion, while the critique took the surprising position that the severity classification was irrelevant. Thus, the critique performed analyses with *total* numbers of incursions, ignoring the difference between a category A incursion—in which a collision was either narrowly avoided or actually occurred—and a category D incursion that posed "little or no risk of collision."

That convention is contrary to FAA's usual practices. An FAA Fact Sheet released on 10/8/09, for example, begins with the statement:

"The reduction in the number and severity of runway incursions is one of FAA's top priorities. The number of serious runway incursions—classified as Categories A and B—dropped by more than 63 percent from fiscal year 2000 through fiscal year 2008. In fiscal year 2009—

which ended September 30—there were 12 serious runway incursions, 50 percent fewer than in the previous fiscal year."

The sheet provided a detailed table of total A and B incursions by fiscal year. It did note in one sentence that "all categories of runway incursions were down by six percent in fiscal year 2009 versus fiscal year 2008—951 in 2009 compared to 1009 in 2008. But it was clear that FAA gave far greater weight to the trend in the few dozen serious incursions than in the nearly 1000 other incursions it did not classify as serious.

The critique challenges our assumption that technologies like AMASS and ASDE-X reduce runway collision risk at LAX-North, stating that there were three incursions per year both before and after these technologies reached LAX North. In our work, we focused on runway incursions that had appreciable potential for collisions, namely, those in categories A through C. For the years 1999-2009 that we considered in our study, such incursions at LAX North exhibited the pattenr shown in Table 1.

Table 1. Runway Incursions at Los Angeles International Airport North Airfield.

	Annual Rate of Incursions		
Period	A	B	C
Before AMASS (1999-2000)	1.00	1.00	1.00
After AMASS (2002-2009)	0.00	0.38	0.50

Table 1 shows that, of the ten A-C incursions at LAX North over 1999-2009, six of them occurred in the two years before AMASS reached LAX, including both of the Category A incursions. The rate of A-C incursions fell from three per year before AMASS to ½ per year after its arrival (i.e. by a factor of six). Yet the critique argues that AMASS brought no safety progress to LAX-North, because three serious incursions in 2000 (one A and two B's) were replaced by three category-D incursions in 2009 that entailed "little or no" collision risk. The Panel cannot take this position seriously.

And neither, apparently, does FAA. In its airport-by-airport analysis the safety benefits of AMASS, FAA used as its key safety metric the "before/after" change in the rate of A and B incursions in the years surrounding the installation. To illustrate its methodology, FAA focused on one airport: LAX. It estimated that the traffic-adjusted level of A and B incursions on the North and South airfields dropped between 59% and 66% when AMASS was introduced. *This statistic meant that AMASS brought safety benefits to LAX wholly in line with those observed elsewhere.*

The critique also noted that experience with Group VI aircraft like the Airbus 380 is so limited at this time that we cannot make direct assessments of whether they pose special risks. We agree, but we tried to cope with this issue by doing the next best thing: examining the historical record of Group V operations at LAX (i.e., we assumed that experience with the 747-400 says something about risk for the 747-800). We found no evidence that Group V planes were involved in runway incursions at LAX to a disproportionate extent. Thus, we concluded that Group VI aircraft—if given the special handling they require—would not pose incremental threats to safety. To put it another way, Group VI aircraft require special cautionary procedures, but these procedures, which are already in place at LAX, counteract the additional risk that might arise in their absence.

To summarize:

The FAA critique took issue with only one aspect of one of the three components of our baseline risk analysis for LAX North. Its objections there strike us as unconvincing and often inconsistent with usual FAA techniques for analyzing runway safety. We therefore reaffirm our confidence in our risk calculation.

The North and South Airfields of LAX

FAA is pleased that the LAX South Airfield was reconfigured in 2008 to include a centerline taxiway between its two runways, which were moved 100 feet further apart. It believes that the reconfiguration may have reduced runway incursions on the South Airfield by 80%. (We think 40% a more plausible estimate, because AMASS/ASDE-X and reduced traffic deserve some of the credit for the drop.) FAA wonders why a similar reconfiguration on the North Airfield (or one that would move the parallel runways even further apart) would not seem a natural step in making LAX safer. That is a reasonable question, and one that we certainly considered in our work. Indeed, we estimated that increasing the separation between the runways would reduce the risk of fatal runway collisions by 40-55%. But that question is separate from the question: how great was the baseline risk in the first place?

The critique pays considerable attention to the point that two runway incursions occurred at LAX-North in March 2010. But the critique did not mention something else that is apparent from a visit to the FAA website (Runway Safety Office Runway Incursion Data Base): the five LAX incursions prior to March 2010 all occurred on the South airfield, and after it received its next centerline taxiway.   Indeed, since the centerline taxiway was opened on June 24, 2008, the LAX incursion pattern is shown in Table 2.

Table 2. LAX Runway Incursions since Center Taxiway Opened in the South.

Airfield	*Runway Incursions*
South	12
North	6

Note: The “North” tally includes the 3/16/10 incursion not yet posted at the FAA website.

Nor were the incursions on the North systematically more severe than those on the South: while two planes on the North got within 3000 feet of one another on March 6, 2010, two planes got within 82 feet of each other on the South on October 25, 2009.

It is also instructive to consider the responses of air traffic controllers who took part in the NASA-Ames simulation. The controllers were asked to compare the LAX-North baseline configuration with the new South Airfield *with its centerline taxiway*. On a scale from 1 to 7, in which 1 meant “LAX North much safer” and 7 meant “LAX South much safer,” the controllers gave an average response of 4.2. In short, they judged the existing north configuration without a centerline taxiway as *about equally safe* as the south airfield with such a taxiway.

We do not mean to be critical, but the critique suffers an inconsistency. It cannot depict the new LAX South airfield as a paragon of safety and yet claim that the North—which appears just as safe as the South now—poses an unacceptable risk to LAX passengers.   If LAX North is really “not good enough,” then it follows that neither is LAX South.

Fortunately, it appears that both LAX airfields are extremely safe. The critique presents comparisons that suggest that, over 2000-09, LAX had a higher incursion rate than Atlanta, Chicago O’Hare, and Dallas-Fort Worth.   But those comparisons give heavy weight to developments on the South airfield prior to its reconstruction, a change that everyone agrees improved safety.   If we focus on the present era that started when the centerline taxiway opened on the South, the critique’s comparison looks quite different (see Tables 3 and 4). If we consider only incursions that pose collision risk (i.e., categories A-C), the picture is more dramatic as shown in Table 4.

Table 3. Runway Incursions, July 2008-December 2009

Airport	*Number of Runway Incursions*	*Rate per 100,000 Operations*
LAX	12	1.43
DFW	19	1.96
ATL	23	1.58
ORD	18	1.42

Table 4. A-C Runway Incursions, July 2008-December 2009

Airport	***Number of Runway Incursions***	***Rate per 100,000 Operations***
LAX	4	0.48
DFW	15	1.55
ATL	14	0.96
ORD	11	0.87

In light of these statistics, we would suggest that it is time to stop describing LAX as a high-risk airport. Both the North and South airfields more than "hold their own" against other major US airports.

The Critique's Other FAA Comments

As noted, we discuss in an Appendix other issues raised in the critique. Some of them do not pertain to our baseline risk estimate for LAX-North. The critique notes, for example, that several studies prior to our own have recommended moving the north runways further apart. But, as we have pointed out elsewhere[1], these studies offered no estimates of the level of risk in the baseline case. Our risk estimates are not inconsistent with previous baseline-risk estimates because there were no such estimates.

We admire FAA's achievements in runway safety and every other aspect of aviation safety, and have repeatedly praised FAA in this regard in our published work. If the FAA critique had presented valid criticisms of our analysis, then we would have hastened to make full corrections: never would concerns about "saving face" have meant anything to us compared to the imperative of saving lives. But we were charged with the task of estimating the absolute level of risk for the LAX North Airfield, and were encouraged by all parties to do nothing but tell the truth. This we have done, and this we will continue to do.

Sincerely,

All Six Members of the Academic Panel (named)

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[1] *Los Angeles Times*, Letter to the Editor, February 28, 2010

2.1. Responses to Specific Comments in FAA Critique

Below we first quote the eleven criticisms in the critique, and then respond.

1. The Academic Panel inappropriately uses an aggregate probability calculation to reach an airport-specific conclusion at LAX.

This statement does not accurately describe what we did. The first stage of our analysis was the estimation of the national risk of a fatal runway collision at 2020 traffic levels. But we did not assume that the national statistic applied to the LAX North Airfield; instead, we moved promptly to the question "if a fatal runway collision occurred in the US at 2020 traffic levels, what is the probability it would do so at LAX North rather than elsewhere?" We obtained answers to this latter question in eight different ways, all of which allowed for the possibility of a much higher risk level at LAX-North than prevailed at other airports.

We do not agree that "the rate of runway incursions (at LAX) is higher than comparable airports." As we showed earlier, the rate of incursions at LAX--both North and South--has been well below the average for Atlanta, O'Hare, and Dallas-Fort Worth since June 2008, when the centerline taxiway was completed on the South. We see little value in calculations that are dominated by events prior to June 2008, a period when everyone agrees that LAX was at greater hazard.

2. The methodology used by the Panel in determining the risk for a runway collision did not adequately consider the specific risk factors of the LAX North Airfield.

Every aspect of our LAX-North risk calculation in the baseline case was sensitive to specific risk factors there. We asked both pilots and controllers to compare baseline safety at 2020 traffic levels with that at the South Airfield or at other airports, taking account of whatever factors they thought relevant. If the specific risk factors at LAX North had led to disproportionate numbers of incursions there, that circumstance would automatically be reflected in several of our metrics for estimating its share of national collision risk.

As for more specific responses:

The LAX North Airfield risk factors (according to the critique) include:

(a) The current LAX waiver to FAA Order JO 721 O.3V, Facility Operation and Administration. This waiver was developed in response to the increasing size of aircraft that use LAX. Waiver 98- T -69D authorizes LAX to hold certain aircraft types at specific taxiway locations even though these aircraft are within the obstacle free zone and the runway safety area.

The Academic Panel had access to all FAA Modifications of Standard (MOS) for LAX and used the waivers in coordination of LAX tower supervisors and NASA to develop FFC simulation procedures. The Panel and NASA consulted with experienced LAX tower personnel on the operational procedures to handle ADG VI aircraft in the North and South airfields. The AP observed and recorded operations of ADG VI at LAX using personal computer data collection analysis, video equipment and ASDE-X display data to understand the impact of FAA MOS waivers at the airport. Before all FFC simulations, all participating controllers and pseudo-pilots were fully briefed on how the airport would be operated under each of the six configurations studied including specific handling procedures of ADG VI aircraft. Such procedures were derived from FAA MOS documents.

(b) The NASS does not address the impact of 2020 aircraft levels and traffic mix on the risk of the hazard introduced by this waiver. The 100-north and 340-north alternatives would eliminate this hazard.

The Panel considered LAX demand scenarios with increased demand levels and substantial variations of ADG VI aircraft in the mix. The analysis done by the AP Panel suggests that hazards can be mitigated but not "eliminated." Specifically a reduction of 55% in runway incursion risk is predicted with 340-N. There are many airports in the NAS with no operational constraints on the aircraft (i.e., no MOS waivers) and yet runway incursions and other hazards continue to occur.

We used the LAWA year 2020 demand scenario prepared by LAWA and Ricondo Associates as a guideline in our demand projections. The baseline 2020 demand scenario was studied carefully and judged to be consistent with the statutory capacity limits of the airport: 153 contact gates and 78 million passengers annually. The baseline LAWA 2020 scenario assumed 2,284 operations daily (~143-157 during the peak hour). This is 10% above the demand levels observed at LAX airport in the peak days of the year 2000 and early 2001. LAX tower record data confirmed the FAA ASPM data used by the Panel to assess historical demand. . By comparison, according to the current FAA Terminal Area Forecast (TAF) projections LAX will not reach the level of daily operations projected in the LAWA year 2020 demand scenario until the year 2028.

The LAWA/Ricondo 2020 baseline scenario assumes up to 4 ADG VI operations per hour in the busiest periods of operation of the airport in the year 2020. The Panel created simulation demand sets with variations of ADG VI aircraft ranging from a low 2 (half of the ADG VI aircraft demand expected at LAX by LAWA) to a high of 6 ADG VI per hour (50% above the LAWA demand scenario). Thus, the number of ADG VI operations is an experimental variable in the simulation study.

(c) The unique air traffic control operating rules at LAX for handling of very large aircraft such as the A380 Operational Plan V.12. This introduces an additional level of complexity into the operating system at the airport. The FAA notes that with a new centerline taxiway, LAX would have air traffic control (ATC) procedures and pilot expectations consistent with other large airports in the United States. This can reduce the potential for human error.

The level of complexity stated was simulated in FFC. Each configuration had operational limits on how ADG VI were handled using approved FAA MOS. The study measured the relative and absolute risks of operating an airport under various configurations. It is important to recognize that other airports in the NAS expected to receive ADG VI aircraft in the future will have similar limitations as LAX, such as no centerline taxiways. One example is SFO. The question addressed by the study was to estimate the level of safety of the existing airport and compare it to the level of safety associated with each of the various configurations suggested by the sponsor and by the community.

LAX accommodates a large number of foreign flag air carriers and a large number of international pilots for whom English is not their native language. The study does not address how language barriers coupled with the special ATC procedures affects the rate of runway incursions or the risk of a fatal runway collision.

The AP Panel recognized this issue early in the design of the study. It was not possible to bring foreign pilots to the study (except for one Cathay Pacific pilot to command the NASA Boeing 747-400 simulator). The study introduced numerous pseudo-pilot errors that attempted to model the foreign language effect. However, it is not clear to us that foreign crews are a primary cause of runway incursions at the numerous international airports.

(e)The north airfield not meeting FAA standards. Design standards not met include:

(i)Insufficient lateral separation between parallel runways for Airplane Design Group (ADG) V and VI aircraft.

The Panel was asked to estimate the safety of operating the North Airfield under certain configurations and levels of demand, and not to assess the consistency of these operations with FAA design standards. The AP Panel recognizes that ***all*** *the North Airfield configurations studied except 3R (a three-runway airport) would fall short of at least one FAA design standard. For example, the recommended lateral separation between parallel runways (for VFR Operations) for ADG V and VI is 1,200 feet (FAA AC 150/5300-13 Paragraph 208). This implies configurations Baseline, Baseline-S, 100-N, 340-N and 340-S all fail to meet the recommended standard. A second recommended standard for simultaneous approaches and departures recommends 1,200 feet of runway separation for ADG V and ADG VI. Again, only 3R would meet such a standard (as there is no parallel runway under this alternative). The South Airfield, as modified with the new centerline taxiway, does not meet that standard either.*

In short, if deviations from recommended FAA design standards were enough to invalidate a configuration, there would have been no point in conducting the study.

(ii) Insufficient area to hold ADG V and VI heavy aircraft between Runway 24R and Runway 24L.

The Baseline configuration has well-known drawbacks of holding capacity between the two runways. This requires special handling of ADG VI and some long ADG V aircraft such as the Boeing 777-300ER. Configuration 100-N improves holding capacity but restricts movements on runway 24L while ADG VI aircraft occupy the centerline taxiway. Configurations 340-N and 340-S improve the holding capacity of the Baseline substantially and further improve in operational efficiency as noted in the report.

The statement seems to imply that these limitations were not considered in the FFC simulations. But they were: there were instances in the simulation where small and large aircraft queued at a single runway exit (a highly undesirable condition). This happens infrequently today.

(iii) Current modifications to standards to allow A380 and other ADG VI aircraft operations at LAX.

FAA Modifications of Standard were considered in the simulations. For example, ADG VI speeds were restricted to 15 mph while taxiing in the airfield. ATC operational procedures for 100-N and on the South considered ADG VI aircraft handling procedures developed at LAX today. This considered the MOS developed for LAX.

(iv) Insufficient runway width for ADG VI aircraft such as the A380 and future Boeing 747-8.

FAA Modifications of Standard contain provisions to operate ADG VI from 150-foot-wide runways with wider shoulders (50 feet on each side). The Panel recommended 200-foot-wide runways early in the project for the outboard runways (25L is already 200 feet wide). This would be consistent with ADG VI aircraft design standards. Runway width in the FFC simulations had no effect on the pilot and ATC responses because pilots flying the Boeing 747-400 were accustomed to runway widths of 150 feet. All configurations studied should be retro-fitted with 200-foot-wide runways. This does not invalidate any of the results of the simulations.

3. The NASS did not include simulation of several hazards that are major risk contributors at LAX.

The NASA simulations, like any simulation, could not cover all conceivable possibilities. However, they were very extensive and did go beyond what was initially planned. More specifically:

The NASA FFC simulator is a high-fidelity, human-in-the-loop simulation. The Panel studied the performance of individual aircraft LAX arrival patterns using PDARS data and modified many of the default performance behaviors of the FFC simulations to enhance the fidelity of these simulations. The Boeing 747-400 flight simulator used in conjunction with the FFC experiments is a Level-D simulator (i.e., replicates both air and ground behaviors of the aircraft at the highest level certified by the FAA). This aircraft simulator had a Boeing 747-400 rated pilot and has the ability to taxi and hold the aircraft at any position in the airfield with the same accuracy as the real aircraft.

While the fidelity of the aircraft performance programmed in FFC can always be improved with the fine-tuning of multiple aircraft parameter databases, the fidelity was generally considered adequate for the experiments. The FAA accepts results of much cruder fast-time simulations to prepare cost-benefit analyses of billion-dollar airport projects using models like SIMMOD and TAAM. These fast-time simulation models do *not address critical pilot-ATC communications workload and other operational issues that can be studied in FFC. They also fall short when it comes to modeling complex real-time ATC decision-making behaviors to balance demand in the airfield. The FFC simulations are complementary to fast-time simulation techniques used to justify large airport investments.*

The simulations did not include air traffic control communication errors to pilots.

That is not the case. Audio tapes from the FFC simulator were reviewed by AP Panel members to understand the errors made by ATC personnel. The errors made by ATC controllers included failure to clear an aircraft, failure to detect a hold line blunder, etc. These were factored in the analysis. We reviewed in detail the audio tapes of local controllers and identified patterns of errors to be used in the analysis. Each FFC simulation includes multiple channels of audio (i.e., 150 GB of data in all) that can be further studied if necessary.

Lastly, the simulation failed to study night instrument meteorological conditions, which are arguably the most hazardous conditions in the airport environment.

For budgetary reasons, it was not possible to include night IMC in the simulations. (The simulations did include day IMC, day VMC, and night VMC.) However, we used a great deal of information from outside the simulation to make risk inferences that include night IMC. For example, if night IMC was especially hazardous at LAX North relative to other venues, then that circumstance would have been expected to show up in the incursion data.

