

IPPW Enabled International Collaborations in EDL: Lessons Learned and Recommendations

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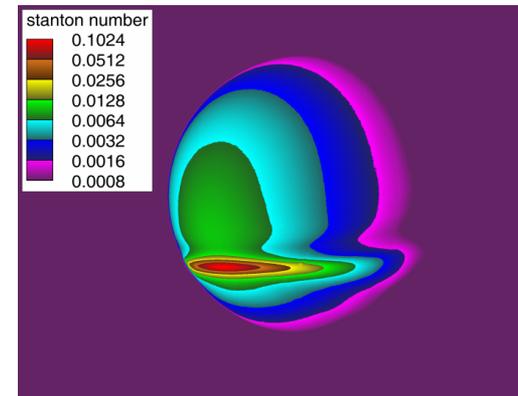
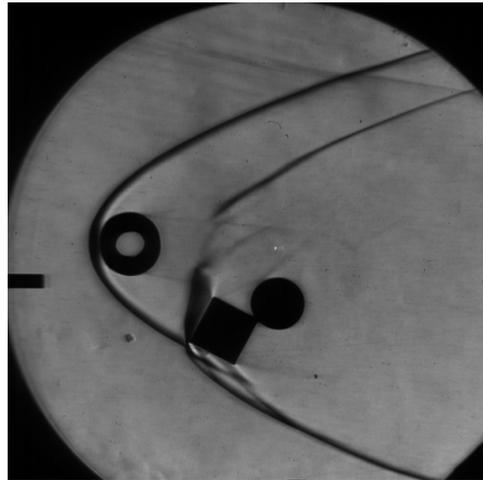
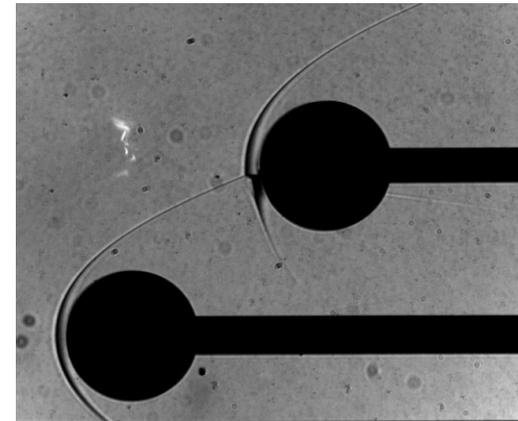
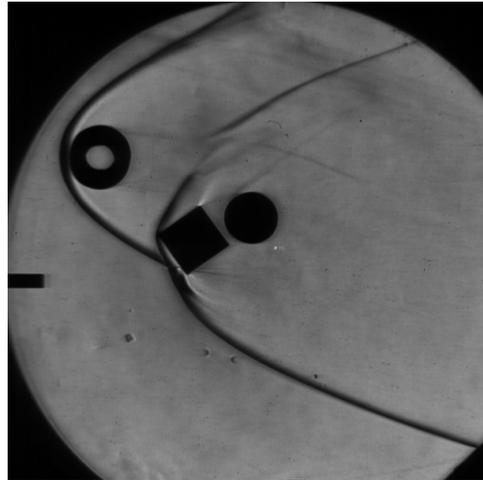
**14th International Planetary Probe Workshop
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Introduction and Outline

- IPPW and International Collaboration
- International Collaborations – How challenging are they?
 - Not New – Space Station, Cassini-Huygens, Hayabusa, MOM Mission
 - Science – Seems easier
 - Technology – Seems more challenging
 - Bi-lateral vs Multilateral
- Constraints – International and National
 - International Agreements on Non-Proliferation (UN Resolution 1540) *to prevent the proliferation of weapons, in particular WMD or the means of their delivery.*
 - National Export Control and Commercial Competitiveness Protection Laws
 - Institutions have the obligation to interpret and enforce
- Outline of the Talk
 - 3 examples of Unique Capabilities at DLR – Dr. Ali Gülhan
 - Corresponding NASA Need and Collaboration Status
 - Concluding Remarks

DLR Unique Capabilities: Hypersonic Testing in H2K

- Unique Capability :
 - Ground experiments on multibody configurations in well characterized hypersonic flow field.
 - Development of accurate measurement methods and data reduction algorithms to study the dynamics of multi-bodies.
- Focus of collaboration:
 - Fundamental studies to provide
 - Creation of reliable experimental data on multi-body aerodynamics for the validation of high fidelity CFD codes.
 - Analysis of flight physics of multi-body configurations in hypersonic flow environment.
- Status
 - Characterized flow field of H2K using PIV at hypersonic Mach numbers.
 - Updated high speed tracking camera system and data reduction algorithm.



