Modeling of MANTA, a Point to Line Generator

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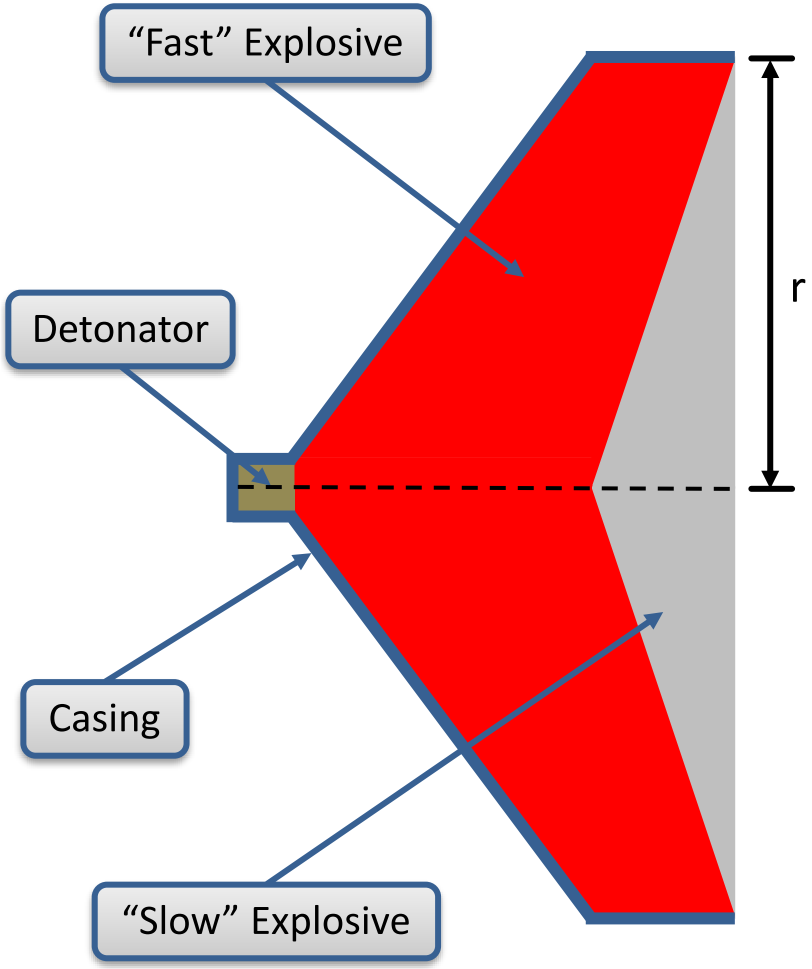
Plane wave generators are used to accelerate flyer plates for the measurement of dynamic material properties.



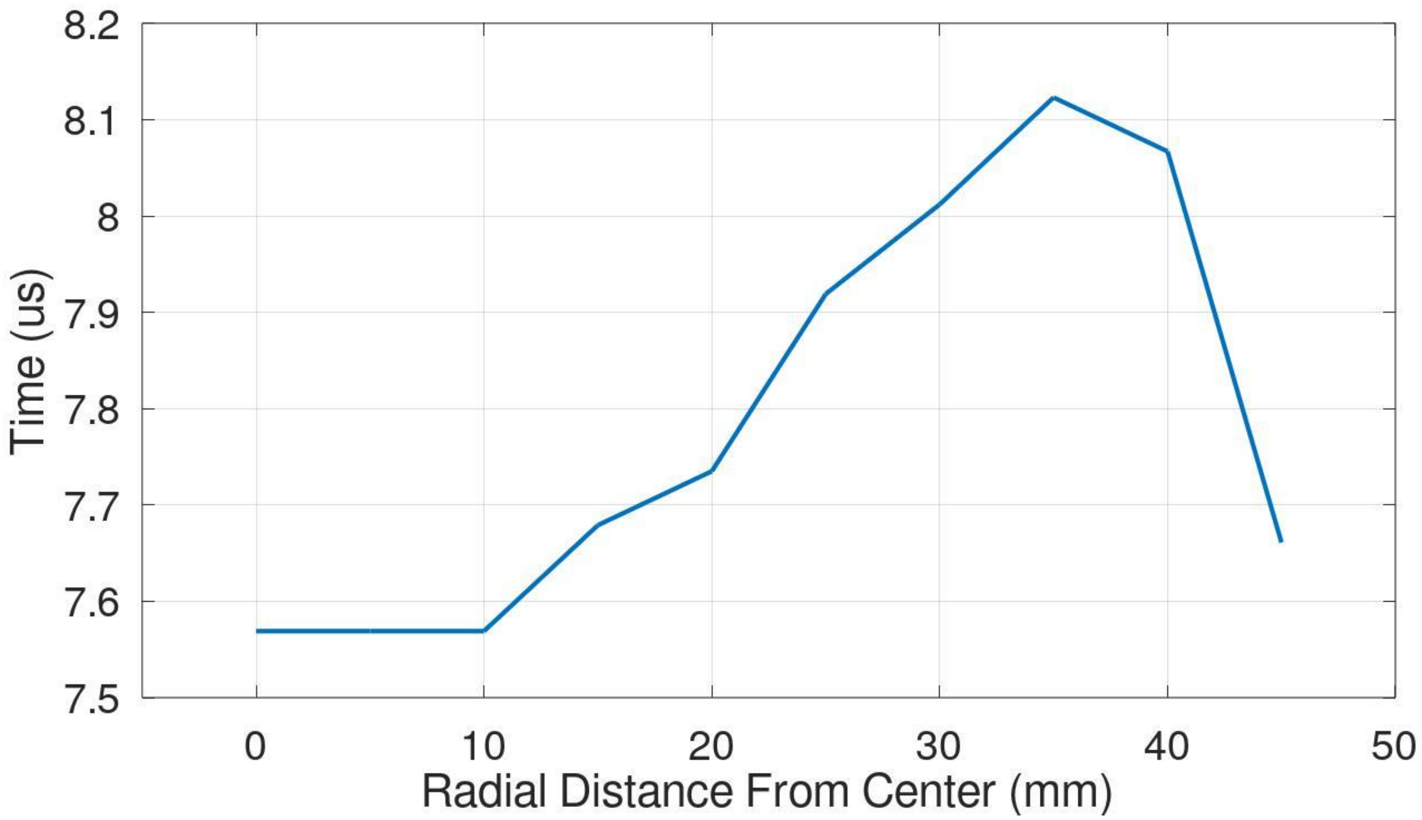
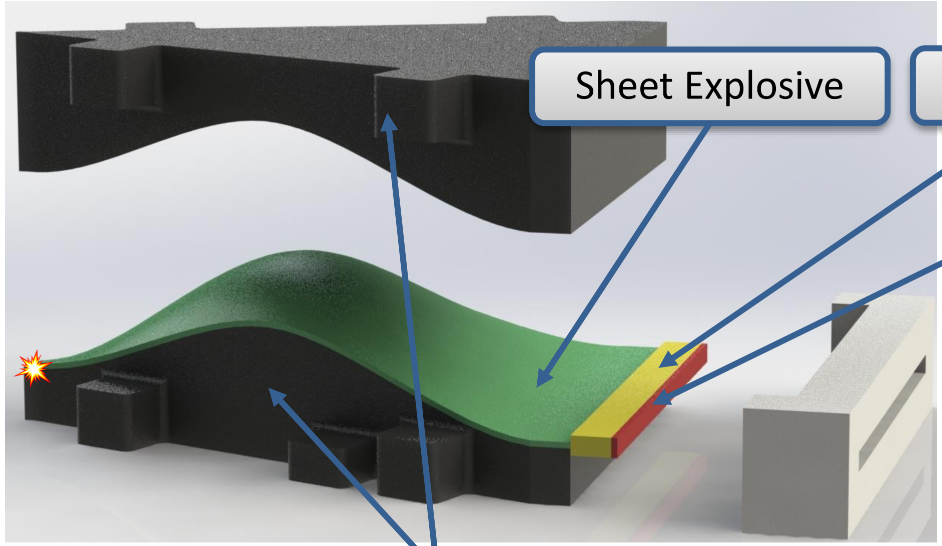
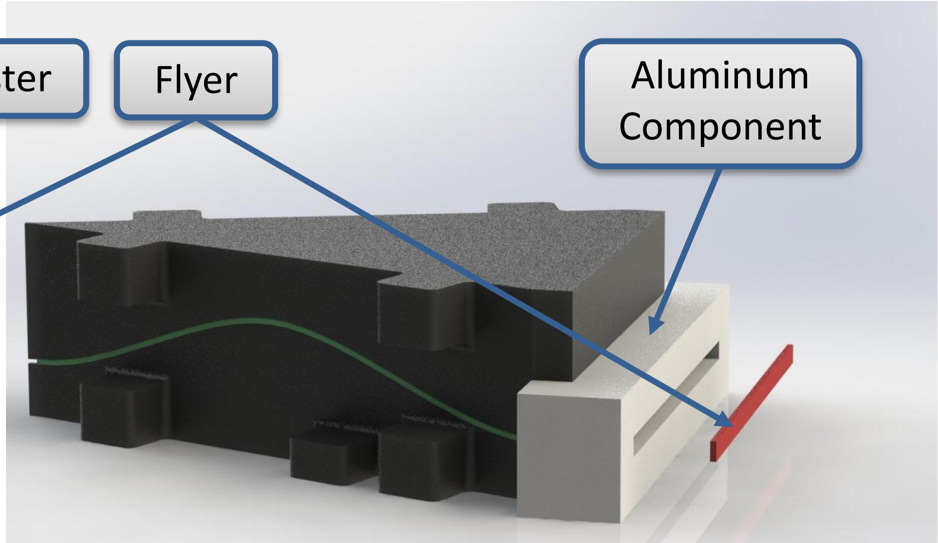


