AIR FORCE
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Despite years of low priority and low budgets, our VTOL program is in surprisingly good health, with a positive plan under way and a number of models about to receive field trials. Under the present schedule we should have VTOL attack and support aircraft in production before 1967. One will be a large, triservice, tilt-wing turboprop. But before it or any of the others now under study move toward the inventory, answers must be found to some vital operational questions:

- ★ **How much hover time will field operations require?**
- ★ **What special problems do unprepared sites present?**
- ★ **What sort of difficulties should pilots expect in all-weather field operations?**

Meanwhile, European VTOL programs—notably British, French, and Dutch—are increasingly sophisticated, and it is likely that for the first time in years the United States may have to take a back seat to Western Europe in the development of an advanced aircraft . . .

THE UPS AND DOWNS OF OUR VTOL PROGRAM

By J. S. Butz, Jr.
TECHNICAL EDITOR, AIR FORCE/SPACE DIGEST

TEN YEARS of low priority and low budget usually add up to an unhealthy situation in any aircraft-development program, but the VTOL (vertical-takeoff-and-landing) effort in the United States has stayed alive during the lean years and today is in surprisingly good health. VTOL priority still is low, but the budget is gradually increasing, and the program now has the encouragement of a positive plan to fill the yawning gaps in US understanding of VTOL operations. But until more is known of VTOL operational problems under field conditions, it will not be possible to bring VTOL aircraft sensibly into military planning.

Even though the US VTOL effort has never enjoyed a high priority, considerable technical progress has been made since the advent of gas-turbine engines made efficient VTOL aircraft feasible. Flight tests have conclusively demonstrated that several types of these aircraft can take off and land vertically without using rotors. During the 1950s, well over $100 million was spent, spread over about twenty different research airplane projects, and a great deal was learned about the basic principles of very-low-speed flight, hovering, the transition from vertical to horizontal flight, and the design of lightweight shafting and gearing for multi-engine VTOLs.

The first successful nonhelicopter VTOL—the Convair XFY-1 tail-sitter fighter—made the first winged airplane flight from vertical takeoff to horizontal flight and back to vertical landing in November 1954. During the next six years an impressive series of such flights was made by other tail-sitters, as well as by a strange-looking assortment of aircraft with tilting wings, tilting rotors, tilting ducts, deflected propeller slipstreams, deflected jet-exhausts, and direct-lift engines.

Today, the US is preparing to take the next step beyond pure research flight—toward operational aircraft. Five new models of VTOL airplanes are being funded by the military. All of them will get extensive field trials to demonstrate clearly the operational capabilities of VTOL aircraft. Hopefully, some of them, with only slight modification, will be suitable for service use.

The largest of these new aircraft is a 35,000-pound-gross-weight, tilt-wing, turboprop-powered transport being built by an industrial team of Ling-Temco-Vought, Ryan Aeronautical Co., and Hiller Aircraft Corp. The contract was signed last February, and the first flight is scheduled for March 1964.

This design was selected from several proposals as

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the primary aircraft in a triservice program to develop a VTOL transport useful to all the services. It is looked on as the most advanced VTOL transport that could be flown in the near future with a good chance of success.

The Army, Navy, and Air Force will contribute equally to a fund of about $125 million for this program. From $60-100 million will be spent for the tilt-wing transport program including development, construction of five aircraft, and flight-testing. Most of the rest of the money will be spent on a "four-duct tandem" configuration (*see cut, page 37*). The Navy is especially interested in this aircraft because its compact size lets it fit on a carrier elevator without having to be folded. This design also has the potential of becoming a very efficient high-speed, low-altitude machine if the ducted propellers are replaced with turbofans. This type of high-speed aircraft is of great interest to many manufacturers and the services.

Douglas Aircraft Corp. and Bell Aerosystems Co. are in competition for this 15,000-pound, four-duct tandem airplane. A winner was scheduled for selection in June. Flight-testing is planned in about two years. Two test aircraft will be built.