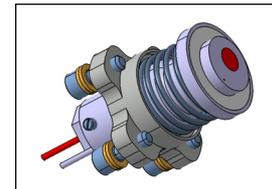
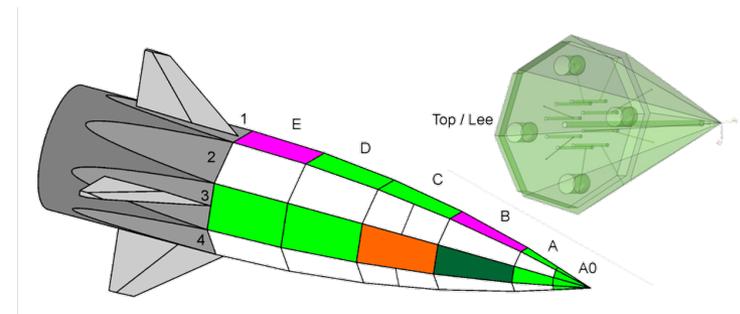
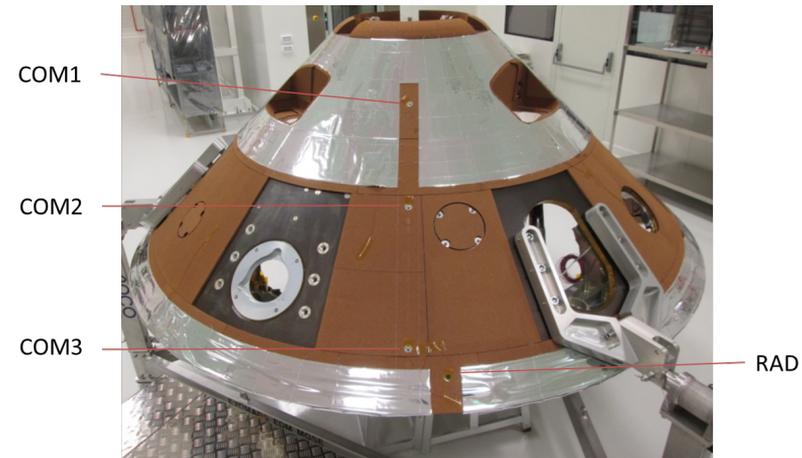
DLR Unique Capabilities: Arc Jet Testing in L2K/L3K

- Unique Capabilities:
 - Qualification of high temperature materials for planetary entry in well characterized high enthalpy flow field **including simulation of the particle or dust impact.**
 - Development and use of spectroscopic measurement techniques for the flow characterization.
- Focus of collaboration:
 - Fundamental studies to provide
 - Characterization of particle loaded high enthalpy flow field using LIF, PIV, MWI, etc.
 - Creation of reliable experimental data on demise behavior of spacecraft component and joint materials
- Status
 - Preparation of L2K for flow field characterization using LIF on O atoms and CO molecules.
 - Preparation of in-situ particle characterization using PIV.



