NASA TM-77952

AIRCRAFT OF THE FUTURE

NASA-TM-77952 19860003850

S. Yeger

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546, NOVEMBER 1985

1. Report No. TM-77952	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle AIRCRAFT OF THE FUTURE		5. Report Date November 1985
		6. Performing Organization Code
7. Author(s) S. Yeger		8. Performing Organization Report No.
		10. Work Unit No.
		11. Contract or Grant No. NASW-4006
9. Performing Organization Name and Address The Corporate Word, Inc. 1102 Arrott Bldg. Pittsburgh, PA 15222		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546		14. Sponsoring Agency Code

15. Supplementary Notes   Translation of "Flugzeuge der Zukunft," Technisch-oekono-mische Information der zivilen Luftfahrt, Vol. 13, No. 2, 1977, pp. 88-90 (Grazhdanskaia Aviatsiia, No. 7, 1976) (A77-39452).

16. Abstract

Some basic problems connected with attempts to increase the size and capacity of transport aircraft are discussed. According to the square-cubic law, the increase in structural weight is proportional to the third power of the increase in the linear dimensions of the aircraft when geometric similarity is maintained, while the surface area of the aircraft increases according to the second power. A consequence is that the fraction of useful weight will decrease as aircraft increase in size. However, in flying-wing designs in which the whole load on the wing is proportional to the distribution of lifting forces, the total bending moment on the wing will be sharply reduced, enabling lighter construction. Flying wings may have an ultimate capacity of 3000 passengers.

17. Key Words (Selected by Author(s))		18. Distribution Statement Unlimited	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 9	22. Price

N 86-13318# A77-39452 (ORIGINAL)   N-155,755

AIRCRAFT OF THE FUTURE

S. Yeger

The steady growth of air traffic in a number of   /88
countries has lead to a substantially increased number of
commercial aircraft in air traffic operations. The result has
been that the carrying capacity of many, even very large
airports, is approaching its upper limit. As a result, air
traffic specialists are confronted with the problem of managing
continued air traffic growth without further increasing the
number of aircraft.

The problem has been solved in various ways, among others by
designing and constructing jumbo aircraft with 300 to 500 seats
to replace several conventional aircraft. One representative of
this genre is the jumbo aircraft IL-86, developed in the USSR.

A number of specialists involved in designing, constructing,
and operating aircraft are of the opinion that the period
between 1980 and 2000 will witness further increases in
dimensions and capacities of passenger aircraft up to 1000 or
2000 seats. Opinions on this matter vary greatly, however.
This may be explained by certain technical problems involved in
producing gigantic aircraft, mainly with difficulties in
obtaining necessary mass relations.

Aircraft exhibiting the largest payload at a given range
possess the highest efficiency. As dimensions change, however,
the relative masses of such elements as the power plant change
while those of fuel and equipment basically do not. .For this
reason, the increase or decrease of the load mass caused

---

*Numbers in the margin indicate pagination in foreign text.

by dimension variations is dependent above all on the aircraft's relative structural weight which has direct influence on economic efficiency.

The battle over reduction of the mass of such structural elements as wings, fuselage, empennage, and undercarriage goes clear back to the origins of air travel. Research on the laws governing changes in dimensions and mass of aircraft parts began at the same time. They came to be expressed in the "Square-Cubic Law."

According to the square-cubic law, the increase in structure weight is proportional to the cube of the increase in the linear dimensions of the aircraft when geometric similarity is maintained (while the surface area of the aircraft, including the wing surface, increases proportionally to the sqare of the linear dimensions). Since the surface load must be kept constant to maintain take-off and landing characteristics, as well as for flight behavior, the take-off mass has to change proportionally to the square of the linear measurements. Therefore, the relative structural mass increases proportionally to the aircraft's dimensions and the payload portion will decrease.

One consequence of the square-cubic law is an uninterrupted increase in construction mass greater than that of other mass portions as when linear dimensions increase. The necessary relative portion is not preserved for the other elements, making it impossible to produce an aircraft with the desired characteristics. This means that the extent to which an aircraft can be enlarged is limited. Practical aircraft   /89 construction has, however, already extended beyond the limitations on aircraft growth formally dictated by the square-cube law.

The principle lies in the fact that only a portion of the structural mass is determined by exterior forces, and it represents mass relevant for guaranteeing strength.

The remaining portion is determined by additional installations and auxiliary elements, with their portion decreasing as the aircraft becomes larger. This increases the structure's mass efficiency. At the same time, excess strength decreases, a factor which is determined by various technological factors and the structure's local strength margins. Stresses increase in the elements working on pressure. Furthermore, practical enlargement of linear measurements allows the similarity of the aggregate and the inner structural elements to remain in tact. This, too, helps to slow down the growth of relative structural mass.

The most essential point, however, is exact consideration of the basic forces involved in the airfoil's progression through the square-cube law. In fact, the bending moment's resultant which puts stress on the airfoil's elements of longitudnal bond is determined by a force which is smaller than the thrust. The amount of this force is smaller than the airfoil structure's mass force, the entire load stored in the airfoil (fuel, equipment), and the load attached tq it (engine with cockpit, landing gear).

This type of surface discharge caused by mass force lightens the structure substantially. An aircraft consisting solely of an airfoil would be the ideal situation. If the entire load in the wing can be adjusted proportionally to engine distribution, as well, bending moment will approache zero, and the structural mass will reache a minimum.