Less than $10 million of the triservice VTOL fund will be spent on another small airplane, similar to the "four-duct tandem" except that it will have unshrouded propellers. This aircraft, developed with company money, is already under construction by Curtiss-Wright. Now the services plan to purchase two aircraft and flight-test them within the next year. A major purpose of these tests is to get early data on the stability and control problems of VTOL aircraft with the propulsion devices widely spaced on the fuselage.

In addition to this triservice program the Army has projects to determine the operational feasibility of two new VTOL lift-propulsion systems which have been highly successful to date. The first, used in the Lockheed VZ-10, employs a jet pump or ejector mounted in the fuselage to augment the thrust of two jet engines and raise the thrust to a level adequate for vertical takeoff. The VZ-10 will fly this summer.

The second propulsion system is a lift-fan driven by hot exhaust gases from a J85 turbojet during vertical flight. In forward flight the lift-fan is closed off, and the engine exhausts normally. Two of these General Electric lift-fan systems will be flown next year in an airframe built by Ryan. GE is the prime contractor—the first time that an engine manufacturer has been named prime on an airplane project.

An indirect but important pressure to speed the US VTOL effort is the growing sophistication of Western European programs for the development of high-performance, vertically rising aircraft. British engine manufacturers are credited in many US quarters with surpassing our own engine industry in VTOL technology. French, Dutch, and British airframe companies are working intensely on several advanced designs. The Hawker P-1127 VTOL strike fighter is well into its flight-test program and is several years ahead of any comparable US project. The DoD recently invested $35 million in this aircraft and its engine—the Bristol Siddeley Pegasus, a vectored-thrust turbofan. The Dassault Mirage III V, using small Rolls-Royce lift engines for vertical flight, has been selected for development by the French Air Force. A number of European companies have designed VTOL transports of several types to meet a NATO specification for an aircraft to supply remote VTOL sites. These VTOL projects are only a portion of those under way in Western Europe. It is becoming increasingly clear that in the VTOL field, the European aircraft industry is in by far its strongest position vis-à-vis the United States since the second World War.

