# HOVERBUGGY

by Dick Henke

All photos by Merv Bristol except as noted.

**HISTORICAL BACKGROUND**—About 40 years ago, aircraft engines became available which had sufficient power to make vertical takeoff and landings (VTOL) possible in non-helicopter (fixed-wing) type aircraft. This set off a frenzy of activity in company- and government-funded projects. One of the first of these to reach flight status was the USN/General Dynamics XFY-1 "Pogo" which was first flown, tethered, on June 2, 1954. The "Pogo" was a tail-sitting, turboprop-powered aircraft, which could transition into normal wingborne flight and then back to a vertical mode for landing. James "Skeets" Coleman demonstrated a full transition in the "Pogo" from Brown Field in San Diego, California, on November 2, 1954.

The VTOL research studies were something like letting an aerodynamic genie out of the bottle. These studies produced VTOL aircraft of almost every imaginative type: Jet tail sitters (with and without wings), jets with deflected exhaust (with and without wings), jets with articulating engines and wings, jets with articulating engines and fixed wings, ducted fans (with and without wings), articulating ducted fans with fixed wings, winged aircraft with both lift and propulsion engines, etc. The majority of these types of research aircraft were built in the United States, with almost every aircraft manufacturer building at least one of a type. France, England, Germany and Russia also produced VTOLs.

These early VTOL aircraft had low thrust-to-weight ratios, were quite unstable, and stability augmentation systems, even if installed, were quite primitive. It took some of the world's finest and bravest pilots to fly these early craft and unfortunately a number lost their lives in the attempt. Probably the most famous VTOL aircraft was the Lunar Excursion Module (LEM) built by Grumman. Neil Armstrong successfully landed the LEM, nicknamed "The Eagle," on the moon on July 20, 1969. Of all the VTOLs built, only two ever entered operational service. The first was the vectored-thrust British P. 1127 *Kestral,* built by Hawker Siddeley which entered service as the *Harrier* and evolving into the McDonnell Douglas AV-8B models. The second was the Russian

**Van Sheppard, North American's original Project Pilot on the *Hoverbuggy*, demonstrates the maneuverability of the vertical takeoff and landing (VTOL) aircraft. Note the LAX control tower and Theme Building in the background. (Photo from the Al West Collection)**

**Al West (L), Test Director, and Dean Melton, 2nd *Hoverbuggy* Project Pilot, in a preflight discussion. This photo was taken after a number of modifications had been made, including a simulated windshield bow supporting the airspeed sensor (actually the fan blades from an old refrigerator driving a small DC generator). At this time the rollover structure to protect the pilot had been expanded and fabric added to simulate the pilot's vision from a VTOL cockpit.**

Yakovlev Yak-36, given the NATO code name *of Forger*. The Yak-36 used a combination of lift and propulsion engines.

**Program Outline**—This story is about one of the more successful research types—a company-funded research and development VTOL project, produced by North American Aviation (NAA), now Rockwell International. The program was given the unimaginative name of *Flight Simulator No. 1* (FS-1)[1] The reason that North American undertook this project was that its management saw a future in VTOL aircraft and wanted to gain the design and flight experience necessary to be competitive in the field. An additional aspect of the FS-1 was to gain flight data that could be fed into NAA's ground-based flight simulator, for future in-house studies and contract efforts.

The approach to produce the FS-1 was unique in that the design and fabrication employed resulted in a craft that was built in a short period of time and at a low cost rarely experienced in aerospace. Yet its "erector-set" construction had the built-in flexibility required as a research vehicle, never intended for production.

**Program Startup**—North American Aviation President, Warren Swanson, approved the funding of the FS-1 in March 1965 under Dr. W.R. Laidlaw, Vice President of Research and Engineering. A budget of $180,000 was provided to carry the program through its first flight. NAA test pilot, Van Sheppard, was chosen as the FS-1 *Hoverbuggy* Project Pilot with Engineering's Bill Barker as Project Engineer, also in charge of purchasing. Barker chose Merv Bristol as his assistant and it was Bristol that coined the aircraft's nickname, Hoverbuggy. Barker knew that the $180,000 budget could never carry the FS-1 *Hoverbuggy* through design, purchasing, manufacturing, testing and through first flight unless extraordinary steps were taken. One of the simpler steps was that engineers were not assigned to the FS-1 program full-time, but on an "as-required" basis. The same technique was used for the testing laboratories and manufacturing. Barker also saw that unusual steps would be required in the area of purchased parts and the choice of manufactured parts. He said, "His purchasing techniques were mostly what the military calls scrounging." Parts and materials were obtained from NAA overstock, surplus and reclamation, storage and test, surplus sales from Edwards and Davis Monthan Air Force Bases and even a few souvenirs from the desks of senior engineers. An idea of the manpower involved in the *Hoverbuggy* is that there were never more than 20 people involved simultaneously during the entire *Hoverbuggy* program, that is except when posing for a "family" portrait. While funds were limited, there was no limit in dedication and imagination of the personnel involved.

