Re-entry Break-up Experiment Assessment

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Contributors

- Fluid Gravity Engineering (UK)
- Belstead Research (UK)
- IRS (DE)
- DLR (DE)
- S[&]T (NL)
- Airane Group (FR)

- Small Study: 75k Euro in total

Re-Entry Experiment

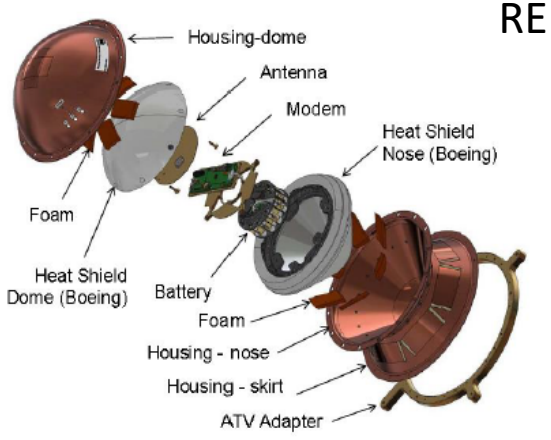
- A number of studies have shown spacecraft fragmentation to be a major driver of casualty risk
- The physical processes associated with re-entry fragmentation are complex and difficult to analyse without empirical support
- Destructive entry fragmentation models should be verified and calibrated against real test data
- A dedicated fragmentation re-entry experiment may be the best way to obtain these data
  - Directly inform modelling approaches in terms of identification of which phenomena need to be modelled
  - Calibrate these approaches in order to generate a representative simulation.

Proposed Re-entry Experiments

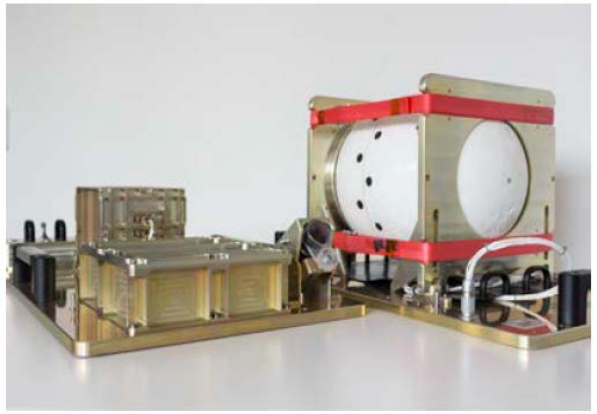
- Historic perspective VAST/VASP: Shallow, targeted entry over highly instrumented range
- REBR: Flown on HTV and ATV, sensors internal to capsule, wireless host-based sensors planned ~10kg capsule
- BUC: Flown on ATV, external IR camera assembly (mounted inside ATV) and capsule based inertial and temperature data, very rapid dev. cycle, connection to IRIDIUM lost after first data packet (30-35km) ~27kg + 16kg camera assembly
- i-Ball: Flown on HTV, internal and external camera integration , internal inertial and temperature data ~25kg capsule including container
- DOC: Yet to fly, target VEGA, possible camera integration, internal inertial, temperature and pressure (plus external pressure) <10kg
- EntrySat (3U): Launched 2019 on Antares NG-11
- QARMAN (3U): Deployed from ISS 2020

