Federal Aviation Administrations

Next Generation Air Transportation System

Consolidated Risk Report

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TABLE OF CONTENTS

Background 3
Risk **4**
Risk Analysis Methodology 4
Identification of Risk 4
Identification of Sources 6
Identification of Objectives 7
Contribution of Sources to Events 8
Linkage of Events to Objectives 9
Risk Measurements and Evaluation Process **10**
Participants and their Roles 11
Measurement Methods 11
Risk Analysis Synthesized Results 13
Overall Risk Landscape 18
Implementation of Controls **22**
Scenarios for Control Implementation **28**
Scenario 1 29
Scenario 2 31
Scenario 3 33
Recommendation and Conclusion **34**

Background

Since the inception of the Federal Aviation Administration, several modernization efforts to air traffic control have been evaluated and implemented. Efforts began in the 1960's with the installment of semi-automated air traffic control systems and continued into the 1980's with the first air traffic control modernization program. The modernization program ultimately failed due to increased budget and timeline of implementation. This initial failure in air traffic control modernization, ultimately led to an estimated $51 million-dollar price tag for future modernization efforts.

By the early 2000s, the FAA was experiencing significant congestion, and delays with approximately one in every four flights delayed. Additionally, trends showed an increase in ridership, with an anticipated forecast tripling air traffic by 2025. For example, in 1981 the U.S. air transportation system carried 281 passengers, by 2008 the system transported nearly 650 million passengers. This ultimately set into motion the implementation of Next Generation (NexGen) air traffic control. NexGen is defined as a system of systems designed to improve operations in all phases of flight, through the replacement of legacy radar-based air traffic control systems with a satellite-based system that includes digital communications amongst other improvements.

NexGen represents a fundamental transformation in modernization of air traffic control. Its dramatic technology improvements coupled with a phased approach seeks a long-term modernization without constant scope changes increasing the price and timeline for implementation. This modernization effort is not without inherent risk, first political disputes over the federal budget constantly threaten the continuation of NexGen. Avionics training, cybersecurity, and stakeholder involvement have been amongst other concerns throughout this process.

NexGen still remains a priority for the FAA to finish implementation. The phased implementation has provided some areas of the country with updated NexGen technology, while others are either in development or have not started. There has been no proper risk assessment conducted on the probability of events that could occur while the instillation of NexGen continues for the next two years. This report looks within the next two years and seeks to identify the probability of risk events, sources of risk, and their impact on the objectives of the FAA.

Risk

Risk Analysis Methodology

The FAA management team, consistent of senior managers and executives, sought an objective process by which to define risk. The search for objectivity brought to light the Riskion software. Thus, the Riskion software was chosen as the preferred methodology as it provides a mathematically sound and practical process for the identification and measuring of risk, sources, and objectives.

The identification of risk, sources, and objectives is an iterative process, allowing the team to start at any point. For this project, the team decided to utilize a top-down approach by first identifying objectives, then sources, and finally risk. It is important to note, that this is note that since this is an iterative process, one can start at any point and still get the same result.

Identification of Risk

Prior to identifying risk, we first had to define risk. Through our research we identified that there are a multitude of definitions, some of which contradict each other. For the purposes of this project we define risk as an uncertain that matters and its occurrence causes a loss to the organization's objectives. Additionally, terminology is important here, and we correlate "Risk", "Event", and "Risk Event" as having the same meaning. Nine (9) risk events were identified and are shown below in table one (1).

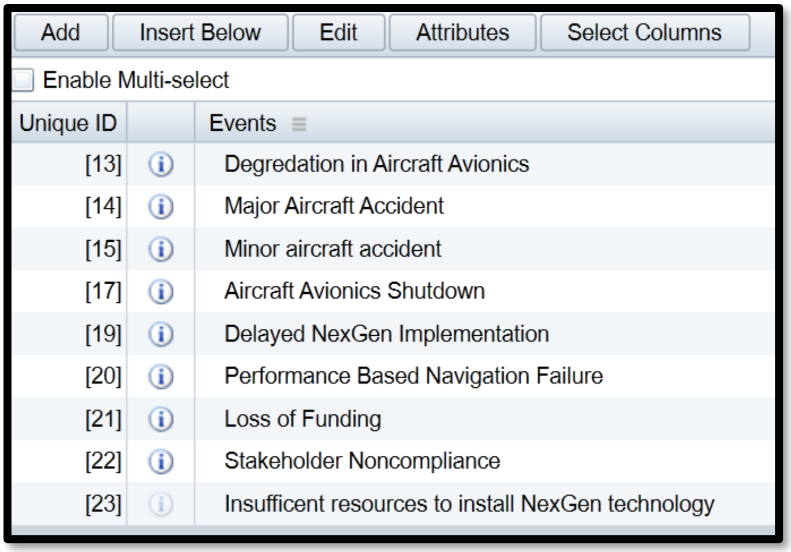
Table 1 Risk Events

Risk Events	Description
1. Degradation in Aircraft Avionics	When interference with satellite and or radio-based communications affect the information provided by pilot to air traffic control and vice versa.
2. Major Aircraft Accident	Characterized by midair or runway collision, includes loss of life or loss of aircraft
3. Minor Aircraft Accident	Characterized by runway congestion or near misses of aircraft
4. Aircraft Avionics Shutdown	Denial of aircraft surveillance technology in determining position via satellite navigation. Eliminates the connection with air traffic controllers and provides little to no information to pilots, other than aircraft instruments.

Risk Events	Description
5. Delayed NexGen Implementation	NexGen has a requirement for most aircraft to be outfitted with NexGen capabilities by January 2020; delays in implementation would cost organizations and tax payers additional monies
6. Performance Based Navigation Failure	NexGen uses Performance Based Navigation (PBN) to produce precise and direct routes for aircraft. Without PBN pilots would be forced to utilize alternate methods of navigation delaying aircraft arrival.
7. Loss of Funding	NexGen is a multibillion dollar investment through the federal government. Lost funding would haul all progress towards a safer airway travel.
8. Stakeholder Noncompliance	NexGen is one of FAA's major objectives and to accomplish this multiple stakeholder from across the federal government and private industry are brought together. The failure or noncompliance of one or many stakeholders has significant ripple effects for NexGen
9. Insufficient Resources to Install NexGen Technology	NexGen requires aviation companies to comply with federal guidelines for installment of NexGen equipment by Jan 2020. Resources are scarce for maintenance and instillation.

The above risk events were risk events were entered into Riskion, as the first step of the analysis process as show in the below figure, Figure 1.

Figure 1: Riskion Events



Identification of Sources

Once again, terminology is important. For this project, we defined sources as the place where risk originates. Unlike risk, sources are not associated with a loss. Additionally, it is important to note that it is not necessary for all events to have a source, and a single source can be responsible for multiple events. Much like risk, sources have synonyms that are used interchangeably throughout this project “source”, “hazard”, “cause”, “threat” all have the same meaning.

We identified five main sources and arranged them in a hierarchical manner with contributing factors associated to each source.   Figure 2, below, depicts the hierarchical structure of sources identified for this project entered into the Riskion software.

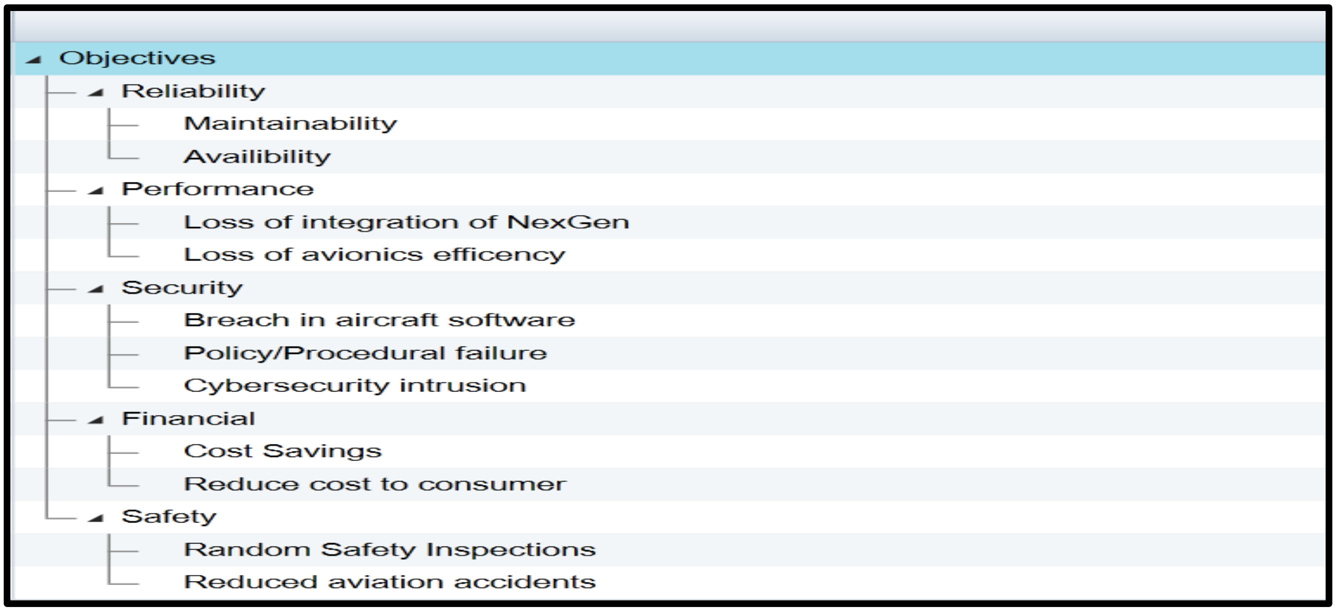
Figure 2: Sources of Threat

- Sources
  - Environment
    - Storm interrupts ground based avionics suite
    - Increased noise leves to communities
  - Political/Financial
    - High maintenance cost
    - FAA does not fund the continuation of NexGen
    - Turnover in FAA administration decides to go in a different direction
  - Human Factor
    - Lack of situational awareness
    - Insufficient training for pilots and controllers of NexGen integrated systems
    - Disregard to policy, procedures, and protocol
    - Requirements scope change post 2020 implementation date
    - Rapid availibity of UAV platforms interfering with commericial flights
  - Terrorism
    - Conventional Attack on Airports
    - Cyber-attack on aircraft avionics
    - Cyber-attack on air traffic control information system
  - Technology
    - Aircraft avionics failure
    - System software technology incompatible world-wide
    - System software technology corrupt
    - Information and Integration management unable to support NexGen requirements

Identification of Objectives

For this project we defined objectives as priorities for the FAA's implementation of NexGen technology. We identified five main objectives and arranged them in a hierarchical manner with contributing factors associated to each source. Figure 3, below, depicts the hierarchical structure of sources identified for this project entered into the Riskion software

Figure 3 Hierarchy of Objectives



Contribution of Sources to Events

Upon completion of identification of risk events, sources, and objectives, the team sought to link the many-many relationships between risk events and sources. As stated before, one source may be linked to multiple events, and a risk event may not be linked to any particular source. Figure 4, below, depicts the linkages of source and events, displaying the many-to-many relationships.

Figure 4: Linkage of Sources to Events

Events	Sources																
	Environment		Political/Financial			Human Factor					Terrorism			Technology			
	Storm interrupts g	Increased noise le	High maintenance	FAA does not fun	Turnover in FAA a	Lack of situationa	Insufficient trainin	Disregard to polic	Requirements sco	Rapid availibility of	Conventional Atta	Cyber-attack on a	Cyber-attack on a	Aircraft avionics fa	System software	System software	Information and In
Degredation in Aircraft Av	✓		✓			✓	✓	✓		✓	✓	✓	✓	✓		✓	
Major Aircraft Accident	✓					✓	✓	✓		✓	✓	✓	✓	✓		✓	
Minor aircraft accident	✓					✓	✓	✓		✓	✓	✓	✓	✓		✓	
Aircraft Avionics Shutdow		✓	✓			✓	✓			✓	✓	✓	✓	✓		✓	
Delayed NexGen Implem			✓	✓	✓				✓								✓
Performance Based Navi	✓	✓	✓			✓		✓		✓		✓	✓			✓	
Loss of Funding				✓	✓				✓						✓		✓
Stakeholder Noncompliar									✓						✓		✓
Insufficent resources to ir			✓	✓	✓				✓						✓		✓

Linkage of Events to Objectives

In continuation of the many-to-many relationships, the team sought to link risk events to objectives. This linkage annotates the consequences of the risk events on the objectives. In following comments and charts, we will depict the measure of the consequences. The below figure, figure five (5) depicts the linkages of source and objectives, displaying the many-to-many relationships.

