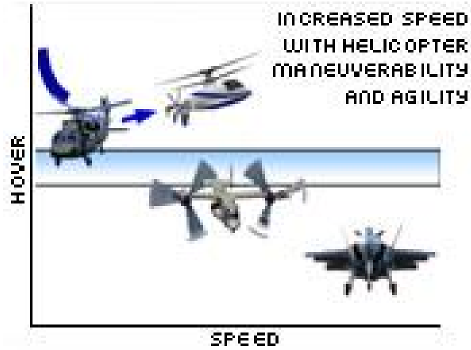
The Moller Skycar: An Simple, Low-cost Alternative to High-Speed Helicopters or Tilt-rotor Aircraft

Why are all the major helicopter companies trying to build faster helicopters? Obviously the short answer is money. A representative from Piasecki says "The military will spend $40 billion over the next 20 years recapitalizing its (helicopter) fleet."

Helicopters



Historically, vertical flight has required a compromise between hover performance and forward speed. Low disk loading aircraft, such as helicopters, fall on the left of the graph below, along with their desirable attributes (hover efficiency, low speed controllability, low downwash, and hover endurance). Higher disk loading aircraft, such as Harriers and the Joint Strike Fighter (JSF), trade off decreased hovering capabilities for speed and increased operating costs.

Enablers for advances in helicopter technology are primarily in aircraft engineering and control systems. Now, rotor vibrations can be reduced using “active control”, which consists of placing sensors around the helicopter to detect the onset of vibration and then using force generators on various parts of the frame to vibrate in such a way that they cancel out the original tremors. Advanced computer modeling has also made it possible to design more efficient rotors. Additional propellers provide additional forward thrust and increase speed and/or assist with braking. Computerized “fly-by-wire” controls allow these new helicopters to be flown relatively easily.

Sikorsky’s X2 design is basically a helicopter with coaxial main rotors

For example, the Sikorsky X2 incorporates several new technologies and has successfully demonstrated them in a flight environment. These technologies include an integrated fly-by-wire system that allows the engine/rotor/propulsor system to operate efficiently, with full control of rotor rpm throughout the flight envelope, high lift-to-drag rigid blades, low drag hub fairings, and Active Vibration Control.

So how fast can one of these new helicopters go? Sikorsky says its new hybrid helicopter can "cruise comfortably" at 250 knots, or 288 mph. That would be a faster than any current rotary wing aircraft. For example, the top speed of a UH-60L variant of   Sikorsky's Blackhawk is about 150 knots, or 173 mph.

The Eurocopter X3 features an extra engine that is used to drive the additional propellers on the vehicle, and that additional engine gives the Eurocopter X3 a significant speed boost. The Eurocopter X3 can reach a top speed of approximately 232 knots or 267 mph.

Eurocopter’s X3 uses two propellers that provide forward thrust. Power for these propellers comes from the main engine.

Piasecki’s military-funded X-49A "SpeedHawk" compound helicopter is its primary entry in the competition. The X-49A features an aircraft wing and five-blade propeller placed in a controllable ring-tail in lieu of the H-60 Black Hawk's standard anti-torque rotor.

Piasecki' s military-funded X-49A.
Note the aircraft wing, five blade propeller and controllable ring-tail

Piasecki envisages its family of compound helicopters will offer vertical take-off and hover performance as well as a 200 knot (230 mph) cruise speed, 45 knots (52 mph) above the 155 knot (178 mph) cruise speed of the standard H-60 helicopter. Piasecki says its new compound Cobra will have a 245 knot (282 mph) cruise speed, 829 mile range and 7,950lb useful load and cost $12 million per vehicle. Drawbacks of the current design are the open loop controls for the propeller pitch, flaps and elevator control and hundreds of pounds of added weight for the tail and wings.

Piasecki first tested the vectored thrust ducted propeller (VTDP) concept in the 1960s, exceeding 195 knots (224 mph) with its Pathfinder II demonstrator in 1966. The SpeedHawk program was originally launched by the US Navy in 2000, but the army became the sponsor in 2004, using congressional "plus-ups" to fund a small development team at Piasecki. "We're doing all this for the unheard-of price of $3-6 million a year," says Piasecki Aircraft president and chief executive John Piasecki. If this is true, the 46+ year development program has cost approximately $200 million dollars to this point.

