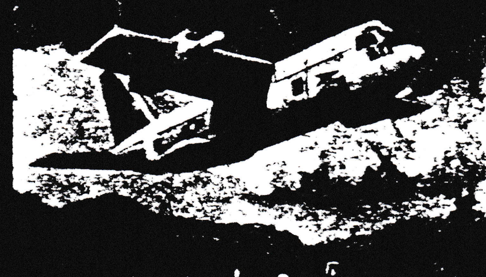
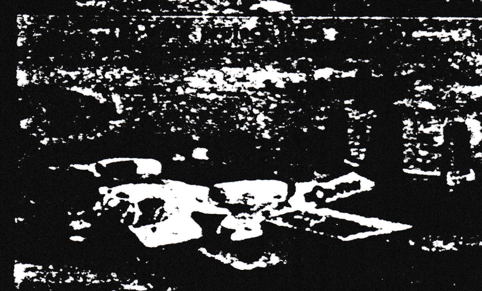
FLYING REVIEW

1962 marks start of new aviation era — VTOL ... WILLIAM GREEN gives first detailed survey of aircraft which are setting trend

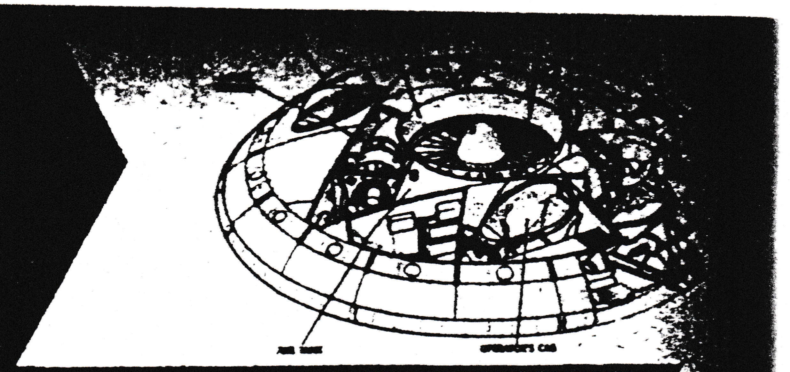
VTOL 1962

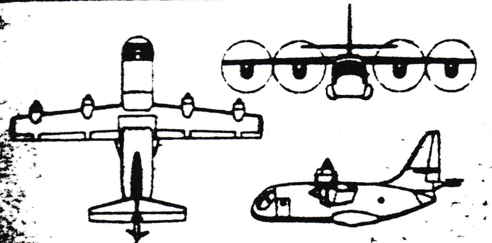
T



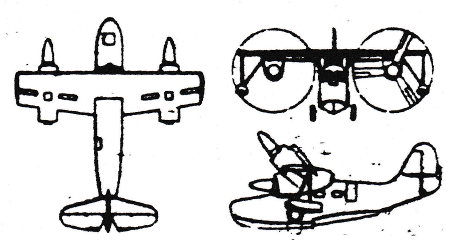


Another Sikorsky theme employing fan-in-wing

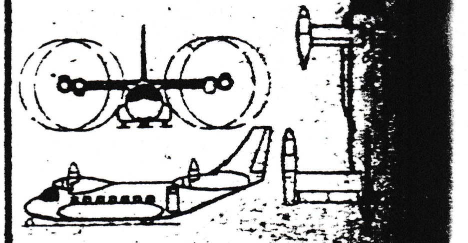




L-T-V/Ryan/Hiller Tri-service transport. Power is provided by four 2,850 s.h.p. General Electric T64-GE-6 turboprops, and the transport has an estimated maximum speed of 460 m.p.h., a cruising speed of 288-345 m.p.h., a combat radius (with 32 fully-equipped troops or equivalent payload of up to 8,000 lb.), of 290-368 n.m. Overall dimensions: span, 67 ft. 6 in., length, 58 ft., height, 26 ft.



The Kaman K-16B is powered by two 1,024 s.h.p. General Electric T58-GE-2A engines. Maximum speeds of 243 m.p.h. at sea level and 247 m.p.h. at 15,000 ft. are anticipated. Maximum inclined climb rate will be 6,400 ft./min., service ceiling being 37,000 ft. Normal loaded weight will be 8,900 lb. Dimensions: span, 34 ft. 0 in., length, 38 ft. 4 in., height, 15 ft. 11 in., wing area (flaps extended) 368 sq. ft.



