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## ABSTRACT

The Hughes Model 600X which was introduced at the 1981 Helicopter Association International Meeting in Anaheim, California, represents a growth version of the highly successful Hughes 500D helicopter. The design philosophy of this new model took into consideration a number of factors. First, whether to grow or develop a totally new configuration. To be cost effective, a growth helicopter would need to produce significant additional advantages which would be offset by the ever present compromises of the old design. Second, how do you grow an egg, especially one with internal structure? Third, does the new model replace the old one or is it to be produced in addition to the old one? Fourth, how do you assess the market potential? The paper discusses each of these subjects and presents the rationale for the selected approach.

After extensive study of three potential configurations, including full scale mockups, the widebody Model 600X was selected and displayed at HAI. Details of each of the approaches are presented with reasons for accepting or rejecting each one.

The Model 600 is not an ultimate helicopter. Five variants are detailed showing the continued growth potential of this configuration.

Results of some market analysis and response of the helicopter public is finally presented to show the viability of the selected configuration.

## INTRODUCTION

This paper presents the design philosophy of the Hughes Model 600 helicopter which was publicly introduced at the 1981 Helicopter Association International (HAI) show in Anaheim, California. The requirement for the Model 600 has been discussed including consideration of whether to grow an existing Model or start with a new center line and design a totally new aircraft. Evolution of the configuration has been examined and a detailed presentation of the selected wide body configuration has been offered. The paper concludes with an assessment of the growth potential for still further market expansion.

## REQUIREMENT

The light turbine continues to dominate the helicopter market. Second generation machines are beginning to arrive on the scene. The first generation light turbine machines were essentially identical to the U. S. Army light observation helicopter (LOH) with a civilian paint job and a plush interior. These helicopters started the phenominal growth that the helicopter industry has experienced in the last 15 years, however, the basic light turbines are not without limitations. Military requirements are not always compatible with civil needs and the requirement for a second generation light turbine with expanded cargo space and seating capacity has become apparent.

The Hughes Model 500 is an exceptional utility machine. Although it offers five seats it does not exhibit an excess of comfort in this configuration. In addition, the rear compartment of the 500, designed as a troop/utility compartment, was deliberately restricted to meet performance requirements of the Army's LOH. This drawback plus the lack of baggage space and limited fuel capacity have long been the major objections cited by owners and potential customers of the Model 500 who, otherwise, were highly impressed with the outstanding performance of the machine. A study of the possibilities to correct the known limitations of the Hughes 500 consisted of two elements. The first element was to review growth possibilities of the existing design and the second element was to start with a clean sheet of paper and a new center line. Every Designer likes to start fresh, unencumbered with the compromises of the past, but sometimes new designs lead to new compromises which are as restrictive as the old ones. There is no question that the new design would be more costly and time consuming than an evolutionary modification so the major thrust of the studies had to center on modification of the existing design if possible.

Unfortunately, as Lockheed found many years ago when attempting to stretch the Constellation, efficient aerodynamic bodies do not always lend themselves to ready growth. Such appeared to be the case with the Model 500 until the

concept of widening the fuselage was suggested by one of the company Service Representatives located half way around the world in Indonesia.

To be successful, a design modification must be simple, provide significant advantages and retain maximum commonality of parts and tooling with the previous model.

The requirements for the Model 600 could be summarized as follows:

1. Modification of present Model 500
2. Seating for six people
3. Minimum performance degradation
4. Increased range/endurance from larger internal fuel capacity
5. Provisions for baggage stowage
6. Maintain simplicity, reliability of Model 500

## HISTORY AND EVOLUTION OF THE MODEL 600

Figure 1 shows the genealogy of the Model 600 helicopter. It began with the OH-6A (Hughes Model 369A) which was the original U.S. Army LOH. Shortly after entering production, a civil version was developed, designated Model 500 (Hughes Model 369H). These original machines shared common airframes and used a four-blade main rotor with maximum gross weight of 2,550 pounds.

In 1969-70, Hughes was awarded a contract by the U.S. Department of Defense to produce a quiet helicopter. This was a limited program which resulted in a growth main rotor with five blades and the capacity for increasing gross weight. A couple of variations later, Hughes certificated the Model 500D using much of the technology developed by the Government program. The 500D resulted in improvements to everything except the basic seating, baggage space and internal fuel capacity.

