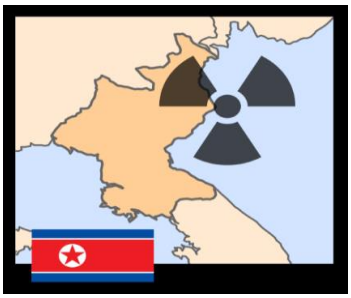
Democratic People's Republic of Korea (DPRK)
Military Nuclear Weapons Program



Risk Assessment

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Executive Summary

The group chose to look at the risks North Korea faces by continuing to technologically advance towards a nuclear weapon and delivery system capability. The group assessed the risk to a timeframe limited to the next six (6) months. The North Korean problem is a real scenario; however, the group evaluated all likelihood, impact, and control effectiveness in positions of North Korean leaders such as the Supreme Leader and the appropriate government officials.

The group implemented the Analytic Hierarchy Process (AHP) to assess risk using the Riskion® software. Figure 1 is an overall summary of the results obtained after several iterations and allowing the software to optimize the perceived controls with a moderate prevention budget. The highest likelihood for an event is imposition of more severe trade sanctions against North Korea – which actually occurred since this project was started.[1] The highest impact was evaluated to be a regional war and global thermonuclear war.

Eleven of sixteen controls were chosen with the restriction of a modest $ 6 million budget. Optimization algorithms indicated that the risk could be reduced from 22 % of the enterprise value to about 17.6 %. Additional risk reduction could have been realized with a higher budget. Although the results are fictional because of the unfamiliarity with a secretive, isolated regime, several key lessons were learned. Well-informed intelligence agencies could leverage their collective knowledge to perform similar "war-game" scenarios to determine the most effective actions against this global threat. Similarly, the intel organizations can predict the likely responses of the North Korea regime to allied actions in an attempt to force the endgame to a specific conclusion.

[1] Gonzalez, R. National Public Radio "U.N. Security Council Approves New North Korea Sanctions", http://www.npr.org/sections/thetwo-way/2017/09/11/550301634/u-n-security-council-approves-new-north-korea-sanctions

Overall Likelihoods, Impacts, and Risks (With Controls) for «*Project: Risk Assessment of North Korea Developing Nuclear Weapons»

No.	Event	All Participants Likelihood Computed	Likelihood Simulated	Impact Computed	Impact Simulated	Risk Computed ▲	Risk Simulated
#02	Global Thermonuclear War - China, DPRK, Japan, ROK, Russia, U.S.	0.035089%	0.040000%	52.840358%	46.426292%	0.018541%	0.018571%
#03	Materials or tecnology stolen from DPRK (nuclear).	0.548776%	0.480000%	4.829061%	4.356577%	0.026501%	0.020912%
#08	Assassination of Kim Jung Un	1.745896%	1.490000%	3.448584%	3.385926%	0.060209%	0.050450%
#09	Destroyed missile	7.892451%	7.500000%	4.829299%	4.441158%	0.381150%	0.333087%
#05	Nuclear test mishap (DPRK).	5.788328%	3.870000%	22.101285%	19.878136%	1.279295%	0.769284%
#01	Enrichment facility mishap (DPRK).	9.209999%	8.880000%	18.337816%	16.577399%	1.688913%	1.472073%
#04	Missile production facility mishap (DPRK).	14.552464%	12.990000%	19.417363%	17.318372%	2.825705%	2.249657%
#10	Tactical Strike on DPRK by US	20.488392%	16.260000%	15.097757%	13.528985%	3.093288%	2.199813%
#07	Increased Sanctions Against DPRK	54.891580%	26.970000%	9.213036%	9.197991%	5.057181%	2.480698%
#06	Regional War (conventional): U.S., ROK, Japan v. DPRK, China	28.501037%	15.780000%	54.011530%	50.578560%	15.393846%	7.981297%

Total Residual Risk: 29.824628%
Average Loss: 17.575840%
Total Risk Reduction: 16.158593%
Cost of Selected Controls: $5,600,000

Figure 1 *Computed and Simulated Risk after Optimizing Controls*

Introduction

North Korea has significantly ramped up their efforts to illustrate their capability in both creating a devastating nuclear weapon and delivering that weapon via an intercontinental ballistic missile (ICBM). Seventeen separate missile launches have been conducted according to sources since the beginning of 2017.[2] North Korea also conducted an underground nuclear test in 2017 several days after we decided to conduct a risk assessment on this topic.[3] The test was reported to be the strongest yield yet for the country and was tentatively assessed as a hydrogen bomb.

The Supreme Leader, Kim Jung Un, is focused on developing these destructive weapons to serve as a deterrent to what he views as an imminent United States threat to his regime. Kim Jung Un believes possessing a nuclear arsenal will dissuade the US from forcibly removing him from power based upon the fear he will use the weapons against reachable ally targets: South Korea, Japan, and Guam. The United States is adamantly opposed to another country developing nuclear weapons. The US has done everything to restrict Iran from the same development efforts. Through a joint agreement, Iran has agreed to limit their uranium enrichment program to create radioactive materials solely for nuclear energy power. Rhetoric on both sides has intensified the situation and since this project was initiated, we have observed several strategies to curtail the North Korean development. Increased sanctions have been imposed and President Trump indicated the threat of "fire and fury" in an impromptu conversation.[4]

[2] https://en.wikipedia.org/wiki/2017_North_Korean_missile_tests
[3] http://www.cnn.com/2017/09/03/asia/north-korea-nuclear-test/index.html
[4] http://www.huffingtonpost.com/entry/trump-fire-and-fury_us_598b2fa8e4b0d793738c0859

The initial concept for this project involved looking at the North Korean situation from multiple perspectives. Perspectives initially included US, China, Russia, South Korea, Japan, and North Korea risk events, defined as an event with a loss. Two representatives from each country, the leader and a UN representative, were going to provide the judgments for specific risk events to their respective country. The project included approximately 45 risk events distributed across the six (6) nations involved. Due to the increasing complexity, we decided to scale back the endeavor to focus on risk events related only to North Korea because of their continued nuclear weapon development. The professor also requested that the projects limit risk events to ten (10) because of how the controls would greatly expand the project workload. Some choice screen shots from the initial effort will be included in the appendix to illustrate the difference in models that we considered throughout the course. Finally, we chose to limit this model to consider the risk over the next six (6) months, anything further in the future will be increasingly difficult to estimate, or predict, especially considering how quickly things have progressed even since this project was started.

Initial Risk Planning and Methodology

Our team used Expert Choice Riskion® software to develop the risk model for this project. Riskion software uses the Analytical Hierarchy Process (AHP) to assist risk managers in analyzing the four basic risk elements and incorporates proven mathematical techniques to measure and synthesize information for use in prioritizing risks and applying controls to optimize management of those risks. The use of AHP allows decision-makers to "incorporate both objective and subjective considerations into the decision process." [5]

The four basic risk elements include Events, Sources, Consequences, and Controls. A risk is an "**Event**" that is uncertain, but if it does occur, will result in a loss. A "**Source**" (also known as a hazard or threat) is an uncertainty that does not result in a loss but can cause an event. A source is not a risk since it does not result in a loss to objectives. We define "**Consequences**" as a measure of the impact of an event, if it occurs, on the objectives of the company or individual (i.e., consequences *to* objectives, or consequences *to* the assets). The last of the basic risk elements are "**Controls**." We implement controls to "reduce the potential for harm or maintain it at an acceptable level. We estimated the effectiveness of various controls and then applied them for optimal effect.

The three basic risk measurements employed in our analysis included estimating "**Likelihood**." Likelihoods are the product of two measures: the likelihood of the source(s) and the likelihood of an event given the source(s). A second measure is "**Impact.**" Impact is also the product of two elements: the importance of an objective and the consequence of the event on the objective. Finally, we calculate the overall "**Risk"** of an event (a loss) as the product of likelihood times the impact to arrive at a prioritized list of overall risks.

[5] Forman, EH, "The Analytical Hierarchy Process as a decision Support System," *Proceeding of the IEEE Computer Society (Fall 1963).*

The analysis process for this report involved identifying events that could result in a loss for the North Korean regime. We then defined sources (causes/threats) for these risk events and mapped these sources to the events by organizing the information in a Risk Breakdown Structure (RBS) to aid comprehension of the sources as they applied to events. "The RBS is a hierarchical structure of potential risk sources."[6] Creating a hierarchy of sources is a key aspect of the Analytic Hierarchy Process (AHP) in that it categorizes sources into homogenous clusters for evaluation and prioritization. The next steps included defining objectives and choosing participants with subject expertise for evaluating likelihoods and impacts. After participants measured likelihoods and impacts, we analyzed the synthesized data and identified controls for use in reducing either the likelihoods or impacts of sources and events. Throughout the process, we used iteration to refine the model. The final steps were the evaluation of control effectiveness and optimizing controls to manage the risks.

Our analysis of the risks face by the DPRK Military Nuclear Weapons Program is a hybrid scenario. We assigned participants to evaluate various risk elements based on their positions within the government of North Korea; however, James and Gary posing as these DPRK officials performed the evaluations.

Identifying Events

The first step in performing a risk analysis using the Analytical Hierarchy Process (AHP) was to identify events that could result in a loss for the North Korean regime. Although we easily identified over 40 potential loss events for this project, due to time constraints we reduced the scope of the analysis to 10 events. Figure 2 illustrates the result of many iterations of identifying risk events.

