Report on Observations from
Review of Charts Generated for
IMESAFR V2.0 Sensitivity Studies
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Observations from IMESAFR 2.0 Sensitivity Studies

March 11, 2015

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Executive Summary

This report contains observations made by Explosives Risk Managers LLC (ERM) at the request of the Institute of Makers of Explosives (IME) to help complete analysis of charts generated by APT Research, Inc. (APT) that represent various IMESAFR functions.

The report is highly technical and written for persons already well-versed in IMESAFR and its function.

No major issues were uncovered that would raise questions over whether the program is doing what was intended by the development team. There were a few observations made that indicate further study may be warranted to ensure certain functions are designed properly.

In general, the observations confirm how widely ranging risk can be under similar circumstances. It gives insight into how significant and under what circumstances risk reaches the extremes. Risk at so-called “safe” Q/D distances are brought into question.

The observations also provide insight into how the different hazard mechanisms interact in various scenarios. The effects of individual hazard mechanisms on risk are observed quantified.
Introduction

In April 2014, the IMESAFR Development Team met to review thousands of charts generated by APT Research, Inc. (APT) that represented outputs from the IMESAFR V2.0.453 engine (as produced by APT’s proprietary IMESAFR surrogate SAMANTHA). The 20,000 charts comprise over one GB of data and are available for download here. A key to charts is shown in Appendix A.

The minutes of the meeting are shown in Appendix B. The group found several minor issues that have been corrected in subsequent code revisions and confirmed the proper appearance of many key functions. The limited time available did not permit full review of all charts or rearrangement of charts to observe other tendencies. As many charts as possible were quickly reviewed in alphabetical order within most of the Series.

The IME requested that ERM conduct a more thorough review of the charts generated for the sensitivity studies. Appendix C describes the inputs and intent for each Series. Appendix C and D summarize observations made by the IMESAFR Development Team and APT. ERM tried to review the charts in a fashion that led to unique observations as reported by APT and shown in Appendix C and D. Following is a description of the observations made by ERM during review of the charts.

ERM did not review charts from Series 1 so that more time could be focused on the other Series. Series 1 compares the outputs of IMESAFR V1.0 to V2.0 and has little value at this time.
Series 2.1: P(f|e) vs PES-ES Structure Type Pairs

The series 2.1 charts plot the individual probability of fatality given an event [P(f|e)] in all of the potential explosion site-exposed site (PES-ES) pairs available in the model at various ranges and angles. Because there are so many different types of PES, the charts were originally separated into three groups; ATF, Heavy and Light.

ERM consolidated all the types of PES together in one sub directory. From there, the consolidated charts were separated into three groups, all the charts at range of 1,856 and 2,485 ft and all charts at K40.

The group of charts at range 1,856 ft was further broken down to groups with explosives with no primary fragments and ES with no glass. This resulted in groups that isolate debris and show how it changes risk at K40 for 100,000 lbs as azimuth changes from 0 and 45. The charts at 90, 135 and 180 degrees were identical to one of the two charts below.

The group of charts at range 2,485 ft (30,000 lbs NEW and K80) was reviewed as a group. Risk varied greatly, from the floor of 1e-8 to 1e-2.
The group of charts from Series 2.1 at K40 provides an assessment of risk at distances most often used in Q/D criteria for storage. This group shows how $P(f|e)$ varies as various site parameters vary at distances that Q/D would say are equal and generally safe.

At K40, $P(f|e)$ varies from 1 to below $10e^{-8}$, the floor for risk when the charts were generated. The program now shows risk below $10e^{-8}$ so the actual variances may be greater. In general, risk goes down about 5 orders of magnitude (OOM) as NEW goes up at K40 distances. The range is greater at 0 degrees as compared to 45 degrees because of horizontal debris. The 0 and 45 degrees group have a noticeably different look about them.

Since the original studies clearly showed the effect of directional debris on risk, ERM tried to isolate how explosive type and glass effects debris risk.

To look at the debris effects of the explosive type, charts at 45 degrees, 10,000 lb NEW and no glass were grouped. The lowest observed was at the floor ($<1e^{-8}$) in scenarios with no primary frags and an open PES and scenarios with a very strong ES such as RC concrete, Med RC masonry with all explosive types.
The highest risk (>=1e-1) was observed with:

- an open ES in many scenarios (as shown above and below),
- all wood ES with IBC and metal cased explosives with most PES, and
- HAS PES in all scenarios.

To isolate the effect of 10% glass vs no glass, a group of charts at K40, with the Light PES, ES at 45 degrees, and 0% and 10% glass was created. The group of charts also shows how glass risk and structural damage, which are both cause by overpressure, interact. By reviewing the data for the Open PES (red line with red squares), we observe the following.

- Glass risk rises above floor (1e-8) at 1,000 lbs to ~1e-6. So for NEW less than 1,000 lbs at K40, 10% glass risk is negligible.

- As NEW increases above 1,000 lbs to 10,000 lbs, 10% glass risks rises to a little less than or equal to 1e-4 for all PES.
• At 30,000 lbs NEW, some ES start to respond to structural damage. The HighBay ES shows the most response and has 1e-5 risk with no glass. Glass risk still surpasses structural response risk for all ES and rises slightly to about 1e-4.

• At 100,000 lbs NEW more ES start to show response to overpressure. Structural response has overtaken glass for the HiBay (2e-3) and is close to it for the Tiltup ES. 10% glass risk in the other ES rises to slightly above 1e-4.
• From 300,000 to 3,000,000 lbs, half of the ES respond to overpressure, more so as NEW increases. But even at 3,000,000 lbs, the small RC, medium RC, small R masonry, small brick, Med UR masonry, small wood frame, steel stud, and vehicle ES show no structural damage. Except for the HiBay and TiltUp, 10% glass still dominates risk at between 1e-4 and 1e-3 for the other ES. In the medium and small PEMB ES, glass and structural damage are both significant. Risk from structural damage in the HiBay and TiltUp is a little under 1e-1.

We grouped the K40 charts with the Heavy PES, ES at 90 degrees, metal cased explosives and 0 or 10% glass to maximize debris effects. When viewed in light of the charts above, the group provides insight into the interaction between debris, glass and structural collapse risks.

• Heavier ES, such as the HAS and ECM contain the blast energy up to about 3,000 lbs NEW.

• Up to 100,000 lbs NEW, debris risk is 1e-3 or higher as shown above and below. The effect of glass openings that allow debris to fly through and hazard occupants can be seen in the stronger ES on the left of the charts.
At 300,000 lbs NEW, the ES are far enough away that debris is no longer an issue in stronger ES. Debris and 10% glass are about equal in terms of risk.

At 1,000,000 and 3,000,000 lbs NEW, 10% glass has an effect on risk in all ES except the HighBay and TiltUp, which still suffer more from structural collapse. The reduction in hazardous debris density at higher NEW at K40 is apparent below.
We grouped the K40 charts with the Light PES, ES at 135 degrees, no primary fragments and 0% glass to maximize structural damage effects. When viewed in light of the charts above, the group provides insight into the interaction between debris, glass and structural collapse risks.

