

# “Aircraft Impact on Reinforced Concrete Structures“

Sami A. Kilic

Research Team at Bogazici University:

Asst. Prof. Sami A. Kilic

Prof. Gulay Altay

Isil Sanri, Ph.D. Candidate

Serkan Karapinar, Ph.D. Candidate

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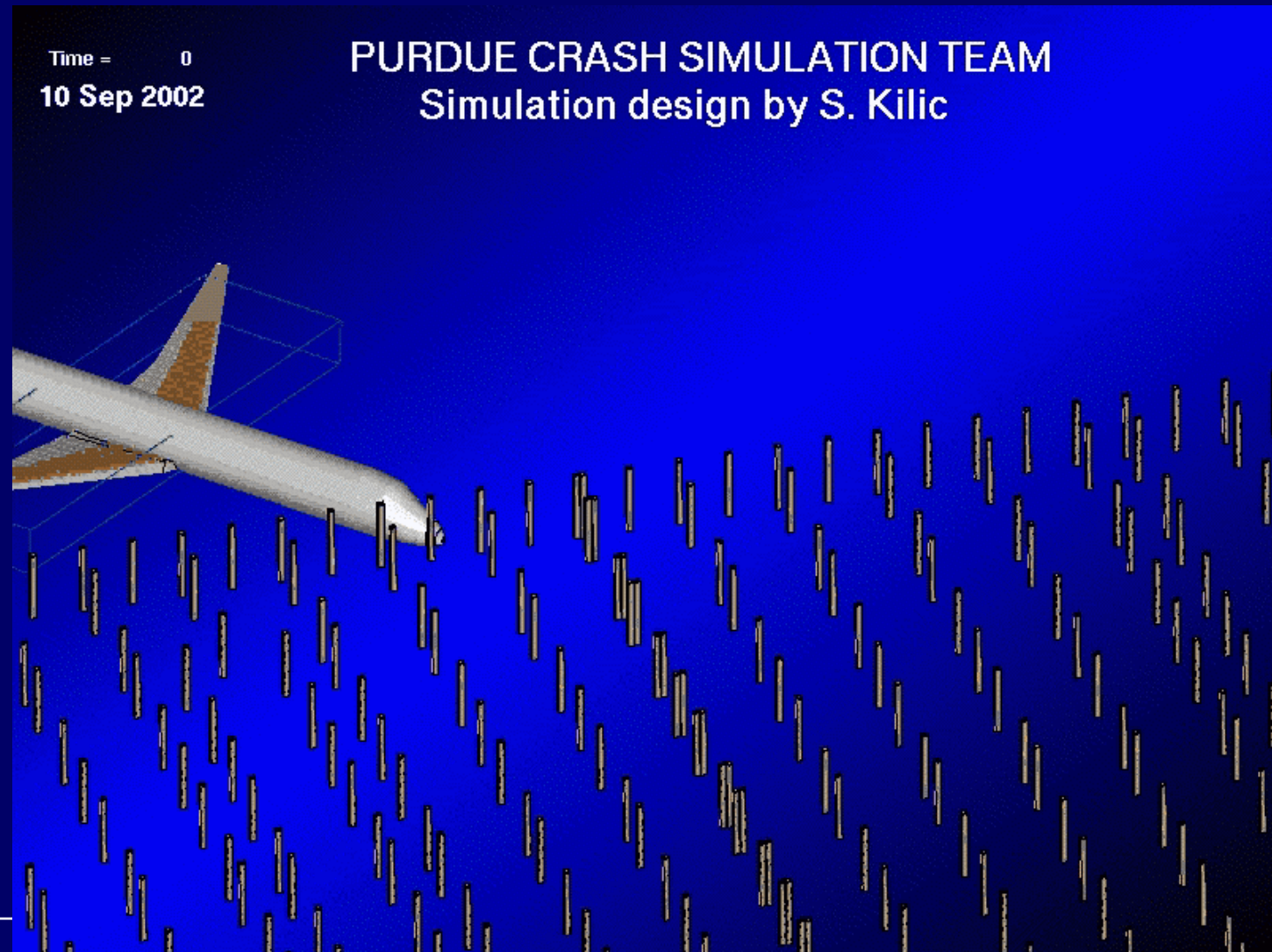


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## Overview of the Presentation

