> **"You hit the igniter and you're in the air in four short seconds, making the X-Racer look more like a rocket with wings"**

BY MICHAEL D'ANGELO

It was in 2006 that *Aersopace Testing International* magazine first wrote about the Rocket Racing League (RRL) concept, and it was a concept. It is now about to become the newest phenomena in sports and entertainment, but fundamentally, it's a canard-style aircraft powered by a rocket engine. You hit the igniter and you are in the air in four short seconds, making the X-Racer look more like a rocket with wings.

Pilots fly the Rocket Racers through a virtual Raceway-In-The- Sky (RITS) superimposed on their helmet displays, a system called Targo-Racer. Spectators see the RITS via JumboTrons or giant screens, and the use of an RRL-developed ground and air-augmented reality system. Four cameras strategically placed in each aircraft give fans the sensation that they are flying the X-Racer right alongside the pilots.

As of summer 2010, the RRL has built, tested, and flown three versions of the

Flying the inside groove

THE LATEST ROCKET-POWERED TEST AIRCRAFT TAKE JUST FOUR SECONDS TO GET IN THE AIR FROM IGNITION. THE BRINK OF TAKE-OFF OF THE RRL

X-Racer, and has demonstrated this flight capability in three public exhibition events: the 2006 New Mexico X PRIZE Cup, Oshkosh Air Venture 2008, and the 2010 Tulsa Air and Rocket Racing Show. Currently the RRL is flight testing two of the three designs, the Mark-II and Mark-III. In more than 50 flights, we have totaled more than 350 in-flight re-lights, mostly in aerobatic but more recently in duo-racer tandem formation.

What have we learned?

The major building blocks of a Rocket Racer are the airframe, the rocket propulsion module, the avionics package and the ground support equipment necessary to operate the vehicle, and of course a highly skilled pilot.

The current Rocket Racer airframes, derived from experimental aircraft manufactured by Velocity Aircraft in Sebastian, Florida, have been through three design iterations to better configure the airframe for the dedicated purpose of rocket racing. Along the way, we have incorporated lessons learned from flight tests, ground tests, public exhibitions and analysis.

The Mark-III design, which had its public debut at the April 24, 2009, Tulsa QuikTrip Air and Rocket Racing Show, contains a number of major improvements over previous designs:

First is a fighter-style canopy which now replaces the traditional gull-wing doors, providing pilots with enhanced visibility for close-in operation, and when competing multiple Rocket Racers are in close proximity. The two-seat, side-by-side configuration has been replaced with a single center seat, adding to the enhanced visibility now possible with the canopy top.

The cockpit was redesigned to reinforce ease of single-pilot operation, which also eliminated the need for a flight engineer to accompany the primary pilot. Design changes in this configuration allowed equipment to be moved to side consoles to free up the front instrument panel. The aft-engine cowling was redesigned for better pressure recovery to reduce overall vehicle

The current Mark-II and Mark-III designs are limited to 300mph

drag for better conversion of velocity to altitude. This involved elongating the aft-engine cowling, also requiring an aft extension on the engine thrust chamber.

Also, the key load-bearing structural components of the airframe have been reinforced and strengthened, enhancing the performance potential for higher *g* flight and off-nominal operation. Reinforced areas include the fuselage area surrounding the main propellant tanks, the main wing spar and the landing gear.

Finally, to enhance yaw stability, fins were added to the aft section of the aircraft. These fins, along with the canopy top, are perhaps the most 'visual' of all the upgrades. The Mark-II design was retrofitted with the same aft fins and canopy top.

Propulsion

X-Racer engines are now being developed and tested by Doom and Quake creator John Carmack and his team at Armadillo Aerospace. The Armadillo propulsion module, a LOX-Ethanol film-cooled, pressure-fed blow-down engine, is well-designed to best suit the needs of the RRL X-Racer. Generating in excess of 2,500 lb of thrust at lift-off, the newest generation of X-Racer lifts off in four seconds; whereas previous versions of the Rocket Racers took 15 seconds. This improvement in performance means that in just a blink of the eye the X-Racer is in the air, after the pilot fires the engine. No one gets off the ground this quickly.

