Exhibit A

SANTA MONICA MUNICIPAL AIRPORT RUNWAY SAFETY AREA STUDY

Dr. Antonio A. Trani
Virginia Tech

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Background of the Problem

The City of Santa Monica and the Federal Government entered into Consent Decree that authorizes provides the option should the City elect to close the Santa Monica Municipal Airport (SMO) in the year 2028 (1). The agreement authorized the reduction of the runway length from 5,000 feet to 3,500 feet. SMO has a generous runway width of 150 feet. With the shortening of the runway, 750 by 150 feet of paved areas are available at each runway end. The reduction in runway length to 3,500 feet limits the number of jet operations at the airport and provides space for Federal Aviation Administration (FAA) mandated Runway Safety Areas (RSA). The RSA areas for this class of airport (considering Runway Design Code B-II) require a minimum of 300 feet beyond the departure runway end and 300 feet prior to the runway landing threshold (2). Figure 1 shows the schematic of the runway length changes.

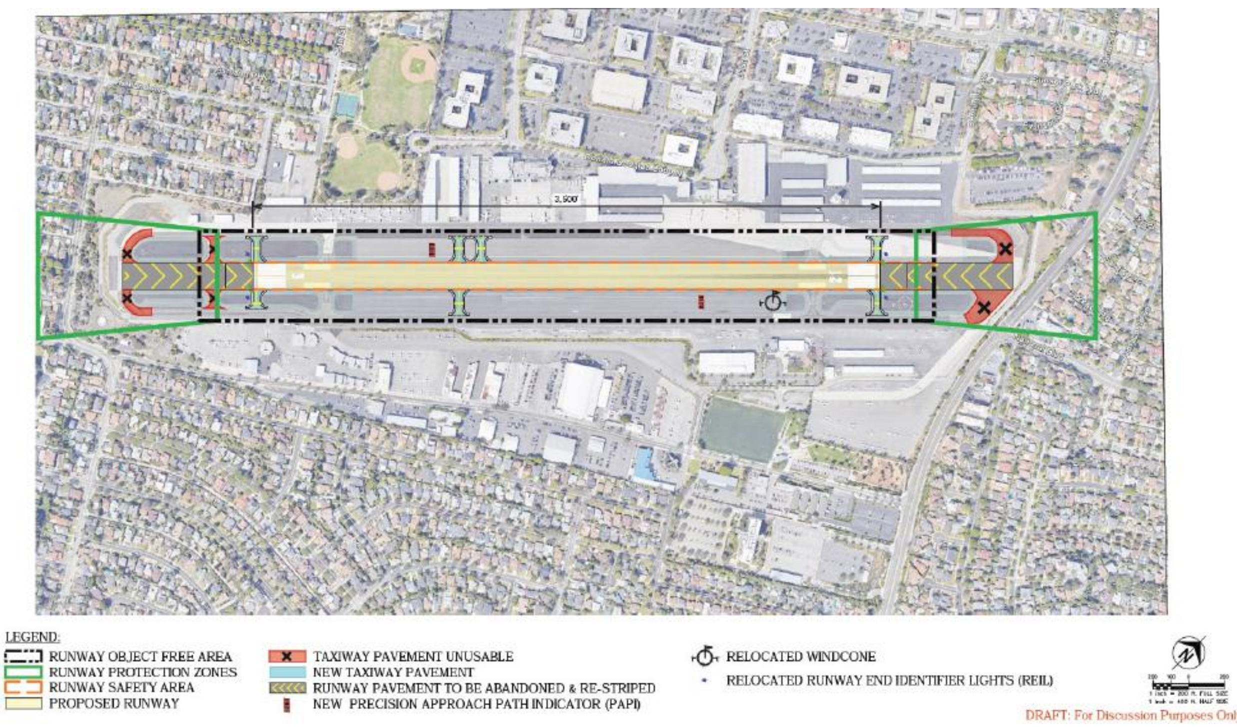


Figure 1 Santa Monica Municipal Airport Runway Shortening Alternative B. Source: City of Santa Monica.

The provision of 750 feet of paved areas at both ends of runway 3-21 provides an additional safety margin for aircraft operating at Santa Monica Municipal airport today. A plan to remove pavement from the existing runway to comply with the minimum 300-foot long RSA area seems unwise and could adversely affect the safety of the operations at SMO for the next ten years. A safety analysis to understand the implications of this decision is the subject of this report.

Runway Safety Analysis Tasks

The following tasks have been completed as part of the safety study for the Santa Monica Municipal airport:

a) Review the accident safety record of the Santa Monica Municipal Airport,

b) Examine existing risk analysis models to estimate the relative safety and accident risk of various runway safety area configurations for the Santa Monica Municipal Airport,

c) Quantify the relative risk and safety margins offered by the existing 750 by 150-foot paved surface compared to the standard 300 by 150-foot unpaved runway safety area mandated by the Federal Aviation Administration.

The analysis presented in this report employs risk assessment methods developed by the Airport Cooperative Research Program (ACRP) for the FAA with adaptations to predict accident risk for General Aviation aircraft.

Air Traffic at Santa Monica Municipal Airport

According to the FAA Terminal Area Forecast historical data (FAA, 2018), Santa Mónica Municipal Airport had a significant decline in traffic from its peak year of 1992 with 240,350 annual operations. In 2017, the airport registered 77,594 operations (see Figure 2). The reduction in the number of operations is consistent with the observed trends in the number of General Aviation operations over the years in the Los Angeles area (see Figure 3) and, more generally, in the United States. In the Los Angeles area, only Los Angeles International Airport has experienced growth in the past 15 years. According to the FAA, Santa Monica Municipal airport projects modest growth of in the next ten years (3.6%). Figure 4 shows the expected growth in operations for SMO.

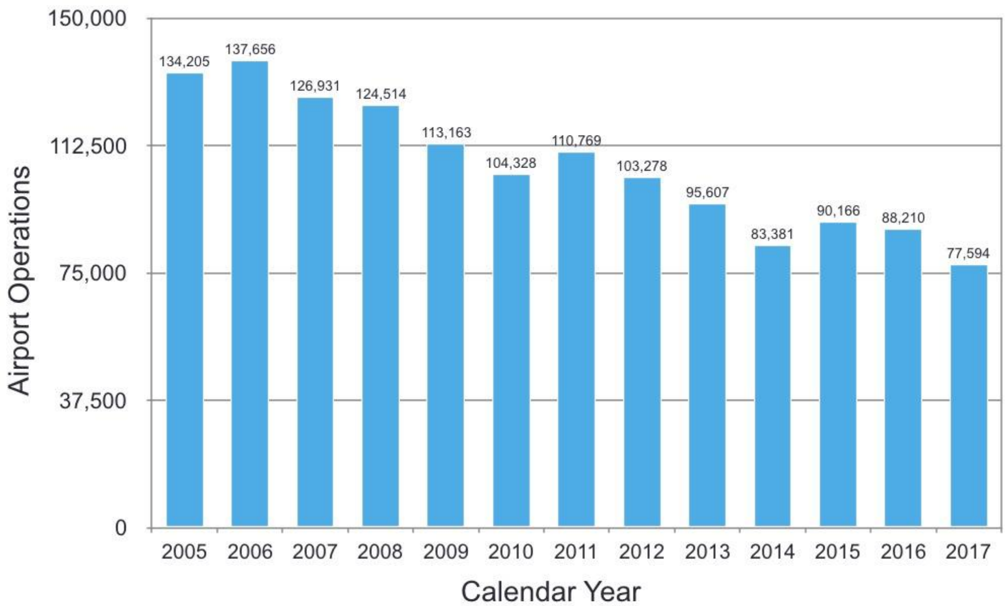


Figure 2 Santa Monica Municipal Airport Traffic (2005-2017). Source: FAA ATADS System.

