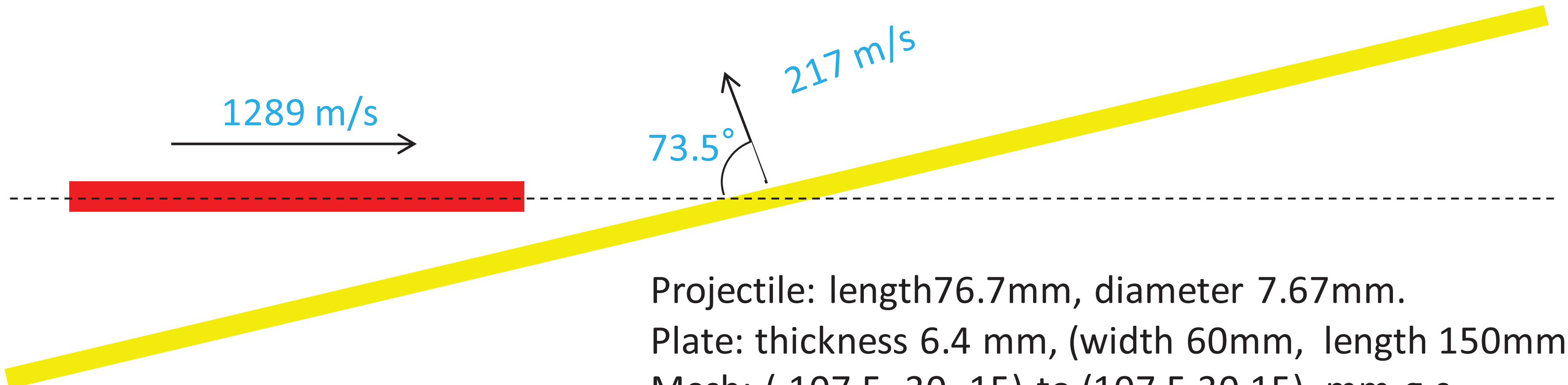
Application: Penetration – Model Description

- A long rod projectile impacting an oblique steel plate (Fugelso & Taylor 1978).
- Model dimensions from ARL-TR-2173 (Schraml & Kimsey 2000)
- Material MAT_JOHNSON_COOK+EOS_LINEAR_POLYNOMIAL, "Numerical Simulation of High-Velocity oblique Impacts of Yawed Long Rod Projectile Against Thin-Plate" (Yo-Han Yoo 2002)