**Designing for Economy**—The *Hoverbuggy* was built on an aluminum frame with a cruciform shape, having a box-beam fore and aft member and truss-type lateral members. Even though the lateral members were sometimes referred to as "wings," there were no aerodynamic lifting surfaces on the *Hoverbuggy*. This frame was assembled "erector-set" style, allowing for easy and rapid modifications for either horizontal or vertical mounted engines, one or two pilots, etc., as required to support its research mission. Not only did this design allow for simple "bolt-on" additions, but for maintenance everything was right out in the open for easy access.

The *Hoverbuggy* was supported on a fixed tricycle landing gear, with spherical pads in place of wheels. The *Hoverbuggy's* nose gear was a salvaged main landing gear strut from a Vultee BT-13 *Valiant (Vibrator)* trainer and the main gear was built from surplus tailwheel struts from NAA P-51 *Mustang* fighters. The pilot's seat came from an NAA F-107 fighter mock-up.

Flight was attained purely by the thrust of two used General Electric YJ85-GE-1 turbojet engines borrowed from Edwards Air Force Base, California. These engines had been stored in the open and were full of sand. As there were no spare parts for these "Y" (prototype) engines, overhaul consisted of just cleaning out the sand and firing them up! The engines were vertically mounted, fore and aft, and canted so as to have their thrust centerline go through the vehicle's center of gravity (CG). This provided a stable line of thrust to minimize rotational forces in the event of an engine failure. Likewise it was also important to keep the thrust line as close to vertical as possible to maximize vertical forces. This required that the engine tailpipes be bent and trimmed to effectively mesh their exhausts into a single thrust line. The engine inlets were screened to prevent injestion of foreign objects. The engine fuel shutoff controls were made from off-road vehicle hood latches.

Flight (orientation) control was through the use of contin-

The proximity of the *Hoverbuggy's* flight area to Los Angeles International Airport's Runway 25L is shown in this photo. It was for this reason that the FAA restricted flight of the *Hoverbuggy* to a height of 50 feet.

Dean Melton (L), the *Hoverbuggy's* 2nd Project Pilot, looks over the sonic valves on the tail of the craft with Test Director Al West. Together with those on the nose, these valves controlled the pitch and yaw of the *Hoverbuggy* using 475-degree Fahrenheit bleed-air from the ninth compressor stage of the General Electric YJ85 engines.

*Hoverbuggy* "family" portrait. This photo was taken as part of a PRIDE (Personal Responsibility in Daily Effort) award to the *Hoverbuggy's* personnel by NAA's Vice President of Research and Engineering, Dr. W.R. Laidlaw. Kneeling (L-R): Cliff Maddox, ukn, ukn, Gerry Peugh, Al Pureed, ukn, Al West, Lynn Rubidoux and Bob Phillips. Standing (L-R): Frank Booth, Boris Palarz, ukn, ukn, ukn, ukn, ukn, Bill Graziano, ukn, Bill Holliday, Dr. W.R. Laidlaw, ukn, Frank Peterson, Oberholster, Lauria?, Bill Barker and Merv Bristol. Cockpit (L-R): ukn and Van Sheppard. (NAA Photo)

