Advantageous Autorotation

The DARPA Heliplane aimed to double helicopter performance in a VTOL platform without the complexity of a helicopter transmission or anti-torque system. (All images via Skyworks Global)

Skyworks Global plans to commercialize affordable autorotating aircraft in regions without aviation infrastructure and looks to revive DARPA Heliplane technology for speed, range and vertical takeoff.

By Frank Colucci

While sustained autorotative flight found a lasting market in recreational gyroplanes, the technology has broader potential. Skyworks Global last year re-branded the Groen Aeronautics line of gyrocraft and plans to commercialize the technology for more users — this summer with the SparrowHawk III kit gyroplane, then with the larger Hawk 5 gyroplane built offshore, and potentially with big, tip-jet-driven gyrodynes that can take off and land vertically and hover. "What we're going to solve is two-thirds of the world's aviation requirements," stated Skyworks' executive committee director, retired US Air Force Brig. Gen. John Michel. "No one has paid attention to the two-thirds of the world with no infrastructure, no educated workforce — gyrocraft are built for that." Skyworks Global's "simple, elegant solution" of a freewheeling rotor with collective pitch control is protected by patents to make gyrocraft safer and more flexible. The company also has long-range, high-speed gyrodyne technology from the US Department of Defense (DOD) Defense Advanced Research Projects Agency (DARPA) Heliplane effort, and according to Michel, "That technology is completely scalable."

Groen Brothers Aviation (later Groen Aeronautics) worked to patent its technologies and continued to invent after the company and the DARPA Tactical Technology Office finished the detailed Heliplane Phase I preliminary design review in 2008. "Given the success of the Heliplane program first phase, I was really surprised that one of the labs didn't pick this up and carry it forward," said former DARPA program manager and current Skyworks Global Chief Technology Advisor Don Woodbury. The demonstration program envisioned a 400 mph (350 kt or 640 km/h) vertical takeoff and landing (VTOL) aircraft with 1,000 nm (1,850 km) range carrying a 1,000 lb (450 kg) payload. Successful

What's in a Name?

Autogiro: the original term, trademarked and licensed by Juan de la Cierva, for an aircraft using an autorotating rotor for lift plus one or more propellers for thrust.
autogyro: the general term for an autorotating aircraft, particularly one that was not a licensed Cierva Autogiro. The FAA recognizes the name "gyroplane" instead.
AutoGyro: a German company that produces over 300 gyroplanes annually.
Gyrocopter: this term was trademarked by Igor Bensen and the Bensen Aircraft Corp.
Gyroglider: the Bensen-trademarked name for its towed autorotating gyroplanes.
gyrocraft: a general term that includes gyroplanes or gyrodynes.
gyrodyne: a hybrid rotorcraft that is capable of VTOL and/or hovering, as well as extended forward flight in autorotation (i.e. a powered gyroplane).
gyronautics: a term coined by Skyworks Global for "the science of sustained autorotative flight".
gyroplane: an aircraft that cruises in autorotative flight (aka an "autogyro").
Heliplane: a DARPA program from 2005 to 2009 for a high-speed tip-jet rotor gyrodyne.

The Groen Brothers: the late Jay Groen, standing, and David Groen in the Hawk 1, which first flew in September 1992.

Phase I component and subsystem tests should have put a full-scale rotor system in a wind tunnel for Phase II. However, with Woodbury promoted to head the DARPA Strategic Technology Office and no military customer paying to transition the technology to production, the Heliplane was abandoned. "I'd love to see DOD pick this up and carry it forward," offered Woodbury. "Consider what the gyrodyne has to offer before you lock into another 30, 40 or 50 years of helicopter or tiltrotor limitations."

Leading the collaborative Heliplane effort, Groen Brothers Aviation in Salt Lake City, Utah, stopped gyroplane kit deliveries in 2007, even though it then claimed about half the market. The small, privately owned company it had created, American Autogyro Inc. (AAI), had delivered more than 100 SparrowHawks and about 50 stability modification kits for popular but accident-prone gyroplanes of another manufacturer. Groen Brothers Aviation founder and Skyworks Global senior advisor David Groen noted, "When we stopped the SparrowHawk, there still was significant demand. We get calls even today from people who want to know if SparrowHawk is available." The two-seat, 1,500 lb (680 kg) SparrowHawk III with its 165 hp (120 kW) Subaru gasoline engine has three hours' endurance and cruises at 65 kt (120 km/h). Without collective rotor pitch control, it takes off with a 100 to 500 ft (30 to 150 m) ground roll.

