Preprint
UCRL-JC-140361

Latest Capabilities of Pov-Ray Ricochet Tracker: Ricochet Flight Path Analysis & Impact Probability Prediction Software

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This article was submitted to
Twenty-Ninth United States Department of Defense Explosives Safety Seminar, New Orleans, LA, July 18-20, 2000

U.S. Department of Energy

Lawrence Livermore National Laboratory

September 5, 2000

LATEST CAPABILITIES OF POV-RAY RICOCHET TRACKER: RICOCHET FLIGHT PATH ANALYSIS & IMPACT PROBABILITY PREDICTION SOFTWARE[1]

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POV-Ray Ricochet Tracker is a freeware computer code developed to analyze high-speed fragment ricochet trajectory paths in complex 3-D areas such as explosives firing chambers, facility equipment rooms, or shipboard Command and Control Centers. The code analyzes as many as millions of individual fragment trajectory paths in three dimensions and tracks these trajectory paths for up to four bounces through the three-dimensional model. It allows determination of the probabilities of hitting any designated areas or objects in the model. It creates renderings of any ricochet flight paths of interest in photo realistic renderings of the 3-D model. POV-Ray Ricochet Tracker is a customized version of the Persistence of Vision™ Ray-Tracer (POV-Ray™) version 3.02 code for the Macintosh™ Operating System (MacOS™).

POV-Ray is a third generation graphics engine that creates three-dimensional, very high quality (photo-realistic) images with realistic reflections, shading, textures, perspective, and other effects using a rendering technique called ray-tracing. It reads a text file that describes the objects, lighting, and camera location in a scene and generates an image of that scene from the viewpoint of the camera. More information about POV-Ray, including the executables and source code, may be found at <http://www.povray.org>.

The customized code (POV-Ray Shrapnel Tracker, V3.02 – Custom Build 2) generates individual fragment trajectory paths at any desired angle intervals in three dimensions. The code tracks these trajectory paths through any complex three-dimensional space, and outputs detailed data for each ray as requested by the user. The output may include trajectory source location, initial direction of each trajectory, vector data for each bounce point, and any impacts with designated model target surfaces during any trajectory segment (direct path or reflected paths). This allows determination of the three-dimensional trajectory of each simulated particle, as well as overall and individual fragment probabilities of impact with any designated target(s) in the three-

[1] Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-Eng-48

dimensional model. It also allows identification of any areas of particular concern due to grouping (in discrete areas) of fragment paths that lead to hits on the target areas of concern.

The default code output includes data for specified fragment paths up through four bounces, with the number of target hits for each path segment listed. Output is grouped by target number, arbitrarily assigned in order as the target objects are declared in the input model text file. Hits on the targets are listed by path segments (e.g., direct path, one bounce, two bounces, etc.). The code has the capability to output a separate data file containing full x, y, and z directional data for each fragment path, to output just the data for a user specified number of bounces, or to output data for just the paths that lead to hits on specified targets.

Output File Examples

Default File Output

```
File CFF NC .1_9
Trace level    5
Nominal trajectory spacing (degrees)    0.100000
Total trajectories        4126180.000000
Origin(x,y,z)  -2.920000 6.630000  4.000000
Object  0 0    46   139  251  247
0.0-10.0  0    0    0    0    0
10.0-20.0 0    0    0    53   11
20.0-30.0 0    0    9    29   59
30.0-40.0 0    13   62   91   90
40.0-50.0 0    17   38   44   34
50.0-60.0 0    0    23   14   17
60.0-70.0 0    16   7    20   36
70.0-80.0 0    0    0    0    0
80.0-90.0 0    0    0    0    0
```

User Requested Path Data File Output

```
Ray start: alt = 44.500002, azimuth = 114.953272, Dir vector =
<-0.700909, -0.300905, 0.646670>
hit at (x,y,z) -25.627517,-11.002076,27.644355
hit at (x,y,z) -2.585912,-21.717526,2.696704
hit at (x,y,z) -2.535055,-21.902535,2.508333 (Object 4)
hit at (x,y,z) -2.488467,-22.072013,2.680891
hit at (x,y,z) -4.672186,-25.271000,6.483473
Ray start: alt = 47.300000, azimuth = 117.641279, Dir vector =
<-0.734915, -0.314622, 0.600761>
hit at (x,y,z) -27.109906,-11.605922,26.161180
```

```
hit at (x,y,z) -7.753786,-21.736249,2.508333 (Object 6)
hit at (x,y,z) -0.999902,-25.271000,10.761464
hit at (x,y,z) 14.556401,-17.129366,29.771000
hit at (x,y,z) 27.271000,-10.474983,14.233978
```