- Full-size aircraft impact on reinforced concrete structure (earlier work)
  - Parametric study on initial impact velocity for a single reinforced concrete column impacted by a block of liquid (Fluid-Structure Interaction – FSI).
  - Example simulations about Explosion/ Blast loading.
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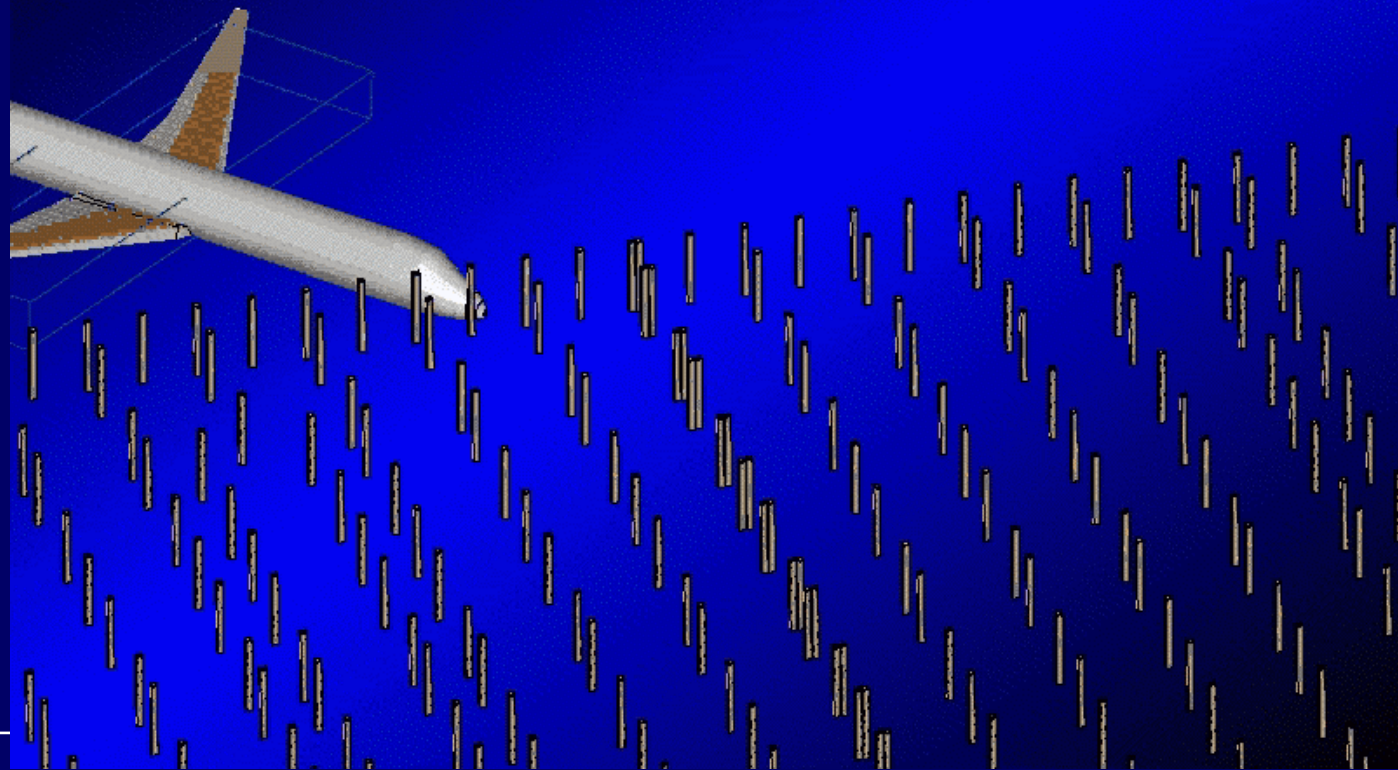
## Earlier Work done on Full-size Aircraft Impact on Reinforced Concrete Structure