Venture capitalist Steve Stevanovich had invested in disruptive technologies previously and saw value in Groen intellectual property. In December 2012, he led an acquisition of Groen Brothers Aviation by forming a new private company which acquired all of the assets of Groen Brothers Aviation in a transaction worth more than $210M. The Skyworks Global transition was finalized in 2016.

Former US Army helicopter pilot and Vietnam veteran David Groen observed, "One of the things we've struggled with these last 32 years, when we get industry partners lined up ... before they invest, they talk to someone from the helicopter world who they believe would know everything about gyroplanes. The helicopter world has known little to nothing about sustained autorotative flight. One would think otherwise because they do know everything about autorotation in a helicopter, but the helicopter rotor system is not optimized for sustained autorotative flight; not even close." Groen explained, "What we did is come up with a rotor blade formula that makes an optimized design. We designed blades from root to tip where chord, thickness and twist change non-linearly; airfoils change non-linearly."

The Fairey Rotodyne (a legacy Westland demonstrator) first flew in 1957 and set a world speed record: flying at an average of 190.9 mph (307.2 km/h), over a 60-mile (100 km) closed circuit.

Skyworks Global intends to deliver new SparrowHawk III gyroplane kits this year sold through subsidiary American Autogyro International. The SparrowHawk law enforcement demonstrator was used briefly for drug interdiction on the Arizona border.

Spinning Up Again

By Groen's count, 36 different companies today make light gyroplanes — delivered in some countries as factory-built aircraft and in others as homebuilt kits, depending on local regulations. German manufacturer AutoGyro GmbH notably sells around 300 factory-assembled aircraft per year. Most gyrocraft are flown by recreational flyers. However, AutoGyro has found customers in law enforcement, cinematography and coastal patrol who use gyroplanes as cost-saving alternatives to helicopters.

With pusher propellers and cyclic-controlled teetering rotors, gyroplanes cannot hover like helicopters, but they can take off and land with an extremely short runway roll. In forward flight, air flows up through the blades to autorotate the rotor and generate lift. Near-vertical landings need little or no runway, and the freewheeling rotor works like an aerodynamic parachute if the engine should fail.

The autorotating rotor also eliminates heavy, expensive, complicated helicopter parts and cuts operating and support costs. "It's only providing lift, not propulsion," summarized Don Woodbury. He added, "With a helicopter, because you're spinning the rotor with a transmission, anti-torque mechanisms consume a lot of power. In a helicopter, you're losing [as much as] 20 to 30% of your power to counter torque."

The payoff in a helicopter is vertical takeoff and sustained hover. However, pre-rotating the gyroplane rotor with a dedicated motor or simplified power transfer from the thruster engine can shorten takeoff run dramatically or provide vertical "jump" takeoff in gyrocraft with a collective pitch control rotor. (Groen has evaluated flexible shaft, hydraulic and electric schemes to pre-spin the rotor.) Slow-turning gyrocopter rotors are also more efficient than helicopter rotors in cruising flight. According to Woodbury, drag rises proportional to the square of rotor speed, and the rotor on the gyroplane typically turns only two-thirds as fast as that on a helicopter.

For sport flyers, the gyroplane is a stable, simple, less-costly aircraft suitable for homebuilders, one that found increasing popularity starting with Bensen kit gyrocopters in the 1950s, with thousands of sets of plans sold over the next thirty years. The booming sport gyroplane community in the 1980s nevertheless suffered a high accident rate, much of it attributed to poor design. According to Dave Groen, "There actually was very little true understanding of the science behind sustained autorotative flight."

Groen Brothers Aviation flew its first single-seat, open-cockpit gyroplane in 1986, followed by a monocoque Hawk 1 in September 1992, and then developed a portfolio of gyroplane design tools and test instrumentation for successive products with an eye to US FAR Part 27 and 29 type certifications. Analyses showed the worst design errors in accident-prone gyrocraft of other manufacturers were in the misplacement of rotor and propeller thrust vectors as related to aircraft center of gravity. Groen designed the hands-off stable SparrowHawk to fix the safety issues of kit gyroplanes.