Curtiss Wright LT-1 VTOL logistic [illegible] based on the private venture Model 200 [illegible] powered by four 2,850 s.h.p. General [illegible] GE-8 estimated cruising speed is 346 [illegible] maximum loaded weight varies from 4[illegible] lb. The pressurised fuselage can accom[illegible] fully-equipped troops. Dimensions: span [illegible] length, 63 ft. 0 in., height, 22 ft. 0 in.

links with concerns in other countries.

The impetus for this apparently sudden concentration on VTOL development has been engendered by a growing realisation that elaborate installations and runways upon which current combat aircraft are entirely dependent can now be knocked out by one small nuclear missile.

The British aircraft industry has been in the vanguard of jet sustained VTOL aircraft development, pioneering the two systems now almost universally considered the most suitable for high-speed combat aircraft with VTOL capabilities. The Short SC.1, employing the composite power plant system, and the Hawker P.1127, using the ducted fan turbojet with rotating exhaust nozzles, are harbingers of the future.

The year 1962 will witness the true beginnings of the race to produce real operational VTOL aircraft using the principles established by the SC.1 and P.1127.

But strike and reconnaissance fighter aircraft are not the only military aircraft to which VTOL characteristics can be applied with benefit. A VTOL tactical transport becomes a vital requirement once the VTOL strike aircraft enters service, while front-line observation, liaison and communications aircraft must also possess VTOL capabilities in the years ahead, and in the wake of the military applications must come civil developments.

Numerous Methods

The ways in which VTOL may be achieved are now extremely numerous, and little purpose will be served in attempting to list here any but those possessing definite applications and being actively pursued at this time, and helicopters and convertiplanes do not come within the compass of this survey. Nor do the tail-sitters, such as the French Coleoptre and the American Ryan X-13, Convair XFI-1, and Lockheed XFV-1, all of which have revealed piloting difficulties.

The problems of achieving VTOL can be specified as:

(1) *Generating a vertical thrust greater than the weight of the aircraft.*

(2) *Arranging to rotate the thrust from the vertical for take-off through a range of angular positions during the transition to wing-borne flight, and, finally, into the horizontal for normal flight.*

(3) *Providing adequate stability for the aircraft during the transition period.*

The following are the principal current methods of achieving VTOL:

(1) *Airscrews with axes swivelling through roughly ninety degrees, with swivelling or fixed wings (Tilt-wing or tilt-prop).*

(2) *Shrouded airscrews with axes swivelling through roughly ninety degrees (Tilt-duct).*

(3) *Lift-producing fans with fixed axes (Lift-fan).*

(4) *Turbojets with axes swivelling through up to ninety degrees or with jet deflection such as rotating jet pipes or louvre-type nozzles (Lift-thrust).*

(5) *Vertically-mounted jet lift turbojets with separate horizontally-mounted thrust turbojet(s) (Composite power).*

The choice of lifting system is largely dependent on the task for which the aircraft is intended and the performance required, but whereas the reconnaissance and strike fighter may be expected to employ either system 4 or 5, the objective being to obtain the greatest installed thrust with the minimum installed weight and volume plus simplicity of operation, the transport can utilise any of these systems or a combination of two or more. Very high forward speeds are not essential, and the optimum lift and propulsive systems can have rather different characteristics. For the front-line observation aircraft of which speeds of the order of 500 m.p.h. are demanded, the lift-fan or an augmented lift/thrust system such as that featured by the Lockheed VZ-10 appear to offer most promise.

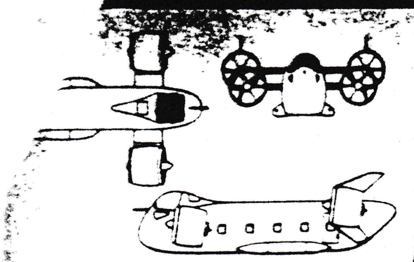
Tilt-wing . . .

The swivelling wing or tilt-wing principle is obviously best suited to tactical transports, and has, in fact, been selected for the new U.S. Tri-service VTOL transport, while feasibility studies employing this principle have been submitted for NATO Military Basic Requirement 4 (NMBR. 4). If provided with reasonable wing area, the tilt-wing transport will offer appreciably superior range and speed performance to that of the conventional or compound helicopter as it overcomes the substantial drag presented by the horizontal rotor. However, the maximum speed of the tilt-wing transport is likely to be limited by airscrew operating speeds.

