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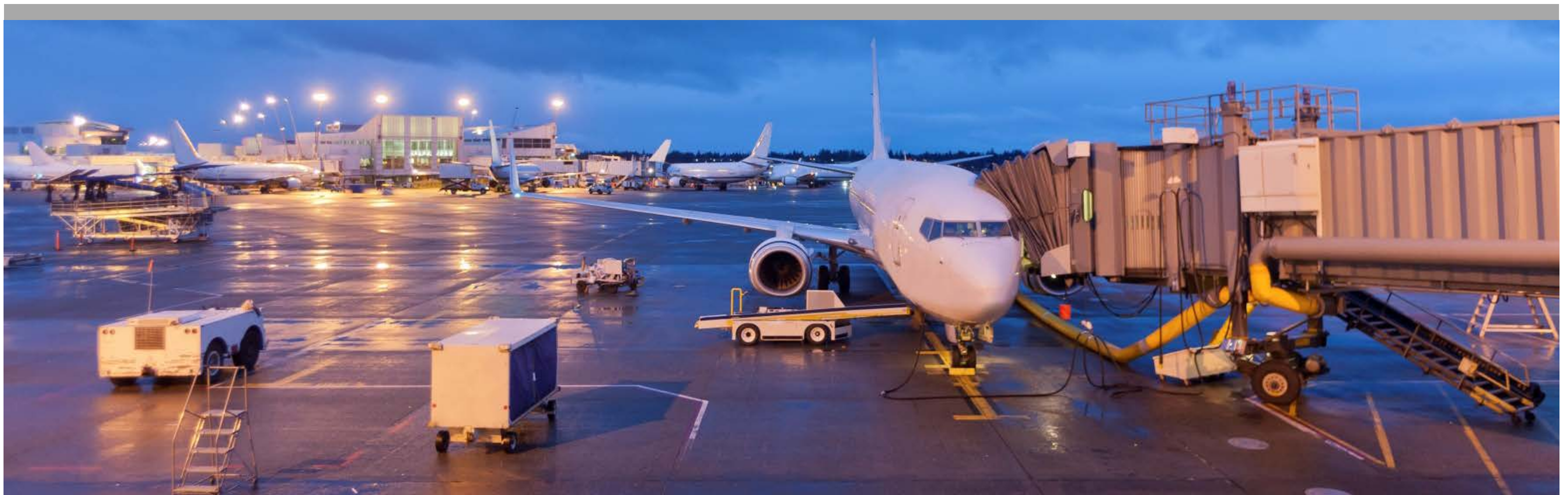

PARAS 0014

August 2018

Blast Mitigation Strategies for Non-Secure Areas at Airports

Guidebook

National Safe Skies Alliance, Inc.

Sponsored by the Federal Aviation Administration

Deborah Blass
Arup USA, Inc.
New York, NY

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National Safe Skies Alliance (Safe Skies) is a non-profit organization that works with airports, government, and industry to maintain a safe and effective aviation security system. Safe Skies' core services focus on helping airport operators make informed decisions about their airport security technology and procedures.

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PARAS PROGRAM OFFICER

Jessica Grizzle *Safe Skies Special Programs Manager*

PARAS 0014 PROJECT PANEL

Timothy Curran *Sacramento County Sheriff's Department*
Sean Cusson *LAM-LHA USA, LLC*
Anthony Lopez *Denver Police Department*
Jeremy Martelle *CHA Companies, Inc.*
Chad Menge *Metropolitan Washington Airports Authority*
Amir Neeman *Amir Neeman Consulting, LLC*
Christian Samlaska *Seattle-Tacoma International Airport*
Larry Studdiford *Studdiford Technical Solutions, LLC*

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SUMMARY

This guidebook facilitates the implementation of effective blast-mitigation strategies in non-secure airport areas to reduce risks of explosive attacks. Certain solutions may be effective at one airport but not at another. Each airport faces unique constraints, such as different vulnerabilities and risks, and varying sizes and financial capabilities. Therefore, this guidebook is not prescriptive but instead provides a process by which airports can implement the most appropriate strategies. A holistic approach is taken to determine risk-reduction measures, whereby a balanced security strategy is achieved by combining physical, technological, and operational solutions.

The main concepts in this guidebook are as follows:

- In the absence of regulations in the non-secure areas of airports, implementing a risk-based approach to identify blast-mitigation strategies is good practice and recommended by international and domestic aviation security guidelines.
- Existing airports' needs are different from new airports' needs, and small airports have different needs from large airports. Further, each airport has a unique risk profile and appetite for managing those unique risks.
- Identifying a blast-mitigation strategy should take into consideration measures that are most effective for the unique characteristics and risk of that particular airport. Good-practice blast-mitigation strategies for non-secure airport areas should incorporate a variety of measures, from physical—structural and facade hardening; to technological—analytics and emerging capabilities like millimeter wave detection; operational—explosives detection canines, patrols, and crowd management; and architectural—terminal and roadway layout, materials, and detailing. Each type of measure has unique pros and cons in terms of functional (i.e., protective capabilities such as deter, detect, and defend) and non-functional (i.e., cost, passenger impacts, and adaptability) effects. Identifying a suitable strategy should consider these characteristics together with the unique needs of that airport.
- A framework process has been developed to identify combinations of measures that should be combined to form a cost-effective, holistic blast-mitigation strategy. The process is applicable to all airports and projects, and is customizable. To facilitate execution of the quantitative portion of the framework process, an Excel-based tool accompanies this guidebook.

SECTION 1: OVERVIEW OF GUIDEBOOK

1.1 Introduction

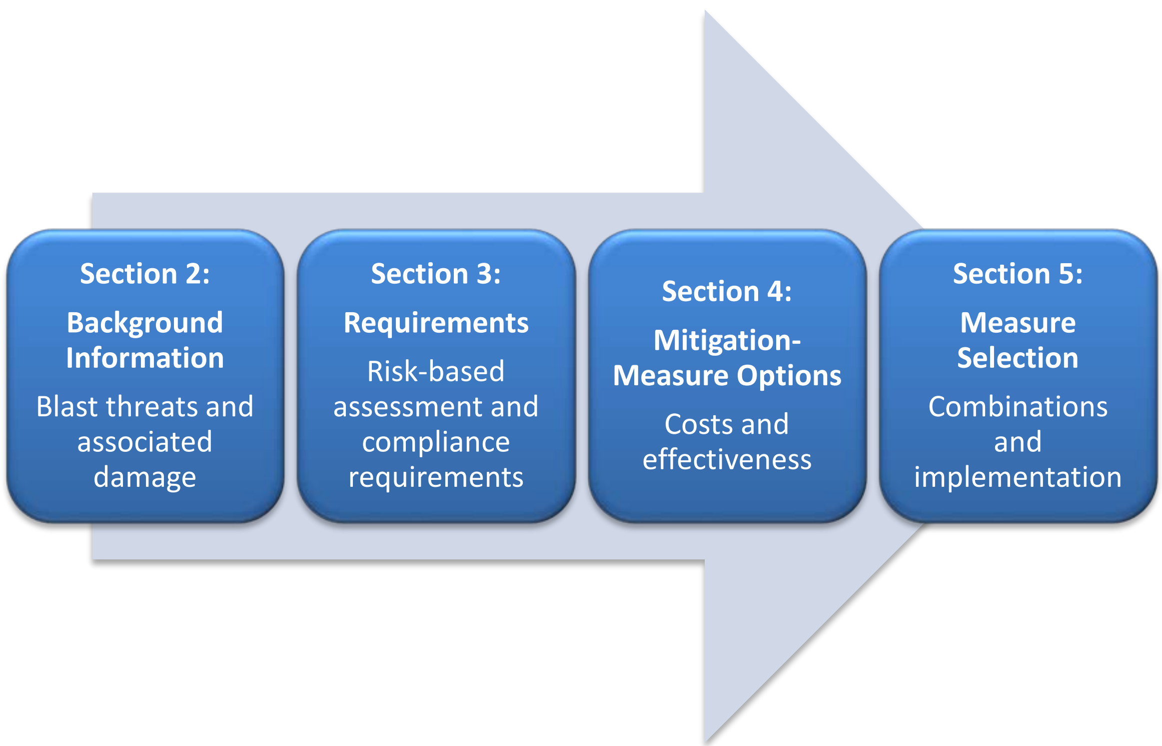
Arup USA, Inc. (Arup) was contracted to develop this guidebook addressing blast-mitigation strategies in non-secure areas of airports by National Safe Skies Alliance, Inc. through their Program of Applied Research in Airport Security (PARAS).

This guidebook helps professionals involved in airport design and operations develop blast-mitigation strategies customized to their specific risks, contexts, and needs. The aim is to answer the following question: ***How can I mitigate the blast risk at my airport?***

This guidebook covers several aspects of effective blast mitigation strategies in detail:

- Damage to be expected as a result of various threats (Section 2)
- Legislation requirements and the need for a risk-based approach (Section 3)
- Costs and effectiveness of various blast-mitigation measures (Section 4)
- Implementation plan (Section 5)

Figure 1-1. Overview of Guidebook Contents



As mitigation measures are considered, a risk assessment will help decision-makers understand the risks unique to the airport and site and, therefore, develop targeted and proportionate measures. Measures must also be compliant with relevant legislation.

After airports have gone through the measure-selection process, residual risks should be evaluated in accordance with the risk-assessment process.

Unless otherwise stated, the terms “risk-reduction measures” and “security measures” refer collectively to nonspecific measures and may include operational, physical, design, or technology security measures, e.g., guards, bollards, standoff distance, or CCTV, respectively. Where reference is specific to the blast threat and risk, the terms “blast protection” and “blast-risk-mitigation measures” will be used.

1.2 Motivation

This guidebook was created to address challenges faced by airports in implementing blast protection. As part of the development of this guidebook, Arup interviewed airport professionals and undertook research to identify existing gaps in currently available guidance.

The information obtained from interviews and gap-analysis research influenced the objective and intended application of this guidebook.

1.2.1 Input from Airports

Arup conducted interviews with airport representatives to better understand the users’ expectations for blast-mitigation-related guidance. Arup interviewed 10 airports of various sizes (Table 1-1). Their feedback is summarized below.

Table 1-1. Airports Interviewed

Airport Category	Airport	Interview Date	Department within Organization
Large Hub	Dallas/Fort Worth International Airport (DFW)	8/10/17	Police Department
	San Francisco International Airport (SFO)	9/26/17	Security Department
Medium Hub	Oakland International Airport (OAK)	8/14/17	Security Department
	San Jose International Airport (SJC)	8/24/17	Operations Department
	Jacksonville International Airport (JAX)	8/18/17	Public Safety and Security Department
	General Mitchell International Airport (MKE)	8/8/17	Planning and Engineering Department
	San Antonio International Airport (SAT)	8/17/17	Security Department
Small Hub	Wichita Dwight D. Eisenhower National Airport (ICT)	8/7/17	Operations Department
	Boise Airport (BOI)	8/3/17	Police Department
	Fresno Yosemite International Airport (FAT)	8/24/17	Public Safety Department

1.2.1.1 Experience Implementing Blast-Mitigation Strategies

PROJECT IMPLEMENTATION

Several of the individuals interviewed have had experience incorporating blast-mitigation strategies at their airports, ranging from structural hardening to operational measures. Almost all were confident that the airport’s security team would be involved in new projects at their airport and could therefore request the consideration of blast mitigation. However, if the security department were not as active in the project planning process, its input could be overlooked or incorporated late in the process. To ensure a cost-efficient and effective security outcome, airport security departments must proactively participate in the early stages of project planning.

Interviewees consistently suggested that to determine design-basis threats, airport security stakeholders (e.g., law enforcement, Transportation Security Administration [TSA], Federal Bureau of Investigation [FBI], private security, and corporate security) should gather intelligence, determine the threat, and identify the assets that require protection. Most airports did not have a pre-existing threat or risk assessment. Almost all interviewees noted that it was difficult to determine how exactly to protect against those identified threats and what level of blast protection was required. They stated that the ultimate decisions regarding blast-protection measures are made by the senior management on the airport board, the chief airport operator, or similar high-level executives; these positions have the authority to make risk-based financial decisions, which are otherwise unregulated. The involvement of the security team in decision-making varied from nonexistent, with decisions made in a private meeting without security's involvement, to significant, with decisions heavily influenced by security.

Just over half of the airports interviewed have taken proactive steps to evaluate vehicle-borne improvised explosive device (VBIED) and person-borne improvised explosive device (PBIED) threats to their airports from physical and design perspectives:

- Some integrated blast-protection measures into their design, based on the airport owner/operator's decision to follow recommendations made by their blast consultant.
- Some excluded blast-protection measures from their design, based on the airport owner/operator's decision to follow the blast consultant's recommendation that physical protection is not necessary, for example, due to large standoffs (i.e., distance between vehicle access and terminal buildings) or robust structures.
- In all cases, the blast-protection studies were incorporated as part of another capital project, such as a terminal renovation, that was not initiated with the objective of providing blast protection.

Although the interviewees were generally familiar with the PARAS 0004 document, *Recommended Security Guidelines for Airport Planning, Design, and Construction* (formerly issued by TSA under the same name), it does not appear to be used frequently by the airports interviewed. A few individuals stated that the architects or designers on the planning team used this document on projects. One airport noted that to understand the application of current best practices, the airport sends a representative to other airports around the world.

Another airport said that although the budget is always considered, the primary concern at their airport is to implement strategies to fix identified problems; however, when it comes to blast mitigation, the airport is unsure how to clearly identify the problem or determine whether there even is a problem.

Some individuals suggested that the incorporation of security measures is dependent on the CEO or COO, and that some CEOs put greater emphasis on security than others. In summary, there is variability among airports regarding the need to include or prioritize blast mitigation in their projects.

CURRENT MITIGATION STRATEGIES

The airport representatives interviewed were overwhelmingly dissatisfied with the amount of currently available information and guidance resources relevant to blast mitigation. However, there was some consistency in the risk-mitigation measures being considered by most airports:

- Law enforcement patrols in and around terminals to look for suspicious packages and persons
- Hostile vehicle mitigation measures at doorways along the landside curb
- Police presence in terminal front of house (FoH) and at curbside to deter aggressors

- Random canine patrols through the terminal FoH and parking garages
- Landside vehicular traffic controls (passive and active)
- Landside loading dock deliveries scheduled and received by the expecting entity; otherwise, they are turned away
- Video surveillance coverage; however, this is mostly used for post-incident investigation, as not all coverage is actively monitored (too many cameras, not enough people for active monitoring)
- Recurrent training for all airport employees, including for non-security personnel, such as incident response and reporting of suspicious activities
- Plans and procedures to achieve greater standoff to vehicles during elevated threat levels
- Contracted security services to monitor areas like parking garages and loading docks (medium and large airports only)

One of the medium-sized airports interviewed is implementing additional measures beyond those typically adopted, including visual explosives screening of all trucks going to the loading dock prior to their admittance near the terminal, new blast-designed facade, video analytics to detect suspicious packages and vehicles, and headway bars to limit the size of vehicles allowed to approach the terminal. These measures have been implemented as a direct result of recommendations made by a consultant. However, a risk assessment was not undertaken to determine these measures.

In a heightened threat condition, most airports interviewed have a plan in place that involves coordinating with TSA and law enforcement to reroute vehicle lanes to achieve more standoff to the terminal, restrict parking to certain areas, and perform vehicle inspections (a TSA requirement for a number of airports). Additionally, most airports will provide increased police presence in the non-secure areas of the airport during elevated threat levels.

1.2.1.2 Challenges of Incorporating Blast Protection

For most airports, the three biggest challenges of incorporating blast-protection measures were as follows:

- Buy-in by decision-makers
- Costs of the measures
- Lack of clarity in determining what measures are needed and where

Every airport interviewed made a direct or implied reference to all three of these challenges.

BUY-IN AND RESOURCE ALLOCATION

Blast-protection measures are not typically considered a high enough priority for a budget to be allocated, with many airports noting passenger experience (e.g., murals, terminal cleanups, etc.) initiatives being prioritized over security investment, including blast protection. Additionally, one airport noted that it was difficult to get the planning department to focus on relatively small-scale projects such as blast protection when they are often focused on large (e.g., $20-30 million) capital projects.

One airport highlighted that the project funding source influenced the prioritization of resources. For example, projects funded by grants—e.g., apron and taxiway rehabilitation, erosion control and drainage improvements, or taxiway lighting—were given resource-allocation priority compared with revenue-funded projects such as terminal expansion/renovation (which would include blast protection).

Buy-in by decision-makers was cited as the biggest challenge for one airport, with another airport stating that understanding the risk was the greatest challenge to establishing buy-in: it is difficult to justify capital investment to mitigate something "that may never happen." This was underscored by another airport's observation that the Brussels Airport attack (March 2016) influenced their ability to secure investment because the event happened to occur at the same time they were seeking funding.

The need to ensure compliance with regulations appears to have an influence on securing buy-in. One airport noted that at the time of their terminal reconstruction, the now-retracted "Special Category Airport 3," also known as the "300-foot rule," was being publicized by the TSA, and it was therefore easier to secure funding for a blast study.

COST OF BLAST PROTECTION

In general, airports reported the high cost of incorporating blast protection as a major challenge. The following examples were cited in the interviews:

- One airport discovered partway through a glass-facade-strengthening project that in order to gain the greatest security value from a blast-protection investment, strengthening the terminal's support structure and columns would also likely be required. This type of unexpected and costly upgrade underscores the "excessive" cost perception of blast protection.
- One individual mentioned that their airport had studied what was required to protect against a van or car explosive adjacent to the terminal and deemed the cost "ridiculous." This view and lack of understanding of the risk further reduced the credibility of blast protection as a valid security measure.
- The level of revenue (investment source) relative to the cost of blast protection, including expert advice/consultancy and the measures themselves, is significant at smaller airports; the money is simply not available.
- One airport noted that blast protection is an "afterthought" in capital projects, resulting in it becoming even more costly and then "nobody wants to do it."
- One airport noted that achieving certain protection measures, such as obtaining greater vehicle standoff and separating the loading dock from the terminal, requires large-scale changes to the existing airport configuration that are neither economically nor operationally feasible.

Several airports cited cost as the overall biggest challenge to implementing blast-protection measures. This perspective highlights the implications associated with not having a risk-based security culture. Without an understanding of what blast-protection measures buy in terms of risk reduction (or return on investment), blast-protection measures are viewed only as a cost. This guidebook aims to help airports realize the value achieved by introducing various blast-protection measures, using a risk-based approach.

PERCEIVED AMBIGUITY IN GUIDANCE

Ambiguity about which guidance to follow, what measures to implement and where, and what scale or level of protection should be implemented was cited by at least one airport as the single biggest challenge in incorporating blast protection.

The interviews indicate there is a perception that blast-protection measures are best determined by an external entity or authority, particularly in an unregulated environment such as landside. This leads to confusion about which guidance to follow, since any guidance documents available on the topic only make recommendations, which do not have the authority of requirements. Furthermore, due to the site-specific nature of security risks, the information varies among the available guidance.

Generally, because the airports do not understand what level of risk or protection they should be pursuing, they do not know which guidance and measures to adopt. Some airports have used expert advice from consultants, but the value of the investment is not always recognized throughout the organization due to the absence of a risk-based culture.

Another consistent desire among the airports interviewed was for an external authority to determine measures and clearly communicate those through authoritative guidance.

1.2.2 Gaps in Current Guidance

In most nations, including the United States, there are no legislated requirements specifically for blast protection; it is up to the airport owner/operator to make these decisions.[1] Australia, for example, legislates that the airport's security program be based on a security risk assessment, which negates the need to dictate blast protection for all airports. This approach is consistent with the International Civil Aviation Organization's (ICAO) expectation that Contracting States, of which the United States is one, "establish and implement policies and procedures … based upon a security risk assessment"[2] and that they ensure "that security measures are established for landside areas to mitigate the risk of and to prevent possible acts of unlawful interference in accordance with risk assessments."[3] Furthermore, the ICAO expects Contracting States to "ensure that landside areas are identified."[4]

The information currently available about risk assessment provides airport owners and operators with clear guidance on the risk-assessment process. However, the guidance is limited to conducting the risk assessment and does not extend to guidance on mitigating the risk, i.e., how to determine which measures to use to mitigate which risks, how to determine an acceptable level of risk reduction, and how to measure the effectiveness of measures in reducing risks, either on their own or in combination. Regarding blast protection, there is little guidance on the level of protection that should be achieved. This is to be expected given that the risks and risk appetites are different for each airport, and therefore the level of protection will be unique to each airport.

The literature review conducted in the process of developing this guidebook found that there is little discussion of the non-security impacts of implementing various blast-mitigation measures (both positive and negative). These include airline and airport operational disruption during implementation, influence on architectural objectives, operational changes required to facilitate implementation/operation and maximize the security value of measures, supporting infrastructure changes required to facilitate the implementation/operation, and indirect benefits of blast-protection measures. Examples include the following:

- Establishment of standoff may require rerouting of approach roads and may influence parking design or result in greater walking distances for passengers.
- Retrofitting of facade glazing for resilience requires the deployment of scaffolding or temporary closure of terminal areas, which could affect passenger experience and airline operations.
- No-parking zones in front of the terminal help improve traffic efficiency in passenger pick-up and drop-off zones.
- Reducing queuing times improves the passenger experience and increases the amount of time passengers spend on the airside, where they are likely to make purchases.

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[1] Except Singapore, which recently passed the Infrastructure Protection Act of 2017, mandating that blast be considered.
[2] Annex 17 Standard 3.1.3
[3] Annex 17 Standard 4.8.2
[4] Annex 17 Standard 4.8.1

- Blast-mitigation requirements may influence the use of particular materials, and the shapes and sizes of various terminal elements, which may impact architectural objectives.
- Changes to screening, resourcing, and training may impact both airport and airline employees, as well as passenger experiences.

Selection of security measures should consider all implications, not just a measure's ability to mitigate a security risk. This is particularly relevant when comparing different measures available to reduce the same risk, e.g., standoff versus structural strengthening. There is, however, little guidance available to assist with this important process. Further, little to no cost information is made available to airports to enable them to assess and compare the whole-of-life cost—capital and operating cost—of specific security measures.

The most widely available guidance documents regarding blast protection are specific to typical building structures. Variations in airport structures can be significant for large airports such that the specific building requirements in these guidance documents are not entirely applicable. Additionally, there is no guidance available relating to nonbuilding areas within airports, such as bus stops or fuel farms.

The Federal Highway Administration's (FHWA) *Bridge Security Design Manual* (June 2017), can be used for the design of elements such as raised roadways common at airports. However, the FHWA document, along with many others (e.g., American Society of Civil Engineers (ASCE) 59-11 *Blast Protection of Buildings* or Unified Facilities Criteria (UFC) 3-340-02 *Structures to Resist the Effects of Accidental Explosions*), is intended for a highly technical audience of specialist engineers. The contents are largely incomprehensible to anyone without significant structural design engineering experience.

Design according to such standards also remains somewhat prescriptive. While blast-resistant design is often identified as a branch of performance-based design, standards such as ASCE 59-11 require the end user of a building to make judgments about the anticipated threat size and desired level of performance. Often such end users are unaware of or lack experience to understand the choices they are being asked to make and the potential outcomes (e.g., costs or aesthetics) of their decisions. It is often difficult for organizations to retain experience or knowledge in this area because blast is typically considered only when assets are built, replaced, or substantially refurbished.

Blast-resistant design requires a holistic approach that demands input from a wide range of individual specialists including but not limited to threat and risk, airport operations, architectural, project management/delivery, airport security operations, communications/IT, quantity surveying, and various engineering disciplines. Despite this multidisciplinary need, guidance tends to be targeted to risk assessments and structural engineering, without reference to this broader input.

Also neglected in many industry guidance documents is the importance of recovery and reinstatement of services following a blast incident. While the documents above reference business-continuity objectives, these are typically ill-defined. The dominant feature of the blast-specific design and guidance documents reviewed was an emphasis on structural and facade performance—critical building services were often referenced only with regard to their physical hardening or placement to reduce exposure to blast effects. Assessment of the consequences of blast effects on services is not well-defined. Furthermore, despite significant law enforcement agency needs following a blast (e.g., time and access control for forensic investigation), there is little to no general guidance available for the industry to draw on to inform their business-continuity planning.

1.3 Guidebook Objective

This document's objective is to guide airports in their development of a blast-mitigation strategy. The strategy proposed herein takes a holistic approach to reducing risks of a blast event, considering both non-security and security needs and impacts. To support this objective, the guidebook includes examples of mitigation measures and their considerations and consequences of implementation, such as the benefits and disadvantages, operational impacts, and rough order-of-magnitude costs.

The guidebook's holistic approach includes:

- Physical factors (e.g., structural and facade hardening, vehicle barriers, etc.)
- Technological factors (e.g., CCTV and analytics, etc.)
- Operational factors (e.g., canine patrols and behavioral detection officers, etc.)
- Architectural layouts (e.g., crowd management, etc.)

The guidebook does not attempt to replicate specific guidance such as risk assessment or structural engineering specifications that are already available. Rather, it clarifies their application in the context of blast mitigation. Since each airport has a unique combination and configuration of size, landside assets, risk profile, and risk appetite, the guidebook does not prescribe particular measures. It is designed to apply to airports of all sizes and addresses risks associated with all non-secure areas. The guidebook also draws upon previously published information, such as the PARAS 0004 document.

As confirmed by the interviews, airports rely heavily on the technical design community, such as architects, to determine security measures. Therefore, this guidebook is also intended for use by designers including architects, planners, and engineers who may be working with airport security stakeholders or airport owners on a project that requires blast protection.

It may not always be obvious when a blast strategy is required—some projects inadvertently introduce or increase security risks without any defined security scope. This further underscores the need for a security risk assessment and early consultation with the airport's security team in any capital project.

1.4 Application

The guidebook is intended for professionals involved in determining blast-protection measures at airports. This includes airport owners and operators as the ultimate security-risk owners; airport security managers who facilitate the implementation of risk-mitigation measures; and the design community, such as architects, engineers, and planners. The guidebook is applicable to all airports in the United States. Although not every strategy will be applicable to every airport, the guidebook is designed to help airports evaluate whether each strategy is applicable to their specific contexts.

This guidebook should be reviewed before the start of any new landside facility, security, transportation planning, or construction project for awareness of potential project implications. It should be used as a reference for the basis of design during the course of any applicable landside projects. In a request for proposals, an airport can require that this guidebook be used as a security reference.

> Implementing appropriate blast-risk-mitigation strategies is the responsibility of the airport. The architect, blast consultant/engineer, and airport security manager are well suited to collectively facilitate and manage the process of blast mitigation for an airport.

SECTION 2: BACKGROUND INFORMATION

This section provides information to improve baseline knowledge about blasts, including the following:

- The basics of blast loading and analysis to help users understand why and how certain mitigations may work
- A review of historical attacks, including means and methods, and the implications associated with certain mitigation measures
- Examples of blast threat sizes and the damage that could be expected as a result of those threats, to provide airports with a greater understanding of the risk management and acceptance process in the blast context

2.1 Basic Principles of Blast Loading

An explosion is typically caused by a chemical reaction. When an explosive material is ignited, it burns quickly. In the burning process, a large amount of hot gas is produced and rapidly expands. This rapid release of gas pressurizes the air around the detonation, which creates a blast wave: air moving faster than the speed of sound. The intensity of the blast wave dissipates over time and distance. Severe damage to structures or individuals occurs immediately adjacent to the detonation source.

The blast wave creates a short-term pressure on any surface it encounters. The surface could be an exterior building facade, an interior structural column, or a person. It is essentially a very high wind load for a very short period of time. Typically, the duration of a sustained wind gust is up to 20 seconds. A typical blast load duration is less than 20 milliseconds, or less than 0.1% of the duration of a sustained wind gust.

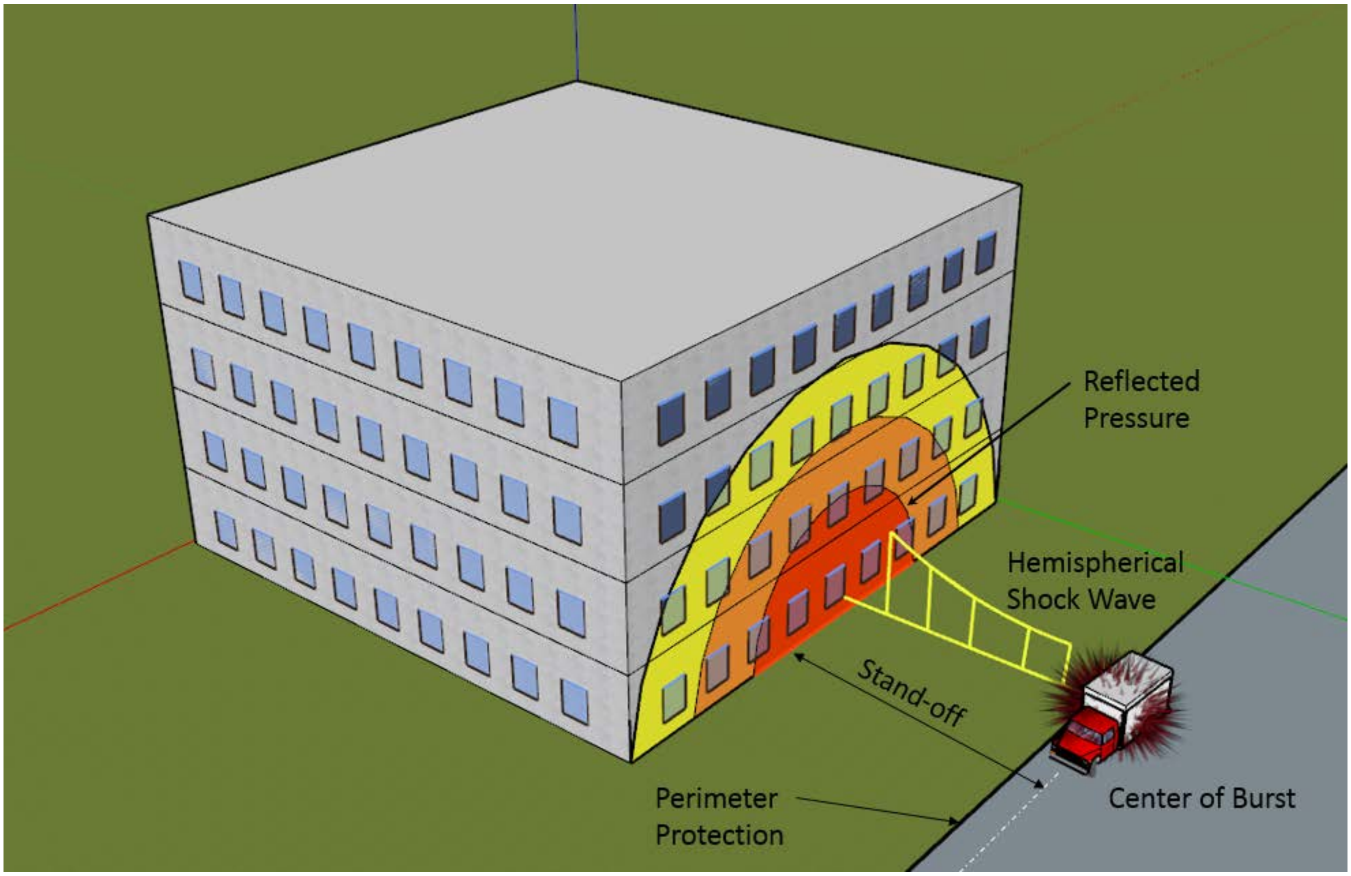
Blast loading is expressed in terms of pressure, time duration, and impulse. The pressure is expressed in terms of psi (pounds per square inch) or psf (pounds per square foot) and defines the peak magnitude at which the blast wave impacts the surface. Blast-designed facades are typically designed for blast pressure in the 4 psi to 10 psi (576 psf to 1,440 psf) range. A typical exterior facade for wind is designed for a continuous load of 30 psf to 35 psf.

Time duration is expressed in terms of msec (milliseconds) and defines how long the blast wave is impacting the surface. Typical building facades are designed assuming the pressure reduces to 0 psi at the end of the time duration. The impulse is expressed in terms of psi-msec and accounts for the total energy impacting the facade based on the peak pressure and time duration. Higher pressures and longer-duration events increase the total energy.

There are three main variables in determining the magnitude of the blast load at any given surface: size of the threat (explosive type and size), standoff (distance from threat to surface), and line of sight (angle) from threat to surface. The standoff distance plays a key role in the blast loading, as the total energy in the blast wave is directly proportional to the standoff. If the standoff is doubled, the impulse is reduced by about 46%. The other design-controlled variable is the line of sight from the threat to the surface. The worst-case scenario is that in which the surface is perpendicular to the blast wave, creating a fully “reflected” pressure loading. If the threat can be restricted to an angle (say, 45 degrees), the impulse is reduced about 15% as it creates a “side-on” loading.

See Figure 2-1 for a simplified picture showing standard design conditions. The threat (truck) is located on the roadway with a standoff from the threat to the building facade. The building facade depicts the intensity of the blast wave on the facade’s surface, with a higher magnitude at the base and a smaller magnitude at the upper levels, as the distance away from the threat increases. In the blast engineering industry, the threat is typically specified in pounds of trinitrotoluene (TNT). Conversion factors for other types of explosives to TNT equivalence are available in various blast engineering references such as ASCE 59-11 and *Blast Effects of Buildings* by Cormie, Mays, and Smith (2009). More information regarding typical explosive sizes are presented in Section 2.3.

Figure 2-1. Simplified Blast Wave Interaction with Building



Source: bmk Engineering

When a threat is in a confined space, such as a lobby or mail room, the blast pressure is confined, which increases the total impulse on surrounding surfaces. The blast wave will reflect off adjacent walls and increase the time duration a surface experiences the blast load. Typical blast-protection measures for confined spaces include pressure relief panels or walls that are designed to fail and alleviate the other walls from the blast load.

After the initial blast wave, a vacuum is created that will almost immediately refill itself with the surrounding atmosphere. This creates a very strong negative pressure on the surface. This negative pressure can minimize debris propelling into occupied space but is hard to accurately predict. Because of the large unknown, this negative pressure is ignored during design to produce a slightly conservative design solution.

Most facade systems are designed to resist the impulse as the controlling factor; therefore, increasing standoff or changing the line of sight will reduce the total energy the surface must absorb.

After a blast wave strikes a surface or body, high-velocity shockwaves will continue to pass through the surface or body. These shockwaves carry energy through the surface. If the individual surface elements are unable to resist these waves, these elements will either break apart and become flying debris or structurally fail, causing major damage to the surrounding area. In people, the shockwaves will travel through internal organs and tissues, causing severe damage. Any flying debris could also cause lacerations and other injuries to anybody inside the buildings. Flying debris is the leading cause of injuries in a blast event.

Additionally, when a bomb explodes, the bomb casing and any additional shrapnel (nails, screws, or other items included in the bomb) will be violently propelled outward and away from the explosion at extremely hazardous speed. This fragmentation from the bomb casing and its shrapnel is referred to as primary fragmentation. When these fragments strike buildings, concrete, masonry, glass, and other facade elements, they may fragment even further and cause even more damage. This is known as secondary fragmentation.

Lastly, the explosion may also create a fireball and high temperatures, which could result in burns on a human body or cause secondary fires, depending on whether other fuel sources or flammable materials are located near the source of explosion. Fire and heat are often mistakenly interpreted to cause the major damage in a blast event; however, the damage described in the paragraphs of this section is primarily due to the pressurized air—the blast wave.

2.2 Historical Explosive Events and Future Trends

Though the nature of terrorism is evolving, historic attacks can prove informative when it comes to mitigating effects of similar events in the future. This section presents a selection of relevant historic explosive incidents at airports and their impacts, based on a review of open sources. A discussion of anticipated future attack methods, reviewed from available intelligence, is also included.

2.2.1 Istanbul Atatürk Airport

On June 28, 2016, a coordinated terrorist attack was launched against Terminal 2 at Istanbul Atatürk Airport in Turkey. The attack occurred while the airport was operating at a higher threat level in response to information provided by intelligence authorities, although post-incident investigation showed that the perpetrators had conducted reconnaissance over a period of two to three weeks prior to the attack and had exploited vulnerabilities observed.

According to information reported, including reports from TAV Security Services (the private security company employed at the airport), the three attackers arrived by taxi and avoided behavioral assessment by being dropped off in a lane at FoH that they knew (from reconnaissance previously conducted) was unlikely to be overseen by police. A CCTV operator identified them as suspicious and sought police assistance. This resulted in a police officer initially following one of the attackers, before intervening inside the terminal, at which time the police officer was shot.

The next attack occurred on the arrivals level, where an area of mass gathering was sought out to detonate the PBIED. The other two attackers sought to access the departures level by shooting at the FoH terminal screening checkpoint (the checkpoint required passage just to enter the terminal). One attacker succeeded in penetrating the departures hall on the first floor of the terminal building, where he opened fire on passengers as he moved inside the terminal, possibly toward the sterile area or the VIP lounge. The attacker detonated a PBIED near the entrance to the departures hall. The third attacker was shot by an armed immigration officer on the arrivals level but was still able to detonate the PBIED.

Post-incident investigations showed that the modus operandi and objectives of the terrorists evolved rapidly during the attack, including moving between departures and arrivals levels. These changes are thought to be a direct result of interventions by law enforcement agencies, which had the effect of reducing the impact of the attacks planned.

The attack resulted in the deaths of 45 people and injured at least 239 others.

The attackers were collectively armed with at least one automatic weapon (AK-47), a handgun, and two grenades. Additionally, each attacker carried a PBIED hidden in a vest. It appears the attackers timed the start of their attack on the terminal screening checkpoint to coincide with iftar, the evening meal that marks the end of each day's fast during Ramadan, most likely in an attempt to catch airport police and security personnel off-guard. Because the event also coincided with a change of shifts, airport security managers were able to deploy additional staff at extremely short notice. The gun attack on the screening checkpoint lasted approximately 10 to 15 minutes. The entire duration of the attack was approximately 45 minutes.

No significant structural damage was caused by the incidents; however, some non-structural elements were damaged, creating debris in the terminal.

The airport was closed for several hours after the attack. The next morning, incoming and outgoing flights were operating, though some were canceled or delayed.

Figure 2-2. Damage after Atatürk Explosion

Source: Associated Press

2.2.2 Brussels Airport

On March 22, 2016, three improvised explosive devices (IED) exploded in Brussels, Belgium, killing 35 people and injuring over 300 others. Two of the IEDs were manually detonated by terrorists nine seconds apart in the main terminal building at Brussels Airport at 0700 GMT, while a third device exploded on a train at Maelbeek Metro station in central Brussels at 0800 GMT. All three attacks were suicide-bomb attacks. Belgian authorities identified the attackers as Belgian nationals. Daesh (Islamic State) claimed responsibility for the Brussels attacks via a statement on its Amaq agency.

The attackers at Brussels Airport utilized automatic weapons and IEDs packed with nails concealed within two suitcases. One exploded at check-in row 11 on Level 3 of the Departures Hall and the second exploded at check-in row 2 in the Departures Hall. Gunfire from automatic weapons (probably AK-47 assault rifles) prior to the explosion was reported. At least 13 people were killed in the explosions and more than 80 injured. A third unexploded IED was discovered and disposed of by security forces in a controlled detonation.

The locations of the explosions in the terminal building suggests that the attackers may have tried to use a pincer-style attack by detonating one device, causing the crowd to run, and then using a second device in the midst of the fleeing crowd. This suggestion is supported by the fact that the IEDs were packed with shrapnel and partially explains the high number of injuries relative to fatalities.

The attack at Maelbeek Metro station involved the manual detonation of an IED in a train carriage as the train ran along the platform at Maelbeek station. The explosion killed at least 15 people and injured more than 170 others. The source of the explosion is suspected to be a belt device worn by the bomber. Maelbeek station is in central Brussels and serves as a transport hub for several European Union administration buildings.

All IEDs used in the attacks are suspected of being composed of triacetone triperoxide (TATP), a highly unstable homemade explosive. TATP has been used by terrorists inspired by Daesh.

The blast did not cause structural damage to the terminal building, but non-structural elements suffered damage, such as the suspended ceiling at some locations within the terminal.

The airport was closed after the attacks, and flights were diverted to other airports. On April 3, flights began resuming. As a response to the attack, an extra 1,600 police officers were deployed to train stations, airports, and border crossings.

2.2.3 Madrid-Barajas Airport

On December 30, 2006, an IED placed in a van exploded in the parking area of Terminal 4 of Madrid-Barajas Airport in Spain. Two people were killed while at least 31 were injured during the incident. The VBIED contained approximately 800 kg (1,800 pounds) of explosives, which, in addition to causing the casualties, led to the partial collapse of the five-story parking garage.

The Basque separatist group ETA has claimed responsibility for the attack. The organization had declared a permanent ceasefire on March 24, 2006; after the attack, ETA still insisted on respecting the ceasefire.

A few days prior to the attack, the vehicle was stolen from southwestern France and later loaded with the explosives. On December 29, the van was parked in unit D of Terminal 4 and the driver left the airport by a taxi. The next day, approximately an hour before the explosion, the authorities were informed by an anonymous caller warning about the event. Police were able to evacuate the area before the van exploded. After the explosion, regular air traffic was suspended at Terminal 4 for several hours, but flights at the other terminals were not affected by the event.

Demolition of the parking garage was required as the damage was uneconomical to repair.

Figure 2-3. Damage after the Madrid Airport Bombing Resulted in Demolition

Source: Enrique Dans/Flickr (CC by 2.0)

2.2.4 Other Notable Incidents

2.2.4.1 1975 – LaGuardia Airport Bombing

On December 29, 1975, an IED exploded in LaGuardia Airport in New York City, killing 11 people and injuring 74. The explosive device was placed in a coin-operated locker in the baggage claim area in the main terminal, populated with people. The explosion (equivalent to the force of approximately 20 to 25 sticks of dynamite) tore apart the locker, resulting in flying shrapnel that caused 11 deaths and injured many others. It is suspected that Croatian nationals were responsible for the attack; however, the case is still unsolved.

2.2.4.2 2011 – Moscow Domodedovo International Airport

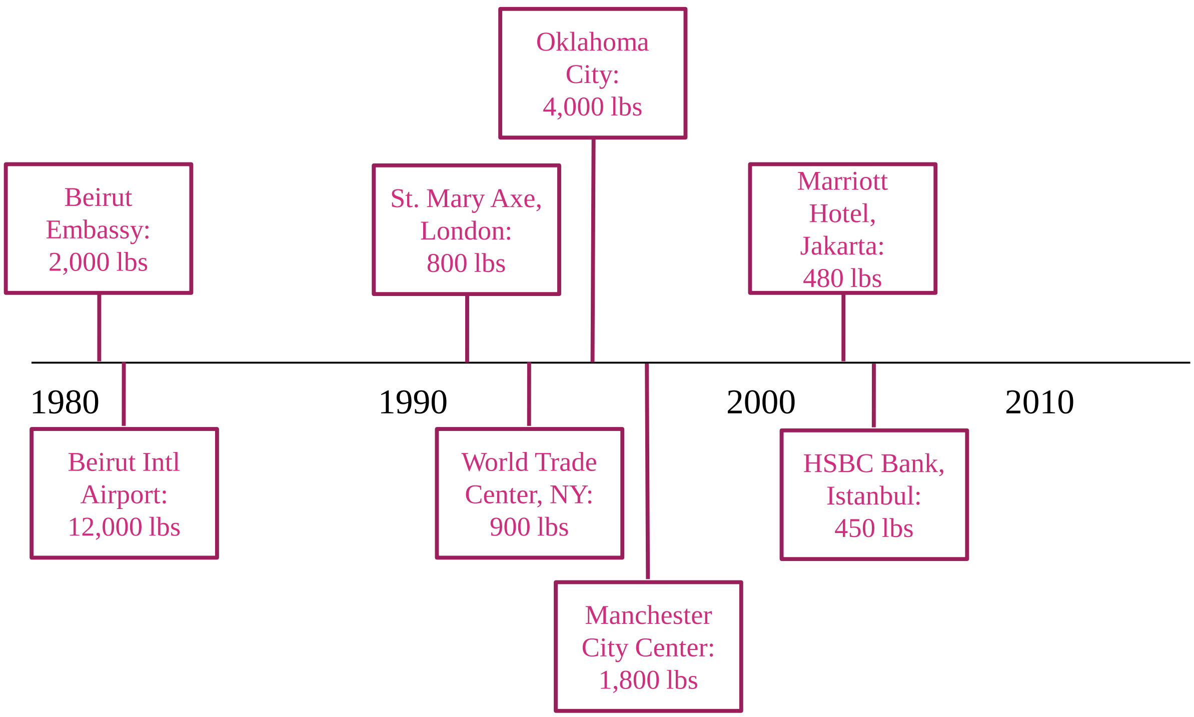
A suicide bombing killed 37 people and injured over 100 others at Moscow Domodedovo International Airport on January 24, 2011. The explosion occurred at the entrance of the international arrivals hall, aimed at foreigners and Russians alike. It is thought that the perpetrator entered the building from the parking garage, avoiding being screened by metal detection on his way to the arrivals hall, carrying 7 kg (15 pounds) of explosives. A few days after the attack, Russia's Investigative Committee announced that the suicide bomber had connections with North Caucasus.

2.2.5 Example Explosive Sizes in Historic Attacks

Credible sources of explosive charge sizes used in PBIED attacks are not widely available. The official account of the London July 7, 2005 bombings estimates the backpack-sized explosives used were between 2 and 5 kg (5 and 11 pounds) of high explosives. This size is also similar to that found in the analysis of the PBIED suicide belt detonated at the Domodedovo Airport in Moscow in 2011. The 2004 Madrid bombings are reported to have involved the use of backpacks each containing 10 kg (22 pounds) of explosives.

The range of VBIED charge sizes also varies. Figure 2-5 shows estimates for historic events.

Figure 2-4. Timeline Showing Approximate VBIED Explosive Sizes for Significant Events in Pounds of Equivalent TNT



Source: FEMA 430, 2007 and Hadden, J.D. et al, 2007

2.2.6 Evolving Threats

Terrorists are constantly changing their methods of attack and targets; adapting quickly and creatively is necessary to achieve their objectives. Our protection implementation must evolve or risk being outpaced by innovative terrorists. For example, the Islamic State (ISIS) has made deadly adaptations to its use of drones, including dropping bombs; drones are a relatively new technology but have become readily available. The nature of terrorism is unpredictable, and methods of delivery are also hard to predict.

Although the greatest progression in creation of successful IEDs and target-shifting to the civilian population has been seen in Iraq, the rest of the world should remain aware of the tactics and technologies being used there, as the methods developed may spread globally. Recently, terrorist groups such as al-Qaeda have implemented changes in their organizational learning by utilizing the internet and social media to transfer knowledge (of bomb-making, for example) to a broader base of followers.

Denying access to explosives is the first step in the reduction of IED incidents. However, when traditional explosives become difficult to obtain, bomb makers will adapt and turn to other materials, such as common chemicals, as precursors to manufacture explosives. Although legislation has been considered to restrict access to these chemicals and some has passed, it is not effective and is not expected to remove all chemicals that may be used to make explosives from retail shelves. Where legislation is not successful, increased information-sharing between intelligence agencies, law-enforcement, and first responders is recommended to help disrupt the process of bomb makers.

Because terrorist events are unpredictable and data about historic events is limited, it is not possible to accurately quantify the savings achieved from blast-mitigation strategies. Although there is merit in making it more difficult for terrorists to achieve their objectives, intelligence suggests that IED attacks will continue and evolve in regard to both composition and method of delivery, the latter in order to attempt to bypass security measures. Implementing blast-mitigation strategies, therefore, may not be able to prevent all attacks, but an achievable objective is to reduce the likelihood and severity of such attacks.

2.3 Introduction to Technical Blast Concepts

Protecting against explosive threats requires identification of credible threat scenarios, within reasonable ability of prediction. For example, a terrorist wearing a suicide vest will carry out the attack in a different way than a terrorist who has loaded a vehicle with explosives. Based on analysis of previous attacks, the former is often permeating into the terminal building or plaza areas, targeting crowds of people, and the latter is often an abandoned vehicle left in a location where detonation could cause structural collapse. Because there are significant differences in threat scenarios, development of criteria for damage acceptance should be similarly distinct.

For example, operational downtime targets for a small blast event should be very low. Impacts of the event should be contained to the immediate affected area so that operations can continue largely unaffected in other areas. However, for a large blast event, operational downtime targets may range from a day to a few days, as the blast event may render a structure too dangerous for personnel. Redundancy and contingency plans for resuming operations are important factors in this latter case, as well. Furthermore, the post-attack needs of law enforcement agencies will impact recovery efforts.

Therefore, it is as important to specify reasonable and achievable performance criteria as it is to specify credible threat scenarios. It is typically expected that the risk assessment process will identify the design-basis threats (DBT) and performance criteria; however, sometimes additional follow-up after the risk assessment process is required to define specifics needed before designing can proceed. The following sections provide information on this topic.

2.3.1 Design-Basis Threat

DBTs are the credible and probable attack scenarios against which something should be designed. Strictly speaking, in blast-resistant design, specifying a DBT ultimately includes identifying the following:

- Explosive size charge, in pounds of TNT equivalence
- Standoff, i.e., the distance between the asset or target and the origin of detonation

Although equivalent TNT size charges are used to define the DBTs, due to tight control and limited availability of these explosive materials, terrorists often use IEDs. These are usually a mix of homemade explosives and commercially available chemicals, such as agricultural fertilizer and household cleaning chemicals. In some extreme cases, nails and other similar sharp metallic objects are included in the explosive mix to increase the damage efficiency and injury radius. The predictability of these devices is low, particularly in regard to impacts from shrapnel; a blast engineer/consultant will be able to make estimates to define the DBTs appropriately. If a type of explosive other than TNT is specified, data from various reference books can be used to convert the explosive to its TNT equivalent. One such reference is *Blast Effects on Buildings*, 2nd edition, by D. Cormie, G. Mays, and P. Smith (2009).

To determine the standoff, the means and methods of the attack should be considered to identify specific locations where the origin of detonation may occur. These details may be developed through conducting a threat, vulnerability, and risk assessment (TVRA). A TVRA is a risk assessment and threat identification exercise that identifies the most credible level of threat to which an asset, such as a building or parking garage, may be vulnerable. This assessment is usually led by a security consultant with expertise in understanding the current threat trends and recent attacks. To ensure the TVRA captures the full spectrum of potential threats and all the development vulnerabilities, it is imperative that all project stakeholders and relevant design disciplines attend the workshop or consultation. This type of workshop can be hosted and facilitated by a blast engineer/consultant with aviation experience.

Table 2-1 provides benchmark DBTs based on Arup's global experience in blast mitigation of airports.

Table 2-1. Common Blast Design-Basis Threats Used for Airports

VBIED		PBIED	
Charge Weight (pounds)	**Standoff (feet)**	**Charge Weight (pounds)**	**Standoff (feet)**
200	100	10	3
500	100	25	3
1,000	100	50	3
2,000	100	75	3
2,000	150	100	3

2.3.2 Performance Criteria

Performance criteria for blast threats identify objectives to achieve in the event of a particular DBT scenario. It is common for these objectives to refer to physical or structural performance of the building and the facade; however, performance criteria may also refer to operational requirements such as downtime. Performance criteria must be identified for designers so they know the extent of mitigation measures that should be incorporated (e.g., 1-inch or 3-inch-thick glass).

Blast performance criteria are often categorized in terms of a "level of protection." Terminology such as *performance criteria*, *level of protection*, *acceptable damage*, and *response limits* are all similar concepts and define the response of a structure, element, building, or even operations objective in the event of a blast.

2.3.2.1 Background

The objectives of existing guidance are best summarized by Chapter 3.2 of ASCE 59-11, which is a technical reference for blast mitigation, primarily focused on structural hardening:

- **Limit Structural Collapse**. All structural elements shall be designed and detailed to respond in a manner consistent with the defined level of protection to the direct and indirect effects of the specified explosive threats in accordance with this Standard. When these blast effects are expected to cause plastic hinging or localized failure of individual structural elements, the damaged state of the structural system as a whole shall be evaluated to verify that global stability is maintained.
- **Maintain Building Envelope**. All exterior structural and nonstructural elements, including openings, shall be designed and detailed to reduce the potential of a breach that would allow the overpressures from the specified exterior explosive threats to enter the interior of the building, consistent with the defined level of protection. For facade components, including windows and doors, both resistance-based and hazard-based design approaches shall be acceptable.
- **Minimize Flying Debris**. Barriers, site furnishings, landscaping features, and structural and nonstructural elements, including exterior openings such as windows and doors, and interior overhead mounted items, shall be located, designed, and detailed to reduce the potential for producing hazardous secondary fragments due to the specified explosive threats, consistent with the defined level of protection.

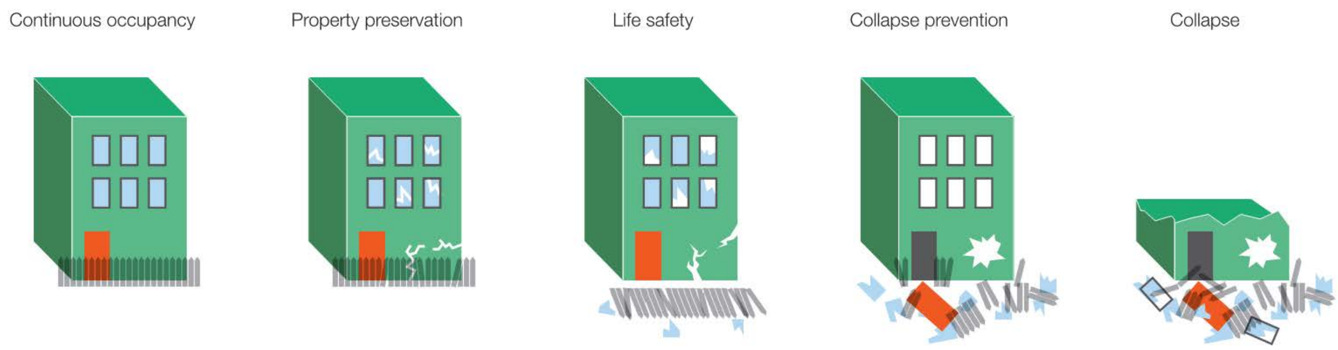
These objectives relate principally to the design (hardening) of building structures and are substantially (although not exclusively) related to the design of such structures to resist vehicle-borne attacks or attacks specifically targeted at the building structure.

This is often specified as a "level of protection." Examples of level-of-protection tiers are specified within ASCE 59-11, as described in Table 2-2 and shown in Figure 2-5.

Table 2-2. ASCE Levels of Protection

ASCE 59-11 Level of Protection	Description of Performance	Expected Structural Damage
I (Very Low)	Collapse prevention; surviving occupants will likely be able to evacuate but the building is unlikely to be safe enough for them to return; contents may not remain intact.	Damage is expected, up to the onset of total collapse, but progressive collapse is unlikely.
II (Low)	Life safety; surviving occupants will likely be able to evacuate and then return only temporarily; contents will likely remain intact for retrieval.	Damage is expected, such that the building is not likely to be economically repairable, but progressive collapse is unlikely.
III (Medium)	Property preservation; surviving occupants may have to evacuate temporarily but will likely be able to return after cleanup and repairs to resume operations; contents will likely remain at least partially functional but may be impaired for a time.	Damage is expected, such that the building is likely to be economically repairable, and progressive collapse is unlikely.
IV (High)	Continuous occupancy; all occupants will likely be able to stay and maintain operations without interruption; contents will likely remain fully functional.	Only superficial damage is expected.

Figure 2-5. Graphical Representation of Performance Criteria



Source: Arup

Although the wording to define a particular tier of performance may vary among industry guidance documents, the principle of performance criteria is the same. Performance criteria or objectives can be defined in accordance with any applicable document, or even modified as required to meet owners' needs.

2.3.2.2 Setting Performance Criteria

As demonstrated above, there is a sliding scale for desirable performance that is more complex than simply requesting a "blast-resistant" design. In order for designers to develop mitigation strategies, specific performance criteria regarding blast-resistance need to be identified by the airport, as this influences the types and quantities of measures that are incorporated into the design. This section of the guidebook provides guidance on identifying those criteria.

PARAS 0004 recommends targeting a Medium level of protection in a blast event as a starting point. Performance criteria are typically defined for each DBT scenario and will be different based on each airport's desired objectives and risk tolerance.

This concept is best explained using an example: A relatively higher level of protection is often specified for a PBIED threat than a VBIED threat. This is because in the event of a PBIED threat, an airport may desire the event to be contained to the area where the incident occurred, and operations should continue in the remainder of the concourse. In contrast, for a VBIED threat, which may have significant structural impacts and require a large emergency response, specifying a higher level of protection would become extremely onerous on the design. Furthermore, although the consequences of a VBIED event may be higher than a PBIED event, the likelihood of a VBIED is often much lower due to the amount of explosive material needed to be gathered and successfully detonated without being caught. Therefore, these items are considered in an airport's risk appetite.

