# Integrated Propulsion/Vehicle System Structurally Optimized

Ongoing research and testing are essential in the development of air-breathing hypersonic propulsion technology, and this year some positive advancement was made at the NASA Glenn Research Center. Recent work performed for GTX, a rocket-based combined-cycle, single-stage-to-orbit concept, included structural assessments of both the engine and flight vehicle. In the development of air-breathing engine technology, it is impractical to design and optimize components apart from the fully integrated system because tradeoffs must be made between performance and structural capability. Efforts were made to control the flight trajectory, for example, to minimize the aerodynamic heating effects. Structural optimization was applied to evaluate concept feasibility and was instrumental in the determination of the gross liftoff weight of the integrated system. Achieving low Earth orbit with even a small payload requires an aggressive approach to weight minimization through the use of lightweight, oxidation-resistant composite materials. Assessing the integrated system involved investigating the flight trajectory to determine where the critical load events occur in flight and then generating the corresponding environment at each of these events.

Structural evaluation requires the mapping of the critical flight loads to finite element models, including the combined effects of aerodynamic, inertial, combustion, and other loads. NASA's APAS code was used to generate aerodynamic pressure and temperature profiles at each critical event. The radiation equilibrium surface temperatures from APAS were used to predict temperatures through the thickness. Heat transfer solutions using NASA's MINIVER code and the SINDA code (Cullimore & Ring Technologies, Littleton, CO) were calculated at selective points external to the integrated vehicle system and then extrapolated over the entire exposed surface. FORTRAN codes were written to expedite the finite element mapping of the aerodynamic heating effects for the internal structure.

Propulsion system
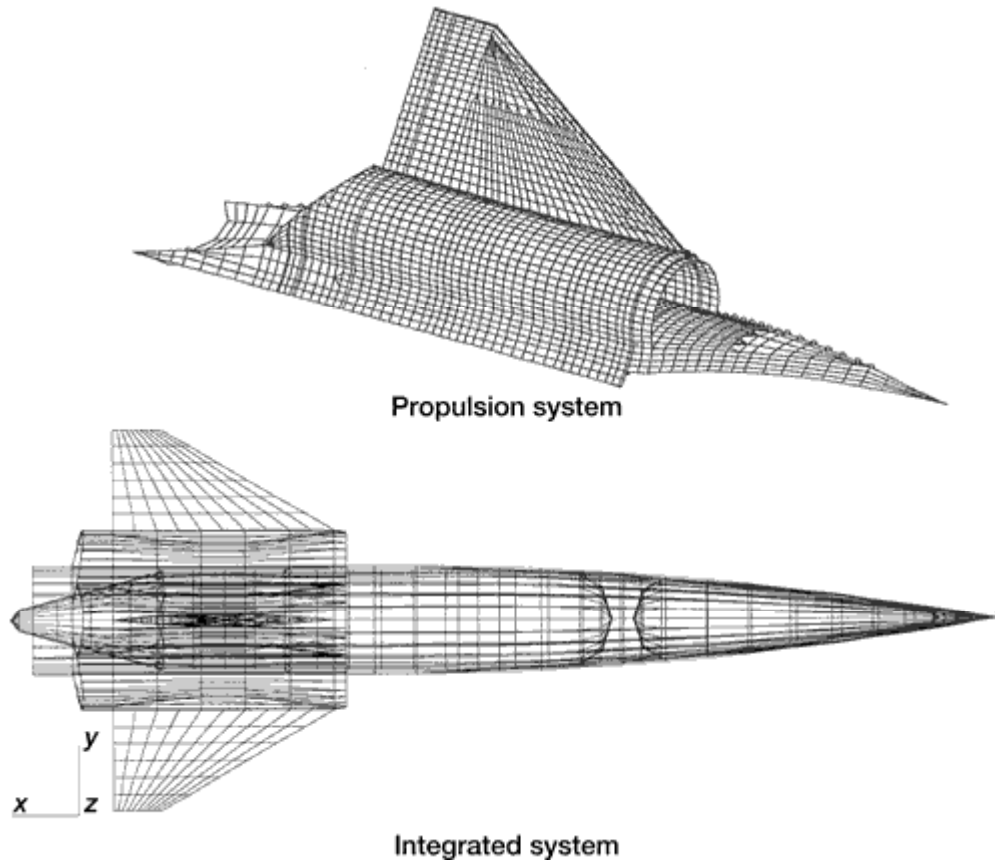


Integrated system
*Finite element models for GTX assessment.*

A detailed finite element model of the propulsion system was generated to establish a flight weight for one engine. A second finite element model, more coarsely meshed, of the full integrated system was generated for the overall assessment, mapping of loads, and system optimization. Loads were applied in a case-consistent fashion using MSC-NASTRAN (MSC.Software Corporation, Santa Ana, CA) for static analysis. NASTRAN has an inertia relief capability to simulate the vehicle in flight so that loads can be balanced. At each critical case in flight, the fuel depletion was taken into account to determine the net result of combined loads acting on the integrated system. The weight of the structure was optimized using HyperSizer (Collier Research Corporation, Hampton, VA). This code allows users to optimize a component structure according to the critical case for each component. This process was completed for each of the primary structures, leading to an overall optimization of the integrated flight system.

The methods used in this assessment were effective in defining and evaluating an integrated propulsion/vehicle structure. Results of the analyses were used to improve scaling laws and increase the accuracy in the GTX sizing tool.

**Find out more about Glenn's research for GTX**
**http://www.grc.nasa.gov/WWW/pfablv/.**

# Bibliography

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