LA-UR-18-22542
Approved for public release; distribution is unlimited.

Title: Test Problems for Programmed Burn

Author(s): Smith, Brandon Michael

Intended for: Report

Issued: 2018-03-26

Test Problems for Programmed Burn

Brandon Smith

March 8, 2018

NNSA
National Nuclear Security Administration
Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

This document presents updated FLAG results for the Kenamond programmed burn test problems.

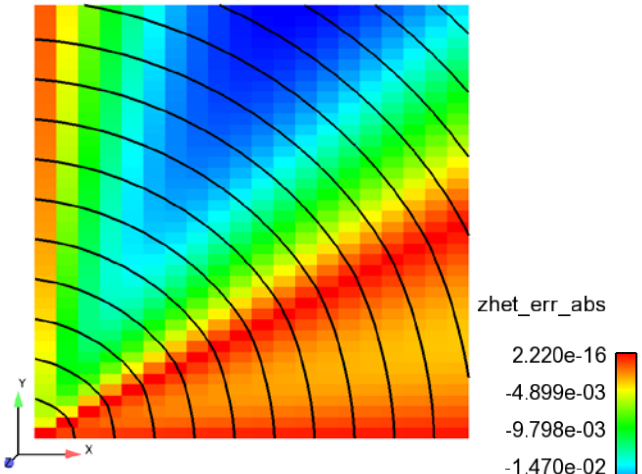
- **Problem definition, exact solutions for constant detonation velocity, and FLAG results using a Huygens solution are provided in Kenamond's "Lund High Explosive Programmed Burn Model in the FLAG Code" LA-UR-09-08297.**
- **FLAG results using Line-of-Sight (LOS) preconditioning of the Huygens solution are presented in Kenamond's "Line-of-Sight (LOS) High Explosive Programmed Burn Model in the FLAG Code" LA-UR-09-08296.**
- **FLAG has an old, serial, uniform-grid "mapped" 2D DSD solver and a new, inline, parallel, conformal mesh 2D/3D DSD solver. These solvers will be exercised with flat Dn-Kappa relations to facilitate comparison with analytic solutions.**
- **The remaining slides document FLAG results with 1) Huygens, 2) Huygens with LOS, 3) old DSD, and 4) new DSD.**
- **By design, these geometries are coarsely meshed. Plotting error with respect to the analytic solutions reveals sensitivities to element type, element aspect ratio, boundary conditions, detonator timing, and discontinuous detonation velocity.**
- **In all plots of this document, color is absolute error relative to the exact solution.**
- **In all plots of this document, contours are burntime isochrones of the numerical solution.**

Problem 1: Unit Cube with a single detonation point

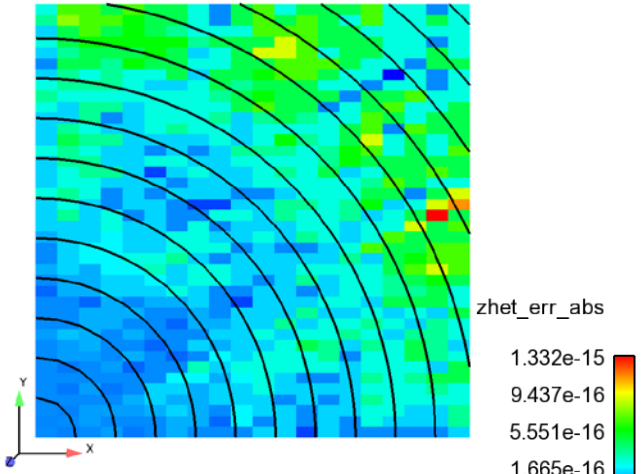
- **Infinite medium meshed as a unit cube**
- **20x40x20 zones in 3D, 20x40 zones in 2D**
- **d=1 cm/μs**
- **Point-detonated at (0,0,0)**
- **DSD solutions use a 0.15 cm radius circle detonator, based on guidance to have a minimum 6-8 zones across the diameter of a circle detonator.**
- ***Solved on uniform 0.035 cm grid—comparable to 0.05 x 0.025 grid of prescribed mesh.**
- ****Mesh is reflected instead of using reflective BCs due to a code issue.**