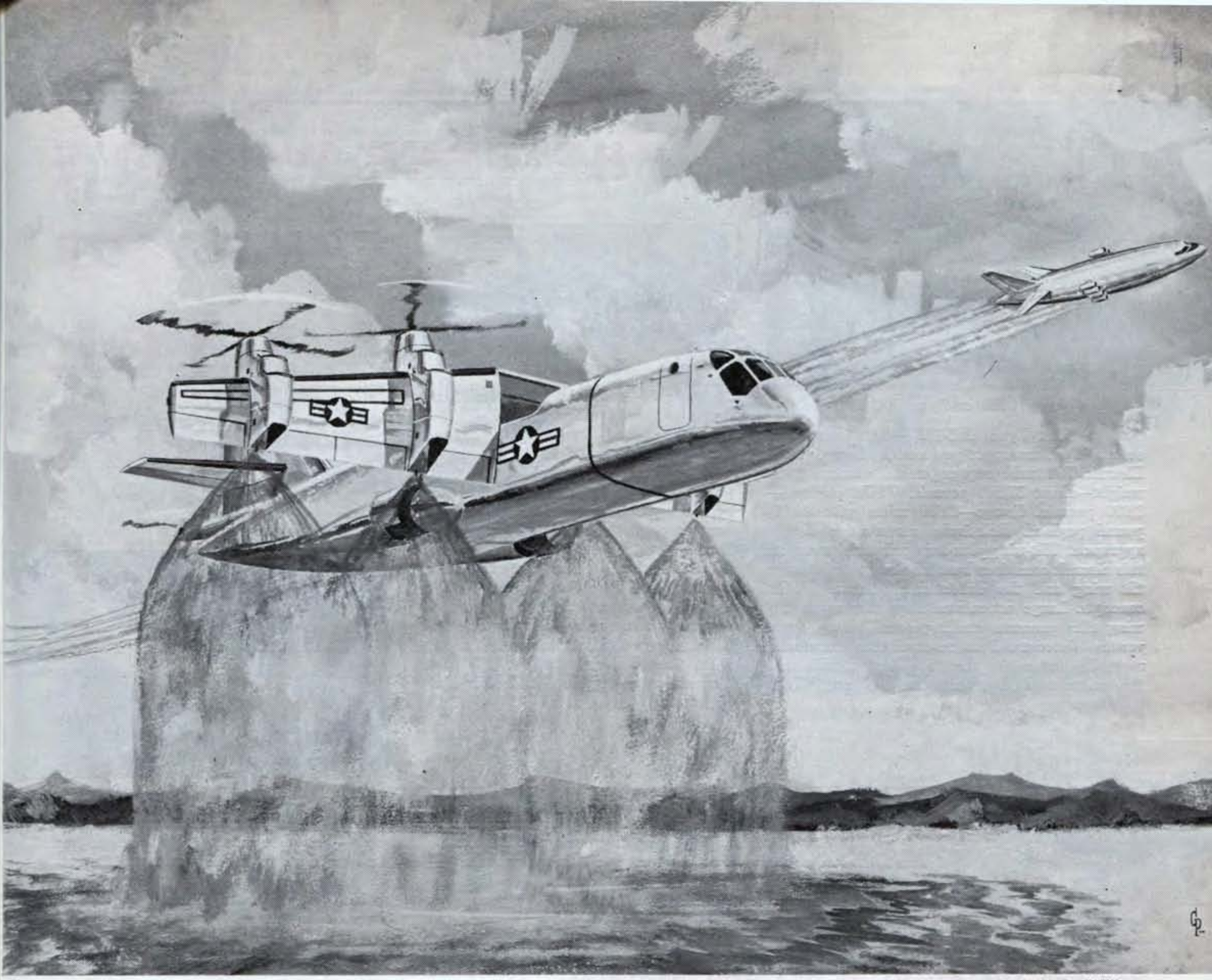
Industry activity in Western Europe has been stimulated to a great extent by military interest. Military planners working in the close confines of Europe see no alternative to VTOL aircraft to reduce their vulnerability to a surprise attack by a modern army. These planners want to be able to operate their aviation from thousands of isolated VTOL sites and get away from the airfields that are expected to be lost during the first minutes of any war. And they want VTOL transports to end their armies' dependence upon the road system, to give them the mobility to outclass an opponent in a nuclear land battle.

Today in the US there are three major technical uncertainties blocking realistic planning for VTOL operations. Research flying of the 1950s failed to answer these questions, primarily because none of the services was willing to pay for operational trials of VTOL aircraft in the field. This will be done during the next two years with the new VTOLs now under development. The three vital operational questions are:

- **How much hover time is needed in practical field operations?** The configuration, cruise speed, and range of a VTOL transport depend directly upon the time spent in vertical flight and hovering during a typical mission. If field trials show that twenty to thirty minutes usually are needed, it may be impossible to improve on the helicopter. Its rotor develops lift almost ideally by moving a large quantity of air at slow speeds, and it is the most efficient hovering vehicle known.

If hover times of about ten minutes will do, then the tilt-wing, turboprop transport becomes attractive. Even though it consumes fuel about four times faster than a helicopter with the same payload, this VTOL's propulsion system weight plus fuel for a ten-minute hover is a little lower than the helicopter's so their "hovering efficiencies" are comparable for about ten minutes or a little longer. And since the VTOL is not hobbled by rotor drag during cruise, it can operate at speeds from 350 to 400 mph compared to about 125 mph for most helicopters. This aircraft will also fly two to three times farther with a given payload, so its productivity in transporting cargo is much higher than the helicopter's.