4. The Panel did not fully account for all the risk associated with the operation of very large aircraft at LAX.

The Panel noted that, so far, there is no evidence that actual Group VI operations around the world have involved heightened risk of incursions. But we did the next best thing absent extensive Group VI data: we conducted a historical review of involvement of Group V aircraft in LAX runway incursions. If, for example, high fatigue might be associated with Group VI operations, that problem should already be present in Group V operations that we studied. (Boeing 777 and Airbus A340 aircraft have been flying ultra-long flights out of LAX; Singapore Airlines now flies nonstop from Singapore to LAX.) The critique notes that "ADG V aircraft do not have many of the same special procedures for operating at LAX" (as ADG VI aircraft do). In fact some ADG V aircraft *have special handling procedures similar to ADG VI at LAX in the North airfield (e.g.,due to lack of holding capacity between runways 24R and 24L). The ADG VI "special procedures" are designed precisely to avoid extra risk for ADG VI aircraft. (The procedures may affect airport capacity, but that is not the same as safety.)*

More specifically:

The risk of a runway collision is calculated by:

*Pr[runway incursion occurs] * Pr[incursion leads to collision]*

Experience with ADG V aircraft provides strong evidence that ADG VI aircraft will not have a significantly higher risk of incursion (the first term) than other aircraft. Both ADG V and VI aircraft cannot align perpendicularly to the inboard runway under the current North (and previous South) architectures. Both have visibility issues – it is true that these may be more severe with ADG VI aircraft but nonetheless they are similar. Further, the ability to look down the inboard runway provides a type of redundancy to controller clearances, but this is exactly what runway status lights also provide.

There is perhaps less evidence one can point to regarding the risk that an incursion leads to a collision (second term). Our conclusion (that there are no significant differences for this case) is based on the following logic. First, the FAA has required many special procedures for ADG VI aircraft. These procedures should substantially mitigate the increased risk associated with ADG VI aircraft, to the degree that such risk exists. Second, we point again to the similarities between ADG V and ADG VI aircraft operations. Finally, while one might argue that runway geometry may impact the risk of a runway incursion, it should have much less impact on the risk that an incursion leads to a collision. In conclusion, we do not believe that the second term changes significantly across the various alternative geometries considered in this study.

5. The NASS overlooks other fatal runway collisions since 1991, giving the impression that this type of event has become rare.

This statement is not correct: our report specifically mentions the 2000 collision at Sarasota, and includes the 1994 event at St. Louis in the risk calculations. We made clear that we (as FAA generally does) focused on the risk at towered US airports: the 1996 collision at Quincy, Illinois took place at an airport without a control tower.

The critique does not challenge our statement that, since the Sarasota collision over ten years ago, there have been no fatal runway collisions at towered US airports. During that period, more than 500 million landings and takeoffs have occurred at these airports. If our report "(gives) the impression that this type of event has become rare," that could be because it has indeed become very rare.

6. The NASS assumes that system-wide reductions in incursions due to the use of technology such as Airport Surface Detection Equipment, Model X (ASDE-X), runway status lights (RWSL) and the Airport Movement Area Safety System (AMASS) apply equally at LAX.

We did not make this assumption. If these technologies were less effective at LAX than elsewhere, then LAX would not have benefitted from the reduction in incursions that these technologies allow. Our metrics would have picked up that pattern. Pilots and controllers in the simulation would also have noted the difficulty in their safety evaluations for LAX-North.

We do not agree that, because incursions remained at about three per year after AMASS arrived, the new technologies made no difference at LAX-North. As we noted earlier, incursions with a potential for collision dropped by a factor of six after AMASS reached LAX. (RWSLs have not yet reached LAX-North, and ASDE-X only arrived in 2009.) FAA itself estimated that AMASS had reduced collision risk at LAX between 59% and 66%, which is in line with the improvements elsewhere. We did not assume a priori that AMASS would be as effective at LAX as elsewhere, but the empirical evidence indicates that it was.

7. In overlooking the fact that technology has not significantly changed the rate of incursions on the north airfield, the Panel fails to capture how the current airfield geometry at LAX can limit the effectiveness of warning technologies and contribute to runway incursions.

As noted earlier, we believe that this "fact" is not informative, and neither does FAA. We never suggested that a centerline taxiway would have no safety benefits: we assume that the 40% reduction in relevant incursions observed at LAX-South would also occur on LAX-North. The issue is: what is the baseline level of risk that would be reduced by 40%?

8. It appears that the Panel did not give adequate weighting to the risk reduction on the South Airfield.

We certainly studied the improvement on the South Airfield closely, and included it in our risk assessment. (Indeed, the critique quotes our own statistics about fewer incursions on the South after its reconstruction.) The critique, however, appears to discount the role of both AMASS and reduced traffic as contributing factors to the decline in South Airfield incursions, despite their apparent role in the years before the centerline taxiway was completed in 2008. We think we gave accurate weighting to the benefits of the centerline taxiway, and assumed the same percentage benefits would arise from such a taxiway on the North.

9. The NASS is overly reliant on historical numbers of fatal runway collisions as the basis of risk.

By no means did we rely solely on fatal runway events in our analysis. We relied heavily on data about the increase in airport operations between now and 2020, and on the effectiveness of new technologies both as estimated by FAA and as evidenced in the reduction of non-fatal incursions. When the critique states that "the Panel should also have examined the rate of runway incursions as a measure of collision risk," it ignores the point that we studied extensively such data, and used them in our estimates of both national risk and risk on LAX-North. On the other hand, we cannot imagine that it is irrelevant that fatal runway collisions have not occurred in the US over the last 500 million operations at towered airports.

The critique appears to suggest that the fatal runway collisions are merely "the tip of the iceberg" and that lower-severity events deserve substantial weight in assessing safety benefits from North Airfield improvements. For this to be true, total costs from non-fatal collisions would have to be of the same or greater magnitude as those from fatal ones. The AP has looked into this issue.

The relative magnitude of fatal and non-fatal runway collision costs depends upon their relative frequency and relative cost. Regarding frequency, the FAA notes that there have been three non-fatal collisions since 2001. The AP reviewed NTSB records and found two such aircraft-to-aircraft collisions on runways since 2001. One, on February 9, 2001 at Leesburg FL, involved a non-towered airport. Since the basis of our analysis is collisions at towered airports, it appears that there have been either one (based on the NTSB records) or two (based on the FAA statement in the critique) non-fatal collisions since 2001, during which time there have been no fatal collisions. Barnett (2000, p. 263) notes that between 1989 and 1998, there were three fatal collisions and *four non-fatal ones. Summing results for these two periods, we obtain four fatal collisions and five or six non-fatal ones. Thus it appears that the frequency of non-fatal collisions is, at most, about twice that of fatal ones.*

We now consider the relative cost of non-fatal and fatal collisions. Our estimate is based upon "Economic Values for FAA Investment and Regulatory Decisions, A Guide" prepared by Gellman Research Associates for FAA in 2004 (Gellman, 2004). This publication includes cost factors for fatalities, injuries, and aircraft damage. To apply these cost factors, we need to assume levels of fatalities, injuries, and damage for fatal and non-fatal accidents. In our analysis, we assumed that a fatal collision caused 100 fatalities, the cost of which, based on the Guide, is $300 million. Assuming both aircraft are destroyed, there is an additional cost of about $23 million based on the Guide values. Let us assume that there are no injuries in fatal accidents. For non-fatal collisions, we reviewed NTSB accident records involving non-fatal collisions (not necessarily on the runways) over the past decade involving Part 121 or Part 135 aircraft. A review of 18 such accidents found a total of 1 serious injury and 6 minor injuries, or an average of 1/18 serious and 1/3 minor injury per accident. Based on ICAO cost factors for serious and minor injuries, the total cost would be about $47,000. Assuming that such an accident involves one destroyed and one damaged aircraft, the total property damage would be $15.2 million, which completely dominates the injury cost.

Thus, it appears that costs of fatal and non-fatal collisions are respectively $323 million and $15.2 million, yielding a cost ratio of about 20 to 1. Taking into account the relative frequency and the relative costs of non-fatal collisions, it appears that the costs of the latter are about 10% or less of the costs of the former. Considering such collisions therefore does not materially affect the results of our assessment.

10. The differences between a cost-benefit approach versus a Safety Management Systems (SMS) approach to safety management.

In context, this comment suggests that the NASS adopts a cost-benefit approach in assessing the north airfield alternatives, and that such an approach is of "limited applicability in airport specific safety-related decisions," because "there are other factors that influence the acceptability of safety risks beyond the economics of fatality, injury, and property loss valuation."

The AP did not explicitly perform a cost-benefit analysis in its study. It does, however, take the view that safety benefits should be assessed in terms of the avoidance of losses from aircraft collisions, which in our view are dominated by fatalities (see answer to comment 9). The FAA routinely performs a cost-benefit analysis (CBA) to evaluate many safety investments. It publishes guidance on safety-related values such as the value of a statistical life, injury costs by severity category, and aircraft damage costs. It has established procedures for performing CBA for airport projects involving navigation aids, lighting, towers, and other facilities, published in Order 7.031C, Airport Planning Standard Number One—Terminal Air Navigation Facilities and Air Traffic Control Services. The FAA does not require a CBA of airport safety projects funded under AIP.

It is not clear what "other factors" FAA believes should be considered.

As has been emphasized repeatedly, the AP has adopted a policy of full disclosure in sharing the assumptions, data, analysis, and reasoning it employed to reach its conclusions. Two tenets of its conclusions were: (1) that the dominant safety benefit from changing the North Airfield was a reduction in losses from runway collisions and (2) that benefits from further reduction in risk from a low baseline level (one event every 200 years) are small relative to the costs of airfield reconfiguration. While both (1) and (2) are consistent with FAA CBA guidance, it is ultimately up to decision makers and stakeholders whether to accept them. The AP also recognized and stated that a case for a reconfiguration of the North Airfield could conceivably be made on the grounds of a combination of safety and capacity/delay benefits. The results of our study should be viewed as one more datum for the process of resolving this complex issue.

Finally, this comment in the critique suggests that SMS and cost-benefit analysis are alternative approaches to safety management. The AP disagrees. Cost benefit analysis is not an approach to safety management, but one for determining whether an expenditure of resources will yield a commensurate benefit. SMS is an approach to managing safety that is performance-based rather than rule based. Under SMS safety improvements are assessed in terms of their effect on risk. SMS can be used to identify measures that do (or do not) have the potential to significantly (in an incremental sense) reduce risk, but it cannot, by itself, be used to determine whether such actions are worthwhile. The latter requires an assessment of the baseline level of risk (like the one *the AP has carried out) and of the costs of the propose measures—in other words a cost-benefit analysis.*

11. The NASS seemingly downgrades the risk potential of runway incursions.

This statement is inaccurate. We gave great weight to incursion data in our work, though we could not go along with the critique's "one incursion, one vote" rule that ignores the FAA's own distinction between "serious" incursions (Categories A and B) and the rest. We recognize that a Category A runway incursion at LAX-North is far more likely to involve a Part 121 aircraft than a similar incursion at (say) Van Nuys. That is why we assumed a fatal collision at LAX-North would take 100 lives, despite a national average of seven deaths per fatal collision over the last forty years. That said, there have been no Category A incursions on LAX-North over the millions of operations there since AMASS arrived. This last circumstance is relevant to probability calculations, though it by no means implies that the risk has dropped to zero.

3. LOS ANGELES TIMES EDITORIAL

Redefining Safety at LAX

A new study of its north field runways should not be the last word on improvements at the airport.

Los Angeles Times (February 23, 2010)

Two years ago, the question of whether the two runways on Los Angeles International Airport's north airfield should be rebuilt farther apart didn't seem hard to answer. A report from the Government Accountability Office found that LAX had the most close calls among aircraft of any of the country's busiest commercial airports and the highest number of severe incidents. The Federal Aviation Administration had been demanding for decades that the airport address the runways' design flaws, and five independent studies on airport safety concluded that they were too close together for comfort.

And then, last week, an academic panel working with NASA unloosed a flock of sea gulls into airline regulators' jet engines. After an 18-month study, it found that although moving the runways farther apart would improve safety, the risk reduction would be so minuscule that the project wouldn't be worth the cost.

This comes as an answer to the prayers of the airport's neighbors, who have long fought to block the project out of fear that moving a runway 100 feet or more closer to their homes would harm their quality of life. Prompted by demands from area City Councilman Bill Rosendahl, airport commissioners ordered the NASA study despite the existing, overwhelming evidence. The tactic worked -- the neighbors finally found some experts who agreed with them. That's good enough for Rosendahl and Mayor Antonio Villaraigosa, who say that runway expansion plans are now essentially dead.

If that pleases airport neighbors, it shouldn't please anyone else. One study in your favor out of six isn't a ringing endorsement. Moreover, the statistical analysis and modeling performed by the NASA panel, although convincing in its assessment that the risk of a deadly accident at the north airfield is very low (expected to happen only once every 200 years at 2020 traffic levels), also found that adding 100 feet of separation between the runways would reduce the risk of fatal collisions by 40%, and adding 340 feet would lower the risk by 55%. With the FAA and airlines putting up the $500 million for the project, isn't that worthwhile?

The NASA panel also found that the 340-foot separation plan could significantly reduce airport congestion and improve capacity -- another notion that alarms neighbors.

We're as puzzled as anybody about how airport experts could come to such widely differing conclusions on safety, and we're less convinced about the necessity of separation than we were two years ago. But we're certain that the Board of Airport Commissioners should not allow this perplexing study to be the last word on the north airfield and its troubles.

3.1. Expanding on an LAX study

Re “Redefining safety at LAX,” Editorial, Feb. 23

The Times wondered why our "perplexing" study about safety on the LAX north airfield reached different conclusions from five studies that preceded it. Actually, it didn't.

All six studies concluded that moving the LAX north runways farther apart would reduce by a substantial percentage the risk of a runway collision. But ours was the first study that directly asked: How great is the risk in the first place? Our frequency estimate -- one fatal collision every 200 years on average -- did not contradict earlier estimates because there were no such estimates.

Given that your editorial board described the analysis behind the 200-year estimate as "convincing," it is unclear what you found "perplexing" in our work.

The Times also wrote that "the [LAX] neighbors finally found some experts who agreed with them." We hope you were not suggesting that we or NASA were chosen for the study because we were predisposed toward a particular conclusion. Neither the community nor Los Angeles World Airports ever asked us to do anything but tell the truth.

We concluded that spending $500 million to reconfigure the north runways would be hard to justify on safety grounds alone, because that money might save more lives if spent in other ways. But we explicitly said that capacity benefits could well make a case for reconfiguration.

Our study offered new information for the debate about LAX's future, but was not intended to end it.

Arnold Barnett

Cambridge, Mass.

The writer, a professor of statistics at MIT, was chairman of the panel that wrote the LAX report. He co-wrote this letter with the five other panel members.

4. RESPONSES TO COMMENTS AND QUESTIONS ABOUT CHAPTER 6:

Safety Assessment in the Baseline Case

As noted, responses to the FAA critique and the *Los Angeles Times* editorial appear earlier in this section. The questions below arose in the other seven documents about the Panel's report.

- What weight was ascribed to pilot and controller responses in the NASA simulation relative to other factors in the assessment that the existing North Airfield would be "extremely safe" at 2020 traffic levels and traffic mix? (LA Airline Airport Affairs Committee)

These responses received a great deal of weight. Simulation pilots who landed in the baseline case (under 2020 conditions) were asked to compare the safety of their landings with those these pilots experience today at other airports in similar visibility conditions. Controllers were asked to compare the safety of the existing North Airfield with the current South Airfield, which has a centerline taxiway. In both cases, the responses indicated that LAX North was about equally safe with the other airfields considered. On a 1-7 scale in which 1 means "LAX North much safer" and 7 means "LAX North far less safe," the average rating was 3.7 among pilots and 4.2 for controllers, right in the middle of the scale.

The pilots who rated LAX-North baseline were asked which other US airports entered their comparisons. The nine airports they mentioned are listed in the Report, and included DFW, JFK, SFO, and ATL. Because the pilots said LAX-North was as safe as these airports, some (though not all) of our eight estimates of the chance that a fatal US runway collision in 2020 would occur at LAX-North were based on safety data from these other airports. The logic was that if LAX-North is as safe as (say) Atlanta, and the risk at Atlanta is X, then X is also an estimate of the risk at LAX North. Numerical risk estimates arising in this way were very similar to other estimates derived exclusively from LAX data.

But suppose the pilots had given LAX-North baseline an average rating of 6 out of 7 rather than 3.7. Then we would have inferred that the pilots considered landings at LAX North perhaps five times as risky as those elsewhere. We would have derived risk estimates for LAX-North that incorporated this discrepancy and, to put it briefly, our estimate of the chance that LAX-North would be the venue of a fatal US runway collision would have risen from 2% to about 5%. This increase would in turn have more than doubled our LAX-North risk estimate. In other words, pilot (and controller) assessments played a large role in our estimates, and our *judgment that LAX-North was extremely safe would not have been possible had they indicated otherwise.*

- Why did the Academic Panel focus on fatalities in runway collisions at LAX-North when its focus was supposed to be on runway incursions? (Inglewood/Culver City)

The Panel always promised to estimate "as specifically as possible" the level of risk under 2020 traffic conditions for each configuration it studied about the North Airfield. There seemed a near-universal consensus that a runway collision with a high death toll was the danger of primary interest. For example, the earlier study titled "Fatal Runway Collisions Over the Next Two Decades" that we cited in our report was prepared at the request of FAA, as part of its decision process about the deployment of ASDE-X radar. While runway collisions can also cause non-fatal problems, we recall the Supreme Court justice who explained that "death is different," and, elsewhere in this Addendum, we estimated (in response to FAA comments) that the economic consequences of non-fatal collisions were an order of magnitude lower than those for fatal events.

- Why include the death toll in the collision at LAX in February 1991 in an assessment of future hazards at LAX-North? Doing so artificially inflates the estimated death toll in a future collision. (Inglewood/Culver City)

Our estimates of the death toll given that a fatal runway collision occurs were based on ***worldwide*** *patterns over many decades, with the LAX event serving as only one data point in our analysis. (Most of that analysis appears in the Appendix to our report, as part of the paper "Fatal Runway Collisions over the Next Two Decades.") While runway configuration may have played no role in the 1991 LAX collision, its outcome is useful in suggesting the degree of survivability when two planes collide, regardless of the particular reason for the crash. (Our risk assessment also considered collisions between planes and ground vehicles or obstacles on the runway.) The 1991 event with its 34 deaths does not "artificially" increase death toll estimates: indeed, the worst aviation accident in history was a 1977 runway collision in the Canary Islands, which killed 583 people.*

- Why compare runway risks to risks not associated with airport runways, an approach that is "potentially misleading?" (Inglewood/Culver City)

We presented absolute mortality risk estimates for LAX-North, but believed we should offer some statistics about other risks to offer perspective to readers. In deciding whether a level of runway risk is large or small, it seems valuable to take note of the overall level of risk that air travelers face, as well as the risks that citizens face that are unrelated to aviation. To cite other mortal hazards faced by residents of Los Angeles is not to imply that all such residents use LAX, *or that all users of LAX are residents of Los Angeles. But doing so provides some "benchmark" that makes the runway risk statistics less abstract. Individuals who consider our comparisons irrelevant or unhelpful are obviously free to ignore them.*

- Given that LAX-North now lacks a centerline taxiway, why make risk assessments for LAX-North baseline using data from other US airports (e.g, ATL, DFW) that have centerline taxiways? (Air Line Pilots Association)

As explained in the first answer above, pilots in the NASA simulation who landed in the baseline configuration at 2020 traffic levels were asked to compare the safety of those landings which those they now perform at other US airports. They were encouraged to consider whatever factors they thought relevant. These pilots presumably took account of that fact that LAX-North lacks the centerline taxiway that other airports have, much as they may have considered that some of those airports have crisscrossing runways while LAX does not. On balance, they concluded that LAX-North was about equally safe with the other airports, meaning that risk estimates for 2020 for those airports could underlie some—but by no means all—estimates about LAX-North.

