

Initial Considerations for a Re-entry Breakup Experiment

Clean Space Industry Days

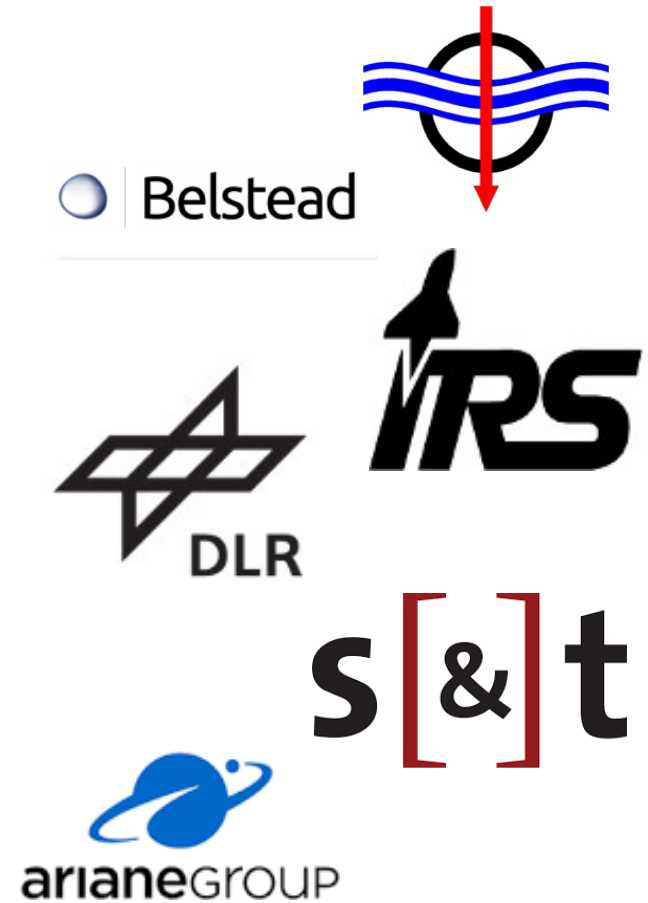
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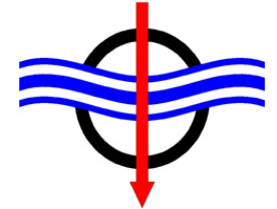
VF081/18

Contributors

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

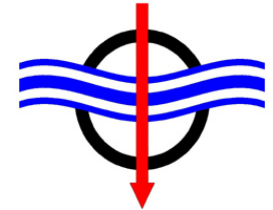


Re-Entry Experiment



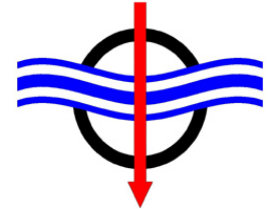
- A number of studies have shown spacecraft fragmentation to be a major driver of casualty risk
- The physical processes associated with re-entry fragmentation are complex and difficult to analyse without empirical support
- Destructive entry fragmentation models should be verified and calibrated against 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.

Work Share



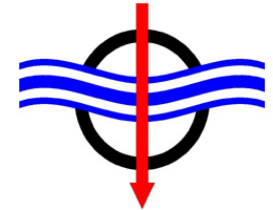
- Scientific Requirements (FGE lead)
 - Identify key data which is required to inform/validate predictive capabilities
 - Review previously proposed experiments
 - Data quality and quantity requirements and respective data collection
 - Need for repeat flights
- Trade Study (IRS lead)
 - Select two feasible, cost effective and high-return experiment concepts
 - Balance experiment cost against what can feasibly be determined through ground testing
- Concept Analysis (DLR lead)
 - More detailed concept definitions (mass, cost tech. maturity, coms requirements)
 - Roadmap to flight
 - Identification of risks

Expert Consultancy



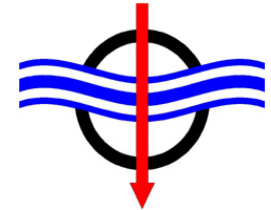
- S[&]T
 - Lessons learnt from DOC development
 - Applicable mission profiles: trade-off performed in the course of DOC study up till PDR
 - Different data collection options (not just images)
 - Technical and programmatic risks
 - Communication issues
- Ariane Group
 - Contribute to identifying key phenomena to be targeted and corresponding measurements specific to launcher upper stage
 - Seek to identify those aspects of a experiment concepts which would be useful to both launcher and spacecraft

