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14. ABSTRACT

The violent winds within tornadoes are among the most powerful forces on the face of the Earth. The Orbital Technologies Corporation (ORBITEC^{TM}) of Madison, WI has discovered a way to harness the forces of a powerful tornado-like vortex flow within a new rocket engine where the chamber walls are protected from the fierce heat of combustion by a vortex flow field.

This tamed tornado exists today as the vortex cooled chamber wall (VCCW) rocket engine and is the focus of an 15-month, million-dollar study contract awarded in June 2005 to an Aerojet-led team including ORBITEC, Space Systems/Loral, and Microcosm. The California Space Authority worked to obtain support for this study through the office of Rep. Anna Eshoo (D-CA), and the funding was derived from efforts of the U.S. Congress and Air Force supporting development of advanced launch vehicles.

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The Vortex-Cooled Chamber Wall Engine: A Tamed Tornado

Designers hope a new rocket engine technology, combined with new vehicle designs and operating models, will dramatically reduce the cost of getting bulk goods to space.

by Andrew E. Turner and William H. Knuth

The violent winds within tornadoes are among the most powerful forces on the face of the Earth. The Orbital Technologies Corporation (ORBITEC™) of Madison, WI has discovered a way to harness the forces of a powerful tornado-like vortex flow within a new rocket engine where the chamber walls are protected from the fierce heat of combustion by a vortex flow field.

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As the following drawing illustrates, the vortex engine involves injecting one propellant, in this case the oxidizer, at the base of the chamber in a tangential direction to generate a tornado-like flow. This flow swirls up the wall to the head end. There it spirals inwards to form a second vortex that descends along the centerline. The core vortex mixes and burns with the fuel, which is injected at the head end.

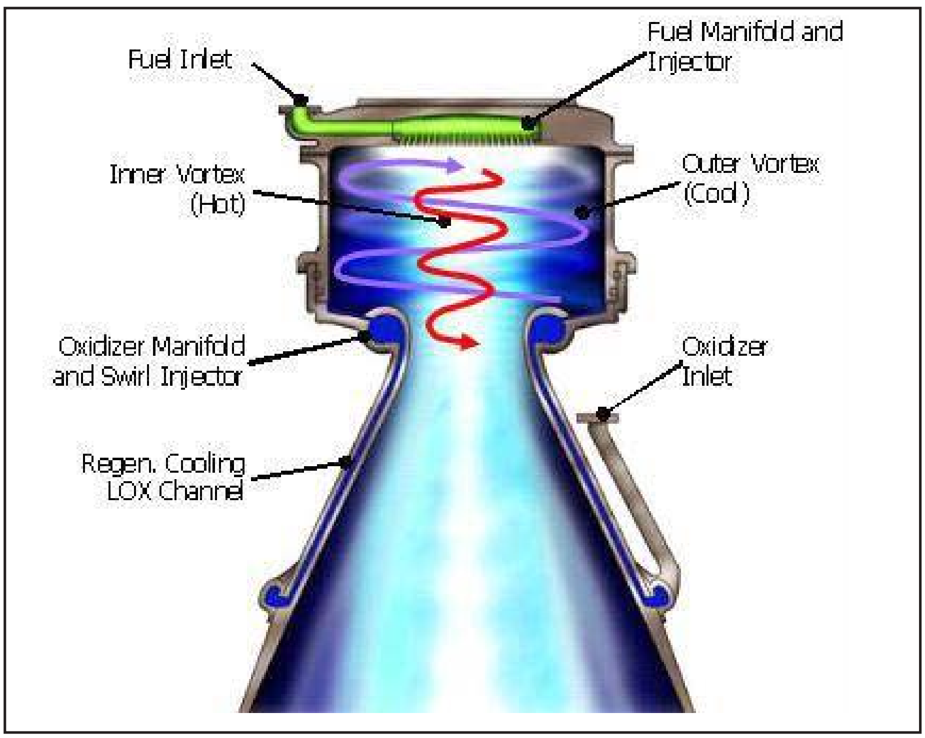
Combustion is confined to the core by vortex-generated dynamic forces. The propellants perform two functions: first one propellant insulates the walls as it works its way to the core. Second, it mixes and burns with the other propellant and releases heat. The result is an exhaust stream of hot, high-pressure gas that produces thrust.