2.3.3 Expected Damage

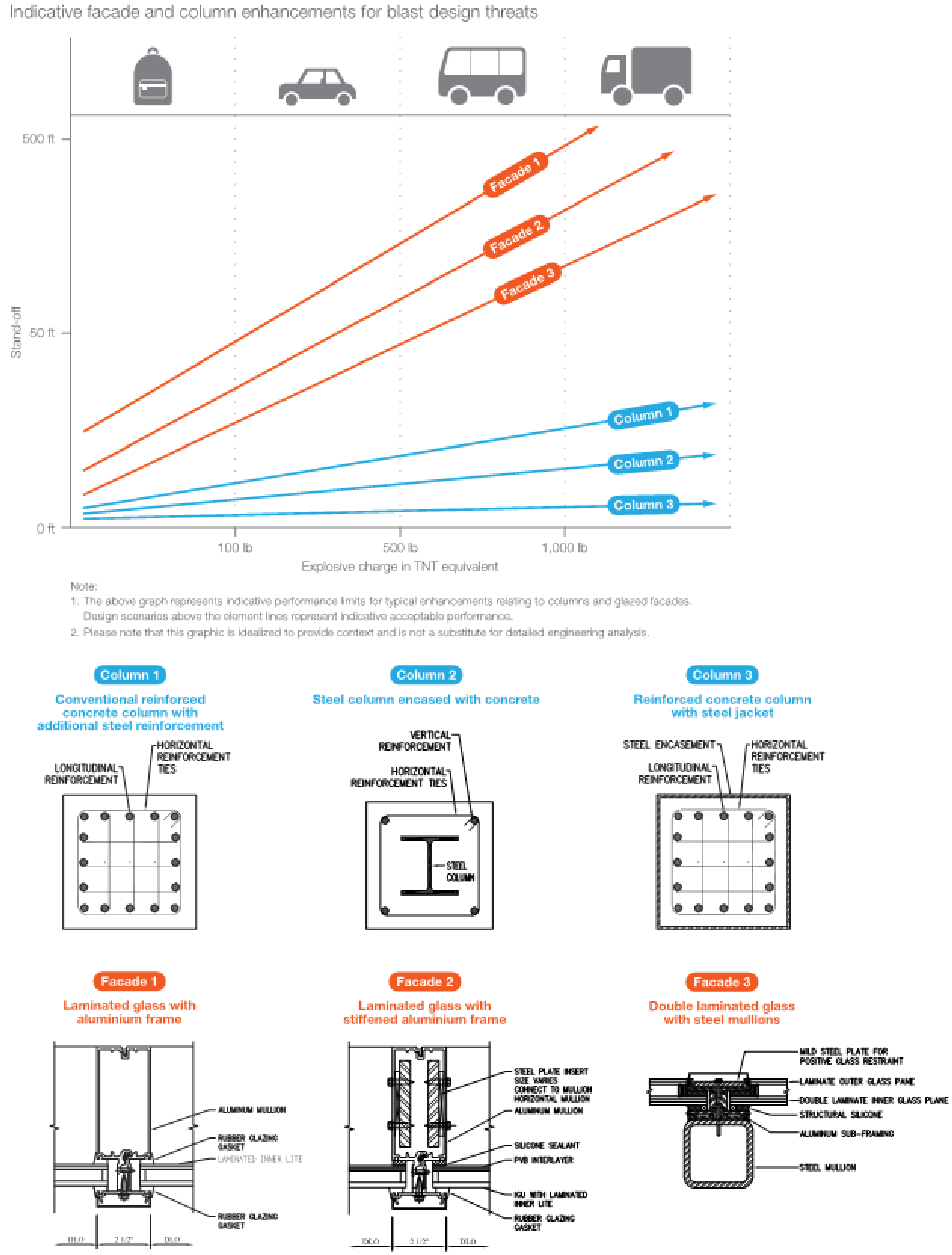
The extent of physical enhancements to either facade or structure varies based upon the following:

- Size of the DBT
- Available standoff to the element being considered
- Performance criteria required

Often decision-makers are not aware of the physical and cost implications of enhancing their structure or facade when choosing a basis for design. Figure 2-6 illustrates a simplified relationship among DBT, standoff, and reasonable mitigation measures. The graphic focuses only on facades and columns, which generally are the most critical components for blast mitigation.

The curves represent the applicability of various types of enhanced measures, showing what can be reasonably achieved in terms of threat size and standoff. The area under the curves represents the scenarios whereby such a measure would not typically meet a reasonable performance. For example, it is not generally commercially feasible to mitigate high threat sizes at relatively low standoffs while still maintaining a high level of protection. This graphic is indicative only and is aimed at providing context for decision-makers in the early stages of a project. Further information on the construction details shown can be found in Appendix D.

Figure 2-6. Demonstration of DBT and Performance of Varying Levels of Enhancement



Source: Arup

2.4 Introduction to Blast Analysis

Once the DBT and performance criteria have been established, the next step in the design process is to perform the actual blast analysis. Blast analysis is a multistep process that begins with the determination of the blast loading, progresses into preliminary calculations, advances to coordination with other design disciplines, and culminates with final design analysis as part of the final building documents.

Blast analysis is a unique subset of structural engineering. When a structural engineer designs a structure, they are designing a building to last over time without any damage. A blast analysis is designed typically to protect the facade and structure enough for people to evacuate the building; however, it is expected that major reconstruction will be required after an event. In this situation, the blast analysis is allowing certain failure under this unique scenario, while the structural engineer is designing for no failure under conventional load scenarios (wind, snow, etc.)

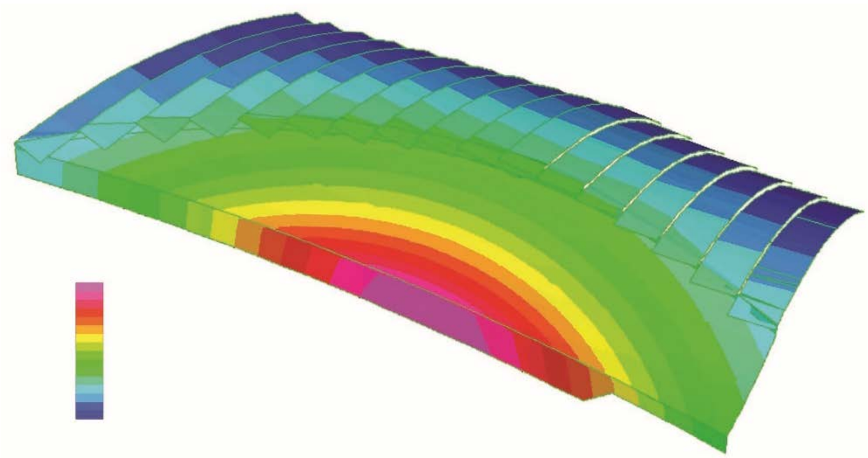
Blast analysis is typically required when either of the following takes place:

- A blast vulnerability assessment of an existing building is performed to understand what the existing building is “good for”
- Physical blast-mitigation measures such as facade enhancements or structural resiliency are identified as required to reduce risks

When blast protection of a building is required as determined by regulatory requirements or desire by the risk owner (typically the owner/operator for airports), analysis is performed to understand and mitigate the blast risk through design options.

The first step is to calculate the applied pressure on the surface to be analyzed. As discussed in Section 2.1, there are three parameters needed: threat size, standoff, and line of sight. With this information, several computer programs can be utilized to calculate the blast loading profile: pressure, impulse, and time duration. See Figure 2-7 for example output.

Figure 2-7. Sample Calculation of Blast Loading

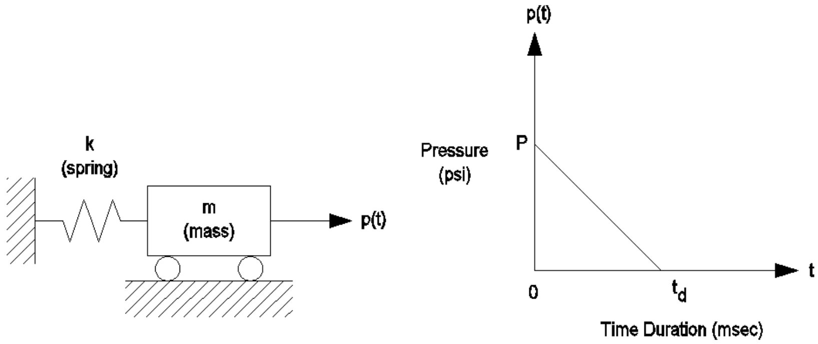


Source: Arup

The second step in the analysis is to perform preliminary calculations based on design parameters from other design professions. For example, the blast engineer will work with an architect on the facade system: glass size, mullion spacing, and the supporting structure. Once these parameters are understood, a single degree-of-freedom (SDOF) analysis is performed. SDOF takes a complex analysis and simplifies an element into a mass (weight of member) and spring (strength of the member).

See Figure 2-8 for a depiction of the mass-and-spring concept. The blast load [p(t)] is applied to the mass (m) and the deflection of the spring (k) is calculated. The deflection is the maximum distance the blast load was able to pull the mass based on the resistance strength of the spring. That deflection is then compared to an allowable deflection, based on the design criteria, to determine if the member (i.e., its m or k) needs to be enhanced.

Figure 2-8. Single Degree of Freedom



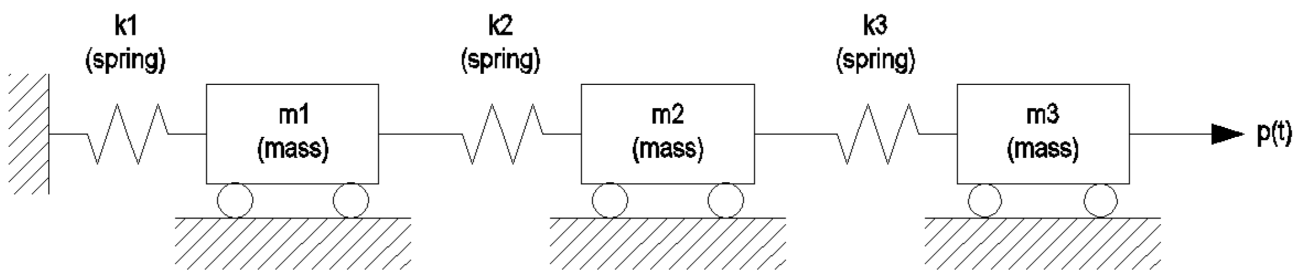
Source: bmk Engineering

Upon completion of the preliminary calculations, it is likely that some changes to the design need to be made. This could be as simple as providing a cost-effective enhancement—heavier beams or thicker glass. However, sometimes the designing engineer needs more of an in-depth study on the overall effect of the analysis on the project. If a cost-effective design solution is unachievable, the team can reevaluate some of the initial assumptions in the design. This could include the standoff, threat size, level of protection, etc.

Depending upon the project site, gaining more standoff might not be achievable without major alterations to the design or function of the facility, especially in existing facilities. Increased standoff is typically incorporated by adding curbs or vehicle barriers. In any project condition, increasing standoff is difficult, as land is a valuable commodity in any design. However, it can be a key aspect to the design and aid in significantly reducing hardening costs to the facility.

During this design process, if warranted, a more detailed analysis could be performed above the SDOF. These processes take additional engineering time but may result in an overall cost savings to the project. The most common analysis is multiple degree-of-freedom (MDOF). In this approach, the SDOF model is applied in a series of elements. For example, the analysis is first performed on the glazing, which will result in some absorption of the blast load. The glazing reaction is then applied to the mullion, so the mullion resists less energy than if analyzed as a SDOF element. See Figure 2-9 for an example of MDOF.

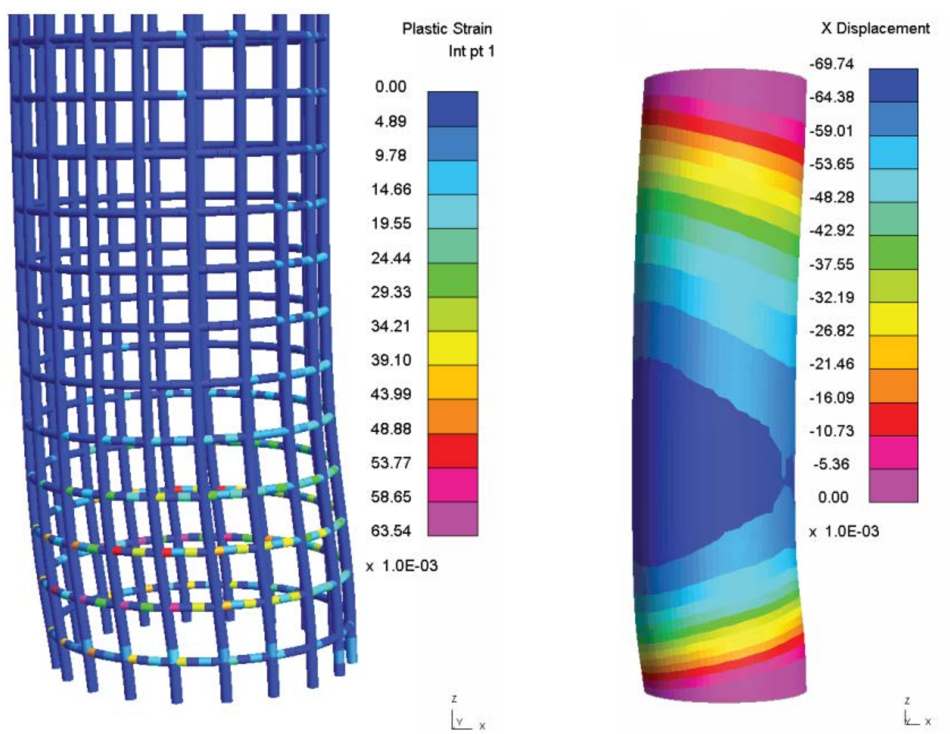
Figure 2-9. Multiple Degree of Freedom



Source: bmk Engineering

Lastly, the most detailed analysis is a finite element analysis (FEA). In a finite element model, the member to be analyzed is subdivided into much smaller, simpler parts called finite elements. Then, the simple equations that model these finite elements are assembled into a larger system of equations that models the entire member. Although more time-intensive, FEA is typically required when complexities exist, such as close-in detonations, curved or atypical geometries, or a need to understand details of performance.

Figure 2-10. Finite Element Analysis



Source: Arup

Upon completion of the analysis, the last step in the design process is to incorporate all the blast design requirements into the construction documents. Most of the structural items such as slabs, beams, and columns are incorporated into the construction documents' drawings. Non-structural items like windows, precast panels, etc. are incorporated into the construction documents' specifications.

2.5 Design and Procurement of Blast-Mitigation Measures

The incorporation of blast-mitigation strategies should be reviewed for all landside projects on a risk basis. The likelihood, credibility, and consequences of such events that might occur at a specific airport will determine what types of blast-mitigation measures should be incorporated.

The need for a blast-mitigation strategy may not be immediately obvious, as some projects inadvertently introduce or increase the risk to the airport even if there is no apparent security scope. For example, changing the design of an approach road could inadvertently increase the attractiveness of a building as a target, or the road design could allow for increased vehicle speed and therefore greater consequences in the event of a penetrative VBIED attack.

2.5.1 Roles during the Design Process

Traditionally, physical security experts and blast engineers are the primary disciplines involved in the development of a strategy to defend the structure against a blast attack. However, as technology has significantly improved security capabilities, greater flexibility is desired to respond to changing threats quickly; there is an increasing recognition of the value of and reliance on operational security measures; and there is increasing pressure on airports to address other business objectives, such as architectural design. Greater benefits can be achieved if the design process includes close collaboration between the various security and planning stakeholders. Thus, the approach to incorporating blast-mitigation strategies should include physical, technological, and operational security stakeholders, as well as designers and planners. As discussed in detail in Section 5, an effective blast-mitigation strategy will encompass measures from all of these areas.

The aim of retaining a threat and risk specialist as well as a blast engineer or consultant is to achieve the following key objectives:

1. Seek expert advice in identifying the real and credible threats, vulnerabilities, and risks of the asset in consideration. This facilitates evidence-based understanding of the risks, therefore allowing objective allocation of limited resources.
2. Reduce cost through use of limited resources targeted to the airport's unique risks, thus avoiding one-size-fits-all security measures, which can result in wasted resources or counterproductive measures.
3. Facilitate continual and informative engagement between the client stakeholders, designers, security consultants, law enforcement, and other relevant stakeholders.
4. Improve security by helping clients and designers mitigate the risks of a blast threat. This includes advising the client on feasible physical mitigation measures, and often is followed by blast analysis to design the measures. Although the blast consultant traditionally specializes in physical measures, in collaboration with a security engineer, technological or operational measures can also be identified where they should be incorporated to supplement physical measures.

The advice from the specialist will initially help the client assess the real and credible threats and the corresponding risks posed. Unfortunately, not all threats can be eliminated, but in many cases the risks can be managed and mitigated through physical protective measures and targeted use of limited resources.

Apart from providing expert advice and assisting in eliminating or mitigating the blast threats, a blast engineer/consultant can also be sought to bring the project cost down by helping the clients and designers understand the project's real threat and produce a final design that is neither under- nor overdesigned. Moreover, early engagement can flag security issues that may be easily solved during the early phases of a project, potentially through other design disciplines, such as landscape architecture and surface transport design.

Table 2-3 shows the design and construction timeline airports should follow for incorporating blast-mitigation measures in design projects from initiation, through planning and development, to implementation in construction. Continual engagement between airport stakeholders, designers, and the blast consultant throughout the process is necessary. The benefit of spending this additional time can be difficult to perceive, but it is instrumental in delivering a successful security strategy with measures that are utilized effectively.

Table 2-3. Design Process Timeline

<table>
<tr><th>Phase</th><th>Airport Role</th><th>Design Team Role</th></tr>
<tr><td>Project Initiation; Request for Proposal (RFP) Development</td><td>The airport project management or planning team should engage the airport's physical, technological, and operational security stakeholders to ensure blast requirements are adequately captured within the RFP. Improperly specified or unclear requirements could result in major bid differences or proposals that do not achieve the airport's security objectives.</td><td>Airports may find it worthwhile to engage an external threat and risk specialist and blast consultant to facilitate the identification of credible threats, credible risks, DBTs, and blast requirements, which vary based on the airport's risk profile and appetite.</td></tr>
<tr><td>Conceptual Design</td><td colspan="2">The design team, including blast and security consultants, the architect, and aviation planners, should engage with relevant airport stakeholders in development of a security strategy that responds to the risk assessment outcomes and meets the airport's risk appetite.

Combinations of mitigation-measure options should be considered at a high level using the framework process outlined in Section 5 of this guidebook. This includes preliminary assessment of operational, technological, and physical measures. Impacts of various measures should be interrogated across disciplines to identify potential conflicts or opportunities to design out vulnerabilities early in the process.

Reasons for decisions should be documented so that the purpose of various measures can be revisited in case modifications are required.</td></tr>
<tr><td>Design Development through Construction Documents</td><td>The operational security strategy should be developed by the airport's security and law enforcement groups, with collaboration from an external consultant if desired.

Airport stakeholders should periodically review the mitigation measures developed by the design team and how these change the risk assessment.</td><td>Mitigation measures should be developed by the design team in consultation with the security consultant and/or airport security team.

If required, blast analysis and technology system design is to determine architectural, structural design, IT, and communications requirements and is to be coordinated with the relevant design disciplines.

The design team should remain engaged with the airport stakeholders to ensure that the airport's operations and commercial and security objectives, including risk appetite threshold, are being met throughout the design developments.</td></tr>
</table>

Phase	Airport Role	Design Team Role
Procurement and Construction	The airport will be involved in the bid process and liaise with the design team as needed to clarify RFIs.	The design team's blast consultant should verify that all blast-mitigation strategies that are to be designed by others are properly specified in the construction documents. Clear identification of blast requirements, particularly deferred design submittals, is imperative.
Integrate and Evaluate	Integrate and apply technological and operational measures. Airport security should actively monitor and evaluate their effectiveness and make modifications as necessary. Revisit the risk assessment periodically to consider whether changes should be made or new measures should be introduced. The framework in Section 5 of this guidebook can be used to consider costs and benefits of changes to the blast-mitigation strategy.	Retaining the security and blast design team for periodic review may be worthwhile to ensure the airport is aware of the latest methodologies and measures, and to recommend modifications to the measures if needed.

2.5.2 The Procurement Process

Procurement of blast mitigation and physical security measures must be discussed at the earliest stage of design. Multiple construction elements could be designed differently, depending on perceived construction challenges at existing facilities.

Depending upon the potential staging of the work to keep most of a facility open, the proper restrictions need to be adequately conveyed to the contractor facilitating the work. This would include noise and time restrictions. If the work is going to occur only at night or during off hours, this will have to be indicated because exterior work becomes more challenging without adequate lighting and additional construction lights would be required. Subject to the location of lighting, this may have flight operations implications. Additionally, it may influence the security risks to the airport, and this will need to be mitigated accordingly (e.g., works that straddle the airside-landside boundary are most likely to require additional guarding resources for supervision and inspection purposes).

If certain clearances and daily screening are required, this must be properly specified. For example, if the contractor must plan over 30 minutes just to mobilize every day to get through screening and onto the construction side, this needs to be conveyed to avoid additional costs for the contractor.

Furthermore, any travel lane restrictions need to be thought out in advance. If an airport has an overhead roadway for departures and a roadway for arrivals, the phasing needs to be coordinated so that the areas of construction are secured on both roadways simultaneously.

Impact on emergency response procedures during the construction period should be considered and adjustments made in consultation with the relevant agencies. For example, whether or not construction could change the location of emergency muster points or interfere with the usual emergency response vehicle access is a possible consideration.

The construction documents should contain as much existing information as possible, including a security-during-construction strategy. While unforeseen conditions can occur at any existing facility, selective demolition during the design phase will prove to be a more cost-saving measure than trying to redesign elements after the contractor has mobilized. Any delay during construction has been reported to cost 10 or more times what could have been saved with some prudent investigations earlier in the process.

For a vendor-supplied blast-mitigation product, a detailed specification is mandatory. The specification needs to properly describe the blast loading, acceptable damage limits or performance criteria, and acceptable design techniques for each product that will be designed and supplied by a vendor. For example, the specification should not say “provide a low level of protection” window system. This will lead to a contractor-favored interpretation and may not provide the security outcome or mitigation to the airport’s risk appetite threshold as was expected during the design process. The specification requirements should either be incorporated within the standard product specification or, if a standalone blast specification is produced, be properly cross-referenced.

During the submission process, the owner and design team may need to be willing to accept slight variations from the construction documents to accommodate vendor-specific products. For example, most blast-tested window mullions are 2.5 inches wide and either 7.5 or 10.5 inches deep. However, some vendors only use a 3-inch-wide mullion, which may be more cost-efficient and could be an approved alternative. If the sight line is a requirement, the specification needs to be strict in the language and should not include the approved equivalent alternative language.

Additionally, if there are any restrictions due to existing conditions that need to be included in the drawings and specifications, they should be clearly stated. For example, it might be a requirement to limit the reaction of a mullion to an existing concrete wall because the wall will not work under a higher reaction. It is incumbent upon the blast engineer during design to verify that a product can be supplied to meet the specification. Providing clear documentation ensures that vendors cannot provide a cheaper alternative that might overstep the limitations of the existing conditions.

SECTION 3: COMPLIANCE AND RISK-BASED REQUIREMENTS

All security measures to be applied at an airport are determined by the need to do the following:

- Comply with legislation and national and airport policies.
- Reduce or accept risks that exceed the airport's risk appetite. This is achieved by the following risk-mitigation process: determining the risks that are unique to the airport/site; agreeing on which of those risks that exceed the airport's risk appetite threshold can be feasibly reduced or must be accepted; identifying risk reduction measures; conducting a comparative analysis to determine which measures are most appropriate to be applied; securing resources to apply those measures; and implementing and monitoring the effectiveness of the measures.

Historically, the non-secure area of airports has not been security-regulated and, consistent with the global trend towards risk-based and outcomes-focused security measures, it would be prudent for airports to manage the area on the assumption that this will not change. Airports should therefore take a risk-based approach to determining the security measures, including blast protection, in the non-secure area.

This section is intended to help airports determine whether they need blast mitigation.

3.1 International Requirements and Risk-Based Approach to Non-Secure Area Security

The ICAO is the specialized United Nations agency responsible for setting the Standards and Recommended Practices (SARP) for civil aviation in accordance with the Convention on Civil Aviation, commonly referred to as the Chicago Convention. ICAO's remit is expansive and includes, but is not limited to, meteorology, safety, search and rescue, facilitation, and security. The SARPs that pertain to security are documented in Annex 17 Facilitation and Annex 9 Facilitation, with those relating to landside security in Annex 17.

Contracting States (states who are signatories) to the Chicago Convention commit to apply (comply with) the SARPs by establishing and maintaining their national aviation program in accordance with the Standards, and will endeavor to apply the Recommendations. States do this by ratifying the SARPs.

The responsibility to align with the SARPs lies with the State's Appropriate Authority. The Appropriate Authority is responsible for the development, implementation, and maintenance of the national civil aviation security program. It is the Appropriate Authority that is to comply with Annex 17 (not airports or airlines). The Appropriate Authority is usually, but not always, the aviation security regulator.

Annex 17 is drafted to be outcome-focused. It is the responsibility of each State to determine how to best apply the SARPs based on its national risk assessment. This expectation is stated in Standard 3.1.3:

> Each Contracting State shall keep under constant review the level of threat to civil aviation within its territory, and establish and implement policies and procedures to adjust relevant elements of its national civil aviation security programme accordingly, based upon a security risk assessment carried out by the relevant national authorities.

Many States have adopted this outcome-focused approach to their own national program—they are requiring industry to conduct their own risk assessments, drawing on national threat and risk information to determine the measures that are necessary to reduce the risks that they identify and that exceed their own risk appetites. This is increasingly prevalent in relation to the landside security risk. But unlike the typical response to past terrorist threats, e.g., liquids, aerosols, and gels, Appropriate Authorities have not issued prescriptive regulation following the high-profile landside attacks such as Glasgow (2009), Brussels (2016), Istanbul (2016), and Fort Lauderdale (2017). This risk-based approach is consistent with ICAO's intent.

While outcomes-focused, ICAO is not silent on the landside security risk with the following SARPs directly relevant to landside:

> **Standard 3.1.5** Each Contracting State shall establish a national aviation security committee or similar arrangements for the purpose of coordinating security activities between the departments, agencies and other organizations of the State, airport and aircraft operators, air traffic service providers and other entities concerned with or responsible for the implementation of various aspects of the national civil aviation security programme.
>
> **Standard 3.2.4** Each Contracting State shall ensure that airport design requirements, including architectural and infrastructure-related requirements necessary for the implementation of the security measures in the national civil aviation security programme, are integrated into the design and construction of new facilities and alterations to existing facilities at airports.
>
> **Standard 3.2.2** Each Contracting State shall ensure that an authority at each airport serving civil aviation is responsible for coordinating the implementation of security controls.
>
> **Standard 3.2.3** Each Contracting State shall ensure that an airport security committee at each airport serving civil aviation is established to assist the authority mentioned under 3.2.2 in its role of coordinating the implementation of security controls and procedures as specified in the airport security programme.
>
> **Standard 4.8.1** Each Contracting State shall ensure that landside areas are identified.
>
> **Standard 4.8.2** Each Contracting State shall ensure that security measures are established for landside areas to mitigate the risk of and to prevent possible acts of unlawful interference in accordance with risk assessments carried out by the relevant authorities or entities.
>
> **Standard 4.8.3** Each Contracting State shall ensure coordination of landside security measures in accordance with Standards 3.1.5, 3.2.2 and 3.2.3 between relevant departments, agencies, other organizations of the State, and other entities, and identify appropriate responsibilities for landside security in its national civil aviation security programme.

The United States became a Contracting State in 1944 and the Appropriate Authority is the TSA. The United States has ratified the security-related SARPs through the following legislation:

- 49 CFR 1540 – Civil Aviation Security: General Rules
- 49 CFR 1542 – Airport Security
- 49 CFR 1544 – Aircraft Operator Security: Air Carriers and Commercial Operators
- 49 CFR 1546 – Foreign Air Carrier Security
- 49 CFR 1548 – Indirect Air Carrier Security
- 49 CFR 1550 – Aircraft Security Under General Operating and Flight Rules
- 49 CFR 1560 – Secure Flight Program

In the United States, and most other nations, there are no regulatory or legislative requirements explicitly for blast protection; actual implementation of risk reduction (including security or blast-specific) measures typically lies with the "industry" or service providers, such as airport owners or operators. Those risk-reduction measures should be guided by the national civil aviation security program and their own/operator security risk assessment.

One exception to the above is Singapore: Singapore's Infrastructure Protection Act requires selected new buildings to integrate counterterrorism security measures, including blast mitigation, within their designs as of September 11, 2017. The bill recognizes that buildings that house essential services, are iconic, or have a high density of persons could be targeted by terrorists and therefore require adequate building security measures in place. Specific measures such as video surveillance, security personnel, vehicle barriers, and strengthening the building against blast effects are noted as efficient ways to secure a building if implemented during design.

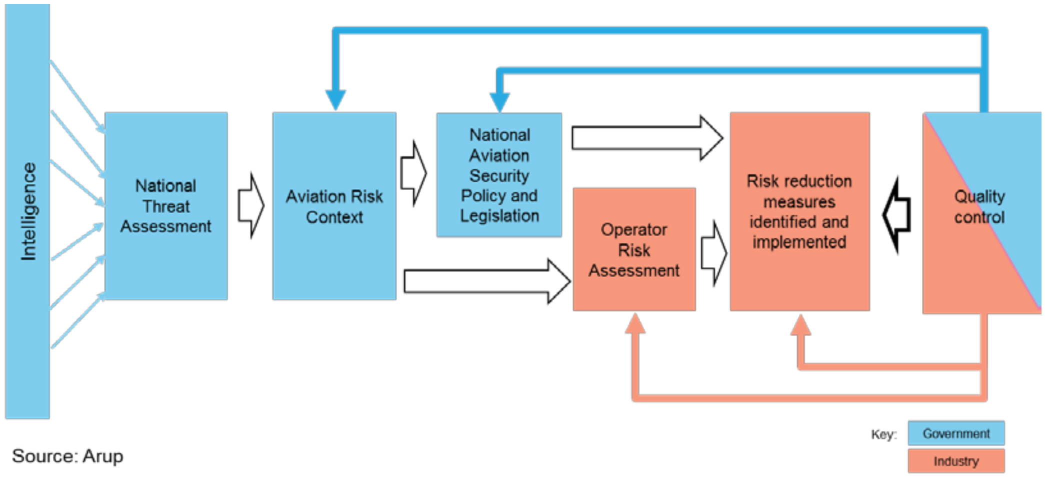
3.2 The Risk Assessment Process

As described above, ICAO sets outcome-based targets for landside areas but leaves the implementation to individual States (i.e., countries). ICAO does not define landside, rather requiring through Standard 4.8.1 the Appropriate Authority to ensure this done. That said, in the past, ICAO has defined landside as "The area of an airport and buildings to which both traveling passengers and the non-traveling public have unrestricted access."

Facilitating aviation security across the industry requires understanding the threat, conducting risk assessments, determining risk appetite thresholds, and applying risk-reduction measures. Given the systemic nature of the aviation industry, these activities will occur at different levels: international, national, operator, and individual.

Figure 3-1 illustrates a risk-based approach to determining local/operator-level risk-reduction measures in the context of the national aviation security framework:

Figure 3-1. Determining Risk Reduction Measures at the National and Operator Level



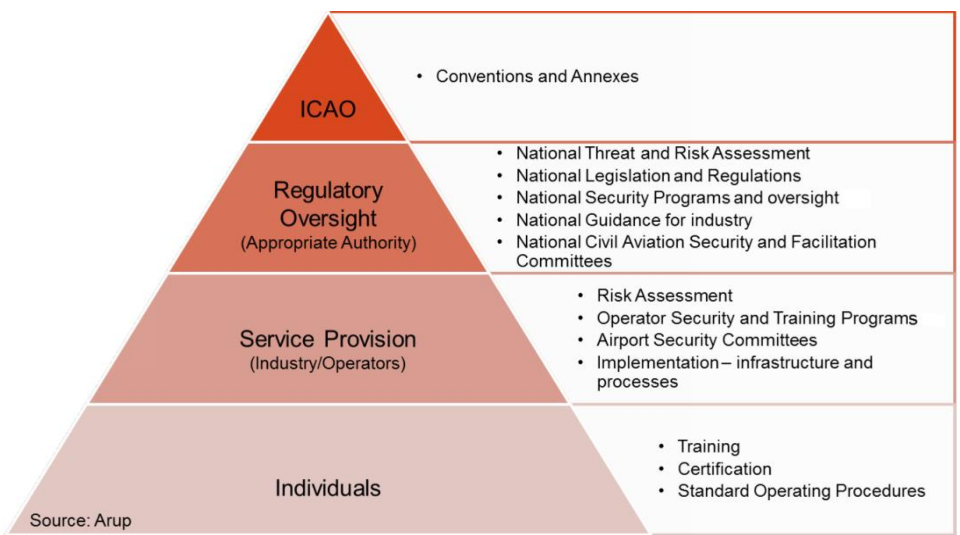
Source: Arup

Compliance with the national civil aviation security program is assessed by the regulator. As States increasingly move to outcomes-focused regimes (i.e., the risk-reduction measures are determined by the operator based on their own risk assessment), the regulatory focus is likely to shift to (a) the quality of the risk assessment and (b) the effectiveness of the applied risk-reduction measures.

In other words, States, via the Appropriate Authority, are expected to comply with Annex SARPs. It is the Appropriate Authority that is audited by ICAO. The industry is not expected to comply with SARPs but is expected to comply with the national aviation security framework. It will be the national aviation security regulator, typically the Appropriate Authority, who will audit the industry.

Figure 3-2 illustrates the national aviation security framework and how the entities and key documents relate to each other.

Figure 3-2. The International Aviation Security Framework



Source: Arup

The individuals are typically employees or suppliers to the industry/operators. In order to implement the necessary risk-reduction measure, the operators are reliant on those individuals to have the knowledge, competence, and empowerment to act as appropriate to the policy and procedures set by the operator.

As described above, the international aviation security framework commences with a state becoming a Contracting State by way of signing the Chicago Convention. It ratifies that Convention through the enactment of legislation and establishment of an Appropriate Authority who is responsible for establishing and maintaining a national aviation security program. The national aviation security program is informed by a national risk assessment and complies with Annex 17.

Industry is then required to identify, develop, and implement their security risk-reduction measures in accordance with their own operator risk assessment and national aviation security program. Individuals engaged with the operators are provided with the knowledge and apply necessary skills to implement the policies and procedures set by the operators. For auditing purposes, ICAO audits the Appropriate Authority and the regulator, typically the Appropriate Authority, audits industry.

3.3 United States Compliance Requirements

Commercial airports are considered operational when issued a Federal Aviation Administration (FAA) airport certification identified in 14 CFR 139 and supplemental FAA Advisory Circulars. As part of 14 CFR 139, a Federal Security Director is an identified TSA official who reviews and approves the Airport Security Program (ASP). The ASP documents how the airport will meet the security requirements identified in 49 CFR 1542. In addition to the ASP, FAA regulations require the airport to develop a safety and security plan that incorporates hazard reporting, risk assessment, risk mitigation, and assurance processes.

The safety and security plan includes a comprehensive risk assessment, covering everything from terrorism to birds on the runway. The ASP is updated at minimum annually or sooner if there are significant changes to the airport or terminal. In addition, when specific national and global threats are identified, airports should consider a targeted risk assessment to adjust their security program to address the specific threat. The complexity or level of the risk assessment is not defined, and airports complete various levels of risk assessments each year as is deemed the best fit. TSA reviews the ASP annually or sooner if significant changes warrant review.

3.4 Note about Blast Risks

Through the airport interviews, investigators observed that converting risk assessments to specific security measures is not typically considered or undertaken, despite the benefits that it brings:

- Objective and justified investment decisions
- Alignment of security risk management with the airport's overall enterprise risk appetite
- Ability to transparently demonstrate how much risk reduction a measure can buy (i.e., the risk return-on-investment)
  - Determines risk-mitigation measures unambiguously
  - Allows for proportionate investment in security (versus under-resourcing or over-engineering)

Contrary to many other security risks, such as theft and vandalism, terrorism and particularly blast attacks can have catastrophically severe consequences. Airports should keep in mind that achieving higher levels of protection against large, credible blast threats is unfeasible and impractical in many cases. Substantial reductions in risk are possible; however, defining blast performance criteria too onerously can quickly kill a project entirely due to financial infeasibility. This would have the opposite effect than what is desired, as providing a baseline level of protection against blast risks is always viewed as a better solution than not providing protection at all. Therefore, carrying out a risk-based approach is recommended to be done in collaboration with a blast engineer or consultant who can advise on this topic.

SECTION 4: MITIGATION MEASURES

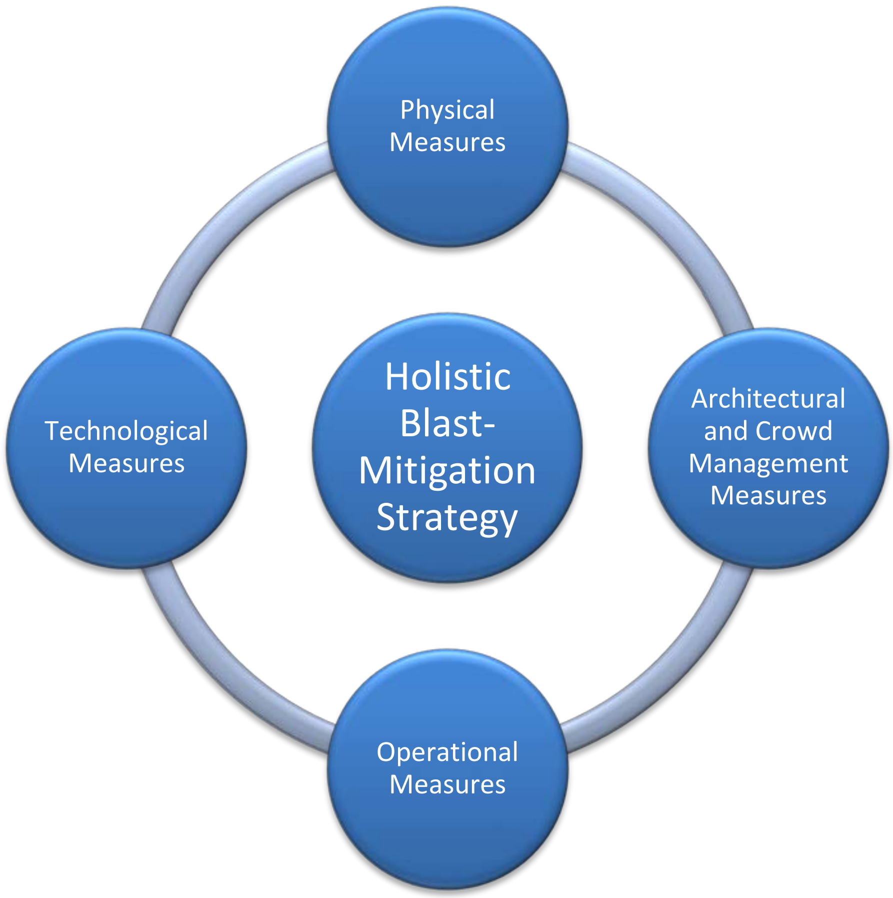
This section is intended to help airports determine which blast mitigation measures are needed, including physical, technological, operational, and other related mitigations such as architectural layout and crowd management. The user should consider which measures are possible for implementation at their airport. In Section 5, these possible measures are analyzed using a decision-making process to determine the most effective strategy.

In addition to the measures within this section, the reader may want to consult other relevant publicly available references that include information on blast-mitigation measures:

- PARAS 0004: *Recommended Security Guidelines for Airport Planning, Design and Construction*
- *ACI Landside Security Handbook*, First Edition
- FEMA 427: *Primer for Design of Commercial Buildings to Mitigate Terrorist Attacks*
- *Blast Effects on Buildings,* Second Edition, by Cormie, et al.

This section outlines many of the blast-mitigation measures that can be employed. A holistic blast-mitigation strategy is most effective when various types of mitigation measures are combined as shown in Figure 4-1.

Figure 4-1. Various Measures That Shape a Blast-Mitigation Strategy



Physical measures generally take the most time to provide protection, as the design and construction process may exceed the time required to hire additional operational staff, for example. Additionally, although modifications can be made, they are also the least flexible type of measure in adapting to changing threats. However, physical measures are capable of defending the asset and providing protection as a last layer of defense in a security strategy. They also offer the most predictable performance, not being subject to human error and not requiring active management to protect. What might be surprising is that, although physical measures require a high initial investment, they require little or no recurring expenditures over many years, resulting in average costs being the lowest of the different types of measures.

On the opposite spectrum, *operational measures* are generally the quickest to implement, the most flexible and the most adaptable. However, although operational measures provide some level of deterrence, they do not provide a reliable defense on their own. They are highly dependent on the effectiveness and response of particular individuals and are subject to human error. Also, providing an additional security staffing position is relatively expensive.

Technological measures lie somewhere in the middle of the spectrum. In addition to the cost of the technology and IT equipment, staffing is almost always required for active monitoring of systems. This renders technological measures on average to be the most expensive of the three. However, technological systems overall are the most effective in protection, able to offer deterrence, delay, and detection capabilities with a relatively high degree of efficiency. Further, technological measures can be implemented relatively quickly, especially if a robust IT structure is already in place. They are also able to be implemented in almost any area of the airport and offer capabilities that can detect all types of blast threats.

If designed-in, *architectural measures* such as roadway layout, terminal layout, thoughtful space configuration, and pedestrian and queue planning require some design costs, but are relatively inexpensive. Architectural design that incorporates principles of security can be effective in reducing risks, but is typically not sufficient on its own.

The benefits of various measure types are summarized in Table 4-1, demonstrating that a holistic approach incorporating all types of measures is necessary to meet protection needs and balance implications. This matrix is just an overview to demonstrate the concept of a holistic strategy—many of the categories are more complex than conveyed in this table.

Table 4-1. Capability Comparison of Various Measure Types

Measure Type	Low Cost	Impact on Passenger Experience	Quick to Implement	Can be Easily Modified Later	Not subject to human error	Ability to Deter	Ability to Detect	Ability to Disarm	Ability to Defend
Physical	X				X	X			X
Technological			X	X		X	X		
Operational		X	X	X		X	X	X	
Architecture	X	X			X	X			X

4.1 Physical Measures

This section describes common structural enhancements that can be adopted to mitigate a blast threat:

- Reinforced concrete (RC) detailing
- Structural steel detailing
- Progressive collapse resistance
- Building envelope
- Hostile vehicle mitigation (HVM) barriers

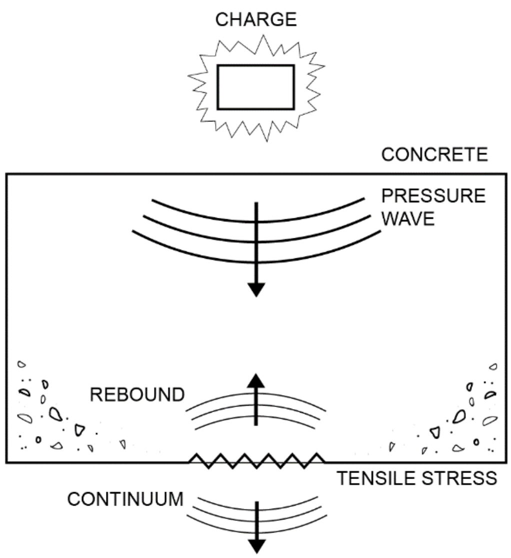
As discussed in Section 2, protection of critical structural members is the primary goal, and protection of non-structural elements is secondary. Therefore, there is significant discussion regarding RC and structural steel enhancements.

4.1.1 Reinforced Concrete Detailing

RC elements designed to withstand blast threats can tolerate large magnitude deformations over a short duration. During this large deformation, the concrete cracks and high stresses occur in the member until the load subsides and the member reaches equilibrium. To handle the large deformations, the reinforcement detailing found in blast-resistant structural elements differs from the reinforcement found in conventional RC structures; particular detail should be put into the connection design. Therefore, it is important that advice from a blast engineer or consultant is sought throughout the design stage or retrofit of RC structures and appropriate reinforcement detailing is implemented in the final RC design.

Spall of concrete is the structural phenomenon that describes the breaking and scabbing of concrete on one side of a RC member, induced by a blast shockwave of high magnitude. As shown in Figure 4-2, spall occurs when the blast shockwave travels through the section, reaches the opposite face, and causes the tension capacity of the concrete to be exceeded. An example of a freestanding RC wall that experienced spall is presented in Figure 4-3.

Figure 4-2. Blast Shockwave Propagation through the RC Member, Which Induces Spall



Source: Adapted from "Spalling of concrete subjected to blast loading" by M. Foglar and M. Kovar (CC 2.0)

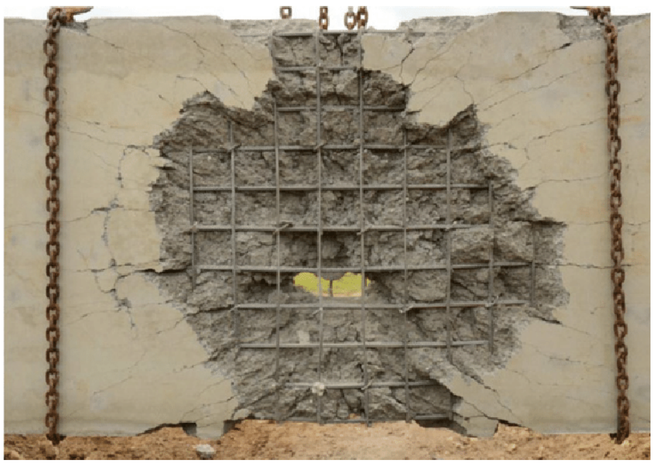
Figure 4-3. An RC Panel Damaged by Spall

Source: "Spalling of concrete subjected to blast loading" by M. Foglar and M. Kovar (CC 2.0)

While spall refers to the loss of part of an RC member, the term “breach” signifies the complete loss of a section thickness over a certain area, as illustrated in Figure 4-4. Breach of a section is usually observed when an explosive charge is placed very close (PBIED or VBIED) or in direct contact (PBIED) with the RC section.

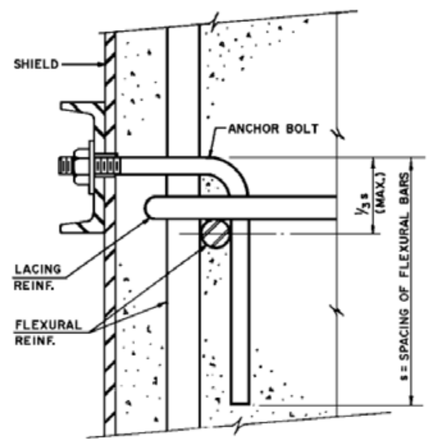
There are a couple of strategies used to counteract spall and breach failure, depending on member type (column or wall) and performance criteria. Typically, a steel plate installed on the back-side of an RC wall will act as a fragment shield to prevent hazardous debris from injuring people or causing other damage behind the wall as a result of spalling. It will also improve the wall’s performance, but may still result in significant loss of concrete in the wall. The plate needs to be anchored sufficiently such that the forces do not also propel the plate. A detail of an installed spall plate is presented in Figure 4-5.

Figure 4-4. Breached RC Panel



Source: “Spalling of concrete subjected to blast loading” by M. Foglar and M. Kovar (CC 2.0)

Figure 4-5. Spall Plate Installed at the Back of an RC Wall



Source: UFC 3-340-02

Column steel jacketing is a structural enhancement used to strengthen RC columns. This type of enhancement is especially used for columns susceptible to placed IED and vehicle attacks where minimal standoff exists. Column steel jacketing involves full or partial-height wrapping of the column with a steel plate. The steel jacket helps the column resist local shear failure due to a close-in charge, in addition to increasing the column’s flexural and vertical load carrying capacities, as shown in Figure 4-6. This type of blast enhancement can be used for both new build and retrofit projects.

Figure 4-6. RC Column Wrapped in a Steel Jacket

Source: Arup

4.1.2 Structural Steel Detailing

As with RC structures, steel-framed structures and steel elements required to withstand blast loads should be able to absorb and dissipate loads through deflection without inducing brittle failure in the section. Also similarly to RC structures, the connection of steel members should be detailed and designed to allow members to deflect before connections are failed. Failure to do so will result in connection failure before the full member strength is realized.

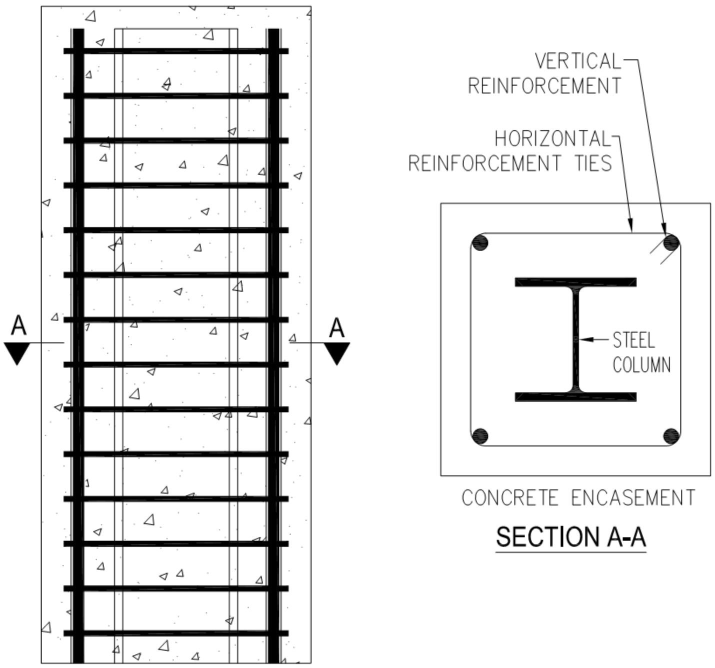
Steel is much lighter and thinner than concrete, and therefore is not able to withstand effects of large close-in blast loads as efficiently. In addition, the rebound in steel sections can be quite considerable when compared to concrete sections.

4.1.2.1 Encased and Concrete-Filled Steel Columns

Where there is a possible threat of a terrorist placing an IED near an exposed steel column, the risk of column failure may be mitigated by encasing the bottom section of the column in a block of concrete, as shown in Figure 4-7 and Figure 4-8 (can also be a circular block). This type of enhancement can be applied to both existing and new-build columns. An alternate option is to install architectural cladding around the column to give the column the architectural look envisaged by the architect or designer, while also increasing standoff.

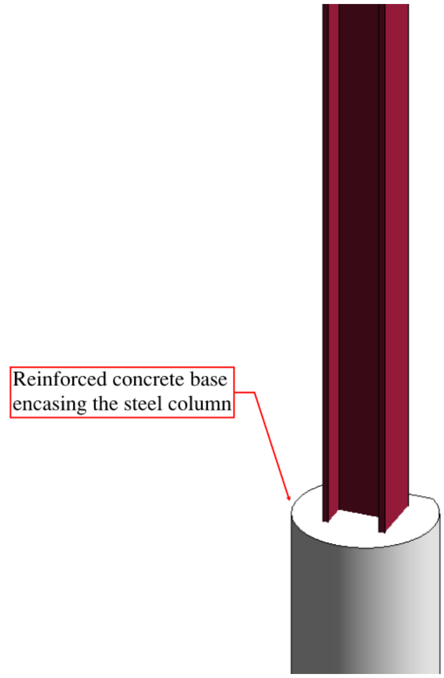
For large VBIEDs, concrete encasement is likely required. For small PBIEDs, columns may be adequate with or without cladding, depending on the performance criteria and DBT size. Other options include welding cover plates to existing columns or filling tube sections with concrete or grout. For new construction, this may not be possible if it has been planned to run utilities down a tube section.

Figure 4-7. Sections of the Base of a Steel-Encased Column



Source: Arup

Figure 4-8. 3-D View of a Steel Column Encased in Reinforced Concrete



Source: Arup

The above blast-mitigation enhancements are usually considered for an open web steel section. When a column is represented by a non-open web steel section (i.e., rectangular, square, or circular-shaped sections), it is more economical and practical to make holes in the section and pump high-strength grout inside the column rather than encasing it in concrete. This method is similar to the steel jacketing system described in the section above. As with the bottom concrete-encased column blast-mitigation measure, this method can be applied to both new build and retrofitting projects.

4.1.3 Progressive and Disproportionate Collapse Resistance

Progressive collapse, not to be confused with disproportionate collapse, is a mechanism of damage whereby structural members fail consecutively. The Institution of Structural Engineers *Practical Guide to Structural Robustness and Disproportionate Collapse in Buildings* defines progressive collapse as:

> The sequential spread of local damage from an initiating event, from element to element, resulting in the collapse of a number of elements. Whilst undesirable, a progressive collapse may not be disproportionate. Hence the term “progressive collapse” is not necessarily equivalent to “disproportional collapse.”

Disproportionate collapse is a collapse that is greater in extent than an amount judged by some scale to be proportionate to the cause. A collapse may be disproportionate without being progressive and similarly may be progressive in nature but remain proportionate. Design against disproportionate collapse generally involves making the structure *robust*. Structural robustness is a quality of a structural system that enables it to sustain local damage without failing to any great degree.

There are several ways in which structural robustness can be designed into a building. Each country has structural codes to achieve robustness, but to varying degrees. The typical design approach methods are as follows:

- Tie-force-based design method
- Alternate load path method
- Key element design method or specific local resistance

4.1.3.1 Design Requirements

TIE-FORCE-BASED DESIGN METHOD

This type of design method achieves structural robustness by providing a minimum level of continuity throughout the structure. This continuity attempts to “tie” the structure together so that in the event of an element loss, the remainder of the structure acts together to resolve the discontinuity due to the loss.

The key factor in the tie-force-based design method is to ensure that the building’s frame members are mechanically connected to each other. This necessitates careful detailing practice in the connections between members, as discussed in Sections 4.1.1 and 4.1.2. Furthermore, through the use of both vertical and horizontal ties in the building, catenary action can be developed so that potential collapse through element disengagement is avoided.

The main advantage of the tie-force-based method is that it is a relatively simple way to ensure a minimum level of structural robustness. However, the disadvantage of the tie-force method is that it is based on several assumptions that should be scrutinized and validated for the type of building construction in question. More detailed and quantitative methods, such as the alternate load path methods and key element design, are necessary to certify structural robustness in the building, especially for structures that are at higher risk of accidental loading.

ALTERNATE LOAD PATH METHOD

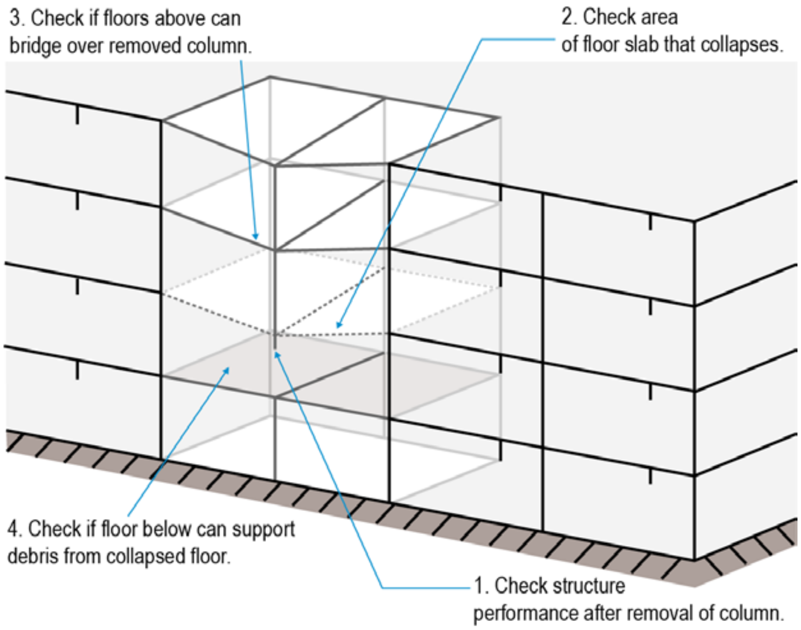
The alternative load path method is a quantitative structural assessment of the building under damaged conditions. This involves the removal of key structural elements, such as columns, shear walls, or beams, and assessing the structure’s resilience to collapse.

By designing for column loss, a structure is equipped with a level of robustness that caters to various underlying events that may or may not be terrorism-related. If a blast event causes the loss of a column, the structure must withstand that loss without collapse to meet the specified performance criteria. Alternatively, a column may be hardened such that it withstands the DBT scenario without failing. However, this does not account for the potential for the DBT to be larger than specified. As the primary structural goal is to prevent collapse, using alternate load path to design against element removal regardless of DBT is largely considered a best practice.

The alternate load path method can be divided into four main steps (Figure 4-9):

1. Check the structure performance after removal of key element(s)
2. Check the area of floor slab that collapses
3. Check if floors above can bridge over the removed column
4. Check if the floor below can support debris from the collapsed floor

Figure 4-9. Alternate Load Path Method



Source: Arup

KEY ELEMENT DESIGN METHOD OR SPECIFIC LOCAL RESISTANCE

This method is based on the design of structural elements to withstand the prescribed accidental loading (in this case a blast load), meaning that each element is proven to withstand the blast threat. The key element design method may be elected in addition to the previous methods to protect elements that are especially critical to maintaining structural stability.

4.1.3.2 Applicability to Airports

Design of airport structures against disproportionate collapse should adopt a risk-based approach. Progressive and disproportionate collapse resistance is not explicitly required in structural code and is therefore an owner-elected mitigation where risks of a blast threat (or other extreme event) are high. Progressive or disproportionate collapse resistance will increase the cost of structural design, as floors and beams will need to span greater distances than in a conventionally designed building. However, the inherent robustness of structures designed in this manner is considered best practice and will significantly reduce the risk of structural collapse in a blast event, which is the primary goal in most identified performance criteria (refer to Section 2.3.2).