While training on Army helicopters, David Groen also recognized the potential value of helicopter-like collective pitch main rotors for gyroplanes. Emergency autorotation

Hawk 5 Design Characteristics

Physical Characteristics	
Seats	1 pilot plus 4 passengers
Max gross takeoff weight	3,800 lb
Empty weight	1,975 lb
Max fuel capacity	102 US Gal
Useful load	1,825 lb
RR 250-C20S Turboprop	420 shp
Rotor type	Two-bladed semi-rigid
Rotor diameter	42 ft
Speed	
Design max cruise speed at MCP	140 kt
Best Range	85 kt
Max speed	159 kt
Range	
Normal fuel capacity	866 nm
MCP	577 nm
Endurance	
Normal fuel capacity	5 hr

The Hawk 4 flew in support of the Salt Lake City Olympics in 2002. Skyworks Global plans to productionize the Hawk 4 gyroplane with improvements for the international market.

Skyworks Global's GyroLiner design could offload crowded airport runways and airspace with vertical takeoff departures and landing approaches. Like the Fairey Rotodyne, the tipjet-driven gyrodyne would transition to wing-borne lift to reach cruise flights above 200 kt (370 km/h).

Groen's optionally piloted ScoutHawk, still in development, is aimed at overseas sales.

Concepts for Skyworks Global's gyroplanes are sized to carry four to six passengers and are tailored to markets without aviation infrastructure.

performance improved dramatically by being able to change collective pitch during descent. Collective pitch control could enhance gyroplane safety, especially in less-than-1G maneuvers. Collective pitch also enables gyroplanes to spin-up on the ground at flat pitch, store energy in the rotor, and take off vertically with rapid collective input as the aircraft accelerates. In addition, it provides a means to optimize rotor speed for greater cruise efficiency. The stable SparrowHawk III entered production without collective control for business reasons. However, collective pitch control will be introduced on the SparrowHawk IV and offered as an improvement kit for the earlier aircraft.

Skyworks Global plans to return the SparrowHawk III to market this July via subsidiary American Autogyro International. The SparrowHawk III is a kit design that already satisfies the FAA "51% rule" for homebuilder assembly, with a completion time around 300 hours or less. The follow-on SparrowHawk IV will integrate a collective pitch-controlled rotor. Final configuration of the SparrowHawk IV is to be determined, but Skyworks Global is ready to pursue an FAA letter covering the addition of vertical takeoff to the kit gyroplane within the 51% requirement.

Re-introduction of the kit gyroplane starts a broader effort to commercialize/productionize Skyworks Global aircraft for developing global markets. Michel served as the Commanding General, NATO Air Training Command Afghanistan and set up a new Afghan Air Force with Russian Mi-24, Mi-17 and American MD 520 helicopters operating alongside fixed-wing assets. He observed, "Helicopters are amazing, but they're expensive as hell." Michel added, "What I did was recognize we're not doing a very good job of making aviation sustainable. Two-thirds of the world has no sustainable aviation technology."

Groen's efforts to productionize the 3,500 lb (1,588 kg) Hawk 4 gyroplane — first with a Continental TSIO-550 air-cooled flat-six piston engine and then with the Rolls-Royce RR250-B17C turboshaft engine as the Hawk 4T — were stalled by the DARPA Heliplane investment. Skyworks Global now plans a five-seat Hawk 5 with turbine power as a runway-agnostic utility aircraft for production in developing nations. A sheet metal body is meant for fabrication in countries without composite manufacturing facilities. Certification efforts with the FAA are expected to begin soon. Skyworks Global is also talking to governments in Africa and the Middle East about local production for transport, patrol and medical evacuation missions. "It's extraordinarily broad what this aircraft can do," said Michel, but he noted that people should "stop comparing us to the helicopter. The gyroplane is an airplane that doesn't need a runway. The market is not to push helicopters out."