[6] Hillson, David, (2003) "Using a Risk Breakdown Structure in project management", *Journal of Facilities Management, Vol. 2 Issue: 1, pp.85-97, https://doi.org/10.1108/14725960410808131*

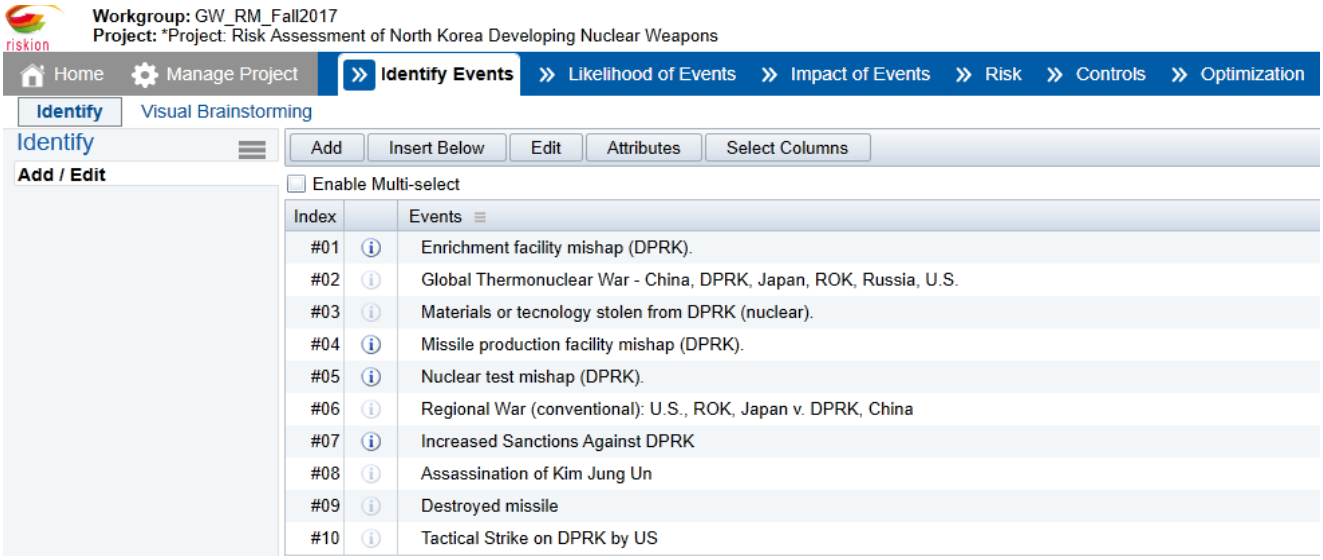

Figure 2 *North Korean Risk Events*

Below is a brief description of each event:

1. Enrichment facility mishap – an accidental or intentional damage/destruction of a NK facility used to produce materials for nuclear weapons.
2. Global thermonuclear war – detonation of nuclear weapon within NK borders.
3. Nuclear materials or technology stolen from NK – intentional theft by adversaries of NK resources for nuclear weapon program.
4. Missile production facility mishap – accidental or intentional damage/destruction of NK facility used to produce ICBM's for delivering nuclear weapons to specified targets (e.g., Guam, Figure 3)[7].
5. Nuclear test mishap – accidental damage/destruction caused within NK borders from the result of a nuclear detonation (e.g. landslides similar to those observed for the September test).[8]
6. Conventional regional war – damage/destruction caused within NK borders due to armed forces conflict.
7. Increased sanctions against NK – economic loss from US and UN forces restricting trade to NK.
8. Assassination of Kim Jung Un – political upheaval from intentional regime change
9. Destroyed missile – loss incurred from anti-missile systems intercepting and neutralizing missile threats from NK.
10. Tactical Strike on DPRK by US – damage/destruction to critical military and political targets from a US tactical missile strike.

[7] Taylor, A., Karklis L., and Meko, T. (2017). "Latest North Korea missile launch suggests Guam is within reach." https://www.washingtonpost.com/news/worldviews/wp/2017/09/15/latest-north-korea-missile-launch-suggests-guam-is-within-reach/?utm_term=.2003dcad16a1

[8] BBC News (September 6, 2017). "North Korea nuclear crisis: Test 'caused landslides'" http://www.bbc.com/news/world-asia-41170940

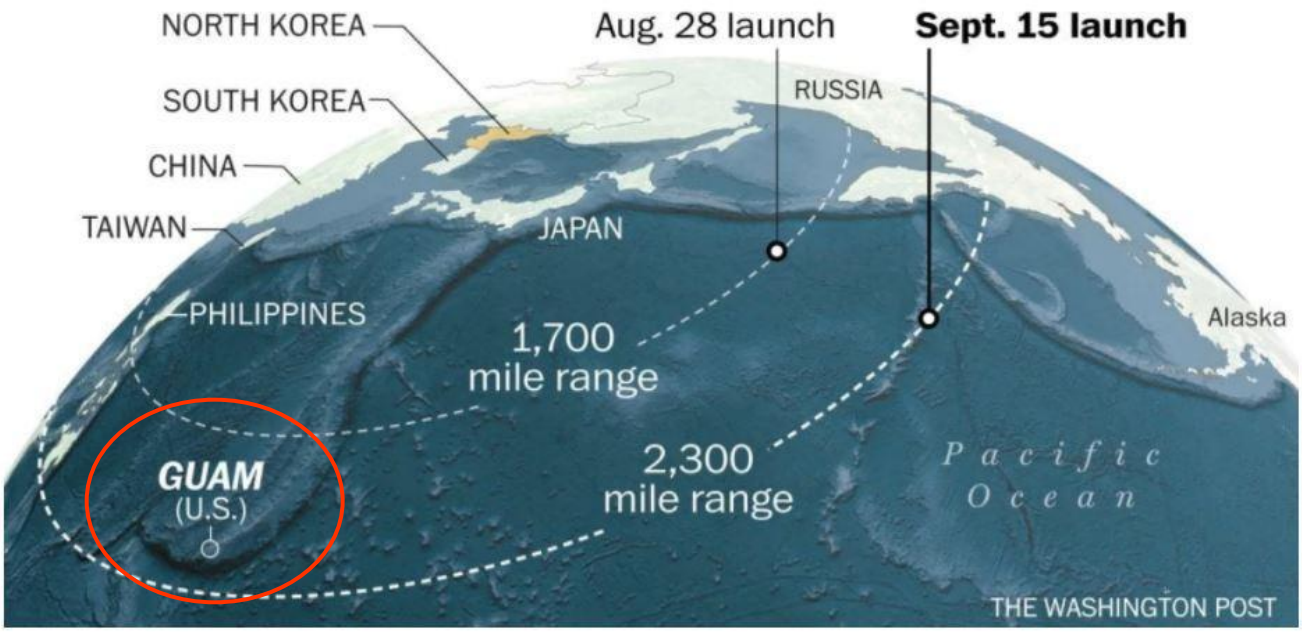

Figure 3 *Current Range of North Korean Missile Technology*

Identifying Sources

Figure 4 shows most of the sources identified for the different risk events. Sources were grouped into five (5) categories: military actions, diplomatic breakdowns, technical failures, human errors, and proliferation. Communication issues are a source listed under the diplomatic breakdowns category. The US and NK do not see eye-to-eye on NK nuclear weapons possession and the political figures involved, especially President Donald Trump, are not providing clear and consistent dialogue as we have seen in recent weeks.