Figure: Arrival Time for Standard Plane Wave Generator [1]

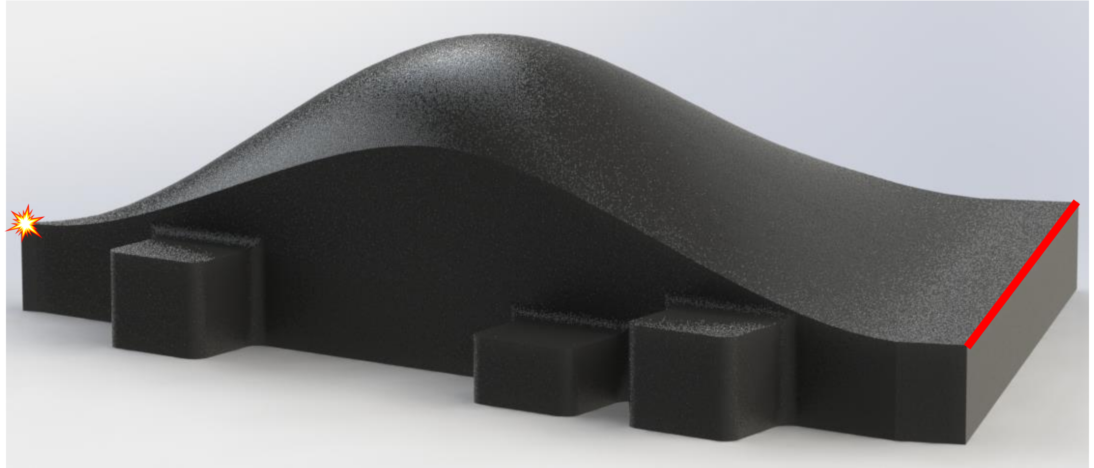
What is MANTA?



