

## Design And Analysis On Scramjet Engine Inlet

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[Numerical Analysis of the Scramjet-inlet Flow Field by Using Two-dimensional Navier-Stokes Equations](#) Cambridge University Press

Renewed interest in hypersonic research has motivated a number of scientists to reinvestigate the efficacy and performance of supersonic combustion ramjets, colloquially known as "scramjets". In this thesis, a 1-D scramjet model is proposed which shall be able to simulate separated flows within the isolator as well as the pressure distributions in a scramjet combustor. The goal is to divine the trends and sensitivities that are most significant in a given engine design, as well as provide a platform for further research into supersonic combustion. The model accurately predicts the stagnation and static quantities within a scramjet and can simulate the trends found in real life experiments. The 1D model gives significant physical insight to scramjet operation as it establishes key trade offs that scramjet analysis necessitate.

[Design and Multifidelity Analysis of Dual Mode Scramjet Compression System Using Coupled NPSS and Fluent Simulation](#) AIAA

This book presents select proceedings of the International Conference on Future Learning Aspects of Mechanical Engineering (FLAME 2018). The book covers mechanical design areas such as computational mechanics, finite element modeling, computer aided designing, tribology, fracture mechanics, and vibration. The book brings together different aspects of engineering design, and will be useful for researchers and professionals working in this field.

[A Hypersonic Waverider Research Vehicle with Hydrocarbon Scramjet Propulsion](#) AIAA

In the aviation field there is great interest in high-speed vehicle design. Hypersonic vehicles represent the next frontier of passenger transportation to and from space. However, several design issues must be addressed, including vehicle aerodynamics and aerothermodynamics, aeroshape design optimization, aerodynamic heating, boundary layer transition, and so on. This book contains valuable contributions focusing on hypervelocity aircraft design. Topics covered include hypersonic aircraft aerodynamic and aerothermodynamic design, especially aeroshape design optimization, computational fluid dynamics, and scramjet propulsion. The book also discusses high-speed flow issues and the challenges to achieving the dream of affordable hypersonic travel. It is hoped that the information contained herein will allow for the development of safe and efficient hypersonic vehicles.

[Scramjet Propulsion](#) Springer

Proposes, develops, and analyzes a hypersonic engine model in three phases: phase 1, the forebody-inlet-isolator design and analysis; phase 2, the combustor-diffuser-nozzle design and analysis; and phase 3, the integration of results from phases 1 and 2 with an optimization perspective. Conducts engine performance studies with the emphasis on manipulating these geometric design parameters to derive engine models of superior thrust performance while maintaining functional aerodynamic engine shapes. Focuses in part on the independent performance validation of this hypersonic engine model.

[Analysis and Design of a Scramjet Inlet](#) Springer Nature

Numerical analysis was performed on a Dual-Mode Scramjet isolator-combustor. Preliminary analysis was performed to form a baseline geometry. Another study validated the results of a 2D model compared to a 3D model. Stable combustion was shown at two different flight conditions,  $M=3.0$  and  $M=2.5$ . A marginal 5% decrease in stream thrust was shown by introducing a 50/50 mix of methane and ethylene. Based on the results of the preliminary analysis, detailed geometry analysis was performed on the 3D baseline geometry. Adding a new set of cavity feeding injectors increased the overall stream thrust and the equivalence ratio in the cavity. Using less fuel than the baseline configuration, revealed a 6.4% increase in stream thrust and an 11% increase in combustion efficiency by placing the second stage injector further upstream. Future analysis includes combining the cavity feeding with closer injector placement, which is expected to yield even better results.

[The SCRAMJET Engine](#) John Wiley & Sons

The flow field inside a scramjet engine combustor involves complex phenomena such as fuel-air mixing, combustion chemistry, and flow separation. In order to determine the properties of the flow along the length of the combustor, mass, momentum and energy balance equations are solved simultaneously using a numerical method. While a full three dimensional computational simulation gives detailed results with high order of accuracy, it demands a great amount of time and computational resource. A low order analysis produces a fast overall picture of the combustor operation which in turn provides valuable information suitable for the preliminary design process. This research work aims to describe the analysis process of the scramjet combustor in which a quasi-one-dimensional, multi-species, reacting real gas model of the flow is developed to address the limitations in previous researches. The Numerical Propulsion System Simulation (NPSS), into which the NASA Chemical Equilibrium with Applications (CEA) code is integrated, is utilized as the platform to perform the analysis. The analytical model is validated by comparison with experimental data from previous researches. The results obtained by this method are expected to shed some light on the advantages of using detailed chemistry with lower order analysis to calculate scramjet engine performance.

