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CURRENT STATUS OF THE IN-FLIGHT INSTRUMENTATION EVELOPMENTS AT IRS

Abstract

Upon entering the atmosphere of celestial bodies, spacecraft encounter gases at velocities of more than 10 km/s, thereby being subjected to great heat loads. This necessitates the use of high temperature thermal protection systems (TPS) to prevent the destruction of the space vehicle. The TPSs as well as the plasma environment during the entry have to be investigated by means of computational and ground facility simulations. The four plasma wind tunnels PWK 1-4 which are in operation at IRS reproduce thermal, aerodynamic and chemical load on the surface of a space vehicle entering a celestial body's atmosphere are equipped with different plasma sources to cover different regimes of the atmospheric entry. Besides, inductively heated plasma generators for basic material investigations (catalysis / plasma wall reaction processes) and the simulation of entry scenarios for celestial bodies such as Mars or Venus have been developed. Numerous material test diagnostic tools e.g. mechanical probes for heat flux and Pitot pressure probes and TPS material tests have been developed and qualified. Parallel to these methods, further intrusive probes like electrostatic probes and non-intrusive diagnostics were applied for detailed investigation of high enthalpy plasma flows and material behavior during the tests. The ground testing facilities and the diagnostic tools provide an excellent opportunity to develop and qualify radiation-cooled materials for reuseable spacecraft and ablative material systems to be used for capsules and interplanetary probes. Additionally, they are much less expensive than space flights. Atmospheric entry mission phases encounter challenging problems, such as hypersonic aerothermodynamics and TPS performance of the spacecraft. Goals include managing the guidance navigation, control, landing technology and inflatable technologies such as ballutes that aim to keep vehicles in the atmosphere without landing. The requirement to save mass and energy for planned interplanetary missions such as the Mars Society Archimedes Balloon Mission, the Mars Sample Return Mission, Mars Express or Venus Sample Return mission led to the need for new atmospheric manoeuvres like aerocapture, aero-breaking and hyperbolic entries e.g.

for sample return missions. All three of the mission phases are characterized by very high kinetic vehicle energies to be dissipated by the manoeuvre. Actually, in this field almost no flights have been performed yet. But the importance of these manoeuvres and the need to increase the knowledge of the required TPS designs and the TPS behavior during such mission phases point out the need for ground testing facilities, numerical codes and, in particular, flight experiments as the aerothermodynamic and aerochemical problems can not be completely solved by ground tests and the supplementary computer simulations. The high-temperature nonequilibrium, the gaskinetic gas-wall interactions (catalysis, rarefaction effects, turbulent flow) and gap flows between flaps and TPS components in the TPS structure are fields where ground testing and CFD calculations cannot fully replace flight experiments. Concepts of such flight experiments require experience and the ability of feasibility analysis using both analytical tools and testing facilities to come up with overall information on the abilities and design steps needed for the successful experiment. As a result of the experience within the plasma diagnostic tool development and the plasma wind tunnel data base acquired during the last 20 years, flight experiments like the PYrometric Entry EXperiment PYREX (capsules EXPRESS and MIRKA) and HEATIN (HEATshield INstrumentation) on MIRKA have been developed at IRS, qualified and successfully flown. Flight experiments such as the catalysis based experiment PHLUX, the pyrometric nose cone heating system PYREX and the miniaturized spectrometer system RESPECT (RE-entry SPECTrometer) are presently in Phase C/D of ESA's EXPERT capsule program. The impact for further development activities with respect to such so-called intelligent instrumentations is evident: As an example the potential designs for the IXV planned within the Future Launcher Preparatory developments. The verification tools developed and corresponding validation tools as e. g. the ground testing facilities and their measurement techniques and the numerical tools (URANUS, PARADE and many more) expand into a new approach of measuring the re-entry situation. A good example for this can be seen in the STARDUST observation mission where an IRS team participated using an external spectrometer system to characterize both the TPS behaviour and the ongoing plasma radiation. The paper outlines past and present developments at IRS within the field of re-entry missions with particular emphasis on obtained results from post flight analysis such as e.g. from EXPRESS, MIRKA and STARDUST. In addition, the new developments are shown together with functional approvals of the measurement systems and corresponding numerical analysis tools. Based on the heritage of measurement systems already flown and being developed (EXPRESS, MIRKA, X38, EXPERT) new techniques are foreseen. Here, particular emphasis is made for the system COMPARE (Combined Pyrometric And Radiometric trajectory Rebuilding Experiment) planned for both the Archimedes Balloon Mission and SHEFEX2 and recently proposed techniques for IXV are presented. The design of these systems is accompanied by extensive mission analysis allowing for the conceptional design of the measurement systems.