Figure 5 Linkage of Events to Objectives

Events	Objectives/Consequences										
	Reliability		Performance		Security			Financial		Safety	
	Maintainability	Availibility	Loss of integration	Loss of avionics ef	Breach in aircraft s	Policy/Procedural	Cybersecurity intru	Cost Savings	Reduce cost to co	Random Safety Ins	Reduced aviation
Degredation in Aircraft Av	✓	✓	✓	✓	✓		✓	✓	✓		✓
Major Aircraft Accident		✓	✓		✓	✓	✓	✓	✓		✓
Minor aircraft accident		✓	✓		✓	✓	✓	✓	✓		✓
Aircraft Avionics Shutdow	✓	✓	✓	✓	✓		✓	✓	✓		✓
Delayed NexGen Implem	✓	✓	✓			✓		✓		✓	
Performance Based Navi	✓	✓		✓	✓		✓	✓	✓		✓
Loss of Funding						✓		✓	✓	✓	
Stakeholder Noncompliar	✓							✓	✓	✓	
Insufficent resources to ir	✓		✓			✓					

Risk Measurement & Evaluation Process

Risk measurement takes on the form of many definitions, some as simplistic as the evaluation of the likelihood and extent of risk, to overly complicated mathematical tools designed specifically for financial investments. To understand the measurement of risk, we must first go over some basic terminology and concepts. There are four levels of measurement: nominal, ordinal, interval, and ratio. Ratio scale measurements are required to produce risk measures that are scientifically meaningful since mathematical operations such as multiplication of non-ratio scale measures, e.g. 1to5 Likert scale measures produce mathematically meaningless results. A comprehensive approach that includes qualitative objectives, such as reputation is necessary for a risk analysis to be meaningful.

Before delving into the risk measurements, we must identify participants who will be measuring the likelihood and impact of risk. Our team consist of seven (7) members from across the FAA. The team members are listed below with a brief description of their job.

Participants and Their Roles

As stated above, Riskion allows for the input of participants with expertise to make their own judgments. The team for the FAA consist of seven (7) members with vast experience from across the organization. Below are the team members with a brief description of their job positions.

- **Bryan Hayes – *Chief Engineer Officer*** – works in a wide range of fields, overseeing the engineering and technicians as they develop designs, approximate cost, and execute plans with highly technical skills.
- **Dan Miles – *Chief Operations Officer*** – tasked with implementing daily operations, aligned with the goal and the company strategy.
- **John Berstein – *FAA Administrator*** – works on a wide variety of tasks, includes managing daily calendars, appointments, answering incoming inquiries.
- **John Paul – *Cyber Security Officer*** – on the forefront of protecting company cyber assets from threats.
- **Kelly Steiz – *Chief Financial Officer*** – develops financial organizational strategies by contributing financial and accounting information, analysis, and recommendations to strategic and direction for the organization
- **Robert Ford – *Chief Systems Engineer*** – responsible for the technical supervision of the development, production or operation of engineering projects
- **Joel Frank – *Weather Forecaster*** – responsible for recording and analyzing data from worldwide weather stations for which might impede on FAA operations.

Figure 6 Participants and their Roles

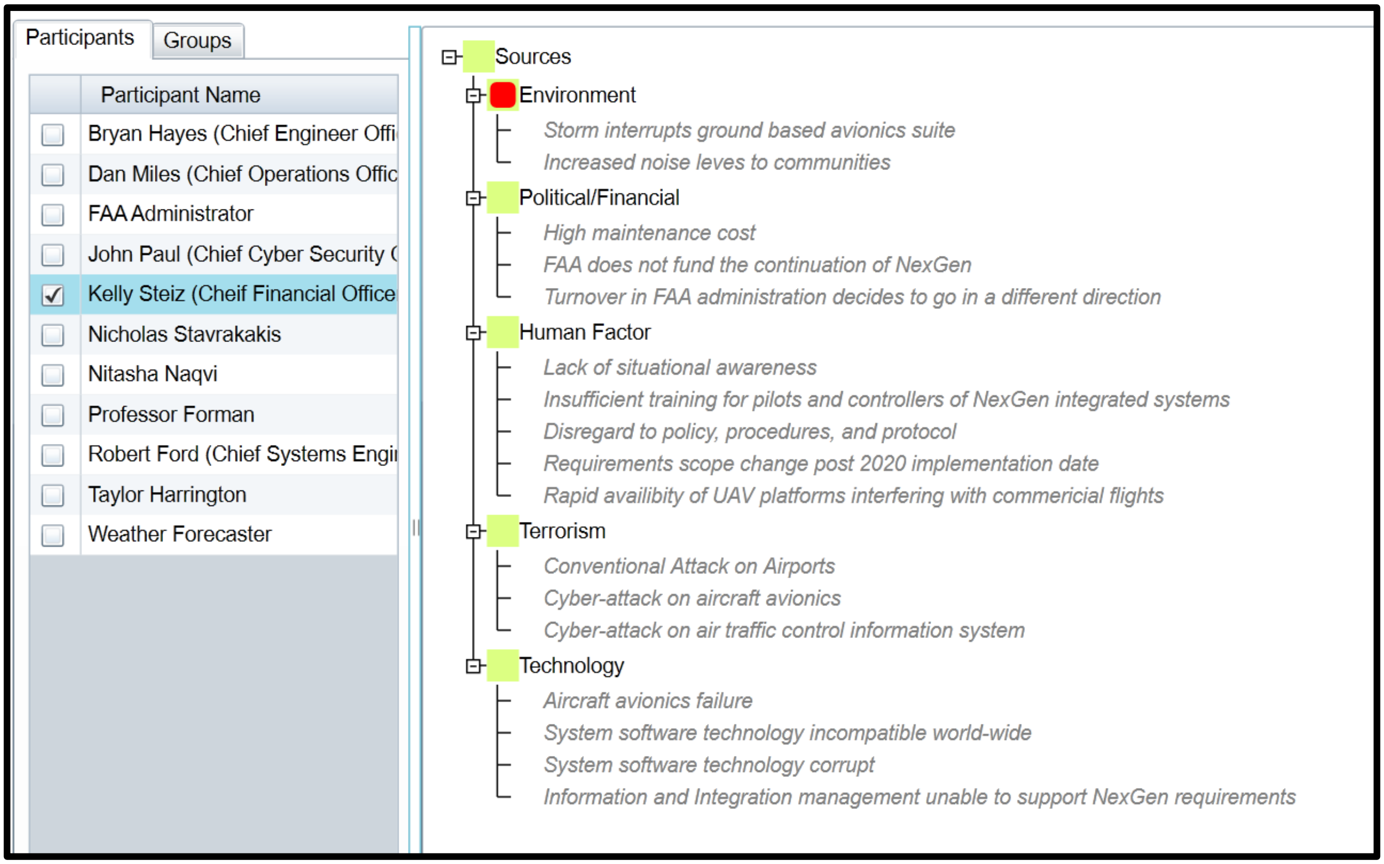


Figure 6, for example, illustrates that Mrs. Kelly Steiz, the chief financial officer, has roles to evaluate the importance of the top level objectives as well as the sub-objectives under each top level objective except the environmental sub-objectives.

Measurement Methods

Before delving into the specific methods of measurement, it is important to understand exactly what we are measuring. We are measuring four (4) things: likelihood of sources, likelihood of events given sources, consequences of events on objectives, and importance of objectives. Based on these measurements, we are able to compute event risk, along with event likelihood and impact through mathematical formulas below.

- Event risk is defined as the event likelihood times event impact (likelihood * impact).
- Event likelihood is defined as the sum of likelihood of sources times the likelihood of events given sources Σ(likelihood of sources * likelihood of events given sources).
- Event impact is defined as the sum of consequences of events on objective times importance of the objectives. Σ(consequence of event on objective * priority of objectives).

We used three measurement methods to assess the likelihood of events given sources and impact of events on objectives: pairwise comparison, pairwise comparison with given likelihood, and direct.

- Pairwise Comparison – the process of comparing entities in pairs to judge which of each is preferred, or has the greater amount of some quantitative property, or whether the two entities are identical.
- Pairwise Comparison with Given Likelihood – the process of comparing entities in pairs to judge which of each is preferred or has a greater amount of some quantitative property. Establishes a realistic likelihood of the events occurrence without letting the risk go beyond a given likelihood.
- Direct – provides a way of comparing the convergence or divergence of entities, or which has the greater amount of associated risk.

Figure 7 Measurement Methods for Sources

Measure Likelihood	Measurement Type	Measurement Scale or Given Likelihooc	Action
Sources	Pairwise Comparis		Copy
Environment	Pairwise with Give	Storm interrupts ground based …: 0.(	Copy
Storm interrupts ground based avionics s			
Increased noise leves to communities			
Political/Financial	Pairwise Comparis		Copy
High maintenance cost			
FAA does not fund the continuation of Ne			
Turnover in FAA administration decides t			
Human Factor	Pairwise with Give	Lack of situational awareness: 0.08	Copy
Lack of situational awareness			
Insufficient training for pilots and controlle			
Disregard to policy, procedures, and prot			
Requirements scope change post 2020 i			
Rapid availibity of UAV platforms interferi			
Terrorism	Pairwise with Give	Conventional Attack on Airport…: 0.3	Copy
Conventional Attack on Airports			
Cyber-attack on aircraft avionics			
Cyber-attack on air traffic control informa			

Figure 7 depicts the measurements utilized in determining the likelihood of sources. Of note, two measurement methods are utilized, pairwise comparison and pairwise with given likelihood. Pairwise with given likelihood is used to anchor the relative likelihoods derived from pairwise comparison to a given likelihood. For example, a given likelihood of .05 or 5% was established for storm interrupting ground-based navigation control site. This restricts the likelihood of storms interrupting ground-based navigation control sites to 5% based off historical data and judgments.

Figure 8 Example Pairwise Comparison

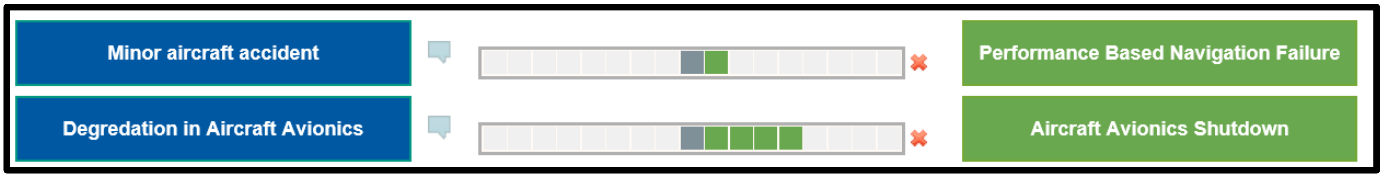
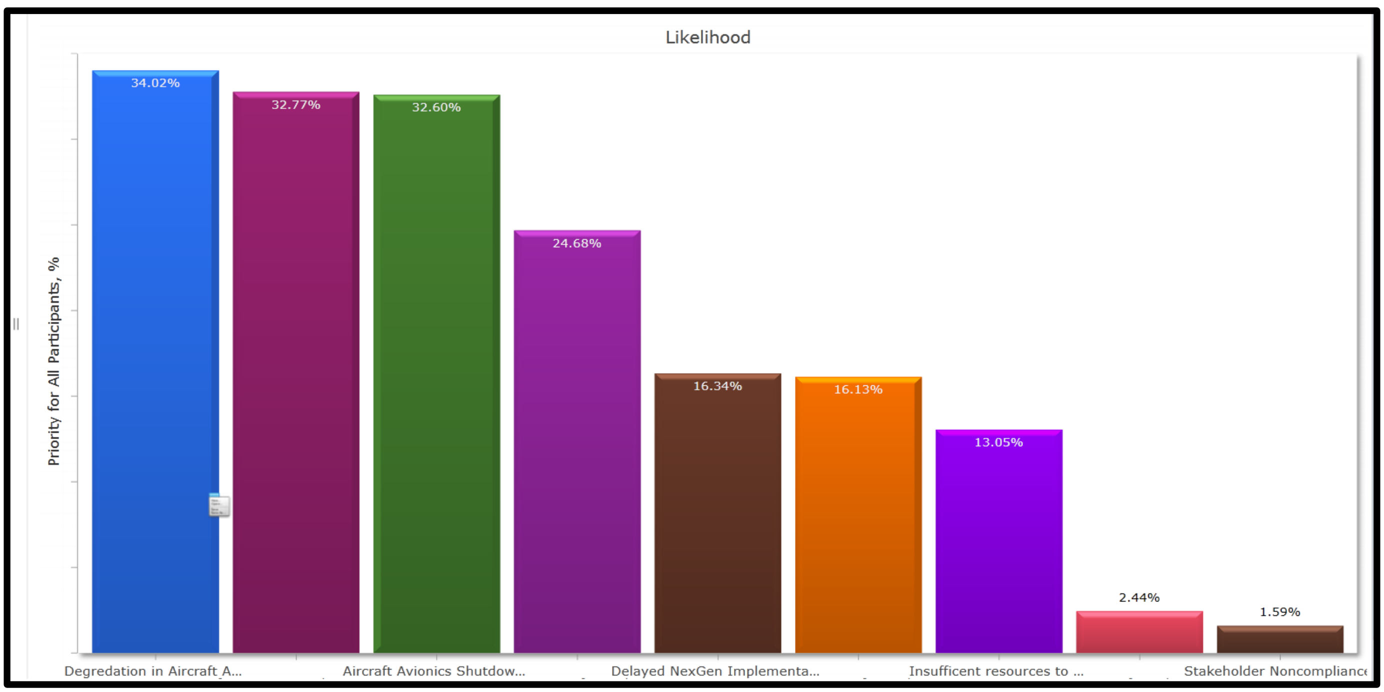


Figure 8 is an example of a pairwise comparison. As you can see, this is the process of comparing entities in pairs to judge the relative likelihood of the two events. This comparison, we are given system software technology corrupt and asked to evaluate the relative likelihood of events occurring.