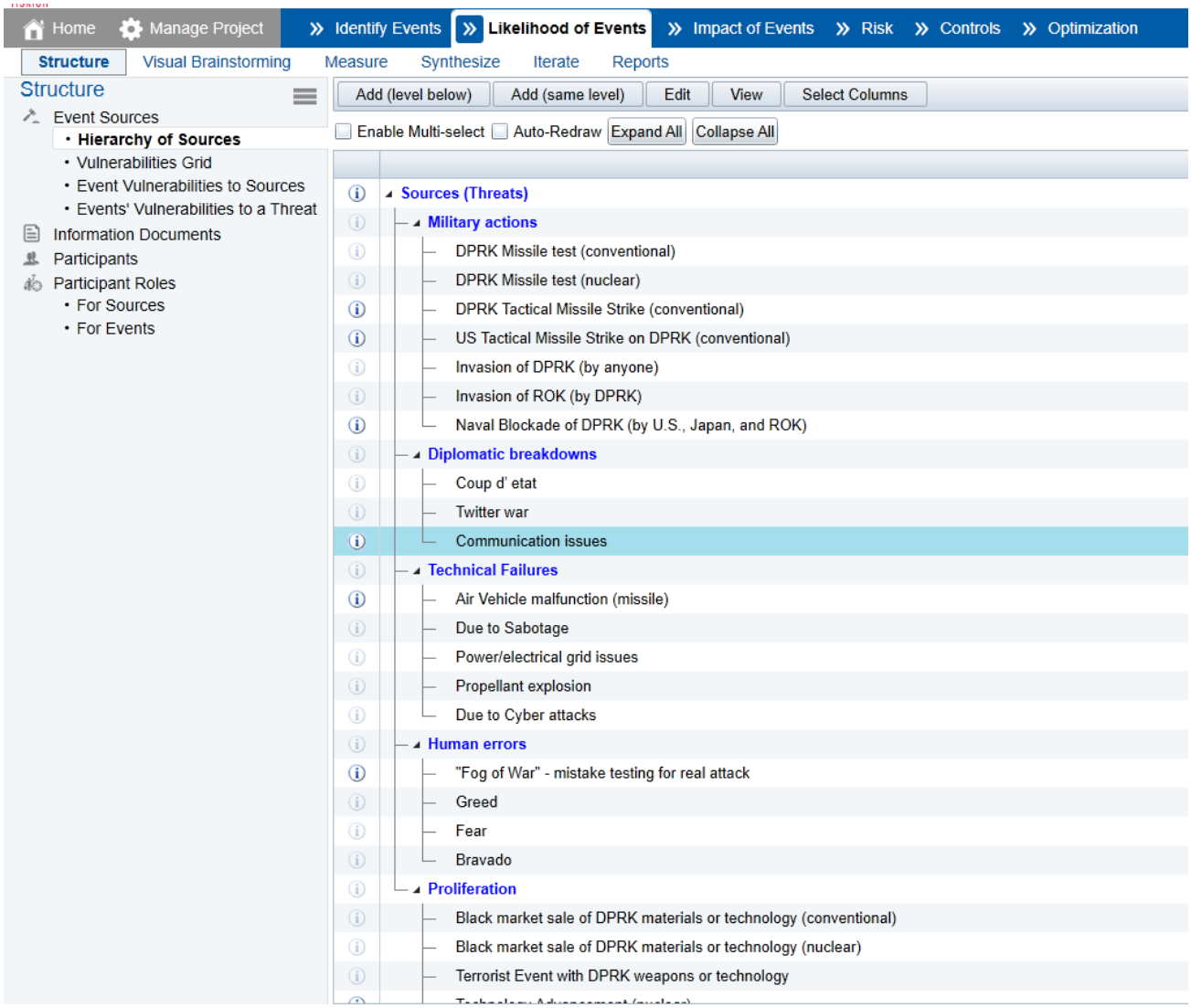

Figure 4 *NK Sources (Threats)*

Mapping Events and Sources

The next step in risk assessment is linking each source to one, or more, specific loss events. Figure 5 depicts a portion of the vulnerability grid where project risk managers can select how each source maps to each event. As an example, communication issues could be a source that causes either a regional war or a US tactical missile strike. From the opposite perspective, a missile facility mishap could be caused by six (6) different sources: US tactical missile strike, sabotage, power/electrical grid issues, propellant explosions, cyber-attacks, or technology advancement.

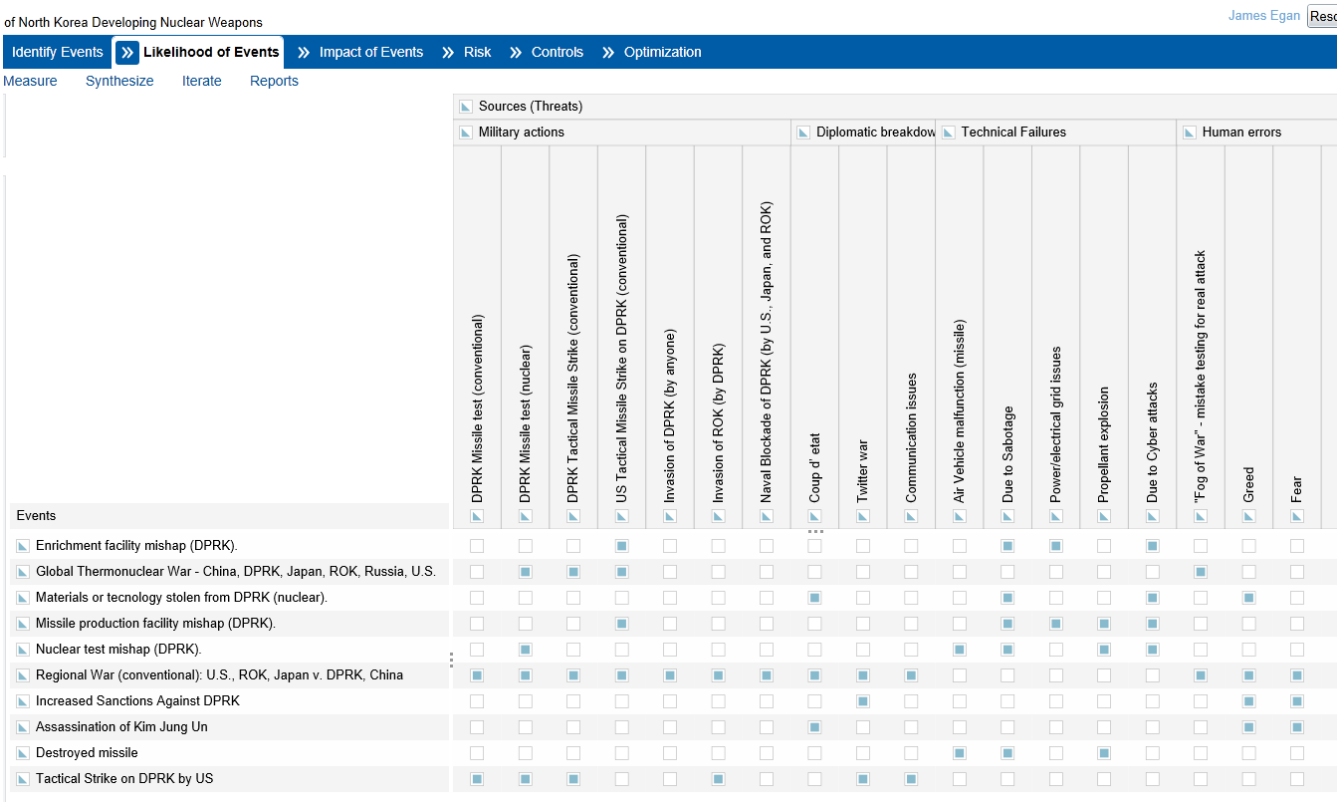

Figure 5 *Vulnerabilities Grid between Sources and Events*

Figure 6 provides another way to visualize sources that contribute to a given event. Note that the diagram matches the text above for sources that may contribute to potential missile production facility mishap event. The "bow-tie" diagram in figure 5 depicts the relationships between sources and events; and as we will show later, impacts, which will complete the right side of the diagram. As we move through the risk evaluation process, we will also add controls to the bowtie diagram.

Figure 6 *Missile Production Facility Mishap, Bow Tie Diagram (left side)*

Choosing Participants

Although North Korea's nuclear weapon development represents a real-world scenario it remains a hypothetical project because we adopted NK personas that would be involved in making judgments concerning event likelihoods based upon sources. We chose eight (8) North Koreans involved in different aspects of the regime's decision-making process[9]:

1. Supreme Leader, Kim Jung Un
2. Atomic Energy Minister, Ri Je-son
3. Chief Scientist, Ri Pyong Chol
4. Defense Minister, Pak Yong-Sik
5. Finance Minister, Choe Kwang-Jin
6. State Security, Pak Yong-sik
7. Trade Minister, Kim Kyong-nam
8. UN Representative, Ja Song Nam

Participants were assigned roles to derive likelihoods for events based upon specific sources. Roles were defined for each person to allow them only to make judgments within their range of expertise while restricting their involvement to areas that were not relevant to their official regime duties. For instance, Chief Scientist Ri Pyong Chol was restricted to making judgments concerning technical

[9] Cabinet of North Korea. (2017, July 11). In Wikipedia, The Free Encyclopedia. Retrieved 00:50, October 13, 2017 , from https://en.wikipedia.org/w/index.php?title=Cabinet_of_North_Korea&oldid=790029381

failures and proliferation (see Figure 7). The same process was used for each participant to define specific roles and restrictions.