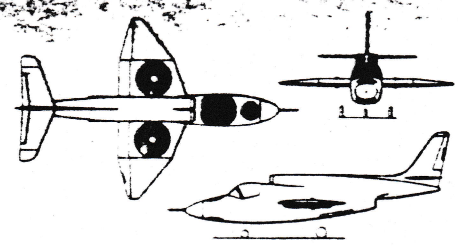
The tilt-wing principle has been pioneered by the Boeing-Vertol VZ-2, or Model 76, which, first flown in April, 1957, has made some five hundred flights, of which about half have included partial conversions to which have been added at least two score full conversions. There can be little doubt that the VZ-2's success influenced the U.S. services in their selection of the tilt-wing aircraft proposed by the team of Ling-Temco-Vought, Ryan and Hiller, from the contenders in the Tri-service VTOL transport contest in which Boeing-Vertol also participated.

One member of the winning team, Hiller, has already gained some experience in tilt-wings with the experimental X-18, which employs the modified fuselage of the Chase YC-122 transport. First flown on November 24, 1959, the X-18 has not yet effected a full conversion, although flights had been made with progressive increases in wing tilt to a maximum of fifty degrees.

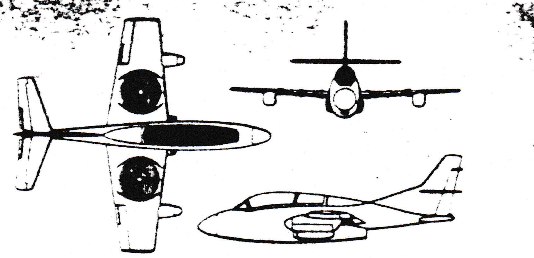
The X-18 is undoubtedly providing



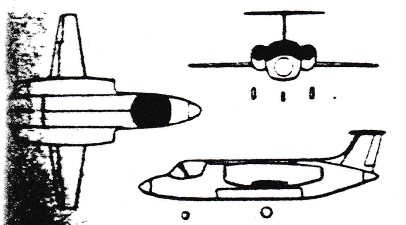
2022 tandem ducted-airscrew assault transport with four 2,850 s.h.p. General Electric T64 ... each mounted centrally in the swivelling ... Similar ducted-airscrew proposals were sub... by Douglas and Lockheed in the U.S. Tri-... VTOL transport contest. Short wing span is ... by the aerofoil function of the ducts.



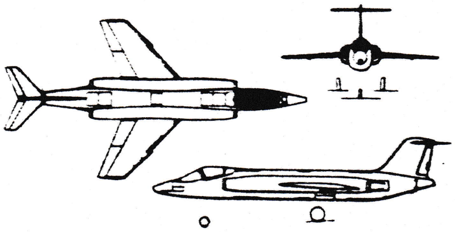
Ryan VZ-11 " fan-in-the-wing " research aircraft, two prototypes of which are under construction for the U.S. Army Transportation Research Command. Powered by two 2,580 lb.s.t. General Electric J85-GE-5 turbojets which drive two 6-ft. diameter fans for VTOL, the VZ-11 will have a maximum speed of 520 m.p.h., span is 30 ft. and length 45 ft.



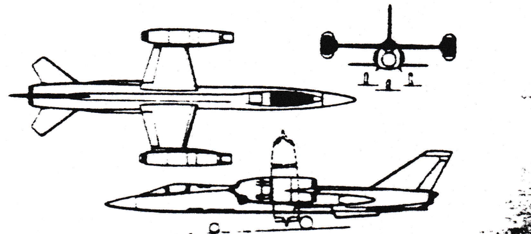
An extensively modified version of the T2J-1 Buckeye trainer proposed by North American as a test-bed for General Electric's " fan-in-the-wing " concept. Modifications include the replacement of the Westinghouse J34-WE-36 turbo-jet by the J85-GE-5 driving two lift fans, the main undercarriage members being moved outboard to provide space for the fans.



...30 Hummingbird powered by two 3,000 ... and Whitney JT12A-3 turbojets will have ... cruising speed of 520 m.p.h., a VTOL ... 300-lb. payload of 340 mls., a VTOL ... of 600 mls., a maximum initial climb rate ... and an approximate service ceiling ... ft. Maximum vertical take-off weight will ... Span is 25 ft., length 32 ft.