"A helicopter does not want to fly. It is maintained in the air by a variety of forces and controls working in opposition to each other, and if there is any disturbance in this delicate balance the helicopter stops flying; immediately and disastrously." – Harry Reasoner.

Tilt-Rotor Aircraft

Originally known as the Bell-Agusta BA609, the nine-passenger tilt-rotor powered lift vehicle reached velocities as high as 310 knots and altitudes up to 25,000ft (7,620m). The BA609 is designed to take off and hover in helicopter mode and cruise at 275 knots (316 mph) after transitioning to fixed-wing mode. Unfortunately, Bell gave up on the idea of a civilian use tilt-rotor, largely because of costs, and sold its share of the BA609 program to Italy's Agusta Westland.

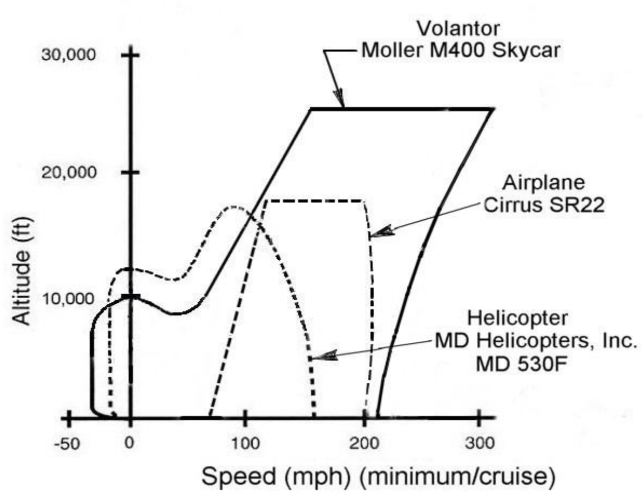
The Bell-Boeing V-22 Osprey is the BA609's predecessor. This military tiltrotor, powered-lift category aircraft was developed by Bell Helicopter, which manufactures it in partnership with Boeing Helicopters. It can hit speeds upward of 240 knots (276 mph), but it's a complicated hybrid-half helicopter and half airplane, with all the complexities of both types of aircraft. However, it can hover when its propellers are turned upward, and when they are turned forward, fly fast like a plane. It is unable to land unless its rotors are in the vertical position. Still, the V-22's complex tilt-rotor concept has performance and cost drawbacks that have limited its adoption to the U.S. Marines and Air Force.

In a recent announcement Terrafugia of Woburn, MA stated that they planned to produce a tilt-rotor, VTOL-capable "flying car" following their development of the Transition®, their current road-able aircraft design. "TF-X™ is Terrafugia's vision for the future of personal transportation. A four-seat, plug-in hybrid electric flying car with fly-by-wire vertical takeoff and landing (VTOL) capabilities, TF-X™ is designed to bring personal aviation to the world. The design will make use of the high power density and reliability of modern electric motors in combination with parallel power and control system architectures to achieve a higher level of safety than modern automobiles. TF-X™ will provide true door-to-door transportation combined with the freedom of vertical takeoff and landing -- creating a new dimension of personal mobility." They state that the development of this aircraft will be lengthy and it will be available sometime after 2020.

