2010 Beijing Orbital Debris Mitigation Workshop

Hypervelocity Impacts

—Tiny debris, Severe damage

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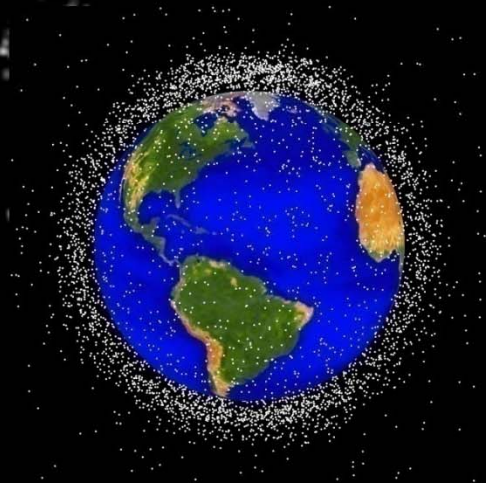
Where is Spacecraft?

How will Spacecraft comeback?

Objects surrounds earth



Do you feel safe to launch Spacecraft?

Picture from nasa website

Hyper Velocity:

*Supperman,100m race man, ~10m/s

- 9.58 Bolt (Jamaica) 2009-08-17 Berlin
- 9.69 Bolt (Jamaica) 2008-08-16 Beijing
- 9.72 Bolt(Jamaica) 2008-06-01 New york
- 9.74 Bowell(Jamaica) 2007-09-09 Italy
- 9.77 Bowell (Jamaica) 2006-08-18Switzerland
- 9.77 Bowell (Jamaica) 2006-06-11 England

From website

Hyper Velocity:
*Car:~340m/s like air wave

- Car in highway: 120km/hour,33.3m/s
- Most fast “Car”:
  Thrust SSC in England， 1228km/h ,
  3km/h faster than sound speed,
  With two Rolls Royce turbofan motor ,
  18 Litre/s。

From website

Hyper Velocity:

*Aircraft:10000km/hour,2777m/s

- 2009,June,X-43,Nasa,3.65m， 1.2ton

Picture from website

Hyper Velocity:
*Spacecraft,7.8km/s

- Spacecraft,7.8km/s
- Aircraft,2.777km/s
- Car,0.34km/s,340m/s
- Supperman,10m/s

Hyper Velocity is a absolute concept?

Velocity is enough high, and depends on materials in impact also

Hyper Velocity:
*orbital debris

- Orbital debris Speed same as to spacecraft;
- Four source:

➢ Launch vehicle;

➢ Mission –related;

➢ Mission-after life of spacecraft;

➢ Breakup of orbital objects.

➢ Attitude lower ,flying faster, earth orbital object speed almost<=7.8km/s.

Hyper Velocity impact material of Orbital Debris:

- Mostly, spacecraft made of AL-Alloy
- Such as 2024 Al, yield stress ~300MPa in static
- Impact Pressure ,~100GPa
- Hypervelocity:Impact Speed is so higher to produce higher pressure than the material yield stress.

Hypervelocity Impact kinetic energy:

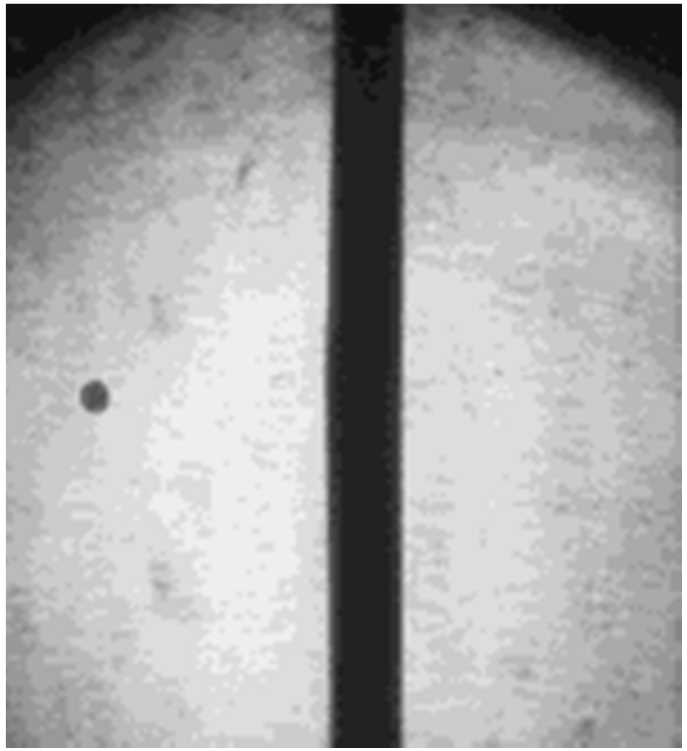
~10mm,that is protected by shield

- 10mm Al-sphere (1.48g)、6.5km/s, Ek= $\frac{1}{2} m v^2$
- ~10g、2.4568km/s
- ~100g、0.7769km/s
- ~1000g、0.2456km/s,884km/hour
- ~55kg、0.033km/s，119km/h（highway）
- ~1500kg、0.00634km/s,22.837km/h（downtown）

Hypervelocity Impact kinetic energy:

~1mm,that happened to penetrate apacecraft wall

- 1mm Al-sphere(1.4mg)、6.5km/s
- ~10g,77.7m/s,279km/hour
- ~55g,33.1m/s,119km/hour (highway）
- ~100g,24.5m/s,88km/hour
- ~1kg,7.7m/s,27km/hour （downtown）



From nasa web

Hypervelocity Impact roles

- Two objects in orbit
- Small to small, more smaller debris happened
- Small to big,

  more smaller debris appear inside bigger one,
  dis-function for big(service spacecraft)
  (that is concerned by shielding designer)
- Big to big,

