

DDESB TP13 Software Update
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Abstract

The Department of Defense Explosives Safety Board (DDESB) Technical Paper (TP) 13 computational process entails the use of three computer applications: SHOCK, FRANG and MUDEMIMP. SHOCK and FRANG are used to compute the shock and gas impulse on each component surface of a donor structure. The outputs from both codes, in addition to several component breakup characteristics that are derived from the results, are used as input for the MUDEMIMP code. MUDEMIMP is used to determine debris dispersion and debris tumble after impact.

The Naval Facilities Engineering Service Center (NAVFAC ESC) has been tasked by DDESB to update an existing NAVFAC ESC software that automates the TP 13 computational process. The existing software, BLibPre, was sponsored by DDESB and was developed in 1998. The software allows the user to model only a single location of the explosive in 3D space. While the designated location may be optimum for one surface it may not be optimum for the other surfaces. NAVFAC ESC has developed an algorithm to optimize the location of the explosive to cause maximum hazardous debris distance for each component being evaluated. The optimization update allows the user to specify an envelope within the donor structure. The algorithm generates a computational grid inside the defined envelope and calculates the debris distance for each surface at each grid point. The results from the entire grid are analyzed and the charge location that maximizes the hazardous debris distance is identified for each component surface. The

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14. ABSTRACT

The Department of Defense Explosives Safety Board (DDESB) Technical Paper (TP) 13 computational process entails the use of three computer applications: SHOCK, FRANG and MUDEMIMP. SHOCK and FRANG are used to compute the shock and gas impulse on each component surface of a donor structure. The outputs from both codes, in addition to several component breakup characteristics that are derived from the results, are used as input for the MUDEMIMP code. MUDEMIMP is used to determine debris dispersion and debris tumble after impact. The Naval Facilities Engineering Service Center (NAVFAC ESC) has been tasked by DDESB to update an existing NAVFAC ESC software that automates the TP 13 computational process. The existing software, BLibPre, was sponsored by DDESB and was developed in 1998. The software allows the user to model only a single location of the explosive in 3D space. While the designated location may be optimum for one surface it may not be optimum for the other surfaces. NAVFAC ESC has developed an algorithm to optimize the location of the explosive to cause maximum hazardous debris distance for each component being evaluated. The optimization update allows the user to specify an envelope within the donor structure. The algorithm generates a computational grid inside the defined envelope and calculates the debris distance for each surface at each grid point. The results from the entire grid are analyzed and the charge location that maximizes the hazardous debris distance is identified for each component surface. The effectiveness of the optimization and its benefit to the explosive safety siting community will be discussed. The original code used a text-based input file and a text based output file. To make the software easier, a Windows graphical user interface will be added to the software to make its use simpler and more interactive.

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1. Introduction

TP 13 presents an analytical model to predict hazardous building debris distances for accidental explosions in explosives storage/operation facilities. The model can be used to predict hazardous debris distances using explosive loading conditions in buildings constructed of reinforced concrete, masonry or lightweight components [1]. The predictive model is comprised of the following general steps: loading prediction on internal surfaces, prediction of component breakup and determination of debris characteristics, debris dispersion and debris tumble after impact. The model requires the use of three computer codes: SHOCK, FRANG and MUDEMIMP. Steps are provided in the model for calculations required to generate input data for the codes [1]. Applying the TP 13 prediction model to a donor structure is a laborious process that requires an analyst to carry out hand calculations, carefully consider the model limitations, generate text input files and execute the three computer codes. A summary of the step by step approach described in TP 13 is given below:

1. Define the threat
2. Determine vent areas and descriptions
3. Calculate the impulse load on each component
 - Calculate Shock Impulse using SHOCK. Analyst must compute the scaled distance, determine if loading is close-in or far-range, run SHOCK based on given guidance for material type (i.e. brittle with significant strength, brittle without significant strength or ductile material).
 - Calculate Quasi-static Impulse using FRANG. Analyst must compute the scaled distance, determine if loading is close-in or far-range, run SHOCK based on given guidance for material type (i.e. brittle with significant strength, brittle without significant strength or ductile material).
4. Calculate the maximum debris velocity expected
 - Calculate relevant shock impulse
 - Calculate total relevant impulse
 - Calculate the maximum debris velocity
 - Calculate the average velocity and velocity standard deviation
5. Calculate the average debris weight
6. Determine the effective destroyed weight of the component
7. Calculate destroyed width of the component
8. Run MUDEMIMP to determine hazardous debris distance

9. Obtain pertinent information from the program output files.
10. Interpretation of the results

The majority of the steps listed must be repeated for every component of the donor structure (i.e. walls, roof, doors, beams, etc.) If the user wishes to consider the effects of a larger charge or the effects of the charge at different locations, the overall procedure must be repeated.

BLibPre is a code developed in 1998 with DDESB support. The code automates steps 2 through 9 above and analyzes all components of the donor structure in one run for a specified charge location. BLibPre requires a text input file containing all the data necessary for a TP 13 analysis. NAVFAC ESC has been tasked to create a graphical user interface written in Visual Basic to collect the input data from the user and generate the input file. The input file contains the following data:

- charge weight and location
- dimension of the donor structure
- identification of surfaces which will reflect the shock wave
- identification of surfaces for which shock computation will be made
- component definition data
- component material properties
- component cover material properties
- frangible panels data
- beam/column properties

The program developed in 1998 calculates the hazardous debris distance for all component surfaces based on one charge location. However, TP 13 states that when a donor structure is analyzed, the user needs to select the worst case location for each surface. NAVFAC ESC has also been tasked by DDESB to update BLibPre to automatically determine the worst case location for each surface within a user specified envelope.

2. TP 13 Automation

The user inputs room and individual component information into the BLibPre program via a text file. The software subsequently creates the data input files necessary to run the computer programs SHOCK, FRANG and MUDEMIMP. BLibPre gives the user the option of running SHOCK only, FRANG only, SHOCK and FRANG only, or SHOCK, FRANG and MUDEMIMP. All data input into the software is echoed back to the user in output reports, along with output summarizing derived and computed results.

The first step in the calculation process is to compute the parameters required to run SHOCK. SHOCK input files are subsequently created for each of the room components (walls, doors, panels, etc.) and the SHOCK program is executed for each component. SHOCK output is subsequently processed and a FRANG input file is created. The version of FRANG used allows for tracking the venting of gas pressure around one or more frangible panels. Once FRANG is executed, the results are processed for use in the TP 13

calculation procedures. The TP 13 calculations are made and summarized in an output report, then the input files for MUDEMIMP are created for each of the donor structure components. MUDEMIMP is called to calculate the debris throw distance for each component and the results are summarized in an output file. The output contains the hazardous debris throw distance for each component of the donor structure.