Consideration for progressive collapse-resistant measures should always be evaluated when a blast threat is introduced. For single-story terminals, the risks may be low enough that explicit design to resist progressive collapse does not warrant the cost, as the cost of replacement will be closer to the cost of repair. However, for multistory terminals, the consequences associated with progressive or disproportionate collapse are more severe.

To minimize risks during the evaluation, the designer may first, for example, design out vehicle-borne threats by maintaining standoff from the structure. Maximizing standoff will minimize the blast load arising from an explosive threat and will increase the size of the DBT needed to overcome the capacity of the structure. Such measures will render the structure relatively insensitive to foreseeable hazards. Where the DBT is increased to a level that is well above a reasonably foreseeable threat size, vulnerabilities are designed out.

After designing out vulnerabilities as far as reasonably practicable, the vulnerability of the structure to the remaining hazards must be undertaken on a case-by-case basis. This may involve one or more of local blast or impact analysis, global analysis of the structural response, and/or element removal analysis to protect against disproportionate collapse.

If the structure can be designed to withstand element loss, this makes the structural design essentially insensitive to assumptions made about the size of the DBT, except where more than one column can be lost in a single threat scenario. As such, it will always be preferable to design the structure for element removal than using key element or specific local resistance methods. These should always be explored first, but it must be recognized that for buildings with large spans, especially larger airport terminals, developing specific local resistance can often be the only practical mechanism.

4.1.4 Facade Measures

The first layer of protection against hazardous blast load is provided by the building's envelope or facade. Facade protection measures are typically employed on the terminal exterior, and other areas of the airport where there are many occupants, such as bus and train stations or stops. Architectural features around the site may also incorporate elements of blast resistance to minimize the risk of hazardous debris.

When the risk of structural collapse has been mitigated sufficiently, a facade appropriately designed to withstand the DBT can protect the building's occupants against both fatal blast pressures and impact from hazardous debris. The facade alone cannot prevent structural collapse; however, if designed improperly, the facade can actually contribute to collapse in a blast event. Therefore, its design and detailing are extremely important.

Typically, an airport terminal landside facade is characterized as a curtain wall system made up of glass panes spanning between framing elements (mullions and transoms), which then spans to a purposely built secondary support structure (such as a truss) or the building's structural frame, such as floor slabs. Framing members should not span to primary structural members, such as columns, as this may induce the failure of the primary structural system.

The facade system and its support structure should be considered together during design, as a change on one may have an effect on the other. For example, strengthening of glass for blast resistance subsequently requires a stronger structural support. If a stronger support cannot be accommodated, the stronger glass results in an increased risk of structural failure, which could be disproportionate. Therefore, strengthening of the glass may not be the best solution from a protection standpoint; the risk of glazing hazards would need to be accepted (as the best option compared to risk of structural failure). These cost, performance, and risk considerations are complex. Sometimes the impacts that might occur from a facade change are not initially evident, and therefore this is one area that should be considered carefully before procuring enhancements.

This section presents common blast-mitigation measures that should be considered during the design stages of a new building's envelope or the retrofitting of an existing facade.

4.1.4.1 Glass

Monolithic glass consists of a single sheet of glass. This type of glazing configuration is not recommended for blast-resistant facades, as during a blast event there is nothing stopping the glass shards from flying into the occupied space and injuring the occupants. To prevent this from happening, the following mitigation measures can be adopted:

- Apply anti-shatter film (ASF) to the glazing units.
- Install or retrofit the facade with blast-engineered laminated glazing units.

ANTI-SHATTER FILM

Anti-shatter film (ASF) is a thin, transparent, adhesive polyester film, which is applied to the internal face of a glass pane to hold the glass fragments together in case of fracture due to a blast threat. ASF does not increase the strength of the glass pane, but acts as a mitigation measure against glass fragments.

The benefits of ASF are that it is applicable to existing glass panes, is not invasive, is inexpensive, and is quick to apply. **It is generally considered to be better than doing nothing, but on its own, it is deemed to be the least beneficial mitigation measure, and is only considered when retrofitting monolithic facades.** Without attachment of the ASF to the frame, the failure mode is most likely to be the entire glass pane flying inwards. This is generally considered to be an improvement compared to an untreated glass pane, where hundreds of small shards fly at dangerous speeds, but it is not able to protect people from blast pressures and will still be hazardous.

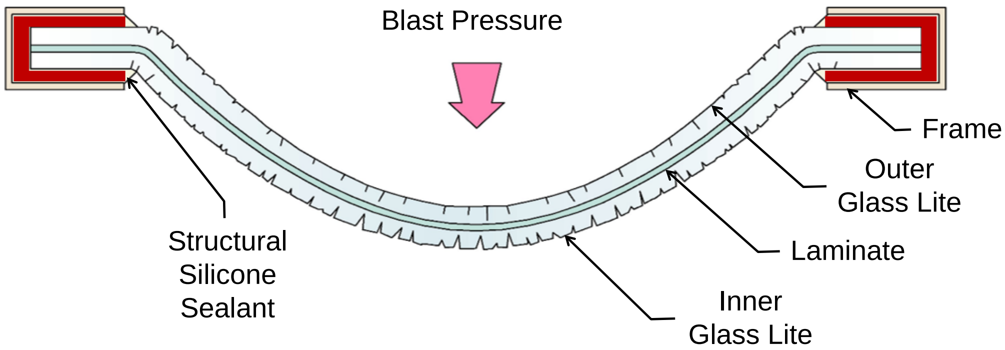
If the film is attached using structural silicone sealant or a mechanical fixing, increased performance can be achieved if the frame can support the additional loads. However, typically existing non-blast-resistant frames would not be expected to support much additional load, and therefore attachment of the film could cause a disproportionate hazard. Engineering evaluation can help determine whether this is the case. It should also be determined whether drilling bolt or screw holes in the frame may void the warranty on the frame.

LAMINATED GLASS

A greater level of protection against a blast threat can be gained by use of laminated glass. Laminated glass consists of a build-up of multiple glass sheets with a polyvinyl butyral (PVB) interlayer in-between. The PVB interlayer is a stretchy bonding material that, upon cracking of the glass pane, retains the glass fragments, preventing them from dispersing inside the building. A laminate glazing unit should be considered as the minimal baseline for a new construction or facade replacement.

An ionoplast interlayer (i.e., SentryGlass) should be used with caution for blast applications because its high strength results in greater reactions that must be carried through to the structure. PVB can range in stiffness as well, and careful specification of PVB should also be considered. If polycarbonate is required instead of glass (for example, due to ballistic needs), polyurethane interlayers may be required instead of PVB due to bonding limitations of polycarbonate. Polycarbonate also results in high reactions, and therefore, in these latter cases, design should be prepared to accommodate larger or stronger structures than glass with PVB. It is noted that these can only be general comments, as project specifics will dictate the actual requirements.

Figure 4-10. Catenary Action of the PVB Interlayer



Source: Arup

Laminated glass is often used with structural silicone sealant (SSS). SSS is applied at the junction of the glass and the frame to attach the two. If specified properly, the SSS can retain the glass in the frame and allow the PVB to achieve its full capability, letting it stretch between the surrounding frames as shown in Figure 4-10. The performance of a laminated glazing unit is highly dependent on the retention system anchoring it to the framing members. This capacity also impacts the strength required for the frame and support structures. Therefore, laminated glass should be selected only after careful consideration of these factors.

Usually, the minimum interlayer thickness used for non-blast application or very low-level blast application is 0.03-inch, while for a typical or higher-level blast application the minimum recommended interlayer thickness is 0.06-inch. There are also manufacturing limitations depending on the pane thickness, size, and glass type that should be coordinated with a glass manufacturer prior to specifying.

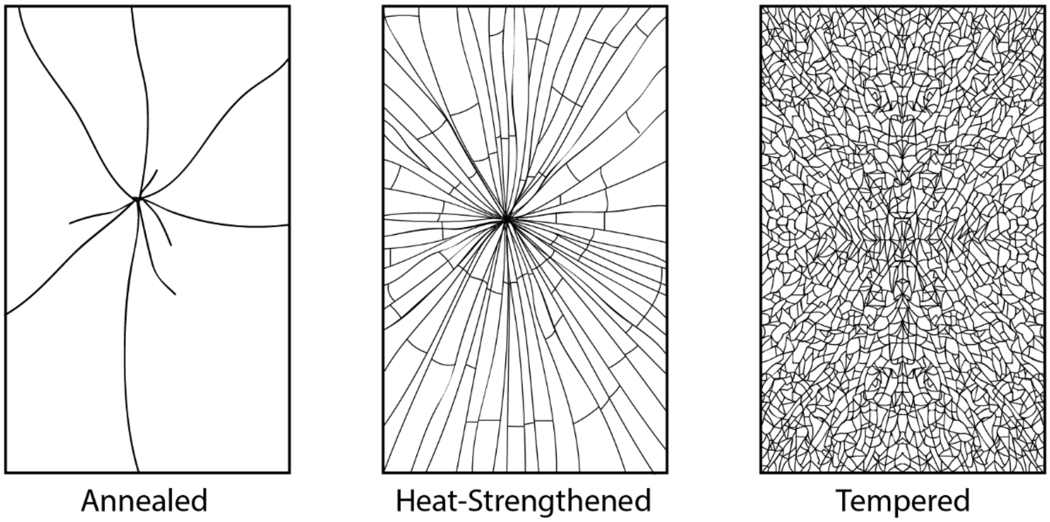
While a PVB interlayer between two or more glass sheets can provide excellent protection against blast loads, different glass types can be specified and each comes with its own characteristics and physical properties:

- **Annealed glass** is the most common type of architectural glass found in building facades and internal glazing. Use of annealed glass in blast-resistant glazing is usually limited due to its relatively low dynamic breaking strength of 11.6 ksi (kips per square inch; dynamic breaking strength slightly varies between manufacturers and countries of production) and tendency to break up into razor-like fragments. This irregular failure mechanism of the glass sheets may cause a high level of hazard to the building's occupants as the shards fly into the building (see Figure 4-11.). Therefore, this glazing type is mostly reserved for external sacrificial layers, where in the case of a blast threat the shards will only disperse on the outer side of the building. Still, the use of annealed laminated glass does provide significant benefit over the use of monolithic glass, regardless of type of glass.
- **Heat-strengthened glass** is essentially annealed glass that goes through a strengthening procedure consisting of precompressing the outer skin through a reheating and cooling process. This gives the glass a dynamic breaking strength of 17.4 ksi. Upon fracture, heat-strengthened glass tends to break in larger shards and fragments compared to annealed glass, as shown in Figure 4-11 and Figure 4-12. Fully tempered glass (or toughened glass) is annealed glass that has been fast-heated and cooled several times. This procedure significantly increases the dynamic breaking strength to about 26.0 ksi. Also, this treatment changes the failure pattern of the glass, making it different from the annealed and heat-strengthened glass. Toughened glass tends to break into small rock-sized, blunt-edged fragments, as shown in Figure 4-11. This specific brittle

failure mode of the glass has led to the reduction of specifying tempered/toughened glass over heat-strengthened glass because the small rock-sized pieces reduce its ability to stick to the PVB. However, for some locations, tempered glass requirements may govern for impact safety. In these cases, use of laminated tempered glass still significantly reduces blast risk compared to monolithic tempered glass.

It is important to consider other requirements and features such as thermal, impact, cleaning, and sunshade integration on a case-by-case basis.

Figure 4-11. Different Glass-Breaking Mechanisms – Annealed, Heat-Strengthened, and Tempered Glass



Source: Arup

4.1.4.2 Glass Retention Systems

Retention of a glass pane can be provided by either a dry gasket system or SSS (the latter is also called “wet glazing”). Glass retention within the frame is very important; if the bond or connection between the glass and the frame were to fail, the glass pane would most likely be propelled into the building and create additional hazard to the public, not to mention the blast pressures that would also enter the building as the envelope failed.

A dry gasket system holds the glass pane through friction between the pane and the frame’s rebate, while the SSS relies on the silicone bond between the glass and the frame.

It is typically recommended that the glass pane be bonded to the frame using SSS rather than relying on a dry gasket system. This is especially recommended when using laminated glass panes, as the SSS bond enables the PVB interlayer membrane to achieve its full capacity. On the other hand, gasket system glass will not be able to achieve the PVB capacity due to the low resistance provided by the friction between the pane and the rebate or frame.

The use of a dry gasket system is often preferred due to the ease of construction and relatively lower cost compared to using SSS. In design cases, where the blast load acting on the facade is not of great magnitude, it is possible to use a gasket system with deeper rebates, giving the system additional redundancy, but this is not usually recommended. Advice from a security or blast consultant should be sought when selecting the type of retention system to adopt in the design.

It should be noted that although it would create a hazardous condition, a strategy may be to allow glazing failure in an effort to avoid a potentially catastrophic structural failure; this is a risk-based decision that may be considered.

4.1.4.3 Framing

Framing elements are commonly represented by mullions and transoms, which are the vertical and horizontal framing members, respectively. The primary function of the framing unit is to support and allow the glass pane to fully develop its maximum resistance without any premature failure.

Framing used in non-blast applications does have some built-in resistance against minimal blast loads, but it is usually not adequate to transfer the reaction forces from the glass pane due to its minimalistic construction. For blast applications, several blast-mitigation measures can be adopted into the facade’s framing. These measures only concern new builds and full replacement work. It is usually not economical or practically feasible to modify pre-existing window frames, and would likely void any manufacturer warranty. In such cases, it is recommended that the building’s facade be re-clad.

FRAME MATERIAL

Aluminum and steel are usually the two materials specified for framing elements that are part of a blast-resistant facade, as they are ductile and therefore allow the member to go through a controlled large plastic deformation without failing unexpectedly. In most cases, aluminum is the material of choice for architects and facade designers, as it is lighter and cheaper than steel. Also, aluminum is highly malleable, and complex extruded sections can be produced to increase the stiffness of the section while keeping a relatively thin frame width and depth. Additionally, aluminum frames can be used in conjunction with steel inserts, which can greatly increase the blast resistance of the section.

Additionally, some manufacturers that make aluminum window systems that may be used in typical single-story buildings (but may be not for larger airport terminals) have blast-tested some of their products. These manufacturers are knowledgeable regarding performance of their tested systems compared to the tested DBT scenarios, but will request a blast engineer/consultant to determine applicability to other scenarios. Most of these blast-tested systems, particularly those of US manufacturers, are tested for blast loads applicable to US Government blast criteria, such as those from the Department of Defense, the Department of Veterans Affairs, or the General Services Administration. For airport applications, these tested manufacturer systems may be limited to single or two-story spanning facades, which are only required to meet a relatively low level of protection. For check-in hall facades at large international airports with complex designs, full-scale blast testing and/or engineering analysis should be incorporated in order to demonstrate that the blast requirements are met.

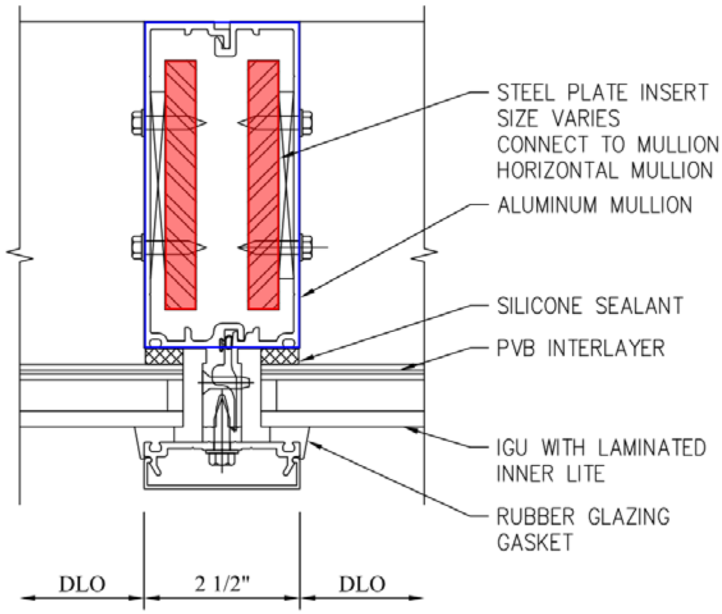
From a blast perspective, steel is the preferred choice when the blast loads are relatively large. Steel support systems are typically required for large curtain walls to support conventional loading like gravity and wind. This may either be a structural backup to an aluminum-framed system or a customized steel support system directly behind the glass. Conventionally designed steel-framed facades, although robust, are likely to require additional enhancements to meet a blast requirement, such as deeper section dimensions, thicker web members, or additional connection capacity.

4.1.4.4 Steel Inserts

As briefly mentioned above, an additional measure that can be taken to increase the resistance of framing elements includes the incorporation of steel inserts in the extruded framing section (typically aluminum). Steel inserts are slotted inside the extruded aluminum frame section, as shown in Figure

4-12. They may also be shaped as channels or other shapes that fit into the particular mullion extrusion. During a blast event, the steel insert works in combination with the surrounding aluminum section to increase the resistance of the overall section. The main advantage of combining steel inserts with an outer aluminum section is that it is possible to achieve a relatively strong section while keeping the overall width of the frame section slim. This approach aligns with most architectural requirements set by architects and facade designers. However, designers should coordinate early with blast engineers as sometimes cabling or utilities are preferred to be run through mullions, which might not be possible if this method of steel support is used.

Figure 4-12. Frame Aluminum Section with a Steel Plate Insert



Source: bmk Engineering

4.1.4.5 Blast Clips

Depending on the facade design, two types of framing sections can usually be specified: split-sections or unitized (box) sections. Split sections are framing members that are composed of two separate entities and are kept together with continuous or intermittent clips or bolts along the length of the frame. Unitized systems, or box framing sections, are usually rectangular extruded sections that come as whole units and do not require any clips or connections to be held together (Figure 4-13).

When split sections are specified on a blast-resistant facade, it is important that special blast clips are also included in the design. Conventional clips are not able to resist the in-plane forces acting on the frame, which will essentially try to split the section open. Figure 4-14 illustrates the framing split section and the blast clips holding it together.

Without blast clips in stick systems, the mullions will most likely come apart at the seam when loaded by a blast-designed glass pane due to the horizontal/in-plane forces created by the laminate in combination with SSS. Therefore, introduction of blast-resistant glass and properly designed rebate is only effective if the stick system is designed to withstand the blast loads imposed by the glass. It should also be noted that blast clips in stick systems are limited in their capacity; unitized systems might be better suited for cases with high blast loads or high performance criteria.

Figure 4-13. Framing Box Section (Unitized)

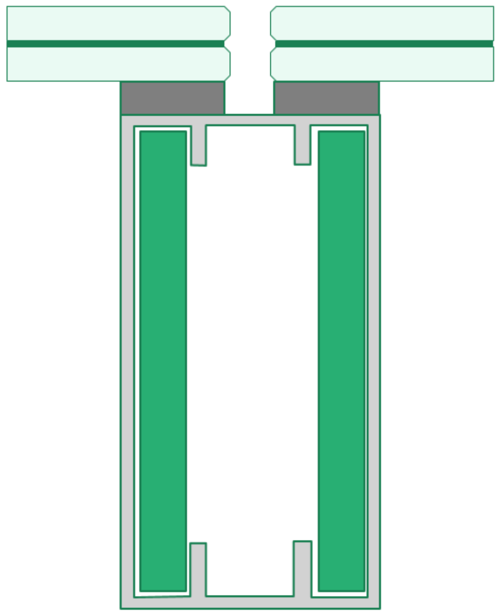
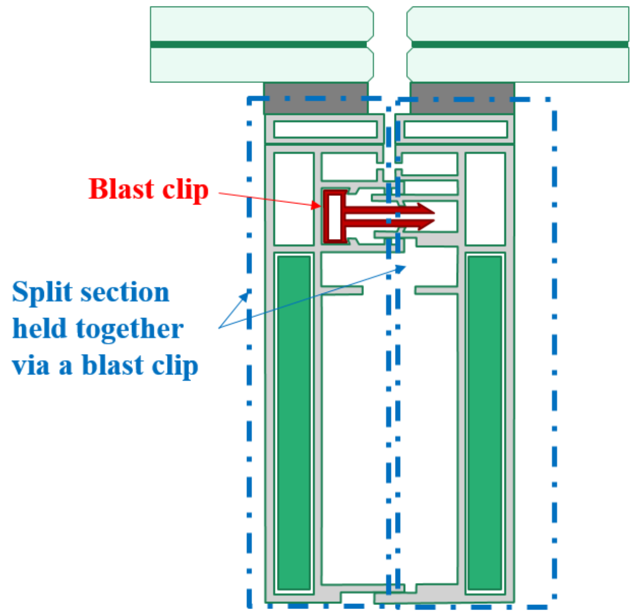


Figure 4-14. Framing Split-Section with a Blast Clip



Source: Arup

Table 4-2 generalizes various level of blast protection that can be provided by a facade, using approximate levels of protection.

Table 4-2. Example Levels of Facade Blast Enhancements

Level of Protection	Glazing	Framing
Very Low	Anti-shatter film (ASF) applied to the glass pane	None
Low	Laminated glass pane with a minimum PVB interlayer thickness of 0.03-in	Blast-resistant framing details that can resist blast pressures around 5 psi and impulses of around 30 psi-msec; dry-gasketed with minimum 1-in rebate or otherwise SSS
Medium	Blast-engineered single-laminated glass panes with a minimum PVB interlayer thickness of 0.06-in	Blast-engineered frame to retain glass to its capacity using SSS, allowing full capability of PVB to be realized
High	Blast-engineered double-laminated glass panes designed to resist larger-sized blast threats	Blast-engineered frame to retain glass to its capacity (per Medium) and also engineered to limit permanent deformation of the frames; includes structural steel backup framing due to higher demands created by the stronger glass

4.1.5 Vehicle Security Barriers

In addition to the hardening of structures, a significant portion of design guidance is directed towards preventing VBIEDs from accessing or encroaching upon protected areas. In the context of blast mitigation, the aim of such HVM schemes is to increase the standoff from VBIEDs, reducing the loads on the protected areas. Furthermore, overt HVM measures can act as a deterrent.

The principles behind HVM are well explained in several sources including Federal Emergency Management Agency (FEMA) 426 and the *United Kingdom (UK) Centre for the Protection of National Infrastructure (CPNI) Hostile Vehicle Mitigation Guide*. Additionally, testing standards for impact-tested vehicle security barriers are well established with ASTM F2656 (predominately US standards), Publicly Available Specification (PAS) 68 (predominately UK standards), and International Workshop Agreement (IWA) 14-1 (various places around the world). It should be noted that a well thought-out HVM strategy encompasses other aspects of design aside from barriers, such as roadway layout, speed limitation measures, etc.

4.1.5.1 Testing and Specifying Barriers

Since their development, these testing standards have become the industry standard for specifying requirements for the design of HVM schemes. However, the high level of protection and impact resistance afforded by such systems is not appropriate in all circumstances.

When specifying the vehicle barrier per ASTM F2656, three components are needed: the threat vehicle, the threat speed, and the allowable penetration distance. Typically, the building facade has been designed for a blast threat located at the line of barriers, so the penetration distance should be limited to less than 3.3 feet (1 meter), which is a P1 designation (see Table 4-3). If P1 barriers are not achievable due to existing condition, construction, architectural, or cost limitations, the design engineer will need to specify a greater penetration early on during the design process, as this could influence the standoff assumed for the blast analysis. Penetration greater than P2 should be avoided unless the implications of this have been considered carefully.

Table 4-3. Vehicle Penetration Rating (ASTM F2656)

Designation	Dynamic Penetration Rating
P1	Less than 1 meter (3.3 feet)
P2	1.01 to 7 meters (3.31 to 23.0 feet)
P3	7.01 to 30 meters (23.1 to 98.4 feet)
P4	30 meters (98 feet) or greater

The different variations for vehicle size and speed are shown in Table 4-4. The vehicle size is typically determined at the beginning of the project based on the risk assessment and design criteria. The speed of each condition can be calculated during the design process by a blast or security engineer. A commonly specified vehicle size and speed for high-risk locations is the M50 (Medium-Duty Truck at 50 mph); however, this speed may be high for most terminal areas. Purposeful specification of the design vehicle should be made during the risk assessment in order to support effective allocation of resources. Very few manufacturers have tests for the heavy goods vehicle or the small passenger car as they are very rarely specified. If specified, manufacturers may want to provide a higher protection level due to greater availability of those products.

Table 4-4. ASTM F2656 Vehicle Size and Speed Rating

Test Vehicle	Weight lbs (kg)	Nominal Minimum Velocity mph (km/h)	Condition Designation
Small Passenger Car (C)	2,430 (1,100)	40 (65) 50 (80) 60 (100)	C40 C50 C60
Pickup Truck (PU)	2,430 (1,100)	65 (45) 80 (50) 100 (60)	PU40 PU50 PU60
Medium-Duty Truck (M)	15,000 (6,800)	30 (50) 40 (65) 50 (80)	M30 M40 M50
Heavy Goods Vehicle (H)	65,000 (29,500)	30 (50) 40 (65) 50 (80)	H30 H40 H50

4.1.5.2 Barrier Types

There are various types of passive and active barriers, each with unique benefits and drawbacks. In all cases, it is important to consider the effects on pedestrian flow and egress for emergencies, especially at airports where passengers have luggage that significantly reduces their ability to flow quickly around barriers. Studies performed by CPNI demonstrate this effect. It is recommended to consult with pedestrian planners and fire protection engineers to verify that code requirements will still be met with the addition of barriers in high volume pedestrian areas.

STEEL BOLLARDS

Steel bollards are probably the most versatile of the passive barriers; they can be arranged to allow for pedestrian movement, covers can be added to make them architecturally pleasing to match the surrounding facility, and they can be operable (raised/lowered). The challenge is that many types need deep foundations, which are not always achievable in existing facilities due to structural or utility limitations. There are some manufacturers with more versatile shallow-bollard foundations, but the costs of these products are high and the footprint plan increases 300% from that of a deep foundation. Despite these negative factors, shallow-mount bollards are often procured anyway in order to avoid invasive construction; most shallow-mount systems can be installed very quickly.

Figure 4-15. Steel Bollards

Source: bmk Engineering, design and construction project: 6711 Gateway Drive, Colombia, MD

At roadway entrances that require access for maintenance vehicles or other authorized vehicles, hydraulic or electric operable/retractable bollards can be used.

Figure 4-16. Steel Retractable Bollards

Source: bmk Engineering, anti-ram testing observation, Adelanto, CA

It should be noted that a continuous slew of bollards along a long terminal's drop-off and pick-up zones does not necessarily represent a well thought-out HVM strategy; security engineers and architects should work together to avoid this and encourage architecturally pleasing barrier solutions, which may be supplemented by other HVM strategies such as architectural layout, technology systems, or operations. Studies by CPNI have recommended to move the line of bollards outwards from any exits (at least 3 m away) so that crowds have time to diffuse before having to move around the bollards.

JERSEY BARRIERS

Jersey barriers can be deployed quickly and easily with little construction time. Jersey barriers do not provide an ASTM security rating and are not considered to be architecturally pleasing. However, they do provide a baseline level of protection and are visual deterrents. These may be useful to deploy at times of elevated threat, or as temporary solutions where a vulnerability has been identified but time is required before procurement of a larger project can be undertaken.

Figure 4-17. Jersey Barriers

Source: bmk Engineering, perimeter security design project

CONCRETE PLANTERS AND KNEE WALLS

Concrete walls can be designed for any requirements and can be made to fit within the surrounding architectural environment with stone facades. They are not pedestrian friendly and typically require deep foundations, which are often a challenge at existing facilities. However, at airports they would be ideal in locations where pedestrian flow is low, or if there is a highly vulnerable area such as a straight-away road or an access point for large trucks.

Figure 4-18. Concrete Knee Wall

Source: bmk Engineering: design project: Bamako, Mali

WEDGE BARRIERS

Wedge barriers are operable and provide the maximum perimeter protection with a low-profile barrier. The wedges are within the roadway, so they can present challenges in some weather conditions if not maintained properly. Different systems have various foundation requirements. The shallow systems are very extensive in horizontal area, while the deep systems do not affect the surrounding pavement. There are also surface-mounted systems if needed for a high-profile event or on a temporary basis. Wedge barriers are best suited at discrete locations such as an access control point to a loading dock or an authorized taxi/shuttle bus entrance, if throughput times can be accommodated.

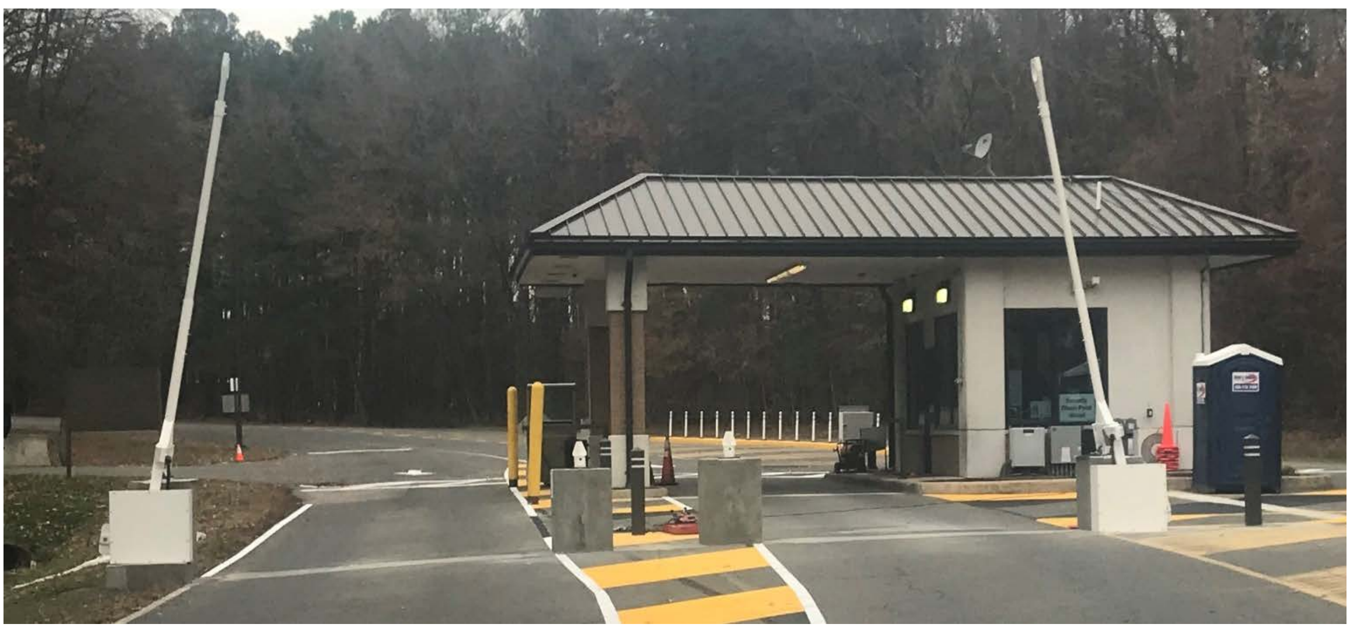
Figure 4-19. Wedge Barriers

Source: bmk Engineering, Inc. Construction project: Tiblisi, Georgia

DROP ARMS

Drop-arm-style barriers can be the least invasive on the roadway as their foundations are typically the smallest. However, they take up the most real estate above ground and can be challenging to use across multiple roadways. At airports, these are best utilized at staff parking, entrances to service yards, or other areas where authorization is required for entrance.

Figure 4-20. Drop Arms



Source: bmk Engineering design and construction project: Gribble Gate, Alexandria, VA

4.1.6 Physical Measure Retrofits for Existing Airports

Existing airports may have been designed without structural blast enhancements or with blast enhancements that are no longer best practice in airport design. Retrofitting landside areas of existing airports is a routine occurrence and often provides an opportunity to invest in security. Existing airports often contain legacy infrastructure that cannot be easily replaced without great financial cost or effort. Such infrastructure may include the following:

- Elevated roadways and drop-off zones in close proximity to the terminal building.
- Structures and facades designed some time ago that incorporate older standards and have little blast resilience.
- Existing/outdated CCTV systems and cabling.
- Terminal layouts that promote crowding at areas such as check-in, drop-off, and security screening.
- Data centers and other functions critical to the airport's operations.

Traditional blast-mitigation strategies for retrofit, in particular physical enhancements, come at a financial cost and effort that is disproportionate to the risk, often stalling an airport's plans to invest in landside security. For that reason, an existing airport may have a blast-mitigation strategy with emphasis on operational measures, which can be easily deployed across landside areas. However, operational measures also come with substantial recurring costs and do not directly reduce the effects from a blast itself.

In regard to retrofit of physical measures, depending on the blast DBTs and performance criteria, costs and implications of retrofitting structures may become expensive and onerous to implement. However, the risk reduction may be necessary to pursue. There are many retrofitting techniques that can be employed, but given the nature of a retrofit, all will need to be customized to the unique conditions of each airport and its particular risk-reduction needs. For most cases, a blast engineer will be needed to help identify the most effective and feasible measures.

4.1.6.1 Structural Retrofits

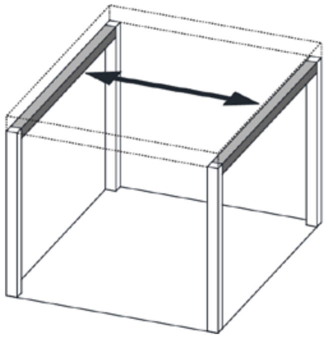
Although not a structural retrofit by technical definition, structural performance can be enhanced significantly by increasing standoff. Increasing standoff will almost always offer improved performance to a DBT. In the case of close-in bombs, increase in standoff may trigger a global response mode (as opposed to localized) that should be evaluated by a blast engineer; nevertheless, increasing standoff is one of the most effective strategies. Increases in standoff should be considered before or in combination with structural enhancement retrofits. For existing airports, increasing standoff may not be functionally possible or is significantly more onerous than making structural enhancements. In this case, the following are common retrofitting techniques that can be applied to an existing structure—all of which require engineers' evaluation:

Increased strength: Increasing the strength of the global or local structure can improve performance. Effective performance enhancements can be achieved by increasing the section depth dimension of the member, as this will reduce the final deformation and thus rotation.

Mass increase: Increasing mass is an economical and fairly straightforward method of increasing the blast resistance. However, this method is only deemed suitable for elements subjected to impulsive loading, and increasing the mass of the structure may negatively affect the foundation and other structural members (e.g., the additional mass may overload existing structural components).

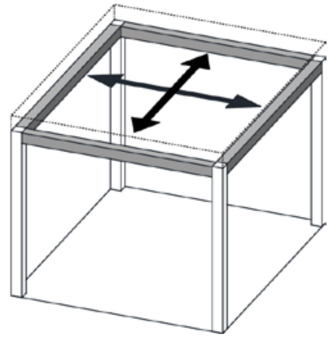
Boundary conditions modifications: Modifying the supporting conditions of a member can increase the capacity of a member. For example, a slab that is spanning between two beams has a lesser load-carrying capacity than a slab spanning onto four beams; an illustrated example is presented in Figure 4-21 and Figure 4-22. Careful consideration should be applied to the new load path distribution of the modified members, as the redistributed load may overstress other structural components.

Figure 4-21. Two-Side Supported Slab (One-Way Spanning)



Source: Arup

Figure 4-22. Four-Side Supported Slab (Two-Way Spanning)



Source: Arup

Span length reduction: Span length reduction can increase the stiffness of the member, effectively increasing the load-carrying capacity. Significant attention should be paid to the end reactions of the shortened members, as they may exceed the capacity of the supporting members.

In addition to the above-described techniques, careful consideration should be placed on strengthening the existing structural components' connections. Table 4-5 presents a selection of structural retrofitting methods that can be adopted to increase the blast resilience of an existing structure.

Table 4-5. Example Structural Retrofitting Techniques

Most Applicable DBT	Structural System	Structural Modification
VBIED	Metal decking over roof joists	• Pour additional concrete and reinforcement* • Install lateral braces to bottom flanges of joists
PBIED	RC slab or composite metal deck support by joists	• Increase section thickness and mass of member by pouring additional concrete and placing additional reinforcement* • Install I-beam on top of existing slab, provide fixing in-between existing joist and new I-beam, and pour additional concrete over existing slab
VBIED & PBIED	Exterior column	• Install steel jacket on RC column; steel column can be encased in concrete or web stiffeners can be welded to the flanges
VBIED & PBIED	RC wall	• Install new vertical beams in the walls • Install high strength fiber-reinforced strips to the wall surface • Increase the wall thickness by increasing the wall section (add concrete and reinforcement)* • Install new blast-resistant wall behind; consideration should be given to the impact of debris from the existing wall on the new wall
VBIED	Roof systems	• Install a new blast-resistant roof on top of the existing structure*
PBIED	Steel joists floor framing	• Install lateral bracing angles to reduce joist effective length • Bolt or weld steel plate to the bottom flange of the joist
VBIED	RC connections	• Install additional steel angles tying RC members together

Most Applicable DBT	Structural System	Structural Modification
VBIED & PBIED	Steel connections	• Add web stiffeners near the supports to improve shear resistance and avoid web buckling • Provide additional bolts and weld material to the connection to allow transfer of moment forces
VBIED	Frame	• Install cross bracing between structural bays • Install new interior shear wall to resist lateral loads*

* Note: It should be considered that enhancements may trigger structural upgrades due to larger gravity loads that are disproportionate to the retrofit intent.

When retrofitting of an existing building is considered, it is crucial that the advice and expertise from a security/blast consultant and structural engineer is sought. Retrofits may impact the global response of the building or have cascading consequences to other disciplines under conventional loading scenarios such as gravity and wind.

4.1.6.2 Facade Retrofits

When considering retrofits to the facade, there are three main options:

1. ASF (i.e., daylight film/fragment retention window film)
2. Mechanically attached ASF
3. Replacement blast-resistant facade systems with laminated glass and blast-resistant frames

Also worth mentioning in this section is retrofit of other architectural features that may contribute to hazards in a blast event if not properly anchored. Hazard-mitigating design details of typical interior elements (including glazing) have been developed and professionally drafted. Refer to Appendix D for the drafted book of details.

ANTI-SHATTER FILM (DAYLIGHT AND MECHANICALLY ATTACHED)

Implications of ASF as a retrofit were discussed previously in Section 4.1.4.1. Further to that discussion, it should be noted that ASF is well known as a blast enhancement primarily because of its cost and ease of implementation for existing systems, not its high performance. Test reports demonstrate that ASF can provide enhanced performance under lower loads, but the performance is variable, and it is only a marginal improvement over the existing glass. ASF is generally regarded as better than doing nothing; however, a significant performance benefit would only come from installing a properly designed laminated glass and an anchored blast-resistant facade.

Without attachment of the film to the frame (i.e., “daylight” application), under a large blast loading like a VBIED at the drop-off curb, the entire pane is likely to come out of its frame. As discussed earlier, this creates a hazard in its own regard, but is generally accepted to be a lesser hazard than the shattering that would occur with glass left untreated. A catchment system could be provided behind the glass with daylight film, but this would have aesthetic impacts and would also need to be anchored properly in order to perform effectively, which in turn would impact the structural design.

There are two options for attaching the film to the existing frame: mechanically using screws or using structural silicone sealant (SSS). Either option may provide superior performance to daylight film, but only if the existing frame and anchorages are robust enough to transfer the additional load that is imparted to the frame through the attachment; the facade system is only as strong as its weakest link.

It should also be noted that if existing glass is laminated, the application of ASF would not be an effective use of resources, as the laminated glass accomplishes a similar result as the anti-shatter film.

4.1.6.3 Hostile Vehicle Mitigation Retrofits

A common site constraint for existing airports is one of minimal stand-off between roadways and the terminal building. This exposes the terminal building and its occupants to severe effects from a VBIED.

Previously, the TSA had developed the “300-foot rule,” also known as the Special Category Airport 3 (SCA-3), which has been since rescinded. The rule was a ban on any unknown vehicle parking within 300 feet of the terminal building. In its place, the TSA instituted a series of operating procedures called the Bomb Incident Prevention Plan (BIPP) to provide relief from the SCA-3. Each BIPP was required to be based on an approved blast analysis performed by a certified engineering firm that would be instituted when the DHS threat level was elevated to Orange. However, without analysis supporting their BIPP, the 300-foot rule remained in effect for Category X airports.

Each airport’s approach to this flexible BIPP required approval by TSA. Although the alternative operational measures are expensive to implement, some airports had elected to accept these circumstances rather than constructing parking facilities 300 feet from the terminal. Some airports also elected to reduce capacity in the garage to achieve the 300 feet instead of building 300 feet away.

Although the SCA-3 rule was rescinded, TSA still requires addressing the threat of a VBIED in the airport’s TSA-approved Contingency Plan, especially for Category X airports. The threat can be addressed by restricting parking and unauthorized vehicles within 300 feet of the terminal, or by implementing alternate procedures that the airport has proposed and have been approved by the TSA. For non-Category X airports, where a risk assessment may suggest a low risk of terrorism, a Contingency Plan is still required, but the alternative procedures for VBIED mitigation may be less strict. In both cases, in practice, the airport is responsible for determining appropriate standoff and mitigation strategies, and a TSA audit will verify that the airport has a plan established.

As was the case with the 300-foot rule, traditionally the focus of an HVM strategy has been to protect the terminal itself. It is important to note that recent attacks indicate that the target has shifted towards crowded places, in general. Before specifying vehicle barriers, evaluation should be undertaken to identify goals for protection and vulnerable areas of the airport, whether that be near the terminal or non-terminal areas where people congregate. A holistic strategy for protection from hostile vehicles should be developed, which includes:

- Definition of the protection objectives
  - e.g., Protect the people or protect the structures
- Identification of the expected threats
  - e.g., Abandoned vehicle in the parking garage, or a suicide VBIED attack on the terminal
- Criteria for evaluating the effectiveness of measures
  - e.g., Is a visual deterrent (reduce likelihood) acceptable, or is a physical barrier (reduce consequence) required?
- Identification of significant vulnerabilities
  - e.g., Minimal standoff or publicly accessible roadways
- Guidelines for redevelopment to mitigate such threats
  - e.g., Roadway rerouting, vehicle barriers, or screening checkpoints

Also of note is that an airport’s HVM strategy should encompass consideration for both VBIED and vehicle ramming attacks, with the former being the focus of this guidebook.

For existing airports, the following measures may be implemented as part of an HVM strategy that encompasses physical, technological, and operational measures:

1. Reduce speed limits
2. Increase curb height
3. Provide signage or physical height restrictions on roadways
4. Install landscaping or roadway impediments to slow vehicles
5. Disperse (i.e., separate and/or additional) drop-off and pick-up zones to reduce crowds and thus reduce the vulnerability of any one area
6. Relocate drop-off and pick-up zones to less vulnerable areas
7. Implement video analytics to help detect illegally parked vehicles, stolen or unregistered cars, etc. (refer to Section 4.2)
8. Provide physical barriers (i.e., bollards, planters, or drop-arms) to prevent vehicles from entering the terminal building, bus plaza, or other identified vulnerable area
9. Screen vehicles prior to entering the terminal areas using a vehicle checkpoint
10. Reconfigure traffic lanes for authorized vehicles to be nearest the terminal or other vulnerable areas, and unauthorized vehicles to be furthest away

4.1.6.4 Summary of Retrofits

An overall summary of physical retrofits and their applicability to VBIEDs and PBIEDs is shown in Table 4-6.

Table 4-6. Summary of Retrofit Measure Applicability

Retrofit Measure	VBIED Applicability	PBIED Applicability
ASF (Daylight Application)	Yes, however the benefit may be small	Yes
ASF (Mechanically Attached)	Yes, however the benefit may be small	Yes
New/Replacement Blast-Resistant Laminated Glazing System	Yes	Yes
Enhancements to Overhead Equipment Anchorages	Yes	Yes
Structural Member Enhancements	Yes	Yes
Incorporation of Progressive Collapse Resistance	Yes	Yes, but it is less likely to be necessary
Hostile Vehicle Mitigation	Yes	No

4.1.7 Physical Measure Cost Estimations

Rough order-of-magnitude (ROM) cost estimates have been calculated for a number of blast-mitigation measures. These costs are summarized in Table 4-7 for structural and facade enhancements, and in Table 4-8 for HVM enhancements. The unenhanced costs are intended to be representative of a conventionally designed system that has not considered blast. Details and assumptions of the ROM cost estimate are provided in Appendix C; costs were developed in 2018. The default cost information from the estimate is also included in the Excel-based tool that accompanies this guidebook to help identify cost-effective measure combinations using the framework process.

Table 4-7. Summary of Physical Enhancement Options and ROM Costs

Enhancement Type	Description	ROM Cost Estimate	Cost Premium
	New Facade		
Unenhanced*	**Glass:** IGU Outer: 3/8" (TT)/Inner 1/4" (HS)+0.03PVB+1/4" (HS) **Mullion**: 10x4x0.125" Aluminum extrusion	Glass: $45.00/ft^2 Framing: $30.00/ft^2 Installation: $9.15/ft^2	Baseline
Enhanced Option 1*	Generic and proprietary 4 psi/28 psi-ms facade	Glass: $33.00/ft^2 Framing: $77.00/ft^2 Installation: $10.30/ft^2	1.4x
Enhanced Option 2*	**Glass:** IGU Outer: 3/8" (TT)/Inner 1/4" (HS)+0.06PVB+1/4" (HS) **Mullion:** 10x6x3/16" Aluminum extrusion + 9.5x1/2" Steel stiffening Inserts	Glass: $65.00/ft^2 Framing: $89.00ft^2 Installation: $10.30/ft^2	2.0x
Enhanced Option 3*	**Glass:** IGU Outer: 3/8" (TT)/Inner 1/4" (HS)+0.06PVB+1/4" (HS) **Mullion:** HSS 12x4x1/4"	Glass: $51.00/ft^2 Framing: $132.00/ft^2 Installation: $11.30/ft^2	2.3x
Enhanced Option 4*	**Glass:** IGU Outer: 1/4" (HS)+0.06PVB+1/4" (HS) Inner: 1/4" (HS)+0.06PVB+1/4" (HS)+0.06PVB+1/4" (HS) **Mullion:** HSS 16x8x1/2"	Glass: $100.00/ft^2 Framing: $197.00/ft^2 Installation: $12.30/ft^2	3.7x
	Existing Facade		
Enhanced Option A	ASF (Daylight Application)	$4/ft^2	Baseline
Enhanced Option B1	ASF (SSS Attachment)	$5/ft^2	1.3x
Enhanced Option B2	ASF (Mechanical Attachment)	$14/ft^2	3.5x
Enhanced Option C	ASF (Daylight Application) with Cable Catchment System	$33/ft^2	8.3x
	Columns		
Unenhanced Option 1*	**Steel column:** W12x106	Materials and install: $4,500/column	Baseline
Enhanced Option 1A*	**Steel Column:** W12 x 106 + 1" stiffener plates to Box section at column base + Grout-filled at column base	Materials and install: $5000/column	1.1x
Enhanced Option 1B*	**Steel Column**: W12 x 106 + 20" Square Concrete encasement	Materials and install: $5400/column	1.2x
Unenhanced Option 2*	**Concrete Column:** 3' Diameter + #4 hoops at 12" on center + 16 x #10 longitudinal bars	Materials and install: $1400/column	Baseline
Enhanced Option 2A*	**Concrete Column:** 3' Diameter + #6 hoops at 6" on center + 16 x #10 longitudinal bars	Materials and install: $2416/column	1.7x

Enhancement Type	Description	ROM Cost Estimate	Cost Premium
Enhanced Option 2B*	**Concrete Column:** 3" Diameter + #4 Ties at 12" on center + 1/2" full height steel jacket + 16 x #10 longitudinal bars	Materials and install: $3700/column	2.6x
	Floor		
Unenhanced Option	**Beam:** W24 x 84 + Shear Studs **Floor Slab:** 8" RC slab (#4 bars at 8" on center)	Materials: $170.24/ft Installation: $52.77/ft	Baseline
Enhanced Option 1	**Beam:** W27 x 146 + Shear Studs **Floor slab:** 10" RC slab (#4 bars at 8" on center) + enhanced connection	Materials: $229.97/ft Installation: $62.28/ft	1.3x
Enhanced Option 2	**Beam:** W30 x 116 + Shear Studs **Floor slab:** 12" RC slab (#5 bars at 8" on center) + enhanced connection	Materials: $301.70/ft Installation: $70.70/ft	1.7x
	Roof		
Unenhanced Option	W21 x 62 (primary Beams-32 ft span) + W21 x 50 (secondary Beams at 16 ft on center) + 6" cold formed Purlins (0.08"t) at 4 ft on center	Materials: $9/ft^2 Installation: $15/ft^2	Baseline
Enhanced Option 1	W24 x 84 (primary Beams-32 ft span) + W21 x 68 (secondary Beams at 16 ft on center) + 8" cold formed Purlins (0.08"t) at 4 ft on center	Materials: $11/ft^2 Installation: $19/ft^2	1.3x
Enhanced Option 2	W30 x 116 (primary Beams-32 ft span) + W24 x 84 (secondary Beams at 16 ft on center) + 10" cold formed Purlins (0.08"t) at 4 ft on center	Materials: $13/ft^2 Installation: $22/ft^2	1.5x

Table 4-7 Notes:

PVB: Polyvinyl Butyral; HS: Heat Strengthened;
IGU: Insulating Glass Unit;
TT: Thermally Tempered;
HSS: Hollow Square Section; RC: Reinforced Concrete
* Indicates member is shown in Figure 2-6.

Table 4-8. Hostile Vehicle Mitigation (HVM) Enhancement ROM Costs

Enhancement Type	Description	ROM Cost Estimate	Cost Premium
	Steel Bollards		
Unenhanced	Steel bollard, not rated	$112/ft	Baseline
Enhanced Option 1	Steel bollard, PU50-P1 rating*	$3,129/ft	28x
Enhanced Option 2	Steel bollard, M30-P1 rating	$1,685/ft	15x
Enhanced Option 3	Steel bollard, M40-P1 rating*	$2,677/ft	24x
Enhanced Option 4	Steel bollard, M50-P1 rating	$2,167/ft	19x

Enhancement Type	Description	ROM Cost Estimate	Cost Premium
Concrete Barriers			
Enhanced Option 1	Raised Curb, not rated	$14/ft	-
Enhanced Option 2A	Jersey Barrier, not rated	$117/ft	-
Enhanced Option 2B	Concrete Bench, not rated	$191/ft	-
Enhanced Option 2C	Concrete Planter, not rated	$238/ft	-
Other HVM			
Enhanced Option 1A	Speed Humps, not rated	$5,000/hump	-
Enhanced Option 1B	Height Restriction Bar over Road, not rated	$7,006/barrier	-
Enhanced Option 2A	Gate Barrier, M50-P1 rating	$28,000/barrier	-
Enhanced Option 2B	Wedge Barrier, M50-P1 rating	$54,000/barrier	-

Table 4-8 Notes: *Costs are unexpectedly high due to the limited availability of barriers tested and manufactured to these ratings.

4.2 Technological Measures

This section describes common technological measures and how they can be adopted to mitigate blast threats at landside areas of airports. Also discussed is application of technologies to existing or new airports.

Although technologies are not perfect, they can supplement the role of operational security in being able to monitor greater areas than would otherwise be possible with operations alone. Active monitoring is expensive due to the operations personnel required behind the technology. As technologies are constantly changing, airports should review their options regularly to evaluate their best options. Further discussion on technology solutions is provided in Section 4.3, where the use of technology to support operational measures is discussed.

4.2.1 Video Surveillance

Video surveillance camera technology has evolved alongside that of computers. With a majority of current systems now using IP-based signal transmission, network video recorders are often able to automatically act upon predefined algorithms identified within the camera feeds. This field is referred to as video surveillance analytics.

A computer's main purpose is to perform vast amounts of repetitive calculations that would take a human much longer to achieve. Analytics aim to work in the same manner by relying on computer vision, a field that has gained much advancement in recent years. Ideally, analytics can make sense of the data in a video feed and relay it as a qualitative, actionable item for a staff member to carry out. For example, if a person is recorded climbing over a fence into a secure area, the system can automatically bring up the live video feed on a security guard's workstation and/or mobile phone, sound a local alarm, and turn on nearby lighting. This saves the employee from the mental fatigue associated with having to stare at numerous camera feeds for many hours at a time.

The maturation of this field means that a system can identify possible problems before they happen rather than just forensically determining what happened afterwards. Below are a few common video surveillance analytics that can be used to help reduce the likelihood of a blast event; a more detailed list can be found in Appendix A.

- Objects left unattended for a specified period of time
- People and objects crossing a predefined digital barrier or zone in the camera's field of view
- Smoke detection, even outdoors
- Tracking a person or object through multiple cameras' views
- Irregular behavior—compares the baseline footage of what a camera sees during a normal day and flags if it detects an action it has not seen before
- Automatic identification of faces and license plates

Just like humans, analytics are not perfect. False positives can have a "boy who cried wolf" effect on security guards, who lose faith in the system if they receive too many incorrect flags. A video surveillance system designer must take into consideration a camera's environment, resolution, frame rate, and other factors to maximize effectiveness. For example, it is unwise to run facial recognition on a 180-degree camera that overlooks the entire check-in area from twenty feet above the floor. Like with any computer, the more data being analyzed at any given time, the less performance will be available for assessing situations in other feeds.

4.2.2 Emerging Technologies

Supplementary systems can be utilized to minimize false positives. One such method is by using the 3D detection capabilities of light detection and ranging (LiDAR). Traditionally used to map an area or building, LiDAR laser scanning has more recently seen use in autonomous vehicles to detect other moving automobiles and pedestrians as well. This real-time 3D capture (up to 20 scans per second with a range of 100 m) can be used to safely detect objects of a particular size and automatically aim and zoom a pan-tilt-zoom (PTZ) camera to view them; a system configured to alert if a human-sized object is climbing over a fence will not be triggered if a squirrel were to do the same (see Figure 4-23).

In addition to autonomous vehicles, autonomous surveillance robots are also beginning to emerge as a method of seeing into places not normally visible to CCTV systems. Most of these are purely for surveillance with some other features (i.e., two-way intercom, public announcement), but some governments have taken steps to militarize their robotic security guards with stun capabilities. Once purely science-fiction, this implementation is certainly not without controversy.

Leveraging the connectivity of the general public has also begun to aid security. Cloud-based systems allow anybody with a smartphone to transmit live video feeds to an operations center, which can also be coordinated with location tracking to determine the location of the event.

Companies are also using millimeter wave detection technology to modernize the standard metal detector. This technology can make use of the naturally occurring radiation from the human body and see where these signals are reflected, which beyond a certain threshold usually indicates some sort of weapon. Using a touchscreen, security guards can then view a diagram of where on the person's body the potential weapon is detected and act accordingly. Some manufacturers also include cameras with facial identification capability and integration with the building's security network for optional record keeping. The fact that this technology can be adjusted based on the site's threat and risk assessment means that they can be adjusted as needed; for an airport, these devices can be set to a threshold that only detects large firearms and explosives at the airside entrance to increase speed at those locations, knowing that a more thorough check will be performed at the TSA checkpoints into the sterile area.

Figure 4-23. LiDAR System Supplementing CCTV

Source: Arup

4.2.3 Technology Systems Cost Estimations

The following ROM costs have been approximated for CCTV, vehicle screening, and explosives detection technologies. Note that the costs only include construction and materials, and do not include staffing the security operations center or manning the security checkpoints, which adds significant cost to the systems. Costs are based on 2018 pricing; further assumptions can be found in Appendix C.

Table 4-9. ROM Costs for Select Technology Systems

Enhancement Type	ROM Cost Estimate	Cost Premium
CCTV		
Unenhanced: CCTV	$14,700/camera	Baseline
Enhanced Option 1: CCTV with Analytics	$16,600/camera	1.1x
Enhanced Option 2: CCTV with LiDAR Analytics	$25,300/camera	1.7x

Enhancement Type	ROM Cost Estimate	Cost Premium
Vehicle Screening		
Enhanced Option 1: ALPR	$19,300/camera	Baseline
Enhanced Option 2: UVVS	$26,400/scanner	1.4x
Explosives Detection		
Enhanced Option 1: TSA mm-wave Body Scanner	$211,200/scanner	Baseline
Enhanced Option 2: High throughput mm-wave Detection	$256,200/scanner	1.2x

4.2.4 Existing Constraints

From a technology standpoint, the most important element is the data network. Most devices can transmit and even receive power over a standardized Category 5 or Category 6 cabling system for telecommunications, which makes each data outlet largely interchangeable for connecting devices. Thus, having a capable network provides room for expansion and modernization for future technologies as well. Smart head-end equipment can enable systems to have a variable amount of integration with other systems, something that has become increasingly necessary with multiple entities needing to operate in the airport environment. For example, specific camera feeds can be made available to all entities' video management systems, while others can be restricted and viewed only by Customs and Border Protection. Without a solid network backbone, many of the technologies discussed in this guidebook cannot be implemented.

Smarter connectivity also brings with it cybersecurity considerations that must be addressed. More connectivity often implies more points of entry for a malicious outside agent to access connected systems. Firewalls and data policies are required to minimize the risk of breach.

Data devices are most optimally run over the latest standard Ethernet cable, and there are options for running these signals over existing analog wiring. Media converters placed both at the edge and at the system head-end can transmit data, and sometimes power, in cases where running new cable is not feasible, or in locations surpassing the maximum distance limits of the data cable (in lieu of creating another intermediate distribution frame). Wireless solutions are also available but are not as reliable as their physically wired counterparts.

4.2.5 New Airport Considerations

The only sure thing about the future of technology is that it will always be changing, so the smartest thing to do when designing a new airport building is to allow room for the network to expand. This can involve purchasing more head-end equipment in the IT closets to create extra device ports and data storage, running extra data cable to locations initially concealed above ceilings or behind walls for future use, or running extra strands of fiber along the network's backbone to link the distribution frames as well as outside connections. As mentioned earlier, data outlets are often able to be repurposed and can connect to different types of devices; for example, two outlets in a space that were originally supporting three standard fixed dome cameras can be repurposed to now support one 360-degree camera, one LiDAR detector, and one access point for Wi-Fi.