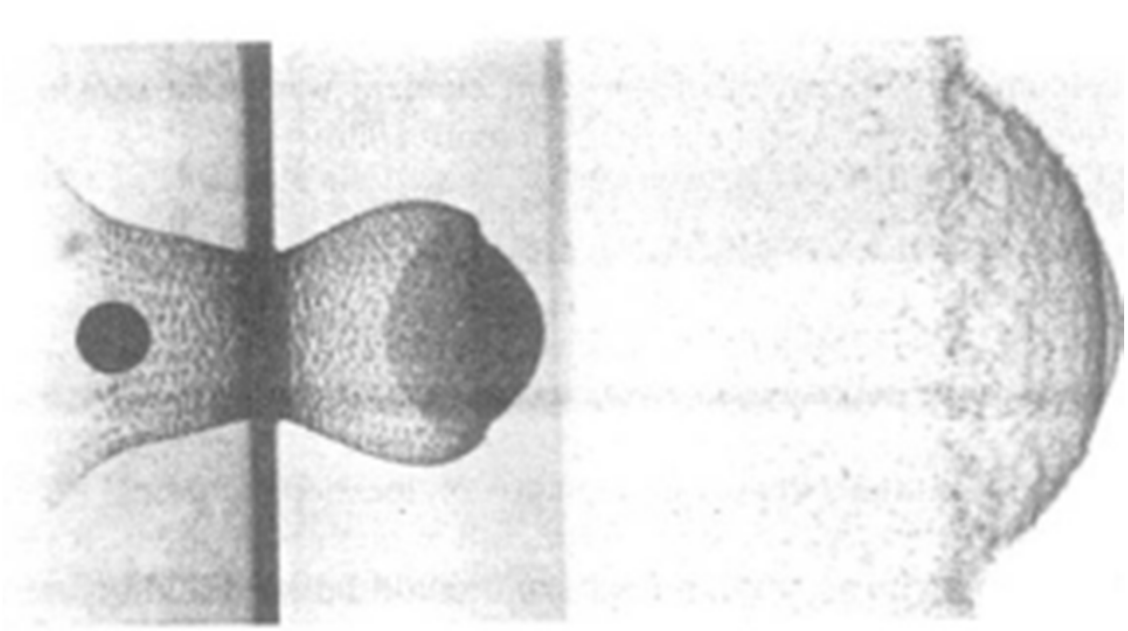
  More smaller debris appear
  some medium debris appear
  few bigger debris appear

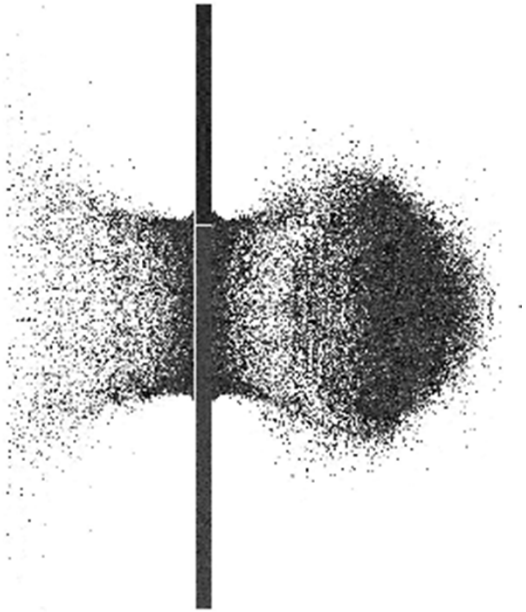
Simulation done…

- Simulation method
- Simple constructer impact
- Some cases…

*Simulation on Experimental Case from reference:

Al Sphere D=9.53mm，V=6.18km/s，Al Plate Thickness=2.2mm

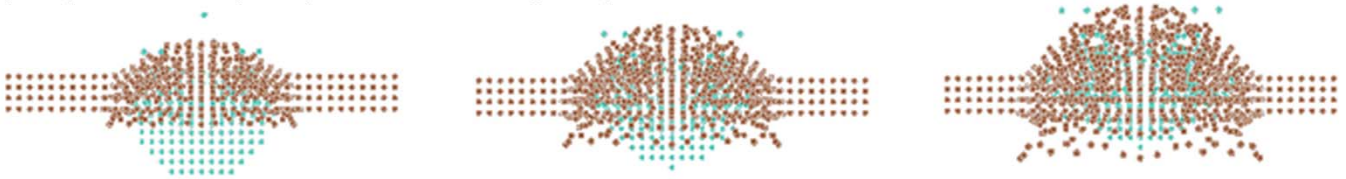




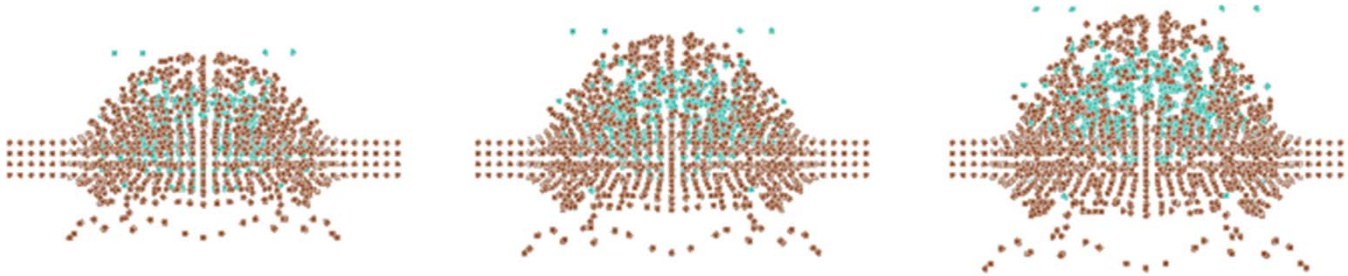
From nasa web

Process of Sphere impact wall…

a)0.2μs b) 0.4μs c) 0.6μs



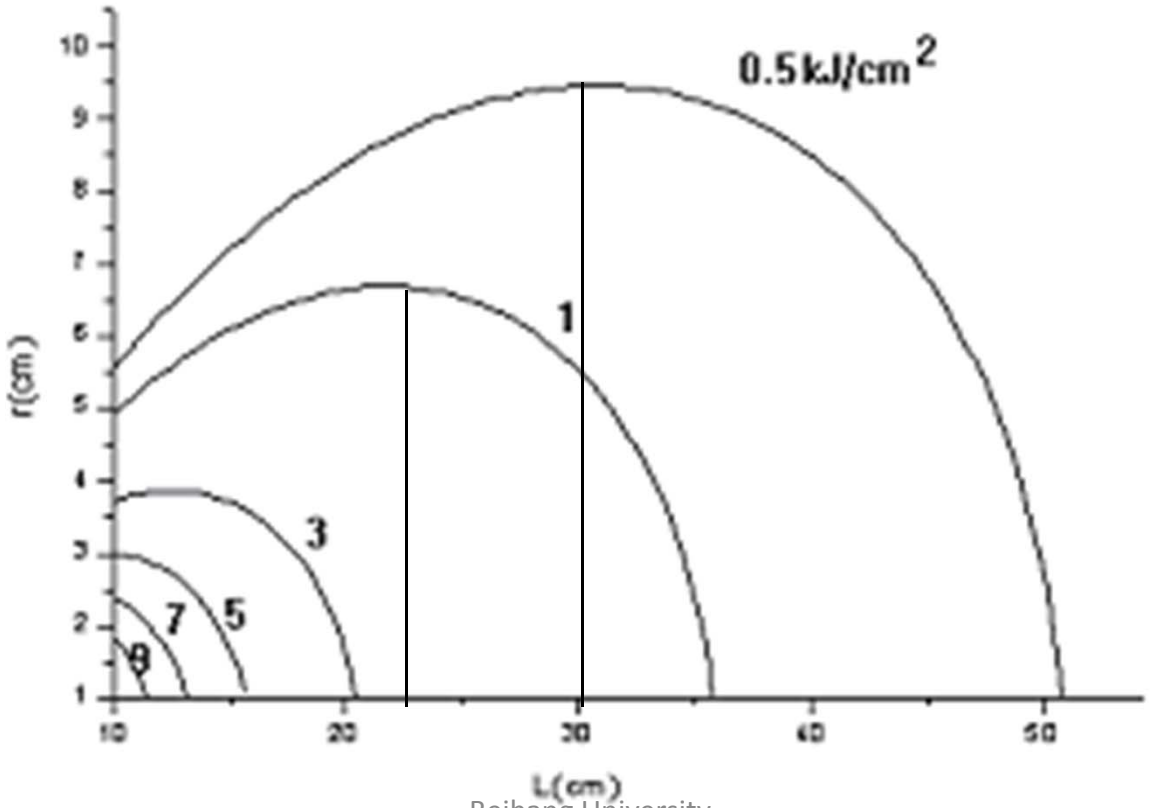
g)1.4μs h)1.6μs i) 1.8μs

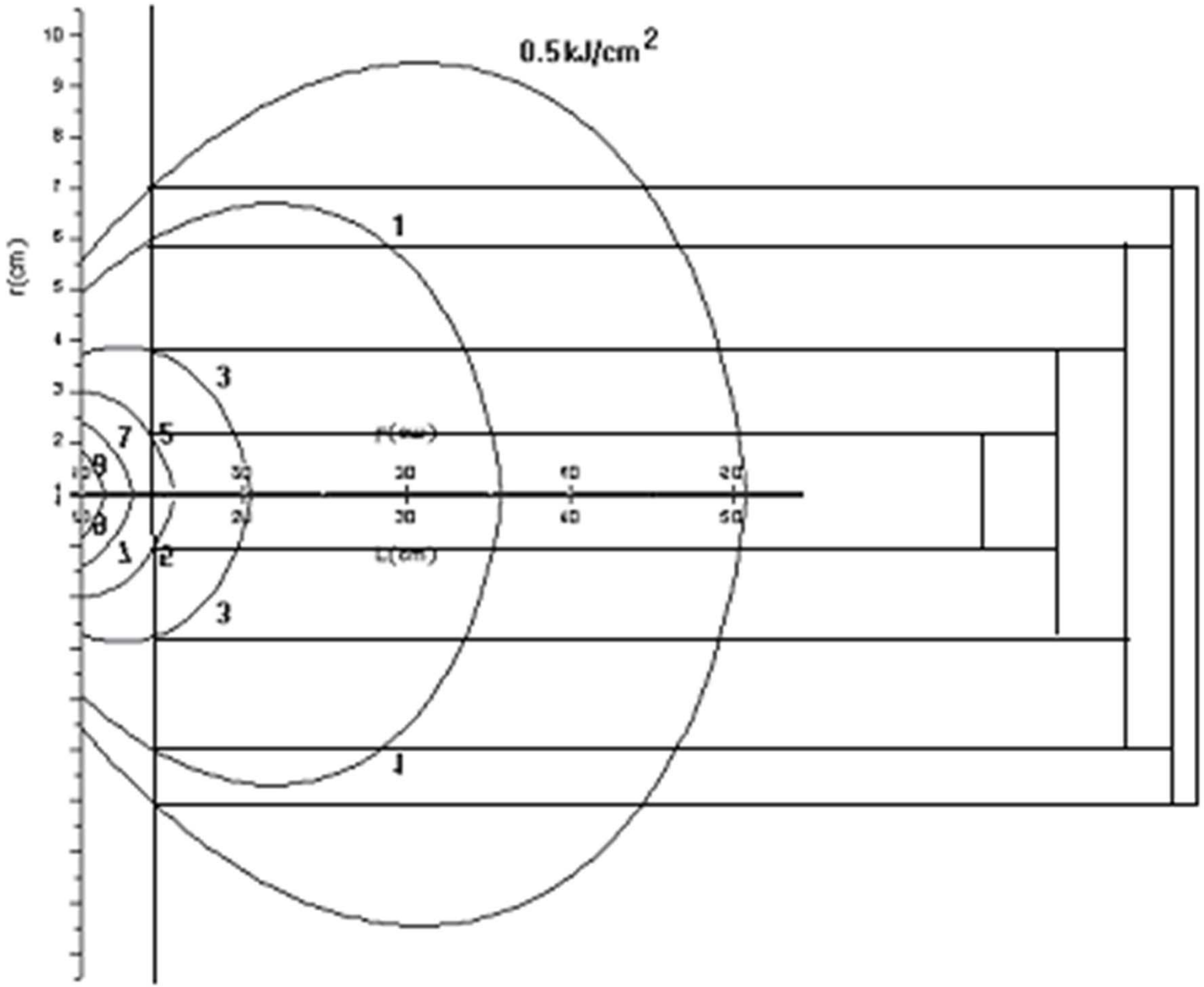


*Inner damage
by Debris cloud behind wall

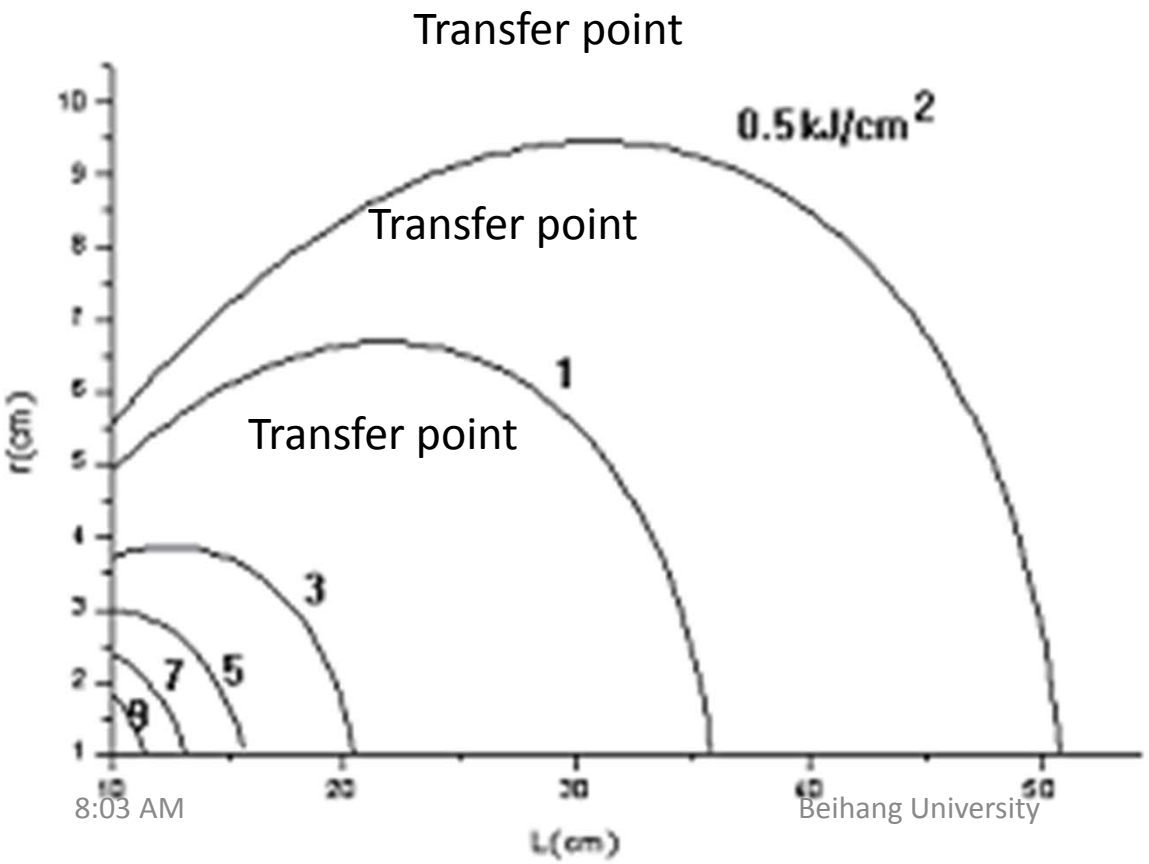
Case: D 9.53mm，V 6.18km/s，t 2.2mm al wall