# LS-Dyna ALE Simulation of Aircraft Impact on a Reinforced Concrete Structure

Time = 0  
10 Sep 2002

PURDUE CRASH SIMULATION TEAM  
Simulation design by S. Kilic

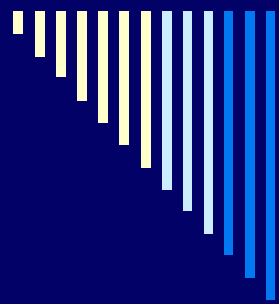




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## Conclusions

- The Arbitrary Lagrangian-Eularian technique is suitable for modeling Fluid-Structure Interaction (FSI) coupling.
  - Wide area damage in the structure is due to the wings. The fuselage causes a narrow tunnel of damage.
  - Most of the mass of the wings come from the fuel stored in the wing tanks. The skin of the wings (wing structure) constitutes a smaller amount of mass in comparison.
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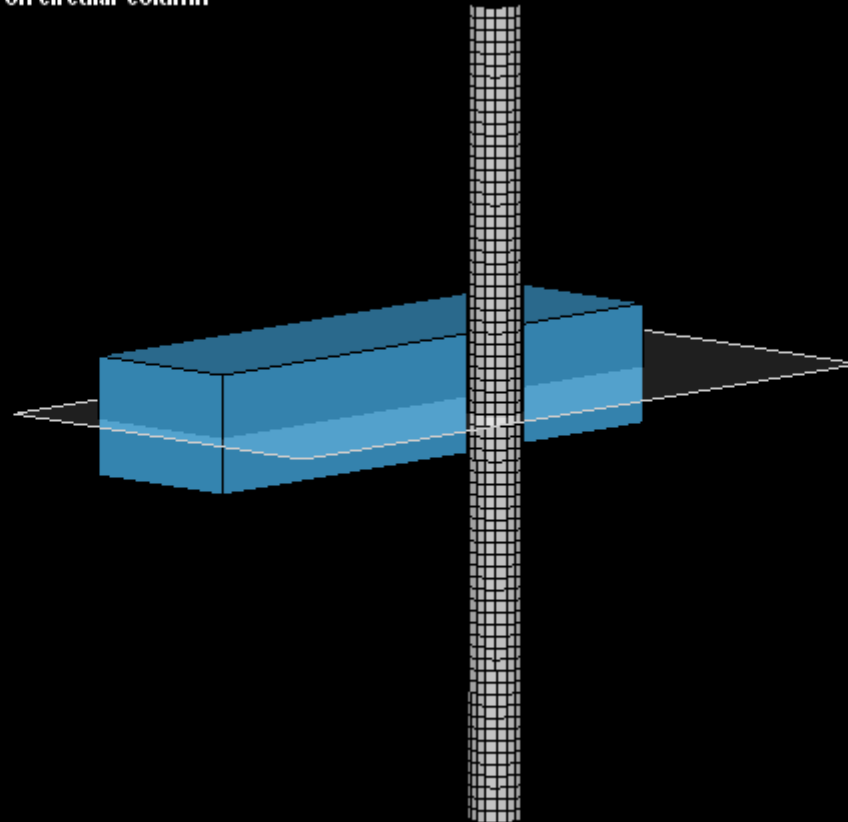


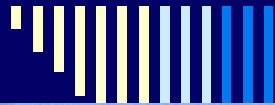
## Simulating Fluid-Structure Interaction (FSI) for a Single Reinforced Concrete Column Hit by a Block of Liquid

- Concrete unconfined compressive strength;  $f'_c = 28$  MPa.
- Yield stress of reinforcement rebars;  $f_y = 310$  MPa.
- Concrete elements erode at a strain level of 0.05.
- Reinforcement rebars rupture at a plastic strain level of 0.20.
- Initial velocities of  $V_o = 25$  feet/sec and  $V_o = 100$  feet/sec are investigated.

Initial  $V_0 = 25$  feet/sec = 7.62 m/sec  
Cross-section Definition for Resultant Force

25ft/s fluid block impact on circular column

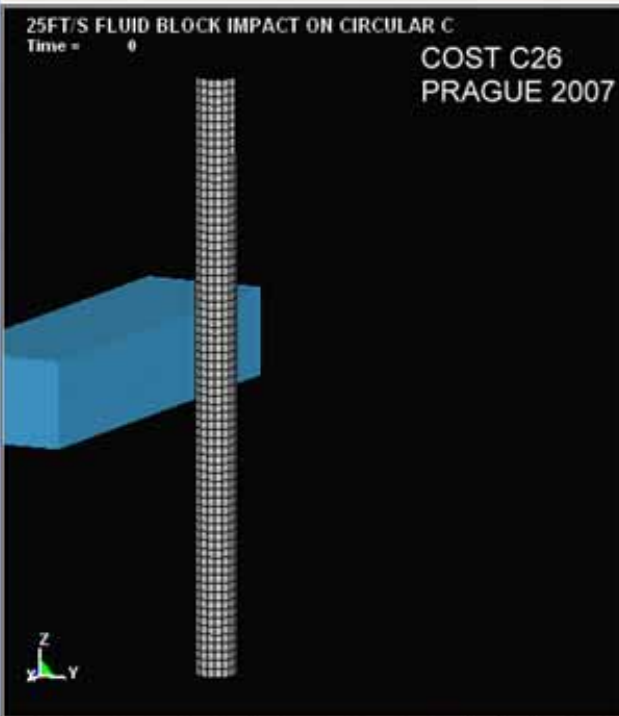




$V_0 = 25 \text{ feet/sec} = 7.62 \text{ m/sec}$

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25FT/S FLUID BLOCK IMPACT ON CIRCULAR C  
Time = 0  
COST C26  
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1 2 3 4 5 6 7 D