Event Likelihood

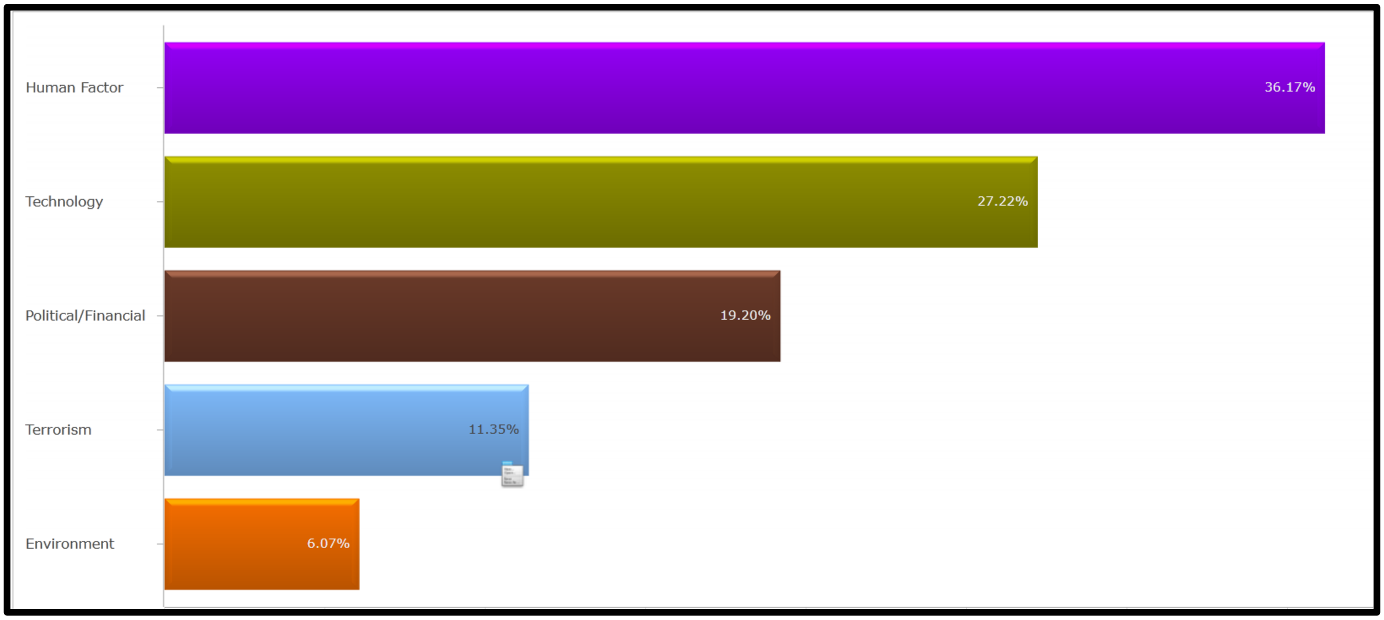
The following graphs and descriptions provide a synthesis for the ratio scale measurements taken previously.

Figure 9: Likelihood of Events



As seen in Figure 9, degradation in aircraft avionics is the most likely event with a computed likelihood of 34%. As we will describe below, compute likelihoods when there are multiple sources can be higher than expected due to ‘double counting’ and Monte Carlo Simulation is preferred to eliminate this bias. Degradation in aircraft avionics is characterized as interference with satellite and or radio-based communications that affect information provided by pilot to air traffic control and vice versa. This comes as no surprise seeing that degradation has many contributing sources, and the technological advancements in aircraft can be susceptible to minute changes in weather conditions, distance from airports or monitoring stations to name a few.

Figure 10: Source Chart Likelihood



The above depiction is a source chart depicting the likelihood of sources. As you can see, human factor is rated the highest by all participants at 36.17%. Human factor is characterized by five (5) contributing factors: lack of situational awareness, insufficient training for pilots and controllers on NexGen integrated systems, disregard to policy, procedures, and protocol, requirements scope change post 2020 implementation date, and finally, rapid availability of UAV platforms interfering with commercial flights. This also comes as no surprise seeing that human factors has a series of wide reaching contributing factors. Additionally, we can see that terrorism and environment are close to the bottom.

Figure 11: Dynamic Sensitivity of Source and Event Likelihood (Before Alteration)

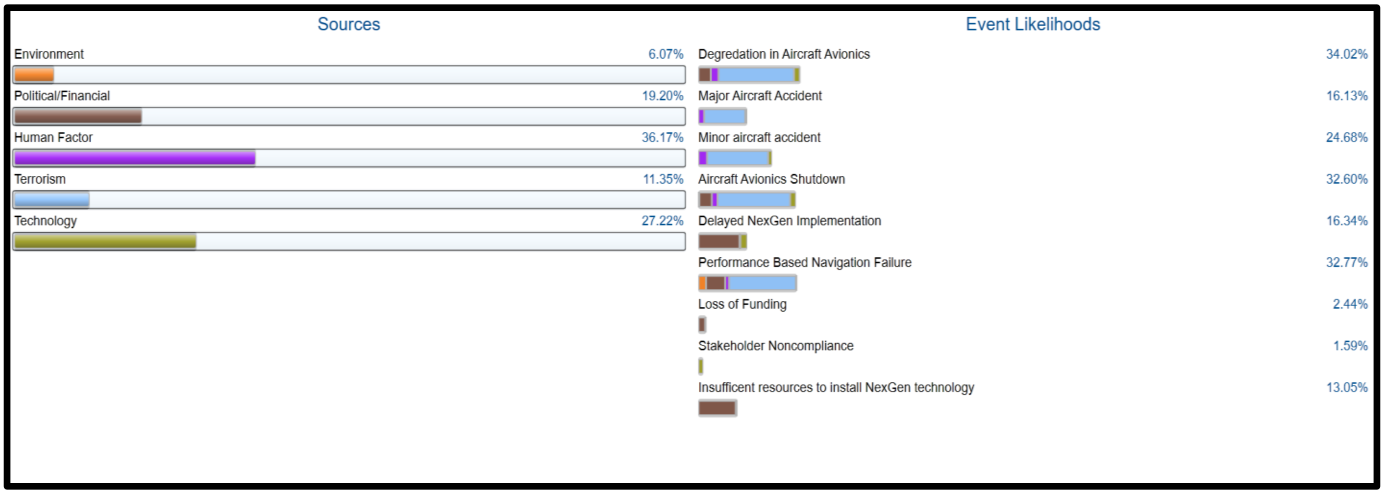
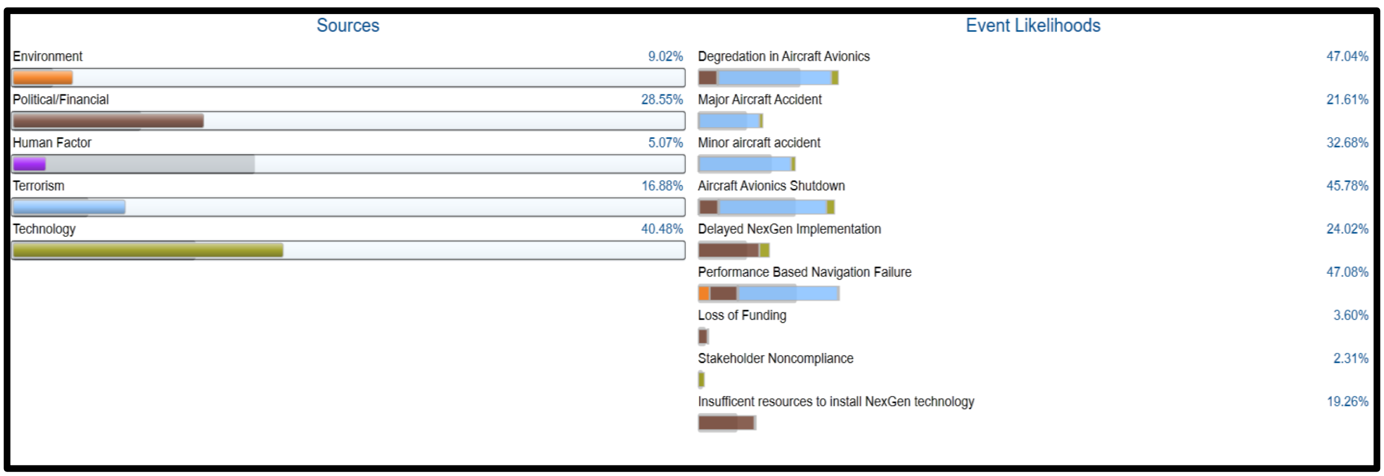
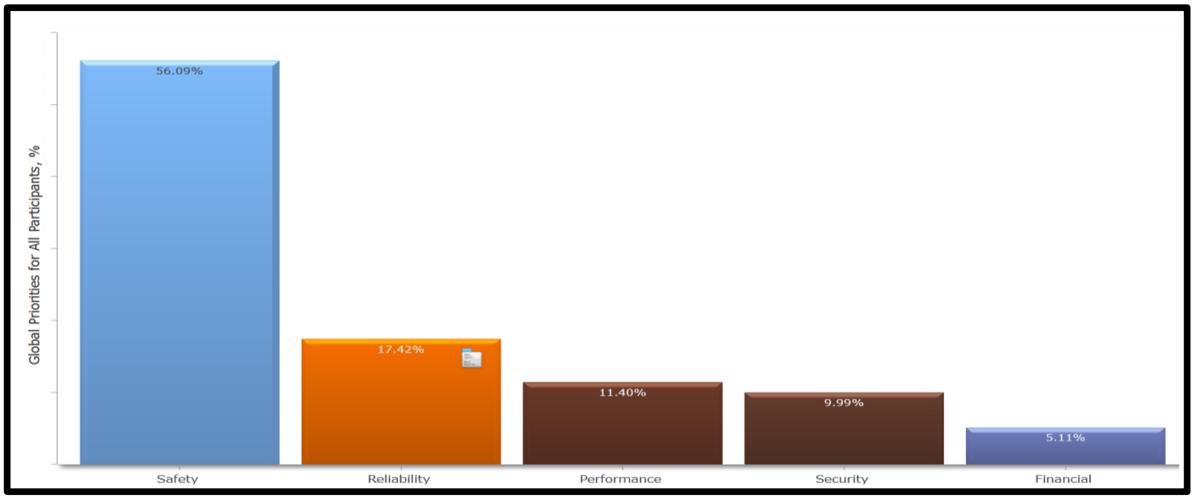


Figure 12: Dynamic Sensitivity of Sources and Event Likelihood (After Alteration)



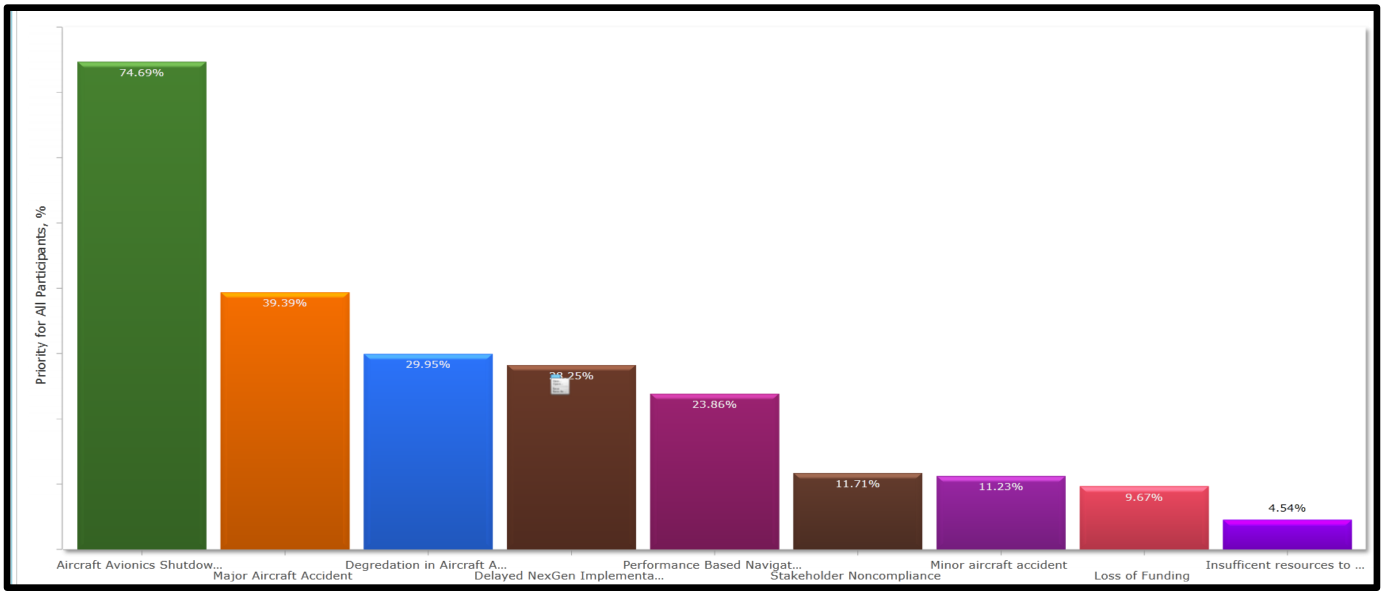
The dynamic sensitivity analysis allows the team to alter the likelihoods of sources and observe the impact it has on other sources and events. In Figure 11 above we can see the generated likelihood of sources and events. In Figure 12 we established a given likelihood of 5.07% for human factors and observed a dramatic increase in likelihood specifically amongst technology which made a jump from 27.22% to 40.48%. In addition, we observed the event performance-based navigation failure likelihood rise from 32.77% to 47.09%.