The Fiat G.95/3 is one of several NMBR.3 contestants of composite power plant conception. Five Rolls-Royce RB.162 jet-lift engines are installed in the centre fuselage and two Bristol Siddeley turbojets are mounted in conventional fashion at the fuselage sides. These are expected to be BS.94s which, derived from the 7,550 lb.s.t. BS.75 turbofan, have swivelling tail-pipes which direct the thrust downward for VTOL.



The Bell D.188A was to have been powered by eight General Electric J85-GE-5 turbojets, and expected to attain 1,520 m.p.h. (Mach 2.3) at 40,000 ft., a range of 1,382 mls. at Mach 0.9 at 35,000 ft., an initial climb rate of 60,000 ft./min., and a ferry range of 2,300 mls. Empty and loaded weights were 13,791 lb. and 23,917 lb. respectively. Dimensions: span, 23 ft. 9 in., length, 62 ft. 0 in., height, 12 ft. 9 in.

...ch valuable data for use in the develop...ent of the L-T-V/Ryan/Hiller Tri-...vice transport. This study was selected ...m those submitted by ten companies ... consortiums which participated in the ...test, and a start is being made this ...r on the construction of five proto-...es, the USAF, U.S. Army and U.S. ...vy all contributing to the development ...m, the USAF being the programme ...nager.

Power will be provided by four General ...ctric T64-GE-6 turboprops turning ... diameter four-blade airscrews, and ...-ft. horizontal tail rotor which will ...ly variable-pitch blades for effective ...udinal control in the hovering state. ...-shafting will be incorporated in the ...mission systems to interconnect all ... power plants and the tail rotor so ... the transport will be capable of ...aining flight on any two engines. ... vertical take-off, the wing will be ... through 100°, leading edge flaps ...ressing stall outboard of the engine ...les during the transition. A feasi-... study based on this transport has ... entered by Ling-Temco-Vought as a ...petitor in the NMBR. 4 contest, and ... subject of an agreement between ... American concern, Fiat and Sud-Avia-..., who will share in its manufacture ... the event of it being selected by NATO.

Another tilt-wing aircraft and one sche-...ed to begin flight trials this year is the ...man K-16B, which consists of the hull ... tail assembly of a Grumman JRF-5 ...ose amphibian and an entirely new ... carrying two General Electric T58-...2A turboprops driving special cycli-... controlled airscrews. The system ...ifies an extension of the Kaman ...flap principles, the 14 ft. 10 in. ...eter airscrews being equipped with ... edge flaps which vary the blade ...cient of lift and provide the pilot ... positive control at speeds below 50 ... The wing will be tilted at an angle ... for vertical take-off, this angle being sufficient as, simultaneously, large Fowler flaps will be extended to deflect the slipstream downward.

Kaman have made a number of studies for VTOL observation and light utility aircraft in co-operation with Grumman and based on the K-16B concept. The Grumman-Kaman team also entered a design study using these principles in the Tri-service VTOL transport contest.

. . . *Tilt-Prop*

The tilting-propeller types of VTOL aircraft offer much the same advantages and most of the development problems of the previously-described tilt-wing concept. Again, reasonable wing area is normally desirable, but Curtiss-Wright, who initiated a private-venture programme of tilt-prop VTOL aircraft development early in 1958, utilise what they refer to as " radial lift force," which, provided by the airscrews when tilted down for normal level flight, supplements the lift of diminutive stub wings which in themselves are too small to support the aircraft in flight.

To be powered by either two General Electric T64 or two Lycoming T55 turbines, the Model 200 will have three-blade airscrews mounted at the tips of tandem pairs of stub wings. The airscrews turn through an angle of roughly ninety degrees, being rotated upward for VTOL and gradually turned forward until transition is accomplished when the airscrews assume a conventional position for forward flight. The airscrews have rigidly-mounted blades which have no cyclic-pitch flapping hinges, dampers or drag hinges, and during take-off, hovering and landing, control is achieved by use of differential thrust and blade angles. Conventional control surfaces are used in forward flight. The Model 200 is expected to attain maximum and cruising speeds of 460 m.p.h. and 345 m.p.h. respectively; initial climb rate will be 2,730 ft./min., and gross weight will be 12,300 lb.

