Status by Task:

Task 1: Terrorist Events Initiated by Aircraft Crashes and Their Consequences

Task 1.1: Large Jetliner Crash into an Independent Spent Fuel Storage Installation

Task 1.1A: Mechanical Analyses

Currently two concurrent efforts are underway to examine the mechanical aspects of this problem. The global effort consists of using the ZAPOTEC and CTH codes to examine which will provide the best solution to the problem of an aircraft impacting a field of casks. The detailed analysis effort consists of using the PRONTO finite element code to provide detailed analysis of the affects of the aircraft impact on the cask. In both cases the analysis effort requires substantial computing resources and represent state of the art calculations. Therefore, the initial results presented here are from original scoping analyses conducted to provide some insight into the physics of the problems and examine the capabilities of the codes. Some parameters of the problems will need to be "fine tuned" for future calculations. For example, the speed of the threats used in the global and detailed calculations. The global analysis uses a speed of This value is consistent with the speed of the aircraft that impacted the . For the detailed analyses, a speed of was used because this is consistent with the incident and the

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Global Analysis Effort:

Initial efforts with the ZAPOTEC code were not providing timely results due to software problems. Therefore, a CTH solution was examined. Currently, there are initial CTH results for a limited subset of this problem, and corrections to the ZAPOTEC software problems have been implemented with some initial results presented bellow.

The initial goals of the global analysis were to determine the following: (1) the momentum imparted to the target by the impacting aircraft, (2) the residual velocity of the target, (3) failure/breach of the target, and (4) the target load history. A simplified aircraft was considered for the analysis. The simplified aircraft model contained the center fuselage, the front wheel section, and the center fuel tank. The wings, wing fuel tanks, horizontal, and vertical stabilizers were not included in the model. Disregarding these components is not thought to significantly affect the outcome of the analysis, as the distributed mass of the components generally resides well outside of the interaction

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region between the target and aircraft center section. The center wheel assembly was also excluded from the model due to a lack of information regarding wheel placement. The center wheel assembly does have significant mass and disregarding this component could lead to an under prediction of applied loads. Future analyses will confirm or deny the validity of neglecting outer aircraft components. A normal impact was considered for the analysis, which is thought to present a "worst-case" scenario with respect to residual velocity of the target and force imparted to the target.

For the CTH analyses, the target did not include the underlying concrete pad. The reason for this was to avoid earlier problems encountered with the CTH interface tracker, which lead to a non-physical attachment between the base of the target and the pad. Consequently, the scenario modeled can be equated to frictionless contact between the target and pad. The CTH mesh resolution was nominally 10 cm; however, the mesh was refined to a 4 cm resolution in the initial region of impact to provide a better assessment of the target structural response. Mesh refinement occurred only along the CTH x-axis, which was aligned with the aircraft velocity vector.

Results for two different CTH analyses are presented in Figures 1.1A-1 to 1.1A-3. The only difference between the two results is a modification on the concrete model used for the cask. As the results show, there is very little difference between the two models. Figure 1.1A-1 shows the momentum imparted to the target. Figure 1.1A-2 shows the average target velocity, and Figure 1.1A-3 shows the total force on the target. A movie of the 150 msec. Analysis is included in the companion CD with this report.

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Figure 1.1A-1. Momentum imparted to the target

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$\frac{1}{2} \times \frac{67 \times 5280}{3600} \times .140$

$\delta = 6.9$ ft sliding

Figure 1.1A-2. Average target velocity

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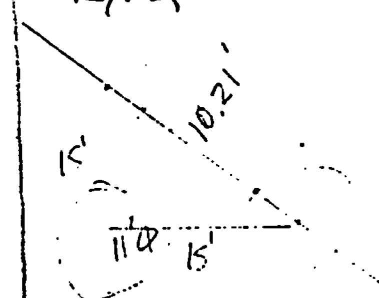