DLR Unique Capabilities: Aerothermal Flight and Ground Instrumentation

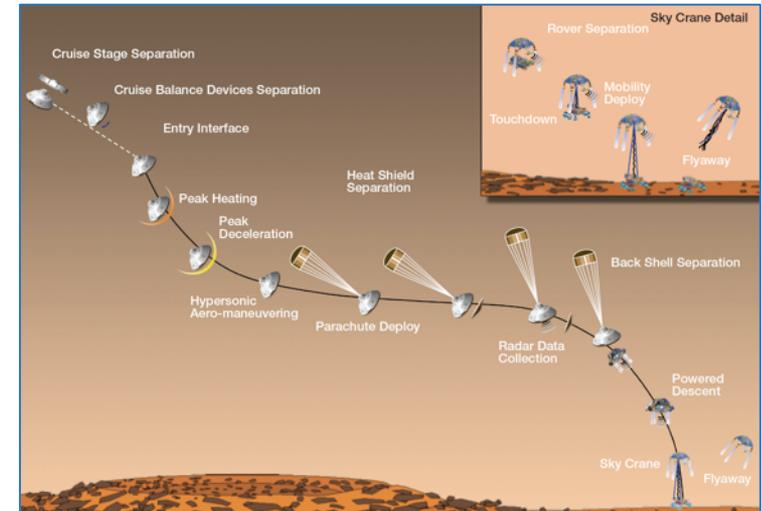
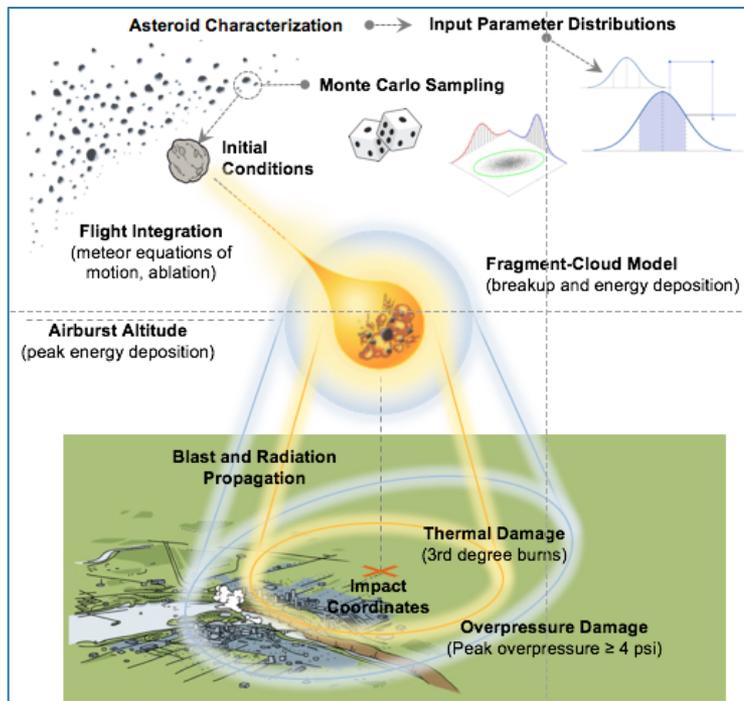
- Unique Capability:
 - Collecting flight data by means of instrumentation with high TRL level.
 - Qualification of instrumentation in flight and ground experiments to increase the TRL level and gaining data on flight physics.
- Focus of collaboration:
 - Fundamental studies to provide
 - Adaptation of DLR instrumentation packages for different planetary missions.
 - Performance of several characterization and qualification activities of the sensors.
- Status
 - Feasibility study of DLR sensors by means of thermo-mechanical and EMC studies.
 - Definition of potential modifications to the instrumentation packages.