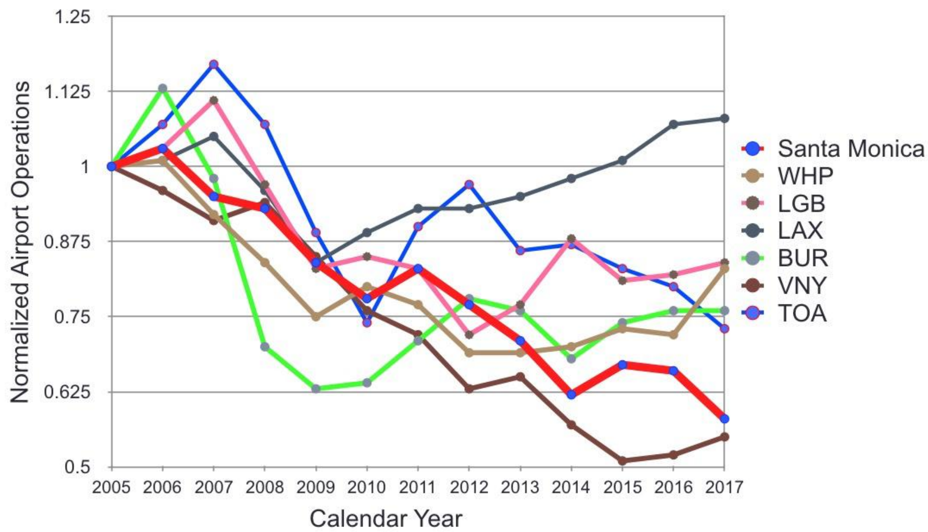


Figure 3 Normalized Airport Operations at Airports in the Los Angeles Area (2005-2017). Source: FAA ATADS System.

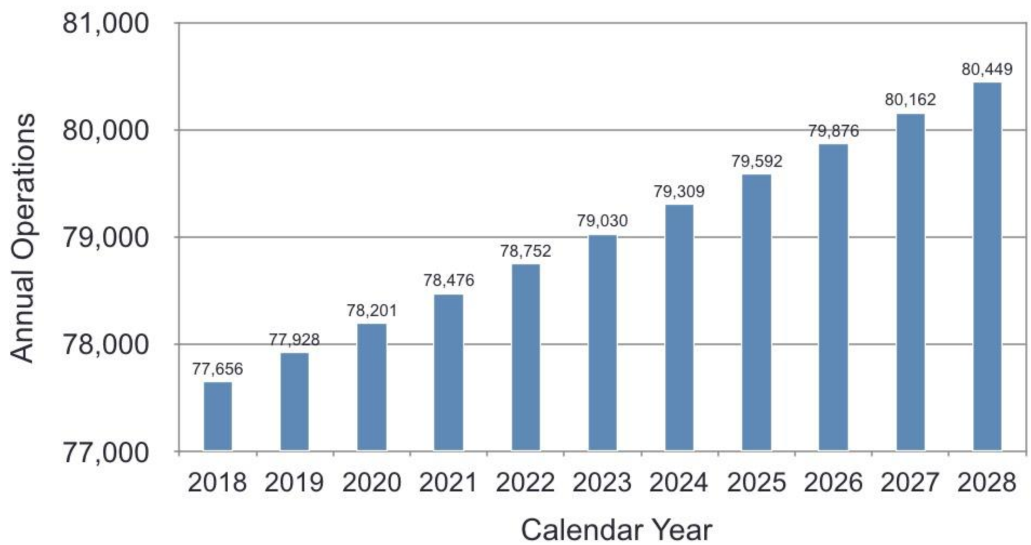


Figure 4 Forecast Annual Operations at Santa Monica Municipal Airport. Source: FAA Terminal Area Forecast (2018).

After the reduction of the runway length from 5,000 feet to 3,500 feet, the aircraft fleet mix has changed significantly at the Santa Monica Municipal Airport (SMO). Large and super mid-size business jets (e.g., Gulfstream G-IV, Bombardier Challenger 300) used to operate regularly at SMO before the reduction in runway length. Today, mostly small business jets (e.g., Embraer Phenom 300) and a few mid-size jets (e.g., Cessna Sovereign) continue to operate at SMO due to the new runway length limitations. Figure 5 shows the distribution of aircraft types operating at SMO using recent traffic statistics (January 1 to June 30, 2018). The figure shows that 73.5% of the airport operations are performed by single and multi-engine piston aircraft. 14.6% of the operations are turboprop aircraft and 5.1% attributed to jet aircraft. 6.8% of the airport operations are performed by helicopters.

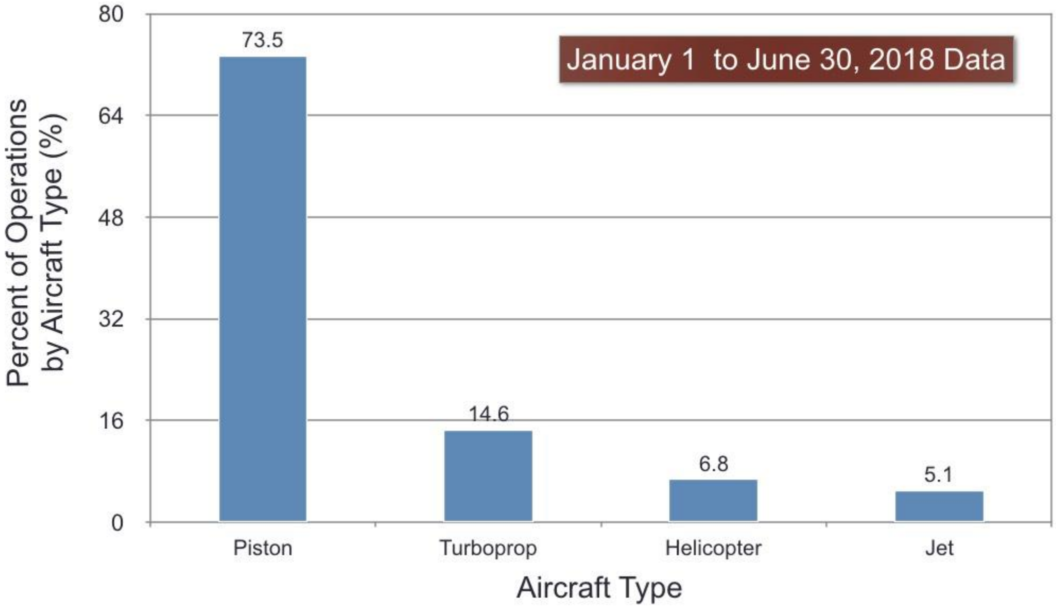


Figure 5 Breakdown of Aircraft Types Operating at Santa Monica Municipal Airport. Source: City of Santa Monica.

