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possible that will affect the structural integrity of the basic airplane.

Short Field Aircraft

"Short-field Aircraft" is a catchall term under which can be lumped all aircraft which use advanced technology to achieve shorter than ordinary takeoff and landing distances. The term embraces short takeoff (STOL), reduced takeoff (RTOL), and vertical-or-short takeoff (V/STOL) types of machines.

RTOL and STOL

There have been two definitions associated with each of the names Reduced Takeoff and Landing (RTOL) and Short Takeoff and Landing (STOL), and much confusion has existed because this fact was not appreciated. The confusion existed because, while Conventional Takeoff and Landing (CTOL) airplane technology and its associated performance were represented by existing types of airplanes, as was Vertical/Short Takeoff and Landing (V/STOL) by the performance of the helicopter, no hardware and no steady performance targets existed for STOL. During the early years in the development of STOL technology, the typical argument was over what single fixed takeoff and landing distances should be striven for through the application of the technology. One of the early "definitions" of STOL was "500 feet over a 50 foot obstacle." It was surprisingly long in coming out that there were actually two entities to define separately.

The first was **STOL technology,** the aggregation of technical developments that would enable the design of an airplane with field length requirements substantially less than those of a CTOL airplane, of the **same payload, range, and speed.**

The second was **STOL airplane,** and to its definition no fixed field performance requirement could be attached except arbitrarily. The field performance of successful airplanes designed to a given state of the art is size dependent as shown in Figure 1-3. A STOL airplane, then, is an airplane which utilized STOL technology effectively to produce some percentage improvement in performance, no matter how short or long its field requirement is.

Potential users, however, insist on thinking in dimensional terms so here is a sample rundown of the various field length performance targets advocated throughout the years, with a little information on each:

(1) 1952: 500 feet; this was the point of departure for many discussions among commercial manufacturers, the Army, and the Office of Naval Research. In 1953, the Cessna Aircraft Company actually produced an airplane capable of taking off and landing over a 50-foot obstacle in 450 feet. The airplane was a heavily-modified L-19A. The "improvement" over CTOL was approximately 25 percent.

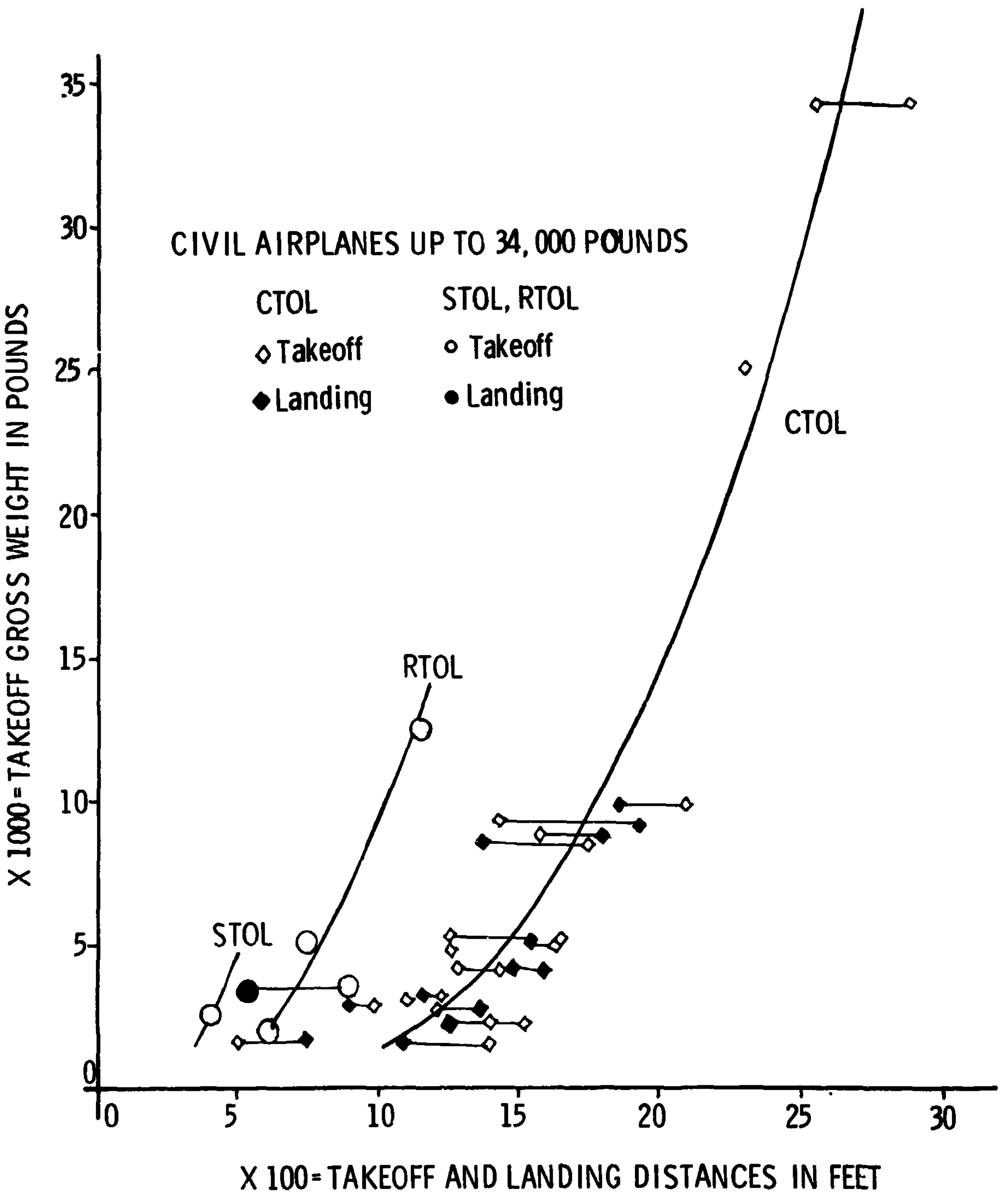
(2) 1959: 1,200-2,000 feet, developed in part by technical studies growing from ONR/Army-sponsored research performed at the University of Wichita. The aircraft associated with these field lengths were transports in the 30,000 - 60,000 pound class [8] At this same time, Lockheed Aircraft started development of a "BLC-130" with comparable performance.