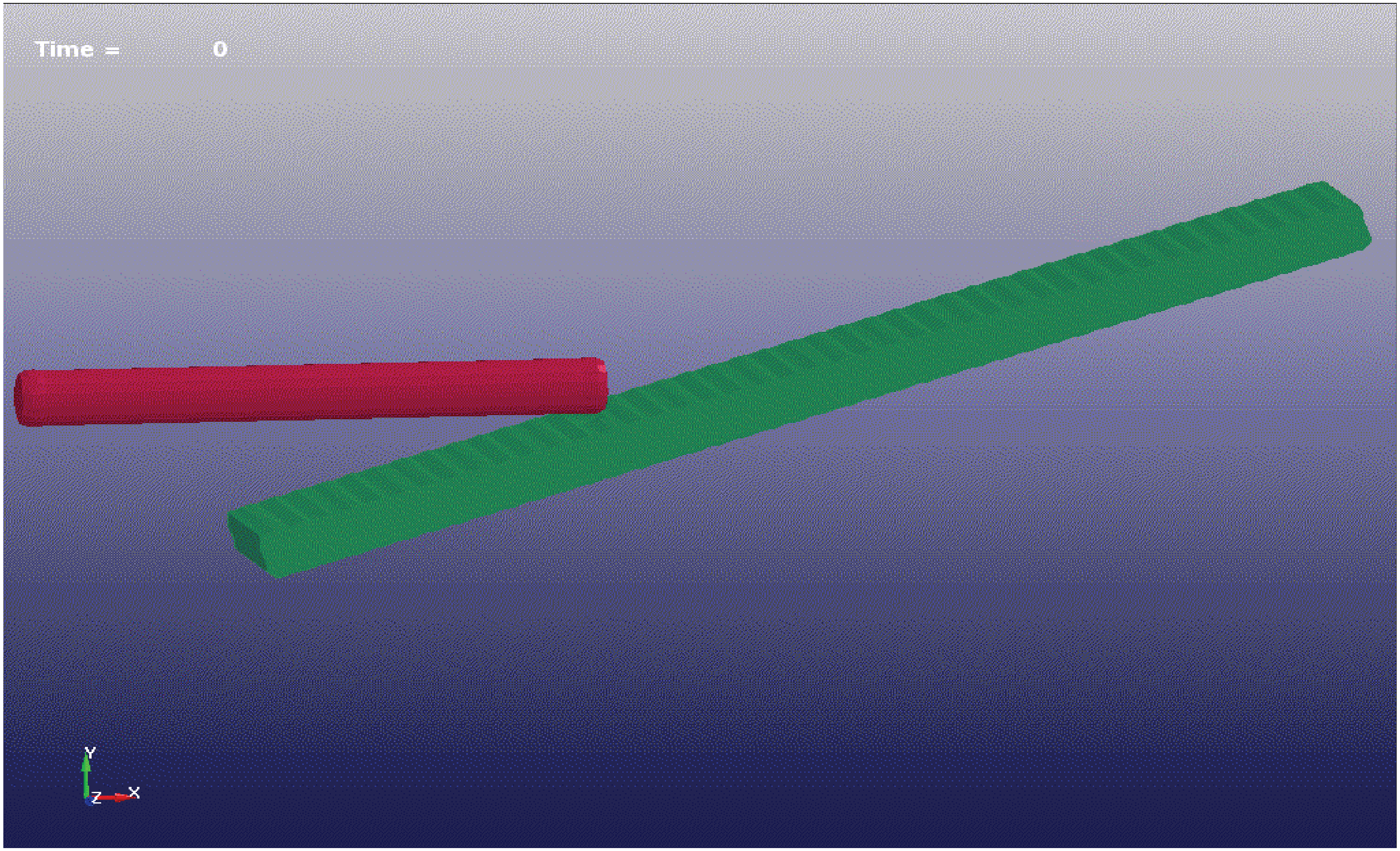


Projectile: length76.7mm, diameter 7.67mm.
Plate: thickness 6.4 mm, (width 60mm, length 150mm)
Mesh: (-107.5,-30,-15) to (107.5,30,15), mm-g-s

	RO	G	E	PR	A	B	N	C	M	TM	TR	C1
ROD	18.6e-3	63.7e3	165.6e3	0.3	1.079e3	1.12e3	0.25	0.007	1.00	1473	283	138.0e3
PLATE	7.87e-3	76.7e3	200.1e3	0.3	0.792e3	0.51e3	0.26	0.014	1.03	1809	283	166.7e3

Application: Penetration – Simulation

- 1mmx1mmx1mm regular HEX mesh with 387,000 elements (215x60x30)
- Simulation time of 0.04s took 7 minutes on a single thread SMP.



Application: Penetration – Model Setup 1

*ALE_STRUCTURED_MESH					
MSHID	PID	NBID	EBID		
1	11	100001	100001		
CPIDX	CPIDY	CPIDZ	NID0	LCSID	
1001	1002	1003			

MSHID: Mesh ID (for future use)

PID: Part ID assigned to the mesh
NO NEED to define *PART card

NBID: Starting Node ID

EBID: Starting Element ID

NID0: Origin Node ID

LCSID: Local Coordinate System ID

*ALE_STRUCTURED_MESH_CONTROL_POINTS	
1001	
1	-107.5
216	107.5

*ALE_STRUCTURED_MESH_CONTROL_POINTS	
1002	
1	-30.0
61	30.0

*ALE_STRUCTURED_MESH_CONTROL_POINTS	
1003	
1	-15.0
31	15.0

Application: Penetration – Model Setup 2

*ALE_MULTI-MATERIAL_GROUP	
PID	PTYPE
1	1
3	1
2	1

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*PART				
PID	SECID	MID	EOSID	HGID
1	1	1	1	1
3	1	2	2	1
2	1	3		1