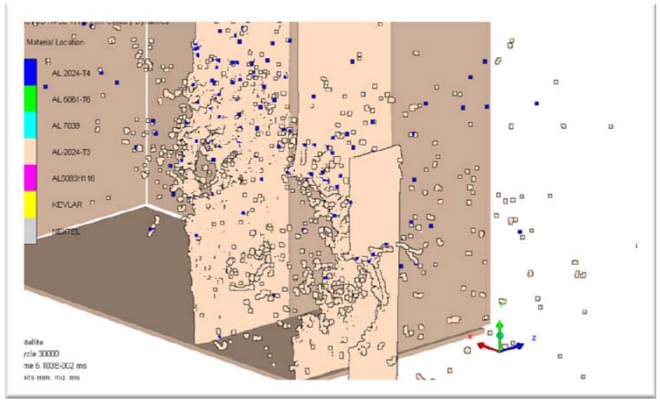
Result:distance 45cm, 1mm al plate; 35cm, 2mm; 20cm, 4mm.

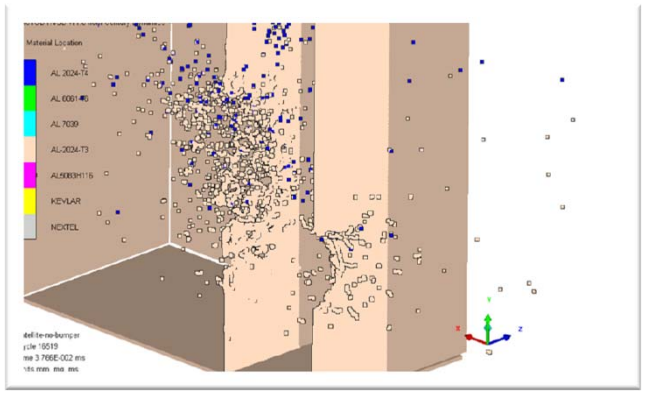



0.5kJ/cm2
r(cm)
1
3
5
7
9
8
1
2
3
1

- Near bigger hole,far small hole?
- Thin plat against bigger ball,hole bigger in second plate(Wall) !