- The same trends observed above are observed in this grouping. At NEWs below 30,000 lbs, debris is the dominant hazard mechanism. As NEW increases, debris becomes less of a problem while structural collapse becomes a major issue for the PEMB and TiltUp ES.

An attempt was made to review all the ATF PES charts to find the one that posed the highest risk at K40. This is somewhat of a subjective exercise but nonetheless is an example of how bad K40 can be. In the examples below, P(f|e) is between 1 and 1e-2, depending on the type explosive.

The American Table of Distances gets more conservative at lower NEW. So the above may be representative of K40, but it is not representative of risk at the ATD distance for 3,000 lbs (1,160 ft). The same parameters at K80 would be representative of the risk at the ATD distance.
for 3,000 lbs. Except for the AN shed, which is not used for such small quantities, the risk is more tolerable. Generally, the risk in these circumstances ranges between 1e-2 to 1e-4.

The two charts below show the risk at approximately the distances specified in the ATD. The chart on the left slightly overestimates risk since it is at a distance about 150 ft closer than that allowed by the ATD. The chart on the right slightly underestimates risk since it is at a distance about 400 feet farther than that allowed by the ATD.

The charts below minimize the effect of azimuth, type of explosive and glass on risk just as they have been maximized above. This shows that a wide range of risk can exist in two equal situations at about the distances specified in the ATD.
An attempt was made to find the chart at K40 with the highest debris risk. Although a subjective exercise, that chart is shown below. Except for the strong PES like HAS and ECM that are capable of containing the energy, a fatality is almost assured given an event.
Series 2.2: P(f|e) Downrange for Each Fatality Mechanism

This series plots the P(f|e) for each of the five fatality mechanisms as range increases. The effects of azimuth have been previously observed and were not a focus point in this study.

The difference in risk between 10% and 25% glass was observed.

- At 30,000 lbs and above, annealed glass becomes an issue far downrange.

- At 100,000 lbs and above, the effect becomes significant with annealed glass.

- At 300,000 lbs NEW and above, tempered glass becomes an issue as well.
• Glass risk can extend to great distances with high NEW.

• Generally speaking, when glass drives risk, a 15% increase in glass equates to about a 1 order of magnitude (OOM) increase in risk.
The charts were grouped by NEW. These groups showed the expected tendencies. At lower NEWs, one of the debris mechanisms, depending on the PES-ES combination, usually dominates throughout.

At high NEW and beyond SCIFM, debris is the first primary hazard and then glass takes over. In scenarios where building collapse is likely, that mechanism can make a hump in the middle.

The group of charts at 1,000 lbs NEW with a medium concrete PES and the ES at 0 degrees showed high levels of risk at the ATD specified distance of 800 feet. This risk was from horizontal debris in all cases.
The Series 2.2 charts with 10% annealed glass with the ES at 90 degrees were grouped by NEW and type of ES. The only observation worth noting was the attenuation effect of the ISO container PES at large NEW. This is apparently due to spreading the relatively large NEW out over many ISO containers as compared to have all the NEW in one PEMB.

Between NEWs of 1,000 and 1,000,000 lbs, two or three fatality mechanisms come into play in most scenarios. Rarely do four or all five mechanisms play a role. Below are several scenarios where all five mechanisms play a dominant role at one point or another after SCIFM.

- PEMB PES vs Med RC ES, 10 or 25% annealed or tempered glass, 300,000 lbs NEW.
• Med Concrete PES vs Med RC ES, 10 or 25% annealed or tempered glass, 3,000,000 lbs NEW.
• PEMB PES vs Large UR Masonry ES, 25% annealed glass, 100,000 lbs NEW.
A scenario with four distinct regions of glass, building collapse, vertical debris and horizontal debris were observed.

- ISO PES vs Large UR Masonry ES, 10% annealed glass, 3,000,000 lbs NEW
A scenario with four distinct regions but only three different primary hazard mechanisms was observed.

- Medium Concrete PES vs Large UR Masonry ES, 10 or 25% annealed glass, 3,000,000 lbs

NEW
Series 3: Effects of Uncertainty

Random sampling was applied to the series of charts, grouping them by certain similar characteristics. The “b” series of charts were separated from the others.

A group of charts with 1,000,000 lbs NEW were assembled and reviewed. No abnormalities were observed.

A group of charts with max exposed = 2 and max exposed = 100 were assembled and reviewed. Large steps were observed in transition areas of 300,000 lb charts.

In the “b” series, a group of charts with max exposed = 2 and uncertain confidence was assembled and reviewed. No abnormalities were observed.

It was observed in the “b” series that when NEW and numbers of exposures are small, there is no perceptible difference in the effect of confidence and correlation factors. On the other end of the extreme, large NEW and numbers of exposures and low confidence give correlation factors a significant effect.
The effect of confidence from one extreme to the other at a mid-range NEW and exposure of 10 people is shown below. Being “uncertain” increases risk by approximately two times as compared to being “certain.”

The “b” series charts only include one PES-ES pair, Med Concrete PES vs Med RS ES. The description in Appendix C says the series includes charts with the HiBay ES, but they are not on Dropbox.

**Series 4: Probabilities of Fatality and Major/Minor Injury**

This series is very similar to Series 2.2 but adds lines for major and minor injuries. The same trends observed in Series 2.2 are observed in this series. ERM reviewed this series with an
attempt to observe the differences between annealed and tempered glass and the dynamics of glass and debris risk downrange.

Two groups of charts with the Open PES vs Medium RC ES at 0 and 45 degrees were created. Both groups are excellent examples of how glass takes over from vertical debris down range, as observed previously. The charts below show how significant the risk of injury from glass can be far downrange from large NEW.

A group of charts at 45 degrees and 25% glass was created and ordered by NEW, alternating annealed and tempered glass type as NEW increased. The group shows interesting transitions in glass risk down range. Up to 300 lbs tempered glass is riskier.
From 1,000 to 300,000 lbs, annealed presents more risk as NEW increases. The difference can become significant at great distances.

Then at 1,000,000 lbs, and up, the differences lessen, which is actually a factor of the scale of the charts. If the scale ran out to farther distances, the differences would become noticeable.
Series 5.1: Debris Risk Downrange by Azimuth

The charts in this series were grouped by NEW and no significant observations were made.

All charts in this series were reviewed for ISURF characteristics and the ones with significant ISURF characteristics were grouped together. The following was observed:

- Only exposures inside structures exhibit ISURF.

- The following PES-ES pairs exhibited ISURF up to 1,000 lbs NEW: ATF Type 1 or 2 vs Medium RC, Medium Concrete vs Medium RC, and ATF Type 1 or 2 vs Large URC.

- The PEMB vs Med RC showed ISURF up to 3,000 lbs. Charts from that group are shown below.
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- Some charts show over 2 OOM from ISURF
Series 5.2: ES Condition when Debris Arrives

ERM assembled and reviewed 23 groups of charts from this series. Many lines overlay on top of one another making interpretation difficult. Nothing beyond what was observed previously was found. The effects of debris arrival time can be significant, but typically only at very close ranges or when the NEW is extremely large (300,000+ lbs).