Figure 6 shows the runway length requirements for selected turboprop and small business jets aircraft operating at SMO. The figure includes two typical mission trip lengths (600 and 1,000 nm) and the takeoff field length at maximum takeoff gross weight obtained from the aircraft manufacturer performance data (Business and Commercial Aviation, 2018). Figure 6 shows that some turboprop aircraft such as the Beechcraft Raytheon King Air B200 have limitations in runway length while operating at SMO today. According to Figure 6, the B200 can operate in shorter 300 nm missions from SMO, but not in the longer mission profiles shown in Figure 6. The runway length requirements for the Embraer Phenom and the Beechcraft King Air B350 are close to the available runway length at SMO. These facts are relevant because the procedure to assess runway safety area risk considers runway length available as a critical parameter in the estimation of the probability of an accident at the airport. The higher the ratio of runway length required and the runway length available, the higher the likelihood of an accident overrun.

Figure 7 shows the runway length requirements for selected piston-powered aircraft operating at SMO. The figure includes two typical trip lengths (300 and 600 nm) and the takeoff field length at maximum takeoff gross weight obtained from the aircraft manufacturer performance data (Business and Commercial Aviation, 2018). Figure 7 shows that Cirrus SR-20 have longer runway length requirements compared to the more powerful Cirrus SR-22.

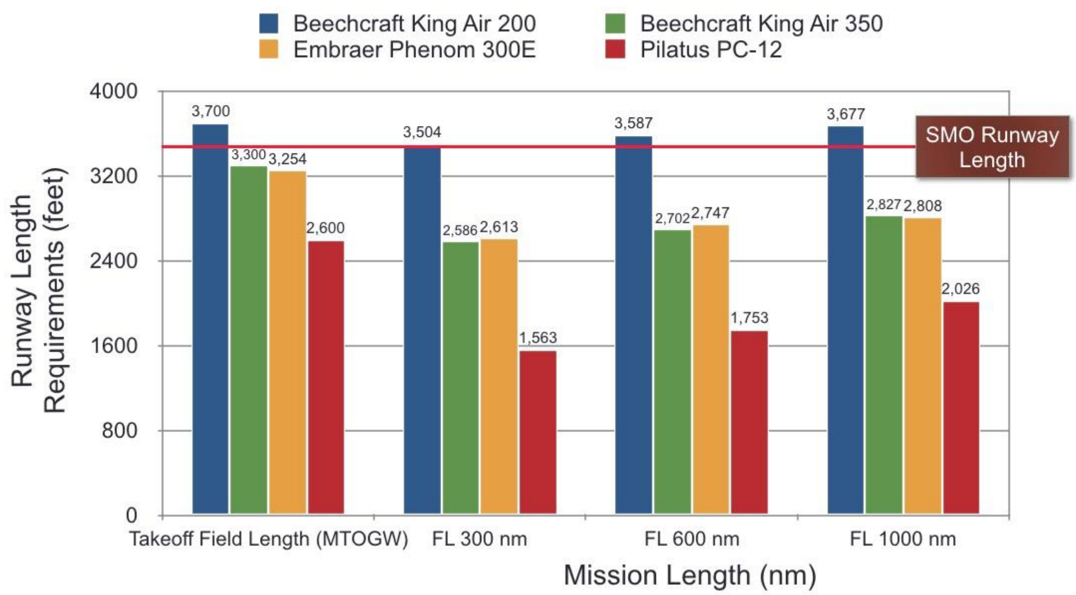


Figure 6 Runway Length requirements for Selected Turboprop and Jet Aircraft Operating at Santa Monica Municipal Airport. Source: Business and Commercial Aviation (May 2018).

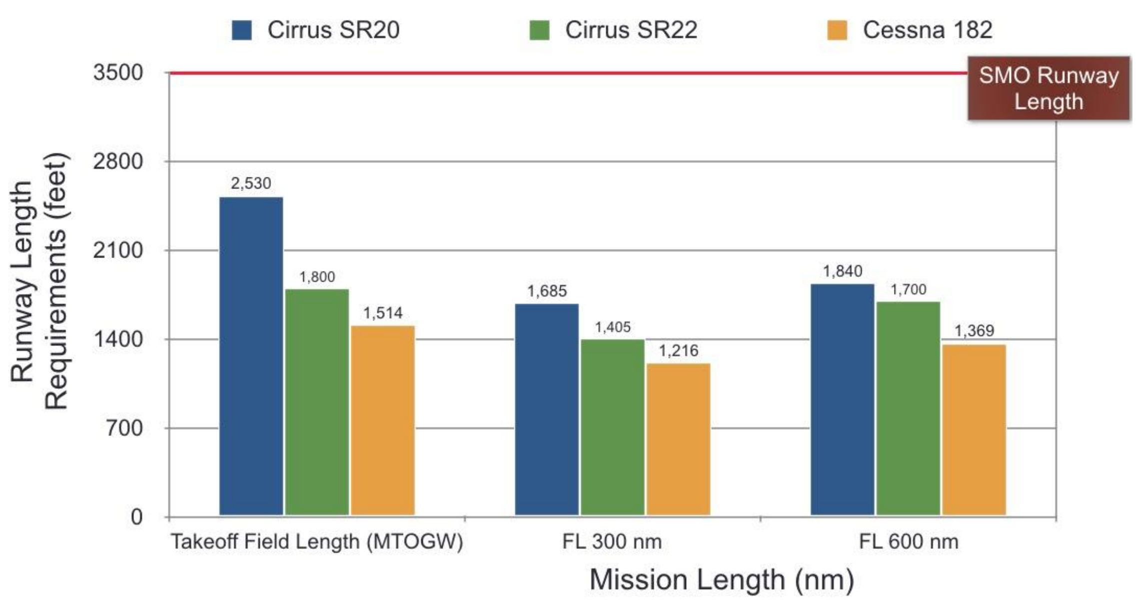


Figure 7 Runway Length requirements for Selected Piston Aircraft Operating at Santa Monica Municipal Airport. Source: Business and Commercial Aviation (May 2018).

Runway Safety Area Alternatives Modeled

To make a risk assessment, we investigated three runway safety area configurations of the runway at SMO. Figure 8 shows the three configurations side by side. Configuration 1 involves a 750 x 200a runway safety area includes a 750 x 200-foot paved area beyond the runway end. Configuration 2 removes 750 feet of pavement on each side of runway 3-21 at SMO. Configuration 2 requires a 150-foot paved blast pad area. Configuration 3 is a 300 x 200-foot paved runway safety area. All RSA configuration areas meet the minimum standard runway safety criteria dimensions required by the FAA for runway code B-II (300 x 500-foot). All RSA configurations studied comply with FAA Runway Safety requirements (300 feet RSA before landing runway threshold and beyond the landing runway end) for aircraft design group II and approach speed group B. A large paved area at each end of the 3,500 foot-runway offers an additional buffer to contain an aircraft that overruns on landing (or takeoff); or a plane that touches down before the runway threshold (undershoot).