- Why didn't you give substantial weight to conditions at LAX in 2000, given that traffic in 2020 will return to 2000 levels and that recent years have been easier given substantial drops in traffic at LAX? (Air Line Pilots Association)

We did give considerable weight to LAX conditions in 2000. In estimating the chance that a US runway collision at 2020 traffic levels would occur at LAX-North rather than elsewhere, we used incursion data for the airfield over 1999-2009. Because the rate of A-C incursions at LAX-North was far higher over 1999-2000 than in the later years, these early years had a highly disproportionate role in the data for the full period. Also, in making risk estimates based on the LAX-North share of (squared) US traffic levels, we used data from 2000 precisely because that was the year when LAX operations reached their peak.

All our calculations recognized that projected 2020 LAX traffic levels would be considerably higher than those around 2009, and would even exceed 2000 levels by about 5%.

- Shouldn't the decline in LAX traffic between 2000 and (say) 2009 be given most of the credit for the decline in LAX incursions over that period? (Air Line Pilots Association)

We are disinclined to think so, although we recognize that the drop in traffic probably had some role in the decline. We believe that the arrival of AMASS, ASDE-X, RWSL's—coupled with improvements in signage and procedures—are the primary factors. As noted in our report, FAA estimated after detailed study that the combination of AMASS, ASDE-X, and RWSL's would reduce collision risk by about 88%. That these estimates were not wildly optimistic is suggested *by the fact that category A and B runway incursions in the US dropped 80% between 2000 and 2009 (and the national drop in air traffic was far less steep than that at LAX). Moreover, there have been no fatal runway collisions anywhere in the US over the last ten years (as of 5/1/10), as compared to six in the previous ten.*

Is it possible that new technologies and procedures will be less effective at LAX-North than elsewhere? As we noted in our response to FAA, the empirical evidence works against that view. When LAX traffic returns to 2000 traffic levels in the years ahead, it will do so at a time when pilots and controllers will benefit from numerous advances in safety since the turn of this century; we therefore believe that the environment will be one of far lesser risk.

- Under the quadratic risk model, wouldn't LAX be safer if traffic were equally divided between the North and South Airfields rather than heavier on the South (as it is now)? (El Segundo)

An interesting question, and the answer is yes. But the effect would be minimal under the model. Now we have a 55% South /45% North traffic split at LAX. If X is the risk that would prevail in 2020 under this split, the risk would only decline to .99X if the split became 50/50 (i.e., by 1%). (More specifically, the risk would proportional to $(1/2)^2 T^2 + (1/2)^2 T^2$ *rather than* $(.55)^2 T^2 + (.45)^2 T^2$*, where T is total traffic at LAX.) And the quadratic model is only an approximation: given the associated changes on the taxiways and in the airspace near the airport, it is not certain that shifting from 55/45 to 50/50 would actually benefit safety.*

5. RESPONSES TO COMMENTS AND QUESTIONS ABOUT CHAPTER 7

Baseline with IRSIP

Several comments referred to potential enhancements at LAX and, more specifically, at the North Airfield with the existing ("baseline") configuration, i.e., in the absence of a centerline taxiway. Since the objectives of such enhancements are consistent with those of the Interim Runway Safety Improvement Project (IRSIP), we have chosen to review and respond to these comments as addenda to Chapter 7 or our report, which dealt with IRSIP.

A. The following four recommendations were submitted by the Los Angeles International Airport Advisory Committee, (representing residents of El Segundo, Inglewood, Lennox, Hawthorne, Culver City and Westchester/Playa del Rey):

(i) Lengthen Runway 24L toward the east to a minimum length of 11,500 feet from the current 10,286 feet.

(ii) Complete the installation of runway status lights (RWSL) at all runway and taxiway intersections.

(iii) Require a full complement of certified air traffic controllers at all times in the LAX tower.

(iv) Undertake the interim improvements to the North Airfield with the additional requirement that closing or relocating Taxiway Yankee be studied further prior to final approval.

<u>*AP's Response*</u>*: Recommendations (ii), (iii) and (iv) are either implicitly assumed in our analysis or explicitly stated. For example, the risk estimates implicitly assume that an adequately staffed air traffic control team will be in place at LAX at all times (with staffing levels possibly varying according to traffic intensity, time of day, etc.). As another example, the point about the need for further study of the proposed closing of Taxiway Yankee was made explicitly in our report. The AP therefore feels comfortable about endorsing these three recommendations, since they are entirely consistent with the AP's report and analysis.*

Recommendation (i) is more complicated, as it falls outside the scope of the AP's charge. The AP was not asked to examine modifications to the North Airfield baseline that go beyond those presented in the IRSIP project's outline. We do, however, recommend that

Recommendation (i) be considered carefully, possibly as part of the study that will also determine the future of Taxiway Yankee (Recommendation 4).

B. Mayor Kelly McDowell of El Segundo in commenting on the AP's report, expresses the desire for better balancing of operations between the North and South Airfields and suggests specifically the lengthening of Runway 24L to the east, as one of the ways that will facilitate such balancing and may implicitly also be calling for a centerline taxiway on the North Airfield (in the interest of "balancing").

AP's Response: The question of how to best allocate operations between the North and South Airfields is a complicated one, because it requires consideration of several issues, such as the complexity of aircraft circulation patterns between gates/stands and runways, the configuration of the terminal airspace, the types of aircraft that will utilize each runway, etc. This topic deserves a study by itself, once the decision is made regarding the future configuration of the North Airfield. As indicated under A above, in the AP's response to the Los Angeles International Airport Advisory Committee, the question of lengthening Runway 24L falls outside the scope of AP's charge, but certainly deserves careful consideration.

6. OTHER RESPONSES

This section contains the AP Panel responses to other organizations.

Chevalier, Allen and Lichman

(i) Corrected Tables 8.5 and 8.6 and added more explanation and sources of information.

(ii) *We note that the comments correctly identified some errors in the numbers provided in our tables. These have been corrected. We also added explanations related to the source of our incursion data.*

(iii) **Response to item III in Chevalier's letter.** *Aviation accidents are almost always the result of many confounding factors "going wrong" at the same time. Similarly, they can be prevented by one of many safeguards. Thus, while runway geometry might not be the root cause of an incursion, it is quite possible that improved runway geometry might prevent an accident that might otherwise occur due to a pilot or controller error. We have discussed the causes of incursions at various locations in the report and certainly the general sequence of events that lead to certain types of incursions played a strong role in our analysis. However, we did not find it particularly useful in our analysis to dwell extensively on whether the primary cause of specific incursions was due to pilot or controller error. For example, the addition of runway status lights could alert a pilot to stop when given an erroneous instruction by a controller (controller error) but could also alert a pilot to stop who was distracted and about to ignore a correct controller instruction (pilot error).*

(iv) **Response to item X in Chevalier's letter.** The study fails to explain why taxi times to and from 100-N would be longer than taxi times to and from 340-N

Table 13-1 of the report presents a summary of the taxi-in time results obtained in the FFC simulations. Statistical analysis of the data for 52 FFC runs shows that there are significant differences in taxi-in times for each alternative (at 95% confidence level). 340-South performs last in terms of taxi-in times with a mean taxi-in time of 708 seconds per arrival. The best alternative in terms of taxi-in times is 340-North with a mean taxi-in time of 612 seconds per operation followed closely by 100-North (630 seconds per operation). While runway 24R in 340-North is located further away from the gates compared to other alternatives, the taxiing times are better than even alternative 100-North because of improved ground flows observed in 340-North. In other words, alternative 100-North produced more frequent aircraft stops on the ground for arriving aircraft compared to alternative 340-N. The ground stops for arriving aircraft are *affected by both arrival and departing traffic flows in the airfield. Since 340-North has the best departure saturation capacity of all alternatives (i.e., fewer departure queues), this produced fewer bottlenecks on the ground network thus reducing taxi times in the airfield for both arrivals and departures in 340-North compared to others.*

(v) **Response to item IX in Chevalier's letter.** *This is beyond the scope of our analysis. NASA and the AP Panel reviewed previous manned simulation studies done for LAX and concluded that it was necessary to introduce a Ground Control Position to direct ground traffic at the busy midfield terminals in the future.*

ARSAC

The AP Panel was given 49 questions by ARSAC. Many of the questions are very general and require separate studies by themselves and fall outside our charge, which was to compare five alternatives for the North Airfield with respect to safety. Many requests for additional analysis lie beyond the scope of the charter given to the AP (and NASA). These include: an analysis of human factors mechanisms, ranking of incremental safety improvements,

Several of the comments ask for a more detailed analysis of the "Nine Questions". We admit that a more thorough analysis of many of these could certainly be done. However, we view such in depth analyses as beyond the scope of our charter and allotted resources.

LAX TEC

We did not undertake a comprehensive capacity analysis. However, as stated above our report indicates it is likely that runway reconfiguration can be justified on capacity grounds. The AP Panel was charged to investigate whether certain configurations of the North Airfield could not guarantee at 2020 traffic levels an acceptably-high level of passenger safety. The AP Panel believes capacity and operational efficiency can be further studied to estimate the economic operational costs and benefits of various airfield configurations.

LAX Airline Airport Affairs Committee

(i) How much weight was attached to the comments of controllers and pilots

The responses by ATC controllers and pilots were considered carefully along with all the other elements of the analysis. The comments about each one of the alternatives were summarized in each of the relevant chapters and the numerical scores were also tabulated and analyzed statistically. When there were comments that stood out as being in conflict with numerical scores or the empirical analyses of incursion data, this was pointed out. But this did *not really happen to any extent that might affect the eventual conclusions of the AP. In any case we did not assign specific weights to the comments or, for that matter, any of the other elements of the analyses that were carried out.*

The absolute risk numbers calculated were based on models that used as a starting point historical data (not pilot or controller survey results). On the other hand, survey results were used to define a set of comparable airports and to estimate the relative standing of LAX against these other airports. Other sources of data were also used to obtain estimates that served as "backups" for the numbers provided by the surveys.

(ii) Further studies that will compare in detail the North Airfield alternatives with respect to other attributes (e.g., capacity and delays) are needed to obtain a complete view.

The AP does not disagree. Our charge was limited to, primarily, assessing safety and, as a secondary objective, performing a preliminary analysis of capacity and operational efficiency. As indicated above our report indicates changes may be justified on capacity grounds

ALPA

(i) ALPA stated "The AP ignored the conditions that existed in Year 2000, when LAX was heavily congested, and instead concentrated on more recent years when the airport was much less congested.

Far from studying LAX in conditions of reduced traffic, the AP's analyses and simulations focused on projected traffic levels in 2020 with the airport assumed to be operating with the maximum number of movements that can be sustained with the expanded set of gates. In addition, the period 1999 - August 2001 is not a good one to draw statistical evidence from, as the incursion-related technologies, as well as the centerline taxiway on the South Airfield, were either partially implemented or were not in place at all at the time.

The restriction to the years 2002 through 2007 in our incursion analysis was specifically used in order to obtain a common basis for comparison of incursion rates before and after the introduction of the center taxiway on the South Airfield. The 2002 to 2007 period, when compared to the 1999 to 2001 period, had reduced traffic levels and the use of new technologies, ASDE-3 and AMASS. The traffic levels after the introduction of the center taxiway have been similar to those in the 2002 to 2007 period and, of course, ASDE-X and AMASS are present. This provides an "apples to apples" comparison for the estimation of the factor by which the ENS incursion rates have been reduced. Note that this analysis was not used to estimate absolute risk levels.

The fact that increased traffic levels generally lead to higher risk levels was certainly taken into account. In particular, the models used to estimate the baseline risk employed the assumption that risk increases according to a quadratic function of the traffic level of an airport. These models certainly assumed that the higher 2020 traffic levels would lead to substantially higher incursion (and collision) risks.

(ii) Influence of ADG VI on Study Results

Another concern of one of ALPA's comments concerns the issue of Group VI aircraft (no A380 pilots in the simulation pilot mix, more Group VI aircraft in the future, RWSL less visible from Group VI cockpits, etc.). This issue has been addressed in our response to the FAA.

The second comment by ALPA pertains to their recommendation that the North Airfield should be redesigned to satisfy "Group VI standards without waivers": none of the alternatives given to the AP Panel satisfy these conditions and the AP study would be entirely irrelevant if this recommendation were to be followed; what we tried to do was to be responsive to our charge.

To the extent that it will be difficult or cumbersome to employ special procedures for Group VI aircraft under higher traffic levels, is predominantly a capacity problem, not a safety problem. The report indicates that it is likely possible to justify runway enhancements based on capacity grounds.

(iii) ALPA Comment on slide # 80 of the AP Panel presentation states "We believe that the data upon which its conclusions were based is flawed. Incursion data between 2004-2008 (pre-centerline taxiway) and 2008-2009 (post-centerline taxiway) is erroneous. The report's time frame primarily reflects a period of waning demand instead of focusing on the peak traffic period where operations were on the edge of the safety envelope and sometimes outside of it. The capacity and operational activity at LAX between 1999 and 2001 was stretched to the point where, at times, operational control broke down. This was not the case during the 2004 to 2009 time frame…"

(iv) Slide #80 contains Table 9-5 of the preliminary report. While including years 1999-2001 would have increased incursion rates for LAX during the pre-centerline taxiway period, this would not change the central conclusions of these tables, which concerns how rates changed between the pre- and post-centerline taxiway periods, and how rates in the latter period compare to those for other airports.

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Los Angeles International Airport North Airfield Safety Study

Addendum to Final Report: Comments to Report

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APR 2 2010

The Honorable Antonio R. Villaraigosa
Mayor of Los Angeles
200 North Spring Street
Los Angeles, CA 90012

Subject: Los Angeles International Airport North Airfield Safety Study

Dear Mayor Villaraigosa:

In the span of ten days this month, two separate runway incursions reminded us of the vulnerabilities and inefficiencies that exist on the Los Angeles International Airport (LAX) north airfield. On March 6, an arriving jetliner got too close to another commercial jet that was taking off. On March 16, a large Boeing 747 was unable to exit the runway completely before another aircraft landed behind it.

The circumstances behind these incidents were all too familiar. The March 6 incursion, like many before it, occurred because there is no physical buffer separating arriving aircraft from aircraft that are taking off on the inner runway. Moreover, the March 16 incursion underscored the difficulty of operating large aircraft on the cramped north airfield.

The Federal Aviation Administration and Los Angeles World Airports are deploying new technologies at LAX, including runway status lights and the new Airport Surface Detection Equipment, Model X ground radar. These are valuable tools that will help increase the safety margin against runway incursions. However, the only complete solution for LAX's safety and efficiency needs must include airfield geometry designed to accommodate modern aircraft.

I am concerned the most recent North Airfield Safety Study (NASS) will be used as a reason not to pursue this solution. That would be a serious mistake. The FAA conducted a detailed review of the study and identified several critical flaws in the study's assumptions, methodology, and conclusions. The enclosed document outlines these technical concerns.

I flew into LAX hundreds of times during my career as an airline pilot. I can tell you from personal experience that the north airfield safety and efficiency would be greatly improved by further separating the two runways and building a center taxiway between them. Multiple expert studies over the past several years have reached the same conclusion. A similar reconfiguration of the LAX south airfield has eliminated the most serious runway incursions there and reduced all types of incursions by nearly 80 percent.

The latest NASS recognizes that increasing runway separation and building a center taxiway would reduce the chances of a runway collision. But surprisingly, the study's summary conclusions downplay that finding; suggesting the airfield is safe enough now. The data and the two incursions earlier this month suggest otherwise. The status quo is not good enough for the FAA, and the city of Los Angeles should not view it as good enough for the traveling public. Everything possible must be done to make the north airfield as safe as it can be.

The north airfield reconfiguration would address equally important issues of standards and efficiency. The present north airfield configuration does not meet design standards for many of the large aircraft that use the airport. This has forced the FAA to implement a series of workarounds to manage these aircraft. These workarounds add an unnecessary level of complexity to an already demanding operating environment.

In addition, a north airfield reconfiguration would relieve congestion caused by the outdated design, thus improving efficiency at one of the world's busiest airports. Air traffic controller and pilot interviews that were conducted as part of the latest NASS simulations clearly demonstrate that increasing runway separation and a center taxiway provides substantial efficiency and flexibility benefits.

I urge you, along with the city of Los Angeles and the Los Angeles Board of Airport Commissioners, to reconfigure the north airfield. The FAA stands ready to assist the city and Los Angeles World Airports to address the known safety risks, improve efficiency, and meet design standards on the LAX north airfield.

Sincerely,

J. R. Babbitt

J. Randolph Babbitt
Administrator

Enclosure

cc: Gina Marie Lindsey, Executive Director
Los Angeles World Airports

The Federal Aviation Administration and industry safety professionals have each identified a safety risk in the current Los Angeles International Airport (LAX) north airfield configuration. This risk, demonstrated by a persistent rate of runway incursions, is the potential for a collision on the north airfield. The FAA has maintained for several years that a reconfiguration of the north airfield to include a new centerline taxiway between the parallel runways is the most effective mitigation measure for this safety risk. The reconfiguration of the north airfield in this manner has been supported by four previous independent studies listed below.

North Airfield Studies	
Study	Date
Los Angeles North Airfield Special Peer Review	March 2007
Los Angeles North Airfield Proposed Runway Configuration Safety Risk Assessment	May 2007
Analysis of Los Angeles International Airport North Airfield Alternatives	May 2007
Los Angeles International Airport North Airfield Assessment	May 2007

Since 1998, there have been 46 runway incursions on the north airfield. The most recent incursions occurred on March 6, 2010 and March 16, 2010. The March 6 incursion involved a Boeing 737 passing the Runway 24L Holdline at Taxiway AA after landing on Runway 24R. This required an Airbus A319 to abort departure on Runway 24L. Each of these aircraft can hold approximately 125 passengers. Therefore, in the instance of this runway incursion alone, as many as 250 passengers and 10 crewmembers were exposed to the risk of a collision. The March 16 event involved a Boeing 747-400. The pilot of this aircraft was not able to clear the aircraft entirely from the runway before an aircraft landed behind it. The pilot also mistakenly taxied the aircraft into a closed area of pavement and had to be towed. Therefore, in the span of 10 days in March 2010 alone, there were two runway incursions.