Further productivity improvement is possible if only about five minutes of hover are required. Then the turbojet-powered VTOL transport could be used, since its "hovering efficiency" is no lower than the helicopter's or the turboprop VTOL's for that short period. All of the advantages of jet-powered flight would also accrue to this aircraft. Cruise speeds would range from



—Drawing by Gordon Phillips

Clouds of sand and debris will be raised by the powerful downwash from VTOL aircraft during landings on many types of unprepared ground. One suggested method of suppressing the debris cloud is illustrated in this artist's conception of an XC-142. It is hoped that chemicals sprayed into the propeller slipstream can damp out the cloud long enough for a quick landing with an immediate engine shutdown. The bullet-shaped, wingless aircraft shown in the background, with its engines on rotatable plates on the fuselage, has been suggested as the ideal low-altitude, high-speed VTOL configuration.

500 mph into the supersonic, and its range and productivity would be substantially higher than the turboprop's.

It is obvious that control of VTOLs in the field is going to be extremely critical. Rapid approaches and departures must be made routinely into large numbers of sites scattered over hundreds of square miles of territory. Every VTOL pilot must be provided with an accurate, reliable fix on his landing site and be able to proceed to it with virtually no impediment. Every minute of delay will have a severe effect on the aircraft's total mission performance. At no other time in aviation history have an aircraft's design and configuration been so severely dictated by its operational patterns.

• **What difficulties are expected when operating from unprepared sites?** Experiments made to date indicate that landings of VTOL aircraft in some types of terrain will be exceedingly hazardous.

Downwash velocity is the best indicator of the trouble expected with each type of aircraft. Heavily loaded helicopters usually have a downwash velocity of around fifty mph. This is enough to raise substantial clouds of sand, dust, or snow, depending on conditions. This flow can also damage equipment and injure personnel on the ground if operations are not conducted carefully.

On propeller-driven VTOLs the downwash velocity is much higher, sometimes reaching 200 mph or more. As this vertical blast of air turns horizontally it spreads out evenly into a flat sheet on the ground three or four feet high. It also digs a hole, directly under the propeller, in all but the hardest surfaces, such as packed clay and rock. Loose particles fly out of these holes and are swept away in the high-speed sheet of air moving along the ground. However, collisions between the particles cause some of them to bounce out of the ground stream with great force and to rise to considerable heights. These particles range from the size of sand grains to baseballs, and some have enough momentum to puncture aluminum skin, recirculate through propellers, and enter engine air intakes with paralyzing effect. The dust clouds raised in this manner can put

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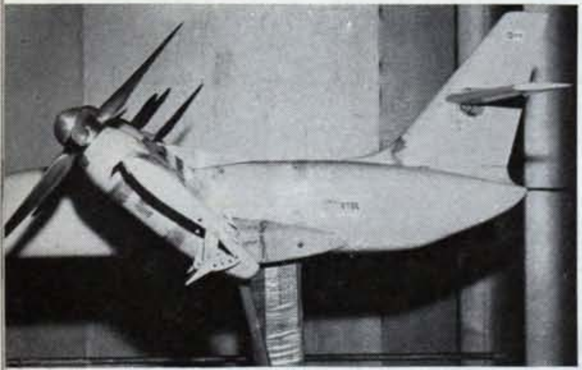
THE FREE WORLD'S FAMILY OF VTOL AIRCRAFT



Vought-Hiller-Ryan XC-142

Vought-Hiller-Ryan XC-142 — Triservice-sponsored VTOL transport powered by four General Electric T64 turboprop engines. Maximum gross weight—about 37,500 pounds. VTOL payload—8,000 pounds. Range—2,600 miles with 4,000-pound payload. Relatively conservative design approach. Tilt-wing-plus-flap principle used on this aircraft combines best features of the simple tilt wing and the deflected slipstream VTOL concepts. Large articulated flaps moving as the wing tilts prevents stalling even during steep vertical descents. Past research has convinced most US authorities that this design will have the shortest development time of any VTOL transport.

Ryan VZ-11

Ryan VZ-11—Powered in vertical flight by two General Electric X353-5B lift-fan engines each driven by the exhaust from a GE J85. Total lift thrust—13,946 pounds. Total horizontal thrust—5,316 pounds. A primary advantage of this system is the ability to deliver the proper amount of thrust in each flight regime. During cruise most aircraft require about one-third of the vertical takeoff thrust. VTOL fuel consumption for this engine is very good. Time to take off vertically over seventy-foot obstacle and accelerate to 125 knots is forty-five seconds. Time to decelerate from 150 knots descend vertically for 100 feet is sixty seconds.