(3) 1968: 1,000 feet. The FAA marked off 1,000-foot sections of runway at Washington National, Friendship, and LaGuardia airports and designated these as "STOL" strips. An airline using Dornier "Sky Servant" heavy twins (7,700 pounds) used these strips. Though this airline operated only for a while, it provided information on the feasibility of introducing STOL airplanes into the mix of traffic at a heavily-used airport.

(4) 1970: 2,000 feet. This was a relaxation of the 1,000-foot "requirement" above. Surveys of the larger commuter operators at that time indicated that they would have been content with about 3,500-foot field performance.

(5) 1975: 3,000-4,000 feet. This length is associated with medium weight transport category airplanes (146,000-206,000 pounds) in a NASA-funded set of short-haul systems studies by Douglas, Lockheed, Boeing, and others. Advanced hi-lift technology and materials were necessary at these

[8] Stalter, J. L., and Wattson, Robert K., Jr., "Experimental Investigation of a Means of Obtaining Independent Control of Lift and Drag in Landing Approach," University of Wichita Engineering Report UWER-315-5, Contract DA 44-177-TC-356, U.S. Army Transportation Research Command, April, 1959



50-FOOT OBSTACLE TAKEOFF AND LANDING DISTANCES
FIGURE 1-3

weights. Environmental considerations were invoked.[9]

From these cases it can be seen that the field length requirements, and the aircraft missions and sizes of principal interest at the moment, were all mixed up together, which frequently happens when most of the application effort over a considerable period is devoted to studies rather than to the production and marketing of actual equipment.

To try to make some sense of the above, a discussion of STOL aircraft is presented using a historical/technical approach. The initial question, of course, is "what is 'short'?" or "short with respect to what?" As has been seen, there is no way to answer using field lengths; thus, a definition based rather on the state of the technical art must be adopted. This definition requires that a technology associated with "conventional" is adopted first, and that "short" (plus recently "reduced") be related to it through inspection of the technological levels habitually associated with them.

Conventional Technology. Perhaps the best period to use to describe "conventional" is the period between 1946 and 1950. By 1946 the biplane and the wooden airplane no longer represented the highest level of technology. The technical product of the war years which appeared first on the civil market was characterized by conventional-airfoil straight wings, single or double-slotted part-span flaps, and propeller engines. The turbojet engine technology of wartime was working its way through the military inventory, and would appear on the civil market in the 1956-59 period in the forms of the Boeing 707, the Douglas DC-8, and the Convair 880. These three airplanes were "CTOL's" in the sense that, though they employed complicated flaps and leading edge devices, the effectiveness of their wings in producing high lift was no better than that of the propeller airplanes that preceded them. Their field length requirements were very long, 9,000-10,000 feet, so from either the performance or the technology standpoint they would have to be considered simply as defining a jet-airplane CTOL developmental level.

STOL Technology. The initial impetus for the development of a STOL technology was provided by the military. Civil propeller airplanes of the 1946-1950 era had no great trouble operating from the airports of the day. The military, however, concerned over operations from short fields or aircraft carriers, thought in terms of better field performance than could be displayed even by the propeller airplanes of the period. They were diverted from the helicopter by its slowness and fearsome maintenance costs, and thought instead of short-field fixed-wing airplanes which, while somewhat heavier and more complicated than conventional airplanes, would offer acceptable logistics and some of the desired performance gains.

Conventional high-lift technology seemed to have reached a plateau, so attention was directed towards "powered lift." The means were to be propellers which bathed most of the wing in their slipstreams and could be used in conjunction with very sophisticated wing flaps and drooped airlerons which deflected the slipstreams downward to obtain additional lift. Further, an old concept called "boundary layer control" (BLC) or "circulation control" was invoked to increase the maximum lift of the flapped wings. The application of BLC delays the breakaway of the airstream over a wing by removing (suction) or re-energizing (blowing) the slow-moving layer of air—the boundary layer—close to the wing surface, the decay of which causes the wing to stall.