The Moller Skycar

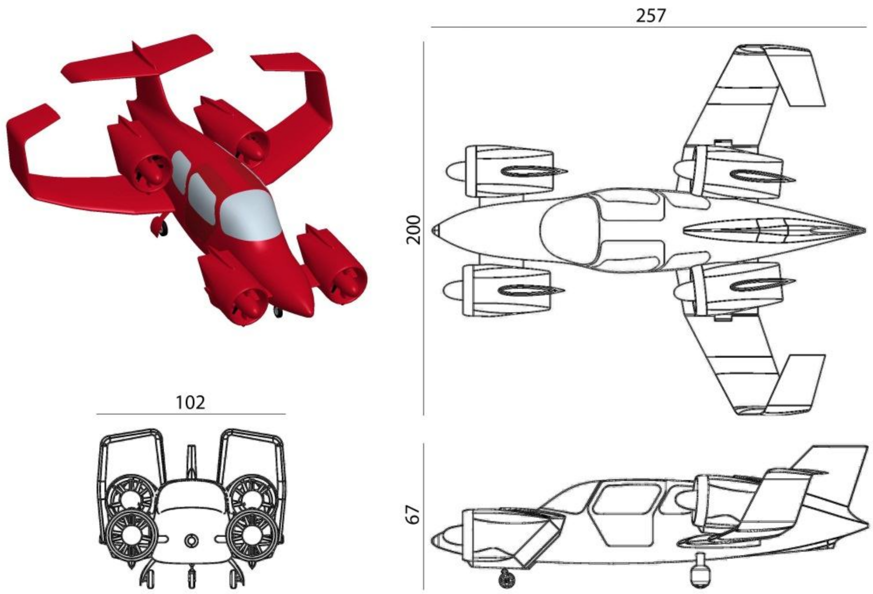
The Moller Skycar is a high-speed, vertical take-off and landing (VTOL) aircraft intended to provide an alternative to the complexities of this new breed of high-speed rotary-winged aircraft or the extreme cost of the tilt-rotor designs represented by the V-22, BA609 or TF-X™ for applications where a modest payload capability is required. While traditional VTOL aircraft design firms like Sikorsky and Eurocopter have pursued the more complex helicopter-like technologies, and tilt-rotor aircraft developers combine complex rotorcraft and fixed-wing technologies, our technical approach was to create a powered-lift aircraft that uses multiple rotating ducted fans rather than open rotors. We use the generic term "volantor" for these aircraft. This technology has allowed us to design a much simpler vehicle that is capable of VTOL, attains high speed (300+ mph) in forward flight, and yet maintains a small size and slim profile making it possible to use it on a roadway for short distances to and from a take-off or landing area. It can land with its ducted fans in either the fully rotated or horizontal position, wings extended or folded, providing maximum landing flexibility in either conventional or VTOL modes. The Skycar volantor can also maintain safe operation in a "engines out" condition. It can land in VTOL mode with one engine out, or land like a fixed-wing aircraft with its wings extended with as many as five of its eight engines out. In the case of a more catastrophic failure, Skycars are equipped with airframe parachutes, enabling a "soft" landing for both aircraft and passengers.

Artist rendering of Skycar 400 in hover



Given these characteristics, we see ourselves as potential providers of a new generation of safe, affordable, high speed aircraft with VTOL-capabilities. But more than that, we intend to provide a state-of-the-art aircraft that leverages its on-board computerized systems to minimize the skill and effort required, enabling it to be safely operated in even the most extraordinary situations. Production versions will integrate the full-range of instruments and sensors required for the Skycar's stability system with its collision avoidance, artificial vision, navigation and communications capabilities.

Over the past 30+ years Moller International and its predecessor companies have been developing the technologies required for the Skycar. To date approximately $100 million have been privately raised and expended on developing these technologies which include the Skycar and Neuera volantors, rotary engines and Aerobots. The Skycar 400 is the 5th VTOL aircraft produced. Successfully demonstrated first in 2002, its ducted fans provide lift and propulsion without the dangerous exposed rotor blades or complex and costly gear boxes of rotary-winged or tilt-rotor aircraft. The vehicle uses directly coupled engines and fans, instantly responsive but low cost rotary engines and computer technology to monitor, control and maintain stability of the aircraft. The result is that the Skycar's projected performance exceeds that of any light helicopter, including a top speed that is up to three times faster. When compared to a high-performance airplane, the Skycar has vertical takeoff and landing capability, is safer and potentially less expensive. The performance boundaries of the Skycar are much less restrictive than those of helicopters, tilt-rotor or fixed-wing aircraft. These expanded operating limits are the natural consequence of combining VTOL and high-speed cruise in a single aircraft. The resulting flexibility allows many transportation applications to be addressed for the first time.