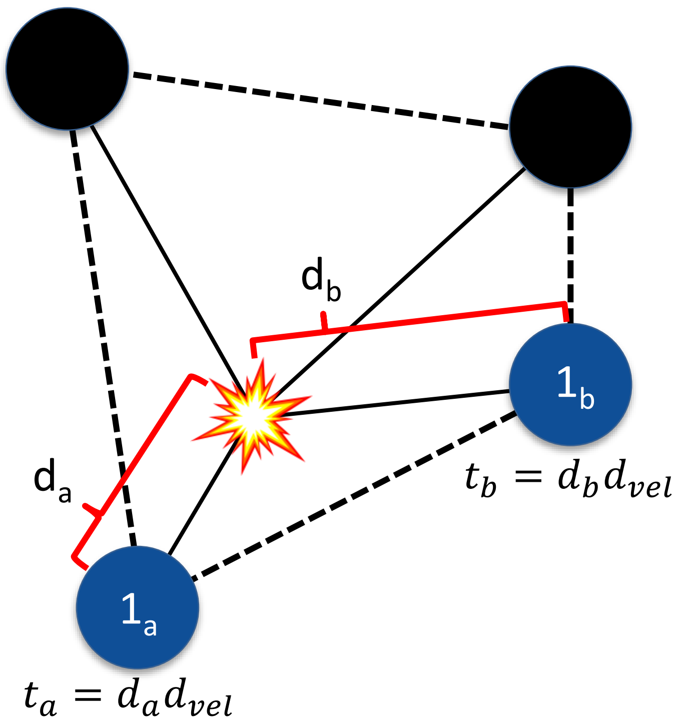


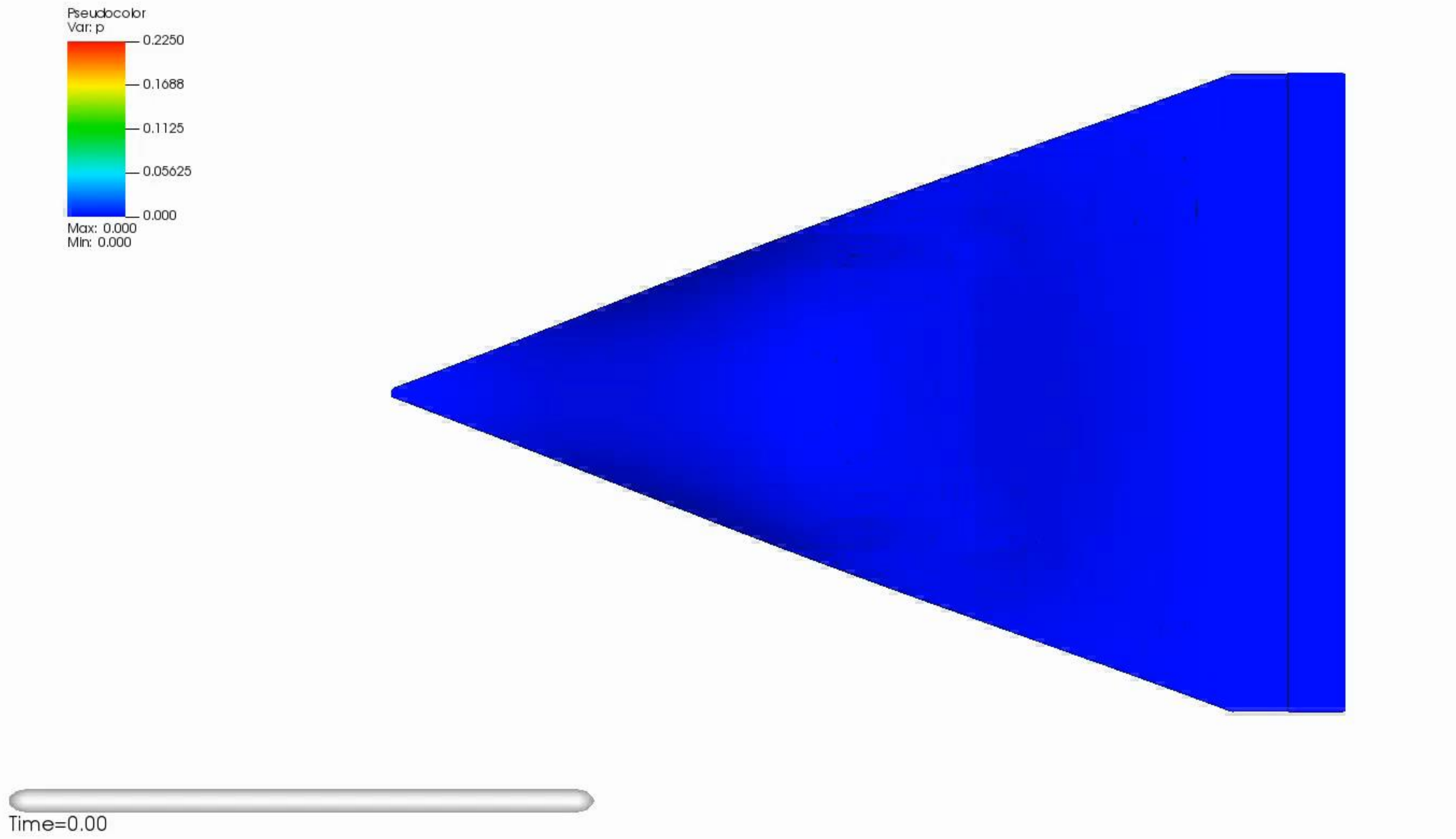
<u>Design Goal</u>

Take a Single Point of Initiation and spread out to a Line Initiation



The Lund programmed burn model yields results qualitatively similar to experimental results.





The relative arrival times of the simulation match best near the centerline of the device.

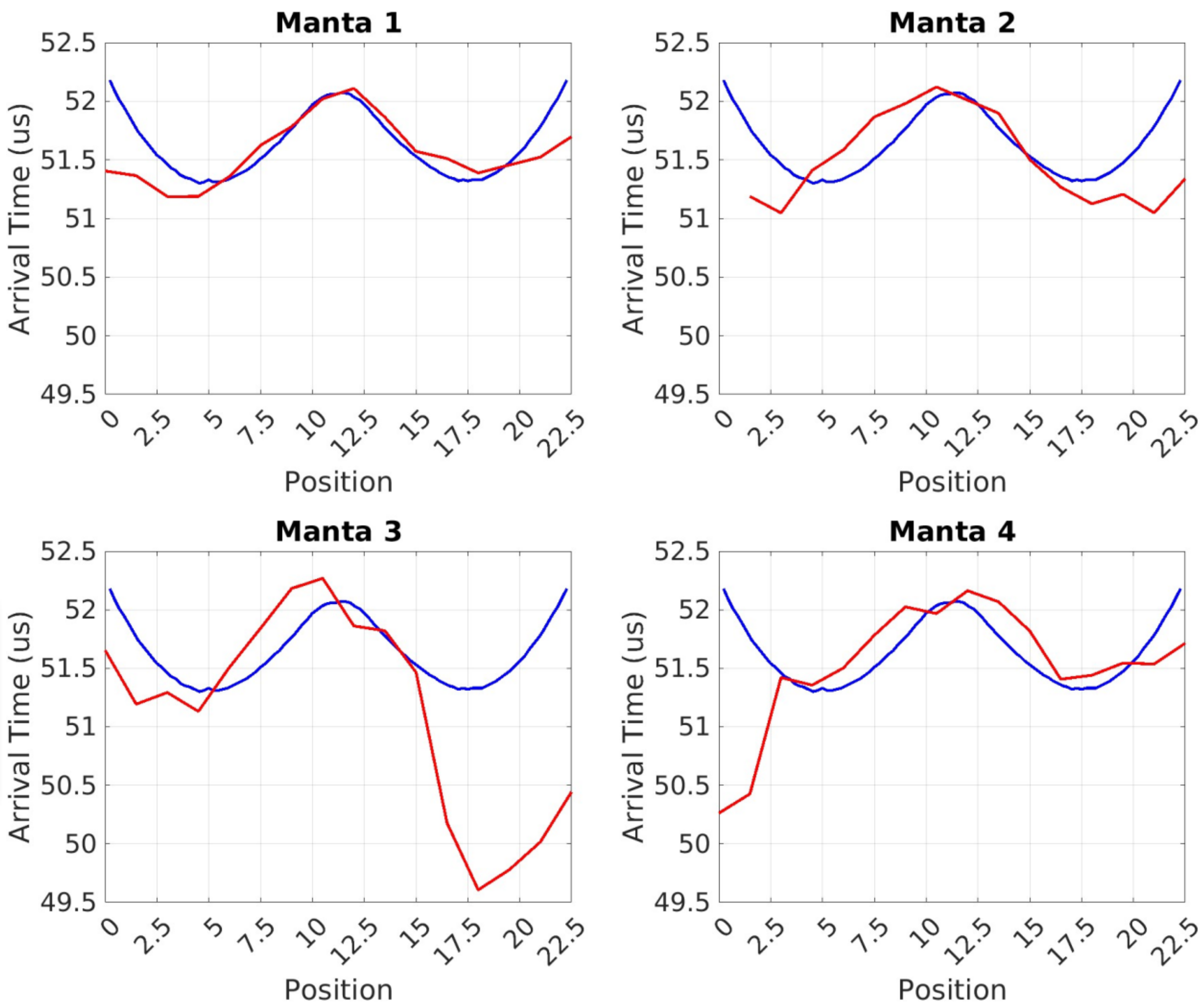
- The best experimental simultaneity was 0.922 μs

- The ALE3D model resulted in a simultaneity of 0.99 µs

- This is a 7.4% relative difference

Why?