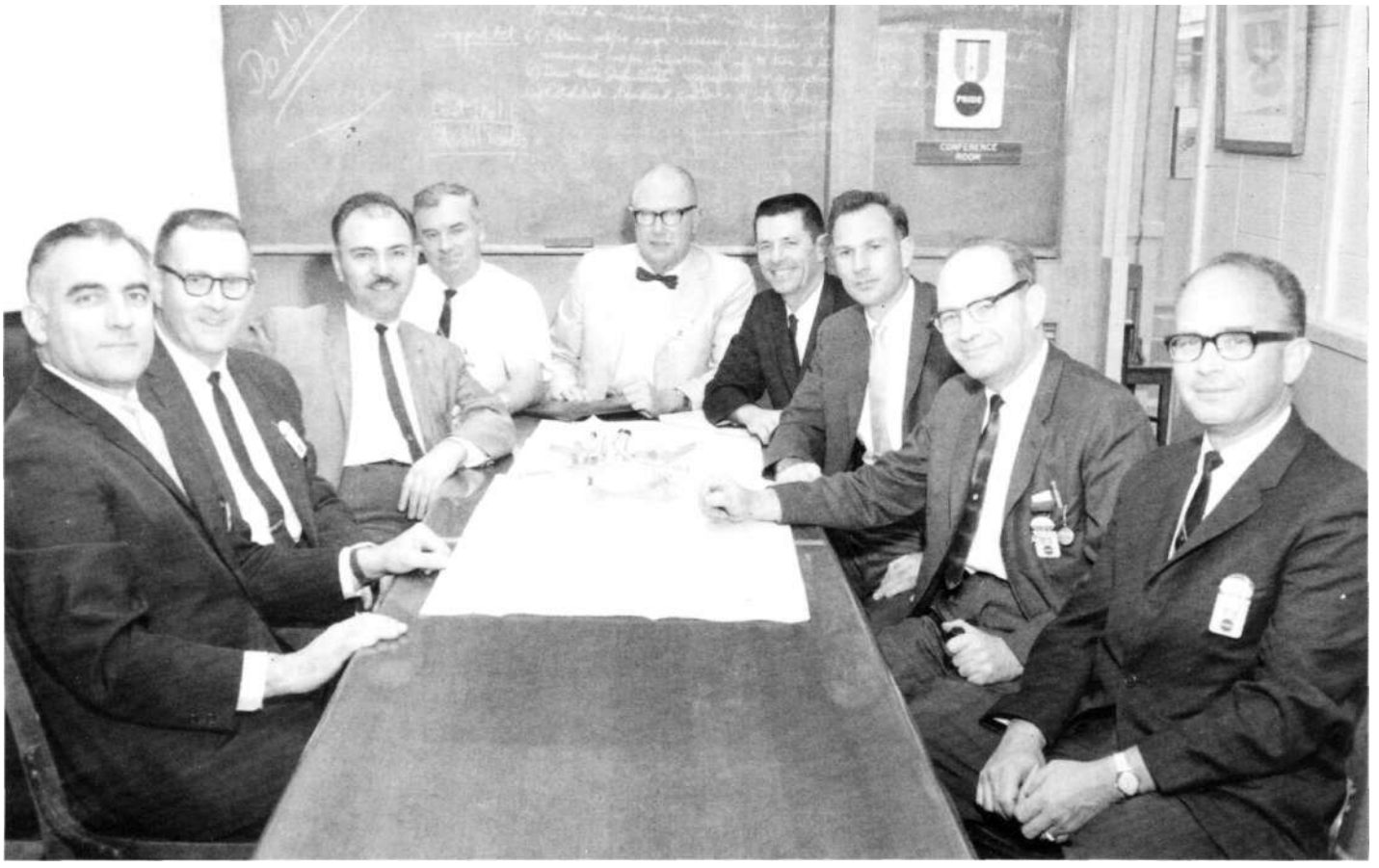
uous flow engine bleed-air nozzles called "sonic valves." All valves were pointing down at the four corners of the cross to also maximize vertical thrust. Each lateral member had only one nozzle, providing right and left roll. Two nozzles were located forward and two aft, pointing 30 degrees laterally, right and left. Both forward nozzles or both aft nozzles operated as a unit to provide pitch control. The right front and left rear nozzles or left front and right rear nozzles provided left and right yaw, respectively. The nozzles were "valved" so that when one was opened, its opposite closed, so that engine bleed-air usage remained effectively constant, minimizing the impact upon engine thrust levels. For manufacturing economy, engine bleed-air was routed to the nozzle valves through ducting formed from high-grade Cadillac exhaust steel tubing, with Corvair exhaust manifold joints and a high-temperature coating all made by a local hotrod shop. The pilot controlled these valves through a set of cables connected to a standard flight control stick and rudder pedal assembly obtained from an NAA F-107 fighter mock-up.

The *Hoverbuggy* was inherently unstable, and so the key to its controllability lay in artificial stabilization through its stability augmentation system (SAS). The SAS was obtained by modifying parts from a Lear F-5 autopilot used on the NAA F-86D *Sabre* interceptor. Some of the parts were cannibalized from F-86Ds stored at Davis-Monthan AFB, Arizona, plus some parts removed from a couple of F-86Ds at Edwards AFB. The Edwards F-86Ds were about to be "shot-up" as part of a missile test by Northrop Aircraft. From these scrounged parts, two usable systems were built for the *Hoverbuggy* (one for operational use and one as a spare). These modified Lear autopilot components were tied into a surplus test computer and gyro package from the NAA XB-70 *Valkyrie* triple-sonic bomber. To minimize mechanical feedback to the pilot due to control-motion interplay, the pilot's mechanical inputs and automatic servo inputs for nozzle controls were differentially summed.