Figure 1.1A-3. Total force on the target

Modifications were made to the ZAPOTEC code and some initial results are available. There are some significant differences between the CTH analyses and the ZAPOTEC analysis. The ZAPOTEC analysis uses the same simplified aircraft model, but includes the underlying soil and concrete pad (these were neglected in the CTH analyses discussed above). The coefficient of friction between the cask and pad was 0.53 and between the target and the aircraft was 0.13. Also, due to some run difficulties, all nodes in the aircraft model were prescribed the ( ) Therefore, the mesh does not decelerate during the impact. Thus, the results presented are still preliminary and there are issues that must be resolved before the results can be considered conclusive. Ex 2

Figures 1.1A-4-6 show the 80 msec. ZAPOTEC results plotted with the CTH results shown above (plots of momentum, average velocity, and force verses time, respectively).

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Note there is a significant difference in the momentum imparted to the target. Consequently, there is a significant difference in the average target velocity (roughly a factor of 3 at 80 msec). Use care when interpreting the computed forces on the target. These are based on momentum output at 5 msec intervals (force was computed as f = d(mv)/dt to get a "ballpark" loading on the target). Essentially, the force data has been filtered for the ZAPOTEC results. So peaks corresponding with the wheel impact will be smaller than normal. However, the trend-wise comparison is useful and shows much lower loads imparted to the target.

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Figure 1.1A-4 CTH and ZAPOTEC - Momentum imparted to the target

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Figure 1.1A-5 CTH and ZAPOTEC - Average target velocity

Ex2

Figure 1.1A-6 CTH and ZAPOTEC - Total force on the target

A movie of the ZAPOTEC results is included with the companion CD (folder TASK11A/ZAPOTEC/z070102.mpeg). Figure 1.1A-7 shows the graphics of the impacts for the CTH and ZAPOTEC analyses at 5.5 msec. The ZAPOTEC results show the [redacted] than the CTH analysis. Also, for the ZAPOTEC results the [redacted] the target by 5.5 msec. Ex 2

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Detailed Analysis Effort:

The PRONTO finite element code is being employed to examine detailed analyses of the cask behavior to impacts of this type. PRONTO is a lagrangian finite element code with explicit time integration. It has been used for many applications analyzing large deformation, highly nonlinear materials, subjected to extremely high strain rates.

A detailed mesh of the cask was developed for the analyses. Figures 1.1A-8 to 1.1A-10 show the finite element model of the cask. Details of the analyses are shown in Appendix A and a pdf file of these figures are included on the companion CD (TASK 1.1A/Mechanical). The projectile speed in these analyses was An initial analysis of the projectile impacting the side of the cask shows

Ex 2

However, the fact that it is confined makes the damage to the inside of the cask It appears that the contents of the package would

The second analysis conducted was a of the cask. This case appears to pose a more severe condition on the contents of the package. However, it is expected that the severity of this type of impact will be highly dependent on the impact angle. The of impact is not considered likely. Further analyses will have to be conducted to examine the damage to the contents of the package for this case.

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Figure 1.1A-8 Pronto finite element model of cask.