Many rocket engines employ ablative material liners to absorb the heat transferred to the walls, these liners are vaporized and expended in the exhaust. Unfortunately, applying ablatives is costly, particularly in the confined space of the chamber, and adds mass as well. With no ablatives needed in the chamber, the vortex engine promises lower cost and mass, and a shorter schedule.

No mere tempest in a teapot, the vortex engine has already been extensively hot-fire tested. Despite the proverbial warning against wrapping fire in paper, successful results have been obtained using walls of combustible Plexiglas, as the picture shows.

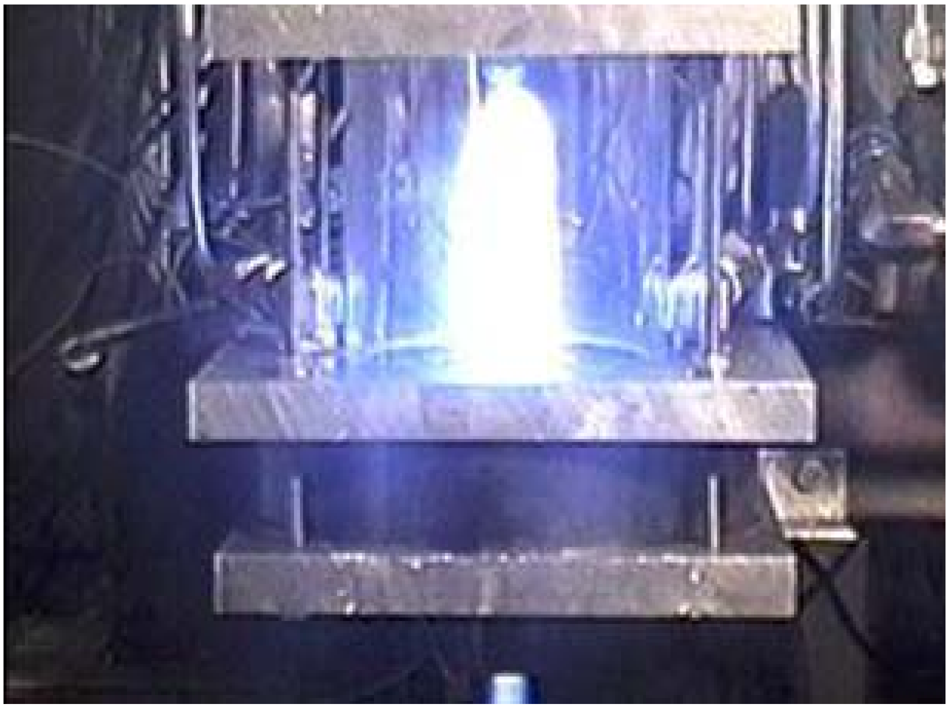
Tests involving a variety of fuels including hydrogen, methane, RP-1 (refined kerosene) and carbon monoxide, with gaseous and liquid oxygen have shown that while the core vortex within the combustion chamber is hot, the chamber walls remain cool. Vortex engines have produced over 850 pounds of thrust. ORBITEC is currently working on designs for higher thrust levels.

The objective of this new study is to validate the design for a vortex engine with a thrust of 100,000 pounds or more, the range required for a low-cost launch vehicle. This work begins