Flight Recorders

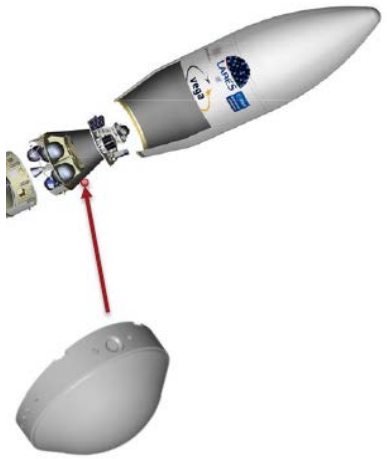
REBR



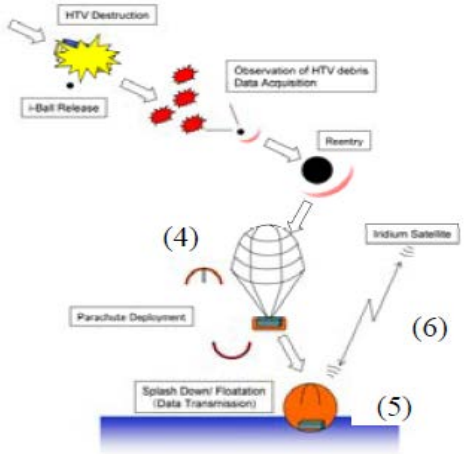
BUC



DOC

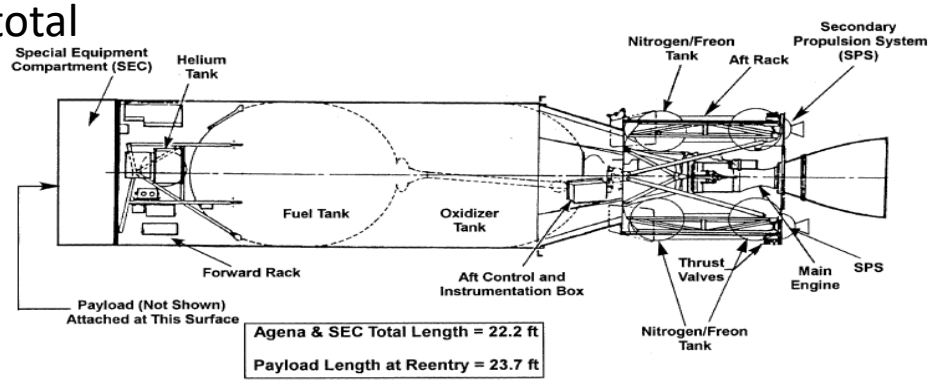


i-ball

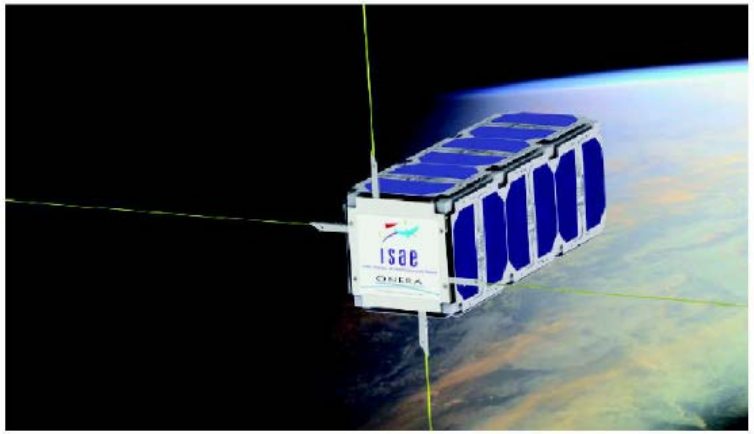


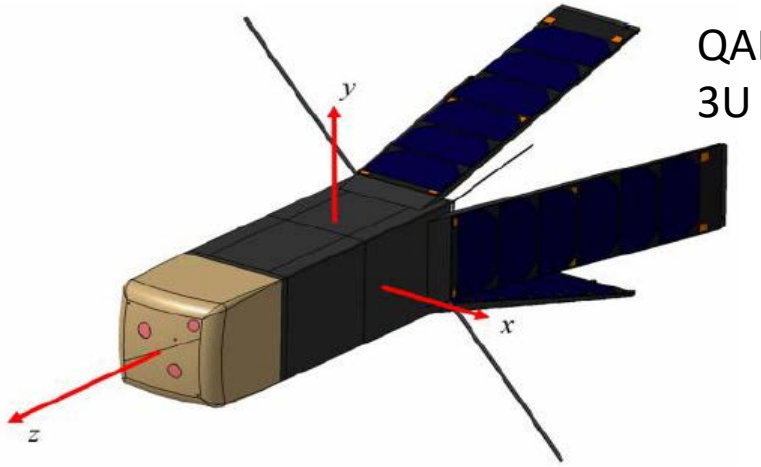
Dedicated Vehicles

VAST
13.9m total

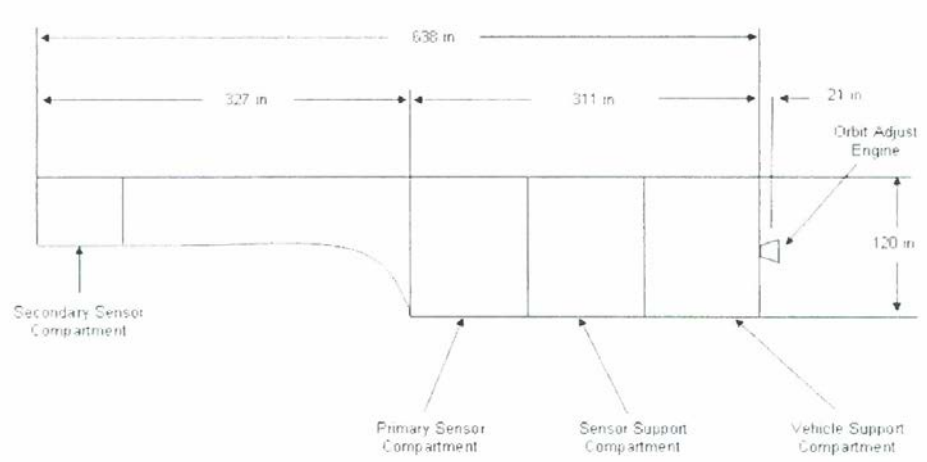


EntrySat
3U



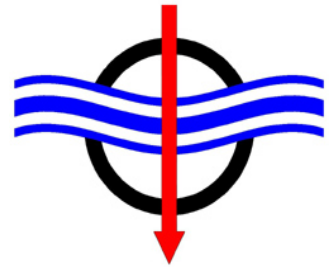


QARMAN
3U



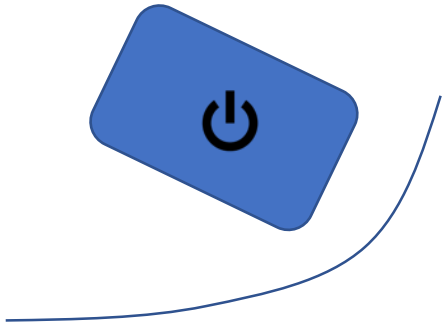
VASP
16.2m

Impact on Field: Flown experiments

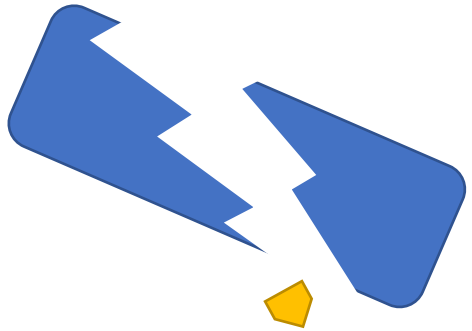


- VAST/VASP
  - Compelling visual data
  - Detailed fragment tracking
  - Remote temperature sensing
  - Origin of “78km rule”
  - High impact but data restricted (could be higher)
- REBR
  - Practical demonstration of flight recorder concept
  - Macro events reconstructed from inertial, pressure and temperature traces
  - No image data collected (context not confirmed)
  - Importance of combined observations or images for context pointed out by Aerospace Corporation
  - Consistency of repeat experiments increase impact
- i-ball
  - First internal/external images recorded and transmitted
  - Captured inertial and internal temperature data (similar to REBR)
  - Pressures not mentioned
  - 9 internal images (8s) and 40 external images (3s)
  - Images “very useful” for determining time of destruction
  - No real detail on how this was achieved from published images
- BUC
  - As i-ball but IR-camera used
  - Temperatures can be accessible from IR image
  - ~10min. video (~6000 images) recorded, 450 images could be sent
  - Video data potentially high impact and shown to be practicable