The Office of Airports, Office of Accident Investigation and Prevention, Runway Safety Office, Western Pacific Regional Flight Standards Division, and Air Traffic Organization (ATO) have each completed a review of the February 19, 2010 Los Angeles International Airport North Airfield Safety Study (NASS) preliminary report. Each of these offices disagrees with the main study conclusion that reducing the risk for a fatal runway collision is of limited practical importance and that reconfiguring the north airfield on the grounds of safety alone is not a compelling argument. The FAA cannot support a conclusion not to implement a demonstrated risk mitigation to a specific condition that has been repeatedly shown to be a known safety risk to the traveling public.

In addition, the FAA notes a major inconsistency between that main study conclusion and the specific findings of the NASS demonstrating the reduction in risk through a reconfiguration of the north airfield. Specifically, the NASS acknowledges that the alternatives could reduce passenger mortality risk by 40-to-55 percent compared to the existing north airfield configuration. The FAA firmly believes this 40-to-50 percent reduction in risk would be more than sufficient justification for the reconfiguration of the north airfield on safety grounds alone.

The FAA offers the following specific concerns with regard to the study analysis, methodology, and conclusions:

1. **The Academic Panel (Panel) inappropriately uses an aggregate probability calculation to reach an airport-specific conclusion at LAX.** The NASS used the 2000 study, *Fatal U.S. Runway Collisions over the Next Two Decades* (authored by the Panel Chairman, Mr. Arnold Barnett) as the basis in determining the probability for a fatal runway collision to occur at LAX. The specific intent of the 2000 study was to determine the probability for a fatal runway collision to occur at ***any*** towered airport in the United States. This applied the risk determination to the system of airports as a whole rather than examining specific risk at individual airports. By determining risk calculations using a national aggregate methodology, it appears that the Panel compared the north airfield with other airports instead of assessing local risk at LAX due to local configuration. The use of generalized systemwide probabilities assumes that risk at LAX is comparable to other airports in the national system even though there are dramatic differences between U.S. airports. This is especially true at LAX where the rate of runway incursions is higher than comparable airports.

   The Panel's reliance on this systemwide risk probability stands in contrast with the NASS findings that there are clear differences in risk potential between airports. In the NASS, the Panel found that comparable airports with a centerline taxiway and airfield geometry comparable to the proposed north airfield alternatives had a fatal runway collision risk of as much as 48 percent less than the existing LAX airfield (page 89). In other words, the NASS found that the current LAX configuration has a greater risk for incursions due to its airfield geometry alone. Also, the NASS estimated that airports with improved geometry suffer nearly 50 percent fewer runway incursions.

   The differences between airports can be further demonstrated by examining runway incursions at busy large hub airports versus runway incursions at LAX. As shown in the table below, the number and rate of runway incursions at LAX were significantly higher than at Dallas/Fort Worth International Airport (DFW), Hartsfield - Jackson Atlanta International Airport (ATL), and Chicago O'Hare International Airport (ORD) over a 10-year period. As shown by this comparison of runway incursion rates, there are different factors at each airport that lead to different rates of runway incursions and, therefore, differences in risk potential. The higher number of runway incursions at LAX leads to a greater risk for a runway collision.

Runway Incursion Comparison (2000-2009)				
	Number of Runway Incursions			
	LAX[1]	DFW	ATL	ORD
Total Incursions	134	78	93	120
Rate Per 100,000 Operations	2.03	1.05	0.98	1.30
Number of Runways	4	7	5	7

[1] Prior to the south airfield reconfiguration, this rate was 2.44 incursions per 100,000 operations.

Calculating the likelihood of an accident occurring throughout the national system of airports, as the Panel has done, is appropriate for determining the collective progress in improving airport system safety overall. It is not an appropriate methodology for determining the benefit or value of any individual project responding to a known risk at a specific airport.

2. **The methodology used by the Panel in determining the risk for a runway collision did not adequately capture the specific risk factors of the LAX north airfield.** These risk factors include:
   a. The current LAX waiver to FAA Order JO 7210.3V, Facility Operation and Administration. This waiver was developed in response to the increasing size of aircraft that use LAX. Waiver 98-T-69D authorizes LAX to hold certain aircraft types at specific taxiway locations even though these aircraft are within the obstacle free zone and the runway safety area. The NASS does not address the impact of 2020 aircraft levels and traffic mix on the risk of the hazard introduced by this waiver. The 100-north and 340-north alternatives would eliminate this hazard.
   b. The unique air traffic control operating rules at LAX for handling of very large aircraft such as the A380 Operational Plan V.12. This introduces an additional level of complexity into the operating system at the airport. The FAA notes that with a new centerline taxiway, LAX would have air traffic control (ATC) procedures and pilot expectations consistent with other large airports in the United States. This can reduce the potential for human error.
   c. LAX accommodates a large number of foreign flag air carriers and a large number of international pilots for whom English is not their native language. The study does not address how language barriers coupled with the special ATC procedures affects the rate of runway incursions or the risk of a fatal runway collision.
   d. The north airfield not meeting FAA standards. Design standards not met include:
      i. Insufficient lateral separation between parallel runways for Airplane Design Group (ADG) V and VI aircraft.
      ii. Insufficient area to hold ADG V and VI heavy aircraft between Runway 24R and Runway 24L.
      iii. Current modifications to standards to allow A380 and other ADG VI aircraft operations at LAX.
      iv. Insufficient runway width for ADG VI aircraft such as the A380 and future Boeing 747-800.

3. **The NASS did not include simulation of several hazards that are major risk contributors at LAX.** The simulation exercises focused on air traffic performance, which is only one segment of the hazards that exist on the north airfield. The study did not consider aircraft performance and the ability of aircraft to taxi and hold positions, hold between runways, and take a high-speed exit on landing. Additionally, the study introduced pilot errors to air traffic controllers such as incorrect read backs. This was done to measure the rate at which air traffic controllers were able to mitigate errors made by pilots. However, the simulations did not include air traffic control communication errors to pilots. While air traffic controllers have an important role in reducing and eliminating runway incursions,

pilots command the aircraft. They also have a significant role in reducing and eliminating runway incursions. Lastly, the simulation failed to study night instrument meteorological conditions, which are arguably the most hazardous conditions in the airport environment.

4. **The Panel did not fully account for all the risks associated with the operation of very large aircraft at LAX.**
   a. The Panel argued that the risk of incursions does not increase with size of the aircraft. However, this argument does not take into account that the pilot sitting height of Group V and VI aircraft makes taxi more difficult, especially during low visibility conditions. This is confirmed by Airbus' decision to add a nose gear camera to the A380 as a taxi aid. The study did examine some of the sight limitations from the cockpit that make it more difficult to see down the runway from certain large aircraft cockpits.
   b. Many of the very large aircraft are capable of flying 17 hours or more. This leads to pilot fatigue being a factor for aircraft use of the north airfield.
   c. The Panel had limited historical data on which to make its determination that the risk of incursions does not increase with the operation of very large aircraft such as the Airbus A380. The Airbus A380 has only provided regular service to a few U.S. airports since 2008. A380 service to LAX commenced in October 2008. While the Panel examined ADG V aircraft runway incursions as a possible indicator of future very large aircraft runway incursion potential, ADG V aircraft do not have many of the same special procedures for operating at LAX.

5. **The NASS overlooks other fatal runway collisions since 1991, giving the impression that this type of event has become rare.** In fact, there have been three fatal aircraft-to-aircraft accidents since 1991. These include a:
   a. 1994 collision at Lambert-St. Louis International Airport between an MD82 and a Cessna 414 that resulted in two deaths.
   b. 1996 collision in Quincy, Illinois, between a Beechcraft 1900-C and a Beech King Air A90 that resulted in 14 deaths.
   c. 2000 collision between two general aviation aircraft at the Sarasota/Bradenton International Airport that resulted in four deaths.

6. **The NASS assumes that systemwide reductions in incursions due to the use of technology such as the Airport Surface Detection Equipment, Model X (ASDE-X), runway status lights (RWSL), and the Airport Movement Area Safety System (AMASS) apply equally to the north airfield at LAX.** However, a review of past incursion rates on the north airfield reveals that incursion rates remained steady or even higher after new runway incursion warning systems were installed at LAX. Between 1998 and 2002, the five-year period prior to the installation of AMASS at LAX, the north airfield incurred runway incursions at a rate of 3.2 per year. Between 2003 and 2007, after the installation of AMASS, the north airfield incurred runway incursions at a rate of 4.4 per year. In 2008, there were three incursions on the north airfield. In 2009, ASDE-X and RWSL became operational at LAX. Even with all three technologies in place, the north airfield still suffered three incursions in 2009. Therefore, in 2009, the rate of incursions was similar to that between 1998 and 2002 when none of the warning systems were in place.

North Airfield Rate of Incursions		
	1998-2002	2003-2007
Total	16	22
Rate Per Year	3.2	4.4

7. **In overlooking the fact that technology has not significantly changed the rate of incursions on the north airfield, the Panel fails to capture how the current airfield geometry at LAX can limit the effectiveness of warning technologies and contribute to runway incursions.** The outdated geometry of the north airfield includes the limited distance between Runways 6L-24R and 6R-24L and the direct taxiway connections between the runways. This limited distance provides little time for pilots to slow an aircraft to an acceptable speed prior to reaching holdlines or another runway. The taxiway connections extending directly between the north airfield parallel runways lead aircraft straight to potential collision points on the runway surface. These two factors are the primary causes of many runway incursions. A new centerline taxiway would be a buffer between the runways, enabling pilots to slow aircraft more after exiting the runway. With a centerline parallel taxiway in place, incursions caused by pilots landing on Runway 24R can be reduced. Disoriented pilots or pilots exiting the runway at too high a speed will be required to maneuver onto a taxiway surface instead of easily blundering across the holdline directly into the path of departing aircraft on Runway 24L.

   The limited distance between runways also compresses the time available for warning systems such as ASDE-X, AMASS, and RWSL to recognize an impending hazard and for pilots to take corrective action. This creates an overreliance on human interface to prevent hazardous situations. ASDE-X and AMASS require air traffic controllers to relay hazard messages to pilots. A May 2009 Charlotte, North Carolina, runway incursion highlights the difficulty an air traffic controller can have in relaying critical hazard information to pilots. In this instance, the controller was not able to fully provide the necessary hazard notification to the specific aircraft after an AMASS alert. While the pilots were able to avoid the hazards themselves, the aircraft were within ten feet of each other. The FAA maintains that the proper design of the airfield is required to provide controllers and pilots sufficient time to recognize, notify, and take corrective action to prevent a hazardous situation. This is similar to the altitude and in-trail separation distances maintained for en route aircraft. These separation distances allow time for pilots to employ the corrective actions necessary to avert a mid-air collision after an in-flight collision warning is issued.

   The NASS correctly found that there is a relationship between proper airfield geometry and the effectiveness of technology such as RWSL. In fact, the NASS found that RWSL technology works best with proper airfield geometry. Through airfield simulation exercises conducted at the NASA Ames Research Center, the Panel found that "RWSL might be especially effective when accompanied by a centerline taxiway" (page xv) and that "the combination of RWSL and a centerline taxiway is a pairing of two measures that are most effective in complementary areas leading to a more pronounced effect" (page 76). Finally, the NASS determined that the incremental improvement of the RWSL applied to the centerline taxiway alternatives is actually greater than the incremental improvement provided by the RWSL to the baseline [existing airfield] (page 73).

8. **It appears that the Panel did not give adequate weighting to the risk reduction on the south airfield.** The NASS acknowledges the safety gains from the reconfiguration of the south airfield; however, it deems similar changes to the north airfield as unnecessary. The dramatic improvement in safety of the south airfield cannot be disputed. Between 1998 and 2007, prior to the new centerline taxiway, the south airfield experienced runway incursions at a rate of 12.5 per year. Following the completion of the taxiway, the south airfield incursion rate dropped to 5.0 per year. Notably, the NASS found that the new centerline taxiway on the south airfield reduced the most series A and B incursions by 100 percent; A, B, and C incursions by 33 percent; and A, B, C, and D incursions by 79 percent (page 73). As a result, north airfield incursions are growing as a percentage of total airport incursions. In 2008-2009, the north airfield represented nearly 40 percent of total incursions at LAX, whereas in the previous ten years, it had represented only 25 percent of all incursions at LAX. The improvements in the rate of south airfield incursions are clear and compelling proof of the potential improvement that can be gained on the north airfield with a similar change in configuration.

9. **The NASS is overly reliant on historical numbers of fatal runway collisions as the basis of risk.** This underestimates the runway collision risk. Since 2001, there have been three aircraft-to-aircraft nonfatal collisions on U.S. runways. The FAA measures safety in terms of frequency and severity of events. High frequency, low severity events (such as runway incursions that do not result in fatalities) are a source of concern for the FAA because they provide an indication of the potential for a more serious event. In accordance with FAA ATO Safety Management System Manual, Category A and B incursions have a hazard severity classification of hazardous and major, respectively. Additionally, a catastrophic hazard is defined as a collision between aircraft regardless of fatalities. The severity of these hazards can easily result in an unacceptable risk as a function of their likelihood. The FAA and industry also consider reducing the risk for serious injury and damage to aircraft as measures of safety. The lack of a fatality, if a runway collision were to occur, does not change the fact that safety was compromised. The Panel should also have examined the rate of runway incursions as a measure of collision risk.

10. **The differences in a cost-benefit approach versus a Safety Management Systems (SMS) approach to safety management.** The NASS essentially takes a cost-benefit approach in assessing the reconfiguration of the north airfield by measuring benefits in terms of the expected reduction in fatalities. However, the cost-benefit result is not the same as finding that safety risks are unacceptable. This follows because there are other factors that influence the acceptability of safety risks beyond the economics of fatality, injury, and property loss valuation. SMS formalizes this idea by explicitly considering other outcomes that affect risk. Considering this, cost-benefit analysis is of limited applicability in airport specific safety-related decisions. Like probability assessment, it can be a useful tool for quantifying costs

and benefits on a global scale, but it can become problematic when it is used to challenge an identified risk mitigation measure to a known safety risk in a particular airport location.

11. **The NASS seemingly downgrades the risk potential of runway incursions.** A review of runway incursions during the same period as studied in the NASS reveals that all Category A runway incursions at LAX involved a 14 CFR Part 121 air carrier. This is approximately 14 percent of all Category A air carrier involved runway incursions nationwide during the same period. In contrast, the NASS provides an estimate that LAX only comprises 1 to 2 percent of total Category A runway incursions nationwide. The total nationwide rate includes both general aviation and military aircraft incursions in addition to air carrier incursions. FAA research shows a statistically significant relationship between the frequency of Category D events and the likelihood of a serious runway incursion. "No conflict" events such as Category D incursions were not considered in the NASS.

Five separate published industry studies agree that the LAX north airfield safety would be greatly improved by the addition of a centerline taxiway. The NASS is the only study to conclude that the current level of risk is acceptable and improvements are unnecessary. Again, even the NASS acknowledges that there would be significant risk reduction, but then discounts that finding in the summary conclusions.

This conclusion is made even though the NASS goes as far to state that "all the proposals to create new configurations on the north airfield would reduce by a substantial percentage the risk of a runway collision" (page xix). A further finding in the NASS resulting from the NASA simulations exercises is that the center taxiway is a significant safety improvement that "would virtually eliminate runway incursions onto 24L of aircraft exiting 24R, either because of excessive aircraft speed or pilot inattentiveness" (pages 83 and 84). Additionally, the NASS found that a centerline taxiway results in operational advantages and has the potential to improve safety by reducing controller workload during certain runway crossing operations (page 63).

The technical findings in the NASS appear to be based on appropriate research and simulation methodology, including extensive input from air traffic controllers and pilots who are intimately familiar with the actual operating environment at LAX. However, these findings appear to have been almost totally set aside in reaching the final study conclusions. Instead, the study focuses on a vastly different set of conclusions based primarily on a probability assessment. Although probability assessment can be a useful methodology in certain types of system-level analysis, it was misapplied in the NASS when assessing the safety benefits of a specific solution to a known safety risk at LAX.

The FAA has been pleased to support the installation of RWSLs, ASDE-X, and other safety-related improvements at LAX. However, these improvements cannot be seen as substitutes for what would constitute the single most significant safety improvement for the north airfield—geometry changes. The FAA supported similar geometry improvements on the south airfield, which significantly reduced runway incursions. The NASS acknowledges these improvements and recognizes that comparable modifications to the north airfield would have comparable results. Reconfiguring the north airfield will also correct runway and taxiway configurations that presently cause pilot distraction and increase the risk of runway incursions. Reconfiguration can also address other identified surface safety risks including lateral safety areas and the elimination of terrain irregularities currently existing on the north airfield.

Pursuing no further improvements to the north airfield (as advocated in the NASS) ignores the role of SMSs in reducing hazards at airports. Runway incursions are precursors to runway collisions. By advocating no further changes to the airfield to reduce the rate of incursions, the Panel implicitly accepts that a fatal accident will occur. Effective safety management requires the FAA and the airport sponsor to identify hazards and reduce/eliminate known risks. The FAA and industry's approach to safety uses many strategies to prevent accidents. Many of these strategies are in place at LAX such as training, technology, and procedures. However, the most basic element for preventing a runway incursion and/or a fatal runway collision on the LAX north airfield remains the reconfiguration of the outdated airfield geometry.

Reconfiguration of the north airfield would also provide capacity and efficiency benefits for LAX. The Purpose and Need in the FAA's 2005 Record of Decision for the LAX Final Environmental Impact Statement included specific consideration of the need to accommodate projected aviation demand in the Los Angeles Basin. LAWA has indicated that while nearby existing commercial service airports in the region can meet some of the forecast increases in demand, some growth will nonetheless need to be accommodated at LAX if the region is to sustain economic expansion in the future. Moreover, LAWA has identified a goal of maintaining LAX's role as an international gateway.

The NASS concluded that a "serious case could be made for building 340-N[orth Alternative] based on its capacity benefits" (page 162). Annual cost savings of $15.3 million were estimated due to reductions in taxi time and runway blocking with the 340-North Alternative. Departure capacity would improve and arrival delays would be reduced. In fact, the $15.3 million in annual cost savings is a low estimate because the cost-benefits of reduced arrival delays were not specifically assessed by the NASS. In addition, both controller and pilot interviews conducted as part of the NASS simulations indicate that a centerline taxiway provides substantive efficiency and flexibility benefits. The controller interviews indicate a "…near universal opinion that a centerline taxiway provides a significant positive impact on airport operations" (page 65). The analysis conducted in the NASS solidifies the capacity and efficiency improvements that can be gained with the reconfiguration of the north airfield at LAX. This coincides with the conclusion of the FAA and other LAX configuration analysis reports that significant benefits in both efficiency and safety are gained through airfield reconfiguration.