[The Scramjet Engine](#)

An almost entirely self-contained engineering textbook primarily for use in undergraduate and graduate courses in airbreathing propulsion. It provides a broad and basic introduction to the elements needed to work in the field as it develops and grows. Homework problems are provided for almost every individual subject. An extensive array of PC-based user-friendly computer programs is provided in order to facilitate repetitious and/or complex calculations. Annotation copyright by Book News, Inc., Portland, OR

[Scramjet Nozzle Design and Analysis as Applied to a Highly Integrated Hypersonic Research Airplane](#)

Models and analyzes the three-dimensional forebody, inlet, and isolator of a conceptual four-point-star morphing ramjet-scramjet engine. Conducts the

analysis using computational fluid dynamic softwares, specifically the air vehicle unstructured solver (AVUS) and FLUENT. Uses a steady, three-dimensional, double precision solver to model and analyse this problem.

[Scramjet Nozzle Design and Analysis as Applied to a Highly Integrated Hypersonic Research Airplane](#)

Describes the development and implementation of an engineering method that can be used for the design and analysis of scramjets.

Calculates the length of the scramjet combustor duct based on the coupled solution of 1D conservation of mass, momentum, and energy equations with heat addition, combustion, and friction. Introduces the design of a minimum length nozzle, which is used as an integral part of the hypersonic configuration. Seeks to document this design methodology and describe in detail the integration of the core elements as they relate to the overall hypersonic vehicle construction process.

[Preliminary Scramjet Design for Hypersonic Airbreathing Missile Application](#)

High speed propulsion systems typically possess relatively simple geometry but the complexity involved in the flow characteristics makes their analysis a challenging task. The current research work introduces a reduced order analytical model for a steady operation of dual mode SCRamjet (Supersonic Combustion Ramjet) propulsion system at design and off-design conditions. The model hopes to reduce analysis time and complexity to carry out parametric sweep studies for preliminary design of SCRamjet engines. The analytical model splits the analysis of SCRamjet engine into five interactive components namely: inlet, isolator, injector, burner and nozzle. Each component is modelled using physics of gas-dynamics and semi-empirical relations. The flow characterization of each component and their interactions are modelled carefully based on observed physical phenomenon reported in the existing literature. The model is developed on MATLAB platform providing flexibility to design a parametrized SCRamjet geometry and to select its free stream and fueling conditions for the analysis. The analytical model proposed in the current work is validated with various experimental and computational data of individual components and its reliability for predicting the flow characteristics inside a SCRamjet propulsion system is discussed in detail.

[Steady One-dimensional Flow Analysis Applied to Scramjet Engine Design](#)

Significant progress has been achieved during the first year of this Challenge effort, in developing and simulating configurations which highlight the main scramjet inlet flow path alternatives. In particular, three different types of inward-turning inlets have been explored, including the rectangular cross-section, scoop and 'jaws' designs. Each flowpath has been discretized and subjected to inviscid laminar and turbulent analyses with highly-scalable solvers at design and off design conditions ranging from Mach 6 to Mach 10. Viscous/inviscid interactions are observed to have a profound impact on the flow, giving rise to distortion of the velocity profile at the exit of the inlet (entrance of the isolator/combustor component). For the jaws approach, the effects of angle-of-attack and yaw have been studied. A complex pattern of low and high total pressure variation is observed, suggesting strategies for the subsequent fuel injection processes. For the rectangular cross-section dual-plane compression inlet, combustor integration has been accomplished with finite-rate chemical kinetics. The effect on mixing characteristics of numerous injection strategies, both upstream and/or in the interior of a wall cavity, are examined. The injection process is observed to yield a separation shock, bow shock and Mach disk, as well as a reattachment shock. Potential phenomena that might generate instabilities and subsequent unstart have been identified, as are locations of high temperature, unburnt fuel gases and combustion efficiency. In a separate, but related effort, simulations have also been performed to yield data for flight-test experiments (HiFIRE program) to ensure survivability of mass capture diagnostic devices.

[Reduced-order Analysis of Dual Mode Supersonic Combustion Ramjet Propulsion System](#)

Various aspects of hypersonic vehicles are being rapidly explored for improved functionality. One of the main areas of consideration is the fueling of a Supersonic Combusting Ramjet (scramjet) engine. Using Computational Fluid Dynamics (CFD), computer simulations can be performed to analyze the flow physics of a scramjet. In this research, an optimization code, Dakota, is integrated with the CFD to optimize a set of parameters to maximum thrust. In this study, the fuel injection and combustion is replaced with heat sources. This simplification greatly reduces the computational requirements. Additionally, the 3D geometry is reduced to an axisymmetric 2D geometry because three dimension effects like mixing and combustion are not being modeled. With this simplified model, the optimization and CFD algorithm is executed to find the heat addition for maximum thrust. Different optimization methods have been explored to reduce computational times. A genetic algorithm was selected because of its robust abilities. Additionally, a sampling algorithm was selected because of its abilities to explore the whole design space. Furthermore, the sampling method enables additional studies, such as sensitivity studies, to be completed. In addition to optimization studies, calibration studies are performed to obtain the heat source values that correspond to a given experimental wall pressure distribution. Knowledge of the optimized heat distribution will assist in the optimization of fueling splits and injector locations for a more detailed combustion investigation in which similar optimization techniques can be applied.