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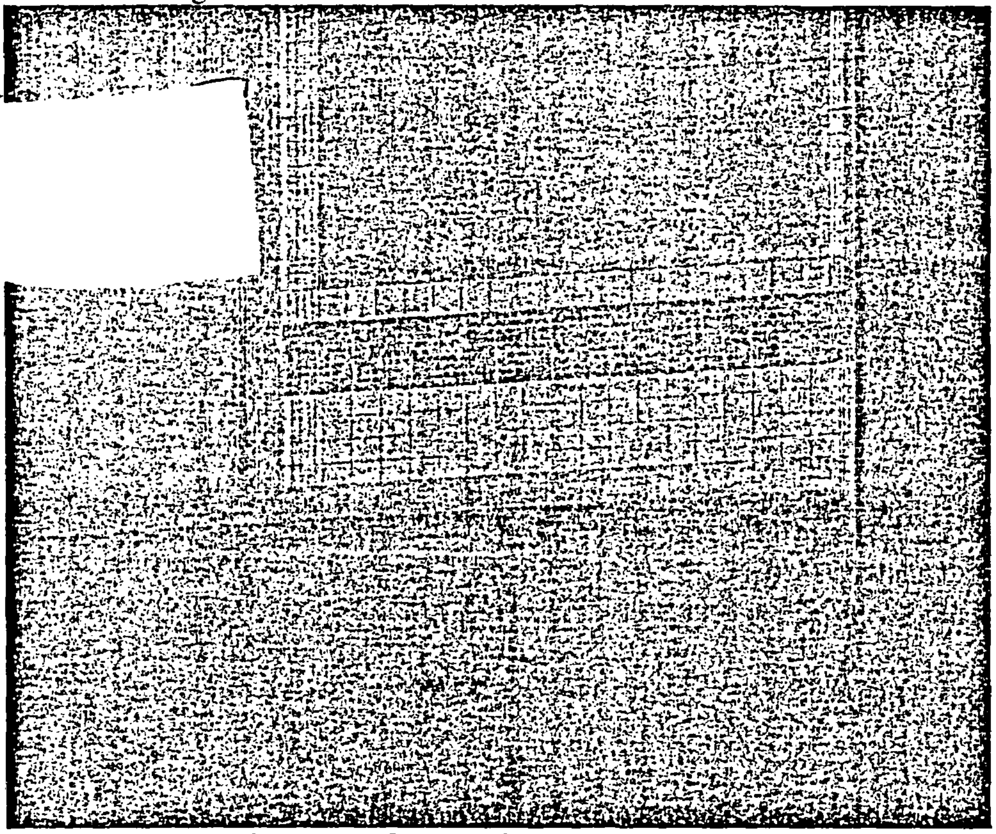

Figure 1.1A-9 Close-up of Pronto finite element model, cask bottom.