Figure 13: Objective Priorities as Evaluated by all Participants



During the judgment process, participants evaluated priorities against each other to identify the priority of objectives. As you can see Figure 13 safety is ranked as the number one priority amongst participants at 56.09%. Understanding that the FAA was responsible for the movement of $650 M patrons in 2008 alone, and with the frequency of air travel on the rise the safety of patrons is paramount to the continuation of services provided by the FAA. Additionally, we see that reliability and performance are second and third portraying that the implementation of NexGen not only has the importance of safety but of reliability and performance. If we refer back to the opening statements, in the early 2000's the FAA was experiencing significant delays with one in four flights being delayed. Therefore, the importance of reliability and performance can't be overstated.

Figure 14: Impact of Event on Objectives



The above depiction is the consequence of events on objectives. As you can see, aircraft avionics shutdown has a 74.69% impact on objectives. Aircraft avionics shutdown is characterized as the denial of aircraft surveillance technology in determining position via satellite navigation. Eliminating the connection with air traffic controllers and the absence of information to pilots other than basic instrumentation. This insight to the significance in consequences to objectives allows the team to target control or mitigation measures in an effort to reduce the consequences to the objectives.

Figure 15: Dynamic Sensitivity Analysis of Consequences of Events on Objectives (Before Alteration)

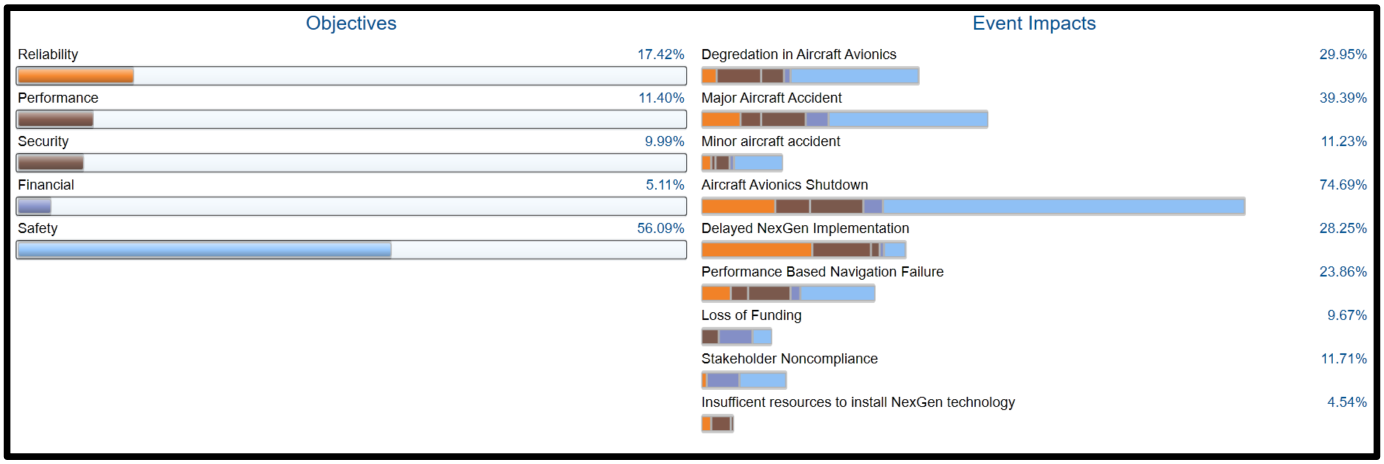
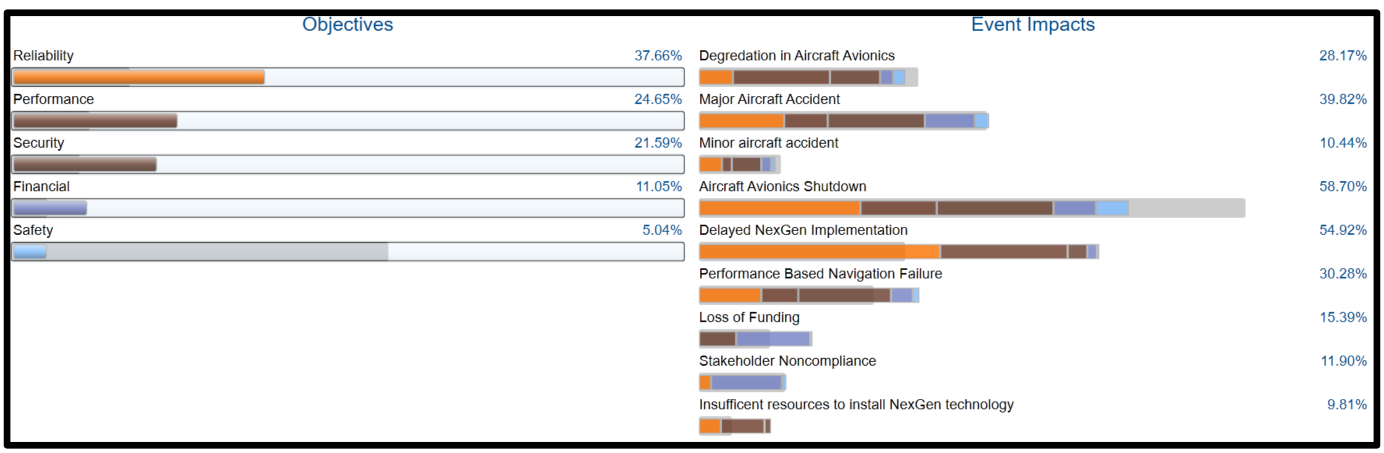


Figure 16: Dynamic Sensitivity Analysis of Consequences of Events on Objectives (After Alteration)



The dynamic sensitivity analysis allows the team to alter the consequence of events on the objectives by altering the importance of the objectives. In Figure 15 above we can see the generated consequence of events on objectives. In Figure 16 we altered the priority of objectives, by changing the priority of safety from 56.09% to 5.04%. This change increased the priority of all other objectives, most notably reliability is not 37.66%. In addition, we observe the consequence of the events change. Specifically, we see the reduction in aircraft avionics shutdown and the increase in delayed NexGen implementation from 28.25% to 54.91%.

Computed and Simulated Event Risk

Upon the completion of judgments, we are provided with an overall risk landscape. We see a computed enterprise risk of 57.11% equivalent to $102 M. The enterprise is valued at $179 M, which was determined by inputting a dollar figure for cybersecurity intrusion of $7 M. The dollar figure for cybersecurity intrusion is a hypothetical figure, based on the amount of funding other companies spend on cybersecurity. The Riskion software computed all other dollar figures based on the singular dollar figure input for cybersecurity intrusion, ultimately providing the enterprise value.

Figure 17 Overall Computed Likelihoods, Impacts, Risk

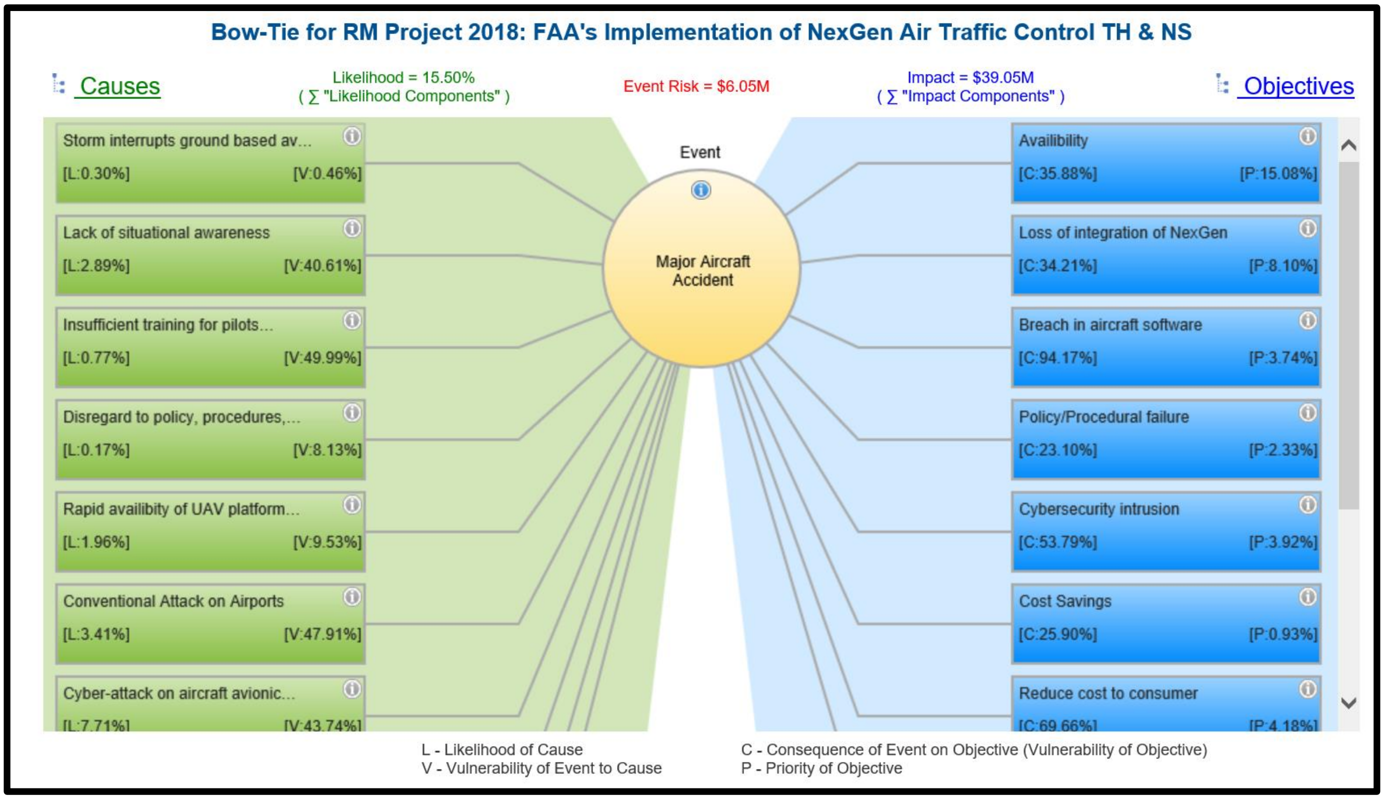
No. ▲	Event	All Participants Likelihood Computed	Impact Computed	Risk Computed
[13]	Degredation in Aircraft Avionics	34.02%	29.95%	10.19%
[14]	Major Aircraft Accident	16.13%	39.39%	6.35%
[15]	Minor aircraft accident	24.68%	11.23%	2.77%
[17]	Aircraft Avionics Shutdown	32.60%	74.69%	24.35%
[19]	Delayed NexGen Implementation	16.34%	28.25%	4.62%
[20]	Performance Based Navigation Failure	32.77%	23.86%	7.82%
[21]	Loss of Funding	2.44%	9.67%	0.24%
[22]	Stakeholder Noncompliance	1.59%	11.71%	0.19%
[23]	Insufficent resources to install NexGen technology	13.05%	4.54%	0.59%
			Total Risk	Computed 57.11%

Figure 18 Overall Simulated Likelihoods, Impacts, Risk

No. ▲	Event	All Participants Likelihood Simulated	Impact, $ Simulated	Risk, $ Simulated
[13]	Degredation in Aircraft Avionics	30.50%	32,420,460	9,888,240
[14]	Major Aircraft Accident	16.10%	39,056,231	6,288,053
[15]	Minor aircraft accident	23.10%	12,140,930	2,804,555
[17]	Aircraft Avionics Shutdown	29.30%	80,312,214	23,531,478
[19]	Delayed NexGen Implementation	18.40%	38,047,472	7,000,734
[20]	Performance Based Navigation Failure	30.90%	26,518,781	8,194,303
[21]	Loss of Funding	1.80%	13,411,602	241,408
[22]	Stakeholder Noncompliance	2.00%	15,337,270	306,745
[23]	Insufficent resources to install NexGen technology	15.00%	5,553,525	833,028
			Total Risk	Simulated $61,007,554

Figure 18 provides a look at the simulated risk. Simulations are computed utilizing the process of Monet carol simulation. Monte Carlo simulations are used to model and predict different outcomes in a process that can't be easily predicted due to the intervention of random variables. Additionally, Monte Carlo simulations reduces the amount of double counting we see in the computed likelihood. This provides a more realistic estimate to the risk faced. As you can see the simulated total risk is $61 M compared to the calculated total risk of $102 M. Additionally, we can see that highest risk is aircraft avionics shutdown which had the highest consequence on objectives.