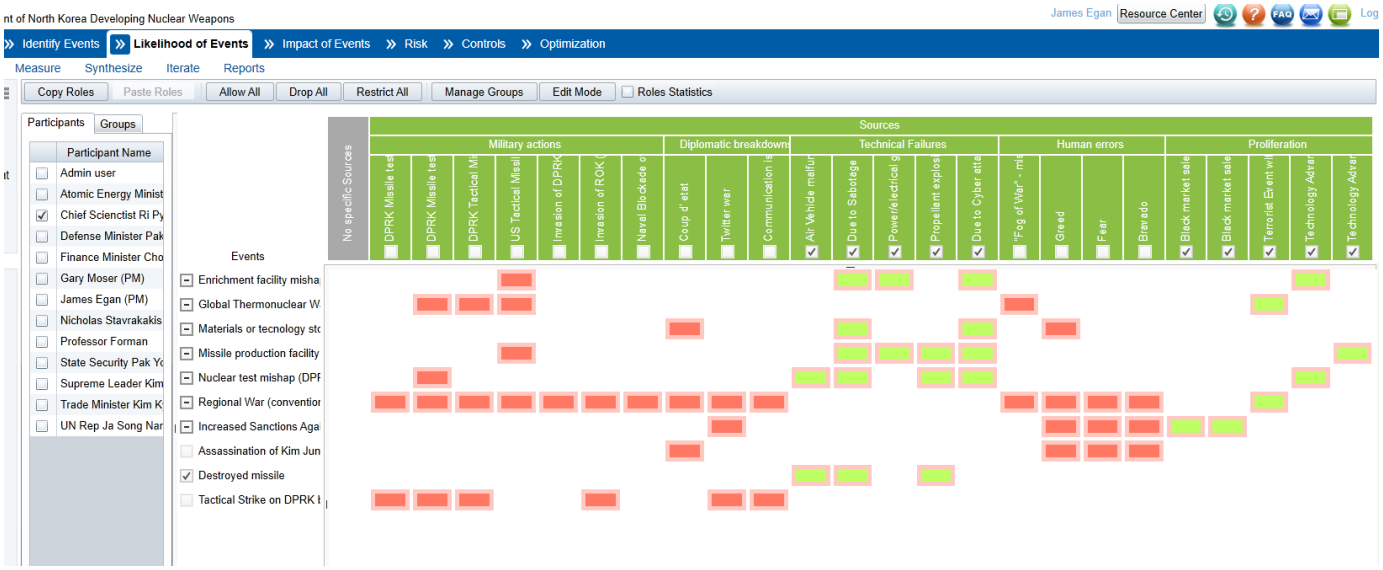

Figure 7 *Chief Scientist Ri Pyong Chol's Roles for Likelihood of Events*

Measurement Methods

Expert Choice Riskion® software provides multiple measurement methods for deriving priorities for the relative importance of sources, events, and impacts to objectives. We chose several different measurement methods for participants to derive likelihoods, or probabilities, for each event and the relative importance of sources. Different measurement methods were chosen to experience how the approach for each method was unique. Most source evaluations involved using pairwise comparisons. Pairwise comparisons require the participant to choose how likely one source occurs with respect to another. The participant must choose a ratio amongst each pairing to add a quantitative value to the likeliness comparison (see Figure 8). When the participant finishes a grouped selection of decisions, based upon the configured hierarchy, an inconsistency value is calculated. The inconsistency value measures how the participant has ordered and defined the pairwise combinations to determine how precise the judgments are relative to one another.

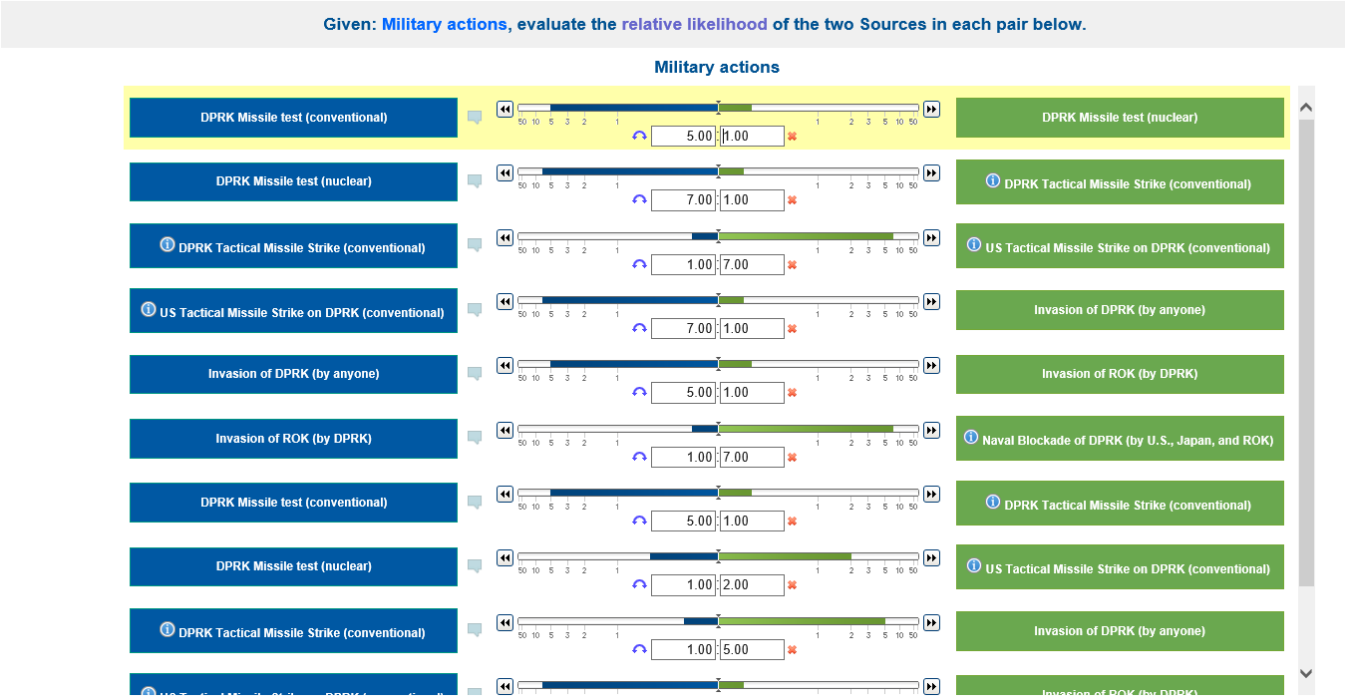

Figure 8 *Pairwise Comparison to Derive Likelihoods*

Another measurement method used for source evaluation involved pairwise comparison with given likelihood. Just as with pairwise comparisons, the participant is asked to provide a measure from 1-9 of how much more likely one element is to another. The critical difference is that one of the elements in the group has a known likelihood that has been measured and serves to define all the other probabilities based upon the participants answers. The group used this comparison technique for technical failures where air vehicle malfunction was defined as 21 % (or 0.21 depicted in Figure 9). The measured value came from the estimated number of 2017 NK missile failures[10].

While evaluating likelihoods for events based upon particular sources, the group used several different rating scales. The scales were labeled high-, mid-, and low-likelihood rating scales. The group was also asked to create their own rating scale, which is shown in Figure 10. Once the measurement methods were established the participants were required to complete their evaluations. Once the event likelihoods and impacts are judged, the software is able to calculate a risk for each loss event by multiplying the averages together: $L_n \times I_n = R_n$.

[10] Wikipedia contributors. "2017 North Korean missile tests." Wikipedia, The Free Encyclopedia, 10 Oct. 2017. Web. https://en.wikipedia.org/wiki/2017_North_Korean_missile_tests