[Thermal-structured Design Study of an Airframe-integrated Scramjet](#)

[Scramjet Propulsion](#) Explore the cutting edge of HAP technologies with this comprehensive resource from an international leader in her field

[Scramjet Propulsion: A Practical Introduction](#) delivers a comprehensive treatment of hypersonic air breathing propulsion and its applications. The book covers the most up-to-date hypersonic technologies, like endothermic fuels, fuel injection and flameholding systems, high temperature materials, and TPS, and offers technological overviews of hypersonic flight platforms like the X-43A, X-51A, and HiFIRE. It is organized around easy-to-understand explanations of technical challenges and provides extensive references for the information contained within. The highly accomplished author provides readers with a fulsome description of the theoretical underpinnings of hypersonic technologies, as well as critical design and technology issues affecting hypersonic air breathing propulsion technologies. The book's combination of introductory theory and advanced instruction about individual hypersonic engine components is ideal for students and practitioners in fields as diverse as hypersonic vehicle and propulsion development for missile defense technologies, launch aerospaceplanes, and civilian transports. Over 250 illustrations and tables round out the material. Readers will also learn from: A thorough introduction to hypersonic flight, hypersonic vehicle concepts, and a review of fundamental principles in hypersonic air breathing propulsion Explorations of

the aerothermodynamics of scramjet engines and the design of scramjet components, as well as hypersonic air breathing propulsion combustors and fuels. Analyses of dual-mode combustion phenomena, materials structures, and thermal management in hypersonic vehicles, and combined cycle propulsion. An examination of CFD analysis, ground and flight testing, and simulation. Perfect for researchers and graduate students in aerospace engineering, *Scramjet Propulsion: A Practical Introduction* is also an indispensable addition to the libraries of engineers working on hypersonic vehicle development seeking a state-of-the-art resource in one of the most potentially disruptive areas of aerospace research today.

#### Design-oriented Analysis of Scramjet Combustor Flowfield Using Combined UNS/PNS Procedure

The analysis of fuel air mixing in a scramjet is often accomplished either with Computational Fluid Dynamics (CFD) algorithms or through experimental research. These approaches, while accurate and reliable, are extremely expensive and thus not well suited for use with conventional design optimization methods. In this investigation, Variable Complexity Modeling (VCM) is used to significantly reduce the number of complex, expensive analyses required to optimize the design of a scramjet fuel injection array. A design problem formulation for a lateral transverse injection array is developed and a VCM approach to design optimization is conducted in two stages. Initially, a simplified analysis model is used to provide relatively inexpensive predictions of design fuel air mixing characteristics. A parametric analysis is conducted to explore the design region, and a preliminary optimal design is found using both Sequential Quadratic Programming and a Genetic Algorithm. In the second stage, response surface methodology is supplemented with preliminary stage information to minimize the number of expensive analyses required to finalize the design. It is shown that only 25 design evaluations are required to develop a near optimal design.

#### NASA Technical Paper

Computer programs have been written to aid the design and analysis of 2-D, axisymmetric, and 3-D supersonic inlets. This report presents the fundamental analytic techniques, the use and operation of the computer programs, and the application to the design of supersonic inlets. The programs are written in FORTRAN IV for use on the 7094 high speed digital computer. The 2-D and axisymmetric programs presented herein are written for generalized inviscid supersonic internal flow problems with uniform or non-uniform inlet entry conditions for entropy, total enthalpy, pressure, Mach number and flow direction. The program capabilities include the intersections and reflections of both family waves, the formation of shocks or expansions at corners, the formation of shocks by coalescence of waves from smooth walls, and the formation of contact discontinuities. The 3-D programs presented herein are written for the calculation of the inviscid supersonic flow fields associated with basic elements of 3-D supersonic inlets. The methods utilized exact and linearized supersonic flow theory with engineering approximations to yield solutions to the following unit problems; delta wing flow, conical shock interacting with a plane surface, plane shock interacting with a conical surface, and the interaction of two different conical flow fields.

