The overall success of 72-year-old Moog, Inc. and its various divisions can be explained in one word: adaptability. Unlike some companies, which cling to legacy products and outdated processes, this developer of precision control components and systems for aerospace and other sectors knows how to read the tea leaves.

The East Aurora, New York, multi-national company has followed the adaptability script since Bill and Art Moog and fellow engineer Lew Geyer formed the valve-making company in 1951 on a shoestring budget “in the corner of a dirt-floored airplane hangar.”

Initial sales to Bendix Aviation, Inc. were followed by larger orders by Boeing and Convair (later incorporated in General Dynamics). Rapid growth occurred over the next 20 years and by the mid-1960s, subsidiaries were formed in Asia and Europe. By the mid-1990s, the company had expanded its flight controls business, becoming a major supplier to the Boeing Commercial Airplane Group and other airplane original equipment manufacturers (OEMs).

Today, the company employs over 13,000 workers in 29 countries and posted $3B in revenue for fiscal year 2022, despite the continuing pressure on the aviation sector due to the COVID-19 pandemic.

By Robert W. Moorman

“Moog owns virtually 100% of the markets they compete in,” said Gordon Pratt, Genesys co-founder. “To grow, they had to

On May 5, 2023, Moog flew its all-electric S250 without a pilot. (Moog)
move out of the dark nooks and crannies of the aircraft and into the cockpit, so they acquired Genesys as a platform upon which to build a world-class avionics business.”

He added, “We chose Moog from among the various bidders because we believed they offered the best cultural fit. That has been our experience over the last two-and-a-half years under Moog.”

In 2012, Bell Helicopter chose Moog as the primary flight control actuation supplier on its 525 Relentless, including the company’s fly-by-wire flight control actuators and triplex-redundant main swashplate and tail-rotor servoactuators. The following year, Bell selected Moog to design, manufacture and qualify an integrated flight control system — consisting of flight control computers, support software and flight control actuation — for its V-280 Valor.

These rotorcraft represent the latest chapter in a 50-year heritage of designing and manufacturing rotorcraft flight control, vibration control and utility actuation products. Notable rotorcraft include the Airbus SA330, AS332 and BK117, Bell Boeing V-22, Boeing AH-64 and CH-47, Leonardo AW101, AW159, AW129 and AW609, and Sikorsky S-61, S-76, CH-53, UH-60, RAH-66 and S-92A.

**eVTOL Developments**

In December 2019, Moog purchased the assets associated with the SureFly electric vertical takeoff and landing (eVTOL) aircraft from its parent company, Workhorse Group, Inc. This followed its 2013 acquisition of Aspen Motion Technologies, a manufacturer of permanent magnet brushless DC motors, integrated digital controls and motorized impellers for electric motors.

Industry analysts have followed Moog’s growth for years.

“We like Moog because they are diversifying into other areas, especially when developing dual-use products, applying commercial technology to military use,” said Sergio Cecutta, founder and partner of SMG Consulting, an aerospace, defense and automotive management consulting firm. “They take advantage of anything that makes sense for their business.”

Moog’s $5M purchase of Workhorse’s SureFly, Inc., subsidiary gave the company greater access to the evolving eVTOL sector. The acquisition included the battery-powered, two-seat prototype of the planned hybrid-electric SureFly S250 quadcopter aircraft (N834LW) which made its first piloted untethered flight in April 2018, at the Cincinnati Municipal Lunken Airport in Cincinnati, Ohio (see [www.eVTOL.news](http://www.eVTOL.news) for more information on the aircraft and its history).

For the past three-and-a-half years, Moog has matured the SureFly S250 subsystems, expanding the flight test envelope and incorporating beyond visual line-of-sight control, which culminated in recent uncrewed testing. The company website notes that Moog’s work increased the endurance from 45 seconds and a calculated failure rate of 1 in 100 in the original SureFly to a 10-minute endurance and a failure rate of 1 in 100,000 with the S250.

In the summer of 2022, researchers from NASA’s Glenn Research Center in Cleveland traveled to Cincinnati Municipal Airport, where they acquired noise data as the piloted Moog SureFly vehicle hovered over an array of 28 ground-level microphones. Glenn researchers will analyze and share the data with Moog.