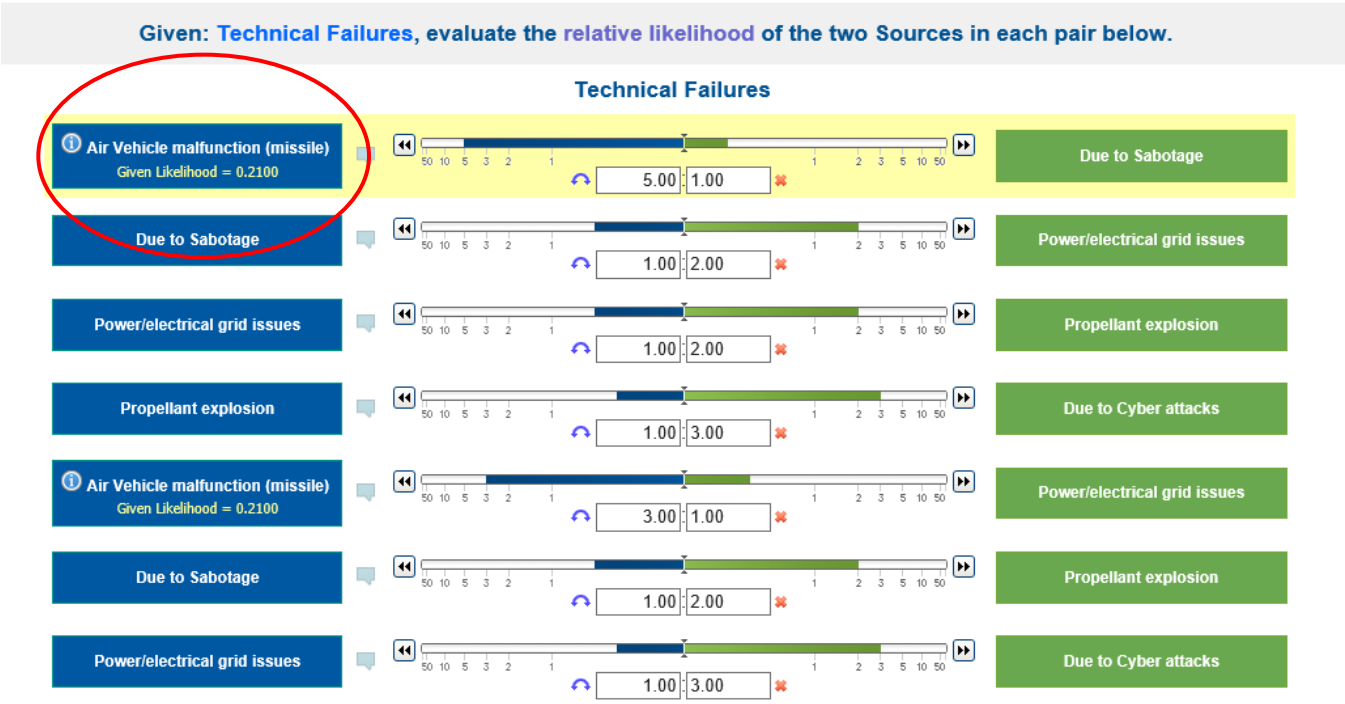

Figure 9 *Pairwise Comparison with Given Likelihood*

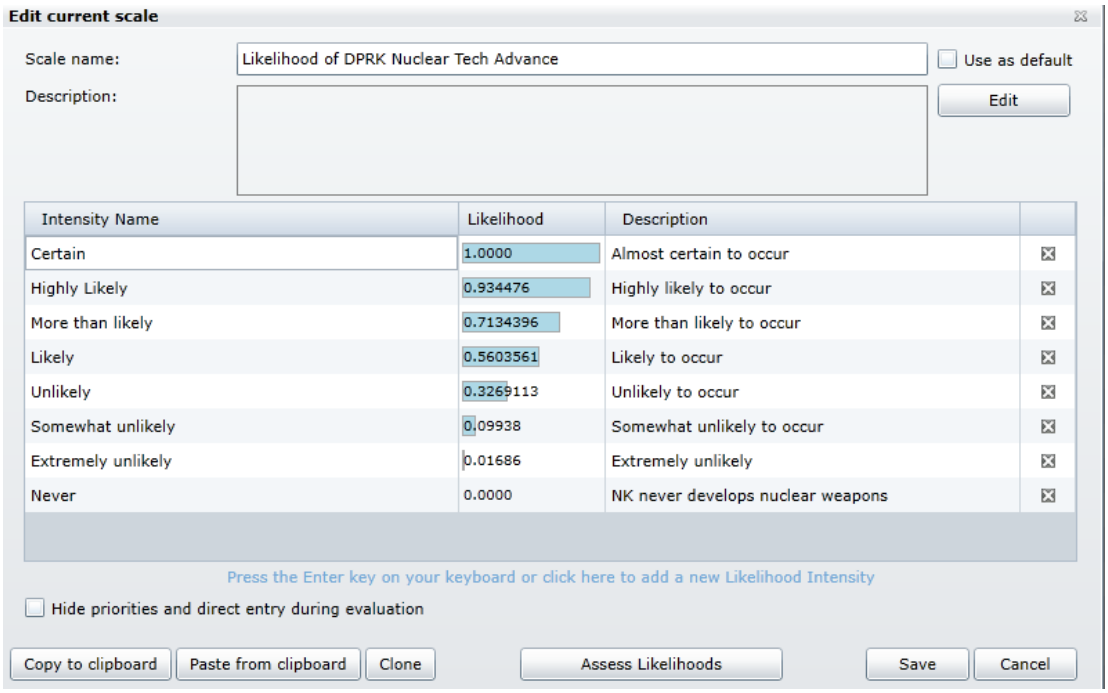

Figure 10 *Group's Customized Likelihood Rating Scale*

Synthesis

The synthesis tab under likelihood of events allows the software to compute the participant evaluation results as a whole. Based upon the combined evaluations the highest risk was found to be increased sanctions, as seen in Figure 11. This is not surprising since it is one of the few non-violent options to curtail technological progress within North Korea. The lowest likelihood was found to be global thermonuclear war. Some of the other high likelihoods are a bit surprising based upon the recent news articles where US leaders have been quoted as saying there are limited to no military options[11]. Keep in mind that the evaluations in this report are from the North Korean cabinet group's interpretation of the North Korean's optic. North Korea and their leaders are concerned with US interference in their regime and use that fear as the main justification for their nuclear weapon pursuit. "Jeffrey Lewis, an arms-control expert at the Middlebury Institute of International Studies, wrote in Foreign Policy in March[11]:

> North Korea's military exercises leave little doubt that Pyongyang plans to use large numbers of nuclear weapons against U.S. forces throughout Japan and South Korea to blunt an invasion. In fact, the word that official North Korean statements use is "repel." North Korean defectors have claimed that the country's leaders hope that by inflicting

[11] Bowden, Mark, (2017) "How to Deal With North Korea: There are no good options. But some are worse than others." *In The Atlantic, https://www.theatlantic.com/magazine/archive/2017/07/the-worst-problem-on-earth/528717/*

mass casualties and destruction in the early days of a conflict, they can force the United States and South Korea to recoil from their invasion.

	Events	[All Participants] 8 with judgments
#07	Increased Sanctions Against DPRK	59.65%
#10	Tactical Strike on DPRK by US	46.69%
#06	Regional War (conventional): U.S., ROK, Japan v. DPRK, China	35.99%
#09	Destroyed missile	31.89%
#04	Missile production facility mishap (DPRK).	22.09%
#01	Enrichment facility mishap (DPRK).	14.00%
#05	Nuclear test mishap (DPRK).	12.50%
#08	Assassination of Kim Jung Un	3.97%
#03	Materials or tecnology stolen from DPRK (nuclear).	2.30%
#02	Global Thermonuclear War - China, DPRK, Japan, ROK, Russia, U.S.	0.05%

Figure 11 *Synthesis Results for Likelihood of Events*

Iteration

Our original project involved looking at risk events for the North Korean situation from multiple perspectives, to include the US, China, Russia, South Korea, Japan, and North Korea. Our goal was to analyze the risks for each country and then aggregate the results to examine overall risks to the participants from a global perspective. We identified over 40 risk events for the participants, assigned group attributes to identify which country would experience a loss, given an event, and completed our probability judgments for likelihoods and impacts. Figures 12 and 13 show a sample of the 42 risk events identified in the original model and categorical attributes used to differentiate between countries when doing measurements and analysis.

During several iterations to assess the reasonableness of our results, we noticed one item that caused concern. Although we had carefully assigned participant roles for sources and events, we noticed that the results for individual judgments included sources "bleeding into" events that did not concern the participant's country of interest or assigned roles. A good example of this was the results for CIA director Mike Pompeo, who only had 27 evaluations. When we synthesized the measurements, Mr. Pompeo had results for all 16 project events despite his judgements being restricted (through

participants roles) to only five events. After consulting with Professor Forman, we found that to do this type of multi-group evaluation in Riskion, we needed to turn off (uncheck) the Combined Input Source (CIS) function. According to the Riskion online help "when some participants do not have roles such that they have provided enough input for them to see results, the combined input source option can be selected: This option will use the combined input of those who have roles to augment the input provided by individual participants to generate results for the individuals. The source for the combined input is the inputs of all other participants that have roles for any sources or events for which the participant does not a role." By turning CIS off, we could see individual results for each country's judgments in isolation.

Time constraints demanded that we reduce the project scope to focus on risks faced by one participant. We chose to examine the risks to North Korea. According to the Riskion® online help documentation, iteration is an important modelling step "to account for feedback that might exist between events and objectives. More importantly, to verify that the results of the AHP model/evaluation make sense and any reasons for the contrary have been accounted for." From a practical standpoint, iteration allowed us to examine the scope of our original project and verify that we had constructed a model that would allow us to examine the risk situation from multiple perspectives, and it provided feedback that showed areas needing additional clarification, such as information documents and descriptions of events, sources, and impacts.

Figure 12 *Sample of Original Project Event Listing*

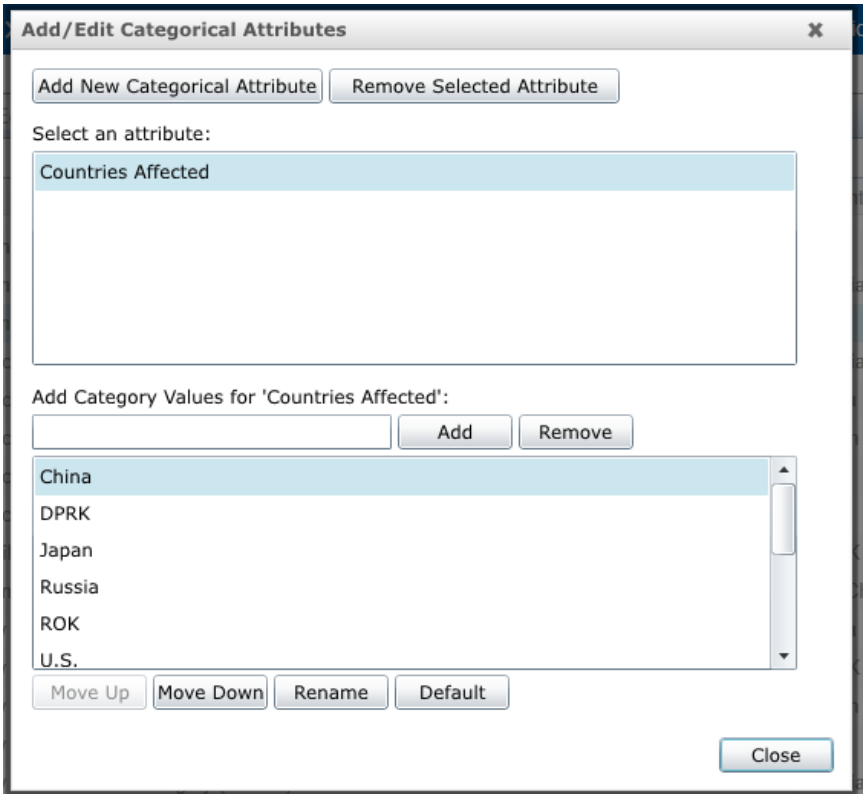

Figure 13 *Category Attributes to Isolate Different Countries of Interest*

Defining Objectives and Event Impacts

The group had to next consider the impact of the events on objectives. The group identified a list of objectives, or consequences. The objectives were organized in four (4) categories: human factors, financial, environmental, and political (see Figure 14). Participants were asked to evaluate the impact of a given source related to an event for each possible consequence. Evaluations were structured much the same way as how the likelihood measurements were performed. Participants first evaluated each objective with respect to each other through pairwise comparisons. Following the hierarchy, participants were asked to use a rating scale to determine the overall impact for each event based upon the ratio-ordered objectives. Participant's roles were established to have specific individuals rate within their areas of expertise. For example, the Trade Minister was restricted to financial objectives.