Standard engine instruments were obtained from a Kingman, Arizona scrapyard, as were many other parts. The *Hoverbuggy* had two 45-gallon fuel tanks, purchased surplus from Douglas Aircraft. These two tanks provided a maximum of 10 minutes of flight. As the *Hoverbuggy* had the glide angle of a brick, it was important that the pilot be given a "low-fuel" warning light. A truck taillight was chosen with its standard lamp being replaced by a high-intensity quartz unit. When "fuel remaining" reached 20 seconds of flight, this light was energized. The lamp was so bright that, if ignored, it would melt the plastic taillight lens after about 10 seconds. Looking into that high-intensity lamp could not be ignored.

The *Hoverbuggy* rollout took place in September 1965 with an empty weight of 1,800 pounds. This was followed by several tethered (restrained) flights beginning on November 1, 1965.[2] While prior VTOL aircraft had used ropes or cables for the tethered flight, the *Hoverbuggy* utilized a telescope device under the aircraft that allowed up to 10 feet of vertical flight. This "tether" rig was a big, water-cooled jack, anchored to a heavy, water-cooled steel pad about 15 feet square. On the top end of the jack was a ball joint which could be attached to a ball socket receptacle on the *Hoverbuggy* near its CG. This device was called the "Iron Inspector," since test runs were made on it before free flights. NAA's Al Purcell of Inspection monitored each of these engine runs. Use of the tethered condition was limited to engine tests, thrust validation, plus pilot preflight training.

The original flight area chosen for the *Hoverbuggy* was just north of NAA's Building No. 1, near the threshold of Los Angeles International Airport's (LAX) active runway 25L. The Federal Aviation Authority was quite concerned about these flights being so close to this busy airport. For this reason



they restricted the flights so as not to exceed 50 feet in height (a height which would exceed the 30-foot height set by NAA for safety purposes).

Into Flight—For the first flight, Merv Bristol arranged a series of helium-filled balloons at a height of 30 feet around the flight area. Al West had been chosen to be Flight Director, and as with all of the "tethered" flights, Van Sheppard made the first *Hoverbuggy* free flight on November 20, 1965, taking the ship up to about 30 feet. *Hoverbuggy* flights, with their accompanying "chase" fire trucks, were distracting to commercial pilots on their final approach to 25L, and together with ''unkind" comments from the LAX tower led to a new flight area. This was a fenced-in area adjacent to the west side of NAA's Hangar 7 on Imperial Highway, near Sepulveda Blvd., still on the south side of LAX.

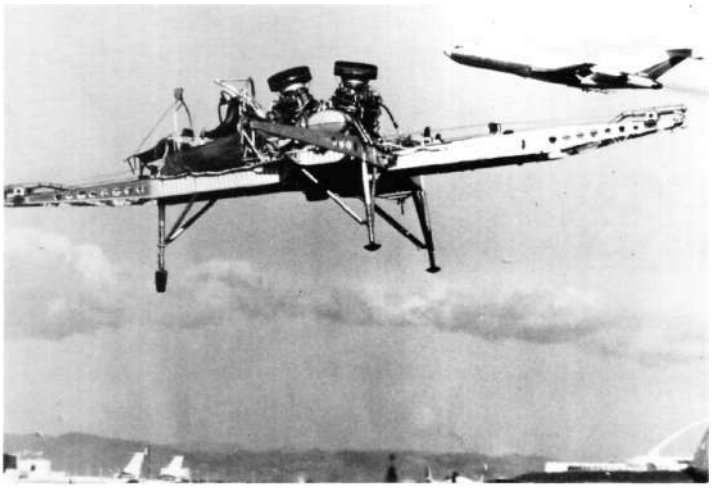
After this, the *Hoverbuggy* flights were so trouble free that by January 1966[3] three more NAA test pilots were checked out to fly the craft. They were Al White, Bob Fero and Dean Melton. Each of these pilots first flew the *Hoverbuggy* in "tethered flight" and then the next day stepped into free flight.

On days when the concrete takeoff and landing areas were wet, *Hoverbuggy* flights proved to be a problem. The hot engine exhaust turned moisture within the concrete into steam, spalling the surface. West was forced into wearing shin guards and a helmet until steel plates could be found and bolted down over the concrete, ending the problem. *Hoverbuggy* flights became real "traffic stoppers" on Imperial Blvd. When the ship would pop up above the fence into view of motorists, they would either slow down or park to see what was going on. One day the gate between the *Hoverbuggy* flight area and Imperial Blvd. was inadvertently left open and the "looky-loos" just drove or walked right in. While West was waiting for security to shoo the people out, he satisfied the questions of the curious by telling them that "They were practicing for the moon landing." That sure got their attention.

By the time the first six months of *Hoverbuggy* flight operations had been completed, it had made 15 "tethered" and 54 free flights. One of its original design features, the "erector-set" approach, proved to work out well. It easily allowed a number of modifications to the *Hoverbuggy* to fine tune the craft to enhance its value in the field of vertical takeoff and lateral structural members ("wings") were extended to improve roll authority and the SAS was modified to provide the pilot with inflight access to alter its sensitivity/ authority. Also to assist the Flight Director working with the pilots, a radio was installed.