The PES and ES structure types play an important role in this scenario. As previously noted, PES that create more debris, such as concrete structures, present more risk than light PES. The charts below show how significant the effect of the type of ES is on debris risk and condition of the ES at debris arrival time.
Series 6.1: Effects of Glass % and Sq. Ft. of ES

This series plots the risk from the different glass types downrange from the PES at 0 degrees. The previous observations were confirmed. Additionally, the following were observed:

- There is almost no difference in risk between a 100 sq ft and 1,000 sq ft ES. There is a very slight decrease in risk with a 10,000 sq ft ES.

- Dashed lines are always above solid lines. This confirms that the %glass function works.

- Dual pane always presents more risk than annealed, except when at the breakage threshold of low NEW. Then annealed shows slightly more risk because it breaks when dual pane does not.
Series 6.2: Downrange Debris Risk

This series plots the debris risk downrange for a wide variety of PES-ES combinations. The effects of various types of PES and ES on debris risk was previously reported. ERM focused on the Open-Open scenarios to hone in on primary debris risk from the various explosives articles.

In the open-open scenarios, lines generally stack as follows, top to bottom on charts up to 3,000 lbs NEW.

1. Metal cased (black)
2. Small frags (red)
3. IBC (green)
4. 1.5 Metal Container (pink)
5. No primary frags (blue)

At 10,000 lbs and above, IBCs become more risky than Small frags. At 30,000 lbs, Small frags drop another place in risk rank as 1.5 Metal Container takes 3rd place. So as NEW goes up, the hazard from Small Frags goes down. At about 100,000 lbs NEW, IBC risk takes over first place in risk order.

At 100,000 lbs NEW and less, the hazard from vertical debris is less than the hazard from horizontal debris. At 300,000 lbs NEW, horizontal debris becomes more hazardous beyond about 2,250 ft. At 1,000,000 lbs, the switch occurs in closer at about 1,100 ft. At 3,000,000 lbs, vertical debris dominates throughout.

The P(f) for horizontal debris from no primary frags (blue line) is not visible on any chart in this series. This confirms no horizontal debris comes from crater ejecta.

The P(f) for vertical debris from no primary frags (dashed blue line) exists and quantifies crater ejecta risk.
Introduction of a PES structure changes the order of hazard to:

1. Metal cased (black)
2. IBC (green)
3. 1.5 Metal Container (pink)
4. Small frags (red)
5. No primary frags (blue)
The charts were grouped by NEW and reviewed with no significant observations. It was somewhat surprising that vertical debris risk is the same at 1,000,000 lbs and above regardless of the type of ES.

The “light blue” lines for “unknown” explosive type are not visible on any chart in this series. These lines are probably hidden behind another line since this selection should default to another type.
**Series 6.3: Effect of Soil Type**

This series plots the vertical debris risk with different soils in Open-Open scenarios with no primary fragments.

At 300K lbs and less NEW, crater ejecta risk with concrete is as much as 8 orders of magnitude (OOM) less than rock/hard clay or crushed stone and about 5 OOM less than loose soil.

The reduction in risk from concrete is hard to comprehend. The detonation of 300,000 lbs would make a crater deeper than any concrete floor. Wouldn’t the material below the concrete be rock/hard clay, crushed stone or loose soil? The program appears to be doing what it is told, but the logic in this branch for concrete should be reviewed. The use of concrete seems like a potential gimmick to reduce risk in a scenario where crater ejecta is a factor.

The dashed blue lines from series 6.2 were compared to the solid blue lines in series 6.3 for the same NEW. The lines matched as expected.
Series 6.4: Effect of ES Roof Type

This series plots the risk from vertical debris for the different roof types in two types of PES and ES.

- The charts were grouped by NEW and reviewed. Charts for each type of PES at same new matched as expected showing that ES wall type has no effect on vertical debris risk.

![Graph 1](image1.png)

![Graph 2](image2.png)

Generally, lines stack as follows, from top to bottom (least protection to most protection):

- Gypsum/fiberboard/steel joist, (orange)
- Plywood panelized (2x6 @ 24”), (grey)
- Plywood/wood joists (2x10 @ 16”), (red)
- Automobile (pink)
- Light steel panel (22 gauge) (light blue)
- Medium steel panel (18 gauge), (rose)
- 2” lightweight concrete/steel deck & joists, (black)
- 4” reinforced concrete, (green)
- 14” Reinforced concrete, (blue)

Curiously, at 1,000,000 lbs and with a medium concrete PES, the automobile roof (pink) provides more protection (over 1 OOM) than the other roofs at medium range.
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Series 7: Effect of User-Defined P(e)

This series shows the effect of the user-defined P(e) function. We would expect the solid rose colored line to be directly on top of and identical to the dashed red line in chart #1 below.

7.0 #1 User-defined activity varying activity hrs - PES 1000 hrs

No other observations were made in this series.
Series 8: Effects of Differences Between Expected and Maximum NEW

This series shows how the spread between the entered values for expected NEW and maximum NEW affect risk. Several observations were made that are hard to understand. It may be worthwhile to investigate the reasons for these observations.

- As expected, if the maximum NEW is held constant and the expected NEW is lowered, risk goes down. But lowering the expected NEW too much causes risk to actually increase in certain situations.

- Graph #2 shows a dramatic and sudden reduction in risk at about 1,700 ft, an almost 2 OOM vertical drop in risk in red line.
In addition to the chart above, some charts show that risk can be highest when the expected NEW is \( \frac{1}{2} \) of the maximum NEW.
• The position of 300,000 expected NEW (light blue), in relation to the other lines, at 3,000,000 lbs max NEW is rather odd in some cases.
Appendix A: Key to Charts in Each Series

SS plots v3 key.pdf
Appendix B: Dev Team Meeting Minutes, 7-9 April 2014

Huntsville (APT)

Attendees:
Lon Santis, IME (Contractor)
John Tatom, APT (Part)
Dean Nichols, APT (Part)
Tyler Ross, APT (Part)
Jo Covino, US DDES B (Webex)
Lou Anne Cotton, US DDESP (Webex)
John Buszard, ERD (Webex)
Mike O’Lena, ATF (Webex)
Bert von Rosen, CERL (Webex)
Ron Thomas, IME (Webex, Wednesday)
Bill Evans, Orica (Secretary/Chair)

I. Safety and Housekeeping
JT gave the safety and housekeeping brief

II. Anti-trust and CVI Policy
Lon Santis provided the standard IME Guidelines

III. Introductions
The participants introduced themselves.

IV. Purpose of Meeting
Brief introduction as to the purpose and goals of the meeting by BE.

V. Meeting Topics/Minutes
   i. GUI Checks
   ii. HCT IV(m)
   iii. Uncertainty

Discussion Points:

- Question raised re advantages of using Gurney Formula to calculate IV based on the known mass of the PES. (See also previous minutes (12/2013)).
- Reminder that ‘we’ are looking at this versus the remit given to APT, i.e. sign off by the Development Team. ‘Imperfections’ not in that remit will need to be dealt with in future versions.

b. Review Previous
   i. Review against original studies
   ii. List anomalies/action needed

Discussion Points:

- All the changes implemented after the first round of sensitivity studies have had the desired effect
- Difference in treatment of SCIFM in ver 2 clearly seen
- Treatment of mass (especially conservation of mass) is giving very conservative results. Future work should include conservation of mass/mass bin limits (and maybe number of bins)
- Overly conservative results can be seen as a negative by users; comparisons to AMRISK are being made
- Overall though, the changes made since the first round of sensitivity studies have significantly reduced the conservatism (as intended)
- Although many thousand individual sets of runs was reviewed, the sensitivity studies were not completed and the remainder will need to be done off line by ‘volunteers’


c. Additional Topics

   i. Response to ATF Letter
      1. Set IME Policies
      2. Provide Response to ATF
      3. Implementation Plan

Outcome

- The original position of the ATF does provide an opening – but it will have very limited applicability in the real world
- This may not have been the intent and we need to explore how open the ATF is to a broader application of IMESAFR/risk based criteria Q/D waivers
- The IME also needs to monitor any submissions to the ATF to ensure that they are high quality and technically correct. We do not want to compromise the reputation of IMESAFR with early inadequate submissions.
- The ‘strawman’ prepared by LS, with significant Orica input, will be cleaned up and reissued for comment (LS)
- This will be further reviewed, revised and presented to the IME
- A final review/sign off will be scheduled for the Spring Meeting
- The Spring Meeting will also be an opportunity to discuss this with ATF (Bill O’Brien and Mike O’Lena) as they have left some things (e.g. uncertainty off/on, scope (whole site or just non-compliant parts), etc) undefined

ii. Consensus Building
   1. General promotion
      a. ATF: MO’L will be presenting on IMESAFR 2 at two ATF training courses this year. ATF continues to look at sites to build a risk vs Q/D baseline. LS has reviewed sites where QRA is more conservative than Q/D. Orica has found examples where non-compliant buildings were at lower risk than compliant buildings.
      b. Others
         i. Domestic: USCG has joined DDESB and is looking at IMESAFR. Presentation to Texas Fire Marshall (West, Aristatek et al)
         ii. International: Aristatek has approached Orica Australia re adoption of their software (the IME failed to permit the sharing of any of the West presentation material with Orica prior to the meeting). There continue to be rumblings of interest from regulators in Australia re more training in Australia. Orica will follow up through AEISG.
   2. Presentations/Conferences/Meetings
      a. Past
         i. ISEE 2014: Paper by LS on sensitivity study observations. C. Johnson also gave a paper which was well received but had some technical errors.
         ii. CIE 2014: a cut down version of the West presentation was given and was very well received. Several regulators expressed interest in a) another training course in Europe and b) the power of IMESAFR as a forensic/diagnostic tool
         iii. ISEE SE regional blasters’ workshop (booth): meeting in Huntsville, DN gave a presentation during HAZMAT Training session
b. Potential future presentations
   i. SAFEX Congress: will attempt to get a paper in (extremely late). Update: no paper will be given as IME has not given permission for a presentation.
   ii. ISEE 2015: Joint APT/ATF/LS presentation on test data vs Q/D vs QRA; need to consider booth and/or training (requires IME to agree/provide for this in the 2015 budget).
   iii. CIE 2015: Many possible presentations: IME as above, Orica on use, ATF on US status, APT on testing.

iii. Software
   1. Tech Support: will support request for more funding (budget mostly used on West work)
   2. Development: bug fixes will be done but there is no scope for any development without IME providing funding (likely none to be requested for 2014; will be part of Three Year Plan (see below))

iv. Documentation
   1. User’s Manual
   2. Tech Manual (TP-14 =): Both have been provided to the IME as drafts for review. Only minor changes will be made (budget spent); significant changes will require funding. The Tech Manual will require a very detailed review and it would be optimal if the DDESB could participate, so LS/JC/BE(?)

v. Training Update
   1. Huntsville May Class: IME needs to get word out about this course
   2. Australia: See above
   3. Europe: Try to firm up interest after CIE Meeting. Around SAFEX Congress would be perfect but very little time to make this happen

vi. Testing Update
   1. Status of proposed IME testing: No progress made on ‘three test program’. Still need to identify a test site.
   2. ATF test interest: ATF is interested in some of the same tests and might be able to supply some resources
   3. DoD/NATO/International: there are tests planned in August in Norway – jointly sponsored by Singapore and Norway; the US DoD will participate and industry participation would be ‘actively welcome’.

d. Optional Topics
   i. Additional data to be included in IMESAFR: Include new test data as it becomes available; where possible, accidental explosion data would be very useful. West was an excellent opportunity that was considered too hot a political potato.
   ii. Discussion of cases used in published scenarios
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1. CIE (BAM): Acceptance by BAM of Orica request for higher explosives transport loads based on an IME analysis
2. SAFEX newsletter: excellent ‘demo article’ by LS

VI. Path Forward
   a. Three-Year Implementation and Development Plan for IMESAFR: drafts will be put together before the Spring Meeting for discussion/agreement (or not) there.
   b. Future Meetings: At least a couple of teleconferences with key people before the Spring Meeting, which will be the timing/venue for the next full meeting.
Appendix C: IMESAFR 2.0 Development Team Sensitivity Studies
Prepared by APT-Research, Inc.
Review Meeting - April 2nd – 4th, 2013   Huntsville, AL

Sensitivity Studies

1. v2.0 versus v1.2
   1.1. Comparisons to existing Orica cases
   1.2. Introduce azimuthal variation

2. Sanity checks
   2.1. Comparison of overall $P_{le}$ (plotted versus scaled range)
      2.1.1. Check all PES and ES combinations (equivalent of SAFER Task 1)
      2.1.2. Introduce azimuthal variation
   2.2. Comparison of fatality mechanisms (plotted versus distance)
      2.2.1. Check all PES and ES combinations (equivalent of SAFER Task 2)
      2.2.2. Introduce azimuthal variation

3. Uncertainty
   3.0 Varying confidence levels
   3.0b Varying correlation factors

4. Consequence level and driver check (determine for fatality, maj inj, min inj; equivalent of SAFER “Brannon Studies”)

5. User settings
   5.1. PDF
   5.2. Step 17 timing

6. Parametric analysis
   6.1. Glass
   6.2. Explosives article
   6.3. Soil
   6.4. Roof type

7. User-defined $P_e$

8. Max-max versus exp-exp results

9. UDEA \textit{(deferred)}
1. GUI check (compare report, to screen, to QR, to System Log) \(\textit{(deferred)}\)

\(\text{v2.0 versus v1.2}\)

**Study description**

This check compares IMESAFR 2.0 runs against the same runs made with IMESAFR V1.2. These cases will be run in SI units. Study 1.1 presents the scenarios along the 0° azimuth, whereas study 1.2 introduces azimuthal variation.