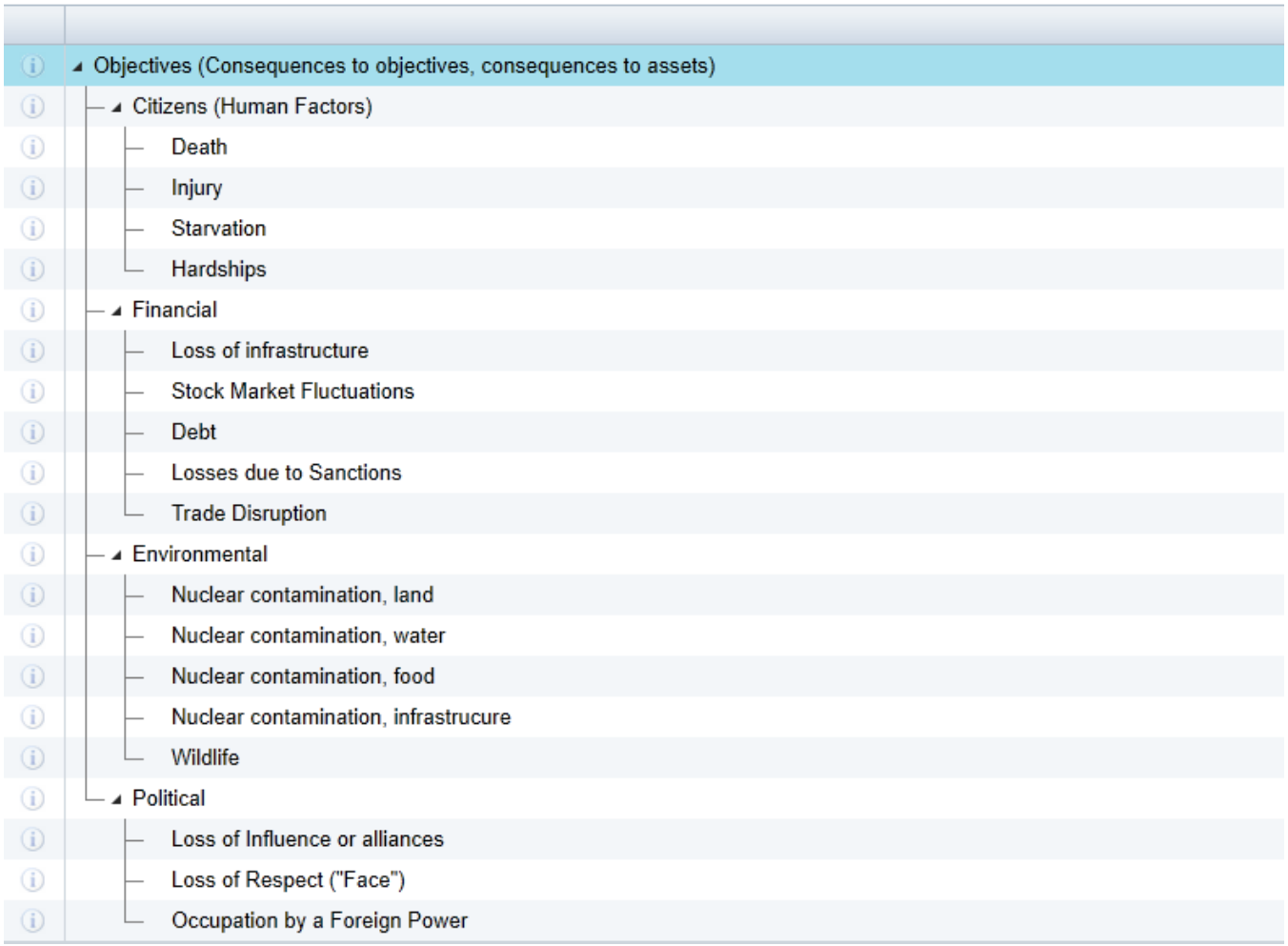

Figure 14 *Objectives Hierarchy*

Synthesis

Once all participants had concluded their evaluations, the group synthesized the data for the impact assessment. The software computed the event impacts as presented in Figure 15. War, either nuclear or conventional armed forces conflict, is a sizeable impact on North Korea. Participants indicated that financial and political objectives were most important. Human casualties and environmental issues were much less important. This perspective is based upon a significant amount of mainstream new stories that portrays:

- Incredibly harsh living conditions
- Work camp imprisonment
- Political executions
- Sacrifice and unquestioning belief to the regime

All these factors indicate that the regime is completely willing to sacrifice its citizens and military forces to protect the regime from collapse.

	Events	[All Participants] 8 with judgments
#08	Assassination of Kim Jung Un	3.45%
#03	Materials or tecnology stolen from DPRK (nuclear).	4.83%
#09	Destroyed missile	4.83%
#07	Increased Sanctions Against DPRK	9.21%
#10	Tactical Strike on DPRK by US	15.10%
#04	Missile production facility mishap (DPRK).	19.42%
#05	Nuclear test mishap (DPRK).	24.93%
#01	Enrichment facility mishap (DPRK).	34.13%
#06	Regional War (conventional): U.S., ROK, Japan v. DPRK, China	54.01%
#02	Global Thermonuclear War - China, DPRK, Japan, ROK, Russia, U.S.	55.84%

Figure 15 *Computed Event Impacts: Lowest to Highest (not normalized)*

Risk

Risk is computed by multiplying the likelihood of events with the impact of events. The table in Figure 16 shows both the total expected risk and the average loss based on the measurements from all

participants. The total risk contains "the flaw of averages" which is a result of over-estimation due to non-mutually exclusive sources of events. The total risk sums up the computed risks of all ten (10) events. The average loss is almost 50 % lower than the total risk. The average loss is determined by conducting a simulation. The simulation determines the likelihood of triggering an event and the same event cannot trigger more than once because of different sources, thus reducing the actual risk computation. The average loss predicts a more accurate depiction of the envisioned scenario when things are not mutually exclusive. The group decided to keep the total risk as a percentage rather than a dollar figure because the enterprise value of a country is difficult to assess.

Overall Likelihoods, Impacts, and Risks for «*Project: Risk Assessment of North Korea Developing Nuclear Weapons»

No.	Event ▲	All Participants Likelihood Computed	Likelihood Simulated	Impact Computed	Impact Simulated	Risk Computed	Risk Simulated
#08	Assassination of Kim Jung Un	3.97%	3.30%	3.45%	3.09%	0.14%	0.10%
#09	Destroyed missile	31.89%	30.00%	4.83%	4.17%	1.54%	1.25%
#01	Enrichment facility mishap (DPRK).	14.00%	14.20%	34.13%	27.32%	4.78%	3.88%
#02	Global Thermonuclear War - China, DPRK, Japan, ROK, Russia, U.S.	0.05%	0.10%	55.84%	29.07%	0.03%	0.03%
#07	Increased Sanctions Against DPRK	59.65%	24.30%	9.21%	9.18%	5.50%	2.23%
#03	Materials or tecnology stolen from DPRK (nuclear).	2.30%	2.10%	4.83%	3.70%	0.11%	0.08%
#04	Missile production facility mishap (DPRK).	22.09%	19.30%	19.42%	15.62%	4.29%	3.01%
#05	Nuclear test mishap (DPRK).	12.50%	7.90%	24.93%	21.28%	3.12%	1.68%
#06	Regional War (conventional): U.S., ROK, Japan v. DPRK, China	35.99%	15.50%	54.01%	47.68%	19.44%	7.39%
#10	Tactical Strike on DPRK by US	46.69%	24.80%	15.10%	13.19%	7.05%	3.27%

Total Risk: 45.98%
Average Loss: 22.92%

Figure 16 *Overall Likelihoods, Impacts, and Risks (computed and simulated)*

The risk map in Figure 17 is a good graphical representation to illustrate the overall risk North Korea faces by pursuing nuclear weapon development. Likelihood is the x-axis and impact is the y-axis. Different background shading highlights isotherms of risk regions: red is over 7 % where regional war and a US tactical strike reside. A regional war has less likelihood but a far greater impact with relation to the US tactical strike. Four (4) events exhibit risk falling in the 2 – 7 % region and the remaining four (4) are below 1 %. Nuclear war is almost on the y-axis with an extremely low likelihood but a substantial impact, if it occurs.