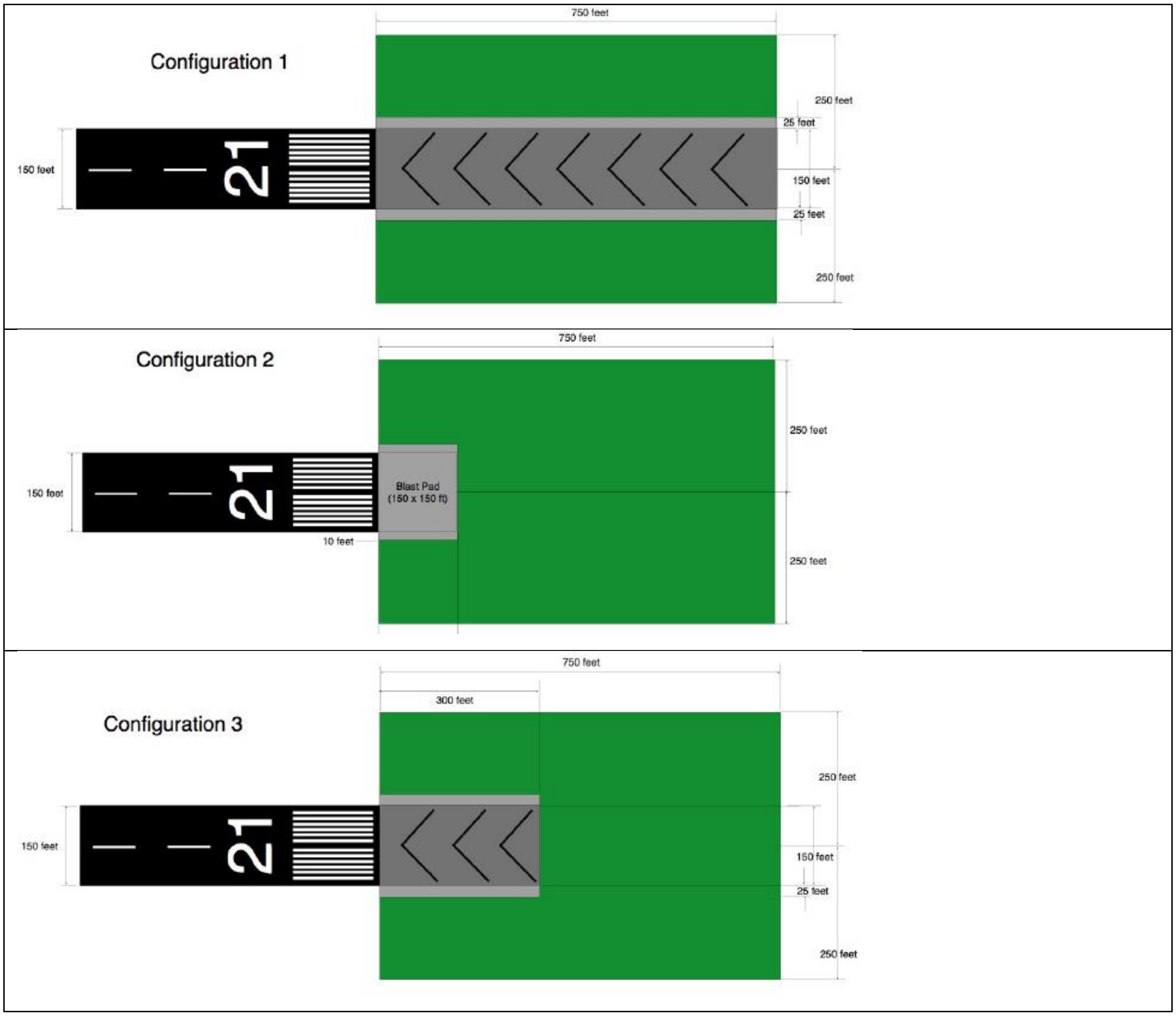


Figure 8 Runway Safety Area Configurations Studied for Santa Monica Municipal Airport.

Risk Assessment Method

The risk assessment method adopted in this study is presented in detail in the Airport Cooperative Research Program report 50 (ACRP, 2011). The risk assessment process requires a three-part risk modeling process: a) determine accident event probability; b) determine the event location and c) modeling consequences (see Figure 9). The analysis presented in this study measures the relative level of safety offered of three configuration RSA alternatives.

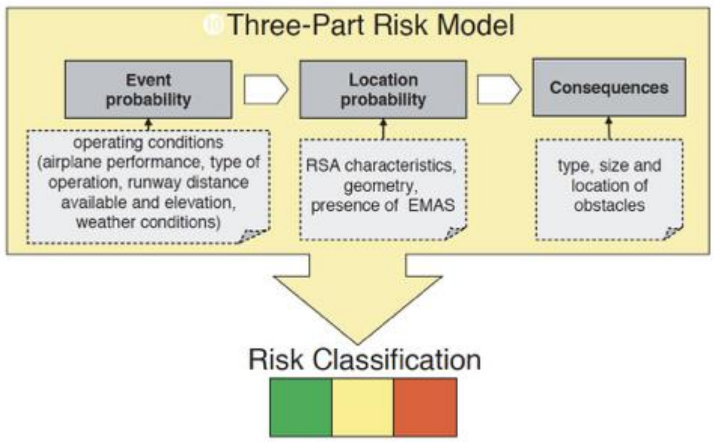


Figure 9 ACRP Runway Safety Area Risk Modeling Process (ACRP Report 50, 2011).

Accident Frequency Models

ACRP Report 50 offers a family of logistic regression models to estimate the probability of an accident at an airport. The models presented in ACRP report 50 consider several independent variables including: aircraft size, aircraft user class, visibility conditions, wind conditions, adverse weather conditions like rain, fog, icing, and the log criticality factor which measures the ratio of the aircraft runway length required vs. the actual runway available for the operation (i.e., landing or takeoff). Figure 10 shows the coefficients of the independent variables and the general logistic regression equation used in the analysis. Figure 10 shows five distinct models developed depending upon the type of accident scenario of interest. For example, the column labeled LDOR represents the independent variable coefficients for the landing overrun events. LDUS is a landing undershoot event and TOOR represents a takeoff overrun event. For this study veer-off events (labeled LDVO and TOVO) were not considered because the relative risk assessment assumes that SMO maintains the same runway/taxiway configuration present today.

In the accident event analysis, we used typical environmental conditions at Santa Monica. The accident database used in the derivation of the coefficients of the independent variables include 41% of business jets. Nevertheless, the authors of the ACRP report ignored many accidents involving aircraft with a gross weight of less than 6,000 lb. This fact requires some corrections in the analysis.

Accident Location Models

ACRP Report 50 developed a family of exponential regression models to estimate the location of an accident from a runway end or the extended runway centerline. Figure 11 shows the family of equations used to estimate the location of an accident for five accident types. This study only considers LDOR, LUS and

TOOR accidents. Figure 12 shows a sample application of the landing overrun location model to demonstrate that a 750-foot paved area beyond a runway end offers a five-fold improvement in containing a landing overrun compared to a 150-foot paved area.

Accident Rates Considering Diverse Aircraft Types

Combining the accident frequency and the accident location model models, we estimate the probability of an accident outside of the paved area for each one of the three RSA configurations (see Figure 8). Tables 1-3 summarize the probabilities of an accident for three aircraft groups typically represented at SMO. For this analysis, we used the runway length requirements of the Cirrus SR20 (piston), the Beechcraft King Air B200 (turboprop) and the Embraer Phenom 300 (jet). These three aircraft represent the three major aircraft groups operating at SMO. The tables contain probabilities that an aircraft of each type has an accident outside the paved area for three accident scenarios considered: Landing Overrun (LDOR, Landing Undershoot (LFUS) and Takeoff overrun (TOOR). The results of this evaluation suggest that Configuration 1 is 6.9 to 3.2 times "safer" compared to Configuration 2 when the safety metric is the probability of having an accident outside the paved RSA area. Table 4 shows the relative risk when comparing Configurations 1 and 2.