On May 5, 2023, Moog flew a series of unmanned flights of the S250 over Springfield, Ohio. These flights provided partial fulfillment of Moog’s contract with the US Air Force’s Agility Prime program. Launched in April 2020, Agility Prime’s objective is the development of solutions through partnerships with private sector industry, including the advancement of the eVTOL industry (see “Agile Change in Air Force ‘Agility Prime’ Launch Pays Off,” [Vertiflite](https://www.vertiflite.com), July/Aug 2020).

Moog is now developing a hybrid-electric autonomous resupply version for the US military, the HE350 Recluse uncrewed aircraft system (UAS). A civil version of the Recluse (named for the spider) could be used for wildfire suppression, humanitarian relief, emergency infiltration and exfiltration of personnel and agricultural spraying. Moog has also held meetings with Spright — the UAS medical transport arm of Air Methods — about using the HE350 to transport human organs.
“We’re going to take all the lessons learned from that flying prototype and build it into the Recluse for next year,” said Stoelting.

To get around the short flight duration of the S250, Moog engineers are modifying subsystems and redesigning the HE350 to accommodate a powerplant that will generate 350 kW to power the aircraft’s eight individual electric motors and vertically mounted propellers (often referred to in the drone community as “rotors”).

“We project a ten-fold increase in mission duration with the incorporation of our hybrid-electric architecture, allowing for much longer missions to be accomplished,” said Michael Brunner, Moog’s director of UAS.

The flight experience gained will better position Moog “to bring the transformational re-supply capability of the HE350 to the Army and Marine Corps, while keeping the warfighter in a sequestered position,” added Brunner.

The HE350 powerplant will be a turbine-generator that will power the electric motors. The aircraft could run on traditional aviation fuel (Jet-A) or sustainable aircraft fuel (SAF).

“Nothing in the market today is like the HE350,” said Brunner. “The size, power generation [and] multi-mission re-configurability make it capable of executing missions at lower altitudes — with relatively quiet [propellers] — in areas where larger, wing borne aircraft can’t travel.”

Moog is testing the critical technology application of hybrid-engine and multi-propeller integration at its “iron bird” test facility in Cincinnati, Ohio.

For the Army, Moog hopes to offer the HE350 for the US Army’s Joint Tactical Autonomous Aerial Resupply System (JTAARS) program. Moog also wants to be part of the Marine Corps Family of Systems (FoS) program. The Air Force is interested in the HE350, but is on a “different timeline,” according to the company.

Inaugural flight of the prototype HE350 (Air Vehicle 1) is tentatively scheduled for the first quarter of 2024.

Neither the Army nor Navy has issued a formal request for proposal (RFP) for autonomous aerial resupply aircraft for a Group 4 UAS — any vehicle with a gross weight of 1,320 lb (600 kg) or greater — the category in which the Recluse fits. Nevertheless, “we’re trying to stay abreast of where the services are going with their requirements development,” said Stoelting.

The carbon fiber HE350 production vehicle will have an empty weight of 1,380 lb (625 kg) and a maximum takeoff weight of 2,500 lb (1,135 kg), including fuel and a 500-lb (227-kg) payload.

The Recluse can be reconfigured from a gunship to a resupply vehicle and can be easily air transported. Fourteen HE350s, each sitting on a 463L pallet, can fit inside a Boeing C-17 Globemaster III transport aircraft.

When not flying missions, the HE350 can provide emergency ground power for deployed troops, or in humanitarian aid for homes, operating rooms, water pumps and refrigerators.
Moog also has bigger plans for the UAS sector. The company is in the early stages of designing a heavy-lift autonomous UAS, dubbed the HE1K, capable of carrying a 1,000-lb (455-kg) payload. Both the HE1K and the HE350 will use turbine powerplants to generate electricity to power the electric motors. The architecture of the multi-propeller of the HE350 is transferable to the next vehicle.

“When the timing is appropriate, we will continue to expand our product family,” said Brunner, referring to the HE1K.