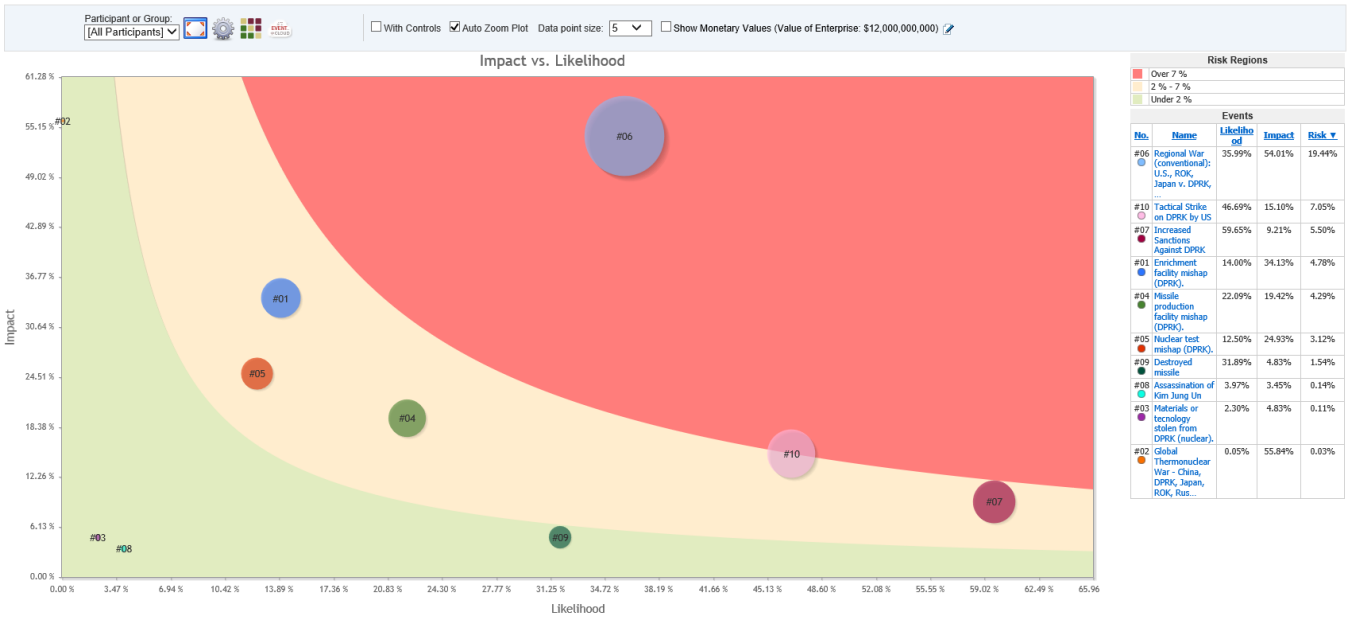

Figure 17 *Risk map Without Controls*

A loss exceedance curve (see Figure 18) was generated to observe loss probabilities for different enterprise percentage values. Two (2) critical set points were defined for the North Korean regime. The first is that there is a 5 % probability that 71.6 % of the North Korean country's value could be destroyed. The second is that there is a 17.4 % chance that half of the country's value could be destroyed.

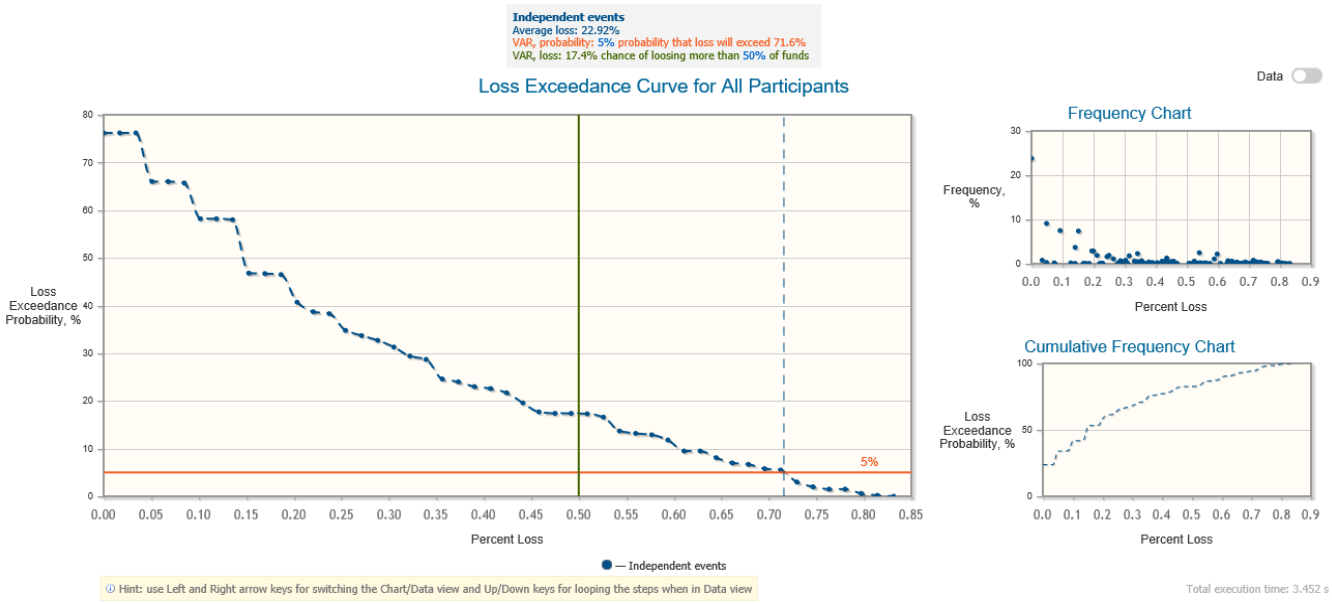

Figure 18 *Loss Exceedance Curve Before Controls*

Controls

The last step in the process was to develop controls to lower the risk North Korea would sustain from specific sources. Controls are specific actions North Korean leaders could take to limit or eliminate specific threats, consequences, or vulnerabilities and lower the overall risk. Figure 19 illustrates the types of controls the project team thought could help. Controls were assigned to whether they could be applied to threats, vulnerabilities, and/or consequences. Each control was also given an implementation cost. The total cost if all controls were implemented was $ 235,600,000. Clearly, that amount of money is not readily available for a small, isolated nation to spend. The project team decided that the budget for controls implementation should be limited to a portion of North Korea's annual gross domestic product ($ 24 billion). The value agreed upon was $ 6 million, especially since abandoning their nuclear weapon investment was not deemed acceptable. However, Figure 19 does indicate that the risk could be lowered to as low as 17 % if all the controls were implemented.

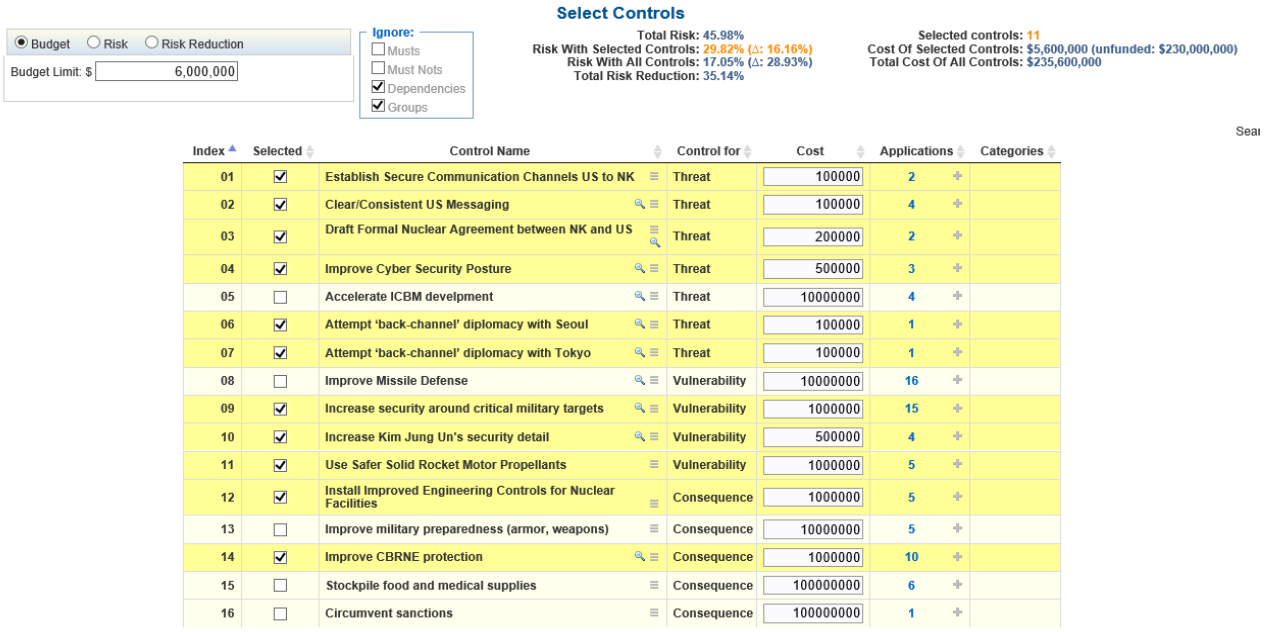

Figure 19 *Potential Controls to Lower Risk*

The participants again evaluated how well they thought specific controls would lower the risk through another survey. The questions were posed such that the participant had to rate from 0 – 1 the effectiveness percentage they thought a given control would be with respect to a threat, vulnerability, or consequence (see Figure 20). Once the measurements were completed, the project team could determine which controls should be selected.