"Four-Propeller Tandem"

Curtiss-Wright, "four-propeller tandem" aircraft—Has about the same advantages and disadvantages as the four-duct tandem configuration. Uses a specially twisted propeller which produces a significant upward lift force during cruise.

Lockheed VZ-10

Lockheed VZ-10—Main selling point is a simple, rugged lift propulsion system that has no moving parts and consists of a series of jet pumps to augment engine thrust for vertical flight. Maximum VTOL weight—7,200 pounds. Two Pratt & Whitney JT12A-3 turbojets delivering about 3,000 pounds thrust each.

THE UPS AND DOWNS OF OUR VTOL PROGRAM

a pilot on IFR during takeoff on a clear day and can put an unmistakable marker on a VTOL site for an enemy.

The downwash problem with jet-powered VTOLs reaches seemingly explosive proportions. Exhaust streams from turbofan and turbojet engines range from 1,000 to 1,500 mph. This hot blast can damage concrete and raise a veritable geyser of gravel and loose earth even when the engines are mounted a considerable distance above the ground.

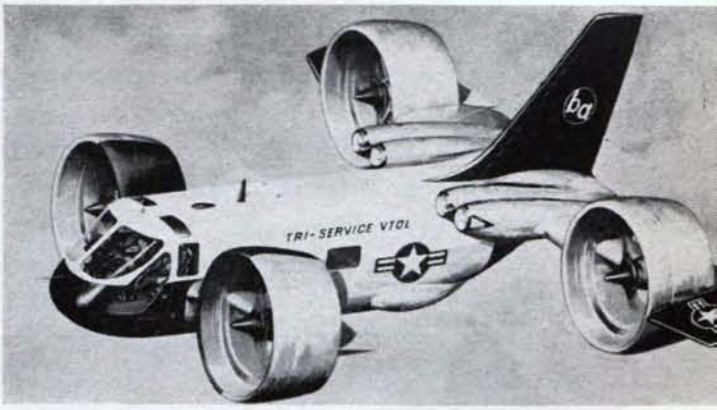
The seriousness of the downwash problem has prompted a variety of suggested solutions. For instance, on prop-driven VTOLs, petroleum-base chemicals might be sprayed out, just before the aircraft settled to a landing, to pack down the earth (*see illustration, page 35*). Or large mats might be dropped and unfurled in the air, when the aircraft is thirty or so feet above the ground. Or in particularly hazardous terrain small teams of parachutists might be dropped just before landing to spread a polyvinyl sheet over the entire landing area. Certainly in the case of the jet-powered VTOL, advance preparation of virtually every landing site is going to be necessary. Large, temperature-resistant mats and soil stabilization are also being considered. Operational tests are absolutely vital not only to learn what ground preparation is needed but also to indicate what aircraft design factors—such as engine height above the ground—are most important in reducing the downwash problem.

• **What are the piloting difficulties of VTOL aircraft in all-weather, field operations?** Even though most VTOL research aircraft have been flown successfully in vertical, horizontal, and transition flight, they all have serious stability and control limitations. None of them is inherently stable in hovering flight, and all are quite dangerous for even the most experienced pilot to fly in gusty weather. Steep descents and transition from horizontal to vertical flight have been especially troublesome.

It now appears that artificial stabilization will be required about all three control axes for any operational VTOL. And extensive field experiments and further research will be necessary to determine what equipment on the ground and in the aircraft will be needed for all-weather operation into confined areas along steep flight paths.

Engine performance has always been the pacing item with VTOL aircraft, and apparently this won't change in the near future. Gas turbines made VTOL possible in the first place, and gas-turbine technology

"Four-duct tandem" aircraft—Advantages include compactness, excellent pitch control during hovering and transition flight, and no wing-stall problem. Disadvantages include relatively poor efficiency in short-takeoff performance compared to the tilt-wing design, and poor stability and performance in high-altitude cruise.