BLibPre has been used to analyze the four example problems in TP 13 and the results verified that it accurately predicts the debris throw distance for each component. The example problems were solved significantly faster using this new application versus manually following all the steps described in TP 13. Furthermore, if one desires to vary parameters after running an analysis, it takes a few moments to edit the input file and re-execute the program. On the other hand, varying parameters with the manual process is a long and tedious process.

3. Optimization

In addition to automating the TP 13 analytical model, an algorithm has been added to BLibPre which determines the charge location within a user defined envelope that produces the largest hazardous debris distance. TP 13 requires the user to select the worst case location for each surface of the donor structure and the new optimized version of BLibPre accomplishes this. The algorithm generates a computational grid inside the defined envelope and calculates the debris distance for each surface at each grid point. The results from the entire grid are then analyzed and the charge location that maximizes the hazardous debris distance is identified for each component surface. Contours of the hazardous debris distance can also be plotted for a plane inside the user defined envelope to illustrate the charge locations that cause maximum or minimum debris hazard.

To illustrate the potential of this functionality, the optimization has been applied to Example problems 1 and 2 in TP 13 and debris contour plots are shown.

3.1. Example 1

BLibPre was used to determine the worse case location of a 250 lb TNT bare spherical charge inside the building described in TP 13 Example problem 1. The building is composed of four 12-inch thick reinforced concrete walls and a Cemesto roof; the dimensions are shown in Figure 3.1.

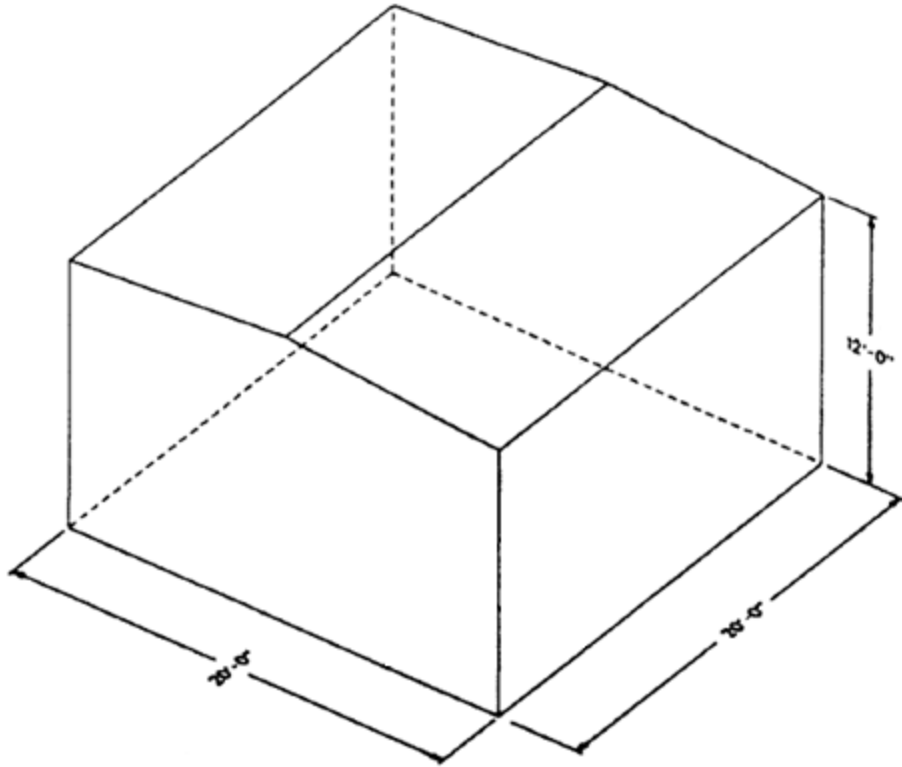


Figure 3.1 Building defined in TP 13 – Example 1

An envelope for the charge is defined by a box 14ft x 14ft x 4ft which is positioned 3 ft from the walls of the donor structure and 2ft above the floor. The envelope is shown in Figures 3.2.

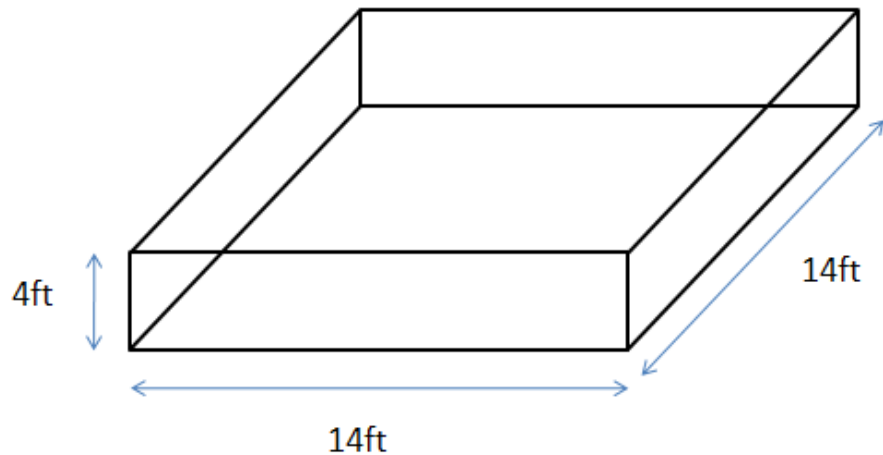


Figure 3.2 User defined envelope for charge location.

The charge envelope and the donor structure are visualized in plan view in Figure 3.3.

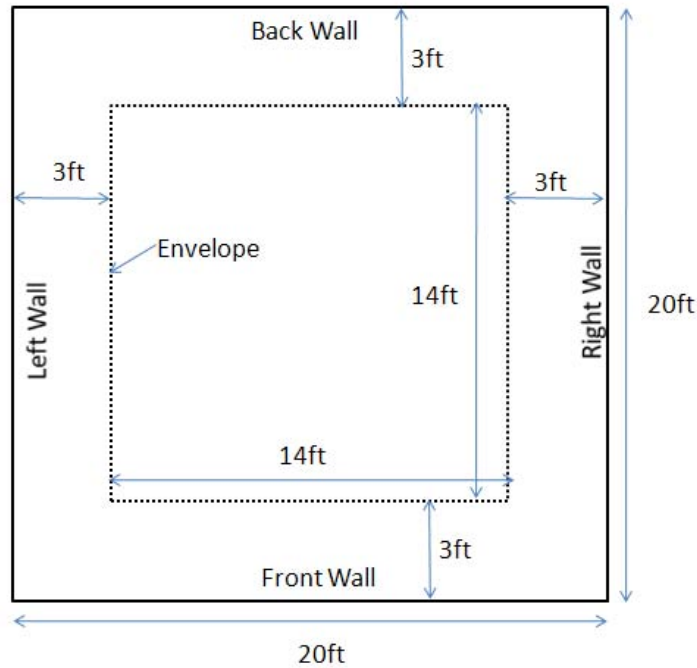


Figure 3.3 Charge envelope inside of building floor plan.