**Inputs**

1.1. Comparisons to existing Orica cases run with IMESAFR v1.2

1.1.1. P2S4 (Scenario 1)

There will be 6 plots. Each plot will be one mechanism (total, overpressure, glass, building collapse, horizontal debris, and vertical debris vs distance). The corresponding V1.2 results will also be shown on each plot.

Scenario 1:

- **PES:** AGBS (medium)
- **Soil Type:** Concrete
- **Explosive Type:** HD 1.5 Metal Container
- **Compatibility Group:** Unknown
- **Explosive/Yield Variation:** Max/Max and Expected/Expected
- **Operating Hours/Explosives Present:** 8,000/100%
- **NEW [kg]:** 1K, 10K
- **Distances [m]:** 0 – 7500m in 1m increments
- **Assumption:** fixed azimuth of 0°
- **Activity Type:** In-transit Storage
- **Environmental Factors:** none
- **ES:** PEMB (medium)
  - **Floor Area:** 464.5 m²
  - **Roof:** Light Steel Panel
  - **Glass:** 10% annealed
- **ES exposure:** 1 person 8,000 hours, Uncertain/1/1/No correlation/No correlation

1.1.2. P2S3 (Scenario 2)

Same as 1.1.1, except:

- **PES:** Open
- **Soil Type:** Crushed Stone
- **ES:** Modular Building/Trailer
  - **Floor Area:** 29.7 m²
  - **Roof:** Plywood panelized
  - **Glass:** 20% annealed

1.2. Comparisons to existing Orica cases run with IMESAFR v1.2

1.2.1. P2S4 (1.1.1 Scenario 1, with azimuthal variation)

There will be 6 plots with the same format as Scenario 1.

Same as 1.1.1, except:

- **Azimuth:** 22.5° and 45°
There will be 6 plots with the same format as Scenario 1.
Same as 1.1.2, except:
Azimuth: 22.5° and 45°

Notes and observation for this series (1.2.1 and 1.2.2)

- 1.2.1 #7 demonstrates the effects of the new Building Collapse SCIFM in V2.0.
- Comparing 1.1.1. #8 and 1.2.1 #8 shows the effect of the azimuthal variation in the debris density. #7 is on a normal and #8 is on a corner. As can be seen, the overall $P_{f_{lo}}$ is lower on the corner than on the normal (all other variables being the same)
- Some plots demonstrate a “lumpy effect” at close ranges. The lumpy effect is the result of the bins adding together. Smaller debris causes lumps closer in while only the larger pieces of debris get thrown to the further distances.
2. Sanity checks

2.1. Comparison of overall $P_{f|e}$ (plotted versus scaled range)

**Study description**

The plots compare the overall $P_{f|e}$ as a function of a PES/ES pair. Plots are separated into three groups, Light, Heavy and ATF. Task 2.1.1 has a fixed azimuth of 0°. Task 2.1.2 introduces azimuthal variation.

**Inputs**

2.1.1. Check all PES and ES combinations (equivalent of SAFER Task 1)

There will be 1,440 plots. The plots compare the overall $P_{f|e}$ as a function of a PES/ES pair. Each of the 1,440 plots is a combination of one input from each of the following categories:

- Explosive Article Types: No primary fragments, metal-cased explosives articles, metal container, intermediate bulk container
- Explosive Weights [lbs]: 100, 300, 1K, 3K, 10K, 30K, 100K, 300K, 1M, 3M
- Glass types: Annealed
- Percent glass: 0, 10
- Scaled Range: 5W^{1/3}, 10W^{1/3}, 20W^{1/3}, 40W^{1/3}, 60W^{1/3}, 80W^{1/3}

Each plot includes every PES and every ES. Plots will be separated into three groups by PES as follows:

- **Light**: Open, PEMB, Hollow Clay Tile, Tractor-Trailer, ISO Container, Small Ship, Medium Ship, Large Ship, Bulk Truck, Van Truck, Drop Trailer
- **Heavy**: Medium Concrete Arch ECM, Medium Steel Arch ECM, Hardened Aircraft Shelter, Small Concrete Building, Medium Concrete Building, Small Reinforced CMU, Large Unreinforced Concrete, Medium Unreinforced Concrete, Small Unreinforced Concrete, Large AGBS, Medium AGBS, Small AGBS, Double Wythe Brick
- **ATF**: T1/T2/T4/T5 Large Steel, T1/T2/T4/T5 Medium Steel, T1/T2/T4/T5 Small Steel, T1/T2/T4/T5 Very Small Steel, Day Box, T3 Standard

Assumption: fixed azimuth of 0°

PES: Open (rock or hard clay), all "standard" types on concrete, ISO Container (8,818 max lbs per container) (rock or hard clay)

ES: all stationary types, including open

Note: Some cases included in the plots are not realistic (like HAS with NEW above the 10K value, or open ES with 10% glass) but it is easier to ignore them than to try and determine which ones to filter out.

2.1.2. Introduce azimuthal variation

Each azimuth is potentially different for each of the runs in 2.1.1 (which looks at the front), so azimuthal variation is introduced here. Using each additional normal and corner creates 5,760 plots.

- Azimuth: 45°, 90°, 135°, 180° (FS, S, SR, R)
- Assumption: 90°=270°, 45°=315°, 135°= 225° (S=S, FS=SF, SR=RS)

Note: Some cases included in the plots are not realistic (like HAS with NEW above the 10K value, or open ES with 10% glass) but it is easier to ignore them than to try and determine which ones to filter out. Also, in some cases the PES walls don’t vary, some of the azimuths should have the same results.

**Notes and observation for this series (2.1.1 and 2.1.2)**

- 2.1.1 #11 and 2.2.1 #93 (K80 and K60 respectively) show added protection (relative to the other ES type) for the Small and Medium Concrete RC and the Concrete tilt-up. At
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K40 (2.1.1 #355), this trend has changed and the Concrete Tilt-up and the Hi-bay PEMB are showing added vulnerability. This is probably due to the onset of building collapse.

- 2.1.2 #369 at K60 shows the same level of protection provided by all ES types (except open) off a corner. 2.1.2 at K40 shows decreased protection levels for the Concrete tilt-up and the Hi-bay PEMB. This is the same behavior as 2.1.1 #355, which is on the normal at K40.

- Some reviewers found the $P_{fe}$ values to be very high. It was agreed by everyone that the numbers did seem overly conservative and future analysis would be done to determine how and why the conservative values appear at lower quantities. For example, one reviewer expressed skepticism about a 100 lb NEW event in a truck throwing an engine block with enough kinetic energy to perforate a concrete wall. Part of the reason for the conservativeness may be that since the tests of an ISO on a truck were performed with NEWs of 1,000 kg and 4,000 kg, the velocities and distances may be overestimated at lower NEWs, thus leading to conservative values for risk. The overall feeling within the team is that the numbers in v2.0 do seem to be on the conservative side, given that the scenario is at a low NEW and the ES is on the normal. The group agreed that continued attention was required for the small NEW cases, and improvements (based on the proposed test program results) should reduce undue conservatism.