Output File Examples [with comments for clarity]

Default File Output [One data block per designated target]

```
File CFF NC .1_9  [Filename, user designated, for user reference when
reviewing data.]
Trace level    5  [Direct path plus four bounces.]
Nominal trajectory spacing (degrees)    0.100000  [Angular resolution of
fragment paths.]
Total trajectories       4126180.000000  [Number of fragments modeled,
determined based on angular resolution. Smaller angles require many more
fragments.]
Origin(x,y,z)  -2.920000 6.630000  4.000000  [3-D model coordinates of
shrapnel point of origin]
Object  0 0    46   139  251  247  [Target number, then hit summaries for
direct path, one bounce, two bounces, etc. This table is repeated for each
user designated target.]
0.0-10.0  0    0    0    0    0  [Same as above, but in angle of impact
groups of 10 degrees, user selectable.]
```

User Requested Path Data File Output [There will be one of these data blocks for EACH fragment being analyzed, so expect LOTS of data if detailed output is selected. For high resolution (low angular spacing) runs, detailed output should be selected for only fragments that hit a target, to limit data file size.]

```
Ray start: alt = 44.500002, azimuth = 114.953272, Dir vector =
<-0.700909, -0.300905, 0.646670>  [Specific info for this fragment, two
forms of data for direction]
hit at (x,y,z) -25.627517,-11.002076,27.644355  [Direct path impact point
in model]
hit at (x,y,z) -2.585912,-21.717526,2.696704  [First bounce impact point
in model]
hit at (x,y,z) -2.535055,-21.902535,2.508333 (Object 4) [Second bounce
impact point in model, note that "Object 4" designates an impact with
target # 4. Since the fragment hit a target, further bounces are usually
ignored.]
```

POV-Ray Ricochet Tracker was recently used to analyze laser power conditioning system module failures for the U.S. Department of Energy (DOE) National Ignition Facility (NIF). NIF is an inertial confinement laser fusion experimental facility currently under construction at the Lawrence Livermore National Laboratory (LLNL). The NIF will be an enormous facility, about 200 meters long by 85 meters wide. The NIF's laser system will have 192 beams that are arranged in 24 bundles of 8 beams each, which will produce about 500 TW of power (1.8 MJ over four billionths of a second). The laser light is in the ultraviolet spectrum at a wavelength of 0.35 μm. The beams will precisely compress and heat a one to three millimeters diameter target containing deuterium-tritium fuel to 100 million degrees. The NIF's construction began in 1997, and experiments may begin in 2003. The NIF mission is to achieve inertial confinement fusion ignition, contribute to the development of inertial fusion for electrical power generation, provide simulation capability for nuclear weapons effects testing, and to support basic science and technology.

The NIF facility will contain four capacitor bays, with as many as 48 2 megajoule capacity laser power conditioning system capacitor modules each. The First Article NIF Test Module (FANTM) at Sandia National Laboratories in Albuquerque is a prototype demonstration facility for the NIF equipment. Demonstration efforts with FANTM took place over a 10-month period in 1998 and 1999. During that time, five catastrophic power module failures occurred. These events resulted in pressurization of the module, and the generation of energetic shrapnel. In some cases capacitor cases ruptured, spraying dielectric fluid into the module cavity, and the oil mist ignited, generating a dramatic fireball.