The height of the charge envelope shown above extends from 2 feet above the floor to 6 feet above the floor. For the front, left, rear and right walls, the charge envelope at two feet above the floor resulted in higher hazardous debris distances than the envelope at higher elevation from the floor.

Figure 3.4 illustrates contours of hazardous debris distance for the front wall from an explosive positioned in a 14 ft x 14 ft plane two feet above the floor and 3 feet from each wall of the building. The color of the contours at any point inside the envelope indicates the calculated debris distance value for the front wall from a 250 lb charge at that location. From the contour plot it can be seen that the debris distance is largest when the charge is located nearest the front wall. Furthermore, the locations that yield the highest distances are the corners closest to the adjacent walls. This result can be expected for such a simple geometry with no doors or other complexities. Although the result is trivial for this donor structure, it does validate that BLibPre works correctly and produces sound results. Figure 3.4 also demonstrates that once the charge is moved more than six feet away from the front wall, the hazardous debris distance does not vary significantly as the charge is moved further back. The same result is expected for the other walls of the donor structure due to symmetry. Figure 3.5 illustrates the contours for the left wall and the overall result is identical except for the orientation. These contour plots give extra insight to a planner or to a structural engineer without having to repeat tedious manual calculations of the analytical model.

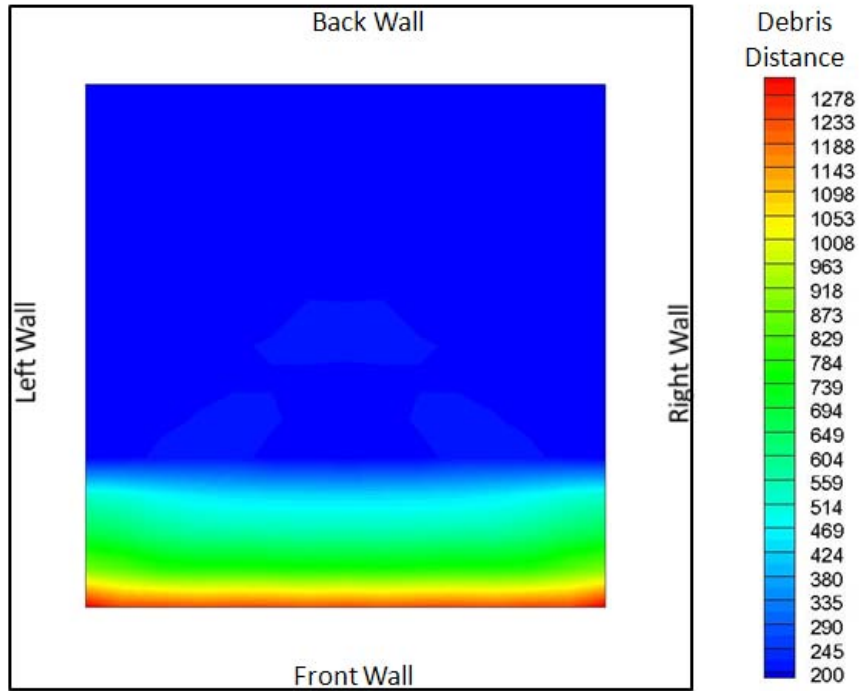


Figure 3.4 Contour plot of front wall hazardous debris distances for charge locations at 2 feet above the floor

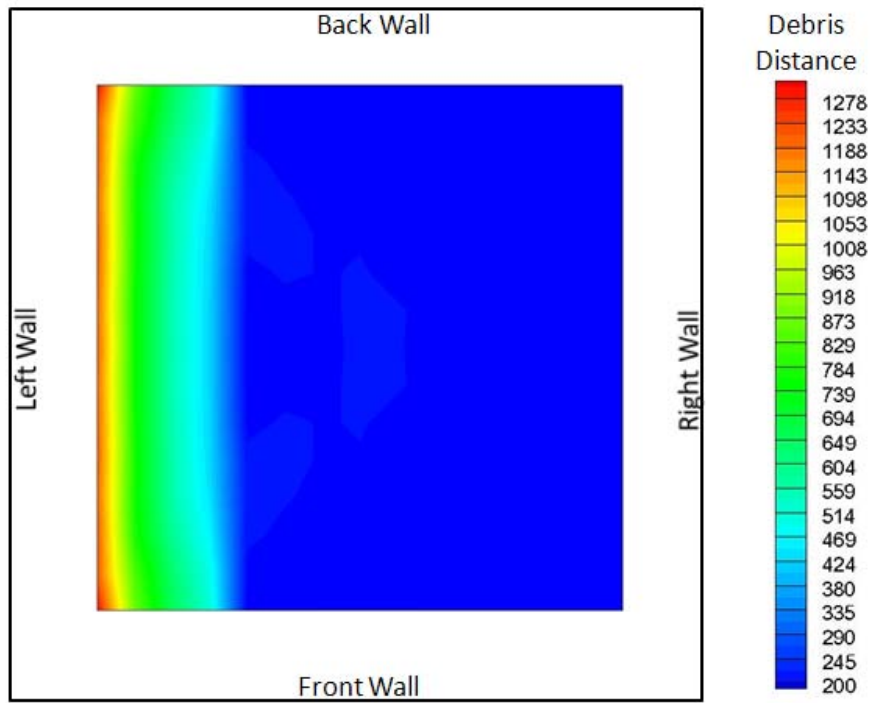


Figure 3.5 Contour plot of left wall hazardous debris distances for charge locations at 2 feet above the floor

The contour plots for the back and right walls for example 1 are not shown since the results are similar to the front and left wall. For the roof, the maximum hazardous debris distance occurs at the highest elevation allowed within the envelope, which is 6 feet above the floor of the building. Figure 3.6 illustrates the contours of debris distance for the roof. The figure shows that the roof maximum debris occurs when the charge is located at the corners and the debris hazard is reduced if the charge is moved to the center. Unlike the other walls, the roof debris distance does not vary significantly within the charge envelope.