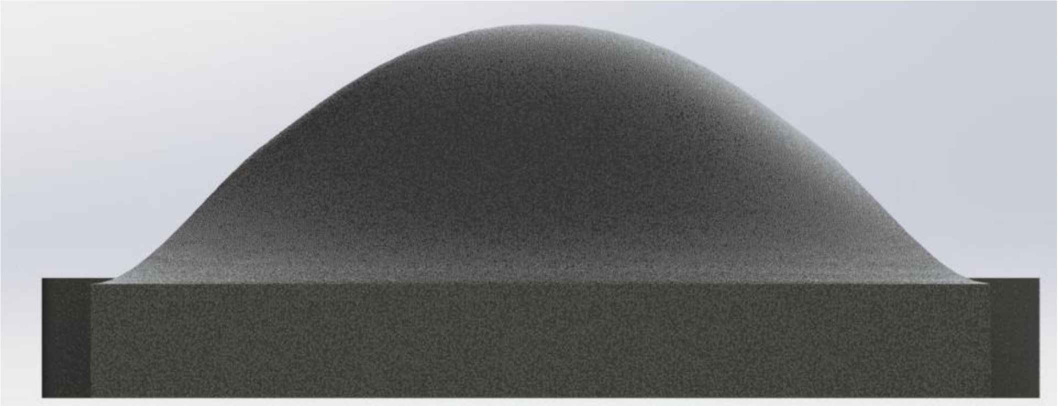
- Density
- Reaction Mechanics
- Edge Effects
- etc…



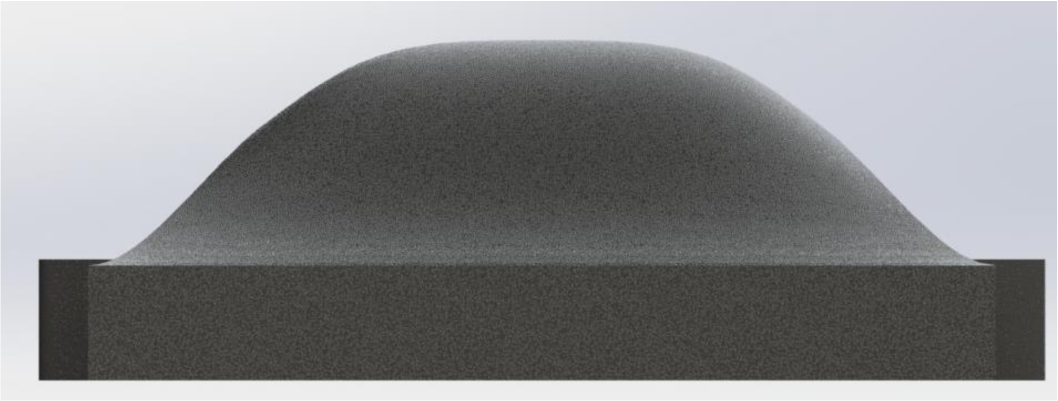
Alignment is best in the middle of the device where outside effects are minimal

Alignment is worst at the edges where the explosive sheet has an exposed edge

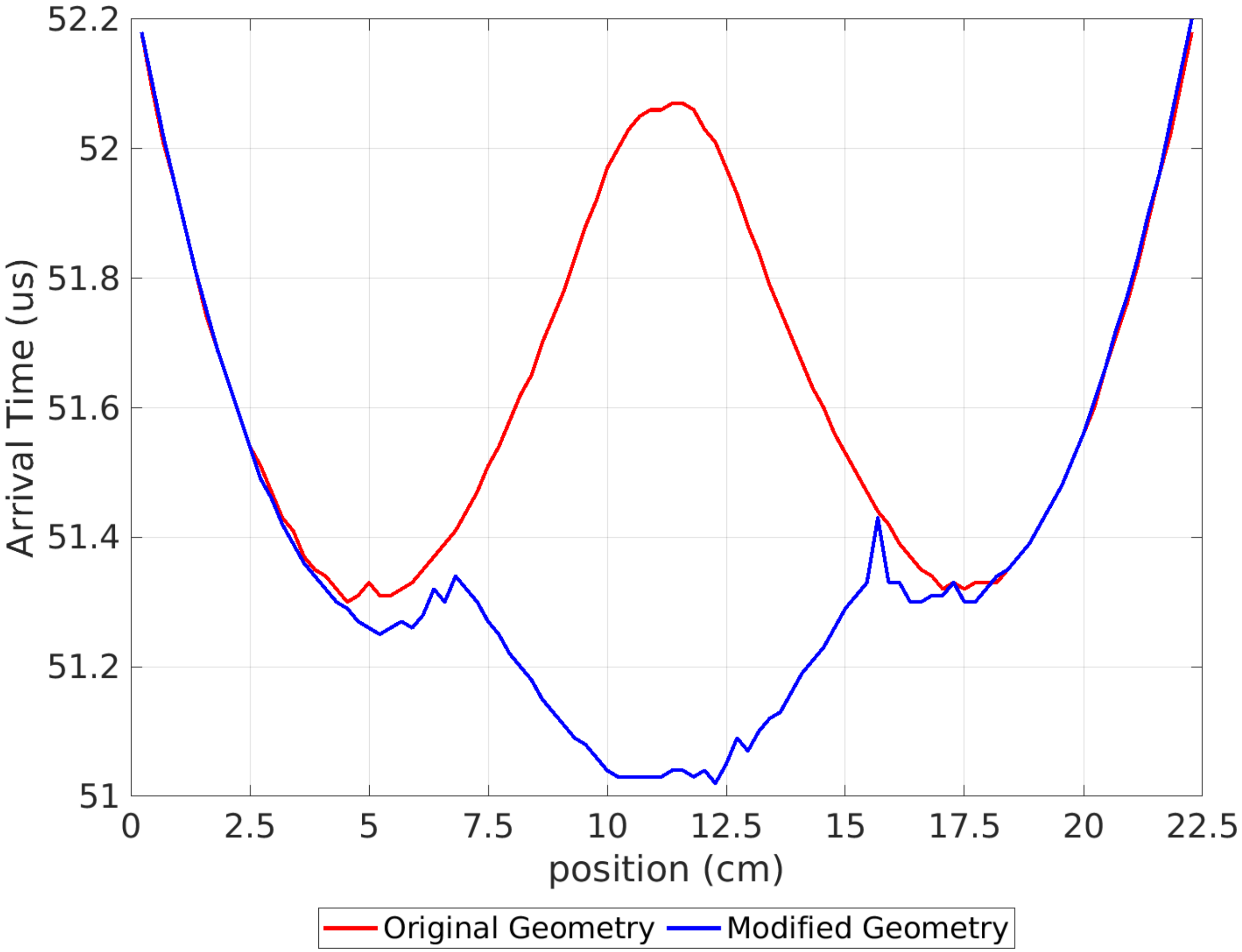
Modifying the geometry such that path lengths differ changes the shock arrival profile, but edge effects remain similar.