Under Army, Navy, and Air Force sponsorship, exploratory programs on prototype versions of liaison airplanes, fighters and transports using BLC with or without propellers went on throughout the 1950's. In France, the Breguet company developed a deflected slipstream, four-propellered airplane with flap and control-surface refinements, the Model 940 transport. In 1967 its successor, the Model 941, was demonstrated in a series of simulated scheduled airline trips, but nothing resulted.

The state of the STOL art by 1960, then, was portrayed by: (1) extremely complex wing flaps and slats with or without BLC; (2) large propellers, with or without interconnects to prevent rolling and yawing in event of engine failure on multi-engined airplanes; (3) roll control refinements (spoilers or drooping ailerons); and (4) large tail surfaces, perhaps with BLC applied.

Airplanes with lifting jet engines or lift fans were studied for their STOL-mode characteristics, but were really overloaded V/STOL airplanes.

Civil jet airplane manufacturers meanwhile had been working. Though there was one test of a large jet airplane with BLC in the mid-1960's, the most notable achievement was

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[9] Savin, Raymond C *et al*, "Summary of Short-haul Systems Studies," NASA TM X-3010, January, 1975

the Boeing 727, not usually thought of as a STOL machine. Through careful tailoring of the wing shape and flap and slat configuration, Boeing engineers produced a high-speed, swept wing whose high-lift performance was almost the equal of the powered-lift straight wings of the experimental STOL airplanes. Using this wing and the higher thrust/weight ratios available from turbofan engines, they achieved a 7,250-foot requirement of the 707-120. Almost at the same time Douglas achieved similar performance gains using early-generation "supercritical" (not Whitcomb) wings with long double-slotted flaps, and fan engines. The second generation jet airliners could thus be called true STOL machines, in terms both of their high-lift technology and of the percentage improvement in field length achieved.

The technological improvements over the first generation jets were low-speed engine thrust/weight ratios up about 30 percent and maximum lift capability up about 60 percent.

Later (1965-1975) efforts have been concentrated in the following areas: (1) "externally-blown flaps" (EBF), an adaptation of the old deflected slipstream concept to the fan engine; and, (2) "Augmentor wings," the addition of auxiliary surfaces using a jet-pump principle to augment the effect of blowing-type BLC. An augmentor-wing prototype airplane exists.

The present situation illustrates a rather curious fact: developments in the powered-lift area did enable wing lift capacity to be raised, but close behind came developments in non-powered lift—carefully tailored wings, flaps and leading-edge devices—which nullified the gains from powered lift. It also appeared that the weight gained by powered lift airplanes of any sort was not tolerable commercially. The little Cessna 319A of 1953 grossed 10 percent more weight than the standard L-19A. The weight penalty diminishes with increasing airplane size until for an airplane the size of the Boeing 367-80 (prototype 707) which was flown with BLC, it is only about two percent. When one considers, however, that two percent of design gross weight is about four percent of useful load and perhaps eight percent of payload, the reason for the unattractiveness of powered lift becomes apparent: with average load factors of 40-60 percent and breakeven load factors in the 40-percent-or-so range, an eight percent penalty in seats available at maximum gross weight is completely unacceptable, even though it may be suffered only part of the time.

The fate of the propeller STOL's was similar except for the Twin Otter DHC-6. The Twin Otter is in regular service as a commuter airliner, but its success is due in part to its simplicity and ruggedness; few of the nation's airports from which it operates tax its capability. The Twin Otter is on the upper end of the present general aviation size spectrum, so it is probable that unless needs for serving progressively shorter fields appear, STOL technology of greater sophistication than the Twin Otter's (double-slotted flaps and droopy, double-slotted ailerons) will be unnecessary at 12,500 pound gross weights and below.

In the large commercial airplane area, which commuter airlines can now enter, the situation is somewhat different. Increases in design gross weight are accompanied by increases in wing loading, from which follow the increases in field length requirement shown in Figure 1-3. Therefore, "to fit" into a given field, progressively heavier airplanes require progressively more sophisticated high-lift devices to increase the supporting capacity of their heavily loaded wings. Conceivably, this requirement would be encountered occasionally by a commuter serving relatively high-volume traffic, but since the relationship between demand and available runway length is generally direct rather than inverse, the occasions calling for large STOL airplanes will probably be exceptional. There exists at this time, however, a large commercial STOL airplane, the DeHavilland DHC-7, which is entering experimental service on a Canadian two-sector route, the airports on which are "close-in" STOL strips. The airplane is at the top of the size range for United States commuters operating under present CAB regulations, but this limitation is not necessarily permanent.

Recently there has been the appearance of the idea of the "Reduced Takeoff and Landing" airplane, a concept sitting somewhere between the present CTOL's and the non-existent "powered-lift" STOL category.

The technical features of RTOL are very low wing loading and/or "a little" powered lift. As explained previously, field-length requirement must be associated with aircraft size as well as with technology. The study by Savin, *et al.*, was built around a range of sizes for 40 to 300 passengers, narrowed finally to 150 passengers.[10] Gross weights of 146,000 to 206,000

[10] *Ibid.*

pounds are developed, depending on the field length requirement and the technology used. It is shown in the study that field lengths of 3,500 and 4,000 feet, at standard sea level conditions, can be realized by airplanes of this size using mechanical flaps or upper-surface-blown flaps, with wing loadings from 72 to 100 pounds per square foot. The increase in direct operating cost of such airplanes over CTOL airplanes of like capacity would be on the order of two percent or so. Interpreted as a fare increase (fixed IOC/DOC ratio) this is probably tolerable in the very special locations for which the aircraft were devised.

