

# Case Study: Junkers 87 'Stuka'

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## 1 ABSTRACT

This case study examines the Junkers Ju 87 'Stuka', a German dive bomber designed and deployed during the Third Reich. The study begins by giving context for the Stuka, and an examination of the motivations behind dive bombing, before proceeding to an in depth analysis of the construction and aeronautic performance of the Stuka. Where possible primary source material such as the surviving Stuka at RAF museum Hendon, and German maintenance manuals have been used. All other evidence has been gathered from secondary historical commentary; and all calculations have been informed by technical reports and textbooks.

When calculating operational parameters for the Stuka, it is necessary to consider that the Luftwaffe deployed the Stuka in the Western and Eastern fronts, as well as the Desert and Mediterranean theatres. Accordingly, calculations have been performed for the hottest and coldest temperatures at which the Stuka operated, as well as using meteorological data from the Battle of Britain as a model for ideal operational conditions.

## 2 JUNKERS JU 87

The Junkers Ju 87 design, the development of which was lead by Hermann Pohlman, began development in 1933. First flown in 1935 (Weal 1997, p. 9), the Stuka succeeded a previous Junkers Ju 47 K dive bombing design, which had been rejected by the German Reichswehr (defense ministry) as too expensive, and replaced the Heinkel He 50 as the dive bomber of choice for the Luftwaffe. Heinkel had also been developing a competing design, the 118, but failed to win the contract when their design could not demonstrate the prerequisite ability to dive at a 90° angle, disintegrating during flight (Killen 1967, p. 68-69) and forcing the pilot and judge of the competition, Ernst Udet, to bail out.

The dive-bomber design emerged as a solution to the need for precision bombing of tactical objectives during the later stages of WW1, and was eventually replaced by improvements in bomb sighting, increased bomb payloads, and guided weaponry. Dive bombers would align themselves laterally before engaging in a dive towards a target, descending to a given height to release their payload and then pull out of the dive. Diving aligned the velocity of the aircraft in the direction of the target, and reduced the distance travelled from release to impact; this significantly reduced targeting complexity, and correspondingly shrank the circular error probable (CEP), the region in which 50% of munitions were predicted to land. In comparison, horizontal bombers using unguided bombs had to compensate for a parabolic bomb trajectory where a bomb had horizontal velocity at launch and was acted upon by drag and gravity during flight. Even in calm weather, using tachometric bombsights, horizontal bombers during WW2 had large CEPs and could not accurately hit small targets, being more suited to mass scale interdiction bombing 'area-denial' sorties.

The increased accuracy offered by dive bombing was tactically significant, enabling both close air support of ground forces in combined arms operations without risk to engaged units, as well as accurate attacks against shipping which had been difficult to accomplish with interdiction bombing; however, diving towards targets placed aircraft at increased risk from surface fire, and steep diving maneuvers limited payload weight and placed increased stress on the craft. Dive bombers were also targets of opportunity for enemy fighters, since their diving manoeuvres were predictable and broke from protective formations, and they could not match the manoeuvrability or speed of fighter craft; this, in conjunction with improvements in bombing technology, lead to the decline of the dive bomber after WW2.

## 2.1 PAYLOAD

# 3 GENERAL DESIGN OF THE JU 87

## 3.1 BODY

The Stuka was a twin seater monoplane, with the fuselage acting as an anchor for two spars, one for each wing, which served to distribute the load caused by lift and enable the cantilever of the wings. The use of an anchored spar had been pioneered by Hugo Junkers in 1915 (Nasa 2016) in the Junkers J 1, who found that the improved strength of an anchored spar provided sufficient support to allow for an all metal design with cantilevered wings. Single wing designs based on this principle then superseded the previous biplane designs, which were hampered by aerodynamic interference between the two wings, as well as by increased drag from the supporting structures necessary to reinforce the wings (Peery 2012, p .37). Due to a complex wing shape, the Stuka used the same principle of anchoring spars in the fuselage, but required two spars instead of one.

The Stuka's fuselage was constructed from two oval chassis sections, which were joined using rivets along the longitudinal axis. Internally, each section was attached to a series of longerons which ran the longitudinal length of the Stuka, and which were attached to a series of u-shaped frames. The use of longerons as opposed to stringers served to reinforce the Stuka for the increased load experienced during pullout from the diving maneuver (Peery 2012). Additionally, to further increase the structural integrity of the tail, which experienced extreme load during pullout, significantly more frames were used in the tail section than the body (figure. 1).