Figures 3.4 – 3.6 can be used in conjunction to determine the ideal location for the charge for a specific application. In order to determine the overall debris hazard for a donor structure one must consider the debris from all the walls and from the roof. The visual representation of the debris for each wall from all possible charge locations provides additional insight and may demonstrate that various charge locations may be considered. This may be especially useful when the donor structure has an irregular shape or multiple frangible panels and the predicted result becomes less obvious. In the next example, a door is added to the donor structure and the contour plot for the door illustrates a charge location that maximizes the debris distance that is different from the corner.

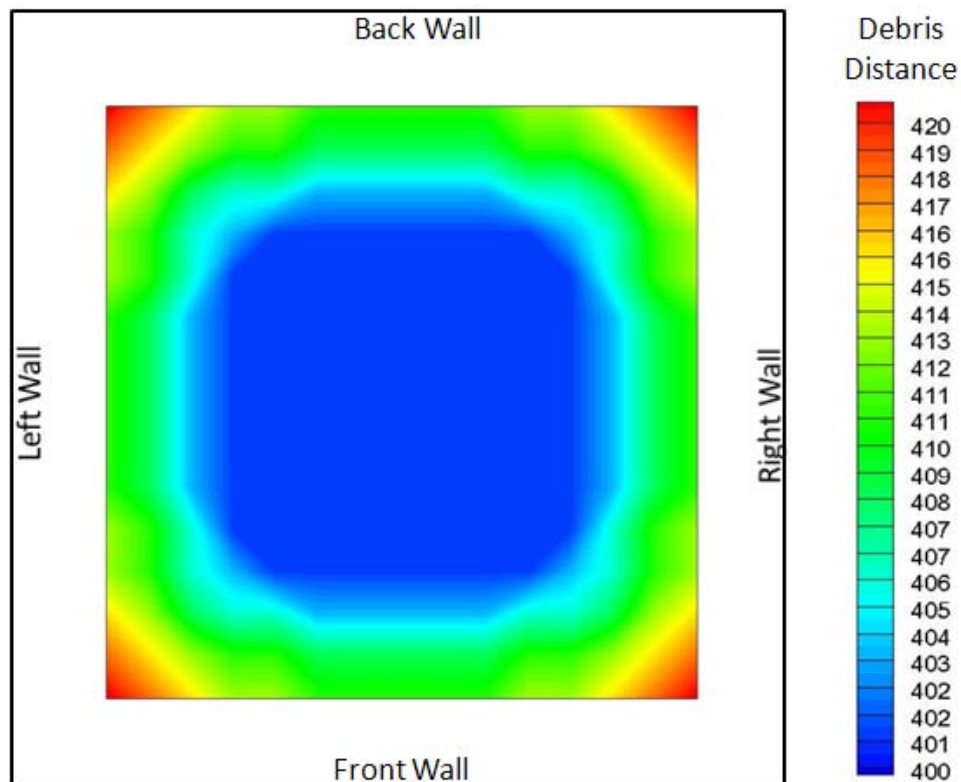


Figure 3.6 Contour plot of roof hazardous debris distances for charge locations at 6 feet above the floor

3.2. Example 2

The donor structure used in Example 2 of TP 13 is identical to the previous example but there's a door located on the front wall. Figure 3.7 illustrates the donor structure with the door. The charge weight for this example is reduced to 25 lbs but is considered in an envelope of the same dimensions as described in Figure 3.3. BLibPre has the ability to analyze the debris hazard from multiple frangible panels similar to the door in this example. The door is hollow and made of 16 gauge steel with dimensions of 3 feet by 7 feet. The worst case location for each surface and frangible panel must be considered. The contour plots help demonstrate where the worst location are and the hazardous debris distance at those locations.

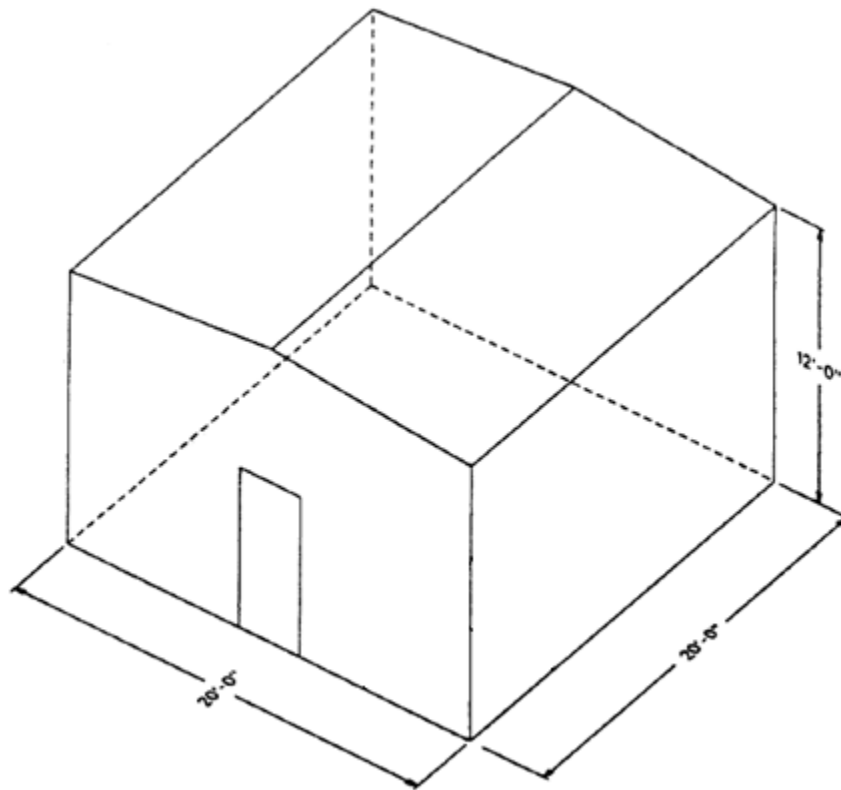


Figure 3.7 Building defined in TP 13 – Example 2

Figure 3.8 illustrates contours for the door hazardous debris distance at the charge envelope at 2 feet above the floor of the donor structure. The contour plot shows that the debris distance is largest when the charge is located directly in front of the door. As the charge is moved further back from the door or to the sides of the door, the debris hazard is diminished. Similar to example 1, the plot in figure 3.8 can be used with other contour plots for the roof and the other four walls of the building to determine the best location to place the charge for a particular application.