Ascii File Operation

File glistat \*  
Load matsum \*  
Uload rcforc \*  
Raise ncforc \*  
Pop spcforc \*  
Done bndout \*  
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Section Data

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PAdd Sec-2  
All Sec-3  
Clear  
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Info  
Total

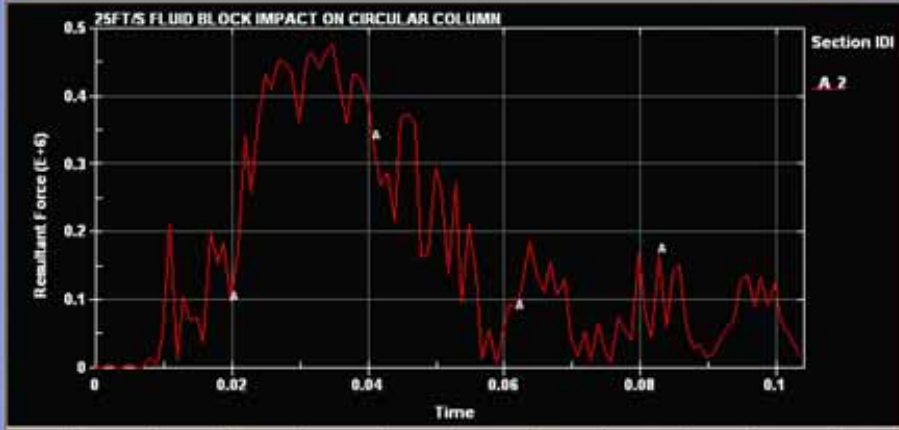
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2-Y-force  
3-Z-force  
4-Resultant Force  
5-X-moment  
6-Y-moment  
7-Z-moment  
8-Resultant Moment  
9-X-centroid

state 1;  
anim forward

Animate forward

PlotWindow 1

25FT/S FLUID BLOCK IMPACT ON CIRCULAR COLUMN



Resultant Force (E+6)

Time

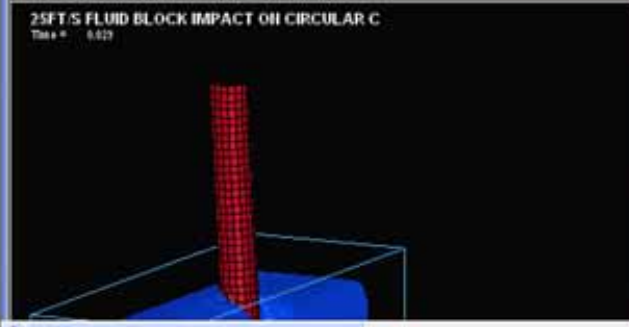
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A 2