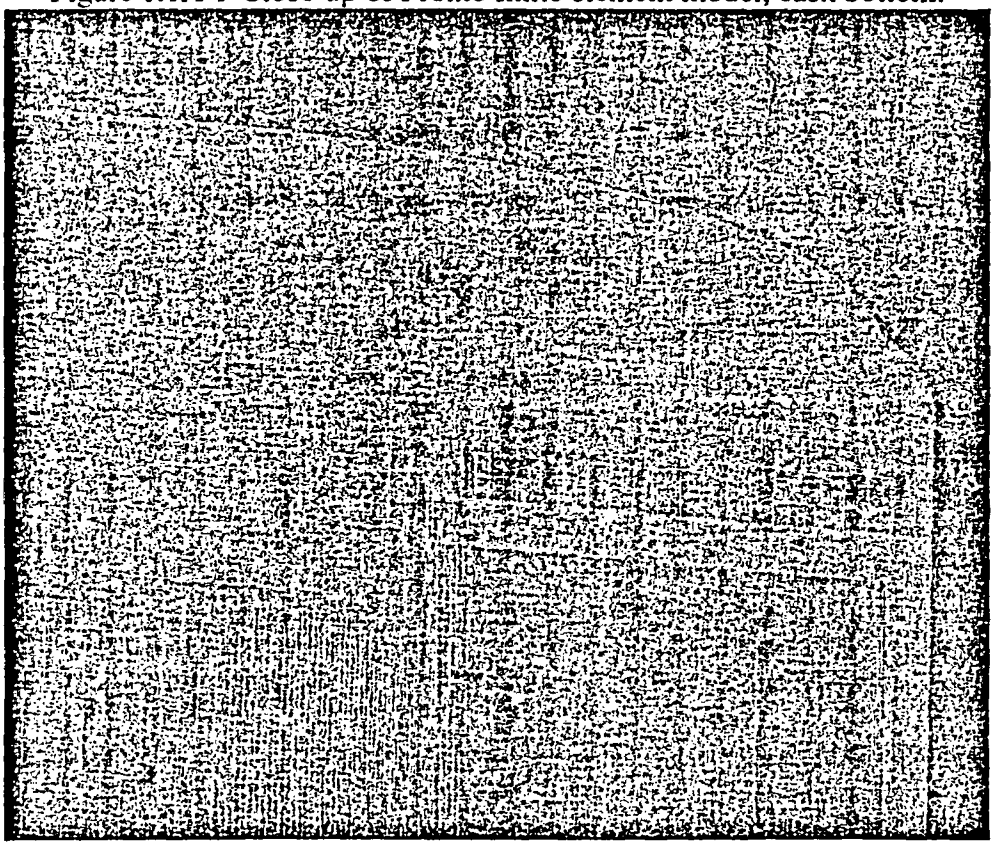

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Figure 1.1A-10 Close-up of Pronto finite element model, cask lid.

In addition to the effort described above, a structural analysis of the MPC canister under a thermal loading is being conducted. This examines the stresses in the MPC canister due to a fire where the canister is has not been damaged. Currently, JAS (a SNL finite element code) and ANSYS have been used in this analysis. Figure 1.1A-11 shows the ANSYS finite element model of the MPC. These analyses are in their preliminary stages and no results are ready at this time.

