Instrumentation and Requirements for Re-entry Observation Campaign (ATV- 5)

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This document gives a short summary of the ATV-5 Instrumentation and Requirements for Re-entry Observation Campaign Workshop held at the Institute für Raumfahrtsysteme at The University of Stuttgart from March 5th till March 7th.

Attendees:

T. Lips (HTG), M. Trujillo (ESA), H. Krag (ESA), S. Ventura (ESA), S. Fasoulas (IRS), S. Weikert (ASTOS), R. Dantowitz (CCO), J. Snively (ERAU), C. Giannopapa (ESA), P. Jenniskens (SETI), J. Vaubaillon (EMCCE), C. de Persis (TCD), E. de Pasquale (ESA), J. Martinez-Schramm (DLR), H. Fulge, U. Bauder, M. Eberhart, T. Hermann, S. Löhle, T. Marynowski, F. Zander, T. Stäbler (all IRS)

Online Attendees:

J. Albers (Lockheed Martin), J. Bacon (NASA), M. Winter (UTK), H. Nielson (UAF).

Presentations

The presentations of the experimenters are available upon request and clearance through ESA.

A brief description of the major points raised in the presentations of ESA, HTG, and SETI with respect to the requirements of an ATV-5 observation are presented below.

Maite Trujillo - ESA

Uncontrolled atmospheric entries have an inherent risk associated with them as parts of the entry body may reach the Earth's surface. Sophisticated modelling tools are required to evaluate these risks and this is particularly valuable for controlled entries where the risk can be actively mitigated. The ATV-1 re-entry was observed with the objectives of characterising the re-entry, characterising the explosion events, measuring the number, size and Δv of fragments, measuring the wake emissions and ablation products and gathering enough data to reconstruct the trajectory. This was the first re-entry of an ATV and it passed all safety criteria.

- Conclusions:
  - Current planning for the ATV-5 vehicle is a re-entry to be observed from the ISS and entry characteristics to be measured using the on-board Re-entry Break Up Recoders (REBR, i-Ball and BUC).
  - In ATV-2, REBR failed.
  - In ATV-3, REBR functioned nominally the release was probably during break-up.
  - ATV-4 was only observed from the ISS.
- ATV-5 observation issues:
  - The objectives for an observation campaign of ATV-5 are a better understanding of destructive atmospheric re-entry particular break-up, fragmentation and trajectory (current observation foreseen from ISS with limited goals in support to ISS End of Life.
  - A flight observation campaign is critical for gathering data for these particular objectives.

Tobias Lips - HTG

Objects entering the atmosphere heavier than 1 ton have fragments that hit the Earth's surface. There is a formal definition for an acceptable risk for re-entry objects that can be controlled but this requires high fidelity modelling tools for proper evaluation. There are various modelling tools available for this analysis but they need more validation. Validation is done in four different ways, backward validation, comparative validation, experimental validation and flight validation.

- Conclusions:
  - Flight validation is the best option.
  - The biggest current uncertainty is the fragmentation below 90 km.
- ATV-5 observation issues:
  - 3D fragment tracking and fragment identification from 90 km down to 50 km is sufficient.
  - Really want $\pm$50 m resolution.

Holger Krag - ESA

A software tool has been developed to simulate an airborne observation. Plasma emission is not yet taken into account.

- Conclusions:
  - Number of fragments is of highest interest.
  - Instruments pixel resolution and field of view drives the detection.
- ATV-5 observation issues:
  - A measurement of the Δv isotropy would be an asset.

Peter Jenniskins - SETI

ATV-5 is planned to perform a shallow re-entry mission to emulate the presumable ISS re-entry. This is the first opportunity to get data relating directly to the ISS re-entry. The Google Gulfstream V is not available.

- Conclusions:
  - Night time re-entry is required.
  - Instruments pixel resolution, field of view, and wavelength coverage are by far better since ATV-1.
- ATV-5 observation issues:
  - The main focus would be the initial explosive event, because the fuel release is still not understood.
  - Painting of parts of the vehicle could be helpful for the fragment identification. Salts are seen as a first good guess.

Emilio de Pasquale - ATV-5 Mission Director

The ATV-5 launch and hence ISS undocking date is not yet fix. Currently undocking is foreseen for 15^{th} December. Another option is an early February undocking. ATV-CC can only offer flight observation mission support limited to trajectory safety, ISS phasing and co-ordination with MCC-H and MCC-M. From undocking to re-entry there will be minimum 4 days (phasing requirement) and a maximum of 22 days (power limit).

- ATV-5 observation issues:
  - Re-entry will be phased with ISS, which requires night re-entry.
  - Significant interest (wrt ISS entry) is in the transition regime (120 – 90 km)

– Currently two re-entry windows: 29/12/14–2/1/15 and 27/2/15–7/3/15.

Airborne Observation Mission

As an outcome of the workshop, a scientific rationale for an airborne observation mission has been discussed and a mission scenario has been designed. Possibilities from an timing point of view have been discussed with NASA with respect to ground based observation constraints, ATV-5 docking times, ISS traffic, and airborne mission planning of the DC-8 crew.

Main Goal

Provide the information on fragmentation and fragment distribution needed to further validate and improve modelling tools for re-entry safety.

Auxiliary goals

- Compared to ATV-1, what is the difference in fragmentation of a shallow entry?
- How and why does ATV-5 fragment and what are the effects of a shallow entry?
- Are there any unthought events from which conclusions of the shallow entry can be inferred?

How to answer the questions

- Observe the timing and evolution of ATV-5 fragmentation and compare to ATV-1.
  - Explosion fragmentation
  - Fragment trajectories after first explosion
  - Atmospheric perturbation for energy release
- Analyse the main explosive event
  - Detection of explosion temperatures
  - Analyse fuel release through spectroscopy
- Identify and track fragments for a longer period of time (20s)
  - High dynamic range imaging to allow simultaneous detection of bright and faint objects
  - Spectroscopy UV-NIR to identify the metallic structures
  - Use a side view (from the aircraft) to provide the Δv distribution

Instrumentation aspects

The instruments of an airborne observation would include:

- A whole set of imaging instruments with high frame rate and accurate timing
- A set of spectroscopic systems for fragment identification and explosion characterisation with high bandwidth in wavelength resolution and coverage
- Spectroscopic instruments dedicated to species of interest
- At least some redundancy of instruments reducing dependency on a single instrument
- Highly resolved imaging for public outreach of the **last** ATV

So far, only ISS observation instrumentation is foreseen for ATV-5 re-entry. The geometrical resoultion is 10-100x worse than the airborne observation capabilities. The spectroscopic possibilities on ISS are weak. The GPS timing is not feasible with onboard instruments of ISS.

Conclusion

The possibilities of an airborne observation are not comparable with the possiblities available from the ISS, not in spatial resolution and not in spectroscopic possibilities. The last ATV is the only vehicle for about a decade that can answer the questions on spacecraft re-entry and ultimately how ISS will re-enter. Therefore an airborne observation campaign supporting the work of NASA/ESA with ISS onboard instrumentation and ground based observation can fulfill the whole set of requested data for the understanding of a re-entry scenario.