2010 Beijing Orbital Debris Mitigation Workshop
Hypervelocity Impacts
—Tiny debris, Severe damage

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Where is Spacecraft?

Do you feel safe to launch Spacecraft?

How will Spacecraft comeback?

Objects surrounds earth

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) 2006-08-18 Switzerland
- 9.77 Bowell (Jamaica) 2006-06-11 England
Hyper **Velocity**:

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

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

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

- 2009, June, X-43, Nasa, 3.65m, 1.2 ton
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 $\leq 7.8\text{km/s}$. 

8:03 AM

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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:
\(~10\text{mm},\text{that is protected by shield}\)

- \(~10\text{mm Al-sphere (1.48g), 6.5km/s, }\frac{1}{2}m v^2\)
- \(~10\text{g, 2.4568km/s}\)
- \(~100\text{g, 0.7769km/s}\)
- \(~1000\text{g, 0.2456km/s, 884km/hour}\)
- \(~55\text{kg, 0.033km/s, 119km/h (highway)}\)
- \(~1500\text{kg, 0.00634km/s, 22.837km/h (downtown)}\)
Hypervelocity Impact kinetic energy: ~1mm, that happened to penetrate a spacecraft 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
Process of Sphere impact wall...

a) 0.2 μs  
b) 0.4 μs  
c) 0.6 μs

g) 1.4 μs  
h) 1.6 μs  
i) 1.8 μs
*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.
• 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 0.2mm AL+kev-epoxy

By Zhou. GD

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*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
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<th>Plot 2</th>
<th>Plot 3</th>
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By 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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