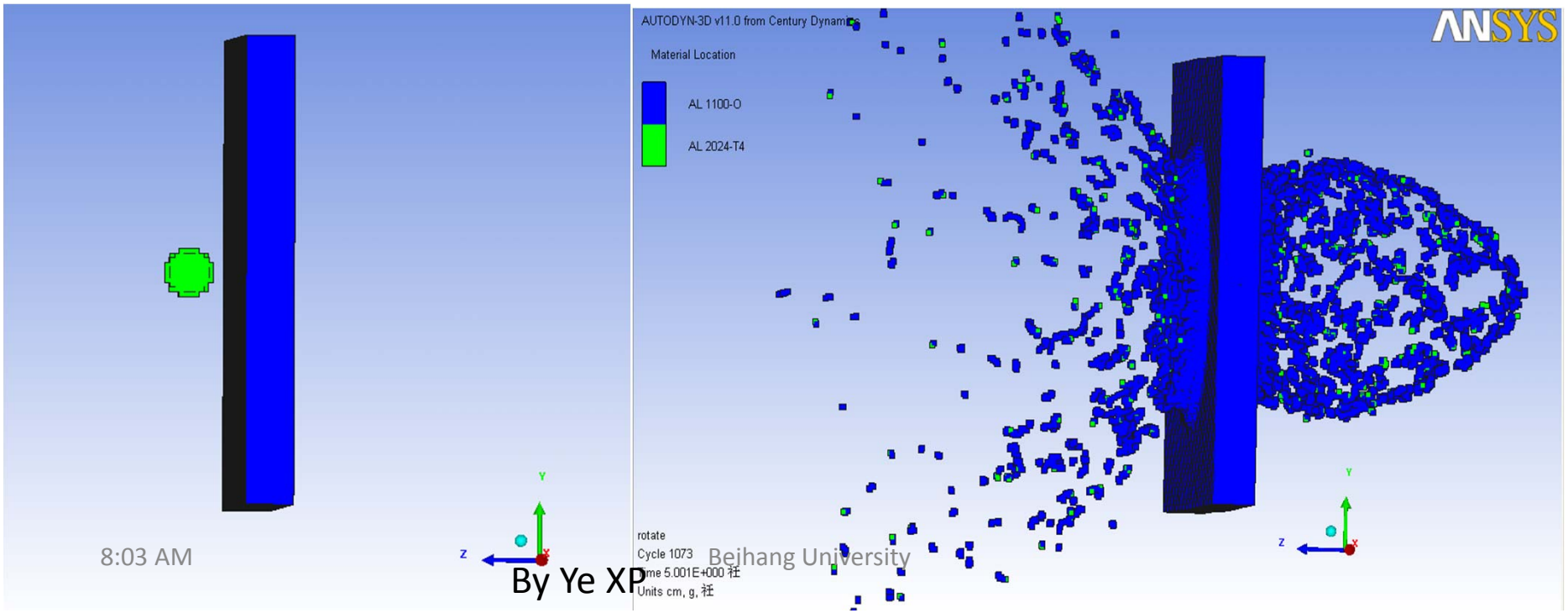




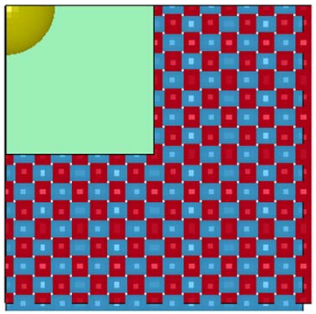


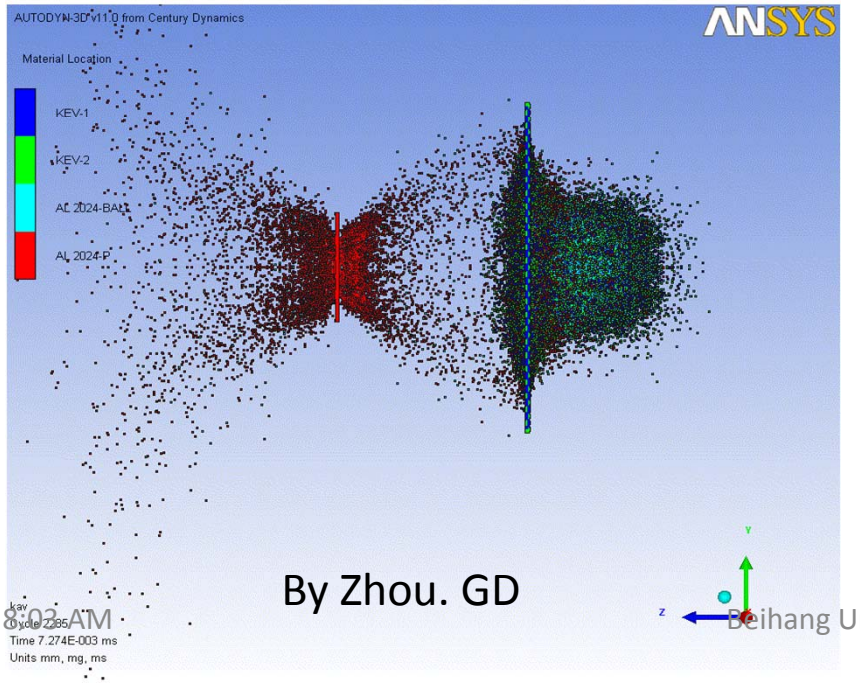
*1mm,5km/s,w/o rotating of ball

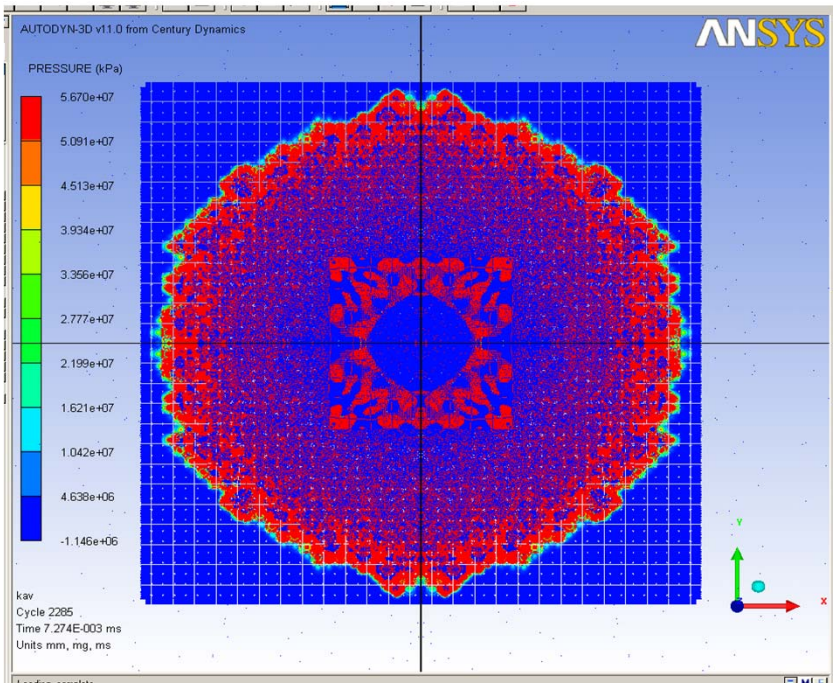
- d=1mm， 10mmx10mmx1mm,h=0.01，SPH,100552.plate-100000， ball-552个。