Table 5 shows the relative risk when comparing Configurations 3 and 2.

$$P\{Accident\_Occurence\} = \frac{1}{1+e^{b_0+b_1X_1+b_2X_2+b_3X_3+\ldots}}$$

where

P{Accident_Occurrence} = the probability (0–100%) of an accident type occurring given certain operational conditions;

X_i = independent variables (e.g., ceiling, visibility, crosswind, precipitation, aircraft type, criticality factor); and

b_i = regression coefficients.

Variable	LDOR	LDUS	LDVO	TOOR	TOVO
Adjusted Constant	-13.065	-15.378	-13.088	-14.293	-15.612
User Class F		1.693		1.266	
User Class G	1.539	1.288	1.682		2.094
User Class T/C	-0.498	0.017			
Aircraft Class A/B	-1.013	-0.778	-0.770	-1.150	-0.852
Aircraft Class D/E/F	0.935	0.138	-0.252	-2.108	-0.091
Ceiling less than 200 ft	-0.019	0.070		0.792	
Ceiling 200 to 1000 ft	-0.772	-1.144		-0.114	
Ceiling 1000 to 2500 ft	-0.345	-0.721			
Visibility less than 2 SM	2.881	3.096	2.143	1.364	2.042
Visibility from 2 to 4 SM	1.532	1.824		-0.334	0.808
Visibility from 4 to 8 SM	0.200	0.416		0.652	-1.500
Xwind from 5 to 12 kt	-0.913	-0.295	0.653	-0.695	0.102
Xwind from 2 to 5 kt	-1.342	-0.698	-0.091	-1.045	
Xwind more than 12 kt	-0.921	-1.166	2.192	0.219	0.706
Tailwind from 5 to 12 kt			0.066		
Tailwind more than 12 kt	0.786		0.98		
Temp less than 5 C	0.043	0.197	0.558	0.269	0.988
Temp from 5 to 15 C	-0.019	-0.71	-0.453	-0.544	-0.42
Temp more than 25 C	-1.067	-0.463	0.291	0.315	-0.921
Icing Conditions	2.007	2.703	2.67	3.324	
Rain		0.991	-0.126	0.355	-1.541
Snow	0.449	-0.25	0.548	0.721	0.963
Frozen Precipitation			-0.103		
Gusts		0.041	-0.036	0.006	
Fog			1.74		
Thunderstorm	-1.344				
Turboprop			-2.517	0.56	1.522
Foreign OD	0.929	1.354	-0.334		-0.236
Hub/Non-Hub Airport	1.334				-0.692
Log Criticality Factor	9.237	1.629	4.318		1.707
Night Conditions			-1.36		

Figure 10 ACRP Probability of Accident Occurrence Model (Source: ACRP Report 50).

$$P\{Location > x\} = e^{-ax^n}$$

where

P{Location > x} = the probability the overrun/undershoot distance along the runway centerline beyond the runway end is greater than x;

x = a given location or distance beyond the runway end; and

a, n = regression coefficients.

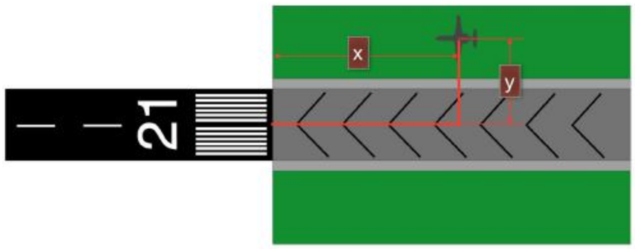
$$P\{Location > y\} = e^{-by^m}$$

where

P{Location>y} = the probability the overrun/undershoot distance from the runway border (veer-offs) or centerline (overruns and undershoots) is greater than y;

y = a given location or distance from the extended runway centerline or runway border; and

b, m = regression coefficients.



Type of Accident	Type of Data	Model	R^2	# of Points
LDOR	X	$P\{d > x\} = e^{-0.00321x^{0.984941}}$	99.8%	305
	Y	$P\{d > y\} = e^{-0.20983\,y^{0.4862}}$	93.9%	225
LDUS	X	$P\{d > x\} = e^{-0.01481x^{0.751499}}$	98.7%	83
	Y	$P\{d > y\} = e^{-0.02159y^{0.773896}}$	98.6%	86
LDVO	Y	$P\{d > y\} = e^{-0.02568y^{0.803946}}$	99.5%	126
TOOR	X	$P\{d > x\} = e^{-0.00109x^{1.06764}}$	99.2%	89
	Y	$P\{d > y\} = e^{-0.04282y0.659566}$	98.7%	90
TOVO	Y	$P\{d > y\} = e^{-0.01639\,y^{0.863461}}$	94.2%	39

Figure 11 Location of Accident Models (Source: ACRP Report 50).

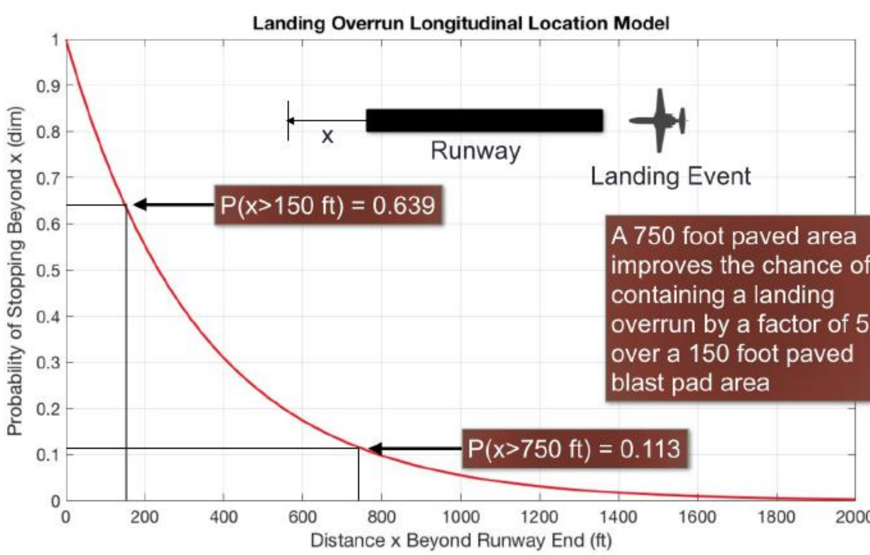


Figure 12 Landing Overrun Longitudinal Location Model.

Table 1 Estimated Probabilities of Accident for RSA **Configuration 1** for Three Aircraft Groups Operating at Santa Monica Airport. The Probabilities in the Table Represent the Chance of an Aircraft having an Accident Outside the Paved RSA Area for that Configuration.

Group	Probability of Landing Overrun	Probability of Landing Undershoot	Probability of Takeoff Overrun
Piston	1.4602E-08	1.7654E-08	8.2249E-09
Turboprop	3.8592E-08	1.9187E-08	2.2357E-08
Jet	3.6479E-08	1.8998E-08	2.2357E-08

Table 2 Estimated Probabilities of Accident for RSA **Configuration 2** for Three Aircraft Groups Operating at Santa Monica Airport. The Probabilities in the Table Represent the Chance of an Aircraft having an Accident Outside the Paved RSA Area for that Configuration.

