Demise Experiment on the Upcoming KREPE 3 Atmospheric Re-entry Mission

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Design-for-demise strategies require accurate understanding of the thermal, mechanical, and fluid environments experienced by spacecraft during uncontrolled atmospheric re-entry. However, in-flight data characterizing the internal conditions of a disintegrating host vehicle remain extremely limited. The KREPE-3 mission, part of the Kentucky Re-entry Universal Payload System (KRUPS) program, provides a unique opportunity to address this gap through a dedicated demise experiment embedded within a multi-capsule re-entry architecture.

The experiment consists of a compact instrumentation package integrating an inertial measurement unit (IMU), pressure sensors, and thermocouples, designed to operate from the initiation of the de-orbit maneuver through the period immediately preceding capsule ejection (KREM separation). This measurement window captures the transition from orbital conditions to the onset of aerothermal loading and structural degradation within the host vehicle. The objective is to quantify the internal environment experienced by payloads during early-stage breakup and to characterize the conditions governing their release.

Particular emphasis is placed on reconstructing the dynamics of capsule ejection. Current debris survivability and dispersion models rely on simplified or assumed initial conditions at release, introducing significant uncertainty in predicted casualty risk and footprint. By correlating kinematic data from the IMU with local pressure and temperature measurements, the experiment aims to establish realistic initial states for multiple embedded objects at the point of separation.

In parallel, the mission includes the KRACO vehicle, a subscale analogue of the ESA DRACO capsule, intended to support design-for-demise validation under flight conditions. KRACO is designed to de-risk DRACO through two primary objectives: (i) evaluation of spectral emission markers to enable reliable airborne optical tracking and identification during re-entry, and (ii) assessment of vehicle stability through the transonic regime, with particular attention to center-of-gravity placement and its impact on attitude behavior. These measurements will provide critical data for correlating ground-based observations with in-flight dynamics and for validating stability predictions in a regime where aerodynamic uncertainties remain significant.

The resulting dataset will support the validation and improvement of demise and debris propagation models, including those used in design-for-demise assessments. In addition, the measurements will provide insight into the timing, sequencing, and variability of payload release from a degrading structure under hypersonic conditions. These findings are expected to contribute to more reliable prediction of fragment behavior, improved spacecraft design practices for controlled demise, and enhanced compliance with emerging space safety guidelines.

The KREPE-3 demise experiment represents a step toward bridging the gap between ground-based testing, modeling assumptions, and true flight conditions for spacecraft breakup and debris generation.