Edit Title Scale Attr Filter Print Save Load Oper Hide Close Quit

Untitled [1280x800x32 bpp] - Mr. Captor

LS-PREPOST 2.1 - 28Jun2006(13:12) C:\1cost.c26.b\30in-25nodamp\id3plot

25FT/S FLUID BLOCK IMPACT ON CIRCULAR C  
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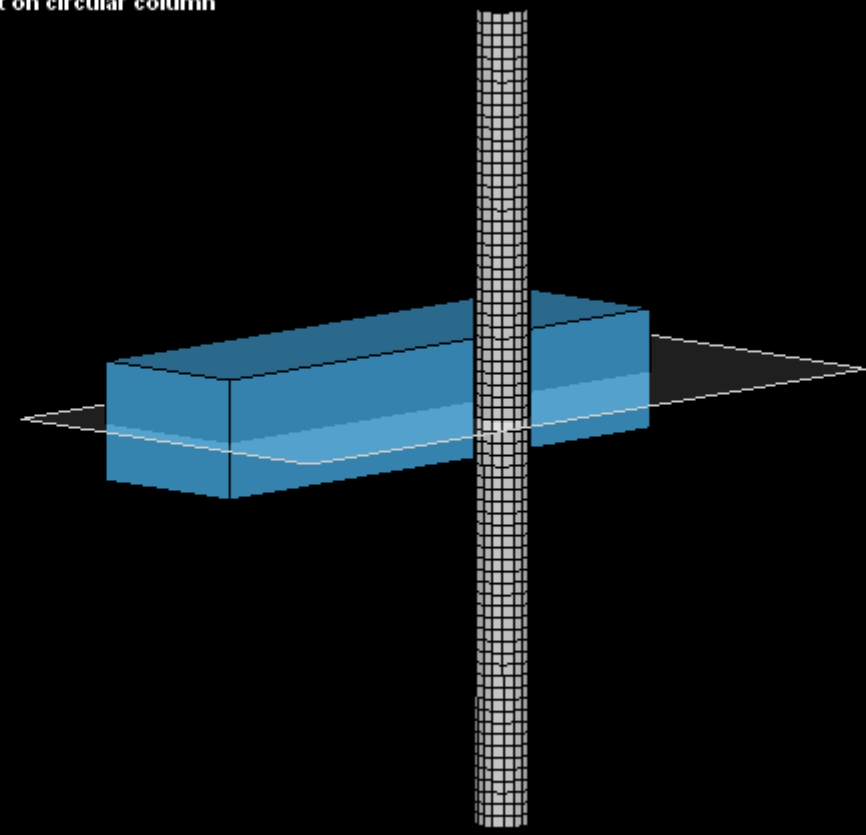
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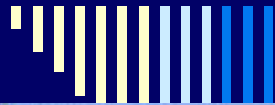
## Conclusions

- The outer face of the concrete column erodes without significantly affecting the overall integrity.
  - A few reinforcement rebars rupture.
  - The column stays in place after the impact.
  - Peak resultant force is 0.48 MN.
-

Initial  $V_0 = 100$  feet/sec = 30.48 m/sec  
Cross-section Definition for Resultant Force

25ft/s fluid block impact on circular column





$V_0 = 100 \text{ feet/sec} = 30.48 \text{ m/sec}$

The image displays the LS-PREPOST 2.1 software interface, showing a 3D model of a fluid block impact on a circular column, a plot window showing the resultant force over time, and an animation control panel.

**LS-PREPOST 2.1 - 28Jun2006(13:12) C:\1cost.c26.b\30in-100nodamp\ld3plot**

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1 2 3 4 5 6 7 D

Part Selection

- Md1
  - H 1
  - B 10
  - H 2
  - H 3
  - 11 Ale group 1
- Beam
- Shell
- Solid
- Tshell
- Nbody
- Mass
- Disc
- Sdelt
- Inerta
- Psurf
- Sphind
- Fluid

• Single  
• Area  
• Poly

Save  
Load

Buff 1

All Selected Info

• Rm • Kp SortBy

All None Rev  
Auto Apply Done

state 1;  
anim forward

Animate forward

**PlotWindow-1**

100FT/S FLUID BLOCK IMPACT ON CIRCULAR COLUMN

Resultant Force (E+6)

Time

Section ID1  
A 2

Edit Title Scale Attr Filter Print Save Load Oper Hide Close Quit

**Untitled [1280x800x32 bpp] - Mr. Captor**

LS-PREPOST 2.1 - 28Jun2006(13:12) C:\1cost.c26.b\30in-25nodamp\ld3plot

25FT/S FLUID BLOCK IMPACT ON CIRCULAR C  
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Group	Blank

1 2 3 4 5

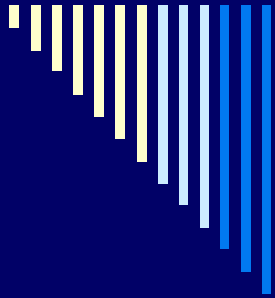
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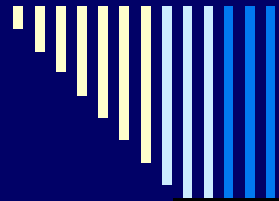
## Conclusions