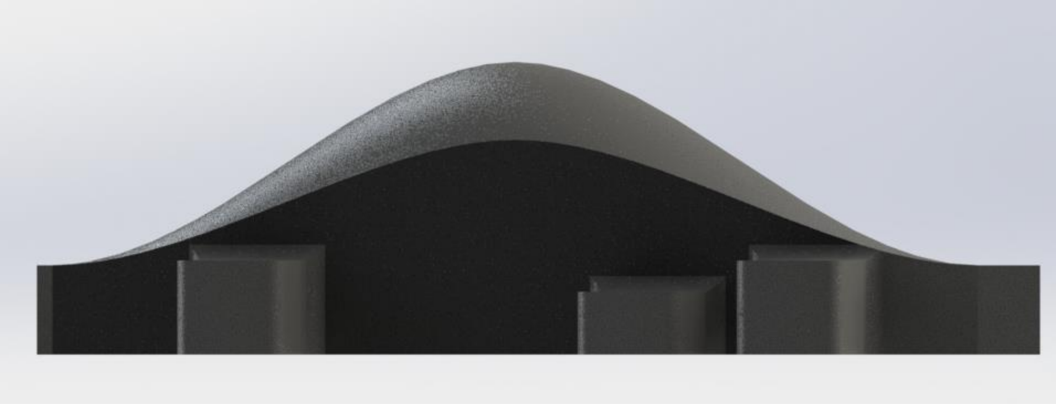
Original Geometry



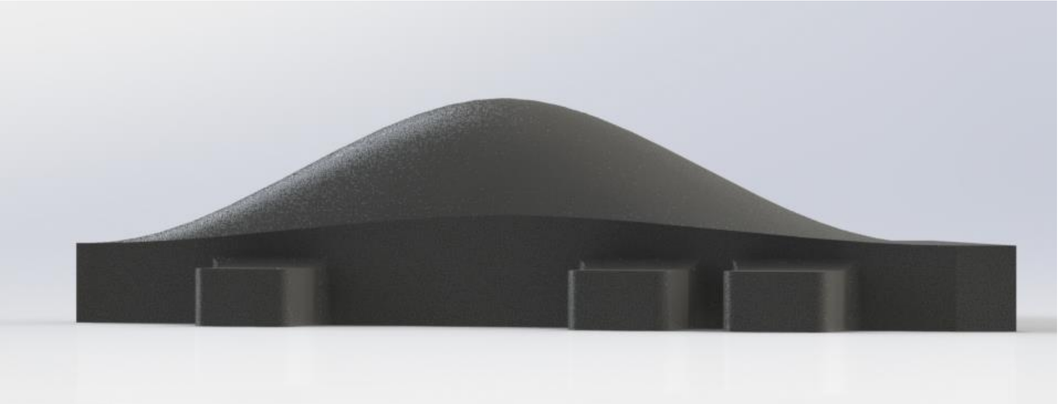
Modified Geometry



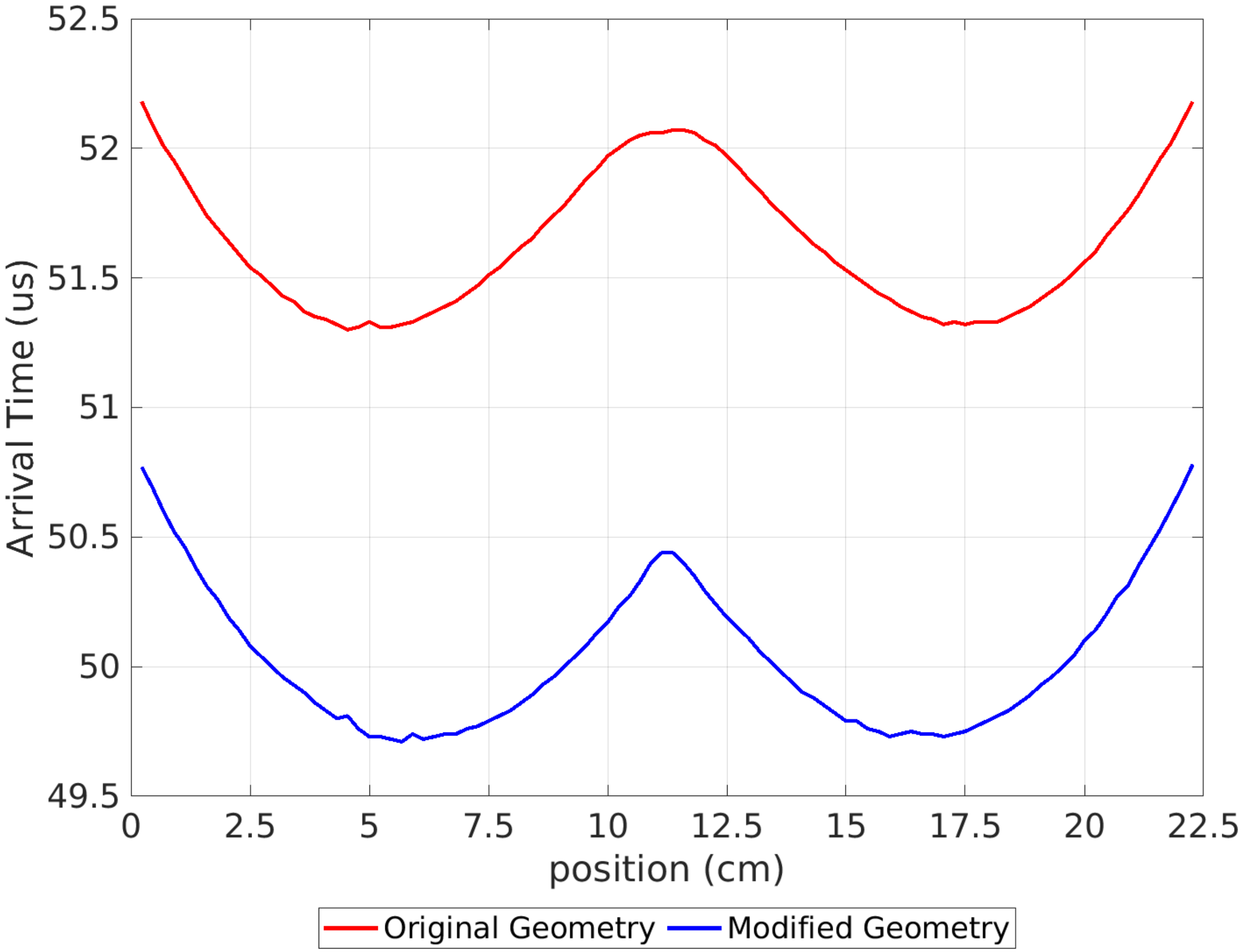
Modifying the geometry such that path lengths remain the same changes the shock arrival time, but edge effects remain similar.



Original Geometry



Modified Geometry



Detonation shock dynamics theory provides an alternative, more advanced programmed burn model.

