Space Debris Reentry Hazards

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Space Debris

- Over 20000 tracked objects (objects larger than 10 cm diameter)
  - 1000 operating satellites
  - Over 13000 tracked objects in Low Earth Orbit (LEO)
- Reentry of larger, uncontrolled objects can be a hazard to people and property
- ~40 large debris objects (objects >800 kg) reenter randomly per year
  - Dead satellites (e.g., UARS, Phobos-Grunt)
  - Launch stages
- Reentry is recommended end-of-mission disposal option for LEO objects
  - Directed reentry to safe area for objects with casualty expectation exceeding defined limit ($1 \times 10^{-4}$ in the U.S.)
  - Random reentry acceptable for objects with lower risk
- Many large objects in LEO lack capability to control reentry location
  - Launched before requirement in place
  - Mission ended prematurely
Reentry Breakup Basics

- Space hardware reenters at very shallow angle (<1 degree)
- ~40 objects weighing more than 1 ton reenter randomly per year
- Major breakup at ~78 km
- 10 to 40% of dry mass on orbit survives and impacts the Earth’s surface; poses hazard to people and property
- Debris spread over long, thin ground footprint

Some Examples of Recovered Debris

- **Oklahoma, 1997**
  - By Brandi Stafford, Tulsa World
- **Texas, 1997**
  - NASA
- **South Africa, 2000**
  - By Nandia Bandorj, Mongol News Media Group
- **Saudi Arabia, 2001**
  - NASA
- **Mongolia, 2010**
  - By Nandia Bandorj, Mongol News Media Group
Models predict number, size, mass of surviving debris
Debris will fall in latitude band defined by orbit inclination
Risk estimated for objects with enough kinetic energy to cause injury or death (> 15 Joules in U.S.)
   Generally assumes standing human outdoors
   Can include sheltering, rolling, other factors
Risk estimated based on population within latitude band
**International Association for the Advancement of Space Safety**

**Where will debris land?**

- **Precise location of reentry point (defined altitude prior to breakup) impossible to predict**
  - Generally assume ±10-25% error in **time of reentry** due to atmospheric and drag uncertainties

**Example:**
- Prediction made with tracking data 1 orbit revolution (90 minutes) from reentry has ±9 minute error
- Object travelling at 7.5 km/sec x ±9 minutes → ±4050 km uncertainty in reentry location

**Impact point for surviving fragments also impossible to predict**
- Spread of fragments will depend on where fragments released, flight characteristics of each fragment
- Fragments for Texas reentry impacted many kilometers from each other
- Local wind can be significant factor
### Typical Risks

<table>
<thead>
<tr>
<th>Risk</th>
<th>Daily Casualty Expectation</th>
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<tbody>
<tr>
<td>Natural Disasters</td>
<td>813 (Deaths, Worldwide, 2010)&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>Natural Disasters</td>
<td>29 (Deaths, Worldwide, 2009)&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>Work Accidents</td>
<td>12 (Deaths, U.S., 2009)&lt;sup&gt;2&lt;/sup&gt;</td>
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<tr>
<td>Motor Vehicle Accidents</td>
<td>99 (Deaths, U.S., 2009)&lt;sup&gt;2&lt;/sup&gt;</td>
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<tr>
<td>Unintentional Poisoning</td>
<td>84 (Deaths, U.S., 2009)&lt;sup&gt;2&lt;/sup&gt;</td>
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<tr>
<td>Assault (homicide)</td>
<td>45 (Deaths, U.S., 2009)&lt;sup&gt;2&lt;/sup&gt;</td>
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<tr>
<td>Falls</td>
<td>68 (Deaths, U.S., 2009)&lt;sup&gt;2&lt;/sup&gt;</td>
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<tr>
<td>Influenza</td>
<td>8 (Deaths, U.S., 2009)&lt;sup&gt;2&lt;/sup&gt;</td>
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<tr>
<td>Meteorite Falls</td>
<td>$1.1 \times 10^{-4}$ (Deaths or Injuries, Worldwide, 1800-1995)&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>Reentry Events</td>
<td>$2.7 \times 10^{-5}$ (Deaths or Injuries, Worldwide)&lt;sup&gt;4&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

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<sup>4</sup> Assumes 100 reentries year, each with Expected Casualty of $1 \times 10^{-4} \rightarrow (100 \times 0.0001/365 = 2.7 \times 10^{-5})$
Reducing Hazards

- New instruments recording what happens during breakup and providing precise information on debris impact locations
  - *Reentry Breakup Recorder (REBR) collected data on reentry and breakup of Japan Aerospace Exploration Agency’s (JAXA’s) HTV-2 vehicle*
  - *Provided latitude and longitude of REBR impact location*

- REBR data will help improve breakup and hazard prediction models

- Future systems may be designed to minimize hazards after reentry (“designed for demise”)

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Reentry Breakup Recorder assembly (recorder is inside heat shield)

Reentry Breakup Recorder during pre-flight testing
Summary

- Over 40 large objects reenter randomly each year
- Variation in Earth’s atmosphere due to solar effects and uncertainty in each object’s aerodynamics and dynamics makes predictions of exact entry location impossible
- Reentry breakup process disperses components of each object along a long, thin debris footprint
  - After release, each object proceeds independently
  - Distance between objects can be many kilometers
- Risks to humans from each event is very low, but not zero
- New instruments increasing understanding of reentry breakup, may lead to designs of space hardware that minimize hazards for random reentry