Group	Probability of Landing Overrun	Probability of Landing Undershoot	Probability of Takeoff Overrun
Piston	1.0111E-07	8.9563E-08	2.6553E-08
Turboprop	2.6722E-07	9.7342E-08	7.2179E-08
Jet	2.5259E-07	9.638E-08	7.2179E-08

Table 3 Estimated Probabilities of Accident for RSA **Configuration 3** for Three Aircraft Groups Operating at Santa Monica Airport. The Probabilities in the Table Represent the Chance of an Aircraft having an Accident Outside the Paved RSA Area for that Configuration.

Group	Probability of Landing Overrun	Probability of Landing Undershoot	Probability of Takeoff Overrun
Piston	5.33293E-08	5.12743E-08	1.82737E-08
Turboprop	1.40947E-07	5.57274E-08	4.96732E-08
Jet	1.33229E-07	5.51767E-08	4.96732E-08

Table 4 Ratio of Probabilities of Accident for **Configurations 1 and 2.**

Group	Ratio of Probabilities of Landing Overrun (Configuration 2/Configuration 1)	Ratio of Probabilities of Landing Undershoot (Configuration 2/Configuration 1)	Ratio of Probabilities of Takeoff Overrun (Configuration 2/Configuration 1)
Piston	6.9	5.1	3.2
Turboprop	6.9	5.1	3.2
Jet	6.9	5.1	3.2

Table 5 Ratio of Probabilities of Accident for **Configurations 3 and 2.**

Group	Ratio of Probabilities of Landing Overrun (Configuration 2/ Configuration 1)	Ratio of Probabilities of Landing Undershoot (Configuration 2/ Configuration 1)	Ratio of Probabilities of Takeoff Overrun (Configuration 2/ Configuration 1)
Piston	1.9	1.8	1.5
Turboprop	1.9	1.8	1.5
Jet	1.9	1.8	1.5

Alternative Evaluation of Relative Risk

The method presented in the previous section is similar to the techniques explained in ACRP report 50. An alternative method used to obtain a second evaluation of relative risk is to use the location models developed in ACRP Report 50 and implement a Monte Carlo simulation to estimate the location of accidents by simulated annealing. This process models the accident locations using the distributions of the location equations provided in ACRP 50 to estimate the distances beyond the runway end and the transverse position of the accident location from the extended centerline location. The probability distributions of longitudinal and transverse location are assumed to be independent random variables. For this analysis, we simulated 10 million landing or takeoff operations for each accident scenario modeled and estimate the probability that an accident occurs within the paved RSA area. A computer program was created to execute the analysis. Figure 13 illustrates the Monte Carlo simulation results for landing overrun accident locations for Configuration 1. The process is repeated for all three runway safety area configurations and three accident scenarios modeled.

Table 6 summarizes the percent of accidents contained within the paved section of the runway safety area for each RSA configuration. For example, 76.3% of the landing overrun accidents occur within the 750x 200 -foot paved section in Configuration 1. Similarly, only 30.2% of the landing overrun accidents are likely to happen within the 150 by 150-foot paved blast pad area of Configuration 2.

Table 7 shows the relative risk reduction between Configurations 1 and 2 and Configurations 3 and 2. A well-maintained, 750 by 200-foot paved area (Configuration 1) at Santa Monica airport decreases the runway risk and damage to aircraft in case of an accident by a factor of 1.8-3.8 (see Table 7) when compared to an unpaved area with a 150 feet long blast pad area (Configuration 2). The reduction in risk is between 1.5-2.0 when comparing Configuration 3 (300 by 200-foot paved area) and Configuration 2.

Dynamics of Aircraft Overruns

The ACRP Report 50 location models were derived from examination of the aircraft wreckage in actual runway overruns and undershoot events. Most airports have runway safety areas that are unpaved. As such, the location models in ACRP 50 have a particular bias in the final locations of the accident aircraft because most of the overruns occur in unpaved runway safety areas. When an aircraft overruns an unpaved area, ACRP reports an average deceleration rate of 2.1 m/s^2. When an aircraft overruns a paved area (such as the existing condition at Santa Monica Airport), pilots can maintain control of the aircraft and can achieve higher deceleration rates (~3.5 m/s^2 or more) as shown in Figure 14. An overrun with an aircraft leaving the runway at 70-knots over an unpaved RSA area results in a typical stopping distance of 272 meters. The same overrun event over a paved RSA requires 187 meters to stop. There is a 31% reduction in the stopping distance. The consequence of such an overrun is clear: the overrun over a paved area would result in little or no damage to the aircraft. The overrun in an unpaved area will result in substantial damage to the aircraft.

Examination of actual overruns provides another data point on the actual dynamics of aircraft during accidents. Figure 15 shows the deceleration rates of a Gulfstream G-IV high-speed takeoff overrun at Bedford, MA. The runway in question had a paved section of 311 meters followed by an unpaved section 192 meters long. The estimated deceleration rates using the National Transportation Safety Board data transcript were 5.0 m/ s^2 for the unpaved section and 2.1 m/ s^2 for the unpaved section. In this accident, the deceleration rate on the paved section was possible with the use of thrust reversers, brakes, and spoilers.

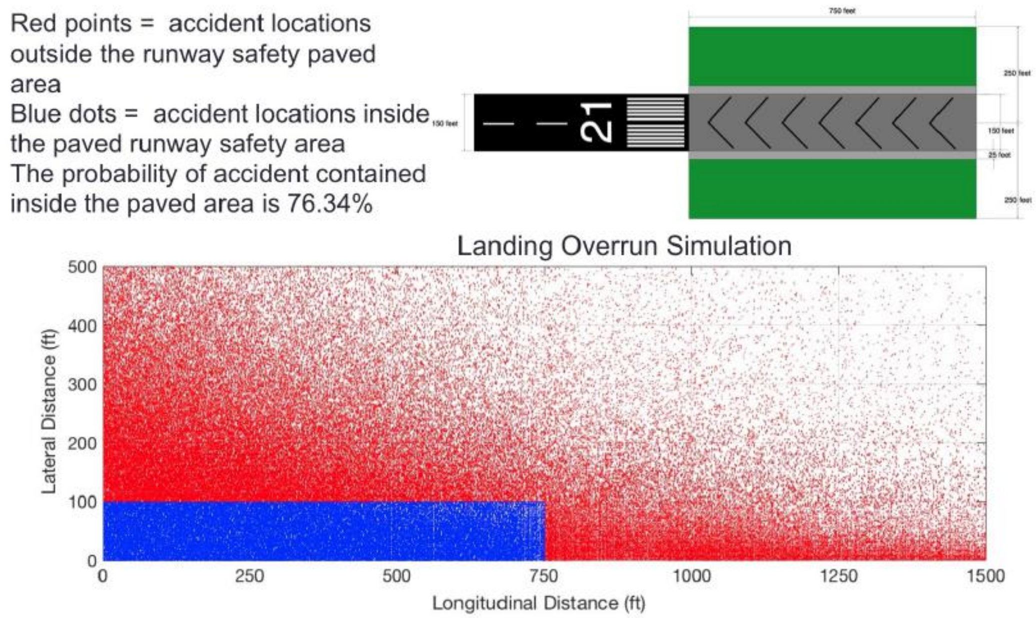


Figure 13 Monte Carlo Simulation of Landing Overrun Accident Locations for Configuration 1. The Blue Dots Represent Accident Locations Inside the Paved RSA Area. The Red Dots are Accidents Outside the Paved RSA Area.