Technologies discussed by Savin, *et al.*, applied to airplanes of general aviation size, would produce far shorter field length capabilities. For example, the well known DHC-6 Twin Otter can in fact be considered technically an RTOL rather than an STOL airplane; its advertised minimum field length is just under 2,000 feet. The nearest counterpart CTOL, the Swearingen Metro, requires 3,550 feet at the same gross weight.

Ideally, aircraft should cruise at maximum weight/thrust or weight/ power speeds. Practically, CTOL airplanes cruise at or near minimum trip-cost speeds, which can usually be shown to be higher than are maximum weight/thrust speeds. The idea that CTOL aircraft might be reoptimized for cruise using STOL technology is attractive from this viewpoint. Using an example from long ago, the Cessna 319A STOL airplane would have had the same field length requirement as its parent, the L-19A, at a gross weight exceeding 3,300 pounds, or about 50 percent more than that of the L-19A. Reoptimizing for high speed cruise instead of short-field performance would have dropped wing area an approximately corresponding amount, and while the gross weight of the airplane would end up little less than the 319A's 2,300 pound weight, the airplane would be more nearly in match—that is, the minimum-cost cruise would be closer to its maximum weight/thrust speed. No present day small airplanes are so matched, for various reasons (the 61 knot stalling speed, for one), but some studies have indicated that energy conservation may be possible. The above example is vastly oversimplified (optimization analyses for jet airplanes, for example, must include wing-fuel volume requirements and their load-relieving effects on structure weight) but the concept is worthy of attention.

From the standpoint of technical feasibility alone, one can design an airplane to any field length requirement at all. There are other constraints, however; here are some:

(1) A short-field airport must accommodate aircraft on ramps and taxiways and terminal facilities, as well as the runway itself. Even if terminal facilities (except runways) were suppressed, the ramp area required to accommodate any reasonble number of aircraft is surprisingly large. It could conceivably be large enough so that, with parking areas laid end to end, it would be longer than the runway required. This would have the effect of relieving the short-field requirement itself!

(2) Short-field aircraft are typically considered as applied to sectors with at least one end in or near a Central Business District. Unless the presence of special features of the area—rivers or lakes, for instance—renders land acquisition cost negligible and noise and obstruction problems tolerable, the city-center "STOLport" is of questionable feasibility from the financial and public acceptance viewpoints.

(3) Short-field aircraft consume more fuel per mile than CTOL aircraft, and have greater hardware weights and greater complexity. They are therefore wasteful of energy compared to their CTOL counterparts. In the past it has been acceptable simply to assign marginal costs and to ask whether the resulting fare increases would be acceptable (the answer has usually been "yes" but nobody really knows). The rising importance of energy conservation now suggests that short-field applications should be inspected on an energy-level basis, using a concept which includes the entire supporting system along with the aircraft, and compares it with alternative systems.

V/STOL Technology

The Airship. The oldest V/STOL aircraft was of course the balloon. Unsatisfactory as a transportation device for use other than sport, the balloon quickly gave place to the airship.

Three classes of airship existed by the end of World War I:

(1) Rigid (envelope fully framed, gas carried in internal ballonets)

(2) Semi-rigid (envelope possessed a "keel" structure running its entire length and part way up the sides)

(3) Non-rigid (unframed envelope, the nickname "blimp" coming from the sound an early non-rigid made when its envelop was whacked sharply with a finger).

Rigid airships were constructed in Germany before and during World War I. The United States had one such machine completed for the Navy as a contribution toward war reparations ("Los Angeles," German number LZ 126), and built three ("Shenandoah" ZR-1; "Akron," ZRS-4; and, "Macon," ZRS-5) all of which were lost. The British built a series, the "R" airships, the last two of which, R-100 and R-101, were constructed concurrently. R-101 was lost The "Hindenburg" had a gas capacity of about 7 million cubic feet. a typical payload of about 30,000 pounds, an all-up weight of about 260,000 pounds, a 159,000 pound useful load and a maximum speed of 88 mph. By the end of the rigid airship era a total of 160 rigids had been built.[11]

Italy produced an early series of semirigid airships, and in the mid-1920's built two large ones, "Norge" and "Italia." "Italia" was lost on a polar exploration flight.

In the years from 1931 to 1972 the Goodyear Corporation built 334 non-rigids, all but 10 of them for the Navy. This represented about 75 percent of the nation's total production. The surviving non-rigids are all used by Goodyear for advertising. The company rebuilds these airships periodically using substantially the technology of the time of their design, thus keeping their Airworthiness Certificates active and current, and avoiding the need to type-certificate an advanced airship.

The airship's total lift is secured by a combination of displacement lift and aerodynamic lift. The displacement lift is of course due to the difference in weight between equal volumes of helium or hydrogen and air; the aerodynamic lift comes from the force of the passing air on the envelope; this is increased or decreased by increasing or decreasing the angle of attack, as on an airplane wing. An airship does not normally valve helium, but maintains its altitude by making the trades between displacement and aerodynamic lift that are necessary as the day progresses and the envelope warms up, expanding the helium gas within (the envelope shape and size in non-rigid airships are maintined by slipstream-air-filled internal ballonets). The larger airships could store ballast in flight by using engine exhaust condensation to replace the old sand bag ballast.