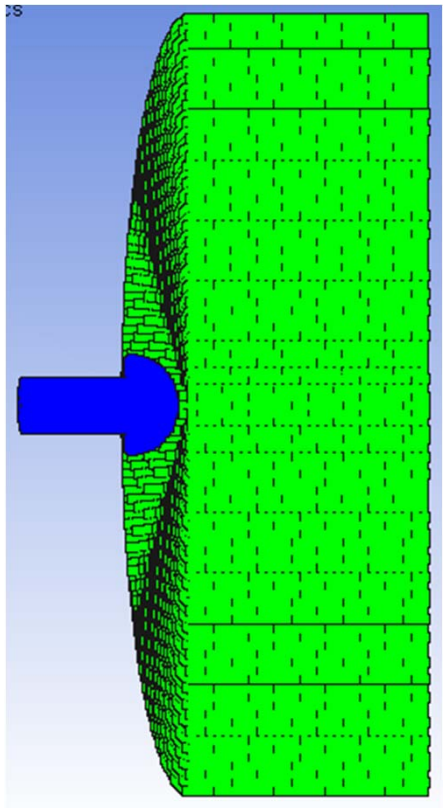
*4mm to 0.2mmAL+kev-epoxy

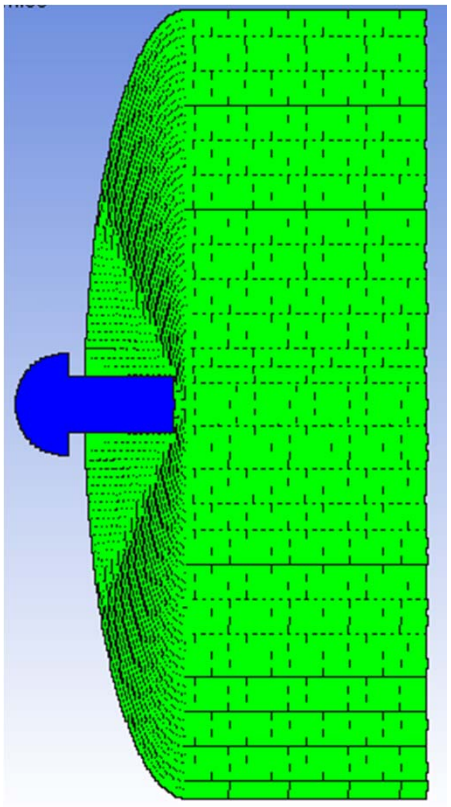


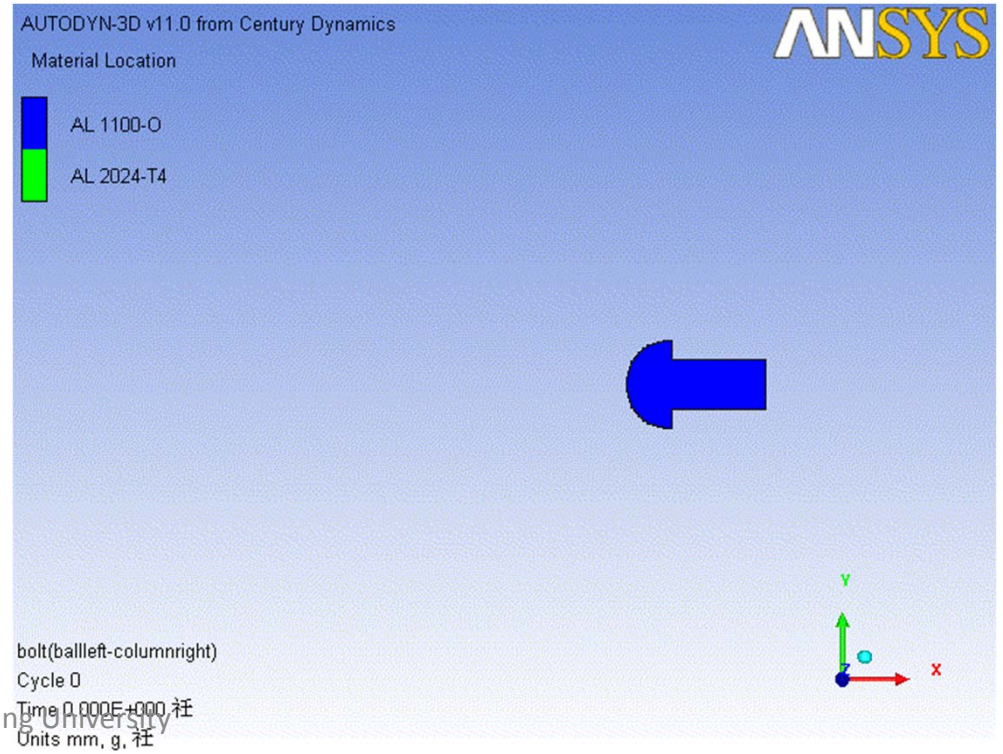




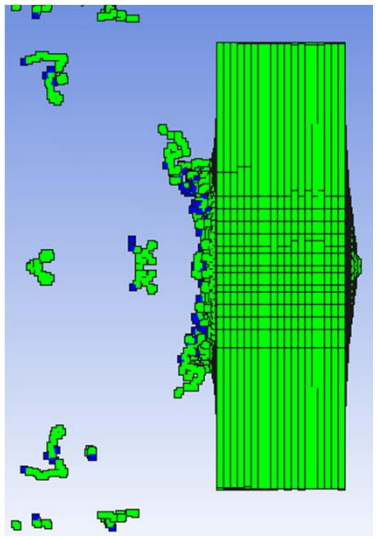
*bolt impact at 4km/s

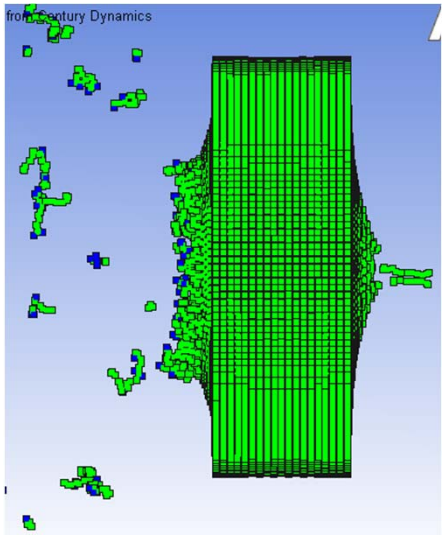






*Shape





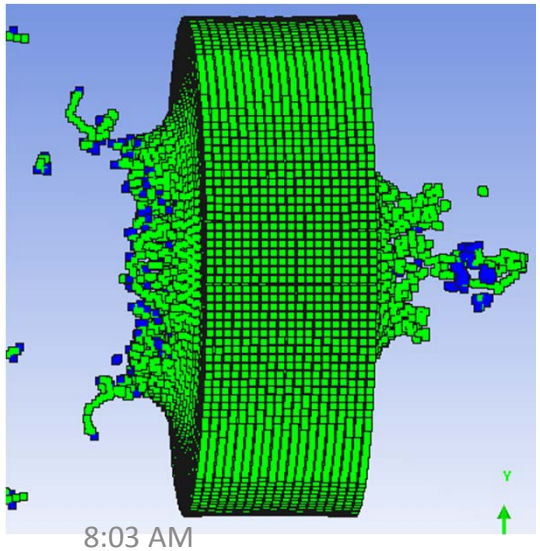
cylinder debris

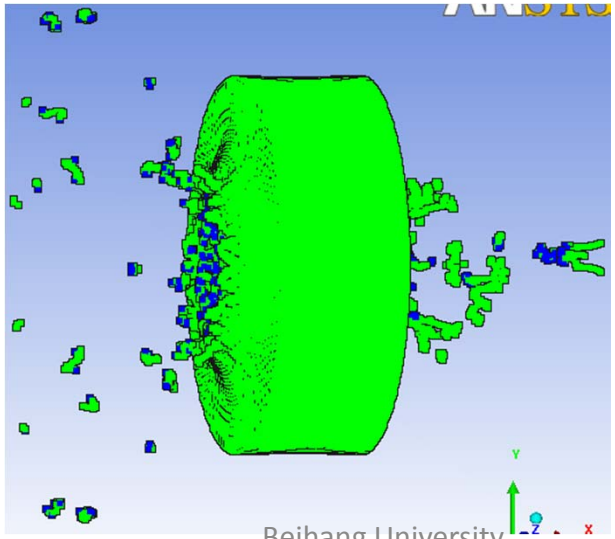
From

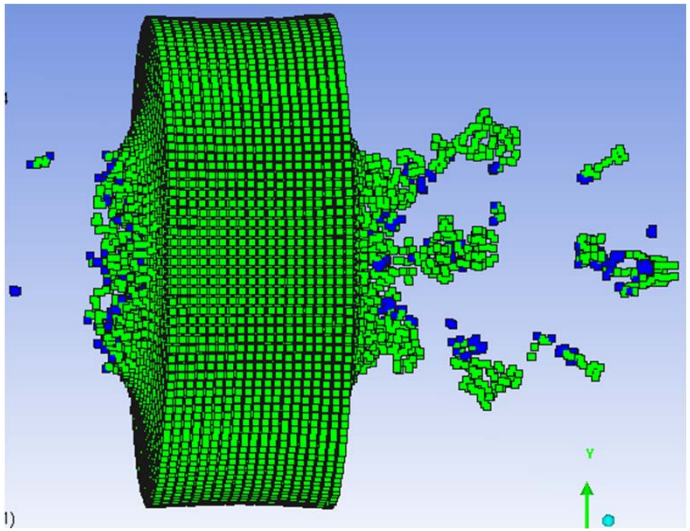
1：2

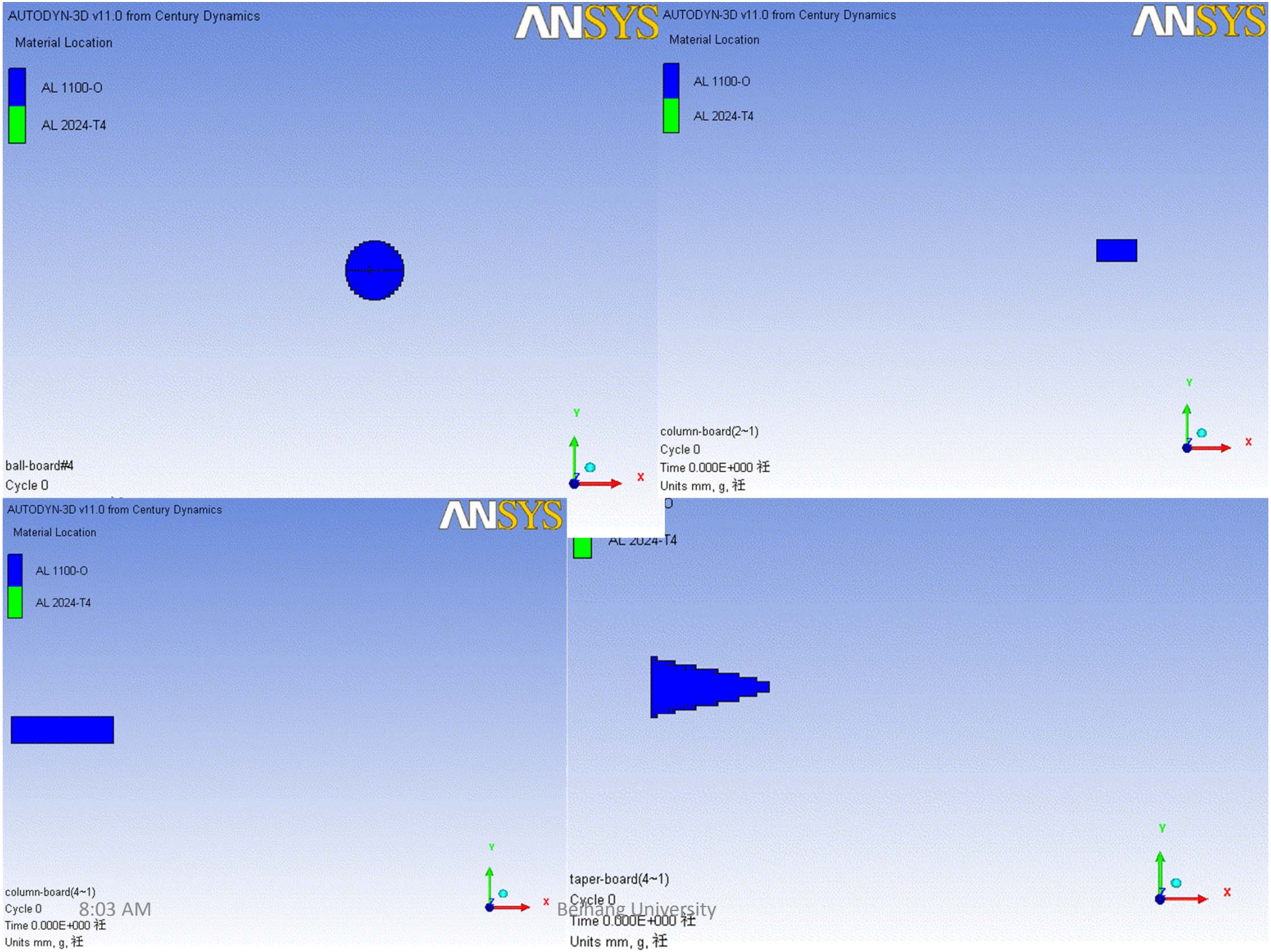
to

4：1





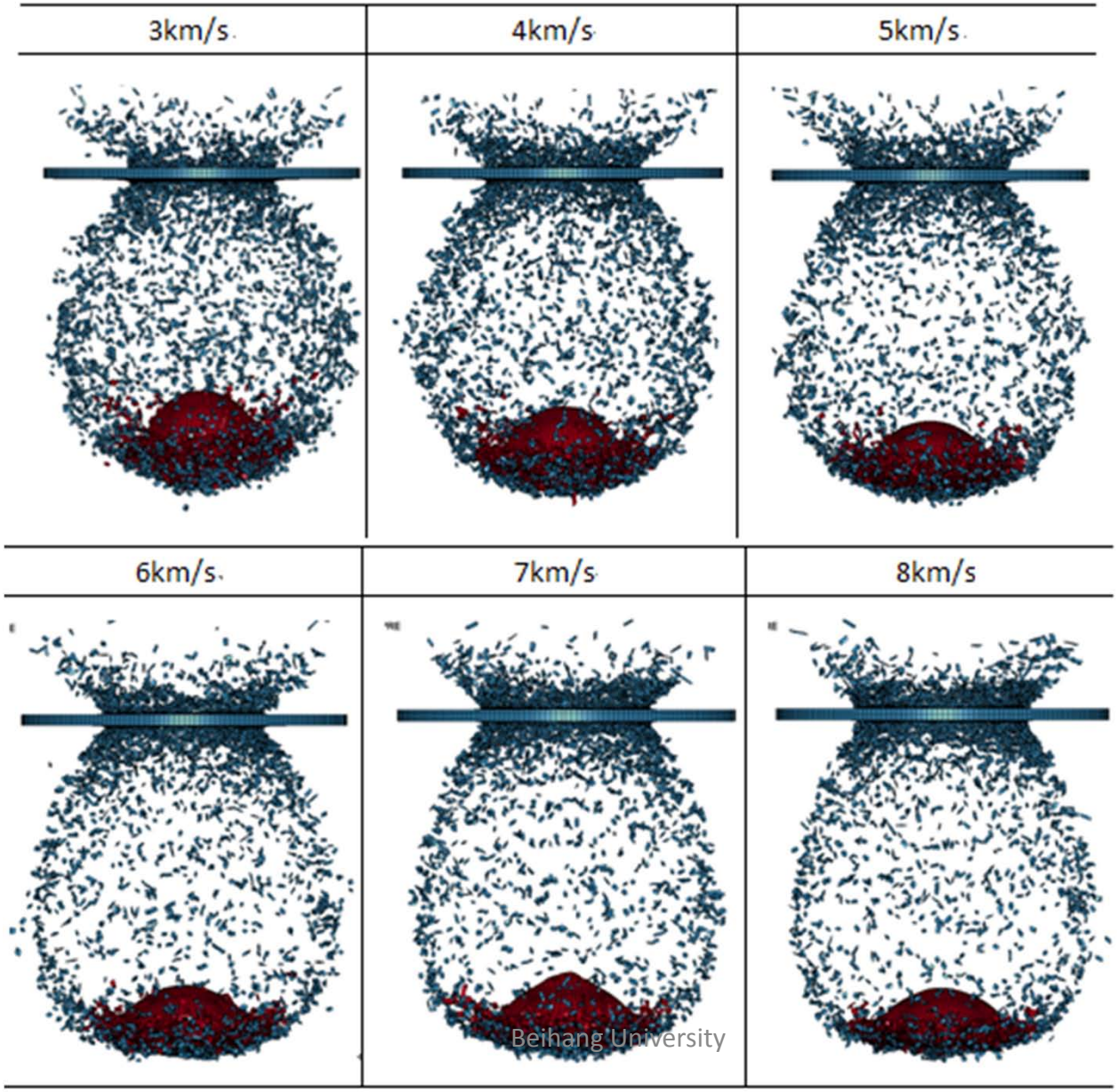




