German V/STOL Rotorcraft and Propellercraft Designs of the Twentieth Century

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11 May 2001
Background

• Second in a series of papers that will form the basis for the V/STOL Encyclopedia series

• Vol 1: German V/STOL Concepts
  – German V/STOL Fighters - AIAA/AHS/SAE IPLC, Nov 2000 (65 concepts)
  → German V/STOL Rotorcraft and Propellercraft - AHS Forum 57, May 2001 (75 concepts)
  – German V/STOL Transports - SAE WAC, Sep 2001 (?? concepts)

• Vol 1 to be published in 2002

• Future volumes in the planning stages
Overview

• Background
• Dawn of Vertical Flight
• World War II Designs
• Post-War Designs
  – Messerschmitt
  – MBB
  – Bölkow
  – VFW
  – Eurocopter
• Summary
V/STOL Wheel of Mis-Fortune

Depicted here are the various types of Vertical and Short Take-Off and Landing (V/STOL) aircraft which have been tested over the past 45 years. All were built to be flown, but only three [shown in bold] have led to operational aircraft. In fact, the Harrier is the only V/STOL aircraft in service today.

The Joint Strike Fighter concept demonstrators (shown in blue), are scheduled to fly in 2000; one of these concepts will serve as the basis for development of an aircraft to replace the Harrier.
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<th>Year</th>
<th>Aircraft/Engine</th>
<th>Notes</th>
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<td>Helicopter Mode</td>
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<td>1955</td>
<td>Curtiss-Wright X-100</td>
<td>Same Propulsion System for Hover and Forward Flight</td>
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<tr>
<td>1960</td>
<td>Bell XV-3</td>
<td>Bell X-19</td>
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<td>1965</td>
<td>Bell XV-5</td>
<td>McDonnell XV-1</td>
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<td>1970</td>
<td>Dornier Do 31</td>
<td>Combined Power Plant for Hover</td>
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<td>1975</td>
<td>Lockheed XV-4B</td>
<td>McD°nnell XV-1</td>
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<td>1980</td>
<td>Nord 500 Cadet</td>
<td>Augmented Power Plant for Hover</td>
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<td>1985</td>
<td>Canadair CL-84</td>
<td>Same Propulsion System for Hover and Forward Flight</td>
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<td>1990</td>
<td>Bell X-22A</td>
<td>Vanguard 2C Omnijet</td>
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<td>1995</td>
<td>BAE Boeing Harrier</td>
<td>Rockwell XFV-12A</td>
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<tr>
<td>2000</td>
<td>BAe Boeing V-22</td>
<td>Bell BA609</td>
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V/STOL History: 1950 - 2000
“The V/STOL Pyramid”

Operational V/STOL Systems:
- Harrier
- Forger

Flight Test:

Large-Scale Testing:

Design Concepts / Small-Scale Testing
Pre-Historical V/STOL Concepts

- 1909 Boris Loutsky, Berlin
  - biplane helicopter (flown?)
- 1909 M. Sagert, Magdeburg
  - biplane helicopter (flown?)
- 1910 Gustave Mees, Charlottenburg
  - twin tilted rotors (design)
- 1925 Jacob Nöggerath, Berlin
  - first tilt-wing? (design)
- 1925 Rudolph Chillingsworth
  - compound quad stopped rotor (built?)
World War II Designs

- Weserflug P 1003/1 Tilt-Wing (design)
- Focke-Achgelis Fa 269 Convertible Helicopter (mock-up/component tests)
- Flettner Fl 185 Powered Autogyro (flown)
- Flettner Fl 201 Dual Rotor Powered Autogyro (design)
- WNF Wn 342 V3 Tip Jet Autogyro (flown)
- WNF Wn 342 V4 Tip Jet Autogyro (flown)
- Focke Rochen (design, later component tests)
Weserflug P 1003/1 Tilt-Wing

- Weser founded in 1933
- P 1003 begun in 1938
- 900 hp Daimler Benz DB 600
- 4 m propellers
- 650 kt
- 2000 kg
- Model testing
Focke-Achgelis Fa 269
Verwandlungshubschrauber

- Focke study began in 1938. Received contract in 1940.
- Vertical take-off and landing fighter
- Design speed: 0 - 325 kt
- 4 m propellers, tilting to 85°
- Initially used two DB 601 or 605 engines in the wings; later changed to a single air-cooled BMW 132 K in the fuselage
- Expected to have a 13° AOA nose bias during level flight
- Mock-up and designs destroyed during Allied raids in July 1942
Prior to building successful Fl 282 Kolibri with intermeshing rotors, Fletter built autogiros.