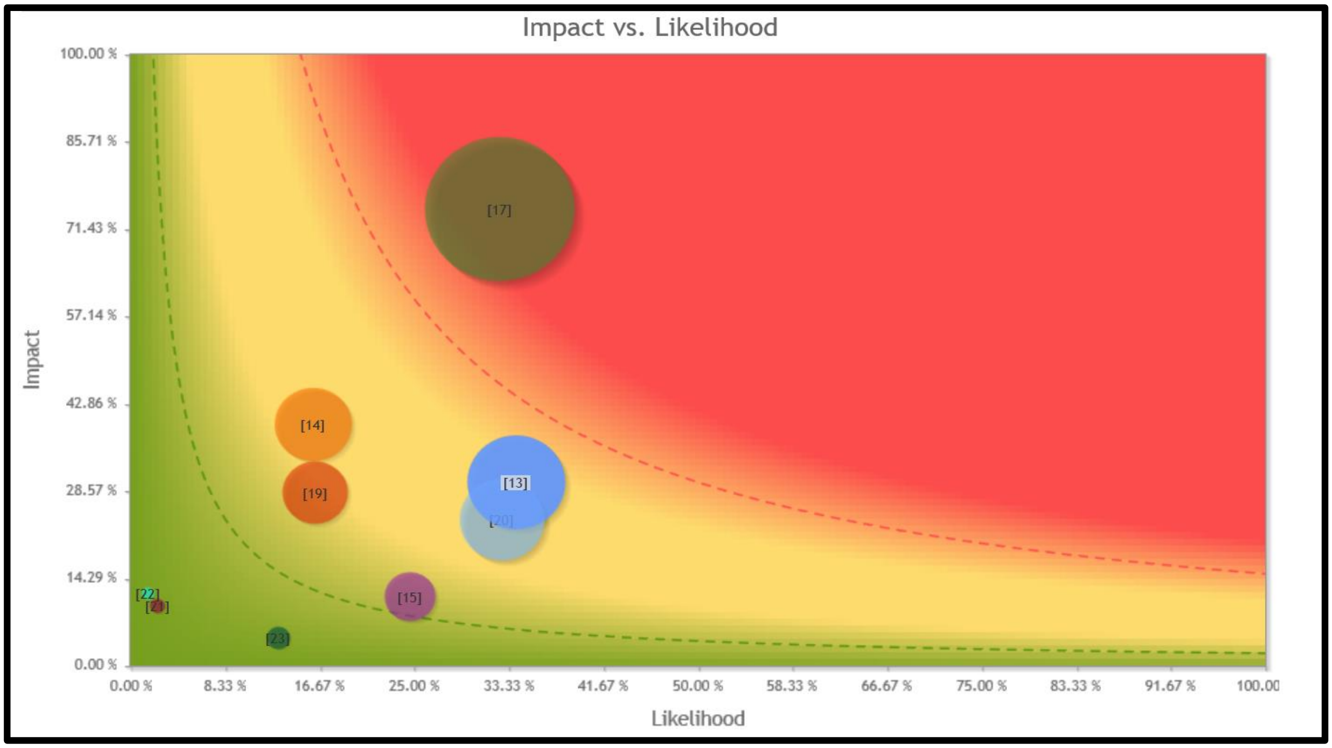
Figure 19: Example Bow Tie Diagram



The bow-tie diagram is a graphical depiction of how event risk is calculated. From left to right we see the causes or sources, risk event, and objectives. The computations can be quite difficult; however, we will break them down into manageable information to understand. Each event has an associated bow-tie diagram that computes the event risk.

- Event risk is defined as the event likelihood times event impact (likelihood * impact).
- Event likelihood is defined as the sum of likelihood of sources times the likelihood of events given sources Σ(likelihood of sources * likelihood of events given sources).
- Event impact is defined as the sum of consequences of events on objective times importance of the objectives. Σ(consequence of event on objective * priority of objectives).

Figure 20 Overall Risk Map



The risk map otherwise known as heat map shows the distribution of events in terms of impact and likelihood. With the likelihood on the horizontal axis and impact on the vertical axis. Each point represents a specific event, and the location is determined by the bow-tie diagram which computed the event's likelihood and impact. Specifically, we will look at risk event 17 (aircraft avionics shutdown), with a likelihood of 32.60% and impact of $133 M, this risk event is calculated at $43.5 M according to the bow-tie diagram. Seeing how the points line up with the axis, Riskion plots each associated risk event according to the computed values from the bow-tie diagram. Additionally, Riskion provides the heat map for risk from sources and risk to objectives depicted in the following two figures.

Figure 21: Risk from Sources (Terrorism)

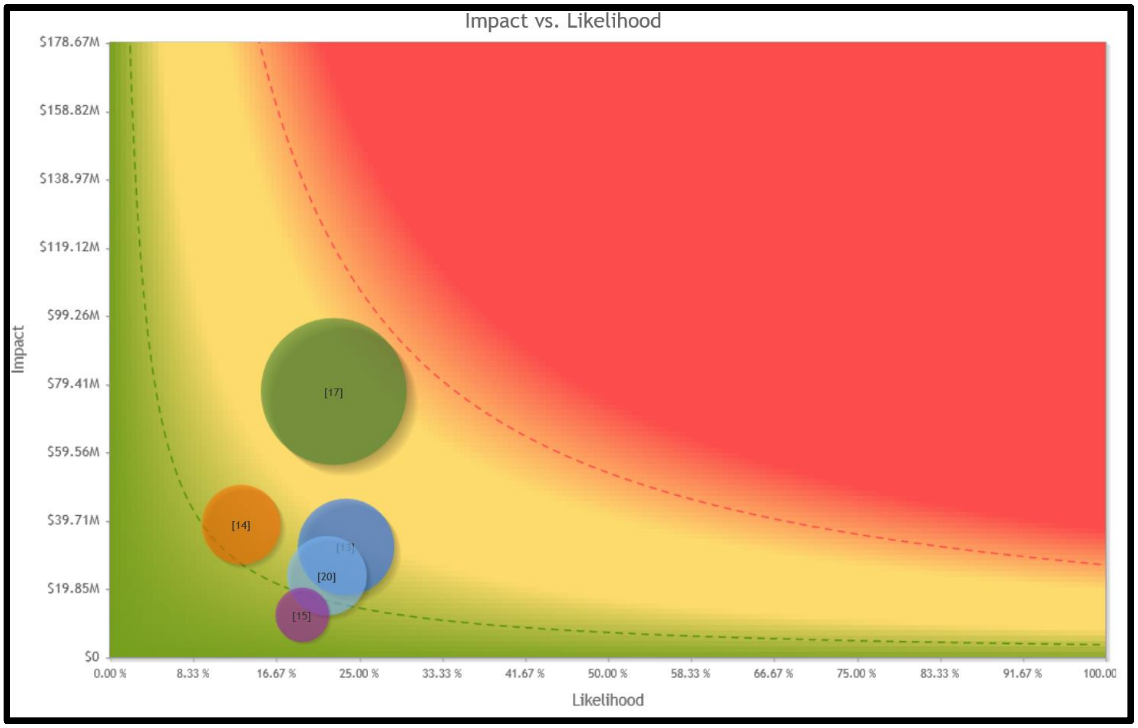


Figure 22: Risk to Objectives (Safety)

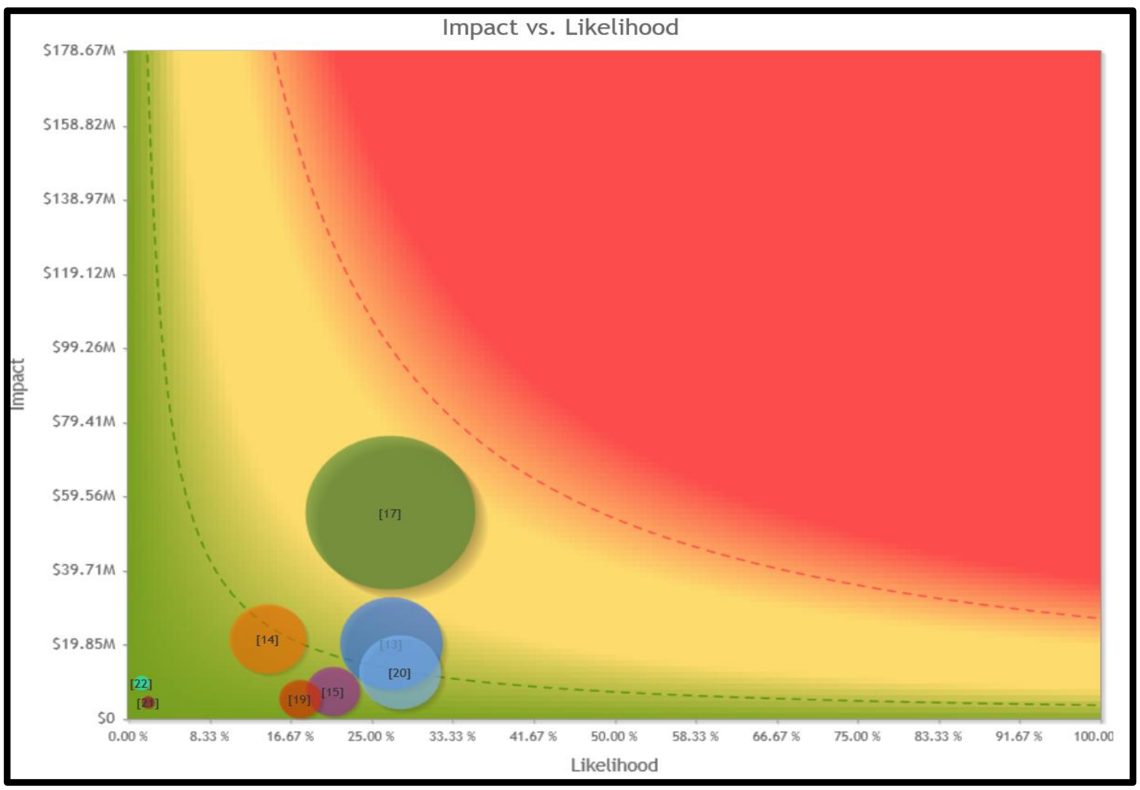
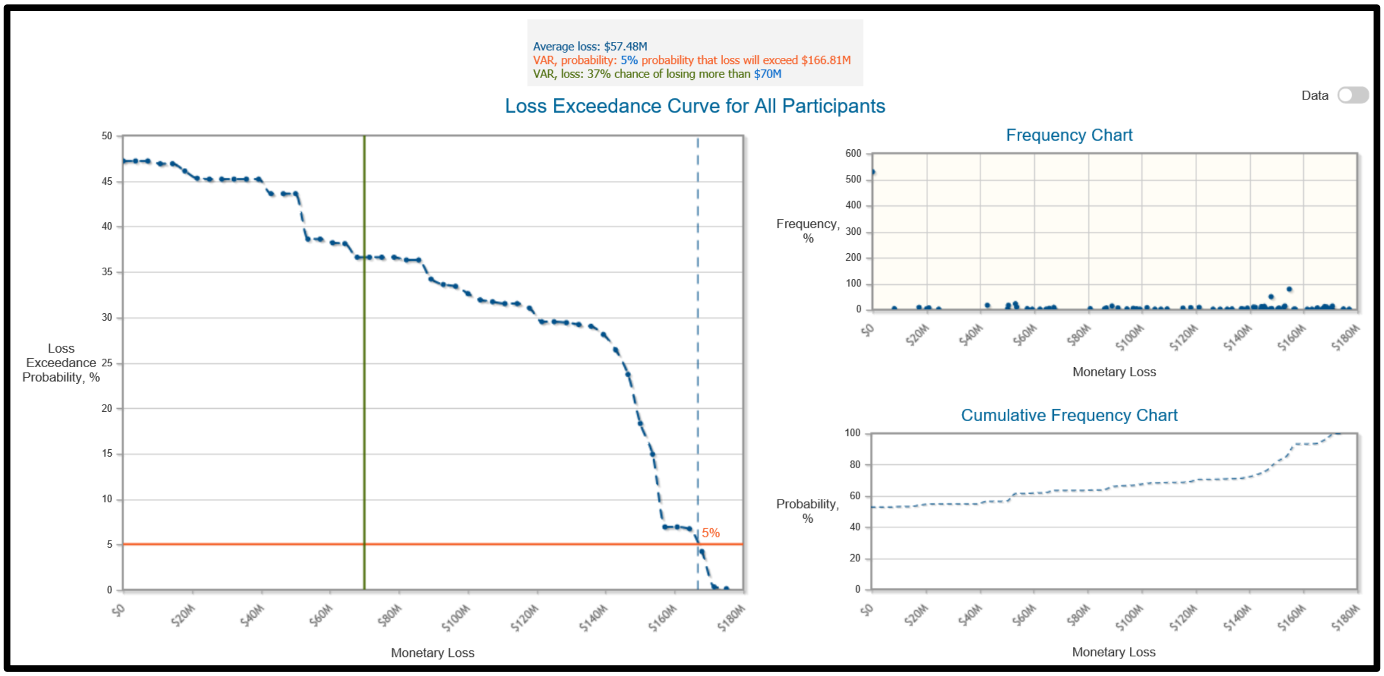


Figure 23 Loss Exceedance Curve



In figure 23 we illustrate a graph called the loss exceedance curve, the line on the graph represents the probability that loss will exceed the corresponding value. For example, there is a 5% chance the that the loss will exceed $57 million! With a Value At Risk (VAR) set at 37% there is a change that the loss will exceed $ 70 million. The curve can be utilized to map out potential losses the company may consider before committing investments.

Implementation of Controls

Terminology is paramount when discussing controls. Controls, otherwise known as treatments, are defined as any measure or action that modifies or regulates risk. Otherwise stated, controls are activities that seeks to deter the impact of specific risk to maintain or negate the overall risk faced to an organization or event.

Realizing the limitation of team members, the team identified Dan Miles, the Chief Operations Officer as the singular individua to make judgment on each of the controls. The purpose for a singular individual to input controls was to reduce the likelihood of misjudgments. The figure below, Figure 19 depicts the selection of Mr. Dan Miles as the singular individual to make judgments on all control measures.