	2D Max Absolute Error [μs]	3D Max Absolute Error [μs]
Huygens	1.959e-2	2.507e-2
Huygens w/ LOS	1.332e-15	4.663e-15
Old DSD	4.319e-3*	-
New DSD	3.940e-2	9.363e-2**

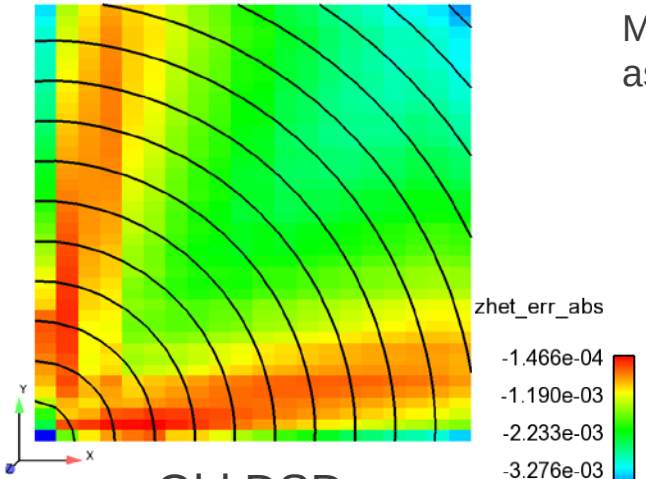
Problem 1: Unit Cube with a single detonation point



Huygens

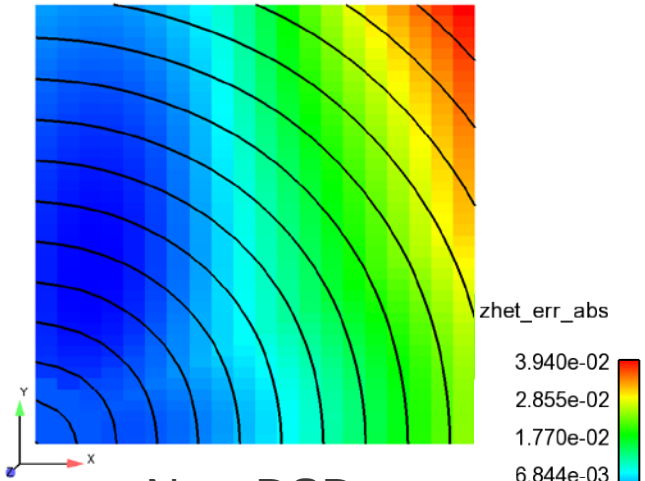


Huygens w/ LOS



Old DSD

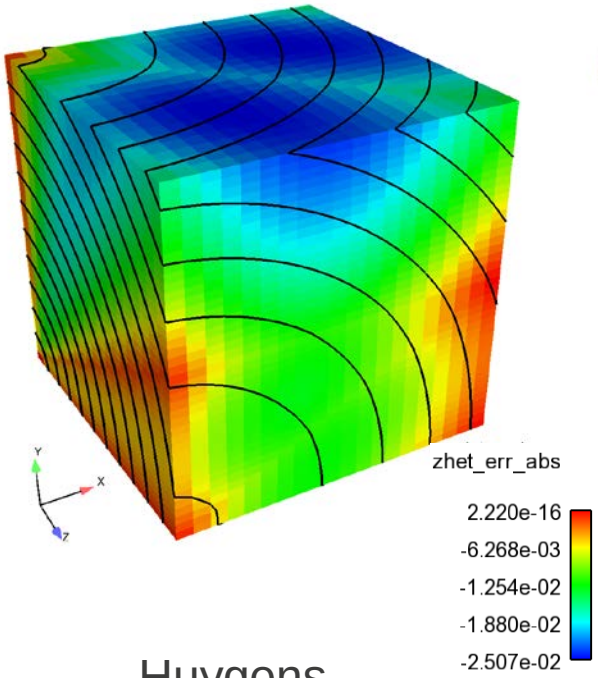
Mesh is 2:1 aspect ratio.