Fl 185 was a powered autogyro with a pusher and tractor propeller.

Gross weight 900 kg (1,985 lb)

In 1938, encouraging flights were conducted at low altitude.

In forward flight, both propellers provided thrust.

In some flight conditions, however, the machine had problems with vibrations.

Fw 61 had much better performance, so design was abandoned.

Larger, proposed Fl 201 “heligiro” used twin rotors augmented by twin turboprops.

30-40 troops, 80-90 ft diameter rotors, 140 mph.
**WNF Wn 342 Tip Jet Autogyros**

- Wiener Neustadter Flugzeugwerke (WNF)
- Design led by Dr. Friedrich von Doblhoff
- Used tip jets for rotor power
- Intended for deployment from U-boats
- First prototype (V1) tested in Oct 1942
- V3 & V4 used tip jets only for take-off/hover
- Clutch transmitted power to propeller for forward flight
- Vienna was overrun before flight testing the V4; later tested in the U.S.
Doblhoff Tip Jet Rotor Head

- Fuel consumption was 9 times higher than conventional helicopter!
- 109 dB noise 3 m from the rotor tips!
Focke Rochen

- 1944 design
- Two counter-rotating propellers
- Vectored downwash via louvers
- Louvers could be closed for gliding if engine was lost
- Engine exhaust ducted for yaw and roll control
Focke Rochen

- After the War, Focke filed a patent in September 1957
- Model tests conducted in Bremen in mid-1950s
DSH J-62

- Deutsche Studiengemeinschaft Hubschrauber (DSH = German Society for the Study of the Helicopter)
- Led by Dr. Walter Just
- 1953 design
- 1,800 kg touring helicopter with 4 to 5 seats
- Powered by twin turboprop engines
- The 12 m tip jets rotor
- Cruising speed 108 kt
- Maximum speed 130 kt
- Range 378 nm
Focke-Wulf Buried Propeller Designs

December 1962
Messerschmitt Me 408 Rotor-Jet

- Between 1962 and ~1972, Messerschmitt studied a number of designs adding folding rotors to otherwise conventional transport aircraft
- Cruise thrust via shaft and gas-powered fans
- Extensive rotor tests conducted
Me 508 Demonstrator
Rotor-Jet Folding Rotors

- 1968 test stand trials with 2 m diameter
- 1968/69 full-scale wind tunnel tests at transition speeds (135 kt)
Rotor-Jet Propulsion System
## Refined Me 408 Concept

**Diagram of the Refined Me 408 Concept**

### Specifications

- **6-8 pax; 2 crew**
- **Cruise speed at 29,500 ft was 405 kt**
- **Range:**
  - 920 nm with 1,590 lb payload
  - 1,650 nm with no payload

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
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<tr>
<td>Wing span</td>
<td>34.5 ft</td>
</tr>
<tr>
<td>Length</td>
<td>35.5 ft</td>
</tr>
<tr>
<td>Rotor diameter</td>
<td>19.7 ft</td>
</tr>
<tr>
<td>Cargo volume</td>
<td>277 ft³</td>
</tr>
<tr>
<td>Empty weight</td>
<td>6,762 lb</td>
</tr>
<tr>
<td>Gross weight</td>
<td>11,023 lb</td>
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www.vtol.org
Me 2020-4 Transport

Wing span 76.4 ft
Length 70.4 ft
Rotor diameter 44.3 ft
VTOL payload 19,975 lb
Empty weight 37,345 lb
VTOL weight 57,320 lb
STOL weight 66,140 lb
Passengers 55
Payload 13,225 lb
Range 650 km
Cruise speed 390 kt
Max speed 470 kt
Bölkow/Heidelberg Hubstrahler

- Research began in 1956 under Götz Heidelberg
- Significant testing on low pressure reaction ‘rotors’ (Hubstrahler)
- Captive hovering testbed, called a Flying Jeep was tested in 1961
- Supplied air by a ground based compressor
- Basis for a turboshaft powered military version
Bölkow/Stöckel Stopped Rotor