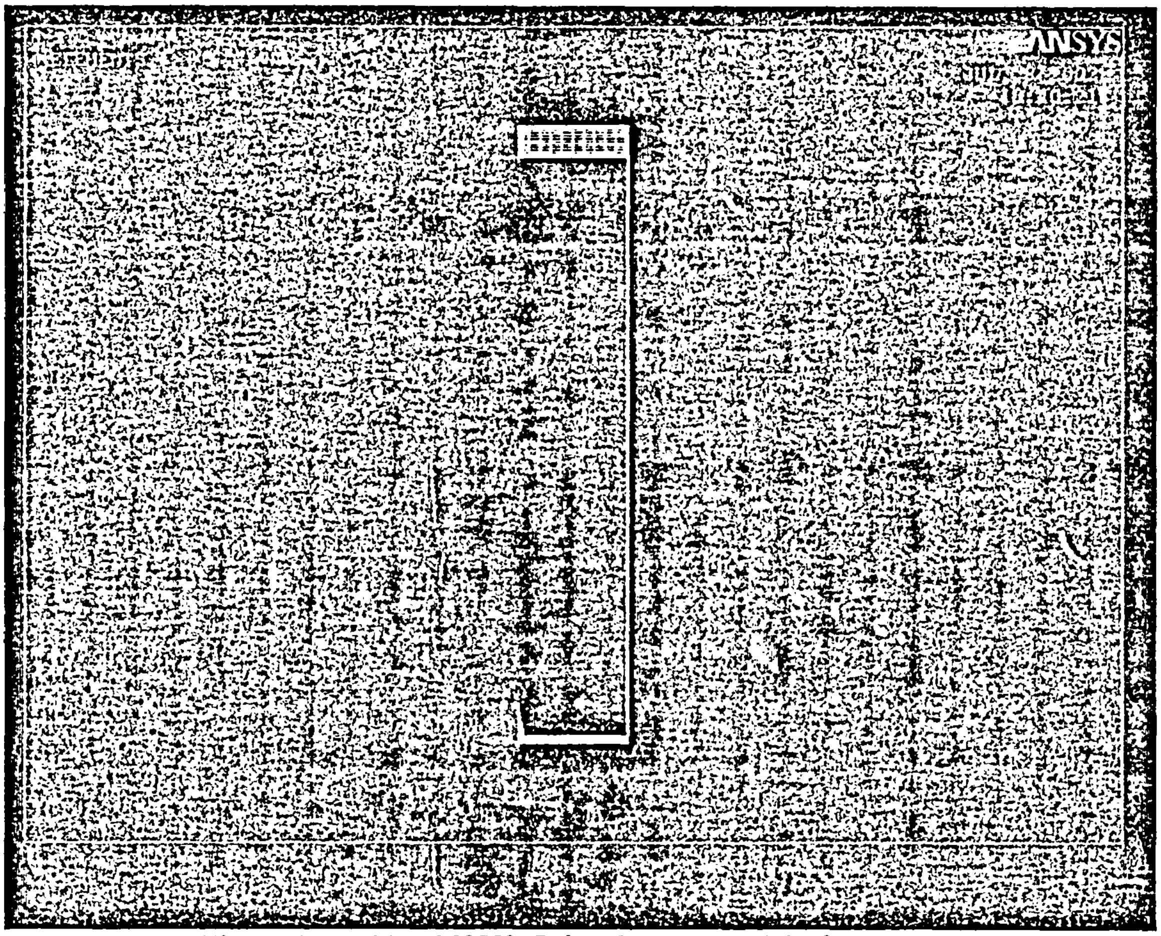

Figure 1.1A-11 ANSYS finite element model of the MPC.

Task 1.1B: Thermal Analyses

Thermal analysis of an HI-STORM cask in the undamaged state has begun. A three-dimensional, quarter symmetry, fire simulation of the HI-STORM storage container was prepared in the Vulcan CFD code. The simulation consists of a standing cask subjected to an engulfing fire. The problem domain extends approximately 25m in all three dimensions and is discretized into approximately 450,000 nodes. Zero-wind boundary conditions were applied to the vertical and top boundaries, and a standard solid wall boundary was used for the ground. The fuel bed was placed at ground level. The bed surrounds the cask and extends approximately 4.5m away from the edge of the cask. The fuel is JP8.

Preliminary results of simulation runs at 45 seconds showed temperatures in the range of 800 to 1400 K at the outer perimeter of the cask (see Figure 1.1B-1). Maximum temperatures were observed near the top of the cask, close to the mouth of the ducts. Temperatures within the first 0.2m of the upper ducts range between 500 and 1300 K (see Figure 1.1B-2). Fire conditions inside the cask are still developing. Temperatures in this region are currently below 500 K.

In summary, current temperature range may not be indicative of the maximum achievable temperatures. The current plans are to run simulation for at least another 60 seconds or until quasi-steady state flow conditions are reached inside the cask. Temperature and heat flux results obtained from this simulation will be used for heat transfer analysis of the MPC canister.