4.3 Operational Measures

The following common operational measures can be adopted to mitigate a blast threat:

- Patrols
- Explosives detection canines (EDC)
- Known vehicle regimes
- Vehicle checkpoints
- Advanced communication techniques
- Security management systems (SeMS)

Operational measures are critical to disabling and disarming the threat, which is something that neither physical, technological, nor architectural measures can achieve. Therefore, to achieve a holistic security strategy, operational measures should be included to cover this protection need. This principle is reinforced in Section 5, whereby various measure types are combined to achieve a spread of protective capabilities.

4.3.1 Agreement on Operational Measures

As discussed in Section 3.2, agreement on security measures is accomplished through a risk-mitigation approach based on local and national risk assessments. Risk and threat mitigation may be defined in the National Civil Aviation Security Program (i.e., 49 CFR) to some degree, but the application of each measure will vary from airport to airport. Therefore, each airport determines which measures are most appropriate to their risk environment under "business as usual" operations, what additional measures should be implemented in heightened threat situations, and with whom the responsibility lies for each.

Airports implement operational security measures based on an operational requirement, which is a statement of need based upon a thorough and systematic assessment of the security problem to be solved and the desirable solutions. Defining the criteria below will inform the application of each operational security measure.

Figure 4-24. Operational Requirements Criteria

Source: CPNI Guide to Producing Operational Requirements for Security Measures, 2016

The above criteria will aid the airport operator in determining which operational security measure to implement based on the security function that is required to mitigate a particular threat scenario.

4.3.2 Operational Measures for Detection, Deterrence, and Prevention

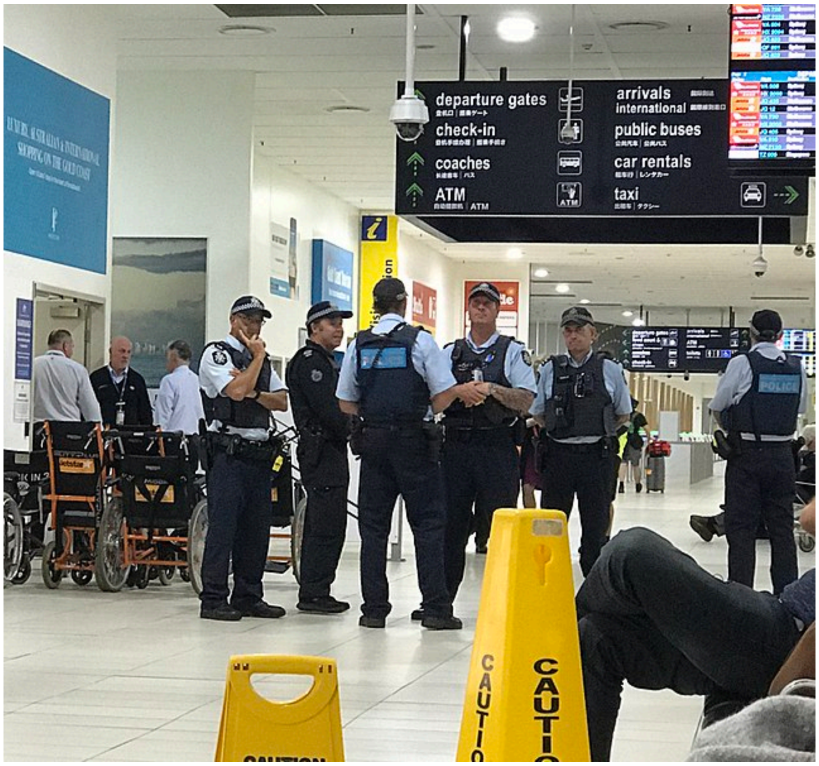
4.3.2.1 Patrols

The main security function of patrols is detecting suspicious activity, but they may also serve as a deterrent to security risks through the active deployment of airport security officers with high visibility jackets. Further, unpredictable or random patrolling is also effective in reducing advantages potential threat actors may have tried to gain through reconnaissance efforts to predict the best times to go unnoticed. Patrolling involves surveillance of sites to monitor the following:

- The boundaries between landside, airside, and security restricted areas
- Areas of, and near, the terminal that are accessible to the public, including parking areas and roadways
- The presentation and validity of persons' identification cards in security restricted areas
- The presentation and validity of vehicle passes when airside
- Hold baggage, cargo and mail, in-flight supplies, and air carrier mail and material in critical parts waiting to be loaded

It is a common practice for airports to have a combination of patrolling personnel such as airport security personnel, law enforcement personnel, airport operations staff, and maintenance staff. Referring to the developed framework (see Section 5), an effective patrolling process should ideally meet a Platinum level of service to ensure a coordinated approach between different personnel groups. While airport patrolling responsibility can lie with a variety of security-related stakeholders, the deployment of any patrolling personnel should complement police patrolling strategies. Vehicle patrols can also be utilized to deter potential threats by ensuring police vehicle presence at outer perimeters of terminals such as pick-up and drop-off zones, vehicle checkpoints leading to airside, heightened points at the outer perimeter, and areas identified by man-portable air-defense systems assessment.

Figure 4-25. Australian Police Officers at Airport

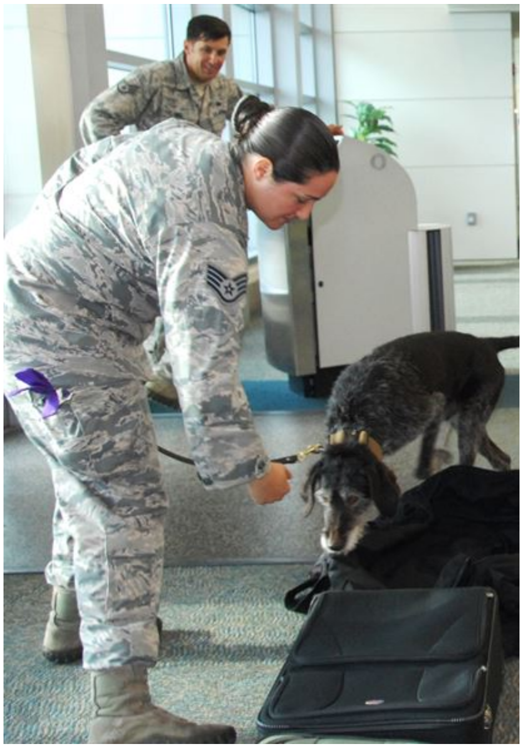


Source: Wikimedia Commons ([CC 4.0](#))

4.3.2.2 Explosives Detection Canines

EDCs may be used to detect and indicate specified and higher individual quantities of explosive material. An EDC and its handler should be approved independently and in combination as a team in order to be used for screening. While canine olfaction (i.e., sense of smell) may be used to detect explosives, illicit materials, or weapons in passenger baggage or on the passengers themselves, EDCs should be single-purpose dogs specifically trained to detect explosives only, and not be subjected to multiple training programs as protection dogs or for narcotics detection. EDCs' detection capability of explosives in terminals may be critical in preventing loss of life, but also plays a major role in reducing the commercial impact on the airport's business. An example of this is the 2017 bombing attempt at Asheville Regional Airport in North Carolina, which was thwarted using the help of EDCs that signaled to the airport security team the presence of dangerous materials in the suspect's bag, preventing impact to the airport, which serves approximately 50,000 passengers every month.

Figure 4-26. Free Running Explosives Detection Canine Accompanied by Handler



Source: Eglin Air Force Base Website
(CC 4.0)

Table 4-10 provides the two methods of security screening practiced by EDCs, with the FREDC method being most applicable to the landside.

Table 4-10. Methods of EDC Security Screening

Free-Running Explosives Detection Canines (FREDC)	Remote Explosive Scent Tracing (REST)
EDCs deployed directly in an operational environment accompanied by handler, e.g., terminal	EDCs kept in sterile rooms
EDCs sniff items such as cabin baggage in terminal	EDCs sniff extracted air samples from cargo containers at stations located in sterile rooms

While EDCs act as an effective detection measure, airport operators tend to procure EDC programs from external providers as the costs of such programs are extensive, amounting to $35,000 USD for the EDC and its training and $6,000 USD per annum for welfare costs. As EDCs can only be deployed for a limited period of time without rest, and due to the high costs associated with this measure, a Silver level of EDC service may be appropriate (see Section 5.3.3), where dogs are deployed sparsely within the airport terminal, bus station, metro station, and other vulnerable areas to conduct random patrols.

Furthermore, the framework (see Section 5) provides a high scoring for combining EDCs with patrols, which stems from the fact that patrolling personnel handling EDCs can act as a key deterrence measure. EDCs give an alarm, in the form of a passive response, when they detect explosive materials, and in order to fully resolve an alarm, a patrol officer may need to question a passenger about what they are carrying.

4.3.2.3 Known Vehicle Regimes

There are certain landside areas of an airport that are dedicated to airport operations, and into which entry is not permitted to passenger vehicles. These may include the following:

- Police operation areas
- Cargo pick-up/drop-off areas
- Taxi operation areas
- Bus operation areas
- Traffic management operation areas
- Perimeter patrol operation areas

While passenger vehicles are not permitted to enter these areas, the only measure used by some airports to restrict access is signage. However, if a threat actor is planning a vehicle-based explosive attack, traffic management rules like signage will not be followed. There are some operational measures used by airports to mitigate this threat scenario to these types of landside areas, and to maintain airport-supporting operations. For example, particular roads around Stansted Airport in the UK that are used for the operations listed above are given a "controlled landside road" status, meaning that although it is not airside or a security restricted road, limitations are placed on its use through vehicle access control points (VACP) on each side of the road.

Instead of staffing the VACP, automatic license plate recognition (ALPR) can be implemented, which uses video surveillance systems to screen the registration plates of all vehicles entering or leaving the controlled landside road. This technology will only recognize license plates of vehicles used for airport operations that require access to the roads. The implementation of ALPR by itself will only meet the detection function and may not mitigate the deliberate breach of traffic management rules. Therefore, ALPR should be used in combination with physical measures such as rated barriers that allow access following approval from the ALPR.

Although ALPR can be easily implemented at existing airports, the use of a known vehicle regime is more effective when introduced early in airport development. This is because sufficient space must be allocated to install the VACP comprised of physical measures and an ALPR system. Furthermore, while this system can detect and permit access to known vehicles only, the risk of an insider threat is not ruled out. Although implementing this known vehicle regime early in airport development can ensure a sufficient standoff distance is maintained between entry point for vehicles and any airport assets that may be in close proximity to the VACP (therefore eliminating the risk of a blast affecting nearby assets), it cannot validate capability and intent of an insider vehicle (i.e., a vehicle may be legitimate in the sense that it is known but may still have an intent to cause damage, such as a VBIED).

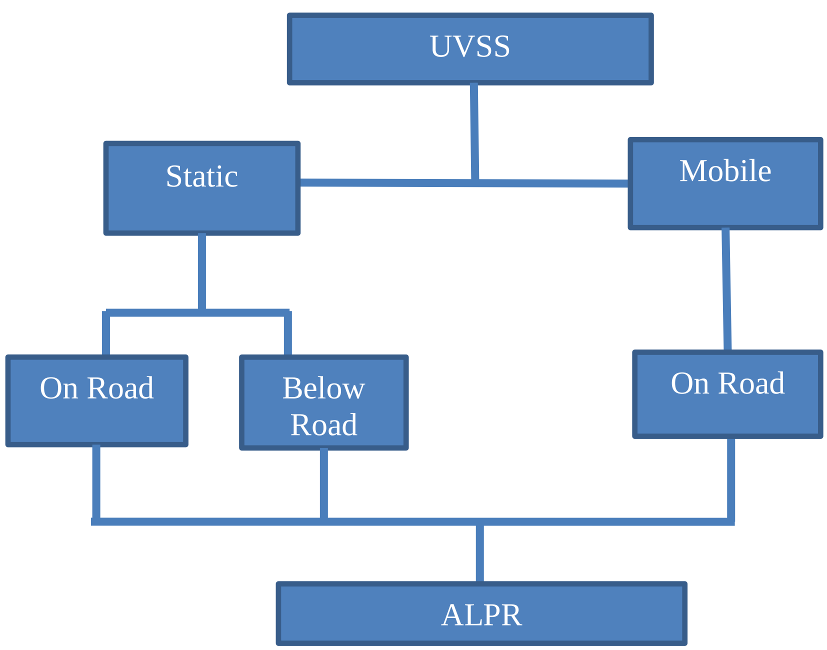
4.3.2.4 Vehicle Checkpoints

Vehicle checkpoints should be deployed on approach roads and where road layout allows in order to not disrupt the flow of traffic. These checkpoints are extremely effective in deterring threats, particularly for heightened threat situations where an additional layer of protection is required. They are also a measure that can be incorporated into an existing airport's security program, requiring no refurbishment of any infrastructure. A good example of this measure being implemented at an existing facility when threat and risk context dictates is Brussels Airport, following the 2016 Brussels bombings. As additional security requirements were imposed by the Belgian government, Brussels Airport managed to protect and maintain its operational function while enhancing its security measures by deploying behavior detection enforcement soldiers on Leopoldlaan Road, which leads to Pier A of the airport terminal. To avoid traffic congestion, vehicles are required to drive slowly past the soldiers rather than come to a complete stop, allowing the soldiers to conduct a quick non-stop visual inspection of the driver and the vehicle, and to stop suspicious vehicles only.

Other examples of vehicle checkpoints include vehicle control posts (VCP) at airports, which are located landside and are used by vehicles to access airside areas of airports. In the event of a blast at a VCP, the operational functions of an airport can be severely affected, as VCPs allow the facilitation of airside deliveries such as in-flight supplies/food and beverage, bulk liquids (e.g., aviation fuel and de-icer), building materials (e.g., aggregates, concrete, and asphalt), and maintenance and construction materials. Mitigating VCP blast scenarios can include the use of an under vehicle surveillance system (UVSS), which enables the scanning of the underside of vehicles.

If the airport operator wishes to implement a Silver to Platinum tier of performance (refer to Section 5.3.3), UVSS can be integrated with an ALPR system in order to cross-check each vehicle against airport databases to ensure all vehicles are approved to access airside or security-restricted areas. The UVSS system can be implemented as shown in Figure 4-27. UVSS can be supplied in either static or mobile configurations. Static systems tend to consist of a permanent deployment and are installed on or below a road surface, whereas mobile systems are portable.

Figure 4-27. Implementing UVSS



PERMANENT SECURITY CHECKPOINT – BEN GURION INTERNATIONAL AIRPORT, ISRAEL

Ben Gurion Airport has a road vehicle checkpoint one mile away from the main terminals where vehicles and passengers are screened before they head to the airport. Speed bumps are present at the checkpoint, reducing vehicle speeds as they are approaching, and armed guards stop, greet, and question all drivers, gauging their mood and intentions and looking for suspicious behavior.

Major international airports tend to have a minimum of two main approach roads leading to terminals, each with three or four lanes of traffic. Having a security checkpoint may not cause any more congestion than toll booths. However, while Ben Gurion Airport claims that their vehicle checkpoint does not lead to any major traffic delays, the airport handles approximately 11 million passengers per annum as opposed to the bigger airports such as Chicago O'Hare, which handles close to 77 million passengers per annum. Furthermore, it may be more appropriate to consider Ben Gurion-like vehicle checkpoints when developing new airports, as the location and footprint of most existing airports, especially at some older terminals, would not allow them due to space constraints. The risk context for Ben Gurion is also unlike that of most airports worldwide.

4.3.2.5 Advanced Communication Techniques

This section provides a selection of communication techniques that can be utilized to deter a blast scenario.

Figure 4-28. Types of Communication Techniques

Passive Communication Techniques	Active Communication Techniques
• Vigilance posters • Vigilance leaflets • Security wallet cards	• Advanced Passenger Information (API) • Targeted passenger screening • Staff-passenger engagement ("Can I help you?")

ACTIVE COMMUNICATION TECHNIQUES

Active communication techniques are seen as more intrusive due to the element of singling out certain passengers and subjecting them to enhanced screening. A method used by Ben Gurion Airport is a risk-based approach to passenger screening. The system in place relies on identifying passengers who are believed to pose a high risk and subjecting them to additional checks. Targeted screening of individuals for landside security is made up of the three layers below:

Figure 4-29. Targeted Passenger Screening

Computer-Assisted Passenger Pre-screening System (CAPPS)

- Used by airlines
- Cross-checking passenger data with watchlists
- Searching for any unusual passenger activity (flight habits, method of ticket purchase, car rentals, etc.) prior to travel

Pre-terminal entrance screening

- Vehicle checkpoint
- Vehicle trunk x-rays
- Vehicle undercarriage scanning

Face-to-face staff-passenger interaction

- Questioning starts at the vehicle checkpoint
- Risk-based screening consisting of questioning in the terminal before check-in
- Failure to answer questions may lead to pat down

Public knowledge of this degree of security implemented at Ben Gurion Airport serves as an effective deterrent that discourages hostiles from targeting the airport. Although this measure is expensive to operate and capital-intensive, it is highly effective in preventing loss of life, as the last notable incident at the airport was in 1979, when an aircraft hijack was attempted. This measure is appropriate to Ben Gurion as it is the only international airport serving Israel, allowing the country to focus all its effort and expertise on this one facility.

PASSIVE COMMUNICATION TECHNIQUES

Less intrusive measures include passive communication techniques, which act as an extremely low-cost deterrent that sends a subliminal message about the (high) level of security at an airport. Measures used tend to be a part of a wider vigilance campaign that includes all airport staff playing their part in maintaining an effective security culture. Vigilance posters such as those below can be put up in visible places around the terminal to discourage any potential threat actors from carrying out reconnaissance.

Figure 4-30. Vigilance Posters

Source: This guidance/poster was created by the UK's Centre for the Protection of National Infrastructure (CPNI) and is subject to Crown Copyright. It is used with the permission of CPNI for our internal purposes. Permission for any wider use should be obtained from CPNI.

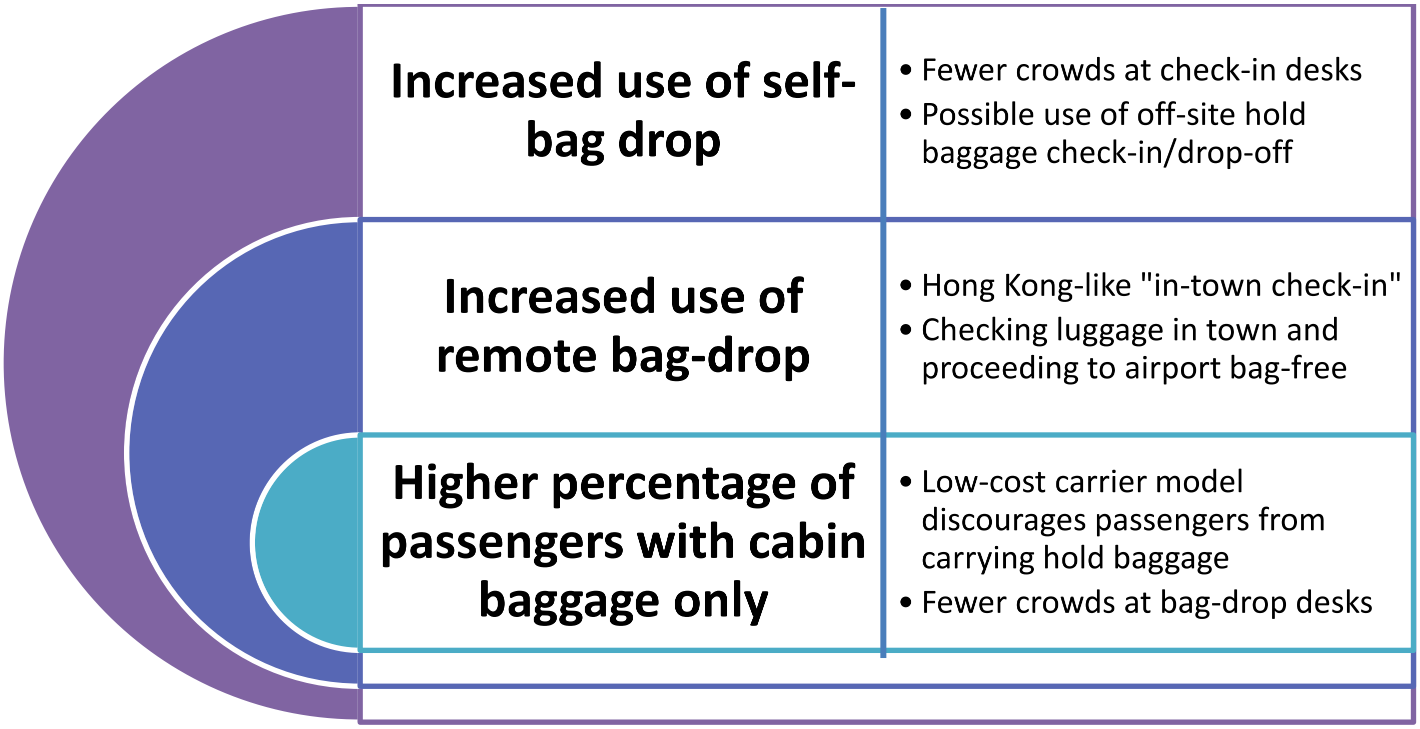
Other staff-driven initiatives include carrying wallet cards that feature security/law enforcement numbers that are visible on their person and are carried around with them when they are on and off site. Also, handing out leaflets with security messages and placing them in passenger areas will serve to reinforce the perception that staff are highly observant and vigilant.

4.3.3 Changing Passenger Habits

The implementation of various security measures mentioned thus far could be difficult due to organizational constraints, costs, critical dependencies, and the need to retrofit or integrate into the existing infrastructure. More creative methods can still be explored to improve blast-mitigation security, and it starts with changing the way each passenger intends to travel and utilize airport facilities.

Changing passenger habits can make a significant difference in reducing the loss-of-life risk if the airport manages to raise awareness about security and promote the mentality that every person has a responsibility in ensuring security. In an operational setting, this may include exploring ways to reduce queues and large gatherings of people in the landside/public area of the terminal.

Figure 4-31. Changing Passenger Habits to Achieve Risk Reduction



Source: Arup

The above procedures have been facilitated through the introduction of various technologies such as online check-in and self-bag drop. Airports can contribute significantly to changing how passengers travel by introducing incentives aimed at airlines and passengers. This may include revised procedures for airlines in which certain airport charges are reduced if the airline can ensure that most passengers do not travel with hold baggage. This would reduce crowding at check-in areas, facilitating passengers to move airside as soon as they arrive at the airport. However, reducing queues from the ticketing area does not necessarily eliminate all queues, especially if not managed properly. Management of crowds and passenger flows are discussed further within Section 4.4.

Changing passenger habits requires a coordinated approach between all stakeholders such as airlines, airports, and travel agencies. As these measures are customer service-driven, they do not guarantee that security outcomes will be achieved. Furthermore, this type of measure will only reduce the loss-of-life risk as opposed to protecting airport infrastructure.

4.3.3.1 Security Management System (SeMS)

An SeMS is a mechanism or management technique used to establish and maintain a security culture, and integrate security into the airport's business. The security culture is utilized to manage security risks, while the inculcation of security into the business provides for more effective, efficient, and sustainable security. The establishment and maintenance of an airport-wide security culture and the integration of security into the airport's business are achieved by establishing and maturing seven elements that, when integrated with each other and the broader airport business, form an SeMS.

The figure below illustrates the seven elements, their relationships with each other, the governance and quality assurance that underpins the system's functionality, and their collective contribution to a positive security culture.

Figure 4-32. SeMS Elements

Source: PARAS 0009

The security measures implemented at an airport will be informed by the SeMS. This is because the SeMS serves as a tool for systematically incorporating security risk management into an airport's day-to-day operations. For an SeMS to be effective, it must be based on a continuous cycle that includes a threat and vulnerability assessment; the identification, capture, and analysis of risk; and the generation and continuous review of risk mitigation plans and the effectiveness of risk-reduction measures (refer to PARAS 0009 for additional guidance).

4.3.4 Operational Cost Measures Estimations

The following ROM costs, shown in Table 4.11, have been approximated for operational security measures. The costs are salary-based and do not include capital costs of materials required to support operations (e.g., metal detectors are excluded). Section 4.4 offers further discussion regarding check-in counter and TSA screening checkpoint staffing.

Table 4-11. ROM Costs for Operational Measures

Measure	ROM Cost Estimate per year
Canine olfaction (Explosives detection dogs)	$881,100 (5) 8-hr shifts, i.e., one person on-duty, 24-hour coverage
Vehicle checkpoint staffing	$1,090,300 (10) 8-hr shifts, i.e., 2 staff per checkpoint, 24-hour coverage
Behavioral detection officers	$597,300 (5) 8-hr shifts, i.e., one person on-duty, 24-hour coverage
Airline check-in counter staffing	$554,900 (5) 8-hr shifts, i.e., one person on-duty, 24-hour coverage
TSA screening checkpoint staffing	$2,147,600 (15) 8-hr shifts, i.e., 3 staff per checkpoint, 24-hour coverage
Law enforcement patrols	$530,100 (5) 8-hr shifts, i.e., one person on-duty, 24-hour coverage
Private security patrols (unarmed)	$364,500 (5) 8-hr shifts, i.e., one person on-duty, 24-hour coverage
SOC staffing	$530,100 (5) 8-hr shifts, i.e., one person on-duty, 24-hour coverage

4.4 Crowd Management

From an operations perspective, airports are considered large passenger-processing facilities, and crowding is inevitable at peak times for busy airports. Air travelers expect queues in check-in halls and at security checkpoints, as well as crowding around bag claim carousels and in arrival halls. These areas of an airport are often non-secure, meaning the public can access them without going through the security checkpoints.

These traits make non-secure areas particularly vulnerable to a blast attack, and therefore measures that reduce the extent of crowding inherently reduce the total consequences of a blast event. Section 4.4.1 discusses the processes that typically generate crowds and potential mitigation measures.

Additionally, crowds of people are vulnerable to the effects of fragmentation hazards from an explosion. Hazard-mitigating design details of typical interior elements (including glazing) have been developed and professionally drafted. Refer to Appendix D for the drafted book of details.

This section discusses crowd-mitigation strategies related to blast risks. Refer to PARAS 0013 for other crowd-mitigation strategies.

4.4.1 Crowding at Airports

Typically, the major non-secure areas that are prone to crowd accumulation from queuing include departure halls, security checkpoints, domestic baggage claim halls, meet-and-greet areas, taxi queues, and mixed-mode transportation hubs.

To subjectively assess the passenger experience at an airport, the International Air Transport Association (IATA) and Airports Council International jointly provide metrics to determine the Level of Service of an airport. The metrics are primarily based on the wait times and space provision at each facility. A well-designed airport has properly sized facilities to process the passenger volumes in a timely manner with acceptable queuing and accumulation, thus limiting crowds.

Table 4-12 and Table 4-13 show the metrics to measure Level of Service, as presented in IATA's 9th and 10th editions of the Airport Development Reference Manual (ADRM). In the remainder of this section, any reference to passenger wait time limits and space requirements is based on these two tables. Another level of service criteria also exists for passageway widths. Table 4-14 shows the Level of Service standards for passageways, measured in passengers/meter of width/minute. This allows for the required corridor width to be determined given the passenger flow.

Most airports aim to provide enough facilities to achieve Level of Service C, or optimum provision, during typical peak hours. Using these standards results in different processor requirements, which are dependent on the operating parameters at each airport that include peak hour volumes, processing rates, and passenger composition.

Table 4-12. Waiting Time Standards (ADRM 9 and 10)

Level of Service Guidelines for Airport Terminal Facilities
Comparison ADRM 9th & 10th Edition

		WAITING TIME STANDARDS FOR PROCESSING FACILITIES (Minutes)										
Passenger Terminal Processor		Economy Class					Business Class/First Class					
ADRM 9th Edition		A	B	C	D	E		A	B	C	D	E
ADRM 10th Edition		Over design		Optimum	Suboptimum			Over design		Optimum	Suboptimum	
Check-in	Self Service Boarding Pass/ Tagging			0–2	>2			0		0–2	>3	
	Bag Drop Desk (queue width 1.4–1.6m)	0		0–5	>5			0		0–3	>3	
	Check-in Desk (queue width 1.4–1.6m)		<12		>12		Business Class		<3		>3	
		<10		10–20	>20			<3		3–5	>5	
							First Class		<3		>3	
								0		0–3	>3	
		1.8	2.4	3				0.6	0.8	1		

Level of Service Guidelines for Airport Terminal Facilities
Comparison ADRM 9th & 10th Edition

Security Checkpoint (queue width 1.2m)	<5		5–10	>10			0		0–3	>3	
Emigration (Passport Control) (queue width 1.2m)	3	4	5				1	1.3	1.7		
	<5		5–10	>10			0		0–3	>3	
Immigration (Passport Control) (queue width 1.2m) Transfers	4.2	5.6	7				1.4	1.9	2.3		
	<10		10	>10			<5		5	>5	
	<5		5	>5			0		0–3	>3	
Baggage Claim Area Narrow Body Aircrafts Wide Body Aircrafts		<12		>12				<12		>12	
	<0		0–15	>15			0		0–15	>15	
	<0		0–25	>25							

Table 4-13. Space Standards (ADRM 9 and 10)

Level of Service Guidelines for Airport Terminal Facilities
Comparison ADRM 9th & 10th Edition

Passenger Terminal Processor		SPACE STANDARDS FOR WAITING AREAS (sf/pax)				
ADRM 9th Edition		A	B	C	D	E
ADRM 10th Edition		Over design		Optimum	Suboptimum	
Public Departure Hall		33.4	29.1	24.8	20.5	16.1
		>24.8		24.8	<24.8	
Check-in	Self Service Boarding Pass/Tagging	24.8	20.5	18.3	17.2	16.1
		19.4		14.0–19.4	14.0	
	Bag Drop Desk (queue width 1.4–1.6m)	24.8	20.5	18.3	17.2	16.1
		19.4		14.0–19.4	14.0	
	Check-in Desk (queue width 1.4–1.6m)	24.8	20.5	18.3	17.2	16.1
		19.4		14.0–19.4	14.0	
Security Checkpoint (queue width 1.2m)		15.1	12.9	10.8	8.6	6.5
		>12.9		10.8–12.9	<10.8	
Baggage Claim Area		28	21.5	18.3	14	10.8
Narrow Body		>18.3		16.1–18.3	<16.1	
Wide Body		>18.3		16.1–18.3	<16.1	
Public Arrival Hall		26.9	22.6	18.3	14	9.7
		>18.3		16.1–18.3	<16.1	

Table 4-14. Level of Service Standards for Passageways (Odoni 2003)

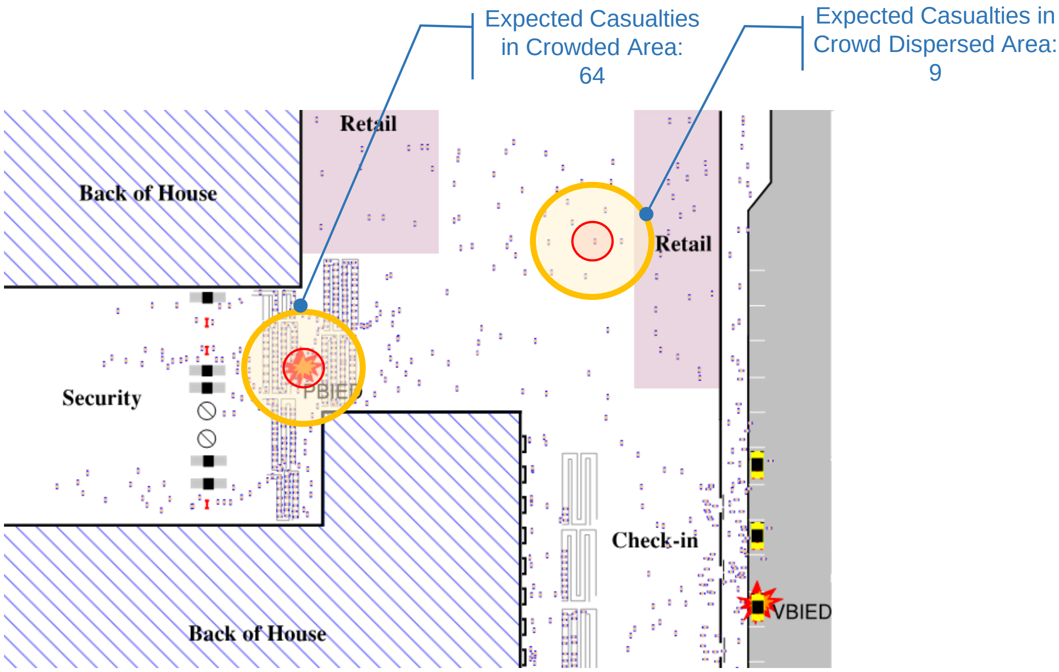
Type of Passageway	Level of Service Standard (passengers/meter/minute)					
	A	B	C	D	E	F
Corridor (Regular Pace)	10	12.5	20	28	37	more
Stairs (Slow Pace)	8	10	12.5	20	20	more

For a given airport condition, pedestrian modeling combined with injury evaluation can be undertaken to determine the volume of passengers that may be vulnerable to a blast event. For example, due to effects of a blast wave itself (ignoring fragmentation), radii of casualties measured from the detonation point would be expected as shown in Table 4-15 and Figure 4-33 below. These calculations are based on UFC 3-340-02, but are only approximations, as injury is highly dependent on the explosive, the environment in which it detonates, and the body type. When overlaid on a pedestrian model, the reduction in vulnerability that occurs in a crowd-dispersed area is evident.

Table 4-15. Example Radii of Casualties due to Blast Wave for Typical PBIEDs

PBIED	Radius of 99% Threshold of Lung Damage	Radius of 50% Threshold of Eardrum Rupture
10 lbs	2.3 ft	16.7 ft
25 lbs	4.6 ft	23.3 ft
50 lbs	6.9 ft	29.5 ft
75 lbs	9.1 ft	34.1 ft
100 lbs	10.8 ft	37.4 ft

Figure 4-33. Example Vulnerability of Crowding



Global air traffic volumes are projected to double in the next 15 years (Airbus 2017). To meet the increasing demand, airports and airlines are continuously adapting their facilities and introducing innovative ways to process passengers. For some airports, it is simply a matter of providing more counters or security lanes for processing passengers; for airports where space is limited, they must adopt innovative and more efficient ways to process passengers.

4.4.1.1 Customer Service and Commercial Benefits

Passengers become dissatisfied and frustrated when they experience long wait times and crowding at check-in, security, or baggage claim. In addition to reducing the attractiveness of the target and potential of injuries and casualties from an attack or blast, reducing crowding in such areas makes for a better passenger experience. This results in more satisfied passengers, which have a positive impact on sales at retail offerings on the secure side of the airport. A study of over 300 airports showed that a 1% increase in passenger satisfaction delivers a 1.5% increase in non-aeronautical revenue (Airports Council International 2016).

A study carried out by DKMA concluded that by improving passenger experiences, passengers would spend 10% more time at the airport, would be twice as likely to shop, and would spend 7% more on duty-paid and 20% more on duty-free products.

4.4.1.2 Recommendations

The positive airport passenger experience is challenged by the security screening checkpoint, which is usually rated as the most stressful part of the airport experience. In addition to screening passengers, a secondary intention of the security screening process is to get people into the airside area as soon as possible. The advantages of this are twofold: faster access to retail areas that generate airport revenue, and the airside area is more secure than the landside areas of an airport. This can be achieved by discouraging people from lingering in higher risk areas, such as the landside retail areas and creating desire and incentives for people to move into the secured area.

Better passenger experience in the checkpoints can reduce levels of stress, which in turn can contribute to passengers' willingness to spend more money in retail areas, thereby generating higher non-aeronautical revenues. In another study, ICF calculated that by increasing passenger dwell times in airside areas by 10 minutes, the airport's revenues would increase by 12%. This dwell time can be increased in different ways; those relevant to this project are faster check-in and security screening processes.

The potential for crowd mitigation to potentially improve customer service and increase airport revenue is a key differentiator from traditional blast-mitigation strategies. It is recommended that crowd mitigation techniques be incorporated to reduce blast risks as part of an airport's holistic security strategy. This includes decreasing queues, dispersing pick-up points, and re-working layouts for meet-and-greet areas.

4.4.2 Departure Flow

The traditional check-in model consists of a group of staffed counters where passengers present identification, select a seat, obtain a boarding pass, and check their luggage. This process typically takes 2-3 minutes per passenger. IATA standards recommend a maximum wait time of 20 minutes at these counters for regular passengers, and under 5 minutes for premium passengers. For some low-cost carriers, wait times of more than 30 minutes are not uncommon. In this model, each counter may have ten passengers waiting during peak times.

The shift to automation has introduced self-serve kiosks to the check-in process. These kiosks can perform many of the check-in tasks that are traditionally performed by airline staff at counters, including seat selection and boarding pass printing. In an automated check-in process, only the passengers with luggage or with difficulties at the kiosks would need to visit the staffed counters. To encourage kiosk use, airlines often provide enough kiosks to maintain nearly free-flow conditions with close to zero queue time at kiosks.

Some airlines and airports go one step further and allow printing of bag tags for checked luggage at kiosks. Passengers then tag their luggage themselves and further reduce contact time at bag drop. Bag drop contact time at the infeed belt is reduced to simply scanning the boarding pass/bag tag and then placing the bag on the conveyor. This drastically reduces wait times and queuing, mitigating the risk of a blast.

4.4.3 Security Checkpoints

Currently, TSA requires that passengers take off their shoes and unpack certain items from their bags. To accommodate these requirements, there is a dedicated space in front of the x-ray machines for passengers to unpack and place their items into bins. Passengers are processed in series with each passenger waiting for the passenger in front to finish.

Automated screening lanes (ASL) differ from traditional lanes by providing multiple parallel divestiture areas. This allows several passengers to unpack simultaneously, which reduces the amount of time passengers need to wait before beginning the divesting process. In order to accommodate the multiple divestiture process, ASL lanes need to have larger divestiture and recomposure areas, and some ASL lanes are designed with additional tables or zones for recomposure. As a result, ASL lanes can reach up to 80 feet, while traditional lanes are typically 54 feet long.

Consider a theoretical case study of two different screening options. The first option uses traditional lanes and the second options uses ASL machines, both with a target of 10-minute maximum wait time. The demand applied to both options is constant, and the number of required lanes open is determined by a discrete event simulation. Passenger accumulation for option two is not lower than that of option one. This is because a faster lane can process more people within the 10-minute period.

In summary, ASL can help, but to get significant reductions in passenger accumulation, the maximum wait time target must be lowered.

4.4.4 Additional Crowd Reduction Measures

4.4.4.1 Staffing and Operations

Airport processors, such as check-in, bag-drop and security screening, are typically not fully staffed outside of peak times. During off-peak times, it is common for only a small portion of the facilities to be staffed. As peak hour approaches, staffing increases to respond to growing queues. However, this is typically a reactive process, meaning that there may already be a significant queue present before the passenger demand peaks. During the peak, queues may grow beyond the designated queuing space, which results in overcrowded areas.

One way to avoid overcrowding is to proactively staff the processors before the peak occurs. This will keep queues at a minimum before the peak hours, and the queues will remain within the designated queue space. Simulation models can be used to study the demand profile at the various processors and inform how to best balance passenger accumulation and staffing cost.

4.4.4.2 TSA PreCheck

At many airports, TSA PreCheck travelers can make use of dedicated security screening lines. TSA PreCheck is a trusted traveler program in which the traveler applies online and undergoes a background check. PreCheck passengers do not need to remove shoes, laptops, liquids, belts, and light jackets when going through security screening. PreCheck travelers usually go through a dedicated security lane, which can often achieve 250 passengers per hour, without requiring the larger ASL machines. This means that as more travelers qualify for TSA PreCheck, the same security facility and staffing level can achieve a higher passenger throughput.

4.4.4.3 Systems Approach with Passenger Simulation

Due to the nature of the airport system, many of the departure processes are coupled together. Passengers flow from one set of processors to the next. For example, if the check-in facilities of an airport are unable to meet the demand, there will be crowding in the check-in hall, and security will experience a lower demand. When the airport and its operators invest in upgrading check-in capacity, the crowding at check-in may dissipate, but security will experience a higher demand. Without a proper analysis of the entire departure flow, congestion may simply move to a downstream process.

Proper facility requirements can be calculated through a simulation study of the entire departure flow. A balanced facility can be designed to meet the passenger demand and manage crowding most effectively. Simulation can also help determine the optimal staffing levels throughout the day, during both the peak and off-peak hours.

4.4.5 Arrival Flow

4.4.5.1 Greeters Accumulation

Greeters are friends, colleagues, or family members of the travelers; they can also be limo drivers or other designated personnel for a traveler. They often wait at the arrival hall of the airport to meet their travelers. They accumulate in non-secured areas at the arrival levels of the terminal building and can potentially form large crowds.

To mitigate concentrated crowding of greeters at the passenger exit doors, some large international airports have installed displays in the arrival halls. These displays are linked to CCTV cameras that monitor the passenger exits from the secure areas. Greeters can watch the displays, which can be scattered in the arrival hall, rather than just at the passenger exits. This helps avoid large crowds in front of the passenger exits and improves flow.

4.4.5.2 Domestic Baggage Claim Carousels

In the United States, domestic baggage claim carousels are typically in the non-secure areas of the airport. Passengers typically wait up to 25 minutes at these carousels. Baggage claim is usually the only task domestic passengers need to perform when arriving at an airport if they have checked luggage. Domestic passengers will typically reach the carousels faster than their bags, which results in passengers accumulating at carousels while waiting for their luggage. A faster bag delivery time can result in passengers picking up their luggage more quickly, which would reduce crowding at the carousels.

Domestic baggage claim halls can be made more secure by limiting access to the public. For some airports, this can be a simple matter of placing security agents at the exits of the baggage claim halls. For others, it may require complex reconfiguration of the layout.

4.4.6 Traditional Analysis versus Passenger Simulation Model

Airport facility requirements can be calculated using traditional static calculation methods and planned peak hour volumes. These traditionally served airport planners before airport simulation became affordable. A thorough simulation of the departure and arrival flow of an airport can investigate the following phenomena that were not viable using traditional static methods:

- The effect of peak spreading and residual queues
- Passenger surge demands (e.g., multiple aircraft de-boarding or train de-boarding)
- Variable staffing levels
- Check-in counter sharing
- Greeter-passenger and passenger-bag matching

Figure 4-34 and Figure 4-35 show the arrival and departure passenger volumes during a planning day for a sample mid-sized airport.

Figure 4-34. Hourly Arrival Passenger Volume for Mid-Sized Airport

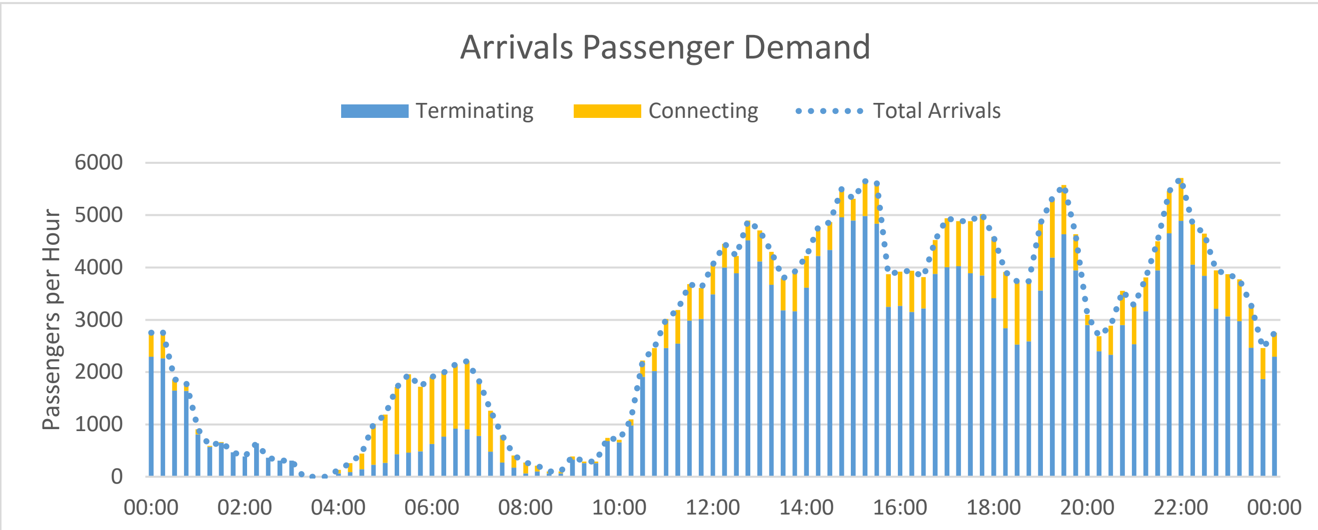
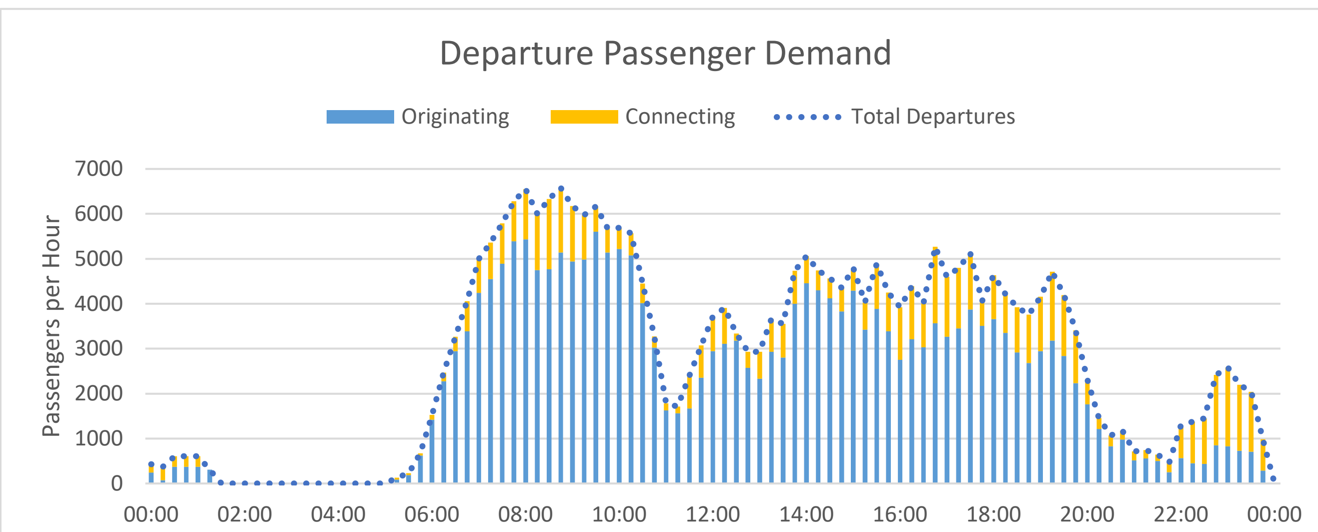


Figure 4-35. Hourly Departure Passenger Volume for Mid-Sized Airport



This type of demand reveals several characteristics about the airport:

- The airport predominantly serves its local population. The large percentage of Originating and Terminating passengers shows that most passengers at this airport either began or ended their trip at this airport. The other type of airport is a transfer hub airport, which serves mostly connecting passengers. Atlanta's Hartsfield-Jackson International airport is an example of a transfer hub airport. An airport with more originating/terminating passengers will expect more landside and non-secure traffic than a transfer hub airport of the same size.

- The main departure peak hour is in the morning. Many domestic US airports have a high departure peak in the morning. Each morning, most airlines aim to have their flights take off as soon as the flight crew is ready to fly, in order to achieve a high utilization ratio of their aircraft. This results in a “rush hour” in the morning that lasts 1–2 hours. The morning departure peak at this airport lasts over 3 hours. This may be an indication of a constrained operation, as there may not be enough runway or aircraft stand capacity to accommodate the morning peak, pushing departures into the late morning.
- There is a small arrival surge in the early morning, and this peak is mostly connecting passengers. As such, the airport needs to be staffed to handle this traffic. If the arrivals are international flights, transfer security and immigration need to be staffed to accommodate this surge in the morning.
- There is a small departure surge late at night, indicating departures of overnight red-eye flights. In the US, airports on the west coast tend to have a higher late-night departure peak, as they have many red-eye departure flights heading to the east coast.

In a simulation model, the demand level of the planning day can be studied closely. Nuances in the passenger demand and facility plans can be scrutinized to determine potential shortfalls in the facility. Passenger crowd levels can be monitored in the simulation model, and the resulting level of service of the facility can be predicted with sufficient time to adjust the plans and designs.

The planning day is often not the same as the busiest day of the year. Instead, the planning day represents a typical busy day at the airport. Depending on the airport, the planning day may be the 95th percentile in daily traffic, or it may be the day with the 30th busiest hour of the year. Airport planners often use the planning day to design airport facilities, and accept a lower level of service during the busiest days of the year (Thanksgiving, Christmas, and New Year’s Day). In these cases, passenger simulation modeling becomes especially useful in predicting how the facility will perform and the amount of crowding that will occur in various parts of the airport.

This leaves airports with greater vulnerability to attack on the busiest days, such as holidays. Airports should offset this vulnerability by managing risks through other measures such as operations. This is one of the key principles of the framework (explained in Section 5).

4.4.6.1 Ground Transportation

There are often many ways to access an airport, including personal vehicles, taxis, buses, subways, and dedicated express rail. For the access modes provided by public transportation, there is a tendency to design the stations and platforms like a typical terminal station. However, it is important to understand that travelers at the airport often have carry-on and checked luggage, and passengers require more space and are less maneuverable. The design parameters for the stations must reflect these realities.

For large airports, the vertical circulation cores connecting the ground transportation hub and the levels of the terminal building can be complex. Pedestrian congestion models are useful in determining the level of crowding within the ground transportation hubs and at critical vertical circulation cores. Using these models, it is possible to determine which facility will experience passenger flow congestion, and at what time of day it will occur. It is also possible to test any proposed solutions, which may be in the form of additional escalators or elevators, widening of corridors and platforms, or relocating any of the existing components. A passenger flow simulation model can be used to inform a holistic security strategy whereby operations and technological measures are put in place to address predicted times of heightened crowding.

4.4.6.2 Curbside and Vehicle Simulation

Airport groundsides are complex spaces with a wide variety of different vehicle types and users interacting in a shared zone. During the planning of airport construction or refurbishment, vehicle simulation is often used to plan lane access and allocation for various vehicles.

It is possible to test various design scenarios to determine vehicle queue lengths, delays, and likely overflow space required. Solutions and mitigation strategies can then be tested. These vehicular simulation models can also inform pedestrian models of groundside areas by determining likely crossing delays.

4.5 Architectural Design Measures

Architectural design measures are best incorporated in new projects where designed-in solutions can be more easily accommodated. This is most important for those strategies that are considered “big picture” such as airport planning and layout; however, “small picture” considerations such as construction materials and furniture selection can also reduce risk, especially for existing airports. This section mentions a few of these architectural strategies that can help reduce blast risks.

Big picture considerations include:

- Roadway layout
    - Design roadways with curves to limit the maximum speed that could be achieved by an attacker.
    - Separate roadways for the public and staff, as well as roadways for authorized vehicles that need to access the loading dock. This way, appropriate access control measures can be incorporated for different types of use.
- Do not locate critical utilities in landside areas vulnerable to explosive attacks, or otherwise provide redundant systems. The minimum standoff distance from utilities to vulnerable areas should be based on the specific DBTs for a particular airport, and the impacts to the construction of that airport. Specifying a one-size-fits-all standoff distance could not ensure a specific performance objective is achieved. There is guidance in government-based criteria, but this guidance is based on the DBTs identified by those government agencies as risks to their particular facility types.
- For a new build, the loading dock should ideally be isolated from the terminal building or otherwise located to minimize impacts of an explosive incident on airport operations.
    - However, in many cases of existing buildings or airports with space constraints, there are many security measures that can be implemented (e.g., access control, vehicle screening, visual inspections, etc.) to reduce risk such that it is possible for loading docks to be located closer to or near critical assets. The framework process in Section 5 can help identify measures for the loading dock, which may result in enough risk reduction that location of the loading dock becomes less critical.
    - It is typically good practice to include a frangible (i.e., allowed to fail) exterior wall on the loading dock such that blast loads can dissipate rather than build up. This may not be necessary if the DBTs identified for the airport in consideration are small enough, or the construction of that particular loading dock can tolerate the blast loading.

- Terminal planning and layout, as they relate to crowd dispersal and management: greeter, check-in, and baggage claim areas can be configured using pedestrian modeling to reduce choke points where crowds or queues could be funneled.

Small picture considerations include:

- Ductile construction materials (i.e., metals instead of unreinforced masonry, laminated glass instead of monolithic for interior glass partitions and handrails, etc.) can be used.
- Critical structural elements can be protected by wrapping them with architectural cladding or furring to increase standoff against a PBIED (even a few inches provides benefit).
- Trash cans or other features that could conceal PBIED explosive devices should be located away from critical structural elements.
- Furniture in non-secure areas should be selected and placed to allow for clear vision and unobstructed lines of sight for patrols and CCTV to more easily detect suspicious objects. Design measures to mitigate other security concerns such as active shooter incidents may have conflicting requirements whereby locations for cover are needed; therefore, the risks of different incidents should be compared and managed on a case-by-case basis.
- Landscaping that reduces the risk of both VBIED and PBIED incidents can be incorporated. Landscaping should be integrated with the HVM strategy.

Refer to PARAS 0004 for additional considerations in terms of airport design for security purposes.

4.6 Elevated Threat Levels

There are some instances in which airport security must adapt to an elevated threat level. This could be due to intelligence information at a particular airport through local law enforcement or the airport's FBI liaison, or when the National Terrorism Advisory System (NTAS) scale issues an elevated, intermediate, or imminent alert.

Category X airports are required to have a TSA-approved Contingency Plan for VBIED threats. This section discusses methods for developing those plans for Category X airports, and considerations for other airports as to how to mitigate risks of elevated threat levels within their security strategy.

It is necessary to quickly deploy temporary solutions to mitigate the increased risk. Operational measures are almost exclusively required for fast deployment, but some technological and physical solutions can be incorporated relatively easily. To be prepared to respond quickly, airports should have a plan in place to adapt to this heightened threat level.

Airports may consider performing a risk assessment that is based on a heightened threat level (i.e., likelihood of threats would be higher, threat scenarios might be different depending on potential intelligence), and evaluating the threats and vulnerabilities that may exist in this heightened scenario. Mitigations can then be theoretically developed for these higher risks. However, the mitigations selected should be those that are needed to bring the airport from the current risk level to the higher risk level. Therefore, they should not necessarily include physical enhancements that are implemented to achieve that absolute level of risk mitigation, as these are permanent and may not be an efficient use of resources.

In the context of this guidebook, the framework process described within Section 5 can be used to support this effort. After mitigation measures have been selected based on the current risk assessment, they can be assigned as a baseline and then supplemented with additional strategies to evaluate the extra level of security that is achieved. It is most likely that this will result in an increase of performance tier for the baseline operational strategies (e.g., adding more EDC patrols to move from Silver to Gold) or the introduction of new operational strategies that are not incorporated into the baseline level of operations (e.g., adding behavior detection officers, or adding vehicle screening checkpoints).

To mitigate risks of a blast threat on an immediate or imminent basis, the following strategies can be considered in the airport's elevated threat plan, or contingency plan:

For VBIED:

- Provide vehicle screening checkpoints with guards
- Reroute traffic lanes away from the terminal using temporary barriers and traffic officers
- Assign staff to actively monitor CCTV for suspicious or abandoned vehicles
- Perform additional EDC patrols in areas with vehicles

For PBIED:

- Perform additional EDC patrols in areas with vehicles
- Increase armed law enforcement patrols (i.e., high visibility as a deterrent)
- Incorporate additional screening of individual measures (e.g., random) before entering the terminal
- Assign staff to actively monitor CCTV for suspicious persons or abandoned luggage

Add staff to check-in and screening to move passengers more quickly to the secure airside

SECTION 5: IMPLEMENTATION

This section examines the feasibility of the measures discussed in Section 4 and facilitates the development of a blast-risk-reduction strategy consisting of a combination of blast-mitigation measures.

The following sections present a framework process to assist airports in evaluating these considerations. Airports should follow the decision-making process outlined in Sections 5.2 through 5.5 to determine which measures to implement and where. An Excel-based tool and corresponding instructions for carrying out the framework accompany this guidebook. Furthermore, two case studies are presented within Appendix B.

Once an implementation strategy is realized, the risk-reduction value can be observed. This will consider both how much the strategy reduces the risk(s) and what the non-risk-related implications of measures might be. Implications may include whole of life costs, disruption required to implement, time to realize value, operational and infrastructure changes required to implement the measures, and impact on priority business objectives like passenger experience and architectural objectives.