Los Angeles International Airport Advisory Committee

Committee: Residents of El Segundo, Inglewood, Lennox, Hawthorne, Culver City and Westchester/Playa del Rey

March 17, 2010

Mike Bonin, Co-chair
Chris Martin, Co-chair
North Airfield Safety Advisory Committee
Office of Councilman Bill Rosendahl
200 N. Spring Street, Room 415
Los Angeles, CA 90012

Dear Messrs. Bonin and Martin:

The Los Angeles International Airport Area Advisory Committee (LAXAAC), a committee of residents of the communities surrounding LAX, is writing to you with comments relating to the recent Preliminary Report of the Los Angeles International Airport North Airfield Safety Study conducted by the academic panel of experts commissioned by the North Airfield Safety Advisory Committee. LAXAAC appreciates the meticulous detail and comprehensive effort made by the academic panel in conducting this study.

Our committee acknowledges the unanimous conclusion of the study that the LAX North Airfield not only is extremely safe under its current configuration, but also is extremely safe for the projected 2020 traffic, despite the repeated calls for reconfiguration by moving Runway 24-R to the north. We also acknowledge the further finding that proposed changes that would move Runway 24-R north would have only minuscule effects on the overall risk that LAX air travelers face, an overall risk level that is itself minuscule because air travel is exceedingly safe.

In concluding that the current spacing of Runways 24-L and 24-R is very safe given the current capacity of the airport, the academic panel has negated the safety rationale for revisiting the separation distance of Runways 24-L and 24-R. In other words, there is no longer any legitimate argument that the communities surrounding LAX must suffer the adverse impacts of runway movement due to safety concerns.

It thus must be recognized that the primary reason for proposing to move Runway 24-R north would be to increase the capacity of the airport. In light of this report, moving Runway 24-R north not only would be inconsistent with the promise of Mayor Villagaroisa to work to increase regionalization of air travel in Southern California, but it would be extremely disruptive to the communities surrounding LAX.

We recognize that this is a Preliminary Report. Inasmuch as we believe that incursions are individual occurrences often involving pilot error, we propose four additional areas that should be studied as instrumental to increasing safety on both the North and South Airfields at LAX:

1. Lengthening Runway 24-L towards the east to a minimum length of 11,500 feet from the current 10,286 feet. On page 143 of the report, the panel notes that the incursion or collision risk could be minimized by balancing operations between the North and South Airfield complexes. Currently, there is an imbalance of 25 to 30% (with more operations on the South complex) due in part to heavier aircraft on the North side having to take off and land on the South Airfield's longer runway. This results because heavy aircraft that depart from the North terminals must taxi counter-flow on the North all the way around to the South complex to take off and vice versa for landing.

As noted in the academic panel's report, the net result is a quadrupling of the incursion risk with this traffic. This means more opportunities for incidents on the North and South Airfield complexes, additional fuel cost and time for the departing aircraft and additional pollution for the local environment from aircraft exhaust. The imbalance also can adversely affect timely operations, particularly as additional heavier aircraft are introduced into the fleets.

It also is desirable to consider lengthening Runway 24-R to allow larger aircraft to land from the east, which the report recognizes would add further safety benefits (see page 11). This would further improve balance between the North and South complexes.

2. Completing the installation of runway status lights at all runway and taxiway intersections. The FAA has agreed to fund the additional installation and maintenance of the entire runway status light system at LAX. However, given the possibility that FAA funding could be curtailed, as has happened in the past, LAWA must assume the funding and maintenance of the runway status lights if the FAA cannot do so or does not do so in a timely manner.

3. Requiring a full complement of certified air traffic controllers on duty at all times in the LAX tower. Air traffic controller staffing problems resulting in controller fatigue have persisted for many years, creating a serious safety issue at LAX.

4. Undertaking the interim improvements to the North Airfield with the additional requirement that closing or relocating Taxiway Yankee be studied further prior to final approval. The Board of Airport Commissioners has placed these interim improvements on the action list, but may not have included the supplemental examination of impacts due to the new location of Taxiway Yankee.

We acknowledge that the academic panel took the position of looking only into matters that pertained solely to the North Airfield, as opposed to looking at matters that might impact both the North and South Airfields, but these last three issues --- the lack of runway status lights, insufficient air traffic controller staffing and the less-than-optimal taxiway positions --- all have played significant roles in the incursions that have occurred on the North Airfield. Therefore, the academic panel should specifically address each of them in the final report as measures to ensure that the North Airfield continues to be safe.

Finally, please keep in mind that "safety concerns" also must include the safety of those on the ground near LAX in our communities. "Safety" not only includes the risk of collisions to those in the air and on the ground, but also includes the air we breathe and the impacts of noise. We firmly believe that only a regional approach to air transportation will mitigate the safety concerns, noise, congestion and air pollution currently impacting the communities surrounding LAX. Only if the air traffic burden can be spread throughout the Southern California region, will we continue to see the economic benefits of a vibrant transportation system without unduly impacting one portion of the Southern California community.

Please let us know if you have any questions regarding our position on these matters.

Very truly yours,

John Dragone

John Dragone, LAXAAC Chair
Los Angeles International Airport Area Advisory Committee
c/o LAX Community Relations
1 World Way, P.O. Box 92216
Los Angeles, CA 90009-2216

Enclosure (description of LAXAAC)

cc: LAWA Board of Airport Commissioners
Mayor Antonio Villaraigosa
Councilman Bill Rosendahl
Supervisor Don Knabe
Supervisor Mark Ridley-Thomas
Mayor Andrew Weissman
Mayor Kelly McDowell
Mayor Larry Guidi
Gina Marie Lindsey, LAWA Executive Director
G. Pacheco, LAX Community Relations

cc Feldman
BOAC
Molina

City of El Segundo

Office of the Mayor

Received

MAR 22 2010

Office of the Executive Director

Elected Officials:

Kelly McDowell, Mayor
Eric K. Busch, Mayor Pro Tem
Carl Jacobson, Council Member
Bill Fisher, Council Member
Don Brann, Council Member
Cindy Mortesen, City Clerk
Ralph Lanphere, City Treasurer

Appointed Officials:

Jack Wayt, City Manager
Mark D. Hensley, City Attorney

Department Directors:

Bill Crowe, Assistant City Manager
Deborah Cullen, Finance
Bob Hyland, Human Resources
Kevin Smith, Fire Chief
Debra Brighton, Library Services
Greg Carpenter, Planning and Building Safety
David Cummings, Police Chief
Stephanie Katsouleas, Public Works
Robert Cummings, Recreation & Parks

www.elsegundo.org

March 19, 2010

Mike Bonin and Chris Martin, Co-Chairs
North Runway Safety Advisory Committee
Office of Councilman Bill Rosendahl
200 N. Spring Street, Room 415
Los Angeles, CA 90012

Mr. Bonin and Mr. Martin:

Although the City of El Segundo was not a participant in the North Runway Safety Advisory Committee process, we have read with interest the recent Preliminary Report. The City appreciates the time, effort, and creative thinking that the academic panel put into answering the difficult questions posed by the North Airfield Safety Study. The panel's Preliminary Report is an important step toward an LAX that safely and efficiently serves the needs of both air traffic and the airport's neighbors.

The City is particularly glad to see the panel's recognition that the South Airfield Improvement Project has already proved a success. As the Preliminary Report notes, shifting Runway 25L 55 feet south and constructing a centerline taxiway have significantly improved safety on the South Airfield. This finding should assure the airport's neighbors that when a construction project is well thought out and closely analyzed, its costs can be outweighed by gains.

Importantly, the Preliminary Report also determines that a similar addition of a centerline taxiway could improve safety on the North Airfield. This, too, is good news. The City must point out, however, that by viewing LAX as a two independent airfields, the Report overlooks further potential safety improvements. Currently, operations at LAX are unbalanced between the North and South Airfields. The South Airfield handles far more of the noisiest aircraft than does the North Airfield, and it handles the large majority of LAX's heavy aircraft. The City has frequently pointed out that this imbalance places an inordinate noise burden on El Segundo. For the purpose of the academic panel's mission, it is important to note that such imbalance is also detrimental to safety.

As the Preliminary Report notes, the risk of runway incursion on a given airfield varies with the square of the field's traffic level. Balancing traffic between the North and South Airfields would therefore lead to a lower level of incursions at the airport as a whole. To achieve such balance, the North Airfield must be able to efficiently handle more operations by heavy aircraft.

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Phone (310) 524-2302 FAX (310) 322-7137

Any improvement that increases the North Airfield's capacity to handle heavy aircraft will improve the airport's balance and will improve safety at LAX. While the Preliminary Report does recognize the potential operational benefits of a centerline taxiway on the North Airfield, and briefly notes the importance of airfield balance, it fails to take the next step and consider whether, by improving the airport's balance of operations, specific operational improvements like a centerline taxiway would improve overall safety at LAX.

Moreover, there are other potential improvements to the North Airfield that could have a similar effect. For example, the lengthening of Runway 24L would increase that field's capacity for heavy aircraft departures. This modification would not only improve balance and relieve some of the noise burden on El Segundo, it would also improve safety. Extending 24L is the most expedient and cost-effective measure that LAX can implement to balance operations across the two airfields and improve safety without increasing adverse impacts on neighbors. At the same time, the extension could provide increased operating efficiencies by allowing the runway to be used for departures by New Large Aircraft. These and other operational improvements to the North Airfield are an essential aspect of any thorough safety analysis.

In sum, future iterations of the North Airfield Safety Study should acknowledge the inter-connected nature of the two airfields at the airport and should consider the overall safety benefits of operational improvements on the North Airfield. Viewing LAX as a single, unified entity, rather than two independent airfields, is essential to operating the airport in a safe and efficient manner that is also fair to its neighbors. The academic panel should carefully consider the relationship between balance and safety. El Segundo trusts that LAWA will keep the issues of balance and fairness in mind as it continues to study the benefits of adding a centerline taxiway and making other improvements on the North Airfield.

Sincerely yours,

Mayor Kelly McDowell

cc: Mayor Antonio Villaraigosa, City of Los Angeles
Gina Marie Lindsey, Los Angeles World Airports
William Withycombe, Federal Aviation Administration
Hon. Janis Hahn, City of Los Angeles
Hon. Bill Rosendahl, City of Los Angeles

LAX Airline Airport Affairs Committee

MEMORANDUM

Date: March 18, 2010

To: Mike Bonin, NORSAC Co-Chair
Chris Martin, NORSAC Co-Chair

From: Greg Casto, NORSAC Representative for the LAX AAAC
cc: LAX Airline Airport Affairs Committee Representatives
Chad Molnar

Re: North Airfield Safety Study
Los Angeles International Airport (LAX)

This memorandum is written on behalf of the Airline Airport Affairs Committee (AAAC) at LAX in my capacity as their designated Representative to the North Airfield Safety Advisory Committee (NORSAC). The comments set forth herein have been reviewed with and approved by the AAAC and are respectfully submitted for consideration by the Panel.

First, with regard to the Panel's conclusion which states:

> *"For projected 2020 traffic levels and traffic mix, the LAX North Airfield is extremely safe under the current configuration"*

Please clarify how much "weight" the Panel ascribed to the responses received from the Pilots and Controllers pursuant to the Human In The Loop Simulation Exercise relative to the other factors upon which the above referenced statement is based?

Second, with regard to one of the Panel's conclusions which states

> *"In terms of capacity, changes in configuration could have major effects."*

This statement as well as such other statements contained on page 136 of the report which suggest that *there are tangible advantages from a capacity and operational efficiency viewpoint that would result from reconfiguration*…… as well as *other effects that would surface if the analysis is carried in more detail*……including but not limited to …..*reduced arrival delays that this Study did not estimate*…….highlight the need for further, more detailed analysis of both the costs and benefits before any decision can responsibly be made to proceed or not proceed with reconfiguration of the north airfield. Recognition of this need (for further studies), however, should not be construed by anybody as an endorsement by the LAX AAAC of their support for moving forward with a capital project to reconfigure the north airfield.

In closing, on behalf of the AAAC I would like to thank both LAWA for including the AAAC as part of the Advisory Committee as well as the Academic Panel and NASA for their intelligence, goodwill, and candor which characterized their efforts related to this Study.

ARSAC ***Alliance for a Regional Solution to Airport Congestion***

322 Culver Blvd., #231 Playa Del Rey, CA 90293

www.RegionalSolution.org

March 18, 2010

Academic Panel Members
c/o Mr. Mike Bonin and Mr. Chris Martin
Co-chairs Northside Safety Committee
200 N. Los Angeles Street, Room 415
Los Angeles, CA 90012

(transmitted via e-mail on Thursday, March 18)

Dear Academic Panel Members:

The "Los Angeles International Airport North Airfield Safety Study (NASS)" draft report was released February 19, 2010. Enclosed are the ARSAC comments to that draft. We hope that you will be able to utilize these comments to prepare the final report for release next month.

ARSAC agrees and supports the conclusion of the preliminary NASS that the existing LAX north airfield is safe as configured and that many of the airfield safety enhancements that ARSAC has championed for years have been valuable in reducing runway incursions at many U.S. airports. These safety enhancements include ASDE-X radar, enhanced runway and taxiway striping, lighting and signage and the installation of Runway Status Lights (RWSL) on all runway and taxiway intersections.

As the report clearly demonstrates, the movement of runways north, which ARSAC adamantly opposes, will bring negligible safety benefits. ARSAC supports safety enhancement measures which will bring high benefits for low costs. ARSAC supports the Interim Runway Safety Improvement Project as one of the low cost/high benefit safety improvement projects. Furthermore, ARSAC strongly believes that regionalizing commercial airline traffic to Ontario and Palmdale airports will help reduce safety concerns at LAX. There appears to be a correlation between airport saturation and numbers of incursions.

ARSAC thanks the Board of Airport Commissioners, the Los Angeles City Council and Mayor Antonio Villaraigosa for their support of this independent review of the north airfield at LAX.

The NASS report takes a critical step beyond previous studies by placing the total accident risk into context. The NASS report states that the probability of a mishap is very remote and that relative improvements achieved by any runway movement are therefore quite small. The NASS report, as evidence of the level of safety, notes that there has not been a single fatal accident at LAX or any other tower controlled airport in the U.S. since before 2000, despite millions of landings and take offs during that period.

We found this citation uplifting and further appreciate the mention that several technological and procedural measures are yet to be instituted which would even further reduce the possibility of a mishap.

We request that the professors more fully relate the factors considered important to creation of the safest possible runways and discuss the specific the human factor mechanisms. We understand the magnitude of this task and wonder if a more comprehensive treatment of mechanisms could be provided if more time were allocated for the report.

The report relates that the South Airfield Improvement Project (SAIP) completed two years ago has substantially reduced the number of incursions per year. For that we are thankful. The SAIP was a significant fix for a major, on-going problem where 80% of the incursions at LAX occurred on the south runway complex. The SAIP was not an absolute fix for all possible incursions, however, as the annual number of incursions on the south continues to exceed the number on the north. We look forward to the completion of the Runway Status Light project at all intersections on both the south and the north, and hope they will dramatically reduce incursions.

Important physical differences exist between the two LAX runway complexes. Aircraft access runways from both sides on the south but only one side on the north and the locations of the embarkment gates relative to the landing positions on the runways may explain this incursion rate difference. We would like to see the final report elaborate on these differences.

Many details and assumptions made over the year and a half course of this study remain unanswered. Although we are pleased that the general conclusions support the position which we have consistently espoused, our membership and Board would like to fully understand the study design and details. We understand that the final conclusion would not have been changed, but ask how much the sublevel safety impressions identified by the pilot and controller post simulation relative safety reviews resulting from varied runway positional movements would have been lessened.

We are reattaching the series of forty-nine questions raised prior to the writing of the draft report. Detail answers to these questions are neither in report nor in the appendix files provided to date.

Examples of items from these questions include a request for a more detailed airport layout assumed. The one provided does not include gate locations, taxiway details, ground movement procedures followed but not documented, or the experience and background of each pilot and controller participating in the simulations.

When the final report is prepared we would like to see an enhanced section covering the safety mechanisms and what can be done to specifically enhance them. As follow up to the draft, we request that all of the possible improvements for the LAX northside runway complex be ranked, with benefits detailed in relative safety terms as well as explaining how they address the human factors causes for incursion aversion. We would also like to see the detailed assessments and categorizations of the types of incursions seen on both sets of runway complexes at LAX. **[** For example:

Please list all possible safety improvements for the north airfield and rank ordered with benefits detailed in relative safety terms as well as explaining how they address the human factors causes for incursion aversion.

1. Considering that human factors, usually pilots and/or controllers, and not runway geometry, are the root cause of runway incursions, please describe what mechanisms can be implemented to address human factors.

2. Please list detailed assessments and categorizations of the types of incursions seen on both sets of runway complexes at LAX.

3. Please elaborate on the physical and operations differences between the north and south runway complexes. These differences include aircraft access runways from both sides on the south but only one side on the north and the locations of the gates relative to the landing positions on the runways.

4. We specified the use of runway status lights at all intersections. We were told that the simulation RSL only covered some locations (for practical software design reasons) and that anomalies were assessed to see if the RSL would have averted the issue. How effective will RSL be for eastern take offs?

5. How would increased tower and TRACON staffing in general and/or different positions/controller locations have impacted the results?

6. What level of safety improvement would a Final Approach Runway Occupancy Signal (FAROS) system provide?

7. What improvements would Electronic Flight Bags (EFB's) with Airport Moving Maps in each aircraft to show ground position of the aircraft and surrounding vehicles provide?

8. What new collision avoidance systems are available and what implementation recommendations are made?

9. How does the new FAA mandated procedure to repeat confirmation of all authorizations to cross a runway help? * (see last page for detail)

10. How would more complete utilization of preferential use runways impact safety? At LAX, the preferential runway use policy (LAWA policy, not an FAA policy) is to use the inboard runways for takeoffs and the outboard runways for landings.

11. What impact on safety would the new airspace redesigns provide (in general, since we don't know what is planned)?

12. If changes in the design day aircraft selection were made, what impact on safety could be gained by changing the flight mixes of aircraft on a runway complex toward size consistency? What if changes in the amount of flight operations were assumed? This could be done by changing airline locations on the ground as well as moving some types of flights to other airports in a regionalization of the total usage needs. Similarly, what peak hour operational changes are recommended?

13. The report assumed A380s only landed on the north (24R) but they also have been taking off on 24L. Does this reinforce the safety of the NLA on the existing layout? Is safety improved with extension east toward Sepulveda for take offs only as previously proposed?