About this time NAA was "chasing" a VTOL Variable Stability System contract which included the requirement to determine cockpit instrumentation and visibility requirements for Series VTOL. In this successful pursuit, the *Hoverbuggy* was modified to add a cockpit bow and side curtains to simulate the pilot's view from an operational aircraft.

It was also time to explore the flight envelope at significant speeds in horizontal flight. Where do you find an airspeed indicator to accurately measure a craft with a top speed of maybe 35 mph? A pitot-static system won't work and a very sensitive doppler was out of the financial question and, as was typical with the *Hoverbuggy* program, innovation paved the



**Photographs can be misleading. The *Hoverbuggy's* rate of climb really wouldn't have been any challenge for a time-to-climb race to altitude with this Boeing 727!**

**North American employees point out *Hoverbuggy* features to EAFB stationed pilots that subsequently flew the *Hoverbuggy.* Upper (L-R): Dean Melton, Rockwell's *Hoverbuggy* Project Pilot, ukn EAFB test pilot in cockpit and ukn North American employee on left "wing." Lower (L-R): Al West, *Hoverbuggy* Flight Director, RAF pilot, Sub-Lieutenant Booths and unknown EAFB test pilot. The "Iron Inspector" can be seen just to the right of the hand of this last USAF test pilot. The "Iron Inspector" was a large water-cooled jack with a ball and socket joint attachment to the *Hoverbuggy's* center of gravity between the two engines. This was used for preflight engine runups. More important, the "Iron Inspector" eliminated the cost, time, complexity and danger of tether systems used on prior VTOL projects. With the "Iron Inspector" a pilot could "fly" up to a 10-foot "ceiling," getting the feel of the *Hoverbuggy* in pitch, roll and yaw.**

**Dick Henke, the author, in a decommissioned *Titan* silo in 1990.**

***Hoverbuggy* Conference (L-R): Van Sheppard, Merv Bristol, Boris Palarz, Lynn Rubidoux, Bill Barker, Al West, Bill Holliday, Bob Phillips and ukn. (NAA Photo)**

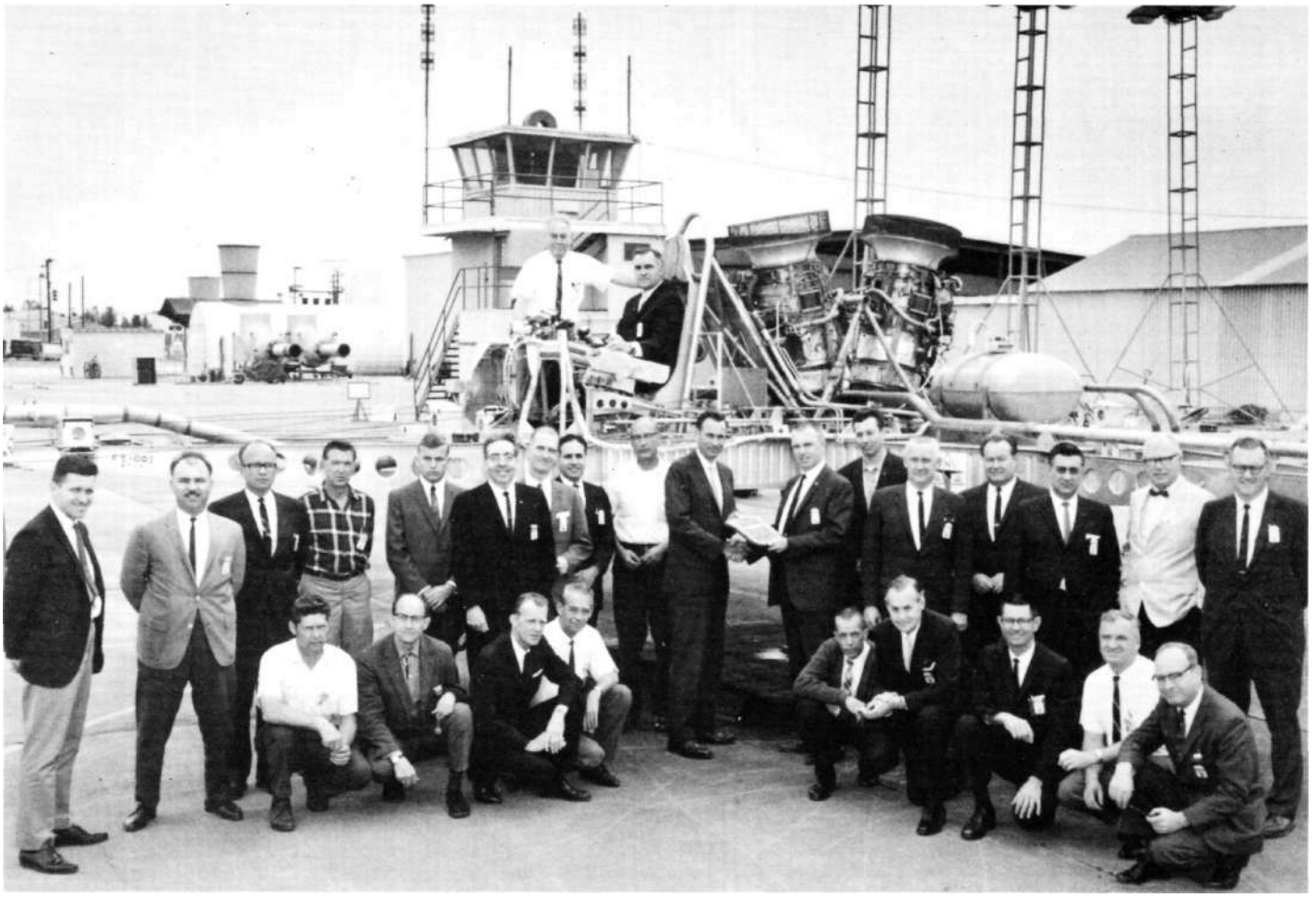
way. A fan was removed from a scrapped refrigerator and its blades attached to a tachometer, shrouded to improve axial air flow. The tachometer electrically fed the receiver in a surplus airspeed indicator, calibrated for 40 knots forward and 10 aft. Another problem inexpensively solved! Later photos of the *Hoverbuggy* show the sensor (fan blade-driven generator) mounted high on the new windshield bow.