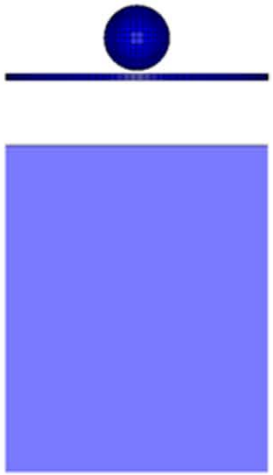
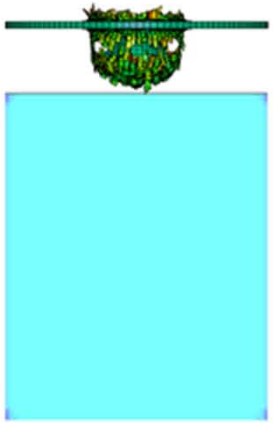
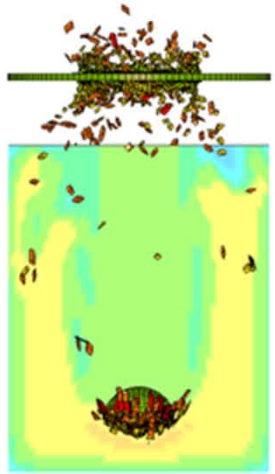
Work underway

- Improve simulation ability about hypervelocity impact;
- Develop more effective method to face more reality

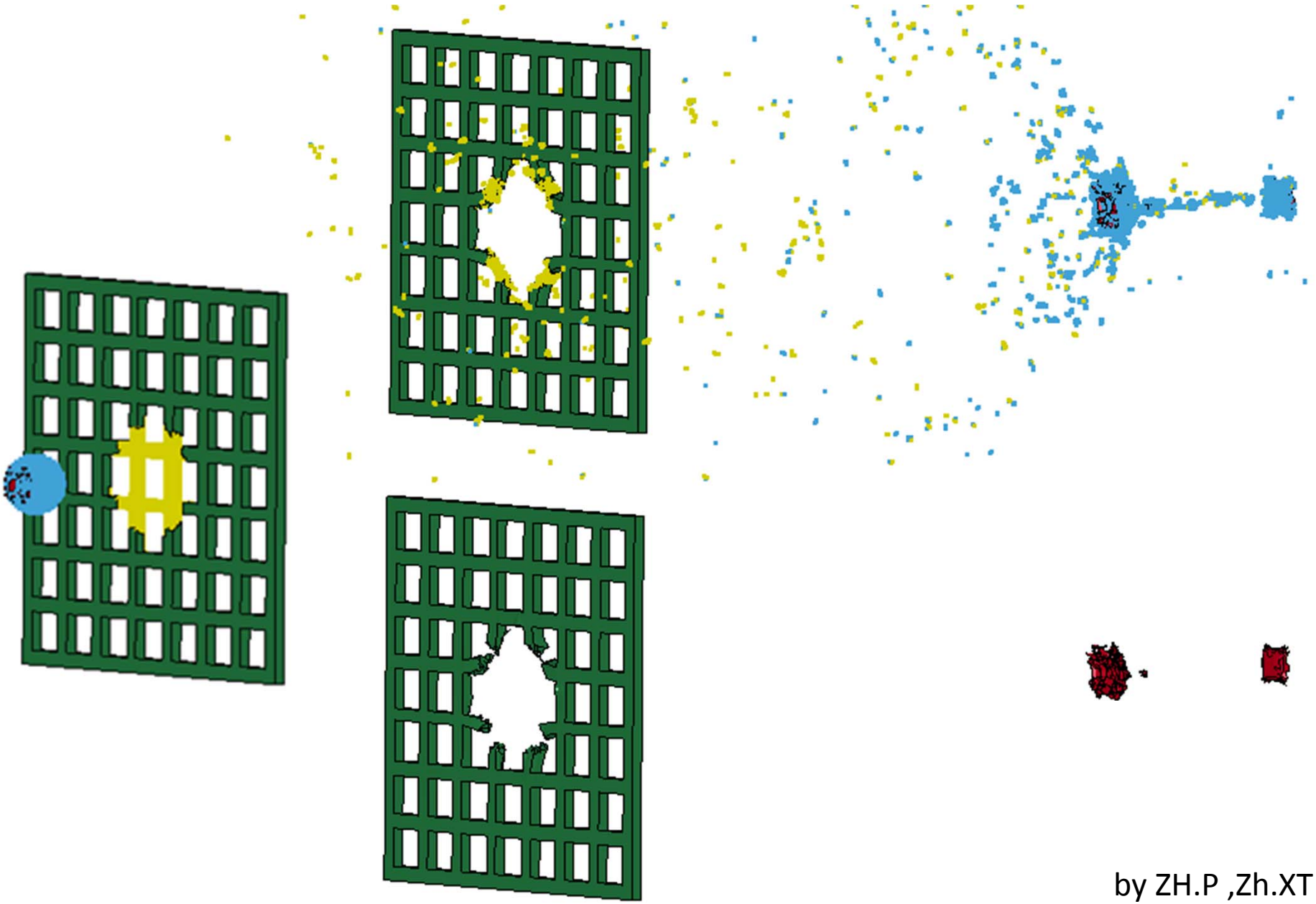
work 1



by Zh.XT

					
0 us	0.5 us	1 us	1.5 us	2 us	2.5 us

by Zh.XT



by ZH.P ,Zh.XT

Summary or Some ideas

- Hypervelocity Impact almost only exists in earth orbit?!
- Impacting event via different mirrors, Experiment and simulation, which one is best choice?!
- Simulation method could give reasonable explain to the experimental phenomena ;
- Exact simulation method could give data as experiment;
- Geometry model of Simulation is relative easy;
- Material model of hypervelocity impact is relative difficult .

Future work

- Get statistic data about different size of debris via hypervelocity impact simulation.
- Find the way to design the spacecraft to avoid lots debris appear in accident impact by big trunk.

Advice to improve

Thank you

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