Node lighting times are determined by the level set equation

$$\frac{\partial \phi}{\partial t} + F(\kappa)|\nabla \phi| = 0$$

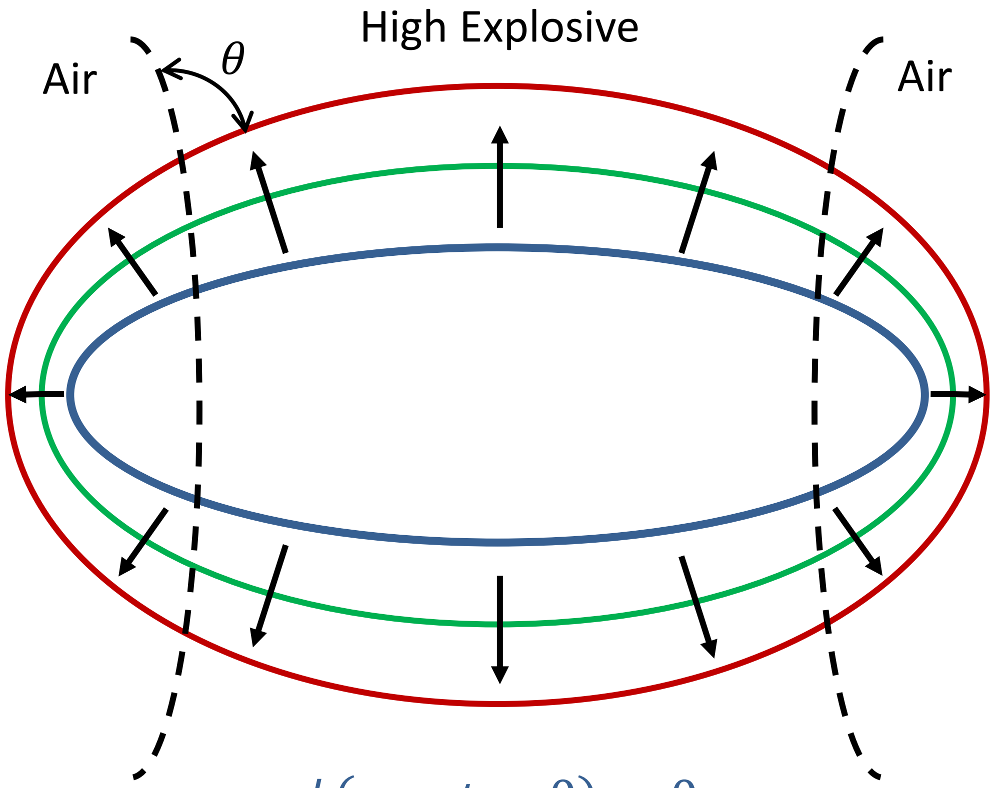
where the $\phi = 0$ surface defines the detonation front. The velocity function, $F(\kappa)$, is