Initial Assessment of Knowledge Gaps

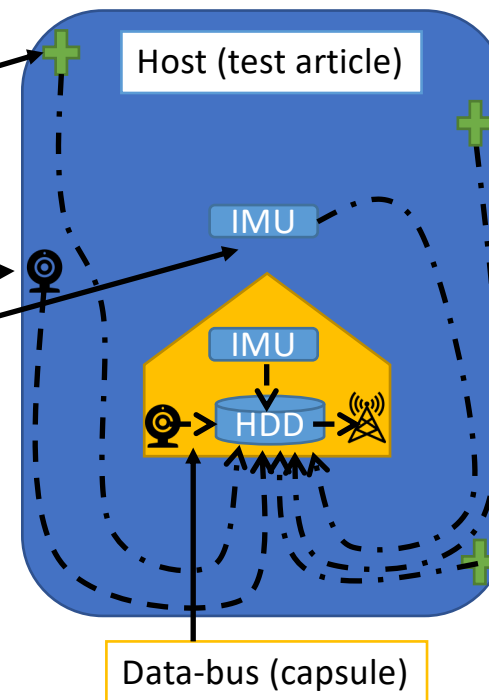


- Spacecraft uncontrolled entry: does panel failure/melt or insert/joint failure initiate fragmentation?
- Launcher upper-stage controlled or semi-controlled entry: Fragmentation correlated to melt (VAST/VASP); role of Aluminum oxide layer?
- How are aero and inertial forces transmitted through structures in free flight to initiate fragmentation when structural components may have lost a significant fraction of their cold strength?
 - Centrifugal forces may play a significant role for uncontrolled spacecraft entry
- Importance of degradation of low temperature bonds
- How would the extensive use of composite materials (especially CFRP struts and structures) alter established views of fragmentation (VAST/VASP heritage)?

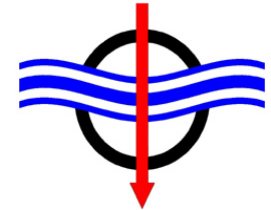
Re-Entry Experiment: Some Options (Just schematic)



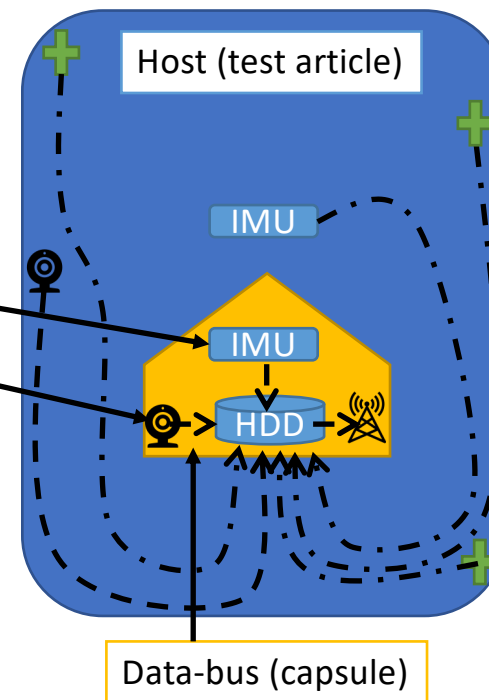
- Host Experiments
 - Host instrumentation
- Host mounted camera
- Host mounted IMU



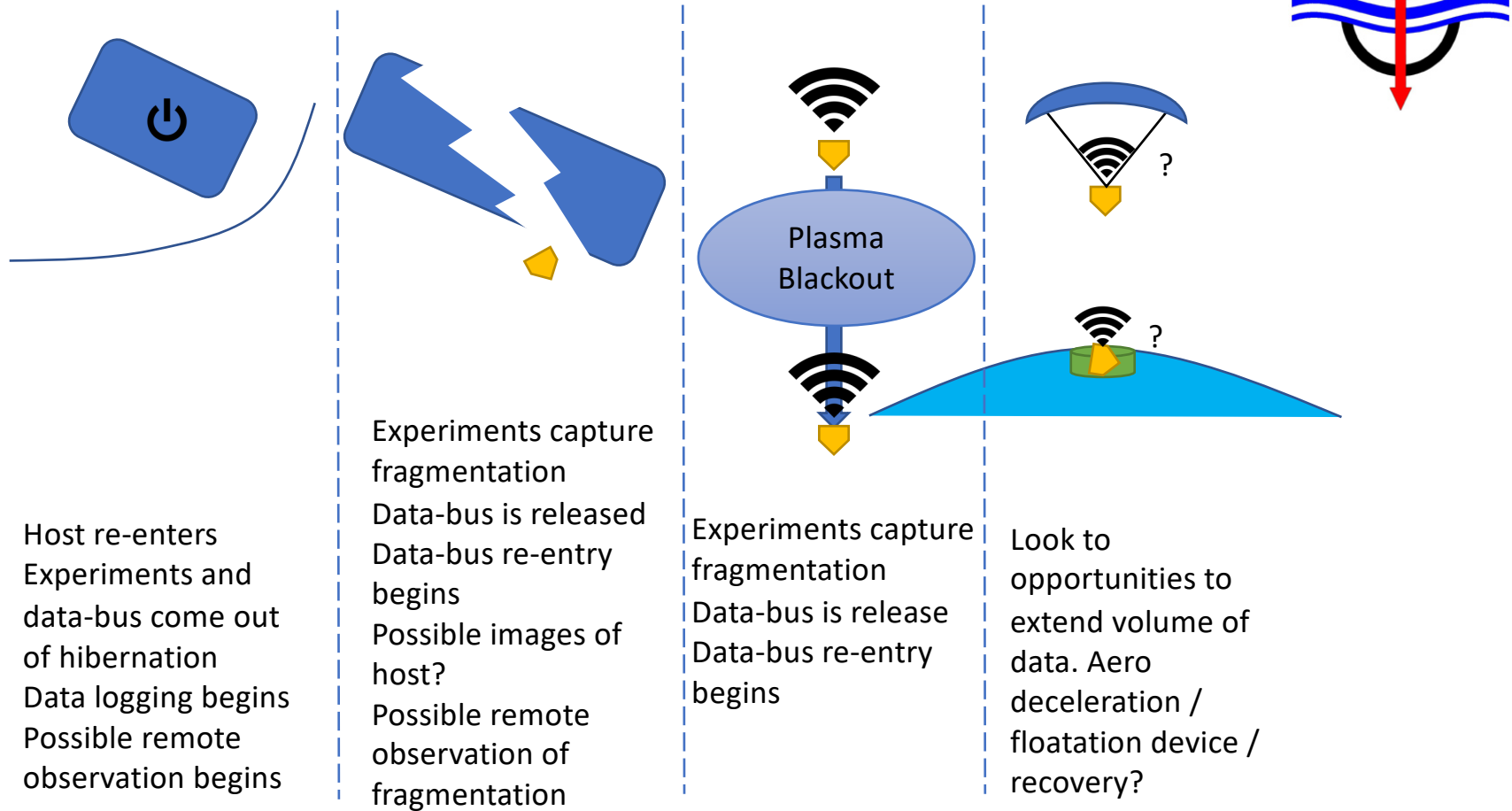
Re-Entry Experiment: Some Options (Just schematic)