This idea was the basis of the flying wing aircraft which was very popular between 1930 and 1950. In spite of its

popularity, however, this construction was no more efficient than conventional aircraft forms.

The flying wing aircraft requires large dimensions and surface areas to accommodate passengers and freight. The specific surface load is small with low flight mass and relatively large surface area. The thrust coefficients attained during flight are small, as well. Therefore, the attainable aerodynamic efficiency in air travel by no means reaches its maximum value.

Speed increases intensify this disadvantage: As thrust increases, lift/drag ratios deteriorate even more. It was more advantageous to use a smaller wing which could be flown at maximum efficiency in air travel. This allowed for accommodation of the load in a fuselage elongated in flight direction. The fuselage possessed a small cross section. However, this made it possible to reduce the total drag only by retaining the conventional set-up.

Calculations reveal, however, that the flying wing aircraft is advantageous for a 1000-seat aircraft. The airfoil dimensions required to attain maximum aerodynamic efficiency are so large that the flying wing can accomodate passengers, baggage, fuel, and equipment.

At present, model procedures are being prepared, and methods have been developed to calculate the mass of aircraft parts, so that it is possible to control structural mass changes while making large alterations on the aircraft (even without maintaining geometric similarity).
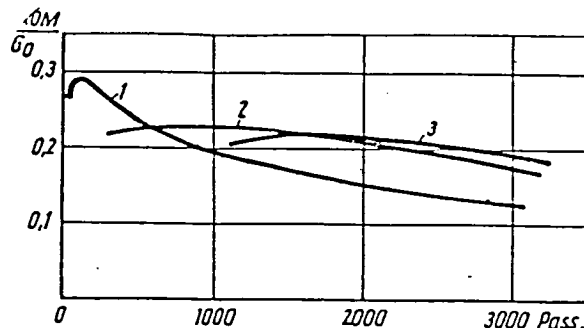
Figure 1:   Change of payload portion on the total mass of
a commercial aircraft as a function of the
number of seats.

Figure 1 shows the payload portion of an enlarged,
conventional subsonic aircraft with an assumed range of 3000
kilometers.

First, the mass of an imaginary aircraft is calculated
without each payload portion (G_{KOM} = 00. Then payload is
increased slightly, so that the total mass G_0 becomes greater
for a payload portion $\overline{G}_{KOM} = \dfrac{G_{KOM}}{G_0} > 0$.

Continuing this procedure by adding to the seating capacity,
we determine that the payload portion increases rapidly. After
reaching a maximum, $\overline{G}_{KOM}$ decreases again, since the relative
structural mass becomes larger.

The figure shows that there is an optimum size for aircraft
with a smaller number of seats at $\overline{G}_{KOM}$ = max. The maximum
payload portion corresponds to aircraft dimensions for which
stress has reached its highest point and strength margin its
lowest point. A two-story fuselage is best suited for more than
500 seats. Such a fuselage is smaller than a one-story
fuselage, can be more densely loaded, and has a smaller mass. A
three-story fuselage is recommended for aircraft with more than
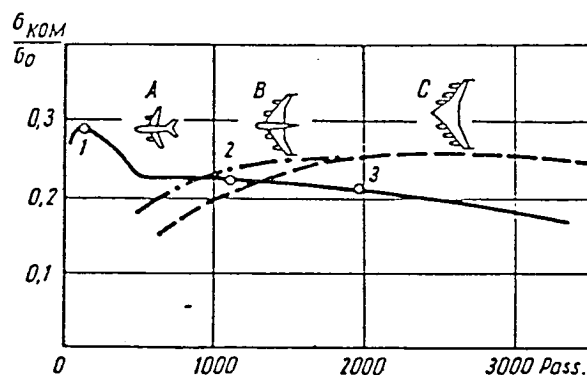1500 seats.

Figure 2: Change of payload portion of the total mass as a function of number of seats for various types of commercial aircraft. A - Conventional set-up (1 - single deck fuselage, 2 - two-story fuselage, 3 - three-story fuselage); B - Flying wing aircraft with cockpit, accomodations for passengers in cockpit and in airfoil, and C - "Pure" flying wing aircraft.

Different aerodynamic aircraft designs under given circumstances are compared in Figure 2. A conventional aircraft with two-story fuselage and a seating capacity over 1000 begins to be disadvantageous with regard to G_{KOM} when compared to a flying wing aircraft with a small cockpit in place of the fuselage (and accommodating passengers in the cockpit as well as in the wing). Partial use of the airfoil for loading payload permits a moderate enlargement of the surface and high aerodynamic efficiency values in flight.

Use of a pure flying wing aircraft is most advantageous for further enlargements of dimensions and increase in seating capacity over 2000, as well as for corresponding surface load enlargement.

Thus, the use of new designs and aerodynamic solutions and the introduction of multiple-story fuselages, aircraft without empannage, and flying wing aircraft lead towards shifts of the maximum attainable payload portion in larger aircraft. This increases the cost-effectiveness of aircraft with 1000 or more seats. More refined construction methods, materials, and equipment, as well as more efficient engines encourage this scientific-technological development for the future.

(Taken from Grazdanskaja aviacija 7/1976; Translator: Dr. Peter Bork)