. . *and Tilt-Duct*

The tilting duct, or swivelling shrouded airscrew, the feasibility of which has been demonstrated by the Doak VZ-4, or Model 16, has several adherents, and Douglas have purchased all test and engineering data acquired with the VZ-4, and have hired two top Doak engineers. The company's interest in this concept was further underlined when one of the two Tri-service VTOL transport proposals submitted by Douglas made use of Doak's tilt-duct configuration. The VZ-4 employs parts of existing aircraft in its airframe, having been built purely to prove the concept, and has an 840 e.s.h.p. Lycoming T53-L-1 turbine, which drives an eight-blade, fixed-pitch airscrew in each of the two wingtip ducts. Upstream of each airscrew are fourteen guide vanes, which provide lateral stability, their pitch changing progressively as the ducts are rotated from vertical to horizontal. The airscrew axes are vertical during take-off and landing, and cruciform vanes in the turbine exhaust flow provide pitch and directional control.

In addition to Douglas, both Bell and Lockheed submitted Tri-service transport studies of tilt-duct concept. Because of the shroud's function to some degree as an aerofoil, wing area and span may be kept small in VTOL aircraft of this type, but there is a possibility of interference drag between the ducts and the fuselage in short-span configurations, and the full efficiency of the ducted airscrew is likely to depend to some extent on the use of variable geometry inlets. However, it is claimed that shrouded airscrews of this type can afford an increase of up to fifty per cent in thrust over unshrouded airscrews.

Continued on page 40

VTOL—1962

Several companies are devoting effort to devising var… forms of lift-fan which, because of its lower jet velocity, o… better fuel consumption and reduced ground erosion. Lift-f… may be mechanically coupled, either directly or through g… ing, gas coupled, or remotely driven by compressed air. … General Electric Company have been developing a combinati… of the lift-fan and conventional turbojet in which the exha… from the latter is used to drive a tip turbine around the rim… the former for VTOL, the turbojet operating in conventio… fashion for forward flight. Such an arrangement can be instal… in either wing or fuselage, but the "fan-in-the-wing" conc… appears to be currently favoured, and in December Ryan w… awarded a sub-contract for the design and construction of … "fan-in-the-wing" aircraft to participate in the U.S. Ar… Transportation Research Command's evaluation programme, … first of these experimental aircraft being scheduled to comme… trials in May of next year.

The Ryan aircraft will take-off vertically by means of a 6… diameter fan in each wing. These fans will be driven by … General Electric J85-GE-5 turbojets, diverter valves direct… the jet exhaust to the tip turbines. The turbojets are desig… to meet optimum cruise conditions, and the lift-fans supplem… the basic thrust for VTOL. Below the fans are variable … louvres to control direction of airflow for hover, transition fr… vertical to horizontal flight and vice versa, and accelera… These louvres close during normal cruising flight to prese… smooth wing surface. With one engine inoperative, the rem… ing turbojet will drive both fans, which will still provide … sixty per cent of their design lift. For forward flight, the diver… valves close the fan off to allow the turbojets to operate in co… ventional fashion. The G.E.C. "fan-in-the-wing" system e… ployed by the Ryan experimental aircraft is designated X353… and a developed version, X353-5A, will weigh 1,145 lb., and w… provide a lift thrust of 7,430 lb. as compared with a horizont… thrust of 2,580 lb. The fan will revolve at 2,640 r.p.m., the ti… speed being 720 ft./sec., and the exit louvre variation will pro… vide —15° reverse thrust to +40° forward thrust.

However, the most intriguing lift-fan VTOL aircraft yet con… ceived is probably Avro's VZ-9V Avrocar. This disc-shaped machine, first conceived during the early 'fifties, employs three Continental J69-T-9 to power a centrally-mounted tip-driven Orenda TLF-1 fan, which, in turn, provides an annular jet supporting the aircraft in hovering flight, the jet being deflected to the rear for forward flight. The U.S. Department of Defence began to evince interest in this machine in 1955, but withdrew their financial support in January, 1962, and tethered trials began on December 5, 1959, the first partial transition and forward flight taking place on May 17 last year. In forward flight, the VZ-9V's body develops aerodynamic lift in the same way as an aerofoil, and a maximum speed and range of 300 m.p.h. and 1,000 miles are anticipated.

Hummingbird

The lift-fan augments the installed power for VTOL, and another method of achieving this aim will be used by Lockheed's VZ-10, or Model 330 Hummingbird, which comes within the fourth of the previously listed methods of achieving VTOL, and which employs what its manufacturers describe as a "jet ejector augmentation principle." This enables the combined installed thrust of 6,000 lb. of two Pratt and Whitney JT12A-3 turbojets to lift an aircraft weighing 7,200 lb.