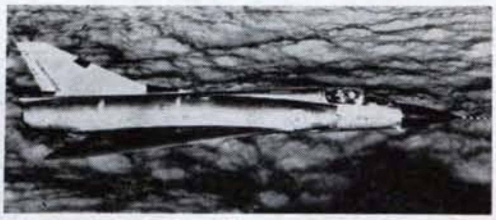


Bell Aerosystem's "Four-Duct Tandem"

Hawker P-1127

Hawker P-1127—Most advanced VTOL flying. Powered by the Bristol Siddeley Pegasus, vectored-thrust turbofan engine which exhausts from four rotatable nozzles. Engine thrust can be changed from horizontal to vertical in one second. In flight tests the engine is checked out at maximum thrust in the horizontal position, then the nozzles are quickly switched to the vertical position, and the aircraft rises immediately with very small downwash trouble. An RAF service pilot made his first vertical takeoff, transition, and vertical landing in the aircraft after only forty-five minutes of familiarization flying. Design work is in progress on several advanced models of both the engine and aircraft to meet RAF and NATO requirements. These developments include engines with burning in the fan section, some models delivering 40,000 pounds of takeoff thrust and some intended for supersonic cruise at very low altitude. Britain, West Germany, and the US have each ordered three P-1127s for flight tests. $35 million in DoD funds is going into the development program.

Dassault Mirage III



Dassault Mirage III V—A Mach 2 VTOL fighter being developed from the successful Mirage III aircraft (*see cut*) on order by five air forces. Eight Rolls-Royce RB.162 lift engines will be mounted in the fuselage for takeoff and landing. Power in horizontal flight will be provided by the SNECMA TF106 engine. A main advantage of this multiple-engine concept, long advocated by Rolls-Royce, is safety in the event of engine failure. Problems include simultaneous starting and heavy downwash effects. Dassault, Boeing, Rolls-Royce, and the British Aircraft Corp. have teamed in offering this aircraft to meet the NATO, VTOL strike-fighter requirement.

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is now advancing so rapidly that it could make most of today's VTOL aircraft obsolete in a very few years. The direction of advance indicates that pure turbojet or turbofans may become the preferred lifting system in the near future.

For instance, today it is possible for turboprop-powered VTOL transports to hold their own in design competitions with turbojet-powered aircraft producing about eight pounds of lifting thrust per pound of engine weight. However, virtually all engine manufacturers say that the next generation of lifting engines will produce fifteen and possibly twenty pounds of thrust per pound of engine. It isn't possible to keep up with such weight improvements when using fixed-weight propellers and shafting to interconnect engines for safety. Therefore, a great advantage in "hovering efficiency" as well as cruise speed and productivity could lie with the pure-jet VTOL if fuel consumption does not rise drastically in the new lightweight engines.

Aerodynamically, VTOL airplanes may bring some major surprises, especially in their military form. If current predictions prove true and if, to reduce vulnerability, most military operations must be conducted at very low altitudes, then wingless aircraft will become increasingly attractive. Any wing—no matter how small—is an aerodynamic burden in high-subsonic speed flight near the ground. Under these flight conditions the wing on all configurations produces little or no lift but a substantial drag. A properly designed fuselage could produce all of the lift necessary. So any airplane which didn't need a wing to take off would not need a wing to fly as long as it operated at high speed near the ground.

If the wing can be discarded, a great weight savings can be realized because on the average aircraft the wing accounts for about ten percent of the maximum gross weight. Adding this ten percent to either the fuel or the payload would be a great performance boon. According to NASA researchers, wingless airplanes have "... markedly superior performance for high-speed, on-the-deck operation."

The next five years will be critical in the development of VTOL aviation for the Western world. It seems certain that flight tests during this period will provide a clear understanding of what is needed for field operations. Undoubtedly the production of VTOL attack and support aircraft will have begun before 1967. But for the first time in years it is possible that the United States will have to take a back seat to Europe in the development of advanced aircraft.—END