Table 6 Percent of Accidents Contained by the Paved Area of the Runway Safety Area for Three RSA Configurations Studied**.**

Configuration	Percent of Accidents Expected to Occur Inside RSA Paved Area Landing Overrun (%)	Percent of Accidents Expected to Occur Inside RSA Paved Area Landing Overshoot (%)	Percent of Accidents Expected to Occur Inside RSA Paved Area Takeoff Overrun (%)
1	76.29	41.18	42.57
2	30.18	23.15	11.35
3	50.49	35.19	22.58

Table 7 Relative Risk of Accidents Contained by Paved Areas for Three Configurations Studied**.** Values are Normalized to 1 for Configuration 1. Higher Values in Table Indicate Improvements in Containing an Accident.

Configuration	Ratio of Probability of Overrun Contained Inside the RSA Paved Areas	of Probability of Landing Under-shoot Contained Inside Paved Area	Ratio of Probabilities of Takeoff Overrun Contained by Paved RSA Area
1	2.50	1.80	3.80
2	1.00	1.00	1.00
3	1.70	1.50	2.00

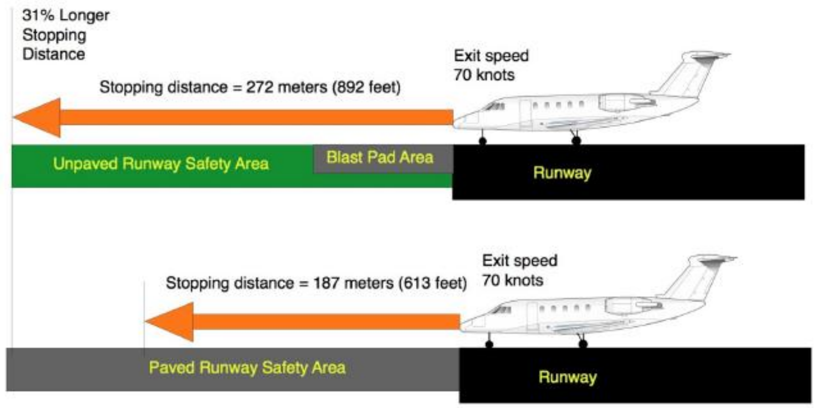


Figure 14 Numerical Simulation Results of a Runway Overrun.

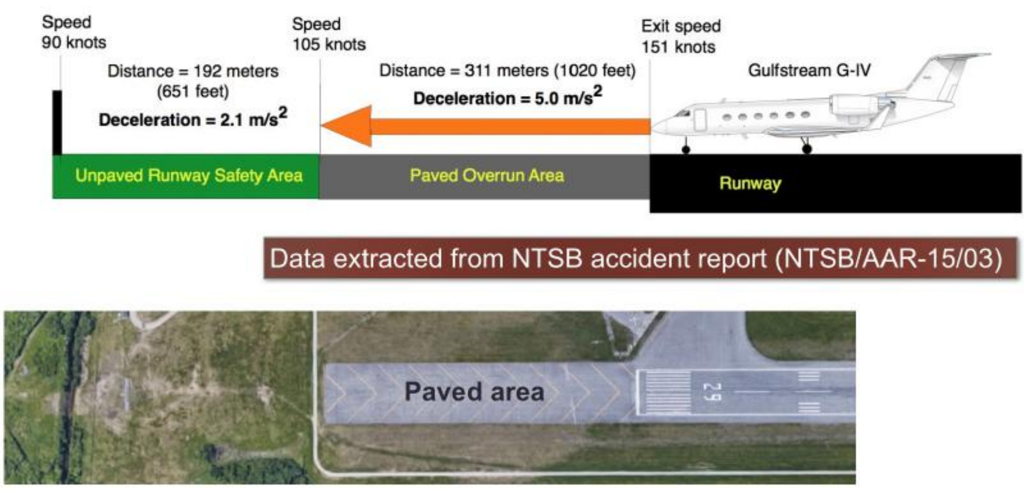


Figure 15 Gulfstream G-IV Takeoff Runway Overrun at Bedford, MA. Source of Data: NTSB/AAR-15/03 Report.

Estimating Accidents Over Time at Santa Monica

Aircraft accidents are rare events. Looking at the National Transportation Safety Board database, we found 36 accident events reported at Santa Monica between 1992 and 2017. Examination of accident events such as landing overruns, landing undershoots and takeoff overruns, we found that on average, SMO experiences one landing overrun every 708,600 landings. Similarly, the landing undershoot events occur once every 1.417 million landings. Figure 16 shows the summary of accident events at Santa Monica. Based on past accident statistics and using FAA forecast operations in the future, Santa Monica is likely to experience 1.53 runway accident excursion events in the next ten years. The methodology to predict accident rates in ACRP report 50 predicts a total of 0.6 runway excursion events over a ten-year period. This discrepancy was expected because the ACRP accident rate equations eliminated most General Aviation operations (aircraft with less than 6,000 lb. of takeoff weight). The analysis suggests that General Aviation runway excursion accidents are at least 2.55 times more frequently than commercial aviation runway accidents. Using this logic, we corrected the final estimate of the potential number of accidents at Santa Monica. Figure 17 summarizes the expected number of accidents at SMO over a ten-year period (2018-2028) showing the contributions to such accidents by aircraft type. As expected, piston-powered aircraft contribute 65% of the total expected accidents at SMO due to the large number of operations of such aircraft. Comparing the expected number of accidents for three RSA configurations, we conclude that a 750 by 200-foot paved RSA area, reduces the potential runway excursion events over a ten-year period by a factor of 2.66 (see Figure 17) compared to Configuration 2.

Table 8 summarizes the consequences of potential accidents at Santa Monica Municipal Airport for three RSA configurations. It is clear from

Table 8, that Configuration 1 offers the best level of protection against aircraft damage and personal injury in case of an aircraft overrun or aircraft undershoot event.

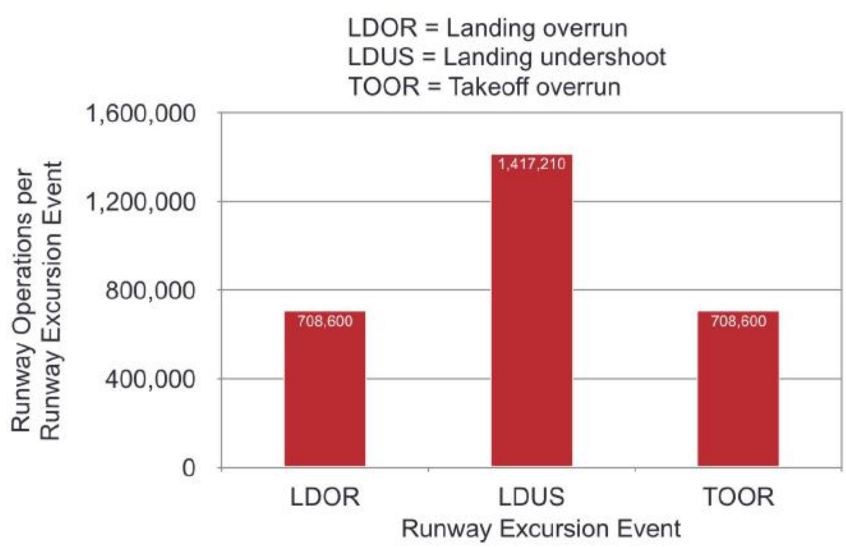


Figure 16 Santa Monica Accident Rates for Accident Events Modeled.