Skycar 400 Specifications

Configuration (Side Entry)	4 tilt thrust nacelles with 2 x 450cc single rotor engines each.	
Seating	2+2	
Dimensions (L x W x H) – Stowed footprint	21.5' x 8.5' x 7.5' – 182 ft^2	6.5 x 2.6 x 2.3 m
Gross Weight	2,400 lbs	1,088 kg
Net Payload	720 lbs	327 kg
Continuous Engine Power (Total)	725 hp	541 kW
Component Articulation Required	Wing fold	
Maximum Speed (Sea Level)	331 mph	533 km/h
Cruise Speed (Sea Level @ 65% power)	284 mph	457 km/h
Cruise / Maximum Speed (20,000 ft)	308 mph	496 km/h
Time – Parachute Safe (50 mph @ 200 ft)	8.54 seconds	
Time to Transition (0-131 mph)	14.49 seconds	
Maximum VTOL Altitude (2 passengers)	10,000 ft	3,048 m
Rate of climb (sea Level)	3,979 fpm	1,213 M/min
Time to climb (20,000 ft)	6.2 minutes	
Roadability (On improved roads)	~ 30 mph	~50 km/h
Range @ economic cruise*	750 miles	1,206 kilometers
Fuel Consumption @ economic cruise*	6.5 gallons per hour	24.5 liters per hour

*Economic cruise speed varies with altitude. At 25,000 feet it is 170 mph while at Sea Level it is 150 mph.

It is anticipated that the Skycar will appear in a military role first. For that reason the following comparison includes some alternatives that are or may be available to the military. Large helicopters and tilt-rotor aircraft have the one advantage over the Skycar of being able to carry a large single piece payload. This advantage vanishes for a specific payload if it can be distributed into smaller packages that can be transported by a Skycar-type aircraft. The following figure shows that the Skycar 400 and its larger variant, the 600, are far more efficient as VTOL transport vehicles versus large VTOL aircraft. It is projected that the Skycar 400 can be sold in low quantities for approximately $500,000 per unit, which is five times less expensive than the V-22 Osprey in net tons of payload delivered relative to its acquisition cost.

	$\frac{\text{NET PAYLOAD[2]}}{\text{ACQUISITION COST}}$ $\left(\frac{\text{Tons}}{\text{Million (\$)}}\right)$	$\frac{\text{NET PAYLOAD x SPEED[3]}}{\text{ACQUISITION COST}}$ $\left(\frac{\text{Tons x MPH}}{\text{Million (\$)}}\right)$	$\frac{\text{NET PAYLOAD x RANGE[4]}}{\text{FUEL CONSUMPTION}}$ $\left(\frac{\text{Tons x Miles}}{\text{Gallons}}\right)$
Skycar® 400 ($500,000 cost)[1]	.75	172	5.7
Skycar® 600 ($750,000 cost)[1]	.83	208	5.4
V-22 Osprey Tiltrotor	.075	21	1.16
Sikorsky H60D Heavy helicopter	.14	21	2.9
MD 520N Medium helicopter	.825	127	2.9
Robinson R44 Light Helicopter	1.15	145	2.75
BA 609 Tiltrotor	.15	47	4
FOR COMPARISON WITH FIXED WING AIRCRAFT			
Cirrus SR20	1.5	230	5.25
EADS TBM 700	.8	280	5.2
Mooney Bravo M20M	.8	182	5.23
Lancair Columbia 400	1.15	203	6.51
Cessna T182T	1.07	136	3.91
Adam A500	.84	203	5.04

[1] These are initial prices for these models. The Skycar is a fundamentally simple vehicle with no critical moving parts except the engines. It therefore lends itself to economy of scale. An independent study by the Boeing Aircraft Company concluded that if produced at a volume of 100,000 units per year the Skycar 400 would cost less than $100,000.

[2]Net payload is useful payload minus fuel.

[3]Uses 45%-55% power for speed and range.

[4]Assumes all aircraft operate with sufficient fuel for 750 mile range

The bottom line is that the Skycar 400 will be a cost effective, VTOL-capable solution for moving up to four people or a total payload of 720 lbs. Helicopters are more efficient for heavier payloads or when there is a requirement to hover for a prolonged period, but if one needs brief VTOL-capability, high-speed, reasonable range, outstanding safety and ease of operation, nothing will beat a Skycar.