#### Dual Mode Scramjet

Hypersonic airbreathing engines mark a potential future development of the aerospace industry and immense efforts have been taken in gaining knowledge in them for the past decades. The physical phenomenon occurring at the hypersonic flow regime makes the design and performance prediction of a scramjet engine hard. Though cutting-edge simulation tools fight their way toward accurate prediction of the environment, the time consumed by the entire process in designing and analyzing a scramjet engine and its component may be exorbitant. A multi-fidelity approach for designing a scramjet with a cruising Mach number of 6 is detailed in this research where high-order simulations are applied according to the physics involved in the component. Two state-of-the-art simulation tools were used to take the aerodynamic and propulsion disciplines into account for realistic prediction of the individual components as well as the entire scramjet. The specific goal of this research is to create a virtual environment to design and analyze a hypersonic, two-dimensional, planar inlet and isolator to check its operability for a dual-mode scramjet engine. The dual mode scramjet engine starts at a Mach number of 3.5 where it operates as a ramjet and accelerates to Mach 6 to be operated as a scramjet engine. The intercomponent interaction between the compression components with the rest of the engine is studied by varying the fidelity of the numerical simulation according to the complexity of the situation. Efforts have been taken to track the transition Mach number as it switches from ramjet to scramjet. A complete scramjet assembly was built using the Numerical Propulsion Simulation System (NPSS) and the performance of the engine was evaluated for various scenarios. Different numerical techniques were opted for varying the fidelity of the analysis with the highest fidelity consisting of 2D RANS CFD simulation. The interaction between the NPSS elements with the CFD solver is governed by the top-level assembly solver of NPSS. The importance of intercomponent interactions are discussed. The methodology used in this research for design and analysis, should add up to provide an efficient way for estimating the design and off-design operating modes of a dual mode scramjet engine.

#### **INVESTIGATION OF THE LOW SPEED FIXED GEOMETRY SCRAMJET. 'INLET DESIGN PRACTICE MANUAL'**

This book presents a step-by-step methodology for the design of ramjet engines. It explores ramjet combustion, provides guidelines on how to size the engines, and discusses performance analysis. The book begins with an introduction to ramjet design, including fundamental definitions in the field. It then discusses ramjet engine performance, and fuels which can be used. Several types of ramjet engines are then explored, and guidelines for their design are presented, including flame holders, injectors, and combustors. Finally, the book concludes with a discussion of the types of materials which should be used for ramjet engines. This book is of interest to engine designers and engineers, researchers, and graduate students, as it collates research in a succinct, clear guide to the issue of designing ramjet engines.

#### Hypersonic Vehicles

An overview is presented of fundamental and practical insights obtained on scramjet flowpaths during a three year Challenge Project utilizing high fidelity methodologies and advanced postprocessing techniques. Simulations are employed to analyze the principal phenomena, including inlet distortion, fuel-air mixing, ignition and thrust generation at freestream Mach numbers between 6 and 8. In addition to guiding the evolution and execution of high-speed ground and flight experiments, the discovery objective of the project identifies trends and suggests optimization strategies for rapid response and kinetic kill hypersonic vehicles. Three inlet designs are considered, including the traditional rectangular cross-section configuration and two streamline traced variants Scoop and Jaws, each attached to a corresponding cavity-based flame-holding combustor. The simulations reveal the characteristic distortion signature of each design. Parametric analyses provide insight into major performance issues, including the effects of distortion on combustion, injector port configurations and gaseous versus liquid (multi-phase) injection of simple and complex fuels. Some results are consistent with intuition: for example, streamwise-staggered and spanwise-interlaced injectors enhance diffusive mixing. Other findings are not intuitive and point to competing constraints.

#### Scramjet Nozzle Design and Analysis as Applied to a Highly Integrated Hypersonic Research Airplane

Low speed operation of a dual mode scramjet engine is important to the development of a two stage to orbit reusable launch vehicle. This study investigates the Mach 3 operation of a dual mode scramjet engine. SRGULL, a one-dimensional cycle code for scramjet engines, and VULCAN, a computational fluid dynamics code capable of solving reacting flows, are used in this study. Staged injection is investigated to allow more heat release at a low flight Mach number condition so that more thrust can be achieved and inlet unstart is avoided. The nominal case has one injector located 1.067 meters downstream of the inlet with a fuel equivalence ratio of 0.488. An increase in thrust of 11.6% is shown in this study by injecting a fuel equivalence ratio of 0.437 upstream and a fuel equivalence ratio of 0.369 at a

location 0.8 meters downstream of the first injector.

#### Thermal-structural Design Study of an Airframe-integrated Scramjet

Demand for high-speed propulsion has renewed development of the supersonic combustion ramjet engine (Scramjet engine) for hypersonic flight applications.