Two VZ-10 aircraft have been ordered by the U.S. Army Transportation Research Command, these being scheduled to commence trials late this year. A small, side-by-side two-seater, the VZ-10, has its turbojets mounted in nacelles alongside the fuselage above the wings with conventional intakes and exhaust pipes. The fuselage centre section between the engines is occupied by a large mixing chamber, and for VTOL two large ventral and dorsal doors are opened, a diverter valve in the jet pipe of each engine directing the high-velocity exhaust gases into the mixing chamber, where, through a combination of friction and vacuum effect, they draw a quantity of air through the open dorsal doors. This air is accelerated by the exhaust gases, boosting the vertical lift thrust by approximately forty per cent without additional fuel consumption.

Stabilization during VTOL is accomplished by gas ducted from the mixing chamber and ejected from valve ports at

Continued on page 46

VTOL-1962 —from pa

the aircraft extremities. Differential adjustment of the ... tail pitch control gas ducts results in a nose down attit... the ejection of the lift-thrust gases in a slightly rearward... tion, thus effecting the first stage of the transition to ... flight. The VZ-10 accelerates forward, lift gradually being ... ferred to the wings and the diverter valves are closed in t... exhaust gases of first one and then, when sufficient f... speed has been attained, both turbojets being ejected re... through the tailpipes, the mixing chamber doors being ...

Both the lift/thrust turbofan as used by the P.1127 a... composite power plant system of the SC.1 have their adv... Lift/thrust turbofans, the progenitor of which is the ... Siddeley BS.53 Pegasus, were developed to make pos... single-engined VTOL combat aircraft; a single power pla... would be fully effective not only during jet-supported ... flight but also during conventional wing-supported take-... landings.

The protagonists of the lift/thrust power plant insist ... greatest simplicity is achieved by having the minimum ... of engines, and simplicity is of paramount importanc... design of VTOL strike and reconnaissance aircraft int... operate in the battle area. An installed thrust around t... cent greater than its weight is needed for a practic... combat aircraft, but under normal cruise conditions ... is likely to require anything like this amount of thru...

With the tactical strike aircraft, the take-off and cr... can be treated separately, different engines being pro... optimised for each function, this composite arrangem... proposed by Rolls-Royce. Because of its low cruising ... tion and very light weight jet-lift engines (jet-lift engi... a thrust of up to sixteen times their own weight are ... developed), the composite arrangement is claimed to ... lowest overall engine-plus-fuel weight, and at first si... appears to be the most attractive solution from the perfo... viewpoint, providing the cruise flight phase is long enoug... advantage in range is obtained, however, at some cost ... plicity.

NATO's Fighter

Several of the entries in NMBR. 3 (surveyed in th... XVII, No. 4 issue) use the lift/thrust engine concept, th... advanced of the feasibility studies being conceived arou... Bristol Siddeley BS.100, which is expected to have a ratin... the order of 38,000 lb. and will employ plenum chamber ... ing (PCB), in which combustion within the by-pass duct ... to boost thrust at high speed for a modest increase in fu... sumption and without ill effect on the rotating nozzle... logical to suppose that PCB will be incorporated in the ... proposed for installation in two of the NMBR. 3 contende... Hawker P.1154 and the Fokker-Republic D.24 Alliance.

Both types may be expected to weigh upwards of 30,0... but whereas the P.1154 employs a conventional swep... with very marked anhedral, the Alliance daringly exp... advantages offered by the variable-geometry wing... speed configuration, this variable-geometry, or po... wing will take the form of a narrow delta with some ... on the leading edges, but a pair of hydraulically ... auxiliary wings, hinged at their junction with the f... will be carried over the leading edges of the delta... auxiliary wings will carry their own conventional ... surfaces, and will be spread for VTOL or STOL ... and landings.

Probably the only serious contestant in NMBR. 3 ba... the use of the BS.53 Pegasus, albeit an extensively develo... version offering some 27,500 lb. thrust (the Pegasus insta... in the P.1127 is reported to be currently rated at 12,500 lb., but the proposed production Pegasus 5 will offer 18,000 lb.) is Focke-Wulf's Projekt 1161, which is essentially the Hawker P.1127 with a redesigned wing and a Rolls-Royce RB.16... vertically mounted jet-lift engine fore and aft of the Pe... lift/thrust engine.