The top speed of the existing non-rigids is about 35 mph, and their usual operating altitudes are very low. A typical Goodyear non-rigid has a six-passenger (about 1,020 pounds) payload, and requires a flight crew of one and a small ground crew of perhaps six. Ground support equipment in the field consists of one large equipment van, a portable mast, and crew transportation.

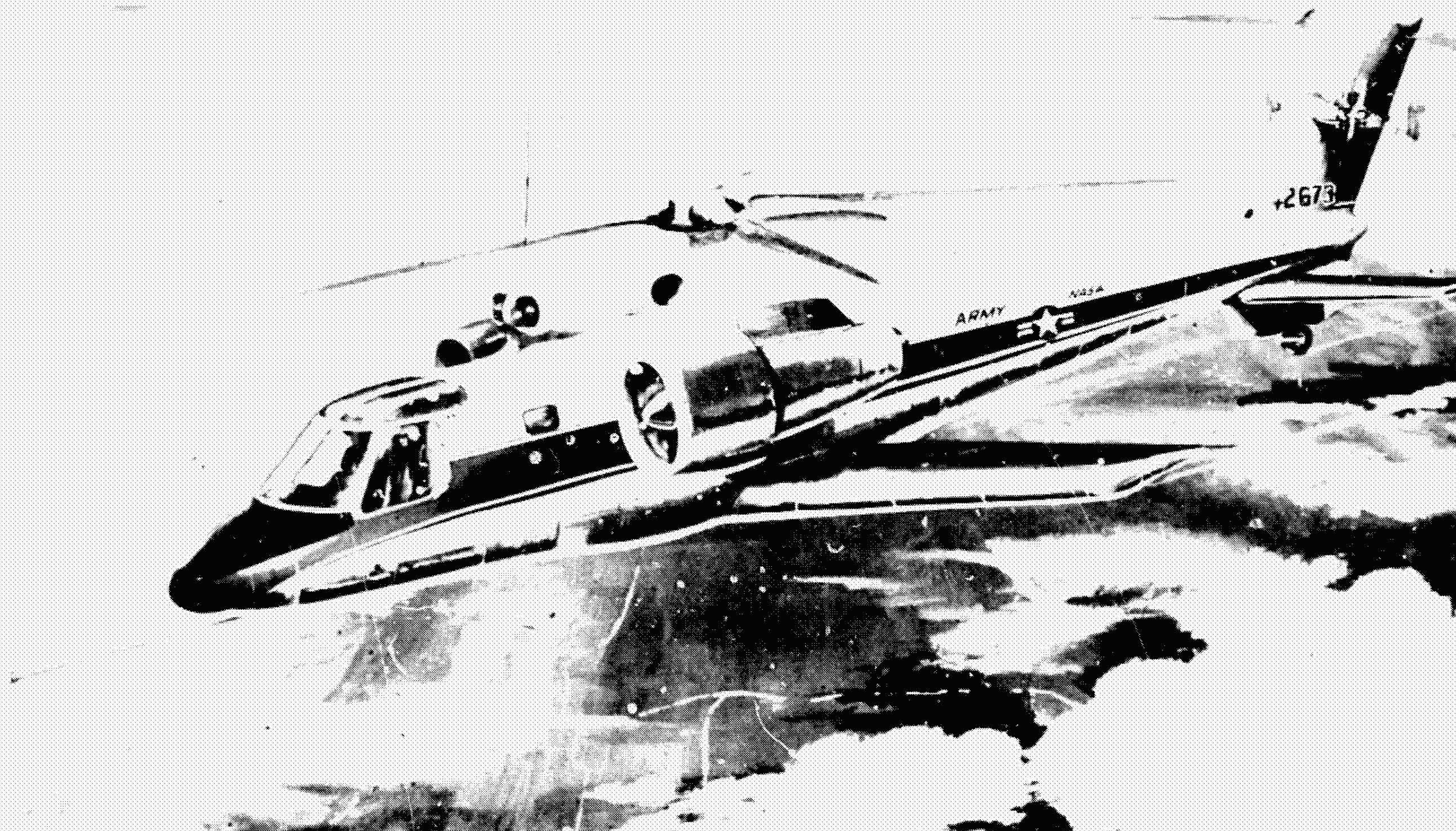
In the recent material on airships, two major technological development possibilities appear.

The first is due to the release from the limitations of the properties of meterials used in the past for hull framing, envelope, and ballonets. The airships of the early 1930's were framed with what amounted to 17ST aluminum alloy. An all-metal airship, the Navy's ZMC-2, helped stimulate the development of Alclad, which is aluminum-alloy coated with pure aluminum. Since then, higher strength aluminum alloys have become available, and synthetic fabrics have replaced the fabrics used in the old airships.