- The column is split into half, losing all of its integrity; complete failure occurs.
  - This example demonstrates the sensitivity of FSI on initial impact velocity.
  - Peak resultant force is 0.70 MN.
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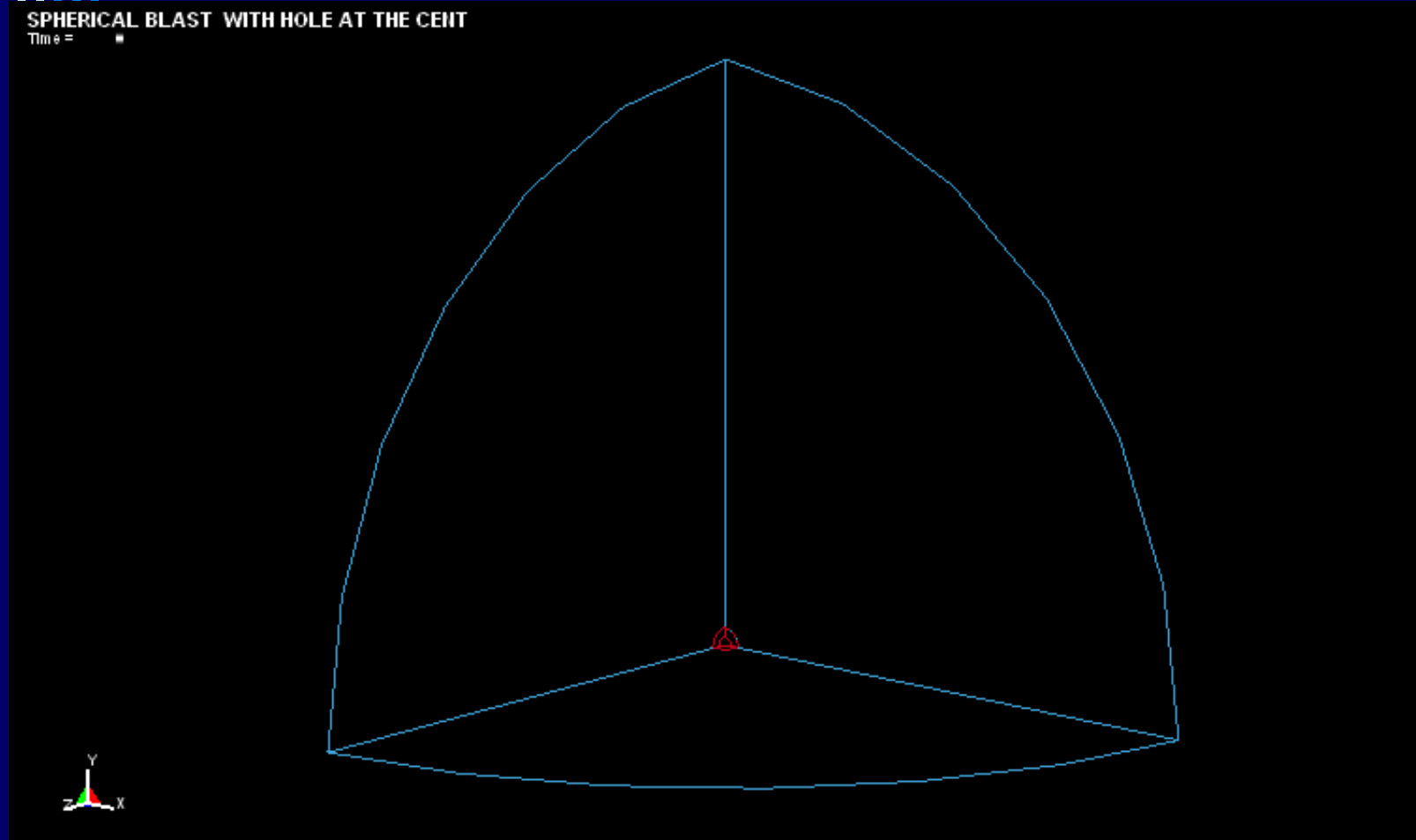


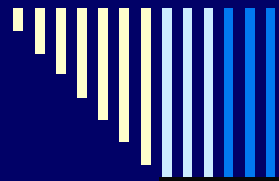
# Example Simulations about Explosion/Blast Explosive Detonated in a Spherical Mesh





