SKYCAR – CASE STUDY

The ultimate fly/drive

The patented AirCar is a four-passenger, advanced-composite craft that is a step closer to making personal door-to-door transportation a reality

The Milner ElectriCar is a direct derivative of the Milner AirCar, utilizing the same chassis and fuselage

Christopher Hounsfield

For Milner Motors in the USA, January 2008 marked a milestone in the company's bid to build a commercially viable, roadworthy aircraft. Although unable to take to the skies just yet, completing the final assembly of a full-scale, proof-of-concept AirCar prototype signals a major accomplishment. Now, following three years of hard work for owner James Milner (who founded the company in 2005), solutions to major design hurdles can be validated and Milner can at last begin to turn his vision into a marketable reality.

The Milner AirCar

With 35 years in the aviation industry behind him – as a flight instructor, airline pilot, and entrepreneur – Milner now finds himself well poised to deliver on his ambition. He is aided by his son, Chris, whose job includes dealing with the on-board vehicle control systems, powertrain engineering, government relations, and industry partnerships. "The task is to build a vehicle that is light enough to fly, yet strong enough to pass automotive crashworthiness standards," explains Milner Jr. "It must be roomy enough to carry at least four people, yet aerodynamic enough to fly at 200mph. It has to have an adequate constant airborne power source of about 300bhp as well as a variable 40bhp ground power source. It also needs controls and instrumentation that adapt to – and are familiar to – both airborne and ground use. The vehicle has to have an adequate wing area. The AirCar has a 28ft span and 150ft^2 area, which is capable of being folded into a size and shape that is road-legal, while also providing a vehicle that will be stable in cross winds on a highway." As a result, Milner says, there must be a means of adjusting the rear-wheel location so that 90% of the weight is on the rear wheels in air mode, but not more than 66% in ground mode, with the front wheels carrying the other 33%.

In 2005, the team began by defining the vehicle's specifications. To keep the design as simple as possible, it was decided early on that the vehicle would carry its wings, rather than have wings that could be removed. They opted for an aircraft with the main wing at the rear and a canard in the front, which provided optimum wing-folding possibilities. To provide adequate comfort, it was decided that the vehicle should feature four doors, carry four passengers, and have four wheels. Dimensionally, it would be roughly the same height and length as popular sedan cars, such as the Honda Accord or Toyota Camry, and would have a 54in-wide fuselage body, the maximum cross-sectional area of which needed to stay close to 1.5m². Other specifications included a cruise speed of 200mph for up to 1,000 miles at altitudes up to 25,000ft, with eventual pressurization. In road mode, though, the AirCar should reach 85mph.

These basic design parameters were taken to Darcorp, a national aeronautical design company. CAD models were used to compare dozens of design permutations to size the vehicle, establish weight and balance limitations and stall speeds, select wing and canard airfoil, size and area, and so on.

Constant comparisons to existing designs were made as guidance. For example, using the LS-0417 airfoil for the main wing requires 125ft² of wing area for an aircraft with 3,000 lbs gross weight and 1,800 lbs empty weight. The wetted area of 538ft² and equivalent parasite area of 3.93ft² are slightly better than the Cessna 210 and Beech 35. As both of these airplanes are six-seaters, the additional weight required for AirCar-specific features – such as heavier landing gear, folding wings, and the ground power engine and drivetrain – provides a reasonable trade-off for the capability to carry two extra passengers.

In terms of power, Darcorp's analysis identified that the aircraft would need about 320bhp to achieve the desired cruise speed of 200mph. Milner believes that this will most likely be accomplished by the use of dual rotary engines with ducted fans: "The 32in fan diameter and the 6,000rpm engine speed provide fan-tip speeds of about Mach 0.70 – a good number for efficiency and reduced noise. Another possibility that would fit into the space available was a six-cylinder Lycoming or Continental 300bhp engine, with a single-pusher propeller."

"The 6,000rpm engine speed provides fan-tip speeds of Mach 0.7"


The foldable wings have a 28ft span and 150ft² area

Darcorp then ran CFD studies at 100, 150, 200 and 300mph at an angle of attack of 0° and 5°. Although confirming the design to be workable, these studies revealed minor areas that need some adjustment between the engine nacelles and the fuselage skin.