Figure 24: Participant Roles

Participant Roles

Allow All | Drop All | Show: ○ All ◉ Controls for Causes ○ Controls for Vulnerabilities ○ Controls for Impacts

	Control Name	☐ FAA Administrator (bernstein34@faa	☐ Bryan Hayes (Chief Engineer Officer) (Bryan.Hayes@fa	☐ John Paul (Chief Cyber Security Officer) (cybersecurity@g	☑ Dan Miles (Chief Operations Officer) (dan.4.miles@faa.	☐ Professor Forman (forman@gwu.edu	☐ Weather Forecaster (Joel.Frank@wea	☐ Kelly Steiz (Cheif Financial Officer) (Kelly.3.Steiz@fa	☐ Nitasha Naqvi (nitashasyed@gw	☐ Nicholas Stavrakakis (nstavrakakis@gv
Controls for Causes										
☐	Technology Consultant	☐	☐	☐	☑	☐	☐	☐	☐	☐
☐	Employee Developmental Training Programs	☐	☐	☐	☑	☐	☐	☐	☐	☐
☐	Continusous Vulnerability Assessments	☐	☐	☐	☑	☐	☐	☐	☐	☐
☐	Monthly review			☐	☑	☐	☐	☐	☐	☐
☐	Establishe Deadlines for Policy Compliance	☐	☐	☐	☑	☐	☐	☐	☐	☐
☐	Establish NexGen Policies with Stakeholders	☐	☐	☐	☑	☐	☐	☐	☐	☐

Continusous Vulnerability Assessments

The FAA determined that it was not willing to lose more than $70 M, to reach that the implementation of controls is necessary. We assumed that there was no budget for controls and established 11 controls worth an estimated $2.5 M. However, as the senior executives begin looking at budgetary constraints for controls, the application and cost of controls comes into question.

Chart 25 Controls

Selected controls: 11
Cost Of Selected Controls: $2,585,175 (unfunded: $0)
Total Cost Of All Controls: $2,585,175

Search:

Index	☐	Control Name	Control for	Selected	Cost	Applications	Categories	Must	Must Not
01	☐	Technology Consultant	Cause	Yes	90000	6		☐	☐
02	☐	Employee Developmental Training Programs	Cause	Yes	250000	8		☐	☐
03	☐	Continusous Vulnerability Assessments	Cause	Yes	75000	12		☐	☐
04	☐	Monthly policy review	Cause	Yes	75	7		☐	☐
05	☐	Establishe Deadlines for Policy Compliance	Cause	Yes	100	6		☐	☐
06	☐	Establish NexGen Policies with Stakeholders	Cause	Yes	0	7		☐	☐
07	☐	Cyber Credentialing Program	Vulnerability	Yes	1000000	39		☐	☐
08	☐	Continusous Network Vulnerability Assessment	Vulnerability	Yes	140000	21		☐	☐
09	☐	Aviation System Mechanics	Consequence	Yes	80000	21		☐	☐
10	☐	Shareholder procedural meetins	Consequence	Yes	0	18		☐	☐
11	☐	Aircraft Safety Inspections	Consequence	Yes	950000	38		☐	☐

Pictured above in Chart 25 are the list of controls selected for implementation. As you can see this depicts where the controls are applied weather that be the causes, vulnerability or consequences. In addition to where the controls are applied we can see the cost for each control. Since this is a hypothetical project, the cost depicted are arbitrary figures. The application is in reference to how many times the control is applied. From this, we can see that the control, cyber credentialing program is applied 39 times. This does not mean that the control is the most effective, more simply is applied more times.

Figure 26: Application of Controls for Source Likelihood

Control Name	Sources								
	Environment		Political/Financial			Human Factor			
	Storm interrupts ground based avionics suite	Increased noise leves to communities	High maintenance cost	FAA does not fund the continuation of NexGen	Turnover in FAA administration decides to go in a different direction	Lack of situational awareness	Insufficient training for pilots and controllers of NexGen integrated systems	Disregard to policy, procedures, and protocol	Requirements scope change post 2020 implementation date
1. Technology Consultant	☐	☐	☐	☐	☐	☐	☐	☐	☐
2. Employee Developmental Training Programs	☐	☐	☐	☐	☐	☑	☑	☑	☑
3. Continusous Vulnerability Assessments	☑	☐	☐	☐	☐	☑	☑	☑	☑
4. Monthly policy review	☐	☑	☑	☑	☑	☐	☐	☑	☑
5. Establishe Deadlines for Policy Compliance	☐	☐	☑	☐	☑	☐	☐	☑	☑
6. Establish NexGen Policies with Stakeholders	☐	☑	☑	☑	☑	☐	☐	☐	☐

Figure 27 Application of Controls on Consequences of Events to Objectives

Select a control: 11. Aircraft Safety Inspections

Event Name	Objectives								
	Reliability		Performance		Security			Financial	
	Maintainability	Availibility	Loss of integration of NexGen	Loss of avionics efficency	Breach in aircraft software	Policy/Procedural failure	Cybersecurity intrusion	Cost Savings	Reduce cost to consumer
13. Degredation in Aircraft Avionics	☑	☐	☑	☐	☑		☐	☑	☑
14. Major Aircraft Accident		☑	☑		☐	☑	☐	☑	☑
15. Minor aircraft accident		☑	☑		☐	☑	☐	☑	☑
17. Aircraft Avionics Shutdown	☑	☐	☑	☑	☐		☐	☑	☑
19. Delayed NexGen Implementation	☐	☐	☑			☑		☑	
20. Performance Based Navigation Failure	☑	☐		☐	☐		☐	☑	☑
21. Loss of Funding						☑		☐	☐
22. Stakeholder Noncompliance	☐							☐	☐
23. Insuffcient resources to install NexGen technology	☑		☑			☑			

The above chart, Chart 26 depicts the application of controls on the likelihood of sources. Additionally, Figure 27 depicts the application of the control aircraft safety inspection on the consequence of events to objectives. We can see that a singular control may have applications across a vast array of causes, vulnerability, and consequences. Of note, not all potential applications are checked. Although there is potential for the application of the source, it is not always necessary.

Figure 28: Example of Control Using Direct Comparison Method

Figure 28 is an example of a direct comparison for a control measure. All controls utilized the direct entry methodology. Specifically, this is an estimate of the effectiveness of the aircraft safety inspection control for mitigating the consequence of degradation in aircraft avionics on the objective reduced aviation accidents.

Figure 29: Overall Simulated Likelihood, Impacts, and Risk with Controls

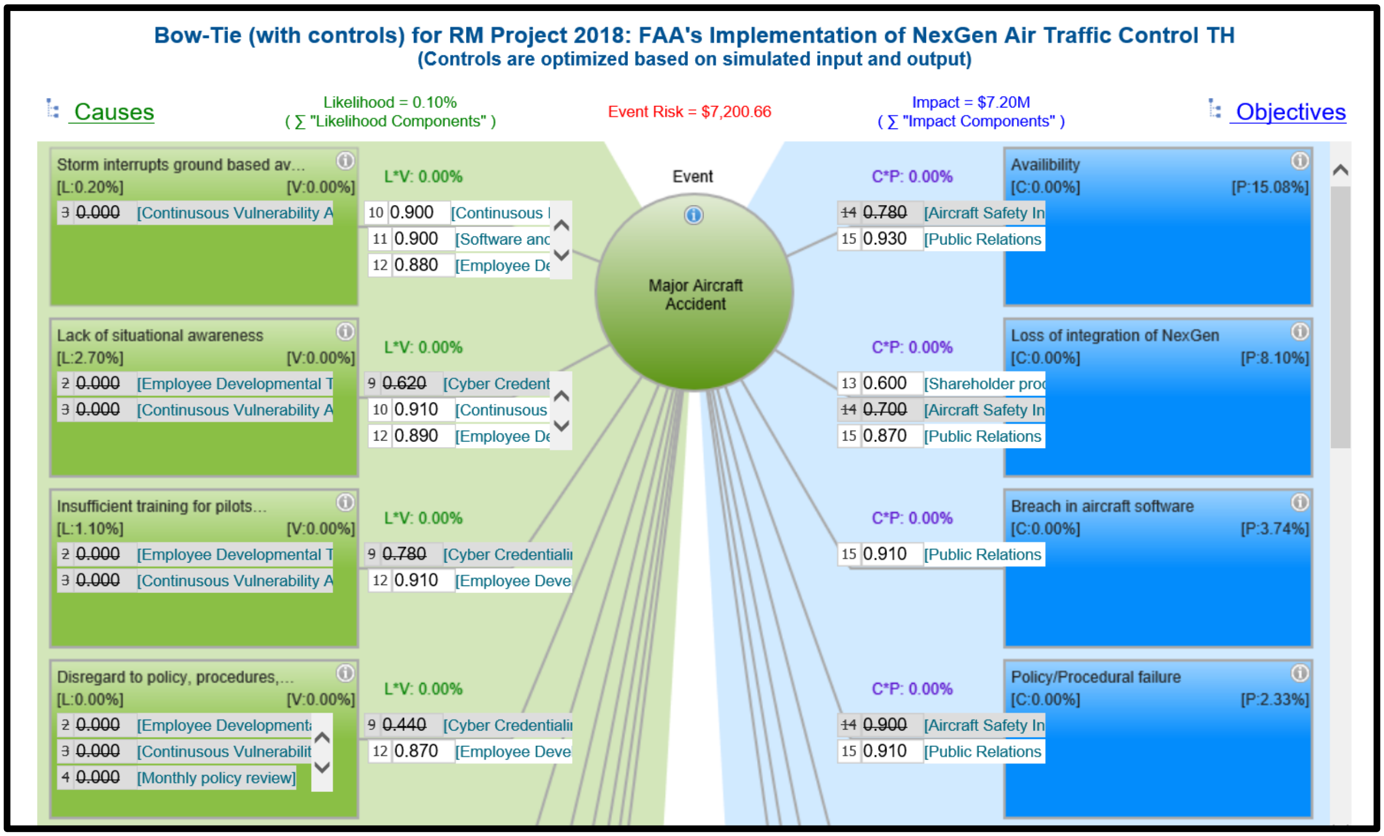
Overall Likelihoods, Impacts, and Risks (With Controls) for RM Project 2018: FAA's Implementation of NexGen Air Traffic Control TH (Controls are manually selected)

No. ▲	Event	Likelihood Simulated (All Participants)	Impact, $ Simulated (All Participants)	Risk, $ Simulated (All Participants)
[13]	Degredation in Aircraft Avionics	0.10%	1,124,855	1,124
[14]	Major Aircraft Accident	0.00%	0	0
[15]	Minor aircraft accident	0.10%	442,879	442
[17]	Aircraft Avionics Shutdown	0.30%	9,074,645	27,223
[19]	Delayed NexGen Implementation	0.00%	0	0
[20]	Performance Based Navigation Failure	0.10%	18,104,940	18,104
[21]	Loss of Funding	0.00%	0	0
[22]	Stakeholder Noncompliance	0.00%	0	0
[23]	Insufficent resources to install NexGen technology	0.00%	0	0

# Controls	Cost of Controls	How Selected		Simulated
15	$2,637,175	Manually selected	Total Risk	$58,382,623
			Risk Reduction	$58,335,727
			Residual Risk	$46,896

After collecting judgments, we analyzed the impact of controls. To get a baseline, we first checked the impact of all 15 controls to see how much the controls will reduce the likelihood of risk events. By selecting all 15 controls with an approximated cost of $ 2.6 million, we can expect a to reduce risk by $ 58.3 million.

Figure 30: Bow-Tie Diagram with Associated Controls



This bow-tie diagram is a graphical depiction of how event risk is calculated with the implementation of controls. From left to right we see the causes or sources, risk event, and objectives. For this specific risk event, we can see the overall risk is $7,200 a decrease in over $5M dollars. As you can see, the controls reduce the likelihood of the causes events and the consequences therefore reducing the overall event risk.

The overall risk map (heat map) with controls depicts the movement Below is figure 25, depicting the overall risk map with all applied controls. all associated controls added. Comparing this to figure 13, overall risk map without controls we can see that all risk events are within the green or under 3% overall risk with the highest being delay in NexGen implementation consistent to the overall simulated likelihoods chart above.