14. There are multiple ways to realign aircraft on taxiways between parallel runways such as an S-curved taxiway instead of a center line to ensure that large aircraft do not extend back into the safety area of a runway. Where these considered in the study of possible improvements?

15. What would the impacts on safety and efficiency be from changes in airline alignment to bring alliance carriers closer together (less taxiing)? What if the low cost, more frequent turn around airlines are concentrated in specific terminals to provide greater homogeneity of aircraft types? Would this reduce the number of aircraft crossing between complexes? Could it generally improve handling of aircraft on the ground?

16. Are there alternative taxiway configurations that provide the same benefits as a center line taxiway? What are they and what are the pros and cons?

17. In assessing the incursions what trends were seen? Was there a time of date relationship to varied causes? How was pilot fatigue an issue? Would changes in air traffic facilitate improvement?

18. 340' movement south was not as highly rated as the equivalent north. What specific reasons exist and how can those be mitigated?

19. To what extent is ground traffic efficiency tied to safety? How could gate location and taxiway changes be made to improve this?

20. What was the source and use of incursion data? Was it provided by LAWA or the FAA? Were the numbers accumulated by calendar year or fiscal year? How was this data formulated into history assessments and projections of future incidents?

21. In some sections of the NASS report, there appear to be missing references. Is this a factor of needing more time to complete the preliminary report? How much more time would have been needed to address the references?

22. Before the SAIP and approval of Alternative D Master Plan in 2004, the LAX Master Plan stated a design capacity of 40 MAP yet handled almost 68 MAP in 2000. What is the correlation between the number of operations (takeoffs and landings) and the numbers of incursions? If the worst condition is at highest rates what can be done to smooth the peaks?

23. The remote gates still exist on the west end of LAX. How does their use impact safety?

All of the questions we have asked are "higher level" and not paragraph specific of the draft document. We have an extensive list of detailed questions and comments. If it is desired by the academic panel preparing the final report, we would be pleased to provide them, but recognize the time constraint placed upon them for completion.

Please feel free to follow up with any questions you may have about these comments or recommendations.

Sincerely,

Denny Schneider, President

(213) 675-1817

Attachment: 49 previously submitted questions before report was written.

* NTSB most wanted improvements:

http://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=11186

Runway Safety

RecommendationA-00-66: Give immediate warnings of probable collisions/incursions directly to flight crews in the cockpit.

FAA Action: We are deploying technologies that address this recommendation. Airport Surface Detection Equipment, Model X (ASDE-X) is being installed at 35 of the busiest airports in the United States. Runway Status Lights (RWSL) is going into 22 major U.S. airports starting this October.

RecommendationA-00-67: Require specific air traffic control clearance for each runway crossing.

FAA Action: We currently are drafting a proposed rule to address this recommendation.

RecommendationA-00-68: Require air traffic controllers to issue an explicit crossing instruction for each runway after the previous runway has been crossed.

FAA Action: We are revising air traffic procedures to require that air traffic controllers issue an explicit clearance to all runway crossings. Multiple runway crossings will be prohibited with an exception for closely spaced runways of less than 1,000 feet. We anticipate implementing both procedures in June 2010.

RecommendationA-07-45: Install cockpit moving map displays or automatic systems to alert pilots of attempted takeoffs from taxiways or wrong runways.

FAA Action: Installation of Class 3 Electronic Flight Bags with moving map displays began in September 2009 on select air carriers serving 21 testbed airports.

RecommendationA-07-57: Require landing distance assessment with an adequate safety margin for every landing.

FAA Action: We are now evaluating recommendations from the Take Off and Landing Performance Assessment Aviation Rulemaking Committee and we intend to start rulemaking in 2010. Meanwhile, we are working with ten airports and two air carriers to validate the accuracy and usability of a reporting system that forms the cornerstone for many of the recommendations from the committee.

Attachment to LAX Northside draft Report Comments - Questions provided prior to draft release
1. List each of the specific factors and conditions that impact runway safety. Address how each factor is assessed in the simulation. How is each simulation factor conclusion extrapolated and readdressed in the secondary review?
2. What was the final flight mix assumption use and how was it used to establish the NASA simulation?
3. Was exclusive use of the preferred runway options assumed? If not, what percentage of alternative runways were assumed? How was runway selection impact determined and extrapolated?
4. Was gate location or taxiway location was used in the NASA simulation? What specific source was that part of the design? We heard (not verified) that a Recondo drawing was used which pictured the Alternative D Configuration that will never be built as a new TBIT is already designed and approved.
5. If gate location is a safety factor how will it be “extrapolated” from the simulation to actual conditions? What actual conditions are assumed for each of the simulation conditions? What gate locations are assumed in TBIT? Alt D or something else like the new one approved to be started?
6. If taxiway location is used in the NASA simulation what was the source? How does it differ from current conditions? How does it differ from that with the one approved crossfield taxiway project? How does it differ from the condition with the two shown in Alt D behind TBIT?
7. Was the Midfield Concourse assumed present in the NASA simulation? Was it as in Alt D or described subsequently? How are these conditions taken into account for the extrapolation?
8. What taxiways are assumed behind TBIT? Same questions as in previous taxiway questions.
9. Please provide a list of expected anomalies from the simulations and how they are extrapolated into safety condition impacts. Who at NASA provided the guidance in the development of the software? Have they been involved in the earlier safety studies? Have they ever stated that runway separation and a middle taxiway are required or that the airport should be expanded?
10. Who participated as the simulation pilots and controllers? What is their background? What questions were specifically asked of them? How did the automated movements differ from actual conditions on the ground? Did the automated movements impact the results? How was this determined?
11. Who participated in the debriefing of the simulation pilots and controllers? What is their background? What questions were specifically asked?
12. How many runs of each simulation were conducted? In what way did any runs differ from each other?
13. What simulation software anomalies were seen? How could they impact the conclusions? Did all of the simulation equipment function properly during all of the tests? How were any anomalies accounted for in the results? Was any data excluded as non-relevant?
14. What landing approaches or take off paths were NOT included in the simulation?
15. A three year review of north taxiway short term improvements was recently released. Were they part of the simulation conditions assumed? If not, why not? How will the results be extrapolated?
16. What assumptions on safety were made about the number of controllers in the tower (how many, what level of experience, what kind of equipment)?

17. What controls of ground vehicles is assumed? How is this extrapolated?
18. What level of air space redesign is assumed? How is this extrapolated?
19. What sophistication of aircraft safety equipment is assumed? On-board “fight bags” or others? How is this included in the evaluation?
20. How was the 78 MAP capacity restriction included in the assessment? How was it assumed to be enforced?
21. What safety improvement conditions were assumed in the auxiliary assessment?
22. How was 100% Runway Safety Lights accounted for in the model and auxiliary assessment since it was in limited locations?
23. Was the safety risk from sink holes taken into account? How, where?
24. Will there be a matrix of the conditions contributing to runway safety? What items will be presented in this and how will each be assessed to contribute to the total safety assessment?
25. As safety risk is assessed and reported will there be a matrix that shows impact and likelihood?
26. What non-runway movement changes to the airfield have been considered to address each of the items identified in questions 23 and 24?
27. When aircraft are directed for landing on a specific runway by TRACON, what assumptions were made about safety risk impacts when aircraft landed on non-preferred runways? What percentage of the time is this expected?
28. Will the assessment include a FAROS system? Since it was not in the simulation how will this be brought into the assessment?
29. Will the assessment include “flight bag” location status and collision avoidance? Since it was not in the simulation how will this be brought into the assessment?
30. Was there a list of NTSB factors considered in the safety review? What were they and how were they applied to each alternative?
31. How many factors are considered to impact runway safety? What amount of time is assumed for the removal of one aircraft before another aircraft lands?
32. Will the report contain a section on actual LAX incursion experience? How will the incursion be classified? What time-frame will be used in the assessment? Will northside experience be compared with southside? How is this measured and developed?
33. Will the report contain a section on actual LAX incursion experience of the south complex since it was rebuilt and expanded to include a centerline taxiway? Will all of the recent incursions be included and assessed for safety risk so that it can be compared with the northside complex experience?
34. Will the report address runway length as well as spacing? How will this impact safety?
35. How will excursions be addressed in this report?
36. What levels of manpower are assumed in the tower for support of aircraft on the ground to ensure safe passage along taxiways? How would increased ATC ground support guidance improve safety? Would “progressive guided” taxiing improve safety? How much?
37. What studies of pilot fatigue were considered for safety? What correlation is there between the numbers of continuous hours pilots have flown to the time that incursions occurred? Was there more incursions during the second day of flying? How can this be reduced?
38. What earthquake zones were included in the study and what was the danger determined to be for LAX for each North Airfield configuration studied? Were the zones general in nature, or recent and particular to the immediate LAX area? What was the basis for the information used in the determination (i.e., title, date, author(s), and authorizing agency or institution of the research information)?
39. What were the ground stability and flooding danger determined to be for each parameter studied? How were the natural watercourse area (near the easterly turn on Lincoln Blvd), sink-hole water collection, and liquifaction dangers factored in? What was the basis for the information used in the determination (i.e., title, date, author(s), and authorizing agency or institution of the research information)?

40. What study was included on the sink holes that have been found in the North Airfield area? How many have been found so far, and how wide and deep have they been? How did the damage and repair of the sink holes deter airfield operations? Was the cost of these repairs included in all North Airfield configurations? What pattern is evident from the sink hole locations and depth and what prediction for future problems has been included, based on the evidence? What was the basis for the information used in the determination (i.e., title, date, author(s), and authorizing agency or institution of the research information)?

41. What studies were included for existing water, power, and sewer lines? Was the committee provided with complete information, showing all the lines and the dates of their installation? Was the past history of inadvertent disruption of these lines (and services) included? What was the basis for the information used in the determination (i.e., title, date, author(s), and authorizing agency or institution of the research information)? Was the cost of repairing the line disruptions and the down-time for airfield operations included? What prediction for future problems was made in the study?

42. Were the FAA-determined areas of a runway safety area and runway protection zone included in studying each configuration? How far into the surrounding residential areas, LAX Northside (sometimes referred to as Westchester Southside by LAWA), Westchester business district, and the Sepulveda Blvd/Lincoln Blvd intersection would each zone penetrate under each configuration? Was the cost of compensation or eminent domain processes for private property included? Was the cost to the City of Los Angeles to create and enforce new building restrictions to prohibit encroachment into the FAA zones included? Was the time and cost for interfacing with CalTrans on roadway revision or relocation included?

43. Was the impact to the 96th Street Bridge, Century Blvd, and Sepulveda Blvd entry/exit areas included in studying each configuration? Was the total cost of any relocation, repair, or replacement included? Were the costs of aircraft departure/landing delays due to construction included?

44. Were the potential additional health hazards due to increased noise and air pollution for those working at or near LAX and for nearby residents considered for each configuration? Did these studies include the damage caused to lungs by ultrafine particulate matter which has been determined to be present in aircraft exhaust? Were the positions and flow of aircraft exhaust and noise determined for each configuration? Were the positions of aircraft on runways and taxiways and the resulting noise and air pollution under different weather conditions included?

45. Were the potentially new flight paths for arriving and departing aircraft and the noise and air pollution impacts they would cause to residential areas studied for each configuration? Were the impacts of revising the air space due to new flight paths included?

46. Were the impacts to traffic flow during and after construction due to any realignment or relocation of intersections or major streets included? Were the additional noise and air pollution impacts included?

47. Have any of the actual incursions experienced been evaluated in terms of how the five study options would have reduced “risk” or fully alleviated them?

48. Safety is not just about the airplanes on the north runway complex, it is also the impact on the surrounding community. Slower deaths can occur from the environmental impacts of noise and pollution which is still part of the major concern for “safety.” How were changes in configuration and Runway Protection Zones (RPZ) and compatible land impact considered in the safety evaluation?

49. How were flight paths for takeoffs and landings during Westerly, Easterly and over-ocean operations evaluated? Also, how were flight paths for aircraft making go-arounds or during inflight emergencies identified and considered? Did the study assume that all aircraft in trouble will get permission to do an emergency landing or go-around? What impacts were considered if a landing is done in an easterly fashion for necessity when LAX is operating westerly?

Frank A. Clark
Executive Director

March 18, 2010

To: Mike Bonin, NORSAC Co-Chair
Chris Martin, NORSAC Co-Chair

Cc: LAX Airline Airport Affairs Committee

Re: North Airfield Safety Study - LAX

This memo is in response to the recently released North Airfield Safety Study, and represents the interests of the international airline community serving LAX.

First and foremost NASA-Ames and the academic panel are to be recognized for the thoroughness and level of detail that was included in this most recent study. However, as noted by the panel themselves this study was inherently limited in scope from the outset with the primary emphasis placed on safety alone.

Airports by their very nature are a highly complex entity with a wide range of organizations involved in their safe, efficient, and cost-effective operation. The City of Los Angeles and LAWA after several decades are just now in the process of modernizing LAX, recognizing the need to have an efficient and modern airport if the city is to remain as a competitive international gateway to the world aviation market.

Until 2007 with the realignment of the south runways the airfield at LAX had undergone little change, and remains in large part a Group IV airport with numerous "workarounds" approved by the FAA to meet current operating requirements. In addition, it is forecast that LAX will have the largest concentration of A-380 operations in North America by 2015.

The international airline community remains concerned that the operating inefficiencies of the airfield will further impact airline operations when the number of Group VI aircraft increase. This becomes particularly important as airlines schedule their aircraft and seek to optimize these valuable resources. Concerns regarding the ability to get to/from the new TBIT-West facility and operate around the airport will potentially influence airline decisions on where to deploy their next generation aircraft, and the cities where they will dedicate additional aircraft as passengers volumes recover from the current global recession.

Therefore, the international airlines that serve LAX urge those responsible to consider this study as only one element for consideration when evaluating the needs to insure that Los Angeles has an airport that is capable to compete for international tourism into the next decade.

Frank Clark

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March 17, 2010

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Re: Cities of Inglewood and Culver City Comments on the Los Angeles International Airport North Airfield Safety Study Preliminary Report

Dear Chairpersons Bonin & Martin:

The following comments on the Los Angeles International Airport North Airfield Safety Study Preliminary Report ("Study") are submitted to the Chairpersons, Los Angeles International Airport North Airfield Safety Advisory Committee ("NORSAC"), by the Cities of Inglewood and Culver City ("Cities").

I. INTRODUCTION.

The Cities are pleased to learn that the Academic Panel ("Panel") has found that the Los Angeles International Airport ("LAX") North Airfield is safe, and that relocation of Runway 24R 100 feet to the north could add an extra measure of safety to the North Airfield complex. Although the Study's conclusion are in complete accord with three previous studies of LAX North Airfield alternatives[1] and the position expressed by the Federal Aviation Administration

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[1] *See*: *Analysis of LAX North Airfield Alternatives*, May 2007, International Aviation Management Group, Inc.; *Los Angeles International Airport North Airfield Assessment*,

("FAA") that LAX is safe in its current configuration, there are a number of revisions that could be made to the Study that would strengthen support for that conclusion. Foremost among them are: (1) inclusion of references and citations to sources for data used in the simulations and analyses, which are currently missing; and (2) use of data that is internally consistent and does not conflict with previously published reports by LAX and the FAA. The Study also sometimes digresses from its core purpose, analyzing the causes and risks of runway incursions, and instead discusses topics such as runway fatalities, risks not associated with airports and cost savings to air carriers, all of which are outside the scope of the Nine Question regarding runway incursion risks presented to the Panel. [p.4][2] Therefore, Cities submit these comments in a spirit of cooperation and support of the Study's main conclusions that the North Airfield is safe as presently configured, and that moving Runway 24R 100 feet to the North would enhance the safety of the North Airfield, and to insure that the analyses leading to those conclusions is beyond dispute.

II. THE STUDY DOES NOT LIST SOURCES FOR MUCH OF THE DATA USED, AND CONTAINS DATA THAT IS BOTH INTERNALLY INCONSISTENT AND IN CONFLICT WITH PREVIOUSLY PUBLISHED LAX RUNWAY INCURSIONS REPORTS AND FAA PUBLISHED DATA.

In any study of this complexity, it is likely that some internal inconsistencies in data will occur. The following is offered for the purpose of reconciling the conflicts to the extent possible. First, the Study would be more understandable if it listed sources for the data used in simulations and calculations, making it possible to evaluate and verify its findings and conclusions. Further, the Study should be revised with an eye on resolving conflicts between data from unidentified sources within the Study, and also with data provided to the Panel by LAWA and data published by the FAA. An example of such conflicting data from unidentified sources is in the historical LAX runway incursion numbers shown in Tables 8-5 and 8-6 at page 77. Table 8-5 shows 41 incursions on the North Airfield from 2002 through 2008. In contrast, Table 8-6 shows 36 incursions on the North Airfield during that period. No source is shown for those numbers. LAX Runway Incursions Reports provided to the Panel by LAWA show that there were 16 incursions on the North Airfield from 2002 through 2008.[3]

May 2007, URS Corporation; *LAX North Airfield Special Peer Review Summary Report*, March 13-15, 2007, Peer Review Group

[2] Unless otherwise indicated, all page references are to the Study.

[3] The LAX Runway Incursions Reports are available on the LAWA website at lawa.org/airops.aspx?id=1112

Total Number of Incursions North Airfield

Year	2002	2003	2004	2005	2006	2007	2008
Table 8-5	4	5	4	9	4	10	5
Table 8-6	3	8	2	7	3	9	4
LAX Runway Incursions Reports	1	2	2	1	2	5	3

The Study does not explain these differences.[4] If "Total Number of Incursions North Airfield" is intended to mean "Number of Heavy Aircraft Incursions North Airfield" and "Number of Group V Aircraft Incursions North Airfield" in Tables 8-5 and 8-6 respectively, the total number of incursions on the North Airfield would be even greater when combined with runway incursions involving aircraft other than Heavy and Group V Aircraft. Even if "Total Number of Incursions North Airfield" is intended to mean "appearances", as defined on page 77[5], not incursions, the numbers shown in Tables 8-5 and 8-6 would still differ markedly from the LAX Reports. For example, there could not have been nine [9] "appearances" in the single 2005 incursion on the North Airfield. Also, the Study states at page 43 that "Group V is a subset of 'heavy.'" If the totals shown in Tables 8-5 and 8-6 are actually Heavy and Group V incursions, there would have been three [3] more Group V incursions than Heavy incursions in 2003. Eight cannot be a subset of five.[6]

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4 The Study states that it relied heavily on empirical evidence based on historical experience at LAX. [p.ix]

5 The term "appearances" does not occur elsewhere in the Study, nor in any LAWA or FAA generated documents.

6 The incursion percentages in Tables 8-5 and 8-6 are also confusing. For example, does the data for Heavy Incursions on the North Airfield in 2003 reflect 0.2 percent, or was it 20 percent? Similarly, was the 2003 Group V Incursion percentage on the South Airfield .07 percent, was it 7 percent? If the Total Number of Incursions on the South Airfield was 20, as shown in Table 8-6, and .07% involved Group V Aircraft, that would mean that .014 Group V aircraft were involved. If 0.07 actually means 7%, there would have been 1.4 Group V aircraft involved. Both are confusing, in that runway incursions must necessarily be expressed in whole numbers.