1 to 1 correspondence

PID	MATERIAL	AMMG
1	ROD	1
3	VACUUM	2
2	PLATE	3

- *PART definitions to define multi-materials reside in S-ALE mesh; one to one correspondence.
- These PART IDs only appear in *ALE_MULTI-MATERIAL_GROUP; NOT to be used anywhere else.
- Material PARTs have neither elements nor nodes; serves as a wrapper to include *MAT+*EOS+HOURGLASS

Application: Penetration – Model Setup 3

*INITIAL_VOLUME_FRACTION_GEOMETRY							
SID	IDTYP	BAMMG					
11	1	2					
TYPE	FILLOPT	FAMMG	VELX	VELY			
1	1	3	-61.631	208.06			
PID	IDTYP						
101	1						
TYPE	FILLOPT	FAMMG	VELX				
4	0	1	1289				
X0	Y0	Z0	X1	Y1	Z1	R1	R2
-103.0	0.0	0.0	-26.33	0.0	0.0	3.835	3.835

1. First set all elements in PART 11 to vacuum (AMMG2)
2. Next switch vacuum (AMMG2) inside LAG part 101 to plate (AMMG3)
3. Finally switch vacuum (AMMG2) inside a cylinder to rod (AMMG1)

Application: Penetration – Model Setup MISC

*CONTROL_ALE							
DCT	NADV	METHOD	AFAC	BFAC	CFAC	DFAC	EFAC
	1	1					
START	END	AAFAC	VFACT	PRIT	EBC	PREF	NSIDEBC

*CONTROL_TERMINATION	
ENDTIME	ENDCYCL
0.04	

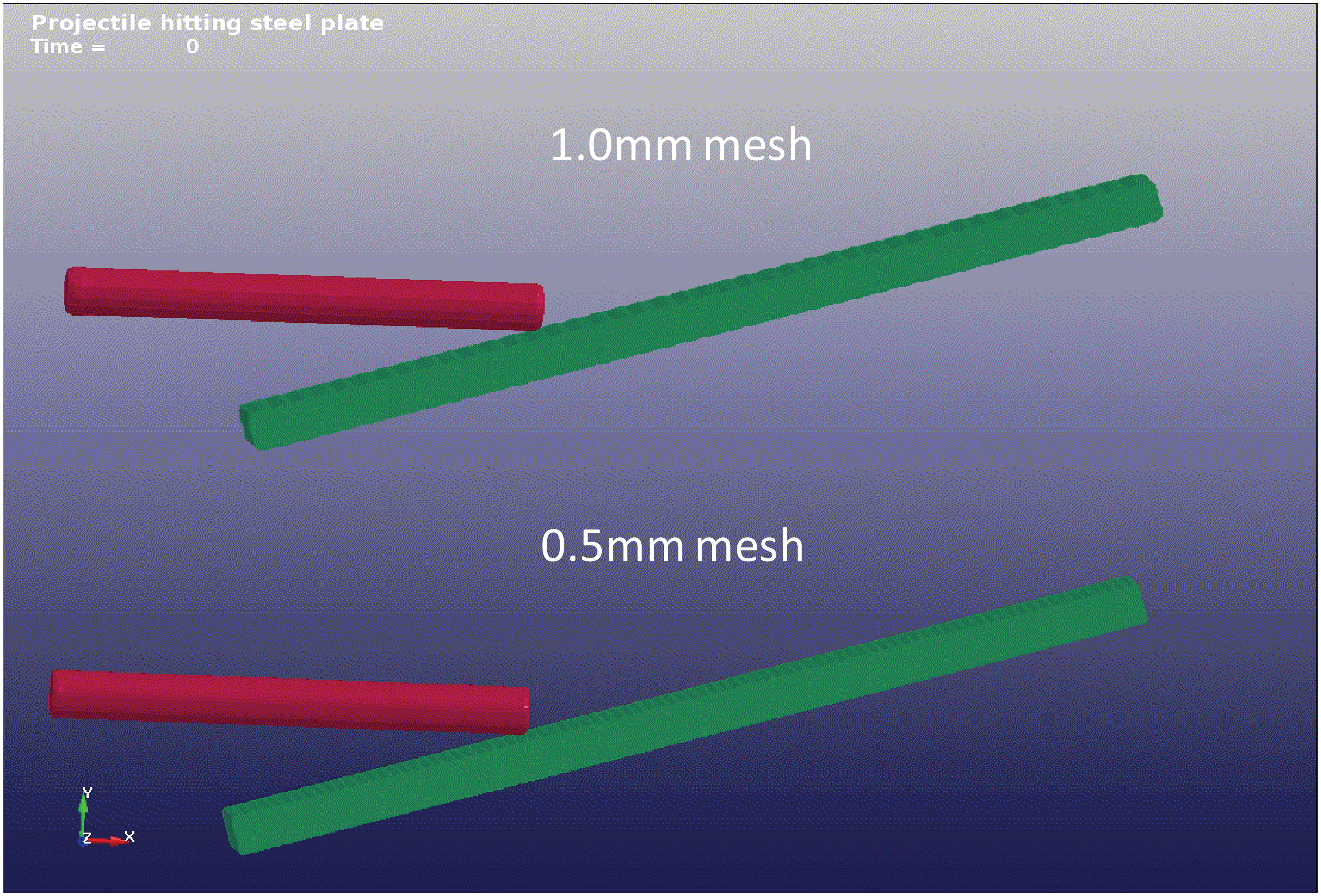
*CONTROL_TIMESTEP	
DTINIT	TSSFAC
	0.600

*DATABASE_BINDARY_D3PLOT	
DT	LCDT
0.001	

Optional card: refine the mesh for better accuracy

*ALE_STRUCTURED_MESH_REFINE			
MSHID	NX	NY	NZ
1	2	2	2

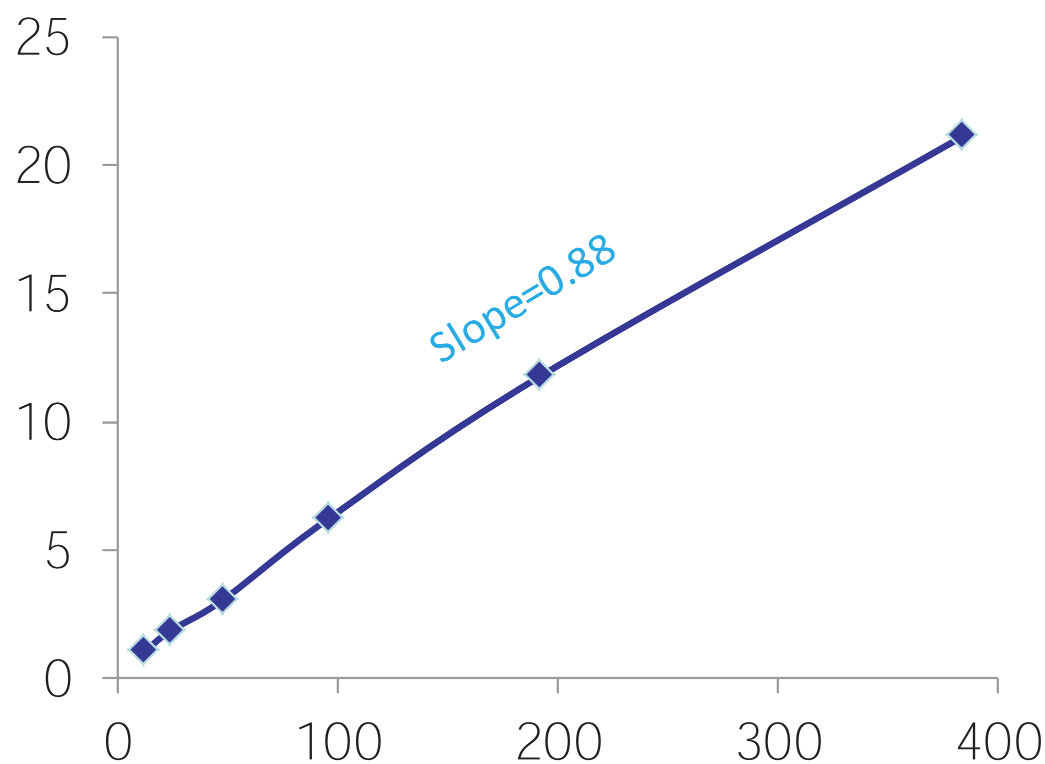
Application: Penetration – Refinement



Model size: 387,000 vs. 3,096,000
Running time: 14m vs. 3h16m.

Application: Penetration – MPP Performance

NCPU	12	24	48	96	192	384
Total Time	2068	1128	680	333	176	98
S-ALE	1327	733	451	220	118	62