P 109: 1954-58

Rotor diameter from 5.6 ft to 9.8 ft
July 1955, Hans Derschmidt filed a patent for a swiveling rotor:
  - lead-lag hinge at about the 40% span of each rotor
  - outer span of the rotor could pivot 40° backwards
  - reducing the tip speed of the advancing blade
  - very high rotational speeds by the retreating blade

Initially called P 87, received the designation Bo 46
Bo 46 (P 87) Design Studies
Dual Derschmidt Rotors
MBB BBH 1 & 2

- speed 200 kt
- climb rate 65.6 ft/s
- load factor 3-4 g
- endurance 2.5 h
- OGE hover 8,200 ft
- 2 seat, armored
- all-weather capable

- MBB = Messerschmitt-Bölkow-Blohm
- BBH = Bewaffneter Begleithubschrauber (armed escort helicopter)
- 1968 RFP
- BBH 1 = 12,600 lb, 6 bladed rotor, small wing
- BBH 2 = 13,000 lb, 4 bladed hingless rotor, large wing, prop
- 1979 Franco-German MOA led to Eurocopter Tiger today!
MBB Bo 120 X1 and X2

- High Speed Helicopter Program
- Intended to use Bo 46 as demonstrator
  - hingeless Bo 105 rotor system
  - wings + lift engine!
- Demonstrator was to provide data for future high speed helicopter programs
- 245 kt planned
- In early 1975, Bo 105 + wings reached 220 kt
- Tilt-rotor and other designs also studied
Dornier Designs

P 407
• Four seats
• Twin engine compound

P 410
• Tail rotor could swivel 35°
• Max speed = 230 kt
• Cruise speed = 200 kt
• Twin engine (T53) compound
Merckel Designs

E 130
- Used automatic blade angle reduction at positive flapping angle
- Max speed = 315 kt
- Each engine also drove an aft fan

M-133
- Demonstrator to prove E 130 concept
- To use Bo 46 fuselage
- Max speed = 295 kt
Weser Tiltpropellers

WPG P 16
- 1963 research design
- Anti-helicopter fighter
- Tail fans for control thrust
- Gross weight = 4,075 lb
- Max speed = 362 kt

WPG P 23
- 1963 design
- civil/transport roles
- Tail fans for control thrust
- Gross weight = 9,700 lb
- Max speed = 351 kt
VFW Compound Helicopters

- VFW = Vereinigte Flugtechnische Werke (United Aeronautical Factory)
- Combined Weser and Focke-Wulf (plus Heinkel, Rhein, and Henschel)
- Studied a number of compound helicopters (H2, H3, H5, H7, H8, H9)

- Used cold compressed air to power rotor
- Used blade tip burners for hover & take-off
- Ground testing began in March 1964 (110 hr)
- First flight April 1965
- 36 flight hours by Sept 1966
- 140 dBA measured at 11.5 ft

Rotor diameter 20.3 ft
Empty weight 335 lb
Flying weight 595 lb
Maximum speed 70.1 kt
Cruising speed 56.7 kt
VFW H3 “Sprinter”

- Design begun in 1966 as prototype
- Rotor powered by compressed air
- Yaw control by engine exhaust vanes
- Three prototypes
- First flight (E1) May 1970
- Second aircraft (E2) January 1971
- 75 hours of flight testing

Rotor diameter: 28.5 ft
Empty weight: 1,091 lb
Flying weight: 2,134 lb
Maximum speed: 162 kt
Cruising speed: 135 kt
Range: 270 nm
• Final design with shrouded propellers was never tested
• Intended to divert air from rotors to propellers for high speed cruise
VFW Follow-On Designs

H5 Mock-Up

- H5 intended for 5 seats and higher speed
- H7 intended for 7-8 seats
- H8 refined combat H7
- H9 armed escort helicopter

H9 Concepts
Eurocopter Eurotilt Design

- MBB + VFW + many others = Eurocopter
- Early 1990s, Eurofar - 30 pax, 14 ton commuter tiltrotor
- Currently, Eurotilt - 12-19 seat executive transport, SAR, offshore
  - 10 tons, 330+ kt, 750 nm range
“The V/STOL Pyramid”

Operational V/STOL Systems:
- Harrier
- Forger

Flight Test:

Large-Scale Testing:

Designs Concepts / Small-scale Testing
Summary

- About 75 different German V/STOL Rotorcraft and Propellercraft documented
- Most were design studies only
- Some achieved significant component testing
- 4 conducted limited V/STOL flight testing
- None were tested extensively or reached production (less than 100 hours total!)