With a functioning airspeed indicator, the *Hoverbuggy* was ready for what turned out to be its one and only long-distance flight. The flight was along LAX's southern taxiway between NAA's Hangars 7 and 1, the distance of about a mile. The flight itself went off without hitch, but not so its effect on neighbors. The *Hoverbuggy's* exhaust threw grass clippings from areas adjacent to the taxiway over to active runway 25L. This upset LAX tower personnel and distracted pilots taking off and landing, thus ending the *Hoverbuggy's* long-distance flying days.

By the time the ship was ready for its 55th flight, Dean Melton took over as *Hoverbuggy* Project Pilot. It was about this time that the spherical pad on the ship's nose gear strut was replaced with a wheel. In 1967, the *Hoverbuggy* celebrated its 150th flight with pilot Dean Melton at the controls.[5] The original engines, borrowed from the Air Force, had been returned and the purpose of this flight was to evaluate the newly installed General Electric YJ85-GE-5 turbojet engines, also used and borrowed, this time from a museum. As payment for the loan, NAA donated a truck to the museum. These engines provided a higher performance level than the originals. Besides engine evaluation and familiarization, Melton also flew the testbed in a continuation of the *Hoverbuggy* flight control system evaluation program. The operating site was changed at about this time to a larger area west of NAA's Hangar 9 (west of Sepulveda Blvd. but still on the south side of LAX).

At its 150th flight, the *Hoverbuggy* had 19 hours and 31 minutes of air time and many of its research goals had been attained. A large data base had been established for NAA's ground-base flight simulator plus handling qualities, damping, control sensitivity, response, power requirements and nozzle configurations had all been studied and essentially optimized. Studies also included the effects of engine re-ingestion, thermal and surface winds and the impact on flight control with variations in ground profiles.

The outstanding flight characteristics of the *Hoverbuggy* came to the attention of the Army Aviation Test Office, NASA and the Air Force at Wright Field Air Development Center. Each of these agencies sent pilots and dynamics tech-



nologists for briefings and to witness the *Hoverbuggy* in flight. The Air Force was impressed to the extent that they "adopted" the program, but not with their wallets, as no funds were forthcoming to continue FS-1 operations. However, substantial data infusion was related to support initiation of the "VTOL Integrated Flight Control System (VIFCS)." In addition to the four NAA pilots, three Air Force and one RAF pilot, all based at Edwards, flew the ship after first being checked out on the "tether rig." All the pilots who flew the *Hoverbuggy* gave it high marks on its controllability. The only area not receiving high marks was the throttle response. The J85 engine was equipped with a "flyball" throttle control which had a response rate that was slow for its use on the *Hoverbuggy*, thereby degrading desirable response.

At that time NAA was distributing ''Mach Buster" certificates to those VIPs who flew supersonic in the NAA F-100 *Super Sabre* fighter. The *Hoverbuggy* program officials were not to be "outclassed," so these USAF and RAF pilots were presented with "Minus Mach" certificates. The local Air Force office expressed a concern that some of the *Hoverbuggy's* surplus parts would make their way into new aircraft. Bill Barker's solution to this concern was to have all its parts marked "Made in Japan." The *Apollo* program crew was quite interested in the *Hoverbuggy* and witnessed several of its flights.