- In the future, the team should consider adding a hazard area unique for debris coming through the window (like in the glass logic) rather than allowing a percentage of debris to pass through the window. The existing logic can lead to overly pessimistic debris fatality predictions inside an ES with a window (if the debris density is very high outside the ES).

- There was a discussion about our need to look into/test the behavior of the trailer and ISO at smaller quantities. The charts are showing more hazardous conditions exist with a NEW of 100 lbs than at 300 lbs. Tests with this sort of PES are typically performed with significantly higher charge weights, thus the uncertainty of behavior at lower weights. These are PES types with attenuation, so the behavior is related to what was seen in the ships. This led to a discussion about the trailer having attenuation when the truck PES types did not.

- One reviewer inquired about the large gap for the trailer PES curve. It was explained that attenuation of the trailers reduces the pressure and impulse to the point where the glass may not be breaking causing a sharp drop in risk.

- Heavy PES types – There, again, was concern with small charge weights causing such high values for heavy/strong PES types. Members assert that the high lethality rates with low NEW are far too pessimistic.

2.2. Comparison of fatality mechanisms (plotted versus distance)

**Study description**

The plots compare the different fatality mechanisms for a given set of inputs by distance. The fatality mechanisms presented in this comparison are:

- $P(ffe)$ – Overall Consequence,
- $P(o|e)$ – Consequence due to Overpressure,
- $P(g|e)$ – Consequence due to Glass Breakage,
- $P(bc|e)$ – Consequence due to Building Collapse,
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\[ P_{f(vd|e)} \] – Consequence due to Vertical Debris,
\[ P_{f(hd|e)} \] – Consequence due to Horizontal Debris

**Inputs**

2.2.1. Check all PES and ES combinations (equivalent of SAFER Task 2)

There will be 480 plots. Each plot is a combination of one input from each of the following categories:

- **PES:** Open (rock or hard clay), PEMB, ISO container(s), Medium Concrete Building
- **ES:** Medium Reinforced Concrete (RC), Large PEMB, Large Unreinforced Masonry (LURM)
- **Weapon Type:** No primary frags
- **Explosive Weights [lbs]:** 100, 300, 1K, 3K, 10K, 30K, 100K, 300K, 1M, 3M
- **Glass types:** Annealed, Tempered
- **Percent of glass:** 10, 25
- **Each plot includes every distance input.**
- **Distances [ft]:** 0 – 10,000 ft in 50 ft increments
- **Assumption:** fixed azimuth of 0°

2.2.2. Introduce azimuthal variation

Each azimuth is potentially different for each of the runs in 2.2.1 (which looks at the front), so azimuthal variation is introduced here. Using each additional normal and corner creates 1,920 plots.

- **Azimuth:** 45°, 90°, 135°, 180° (FS, S, SR, R)
- **Assumption:** 90°=270°, 45°=315°, 135°= 225° (S=S, FS=SF, SR=RS)

Note: Some cases included in the plots are not realistic (like HAS with NEW above the 10K value, or open ES with 10% glass) but it is easier to ignore them than to try and determine which ones to filter out. Also, some variables (like glass percentage) only matter in the sense you can see the relative importance of debris.

**Notes and observation for this series (2.2.1 and 2.2.2)**

- This study is straightforward, showing the magnitude of each hazard mechanism relative to one another.
- The red line represents the aggregation of all hazard mechanisms and is always the greatest value.
- A question was brought up regarding the “wave” effect in the red and green curves. The team’s best guess was that it was an effect of the hyperbolic interpolation of asymptotic PI curves; APT took action to determine the cause of the wavy effect.
- One reviewer noticed the “bump” in building collapse at 3,000,000 lbs NEW. John explained that as you get to close-in distances, impulse has a slight drop as determined by the Kingery-Bulmash curves. This causes the \[ P_{f(bc)} \] to have a dip at very close distances.
- There was a brief discussion concerning the near zero amount of horizontal debris off of the corners of the PES. The GAD curve indicates that the amount of horizontal debris fragmentation is so low, that it multiplied by just about any plausible value yields a number approaching zero.
3. Exposure Uncertainty

**Study description**

The goal of this sensitivity study is to quantify the effects of various parameters related to the uncertainty calculation. The minimum and maximum effects of uncertainty will be determined. Each plot will show expected fatality (Ef) versus range in feet.

**Inputs**

3.0

PES: PEMB, Medium reinforced concrete
Activity: Long-term storage
Explosives: Boxes and bags – no primary fragments. HD 1.1, CG A
ES: Medium concrete, Large PEMB (Hi-bay)
Glass type: Annealed
Percent glass: 10%
Exposure: 1 person, 2000hrs, 100%
Explosive Weights [lbs]: 10k, 30k, 100k, 300k, 1M, 3M
Exposure confidence levels: Confident, somewhat confident, uncertain
Activity Correlation levels: Strong positive, positive, none
Maximum personnel: 2, 10, 100, 1000
Distances: 0 – 5000 ft in 10 ft increments
Assumption: fixed azimuth of 0°

3.0b

Same as 3.0, except:
Exposure confidence levels: Confident (only)
NEW Correlation levels: Strong positive, positive, none

**Notes and observation for this series (3.0 and 3.0b)**

3.0

- Straightforward study produced no surprises
- Study useful in showing relative effects produced by varying either the correlation or the confidence levels (correlations are more significant)

3.0b

- Adjusts the activity and NEW correlation separately. However, since the NEW correlation is always coupled with a zero coefficient, it doesn't make a difference. Hence there are only three visible series (the rest are “covered up”).
4. Consequence level and driver check (determine for fatality, maj inj, min inj; equivalent of SAFER “Brannon Studies”)

**Study description**

This set looks at the consequence severity levels organized into 3,200 plots. The plots compare the overall $P_{f|x}$, $P_{maji|x}$, & $P_{min|x}$ for a given set of inputs by distance, and the tables summarize the driver for each case.

**Inputs**

Each of the 3,200 plots is a combination of one input from each of the following categories:

- **PES**: Open (rock or hard clay), PEMB, ISO container(s), medium concrete operating building
- **ES**: Open, Medium Reinforced Concrete (RC), Large PEMB, Large Unreinforced Masonry (LURM)
- **Weapon Type**: No primary frags
- **Explosive Weights**: 100, 300, 1K, 10K, 30K, 100K, 300K, 1M, 3M
- **Glass types**: Annealed, Tempered
- **Percent of glass**: 10, 25
- **Each plot includes every distance input.**
- **Distances [ft]**: 0 – 5000ft in 20 ft increments
- **Azimuth**: $0^\circ$, $45^\circ$, $90^\circ$, $135^\circ$, $180^\circ$ (F, FS, S, SR, R)

**Notes and observation for this series**

- This study is straightforward, showing the magnitude of each hazard mechanism relative to one another.
- The data are presented for fatality, major injury and minor injury.
- The red line represents the aggregation of all hazard mechanisms and is always the greatest value.
- There is an inherent weakness in the tempered model which is due to the fact that tempered glass breaks into more pieces and it is thus treat as more hazardous, despite the fact that the tempered cubes have a less hazardous shape than the annealed shards.
5. User settings

5.1. PDF

**Study description**

Quantify the effects of turning off the default azimuthal variation for secondary horizontal fragments. This should be quantifying the differences between the cruciform ISURFGAD and the Toroid on the normals and off-normal.