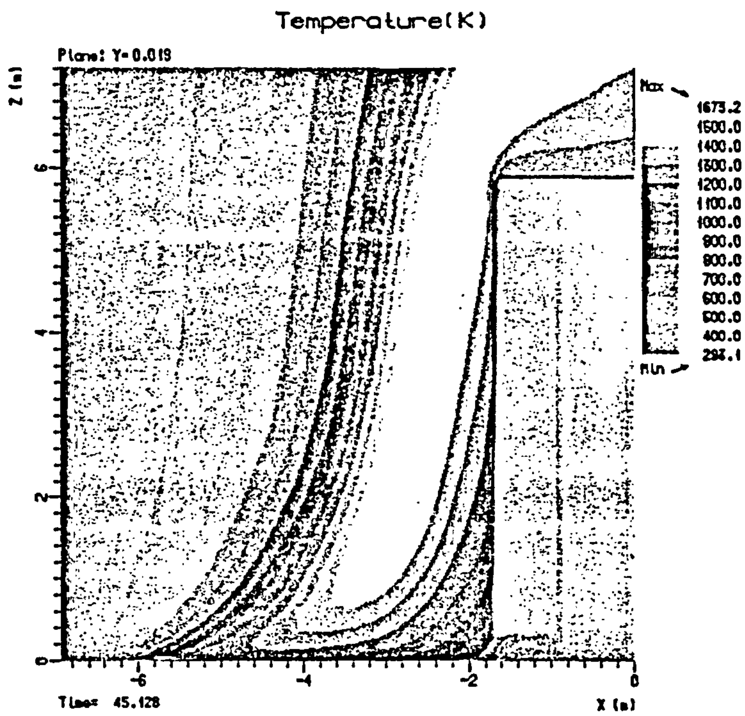

Figure 1.1B-1. Front View of High-Storm Container

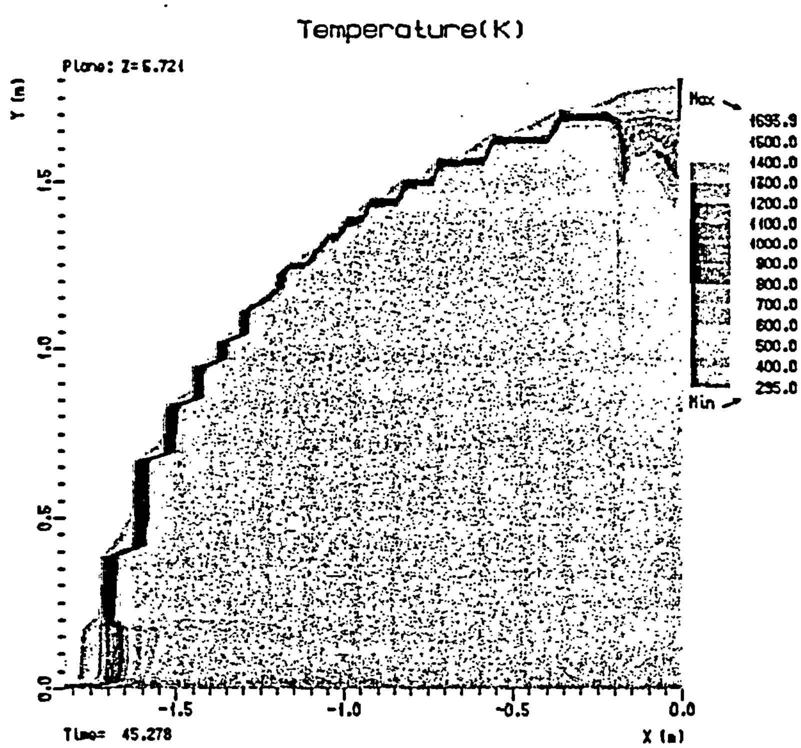

Figure 1.1B-2. Top View High-Storm Container

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Task 1.2: Crash of Small Plane Loaded with into an ISFSI

Ex 2

Task 1.2A: Planes, Scenarios

Progress has been made on Tasks 1.2Ai-v. The NRC was briefed on this effort at the meeting at SNL in June. The spreadsheets with the tables developed and the PowerPoint presentation from that meeting are included on the companion CD with this report. The files are located in the directory TASK1-2.

Task 1.3: Simplified Large Plane Model

This task calls for the development of a simplified finite element model of a aircraft and also of the HI-STORM cask for analyses to be conducted on a PC using ANSYS/LS-DYNA. Currently, an approach for this task is being developed. However, hardware problems have been encountered with ANSYS/LS-DYNA on our PC running Windows 2000. ANSYS support has been contacted to examine if there is a solution. If that cannot be resolved, we believe ANSYS/LS-DYNA will work on this PC running LINUX. Therefore, one possible solution is to convert to that operating system. Once the hardware problem is resolved we will examine running a problem similar to those run in Task 1.1a. We expect it to be difficult to model the aircraft on a PC. However, we do expect to be able to examine simplified cask models impacted by simplified hard-points on the aircraft. We expect to be able to submit a suggested methodology for this task to the NRC by July29th. Ex 2

Task 1.4: Large Jetliner Crash into a Spent Fuel Rail Cask

Task 1.4A: Mechanical Analyses

Currently, a PRONTO model of the cask has been developed. No analyses have been conducted.

Task 1.4B: Thermal Analyses

Carlos

Task 2: Weapons, Radioactive Materials, Consequences

Ex 2 portions