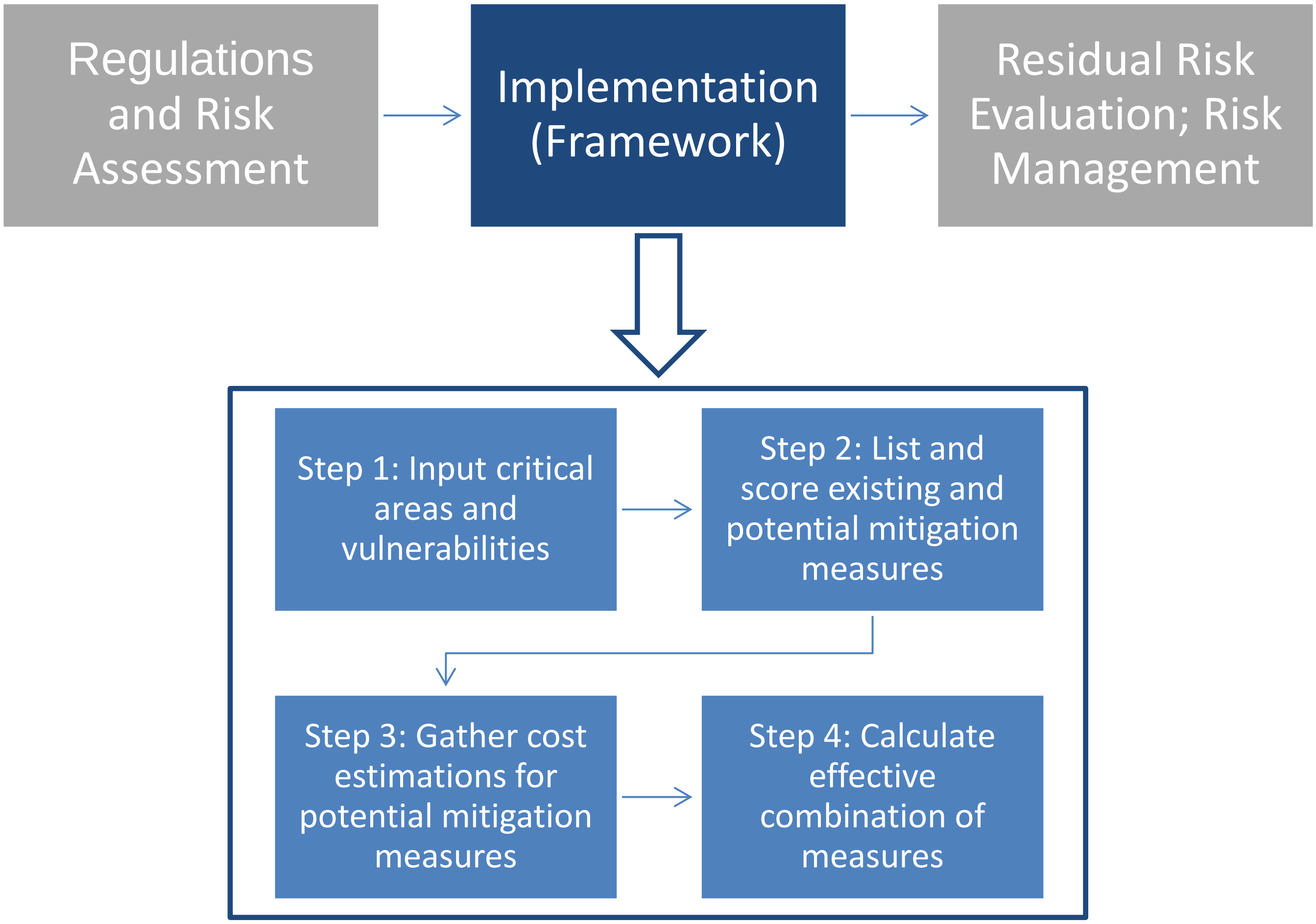
5.1.1 Framework Objective

The framework is a process for identifying cost-effective security measures that mitigate blast risks to an acceptable level. Figure 5-1 shows how the framework process fits into an airport's overall risk management process and outlines the four steps of the framework.

The framework is to be performed after a risk assessment that has identified credible blast threats, vulnerable locations to those blast threats, and the consequences of those threats. After using the framework process to determine viable combined security measures, the reduced or residual risk when the measures are implemented should be confirmed to be acceptable.

The framework is intended to be used following a robust security risk assessment process. It does not provide a method to identify risks, but attempts to methodically break down the risks and vulnerabilities identified and couple them with optimum mitigation measures.

Figure 5-1. Framework Process



5.1.2 Role of the Risk Assessment in the Framework

PARAS 0016 *Airport Security Vulnerability Assessments* is in progress as of the publication of this document. A security vulnerability assessment is a prerequisite to the use of this framework. A simple explanation and definition of the risk assessment process is included as part of this guidebook to provide the context for the framework used in selecting blast-mitigation measures.

Decisions regarding site vulnerabilities are a required input. For the purposes of demonstrating this framework, generalizations regarding vulnerabilities and risk appetite specific to life safety, commerce, and operations have been made within this section. The intent of the framework is not to substitute for a robust risk and vulnerability assessment undertaken by airports and relevant stakeholders.

When the risk assessment is conducted and it is agreed which risks need to be mitigated (based on risk appetite), the measures that will be relevant and effective in reducing the risk(s) can then be identified. In some cases, there may be more than one measure (or combination) that can reduce the risk, and a decision will need to be made to determine the most appropriate measures. The following are considerations that may be useful in making that determination:

- How much does each measure, or combination of measures, buy down the risk? (i.e., what is its return on investment?) It may be that one measure reduces the risk more than others but the reduction is far beyond what is necessary.

- Consider whole-of-life costs as well as the cost of other security resources/measures required to realize this measure's risk-mitigation value; e.g., active vehicle barriers will require operational resources such as a static guard or electronic access control passes to operate the barrier.
- Subject to the airport's financial management arrangements, funding may be sourced differently based on the type of measure, e.g., capital expenditure versus operating expenditure or grant versus self-funded. Additionally, and again subject to the airport's financial arrangements, the time at which the measure is needed versus the time within the financial year may be an influencing consideration.
- Time to realize the measure's risk mitigation value—in some cases, the implementation time is not feasible relative to the current need. For example, installing blast film on a facade may take up to six months (including procurement process), whereas the establishment of a standoff zone could take less than four hours.
- Impact on other business objectives, e.g., architecture, passenger experience, airport image, and non-aeronautical revenue.
- Impact on regulatory requirements, e.g., fire safety, health, and safety.
- Indirect benefits, e.g., improved wayfinding, pedestrian safety, reduced accidental incursion, and architecture.
- Relative ease or "hassle factor" to implement, e.g., rerouting of traffic, use of scaffolding, after-hours work, or incorporation into another project scope to enable works required.
- How available is the resource? Can the measure be achieved in-house or is external resourcing required?

The value or weighting of each of these considerations will be different for each airport and most likely in each circumstance. The framework is a process for decision-making that can be customized. This guidebook makes assumptions about the inputs in order to demonstrate the process. These or other factors can be customized into the framework process for a more unique assessment.

5.2 Step 1: Assessment of Vulnerabilities

As part of the risk assessment process, various landside areas of the airport may be identified as being vulnerable to blast threats. Step 1 of the framework is to take these vulnerable areas and classify the specific vulnerabilities into definitive categories. As a basis for demonstrating the framework process, three vulnerability classifications that could be exposed from a blast threat are as follows:

- Life safety
- Commerce
- Operations

Ultimately, these vulnerability classifications for various areas will be used to identify mitigation measures that have strengths for reducing a particular vulnerability type.

5.2.1 Life Safety

In most instances, life safety is the primary objective for the application of blast-mitigating measures in most landside airport areas. Simply, it is the ability of mitigation(s) to reduce or prevent the number of casualties or injuries from a potential blast attack. With regards to life safety specifically, the vulnerability of an area can be assessed on the basis of the following:

- Number of people
- Concentration of people
- Predictability with which the crowded places occur
- Exposure of the crowd to potential PBIED or VBIED effects

5.2.2 Commerce

Airports are inherently businesses; the ability of mitigations to reduce the commercial impact on the airport's business is important in enhancing the resilience of the airport's business. The commercial vulnerability of an area is assessed on the basis of the following:

- Proximity to areas that generate airport revenue such as a parking garage, tenancies, shops, etc.
- Proximity of areas that contain or house infrastructure or equipment
- Reputational loss
- Financial replacement cost

5.2.3 Operations

While in some ways tied to the commercial aspect of an airport, the airport's ability to restore its operational function is a key objective following a blast event. Evacuation, rescreening, airport shut downs, and flight delays have large economic consequences for the airport, airlines, passengers, and the region. With regards to operations, the vulnerability is assessed on the basis of the following:

- Disruption to flight schedules – delay or cancellation of flights
- Proximity to critical infrastructure and equipment necessary for airport operation
- Proximity to airline areas of operation
- Disruption to transport modes to the airport
- Disruption of evacuation and recovery procedures for an airport
- Lack of redundancy of any area, system, or equipment critical to airport operation

5.2.4 Managing Vulnerabilities

Any decision-making process regarding the allocation of blast-mitigating measures should consider the applicability of those measures to reduce the landside area's vulnerability. The vulnerabilities of two very different landside areas at a theoretical airport have been used as an example. These are theoretical weightings, and it is expected that vulnerabilities for a particular airport would be based upon a risk assessment process.

As shown in the example, the arrival and departure halls are largely vulnerable to life safety given the density and frequency of crowds. However, the fuel farm is largely vulnerable to operational considerations, with fuel a necessity for aircraft flight. It would therefore be expected in this instance that mitigation measures for a blast would differ substantially between the two areas.

To complete Step 1, identify these weightings for each vulnerable area using ratios. Noting that the example ratios can be modified to suit a particular airport, in the example above, this would be as follows:

Table 5-1. Example Vulnerability Weightings for Theoretical Airport

Vulnerable Area	Life Safety Weighting	Commerce Weighting	Operations Weighting
Arrival and Departure Halls	0.85	0.05	0.10
Fuel Farm	0.05	0.35	0.60

Table 5-1 demonstrates default vulnerability weightings for a number of landside areas of a theoretical airport. These vulnerability weightings are used in the framework (Step 2) to identify mitigation measures that have strengths in mitigating against certain vulnerabilities.

The vulnerability weighting of the arrival and departure halls and fuel farm have been graphically shown within Figure 5-2.

Figure 5-2. Example Vulnerability Assessment, Arrival and Departures Hall (left); Fuel Farm (right)

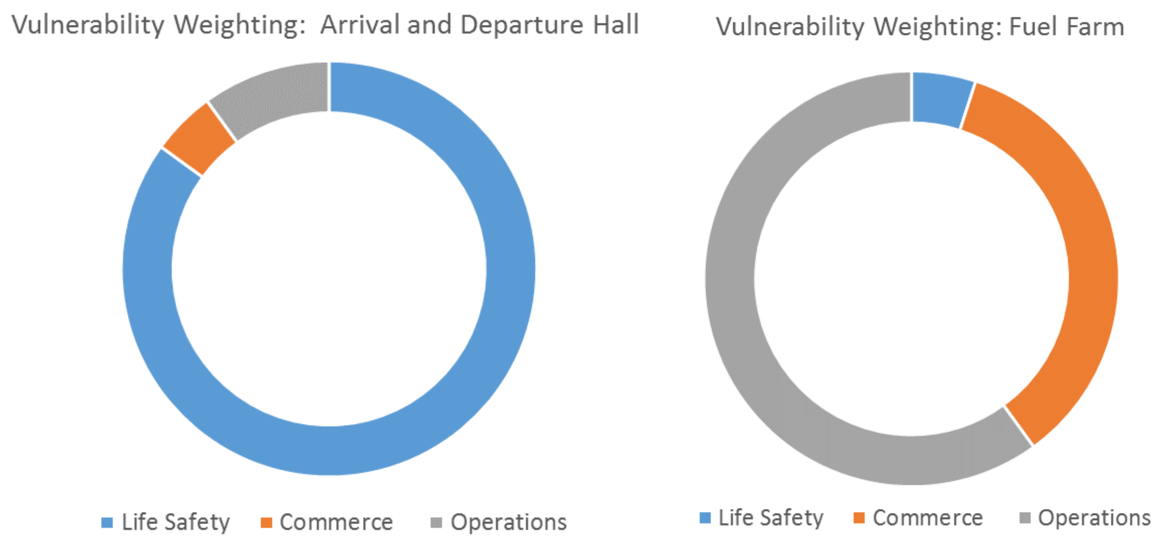
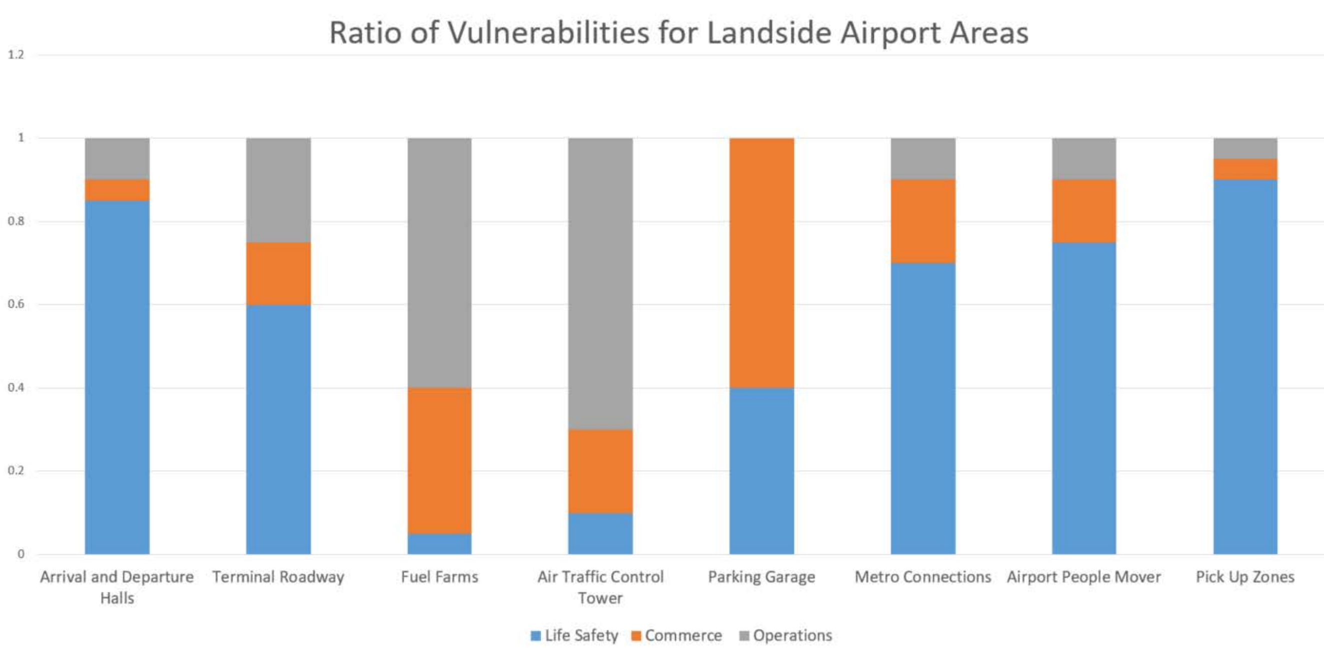


Figure 5-3. Vulnerability Weightings for Various Areas of a Theoretical Airport



In addition to the landside areas shown in Figure 5-3, the following areas may be considered in the airport's risk assessment process:

- Emergency electrical or mechanical areas, e.g., generator or switchgear and cooling systems for server rooms that support critical electrical systems
- Rental car facility
- Loading dock

5.3 Step 2: Assessment of Measures

Step 2 of the framework encompasses three parts:

- List: Cataloging a "shopping list" of security measures available to reduce the likelihood or consequence of a blast attack at each vulnerable area.
- Classify: Classification of the listed measures under the previously defined vulnerability categories: life safety, commerce, and operations.
- Score: Evaluation of existing-measure performance tiers and desired level of new-measure performance tiers (if applicable).

5.3.1 List

Compile a list of measures applicable to each vulnerable area that ideally includes physical, technological, operational, and architectural/crowd-management measures. Some example measures for consideration on the list were discussed in Section 4. The lists should include measures that currently exist, if any. The lists should exclude measures that are not feasible to implement or not applicable for a particular area. For example, within the departure hall, an airport may exclude a new blast-resistant facade or structural enhancements if terminal construction was just completed. As another example, an airport would exclude a new blast-resistant facade from consideration at the fuel farm, where it is not applicable.

5.3.2 Classify

This step will ensure that when combinations of measures are created in upcoming Step 4, measures are selected based upon their suitability for mitigating the particular vulnerabilities of the area in question. For example, this process will eliminate behavioral detection as a measure for fuel farm areas. To complete the measure classification, classify each listed measure with respect to the three vulnerabilities if it achieves one or more the following:

Life Safety: Mitigation measures should aim to reduce injuries and fatalities to passengers and people within landside areas. This can either achieved by preventing the attack from occurring or reducing the consequence of a blast event.

Commerce: Mitigation measures should aim to reduce the commercial consequences from a blast attack such as investor value, cost of recovery, cost of operational disruption or opportunity cost of future additional security measures. This can be achieved by either preventing the attack from occurring or reducing the consequence of a blast event.

Operations: Mitigation measures should aim to reduce the period in which the airport is operating in crisis-management mode and to improve the efficiency and effectiveness of the recovery period before returning to normal operations following an attack. This includes minimizing damage to assets, business continuity preparedness, incident management, and assisting in the emergency response.

For example, EDCs are classified as a life safety measure because they aim to proactively detect suspicious persons and neutralize them, thus potentially preventing an attack from occurring and mitigating the life safety vulnerability. EDCs are typically deployed within areas of crowds and, therefore, are not considered a commerce or operational-driven mitigation measure.

Table 5-2 lists and classifies mitigation measures under the vulnerabilities of life safety, commerce, and operations.

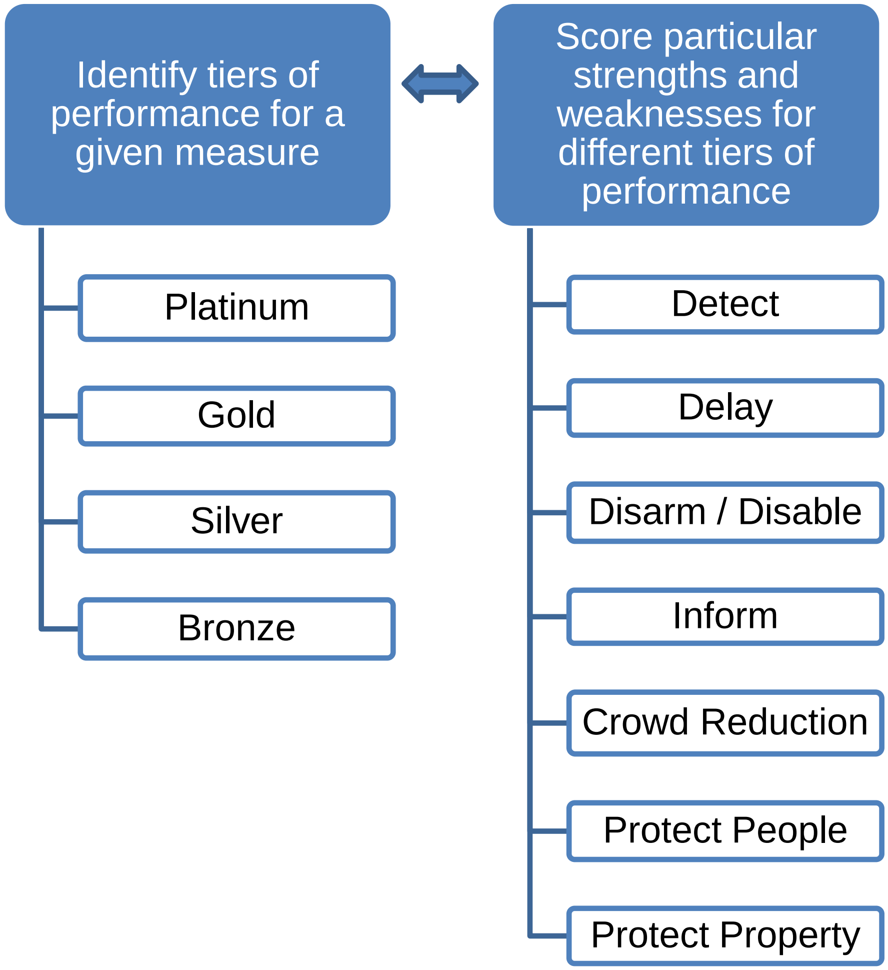
Table 5-2. Mitigation Measure Classification

Life Safety	Commerce	Operations
• Terminal Finishes and Furniture • Hostile Vehicle Mitigation (HVM) • Structural Hardening • Facade Enhancement • Security Patrols • Explosives Detection Canines (EDC) • CCTV • Screening of Individuals • Crowd Reducing Measures • Vehicle Checkpoint and Screening • Behavioral detection • Changes to passenger behavior and habits • Evacuation procedures and emergency response • Advanced Passenger information	• Hostile Vehicle Mitigation (HVM) • Structural Hardening • CCTV • Security Patrols • Vehicle Checkpoint and screening • Access control	• Hostile Vehicle Mitigation (HVM) • Evacuation procedures and emergency response • Structural Hardening • CCTV • Facade Enhancement • Security Patrols • Vehicle Checkpoint and Screening • Communication techniques • Security management systems • Business continuity preparedness

5.3.3 Score

Scoring requires evaluating the performance of each measure and assessing how its performance is effective in mitigating a blast threat. This comprises two factors that are interrelated as shown in Figure 5-4.

Figure 5-4. Tiers of Performance and Scoring



This step can be customized to identify performance metrics that are important to that airport. More formally, to encompass the sliding scale of a measure's performance, measures are divided into four tiers — Bronze, Silver, Gold, and Platinum. Each tier of a measure is determined based on a subjective incremental score for various security metrics (e.g., ability to detect, ability to protect, or aesthetics), with Platinum levels representative of very best practice. It is expected that a Platinum level of performance carries a higher cost than a Bronze level of performance.

The tier approach is intended to draw out the relative merits and implications associated with each risk mitigation measure on the "shopping list" rather than an absolute and actual/guaranteed reduction in risk. The model is purposefully idealized for ease of use, but with that comes the inability to capture all the complexities associated with operating an airport in a rapidly changing threat environment. For example, the effectiveness of a security guard measure is dependent upon organizational culture, which will be unique to the airport, the guard company, and potentially the locations to which guards are deployed (e.g., terminal versus fuel farm versus tenants). This will need to be considered by the airport, hence the need for the airport to calibrate the framework model when using it. The model is designed to provide airports with a greater insight into the implications and value of the various risk reduction measures so they can in turn make investments that are better aligned to their risk appetite and business objectives.

Following is a worked example of this step using HVM (as a stand-alone measure) and its effectiveness across multiple security metrics shown graphically within Figure 5-5. In relation to the definition of these levels for HVM, please refer to the broad definitions contained within Table 5-3. These definitions have been formed by weighing cost and performance using professional opinion of already established measures. It should be expected that a Platinum level of HVM performance carries a higher cost than a Bronze level of performance. These tables have been developed for all proposed mitigation measures and are shown in Appendix A.

Table 5-3. Definitions for the Various HVM Tiers of Performance

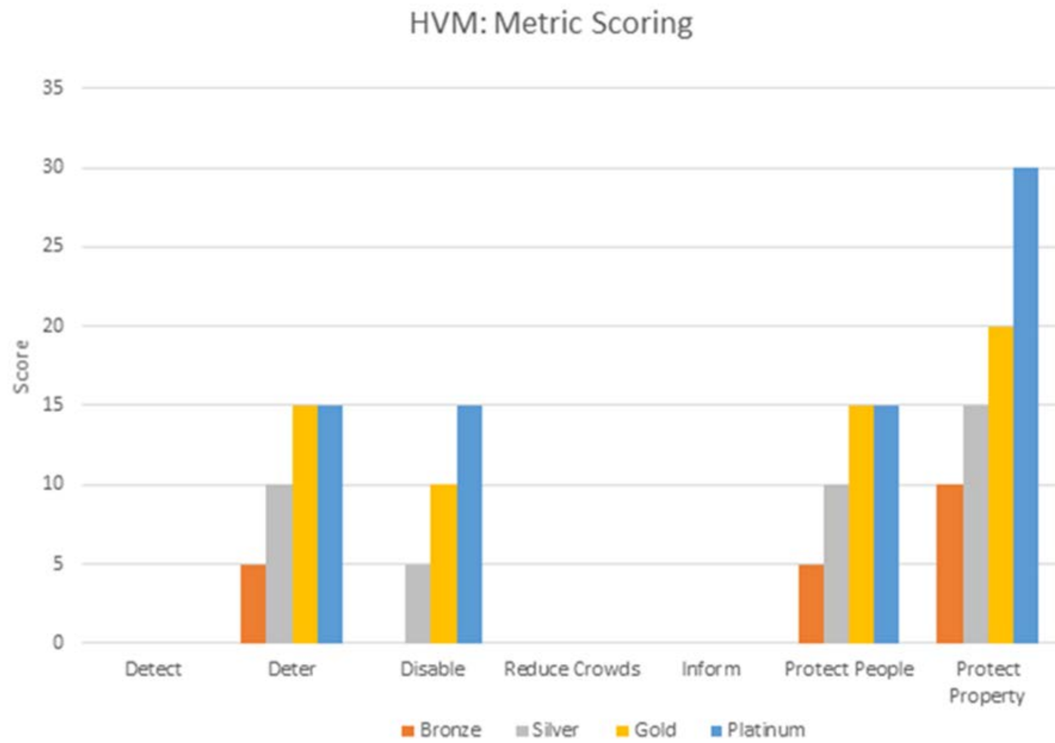
Hostile Vehicle Mitigation	
Tier	**Description**
Bronze	Provides visual deterrent with limited vehicle physical impairment. Following impact with hostile vehicle, vehicle speed largely consistent, leaving the vehicle drivable. Examples include architectural bollards and raised curbs.
Silver	Provides visual deterrent with moderate level of vehicle physical impairment. Following a collision, a vehicle will sustain heavy damage but may still be drivable. Barriers are generally untested for hostile vehicle impact. Examples include jersey barriers, trees, street poles, and street furniture.
Gold	Provides visual deterrent with high level of physical impairment. Barriers have been assessed using engineering calculations and analysis. Does not have the impact and penetration assurance compared to a barrier that has been impact tested.
Platinum	Provides visual deterrent and significant physical impairment. Barrier is impact rated to ASTM, DOS, IWA, or any other industry-recognized standard. Barrier has a suitable vehicle penetration performance.

Using the scoring metrics on the right side of Figure 5-4, Step 4 of the framework will select combinations of measures that complement each other. For the framework to achieve this, measures need to be assigned subjective values to distinguish their means of providing blast mitigation and their impacts (i.e., ability to deter a threat, ability to detect a threat, adaptability/flexibility, aesthetics, etc.). An example of what is required for each measure is shown in Table 5-4 and Figure 5-5 for HVM.

Table 5-4. Default Effectiveness Scores for the Various HVM Tiers of Performance

Tier / Score	Detect	Deter	Disable	Inform	Crowd Reduction	Protect People	Protect Property
Bronze	0	5	0	0	0	5	10
Silver	0	10	5	0	0	10	15
Gold	0	15	10	0	0	15	20
Platinum	0	15	15	0	0	15	30

Figure 5-5. Scoring of Hostile Vehicle Mitigation as a Blast-Mitigation Measure



Additional default scores have been developed for several mitigation measures and are included in the Excel-based tool that accompanies this guidebook. The scoring can be customized, but the default scoring is based out of 100, whereby 0 means a measure has no contribution to the performance metric and 100 means a measure completely achieves that performance metric (i.e., a Detect score of 100 would mean the threat is detected 100% of the time). Using this scoring system, none of the default values inputted for measures exceed a score of 40. This is because none of the measures on their own can achieve such high performance. This is an important realization of managing security mitigations and should be considered carefully by the user before implementing.

5.4 Step 3: Financial Costs

Step 3 is to prepare a rough order-of-magnitude (ROM) cost estimate of the various mitigation measures. To accurately compare capital and operational costs, these estimates should consider total life costs. The estimate should account for the costs of the measure over all four tiers, or at minimum over any tiers that the airport wishes to assess.

The aim of this exercise, together with the scoring of mitigations, is to provide airport operators or stakeholders a methodology to put forward a simple business case to implement security measures. This financial exercise is by no means exhaustive, and is targeted to make educated financial decisions regarding security.

To compare the expense of measures that have capital costs (one-time investment) to measures that have operational costs (recurring every year), Net Present Value (NPV) calculations should be performed. As a default, the following assumptions can be used when combining the costs:

- Structural costs (assumed to recur every 25 years)
- Major capital costs (assumed to recur every 10 years)
- Minor capital costs (assumed to recur every 4 years)
- Operational costs (assumed to recur every year)

To apply costs to the framework, costs are only required for the measure tiers that the airport wishes to consider in the process. However, it is beneficial to include more measures, tiers of measures, and associated costs, as a greater number of measure combinations can be assessed during Step 4.

Example measure ROM costs are provided in Appendix C. The estimate is based on a medium-sized airport and medium-sized city within the United States. This would include airports and/or cities like Pittsburgh, Austin, New Orleans, etc. A factor can be used to translate the baseline estimate to large cities (such as New York, San Francisco, Chicago, etc.) and conversely to small cities (such as Fresno, Syracuse, Wichita, etc.) Factors for these examples are provided in Table 5-5. Because costs can vary significantly by location, the relative cost difference of various measures should be assessed when using the baseline data. The cost estimate does not include design costs, but only construction or operation costs.

Also, note that this document is not dynamic; the cost data provided in this assessment was completed during the beginning of 2018. There are many assumptions incorporated into the cost estimate. It is meant to provide a relative reference between costs of different measure types, and it should not be used to make explicit decisions about an actual project.

Table 5-5. Factors to Apply to Baseline Cost Estimate for Example Cities

Large City Airports			Small City Airports		
New York	San Francisco	Chicago	Fresno	Syracuse	Wichita
155%	142%	130%	116%	94%	71%

In continuing with the above HVM example, Table 5-6 shows example ROM costs for constructing HVM at a medium-sized airport. To determine this, a security or blast engineer and potentially civil engineer would need to be consulted to identify which type of HVM measure is to be implemented, where it should be implemented, and any construction issues.

Table 5-6. Example ROM Costs for HVM

Tier	ROM Cost
Bronze	$390,000
Silver	$520,000
Gold	$1,001,000
Platinum	$1,300,000

5.5 Step 4: Effectiveness of Measure Combinations

Step 4 is the last step whereby all the information is consolidated for the purpose of decision-making. Effective combinations of security measures are selected for review and cost comparison. Step 4 needs to be completed separately for each vulnerable area in question.

Each time Step 4 is performed for a vulnerable area, each existing measure should be assigned the appropriate tier for its current state. For example, when considering the departure hall, an airport may have jersey barriers that separate the traffic lanes from the pedestrian space. The departure hall HVM could be assigned a tier of Silver but no costs associated. For measures that are not currently existing but are desired or known, a different tier can be selected and costs associated with it.

The calculation in this step will identify if effective measure combinations at the departure hall include a Gold or Platinum level of HVM, thus indicating if improvements to the current state of HVM should be considered.

While all of the mitigation measures presented within this section serve to reduce the blast risk, they do so in various ways. Consistent with the traditional layered security approach, this proposed framework attempts to capture a range of security objectives that act against the threat itself and/or its consequences. The outcome of this methodology is to provide a basis for security investment spending across multiple potential and feasible (for that airport) mitigations to achieve the desired security and business outcome.

As the number of measures increases, an automated process is needed to support the model. The accompanying Excel-based tool includes this process; customization of the tool is necessary. **While a qualitative approach has been used to calculate and illustrate the relative merits of security measures, the resulting functional security score itself does not have quantifiable value. The scoring instead keeps track of the qualitative assessments of measures.**

Once the functional security scores are calculated, the decision-making can be evaluated. Figure 5-6 shows an example output of such an assessment. Each blue dot represents a combination of various security measures for a particular vulnerable area. The combinations plotted in the lower left likely include only one or two measures, so therefore they are relatively inexpensive and less functionally effective (low functional security scores). On the other hand, the combinations plotted on the top right are the most expensive, but also the most effective (high functional security scores).

Figure 5-6. Example of Combined Mitigation Measure Output

As an example exercise, if an airport has a budget of $60 million, the most cost-effective, relevant measure combinations for the departure hall are shown graphically within the red circle in Figure 5-6, acknowledging there is a degree of error and subjectivity to the measures rather than being an absolute quantitative assessment. The airport would then evaluate the measure combinations within that red circle to determine if any of them meet their blast risk objectives for the departure hall. Comparisons can also be made between expenditure splits (physical, operational, and technology) of all measures under consideration as shown within Figure 5-7.

Figure 5-7. Example of Expenditure Splits for Security Combinations under Consideration

Taking a broader view of the framework and applying it to various types of airports, relationships or patterns can be made on the various optimum splits of combinations. For example, Figure 5-8 and Figure 5-9 illustrate two theoretical outcomes for both an example new and an example existing airport. For a given cost, two potential combinations of measures have been evaluated. While the new and existing airports pose very different breakdowns of measures as would have been listed during Step 2, their overall resulting functional security score is similar. Not surprisingly, the idealized new airport had a higher weighting of physical measures, whereas the existing airport favored operational measures. It should be noted that within the framework process, crowd-management techniques are considered to be operational strategies.

Figure 5-8. Breakdown of Mitigation Measures (Vulnerability-Based): Example New Airport vs. Example Existing Airport

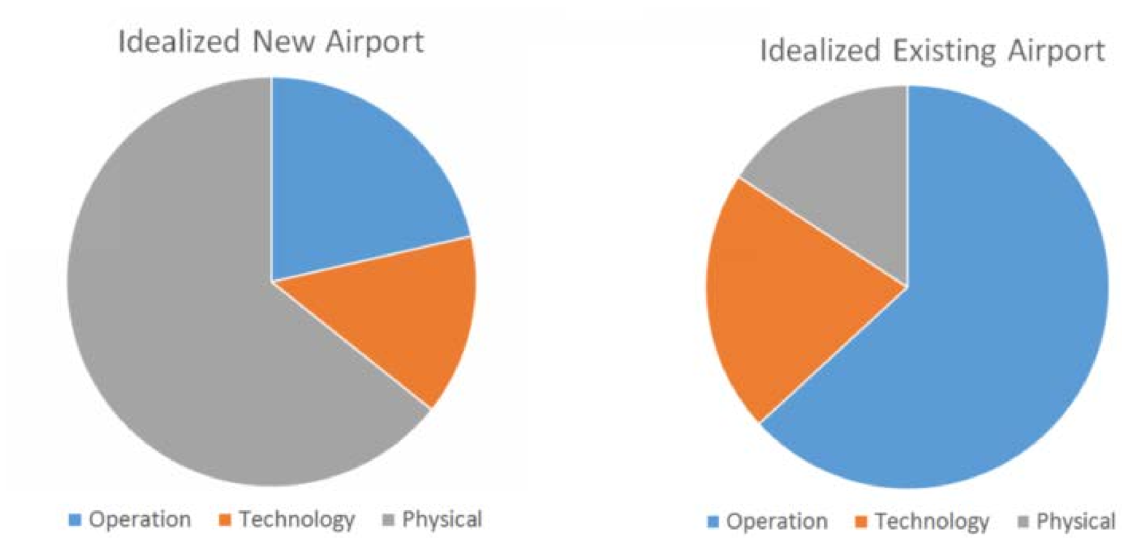
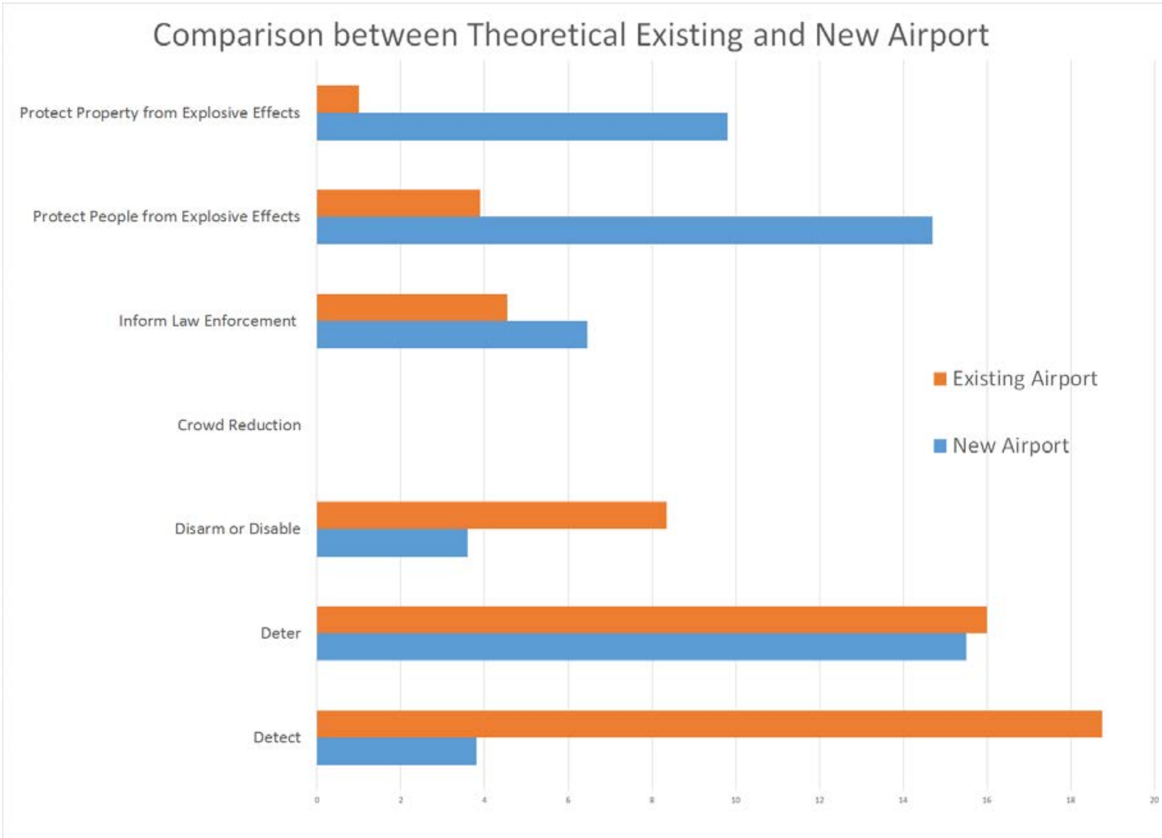


Figure 5-9. Breakdown of Mitigation Measures (Metric-Based): Example New Airport vs. Example Existing Airport



Once the effective measure combinations have been assessed, the airport would select which mitigation measures to employ in that particular vulnerable area. This concludes the framework process (middle box in Figure 5-10). Returning to the overall risk-based process, the airport would need to confirm that the implemented measures have reduced the risks and have been managed appropriately.

Figure 5-10. Summary of Framework Relationship to the Risk Assessment Process

The entire framework procedure (Steps 1–4) needs to be repeated for each vulnerable location in consideration. Refer to Appendix B, which demonstrates a case study of the framework's application.

Not included in this process, but an important concluding note, is that identification of the security strategy on paper is different from its actual implementation; by design, the strategy can only be as good as how it is implemented by the responsible managers and staff. The framework process should provide a sound basis to start from, but it does require some level of subjectivity by those implementing it; refinement and modifications to the outcomes of the framework are undoubtedly required. Furthermore, the strategy's effectiveness in operation should be evaluated and re-evaluated on a regular basis to make sure the strategy is working as intended.

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ABBREVIATIONS, ACRONYMS, & INITIALISMS

ADRM	Airport Development Reference Manual
ASCE	American Society of Civil Engineers
ASF	Anti-Shatter Film
ASL	Automated Screening Lanes
ASP	Airport Security Program
CAPPS	Computer-Assisted Passenger Pre-screening System
CCTV	Closed Circuit Television
CFR	Code of Federal Regulations
EDC	Explosives Detection Canine
FAA	Federal Aviation Administration
FBI	Federal Bureau of Investigation
FHWA	Federal Highway Administration
FoH	Front of House
HVM	Hostile Vehicle Mitigation
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IED	Improvised Explosive Device
IP	Internet Protocol
IT	Information Technology
FEA	Finite Element Analysis
FOV	Field of View
LiDAR	Light Detection and Ranging
MDOF	Multiple Degree of Freedom
msec	Millisecond
ONVIF	Open Network Video Interface Forum
PBIED	Person-Borne Improvised Explosive Device

PVB	Polyvinyl Butyral
Psi	Pounds per Square Inch
PSIA	Physical Security Interoperability Alliance
RC	Reinforced Concrete
ROM	Rough Order of Magnitude
SARP	Standards and Recommended Practices
SDOF	Single Degree of Freedom
SeMS	Security Management Systems
SSS	Structural Silicone Sealant
TATP	Triacetone Triperoxide
TNT	Trinitrotoluene
TSA	Transportation Security Administration
TVRA	Threat, Vulnerability, and Risk Assessment
UFC	Unified Facilities Criterion
UVSS	Under Vehicle Surveillance System
VACP	Vehicle Access Control Points
VBIED	Vehicle-Borne Improvised Explosive Device
VCP	Vehicle Control Post
VMS	Video Management System

APPENDIX A: EVALUATION OF MITIGATION MEASURES

ASSESSMENT OF VARIOUS MEASURES

Explosives Detection Canines

SUMMARY

Explosives detection canines may be used to detect explosives, illicit materials, or weapons within passenger bags or on the passengers themselves. The process is undertaken using specially trained dogs and handlers, and may be performed either by law enforcement agencies or by specialist contractors. The provision of the service should be incorporated within the wider security operation plan. It should be noted that when the service is provided by law enforcement agencies, it is they who dictate the provision and scheduling of patrols. When a private contractor is used, the asset operator has control over coverage and scheduling.

As a result of recent events, canines are being trialed by Istanbul Atatürk Airport to detect suspicious behavior. While this is not yet proven as effective, it is worth considering as a future operation that police may utilize.

There are more than 900 TSA canine teams deployed nationwide that are tasked with screening passengers and cargo, and supporting other security missions.

- In 2016, there were more than 200,000 canine utilization hours throughout the nation's transportation system.
- Canine teams work at more than 100 of the nation's airports, mass-transit, and maritime systems

CONSIDERATIONS

Asset owners may want to procure canine programs from external providers as the costs of such programs are extensive: approximately $35,000 for the dog and training and $6,000 annual welfare costs.

Key factors to consider when using explosives detection canines include:

- A single dog may operate for up to 8 hours per day with alternating on-duty/rest shifts of 30–90 minutes.
- Welfare and rest facilities (air conditioning, water, defecation) are required that may not be available in transport areas.
- Dogs are trained to detect specific scents; programs may take 15 weeks for explosives and 25 weeks for a broader range of chemicals.
- Detection canines can either be trained to detect illicit drugs or explosives, but not both.
- Conventional explosives detection canine handlers undergo a 10-week training course. Passenger screening canine handlers undergo a 12-week training course.

EFFECTIVENESS

- Dogs are able to detect explosive material through sense of smell rather than visual observations.
- Dogs can act as a deterrent.
- Explosives detection canines can be deployed on a risk basis and to new and existing terminals.
- Dogs can be deployed anywhere within the FoH areas.
- Dogs can be used for random searches.

- Dogs are effective in areas of patrol, depending on the number and frequency of patrols.
- Canine detection can be subject to handler biases.
- Dogs are normally trained to detect commonly used explosives such as TNT, C4, commercial dynamite and Semtex. As terrorists adapt with different devices containing household chemicals (e.g., TATP), the challenge of detection becomes harder.

Millimeter Wave Detection

SUMMARY

Millimeter wave (MMW) scanning constructs 3D scans by measuring how much of the radio signal is reflected. MMWs are able to penetrate through certain surfaces (such as clothing) and reflect off of others (such as metals). MMW systems have been adopted for use at airport security checkpoints, where a 3D body scan of a person may be captured without them having to remove their clothing. Some manufacturers may use microwaves to accomplish the same thing.

CONSIDERATIONS

- MMWs are considered non-ionizing, which makes them safer than x-rays. While there are still concerns about their overall safety given that they do slightly penetrate human skin, it should be noted that even humans naturally produce MMWs, enough to the point where scanners are able to now passively operate and not emit their own radiation.
- Earlier implementations of MMW scanners at airports would reconstruct an x-ray-like image of the person passing through, which caused concern that essentially nude images were being captured and stored. Current scanners forego complete reconstruction and instead usually only show possible locations of detected objects on a generic human body outline so that officers can further inspect.
- There has been work to extend the range of MMWs for use in surveillance cameras. Considerations for this include the possibility of needing an active MMW source with no natural emitting sources guaranteed to be in the camera's field of view.
- Outside of security, MMWs are being sought for use in communications networks, including cell phones and even autonomous vehicles. The reason for this is that the current bandwidth range is nearing saturation as more and more connected smart devices come into existence, whereas the MMW spectrum is relatively unused. There do not seem to be concerns over whether this will interfere with the current security screening technology, as the specific frequencies at which these different categories of devices operate can be regulated.

EFFECTIVENESS

- Along with the standard metal detectors, MMWs are commonly found at TSA security checkpoints. While the agency has deemed the systems' effectiveness to be suitable enough for their standards, there have been reports of individuals being able to smuggle through prohibited items.
- A new generation of devices aim to only detect large firearms and explosives while maintaining a high throughput. These systems use passive MMW sensing and project any areas of sensed disturbance onto an image captured of a person using a standard embedded RGB camera.

Stand-Off Explosive Detection and Mass Transit Metal Detection Equipment

SUMMARY

Walk-through equipment detects prohibited articles. Equipment is available that can detect anomalies on the human body, whether metallic or not, including plastic explosives, hot or cold weapons, drugs of various kinds, liquids, powders, gels, and other unauthorized items. The technology behind the equipment may include MMW and micro-power non-ionized radio waves.

This type of equipment can also be integrated with threat analytics platforms, where alerts provide assessment with classification information about the detected item overlaid on real time video, and updates via the cloud. Also, these systems can be integrated with facial recognition systems to identify known high-risk individuals.

Because there are no statutory requirements for screening at the terminal entrance, there is no legal obligation for a person to submit themselves for screening. In the UK, private security guards do not have authority to require persons to submit to a screening process or to undertake searches, so any search would have to be conducted with explicit consent of the individual.

CONSIDERATIONS

- This technology is costlier than walk-through metal detectors, and given that it is primarily intended for landside deployment, it is currently not required by regulators and therefore does not meet any existing aviation screening regulations.
- Detection is not limited to metallic objects.
- There may be higher maintenance costs.
- The technology requires staff presence to respond to alarms.
- These systems may occupy significant space, or airport’s existing infrastructure may not allow deployment.
- These systems require specific conditions to operate (e.g., operating temperatures), and therefore should be deployed inside the terminal entrance.
- The equipment may have a high false alarm rate and may not be suitable for permanent deployment at terminal entrance, where there is a high number of passengers.
- In poor weather conditions when passengers are wearing wet outer clothing, detection capability can be impaired.
- The equipment tends to be deployed at the terminal entrance, and while there may be some overlap with other security processes, the landside deployment is an additional layer that supplements other security requirements, including those for the passenger checkpoint.
- The operation of the equipment needs to be considered in conjunction with other security measures, and in particular with ConOps, which define the security process and the response to any alarm. The technical system to screen persons entering the terminal, the exact approach to its deployment, the role of security staff and law enforcement officers (LEO), in particular, relating to alarm response should be covered in a detailed ConOps document, development of which should involve all the relevant stakeholders.

EFFECTIVENESS

- 700 –800 pph throughput may be achieved.
- The systems provide ‘no pose’ screening, but the technology does not currently support multiple passenger walk-through as stand-off detection.

- Compared with other pre-entry screening processes, it may eliminate long queues, as it allows passengers to keep all their clothing on during the inspection—including coats, jackets, leather items, etc.— without the need to remove those items before entering the system and then put them back on after exiting.
- Most systems are portable and easy to install, and therefore can be effectively deployed on a random basis to provide a deterrence and detection measure.
- The equipment supports a wide range of deployment scenarios that may be applicable to all types of airports.
- Deployment of pre-terminal screening systems improves deterrence and detection capabilities, while blast hardening mitigates the impact and consequence of any attack.
- These systems may be preferable to use for staff screening rather than passenger screening. Passengers may carry other baggage that will trigger alarms if they go through the equipment. Further operational evaluation and experience may be required to establish false-positive alarm rates.
- The equipment provides an effective deterrence, but is unlikely to be a measure that can be deployed 24/7 at all terminal entrances because it could cause unacceptable delays and also create queues in public areas, which in itself would be a vulnerability.
- Some of the screening systems include facial recognition cameras. These can monitor persons going through the system and then scan databases against a watch list or employee database. This depends on the operator of the system having a suitable database with the right biometric, and/or having access to such a database. In the case of an employer list (for example, at a staff access post) this would probably be feasible, while in the case of a public entrance, owners of watch lists or relevant databases may not be willing/able to share them (even assuming the database includes the right biometric, such as facial recognition) and therefore, at this time, the potential for finding known terrorist suspects could be limited by the availability of databases to the system operators. However, the ability to integrate the screening process with a facial recognition system does exist. If the equipment operator was an LEO, the ‘access to database’ obstacle may be overcome, at least in part. System integrators are analyzing the potential for real time tracking of individuals through the terminal based on a range of biometrics, including facial recognition, and physical characteristics, such as walking gait.
- Response to any alarm is critical and needs to be set out in a detailed ConOps, to clarify whether the person should be stopped and the cause of the alarm verified, or tracked using technology or Behavior Detection Officers.
- Theoretically, the system could be deployed without staff and could operate discreetly, with alarms being sent to a control room and the person being tracked in the terminal, but this would depend on false/false-positive alarm rates.
- It would also depend on the availability and proximity of response agencies.

‘Known’ Vehicle Systems

SUMMARY

There are certain landside areas of an airport, that are dedicated for bus, taxi, or cargo drop-off, and that passenger vehicles are not permitted to enter. In some airports, the only measure in place to restrict access is signage. However, if a threat actor is planning a vehicle ramming attack, there are no physical or access control measures in place. An option using a combination of Automated License Plate Recognition (ALPR) and physical measures to manage and mitigate this may be viable.

ALPR can record and display the registrations of all vehicles entering or leaving a site. Vehicle screening system (VSS) cameras can record all other site activity, which can be viewed and controlled from a single location.

ALPR could be used for loading docks and pre-authorized vehicles, but the technology will only identify a specific vehicle registration. The vehicle and/or the driver/occupants may still present a threat.

Airport operators issue permits or passes to vehicles operating airside. Some airport operators may implement a known vehicle process that may involve issuing a landside pass. This may provide a degree of reassurance for vehicle status, but some airports do not recognize value in such programs on the basis that the system may identify vehicles but not necessarily the threat they may pose.

CONSIDERATIONS

- ALPR VSS also include options for capturing image and vehicle registration details to keep on record.
- ALPR will need to be used in conjunction with physical measures, such as hostile vehicle mitigation road blockers, barriers, bollards, or gates, to ensure a physical barrier.
- Sufficient space must be allocated for installing physical measures as well as ALPR systems.

EFFECTIVENESS

- These systems may prevent VBIED in car parking through deterrence.
- Passengers are required to register details before arriving and parking their cars.
- All airport employee vehicle details can be stored in ALPR database. This can be effective in preventing hostile vehicle ramming of critical infrastructure that employees can access.
- While ALPR can identify vehicles and individuals, it cannot validate capability and intent (e.g., a vehicle may be legitimate in the sense that it is ‘known’ but still contain a viable VBIED).

Vehicle Checkpoints

SUMMARY

Below are some examples of vehicle checkpoints on approach roads:

- Brussels airport employed trained behavior detection enforcement officers/soldiers for spotting suspicious vehicles on roads leading to the terminal drop-off.
- Ben Gurion Airport has a vehicle checkpoint.
- Other airports may also utilize vehicle checkpoints on approach roads, typically when threat and risk context requires an additional layer of protection. An example was Belfast International during the 1990’s when local PIRA activity posed a serious threat.

In these types of instances, the checkpoint may be manned by Police/LEO or military, and will be located a significant distance from the airport terminal. The actual process may vary according to the threat and risk (and also can be varied specifically to provide unpredictability), but may include:

- Driver and vehicle documentation checks
- Driver and vehicle searches (including underside and interior)
- Travel documentation

The process of searching vehicles is time consuming, so to process vehicles into airside, airport operators often compartmentalize each vehicle into five areas such as trunk, under hood, interior, glove box, and underside. This provides two variables to work with in changing threat and risk contexts: the number of compartments to be searched and which compartments are searched for each vehicle.

Airports can use Under Vehicle Video Surveillance (UVVS):

- This practice involves scanning underneath vehicles.
- It offers stand-off identification of suspicious items/objects that are attached to vehicles.
- Some UVVS technologies take a snapshot of the undercarriage of each vehicle and compare it to a database of undercarriages (based on model or previous snapshots of the same vehicle). If something is out of place, an alarm will sound.
- Gatwick Airport uses UVVS for four new lanes leading to airside, but this represents only one element of the vehicle security process. The technology can be integrated with ALPR so that vehicle registrations are checked in real time against a database of known vehicles.

CONSIDERATIONS

Vehicle checkpoints on approach roads:

- Vehicles are required to slow down as they drive on Brussels airport approach road. This is to allow officers/soldiers to carry out a non-stop visual inspection of the vehicle.
- If an officer/soldier notices anything suspicious, they can stop vehicle and ask for ID documentation.
- This practice may slow down traffic and cause congestion.

UVVS:

- These systems may slow down traffic and therefore cause delay (but this can bring a security benefit).
- A typical throughput speed is 18 mph.
- These systems can either be mobile, which may take around 20 minutes to deploy, or static, which is installed in a small pit in the entrance road.
- UVVS can be integrated with ALPR.

EFFECTIVENESS

- Vehicle checkpoints are extremely effective in deterring a threat.
- From an operational point of view, UVSS and vehicle checkpoints will disrupt traffic flows and may lead to congestion.
- Provision can be made for vehicle checkpoints on approach roads, and then they can be operational on a random basis, or when required by threat and risk assessment.
- As first point of contact with the airport for many passengers, a vehicle security checkpoint can be intimidating and create an adverse passenger experience.
- Vehicle checkpoints are facilitated if approach roads accommodate a dedicated lane for processing any vehicles that require secondary inspection.

- Trace detection on vehicles is an effective detection process that could be introduced into the vehicle checkpoint operation. (This is currently deployed at UK ferry terminals and the UK Channel Tunnel).
- UVVS will not detect threat items within the vehicle.
- Depending on space capacity on approach roads, it can be easy to deploy temporary vehicle checkpoints on approach roads (e.g., after March 2016 attacks, Brussels Airport deployed a vehicle checkpoint on the approach road leading to the terminal, where vehicles were asked to slow down and soldiers standing in between lanes visually inspected drivers to spot anything suspicious).
- Vehicle scans can be performed in either static or mobile configurations. The static system is a permanent deployment and is installed on or below the road surface. The mobile system is a rapidly deployable portable version that is integrated into a heavy-duty rubber ramp assembly. The static system is housed in a small pit in the road at the entrance to a security area. It can be easily retrofitted into existing search bays and is non-intrusive to the driver. The mobile system takes only 20 minutes to deploy. Durable and suitable for any temporary security measure, this technology can also be used for permanent installations where alterations to the road surface are not possible.

Advanced Communications Techniques

SUMMARY

The use of advanced messaging techniques can inform staff and passengers about security issues and potentially send a subliminal message about the (high) level of security at an airport. Posters in terminals/buildings with messages such as:

- "Undercover patrols are in use in the Terminal"
- "CCTV is working: if you can see this, we can see you"
- "This airport implements security measures that are both seen and unseen"

The use of coded messages and announcements encourages employees to be extra vigilant, without alarming passengers; this method is employed by some airports very effectively.

Other related methods include running a staff vigilance campaign.

CONSIDERATIONS

- These techniques are an extremely cheap mitigation measure.
- They promote a 'reporting' culture where all airport staff feel involved in ensuring security.
- Advanced communication techniques should be considered as part of a wider security culture initiative such as a Security Management System (SeMS).

EFFECTIVENESS

- These techniques may be extremely effective for deterring a threat.
- They can disrupt a hostile reconnaissance.

Security Management Systems (SeMS)

SUMMARY

This is more of a general security approach involving culture rather than a specific measure. A Security Management System (SeMS) is described as an organized, systematic approach to managing security, which embeds security management into the day-to-day activities of an organization. It provides the necessary organizational structure, accountabilities, policies, and procedures to ensure effective oversight. Its purpose is to enable an organization to identify and manage its security risks and be assured right up to Board level that the security measures taken to manage those risks are effective.

CONSIDERATIONS

The key components of SeMS include:

- Management commitment
- Threat and risk management
- Accountability and responsibilities
- Resources
- Performance monitoring, assessment, and reporting
- Incident response
- Management of change
- Continuous improvement
- Training and education
- Communication

EFFECTIVENESS

For security management to be effective, it has to be a continuous cycle that includes a threat and vulnerability assessment, the identification, capture, and analysis of risk, and the generation and continuous review of risk-mitigation plans. Risk is a dynamic area and will require continual review against an ever-changing threat landscape.

Changing Passenger Habits

SUMMARY

The aim of this approach is to look at methods to reduce queues and large gatherings of people in the landside/public area of the terminal and adjacent areas. This may include revising procedures for validating passengers for certain international destinations while waiting in the queue for check-in. Airport authorities, such as operators or security personal, as well as airlines, can help reduce queues significantly by reviewing and revising their procedures.

CONSIDERATIONS

The introduction of mobile technology means that more passengers are changing the way they plan their travel.

- There is an increased use of internet check-in, potentially resulting in less crowding at check-in desks as passenger go directly to the security checkpoint and into the airside area of an airport.
- There is an increased use of self-bag drop, which may mean there is less crowding at check-in desks. Possible use of off-site hold baggage check-in/drop-off should be considered.