NASA Needs: Validation of Predictive Capabilities

Multi-body Aerodynamic Interactions

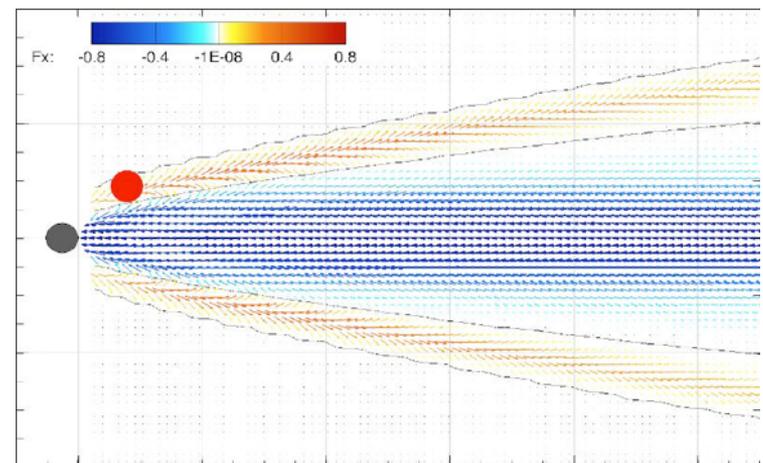
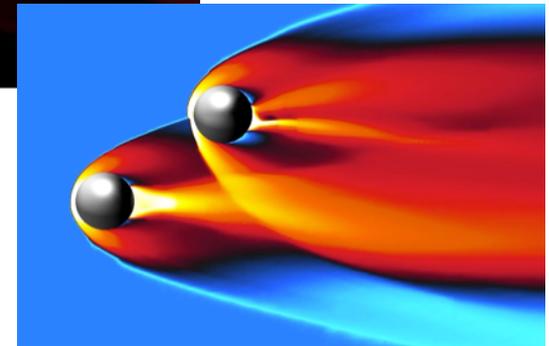
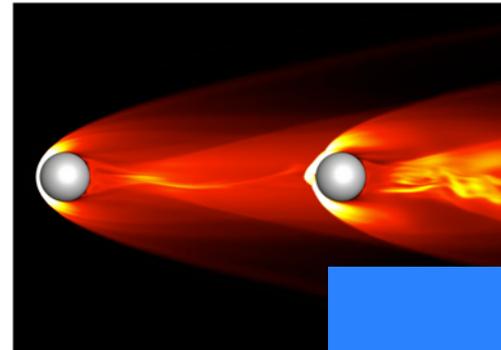
- Need:
 - Asteroid break-up and impact prediction
 - Spacecraft demise
 - EDL - Heatshield and backshell separations



NASA Needs: Validation of Predictive Capabilities

Multi-body Aerodynamic Interactions (Cont.)

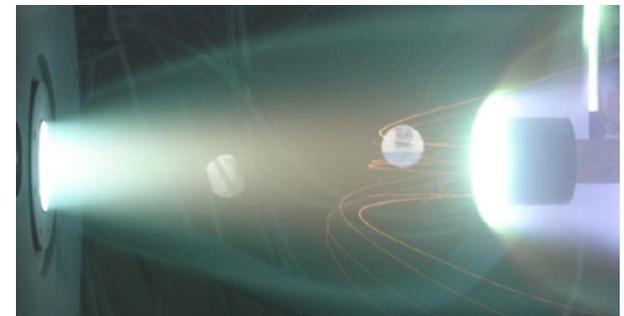
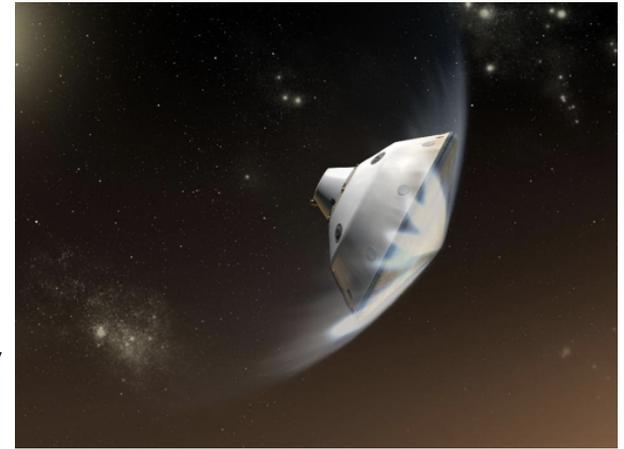
- Framing the Need:
 - Predictive capabilities are used extensively for design and mission assurance – How good are these?
 - Advancing the predictive capabilities requires understanding, implementing and validating the fundamental physics
- Focus of collaboration:
 - Fundamental studies to provide
 - Greater understanding of the important flow physics
 - Validation data for assessing current predictive capabilities
- Status
 - Collaboration was approved by NASA and DLR – April, 2016
 - On-going collaborative efforts are providing useful fundamental data