**Inputs**

There will be 192 plots. Each plot will have one PES/ES/Explosive /NEW combo and will plot $P_f(hd|e)$ vs distance for all azimuth values (ISURFGAD and ISURF).

Outputs for plots (separate plots): $P_f(hd|e)$, $P_f(vd|e)$

- **PES:** Type 1 - Large Steel (square), PEMB (rectangular), Medium Concrete Operating Building (square), Large URC (rectangular)
- **ES:** Open, Medium PEMB, Medium Reinforced Concrete (RC)
- **Explosive article:** No primary frags, metal-cased explosive article
- **Explosive Weights [lbs]:** 100, 300, 1K, 3K, 10K, 30K, 100K, 300K
- **Glass types:** none
- **Percent of glass:** 0
- **Each plot includes every distance input.**
- **Distances [ft]:** 0 – 5000ft in 20 ft increments
- **Azimuth for ISURFGAD runs:** 0°, 22.5°, 44°, 46°, 67.5°, 90°, 112.5°, 134°, 136°, 157.5°, 180° (F, FFS, FS, SFS, SSR, SR, RSR, R)
- **Azimuth for ISURF(toroid) runs:** 22.5°, 44°, 46°, 67.5°, 112.5°, 134°, 136°, 157.5° (FFS, FS, SFS, SSR, SR, RSR)

**Notes and observation for this series**

- This study is straightforward, showing the horizontal debris vs. range at various azimuth angles (solid lines). This type of plot can be used to visualize the shape of the ISURFGAD probability density function. The relative density “dropoff” from the normal to the diagonal can be visualized.
- The highest densities are along the normal (0°, 90°, 180°).
- The dashed lines represent the same debris density over the selected quadrant with the azimuthal variation turned off. This is a type of average for the 90° sector.

5.2. Step 17 timing

**Study description**
The purpose of this study is to quantify the effects of the debris arrival time conservatism switch provided to the user in v2.0. This study quantifies the differing hazards to personnel at an ES due to fragment hazards arriving before or after overpressure effects.

**Inputs**

There will be two sets of 420 plots. Each plot will have one PES/ES/Explosive /NEW/Azimuth combo and will plot either $P_f(\text{hd|e})$ or the total $P_f(\text{all hazards})$ for the four options vs distance.

Outputs for plots: $P_f(\text{hd|e})$, $P_f(\text{vd|e})$ and overall $P_f$ for the four options (total of 12 data lines on each plot)

PES: Type 1 - Large Steel, Large URC

ES: Open, Medium PEMB, Medium Reinforced Concrete (RC), Medium reinforced masonry, Medium unreinforced masonry, Medium Stud wall building, Wood frame (modular), Stationary vehicle

Explosive article: metal-cased explosive article

Explosive Weights [lbs]: 100, 300, 1K, 3K, 10K, 30K, 100K, 300K

Glass types: none

Percent of glass: 0

Each plot includes every distance input.

Distances [ft]: 0 – 5000ft in 20 ft increments

Azimuth for runs: 0°; 22.5°; 45°

**Notes and observation for this series**

- This study shows that effects of debris arrival time can be significant, but typically only at very close ranges or when the NEW is extremely large (300,000+ lbs.).
- The PES and ES structure types play an important role in this scenario.
6. Parametric analysis

6.1. Glass

**Study description**

This study compares the different glass types by plotting $P_f_{\text{glass}}$ as a function of range (distance between the PES and ES). It also examines the relationship between the percentage of glass at the ES and the floor size of the ES. In general, more glass at the ES should increase the probability of fatality due to glass and increasing floor area should reduce it slightly.

**Inputs**

There will be 30 plots. The plots compare the $P_f_{\text{e}}$ for glass as a function of glass details for a PES/ES pair for 10 NEWs over range. Each of the 30 plots shows a different charge weight and a different ES floor area, with a “curve” each glass combo.

- **PES:** Open
- **ES:** Medium RC
- **Explosives Article:** No primary fragments
- **Explosive Weights [lbs]:** 100, 300, 1K, 3K, 10K, 30K, 100K, 300K, 1M, 3M
- **ES floor area [ft²]:** 100; 1000; 10,000
- Each plot includes all ranges up to K80 and each glass combo:
  - **Scaled Range:** 0 – K80 in ft
  - **Glass type:** Annealed, tempered, dual pane
  - **Percent of glass:** 10, 25
  - **Assumption:** fixed azimuth of 0°

**Notes and observation for this series**

**Expected results:**
- Increasing the percentage of glass increases the probability of fatality from glass. - Confirmed
- Tempered glass is generally stronger than the other types. - Confirmed

**Observations:**
- Output for tempered glass does not appear as smooth as the other types.
6.2. Explosives article

**Study description**
This study compares the effects of the size and number of primary fragments from the different explosive articles by plotting the probability of fatality for vertical and horizontal debris as a function of range (distance between the PES and ES). The PES type is always Open so there will be no secondary debris besides crater ejecta. The ES types selected are in general Open, a weak ES, and a strong ES.

**Inputs**
There will be 30 plots. The plots compare the Pf|e for horizontal debris and the Pf|e for vertical debris as a function of explosive article for each ES for 10 NEWs at multiple ranges. Each of the 30 plots shows a different charge weight, with a "curve" each consequence for each explosives article.

- PES: Open
- ES: Open, PEMB, Medium RC
- Explosives Article: {each option}
- Explosive Weights [lbs]: 100, 300, 1K, 3K, 10K, 30K, 100K, 300K, 1M, 3M
- Glass types: None
- Percent of glass: 0
- Distances: 0 – 5000 ft in 20 ft increments
- Assumption: fixed azimuth of 0°

**Notes and observation for this series**
- Effect of crater ejecta on \( P_{\text{vertical}} \) can be seen in the no primary fragment series.

- In the cases of a non-open type ES, the “stair step” quality to the series is a visible artifact of mass bin effects. In the case of horizontal debris, there’s a distance at which a particular mass bin’s fragments cannot perforate the walls of the ES and are stopped. The effect is even more pronounced for the vertical debris.

- The stronger medium reinforced concrete ES stops all horizontal fragments at a relatively close distance.
6.3. Soil type

**Study description**

This study shows how soil type selection affects crater ejecta by plotting the probability of fatality due to vertical debris as a function of range (distance from the PES to ES). Both the PES and ES are Open types and the explosive article has no primary fragments so the only vertical debris will be crater ejecta.

**Inputs**

There will be 10 plots. The plots compare the overall $P_f|e$ for vertical debris as a function of soil type for 10 NEWs at 5 multiple ranges.