If we assume that "Total Number of Incursions" actually means total number of incursions, the total numbers of incursions shown in Tables 8-5 and 8-6 on the North and South Airfields combined would differ from each other, and would be significantly greater than reported in the LAX Runway Incursions Reports:

Total Number of Incursions at LAX

Year	2002	2003	2004	2005	2006	2007	2008
Table 8-5	23	24	13	28	16	36	10
Table 8-6[7]	23	28	17	27	16	36	12
LAX Runway Incursions Reports	6	11	5	6	9	12	7

The numbers of North Airfield incursions shown in Tables 8-5 and 8-6 also differ markedly from the numbers published by LAX. Table 8-5 shows that there were forty-one [41] runway incursions on the North Airfield from 2002 through 2008. Table 8-6 shows that there were thirty-six [36] during that time. The LAX Reports show that there were sixteen [16], and previous studies were based on that number.[8]

Total Number of Incursions North Airfield

Year	2002	2003	2004	2005	2006	2007	2008
Table 8-5	4	5	4	9	4	10	5
Table 8-6	3	8	2	7	3	9	4
LAX Runway Incursion Reports	1	2	2	1	2	5	3

According to LAX Runway Incursion Reports: (1) there was one [1] runway incursion on the North Airfield in 2002 (B-757 and B-747); (2) there were two [2] runway incursions on the North Airfield in 2003 (Canadair CRJ2 and B-737; Military C-12 and A-320); (3) there were two

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[7] "Group V Incursions (%) North Airfield" in Table 8-6, Row 3 should be changed to "Group V Incursions (%) South Airfield."

[8] *See, e.g.*, *Analysis of LAX North Airfield Alternatives*, May 2007, International Aviation Management Group, Inc., p.14, Figure 10

[2] runway incursions on the North Airfield in 2004 (B-737 and B-739; B-747 and B-737); (4) there was one [1] runway incursion on the North Airfield in 2005 (two B-737s); (5) there were two [2] runway incursions on the North Airfield in 2006 (B-737 and Embraer E120; B-737 and A-320); (6) there were five [5] runway incursions on the North Airfield in 2007 (B-737 and Turboprop; A-340 and Turboprop; B-737 and A-320; two B-737s; B-737 and Turboprop); and (7) there were three [3] runway incursion on the North Airfield in 2008 (A-320 and MD-80; B-737 and Turboprop; B-777-300 and MD-80).[9]

Finally, the total numbers of runway incursions at LAX during 2004 through 2007 shown in Tables 8-5 and 8-6 conflict with those shown in the *FAA Runway Safety Report, June 2008*[10] [cited in the Study at page 35]:

Total Number of Incursions at LAX

Year	2004	2005	2006	2007
Table 8-5	13	28	16	36
Table 8-6	17	27	16	36
FAA Runway Safety Report, June 2008[11]	7	8	8	8

In summary, without knowing the source, or sources, of runway incursion data used in the Study, it is impossible to verify the data, or to reconcile the differences between Table 8-5, Table 8-6 and the LAX Runway Incursions Reports and *FAA Runway Safety Report, June 2008*. Use of officially published LAX and FAA runway incursion data as the baseline for the Study would provide greater, readily verifiable, support for the Study's finding that the North Airfield is safe.

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9 *Source* - LAX Runway Incursions - 2002 - 2008

10 *FAA Runway Safety Report, June 2008*, Appendix D, p. D-5

11 Runway incursions shown in the *FAA Runway Safety Report, June 2008* are listed for Fiscal Years. Tables 8-5 and 8-6 show incursions in calendar years. However, that slight variation does not explain the vast difference between incursions shown in Tables 8-5 and 8-6 and those shown in official FAA records.

III. THE STUDY DOES NOT ANALYZE THE ***CAUSES*** OF PAST RUNWAY INCURSIONS AT LAX.

The Study does not analyze the causes of past runway incursions at LAX, and if and how North Airfield reconfiguration might affect those causes. Pilot deviations account for 58% of runway incursions, operational errors account for 23%, and "vehicle/pedestrian deviations" account for the remainder.[12] [Note that the FAA does not directly attribute any runway incursions to airfield configuration.] Recent LAX Runway Incursions Reports show that: (1) both of the two runway incursions that occurred on the North Airfield in 2006 were caused by controller error; (2) the five runway incursions that occurred on the North Airfield in 2007 resulted from pilot deviation/error; and (3) two of the three runway incursions that occurred on the North Airfield in 2008 were the result of pilot error, the other was attributed to "Operational Error/System Error."[13] The FAA has stated that airport layout and design can play a contributory role in runway incursions.[14] However, the Study does not consider whether runway reconfiguration under the various alternatives might prevent, ameliorate or exacerbate the conditions under which those errors occurred, or are likely to occur. Similarly, the Study does not examine the causes of runway incursions on the South Airfield, both before and after separation of the runways and installation of a centerline taxiway, and how those occurrences might inform the North Airfield runway incursion analysis.

IV. RUNWAY FATALITY ESTIMATES DISTRACT FROM THE STUDY'S IMPORTANT CONCLUSION.

Runway fatalities is not a proper metric by which to assess airfield safety. The Study is replete with terms such as "fatal runway collisions", "runway fatalities", "lives per decade", "death risk per flight", "total deaths", "casualties", "dying", "perish", "mortality risks", *etc.*. Section 6 (Safety Analysis; The Baseline Case) [p.33] is devoted almost entirely to fatal runway collisions.[15] Section 12 [Comparative Summary of Safety Assessments] compares the risks to air

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12 *Source - Final Environmental Impact Report (Final EIR), Los Angeles International Airport (LAX) Proposed Master Plan Improvements*, Part II, Volume 11, p. 3-6590.

13 *Source* - LAX Runway Incursions - 2006, 2007, 2008

14 *See*, fn 12

15 "The focus is on *fatal* runway collisions . . ." (emphasis in original) . . . "what would be the baseline frequency of fatal runway collisions on the LAX North Airfield . . . what would be their consequences in lives lost?" [p.33]

travelers in terms such as "*deaths per decade*" (emphasis in original) [p.108] and "*one life every four years*" (emphasis in original) [p.109] This body count approach introduces a "death vs. cost" element into the decision making process and could foster an "even one death is to many" mentality in those using the Study to decide which configuration to adopt, or to justify one configuration over another. The Study confirms that possibility by stating "[t]he question is whether the sums spent in the reconstruction might save many more lives if used in other ways." [p.109] Given that eight of the nine questions presented to the Panel [p.4] focus on runway incursions and the risk of runway incursions, the focus of the Study should be on the relative risks of runway incursions [not mortality risks] for the various North Airfield configurations, without regard to potential fatalities.

Even the most serious FAA runway incursion classification, Category A [Separation decreases and participants take extreme action to narrowly avoid a collision, or the event results in a collision] [p.35] does not include fatalities. The Study relies heavily on the paper "Fatal US Runway Collisions Over the Next Two Decades" co-authored by Dr. Arnold Barnett, one of the Panel members. [Study, Appendix B]. However, the focus of that paper is runway fatalities. Here, the focus of the Study is comparative runway safety and, more narrowly, assessment of runway incursions. The Study should assess the risk of runway incursions under each North Airfield configuration and use reliable historical data to estimate the number of likely incursions in each runway incursion category. If reliable data is available showing the ratio of collision and non-collision Category A incursions, the Study could estimate the numbers of each, and stop at that. To go further by estimating the potential number of fatalities is too speculative for this type of study, especially where the Study makes no assumptions regarding factors such as aircraft types, sizes[16], runway and taxiway locations, closing velocities, points of impact, passengers and fuel on board, along with factors such as the possibility of fire, the effectiveness of emergency response personnel in saving lives, and other survival factors. Runway fatality estimates should not be included in the Study. To use a Panel metaphor, the risk of runway incursions is the cake. Runway deaths are the icing on the cake. LAWA and NORSAC ordered the cake without icing.

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16 The statement that when two planes of unequal size collide, the percentage killed is generally far higher on the larger plane than on the smaller one [p.45] is contradicted by the sentence that follows: "In the 1991 collision at LAX . . . the death rate was 100% on the small computer plane and 25% on the 737 jet that crashed into it." It seems likely that the percentage killed would be generally higher in the smaller aircraft because of the probability of greater damage to, and fewer passengers aboard, the smaller aircraft, as was the case in the 1991 accident.

V. IF RUNWAY DEATH ESTIMATES CONTINUE TO BE A MEASURE FOR THE STUDY, THE DEATH TOLL IN THE FEBRUARY 1, 1991 AIRCRAFT ACCIDENT AT LAX SHOULD NOT BE INCLUDED.

Even if the Study were to continue to consider fatalities as a measure of safety, the death toll in the February 1, 1991 aircraft accident at LAX should not be included in the Study. That is because: (a) the accident was caused by factors unrelated to airfield configuration; (b) the accident occurred prior to installation of AMASS and ASDE-X radar; and (c) use of the death toll artificially inflates the runway death estimates.

A. The February 1, 1991 Aircraft Accident at LAX Involving US Air Flight 1493 and Skywest Flight 5569 Was Caused by Controller Error, and Was Unrelated to Airfield Configuration.

The 1991 accident was not the result of a runway incursion of the types identified in the Study, *i.e.*, where a pilot proceeds to cross a runway after having observed a red runway entrance light [*i.e.*, "bust the hold bar"], or has exited an outboard runway at a high speed, failed to slow down and proceeds to cross the inboard runway ["Exit No Stop" ("ENS")] [p. 74]. The accident occurred after a local controller [LC2] failed to maintain an awareness of the traffic situation when she forgot that she had placed SKW5569 into position for takeoff on Runway 24L and issued a landing clearance to USA1493 on that same runway.[17]

Second, airfield configuration was not a contributing factor in the 1991 accident. In fact, airfield configuration was not even considered by the NTSB in its investigation.[18] No airfield configuration could prevent a collision when a controller clears an aircraft to land on top of another aircraft positioned for takeoff.

Third, the Study improperly uses fatality data originating prior to the installation of the Airport Movement Area Safety System (AMASS) at LAX to estimate fatalities that are likely to occur in the future after AMASS has been installed. The NTSB stated that AMASS, which was being tested by the FAA at the time the NTSB issued its Report, could provide warnings to preclude accidents similar to the SKW5569/USA1494 collision. Further, the Study's "fatal runway collisions" estimate "assumes high effectiveness for new technologies like AMASS" [p. xii]. Thus, according to both the NTSB and the Panel, it is extremely unlikely that an accident

[17] *See* NTSB Aircraft Accident Report AAR-91/08, pp. 74-76 - Conclusions, Findings and Probable Cause.

[18] *See* NTSB Aircraft Accident Report AAR-91/08, p.*vi*.

such as the 1991 accident would occur in the future on the North Airfield complex equipped with AMASS.[19]

Because: (1) the subject of the Study, runway configuration, was not a factor in the 1991 accident; (2) the 1991 accident did not result from a runway incursion of the types studied by the Panel; and (3) AMASS and other new airport surface traffic detection and automation technologies have since been installed on the North Airfield, the death toll from the 1991 accident should not be included in the Study.

B. Use of the 1991 Accident Death Toll Artificially Inflates the Runway Death Estimates.

Use of the high death toll from the 1991 accident serves only to inflate the runway death estimates. On the one hand, the Study finds that: (a) the Baseline configuration is extremely safe [pp. 153, 155], or exceedingly safe [p. xix]; (b) the 100-North configuration is 40% safer than the Baseline [p. xv]; (3) the 340-North configuration is 55% safer than the Baseline [p. xvi]; (4) Category A and B runway incursions have declined at 32 of the largest U.S. airports subsequent to installation of AMASS [p.35]; (5) the Study assumes that AMASS and ASDE-X are in use [p.34] ; and (6) the FAA believes that the combination of AMASS, ASDE-X and runway status lights can cut by approximately 7/8 (87.6%) the risk of runway collisions that prevailed prior to their introduction [p.34]. On the other hand, however, the Study estimates that runway deaths will increase from none [there have been no deaths attributable to the airfield configuration at LAX in recent decades, including pre-AMASS] to **five** per decade with the current runway layout, **three** per decade with 100-N, and **two and one-half** per decade with the 340-N configuration. [p. 108] This estimated increase in runway deaths, even at 2020 traffic levels, is inconsistent with the increased safety findings, and appears to be a function of introducing the death toll from the "worst runway accident in US aviation history" [p. 30] into the calculation.

VI. THE STUDY SHOULD DEFINE KEY TERMS USED IN THE STUDY.

The Study should also define certain key terms as they are used in the Study, perhaps in a separate introductory "Glossary." Doing so would add clarity and consistency to the Study and make the Study more understandable to the reader. For example, the Study sometimes refers to "safety" in terms of runway incursions, at other times in terms of runway collisions, and all to often in terms of runway fatalities. [See Section IV above] Moreover, the Study's surrogates for "safety", its broadly defined dependant variable, vary from "Fatal Collisions" to "AB Collision Risk" to "Incursion Risk" to "ENS Incursion Risk" and are used interchangeably throughout the

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[19] The Study assumes that AMASS is installed. [p. 73]

Study. "Safety" should be defined consistently throughout the Study, preferably in terms of runway incursions[20], not in terms of collisions and deaths.

VII. ESTIMATES OF COST SAVINGS TO AIR CARRIERS ARE EXTRANEOUS TO THE ANALYSES OF AIRFIELD SAFETY.

Estimates of the annual cost savings, presumedly to air carriers, [*see* pp. xvii, 119-120, 134-136] are outside the stated goals of the Study, *i.e.*, to estimate the level of future safety of several alternate configurations of the LAX North Airfield and to provide useful information about the capacity implications of the various configurations. [pp. xiv, 153] Estimates of cost savings introduce an extraneous factor, unrelated to safety or capacity, which should not, but might, be considered by decision makers in deciding how to use the Study. Just as the Panel was "not expected to estimate the dollar cost of reconfiguring the North Airfield" [p. 5], cost savings to air carriers are not a relevant consideration in the Study.

VIII. COMPARISONS OF RUNWAY INCURSION RISKS TO RISKS NOT ASSOCIATED WITH AIRPORT RUNWAYS ARE POTENTIALLY MISLEADING.

The Study should adhere to the "how much safer is X than Y?" and "how safe was Y in the first place?" approach described at p.3, where Y = the existing Baseline configuration and X = the alternative configuration under evaluation, *i.e.*, 100'-North or 340'-North. The Panel was not asked to assess the "relative risk compared to other safety hazards that face Los Angeles residents" or "runway risk relative to other mortality risks that air travelers face" [p.3]. Introduction of such unrelated risks involving events that occur outside airports has the potential to mislead or influence decision makers who rely on the Study.

For example, comparing the mortality risks to LAX passengers to "other mortality risks that face residents of Los Angeles" [p.47] is of questionable value, in that (1) not all residents of Los Angeles use LAX; and (2) many, if not most, LAX passengers are not residents of Los Angeles. The focus of the Study should be on the comparative safety of the various North Airfield configurations. Comparing LAX runway risks to the risks of dying in an auto accident or "the menace posed by the San Andreas Fault" [p. 46] is like comparing LAX runway risks to the risk of typhoons to Kansas travelers, or the risk of hurricanes to Southeast travelers. It serves no analytic purpose in assessing comparative runway safety.

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20 Eight of the nine questions presented to the Panel [p.4] focus on runway incursions and the risk of runway incursions.

IX. THE STUDY SHOULD ASSESS CONTROLLER WORKLOAD AND ITS IMPACT ON RUNWAY SAFETY IF THE GC3 GROUND CONTROLLER POSITION IS NOT STAFFED.

The Capacity and Workload Assessments analysis [Section 13] assumes the addition of a new ground control position [GC3] to deal with the added complexity of a new midfield terminal and additional gates on the west side of the Tom Bradley International Terminal [p.123]. The GC3 position was "created" in the FCC simulation [p.20], and assumes that the GC3 position is filled. The Study states that the GC3 position "will be critical in future operations at Los Angeles International Airport . . ." [p.127]. The Study does not analyze LAX air traffic controller workload if the GC3 position is not staffed. Given historical air traffic controller staffing levels at LAX, the Study should also analyze controller workload without the GC3 controller, *i.e.*, at the current air traffic controller staffing level, and its impact, if any, on North Airfield safety if the GC3 position is not staffed.

X. THE STUDY FAILS TO EXPLAIN WHY TAXI TIMES TO AND FROM 100-N WOULD BE LONGER THAN TAXI TIMES TO AND FROM 340-N.

Figure 13-7 [p. 118] shows taxi-in times of 630 seconds from 100-N and 612 seconds from 340-N. Figure 13-8 [p.119] shows taxi-out times of 1257 seconds to 100-N and 1198 seconds to 340-N. The Study does not explain why taxi times to and from 100-N are longer than taxi times to and from 340-N, which is located farther from the gates where taxi times begin and end.

XI. EDITORIAL ERRORS CONFUSING RUNWAY 24R AND RUNWAY 24L SHOULD BE CORRECTED.

The confusion of Runways 24R and 24L frequently throughout the Study are likely typographical errors that do not change the Panel's analysis. However, they are confusing to the reader and should be corrected to enhance understanding of the Study.

Examples: Page xiv, last paragraph, line 2; "planes landing on Runway 24L" should read "planes landing on Runway 24R"

Page xv; Heading at top of page should read "Moving Runway 24R 100 Feet North"

Page 6, 4th and 3rd lines from bottom; should read "if runway 24L is unsafe for entry or crossing"

Page 157, Section 17.4.2, line 4 - "24R" should be changed to "24L"

Page 157, Section 17.4.2, line 6 - "24R" should be changed to "24L"

Page 157, Section 17.4.3 heading should be changed to "Moving Runway 24R 100 Feet North (100-N)"

Page 158, Section 17.4.4 heading should be changed to "Moving Runway 24R 340 Feet North (340-N)"

Page 158, Section 17.4.4 lines 3-4 should read pilots crossing 24L"

Page 158, Section 17.4.5 heading should be changed to "Moving Runway 24L 340 Feet South (340-S)"

XII. ADDITIONAL EDITORIAL SUGGESTIONS.

Pages xii and 155 - A decrease from 67 to 12 runway incursions is an 82% [not 80%] decrease.

Page 7, mid-page - "a departure on 25L" should read "a departure on 25R"

Page 46, Section 6.11., 2[nd] paragraph, line 3 - "350 million" should read "750 million". [750 million ÷ 5 = 150 million]

Page 56, 2[nd] paragraph, lines 5-6 - "arrivals on runway 25R" should read "arrivals on runway 24R"

Page 88 - When read in context, it appears that the last sentence of the paragraph beginning "[i]n both of these equations . . ." should read "we did **not** consider incursions involving ground vehicles".

