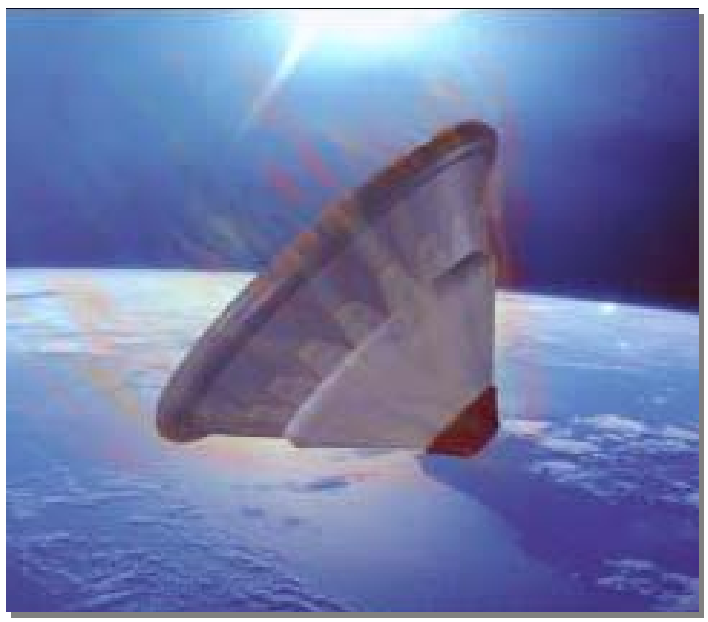
Fundamental Aeronautics Program

Supersonics Project

Entry, Descent, and Landing Overview



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SUP.12.0 – Entry, Descent and Landing (EDL)

SUP.12.0 Entry, Descent and Landing – Major Technical Challenges Addressed			
	Supersonic Cruise Efficiency		High Altitude Emissions Reduction
	Lightweight and Durability at High Temperature		Aero-Propulso-Servo-Elasticity (APSE)
	Airport Noise Reduction	X	Supersonic Entry, Descent and Landing
	Sonic Boom Modeling		Multidisciplinary Design, Analysis & Optimization

Problem Statement: Tools and technologies for designing and analyzing new classes of aerodynamic and propulsive decelerators for large, high-speed planetary entry vehicles need to be developed. These decelerators are needed to permit the safe entry and landing of substantially larger spacecraft on Mars than what has been done before with Viking-class parachute EDL systems. Potential applications include human-scale missions to Mars as well as robotic spacecraft to other planets and sample-return missions to Earth. Parachutes are generally regarded as being effective as decelerators for vehicle masses less than 3 metric tons, far short of the 60-80 MT vehicles expected to have to be placed on Mars for human missions. New decelerators capable of deployment or ignition at hypersonic or supersonic speeds and having excellent drag characteristics and stability throughout the operating speed range are required. The supersonic decelerator needs to be integrated into an optimized EDL system that also considers the Hypersonic (Entry) and Subsonic (Landing) elements of the flight profile.

Previous Related Research: Parachutes, inflatable decelerators, and propulsive decelerators have been studied in government, industry, and academic programs since the 1960's, and there is a vast amount of information from flight and ground-based tests, analytical studies and computational simulations available in the literature. The Viking landers launched in the 70's required an extensive development and qualification program for the disk-gap-band parachutes used to decelerate the landers from supersonic to subsonic speeds, and that parachute technology has been used in succeeding missions to Mars and other planets. The cost of such qualification testing is a significant driver of the need to develop new high fidelity analysis and design tools.

Research Approach: New computational tools will be developed for calculating the dynamics and aerodynamics of the deployment and inflation of decelerators, as well as the static and dynamic stability of the decelerators in their fully deployed state. These tools will be capable of assessing the interaction of the unsteady fluid flow and the dynamics of the structure, particularly in cases of highly deformable structures. Performance predictions of the vehicle/decelerator combination will be critical to ensuring mission success, and the calculated trajectory of the system during entry will be key to minimizing landing dispersion and increasing confidence in reaching the targeted landing area. High-speed, high-resolution experimental techniques for measuring the deployment and stability of the decelerators will be developed both for CFD validation and for supplementing the computational performance predictions. Investigations into novel approaches for using rocket propulsion for slowing an entry vehicle through the supersonic speed regime in a planetary atmosphere will be conducted.

The EDL discipline of the Supersonics Project is broken down into the following elements:

12.02. Static Aerodynamic Performance Prediction

Computationally simulate the fluid dynamics of entry vehicles, the interactions of these wakes with static parachutes or other decelerators, and the loads on and performance of the decelerator system.

12.03. Dynamic Performance Evaluation

Develop an integrated conceptual analysis capability for analyzing and comparing potential EDL systems for large payloads. Variable-fidelity discipline analyses, including aerodynamics, trajectory, structures, propulsion, mass estimation, and heat transfer, will be incorporated into the ModelCenter tool to allow assessment of various system architectures.

12.04. Computational Fluid-Structures Interaction Methods

Extend the static aerodynamic calculations of element 12.02 to calculations of the unsteady aerodynamics of a vehicle/decelerator system, and to develop tools for computing the interactions between the fluid mechanics and the structural response of flexible parachutes and other decelerators.

12.05. Decelerator Testing

Develop ground and flight test capabilities for evaluations of various supersonic aerodynamic decelerator concepts.

12.06. Propulsive Deceleration

Investigate novel experimental approaches for using rocket propulsion for decelerating an entry vehicle through the supersonic speed regime in a planetary atmosphere.