NMBR. 3 contestants employing the composite powe... arrangement include the G.A.M. Dassault Mirage III V ... battery of eight RB.162 jet-lift engines in the centre ... and a SNECMA/Pratt and Whitney TF-106 thrust engi... Fiat G.95/3 with five RB.162 jet-lift engines in the ... and two Bristol-Siddeley turbojets (probably BS.94 s... tailpipe versions of the 7,550 lb. thrust BS.75 turbo...

Continued o...

VTOL-1962

—from page 46—

the Short-Lockheed VTOL Starfighter development, and the VJ-101 proposed by the Entwick-lungsring Süd, a consortium of Messerschmitt, Heinkel and Bölkow. The last-mentioned project introduces a variation on the composite power plant theme, however, as it follows the concept of Bell's D.188A proposal of a couple of years ago. In fact, the VJ-101 design team, led by Messerschmitt's Dr. Robert Lusser, has received valuable assistance from Bell Aerosystems, while further aid has been obtained from Boeing, Lockheed and Martin, and Northrop are providing technical assistance on laminar flow techniques and are assisting in the design of the VJ-101's weapons system.

The Bell concept overcomes one of the major problems of composite power systems, namely, ground erosion, as the wingtip engine pods can be swivelled to face rearward for taxying, all ground running and forward flight, thus offering some of the advantages of the nozzles of the lift-thrust engine. Bell's D.188A was to have employed eight General Electric J85-GE-5 turbojets—two mounted conventionally in the rear fuselage, two in each of the swivelling wingtip nacelles, and two mounted vertically just aft of the cockpit. The two forward mounted engines, furnishing lift thrust only, were rated at 2,600 lb.s.t. each, but the thrust of all six remaining engines was boosted to 3,850 lb. by afterburning. The wingtip nacelles were designed to rotate from horizontal to 10° beyond the vertical. The transition from vertical to horizontal flight was to have been effected by lowering the nose to gain forward speed, simultaneously starting the gradual rotation of the wingtip nacelles towards the horizontal. Transition completed, the forward-mounted pair of engines were to have been shut down. The swivelling wingtip nacelles of the VJ-101 will each house four RB.162 turbojets, but difficulties in synchronising thrusts of swivelling engines may mean abandonment of this configuration. Current version is said to be designated VJ-101D.

Contrary to general belief, NMBR. 4 does not insist on VTOL characteristics but stipulates a take-off run not exceeding 500 ft., a cruising speed of 345 m.p.h., and a payload of 12,000 lb. Nevertheless, many of the contestants in NMBR. 4 are aiming at full VTOL characteristics. As previously mentioned, Ling-Temco-Vought have entered a study based on the winning design in the Tri-service VTOL transport contest and employing tilt-wing principles; Douglas, teamed with Piaggio, have also submitted a study based on one of their Tri-service entries; Focke-Wulf are entering the Fw 260, which reportedly has twelve BS.59 or R.B.162 jet-lift engines in wingtip pods, plus two BS.75 turbofan thrust engines. Most other entries are STOL suitable for development for full VTOL.

The Hawker Siddeley Group studied several V/STOL transport concepts, including tilt-wing types, and, December 15th, signed a collaboration agreement with de Havilland (Canada), Bell Aerosystems, Avions Fairey and Nord Aviation. The British Aircraft Corporation, which have entered a scaled-down version of the BAC 208 in NMBR. 4, are co-operating with Finmeccanica and the Dornier-Werke; the Dornier-Werke have an independent design incorporating BS.53 engines podded beneath the wings; Agusta have entered a novel design in which General Electric T64s are mounted in both tractor and pusher installations, and Handley Page are entering a T64-powered STOL version of the Herald.

Both BAC and Whitworth-Gloster have had potential STOL replacements for the Beverley on the drawing boards for a long time. these, the BAC 208 and the A.W. 681, competing for MoA sponsorship, and VTOL Mark 2 versions of both designs are proposed, with BS.53 Pegasus lift/thrust engines coupled with batteries of jet-lift engines.

There can be little doubt that VTOL has an assured future, but many, many problems have still to be solved before aircraft endowed with these characteristics become commonplace, and it still remains to be seen if the large, fixed-wing aircraft relying on vast and expensive runways will prove to have been no more than a passing phase in flight's history as some already believe! ●