Figure 20 *Sample: Control Effectiveness Question*

The team chose to use the software's optimization calculations to determine the best set of controls to implement with the given budget. Referring back to Figure 19, you can see it displays that the software found the optimal solution to be 11 of the 16 controls, as seen from the yellow-highlighted rows, which cost $ 5.6 million dollars. The result is depicted in the table (Figure 21). The percent average loss has been reduced from 22 % prior to controls down to 16 %. This represents a 16 % total risk reduction when controls are applied. The project team worked monetary values as well with the enterprise (North Korea's net worth) in the neighborhood of half its annual gross domestic product monetary value - $ 12 billion. In that case, the $ 6 million in control costs was found to save a little less than $ 2 billion. One

of the things we noticed is there is no real way to consider partial controls, such as trying to circumvent certain sanctions rather than all sanctions. If there were additional time, the team would have considered having multiple levels of identical controls to determine if some controls could be helpful even at a less than complete implementation.

Overall Likelihoods, Impacts, and Risks (With Controls) for «*Project: Risk Assessment of North Korea Developing Nuclear Weapons»

No.	Event	All Participants Likelihood Simulated	Impact Simulated	Risk Simulated
#02	Global Thermonuclear War - China, DPRK, Japan, ROK, Russia, U.S.	0.100000%	52.840358%	0.052840%
#03	Materials or tecnology stolen from DPRK (nuclear).	0.800000%	4.218455%	0.033748%
#08	Assassination of Kim Jung Un	1.000000%	3.264526%	0.032645%
#09	Destroyed missile	8.800000%	4.480701%	0.394302%
#05	Nuclear test mishap (DPRK).	2.800000%	20.017078%	0.560478%
#01	Enrichment facility mishap (DPRK).	7.600000%	16.808449%	1.277442%
#04	Missile production facility mishap (DPRK).	11.500000%	17.136990%	1.970754%
#10	Tactical Strike on DPRK by US	16.800000%	13.577769%	2.281065%
#07	Increased Sanctions Against DPRK	25.600000%	9.195826%	2.354132%
#06	Regional War (conventional): U.S., ROK, Japan v. DPRK, China	14.100000%	50.324999%	7.095825%

Total Residual Risk: 29.824628%
Average Loss: 16.053231%
Total Risk Reduction: 16.158593%
Cost of Selected Controls: $5,600,000

Figure 21 *Overall Likelihood, Impacts, and Risks (with controls)*

The risk map was also altered after the controls (figure 22). Each event was now shifted toward the x- and y-axis to show a reduction in impact and likelihood, respectively. Now six (6) of the ten (10) events are in the below 2 % risk range. Only the regional war event continued to fall into the high-risk region, above 7%.

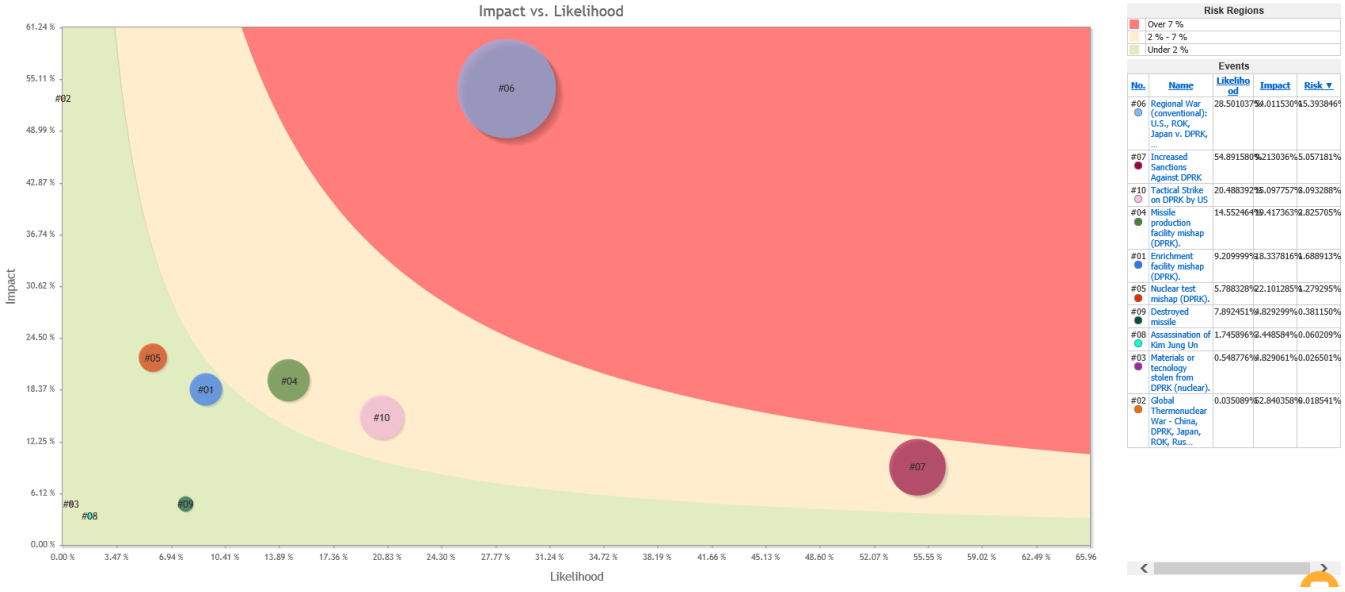

Figure 22 *Risk Map with Controls*

Finally, the loss exceedance curve in Figure 23 illustrates just how well the controls have lowered the probabilities for threshold losses. The project team decided for this final graph to show losses as a function of the enterprise cost of $ 12 billion (half North Korea's annual GDP). Without controls there is a 5 % chance, North Korean loss could exceed $ 8.6 billion, while that same loss would only be $ 7.8 billion with controls. Controls were helpful in obtaining a 50/50 chance of a $ 1 billion loss.

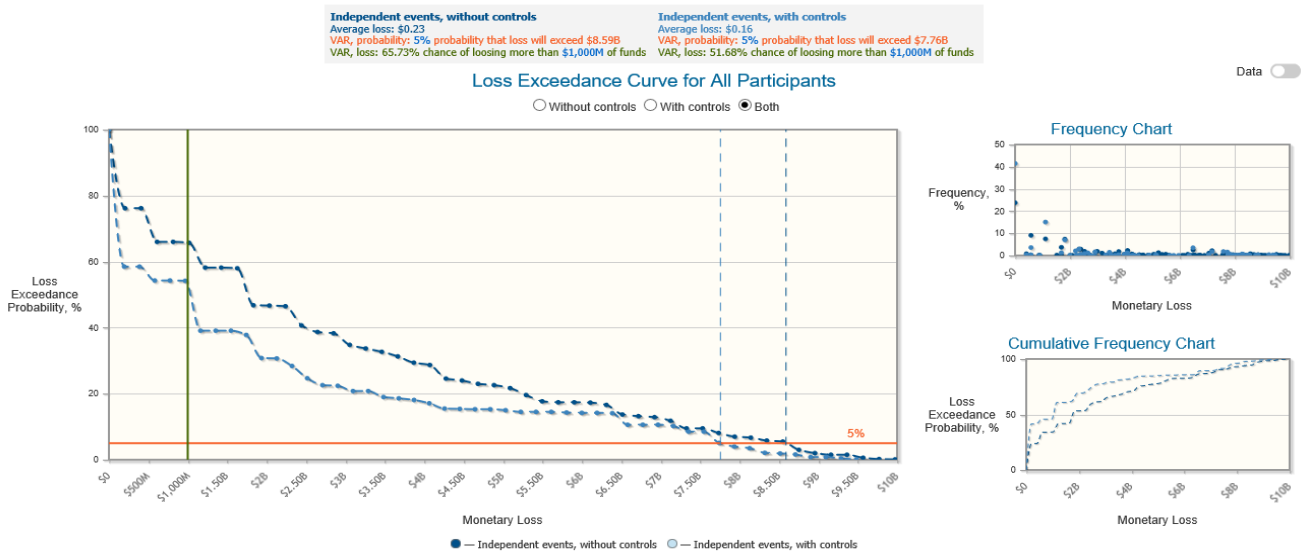

Figure 23 *Loss exceedance Curve ($5.6 M in Controls Applied)*

Conclusions

The group enjoyed using the Riskion software for analyzing a very real threat to global peace. Using this software allows one to chart out the potential scenarios that could play themselves out. Despite not completely understanding the North Korean mindset, the project members tried to envision themselves as an upstart nation trying to protect their dominion from a perceived nationalistic, unpredictable world leader. The group hopes exercises such as these are an ongoing strategy used by our nation's ambassadors, intelligence analysts, and military leaders to predict and prevent catastrophic events with repercussions that could endanger our nation, our people, and our planet. By playing out unlimited scenarios, maybe our nations could come to an understanding that the least costly path forward is one of talk and compromise.

By no means do we think an exhaustive list of sources, events, vulnerabilities, or controls were identified. However, it was clear if you understood the basic problems, one could fashion a set of controls to prevent the worst from happening and perhaps steer the conversation to mutual agreement.