The second is an evolutionary development in hull shaping. This development has gone in several directions at once, helped by various advocates, but essentially the technical basis is the following: The cigar-shaped hull of the conventional airship is not an efficient producer of aerodynamic lift. The lift force is very weak, and is accompanied by a penalty known as induced drag (induced by lift, that is). Also this hull is unstable and tends to nose in the direction of the lift force being developed, so it must be fin-stabilized like a missle or bomb. It has thus been clear that while the cigar shape was desirable from the standpoint of minimizing drag from head-on winds, it was addressed to only a small part of the total aerodynamic problem, since an airship is seldom exposed to direct head-on winds.

On the other hand, the airplane deals with "induced" drag and stability problems relatively successfully There should, then, be some benefit to be gained from shaping an airship hull somewhat like an airplane, enabling it

[11] Vittek Joseph A Jr. (ed.) "Proceedings of the Interagency Workshop on Lighter Than Air Vehicles," MIT Flight Transportation Laboratory Report R75-2 January, 1975



ARMY-NASA EXPERIMENTAL RESEARCH HELICOPTER
(UNLOADED ROTOR WITH WINGS)
FIGURE 1-4

to take more advantage of aerodynamic lift, and alleviating somewhat the stability and control problems. The recent proposals of methods for doing this have ranged from slightly modified conventional hulls to what in the end amount to fat, light, and slow airplanes.

The results of "rational" analysis available on conventional and "hybrid" machines indicate so far that, from a cost per available ton-mile standpoint: whether conventional or hybrid, (1) the airship should be large. (2) Either type should be slow. "Slow" is on the order of 50-120 knots. As design speed increases the proportion of total lift which should be aerodynamic lift also increases. (3) Either type should fly low. The cost per ton-mile for either conventional or hybrid machines becomes forbidding at altitudes above 10-15,000 feet.[12]

If the analyses are valid and results sufficiently accurate for predicting purposes, the best field of application for a commercial airship of almost any sort should be low-urgency cargo-hauling on over-water routes, in large cargo weights. Except for such special purpose duties in performing which the airship could compete with the helicopter, this would seem to eliminate the airship from the general aviation field.

The Helicopter. Almost as soon as powered flight was achieved, the desire to fly, period, was supplemented by the desire to be able to fly straight up and to hover, in a heavier-than-air machine (see Figure 1-4).

Experiments with helicopters date back to before World War I, but the first technically practical machine was built by Sikorsky in 1939. Helicopter development since then has been evolutionary rather than revolutionary. Only three basic configurations now exist as hardware; turbine engines have replaced piston engines in the larger size machines. A helicopter-like machine, the autogyro, with unpowered rotor, has almost disappeared as a type.

Vibration problems plagued the early helicopters, but have been alleviated by replacement of the piston engine and by refinements in drive train and rotor design, particularly in large-size machines. The type, however, still suffers from relatively high initial and maintenance costs. Possibly due also in part to the paradox that its most useful flight condition, hovering fairly near the ground, is also its most inefficient and dangerous one, the helicopter in civil use is still principally a special purpose machine.

A recent configuration refinement, the compound helicopter, is being explored for the military as part of an attempt to relieve the performance limitations of low cruising speed and short range (the fastest civil helicopter can cruise at 144 knots and has a range of only 380 nautical miles with maximum cabin load).