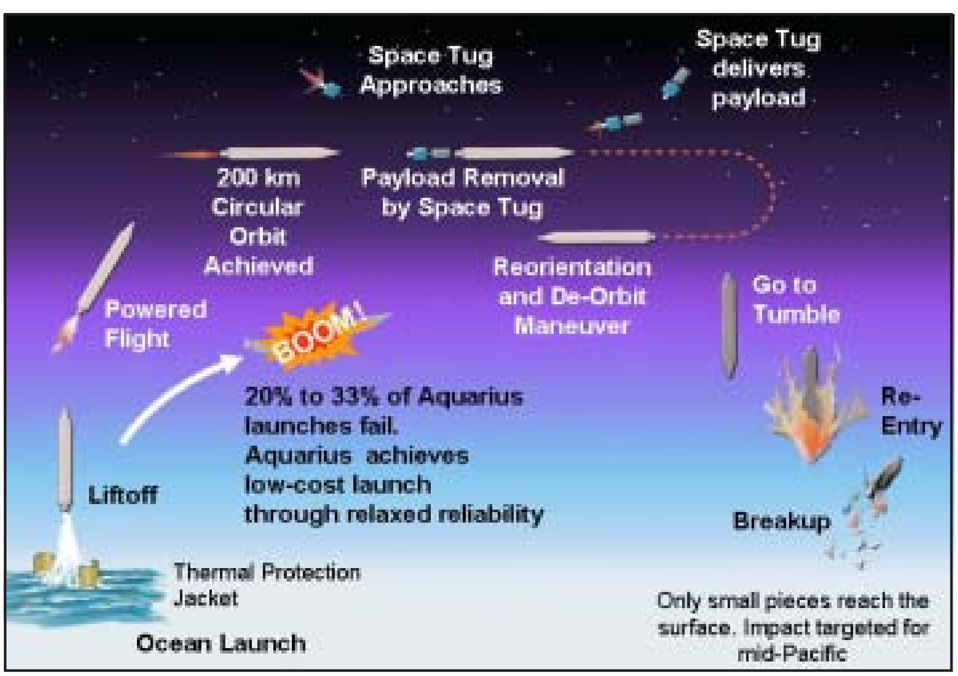
The vortex cooled chamber wall engine contains two co-axial vortices. The oxidizer flowing up from the base forms the outer, insulating vortex, and then spirals in at the head end to form the second vortex that descends to flow out of the engine nozzle. Fuel is injected at the top of this inner combustion vortex. (Source: Orbital Technologies Corporation (ORBITEC™))

Distribution A: Public Release; distribution unlimited with physical testing utilizing cold gas and water flows within highly instrumented large scale engine model. Issues to be resolved include whether this flow can be made to spiral within the vortex core to keep it isolated from the walls even at a large scale where huge quantities of fluid are involved. Can the vortex flow of the combustion gases within the core be expanded into an exhaust jet to efficiently generate thrust at the larger scale? Will the inner and outer vortices remain stable and in a predictable relationship as scale increases? Will additional design features be needed to fully exploit the unique vortex properties and achieve the desired cold wall operation?



ABOVE: *Oxygen and hydrogen burn in a VCCW chamber. The combustion chamber, constructed of Plexiglas, demonstrates the vortex cooled chamber wall concept. The Plexiglas walls remain cool and undamaged even though the temperature in the core vortex is 3000 C. (Source: Orbital Technologies Corporation (ORBITEC™))*

BELOW: *Aquarius Mission Profile. Low cost launch is achieved through relaxed reliability. (Source: Space Systems/Loral)*



The applicability of this new engine is being investigated for a new launch vehicle: Aquarius. The engine and vehicle are well matched from the perspectives of simplicity and economy. For many launchers engine reliability must be close to 100% even if cost is high and schedule tight. As will be discussed, for Aquarius such high engine reliability is not required. Though unlikely, if it were to be found that achievement of high initial reliability of the vortex engine is dependent on an extensive effort, no issue is posed because high reliability is not required for Aquarius economic success.

The Aquarius launch vehicle was discussed in a previous article (*Space Times*, May/June 2001), and requires a total liftoff thrust of 400,000 pounds. Here low cost launch is obtained by relaxing reliability. Aquarius system reliability might be only 67%, so engine reliability might be 93%. Aquarius will ship low cost consumables and low-cost, replaceable spacecraft and other equipment to orbit. Since stringent protection of reliability is not required, the cost per pound to orbit could be $500, an order of magnitude below that of any present launcher.

Lastly, work will be performed on this study to prepare for the next effort, which will involve actual hot-fire testing of a high-thrust vortex engine. A design of a workhorse version of this engine is a goal of the current effort and will be ready when the time comes to take this next major step on the road to flight and, finally, operational use. ■

Andrew E. Turner **is the project manager of the Aquarius launch vehicle development at Space Systems/Loral and was the lead mission analyst for the Globalstar constellation established by Loral and its partners; he can be reached at turner.andrew@ssd.loral.com.**

William H. Knuth **is chief engineer of Orbital Technologies Corporation (ORBITEC™) and is one of the inventors of the vortex cooled chamber wall engine.**