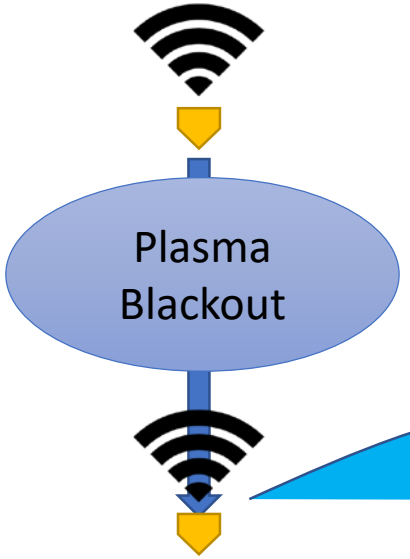
Re-Entry Experiment: Initial thoughts



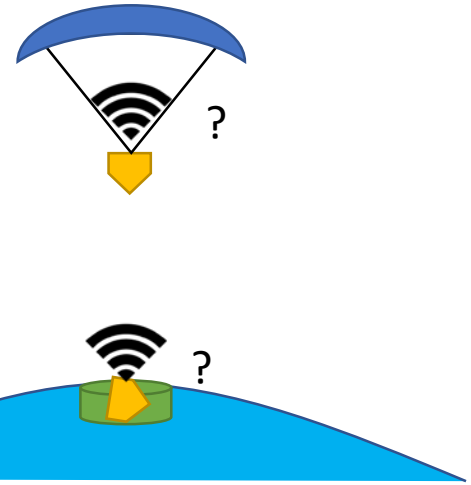
Host re-enters
Experiments and data-bus powers up.
Data logging begins
Possible remote observation begins



Experiments capture fragmentation
Data-bus is released
Data-bus re-entry begins
Possible images of host?
Possible remote observation of fragmentation

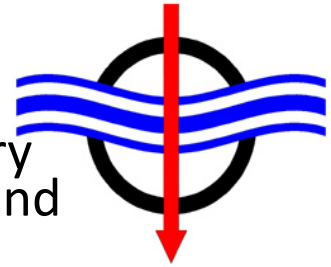


Data bus transmits data e.g. via IRIDIUM and/or alternative telemetry



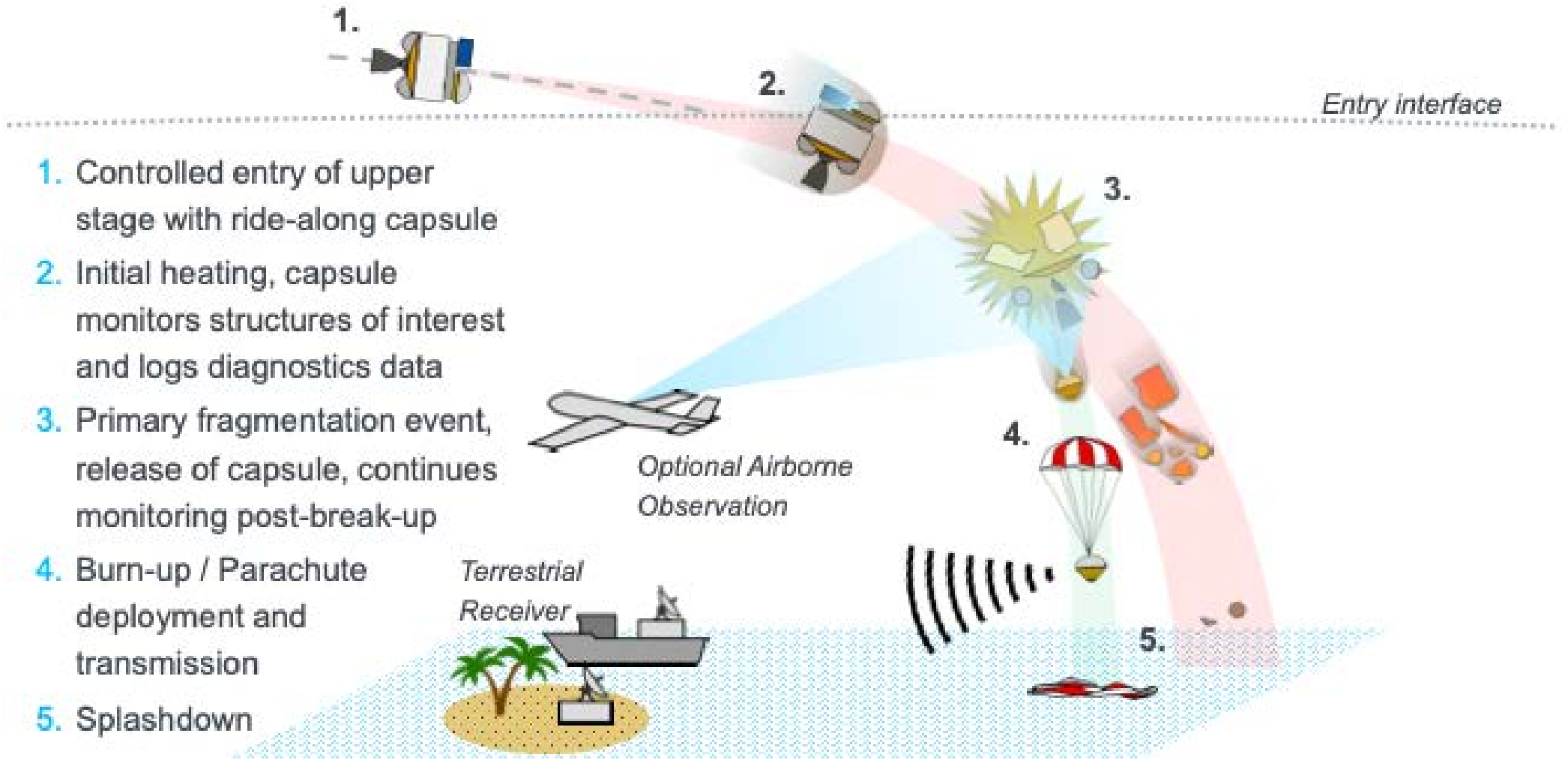
Look to opportunities to extend volume of data. Aero deceleration / floatation device / recovery?