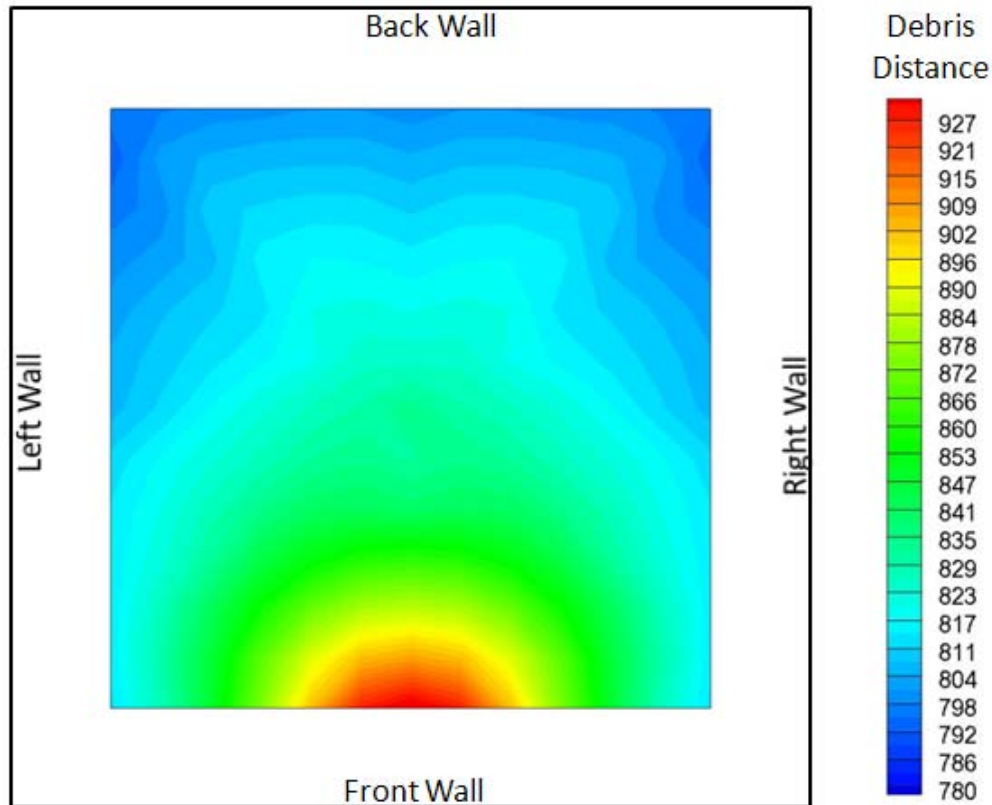


Figure 3.8 Contour plot of door hazardous debris distances for charge locations at 2 feet above the floor

4. Conclusion and Future Work

BLibPre is a tool that automates the approved analytical model presented in TP 13 to predict the hazardous building debris distances. The tool substantially reduces the amount of time and manual calculations needed to perform an analysis for a donor structure. Currently, BLibPre requires a text input file but work is in progress to create a friendly user interface to guide the user to input all the necessary parameters to carry out the analysis. Output format is also under development to include automatic generation of contour plots similar to those presented in this report.

The BLibPre tool also offers the ability to optimize the location of the charge for maximum hazardous debris distance for each component surface. This feature helps the user satisfy the TP 13 requirement of analyzing each surface using the worst case location of the charge. Over the next few months, there will also be an option developed to optimize the location of the charge for maximum total impulse or for maximum hazard debris distance. While in some cases it may be obvious to determine the worst location for each surface of the donor structure, BLibPre may be useful for cases where this may not be obvious.

References

1. Technical Paper 13. "Prediction of Building Debris for Quantity-Distance Siting"
Department of Defense Explosives Safety Board. Alexandria, Virginia.