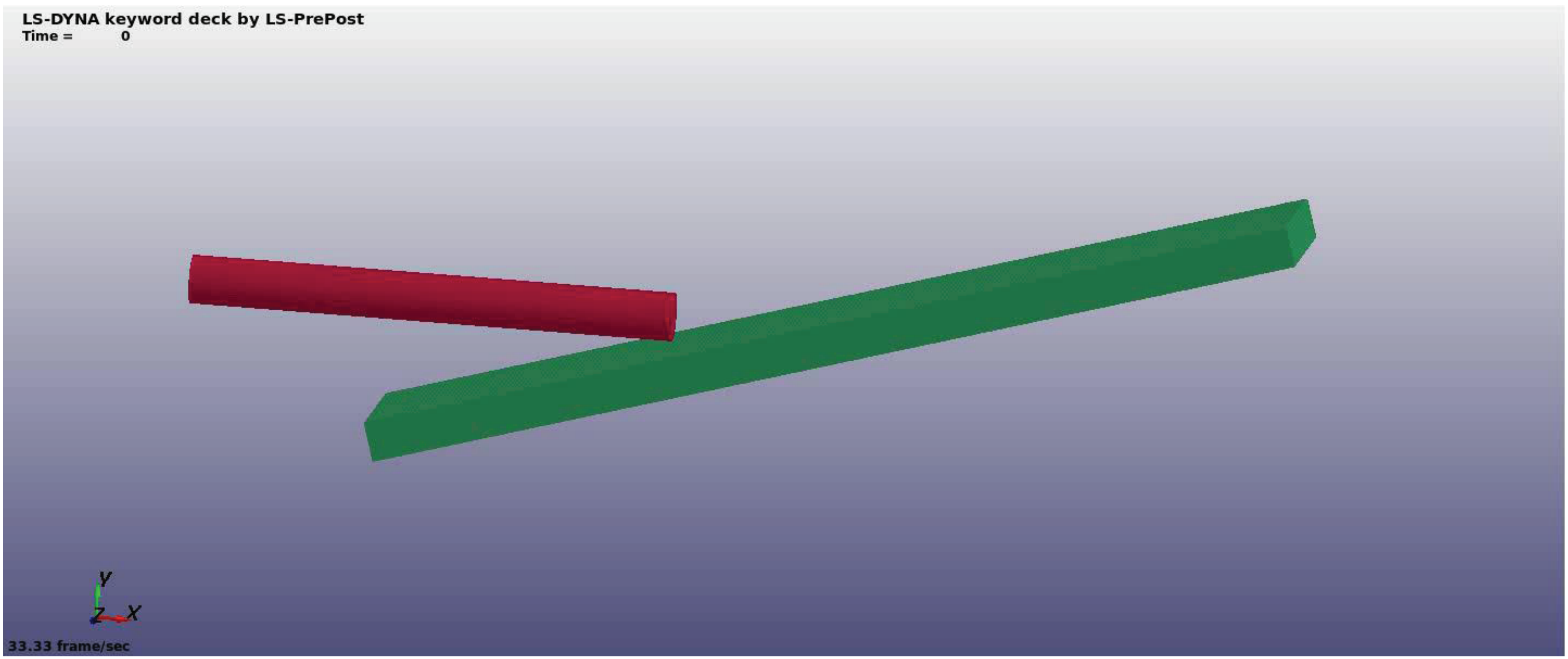


Note: 3 million elements, total time excluded MPP decomposition time

Application: Penetration – 50 million model

*ALE_STRUCTURED_MESH_REFINE			
MSHID	NX	NY	NZ
1	5	5	5

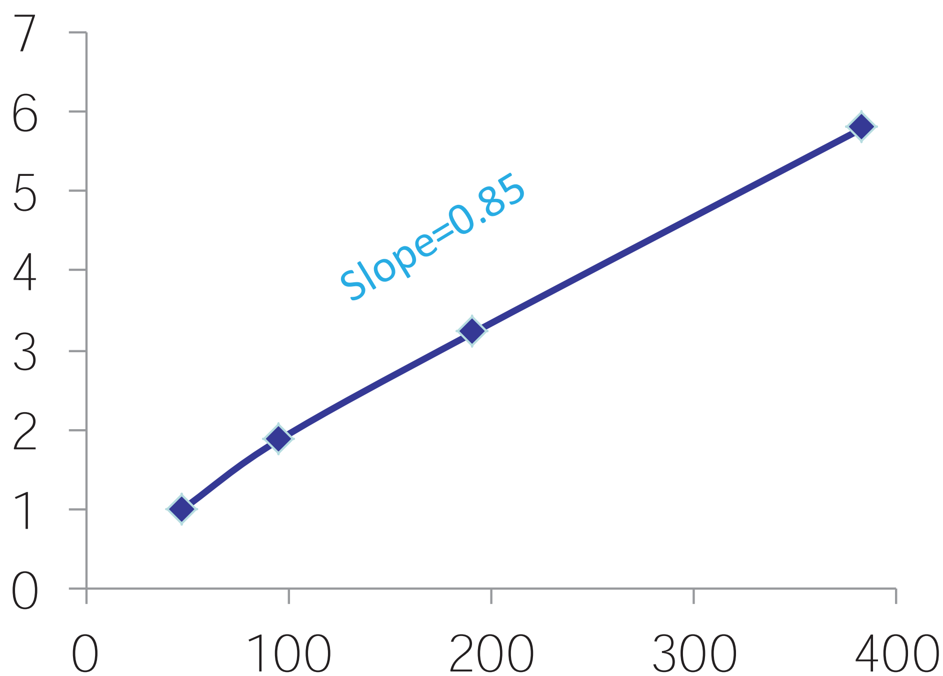
50 million model
1075 x 300 x 150



Application: Penetration – 50 million model

Memory Usage: PHASE 1 (Keyword) – 1028M; PHASE 2 (Decomposition) – 1406M

Maximum memory usage occurs in decomposition phase. We have a 2G memory limit for **single precision.** So this means by **single precision** executables S-ALE model size can be around 50 million to 70 million.



NCPU	Total Time	Advection
48	34966	17323
96	18624	9228
192	10837	5230
384	6032	2616

MPP scalability with 50m model

Application: Penetration – Memory Usage

Comparison of MPP Memory usage between ALE solver and S-ALE solver

With 48 CPU MPP single precision executable, we find the maximum number of elements ALE can handle. Then we run the same model using S-ALE to compare the memory usage.

*ALE_STRUCTURED_MESH_REFINE			
MSHID	NX	NY	NZ
1	4	4	2

12.5 million model
860 x 240 x 60

Memory usage	ALE	S-ALE
Keyword	812 M	267 M
Decomposition	2020 M	361 M

During decomposition phase, ALE uses ~5 times more memory than S-ALE. This makes the model size ALE can run with **single precision** is only 12.5 million.