Instrumentation and Objectives



- Flight data is needed to improve the accuracy, reliability and quality of destructive entry safety assessments because they can access data that high fidelity simulation and ground testing cannot
- Visual data (Qualitative)
  - Visual data has proved invaluable in interpreting ground test campaigns
    - Provides context for quantitative data (thermocouple traces)
    - Interpretation of failure phenomena
  - Exploits one of the main advantage of flight testing over ground testing
    - Capturing representative phenomenology
  - Dominates data rate requirements over time-trace data (e.g. thermocouple data)
- Quantitative data
  - Thermocouple data a high priority
    - High data rates not required (4Hz certainly adequate)
    - Forms basis for main comparison with existing models
      - Added value when combined with internal images to provide context
      - Combine with panel contact switches to compare / calibrate joint failure models (can also be implemented in places that aren't optically accessible)
  - Inertial data
    - Flight recorder IMU and possible data acquisition from host IMU
    - Forms basis to reconstruct trajectory and mechanical environment of components / panels
    - Could be augmented with strain gauges or optical strain methods (particularly where high strain anticipated due to thermal weakening)
    - Higher data rate required to mitigate against potentially misleading transient response (50-100 Hz for information about breakup events)

Example Concept



1. Controlled entry of upper stage with ride-along capsule
2. Initial heating, capsule monitors structures of interest and logs diagnostics data
3. Primary fragmentation event, release of capsule, continues monitoring post-break-up
4. Burn-up / Parachute deployment and transmission
5. Splashdown

Closing Remarks

- A Re-entry Experiment is required to improve the reliability and accuracy of destructive entry assessments
  - Empirical evidence is needed to develop and calibrate fragmentation models
- The biggest need for data comes from spacecraft on uncontrolled destructive entries
  - Uncontrolled entry presents a significant difficulty for data transmission, experiment reliability and remote observation
  - Controlled re-entry (upper-stage / cargo vehicle) scenarios are significantly lower risk, have greater opportunity for repeat experiments, can be remotely observed and present more options for data transmission than Iridium only (c.f. uncontrolled experiments)
  - Current lack of data is such that is makes sense to target lower risk mission (i.e. controlled re-entry) in the present phase
  - Instrumenting spacecraft-representative materials (e.g. sandwich panel structures) adds significant value to these experiments
- The ability to extend these experimental methods to an uncontrolled re-entry should be monitored for future activities
  - Most likely requires a higher performance and more reliable transmission technology than Iridium