# Example Simulations about Explosion/Blast -Explosive Detonated in a Spherical Mesh





# Example Simulations about Explosion/Blast -Explosive Detonated in a Spherical Mesh





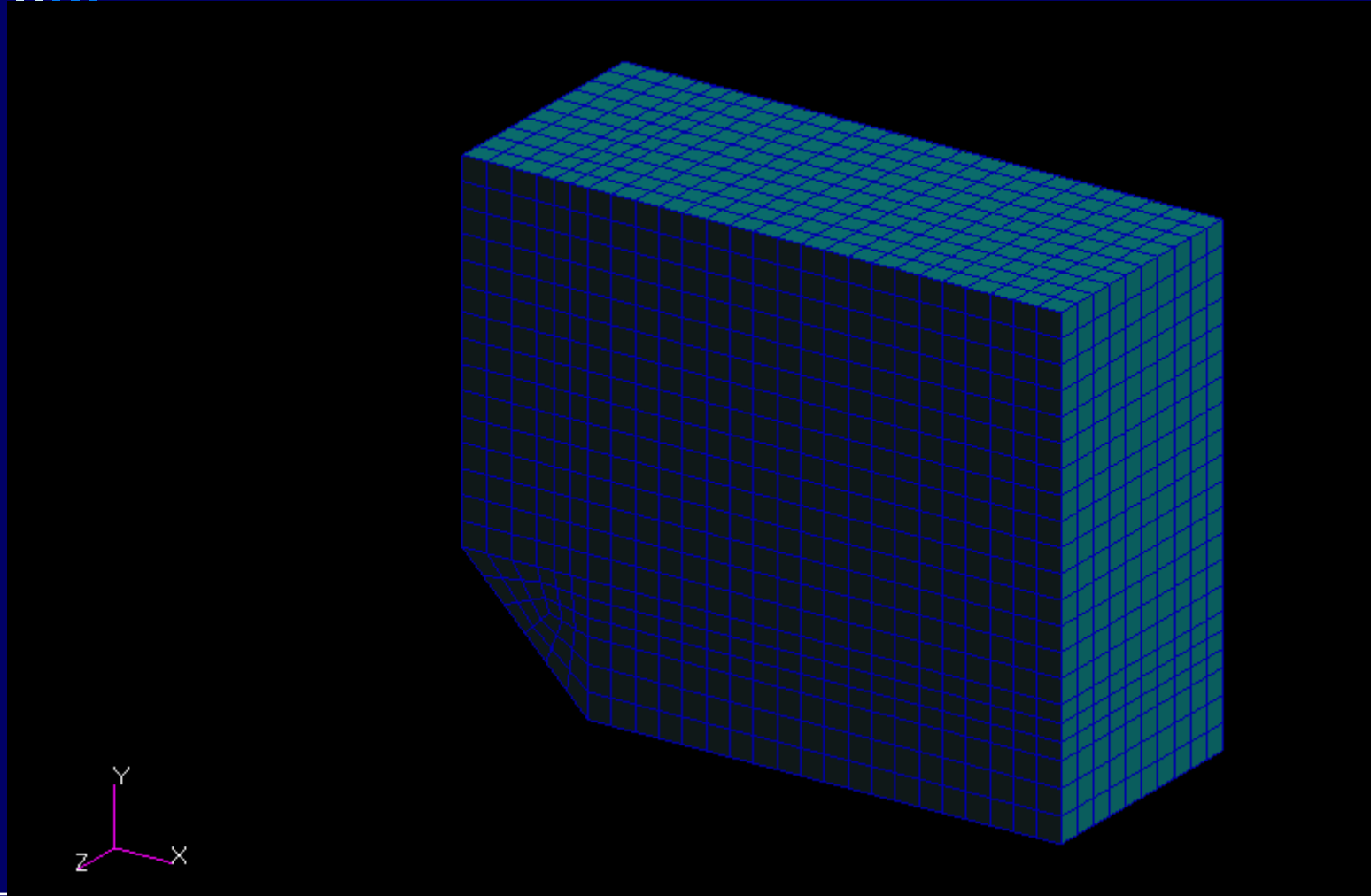
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## Remarks:

- \*MAT\_HIGH\_EXPLOSIVE\_BURN constitutive model available in LS-Dyna for modeling explosive material.
  - \*EOS\_JWL equation of state available for pressure-volume relationship of the blast wave.
  - Need more data for the various parameters used in these models.
  - Blast wave pressure propagation should be checked against available:
    - (a) experimental data
    - (b) numerical data from CONWEP or ATBLAST or AIR3D (Cranfield University, UK) programs.
-