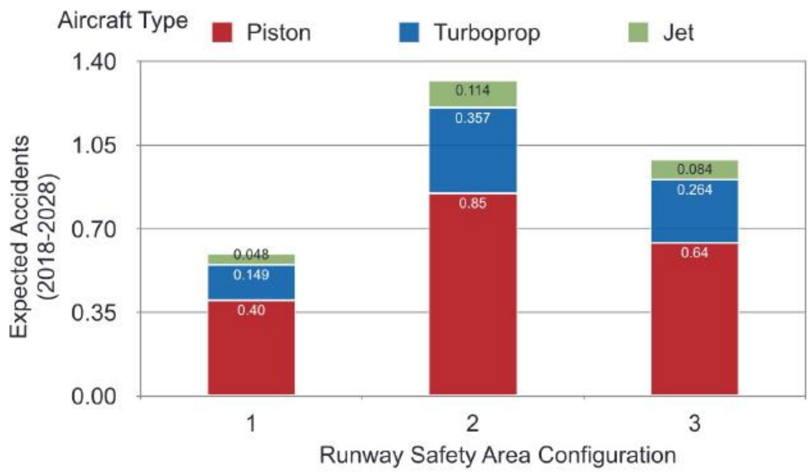


Figure 17 Santa Monica Municipal Expected Accidents Over a Ten-Year Period (2018-2028).

Table 8 Consequence Analysis Table of Accidents at Santa Monica for Three RSA Configurations.

Configuration	Landing Overrun	Landing Undershoot	Takeoff Overrun
1	No damage if overrun is contained to central 750 x 200-foot paved area Major damage if aircraft departs the central 750 x 200-foot paved area Catastrophic damage if aircraft departs the 750 x 500-foot RSA	Minor damage if undershoot is contained to central 750 x 200-foot paved area Major damage if aircraft touches down outside the central 750 x 200-foot paved area Catastrophic damage if aircraft departs the 750 x 500-foot RSA	No damage if overrun is contained to central 750 x 200-foot paved area Major damage if aircraft departs the central 750 x 200-foot paved area Catastrophic damage if aircraft departs the 750 x 500-foot RSA
2	Minor damage if overrun is contained to 150 x 150-ffot blast pad paved area Major damage if aircraft departs the 150 x 150-foot paved area Catastrophic damage if aircraft departs the 750 x 500-foot RSA	Minor damage if overshoot is contained to 150 x 150-foot blast pad paved area Major damage if aircraft touches down outside the 150 x 150-foot paved blast pad area Catastrophic damage if aircraft departs the 750 x 500-foot RSA	Minor damage if overrun is contained to 150 x 150-foot blast pad paved area Major damage if aircraft departs the 150 x 150-foot paved area Catastrophic damage if aircraft departs the 750 x 500-foot RSA
3	No damage if overrun is contained to 300 x 150-foot paved area Minor damage if aircraft departs the central 300 x 200-foot paved area Catastrophic damage if aircraft departs the 750 x 500-foot RSA	No damage if undershoot is contained to the central 300 x 200-foot paved area Major damage if aircraft touches down outside the central 300 x 150 ft paved area but inside the 500 ft wide RSA Catastrophic damage if aircraft undershoots the 750 x 500-foot RSA	No damage if overrun is contained to 300 x 200-foot paved area Minor damage if aircraft departs the central 300 x 200-foot paved area but inside the 500-foot wide RSA Catastrophic damage if aircraft departs the 750 x 500-foot RSA

Other Benefits of Paved Runway Safety Areas

Paved runway safety areas have the added benefit of a potential reduction of wildlife strikes. Wildlife strikes are rare events (just like aircraft accidents). According to the national wildlife strike database, in 2016 there was one wildlife strike for every 5,966 operations (i.e., landings or takeoff) in the National Airspace System. Santa Monica reported 20 wildlife strikes in the period between 1996 and 2016, or one wildlife strike for every 113,000 operations at the airport. The average of wildlife strikes at SMO is well-below the national average. Adding a grassy area as part of the proposed runway safety area (Configuration 2) are likely to attract birds and increase the risk of a wildlife strike.

Conclusions and Final Recommendation

The following conclusions are the final results of the study.

1) A well-maintained, 750 by 200-foot paved area (Configuration 1) at both runway-ends of runway 3-21 at Santa Monica Municipal Airport decreases the expected number of hazardous accidents over a ten-year period by a factor of 2.26 (66% reduction in expected accidents) compared to an unpaved area with a 150-foot long blast pad area (Configuration 2).
2) Configuration 3 (paved area of 300 x 200 feet) could reduce by 25% the number of hazardous accidents compared to Configuration 2 (unpaved area with a 150-foot blast pad area).
3) A well-maintained, 750 by 200-foot paved area (Configuration 1) at Santa Monica airport decreases the runway risk and damage to aircraft in case of an accident by a factor of 1.8-3.8 (see Table 7) when compared to an unpaved area with a 150-foot blast pad area (Configuration 2).
4) The reduction in risk is between 1.5-2.0 when comparing Configuration 3 (300 by 200-foot paved area) and Configuration 2 - an unpaved area with a 150-foot blast pad area.
5) Paved runway safety areas provide an additional reduction in risk that is not completely addressed with the ACRP report 50 location models used in the analysis. When an aircraft overruns an unpaved area, the average deceleration rate is 2.1 m/s^2. When an aircraft overruns a paved area (such as the existing condition at SMO), pilots can maintain control of the aircraft and can achieve higher deceleration rates (~3.5 m/s^2 or more).
6) Paved areas beyond the runway end are desirable to reduce hazardous and catastrophic damage to aircraft and property.
7) The consequences of aircraft overruns are critical and should be considered in the final decision for SMO. An overrun over a paved area would result in little or no damage to the aircraft. The overrun in an unpaved area will result in substantial damage to the aircraft.

Given that Santa Monica airport has 750-foot paved sections on both runway-ends, it is our recommendation to keep this configuration to maintain the level of safety of operations at the airport

References

1) City of Santa Monica Airport Air Quality Study: Scope of Work, 2018, Available at: https://www.smgov.net/uploadedFiles/Departments/Airport/2017.10.23%20City%20of%20Santa%20Monica%20Air%20Quality%20Study%20Scope%20of%20Work.pdf

2) Federal Aviation Administration, Airport Design, FAA Advisory Circular 150/5300-13a, Retrieved September 2016.

3) Ayres, M., Shirazi, H., Carvahlo, R. Hall, .Speir, R., Arambula, E., David, R., Wong, D., Gadzinski, J., Improved Models for Risk Assessment of Runway Safety Areas, Airport Cooperative Research Program Report # 50, Washington, DC, 2011.

4) Hall, J., Ayres, M., Wong, D., Appleyard, M., et al., Analysis of Aircraft Overruns and Undershoots for Runway Safety Areas, Airport Cooperative Research Program Report # 3, Washington, DC, 2008.

5) Federal Aviation Administration, Air Traffic Activity System (ATADS), Data Collected in July 2018, Available at: https://aspm.faa.gov/opsnet/sys/Main.asp?force=atads.

6) Federal Aviation Administration, Safety Risk Management Policy, Order 8040.4B, Washington, DC, May 2, 2017.

7) Business and Commercial Aviation, Aircraft Purchasing Handbook, May 2018, Penton Publishing Co.