Smaller cargo UAS are gaining ground with the military. In April 2023, Maryland-based Survise Engineering Co. was awarded an $8.4M contract to manufacturer and deliver 21 TRV-150C Tactical Resupply Unmanned Aircraft Systems (TRUAS) drones. This is the US military’s first production order for a cargo UAS, with a potential of up to 180 TRV-150C systems, each of which can carry 150-lb (68-kg) of payload.

While unrelated to Moog’s efforts, the Navy’s award announcement signals the US military’s desire for nimble, cost-effective multi-purpose UAS that won’t put the pilot in harm’s way.

**Rotorcraft Advancements**

Among Moog’s other aircraft-related endeavors has been the work of its Growth and Innovation Team to develop safer and smarter systems that alleviate helicopter pilot fatigue and increase situational awareness.

In 2019, the company started to develop an advanced autopilot system for a Robinson R44 before it acquired Genesys. This system initially used a mechanical system (like a robot), named Lucy, that used actuators to move the pilot’s collective, cyclic and pedals. In 2021, Moog researchers successfully conducted fully automated flight tests at Union County Airport in Marysville, Ohio, with a safety pilot. The team later conducted a kidney transport demonstration.

The actuators were the same ones used on the Genesys Helicopter Stability Augmentation System (HeliSAS) autopilot, and collaboration between the teams increased after Moog bought Genesys in December 2020.

Moog displayed a mockup of the HE350 Recluse in gunship configuration at the Quad-A Mission Summit this past April. (Moog)

“Currently, we are only flying an R44 in a fully automated fashion,” said Aric Schorr, business unit engineering manager at Moog, Inc. "We do have plans to fly other aircraft autonomously, but can’t say which at this point.”

Moog’s website boldly states, “We are the market leader in providing innovative flight control and utility actuation solutions to the aerospace industry. We have been designing and manufacturing helicopter flight control, vibration control and utility actuation products for more than 50 years.”

In 2015, Metro Aviation became the launch customer for the Airbus EC145e, which has a 330-lb (150-kg) lower empty weight than the company’s current Fenestron-equipped H145. Metro worked with Genesys Aerosystems to develop an instrument flight rules (IFR) version with a two-axis HeliSAS system, providing functions for pitch and roll; this was later followed by a second-generation three-axis system that included functions for yaw.

The Genesys avionics suite for the EC145e also features four IDU-450 displays in a dual-sided primary flight display (PFD)/multifunction display (MFD) format, dual redundant air data/attitude/heading reference system (ADAHRS) and a dual GPS/Flight Management System (FMS).

Moog is currently working on the technical standard order (TSO) and supplemental type certificate (STC) for the GRC 4000 four-axis autopilot — part of the company’s Genesys Rotorcraft Controls (GRC) products — for the EC145e and the UH-60 Black Hawk. The GRC 4000 is flying already in Genesys’s UH-60A and OH-58A demonstrators in Mineral Springs.

The GRC 4000 four-axis autopilot, the follow-on to the Genesys Aerosystems HeliSAS autopilot, adds the fourth axis “hover and hold” functionality, plus collective control. The next-generation autopilot provides the pilot with “single-button access to put helicopter into a stable fixed-position hover and...
hold orientation, allowing the pilot to focus on other tasks.” It also has a decelerate-to-hover feature.

Certification and issuance of the STC is expected by late 2023, according to Moog.

Moog also provides various flight controls for the Black Hawk, including the pitch trim actuator, roll trim actuator and hydraulic accumulator, as well as the company’s vibration control actuation system.

Moog’s avionics offerings also include the Genesys digital radio for both fixed-wing aircraft and helicopters, as well as fixed-wing autopilot systems. These include the S-TEC autopilot for Part 23 and Part 25 aircraft, the S-TEC 5000 Digital Autopilot, System 55X autopilot and S-TEC 3100 Digital Flight Control System.

Moog said it has STCs on 1,000 airframes and shipped more than 40,000 autopilots for commercial, military and government aircraft worldwide.