Each of the 10 plots shows a different NEW, with a “curve” for each soil type.

PES: Open
ES: Open
Explosives Article: No primary fragments
Explosive Weights (lbs): 100, 300, 1K, 3K, 10K, 30K, 100K, 300K, 1M, 3M
Glass types: None
Percent of glass: 0
Distances: 0 – 5000 ft in 20 ft increments
Soil type: concrete, rock or hard clay, loose, crushed stone
Assumption: fixed azimuth of 0°

**Notes and observation for this series**

- Crushed stone is fairly uniform in size and has a fairly uniform distribution in the smaller fragment mass bins. Therefore the density drops off in a fairly uniform manner as the range from the PES increases.
6.4. Roof type

**Study description**

This study shows the differences between ES roof types by plotting the probability of fatality from vertical debris for a strong ES with the different roof types as a function of range (distance between the PES and ES).

**Inputs**

There will be 40 plots. The plots compare the overall Pf|e for vertical debris as a function of roof type for a PES/ES pair for 10 NEWs at multiple distances. Each of the 40 plots is a combination of one input from each of the following categories.

- **PES:** Medium Concrete Building, PEMB
- **ES:** Medium RC, Medium Stud Wall
- Explosives Article: No primary fragments
- Explosive Weights [lbs]: 100, 300, 1K, 3K, 10K, 30K, 100K, 300K, 1M, 3M
- Glass types: None
- Percent of glass: 0
- Distances: 0 – 5000 ft in 10 ft increments

Roof: 4” reinforced concrete,
14” Reinforced concrete,
Plywood/wood joists (2x10 @ 16”),
Gypsum/fiberboard/steel joist,
Plywood panelized (2x6 @ 24”),
2” lightweight concrete/steel deck & joists,
Medium steel panel (18 gauge),
Light steel panel (22 gauge)

Assumption: fixed azimuth of 0°

Note: some of these cases will be unrealistic combinations, but the software currently allows user to try them.

**Notes and observation for this series**

- The effects of the new debris distributions can be seen by the dip and then increase in probability close in to the PES.
- Mass bin/max throw effects are shown by the sudden drops in probability as range increases.
7. User-defined $P_e$

**Study description**

Vary the parameters associated with the $P_e$ when using the new user-defined activity option. The results must be in terms of $P_f$ (or risk) rather than $P_{fe}$. So, with fixed assumptions about consequence ($P_{ne}$ and exposure level), the hypothetical activities will be plotted versus two reference activities, commercial long-term storage (low $P_e$) and disposal (high $P_e$).

**Inputs**

Variables:

- $P_e$: 1.0E-06; 3.0E-06; 1.0E-05; 3.0E-05; 1.0E-04; 3.0E-04; 1.0E-03; 3.0E-03; 1.0E-02
- UBM: 2; 3; 10; 30; 100
- Nominal Operating Hours: 1,000; 2,000; 4,000; 6,000; 8,760
- Actual Operating Hours: 1,000; 2,000; 4,000; 6,000; 8,760
- Points:
  - $P_{fe}$: 1e-9; 1e-6; 1e-3; 1e-2; 1e-1
  - Exposure: 0.125; 0.25; 0.5; 1.0

Fixed assumptions: No environmental factors, Compatibility Group A

Five plots will be created:

Plot 1: $P_f$ individual versus $P_{fe}$
Details: Long-term storage, disposal, long-term storage at each of the activity operating hours

Plot 2: $P_f$ individual versus $P_{fe}$
Details: Long-term storage, disposal, custom activity (long-term storage as a base with activity operating hours set to 1000, PES operating hours set to 100, varying $P_e$)

Plot 3: $P_f$ individual versus $P_{fe}$
Details: Long-term storage, disposal, custom activity (long-term storage as a base with activity operating hours set to 1000, PES operating hours set to 1000, $P_e$ set to 0.01, varying upper bound multiplier)

Plot 4: $P_f$ individual versus Upper bound multiplier
Details: Custom activity using long-term storage as a base, PES operating hours set to 1000, varying activity operating hours

Plot 5: $P_f$ individual versus activity $P_e$
Details: Custom activity using long-term storage as a base, PES operating hours is 1000, varying activity operating hours

**Notes and observation for this series**

- Plots 1-5: Difficult to quickly grasp format/purpose, but exercises confirm what is expected.
8. Max-max versus exp-exp results

Study description

This comparison will compare variations between maximum and expected NEW, showing how uncertainty could affect the answer.

Inputs

There will be two sets of 24 plots. Each plot will be Pf individual or Pf|e (depending on the set) versus range. Each series will be the maximum NEW, maximum yield case or a case where the expected NEW is a fraction of the maximum. The inputs for the case are shown below:

- PES: Medium Concrete Building, PEMB
- ES: Medium RC, Large PEMB
- Explosives Article: No primary fragments
- Explosive Weights [lbs]: 10K, 30K, 100K, 300K, 1M, 3M
- Activity type: Long-term storage
- Exposure: 1 person, 8760 hrs, 100%, 1 person maximum, uncertain, no correlations
- Glass types: Annealed
- Percent of glass: 10%
- Expected NEW fractions: 1E-4, 1E-3, 0.01, 0.1, 0.5, 1.0
- Distances: 0 – 10,000 ft in 10 ft increments

Notes and observation for this series

- Varying the expected NEW while holding the max NEW constant will produce no change to the max NEW results (naturally), but will create two changes in the expected NEW results
  1. The Pf|e will change as the NEW changes, as expected (unless the difference in NEW has no effect on the controlling consequence mechanism). The first set of plots isolates this single effect.
  2. The Pf will change due to both the change in Pf|e and the effect of uncertainty (which increases as the difference between the expected NEW and max NEW increases). The second set of plots shows the combined effect. The effect of uncertainty can be seen by comparing back to the equivalent case in the first set of plots to see the contribution of the change in Pf|e.

- The second set of plots shows that the uncertainty routine will produce unpredictable and counter-intuitive results when the difference between max and expected NEW is extreme. This is a strong warning to avoid cases where the expected NEW differs significantly from the max, if the expected NEW results will be considered. Note that the cases that produce the strange results are probably unrealistic (e.g., max NEW = 30,000 lbs, expected NEW = 3 lbs).

- It should be noted that this recreates the infamous “Lyn Little Case” from some years ago.

- The plots can also be used to confirm the anticipated difference in results when the expected NEW is equal to the max NEW (due to the difference in yield, owing to the different percent contribution values for a given hazard division).
Appendix D: APT Briefing for DDES on IMESAFR Sensitivity Studies
Disclaimer

Because of the inherent limitations of any assurance engagement, it is possible that fraud, error or non-compliance may occur and not be detected. This analysis was not designed to cover all aspects of every piece of data analyzed. This analysis was performed on a test basis. A thorough analysis of every potential detail within the data analyzed was not possible in the amount of time allocated. The conclusions and recommendations expressed in this report have been formed on the above basis.