With safe speeds down to 25 kt (46 km/h), the gyroplane is a notably effective surveillance platform. "A helicopter costs too much. An airplane can't do the job safely. In much of the developing world, they don't have the infrastructure." Hawk 5 production would start in the US and migrate to a European partner before it transitioned to developing market regions. Target price of the turboprop Hawk 5 is under $1M.

In November 2001, *Time* magazine listed Groen Brothers Aviation's Hawk Gyroplane as one of its featured "Inventions of the Year." During the 2002 Winter Olympics and Paralympics in Salt Lake City, Utah (only a few months after the US terrorist attacks of Sept. 11, 2001), Groen flew its Hawk 4 in support of the Utah Olympic Public Safety Command for aerial observation to provide additional perimeter patrol security for Salt Lake International Airport and surrounding areas. The gyroplane completed 67 missions over 75 hours of flying time during the 90-day contract, without any required maintenance.

Skyworks Global recently demonstrated a SparrowHawk gyroplane for US Customs and Border Protection in Atlanta and has been in talks with other government users on SparrowHawk demonstrations. Concepts of operations include manned, unmanned and optionally-manned gyroplanes. Meanwhile, the optionally manned "ScoutHawk" still in development is aimed at overseas sales on a case-by-case basis given existing State Department guidance on exporting UAS-capable technologies.

Skyworks Global also signed an agreement with Switch Mobility service to consider gyroplanes as one element of a "comprehensive multimodal Mobility as a Service (MaaS) application." Gyroplane energy demands are less than those of helicopters or tiltrotors. Skyworks is meeting with potential international partners on an all-electric Hawk 6. The company is also talking with Argonne National Laboratory about a study of gyroplanes with hybrid-electric propulsion including regenerative power technology. According to Michel, "Once we identify a salient market, we go."

Heliplanes and Gyrodynes

DARPA's Heliplane was a compound gyrodyne with a tip-jet rotor and fixed wing. Groen planned to marry an Adam Aircraft A700 business jet fuselage with a new-technology tip-jet rotor. "For the Heliplane, it was all about speed and efficiency," observed Woodbury. "We put a line on the ground at DARPA: We're going to more than double the performance of what others can do and demonstrate the reduced complexity that will translate into reduced development costs, operating and support costs."

Groen led a respected team including Georgia Tech and small jet engine maker Williams International. The compound gyrodyne was to take off and land vertically with its reaction rotor and rapidly transition lift from the rotor to the fixed wing and propulsion from the rotor to the turbofan engines. The fixed wing would have provided 90% of cruise lift at 350 kt (650 km/h). Woodbury said, "It was both the performance and the potential for cost reduction that had me excited about the Heliplane at DARPA. It's unfortunate that as we improve VTOL systems, we do it with increasing complexity and cost, with a significant reduction in sustainability."

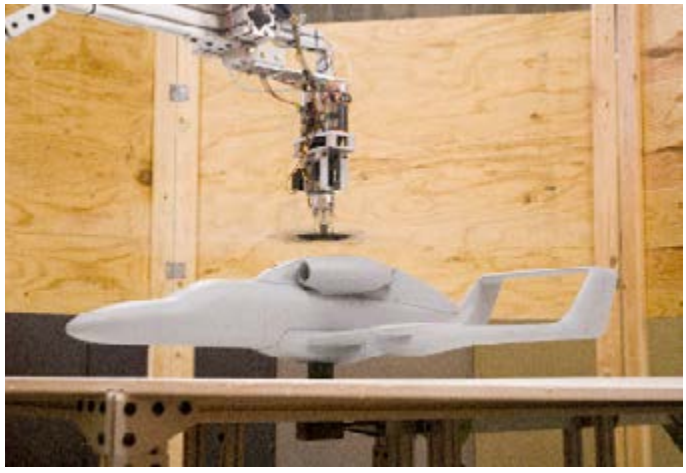
The Heliplane program advanced technologies from previous experimental VTOL platforms. Woodbury explained, "As you transferred lift from the rotor to the wing, you had the opportunity to slow the rotor. ...That would happen through the use of collective pitch control. ... It could be gradual; it could be step-wise. I don't know that there's a need to be constantly fine-tuning rotor speed."