The *Hoverbuggy* program continued to its 200th flight, when on January 27, 1967, the program was shut down, having accumulated approximately 26 hours in the air. This was a very sad day for NAA, as it was the same day three astronauts were lost in the *Apollo* fire, the capsule being built by another division of NAA.

At this time, the *Hoverbuggy* had covered all low-speed points established for NAA's ground-based flight simulation and had met all the goals established in the beginning. About the only unfinished task was the installation of an Autonetics Division of NAA-designed electronic height control (throttle assembly).

All this flight time without any accidents was a tribute to piloting skills, good basic engineering and excellent mechanical service by *Hoverbuggy* crew chief Cliff Maddox, assisted by mechanic Russ Pindley. Barker said that a number of persons led to the success of the program, but outstanding was the efforts of Jay Gaines in the stress laboratory who conducted the loads and drop tests as well as build the "Iron Inspector." Barker also referred to Engineering System's Boris Palarz as "The brains of the outfit."

The only untoward accident was a hard landing that took place on its 147th flight. This was due to the pilot attempting a landing with the SAS disconnected. Only the pilot's pride was hurt and the *Hoverbuggy* sustained some minor damage to one of its landing gear struts and a roll nozzle. The ship was quickly repaired and back in service within a couple of weeks.

Epilogue—After its last flight, the *Hoverbuggy* was dismantled and its borrowed engines returned to the Planes of

Fame and Cars of Stars Museum, which in turn had them on loan from Northrop. Some of its vital parts and data were given to the San Diego Aerospace Museum, and the *Hoverbuggy's* nose landing gear strut ended up back on a flying BT-13. Continued use of the *Hoverbuggy* frame was made to support contract effort in which tests were conducted on several VTOL thrust concepts: such as annular or scroll type exhaust and wing-mounted ducted fans (of the type used in the Ryan XV-5A vehicle). The hardware was installed in the *Hoverbuggy* structure which had now been relocated to NAA's Santa Susana Test Laboratories.

A quote from "Buzz" Aldren, the second human to walk on the moon, rather catalogs the *Hoverbuggy*'s place in aviation history as follows: "Project *Apollo* was the single most audacious endeavor in human history." The FS-1 was probably the least audacious, but its potential could unlock the secrets of a whole new realm of flight. •


**ACKNOWLEDGEMENTS**

The author wishes to thank Bill Barker, Boris Palarz and Al West for their willingness to share their files and memories of their *Hoverbuggy* association during the many telephone calls and letters required in the research needed for this article.


**REFERENCES**


1. Biography: Lee Atwood, Dean of Aerospace by Russ Murray. Printed by Rockwell International, California Chapter, National Mgt. Assn., 14 Apr. 1980.
2. North American Aviation, Inc. *Skywriter,* Vol. XXV, No. 48, dated Dec. 3, 1965.
3. North American Aviation, Inc. *Skywriter,* Vol. XXVI, No. 3, dated Jan. 21, 1966.
4. North American Aviation, Inc. *Skywriter,* Vol. XXVI, No. 17, dated Apr. 29, 1966.
5. North American Aviation, Inc. *Skywriter,* Vol. XXVII, No. 2, dated Jan. 20, 1967.


**ABOUT THE AUTHOR**

Dick Henke was a graduate of the University of Alabama earning a B.S. degree in Aeronautical Engineering. In 1947, he was hired as an Engineering Draftsman in the Instrument Group of North American Aviation. He worked on the cockpit designs of the XFJ-1 *Fury* fighter, XAJ-1 *Savage* attack bomber and XFJ-2 fighter, all built for the U.S. Navy and the cockpit designs of the XF-107 and F-86H fighters for the U.S. Air Force.

It was soon obvious that not only was Dick a good engineer, but that he had a talent for teaching. Dick wrote and published a booklet called *Henke's Little Instrument Primer.* This became the standard reading text for those engineers entering the field of aircraft instruments.

His experience led him to the X-15 where he was responsible for the design of the flight instrument system. Moving from the world's fastest winged aircraft, Dick was then assigned to the *Apollo* Space Program which would carry America to the moon. Dick's design efforts were utilized while on loan to MacDonnell Douglas on the C-17 cargo/transport. Later, Dick became responsible for the flight instrument system on the B-1A and B-1B bomber. It was from the B-1B program that Dick retired in 1984 as a Senior Design Engineer after 36 years of service for the company that was now known as Rockwell International.