Page 90 - It appears that the last word in the first paragraph should be changed from "south" to "**north**".

Page 92 - When read in context, it appears that the last sentence on page 92 should read "Alternative D did **not** mention any difference . . ."

In summary, the Cities thank the Panel Members for their efforts, and are confident that the preceding comments will be incorporated into the analysis in any following addendum to the Study.

Sincerely,

CHEVALIER, ALLEN & LICHMAN, LLP

Berne C. Hart

cc: Academic Panel Members
c/o Chair, Arnold Barnett, Ph.D.
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Los Angeles International Airport North Airfield Safety Study

FFC LAX Simulation Data and Academic Panel Demand Files

Compiled by the Academic Panel and Betty Silva (NASA Ames)

April 19, 2010

Files Delivered to LAWA as part of the LAX FFC Simulation Study (North Airfield Safety Study)

The NASA FFC simulations collected a large variety of data. In order to run all FFC simulations, the Academic Panel generated significant amount of data that was processed by NASA Ames. The hard drive delivered to LAWA is organized in several folders as shown in Figure 1. Five folders contain both NASA and Academic Panel generated data files. If there are any questions about these files please direct them to:

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Name	Date Modified	Date Created
LAX FFC Simulation Deliverables.doc	Today, 1:31 PM	Today, 1:31 PM
NASA FFC Outputs	Apr 19, 2010 9:36 PM	Aug 19, 2009 12:49 AM
AP Panel Support Files	Apr 19, 2010 9:33 PM	Apr 13, 2010 9:43 PM
FFC Demand Scenarios by AP Panel	Apr 13, 2010 9:56 PM	Apr 13, 2010 9:12 PM
CVS Sim Outputs	Jan 5, 2010 12:32 AM	Aug 19, 2009 12:49 AM
Surveys and Interviews	Sep 29, 2009 2:33 PM	Sep 10, 2009 12:18 PM

Figure 1. Organization of the Files in the LAWA Hard Drive.

Figure 2 illustrates the organization of the NASA FFC Outputs folder. This folder contains all FFC audio files for each simulation run (54 runs total). FFC audio files are posted in WAV format. Audio log files contain summary communication data between pilots and controllers for each simulation run. These files contain numeric and text data sets. The ATG history Files Folder contains detailed information on aircraft positions for each simulation run. These are organized by date.

Name	Date Modified	Date Created
LAX FFC Simulation Deliverables.doc	Today, 1:33 PM	Today, 1:31 PM
NASA FFC Outputs	Apr 19, 2010 9:36 PM	Aug 19, 2009 12:49 AM
FFC Audio Files	Apr 19, 2010 9:27 PM	Apr 16, 2010 3:20 PM
Audio Log files	Sep 30, 2009 12:53 PM	Sep 1, 2009 8:12 PM
ATG_History_Files	Sep 26, 2009 9:23 PM	----
Statistics	Sep 18, 2009 5:19 PM	Sep 1, 2009 8:17 PM
AP Panel Support Files	Apr 19, 2010 9:33 PM	Apr 13, 2010 9:43 PM
FFC Demand Scenarios by AP Panel	Apr 13, 2010 9:56 PM	Apr 13, 2010 9:12 PM
CVS Sim Outputs	Jan 5, 2010 12:32 AM	Aug 19, 2009 12:49 AM
Surveys and Interviews	Sep 29, 2009 2:33 PM	Sep 10, 2009 12:18 PM

Figure 2. NASA FFC Output Folder Contents.

Figure 3 illustrates the organization of the AP Panel Support Files folder. This folder contains spreadsheets with the aircraft mix and LAWA 2020 demand files used by the AP Panel to derive hourly demands in every FFC simulation run. The PDF file called Aircraft_mix_rationale.pdf contains the design rationale to estimate the future aircraft mix at LAX. The file Runway_Status_Lights.pdf contains the AP Panel suggested locations of runway status lights in the airfield and used in the FFC simulations.

Name	Date Modified	Date Created
LAX FFC Simulation Deliverables.doc	Today, 1:35 PM	Today, 1:31 PM
NASA FFC Outputs	Apr 19, 2010 9:36 PM	Aug 19, 2009 12:49 AM
AP Panel Support Files	Apr 19, 2010 9:33 PM	Apr 13, 2010 9:43 PM
Runway_Status_Lights_forFFC	Apr 13, 2010 10:18 PM	Apr 13, 2010 10:18 PM
Aircraft_mix_rationale	Apr 13, 2010 10:08 PM	Apr 13, 2010 10:08 PM
demand_lawa_2020.xls	Apr 13, 2010 9:45 PM	Jan 14, 2010 6:36 PM
demand_lawa_2007.xls	Apr 13, 2010 9:45 PM	Jan 14, 2010 6:36 PM
AircraftFleetMixLAWA2020.xlsx	Feb 14, 2010 12:31 AM	Oct 17, 2008 4:16 PM
aircraft.xlsx	Oct 15, 2008 10:00 PM	Oct 15, 2008 10:00 PM
airlines.xlsx	Oct 15, 2008 9:52 PM	Oct 15, 2008 9:52 PM
FFC Demand Scenarios by AP Panel	Apr 13, 2010 9:56 PM	Apr 13, 2010 9:12 PM
CVS Sim Outputs	Jan 5, 2010 12:32 AM	Aug 19, 2009 12:49 AM
Surveys and Interviews	Sep 29, 2009 2:33 PM	Sep 10, 2009 12:18 PM

Figure 3. AP Panel Support Files Folder Contents.

Name	Date Modified	Date Created
LAX FFC Simulation Deliverables.doc	Today, 1:37 PM	Today, 1:31 PM
NASA FFC Outputs	Apr 19, 2010 9:36 PM	Aug 19, 2009 12:49 AM
AP Panel Support Files	Apr 19, 2010 9:33 PM	Apr 13, 2010 9:43 PM
FFC Demand Scenarios by AP Panel	Apr 13, 2010 9:56 PM	Apr 13, 2010 9:12 PM
LAX_FFC_Demand Sets_ExcelExplanation	Apr 13, 2010 9:55 PM	Apr 13, 2010 9:55 PM
VMC Scenarios	Apr 13, 2010 9:22 PM	Jul 31, 2009 6:33 PM
Night Scenarios	Aug 1, 2009 12:12 AM	Aug 1, 2009 12:12 AM
IMC Scenarios	Jul 31, 2009 6:33 PM	Jul 31, 2009 6:33 PM
CVS Sim Outputs	Jan 5, 2010 12:32 AM	Aug 19, 2009 12:49 AM
Surveys and Interviews	Sep 29, 2009 2:33 PM	Sep 10, 2009 12:18 PM

Figure 4. FFC Demand Scenarios by AP Panel Folder Contents.

Name	Date Modified	Date Created
LAX FFC Simulation Deliverables.doc	Today, 1:38 PM	Today, 1:31 PM
NASA FFC Outputs	Apr 19, 2010 9:36 PM	Aug 19, 2009 12:49 AM
AP Panel Support Files	Apr 19, 2010 9:33 PM	Apr 13, 2010 9:43 PM
FFC Demand Scenarios by AP Panel	Apr 13, 2010 9:56 PM	Apr 13, 2010 9:12 PM
CVS Sim Outputs	Jan 5, 2010 12:32 AM	Aug 19, 2009 12:49 AM
LAX-NASS B747 LogPart 1.pdf	Sep 8, 2009 1:40 PM	Sep 3, 2009 6:18 PM
LAX-NASS B747 LogPart2.pdf	Sep 8, 2009 11:32 AM	Sep 8, 2009 11:31 AM
09012009	Sep 2, 2009 4:03 PM	Sep 2, 2009 4:01 PM
08312009	Sep 2, 2009 4:01 PM	Sep 2, 2009 4:00 PM
08282009	Aug 28, 2009 7:15 PM	Aug 28, 2009 7:13 PM
08272009	Aug 27, 2009 6:58 PM	Aug 27, 2009 6:57 PM
08262009	Aug 26, 2009 8:19 PM	Aug 26, 2009 8:17 PM
08252009	Aug 25, 2009 6:50 PM	Aug 25, 2009 6:48 PM
08052009	Aug 23, 2009 6:24 PM	Aug 19, 2009 3:08 PM
08042009	Aug 23, 2009 6:22 PM	Aug 19, 2009 3:05 PM
08202009	Aug 20, 2009 8:03 PM	Aug 20, 2009 8:01 PM
08192009	Aug 19, 2009 8:07 PM	Aug 19, 2009 8:05 PM
08182009	Aug 19, 2009 3:23 PM	Aug 19, 2009 3:21 PM
08172009	Aug 19, 2009 3:21 PM	Aug 19, 2009 3:19 PM
08142009	Aug 19, 2009 3:19 PM	Aug 19, 2009 3:17 PM
08132009	Aug 19, 2009 3:17 PM	Aug 19, 2009 3:16 PM
08112009	Aug 19, 2009 3:16 PM	Aug 19, 2009 3:14 PM
08102009	Aug 19, 2009 3:14 PM	Aug 19, 2009 3:13 PM
08072009	Aug 19, 2009 3:13 PM	Aug 19, 2009 3:11 PM
08062009	Aug 19, 2009 3:11 PM	Aug 19, 2009 3:09 PM
Surveys and Interviews	Sep 29, 2009 2:33 PM	Sep 10, 2009 12:18 PM

Figure 5. CVS Sim Outputs Folder Contents.

Name	Date Modified	Date Created
LAX FFC Simulation Deliverables.doc	Today, 1:39 PM	Today, 1:31 PM
NASA FFC Outputs	Apr 19, 2010 9:36 PM	Aug 19, 2009 12:49 AM
AP Panel Support Files	Apr 19, 2010 9:33 PM	Apr 13, 2010 9:43 PM
FFC Demand Scenarios by AP Panel	Apr 13, 2010 9:56 PM	Apr 13, 2010 9:12 PM
CVS Sim Outputs	Jan 5, 2010 12:32 AM	Aug 19, 2009 12:49 AM
Surveys and Interviews	Sep 29, 2009 2:33 PM	Sep 10, 2009 12:18 PM
Pilots	Sep 29, 2009 3:58 PM	Sep 10, 2009 12:18 PM
Scanned Surveys	Sep 29, 2009 3:58 PM	Sep 11, 2009 12:41 PM
Pilots MP3	Sep 28, 2009 1:37 PM	Sep 10, 2009 1:57 PM
Pilot Surveys.xls	Sep 10, 2009 6:44 PM	Sep 10, 2009 6:44 PM
Pilots WAV	Sep 10, 2009 2:49 PM	Sep 10, 2009 2:49 PM
Controllers	Sep 29, 2009 2:33 PM	Sep 10, 2009 12:18 PM

Figure 6. Surveys and Interviews Folder Contents.

Explanation of NASA FFC Outputs

This section is a description of the NASA Ames FFC simulation outputs. This section was prepared by Betty Silva (NASA Ames Research Center).

There were three systems that collected scenario data during the simulation: 1) MaxSim, 2) Airspace Traffic Generator (ATG) and 3) B747 Flight Simulator. MaxSim is the system which drove the out-the-window views. The ATG generated the scenario was sent to MaxSim and the pilot stations.

1. MaxSim Event Data (raw)
2. MaxSim Trajectory and Airport Surface data (processed from the MaxSim Event Data)
3. ATG History Data (raw)
4. B747 Flight Simulator Data (e.g. altitude, speed, latitude, longitude)
5. Processed communication data (e.g. number of passages, duration of each passage)

The qualitative data collected are as follow:

a) Controller background information

b) Controller post-run questionnaires

c) Controller post-participation questionnaires

d) Pilot background information

e) Pilot post-landing questionnaires

f) Pilot post-hour questionnaires

g) Pilot end of day questionnaires

h) Spreadsheets containing tabulated controller and pilot survey responses

i) Pilot and controller hand-written interview notes and digital recorded interviews in wav format.

LAX FFFC Simulation Deliverables

This section contains a short description of the deliverables for the LAX-NASS project that are generated in the post-processing of the data recorded by the Maxsim software. Some of the data described here is redundant with data recorded by the Airspace Target Generator (ATG) and its associated subsystems. This document only describes the files generated from the Maxsim-recorded data.

All of the files described here result from processing the Maxsim "data recording" data. This data is all published as part of the High Level Architecture (HLA) messaging system and was recorded by the MAK Logger running during the simulations as part of the Maxsim software.

The processing is accomplished in two steps:

1. Read the HLA file, extract aircraft trajectory data, and generate a ground event file by comparing the time-history trajectory data for each aircraft with the set of ground points used by ATG to control aircraft on the ground. This ground-event file is an emulation of the "data collection" file normally generated by Maxsim for its own aircraft. Also, generate a set of files based on the HLA data.

2. Process the ground event file, compute various statistics from the ground events, and produce various reports from the data about number of operations, taxiing times, hold times, runway crossing times, and runway occupancy times.

Seventeen files are produced for each run by this processing: 8 in phase 1 and 9 in phase 2. Each file, except one, is a plain text file and is either a data file without formatting or a report file with some minimal text-based formatting. One file is an Excel spreadsheet document containing a summary of that run, with rows of data for each flight.

The files have names based on the run descriptor entered by the FFC Test Engineer at the time of the run. The naming convention used for runs during the LAX-NASS simulations is 'laxA_XY_Z_runNB', where

A Airport database (A = 3, b, d, m, n) XYGroup VI operations (X = 2, 4, 6; Y = B, S)

Z Meteorlogical conditions (Z = V, I, N)

NB Run number (N = 1,54; B = '',a,b,etc. for repeated runs)

For example, the first run was done with the LAXB airport database, with 2 Group VI aircraft using both sides of the airport and under VMC conditions, so the run identifier used was 'laxb_2b_v_run1'. Run 2 was the LAXB database with 6 group VI aircraft on both sides and IMC conditions, and the run was restarted because of a technical problem, so the run identifier was 'laxb_6b_i_run2a'.

In the descriptions below, 'laxx' will represent the full run identifier.

Those repeated runs that were 15 min or more in duration are included, while runs less than that are not.

Phase 1 Files

Eight files are generated from the HLA data in the first processing phase:

1. laxx.act A time history of the number of aircraft active in the simulation. Format is: 'time number', with time in seconds and number of active aircraft. A line is written every time an aircraft is activated or terminated.

2. laxx.csv File of ground events. The format is: Time, callsign, location, status, UTC

Time is in hh:mm:ss from start of simulation. Location is name of ground point (see laxx.rts file, described below) or a runway designator. Status is one of (HOLD,IN,OUT,PUSHBACK,THRESHOLD,TOUCHDOWN, ON,OFF,START,STOP). UTC is wall-clock time, but is always zero for this project.

3. laxx.dat Comma-separated file giving summary for each flight in run. The format is: Callsign, Category, A/C Type, Takeoff, Liftoff, Threshold, Touchdown, Missed approach

Where:

Category is 'A' for arrivals, 'D' for departures Takeoff, Liftoff, Threshold, Touchdown are times in seconds Missed approach is time in sec. of missed approach, if any.

4. laxx.rpt Report of missed approaches. Each possible go-around will be described, giving the callsign, runway, time in sec., position in X,Y m., altitude in ft., and heading in deg.

5. laxx.rwml Report of Runway Status Light (RWSL) activity. The format is: Time, Object, Airport, Runway, Taxiway, Type, Status, Name where:

Time - Time in sec. from start of simulation Object

HLA object number of RWSL light set Airport

LAX3, LAXB, LAXD, LAXM, LAXN Runway

Runway designator Taxiiway Name of closest taxiway Type

Either REL or THL Status

Light intensity from 0 to 5 Name

Name of RWSL light set

6. laxx.sum Standard output of summary program that processes the HLA data. Contains paths of input and output files. Also includes a summary table of all flights in the simulation, giving HLA object number, HLA object tag, callsign, aircraft type, visual representation file, flag, and number of update packets recorded in file. This is followed by a summary of arrivals, giving landing runway and times for threshold crossing, touchdown, and missed approach. A summary table for departures gives runway and times for takeoff, liftoff, and threshold crossing.

7. laxx.trk Aircraft trajectory file. This file includes the position of flights as recorded by the MAK Logger. The format is: Object #, Callsign, Time (sec.), State, X (nm.), Y (nm.), Altitude (ft.), Heading (deg.), Speed (fps), Vertical Speed (fps), Pitch (rad), Yaw (rad), Roll (rad) Lines are given in the order received. The X,Y values are displacements from the airport reference point.

8. laxx.rts Ground points file giving the name and location of the ground points used to generate the ground events from aircraft trajectories. The information in this file was derived from the routes file that ATG uses to control aircraft on the ground. The format is: Name, X (m.), Y (m.), Index, Type, Description.

Where:

X,Y Displacement from airport reference point in m.

Index Index in original routes file (not all points in routes file are used)

Type Type of point: 0 = ordinary, 1 = gate, 2 = runway, 4 = runway exit,

Phase 2 Files

Nine additional files are generated from the HLA data in the second processing phase:

9. laxx_arr.csv Summary of arrival flights as a comma-separated text file. The format is: Callsign, A/C Type, Runway, Touchdown, Runway Exit, Runway Occupancy, Spot, Spot Time, Gate, Gate Time, Taxi Duration, # Holds, Hold Point 1, Hold 1 Time, Hold 1 Duration, etc.

Spots were not used at LAX, and hold points and times were not calculated.

10. laxx_arr.txt Ground events generated for arrival flights, grouped by individual flights in order of activation. Warnings generated for each flight are also included.

11. laxx_dep.csv Summary of departure flights as a comma-separated text file. The format is: Callsign, A/C Type, Runway, Gate, Pushback, Spot, Spot In Time, Spot Out Time, Spot Duration, Runway Hold, Takeoff, Liftoff, Runway Occupancy, Taxi Duration, # Holds, etc.

12. laxx_dep.txt Ground events generated for each departure flight, grouped by individual flights in order of activation. Warnings generated for each flight are also included.

13. laxx_unk.txt Ground events generated for each flight, for which a determination of arrival or departure cannot be made.

14. laxx_err.txt Errors or anamolies encountered in processing ground events.

15. laxx_stats.log Standard output of the stats.pl program, which calculates statistics from ground events file.

16. laxx_rpt.txt Report file giving summary and detailed statistics calculated from ground events. Report sections include the following:

Overall program summary Arrival Statistics Departure Statistics Arrivals Taxi-in Statistics Departures Taxi-out Statistics Runway Crossings By Runway Runway Statistics For Five Minute Intervals Operation Counts Per Time Interval Taxi and Runway Occupancy Durations Runway Takeoff Occupancy Times Runway Landing Occupancy Times

17. laxx.xls Spreadsheet giving summary statistics for each flight in simulation. Arrivals and departures are placed in separate worksheets.