The propulsion module has the capability to dye the rocket plume with a variety of colors, by injecting into it a mixture of water and a specific chemical that when heated emits color in desired spectra. This 'plume seeding' has been demonstrated in green (barium), red (strontium) and yellow (sodium) to allow for a more exciting visual display and to make it easier for fans to follow their favorite team's Rocket Racer.

Similar to the airframe, the engine has undergone several iterative design improvements, better suiting it to the needs of the Rocket Racing League in the areas of safety, reliability, and performance, all based on actual runtime experience in ground and flight testing. The current propulsion module contains four major upgrades over previous designs, retrofitted into the two Rocket-Racers currently in the air:

First, flight test showed that restarting the engine multiple times while aloft, at different attitudes, loading and in different atmospheric conditions proved to be a challenge for a variety of reasons. By redesigning the igniter to eliminate the possibility of igniter plume impingement on the face of the injector manifold, the life of the engine overall was greatly enhanced.

Second, an enhanced thrust-containment system was incorporated to eliminate the introduction of a destabilizing side-thrust event following an unlikely certain mode of engine failure. Third, a so-called burn-through sensor system for early detection of a certain combustion chamber anomaly was installed, enabling the safe shutdown of the engine and return home. And, lastly, the injector manifold for higher performance and longer life was redesigned. The injector manifold is the component that mixes fuel and oxidizer in the combustion chamber.

The pilots are selected and include aerobatic pilot Sean Tucker, Len Fox, Dave Morss and Jim Bridenstine. They typically possess backgrounds in aerobatics and military fighter jet domains

"The propulsion module has the capability to dye the rocket plume with a variety of colors"

Raceway avionics

Whether for a demo exhibition or an actual race competition, RRL pilots navigate their Rocket Racers within a three-dimensional track in the sky. RRL's RITS can be created in an unlimited number of race formats, shapes and locations. The raceway consists of a course created through a simulations tool that is then uploaded to the RRL's custom avionics package – melding the real world with the virtual, and presenting to the pilots and spectators a real-time depiction of the virtual raceway, navigation metrics and safety aids. Rocket Racer pilots are able to navigate the

raceways using a variety of displays from in-panel to helmet-mount. Each Rocket Racer vehicle draws from precise differential GPS tracking with an integrated inertial navigation system, providing spatial accuracy within a few meters.

In 2009 RRL partnered with Elbit Systems to migrate our raceway avionics from the instrument panel to the pilot's direct line-of-sight. What this specifically means is that previously, we projected the raceway on an in-panel cockpit display, HDD, for heads-down-display. This required the pilots to look through the windscreen with his head 'up' in order to see the outside world (specifically, his Rocket Racing competition, and the earth), and then quickly look down, in a heads 'down' position to orient himself in the RITS – a cumbersome task at best.

Now, though our partnership with Elbit, we provide RRL pilots with specialized helmets that project the RITS on the pilot's visor. This puts the raceway, and race-critical information directly on the pilots line-of-sight, negating the need to look anywhere except at the outside world to navigate the track.

The HMD, or helmet-mount display, designated as TargoRacer, is built, tested, and under flow and operational test and evaluation. The foundation containing the hardware, firmware and software to enable the projection of the raceway onto the pilot's line-of-sight is complete and in a refinement phase to perfect it for the purpose of Rocket Racing.