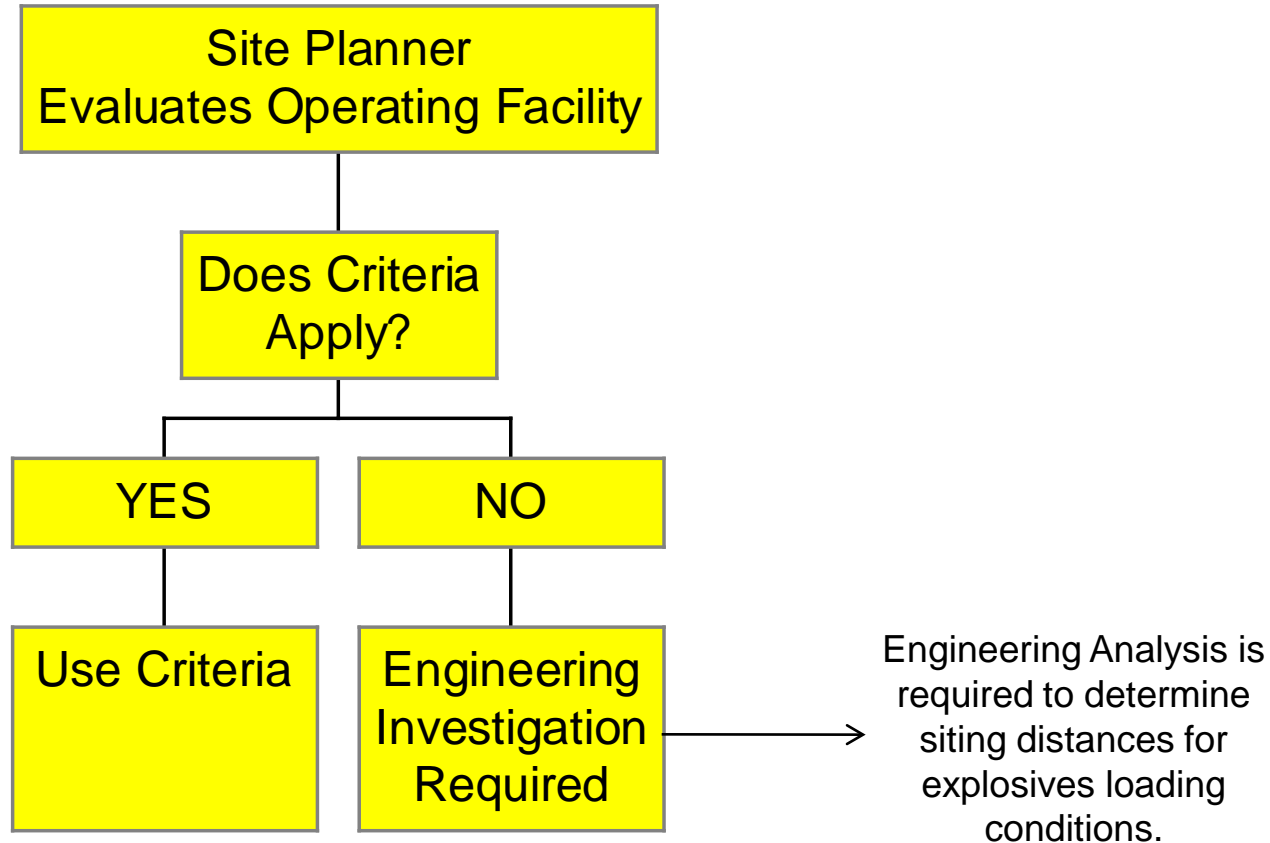
Technical Paper 13 Software Update

by

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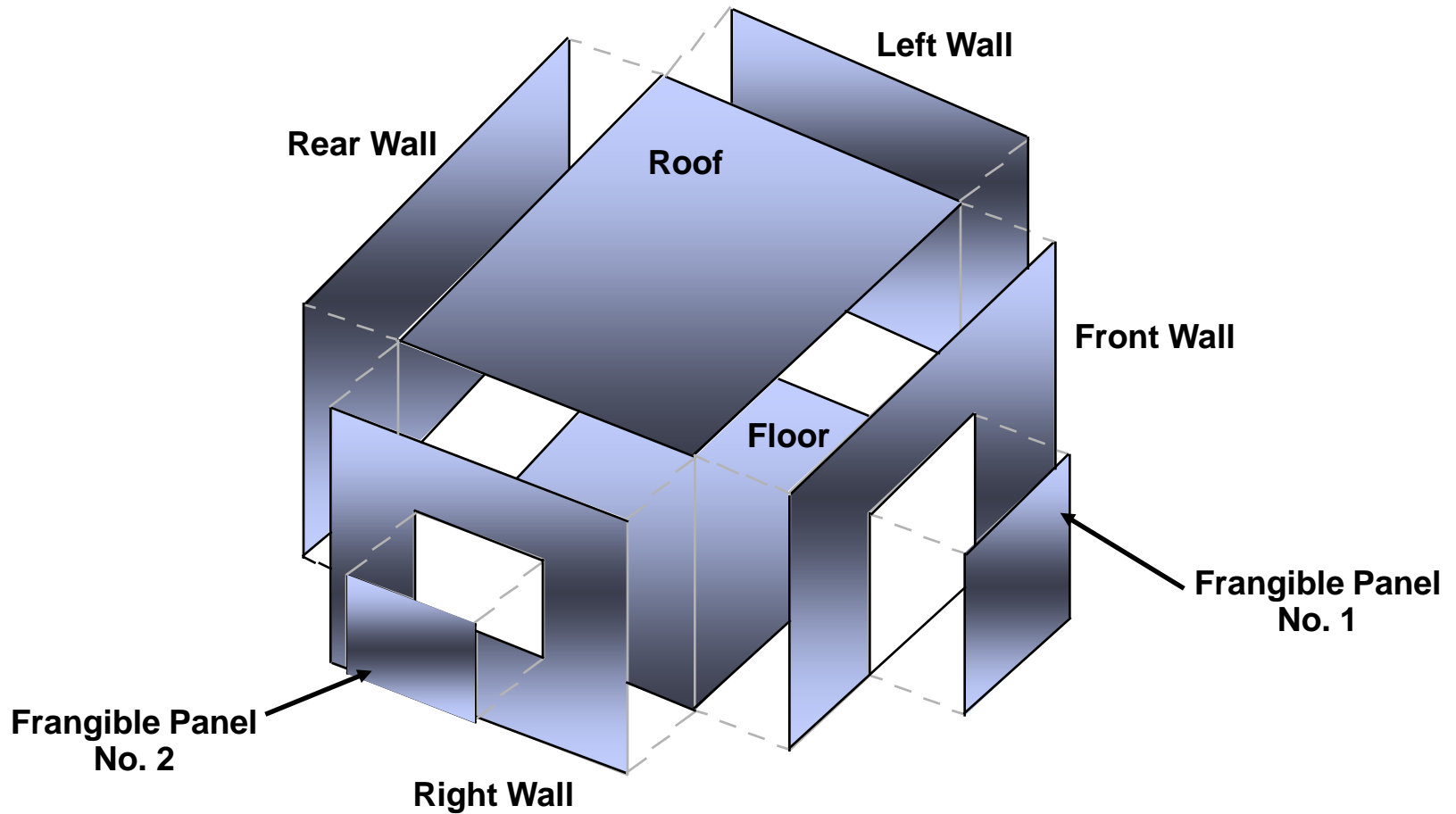
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**2010 Department of Defense
Explosives Safety Seminar
13-15 July 2010**



- **Approved analytical model to predict hazardous building debris distances for accidental explosions in explosives storage/operation facilities.**
- **Valid up to 250 lbs of NEW**
- **The model requires the use of three applications: SHOCK, FRANG and MUDEMIMP.**