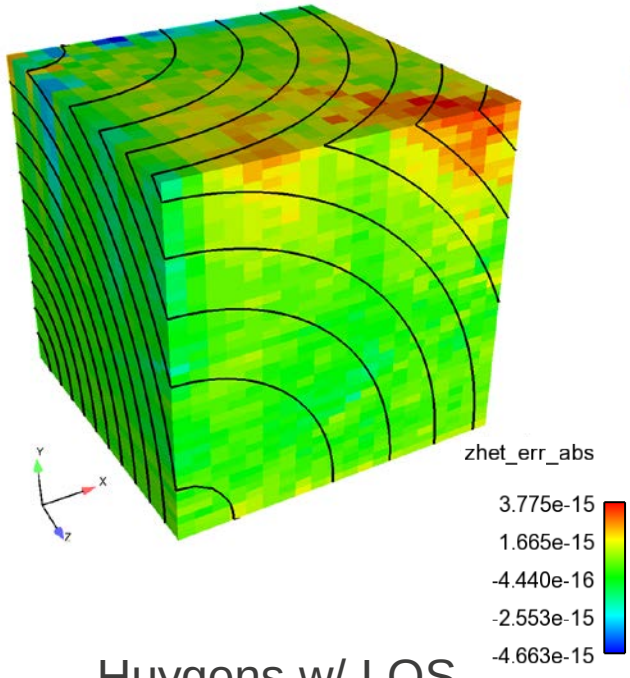
New DSD

Problem 1: Unit Cube with a single detonation point

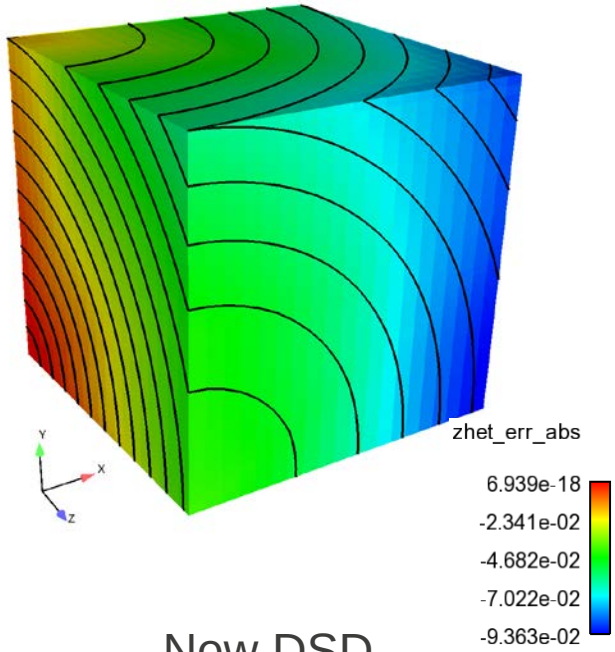
Mesh is 2:1:2 aspect ratio.



