The Reentry Breakup Recorder (REBR)
“A Black Box for Space Hardware”

Overview & Status

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Outline

• **Background**
  - What is REBR?
  - Why REBR?
  - Reentry survival modeling
  - Need for break-up data
  - Reentry survival models

• **Design**
  - System guidelines
  - Packaging concept
  - Simple interface
  - System characteristics
  - Design goals
  - Notional concept and timeline

• **Current status**
  - Near-term development efforts/testing
  - Participation opportunities
  - Potential related applications

• **Summary**
What is REBR?

• Flight recorder
• Small
• Lightweight
• Autonomous
• Self-contained
• Rugged for reentry
• Global coverage
• Flexible sensor suite
• Simple interface with host
Why REBR?

- Data recording and transmission
- Calibration and validation
- Risk analysis
- Satisfy Government Regulations
- Launch and Safety

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Reentry Survival Modeling

- **Typical survivability model based on laws of physics**
  - Flight trajectory and attitude rates
  - Heating environment
  - Body response models

- **Time integration of governing equations** (with simplifying assumptions) provides
  - Sequence of events for spacecraft break-up (component separation)
  - Size and mass of components surviving to impact
Need for Breakup Data

• **Very little information available to calibrate models**
  – Most debris not found
  – Little known about what happens during break-up
  – No information on new materials (e.g., composite structures)

• **Time histories from actual reentries**
  – Facilitates model validation and calibration

• **Casualty expectation and risk analyses**
  – Becoming increasingly important

• **Worldwide space community**
  – Needs reentry break-up data
Reentry Survival Models

• Operational models now in use
  – Object Reentry Survival Analysis Tool (ORSAT)
    NASA/Johnson Space Center
  – Spacecraft Atmospheric Reentry Aerothermal Break-up (SCARAB)
    European Space Agency
  – Atmospheric Heating and Break-up (AHaB)
    The Aerospace Corporation
System Guidelines

• Need
  – Data collection during break-up of reentering objects
  – Independent collection and transmission of critical telemetry

• Characteristics
  – Attach to host spacecraft or launch vehicle
  – Dormant during launch and operational lifetime of host
  – Wakes up near beginning of reentry
  – Acquires and stores data during reentry and break-up
  – Separates from host after break-up
  – Transmits data to overhead communications system
Packaging Concept

Deployable Cover (shown transparent for clarity)

Communications Board

Separation Mechanism

Outer Enclosure/Heat Shield

Parachute Canister

Patch Antenna

Command & Data Handling/Sensor Boards

GPS Board

Batteries
Simple Interface

Host Spacecraft

Wall of Host Spacecraft

REBR
System Characteristics

• **Data acquired**
  - Temperature at wall of host vehicle
  - Linear accelerations (3 axis) of REBR
  - Angular rates (3 axis) of REBR
  - GPS (position, velocity, time)

• **Flexibility to add sensors**
  - Capability to acquire additional measurements within REBR and at nearby host locations
Design Goals

Current Protoflight

Mass: 2.0 kg
Size: 13 x 6 x 4 in
Average power: 5.1 W

Production Flight Unit

Goals

Mass: <1.0 kg
Size: 50% reduction
Average power: 25% reduction

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Notional Concept and Timeline

- **Host Spacecraft**
- **REBR Orbit**
- **Decay**
- **On-Orbit**
- **Passive Wake-up**
- **Host Break-up and REBR Release**
  - (t+50 min)
- **Communications Blackout**
- **Max Heating**
  - (t+52)
- **Reentry Begins@ 120 km (t=0 min)**
- **Iridium**
- **780 km**

<table>
<thead>
<tr>
<th>Event</th>
<th>Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total time for reentry</td>
<td>~65 – 85</td>
</tr>
<tr>
<td>Blackout duration</td>
<td>~4</td>
</tr>
<tr>
<td>Time from break-up to impact</td>
<td>~7 – 30</td>
</tr>
</tbody>
</table>

Acquire GPS Signal and Transmit to Iridium
(t+55 min to impact)
Near-Term Development Efforts/Testing

• **Communications system test**
  – Demonstrate communication to Iridium
  – Verify published data rates
  – Demonstrate signal acquisition with expected Doppler shift
  – Measure antenna gain pattern and frequency filtering

• **Wake-up sensor test**
  – Demonstrate performance in expected thermal environment

• **Separation mechanism test**
  – Demonstrate performance in expected thermal environment

• **Identify**
  – Candidate hardware

• **Refine requirements**
  – System, heat shield, structural
Near-Term Development Efforts/Testing (continued)

• **Lab prototype**
  – Demonstrate electronic interfaces
  – Commanding of sensors and subsystems
  – Storing of sensor data
  – Communication of stored data

• **Environmental tests**
  – Thermal, vacuum

• **Drop test**
  – Demonstrate passive attitude control
  – GPS signal acquisition
  – Communications link at high altitude with Doppler shift
Participation Opportunities

• **Seeking partners with common interest**
  – Military, civilian, commercial, international agencies

• **Partnership benefits**
  – Acknowledgment of partner participation and contribution
  – Priority access to reentry data
  – Customization of REBR for acquisition of partner-specific data
  – Membership in Reentry Break-up Special Interest Group: obtain latest information on reentry break-up
  – Technical contribution on the design team

• **Another possible option**
  – License use of REBR design
Potential Related Applications

Autonomous Critical Event Recorder (ACER)

- Memory
- Battery
- Transmitter
- Self-contained

Reentry (Reentry Breakup Recorder)
- Heat shield for reentry
- Temperature sensors
- Attitude/angular rate Sensors
- GPS receiver
- Commercial comms

Spacecraft “Black Box”
- Rugged to survive landing
- Store and forward
- Planetary comms

Unattended Ground Sensor
- Harsh environments
- Sensor suites
- Event triggered Sensor

Others
Summary

• **Current reentry survivability models**
  – Require validation and calibration with actual flight data

• **Developing small, robust, self-contained data acquisition and transmission system**
  – Designed to provide *in situ* data on reentry break-up
  – Measures temperature, acceleration, angular rates, trajectory
  – Broadcasts data before impact with the ground
  – Simple integration with host: no power or data interfaces
  – Lightweight, simple

• **Completed concept design by FY03**
  – Preliminary design continuing as subsystems mature

• **Partnerships**
  – Actively working to identify technical collaborations

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Backup Charts
Delta II Second Stage

Nitrogen Sphere
- Diameter: 0.413 m
- Thickness: 4.25 mm
- Material: Ti - 6Al-4V

Miniskirt
- Height: 0.279 m
- Diameter: 2.6 m
- Material: Aluminum

Helium Spheres (3)
- Diameter (2 large): 0.587 m
- Thickness (2 large): 5.66 mm
- Diameter (1 small): 0.413 m
- Thickness (1 small): 4.25 mm
- Material: Ti - 6Al-4V

Propellant Tank
- Diameter: 1.745 m
- End ø radius: 0.873 m
- Length (total): 2.735 m
- Length (cylinder): 0.990 m
- Thickness (cylinder): 1.91 mm
- Thickness (end ø): 1.07 mm
- Material: AISI 410 stainless steel

V-Struts (I-Beams)
- Length (each leg): 1.135 m
- Thickness (web): 4.1 mm
- Width (web): 0.03 m
- Thickness (flange): 4.1 mm
- Width (flange): 0.06 m
- Material: 7075 T7 Al

Guidance Section
- Height: 0.530 m
- Width (fwd): 1.5 m
- Width (aft): 1.38 m
- Material: Aluminum

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Candidate Locations

- Guidance Section (internal mount)
- Forward Skirt (internal mount)