Surface Definition



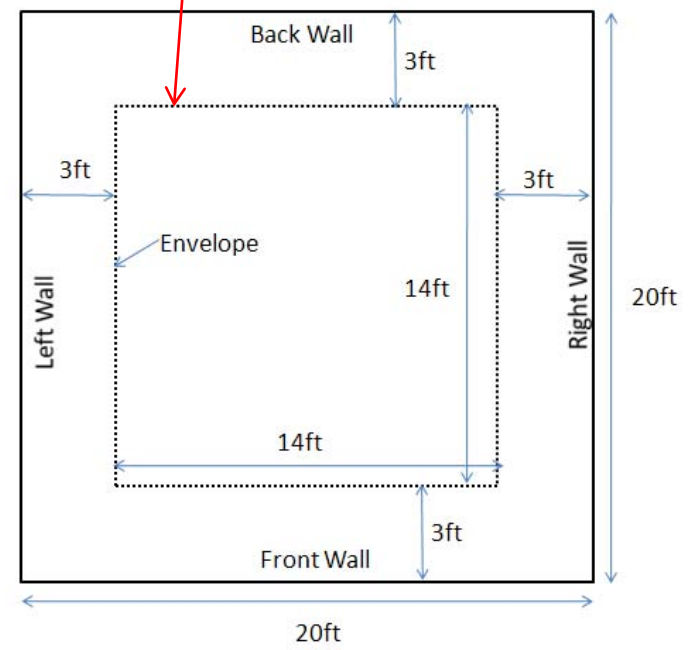
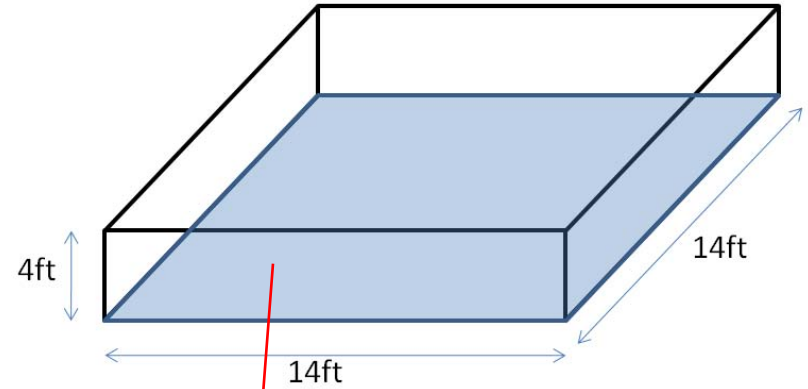
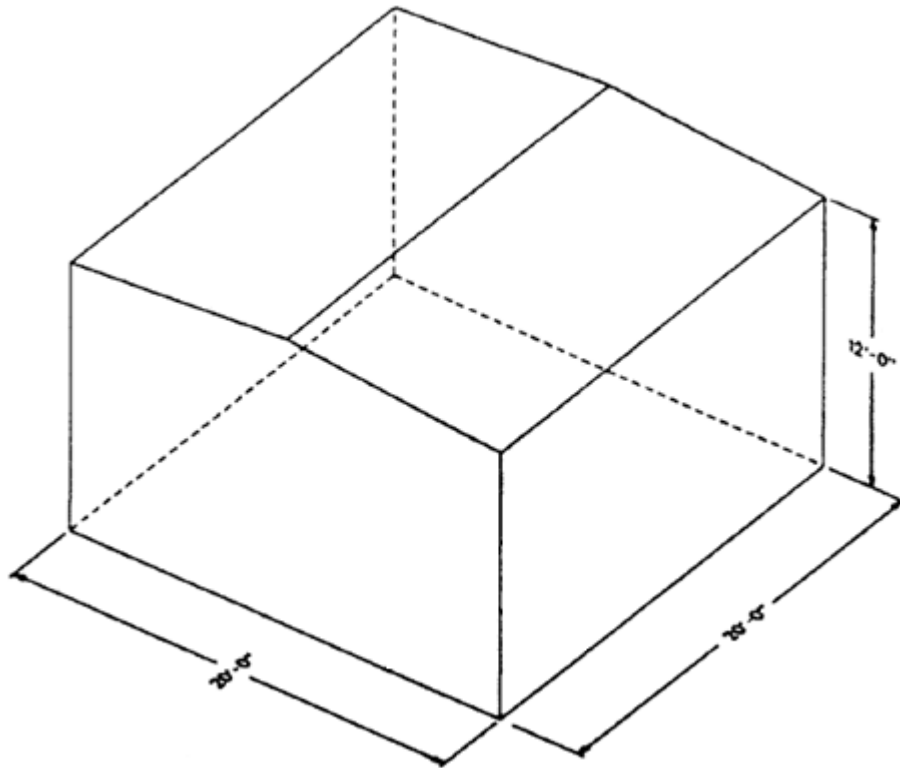
- **Shock pressure loads on**
 - front wall
 - side walls
 - rear wall
 - ceiling
- **Gas pressure buildup inside structure**
- **Frangibility of lighter surfaces**

- **Building component breakup**
- **Debris Characteristics**
- **Hazardous debris distance and debris dispersion for the structure**
- **Debris tumble after impact**

- **Model requires:**
 - Hand calculations
 - Careful consideration of limitations
 - Three applications
- **Applications require engineering judgement to properly use.**
- **Analysis must be repeated for each component surface using worst case charge location.**

- **BLibPre is a tool that automates the approved analytical model presented in TP 13 to predict the hazardous building debris distances.**
- **Optimize the location of the charge for maximum hazardous debris distance.**
- **Option of running SHOCK only, FRANG only, SHOCK and FRANG only, or SHOCK, FRANG and MUDEMIMP.**