Huygens



Huygens w/ LOS



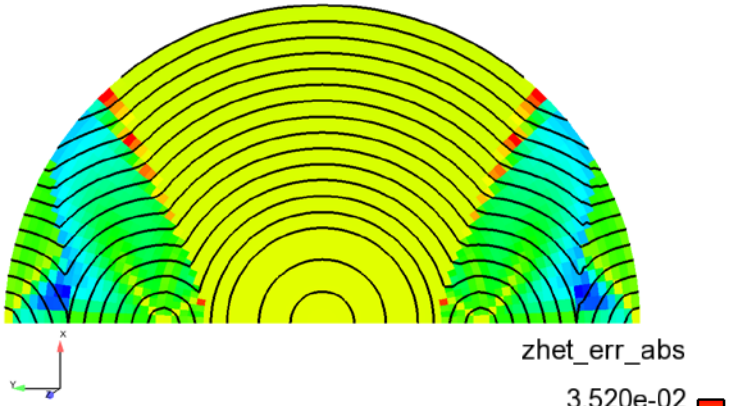
New DSD

Problem 2: Hemisphere with inner/outer HE regions and five detonation points

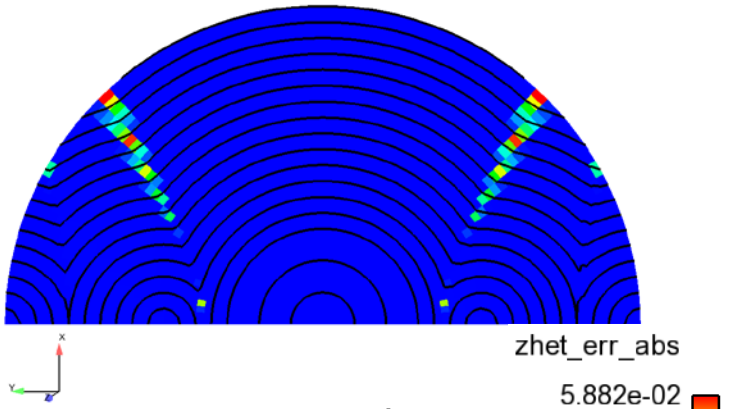
- **Two nested, concentric spheres of different HE with radii of 3 and 10 cm**
- **Uniform mesh of 40 radial zones from origin to r=10 cm and 64 azimuthal zones (180 degrees), 8 spun zones through 90 degrees.**
- **Inner HE d=2 cm/μs, outer HE d=1 cm/μs**
- **Five detonation points along an axis of symmetry at radii of 10, 5, 0, -5, and -10 cm**
- **Detonation times are asynchronous at 2, 1, 0, 1, and 2 μs**
- **DSD solutions use a 0.75 cm radius circle detonator, based on guidance to have a minimum 6-8 zones across the diameter of a circle detonator (10 cm/40 * 3 = 0.75 cm).**
- ***Solved on uniform 0.25 cm grid—matches dr of prescribed mesh.**
- ****Test reveals a code crash when applying symmetry BC.**

	2D Max Absolute Error [μs]	3D Max Absolute Error [μs]
Huygens	9.342e-2	9.009e-2
Huygens w/ LOS	5.882e-2	2.286e-2
Old DSD	1.182e-1*	-
New DSD	6.885e-1**	Code bug revealed.

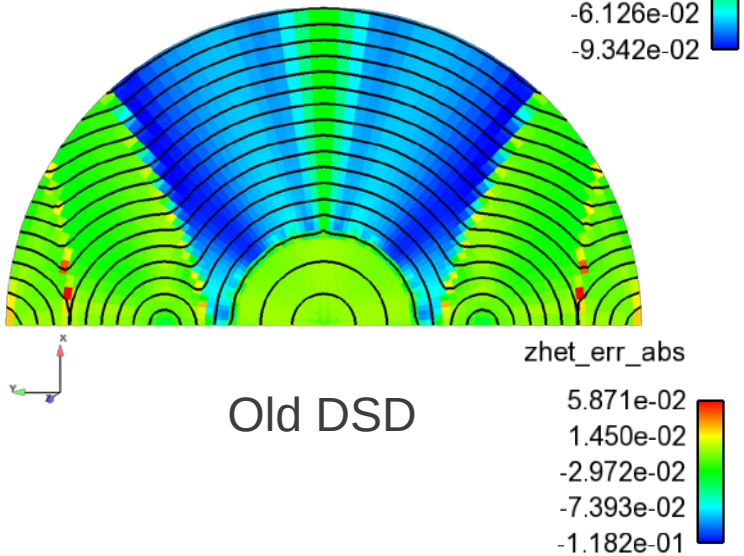
Problem 2: Hemisphere with inner/outer HE regions and five detonation points