The Milner ElectriCar

As the design and specifications for AirCar came together, it dawned on Milner and his team that their work in designing a flying car could also produce another application. Lightweight yet strong, and aerodynamic yet practical, such design parameters could also yield a design for a new class of automobile: a lightweight, energy-efficient hybrid-electric car.

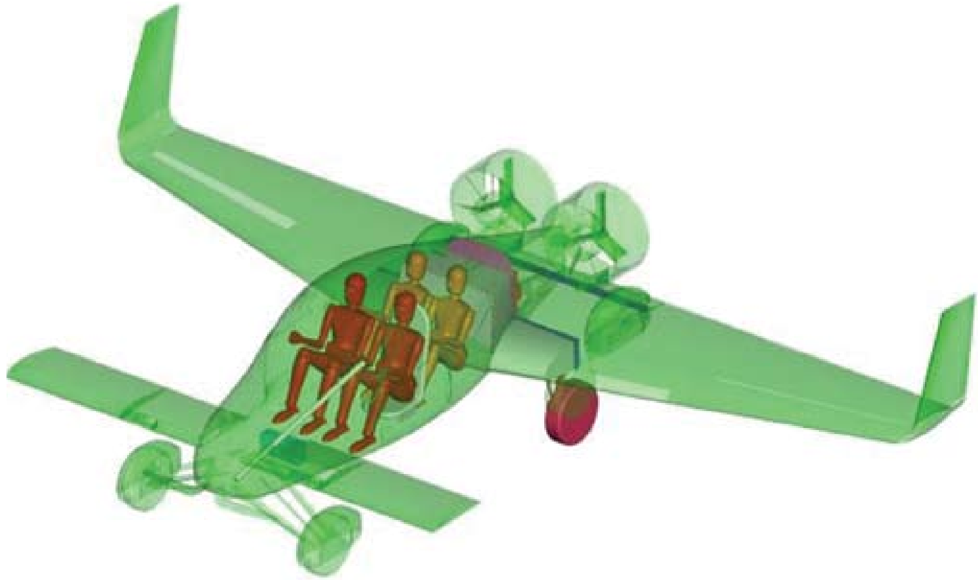
So, by early 2006, it was decided to build ElectriCar alongside AirCar. The ElectriCar utilizes the same fuselage as the AirCar and incorporates many of the AirCar design features, although much higher volumes are predicted for ElectriCar. However, identical components in both vehicles will be produced in higher volume and therefore at a lower cost.

Both AirCar and ElectriCar will eventually conform to all relevant US Federal Motor Vehicle Safety Standards (FMVSS) and National Highway Traffic Safety Administration (NHTSA). An initial review of the standards for crashworthiness has already been conducted and, in most cases, the FMVSS crashworthiness requirements (frontal crash, rear crash, side impact, rollover and roof

FLYING CAR: THE DREAM

Over the last 75 years, there have been over 100 US patents issued for flying cars. From gyroplane-type vehicles with foldable rotors to vertical take-off vehicles, each has attempted to demonstrate a vehicle that would provide door-to-door transportation.

The benefits of a flying car are well known. People dream of being able to leave their garage, drive to the nearest airport (in the USA there is an airport within 20 miles of 98% of the population), extend the wings, and fly at 200mph to their destination airport, then land, fold the wings and drive on to their actual destination. For trips between 100 and 1,000 miles, flying cars would provide the fastest door-to-door travel time. They use the existing infrastructure of over-utilized roads and under-utilized airports, provide convenient, ready-to-go transportation and at a lower cost than existing methods. The flying car also provides the option of avoiding hazardous weather – it can land, drive through the weather, then take off again when the weather clears.



Initial fabrication and prototype construction has been carried out using hand-crafted fiberglass

The wings, canards and rear wheel fixtures are able to move, then lock into flying or driving mode

crush) are more strict than Federal Aviation Regulation (FAR) requirements.

A computer-aided engineering firm in Detroit, Michigan, was sought to perform initial model development using ProEngineer, and crashworthiness analysis was assisted using LS-DYNA. Finite element meshing was performed using Hypermesh. A preliminary design of the crumple zones and the front bumper (using simulated steel and aluminum components) was then developed and crashworthiness analysis of structural energy absorption performed. "This showed that our fuselage design has sufficient packaging room to include the crumple zones necessary," Milner confirms. "Further crashworthiness work will need to be conducted when we engage in more engineering work, deciding on materials for fuselage skin, frame and chassis components, and so on."