As of summer 2010, we have completed our initial flight-test program with excellent results,

The engines burn liquid oxygen (LOX) and ethanol, producing a maximum of 2,500 lb of thrust emitting a brightly, colored, 10-15ft long flame

Virtual race

Rocket Racing League's gaming platform has been designed to combine the virtual and real world, and the spectrum of game coverage is real-time to offline. Participation is expected to range from single user to multiplayer and from hand-held to console to arcade games. Through games, fans can design and fly their own Rocket Racers and also network online with other virtual 'owners' and 'pilots' for a year-round gaming platform. Games will enable fans to fly in real-time against the actual Rocket Racers with combinations of virtual and live action and it is further contemplated that gaming finalists may come to actual races to compete with real Rocket Racers in cockpit-based gaming modules.

RRL's iPhone game, released on June 16, 2010, and available through Apple's iTunes online store, should help promote the RRL vision/brand and create immediate opportunities for sponsors. At its core, RRL's iPhone game is a rocket-racing simulator, allowing players to sit in the pilot seat and race against both the computer and other gamer opponents. Beyond the first release of RRL's iPhone game, an evolving family of iPhone games is envisioned to include tournaments and other advanced features. RRL's iPhone game will represent the leading edge of applications thus far developed for the Apple mobile platform.

validating that the raceway projected on the pilot's line-of-sight not only tracks with the movement of the rocket racer itself, but also with the movement of the pilot's head within the Rocket Racer.

Operationally what this means is that no matter where the pilot looks when flying a Rocket Racer, he or she will see the raceway in that portion of the sky within their line-of-sight. The TargoRacer is a major development for the RRL, bringing to the mix of enabling technologies a capability that permits safe, engaging, head-to-head racing in a form previously available only to military organizations with many millions, and perhaps billions of dollars to spend in the acquisition process.

Augmented reality

The various augmented reality systems being deployed within the RRL are designed to provide a rich, immersive viewing experience, from the perspective of pilots in the sky to the fans on the ground, deployed live and remotely to television and web audiences. These augmented reality systems enable end users to experience the nexus of the real world with the virtual world.

The groups of end users include, but are not limited to: fans on-site at events (large screens stationed around the grandstands, hand-held devices); remote fans (broadcast on television and internet). Both live-action and remote fans can tap into RRL's virtual world with streaming video. Such categories include: gamers, FAA (safety), race officials (scoring, safety, control), race teams (real time monitoring) and archives (repackaging to end-users).

The RRL will work carefully follow all air show regulations set by the FAA, airport authorities, the RRL safety board and other governing bodies

The events will be held at selected venues across the USA and select overseas locations

At its simplest level, the virtual world consists of the RITS. At the next level, it contains a means to recreate for fans and other end users, exactly what is happening in the cockpit of a Rocket Racer as, for example, one pilot attempts to overtake another pilot in the final lap of a head-to-head race to the finish.

The progress that has been made in the past 12 months with viewer-based augmented reality systems is significant. A capability to create for end users a RICS where ship-raceway interaction occurs based on the performance of a pilot through the track has also been developed. If a pilot flies perfectly through a designated gate that is part of a more expansive track, the gate will undergo a change in appearance to reflect positive scoring; likewise if a pilot misses a key part of the raceway, or violates a rule, the gate will alter its appearance to reflect a penalty.

This proximity-aware raceway is at the core of RRL augmented reality, delivering to the fans and other end users, a highly interactive, intuitive depiction of the race that combines real-world live imagery and video streams with virtual effects to visualize the raceway and other race metrics to create an unprecedented vantage-point experience for fans.

Future Rocket Racers

Beyond the initial 2009-2012 flying schedule, RRL plans to develop next-generation versions of the Rocket Racer based on lessons learned during the first racing season to increase speed and maneuverability, safety and performance. RRL plans to roll out different Rocket Racer designs to meet different performance specifications, ultimately building a vehicle from the ground up, deliberately designed for the sole purpose of rocket racing.

2010 is a year of enhanced development and testing for the RRL. In the next two years, multiple teams will compete at airfields, spaceports and skyways all over the planet. ▮

Michael R. D'Angelo is chief operating officer of the Rocket Racing League in the USA

"RRL plans to develop next-generation versions of the Rocket Racer based on lessons learned"