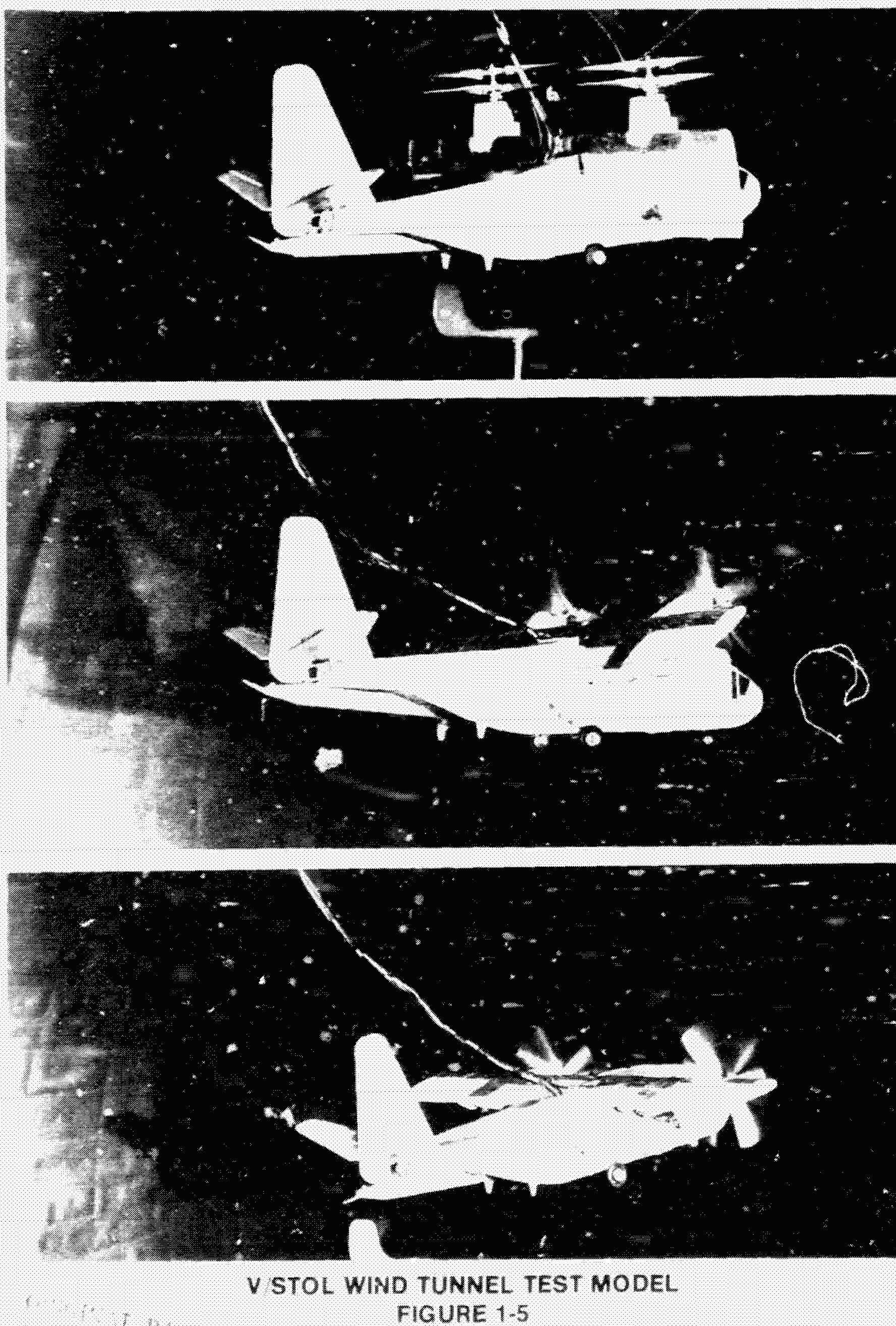
The configuration called the helicopter is definitive, though with a little more variety than hat of the airplane. During the years of greatest V/STOL research activity several other configurations were proposed: tilting rotor (which actually flew), unloaded rotor, stopped rotor, and stowable rotor compounds. These machines were attempts to break the speed limitations of the basic helicopter and some were seriously put forward for civil use. Other than the unloaded rotor compound helicopter with wings, none of these machines is now flying since their high development costs suggest that they will not be available commercially until they work their way through the military.

Non-helicopter V/STOL. There are no non-helicopter V/STOL heavier-than-air machines in production except for one subsonic attack airplane, but ideas have proliferated to a greater extent in this technological area than in any other.

A great upsurge of interest in non-helicopter V/STOL technology commenced at almost the same time as the interest in STOL technology started to be productive of hardware. The impetus was the desire to be relieved of the flying field requirement of the fixed-wing airplane along with the low top speed and poor economy of the helicopter. The military again headed the drive for development work.

By the mid-fifties several configuration and propulsive concepts were being explored (see Figure 1-5) and by the early 1960's a series of small exploratory airplanes, and three large ones, had flown briefly, all under various combinations of military support. Most exhibited marginal thrust-weight ratios and poor handling characteristics, and by now have either crashed or become museum pieces. Two airplanes had longer lives—the XC-142 "tri-service transport," on which development started late in 1960, the single prototype being turned over to NASA for research, and the British Hawker P-1127, nicknamed "Harrier" in the Unites States Marine fighter aviation inventory. The XC-142 was a four-propeller tilting wing type, with interconnected powerplants and special propellers a little like helicopter rotors.

[12] *Ibid.*



V/STOL WIND TUNNEL TEST MODEL
FIGURE 1-5

The "Harrier" is a single-engine monoplane, its turbofan engine incorporating four exhaust stacks which can swivel downward over 90 degrees for hover.

Exotic Aircraft

There is a small group of aircraft which fits into no single category such as those used above. Their performance and technology is mixed, and they are included in this section as indications of the variety of concepts that have been considered in attempts to solve aviation's problems or to increase its versatility.

Flying Jeep

The Flying Jeep was a military development intended to provide one to four soldiers with airborne battlefield transportation of the same nature as was provided on the ground by the quarter-ton truck. A V/STOL aircraft was executed; it had two shrouded propellers in tandem (or in one version four free propellers) with axes vertical, between which sat the pilot and his passengers. No version of the machine proved tractable in the air or maneuverable on the ground, and the concept was shelved.

Airplane/Car

In one form or another the hybrid airplane/car has been around for a long time, for an obvious reason—again it offers the hope of traveling in either of two transportation systems using only one vehicle. A small car has added to it a power-takeoff drive and extra components of its control system. To the car are attached, when desired, a tail containing an extension shaft for the propeller and mounting tail surfaces, and the wing. The airplane part of the assemblage can be towed home to the garage in one concept, or left at the airport in another.

The difficulties with this attractive idea seem to be the following:

(1) as an automobile the vehicle is cramped (more at least than the "family car") and laden with extra machinery;

(2) as an airplane it suffers from having to drag the car around, diminishing its efficiency as a flying machine;

(3) it has an interface problem Either it must be hauled through the streets, vulnerable to minor traffic accidents any of which can render it immediately useless as an airplane, or the airplane part must be left at the airport to accrue the usual tie-down fees or hangar rent;

(4) in flight it must be operated by a pilot; in the present state of requirements for airman training and certification the vehicle is not the answer to every householder's dream; and

(5) for airworthiness certification purposes it is an airplane, with the costs that this implies.