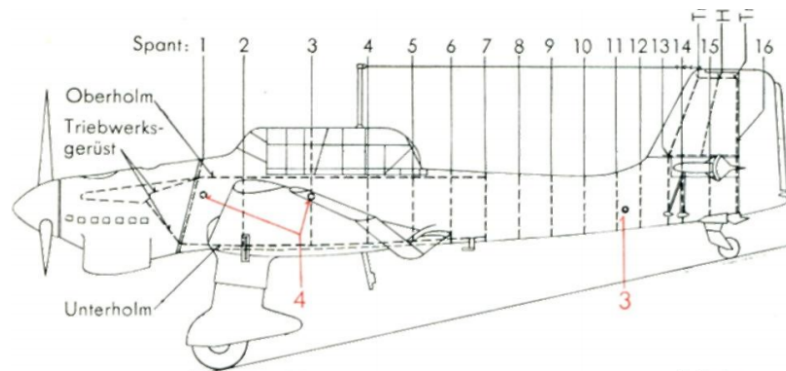


Figure 1: Frame or rib (German: *spant*) distribution in the Stuka body (Unknown 1939)

## 3.2 WINGS

The Stuka had low mounted polyhedral wings which were formed from two spars, and consisted of three sections; a central section and a port and starboard section. The central section was depressed to an anhedral angle of 8 degrees, while the two other wing sections had a dihedral angle of 12 degrees. The total wingspan was 13.8m, giving a total wing area of 31.90m<sup>2</sup>; the length of the anhedral part of the wing on one side of the Stuka was 1.05m, while the dihedral part was

5.5m (approximate) <sup>1</sup>. The justification for using an inverted gull-wing is not clear from documentation, since the polyhedral design complicated manufacture and added weight; however, a similar wing configuration can be found in the 1940 F4U Corsair, where the polyhedral design allowed shorter landing gear while still providing clearance for a 4m propeller (Sibila 2016) - the Stuka's own propeller was 3.5m. As the landing gear of the Stuka were fixed, reducing their length would reduce drag. Another effect of the design was to cause the low mounted wings to protrude from the fuselage at a perpendicular angle, which would reduce interference between the wing and the body (Hartshorn 1931, p .203). A final reason for the design could have been to improve the pilot's visibility of the ground; the cockpit was located above wings of the Stuka, and so the low mounting and anhedral angle would act to remove the wings from the pilot's field of view (Guardia 1914, p .16).

### 3.2.1 LIFT CALCULATION

For the purposes of simplification the anhedral portion of the wing is treated as flat, since no mathematical model could be found to calculate a polyhedral wing with anhedral and dihedral parts. Calculation is done for temperatures of **-20.7 C** (Battle of Stalingrad low (Hartshorn 1988, p. 731)) and **23.6 C** (Battle of Britain high (*Meteorological data, Oxford, 1853 - 2016* 2016)). Given these conditions, the following values are used for calculation.

$$L = \frac{1}{2} \rho V^2 S_{ref} C_L$$

$L$	Lift	
$\rho$	Density	
$V$	True Airspeed	
$S_{ref}$	Reference Area	
$C_L$	Lift Coefficient	(1)

### 3.3 CONTROL SURFACES

Beneath the trailing edge of the wing were hinged full-span ailerons which were operated using hydraulics. To fit the wing, these ailerons were also divided into three sections.

### 3.4 MATERIALS

The body itself was made principally from duralumin, an aluminum alloy composed from copper, magnesium, and manganese<sup>2</sup>, except in cases where parts were required to be more resilient to daily wear, in which case stronger magnesium alloys were used to reduce the need for maintenance (Guardia 1914, p. 15).

<sup>1</sup>No exact values could be found for wing sections, so lengths were calculated based on known wingspan and cockpit width, and proportions from scale drawings found in Junkers manuals (Unknown 1939)

<sup>2</sup>Unfortunately, precise values for the alloy could not be located, but the general composition of duralumin is 93.5 - 95% aluminum, 4% copper, 0.5 - 1.0% manganese, and 0.5 - 1.5% magnesium (Wardlaw 1933, p. 102-103)

## 4 TESTING, PRODUCTION, VARIANTS

### 4.1 TESTING

### 4.2 PRODUCTION

All Stuka variants featured reversed gull wings, a 'broken nose' [reference] hump to the fore of the cockpit, and fixed landing gear with aerodynamic spatting(Curry 1988, p. 4), lending the appearance of [quote, reference].

As a wartime plane, the Stuka had a number of evolutionary variants as Luftwaffe requirements changed during the course of the war. Principal among these were the Ju 87A (pre-war prototype), Ju 87B (early war, Battle of Britain), Ju 87D (late war, improved performance), and Ju 87G (anti tank close support role).

### 4.3 JU 87A

The 87A went through a number of iterations in the lead up to WW2, until it was eventually replaced by the Ju 87B production design.

image of Ju 87A

### 4.4 JU 87B

Motor : Jumo 211 A/1

### 4.5 JU 87D

### 4.6 JU 87G

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