In February 2023, Genesys announced it had completed certification of its Genesys Avionics Suite for the Hindustan 228-201 LW, an Indian variant of the 19-seat Dornier 228.

That month, the Indonesian Navy also took delivery of the first Genesys avionics suite-equipped CASA/PTDI CN-235, a high-wing twin turboprop, to be used for maritime patrol and other missions. The avionics suite includes electronic flight instrument system (EFIS) flight displays with embedded Flight Management System (FMS) and Class-A Terrain Avoidance and Warning System (TAWS), dual ADAHRS, dual GPS/Satellite Based Augmentation System (SBAS) receivers, Genesys Digital Radio (GDR) with integrated VHF/UHF software-defined digital radios, and an S-TEC digital autopilot.

In March 2023, Airbus Helicopters announced it would partner with Genesys to develop IFR capabilities for the versatile single-engine H125. The Genesys Helicopter Suite will allow Airbus H125 operators to fly in all weather conditions. This would make the H125 only the third modern IFR-certified single-engine helicopter in the US, after the Leonardo TH-119 and Bell 407GXi.

**Multi-Faceted Company**

To describe Moog as a large, first-tier vendor to commercial and military OEMs of fixed-wing and rotorcraft would be accurate, if incomplete.

The company’s flight, engine and vibration controls — plus hydraulic, mechanical and electromechanical actuators and flight control computers — are on numerous commercial and business aircraft, including the Boeing 737, 777, 787, 767, 757 and MD-11; Airbus A320, A330, A350 and A380; Bombardier Q400 and various models of the Challenger and Global Express; Gulfstream G500/G550/G600/G650/G700; and Cessna Citation X business jets.

Moog provides fly-by-wire control systems for the Embraer E2 jets, including the E175-E2, E190-E2 and the E195-E2. The package includes flight control computers, hydraulic actuators of primary surfaces, spoilers and ground spoilers.

Military aircraft on which Moog’s products are integrated include the Boeing F/A-18, F-22 Raptor, Rockwell B-1B bomber, Eurofighter Typhoon, Lockheed Martin F-35 fighter, and other transport and combat aircraft, in addition to the military rotorcraft mentioned above.

At present, Moog’s business is 43% military and 28% commercial aircraft OEM, plus 16% military aircraft aftermarket and 13% commercial aircraft aftermarket.

The company has six facilities in the Americas, five in Europe, and three in the Asia/Pacific region.

Noteworthy, too, is Moog’s missile and space business. The company provided components for the Space Shuttle orbiter and control systems for the US strategic ballistic missiles, including the Trident and Peacekeeper.

Moog’s hydraulic servo-valves are part of the Patriot missile defense system. Its thrust vector control (TVC) system is on the Titan IV launch vehicle, and the French heavy-lift launch
Moog’s quadcopter eVTOL aircraft. The Workhorse SureFly was originally intended to be a hybrid-electric aircraft, but could only get off the ground for a few seconds on batteries.

<table>
<thead>
<tr>
<th>Envisioned SureFly</th>
<th>HE350</th>
<th>HE1K</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Empty Weight</strong></td>
<td>1,100 lb (400 kg)</td>
<td>1,380 lb (625 kg)</td>
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<tr>
<td><strong>Gross Weight</strong></td>
<td>1,500 lb (680 kg)</td>
<td>2,500 lb (1,135 kg)</td>
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<td>jet fuel/SAF</td>
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<td><strong>Fuel Capacity</strong></td>
<td>13 gal (49 liters)</td>
<td>20 gal (75 liters)</td>
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<tr>
<td><strong>Payload</strong></td>
<td>400 lb (180 kg)</td>
<td>500 lb (227 kg)</td>
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<tr>
<td><strong>Cruise Speed</strong></td>
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<tr>
<td><strong>Max Speed</strong></td>
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<td>112 kt (207 km/h)</td>
</tr>
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<td><strong>Endurance</strong></td>
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<td>133 min</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>60 nm (112 km)</td>
<td>127 nm (235 km)</td>
</tr>
</tbody>
</table>

In May 2021, Moog demonstrated the potential to deliver transplant organs via an autonomous helicopter. (Moog)