Figure 31 Overall Risk Map with Controls

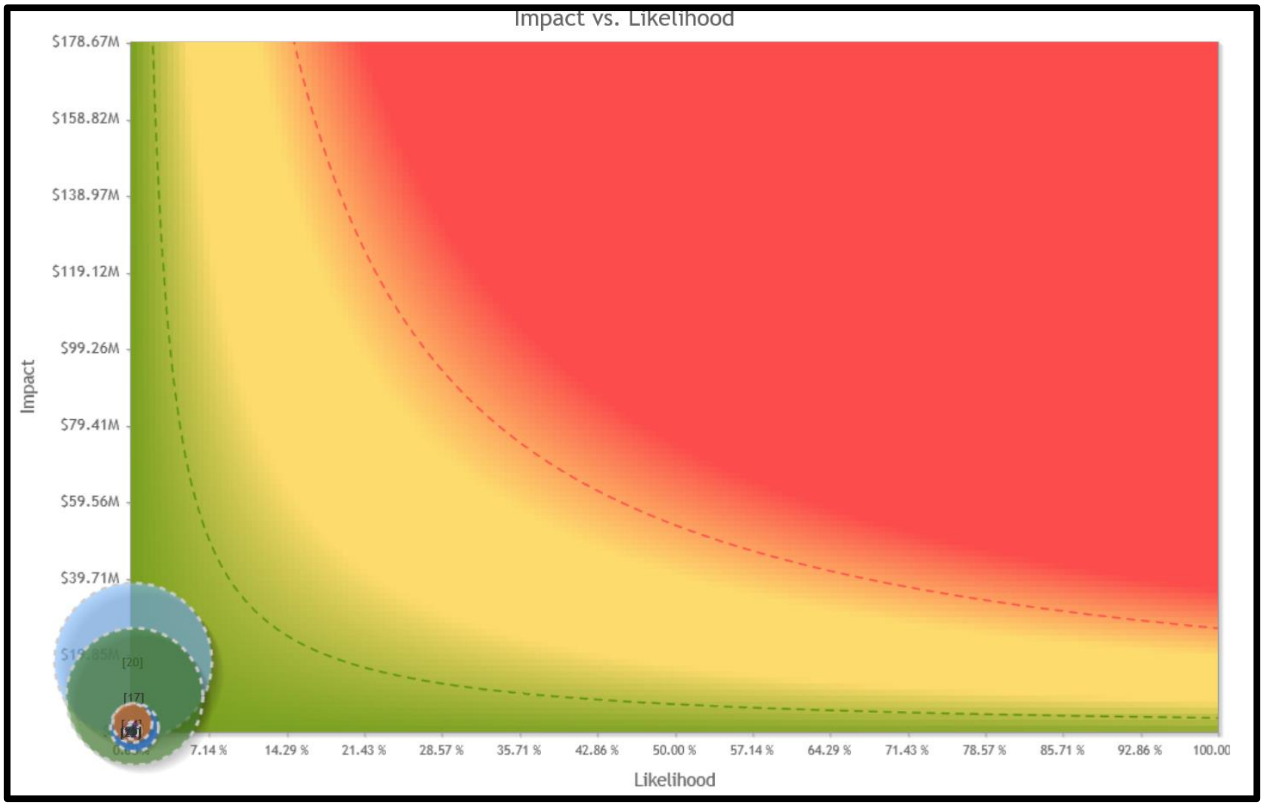
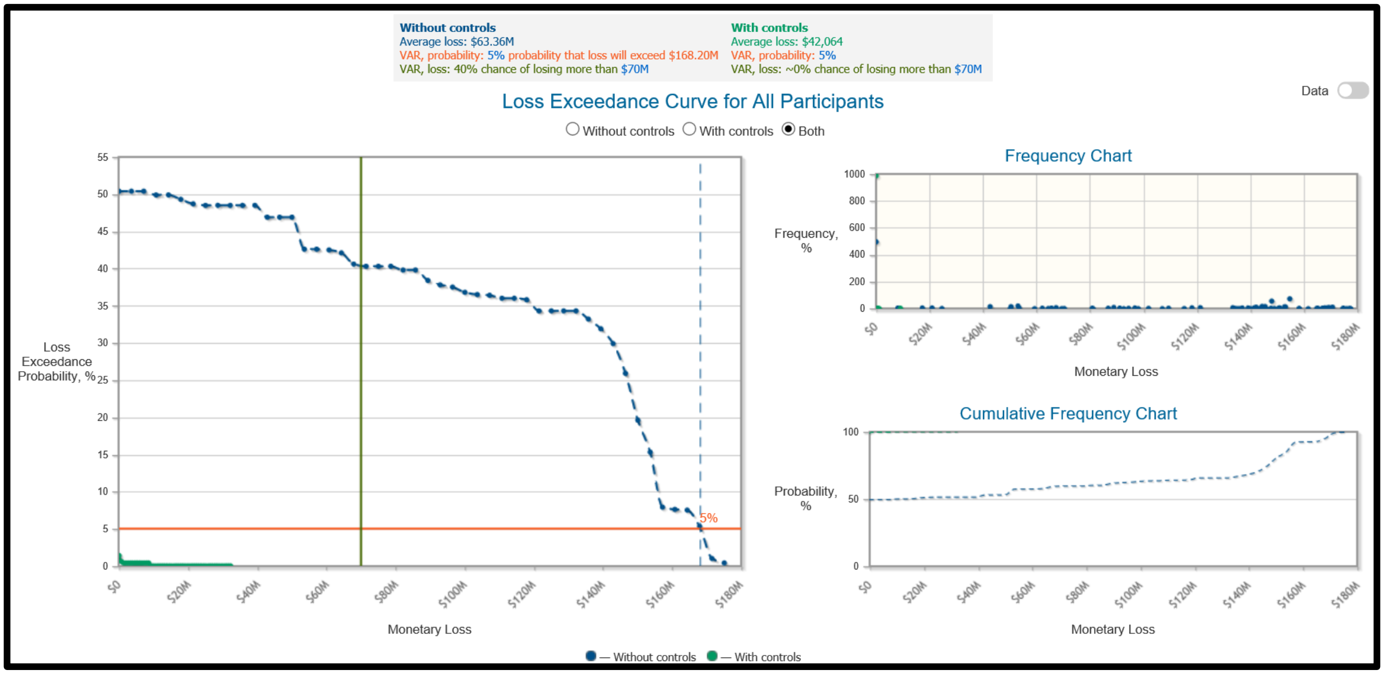


Figure 31, depicts the overall risk map with all 15 controls. It is noticeable that by using controls, the bubbles shifted to the left and the likelihood and impact of risk reduced compared to Figure 20. Based on the overall risk map utilizing all controls, the two major events are Performance based land navigation failure (Risk = $ 36, 209), and Aircraft avionics shutdown (Risk = $ 27,223).

Figure 32: Loss Exceedance Curve with Controls



Earlier we noted there was a 40% probability that loss would exceed $ 70 million without controls.

Without controls there was a 5% probability that loss would exceed $ $ 168.2 million. After adding controls, it appears the probability of losing more than $ 70 million or more dropped to 0%. The average loss with controls appears to be $ 42,064.

Optimizing Controls

Through statements we know that the project is expected to be complete in two years and the controls can affect the implementation of different aspects of the project increasing the timeframe beyond the two-year mark. For example, we can use stakeholder procedural meeting to track the project and ensure federal regulation compliance. Or implement employee development training to ensure employees understand the intricates of the new system before implementation. Since the project has a limited budget we are unable to select all controls, additionally we must weigh the fact that adding additional controls is not cost effective or beneficial. Controls were selected based on three budgetary constraints of $2 million, $1 million, and $700,000.

Scenario 1

The optimization of controls with a budget of $2 Million, we observe the selection of 8 controls with the expected risk reduction of $55.9 Million.

Figure 33 Controls Selected with a Budget of $2 Million

Controls optimization for "RM Project 2018: FAA's Implementation of NexGen Air Traffic Control TH"

(◉) Budget ( ) Risk ( ) Risk Reduction

Budget Limit: $ 2,000,000

Total Risk*: $58,081,611
Risk With Selected Controls*: $255,680 (Δ: $57,825,930)
Risk With All Controls: $29,992 (Δ: $58,051,618)

Selected controls: 8
Cost Of Selected Controls: $1,272,000 (unfunded: $1,365,175)
Total Cost Of All Controls: $2,637,175

☑ Show Monetary Values (Value of Enterprise: $178,673,883,Value of "Cybersecurity intrusion": $7,000,000)

Ignore: ☐ Musts ☐ Must Nots ☑ Dependencies ☑ Groups

Simulations Settings Number of trials: 1000 Seed: -1 ☐ Keep Seed

Select: All | None

Search:

Index	Selected	Control Name	Control for	Selected	Cost	Applications	Categories	Must	Must Not
01	☐	Technology Consultant	Cause		90000	6		☐	☐
02	☐	Employee Developmental Training Programs	Cause		250000	8		☐	☐
03	☐	Continusous Vulnerability Assessments	Cause		75000	12		☐	☐
04	☐	Monthly policy review	Cause		75	7		☐	☐
05	☐	Establishe Deadlines for Policy Compliance	Cause		100	6		☐	☐
06	☐	Establish NexGen Policies with Stakeholders	Cause		0	7		☐	☐
07	☑	Aviation System Mechanics	Cause	Yes	80000	6		☐	☐
08	☑	Project Management Advancement Training	Cause	Yes	15000	8		☐	☐
09	☑	Cyber Credentialing Program	Vulnerability	Yes	1000000	60		☐	☐
10	☑	Continuous Network Vulnerability Assessment	Vulnerability	Yes	140000	42		☐	☐
11	☑	Software and Hardware Technology Assessment	Vulnerability	Yes	2000	39		☐	☐
12	☑	Employee Developmental Training Program	Vulnerability	Yes	15000	62		☐	☐
13	☑	Shareholder procedural meetins	Consequence	Yes	0	27		☐	☐
14	☐	Aircraft Safety Inspections	Consequence		950000	45		☐	☐
15	☑	Public Relations Team	Consequence	Yes	20000	45		☐	☐

Figure 34 Overall Risk with a Budget of $2 Million

Overall Likelihoods, Impacts, and Risks (With Controls) for RM Project 2018: FAA's Implementation of NexGen Air Traffic Control TH
(Controls are optimized based on simulated input and output)

No. ▲	Event	All Participants Likelihood Simulated	Impact, $ Simulated	Risk, $ Simulated
[13]	Degredation in Aircraft Avionics	0.20%	6,375,989	12,751
[14]	Major Aircraft Accident	0.10%	7,200,657	7,200
[15]	Minor aircraft accident	0.20%	2,129,937	4,259
[17]	Aircraft Avionics Shutdown	0.00%	0	0
[19]	Delayed NexGen Implementation	0.00%	0	0
[20]	Performance Based Navigation Failure	0.20%	35,654,288	71,308
[21]	Loss of Funding	0.00%	0	0
[22]	Stakeholder Noncompliance	0.00%	0	0
[23]	Insufficent resources to install NexGen technology	0.00%	0	0

# Controls	Cost of Controls	How Selected
8	$1,272,000	Optimized based on simulated input and output with budget of $2,000,000

	Simulated
Total Risk	$55,045,457
Risk Reduction	$54,949,936
Residual Risk	$95,521

Scenario 2:

The optimization of controls with a budget of $1 Million, we observe the selection of 7 controls with the expected risk reduction of $58 Million.

Figure 35 Controls Selected with a Budget of $1 Million

Controls optimization for "RM Project 2018: FAA's Implementation of NexGen Air Traffic Control TH"

◉ Budget ○ Risk ○ Risk Reduction

Budget Limit: $ 1,000,000

Total Risk*: $57,804,808
Risk With Selected Controls*: $958,379 (Δ: $56,846,429)
Risk With All Controls: $36,475 (Δ: $57,768,333)

Selected controls: 7
Cost Of Selected Controls: $272,000 (unfunded: $2,365,175)
Total Cost Of All Controls: $2,637,175

☑ Show Monetary Values (Value of Enterprise: $178,673,883,Value of "Cybersecurity intrusion": $7,000,000)

Ignore: ☐ Musts ☐ Must Nots ☑ Dependencies ☑ Groups

Simulations Settings Number of trials: 1000 Seed: -1 ☐ Keep Seed

Select: All | None

Search:

Index	Selected	Control Name	Control for	Selected	Cost	Applications	Categories	Must	Must Not
01	☐	Technology Consultant	Cause		90000	6		☐	☐
02	☐	Employee Developmental Training Programs	Cause		250000	8		☐	☐
03	☐	Continusous Vulnerability Assessments	Cause		75000	12		☐	☐
04	☐	Monthly policy review	Cause		75	7		☐	☐
05	☐	Establishe Deadlines for Policy Compliance	Cause		100	6		☐	☐
06	☐	Establish NexGen Policies with Stakeholders	Cause		0	7		☐	☐
07	☑	Aviation System Mechanics	Cause	Yes	80000	6		☐	☐
08	☑	Project Management Advancement Training	Cause	Yes	15000	8		☐	☐
09	☐	Cyber Credentialing Program	Vulnerability		1000000	60		☐	☐
10	☑	Continuous Network Vulnerability Assessment	Vulnerability	Yes	140000	42		☐	☐
11	☑	Software and Hardware Technology Assessment	Vulnerability	Yes	2000	39		☐	☐
12	☑	Employee Developmental Training Program	Vulnerability	Yes	15000	62		☐	☐
13	☑	Shareholder procedural meetins	Consequence	Yes	0	27		☐	☐
14	☐	Aircraft Safety Inspections	Consequence		950000	45		☐	☐
15	☑	Public Relations Team	Consequence	Yes	20000	45		☐	☐

Figure 36 Overall Risk with a Budget of $1 Million

Overall Likelihoods, Impacts, and Risks (With Controls) for RM Project 2018: FAA's Implementation of NexGen Air Traffic Control TH
(Controls are optimized based on simulated input and output)

No. ▲	Event	All Participants Likelihood Simulated	Impact, $ Simulated	Risk, $ Simulated
[13]	Degredation in Aircraft Avionics	0.30%	6,375,989	19,127
[14]	Major Aircraft Accident	0.10%	7,200,657	7,200
[15]	Minor aircraft accident	0.20%	2,129,937	4,259
[17]	Aircraft Avionics Shutdown	0.30%	18,622,056	55,866
[19]	Delayed NexGen Implementation	0.00%	0	0
[20]	Performance Based Navigation Failure	3.10%	35,354,042	1,095,975
[21]	Loss of Funding	0.00%	0	0
[22]	Stakeholder Noncompliance	0.00%	0	0
[23]	Insufficent resources to install NexGen technology	0.00%	0	0