$$F(\kappa) = D_{CJ}(1 - \alpha\kappa),$$

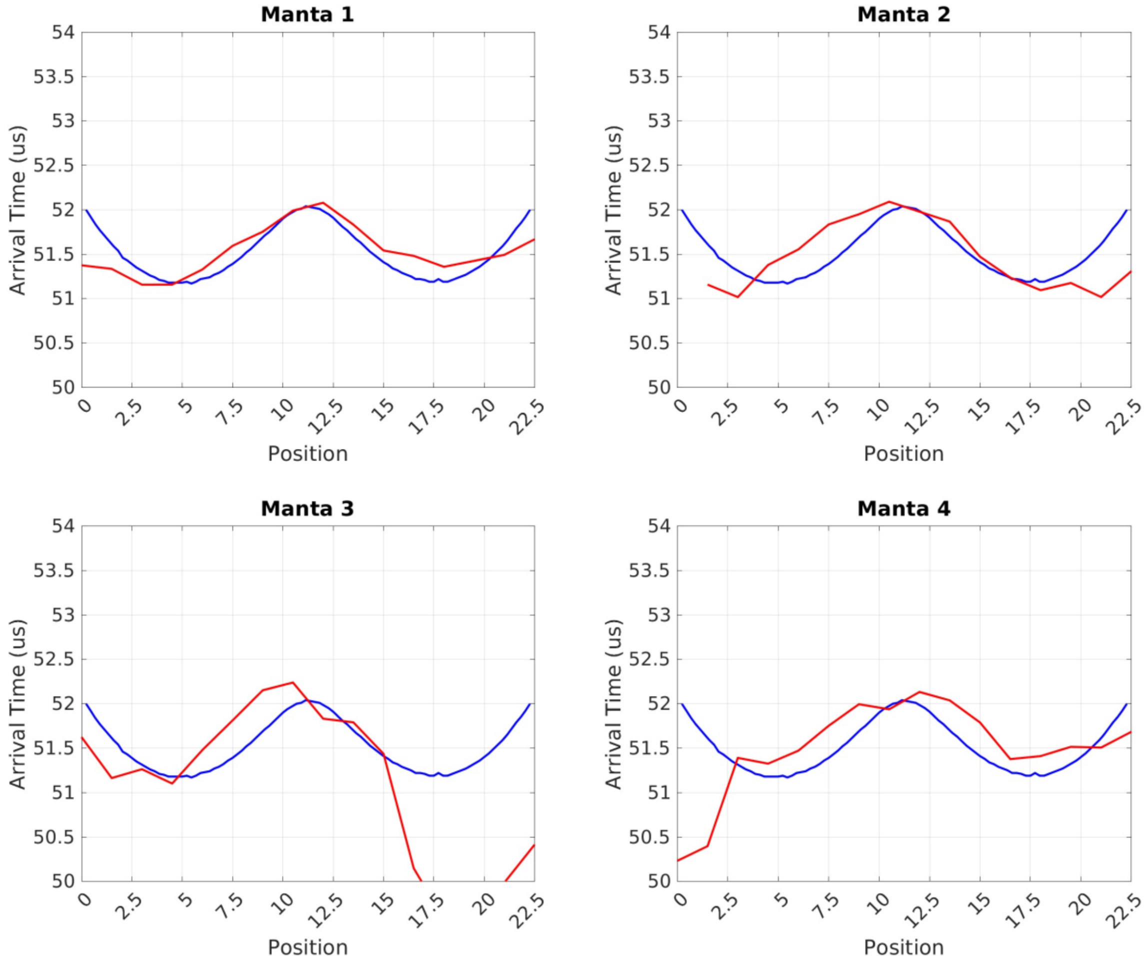
where

$$\kappa = \nabla \cdot \left(\frac{\nabla \phi}{|\nabla \phi|} \right)$$

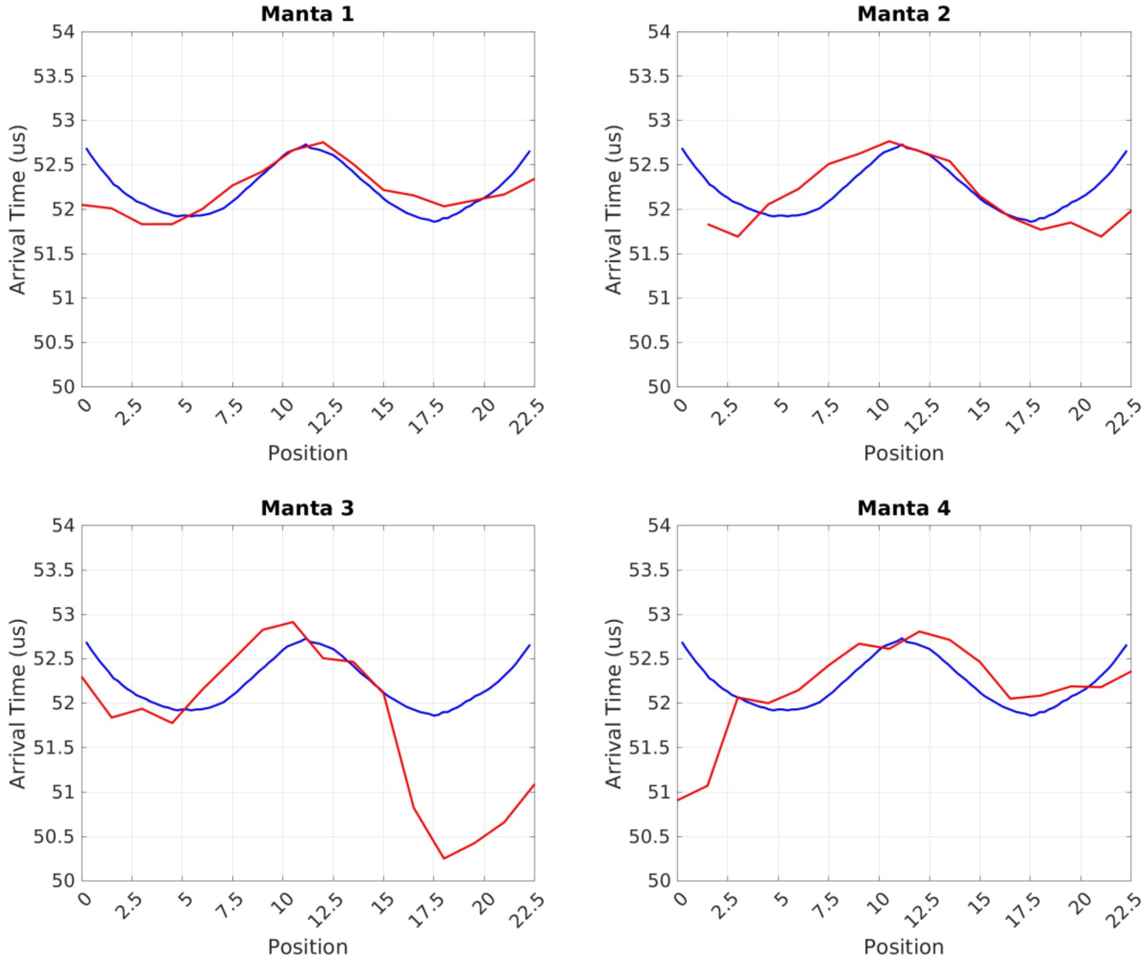
is the curvature of the $\phi = 0$ surface and α is a tunable parameter.



Unfortunately, this model does not lead to improved results for a variety of model parameters.

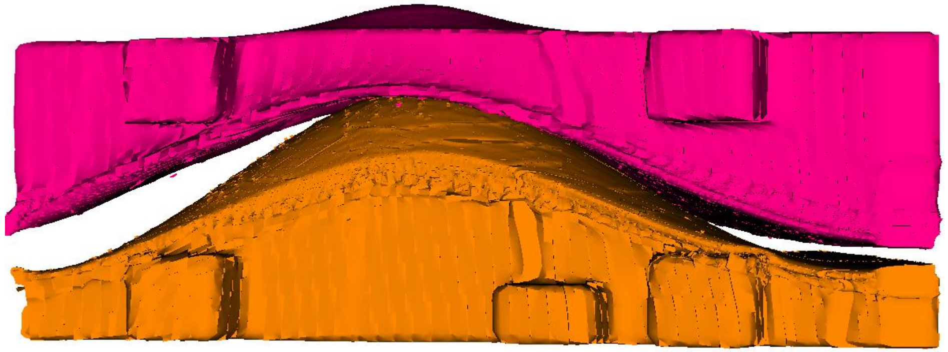


$\alpha = 0.00, \Delta t = 0.98\ \mu s$

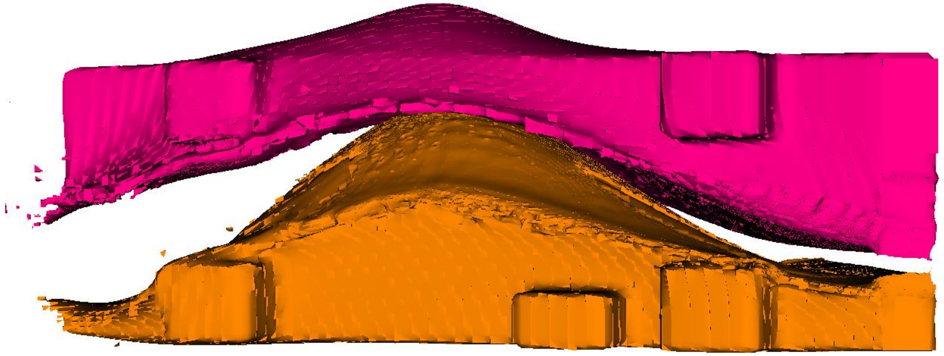


$\alpha = 0.12, \Delta t = 0.98\ \mu s$

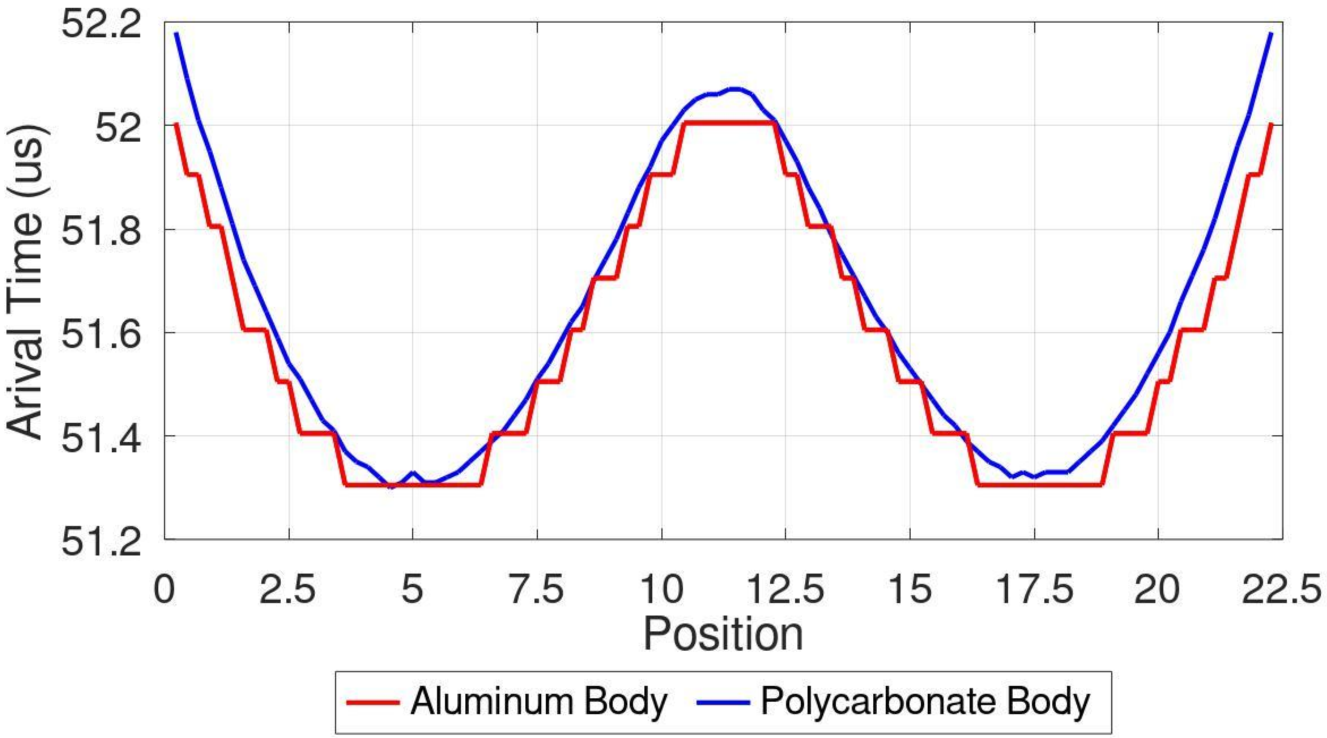
The material of the device has little effect on the detonation front.