- There is an increased use of remote bag-drop. Hong Kong International Airport has an in-town check-in. Airport Express travelers can check their luggage in town and then proceed to the airport bag-free. In-town check-in service is provided for any passenger with baggage where the total size does not exceed 58 inches (length) x 39 inches (width) x 33 inches (height) and weight not exceeding 200 lbs.
- A higher percentage of passengers have cabin baggage only (due to airline fees for hold baggage), which may mean less crowding at check-in/bag drop desks.

EFFECTIVENESS

- These techniques reduce the potential for mass casualties and deaths, as there is less crowding.
- These measures are more concerned with people security rather than airport infrastructure security. Most of these measures are customer service-driven, but nevertheless introduce a security benefit. All of these measures require airports, airlines, and other stakeholders to be involved. Processes that take place off-site can reduce the risk exposure.

Security Patrols

SUMMARY

Perimeter patrols serve as a deterrent to breach attempts, allow for identification of persons on the airfield who may have breached the perimeter, and enable inspection of the perimeter fence to locate where breaches occurred or were attempted.

It is a common practice for perimeter patrol to be carried out by security personnel, LEOs, airport operations staff, maintenance staff, or any combination of these groups. In some airports, operations staff may carry out perimeter and airfield patrol duties, while in others, security staff and LEOs are trained in and carry out some operations duties.

Where threat and risk context requires, airport operators will also arrange a security presence at pickup/drop-off zones to ensure that vehicles are not left unattended. In the United States, this is usually provided by airport staff, but may be supplemented by an LEO presence when required for traffic management. Occasionally, patrols and security staff presence is supplemented by signage and announcements to ensure that travelers are aware of the security requirements—but this is not always the case.

CONSIDERATIONS

- The patrol of large airports may take several hours and require getting in and out of the vehicle to ensure perimeter integrity. In some cases where airports use fencing that allows a vehicle to breach under the fence, the fence may return to its normal position so that a breach may not be noticeable.
- In some cases, portions of perimeter fencing must be inspected from landside due to factors such as wetlands and wooded areas.
- Inspection of fencing around terminals and other busy areas where cargo containers and other equipment are parked may require patrol observation from landside.
- In some very small airports, LEOs are required to be present at the passenger screening checkpoint, to patrol inside the terminals, enforce the challenge program, monitor vehicles at terminal curbsides, and patrol the Secured Area, which leaves little time for accomplishing multiple perimeter patrols during an individual shift.

- The presence of security patrols walking or driving up and down the pickup/drop-off zones to ensure that vehicles are not left unattended will add to the security costs of the airport. A more cost-effective method would be to limit the space allocated for pickup/drop-off zones.
- Pickup/drop-off and loading zones should be set as far away from the terminal as practical to minimize the blast effects of a vehicle bomb. Planners should consider the use of moving sidewalks or access to luggage carts to help passengers bridge the gap.

EFFECTIVENESS

- Airports are always seeking to optimize the patrol mission, and often use increased frequency, reconfiguration, and unpredictability of patrol tours in their efforts.
- Allocating enough space at pickup/drop-off zones to park a police car may act as a cheap measure of deterrence.

Terminal Finishes and Furniture

SUMMARY

Consideration should be given to the materials used for fitting out terminals (furniture, signs, check-in desks, etc.) to reduce potential damage in the event of an explosion. Heathrow's new Terminal 2 designed, manufactured, and installed all check-in and associated desk/counter furniture taking blast impact into account.

There should be no hidden places or corners where terrorists could place an IED (e.g., underneath or behind seats and couches). The use of Tensa stanchions should be reviewed; these may become a javelin in an explosion. Blast-proof protection may be built into separating walls and structures to reduce injuries and provide protection from active shooters.

The type and style of commercial offerings should take into consideration security requirements. The airport security and commercial departments should discuss the way the commercial offering is set up to limit possible damage from a bomb blast.

CONSIDERATIONS

Planners must ensure that furniture fixtures and fittings are suitable with existing airport infrastructure constraints.

EFFECTIVENESS

- Examples of these measures are compliant check-in counters and hybrid check-in counters, security preparation (liquid/aerosol/gels), furniture, signage and beacons, wall linings, passport control counters, retail frontages with bullet-resistant glazing screens, and immigration counters with swing gates.
- Copenhagen Airport uses blast-proof trash cans.
- Bomb-resistant trash cans and suspect package isolation units used by Gatwick Airport (at the new departure level).

Hostile Vehicle Mitigation – Physical Barriers

SUMMARY

Hostile vehicle mitigation is the practice of deploying measures to reduce risk of a vehicle-borne attack, both vehicle ramming and VBIED.

Measures most often considered are physical barriers. Barriers are primarily installed for the following objectives:

- Restrict vehicle access to authorized areas
- Prevent malicious vehicle ramming attacks on pedestrians or structures
- Maintain standoff when considering blast-load effects of a VBIED, thus reducing impacts to structures and people

Barriers are commonly concrete-filled steel bollards or concrete knee-walls, with robust reinforced concrete foundations. Other anti-ram features such as berms, planters, or trees may also be used, but unless they are specifically designed to resist malicious vehicle attacks, they may only provide a visual deterrent.

Crash-test certification standards, such as ASTM F2656, PAS 68 & 69, and IWA 14 are typically used to specify the performance of the barrier. A barrier rating is based upon the vehicle size and approach speed, its angle of impact with the barrier, and how far the vehicle can penetrate the barrier, if at all. An engineering evaluation, often called a vehicle dynamics assessment, which takes into account achievable radii of curvature for specified vehicle sizes, speeds, and road layouts, is typically performed. Penetration is often restricted to 1 meter, and for trucks is based upon the distance that the front of the cargo bed reaches past the original/reference point of the barrier at any time during the test.

In addition to physical barriers, a hostile vehicle mitigation (HVM) strategy may include operational and technological methods that help detect or deter hostile vehicles. This can include measures such vehicle screening and license plate video camera analytics. These measures are addressed separately.

Airports often implement HVM in some form, but a holistic strategy to address highest risk areas by means of physical, operational, and technological measures may be overlooked.

CONSIDERATIONS

- Physical barriers as part of an HVM strategy may take away from the aesthetics of an airport terminal.
- Typically, barriers are performance specified to be certified or to meet a crash-rating. Unless conditions allow for deep foundations (i.e., no utility disruption or elevated slabs), installation without any engineering analysis is difficult.
- Integration of HVM with site landscaping is imperative for using resources effectively (i.e., if the landscaping considers HVM, explicit vehicle barriers may be redundant) and creating an aesthetically-pleasing environment that is also secure.
- For elevated slabs such as at the raised departures-level viaduct of an airport, shallow-mount barriers are required because standard depth excavation for the foundation is not possible.
- HVM is most applicable to terminal drop-off and pickup roadways.
- Placement needs to allow for vehicle doors to open and passengers to flow freely.

- Temporary/portable barriers may be deployed, but are less common and cannot achieve as high of a crash-rating.
- Removable/operable barriers provide flexibility for use.

EFFECTIVENESS

- Physical HVM barriers do not have detection capabilities.
- HVM is an effective visual and physical deterrent.
- Little maintenance is required for physical barriers.
- No operational support is required for physical barriers.
- When specified and deployed appropriately, HVM is highly effective.
- HVM is sometimes deployed without consideration of a vehicle dynamics assessment, nor in a holistic manner that considers other measures such as vehicle screening; this results in a less effective design.
- Many HVM deployments are falsely assumed to be anti-ram or otherwise have unknown performance (i.e., planters that are not crash-tested are often deployed in front of doors).
- HVM can be expensive.
- In large stretches of areas, barriers cannot be fully deployed due to limited resources; therefore, this limits their effectiveness in certain scenarios.
- Barriers are generally permanent and thus not flexible to change with changing threat environments or site reconfigurations.
- Failures may occur due to a vehicle being larger or having a greater speed than was determined credible. Failures may also occur if removable bollards are used and the bollard is not replaced. Failure may also occur due an improper assessment of where the barriers should be located.

Hostile Vehicle Mitigation – Roadways

SUMMARY

Roadways should be designed to reduce the speed of vehicles approaching the terminal: for instance, having bends and corners so as not to allow a vehicle to build up speed. Management of flows of vehicles entering/exiting the airport through separation of traffic by various configurations, including arrivals/departures, public vehicles/taxis, and general/premium or valet, will also help minimize the impact of a vehicle used as a weapon.

Structural Hardening

SUMMARY

The primary physical hardening objective for blast mitigation should be to limit structural collapse. This will reduce risk of casualties. ASCE 59-11 defines reasons for blast enhancements in general.

Structural hardening is often provided to critical or primary structural elements, followed by secondary structural elements, which may be allowed to experience slightly greater damage than primary elements. Structural robustness is often included as a goal, which involves designing a structural system to sustain local damage without failing to any great degree.

Hardening consists of increased shear and flexural strength as needed to withstand the loading associated with the design basis threat. Additionally, increased capacity in connections is provided in order to promote a ductile/flexural response rather than failure of members at their connection points.

CONSIDERATIONS

- Architectural furring or coverings may be installed on columns to reduce the effects of a PBIED.
- Locating high-risk areas for VBIEDs as far away from the building as possible will help reduce the effects on structural hardening.
- Hardening of a parking garage against progressive collapse significantly increases the cost, and is often not considered due to the lower occupancy and lower risk of downtime associated with the loss of a parking garage.
- The minimum structural integrity provisions defined in US building codes, such as the IBC and ASCE 7, provide a small degree of tying and otherwise include the general requirement that collapse should not be disproportionate to the cause. Tying provides a minimum/baseline level of robustness and is not based upon any specific initiating event (i.e., an explosion). Specific progressive collapse analysis criteria to resist a design basis threat, such as an explosive event, are not mandatory unless elected by the owner or authority having jurisdiction. There are a few guidelines that are used as best-practice, primarily the UFC 4-023-03. Additionally, the Structural Engineering Institute of ASCE is currently drafting a design standard. Using these methods for blast resistance, a structure is explicitly designed to achieve an identified performance after the loss of columns.
- Protection of critical infrastructure should be considered. A hardened envelope (i.e., reinforced concrete walls) may be installed around fuel tanks or power supplies that are especially vulnerable to PBIED or VBIED threats.
- The costs associated with structural hardening for an explosive event are often significant. However, when considering the risks associated with costs of potential structural loss, downtime, and casualties, it is often considered to some extent in terminal design.
- Retrofit of structural elements is difficult, but achievable.

EFFECTIVENESS

- Increasing the robustness of a structure is an effective means of preventing casualties disproportionate to the event, but will not prevent casualties caused by the primary blast load effects and fragmentation.
- Structural hardening will also reduce the risk of major downtime, such that only minor repairs are required instead of major structural repairs.
- It is not economically feasible to harden a large structure like a terminal facility to prevent damage in the event of all viable VBIEDs.
- Structural hardening is permanent and not flexible to change with a changing threat environment.
- These measures can incur large costs, particularly for retrofit activities.

Facade Enhancement

SUMMARY

The hazards created from glazing failure in an explosion are lethal. Monolithic glass is a brittle material that fails suddenly and fragments are projected at high velocities. However, with a properly designed blast-resistant laminated glass facade, the glass can respond in a ductile manner and the fragmentation hazard can be reduced.

ASCE 59-11 recommends that exterior structural and non-structural elements be designed and detailed to reduce the potential of a breach that would allow overpressures to enter the building. Additionally, ASCE 59-11 recommends flying debris be minimized to reduce the potential for hazardous secondary fragments.

Laminated glass with a polyvinyl butyral (PVB) interlayer used for blast resistance is highly ductile when loaded at high strain rates, and will stay bonded to the glass after the glass has cracked.

Blast performance of glazing is typically based on the GSA Performance Condition scale, which is based upon the distance glass fragments enter the space after an explosion (if at all). Ratings range from Performance Condition 1 – No Breakthrough to Performance Condition 5 – Hazardous Failure. Typical performance for a blast-resistant facade is between Performance Condition 2 and 3B.

Glass performance is also measured using ASTM F2912-17 hazard ratings. The hazard ratings are measured H1 through H5, and have corresponding descriptions of glazing response from no glass breakage through moderate hazards, similarly measured to GSA Performance Criteria via how far fragments enter the space.

CONSIDERATIONS

- An essential part of laminated pane design is the detailing of the edge retention and frame and fixings to support the glass. Laminated glass on its own may not provide appropriate enhancement. The glass should be designed to remain in the frame and the frames should be designed to carry the load of the glass.
- For retrofit, adhesive film can be applied to the inside surface of a pane to hold the glass fragments together. A cable catchment system or mechanical anchorage of the film to the frame may be warranted since proper detailing of the rebate in retrofit scenarios is not possible. However, this may be a difficult retrofit for large airports that have large landside façades on their terminals.
- Application of structural silicone sealant is required between the glass and the frame; otherwise, large capture of the glass within the frame is required.
- The structural system needs to be designed to take the load from the facade.
- Glazing not only includes the exterior facade, but balustrades, handrails, smoke screens, and overhead glass that may shatter.
- Maximum pane size may be limited; similarly, minimum pane size may be limited, especially if there is a balanced design requirement.
- Balanced design is sometimes considered, where the frames and anchorages and supporting structure are designed to withstand the maximum capacity of the glass, rather than the load that is transferred as a result of the design basis threat. This provides some robustness in that it is threat-independent; however, it can be a costly design requirement.
- US facade manufacturers have primarily blast-tested their products to prescribed government criteria; deviation from this requires custom design by a blast engineer. Often, standard designs do not fit within the aesthetic or architectural intent of an airport.

EFFECTIVENESS

- Properly designed glazing systems that achieve GSA Performance Conditions between 1-3B can significantly reduce casualties in the event of an explosion and eliminate or reduce the blast pressures that enter the building interior.
- Laminate can reduce fragments.
- Allowing a percentage of facade failure is often considered for economic reasons; this may reduce the effectiveness of the mitigation in areas directly near the explosion.
- The measures, once installed, are permanent and not flexible.
- Failure can occur if the design basis threat is greater than what was designed, or if rebate detailing was not specified properly.
- Failure can also occur if the supporting structure is not properly designed to withstand the greater strength of the glass system. Blast-resistant facades are increasingly common at airports. The cost is not insignificant; however, the cost-benefit is often judged to be worth the investment.

CCTV Analytics

SUMMARY

In the most basic sense, CCTV analytics are the application of computer vision on surveillance camera feeds so that security guards do not have to stare at computer monitors for hours on end. The premise is based on quantifying the events that may interest a security team (and others as well, such as departments of transportation and retail, for example) so that a computer is able to then bring a particular camera's feed to the guard's attention upon trigger.

The analytics most applicable to blast prevention are listed below. Each manufacturer may have different names for their own implementations.

- Object left behind: Items such as bags and suitcases can be detected in feeds, especially when the computer can compare to a baseline of the camera's view (at a time with no people or other items present). Settings can usually be set for how long an item can be in the scene unattended (when no nearby person is detected) before alarm trigger.
- Virtual barrier: A line can literally be drawn on the feed of a camera so that the system is triggered when a moving object is seen crossing that line.
- Smoke detection: Especially in outdoor areas, smoke can sometimes be detected through CCTV feeds faster than by standard detectors.
- Person tracking: One person of interest will usually be captured by multiple cameras at slightly different times. Some video analytic systems are able to detect the same person and/or item in multiple feeds and automatically piece together a chronological montage of this footage, as long as these feeds are synchronized properly. This can be used to actively or forensically track a person and/or thing throughout an entire site automatically.
- Behavior: More advanced analytics are able to make use of machine learning to become more robust over time. The computer is continuously establishing baselines depending on what is captured by the camera during normal operations and is then able to detect abnormal behavior. One example may be a camera that looks at a train tunnel where train exiting happens many times a day, but the analytic is triggered if it notices a car going into the tunnel in the opposite direction.

Other common analytics that can also play a role in blast prevention include more specific detection, such as facial and license plate recognition.

CONSIDERATIONS

- As with general design of a video surveillance system, including both the head-end equipment and the cameras deployed around a site, proper thought must be given to enabling each feed to have sufficient definition in order to perform the desired analytic. For example, facial detection analytics are often quoted to require higher than 60–80 pixels per foot at the target length away from the camera, which is also subject to depth of field, lighting, and other conditions. For applying analytics to a system of cameras that has already been installed, one must consider each camera's environment and specifications beforehand.
- Legacy CCTV systems are often able to be upgraded with analytic capability, even older analog systems. There are certainly restrictions that vary by manufacturer, and the method of implementation (whether the analytic is being run on the edge device out in the field or on the head-end server) and different licensing models can also complicate things. Some companies even sell small physical attachments that can be retrofitted into the transmitting wire of an older CCTV camera to enable analytics on it. Whether the analytics are calculated on the edge or in the head-end could have a large influence on the amount of data being transmitted over the network.
- Some analytics such as license plate reading may require the use of an additional server to store and sort through the database(s) of records. If these servers are not on the same local network of the video management system, further consideration into firewalling this connection is necessary, especially if that database is hosted by external agencies.
- Different manufacturers have different ways of implementing the same analytic. Video surveillance regulatory organizations such as the Open Network Video Interface Forum (ONVIF) and the Physical Security Interoperability Alliance (PSIA) are mainly concerned with ensuring that camera technology, including analytics, is able to work across multiple different systems; these should not be mistaken as agencies that make sure the analytics meet any sort of minimum performance criteria.

EFFECTIVENESS

- As is with most of the technology world, the field of CCTV analytics is rapidly changing; to take a snapshot of its current effectiveness at any given time may not be indicative of even a few months later. Most manufacturers do not publicize failure rates, which could include both false positives and neglecting or missing the accurate identification of an item/person, but in their defense, it is difficult to quantify this as a statistic independent of other factors or even against rates of human monitoring. There seems to be a tendency in the airport industry to be hesitant to trust a computer to conduct this type of work, but the independent testing organization IP Video Market Info has shown at least some analytics use/acceptance steadily climb to north of 80% among responders in 2016.
- Modern computer processing has turned analytics from what was mostly only able to be used as a forensic tool into a live, real-time monitoring detection system. Even implementing basic analytic functionality can allow for fewer guards to be needed in a security operations center, which could in turn allow for them to be deployed on site. The fact that many video management systems are embracing mobile device access enables guards to be instantly notified of events, complete with location and video, right on their smartphones.

- A well-designed CCTV system that has both identification capability (resolution) at key points, as well as overall awareness (coverage), can be enhanced with analytics without the need of changing out the physical devices; remotely-deployed firmware upgrades allow for fast and efficient system improvement.

LiDAR 3D Detection

SUMMARY

Light Detection and Ranging (LiDAR) projects a laser onto an object and measures the time it takes for the beam to return to the source, after which the distance travelled by the light is used to determine distance. When this laser is directed in many different directions via a rotating mirror, it is able to reconstruct a 3D scan of a scene. Traditional LiDAR scanning can take many minutes as a scanner rotates 360 degrees on a tripod to capture everything in high detail. However, lessening the detail (amount of points captured per square meter, for example) can greatly speed up the process, enough so that real-time 3D awareness can be attained. This use of the technology has its roots in autonomous vehicles but the security industry is quickly realizing how it can be used for surveillance. A real-time 3D map of an area can supplement CCTV analytics for further detection capability, especially in places with low CCTV resolution and therefore lower analytic efficacy.

CONSIDERATIONS

- LiDAR is not able to detect 3D through physical geometry. In the 3D scanning sector, this fact is overcome by simply moving a scanner to different points around a site and then stitching these disparate scans together to reconstruct a cohesive overall scene. The solution for implementing this in a real-time detection system is similar but instead of moving the scanner, a network of different scanners can be planned and installed to cover for each other's blind spots, as well as have enough overlap with one another to capture the full area. Individual scanners typically have a range of 100 meters; combining multiple scanners will extend this reach.
- Because enabling real-time scanning is achieved through the coarsening of resolution, LiDAR is best used when supplementing another system such as CCTV analytics. This currently would involve custom applications that make use of various software development kits given that the technology is fairly new. LiDAR detection is able to classify objects based on their absolute size (vs. 2D camera feeds that can only judge relative, pixel-based size) and can therefore filter out objects smaller than, say, a small human before triggering alerts. The scanners themselves are small devices that can be installed just like CCTV cameras. They rotate their laser emitter and receivers at high frequency to capture at a 360-degree horizontal field of view (FoV) although their vertical FoV is drastically reduced, which necessitates clever planning of the system's physical layout. Once set up, the technology requires no active human intervention.

EFFECTIVENESS

Even though it is in real-time (up to 20 frames/second), this low-resolution 3D scanning is not a security solution until used in conjunction with something else, such as a video management system (VMS). Upon recognition of a large enough object, the LiDAR system can transmit precise coordinates to the VMS, which could in turn pan and zoom a camera to get a visual and bring it up on a security guard's screen and/or mobile device. The 3D nature of the scan is certainly more robust than using a tracking CCTV analytic for this same purpose.

Unmanned Surveillance Touring

SUMMARY

As much as CCTV can be a cost-effective way to monitor large areas from a single central location, the cameras are in fixed locations (even if they have PTZ capability). As versatile as security guards may be, they are subject to human error, do not automatically document what they observe, and are much more expensive than operating even a number of cameras. Leveraging the above topics of video analytics and 3D detection are autonomous vehicles, and some have begun to apply these concepts to using self-driving robots to conduct surveillance and even enforcement measures.

Utilizing self-driving robots also removes the security guard from potential physical harm.

CONSIDERATIONS

- Unlike dedicated bomb detecting and disarming robots, this technology has an implicit dependency on the machine's ability to make decisions, interpret human behavior, and self-navigate using artificial intelligence. Because many jurisdictions have had to create legislation to regulate autonomous vehicles, especially during the technology's infancy, similar legislation could be created regarding self-navigating security robots as well. Instances in the news regarding autonomous vehicles and security robots getting into accidents, which have resulted in human injury and even death, certainly make the public wary of implementing such a solution.
- There are also political ramifications to be considered, as some may see the adoption of such machines as replacing jobs. Security guard unions, for example, could attempt to get legislation passed to prevent transitioning jobs away from its unionized members.
- Whereas the artificial intelligence associated with more advanced CCTV analytics will usually not be noticed by the public, this is not the case with security robots, especially at first due to their novelty. Machines without enough intelligence could get lost or into accidents, and machines with too much intelligence, while currently only realized in science fiction stories, is something the scientific community has recently acknowledged as a potential real threat to humanity.

EFFECTIVENESS

- Robots that function properly can offer a cost-effective way of actively preventing crime, and they can extend the reach of monitoring systems into places that mounted CCTV cameras might not be able to reach.
- There are many tests being done in academia with auto-piloted drones, but there do not seem to be any actual products on the market quite yet. The very nature of an airport may prohibit the use of any drone, automated or not.
- Alarming to many is the rather quick militarizing of these robots.

Mass Notification and Crowdsourcing

SUMMARY

In the smartphone age, at least one company has sought to leverage the general public's proclivity to photograph and record everything it sees by establishing a web platform where they can feed this data to security centers in real-time. Essentially the modern day equivalent to calling 911, these systems can enable live incident video sharing to entire workforces or even public populations. The GPS locations of the phones are automatically shared with security so that response times can be shortened.

While not demonstrated, a system such as this and its Application Programming Interface (API) could be leveraged for other uses such as people counting. In essence this can provide another Big Data source that can be used for future planning.

CONSIDERATIONS

- While manufacturers will provide the supporting network infrastructure, there are too many different models of cellular devices in circulation to guarantee that each is compatible with each program's mobile website and/or app. It is also subject to the network's uptime and individual cell connections of those devices.
- Pinpointing specific locations inside buildings is not attainable solely by using GPS and the emergence of better technologies might be required to fully realize the benefits of these systems.
- When location tracking is functioning fully, these networks are able to locate any person on the system. And even though there are assurances by manufacturers that this feature is disabled once the app/site is closed, there will still undoubtedly be privacy concerns.
- Implementing these systems that are open to letting the public report suspicious activity can also make them subject to being manipulated. Similar in concept to a Distributed Denial-of-Service attack, a group of people can plan to disable the system by flooding it with massive amounts of false data.

TIERS OF PERFORMANCE

Facade Enhancements	
Level of Service	**Description**
Bronze	Reduces the extent of hazardous fragmentation for relatively small devices. An example is the application of anti-shatter film daylight-fixed to window glazing.
Silver	Laminated glazed facade with enhanced frame explicitly designed to maintain greater than 50% of the building envelope and reduce fragmentation for PBIEDs or small-sized VBIEDs.
Gold	Laminated glazed facade with enhanced frame explicitly designed to maintain building envelope and reduce fragmentation for moderate-sized VBIED threats. 90% of the facade system achieves GSA Performance Condition 3B for a moderate-sized threat.
Platinum	Laminated glazed facade with enhanced frame explicitly designed to maintain building envelope and reduce fragmentation for large blast threats. An example is double-laminated glass panes. 90% of the facade system achieves GSA Performance Condition 3B for a large-sized threat.

Structural Enhancements	
Level of Service	**Description**
Bronze	Building structure designed to current structural design codes, incorporating ductility and robustness requirements in accordance with ASCE-7.
Silver	In addition to Bronze, in general, the structure has been designed for life safety outcomes with respect to the identified blast threats.
Gold	In addition to Silver, the structure has been designed with progressive collapse requirements stipulated within UFC 4-023-03, or equivalent methods.
Platinum	The structure has been designed with progressive collapse requirements stipulated within UFC 4-023-03, or equivalent methods. In general, the structure has been designed for property preservation or business continuity outcomes with respect to the identified blast threats.

Crowd Mitigation	
Level of Service	**Description**
Bronze	Consideration of flight schedules for airline, airport, and TSA staffing. Level of service equal to Level D in accordance with ADRM 9 and 10.
Silver	Majority of airlines incorporate technology for check-in processes and bag drops. Consideration of flight schedules for airline, airport, and TSA staffing. TSA PreCheck available. Airport Level of Service equal to Level C in accordance with ADRM 9 and 10.
Gold	Almost all airlines incorporate technology for check-in processes and bag drops. Consideration of flight schedules for airline, airport, and TSA staffing. TSA PreCheck used extensively. Airport Level of Service equal to Level B and space and wait times in accordance with ADRM 9 and 10.
Platinum	Almost all airlines incorporate technology for check-in processes and bag drops. Consideration of flight schedules for airline, airport, and TSA staffing. TSA PreCheck used extensively. Airport Level of Service equal to Level A and space and wait times in accordance with ADRM 9 and 10. Integrated Pedestrian planning and modeling exercises undertaken for the majority of landside areas.

CCTV	
Level of Service	**Description**
Bronze	CCTV system installed sparsely across landside areas. CCTV primarily used as deterrence.
Silver	CCTV installed with medium density across landside areas. CCTV monitored with an adequately staffed control room.
Gold	CCTV installed with high density across landside areas. CCTV monitored with an adequately staffed control room with a moderate level of applied video analytics.
Platinum	CCTV installed, designed for 100% coverage at areas of high-risk on the landside. CCTV monitored with an adequately staffed control room with a high level of applied video analytics. 3D scanning technology, thermal imaging, etc. is also applied.

Screening of Individuals[1]	
Level of Service	**Description**
Bronze	Screening of suspicious individuals in the terminal (or other high-risk landside area).
Silver	In addition to Bronze, implementing a policy of random screening of individuals and their belongings entering the terminal (or other high-risk landside area).
Gold	In addition to Silver, implementing a non-invasive technology system capable of screening some individuals (greater than random screening), but may be limited in its deployment either due to location or staffing available to actively monitor the system.
Platinum	Implementing a non-invasive technology system capable of screening most individuals in all high-risk locations, and adequately staffed to actively monitor and resolve alarms.

1: This refers to screening of people entering landside areas (not passenger security screening to access the airside). Although not currently deployed in US airports, technologies are currently being tested in US rail/metro stations and internationally at airports that could be non-invasively and improve speed of screening. Therefore, this concept is a possible category for consideration in the future, given emerging technologies may result in screening of people entering the airport becoming feasible.

Explosives Detection Canines	
Level of Service	**Description**
Bronze	Canines deployed sparsely within the airport terminal.
Silver	In addition to Bronze, canines are deployed sparsely in other high-risk landside areas including bus stations, rail stations, parking garages, etc.
Gold	Canines deployed moderately within high-risk landside areas.
Platinum	Canines deployed heavily in high-risk landside areas.

Security Patrols	
Level of Service	**Description**
Bronze	Security patrols with a low level of training deployed sparsely throughout the airport terminal.
Silver	Security patrols with moderate level of training deployed sparsely throughout all vulnerable landside areas.
Gold	Security patrols with high level of training deployed in moderate density throughout all vulnerable landside areas. Patrols are coordinated between private security patrols and law enforcement/public safety officers.
Platinum	Coordinated security patrols with high level of training and integrated with a security management system. Patrols deployed in high density throughout all vulnerable landside areas. Patrols are coordinated between private security patrols and law enforcement/public safety officers.

Vehicle Screening	
Level of Service	**Description**
Bronze	Airport is capable of carrying out visual vehicle inspection on an ad hoc basis; operational plans to introduce a checkpoint are documented.
Silver	Visual vehicle inspection carried out by personnel on ad hoc basis in high-risk curbside or parking areas.
Gold	In addition to Silver, ALPR is used to assist in the identification of high-risk vehicles. Under vehicle screening technology is capable of being deployed at the checkpoint for times of elevated threat levels.
Platinum	Visual vehicle inspection is carried out by personnel on a regular basis in times of elevated threat levels. Checkpoints are adequately staffed to accommodate increased screening frequency in high threat levels. Visual inspections are compounded with active use of ALPR and under vehicle screening technology, which is deployed at the checkpoint.

Resilient Finishes	
Level of Service	**Description**
Bronze	Internal finishes designed in accordance with current design codes. Architectural items adequately restrained to the structure.
Silver	Internal finishes designed in accordance with current design codes. Architectural items and building services adequately restrained to the structure. Partition glazing (i.e., single-story walls) within the landside area is laminated.
Gold	Internal finishes designed in accordance with current design codes. Architectural items and building services restrained to the structure should be designed, detailed, and installed to substantially reduce the potential for producing hazardous secondary fragments and debris. All glazing within the landside area is laminated and silicone-fixed to robust supports.
Platinum	In addition to Gold, explicit evaluation and protection for blast impacts to architectural items or building services is provided, including materials and anchorage.

Behavioral Detection	
Level of Service	**Description**
Bronze	Few security officers have had training in behavioral detection.
Silver	A moderate proportion of security personnel have had training in behavioral detection.
Gold	A high proportion of security personnel have had training in behavioral detection. Behavior detection officers are explicitly provided in terminal areas during high-risk flight check-in, or in select crowded locations at peak-times.
Platinum	A high proportion of security personnel and other airport employees have had training in behavioral detection. Behavior detection officers are an explicit program at the airport, on duty on a regular, frequent basis, across all high-risk landside areas.

APPENDIX B: CASE STUDY USING THE FRAMEWORK

Introduction

Existing airports often present significant challenges and restrictions to mitigation of blast threats. Undertaking a substantial redesign of non-secure areas for the purpose of increasing the standoff distance between blast threats and the terminal is often not possible for such locations. This fact signals the importance of identifying logical retrofit options to address such threats. This case study demonstrates how blast mitigation may be retrofitted to an existing example airport to address these threats in the context of the existing site. Furthermore, the case study demonstrates the application of the framework to prioritizing mitigations.

Airport Overview

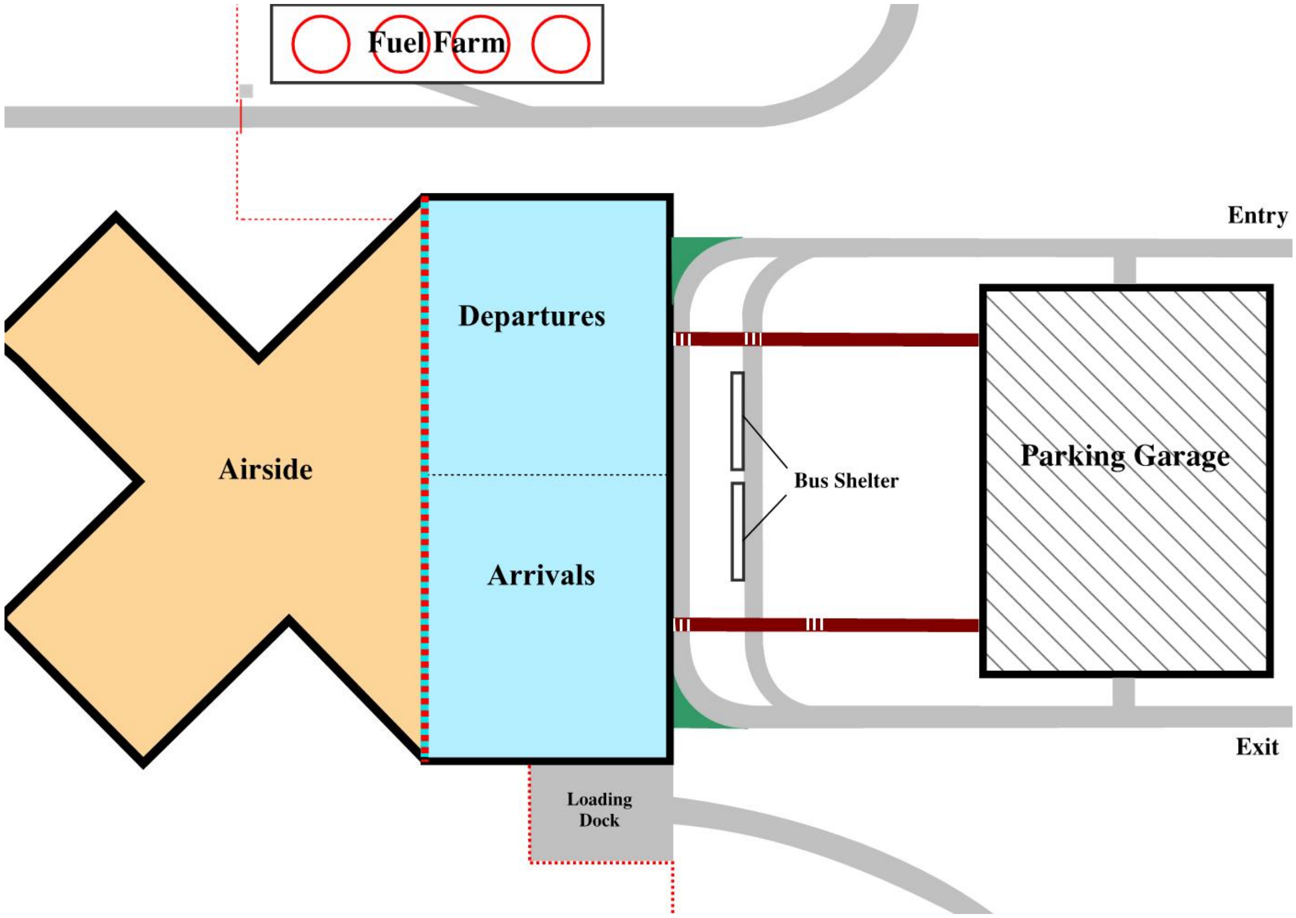
The fictional airport considered for this case study is a major international airport, servicing approximately 35 million passengers each year (for both domestic and international travel) with planes departing every 2 minutes.

For the purpose of this case study, the airport is characterized by the following elements:

Characteristic	Description
U-shaped roadway	A U-shaped roadway leads to the terminal pick-up/drop-off areas. This roadway is one-directional.
Public parking	A multistory parking garage stands approximately 300ft away from the terminal, connected by a pedestrian walkway and road crossings.
Loading dock	The loading dock is adjacent to the building at arrivals level.
Pick-up/drop-off area	The pick-up/drop-off areas are located outside the terminal entrances. Cars pull into parking bays (with an unenforced time limit of 5 minutes) to drop off or pick up passengers. Bus pick-up zones are located in designated areas.
Terminal facade	The terminal has a glazed facade with automatic sliding doors to facilitate entry.
Check-in hall	The terminal entrances open into the check-in hall. Electronic check-in terminals are located closest to the entrances, with a number of rental car tenancies occupying the wall-side of the structure. A queuing area is facilitated by rope barriers.
Security screening	Passengers for domestic flights proceed directly to security screening following their check-in and then on to their boarding gate.
Baggage claim	Arrivals head to the baggage claim hall that has approximately 12 baggage carousels.
Fuel farm	Large cylinders containing jet fuel for flights are located landside approximately 150ft from the terminal structure.
Data centers	Data centers are located within the terminal building. These are within the airport's back-of-house area, segregated from the public area by a secure corridor.
Airport age	Approximately 25 years.
Structure	The structural characteristics of the airport include: steel beams with concrete floor, steel roof and columns. The baseline structural design already considers design against disproportionate collapse.
Threat level	The airport is currently at a heightened threat level due to a recent bombing attack at an airport abroad. The selected mitigation measures reflect this threat context.

Figure B-1 provides a general overview of the fictional airport's layout.

Figure B-1. Airport Layout



Risk Assessment and Threat Profile

To demonstrate the implementation of the proposed framework, consider that a risk assessment undertaken by the airport's security team identified the blast threats requiring mitigation in Table B-1 and Table B-2. This is Step 1 of the framework process.

Table B-1. Airport-Specific Areas Vulnerable to a VBIED

Location	Description	Life Safety	Commerce	Operations
Roadway adjacent to terminal	Ramming attack through terminal facade followed by explosion	0.75	0.05	0.2

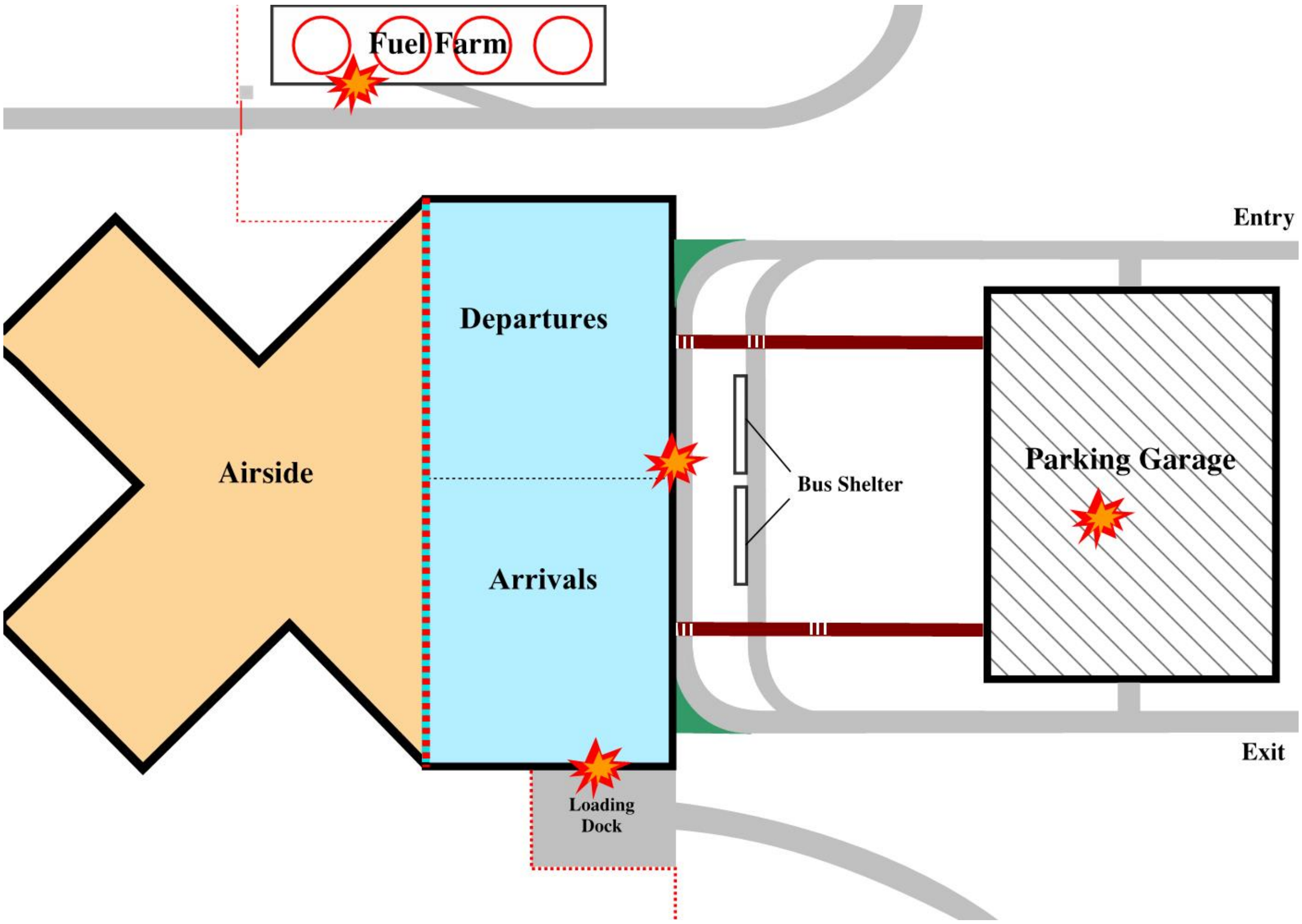
Table B-2. Airport-Specific Areas Vulnerable to a PBIED

Location	Description	Life Safety	Commerce	Operations
Terminal Arrival Hall	PBIED with explosive vest or backpack detonated in a crowded place	0.9	0	0.1

Case Study 1: VBIED

Effects of a VBIED in close proximity to the terminal building cannot be completely eliminated. However, this section describes a process for addressing this threat scenario and adopting mitigation measures that are proportionate to this threat.

Figure B-2. VBIED Risk



This section outlines the various operational, technical, and physical mitigation strategies that this airport can implement to reduce the potential consequences of VBIED threats. The below sections describe mitigation measures that could be applied to manage this risk.

Step 1 of the framework process has been completed during the risk assessment (see Table B-1). Step 2 incorporates listing the measures that can be used to mitigate this risk at this particular airport.

Physical

Physical mitigation strategies provide a *passive* benefit against a blast threat by directly mitigating the effects that harm people and structures. Physical measures that may be implemented include:

- Impact-rated vehicle security barriers such as bollards. These barriers create standoff between a VBIED and terminal facade, but also provide anti-ram capability, preventing a VBIED from entering the building space

- Anti-shatter film (ASF) applied to glass panels to reduce fragmentation from entering the interior terminal space from an outside explosion
- Installing replacement blast-resistant facade systems with laminated glass and blast-resistant frames
- Enhancing existing overhead equipment anchorages to reduce overhead equipment falling from a height
- Installing architectural furring and cladding around columns
- Installing fiber-reinforced polymer (FRP) wraps on concrete columns or concrete encasement around structural steel columns.

Operational

There are several operational control measures that an airport can implement to reduce the impact of VBIEDs. These measures generally do not reduce the effects of a blast, but predominately act as a means of detection and deterrence, and potentially have the capability to disarm an assailant in some instances. Operational measures often work best when implemented in tandem with technology.

- Patrolling the terminal roadway
- Vehicle screening
- Active monitoring of video surveillance within a control room.

Technology

Technological solutions can be used to enhance the effect of operational staff in detecting and deterring blast threats. The following may be undertaken to enhance the airport's electronic security systems, or provide additional tools for operational staff to mitigate against the VBIED threat:

- Monitored CCTV surveillance of vehicles on and before the terminal roadway. This may be supported by CCTV analytics to identify idle vehicles (or unusual vehicle behavior) in designated areas. Note: CCTV cameras may need to be upgraded to a higher resolution to support analytics software.
- License plate recognition systems to verify authorized vehicles for secure areas. This requires coordination with authorities or agencies.
- Replacing fixed lens cameras with PTZ cameras or multi-imager cameras to facilitate an increase to the potential field of vision provided by surveillance systems.
- Under vehicle screening devices used at checkpoints to thoroughly check a vehicle for explosive materials.

Mitigation Assessment

Following a qualitative assessment of all the proposed measures to protect against the blast threats, the following mitigations have been selected as potentially being able to be incorporated as part of the holistic blast strategy. The extent of mitigations listed are for example purposes only, and mitigations may vary depending on the risk assessment process and individual airport characteristics being considered.

After further evaluation of the possible measures, the measures listed in Table B-3 have been identified for moving forward with the framework process.

Table B-3. Individual VBIED Mitigation Measures Considered at the Example Airport

Mitigation	Description
Vehicle Security Barriers	Impact-rated vehicle security bollards installed 12 feet in front of the terminal facade.
Vehicle Screening	Vehicle screening checkpoint with under vehicle screening technology. Inspections undertaken on a random basis.
Facade Enhancement	Anti-shatter film installed on existing terminal facade. Provides improvement by reducing glass fragments that enter the terminal building. Replacement of the facade was seen as unfeasible in this specific example.
Crowd Reduction	Additional taxi ranks provided to reduce the concentration of people along the roadway. Ride-share pick-up locations spread over more terminal exit doors. General public pick-up areas relocated to near bus zones.
Security Patrols	An increase in the number of security personnel patrolling the roadway acting as a show of security presence and capable of detecting parked/suspicious vehicles.
CCTV	Monitored CCTV with video analytics capable of picking up parked cars or suspicious vehicles. License plate recognition linked with authorities capable of picking up suspect vehicles.

Moving on to the scoring portion of Step 2, these mitigation measures have then been assessed against metrics that achieve a security outcome. The scoring and metrics used in this example are summarized in Table B-4. The list of security metrics and scoring was undertaken collaboratively with airport stakeholders, airport management, and an external protective security professional. The scoring below is for example purposes only, and may differ depending on individual airport characteristics and risk profile.

Table B-4. Example Scoring of Mitigation Measures Against Proposed Security Metrics

Mitigation	Detect	Deter	Disable	Reduce Crowds	Inform Law Enforcement	Protect People	Protect Property
Vehicle Security Barrier	0	30	20	0	0	30	30
Vehicle Screening	30	50	0	0	0	0	0
Facade Enhancement	0	0	0	0	0	30	0
Crowd Reduction	0	0	0	40	0	0	0
Security Patrols	10	30	0	0	10	0	0
CCTV	20	10	0	0	20	0	0

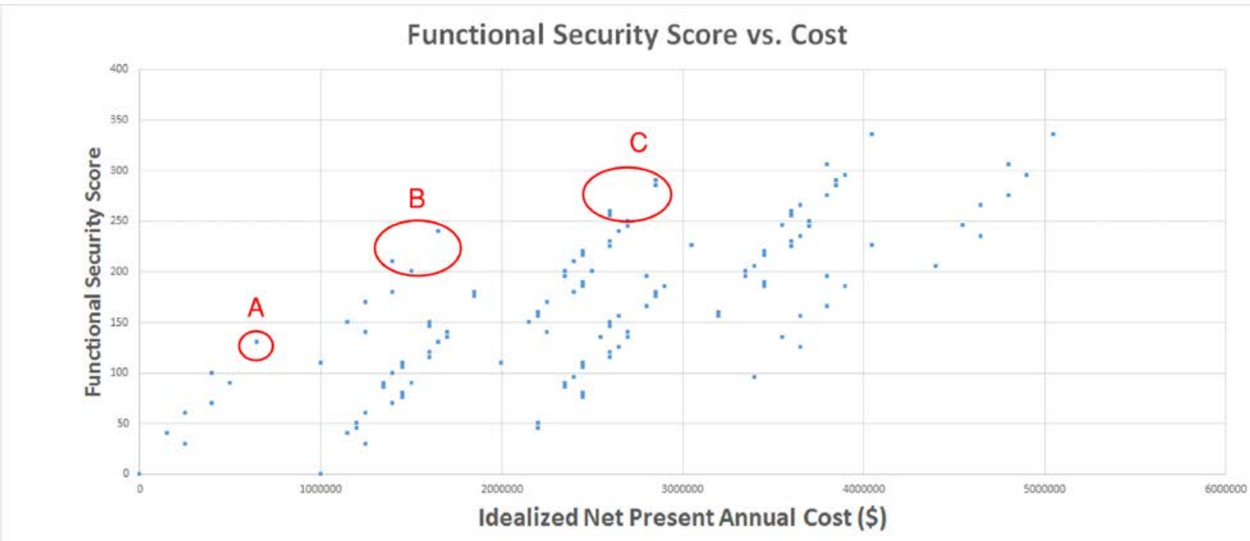
Step 3 of the framework includes developing ROM cost estimates. For this step, a blast engineer was consulted for a nominal fee to develop conceptual ideas of the mitigations and where they would be located. The airport's cost estimator was used to develop annual costs, annualized over 15 years using Net Present Value. The engineer would be retained to do a more detailed design once the airport has considered which measures should be pursued after completion of Step 4.

Table B-5. Mitigation Measures and Listed Annual Financial Cost

Mitigation	Annual Cost (annualized over 15 years)
Vehicle Security Barrier	$1,200,000
Vehicle Screening	$300,000
Facade Enhancement	$350,000
Crowd Reduction	$250,000
Security Patrols	$900,000
CCTV	$1,500,000

These mitigation measures, scores, and costs were inputted into the framework for evaluation of the exterior drive-up area as it relates to the VBIED vulnerability. Figure B-3 shows the output from the Excel-based tool for this case. The combinations within circles A, B, and C were independently selected by the airport for evaluation, as they have the highest functional security score for a given financial cost region.

Figure B-3. Output from the Excel-based Tool – Measure Combination Options



The airport's assessment of the combinations within circles A, B, and C is summarized within Table B-6.

Table B-6. Assessment Summary of A, B, and C Mitigation Combinations

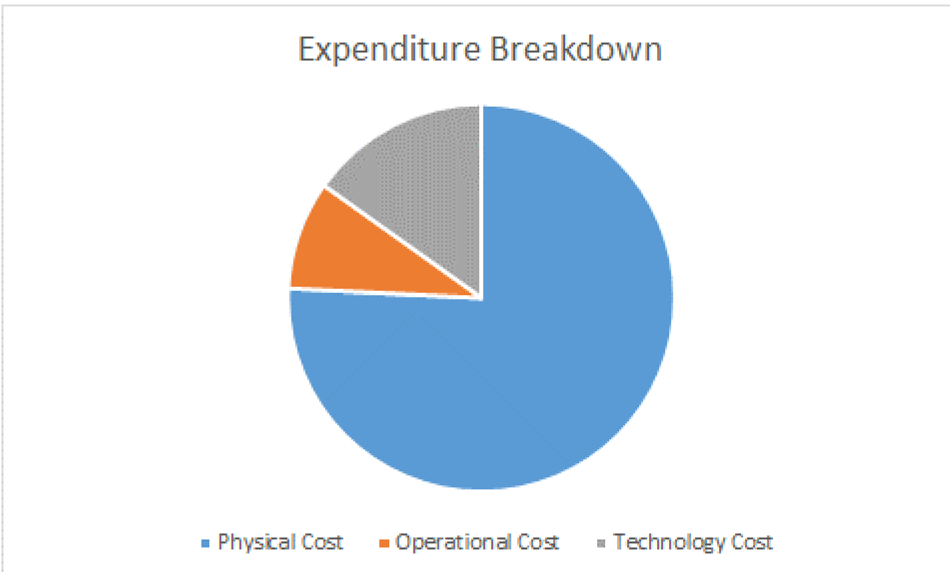
Combination Groups	
A	When referenced back to the risk assessment, it was deemed that these were not adequate in reducing risk to an acceptable level.
B	These mitigations are to be considered for implementation and interrogated in more detail.
C	Mitigation combinations are acceptable but expenditure is too high and not proportionate to risk.

The three measure combinations within circle B were further evaluated by reviewing the specific measures in each combination along with their functional security scores and financial costs. A summary of this assessment is shown in Table B-7. A summary of the breakdown of costs between physical, operational, and technological was also investigated as shown in Figure B-4. The airport has enough initial funding to make capital investments and would prefer this to longer-term operational expenditures. Additionally, the airport is not comfortable with the first two options in terms of their ability to meet their risk-reduction goals. Therefore, the last combination was chosen.

Table B-7. Comparison and Selection of Combination Measure

Combination	Functional Security Score	Financial Cost
Vehicle Security Barriers + Facade Enhancement and Vehicle Screening	200	$1,400,000
Vehicle Security Barriers + Vehicle Screening and Crowd Reduction	210	$1,500,000
Vehicle Security Barriers + Vehicle Screening and Crowd Reduction + Facade Enhancement	**240**	**$1,650,000**

Figure B-4. Expenditure Breakdown for Selected Combination of Measures



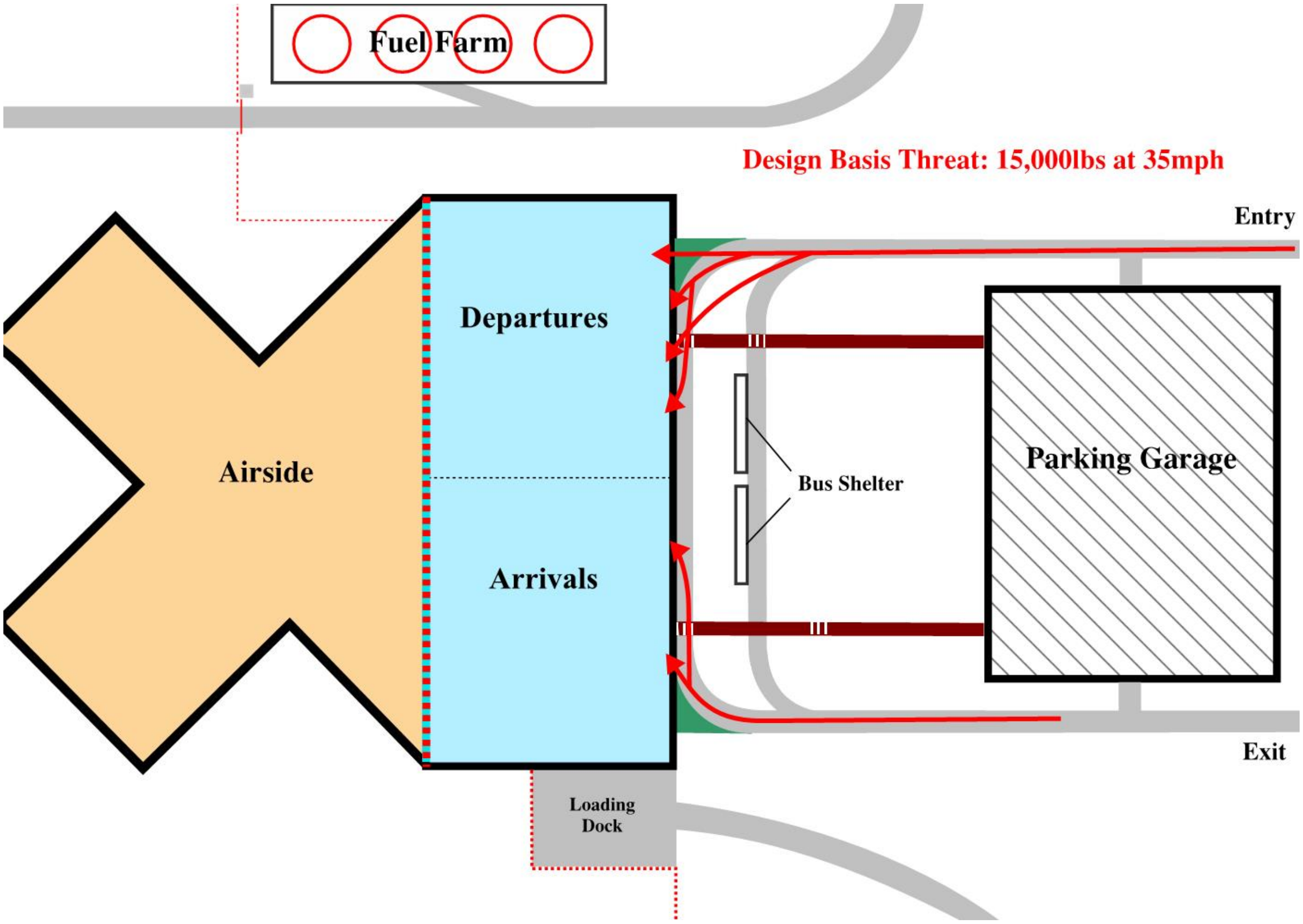
Design Process

This section briefly describes the design process for implementing the prioritized security measures.

Vehicle Security Barriers

The airport has hired a protective design consultant to assess the vulnerability of the airport to vehicle ramming attacks and VBIEDs. The following attack paths were identified in the consultant's report with associated vehicle attack paths and mass. This allows the airport to select a specific barrier that meets their protective needs. The design-basis vehicle selected by the airport was a large-duty vehicle (approximately 15,000 pounds). The HVM consultant calculated a potential impact speed of 35 mph. The maximum allowable penetration distance of the vehicle once it has contacted the bollard has been specified as 12 feet, representing the distance between the barrier and the terminal facade.

Figure B-5. Attack Paths and Design Basis



Shallow mounted bollards have been selected due to the presence of underground services beneath the footpath outside the entrances to the airport. These foundations (depth less than 12 inches) can sit atop these services.