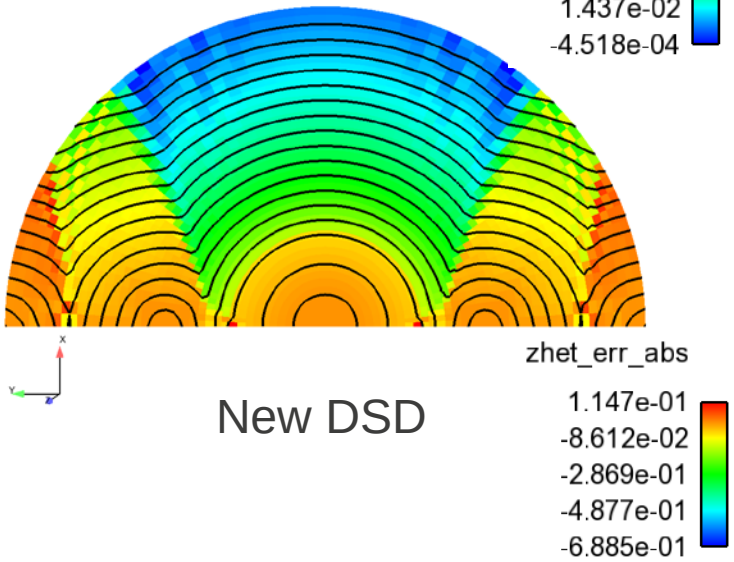
Huygens



Huygens w/ LOS

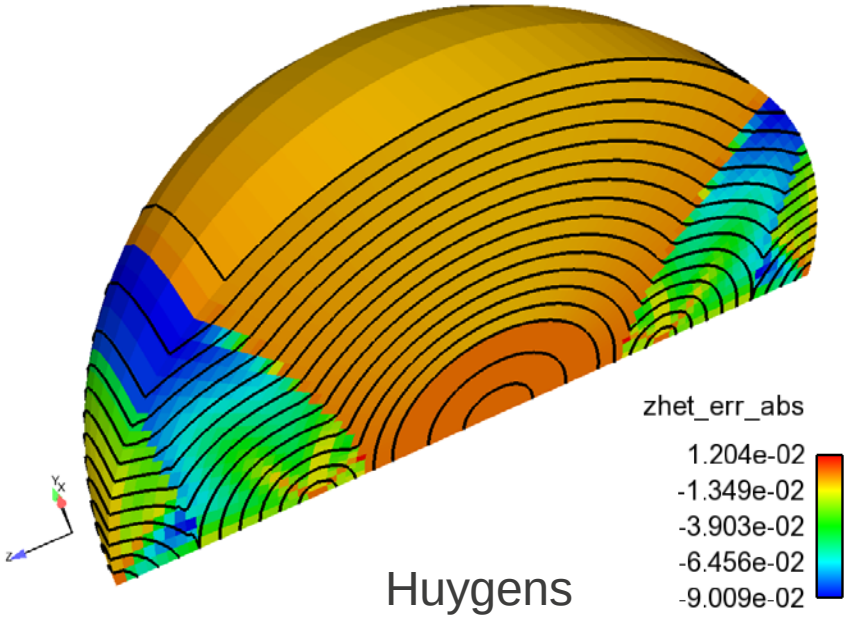


Old DSD

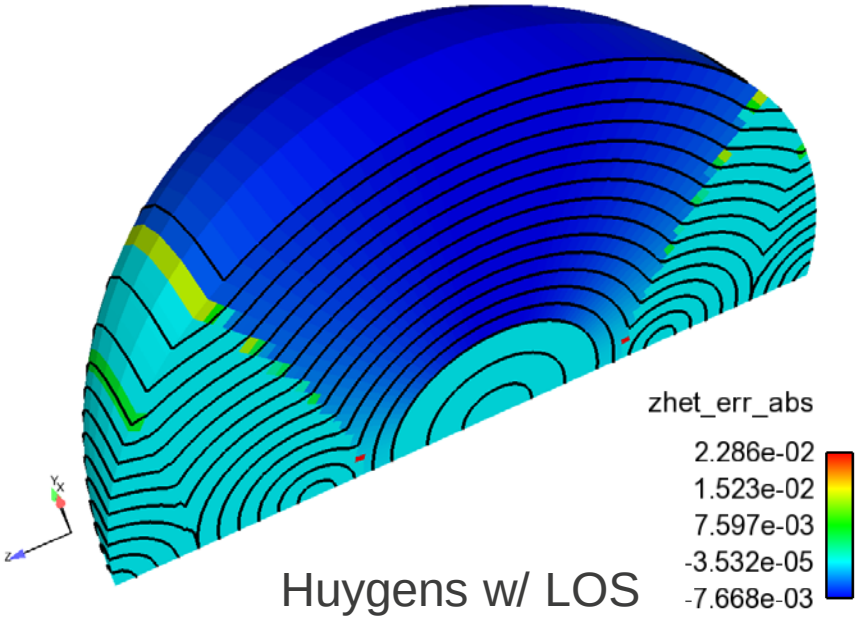


New DSD

Problem 2: Hemisphere with inner/outer HE regions and five detonation points



Huygens



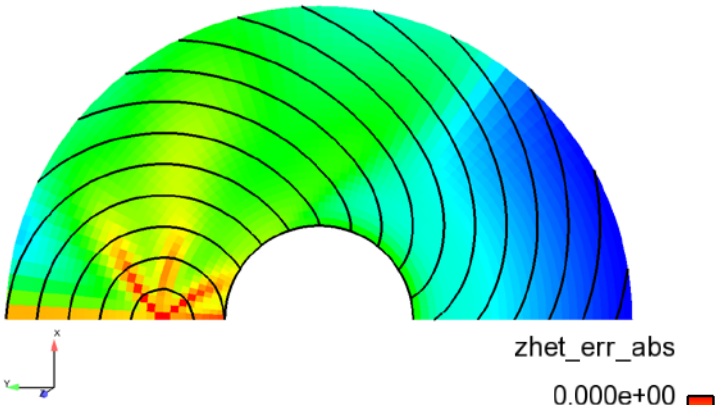
Huygens w/ LOS

Problem 3: Hemispherical annulus with a single detonation point

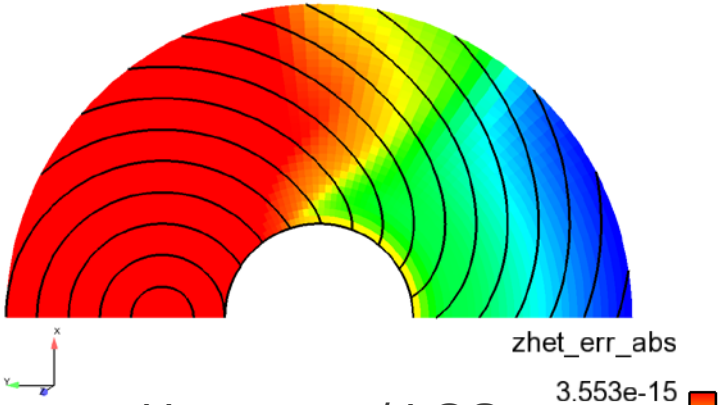
- **Two nested, concentric spheres of with radii of 3 and 10 cm**
- **Inner sphere is inert**
- **Uniform mesh of 40 radial zones from origin to r=10 cm and 64 azimuthal zones (180 degrees), 8 spun zones through 90 degrees.**
- **Mesh is translated such that the center of the sphere is at (0,10,0)**
- **d=2 cm/μs**
- **Point detonated at (0,15,0)**
- **DSD solutions use a 0.75 cm radius circle detonator, based on guidance to have a minimum 6-8 zones across the diameter of a circle detonator (10 cm/40 * 3 = 0.75 cm).**
- ***Solved on uniform 0.25 cm grid—matches dr of prescribed mesh.**