Aluminum Body



Polycarbonate Body



Next Steps: Match the experimental results with the model.

JWL++

$$P = (1 - f)P_{unreacted} + fP_{reacted}$$
$$\frac{df}{dt} = G(P + Q)^b(1 - f)$$

- Two EOS model
- Less idealized than JWL

Ignition and Growth

$$\frac{dF}{dt} = \frac{dF_{ignition}}{dt} + \frac{dF_{growth}}{dt} + \frac{dF_{completion}}{dt}$$

- Complicated two EOS model
- Intended for shock initiation of explosives
- Pressure dominated burn rate

Chemical Materials

- Model the chemical reaction occurring in the high explosive
- Allows for the inclusion of intermediate reaction states
- May be able to incorporate density into reaction rate

Density Dependent Burn Velocities

$$V(\rho) = \begin{cases} 3.19 + 3.7(\rho - 0.37), & \rho < 1.65 \\ 7.92 + 3.05(\rho - 1.65), & \rho \geq 1.65 \end{cases}$$

- A non-reactive approach with a high barrier to implementation

Next Steps: Explore the effects of piercing the detasheet as done in existing literature

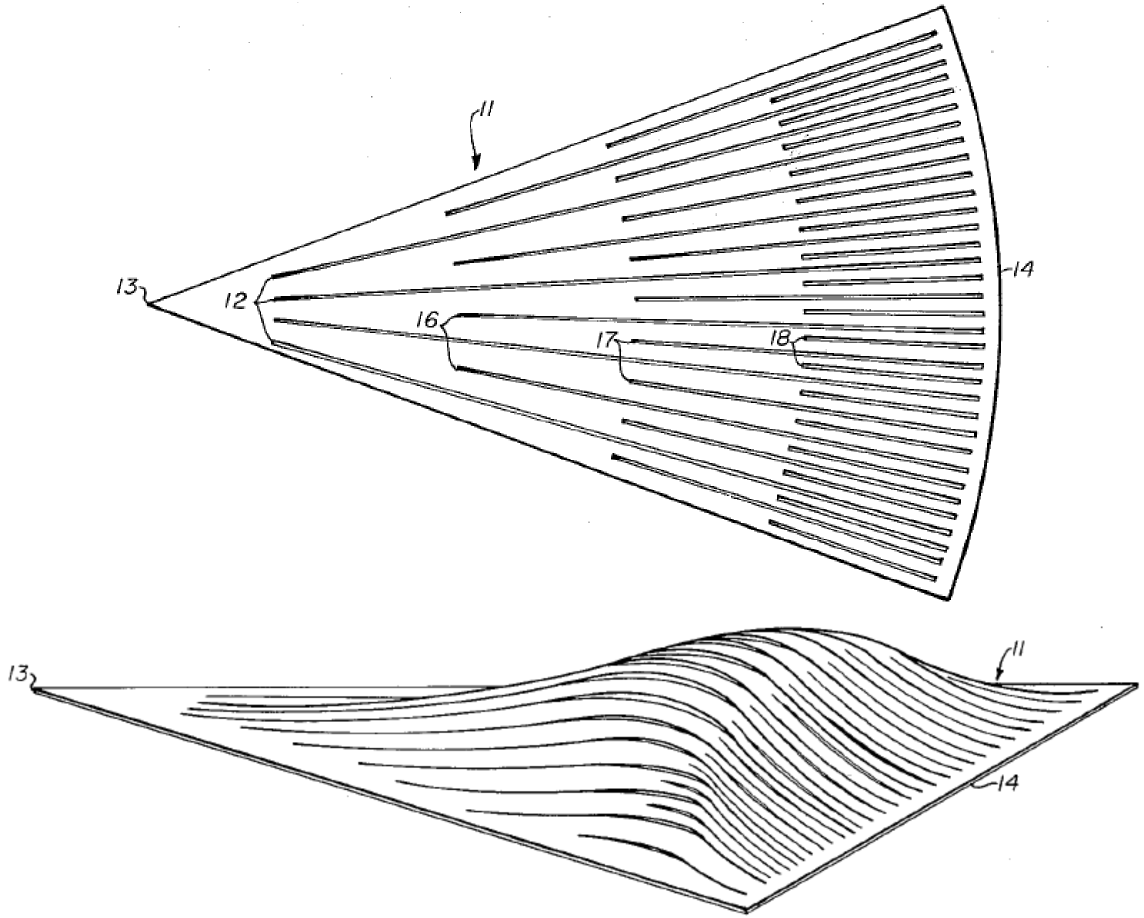


Figure: Alternative Approach to Plane Wave Generation [2]

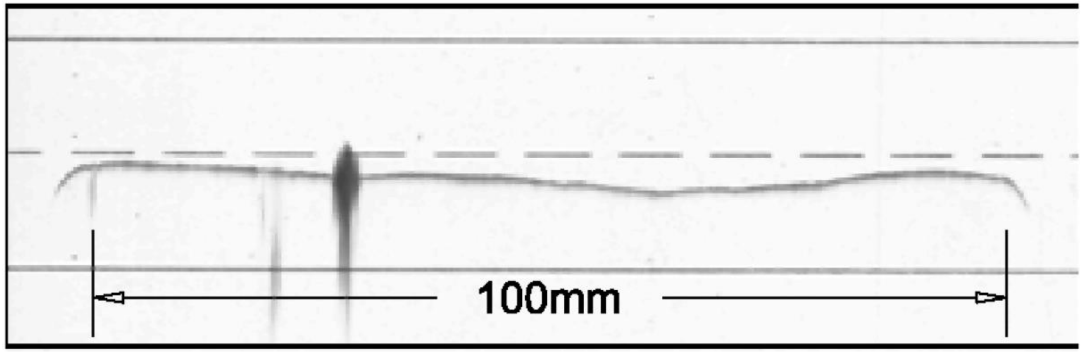


Figure: 124 ns Simultaneity achieved with this approach [3]

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References

[1] K. Naeem *and* A. Hussain, “Development of a Matlab Code for Plane Wave Lens and its Validation by Autodyn-2D”, *Engineering, Technology & Applied Science Research, 8(6),* 3614-3618, https://doi.org/10.48084/etasr.2415

[2] D. H. Gipson, “Explosive Line Wave Generator”, US Pat. US3242863A (1964), https://patents.google.com/patent/US3242863A/en

[3] John S. Morris, Scott I. Jackson, *and* Larry G. Hill, "A SIMPLE LINE WAVE GENERATOR USING COMMERCIAL EXPLOSIVES", AIP Conference Proceedings 1195, 408-411 (2009), https://doi.org/10.1063/1.3295158