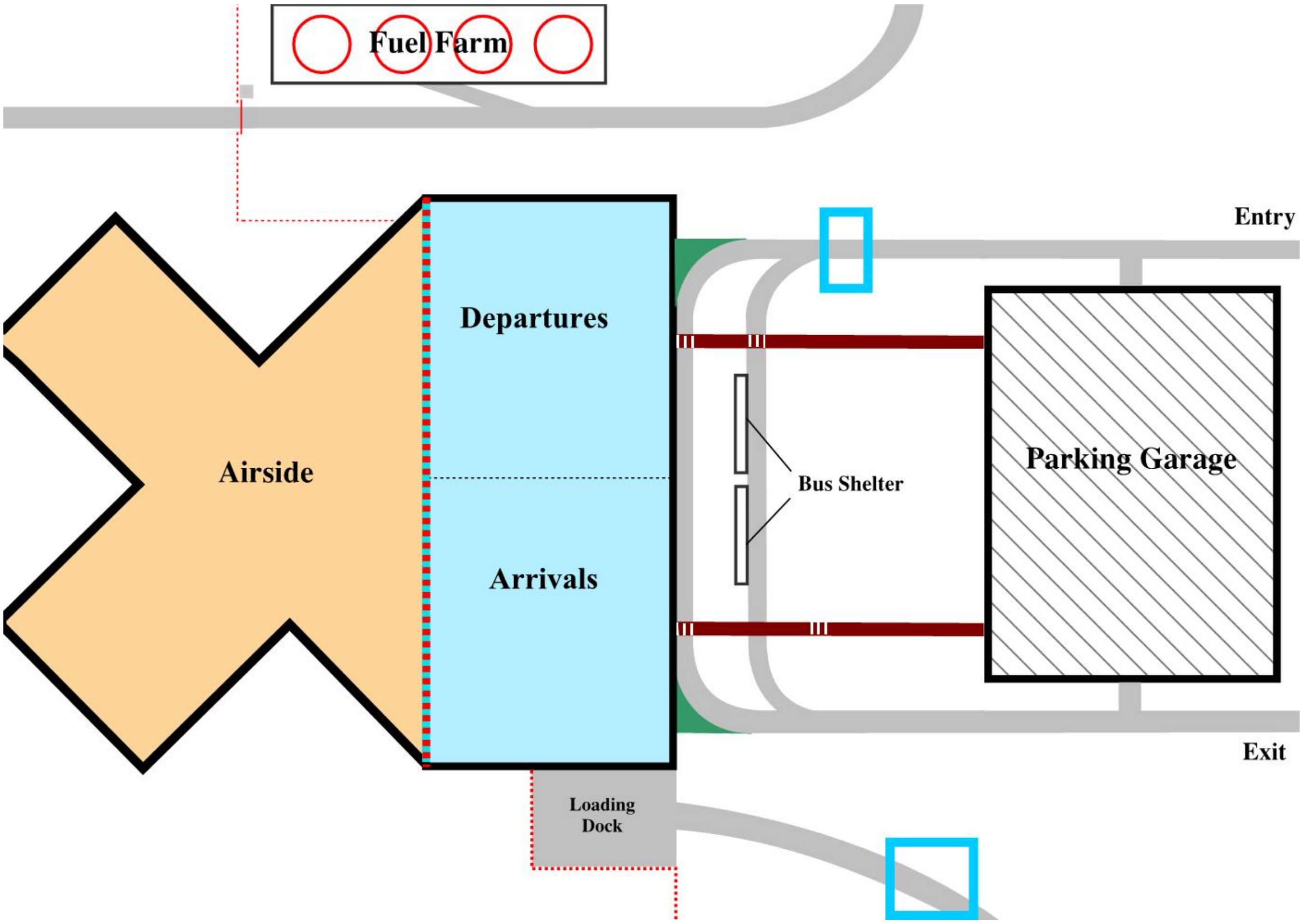
Therefore, the airport has implemented shallow-mounted bollards with a condition designation of M40 P2 (ASTM F2656-15).

Vehicle Screening

Due to the heightened threat level, the airport has decided to implement a vehicle-vetting procedure to better control access of vehicles to its roadways. Authorized taxis and buses are permitted to enter the lane closest to the terminal, and public drop-off/pick-up has been pushed back to the second lane. Doing so has generated a further 25 m of standoff and added a level of screening to drivers using the roads closest to the terminal. Passengers are also now spread across a large number of vehicle pick-up locations, reducing the number exposed to a specific blast event.

Furthermore, delivery vehicles are to be screened further down the loading dock access road to allow for greater standoff distance. This has been combined with a procedure whereby deliveries require prior authentication, and driver identity is verified at the screening point along with the vehicle registration.

Figure B-6. Selected Vetting Points (Highlighted in Blue)



Crowd Reduction

With the objective of reducing crowd density outside the arrivals and drop-off halls, public pick-up and drop-off zones have been located away from the terminal near the bus shelters, reducing the total number of people along the terminal roadway. Through collaboration with ride-share services, pick-up locations have been spread over a number of airport doors, spreading arriving passengers across the terminal building to disperse crowds.

Facade Enhancement

The installation of ASF to the monolithic glass pane of the airport terminal facade will assist in holding glass fragments together upon fracture under blast loads. It is not expected that this measure will maintain the building envelope or reduce the expected hazard level of the glazing under blast, but it will provide a nominal benefit.

This measure is seen as temporary until such time the airport undergoes major redevelopment and replaces its glazed terminal facade.

Case Study 2: PBIED within Terminal

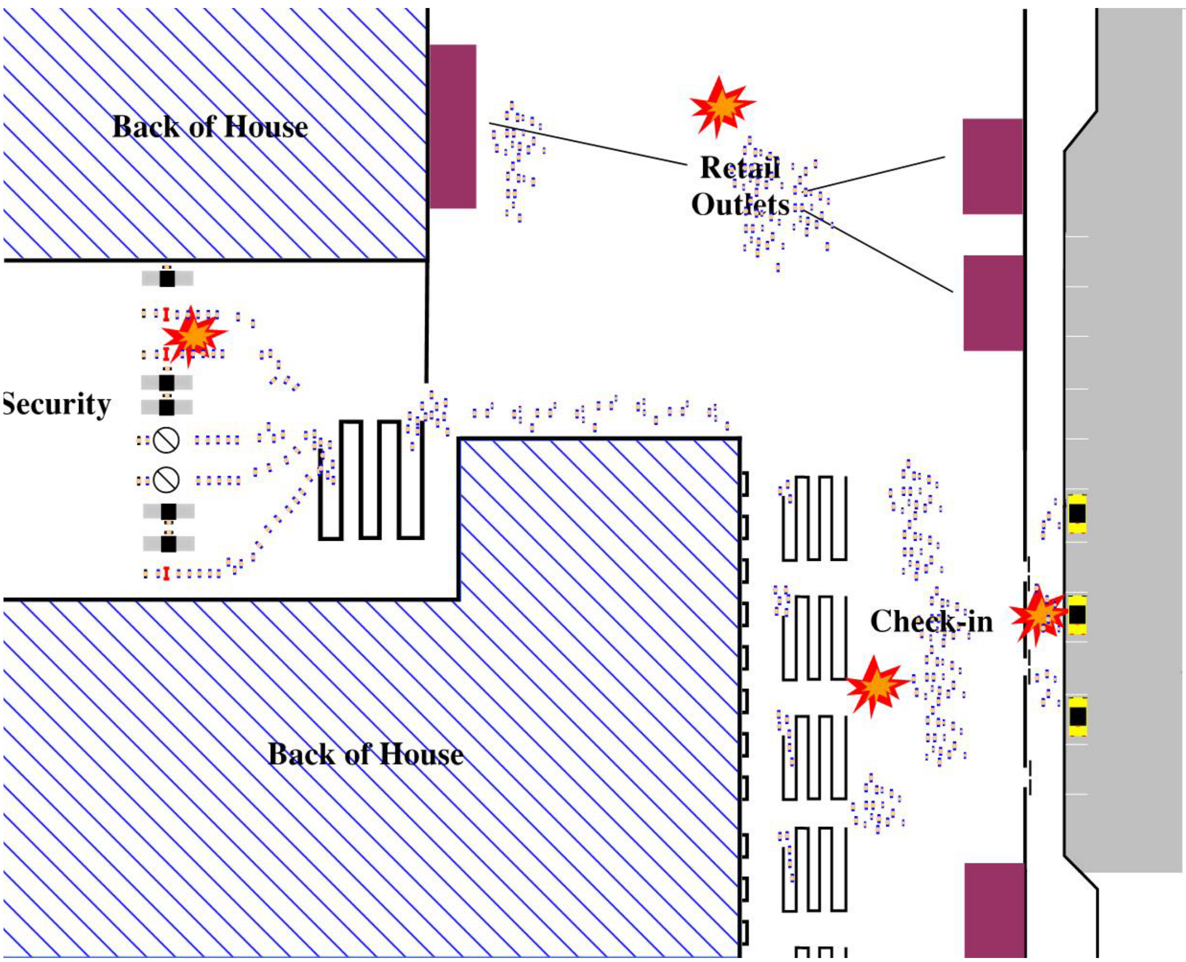
PBIEDs are a particularly challenging threat to mitigate against within non-secure areas. Given their ease of concealment, these threats often go largely undetected until detonation. The focus of retrofit items should therefore be:

- Identifying the threat (where possible)
- Responding to the threat
- Reducing its potential impact

The specific threat identified is located at the queuing area for passenger screening, as shown within Figure B-7 below.

This section outlines the various operational, technological, and physical mitigation strategies that this airport can implement to reduce the potential consequences of the identified PBIED threat. The below sections describe mitigation measures that could be applied to manage this risk.

Figure B-7. Indicative Threat Areas: PBIEDs



Step 1 of the framework process has been completed during the risk assessment (see Table 5-8). Step 2 incorporates listing the measures that can be used to mitigate this risk at this particular airport.

Physical Measures

As with VBIED threats, there are several physical measures that have been implemented to protect against PBIEDs.

- Adequate design and restraint of miscellaneous architectural components to reduce the effects of fragmentation from a blast event
- The glazing treatments implemented to protect from VBIEDs provide additional protective benefits in reducing the potential impact of PBIEDs detonated in close proximity to the terminal facade
- Structural hardening of steel columns through concrete encasement to protect against progressive collapse from a placed device

Operational Measures

Operational measures that could be considered to mitigate against a PBIED threat include:

- Increase in security patrols in front of house (FoH) areas to identify suspicious behavior and left objects
- Patrolling activities enhanced by explosives detection canine patrols throughout the front of house and drop-off/pick-up areas
- CCTV surveillance monitored 24/7 by operational staff within a control room

Technology

The airport has determined the following technology will be implemented to support the operational and physical security elements:

- CCTV analytics to identify abandoned objects and to facilitate the tracking of suspicious persons through the airport
- Controlled access (via an electronic access control system) to back of house (BoH) areas—access to various BoH departments should be person-based rather than discipline-based—to facilitate greater oversight and control of access to critical FoH areas
- Screening through the deployment of millimeter wave standoff explosive detection equipment at terminal entrances

Mitigation Assessment

Following a qualitative assessment of all the proposed measures to protect against the blast threats, the following mitigations have been selected as potentially being able to be incorporated as part of the holistic blast strategy. The extent of mitigations listed are for example purposes only, and mitigations may vary depending on the risk assessment process and individual airport characteristics being considered.

Table B-8. Individual PBIED Mitigation Measures Considered at the Example Airport

Mitigation	Description

Explosives Detection Canines	Canines trained in explosive detection deployed within the building terminal area to support security patrols
Crowd Reduction	Additional staffed check-in lanes provided to reduce crowding within the security checkpoint
Security Patrols	An increase in the number of security personnel patrolling the departure hall—some security staff are trained in behavioral detection
Resilient Finishes	All miscellaneous glazing replaced with laminated glass and enhanced restraint to overhead equipment within the ceiling space
CCTV	Monitored CCTV with video analytics capable of picking up unattended bags

The measure-scoring portion of Step 2 is shown in Table B-9, followed by the cost estimation for Step 3 of the framework process in Table B-10.

Table B-9. Example Scoring of Mitigation Measures Against Proposed Security Metrics

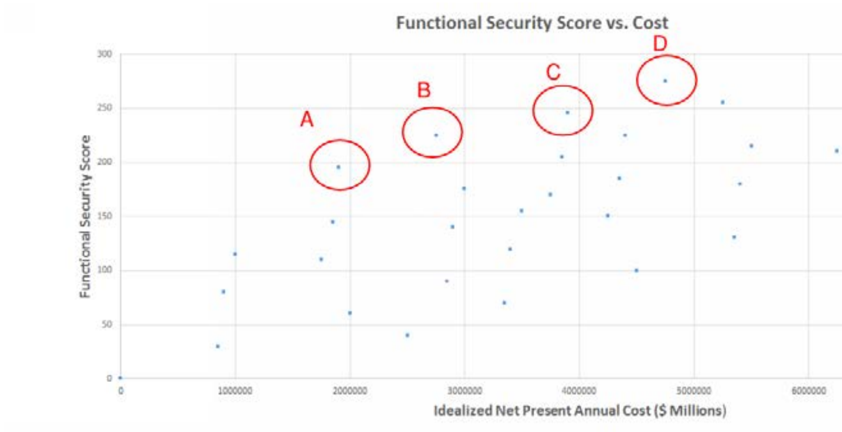
Mitigation	Detect	Deter	Disable	Reduce Crowds	Inform Law Enforcement	Protect People	Protect Property
Explosives Detection Canines	40	40	20	0	15	0	0
Crowd Reduction	30	0	0	50	0	0	0
Security Patrols	15	30	20	0	15	0	0
Resilient Finishes	0	0	0	0	0	30	0
CCTV	20	20	0	0	20	0	0

Table B-10. Mitigation Measures and Listed Annual Financial Cost

Mitigation	Annual Cost (annualized over 15 years)
Explosives Detection Canines	$1,000,000
Crowd Reduction	$2,500,000
Security Patrols	$900,000
Resilient Finishes	$850,000
CCTV	$2,000,000

The outcome of using the Excel-based framework tool is shown in Figure B-8. The combinations within circles A, B, C, and D were chosen, as they have the highest functional security scores for their respective cost brackets.

Figure B-8. Graphic Representation of Combined Mitigations vs. Cost



The airport's assessment of these four combinations is summarized within Table B-11. Combination B was selected, as it provides an acceptable level of risk reduction within budget. The airport assessed that they can achieve the budget required over the upcoming years for the operations costs required as summarized in the expenditure breakdown of Figure B-9.

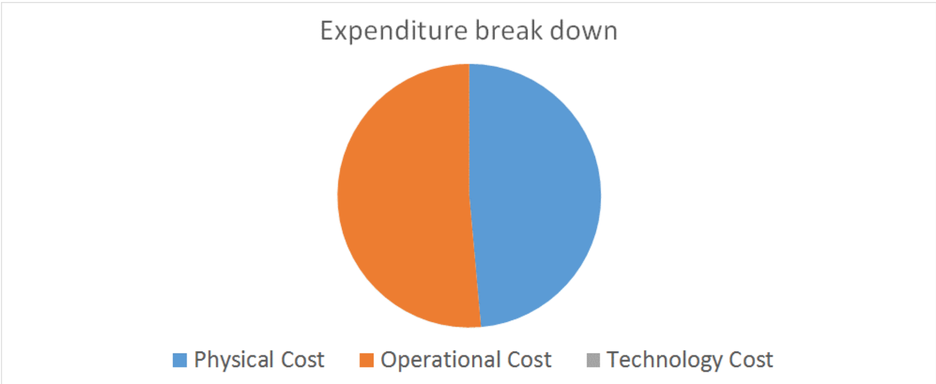
Table B-11. Assessment Summary of A, B, C, and D Mitigation Combinations

Combination Groups	
A	When referenced back to the risk assessment, it was deemed that these were not adequate in reducing risk to an acceptable level.
B	This mitigation is to be considered for implementation and interrogated in more detail.
C	Mitigation combination is acceptable but expenditure is too high and not proportionate to risk.
D	Mitigation combination is acceptable but expenditure is too high and not proportionate to risk.

Table B-12. Summary of Selected Combination Measure (Combination B)

Combination	Security Score	Financial Cost
Security Patrols, Explosives Detection Canines, and Resilient Finishes	225	$2,750,000

Figure B-9. Expenditure Breakdown for Selected Combination of Measures



Design Process

This section briefly describes the design process for implementing the prioritized security measures.

Security Patrols

Security patrols are an integral component when implementing a security strategy. They can serve as a deterrent and respond to a security event as it unfolds. Security patrols have some detection capability, but are most effective when deployed in combination with supporting measures such as canines and CCTV technologies. The number of security personnel patrolling the airport can also be readily increased in an increased threat environment.

Explosives Detection Canines

Trained explosives detection canines, along with trainers, are to be deployed within the terminal building. Dogs are to be trained in explosive substance detection and used to sniff oncoming passengers within landside terminal areas on a random basis. BoH areas to support canines are to be provided.

Resilient Finishes

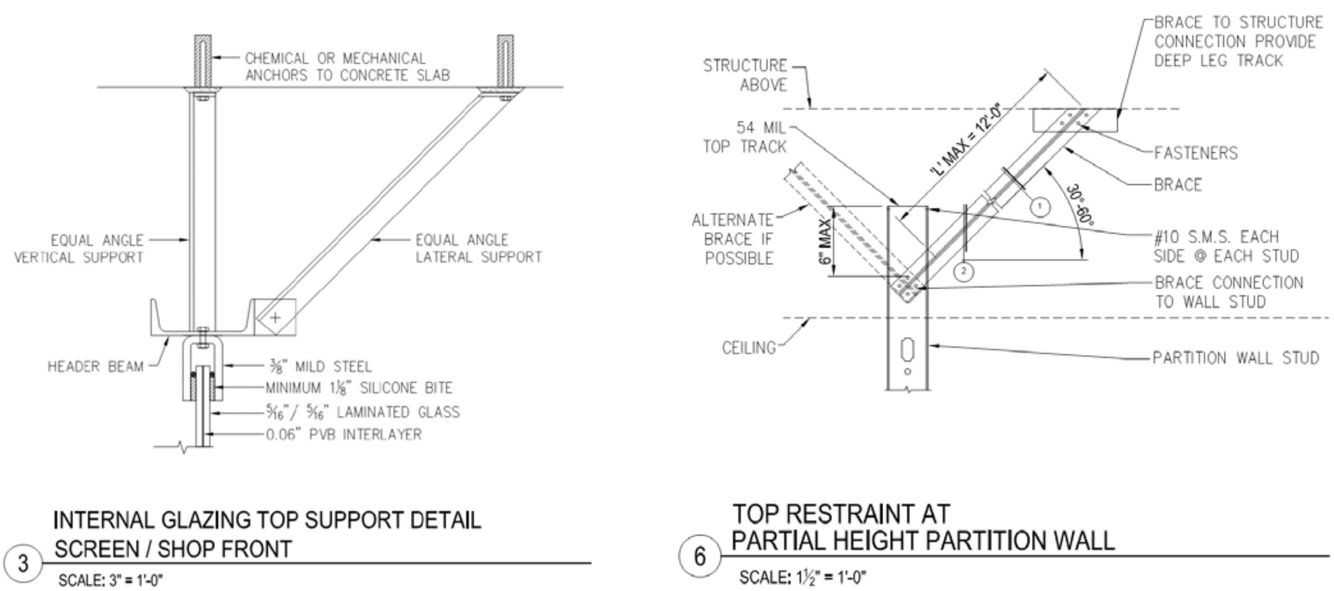
Miscellaneous architectural items and building services are not usually designed for blast loads, and therefore are likely to add to the level of fragmentation in a blast event. It is generally not practical to enhance these items to directly withstand the blast overpressures; however, practical enhancements to these elements can significantly reduce the risk to personnel.

As part of the project, a structural and a facade engineer have been asked to incorporate the following within their design:

- All glazing within the terminal building to be replaced (if required) with laminated glass
- All glazing to be silicone-fixed with a minimum bite length
- Fixing of all miscellaneous architectural items (including glazing) and building services to the structure is to be designed for a force equal to two times the items' weight in all directions.

Examples of details incorporating the above are shown within Figure B-10 below.

Figure B-10. Example Details to Improve Finishes Resilience against a PBIED



APPENDIX C: COST DATA

1. Basis of Pricing

The rough order of magnitude (ROM) estimate is a Class 5 according to Arup's estimate classification matrix (Level 5), which was developed from the Association for the Advancement of Cost Engineering (AACE) best practices.

The accuracy range is a gauge of likely bid prices if the project were issued to tender at the current stage. The accuracy range of this estimate has been determined to be between -25% and +50%.

This document is based on the measurement and pricing of quantities wherever information is provided, and/or on reasonable assumptions for other works not covered in the drawings and programs as stated in this document. The unit rates reflected herein have been obtained from experience with projects of this nature.

2. Scope of the Project

This exercise provides ROM costs for technological security measures (e.g., CCTV) and operational security measures that might be used at airports. This work is for informational and comparison purposes for National Safe Skies Alliance's (Safe Skies) research study only; there is no actual construction project.

The estimate is based on a medium-sized airport and a medium-sized city in the United States. Examples of these airports/cities are Oakland, San Jose, Pittsburgh, New Orleans, Nashville, Milwaukee, etc.

This exercise provides factors that translate the medium/baseline costs to large city costs (e.g., New York, San Francisco, Chicago, etc.) and one factor to translate the cost to a small/rural city cost (e.g., Fresno, Syracuse, Wichita, etc.)

3. Scope of Works

The scope of this cost estimate includes the following:

- Capital costs for different works, which will be applicable for locations within an airport
- Operational costs for different operational measures, which will be applicable for locations within an airport
- Life cycle costs over a period of 20 years, including capital, maintenance, and replacement costs

4. Documentation

Documentation has been prepared by the project consultant, Arup, for developing this cost estimate: PARAS 0014 Safe Skies Project, December 03, 2017.

5. Project Construction Schedule

An overall construction duration has not been calculated for this exercise.

6. Other Costs

- Capital Cost
  - An allowance of 20% from direct cost is considered a general requirement, which covers costs related to general staff wages and fringes, site conditions, and temporary power
  - Allow a project reserve of 15% from the total direct cost due to the project's uncertainty
  - Allow 10% from the total cost for the contractor's overhead and profit
  - Allow 2.5% from the total cost for the contractor's bonds and insurance
- Operational Cost
  - Allow a project reserve of 15% from the total operational cost due to the project's uncertainty
  - Allow 10% from the total cost for the contractor's overhead and profit

7. Escalation

- An escalation allowance is excluded for the capital cost
- An escalation of 3.5% per year is consider for the 20-year life cycle cost projection

8. General Assumptions

- The values are in US dollars
- The values are from the fourth quarter of 2017
- Material costs are calculated from databases such as RS Means, similar project costs, and vendors
- Labor rates, fringes, and taxes are calculated based on data from the US Department of Labor, Bureau of Labor Statistics
- Material, labor, and equipment rates are considered from an average of medium-sized airport cities
- The medium-sized airport cities considered for this exercise are: Oakland, San Jose, Pittsburgh, New Orleans, Nashville, and Milwaukee
- The location factor for the different cities was obtained from the portal of RS Means
- The operational cost estimate is not a life cycle cost, meaning that there might be other costs involved to operate an airport
- The total first year investment is defined as the sum of the capital and operational costs
- A 5% preliminary engineering cost is suggested as part of the total price; however, it is excluded
- The structural, civil, and architectural costs are provided by the sub-consultant BMK Engineering

9. Working Assumptions

- Capital Cost
  - The total unit cost is compounded by material, crew, and sub-contractor overhead and profit
  - Crews are composed of labor and equipment, and are defined based on similar project costs and the RS Means portal
  - A 150-foot length of cabling is considered per camera, scanner, and other security equipment as part of its installation
  - A 15% allowance of the material and crew cost is considered as sub-contractor overhead and profit
  - The security devices include the material, labor, and equipment needed to operate as a whole system
- Operational Cost
  - The operational costs are calculated for a year of operations, which is equivalent to 365 days

  - Operations occur over 24 hours per day
  - The operations define 12 hours for day time and 12 hours for night time
  - The labor rates increase 25% for night time
  - For officers/handlers/guard staffing, five workers are considered per day, one for each shift plus two as a contingency. The frequency of each activity is considered based on similar projects
  - An allowance of security staff training is considered based on experience
- Replacement Cost
  - It is assumed that a replacement cost per activity equals the capital cost of that same activity
  - A replacement period of 10 years is considered for non-moving components
  - A replacement period of 4 years is considered for moving components
  - No replacement of civil, cable, or structural works is considered

10. Items Excluded from the Cost Estimate

- Costs or impacts of latent environmental issues that result in litigations or development delays
- Owner contingency
- Planning and enquiry costs, including legal expenses and fees
- Local planning obligations and agreements
- Site investigation
- Local taxes and duties
- Right-of-way and/or land acquisition costs
- Risk-based contingency analysis
- Tests and inspections performed by others, apart from that listed in the estimate
- Program management and construction management costs
- Compensatory costs to other interested parties
- Cost benefits and impacts associated with improvements in construction technology, more severe regulatory requirements, and future construction that may impact the work contemplated under this project
- Removal and disposal of hazardous materials, unless otherwise stated in the cost estimate
- Integration to the building management or communication systems unless otherwise stated
- Structural, civil, and architectural costs unless otherwise stated
- Consultant fees
- Owner costs
- Preliminary engineering costs
- Detailed engineering costs
- Escalation allowance

11. Items that May Affect the Cost Estimate

- Modifications to the scope of work included in this estimate
- Special phasing requirements
- Restrictive technical specifications or excessive contract conditions
- Any other non-competitive bid situations
- Bids delayed beyond the projected schedule
- Loss of labor productivity
- Future market conditions

12. Statements of Probable Cost

Arup has no control over the cost of labor and materials, general contractor's or any subcontractor's method of determining prices, or competitive bidding and market conditions. This opinion of probable cost of construction is made on the basis of the experience, qualifications, and best judgment of the professional consultant familiar with the construction industry. Arup cannot and does not guarantee that proposals, bids, or actual construction costs will not vary from this or subsequent cost estimates.

Blast Mitigation Strategies for Non-Secure Areas at Airports
Rough Order of Magnitude Cost Estimate
Monday, May 14, 2018

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CAPITAL AND REPLACEMENT COST ESTIMATE

	SCOPE OF WORK	QUANTITY	UNIT	Material Cost [$/unit]	Crew Code	Crew Labor Rate [$/hr.]	Crew Labor Unit [unit/hr.]	Crew Cost [$/unit]	Sub Contr OH & P [$/unit]	Total Unit Cost [$/unit]	Total Cost [$]
Direct costs											
Technological Measure											
T1	**CCTV**			**$ 10,787**				**$ 3,365**	**$ 505**	**$ 6,823**	**$ 14,700**
	CCTV Camera	1	EA	$ 1,500	SPI03	$ 253	3.00	$ 759	$ 114	$ 2,373	$ 2,373
	Cabling, connections and installation	150	FT	$ 44	SPI02	$ 234	0.03	$ 7	$ 1.12	$ 53	$ 7,886
	Civil and architectural works	1	LS	$ 500	LAB03	$ 178	4.00	$ 713	$ 107	$ 1,320	$ 1,320
	Security Operation Center per camera	1	LS	$ 2,193				$ 769	$ 115	$ 3,077	$ 3,077
	Consoles and Equipment	1	LS	$ 1,096				$ 384	$ 58	$ 1,538	$ 1,538
	Audio Visual Systems	1	LS	$ 783				$ 275	$ 41	$ 1,099	$ 1,099
	Infrastructure / network	1	LS	$ 313				$ 110	$ 16	$ 440	$ 440
T2	**CCTV + Analytics**			**$ 12,305**				**$ 3,722**	**$ 558**	**$ 8,751**	**$ 16,600**
	CCTV Camera	1	EA	$ 2,000	SPI03	$ 253	3.00	$ 759	$ 114	$ 2,873	$ 2,873
	Cabling, connections and installation	150	FT	$ 44	SPI02	$ 234	0.03	$ 7	$ 1.12	$ 53	$ 7,886
	Civil and architectural works	1	LS	$ 500	LAB03	$ 178	4.00	$ 713	$ 107	$ 1,320	$ 1,320
	Security Operation Center per camera	1	LS	$ 3,211				$ 1,126	$ 169	$ 4,505	$ 4,505
	Consoles and Equipment	1	LS	$ 1,566				$ 549	$ 82	$ 2,198	$ 2,198
	Audio Visual Systems	1	LS	$ 1,253				$ 439	$ 66	$ 1,758	$ 1,758
	Infrastructure / network	1	LS	$ 392				$ 137	$ 21	$ 549	$ 549
T3	**CCTV + Analytics + Light Detection and Ranging (LiDAR) Analytics**			**$ 20,263**				**$ 4,408**	**$ 661**	**$ 17,499**	**$ 25,300**
	LiDar 3D laser technology device by Velodyne	1	EA	$ 8,000	SPI03	$ 253	3.00	$ 759	$ 114	$ 8,873	$ 8,873
	Cabling, connections and installation	150	FT	$ 44	SPI02	$ 234	0.03	$ 7	$ 1.12	$ 53	$ 7,886
	Civil and architectural works	1	LS	$ 500	LAB03	$ 178	4.00	$ 713	$ 107	$ 1,320	$ 1,320
	Security Operation Center per camera	1	LS	$ 5,169				$ 1,812	$ 272	$ 7,253	$ 7,253
	Consoles and Equipment	1	LS	$ 2,506				$ 878	$ 132	$ 3,516	$ 3,516
	Audio Visual Systems	1	LS	$ 2,193				$ 769	$ 115	$ 3,077	$ 3,077
	Infrastructure / network	1	LS	$ 470				$ 165	$ 25	$ 659	$ 659
T4	**Automatic Number Plate Recognition (ANPR), including server for data storage and database searching**			**$ 14,263**				**$ 4,408**	**$ 661**	**$ 11,499**	**$ 19,300**
	Intelligent ANPR Camera	1	EA	$ 2,000	SPI03	$ 253	3.00	$ 759	$ 114	$ 2,873	$ 2,873
	Cabling, connections and installation	150	FT	$ 44	SPI02	$ 234	0.03	$ 7	$ 1.12	$ 53	$ 7,886
	Civil and architectural works	1	LS	$ 500	LAB03	$ 178	4.00	$ 713	$ 107	$ 1,320	$ 1,320
	Security Operation Center per camera	1	LS	$ 5,169				$ 1,812	$ 272	$ 7,253	$ 7,253
	Consoles and Equipment	1	LS	$ 2,506				$ 878	$ 132	$ 3,516	$ 3,516
	Audio Visual Systems	1	LS	$ 2,193				$ 769	$ 115	$ 3,077	$ 3,077
	Infrastructure / network	1	LS	$ 470				$ 165	$ 25	$ 659	$ 659
T5	**Vehicle Checkpoint - Under Vehicle Video Surveillance (UVVS)**			**$ 16,305**				**$ 8,792**	**$ 1,319**	**$ 18,582**	**$ 26,400**
	Permanent UVIS Scanner	1	EA	$ 5,000	SPI06	$ 426	12.00	$ 5,116	$ 767	$ 10,884	$ 10,884
	Cabling, connections and installation	150	FT	$ 44	SPI02	$ 234	0.03	$ 7	$ 1.12	$ 53	$ 7,886
	Civil and architectural works	1	LS	$ 1,500	LAB03	$ 178	8.00	$ 1,426	$ 214	$ 3,140	$ 3,140
	Security Operation Center per camera	1	LS	$ 3,211				$ 1,126	$ 169	$ 4,505	$ 4,505
	Consoles and Equipment	1	LS	$ 1,566				$ 549	$ 82	$ 2,198	$ 2,198
	Audio Visual Systems	1	LS	$ 1,253				$ 439	$ 66	$ 1,758	$ 1,758
	Infrastructure / network	1	LS	$ 392				$ 137	$ 21	$ 549	$ 549
T6	**High-throughput standoff explosive detection sensors (passenger / pedestrian)**			**$ 231,500**				**$ 21,458**	**$ 3,219**	**$ 256,176**	**$ 256,200**
	Passenger Explosive Detection, Eqo by Smiths Detection	1	EA	$ 225,000	SPI07	$ 364	40.00	$ 14,555	$ 2,183	$ 241,739	$ 241,739
	Civil and architectural works	1	LS	$ 1,500	LAB03	$ 178	16.00	$ 2,853	$ 428	$ 4,781	$ 4,781
	Monitoring and visualization equipment	1	LS	$ 5,000	SPI03	$ 253	16.00	$ 4,050	$ 607	$ 9,657	$ 9,657

	CAPITAL AND REPLACEMENT COST ESTIMATE										
	SCOPE OF WORK	QUANTITY	UNIT	Material Cost [$/unit]	Crew Code	Crew Labor Rate [$/hr.]	Crew Labor Unit [unit/hr.]	Crew Cost [$/unit]	Sub Contr OH & P [$/unit]	Total Unit Cost [$/unit]	Total Cost [$]
T7	**Mass Notification system (i.e. audio announcements)**			**$ 122,094**				**$ 700,379**	**$ 105,057**	**$ 3,369**	**$ 1,000,700**
	Mass notification device	460	EA	$ 250	SPI03	$ 253	6.00	$ 1,519	$ 228	$ 1,996	$ 918,323
	Cabling, connections and installation	150	FT	$ 44	SPI02	$ 234	0.03	$ 7	$ 1.12	$ 53	$ 7,886
	Civil and architectural works	1	LS	$ 500	LAB03	$ 178	4.00	$ 713	$ 107	$ 1,320	$ 1,320
	Notification System, includes software, training and integration	462,400	SF							$ 0.16	$ 73,161
T8	**Mass Notification system integrated with smartphones**			**$ 122,094**				**$ 700,379**	**$ 105,057**	**$ 3,369**	**$ 1,019,000**
	Mass notification device	460	EA	$ 250	SPI03	$ 253	6.00	$ 1,519	$ 228	$ 1,996	$ 918,323
	Cabling, connections and installation	150	FT	$ 44	SPI02	$ 234	0.03	$ 7	$ 1.12	$ 53	$ 7,886
	Civil and architectural works	1	LS	$ 500	LAB03	$ 178	4.00	$ 713	$ 107	$ 1,320	$ 1,320
	Notification System, includes software, integration and notification (smartphone)	462,400	SF							$ 0.20	$ 91,451
T9	**Advance Passenger Information System (APIS)**										**$ 400,000**
		1	LS								$ 400,000
T10	**Blast-resistant trash containers**			**$ 5,500**				**$ 693**	**$ 104**	**$ 6,297**	**$ 6,300**
	Blast mitigation trash receptacles	1	EA	$ 5,000	LAB02	$ 116	2.00	$ 231	$ 35	$ 5,266	$ 5,266
	Civil works and foundations for trash receptacles	1	LS	$ 500	LAB02	$ 116	4.00	$ 462	$ 69	$ 1,031	$ 1,031
T11	**Millimeter Wave Detection Screening – at a TSA checkpoint**			**$ 186,500**				**$ 21,458**	**$ 3,219**	**$ 211,176**	**$ 211,200**
	TSA standard body scanner	1	EA	$ 180,000	SPI07	$ 364	40.00	$ 14,555	$ 2,183	$ 196,739	$ 196,739
	Civil and architectural works	1	LS	$ 1,500	LAB03	$ 178	16.00	$ 2,853	$ 428	$ 4,781	$ 4,781
	Monitoring and visualization equipment	1	LS	$ 5,000	SPI03	$ 253	16.00	$ 4,050	$ 607	$ 9,657	$ 9,657

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OPERATIONAL COST ESTIMATE

	SCOPE OF WORK	QUANTITY	UNIT	Cost per unit	Frequency per year	Total Unit Cost [$/unit] per year	Total Cost [$] per year
Technological Measure							
O1	**Canine olfaction (i.e. explosive-sniffing dogs)**						**$ 881,100**
	Canine Olfaction						$ 296,250
	Trained dog	5	EA	$ 35,000	1	$ 35,000	$ 175,000
	Equipment	5	EA	$ 250	1	$ 250	$ 1,250
	Food and consumables	5	MO	$ 500	12	$ 6,000	$ 30,000
	Shelter and Care	5	MO	$ 1,500	12	$ 18,000	$ 90,000
	Handler						$ 584,834
	Trained Handler / Staff	5	MO	$ 9,372	12	$ 112,467	$ 562,334
	Equipment and uniforms	5	EA	$ 2,000	1	$ 2,000	$ 10,000
	Training	5	EA	$ 2,500	1	$ 2,500	$ 12,500
O2	**Vehicle Checkpoints staffing (i.e. law enforcement personnel checking IDs or trunks)**						**$ 1,090,300**
	Security Checkpoint Guard	10	MO	$ 8,502	12	$ 102,027	$ 1,020,272
	Staff's equipment and uniforms	10	EA	$ 3,500	1	$ 3,500	$ 35,000
	Training	10	EA	$ 2,500	1	$ 2,500	$ 25,000
	Checkpoint equipment and consumables	1	EA	$ 10,000	1	$ 10,000	$ 10,000
O3	**Behavioral Detection officers (i.e. passenger profiling)**						**$ 597,300**
	Behavioral detection officer	5	MO	$ 9,372	12	$ 112,467	$ 562,334
	Officer's equipment and uniforms	5	EA	$ 2,000	1	$ 2,000	$ 10,000
	Training	5	EA	$ 5,000	1	$ 5,000	$ 25,000
O4	**Queue Reduction – Open another airline check-in counter**						**$ 554,900**
	Airline operator	5	MO	$ 8,790	12	$ 105,480	$ 527,400
	Operator's equipment and uniforms	5	EA	$ 2,000	1	$ 2,000	$ 10,000
	Training	5	EA	$ 2,500	1	$ 2,500	$ 12,500
	Check in counter equipment and consumables	1	EA	$ 5,000	1	$ 5,000	$ 5,000
O5	**Queue Reduction – Open another TSA screening checkpoint**						**$ 2,147,600**
	Security Transportation Screeners	15	MO	$ 11,375	12	$ 136,505	$ 2,047,582
	Staff's equipment and uniforms	15	EA	$ 3,500	1	$ 3,500	$ 52,500
	Training	15	EA	$ 2,500	1	$ 2,500	$ 37,500
	TSA screening checkpoint equipment and consumables	1	EA	$ 10,000	1	$ 10,000	$ 10,000
O6	**Random law enforcement patrols (i.e. Police staffing)**						**$ 530,100**

	OPERATIONAL COST ESTIMATE						
	SCOPE OF WORK	QUANTITY	UNIT	Cost per unit	Frequency per year	Total Unit Cost [$/unit] per year	Total Cost [$] per year
	Security Patrol Guard	5	MO	$ 8,502	12	$ 102,027	$ 510,136
	Staff's equipment and uniforms	5	EA	$ 3,500	1	$ 3,500	$ 17,500
	Training	1	EA	$ 2,500	1	$ 2,500	$ 2,500
O7	**Random private security patrols (i.e. Contract security staffing – don't carry guns)**						**$ 364,500**
	Security Staffing services includes, staff, training, benefits and insurances	5	MO	$ 6,075	12	$ 72,900	$ 364,500
O8	**Security Operations Center Staffing**						**$ 530,100**
	Security Operations Center Guard	5	MO	$ 8,502	12	$ 102,027	$ 510,136
	Staff's equipment and uniforms	5	EA	$ 3,500	1	$ 3,500	$ 17,500
	Training	1	EA	$ 2,500	1	$ 2,500	$ 2,500

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STRUCTURAL CAPITAL COST ESTIMATE

	SCOPE OF WORK	QUANTITY	UNIT	Material Cost [$/unit]	Crew Code	Crew Labor Rate [$/hr.]	Crew Labor Unit [unit/hr.]	Crew Cost [$/unit]	Sub Contr OH & P [$/unit]	Total Unit Cost [$/unit]	Total Cost [$]
Direct costs											
Façade Descriptions											$ 819
F1	Option 1 - IGU Outer: 3/8"mm (TT)/Inner 1/4" (HS)+0.03PVB+1/4" (HS)	1	SF							$ 75	$ 75
F2	Option 2(a+b) - Standard 4/28 and 10/89 Façade Systems that would suit an airport – Performance Condition 3b	1	SF							$ 110	$ 110
F3	Option 3 - IGU Outer: 3/8" (TT)/ Inner 1/4" (HS)+0.06PVB+1/4" (HS)	1	SF							$ 154	$ 154
F4	Option 4 - IGU Outer: 3/8" (TT)/ Inner 1/4" (HS)+0.06PVB+1/4" (HS)	1	SF							$ 183	$ 183
F5	Option 5 - IGU: Outer: ¼" HS 0.06PVB/ ¼" HS Inner: ¼" HS 0.06PVB ¼" HS 0.06 PVB ¼" HS	1	SF							$ 297	$ 297
Column (Floor to Floor, height = 20-30ft for steel columns and height = 12ft concrete columns)											$ 22,416
C1	Option 1 - W12x106	1	EA							$ 4,500	$ 4,500
C2	Option 2 - W12 x 106 + 1" stiffener plates to Box section at column base+ Grout filled at colu	1	EA							$ 5,000	$ 5,000
C3	Option 3 - W12 x 106 + 20" Square Concrete encasement	1	EA							$ 5,400	$ 5,400
C4	Option 4 - 3' Diameter Concrete Column + #4 hoops at 12" centers + 16 x #10 longitudinal ba	1	EA							$ 1,400	$ 1,400
C5	Option 5 - 3' Diameter Concrete Column + #6 hoops at 6" centers + 16 x #10 longitudinal bar	1	EA							$ 2,416	$ 2,416
C6	Option 6 - 3" Diameter concrete Column +#4 Ties at 12" centers+ ½" full height steel jacket +	1	EA							$ 3,700	$ 3,700
Roof Beam (32ft span, 32ft load width): PBIED											$ 12,958
RB1	Option 1 - W21 x 62	1	EA							$ 3,114	$ 3,114
RB2	Option 2 - W24 x 84	1	EA							$ 4,150	$ 4,150
RB3	Option 3 - W30 x 116	1	EA							$ 5,694	$ 5,694
Roof Structure (32ft span, 32ft load width): VBIED											$ 28,405
RS1	Option 1 - W21x 62 (primary Beams-32ft span) + W21x50 (secondary Beams at 16ft centers)	1	EA							$ 7,136	$ 7,136
RS2	Option 2 - W24x 84 (primary Beams-32ft span) + W21x68 (secondary Beams at 16ft centers)	1	EA							$ 9,352	$ 9,352
RS3	Option 3 - W30 x 116 (primary Beams-32ft span) + W24 x 84 (secondary Beams at 16ft cente	1	EA							$ 11,917	$ 11,917
Floor Beam (32ft span, 20ft load width)											$ 2,848
FB1	Option 1 - W24 x 84 + Shear Studs + 8" RC slab (#4 bars at 8" centers)	1	EA							$ 768	$ 768
FB2	Option 2 - W27 x 146 +Shear Studs +10" RC slab (#4 bars at 8" centers) + enhanced connecti	1	EA							$ 960	$ 960
FB3	Option 3 - W30 x 116 +Shear Studs +12" RC slab (#5 bars at 8" centers) + enhanced connecti	1	EA							$ 1,120	$ 1,120
Vehicle Security Barrier Pricing											$ 17,422
VB1	Steel Bollard - N	1	FT							$ 113	$ 113
VB2	Jersey Barrier - N	1	FT							$ 117	$ 117
VB3	Concrete Planter - N	1	FT							$ 239	$ 239
VB4	Concrete Bench/street furniture - N	1	FT							$ 191	$ 191
VB5	Raised Kerb - N	1	FT							$ 14	$ 14
VB6	Concrete Wall - N	1	FT							$ 421	$ 421
VB7	Bollard - PU50-P1	1	FT							$ 3,129	$ 3,129
VB8	Bollard - K4 (M30)	1	FT							$ 1,685	$ 1,685
VB9	Bollard - K8	1	FT							$ 2,677	$ 2,677
VB10	Bollard - K8	1	FT							$ 2,355	$ 2,355
VB11	Bollard - K12	1	FT							$ 2,414	$ 2,414
VB12	Bollard - K12	1	FT							$ 290	$ 290
VB13	Bollard - H30 P1 M30	1	FT							$ 266	$ 266
VB14	Shallow mount bollard (8' wide) - Typical Rating – K4	1	FT							$ 1,654	$ 1,654
VB15	Shallow mount bollard (8' wide) - Typical Rating – K12	1	FT							$ 1,857	$ 1,857

Façade Cost Alternatives	Unenhanced			Option 1			Option 2			Option 3			Option 4		
	UNIT	QUANTITY	Total Cost [$]	UNIT	QUANTITY	Total Cost [$]	UNIT	QUANTITY	Total Cost [$]	UNIT	QUANTITY	Total Cost [$]	UNIT	QUANTITY	Total Cost [$]
Glass	**SF**	**1**	**$ 45**	**SF**	**1**	**$ 33**	**SF**	**1**	**$ 65**	**SF**	**1**	**$ 51**	**SF**	**1**	**$ 100**
IGU HS Outer 3/8"	SF	1	$ 14	SF	1		SF	1	$ 14	SF	1	$ 14	SF	0	$ -
IGU HS Outer 1/4"	SF	1	$ 12	SF	1		SF	1	$ 12	SF	1	$ 12	SF	1	$ 12
IGU HS Outer 1/4"	SF	0	$ -	SF	0		SF	0	$ -	SF	0	$ -	SF	1	$ 12
PVB, First layer 0.03	SF	1	$ 7	SF	1		SF	0	$ -	SF	0	$ -	SF	0	$ -
PVB, First layer 0.06	SF	0	$ -	SF	0		SF	1	$ 13	SF	1	$ 13	SF	1	$ 13
HS medium glass 1/4"	SF	0	$ -	SF	0		SF	0	$ -	SF	0	$ -	SF	1	$ 12
PVB, Second layer 0.06	SF	0	$ -	SF	0		SF	0	$ -	SF	0	$ -	SF	1	$ 13
HS Inner glass 1/4"	SF	1	$ 12	SF	1		SF	1	$ 12	SF	1	$ 12	SF	1	$ 12
PVB, Third layer 0.06	SF	0	$ -	SF	0		SF	1	$ 13	SF	0	$ -	SF	1	$ 13
HS Inner glass 1/4"	SF	0	$ -	SF	0		SF	0	$ -	SF	0	$ -	SF	1	$ 12
Framing	**SF**	**1**	**$ 30**	**SF**	**1**	**$ 77**	**SF**	**1**	**$ 89**	**SF**	**1**	**$ 132**	**SF**	**1**	**$ 197**
Aluminum extrusion 10 x 4 x 0.125	SF	1	$ 30	SF	1		SF	0	$ -	SF	0	$ -	SF	0	$ -
Aluminum extrusion 10 x 6 x 3/16	SF	0	$ -	SF	0		SF	1	$ 67	SF	0	$ -	SF	0	$ -
HSS 12 x 4 x 1/4	SF	0	$ -	SF	0		SF	0	$ -	SF	1	$ 132	SF	0	$ -
HSS 16 x 8 x 1/2	SF	0	$ -	SF	0		SF	0	$ -	SF	0	$ -	SF	1	$ 197
Steel stifening inserts	SF	0	$ -	SF	0		SF	1	$ 22	SF	0	$ -	SF	0	$ -
TOTAL Direct Cost per SF			**$ 75**			**$ 110**			**$ 154**			**$ 183**			**$ 297**

Façade option $ / SF

Summary	$ / SF
Unenhanced	$ 75
Option 1	$ 110
Option 2	$ 154
Option 3	$ 183
Option 4	$ 297

Note:
Direct Cost include material, labor and equipment

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	Additional Physical Measures				
	SCOPE OF WORK	QUANTITY	UNIT	Total Unit Cost [$/unit]	Total Cost [$]
Direct costs					
Security Film					**$ 6,206**
SF1	3M shield against blasts Ultra S600	260	SF	$ 4	$ 1,030
SF2	3M shield against blasts Ultra S600 + mechanical attachments	260	SF	$ 14	$ 3,764
SF3	3M shield against blasts Ultra S600 + silicone sealant	260	SF	$ 5	$ 1,412
Cable Catching System					**$ 7,556**
CC1	Cable Catching System, 80FT 0.5" cable, 8 attachments pero window	260	SF	$ 29	$ 7,556
Reinforced Polymeter (FRP)					**$ 10,400**
RP1	Fiber Polymeter on existing structure	260	SF	$ 40	$ 10,400
Polymer Sprays					**$ 7,800**
PS1	Polymer Sprays Line-X PAXCON	260	SF	$ 30	$ 7,800
Architectural cladding					**$ 10,232**
AC1	Architecural cladding, Column 14' diameter	30	FT	$ 341	$ 10,232
Curb Height					**$ 10,992**
CH1	Increase the curb height (from 6in to 12in)	600	LF	$ 18	$ 10,992
Physical height restriction					**$ 7,006**
HR1	Physical height restriction 6" height 32" width	1	EA	$ 7,006	$ 7,006
Speed humps					**$ 5,000**
SH	Speed Humps, includes signs and civil works	1	EA	$ 5,000	$ 5,000

PARAS0014
Rough Order of Magnitude Cost Estimate
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escalation	3.5%
discount rate	6.3%

Example / Theoretical Life Cycle Cost with escalation and discount rate			
			NPV
A	Inside the check-in hall and baggage claim / arrivals hall of the terminal (just one number for both of those areas).	TOTAL	$ 89,000,000
B	Outside the terminal along the passenger drop-off / pick-up curb	TOTAL	$ 55,000,000
C	At the TSA security screening queues	TOTAL	$ 95,000,000
D	A parking garage adjacent to the airport	TOTAL	$ 49,000,000
E	At a bus terminal or plaza / bus stop at the airport	TOTAL	$ 48,000,000
F	At the fuel farm of the airport (i.e. where the fuel is kept – this is usually a fenced in area somewhere at the perimeter of the taxiway)	TOTAL	$ 7,000,000
G	At an airport metro connector station / people mover station (e.g. BART's SFO station)	TOTAL	$ 99,000,000
H	At the central utilities room (i.e. the room or building housing the power feed / main electrical switchgear / mechanical systems, etc.)	TOTAL	$ 7,000,000
TOTAL			**$ 449,000,000**

Notes:

i) A time frame of 20 years is considered as part of the Life Cycle Cost analysis
ii) Capital, operational and replacement costs considered
iii) Maintenance cost is excluded
iv) A yearly escalation is considered as a 3.5%
v) A yearly discount rate is considered as a 6.34%
vi) The values are reflected in a year basis

APPENDIX D: INDICATIVE BLAST-MITIGATION DETAILS

National Safe Skies Alliance
PARAS 0014

Indicative Blast Mitigation Details
For Architectural and Building Service Components

NOT FOR CONSTRUCTION

August 10, 2018

NOTE:
These details are indicitive for blast performance only. All details to be checked by licensed engineer prior to design implementation.