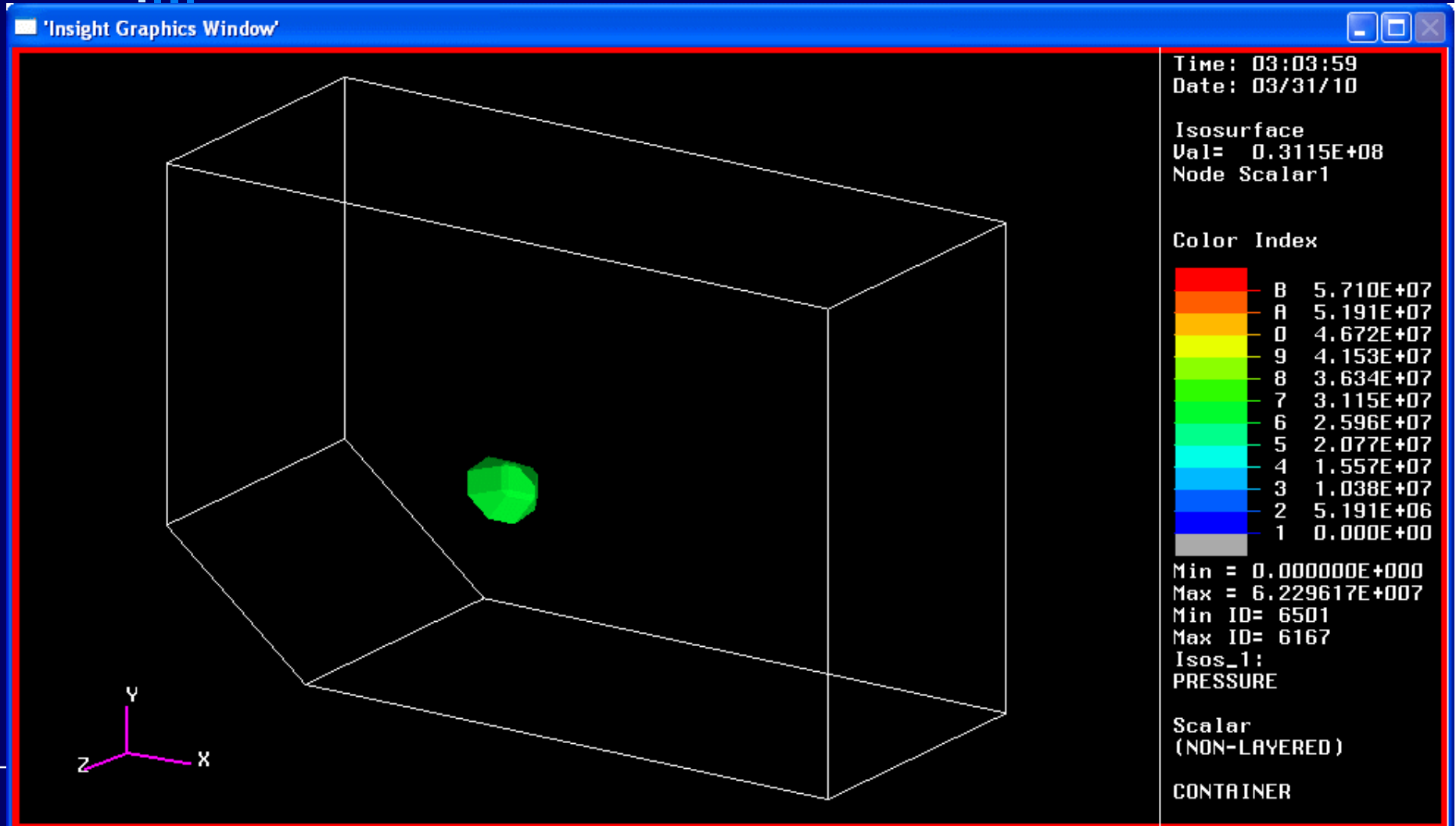


# Example Simulations about Explosion/Blast -Blast in a Closed Luggage Container



# Example Simulations about Explosion/Blast

## -Blast in a Closed Container





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## Conclusions

- For the lower speed of  $V_0=25$  feet/sec, the single column survives the impact without losing integrity.
  - Quadrupling the initial speed of the liquid increases the kinetic energy 16-folds. The higher speed of  $V_0=100$  feet/sec cuts the column in half, causing complete failure.
  - The Arbitrary Lagrangian-Eulerian technique will be extensively used to model blast wave propagation and blast-structure interaction. Simulation will be carried out using both LS-Dyna and MSC.Dytran finite element codes using explicit time integration.
  - Benchmark problems are needed for the blast wave propagation simulations (both experimental and numerical).
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