	2D Max Absolute Error [μs]	3D Max Absolute Error [μs]
Huygens	5.673e-2	5.804e-2
Huygens w/ LOS	3.796e-2	3.932e-2
Old DSD	3.062e-1*	-
New DSD	2.439e-1	2.606e-1

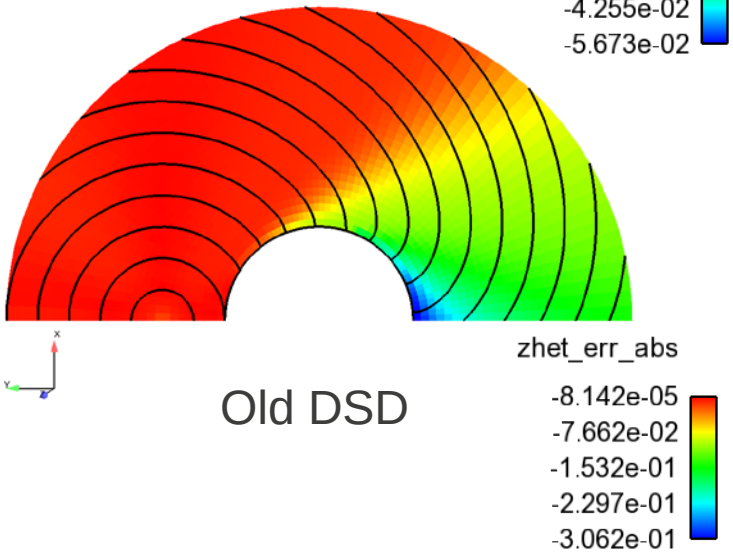
Problem 3: Hemispherical annulus with a single detonation point