As a historian, Dick put together several audio-visual programs that he presented at seminars on the evolution of aircraft during the Great War (World War I). These seminars were conducted at North American Aviation and at a number of aircraft societies in the Southern California area. In addition to aircraft, Dick was an avid reader and was planning on writing a book on the Civil War. Dick had essentially completed his basic research for the *Hoverbuggy* article when he passed away in 1991. It was at this point that his wife, Blanche, and his friend, Jim Tuttle, thought Dick's efforts and the historical significance of the *Hoverbuggy* program warranted the story be completed and published here in the *Journal.*

**HOVERBUGGY SPECIFICATIONS**

Span: 23' 0"
Length: 36' 0"
Height: 9' 0"
Empty Weight: 1,800 lbs.
Takeoff Weight: 3,350 lbs.
Landing Weight: 2,200 lbs.
Engines: Two—General Electric YJ85-GE-1 turbojets, each rated at 2,200 lbs. sea level static thrust (early flights)
Two—General Electric YJ-85-GE-5 turbojets (later flights)
Maximum Speed: 50 knots
Maximum Roll Angle: 45 degrees
Range: 10 miles (testing never exceeded 1 mile)
Maximum Altitude: 5,000 feet (testing never exceeded 100 feet)

**SOME *HOVERBUGGY* CONTEMPORARIES**
(Listed in Order of First Flights)

| Country | Manufacturer | F-F Date | Type of **VTOL** |
|---|---|---|---|
| USA | Lockheed XFV-1 *Salmon* | Mar 54[1] | Tail Sit Turboprop |
| USA | Convair XFY-1 *Pogo* | Jun 2, 54[2] | Tail Sit Turboprop |
| Britain | Rolls-Royce *Flying Bedstead* | Aug 3, 54 | **Jet** Thrust |
| USA | Bell ATV | Nov 16, 54 | Defl. Thrust |
| France | Snecma Attar Velom | 1955 | Tail Sit. **Jet** |
| USA | Bell XV-3 *Convertiplane* | Aug 23, 55 | **Tilt.** Rotor |
| USA | Ryan X-13 *Vertijet* | Dec 10, 55[3] | Tail Sit. Jet |
| USA | Bell X-14 | Feb 19, 57 | **Defl.** Jet Thrust |
| Britain | Short SC.1 | Apr 2, 57[3] | Lift Engines |
| USA | Boeing-Vertol VZ-2A | Aug 31, 57 | Tilt Wing |
| USA | Doak **VZ-4DA** | Feb 25, 58 | Tilt Ducted Fan |
| USA | Ryan VZ-3RY *Vertiplane* | Dec 29, 58[3] | Defl Prop Thrust |
| France | Snecma C.450-01 *Coleoptere* | May 6, 59 | Tail Sit Ducted Fan |
| USA | Fairchild VZ-5FA *Fledgling* | Nov 18, 59 | Defl Prop Thrust |
| USA | HillerX-18 | Nov 24, 59[3] | Tilt Wing |
| USA | Curtiss-Wright X-100 | Mar 1960 | Tilt Prop |
| Britain | Hawk Sid. P. 1127 *Kestral* | Oct 21, 60[2] | Defl. Jet Thrust |
| France | Dassault V-001 *Balzac* | Oct 12, 62 | Lift Engine |
| USA | Lockheed XV-4A *Hummingbird* | Jul 7, 62[3] | Aug Jet Eject Lift |
| USA | Piasecki VZ-8P | Summer 62 | Defl Duct |
| Germany | EWR VJ 101 | Apr 10, 63 | Tilt Jets + Lift Eng |
| USA | Ryan XV-5A | May 25, 64[3] | Fan in Wing |
| USA | North American *Hoverbuggy* | Nov 1, 65[2] | Jet Thrust |
| USA | Bell X-22A | Mar 17, 66 | Tilt Duct |
| Germany | Dornier Do 31 | Feb 10, 67 | Lift Engines |
| Russia | Yakovlev Yak-36 | 1967? | Vectored Jet Thrust |
| France | Nord 500 | July 1968[2] | Tilt Duct |
| USA | Grumman Lunar Ldg Rsch Veh | 1968? | Jet Thrust |
| USA | Grumman LEM | Jul 20, 69[5] | Rocket Thrust |
| Germany | VFW-Fokker VAK 191B | Sep 10, 71[2] | Lift Jets |
| USA | **Bell** XV-15 | May 3, 77 | Tilt Rotors |
| USA | Williams Research *Wasp* | 1974?[2] | Turbofan Lift |
| USA | Bell/Boeing V-22 *Osprey* | Mar 19, 89 | Tilt Rotors |

1. Conventional first flight date, never flew in VTOL mode.
2. Tethered, first flight date.
3. Conventional takeoff, first flight date.
4. First translation date.
5. First manned moon landing date.