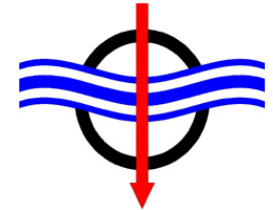
- Data-bus Instrumentation
 - IMU
 - Camera
- Data storage and transmission
 - Digital sampler and storage
 - Transmitter



Re-Entry Experiment (Just schematic)

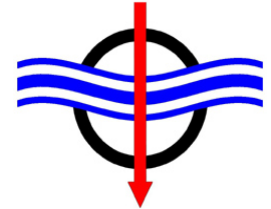


Important Initial Trades



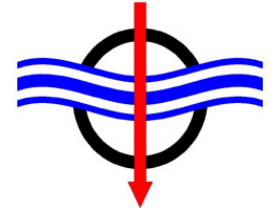
- Type of host
 - Launcher or spacecraft representative (what is useful for both)?
 - Real mission or custom build?
- Prioritization of quantitative and qualitative (images) data
 - Images take a higher data budget but can reveal phenomenology (currently uncertain)
 - Remote (terrestrial / airborne) observation
- Host trade-off
 - CubeSat patter (8U-24U)
 - Larger custom build (RemoveDebris size)
 - Real LEO platform
 - Real upper stage

Preliminary Considerations



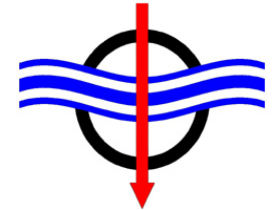
- Strong incentive to collect data relevant to satellite type sandwich panel structures
 - Presently available observational data is more relevant to launcher type structures
 - Even so, high value US data (VAST/VASP) is not fully visible to European entities
- Scientific requirements
 - Focus on phenomena which are difficult to simultaneously recreate on ground
 - Gradual heating relevant to uncontrolled entry with rarefied / transitional effects
 - Investigate role of free flight inertial forces to initiate fragmentation
 - Mitigate significance of edge/scale effects on material demise
 - Opportunity to test sizable structures

Preliminary Considerations



- Instrumentation prioritisation
 - Significant number of thermocouples using invasive instrumentation (e.g. potting material, panel front and back skin) if possible
 - Panel-to-panel contact-switches to determine separation events
 - Internal imaging to provide context
 - Tech. maturity and feasibility to be established
 - Vibration sensors to provide dynamic loads (augment IMU data)
- A question of scale and time
 - CubeSat pattern could be cost effective but problems implementing a realistic sandwich-panel structure
 - Consider larger scale custom-build
 - Real LEO platform too long-lived to offer scientific return in a practical time-scale

Summary



- Re-entry break-up experiments represent a unique opportunity to improve our predictive capability with respect to destructive entry
 - Equivalent ground test lead to complex experiment design which will always leave some questions regarding representative quality
- Collecting the most valuable data and flying a test article of suitable scale is challenging
 - Prioritizations and compromises will need to be sought
- Initial trades and prioritizations are important for a prospective project which could require significant investment
 - Feedback from the community is necessary in order to make sure future challenges associated with spacecraft fragmentation and D4D are being addressed