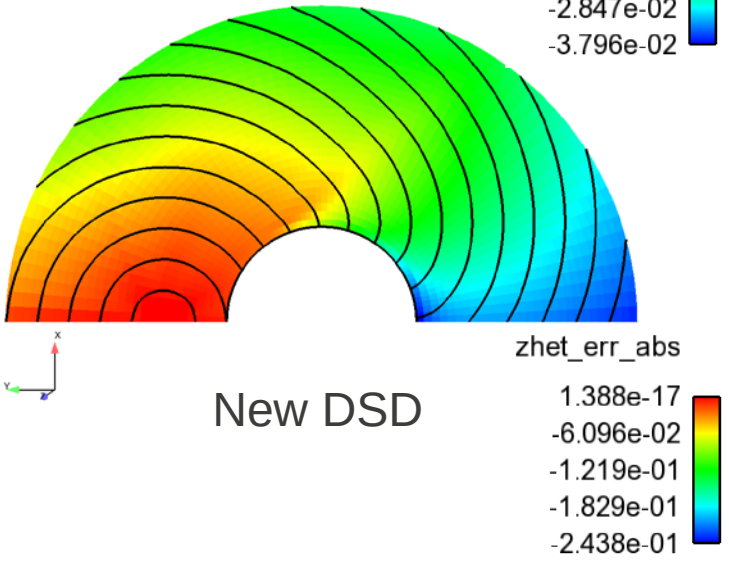
Huygens



Huygens w/ LOS

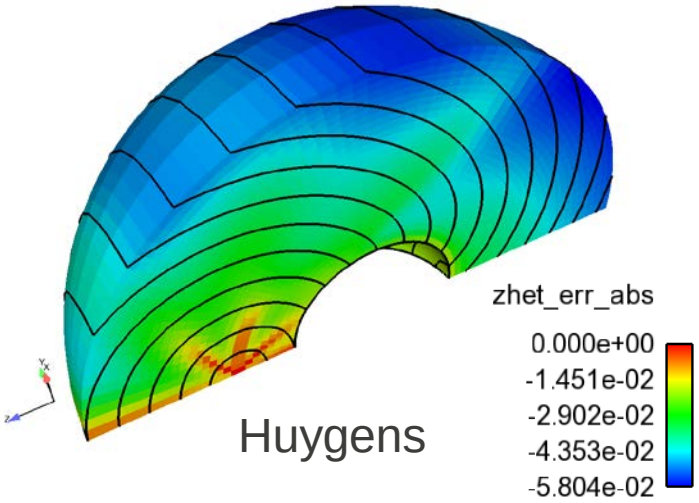


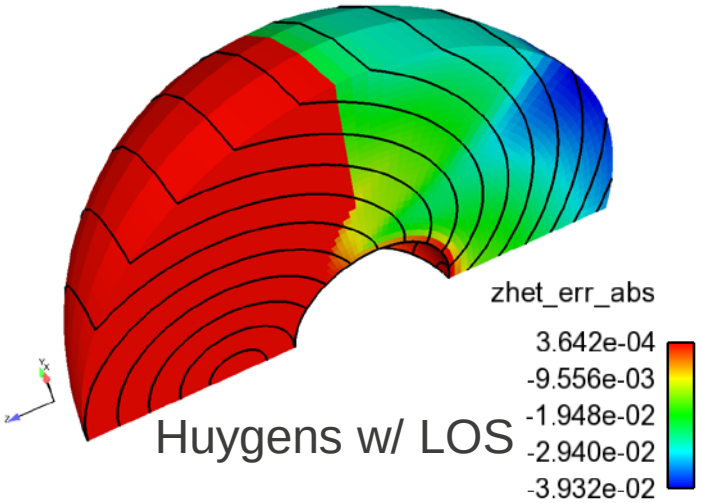
Old DSD

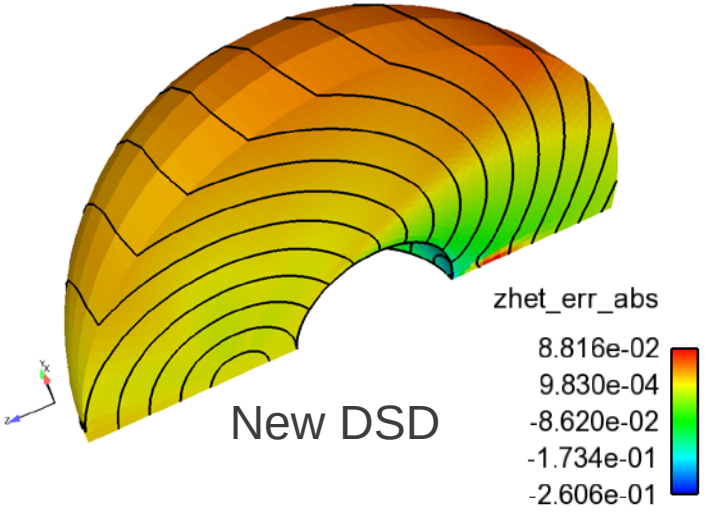


New DSD

Problem 3: Hemispherical annulus with a single detonation point







Two Huygens solvers and two DSD solvers were applied to the Kenamond programmed burn test problems.

- In all cases the Huygens solution with line-of-sight preconditioning resulted in the least absolute error.
- Although not shown here, DSD solutions using Flag's new algorithm are expected to have superior accuracy due to conformal mesh boundaries.
- The ability of Flag's old DSD algorithm to use its own mesh decouples the accuracy of the DSD solution from the underlying Flag mesh. This is an advantage for coarse Flag meshes.
- This was a valuable exercise. While the new DSD solver performed well in Problem 3, issues were revealed by Problem 1 and Problem 2.