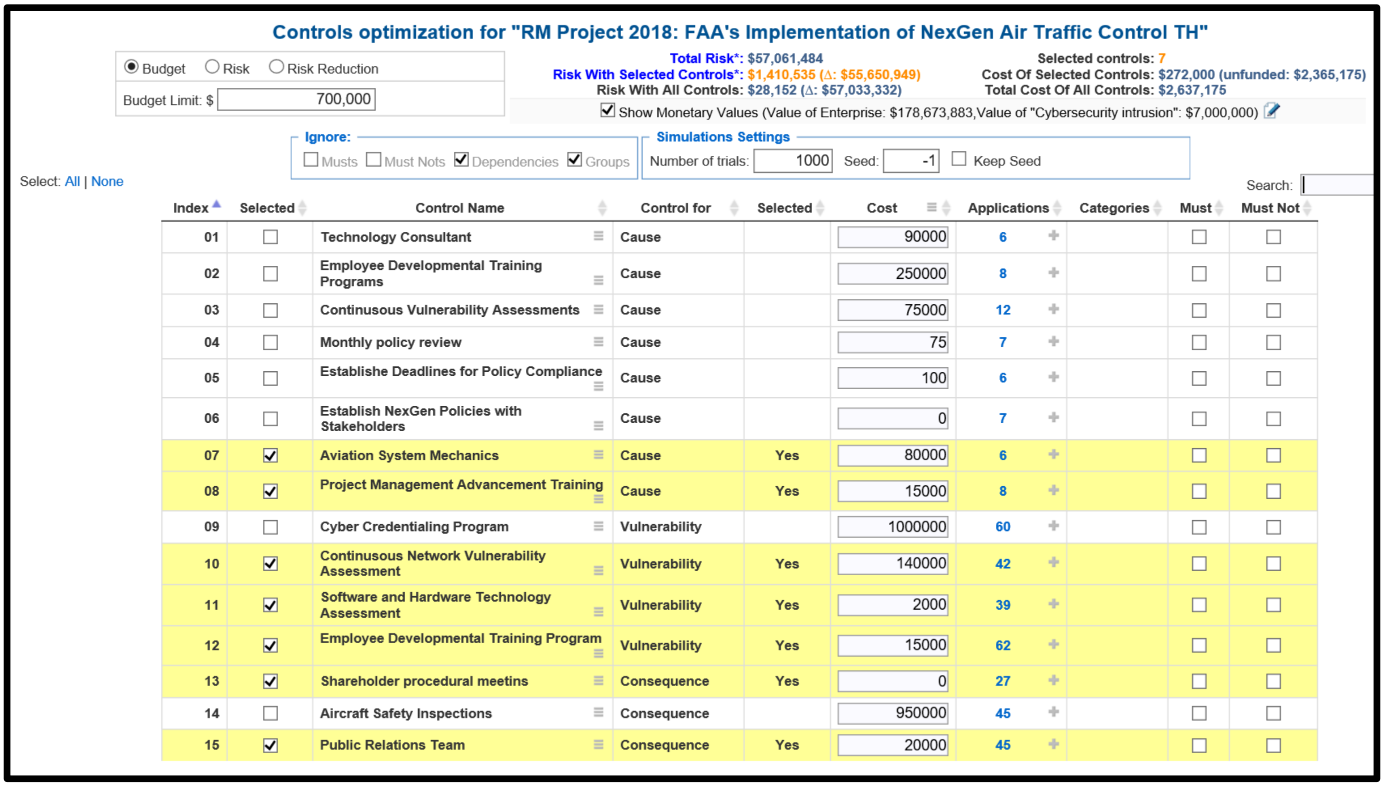
# Controls	Cost of Controls	How Selected
7	$272,000	Optimized based on simulated input and output with budget of $1,000,000

	Simulated
Total Risk	$59,295,903
Risk Reduction	$58,113,473
Residual Risk	$1,182,429

Scenario 3:

The optimization of controls with a budget of $700,000, we observe the selection of 7 controls with the expected risk reduction of $55.6 Million.

Figure 37 Controls Selected with a Budget of $700,000


Controls optimization for "RM Project 2018: FAA's Implementation of NexGen Air Traffic Control TH"

Budget | Risk | Risk Reduction
Budget Limit: $ 700,000

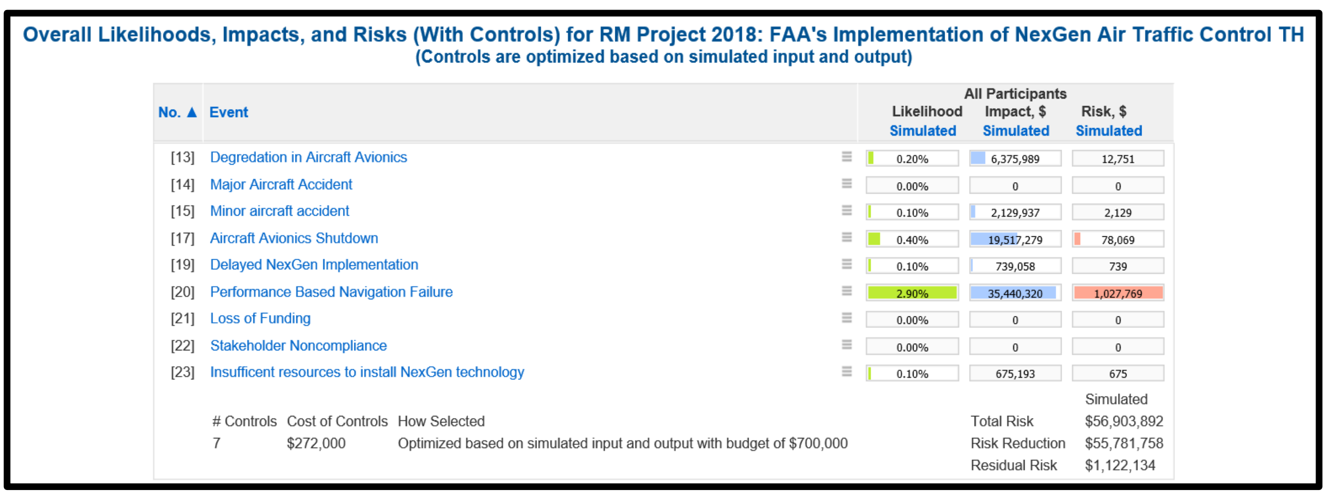
Total Risk*: $57,061,484
Risk With Selected Controls*: $1,410,535 (Δ: $55,650,949)
Risk With All Controls: $28,152 (Δ: $57,033,332)
Selected controls: 7
Cost Of Selected Controls: $272,000 (unfunded: $2,365,175)
Total Cost Of All Controls: $2,637,175
Show Monetary Values (Value of Enterprise: $178,673,883,Value of "Cybersecurity intrusion": $7,000,000)

Ignore: Musts, Must Nots, Dependencies, Groups
Simulations Settings: Number of trials: 1000 Seed: -1 Keep Seed

Select: All | None
Search:

Index	Selected	Control Name	Control for	Selected	Cost	Applications	Categories	Must	Must Not
01	☐	Technology Consultant	Cause		90000	6		☐	☐
02	☐	Employee Developmental Training Programs	Cause		250000	8		☐	☐
03	☐	Continusous Vulnerability Assessments	Cause		75000	12		☐	☐
04	☐	Monthly policy review	Cause		75	7		☐	☐
05	☐	Establishe Deadlines for Policy Compliance	Cause		100	6		☐	☐
06	☐	Establish NexGen Policies with Stakeholders	Cause		0	7		☐	☐
07	☑	Aviation System Mechanics	Cause	Yes	80000	6		☐	☐
08	☑	Project Management Advancement Training	Cause	Yes	15000	8		☐	☐
09	☐	Cyber Credentialing Program	Vulnerability		1000000	60		☐	☐
10	☑	Continuous Network Vulnerability Assessment	Vulnerability	Yes	140000	42		☐	☐
11	☑	Software and Hardware Technology Assessment	Vulnerability	Yes	2000	39		☐	☐
12	☑	Employee Developmental Training Program	Vulnerability	Yes	15000	62		☐	☐
13	☑	Shareholder procedural meetins	Consequence	Yes	0	27		☐	☐
14	☐	Aircraft Safety Inspections	Consequence		950000	45		☐	☐
15	☑	Public Relations Team	Consequence	Yes	20000	45		☐	☐

Figure 38 Overall Risk with a Budget of $700,000


Overall Likelihoods, Impacts, and Risks (With Controls) for RM Project 2018: FAA's Implementation of NexGen Air Traffic Control TH
(Controls are optimized based on simulated input and output)

No. ▲	Event	Likelihood Simulated	Impact, $ Simulated	Risk, $ Simulated
		All Participants		
[13]	Degredation in Aircraft Avionics	0.20%	6,375,989	12,751
[14]	Major Aircraft Accident	0.00%	0	0
[15]	Minor aircraft accident	0.10%	2,129,937	2,129
[17]	Aircraft Avionics Shutdown	0.40%	19,517,279	78,069
[19]	Delayed NexGen Implementation	0.10%	739,058	739
[20]	Performance Based Navigation Failure	2.90%	35,440,320	1,027,769
[21]	Loss of Funding	0.00%	0	0
[22]	Stakeholder Noncompliance	0.00%	0	0
[23]	Insufficent resources to install NexGen technology	0.10%	675,193	675

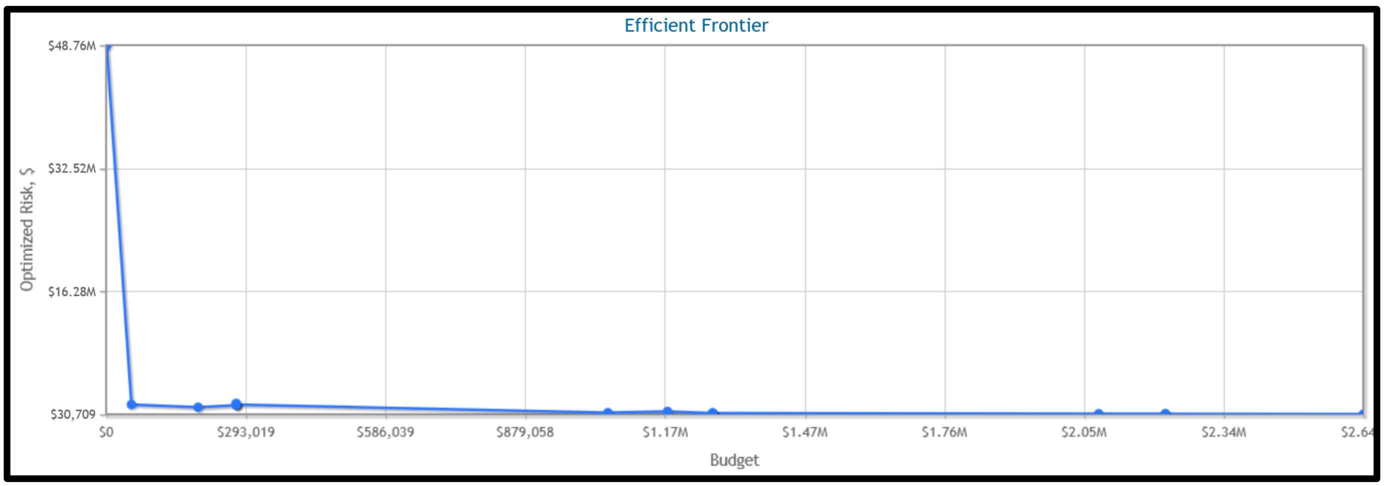
# Controls	Cost of Controls	How Selected		Simulated
7	$272,000	Optimized based on simulated input and output with budget of $700,000	Total Risk	$56,903,892
			Risk Reduction	$55,781,758
			Residual Risk	$1,122,134

Optimization Analysis

If we were to use all 15 controls, it would cost $2.6 Million. We optimized the controls with budgetary constraints of $2 Million, $1 Million, and $700,000 for a selection of 7 to 8 controls. Utilizing a budget of $1 Million means that we could save $1.5 Million at the beginning of the project. Based on results obtained, utilizing a budget of $1 Million can reduce the risk by $55.7 Million. The addition of $1 Million hinders the efficiency of controls and increases the residual risk. Therefore, it makes sense to consider spending the money at the beginning to mitigate the risk throughout the project.

According to Efficient Frontier, it is clear that, by spending between $1.05 and $1.32 Million, it is no longer efficient to add additional controls. The organization may consider double checking the optimization and consider increasing the budget to $1.32 (if needed) and determine if the risk reduction amount justifies the additional spending.

Figure 39 Efficient Frontier



6. Recommendation and Conclusion

Air travel remains the safest form of transportation for individuals looking to travel long distances across the country. The implementation of NexGen technology is the result of years of research and development with oversight from government accountability offices. The technological improvements NexGen seek to adapt will continue to make the airways the safest form of travel. It is however obvisous that a high degree of risk will be involved in this project, and it is best to identify and associate risk at the earliest possible opportunity.