Specifications of the ElectriCar include a curb weight of 1,250 lbs, a 40bhp electric motor with continuously variable transmission (CVT), a maximum speed of 85mph, and 15kWh of battery storage with household plug-in charging. A smaller gasoline engine providing electrical charge to the batteries will provide a 'range assist' for distances greater than the 100 miles that the batteries are able to provide. With the average daily use of a car being around 40 miles, most driving will require no gasoline at all.

Aerodynamic testing has also now been completed, which determined the drag coefficient and coefficient of rolling resistance. The ElectriCar was towed at speeds from 10-60mph to gather measurements of total drag at each speed. Coast down tests from 60mph to a resting stop were also completed using GPS speeds logged into a computer. A coefficient of rolling resistance of 0.022 (CdA) was obtained, a figure that equates to about four times the 0.006 that should be obtained in the next-stage optimized design. Additionally, a coefficient of aerodynamic drag of 0.209 was calculated, which with the maximum cross-sectional area of $1.5m^2$ provided a CdA of 0.313. At 60mph, the vehicle requires 5bhp to overcome aerodynamic drag and another 5bhp to overcome rolling resistance. However, it is expected that the rolling resistance can be reduced to 2bhp, requiring 7bhp or 5kW to maintain 60mph on level ground.

Fabrication

Pacific Roadster, a local company experienced in fiberglass fabrication, handcrafted a full-sized fuselage in addition to fiberglass fuselage molds and three fuselage skins. The fuselage skin weighs about 1 lb/ft^2. Patterns, molds and body parts for the canards, wheelpants, windows, door frames, wings and dashboards were also fabricated. Wings and canards for the ElectriCar were downsized by 10% and also attached to the fuselage with a 3° nose down angle-of-incidence to offset any lift provided by the fuselage. Meanwhile, a chrome-alloy steel tubing frame provides mounting points for the suspension, doors and drivetrain. Doors and windows were cut out of the fuselage skins and the team developed the door frames, window frames, window molds, headlight and tail light inserts and lenses.

"By mid-2007, the AirCar engine nacelles and vertical stabilizers were created, then the articulation of the main wing fold, the goal of which was to create as compact a unit as possible," Milner says. "Top and bottom molds and skins were developed for the six sections of the AirCar's full-sized main wing, then attached to the steel frame. "Windows were formed by heating plexiglass, then placing them in a vacuum form that was constructed from the window molds. Subsequently, the vehicles were painted and all parts assembled."

Two long years after starting to build the vehicles, the first two prototypes were complete.

"We must perform the necessary work to build the AirCar as a flyable aircraft"

Looking ahead

As of January 2008, the interiors of the vehicles were still being fitted with seats and upholstery, carpeting, dashboards, and instrumentation. A 180° side- and rear-view mirror system is displayed on the top half of the primary instrument computer monitor. The AirCar's wings, canards and rear-wheel placement are able to move and are locked between air and road mode by mechanical means.

At the outset of the project, many problems needed to be solved and questions answered. Realizing that these were issues that would naturally be resolved along the way, the Milners decided to go ahead and fabricate both vehicles. But the pair also appreciated that some issues would not be resolved, and that second prototypes would have to be built that might require further engineering work.

Work is still ongoing and two engineering challenges remain for 2008: "First, we must conduct a comparative engineering study for cost, weight and manufacturing ability to decide which materials will be used for the fuselage skin, frame and chassis," Milner says.

The options for the skin include fiberglass, carbon fiber, or other advanced composites and aluminum. Chassis and frame options include pultruded composites, hydroformed aluminum and chrome-alloy steel. Although each has its advantages and disadvantages, this study will be conducted in conjunction with the next-level crashworthiness engineering work.

"Secondly, we must perform the necessary engineering work to build the AirCar as a flyable aircraft," Milner concludes. "As this work continues, some smaller refinements will be made regarding door size, side-window attachment and opening, and rear-seat size."

As the certification and manufacturing processes for both ElectriCar and AirCar are huge undertakings, decisions have to be made. One such decision will inevitably focus on involving partners, either another company that already has appropriate manufacturing capabilities, or several companies that each have a portion of the required expertise and experience. ∎