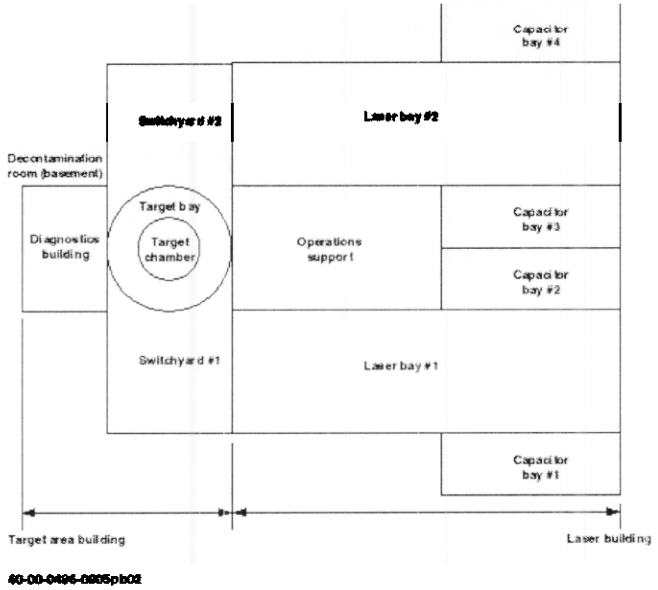

Figure 1. Layout of the National Ignition Facility

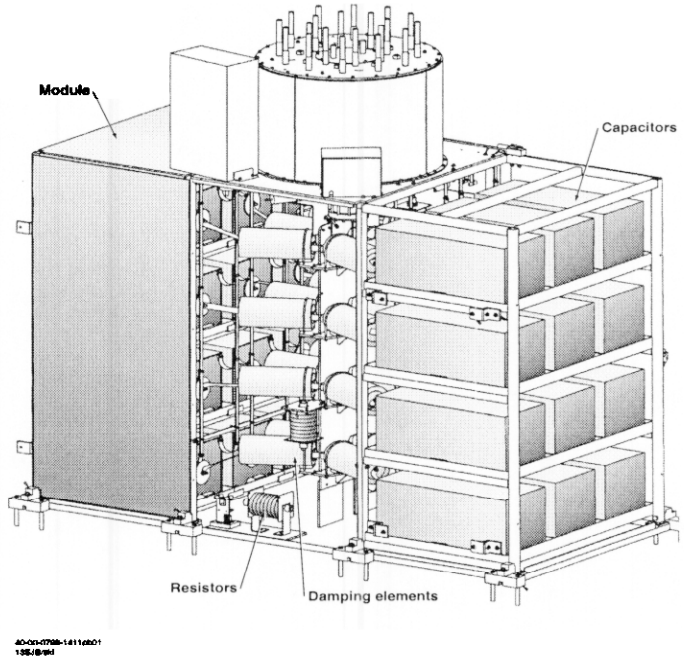

Figure 2. Schematic of a Capacitor Module Approximately 11'3" x 5'2" x 10' 1 1/2"

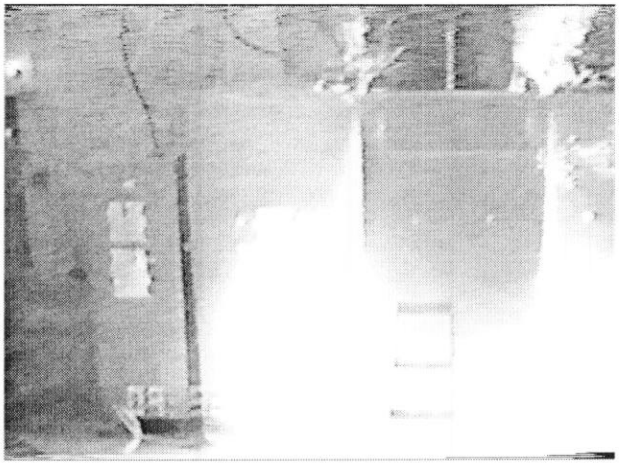

Figure 3. Fireball exiting the capacitor module during FANTM Event #1

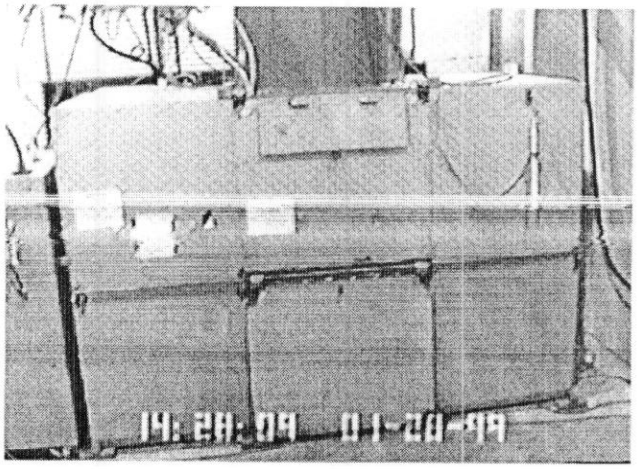

Figure 4 View of capacitor module for FANTM Event #5 (the bottom-half door, the top-half door, and the small flapper door at the center could all swing open)