Technology Validation Strategy: Computational methods developed and applied in SUP elements 12.02, 12.03, and 12.04 will be validated through the use of past aerodynamic, aerothermal, and propulsive databases, new wind tunnel and subscale flight experiments, and the new test techniques to be developed in elements 12.05 and 12.06.

SUP.12.0 Entry, Descent and Landing – Key Deliverables	Date
Inflatable Re-entry Vehicle Experiment (IRVE) aeroshell inflation and survivability demonstrated	2007
Report on wind-tunnel and ballistic range tests of candidate inflatable aerodynamic decelerator shapes	2007
Creation of aerodynamic database on flow field about nozzles during entry conditions	2007
Demonstration of test technique for synchronized photogrammetry, PIV and drag measurements of parachutes and inflatable decelerators	2008
Generation of flow stability regimes for successful ignition of rocket nozzles during EDL conditions	2008
Coupled aerodynamics and fluid-structure interaction NS code for supersonic parachutes and decelerators	2009
Database of ignition limits for purged and unpurged engines and the need for engine covers to supplement purging	2009
Development of database of aerodynamics and ignition transients for application to EDL requirements	2010
Creation of heat transfer database for nozzles and chambers in EDL and landing site environments	2010

The Supersonics Project technology level designation is included with each milestone. In NASA's Fundamental Aeronautics nomenclature, discipline-focused efforts are categorized as Level 1 (L1) for foundational research and Level 2 (L2) for discipline research. Multi-disciplinary focused efforts are referred to as Level 3 (L3) for discipline integration and Level 4 (L4) for system-level integration.

SUP.12.0 Entry, Descent and Landing – Milestones				
Number	**Title**	**Year**		**Level**
SUP. 12.02.01	Report on evaluation of predictions vs. experimental data	4Q FY07	Draft evaluation report prepared for either NASA TM or conference paper	L1
SUP. 12.02.02	Complete fully viscous supersonic CFD code	4Q FY07	Demonstrate use of fully viscous supersonic CFD code on MSL geometry	L2
SUP. 12.03.01	Complete Conceptual Analysis Framework	2Q FY08	Demonstrate use of framework in evaluating merits of various decelerator systems	L2
SUP. 12.04.01	Lower-order Performance Predictions Evaluation Complete	2Q FY08	Write evaluation of lower-order performance prediction methods	L1
SUP. 12.04.02	Complete Generalized Unsteady Viscous Supersonic Code	4Q FY08	Demonstrate representative unsteady supersonic flow simulation capability around a flexible parachute and reentry vehicle	L2
SUP. 12.04.03	Fluid-Structure Interaction Technology Development	4Q FY09	Demonstrate the use of the FSI code on flexible as well as rigid parachutes/decelerators and compare with experimental data	L2
SUP. 12.04.04	Integrated Aerodynamic/Structures Analysis for Flexible/Inflatable Supersonic EDL Deceleration Systems	2Q FY10	Establish capability to analyze the aerodynamic and structural performance of supersonic EDL decelerator systems in which highly unsteady flow interacts with highly flexible thin wall structures	L3
SUP. 12.05.01	IRVE Flight Test Complete	4Q FY07	Successful conclusion of IRVE flight operations	L2
SUP. 12.05.02.01	PAI-DAE Atmospheric Deployment Test Report	2Q FY08	Publication of final Atmospheric Deployment Test Report including data reduction & analysis	L2
SUP. 12.05.02.02	PAI-DAE Ballistic Range Test Report	2Q FY08	Publication of final Ballistic Range Test Report including data reduction & conclusions	L2
SUP. 12.05.03	Synchronized Photogrammetry, PIV and Drag Measurements	4Q FY08	Demonstration of optical measurements of flexible decelerator deployment in supersonic wind tunnel	L1
SUP. 12.05.04	Decelerator Experimental Evaluations	4Q FY09	Wind-tunnel test contributions to decelerator design studies reduce uncertainty in decelerator drag by 50%	L2
SUP. 12.05.05	Photogrammetric Shape Measurement Technique for Flexible Canopies	4Q FY07	Demonstration of photogrammetric shape measurement technique showing deployment time history and inflation dynamics for flexible canopies	L2
SUP. 12.05.06	Supersonic Decelerator Aerodynamic Performance Validation Data Set Complete	4Q FY09	Complete Assessment of data from supersonic inflatable decelerator wind tunnel and ballistic range tests. Validation data published for use in Supersonic EDL tools validation. Assessment of supersonic inflatable decelerator.	L3
SUP. 12.06.01	Nozzle Flow Field Database Development	4Q FY07	Creation of aerodynamic database on flow field about nozzles during entry conditions	L2
SUP. 12.06.02	Flow Instabilities Database Development	4Q FY08	Generation of flow stability regimes for successful ignition of rocket nozzles during EDL conditions	L2

SUP. 12.06.03	Ignition Requirements for Rocket Engines in a Vacuum	4Q FY09	Database of ignition limits for purged and unpurged engines and the need for engine covers to supplement purging	L2
SUP. 12.06.04	Aerodynamic Database for Large Expansion Ratio Nozzles	4Q FY10	Development of database of aerodynamics and ignition transients (shock structure in nozzle) for application to EDL requirements	L2
SUP. 12.06.05	Heat Transfer Database for Rocket Nozzles and Chambers	4Q FY11	Creation of heat transfer database for nozzles and chambers in EDL and landing site environments	L3
SUP. 12.06.06	Optimal Propellant and Propulsion Mode Selection for Post-EDL and in situ resource utilization (ISRU) Environments	4Q FY11	Evaluate propellant selection effects, including ISRU	L3