Tip jets worked with limited success on the Austrian Doblhoff WNF 342 in 1943 (see page 3) and, a decade later, on the huge Hughes XH-17 and the little Sud-Ouest S.O.1221 Djinn (the only reaction rotor design to go into production). All were tip-jet helicopters, not gyrodynes. The commuter airliner-sized Fairey Rotodyne flew successfully with tip jets in 1957. "What they accomplished in the late '50s was truly impressive," acknowledged Woodbury. "It flew faster and farther than any helicopter. ...Imagine just modernizing that aircraft with modern materials, flight controls and propulsion."

Heliplane engineers collected extensive background research on the Rotodyne, including plans for tip-jet noise reduction. "The Heliplane had a very simple ejector design to reduce noise when the tip jets were operating," said Woodbury. "We'd take cold air flow from engine, duct it up to the tip, and burn fuel there." Williams International demonstrated full-scale Heliplane tip jets and ejectors on a ground rig. "You're adding some additional complexity because you're ducting air and fuel to the tip and adding an igniter," Woodbury acknowledged. "The technology is tried and true, but there is added complexity associated with that."

Cancellation of the Rotodyne in 1962 has been blamed in part on tip-jet noise that precluded operations from urban vertiports.

The conceptual ArrowHawk 6 gyroplane can be sized for six to nine seats in single-engine configuration and 10 to 16 seats in multi-engine form, depending upon market demand.



Groen built a sub-scale Heliplane model to measure airframe downloads.

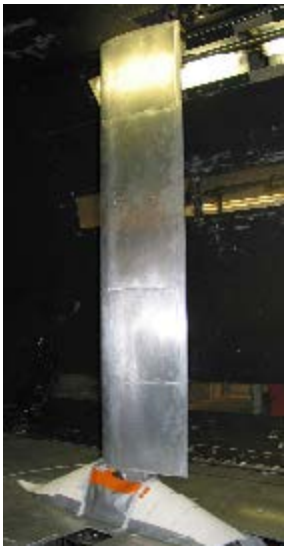
According to a BBC story, UK government monitors claimed noise levels within 500 ft (150 m) of takeoff or landing were "intolerable." By the time the program had been canceled, however, tip jets with significantly reduced noise had been designed.

DARPA included reduced noise as a Heliplane goal. "I think that was my biggest mistake," observed Woodbury. "Everything is a tradeoff. In flight or cruise, a gyrodyne is much quieter than a helicopter. ... In a multi-hour flight, the tip jets might burn for a couple of minutes." A Heliplane could also perform silent autorotative landings with the tip jets off. "I think the whole noise issue is a red herring."

As part of the DARPA preliminary design phase, the Groen team built full- and sub-scale rotor system components and characterized their performance. Full-scale hardware included a rotor blade structural test article to measure loads, a tip-jet nozzle to gauge propulsive efficiency and noise, and reaction drive ductwork from turbofans to blade tips to characterize pressure losses. A sub-scale aircraft model, rotor pylon model and blade section were tested in the Glenn L. Martin wind tunnel at the University of Maryland. According to Woodbury, "This testing was done in part to collect data that we used to validate models that were being used in regions where there was little prior data. And we did it in part to front-load the identification and reduction of key risks associated with a gyrodyne rotor system."

Heliplane researchers also tested a full-size blade tip model.

Skyworks Global/Groen Brothers Aviation has drawn plans for ArrowHawk gyroplanes big enough for 6 to 16 passengers; each could also be designed in gyrodyne form. Company analyses indicate autorotative flight aircraft up to 150,000 lb (68,000 kg) gross weight are possible; larger aircraft have not been studied so far, but even its ultra-heavy "GyroLifters" promise the hover and VTOL capability of smaller gyrodynes. Analyses also conclude — because bigger GyroLifters would need more blades, longer blades and more tip jets — thrust per pound of aircraft per blade tip would decrease as aircraft size increases. Tip jets are admittedly less fuel-efficient than helicopter drivetrains, but would be used only for hover and VTOL operations.



Skyworks Global is seeking a public-private partnership to design and build a gyrodyne X-Plane demonstrator with federal and commercial funds. Woodbury concluded, "It's an aircraft configuration that isn't new and isn't unproven. The community needs to explore the gyrodyne configuration and see what it can do."

Full-sized Heliplane test hardware included a rotor blade aerodynamic test article.

About the Author

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