NASA Needs: Predictive Capabilities Validation

Modeling Material Response to Dusty Flows

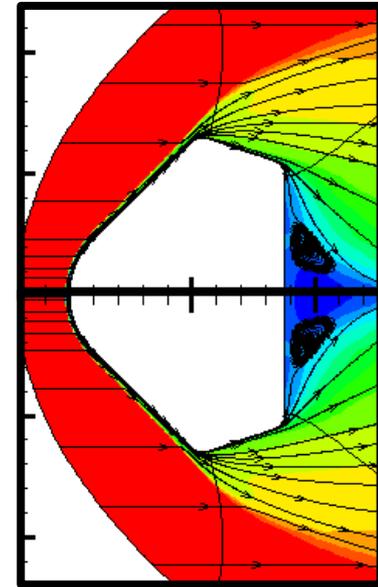
- Framing the Need:
 - Mars robotic and human missions will require heatshields that can tolerate dusty environment
 - Mission assurance requires validated tools.
 - Focus can be on fundamental studies
 - To develop understanding of flow physics
- Challenge:
 - Ablative Thermal Protection System – extra scrutiny due to Non-proliferation and ITAR concerns.
- Approach:
 - Use of experiments to obtain validation data
 - Use surrogate material in experiments and analysis and avoid real-world ablative TPS.
 - Focus is on Mars dusty environment
- Status
 - Proposed collaboration under evaluation



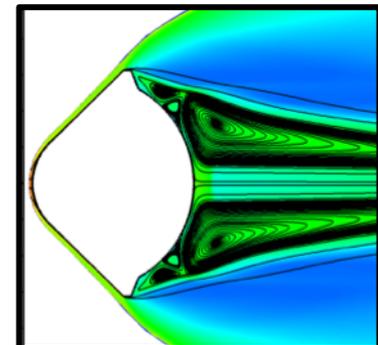
NASA Needs: Predictive Capabilities Validation

Engineering Science Instrumentation for Flight

- Framing the Need:
 - Importance of Engineering Science Investigation (ESI)
 - NASA's commitment expressed via requirements in Discovery and New Frontiers Missions
 - Saturn, Venus, Titan and Sample Return missions require atmospheric entry
 - Collaboration can result in collecting valuable (and sharable) data at much reduced cost to NASA and DLR
- Opportunity, Constraints and Approach:
 - New Frontiers-4 competed mission selection process is a perfect opportunity
 - Competed process allows international collaborators to propose instruments (follow the scientist)
 - During proposal development, collaboration is easier if exchange of information is limited to non-ITAR and publicly available information.
- Status:
 - We are working together along with proposal teams.



Entry Aeroshell



Saturn Probe (Galileo)

Recommendations from Lessons Learned

- **Collaboration is feasible but requires effort at multiple levels**
 - **Requires careful understanding of the international, national and institutional rules and constraints**
 - Existing bi-lateral agreements facilitate the collaboration
 - Work closely with the Office of International and Interagency Relations at NASA-HQ, in the US
 - **Collaboration has to have value to all parties**
 - Each party has to articulate the value to themselves and to management/sponsors
 - There is cost to each party, and this has to be taken into account
 - **Examples shown emerged as a result of IPPW**
 - Multi-body Aerodynamics – the last day of the IPPW-12, Cologne
 - Dusty Flow and Flight Instrumentation – during IPPW-13, Maryland
- **Easier to collaborate on efforts involving:**
 - Fundamental aspects
 - Use of well-defined and proven hardware or test techniques
- **Difficult to collaborate in technology development (TRL 3 – 7)**

Backup

What is Export Control?

- *Export Controls are guided by the United Nations Resolution 1540 to prevent the proliferation of weapons, in particular WMD or the means of their delivery. Those last few words are particularly important here at NASA: “**the means of their delivery.**” This concern is specifically addressing rocket technologies*
- *Export Control is an international cooperation by the governments.*
- *With the UN’s mandate and guidance, each nation has developed their own series of rules and regulations to control the flow of their exports. Regulates the trade and transit of weapons, notably items and technologies that could be used to create Weapons of Mass Destruction (WMD) or the means of their delivery*
- *Export Control is an international initiative, it is not an American initiative. It is a global response to a global threat.*
- *Export Control is not intended to restrict trade. It is intended to strike a balance between enabling and promoting legitimate global trade while also keeping dangerous items out of the hands of bad actors.*