PREPARED FOR
ARUP Advanced Technology and Research

PREPARED BY
bmk CONSULTING SERVICES bmk Consulting Services

SKETCH INDEX

SKETCH NUMBER	SKETCH TITLE
1	BALUSTRADE DETAIL - BOTTOM CONNECTION
2	INTERNAL GLAZING SCREEN / SHOP FRONT - BOTTOM CONNECTION
3	INTERNAL GLAZING SCREEN / SHOP FRONT - TOP CONNECTION
4	GLASS SMOKE - BAFFLE DETAIL
5	GLAZED PANEL TO STUD WALL
6	TOP RESTRAINT AT PARTIAL HEIGHT PARTITION WALL
7	ENHANCED COLUMN - CONCRETE ENCASEMENT
8	ENHANCED FLOOR BEAM
9	BASELINE FLOOR BEAM (Not designed for blast)
10	BASELINE CONCRETE COLUMN
11	CONCRETE COLUMN WITH STEEL JACKET DETAIL - 1
12	CONCRETE COLUMN WITH STEEL JACKET DETAIL - 2
13	3D ISOMETRIC OF TYPICAL AIRPORT FACADE
14	STANDARD WINDOW MULLION (Not designed for blast)
15	BLAST ENHANCED WINDOW MULLION
16	STANDARD UNITIZED WINDOW MULLION (Not designed for blast)
17	BLAST ENHANCED UNITIZED WINDOW MULLION
18	ENHANCED STEEL MULLION
19	RESTRAINT OF CEILINGS
20	TYPICAL RESTRAINT OF LIGHTING FIXTURE
21	RESTRAINT OF SERVICES
22	RESTRAINT OF SERVICES
23	RESTRAINT OF PIPEWORK WITH UBOLT

ABBREVIATIONS

DLO	DAYLIGHT OPENING
EA	EACH
IGU	INSULATED GLAZING UNIT
MAX	MAXIMUM
MIN	MINIMUM
PVB	POLYVINYL BUTYRAL
SMS	SHEET METAL SCREWS
TYP	TYPICAL
UON	UNLESS OTHERWISE NOTED

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ARUP Advanced Technology and Research
560 Mission Street, Suite 700
San Francisco, CA 94105 USA

PROJECT NAME

National Safe Skies Alliance
PARAS 0014

PREPARED FOR

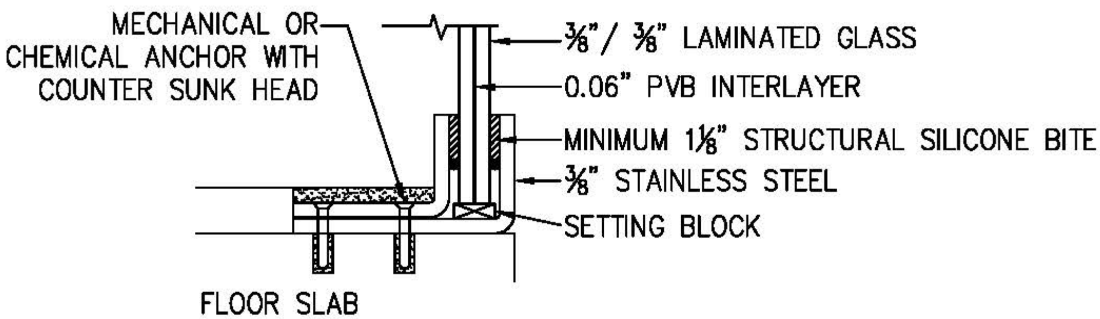
bmk Consulting Services
Village Square Professional Center
13625 Office Place, Suite 201
Woodbridge, Virginia 22192
TEL (703) 490-2212
FAX (571) 659-0688

DRAWING TITLE

Indicative Blast Mitigation Details
For Architectural and Building Service Components

SCALE: AS NOTED | DATE: 8-10-2018 | SKETCH: INDEX

NOT FOR CONSTRUCTION



1 BALUSTRADE DETAIL BOTTOM CONNECTION

SCALE: 3" = 1'-0"

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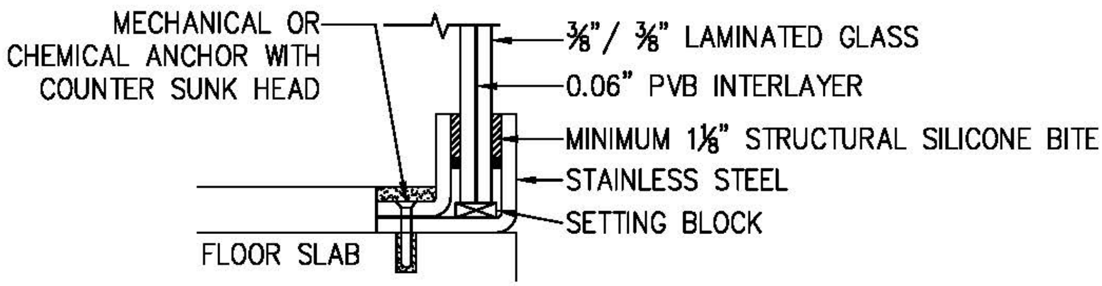
	SCALE: AS NOTED / DATE: 8-10-2018 / SKETCH: 1

NOT FOR CONSTRUCTION



2 INTERNAL GLAZING BOTTOM SUPPORT DETAIL SCREEN / SHOP FRONT

SCALE: 3" = 1'-0"

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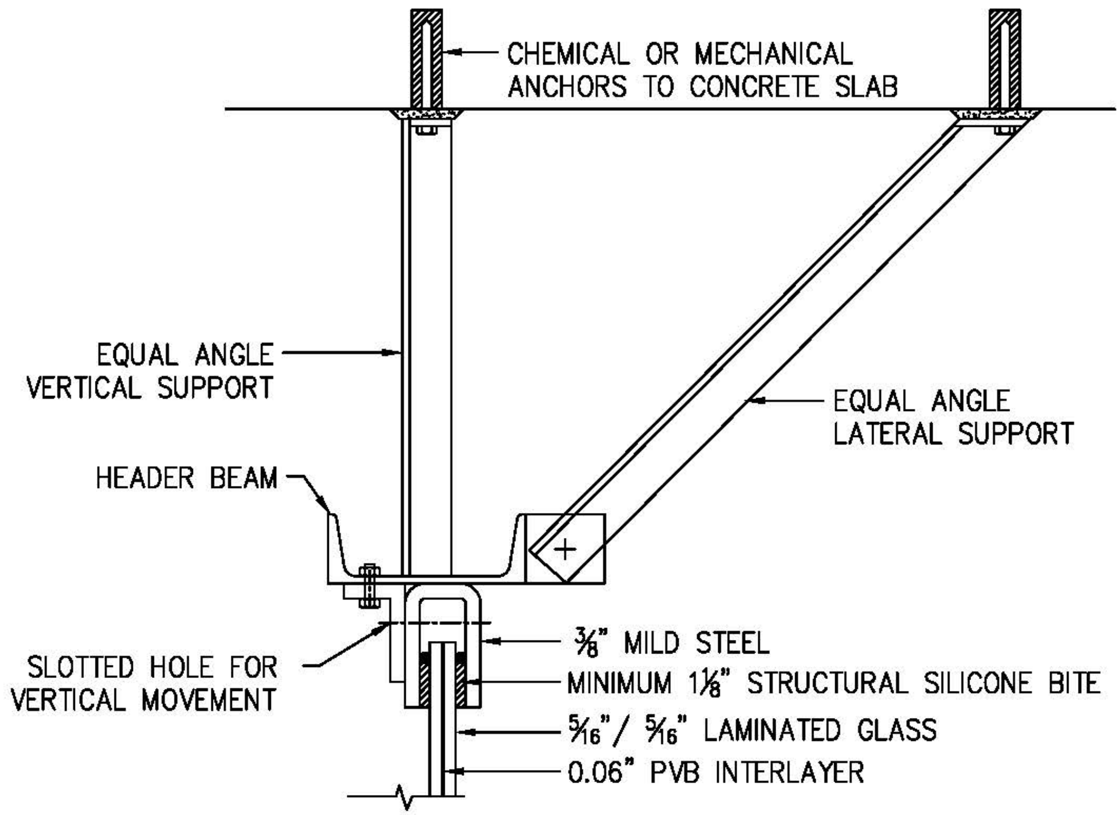
NOT FOR CONSTRUCTION



INTERNAL GLAZING TOP SUPPORT DETAIL SCREEN / SHOP FRONT

3

SCALE: 3" = 1'-0"

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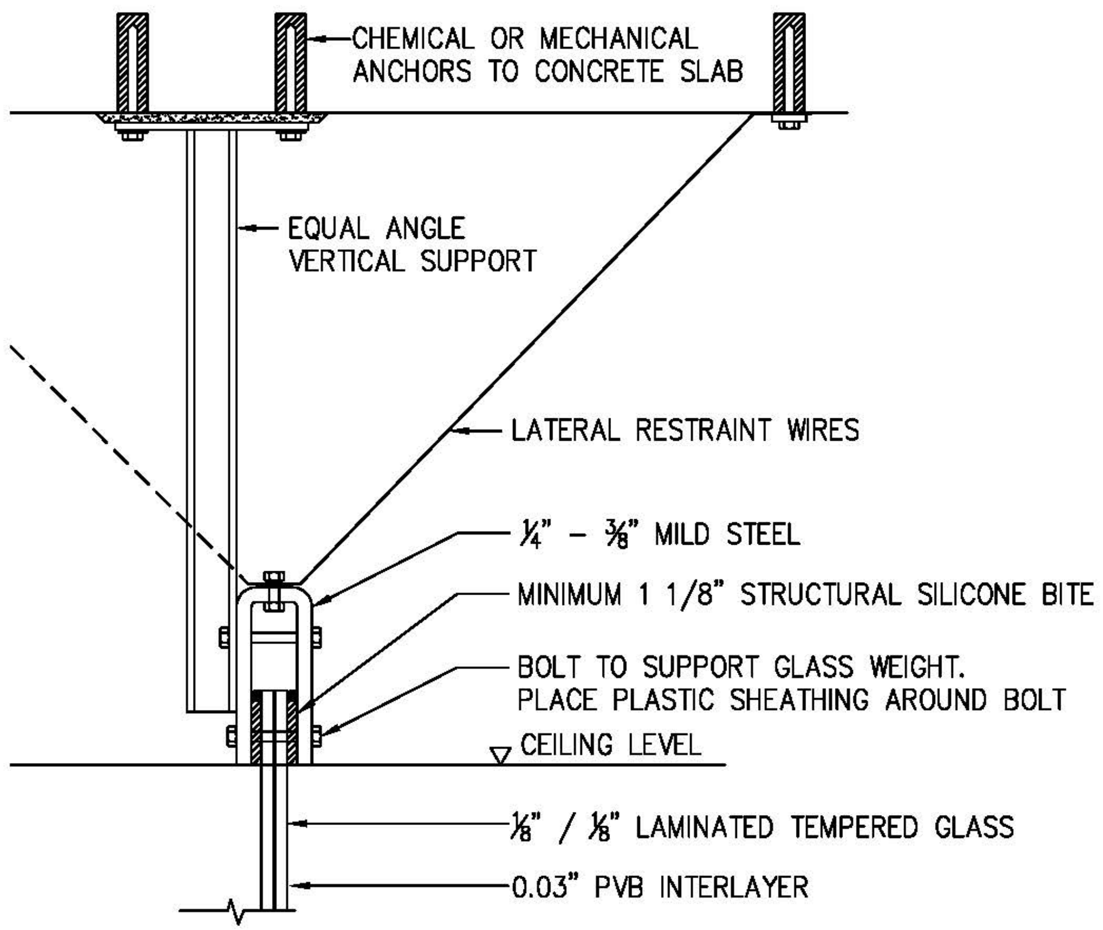
NOT FOR CONSTRUCTION



4 **GLASS SMOKE BAFFLE DETAIL**

SCALE: 3" = 1'-0"

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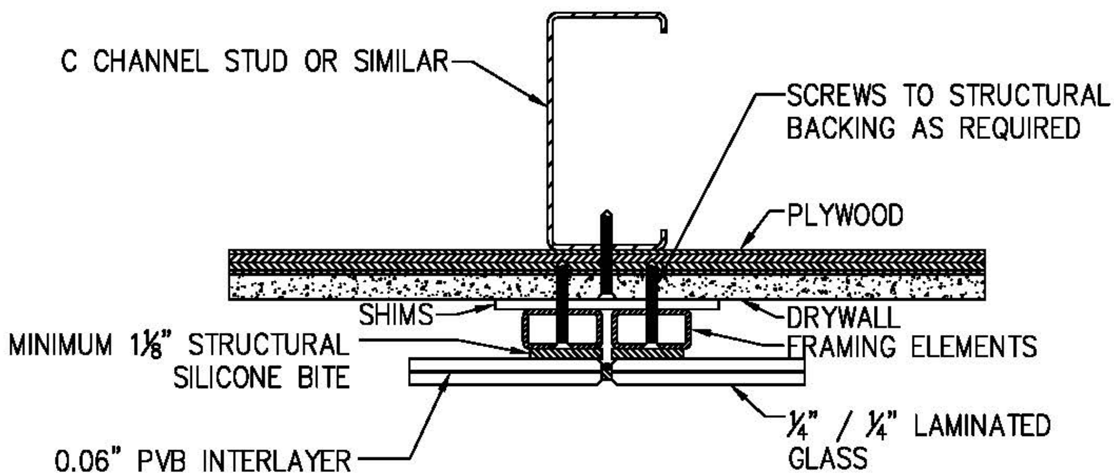
NOT FOR CONSTRUCTION



5 GLAZED PANEL TO STUD WALL

SCALE: 3" = 1'-0"

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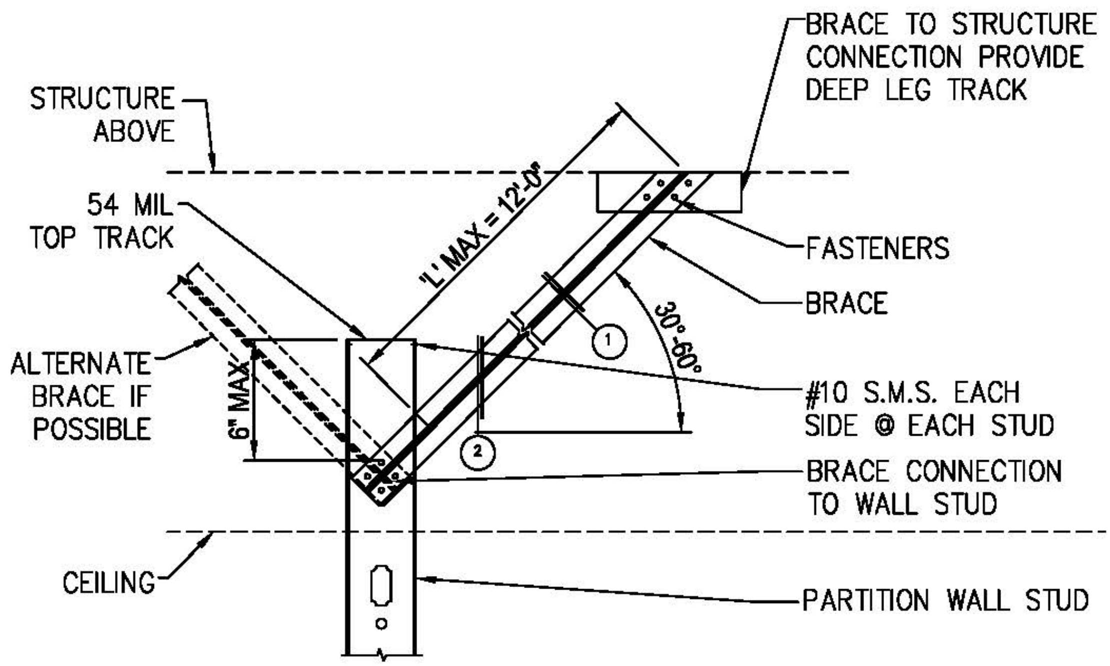

TOP RESTRAINT AT PARTIAL HEIGHT PARTITION WALL

6

SCALE: 1½" = 1'-0"

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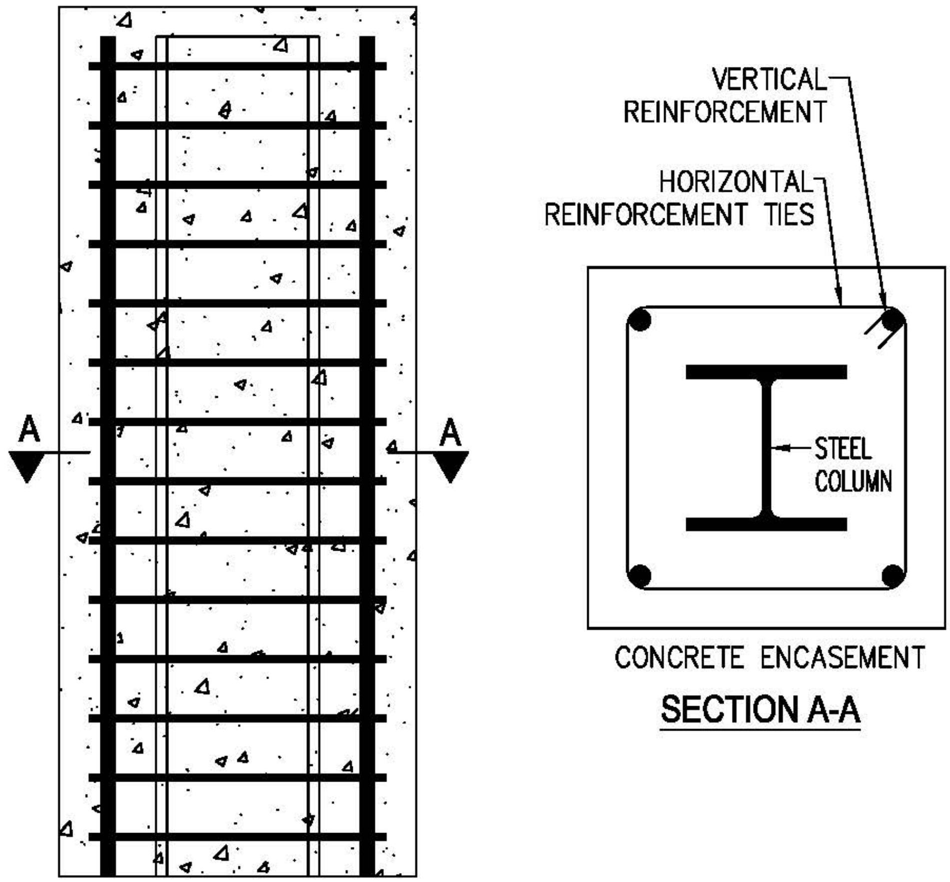
NOT FOR CONSTRUCTION



7 ENHANCED COLUMN - CONCRETE ENCASEMENT

SCALE: 3" = 1'-0"

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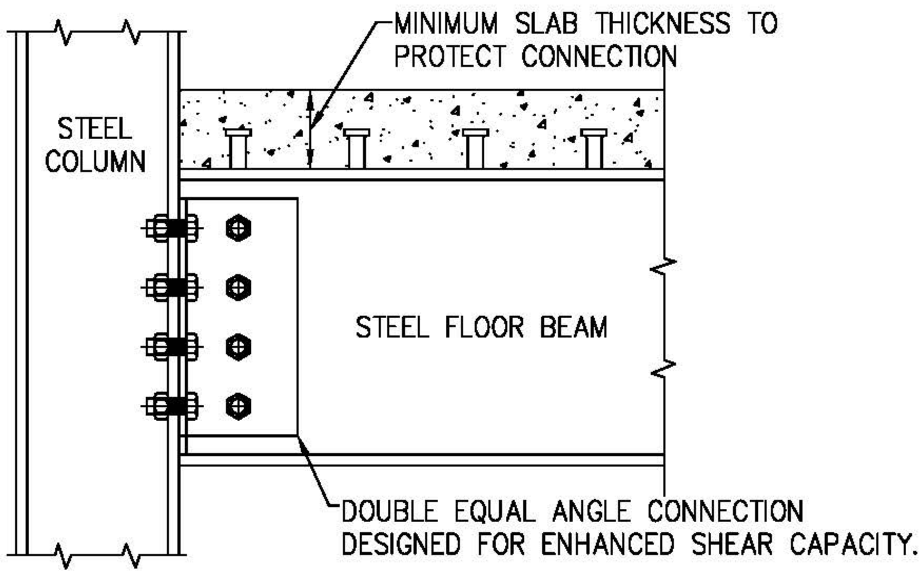
NOT FOR CONSTRUCTION



8 **ENHANCED FLOOR BEAM**

SCALE: 1½" = 1'-0"

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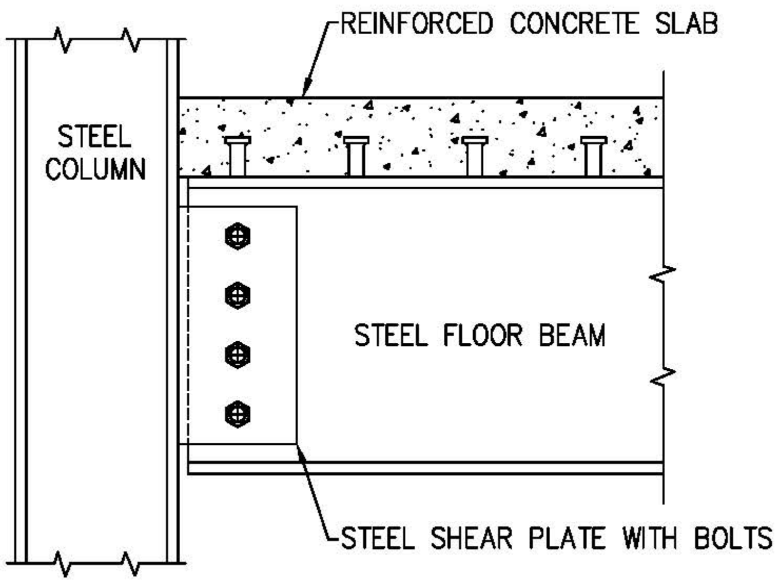
NOT FOR CONSTRUCTION



9 **BASELINE FLOOR BEAM** (NOT DESIGNED FOR BLAST)

SCALE: 1½" = 1'-0"

PREPARED FOR ARUP Advanced Technology and Research 560 Mission Street, Suite 700 San Francisco, CA 94105 USA	PROJECT NAME National Safe Skies Alliance PARAS 0014
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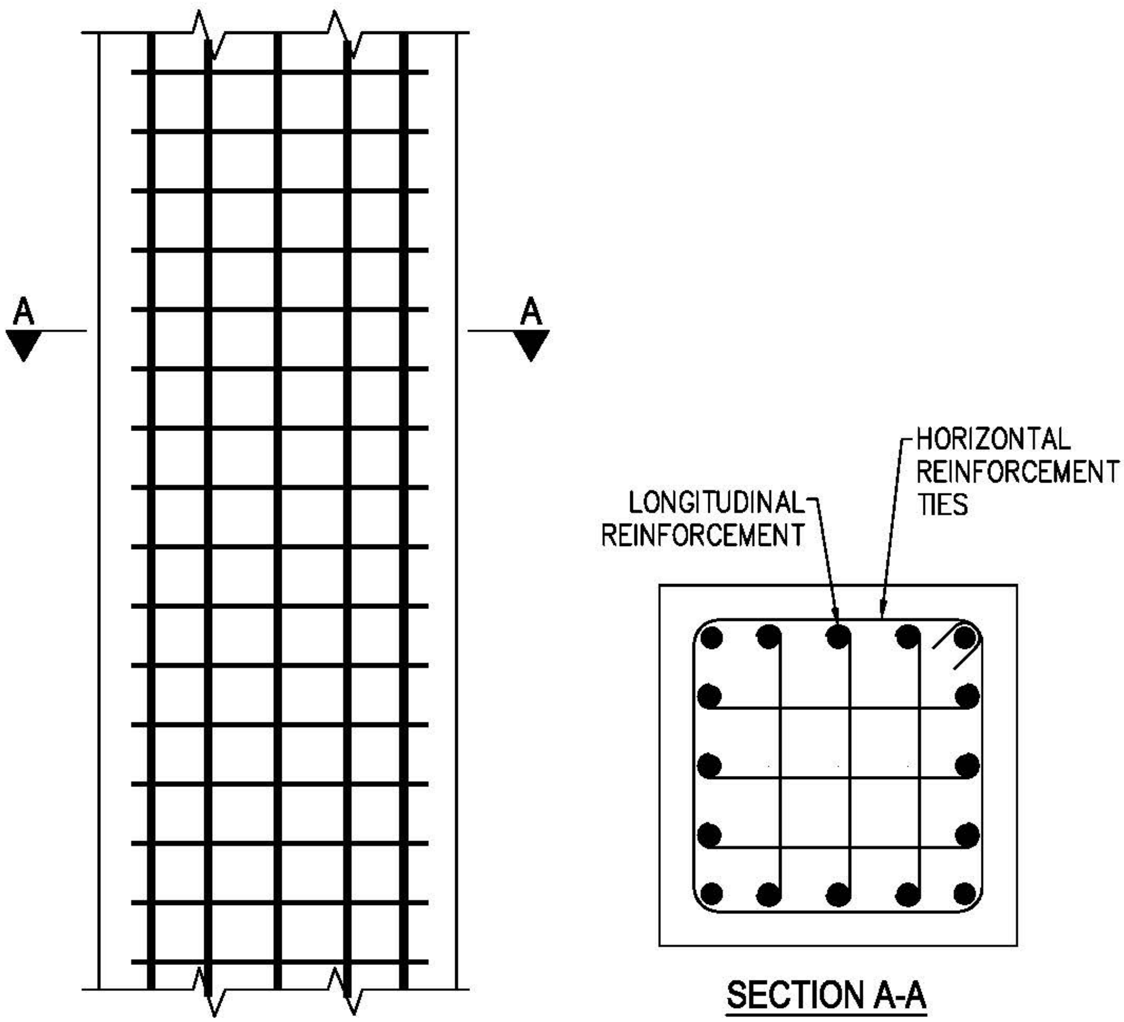
NOT FOR CONSTRUCTION



SECTION A-A

10A BASELINE CONCRETE COLUMN

SCALE: 1½" = 1'-0" (NOT DESIGNED FOR BLAST)

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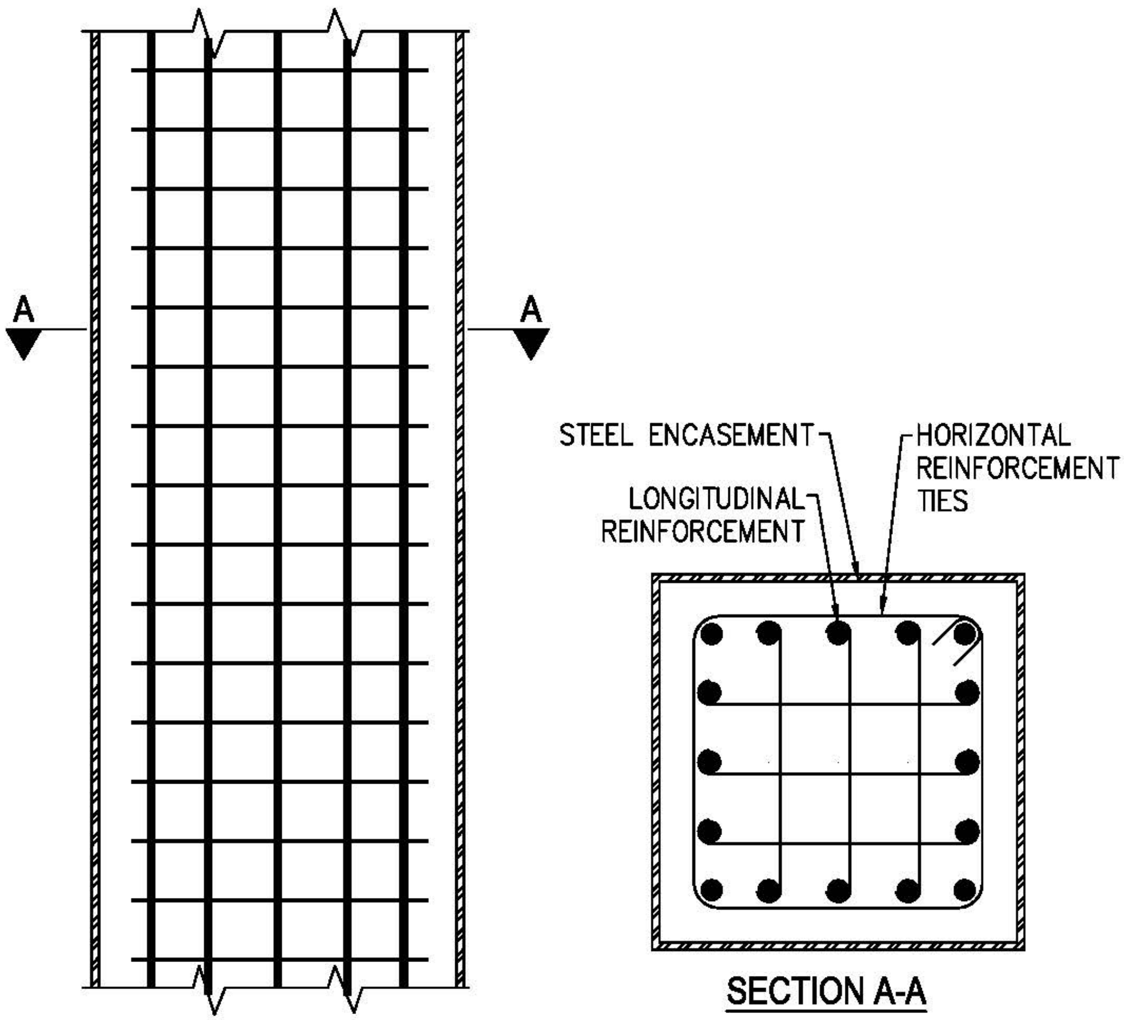
	SCALE: AS NOTED	DATE: 8-10-2018	SKETCH: 10

NOT FOR CONSTRUCTION



10B CONCRETE COLUMN WITH STEEL JACKET DETAIL-1

SCALE: 1½" = 1'-0"

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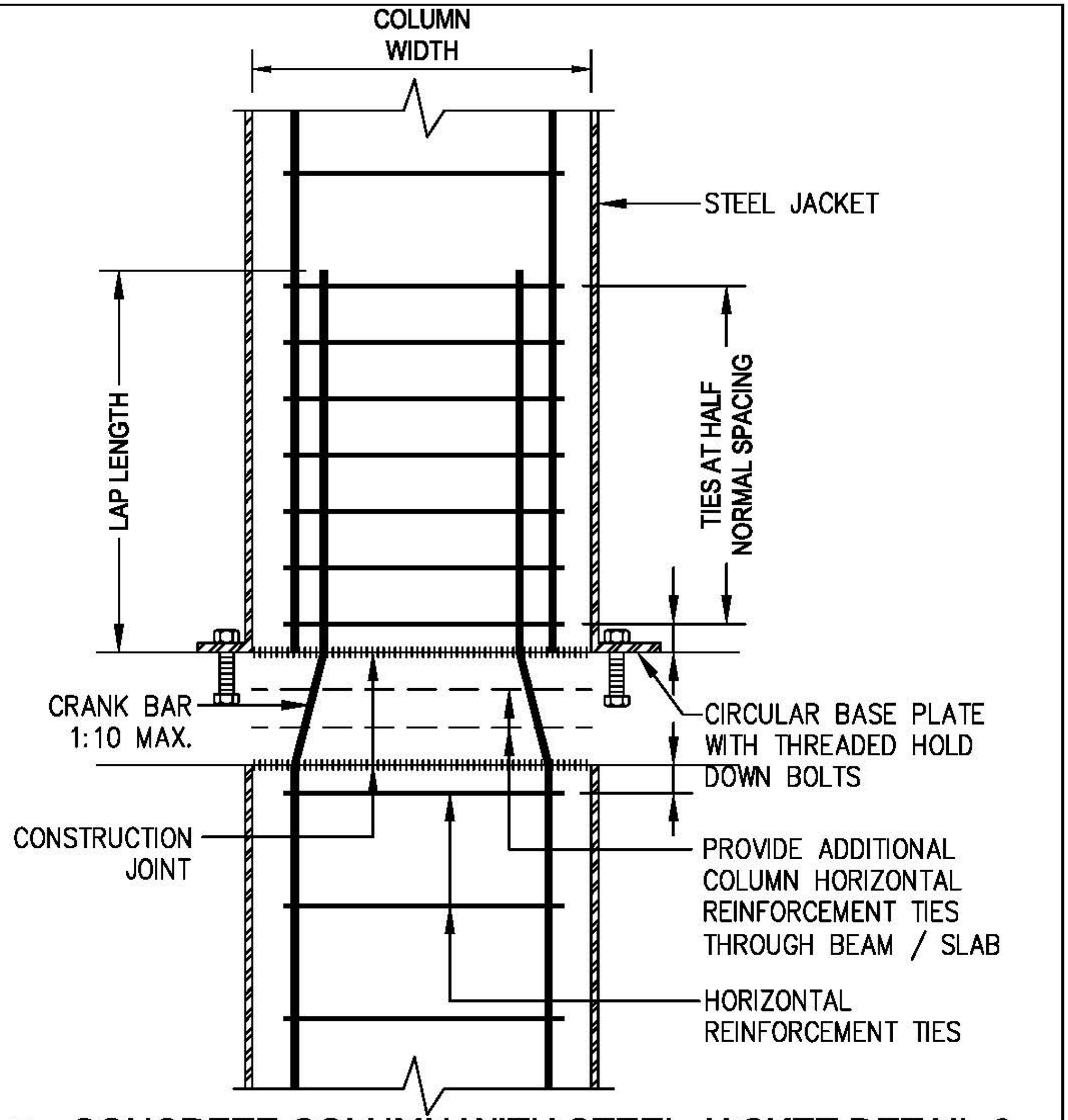
Indicative Blast Mitigation Details For Architectural and Building Service Components

SCALE: AS NOTED | DATE: 8-10-2018 | SKETCH: 11

NOT FOR CONSTRUCTION



10C CONCRETE COLUMN WITH STEEL JACKET DETAIL-2

SCALE: 1½" = 1'-0"

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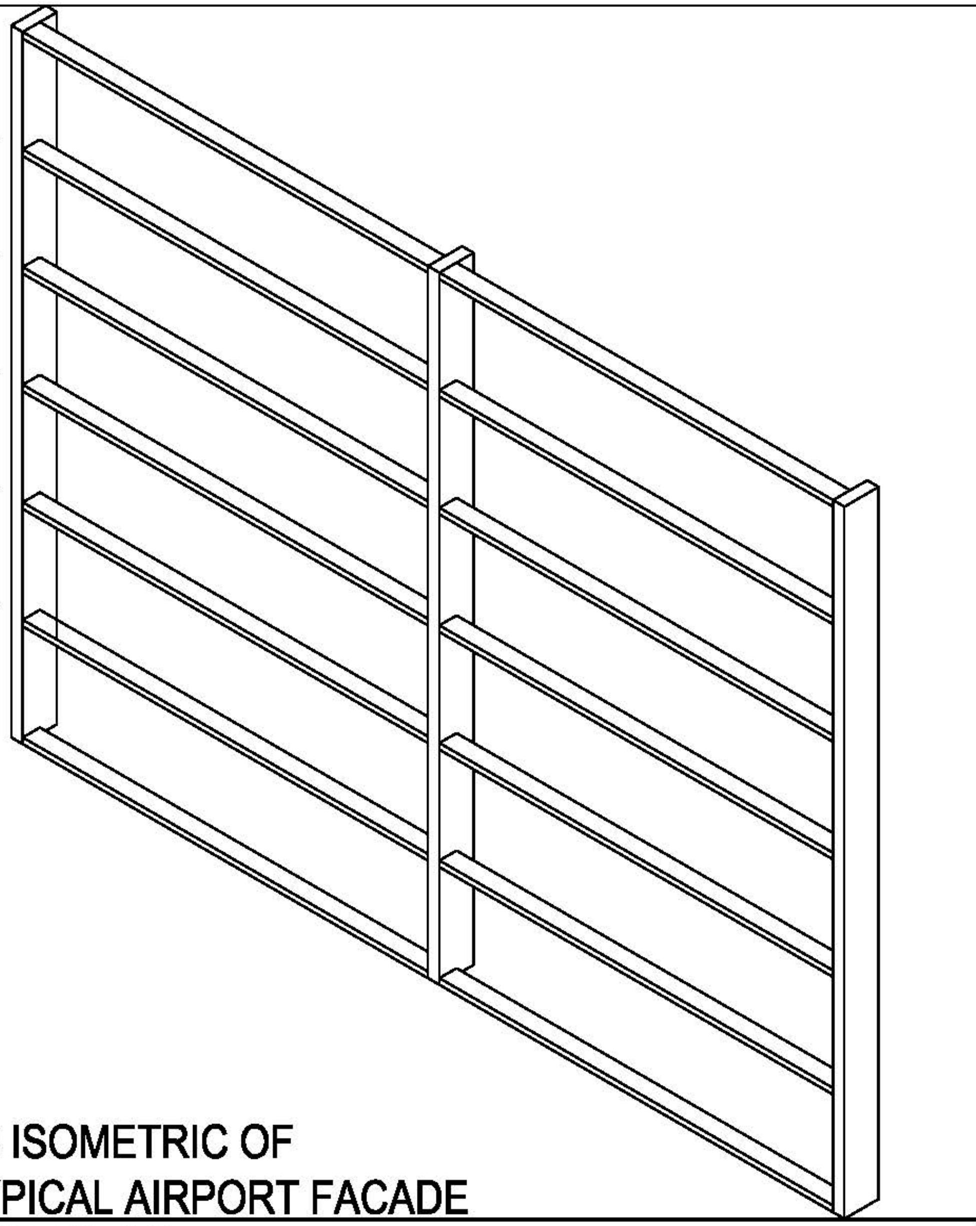
	SCALE: AS NOTED — DATE: 8-10-2018 — SKETCH: 12

NOT FOR CONSTRUCTION



3D ISOMETRIC OF TYPICAL AIRPORT FACADE

11

SCALE: 1½" = 1'-0"

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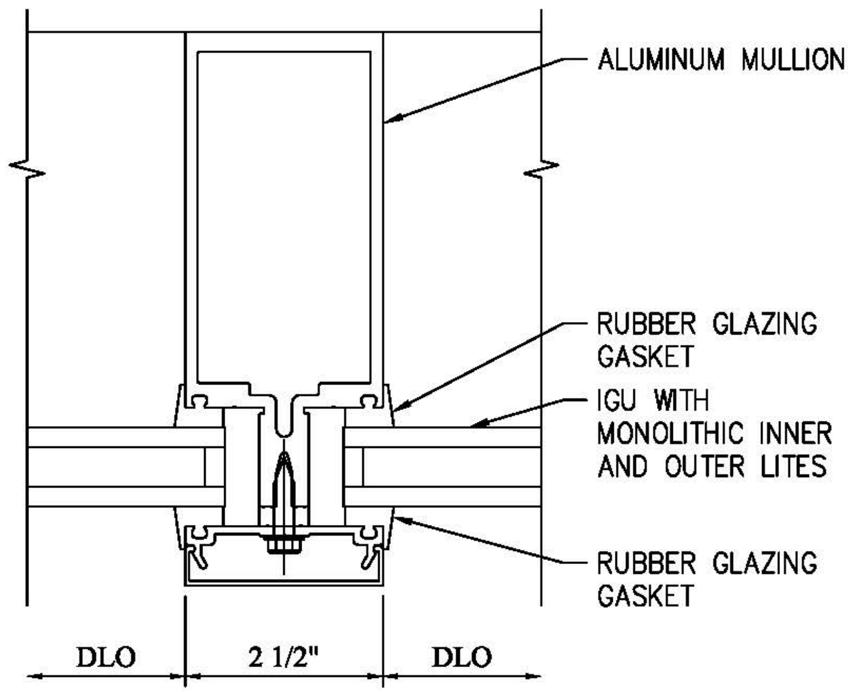

12 **STANDARD WINDOW MULLION** (NOT DESIGNED FOR BLAST)

SCALE: 6" = 1'-0"

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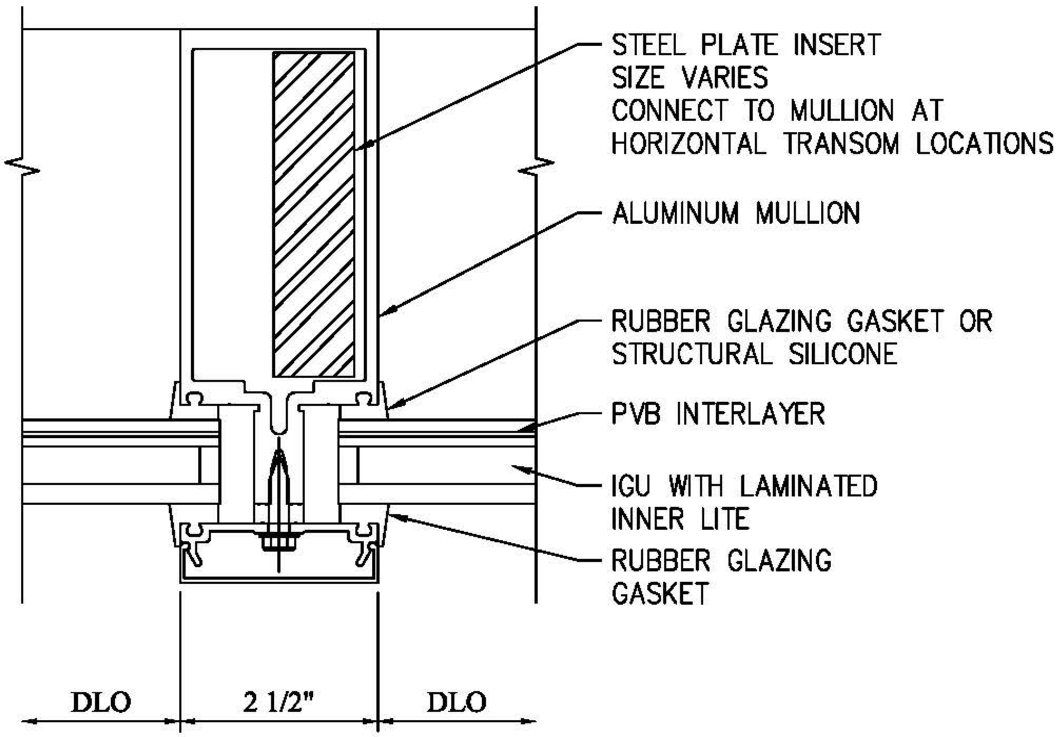
NOT FOR CONSTRUCTION



BLAST ENHANCED WINDOW MULLION (STEEL PLATE OR STEEL CHANNEL)

13

SCALE: 1½" = 1'-0"

PREPARED FOR ARUP Advanced Technology and Research 560 Mission Street, Suite 700 San Francisco, CA 94105 USA	PROJECT NAME National Safe Skies Alliance PARAS 0014
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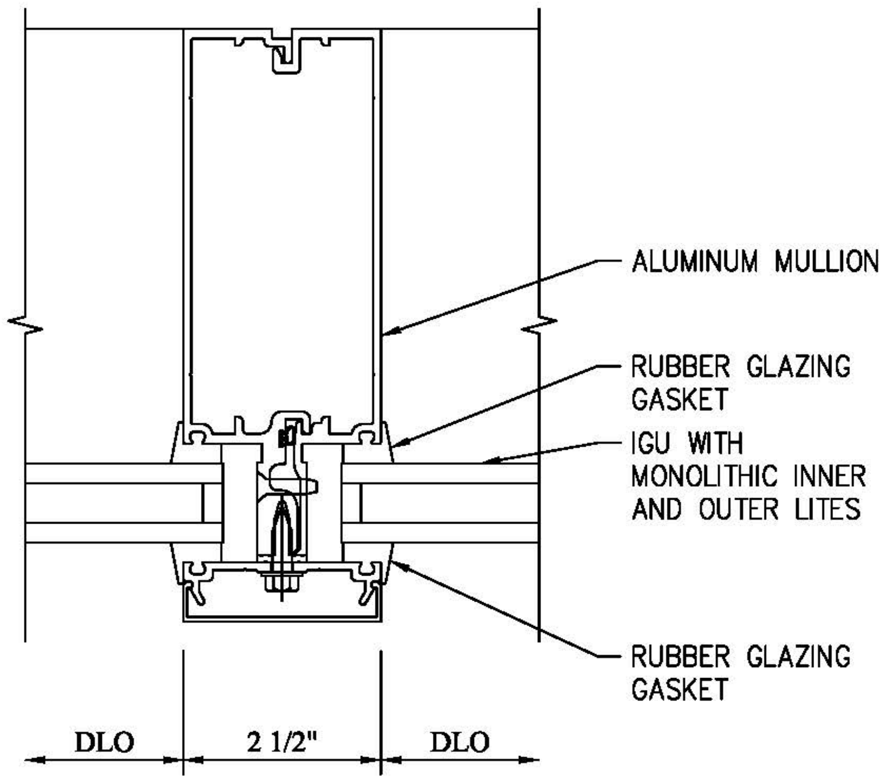
NOT FOR CONSTRUCTION



14 STANDARD UNITIZED WINDOW MULLION

SCALE: 1½" = 1'-0" (NOT DESIGNED FOR BLAST)

PREPARED FOR ARUP Advanced Technology and Research 560 Mission Street, Suite 700 San Francisco, CA 94105 USA	PROJECT NAME National Safe Skies Alliance PARAS 0014
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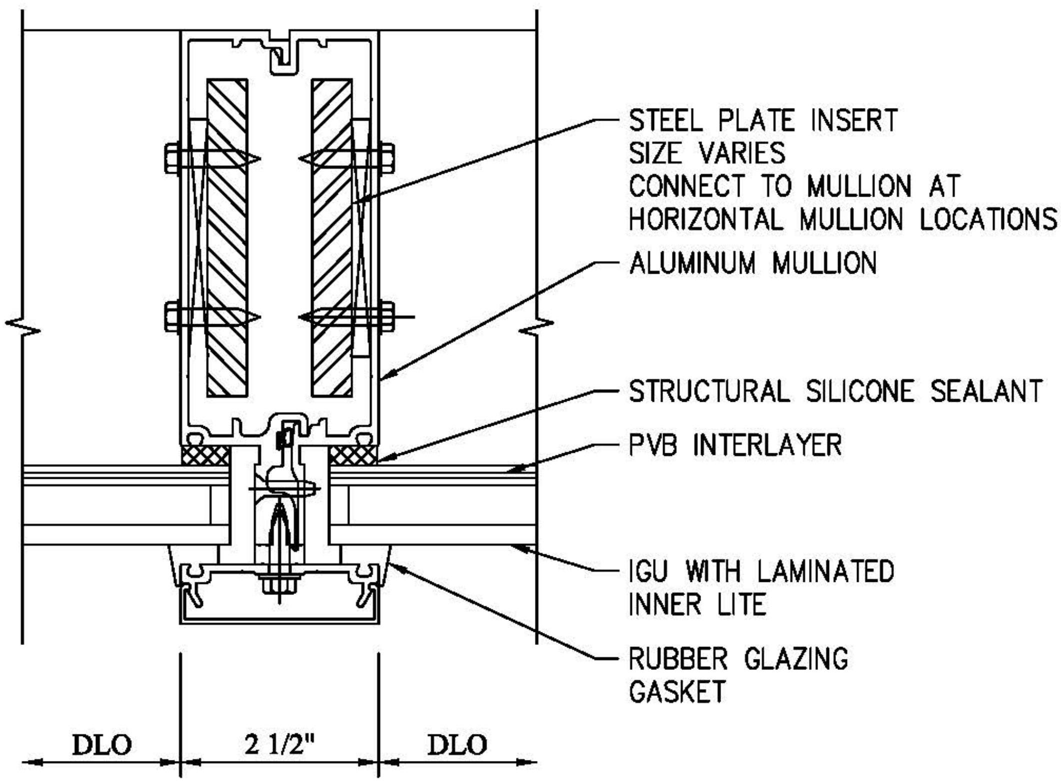
NOT FOR CONSTRUCTION



BLAST ENHANCED UNITIZED WINDOW MULLION (STEEL PLATE)

15

SCALE: 6" = 1'-0"

PREPARED FOR ARUP Advanced Technology and Research 560 Mission Street, Suite 700 San Francisco, CA 94105 USA	PROJECT NAME National Safe Skies Alliance PARAS 0014
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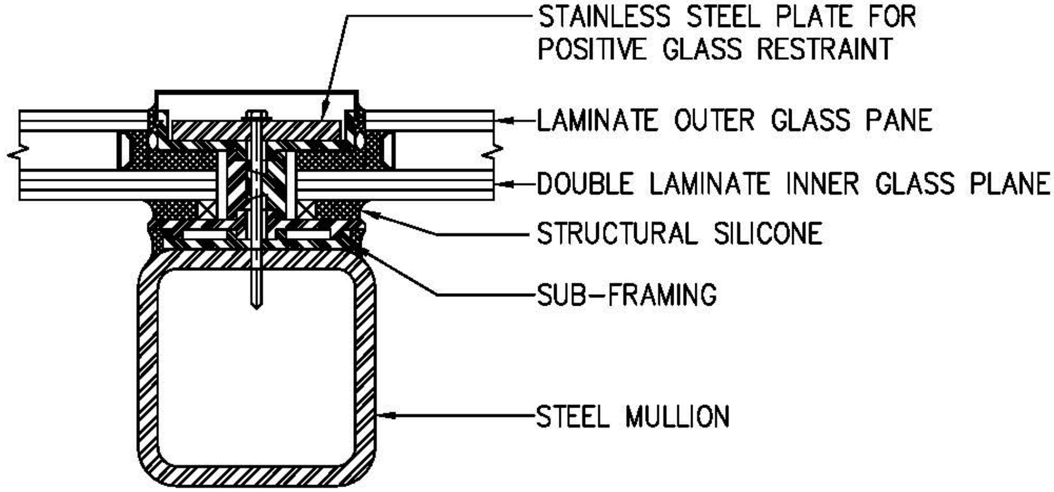
NOT FOR CONSTRUCTION



16 ENHANCED STEEL MULLION

SCALE: 3" = 1'-0"

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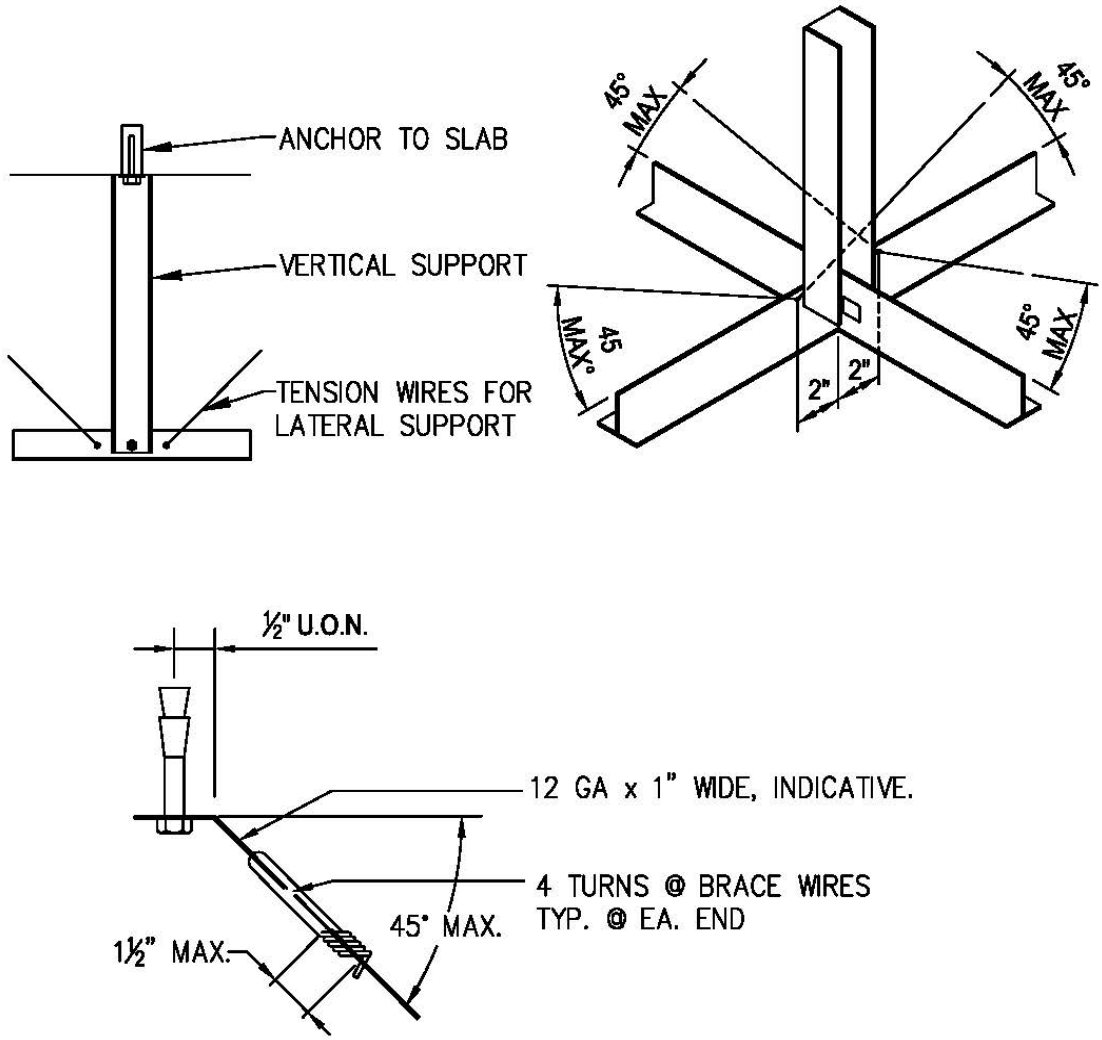

17 RESTRAINT OF CEILINGS

SCALE: 3" = 1'-0"

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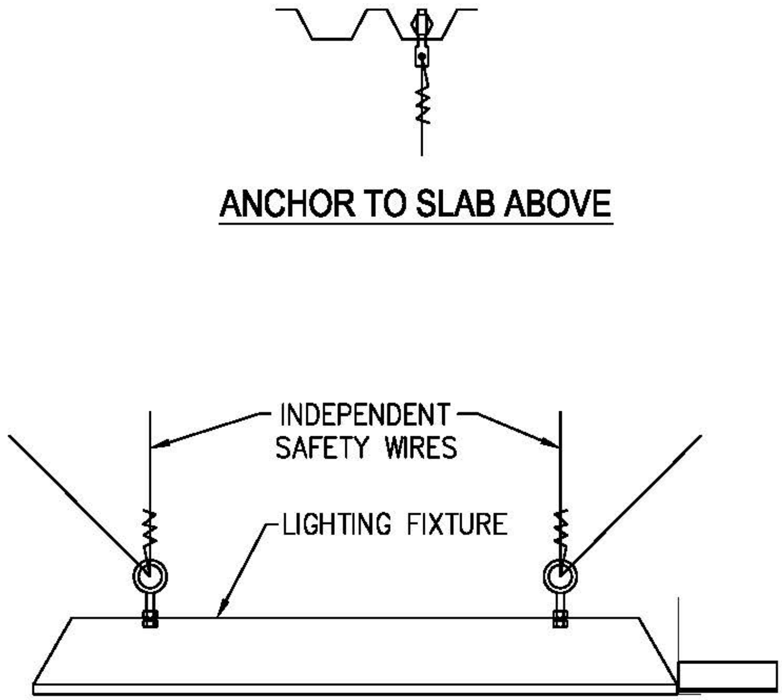

18 TYPICAL RESTRAINT OF LIGHTING FIXTURE
SCALE: 3" = 1'-0"

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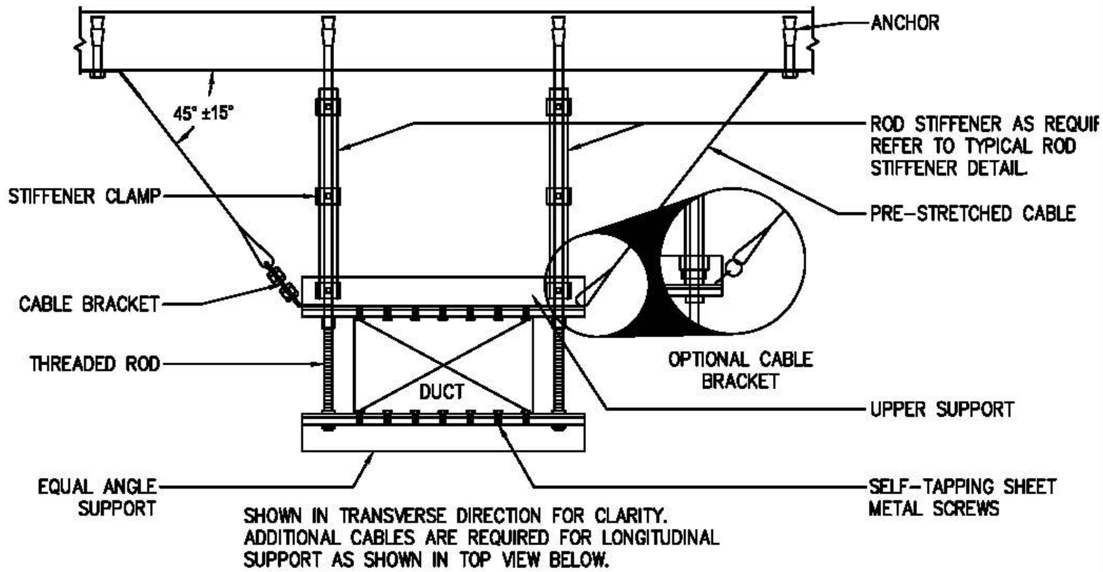
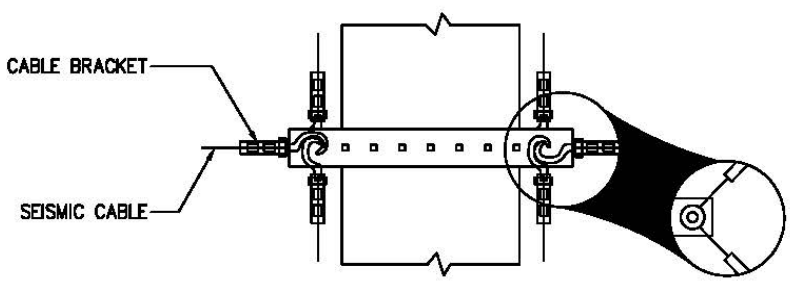
NOT FOR CONSTRUCTION



FRONT VIEW



TOP VIEW – ALL DIRECTIONAL BRACE

CABLE DUCT BRACING

19 RESTRAINT OF SERVICES

SCALE: 3" = 1'-0"

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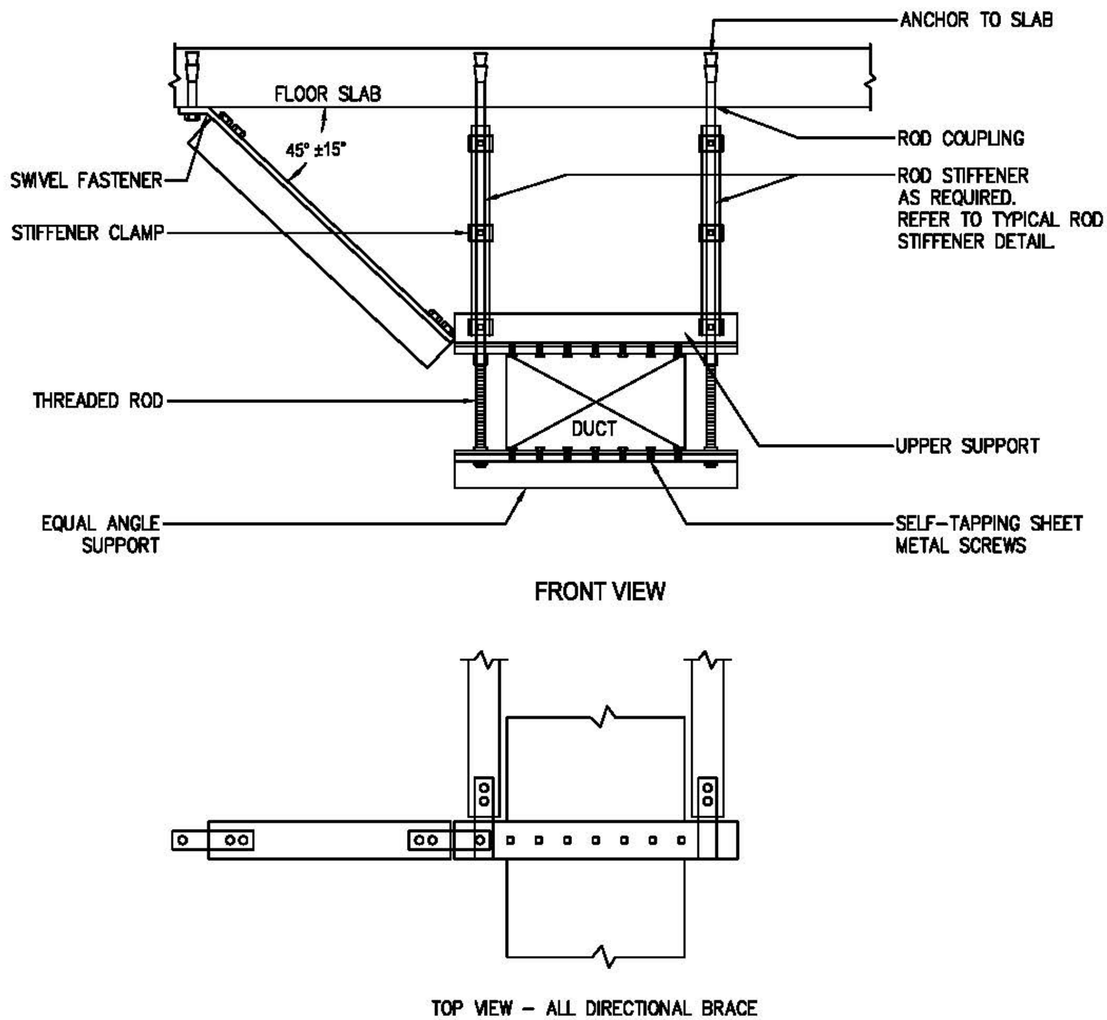
NOT FOR CONSTRUCTION



RIGID DUCT BRACING DUCT BRACING

20 RESTRAINT OF SERVICES

SCALE: 1½" = 1'-0"

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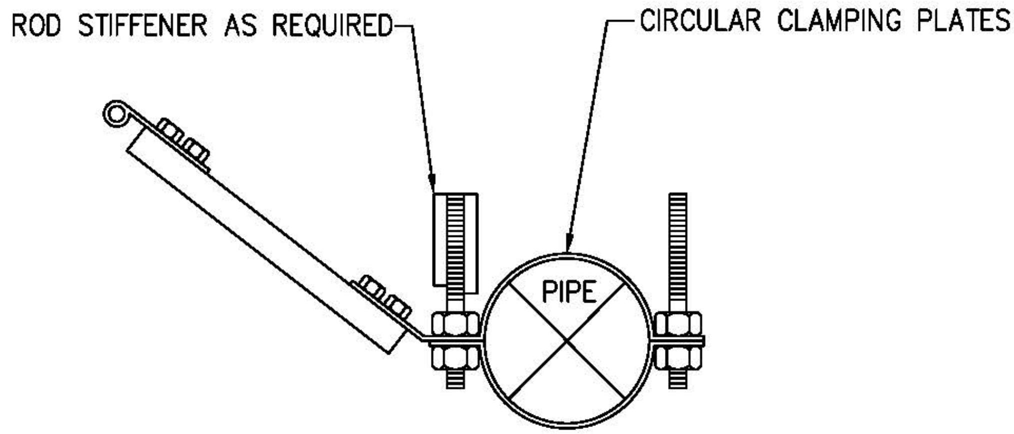
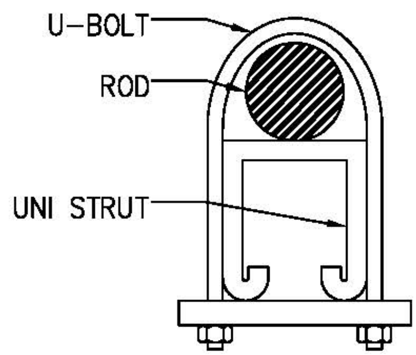
NOT FOR CONSTRUCTION



21 **RESTRAINT OF PIPEWORK WITH U-BOLT**

SCALE: 1½" = 1'-0"



22 **ROD STIFFENER DETAIL**

SCALE: 1½" = 1'-0"

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NOT FOR CONSTRUCTION