Considerable engineering genius nevertheless has been brought to bear on the concept, and one type is flying today, though not in commercial quantity production.

Everyman's Helicopter

The idea here is that of the absolute minimum one-man machine, consisting of a seat, a rudimentary undercarriage, a small engine, a rotor, and a handle by which to steer Such machines surface occasionally, and enjoy brief notoriety before unaccountably disappearing.

This history of appearances and vanishings seems to be the outgrowth of the fact that each such machine is a true helicopter, with the teething troubles and unstable behavior in the air that are characteristic of such craft. By the time these are ironed out, the device has grown to perhaps 400-500 pounds empty weight, no longer a plaything but a real aircraft, which must thereupon be certificated, maintained as an aircraft, and so forth.

Flying Saucers

The term "flying saucer" is not technically definable As a name for "something" the saucer seems to be on its way into the national folklore As a device or class of devices, the saucer possesses an attraction based partly on the inherent difficulty of making it fly at all; it presents a challenge.

Considered as an aircraft, the saucer-shaped vehicle can be viewed as airplane and as hovering device

As an airplane, the saucer-shaped vehicle is simply a round-winged varient of the fixed-wing aircraft The round wing is under a considerable aerodynamic disadvantage (that of excessive induced drag) compared with the slender wings with which all viable subsonic airplane types are equipped Round-winged airplanes have, however, been built and flown, most notably one conceived during World War II for the Navy as the minimal "container" for two of the heaviest piston engines. A reduced-scale prototype was flown, but the full-scale machine was rendered obsolete by the advent of the jet engine The round-winged fighter's entire wing was bathed in the slipstreams from

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its large propellers, and though not a V/STOL, the fighter did signal the resurgence of the idea of the wing-deflected slipstream and its application to V/STOL.

To hover, a vertical flow of air must be established to provide the sustaining force on the aircraft. To hover efficiently—that is, without the expenditure of much energy—the diameter of the vertical airstream must be as large as practicable and its velocity very low. This the helicopter provides admirably with its large diameter rotor. Attempts to produce a sustaining force equal to that of a helicopter, but using a device that accelerates a smaller diameter airstream faster, use more energy than the helicopter uses.

It follows that unless space limitations are critical, the helicopter is the way to go. If rotor diameter is limited (the slipstream small and fast) a ring-shaped shroud can be put around the rotor and will help some (this is the "shrouded propeller" of the flying jeep). The ring can even be configured to look like a "saucer" but there is no aerodynamic advantage in doing so, though some needed stiffness of the shroud may be gained.

There are classes of V/STOL aircraft concepts which use shrouded propellers because of diameter limitations, but they do not resemble saucers because of the inefficiency of the round wing in forward flight.

As matters stand, none of the exotic aircraft in this group has found a commercial application. Although there is always room to say "but they might in the future" and always danger in saying "they never will," there is no present reason for thinking that the compromises and inefficiencies that have characterized them in the past will be overcome to an extent that will give them a place, relative to the successful types of aircraft, more important than they now occupy.

AIR SUPPORT FACILITIES

Introduction

The interface between ground and air is a landing facility which links the air and the surface transportation systems. This facility is commonly identified as an "airport" since most of the landing facilities fall into the category of serving primarily land airplanes as opposed to seaplanes, helicopters, airships, or balloons.

More than 50 years ago it was recommended that "flight stops" be placed along the highway. Such stops would be nothing more than a landing and take-off strip adjacent to a gasoline service station. This would combine motor car and airplane service to assure maximum and dependable service. Flight stops were to be a part of the national highway system.[13] A recommendation was made that

> No arterial motor highway should be built in the future without including adjacent flight stops every 30 to 50 miles for the personal flyer. Flight stops will mean a landing area for practically every town and hamlet located on such superhighways, thus providing those small communities with an additional means of transportation.[14]

This scheme, started in the late 1920's by the Richfield Oil Corporation, failed largely due to the fact that personal aircraft were still too expensive in both initial and maintenance costs. The depression of the 1930's also played its part in preventing the commercial success of the venture.

This section will discuss various types of landing facilities with particular emphasis on general aviation airports. The discussion will include airport classification, airport design and layout, airport administration and operation, and general aviation support facilities on the airport.

Airport Classification

Classification by Aircraft Type

The ground-air interface in the United States consists of a national network of landing facilities which can be categorized by the types of vehicles served as follows:[15]

Airports serving land airplanes	11,160
Seaplane bases serving seaplanes	472
Heliports	1,430
Total	13,067

Airports are designed around one or more landing areas called runways which may range from 50 feet wide and 1,500 feet long to 500 feet wide and 14,572 feet long.[16] Seaplane bases are primarily docking facilities adjacent to natural lakes, rivers, and ocean or bay areas which support seaplanes (land airplanes with pontoons) and flying boats (airplanes designed

[13] Froesch Charles and Prokosch Walter *Airport Planning*, 1st ed. (John Wiley and Sons 1946), p 165

[14] *Ibid*, p 74

[15] Federal Aviation Administration, January 1, 1975, Statistics released in news release 75-83, May 27, 1975

[16] John F Kennedy International Airport, New York