The POV-Ray Ricochet Tracker code was used to perform two different analyses for NIF: to quantify the probability of shrapnel hits on specific areas of the equipment room walls and ceiling, and to optimize the design of shrapnel trapping doors for the modules. With the original design of hinged doors, any energetic shrapnel was free to hit any object in the room. With a bolted door design, the doors need vent openings to relieve the pressure from any capacitor failure initiated oil deflagration. After several proposed design variations were modeled with POV-Ray Ricochet Tracker, a labyrinth door design that will trap all shrapnel through at least three bounces was developed.

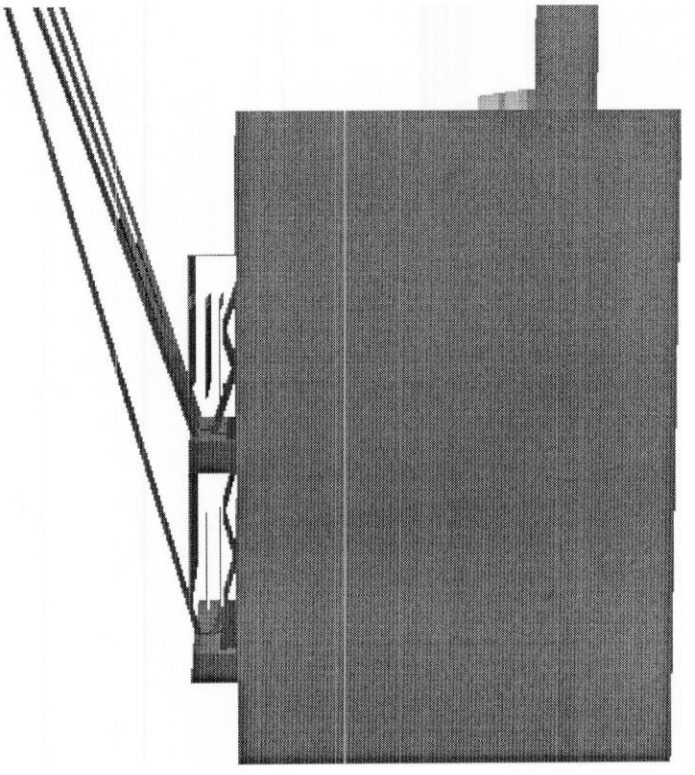

Figure 5. Side view of a modified capacitor module with shrapnel trapping doors, with representative shrapnel paths depicted.

Due to specific requirements of this analysis, new capabilities were added to the POV-Ray Ricochet Tracker code. Capabilities added include: user selectable automatic focus of the analysis on high impact probability targets; user selectable automatic generation of graphical ricochet path rendering data, with automatic selection of highest probability paths for rendering; and an unlimited number of designated impact targets.

In a space as large as the NIF capacitor bays it is desirable to concentrate the analysis effort on the areas of the highest impact probability. The automatic focus feature of POV-Ray Ricochet Tracker selects the areas of highest impact probability and performs a higher resolution analysis of these areas. Both the coarse resolution and the high resolution angular spacing is user selectable.

With millions of possible shrapnel paths, it is difficult for the analyst to quickly select the proper shrapnel paths to render graphically to aid in visualization of the impact of probable shrapnel paths. The automatic rendering data feature selects the shrapnel paths with the highest impact probability with designated targets and generates the data to graphically depict just those paths.

Summary:

POV-Ray Ricochet Tracker provides an analysis method for quantifying potential shrapnel impact probability for discrete target areas in any complex three-dimensional space. Its user selectable output allows for identification and graphical visualization of the flight paths and potential impact areas of the shrapnel paths of most concern with any designated target(s) in the 3-D model. This allows identification of specific areas contributing to impacts, and aids shielding design or facility modification to reduce shrapnel impact frequencies on specific areas or objects.