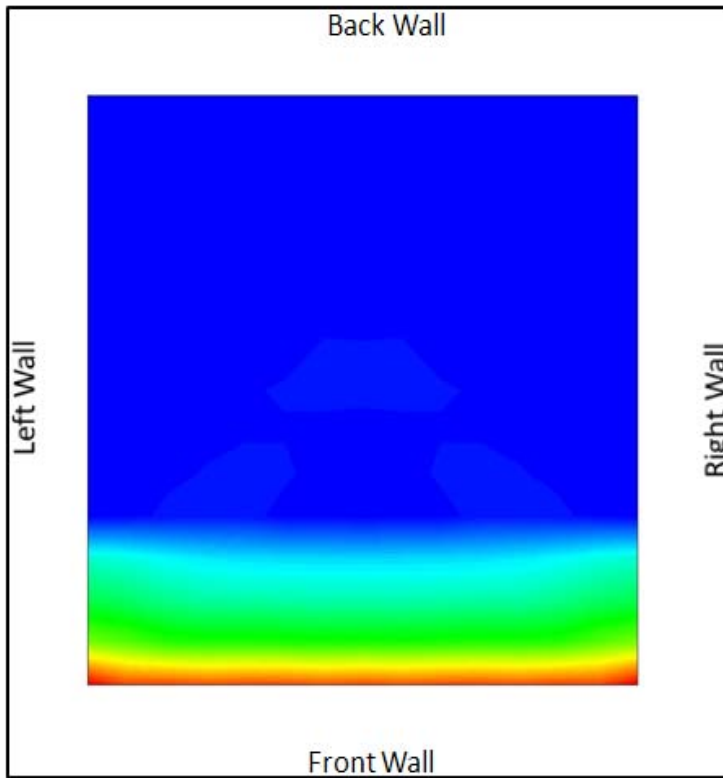
User defined charge envelope



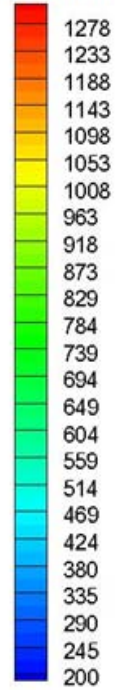
Contours of hazard fragment distance



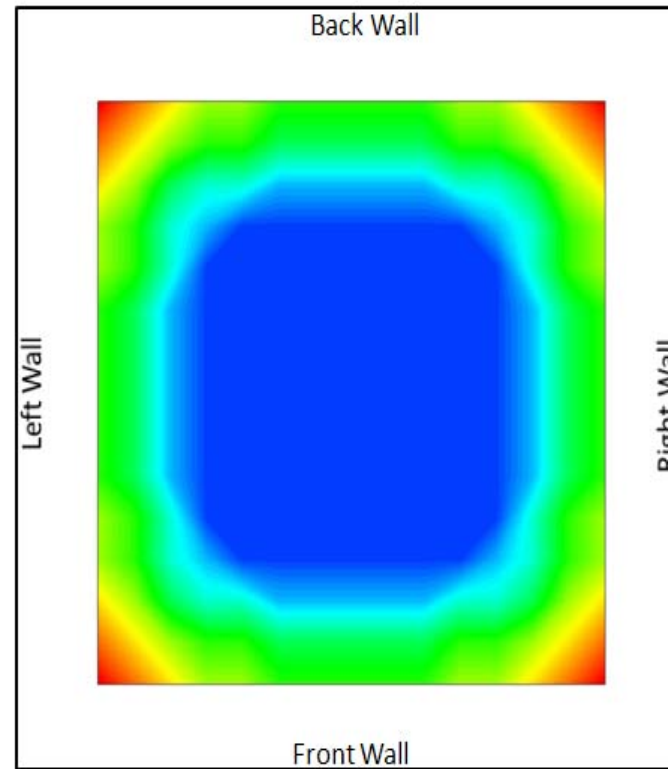
Front Wall Debris



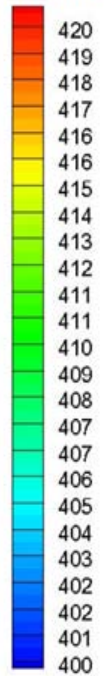
Debris Distance



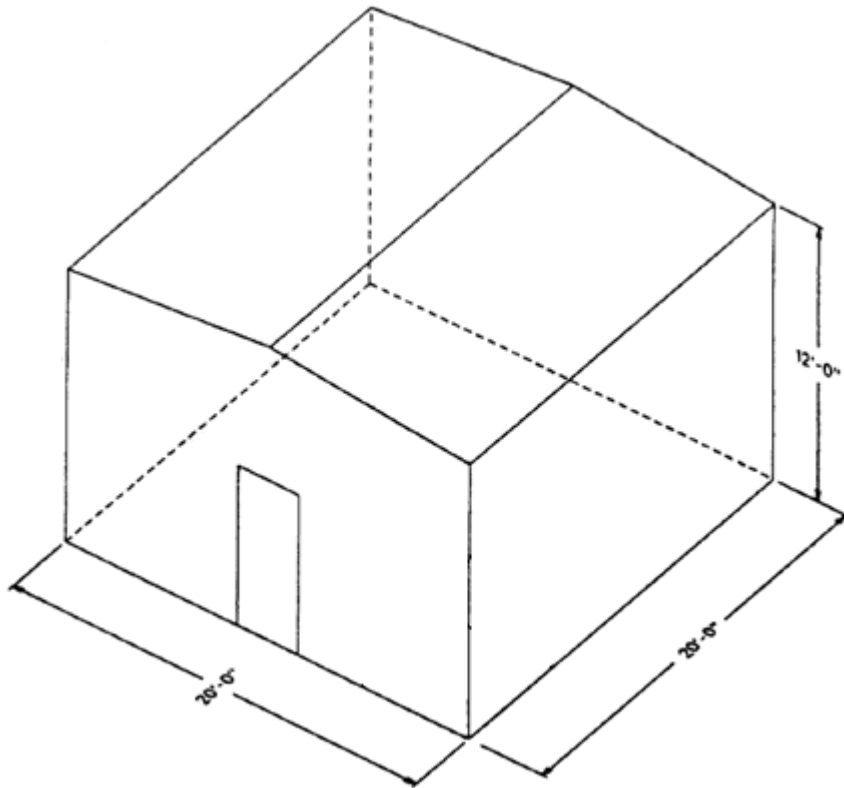
Roof Debris



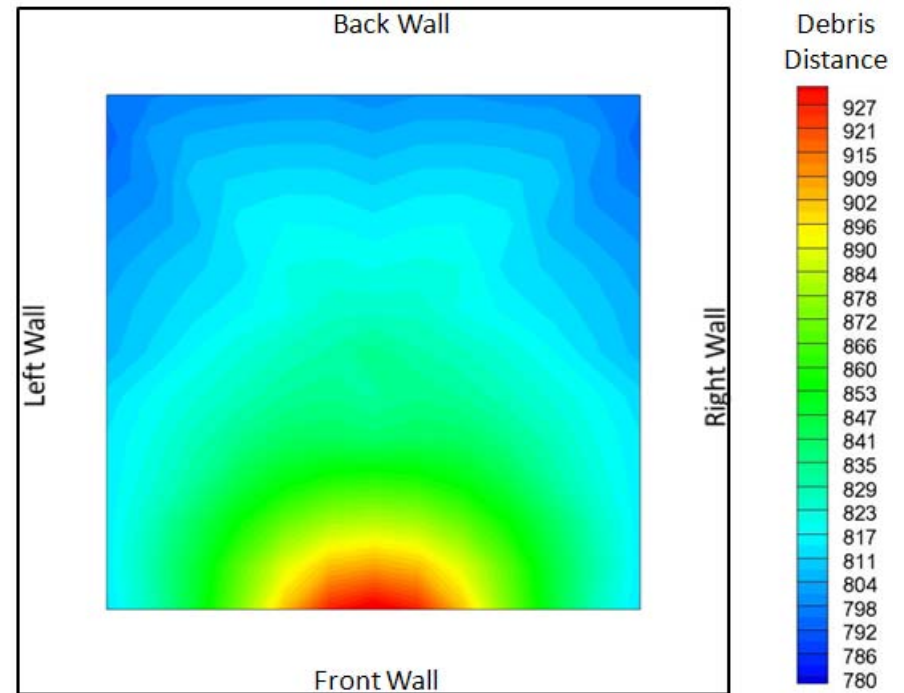
Debris Distance



Steel door example



Door Debris



- **Add a friendly graphical user interface to collect input data and generate input file**
- **Optimize solution based on maximum hazard debris distance or total impulse**
- **Graphical output**
- **Questions?**