## LONGITUDINAL STRETCH CONCEPT

Prior to certificating the 500D, Hughes studied the possibility of a longitudinal stretch and even did some full scale mockup work. Figure 2 shows the original concept in side view. In this limited perspective the task looked simple and an efficient 3 + 3 + 2 seating arrangement was suggested.

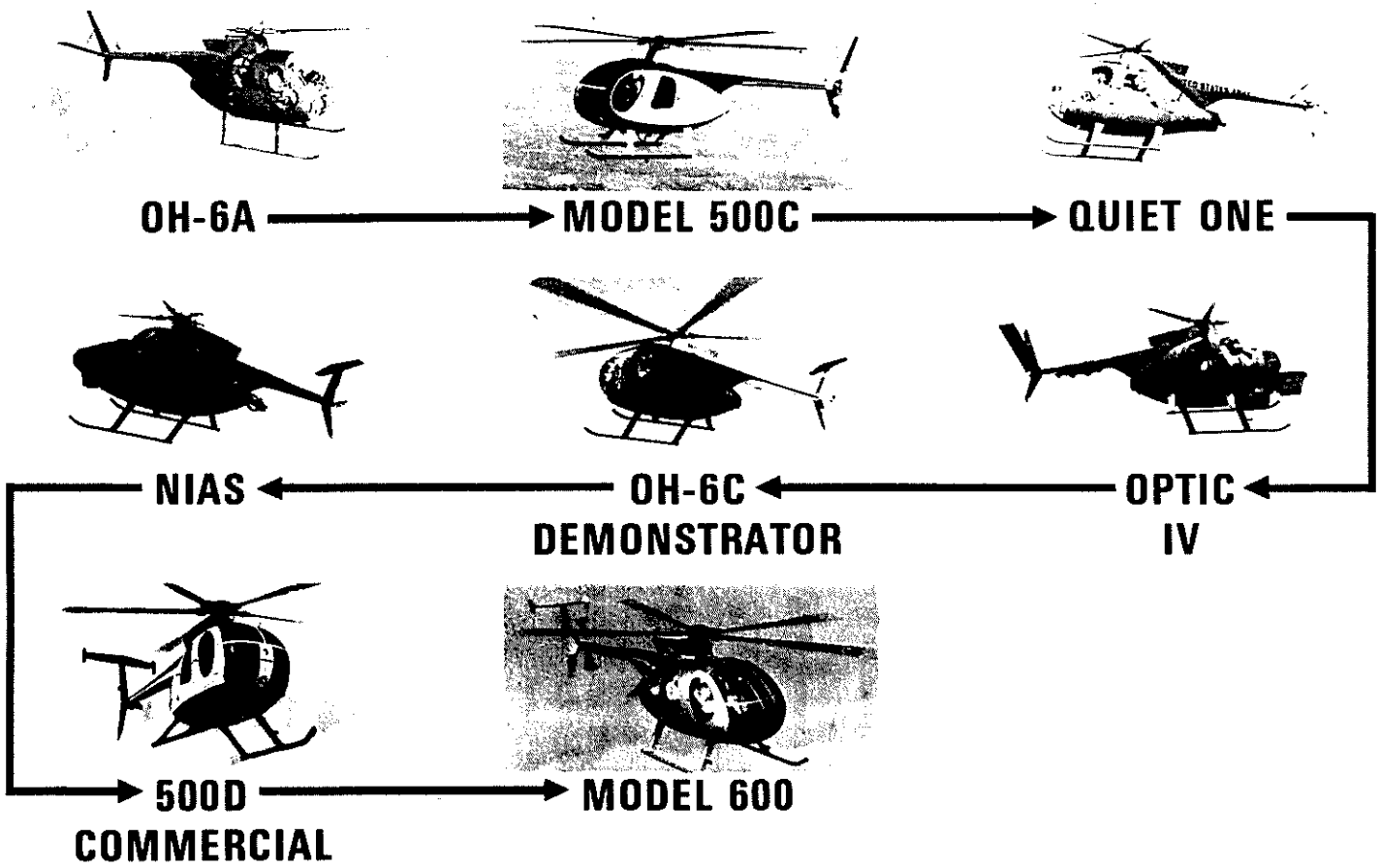


Figure 1. Genealogy of the Model 600 Helicopter

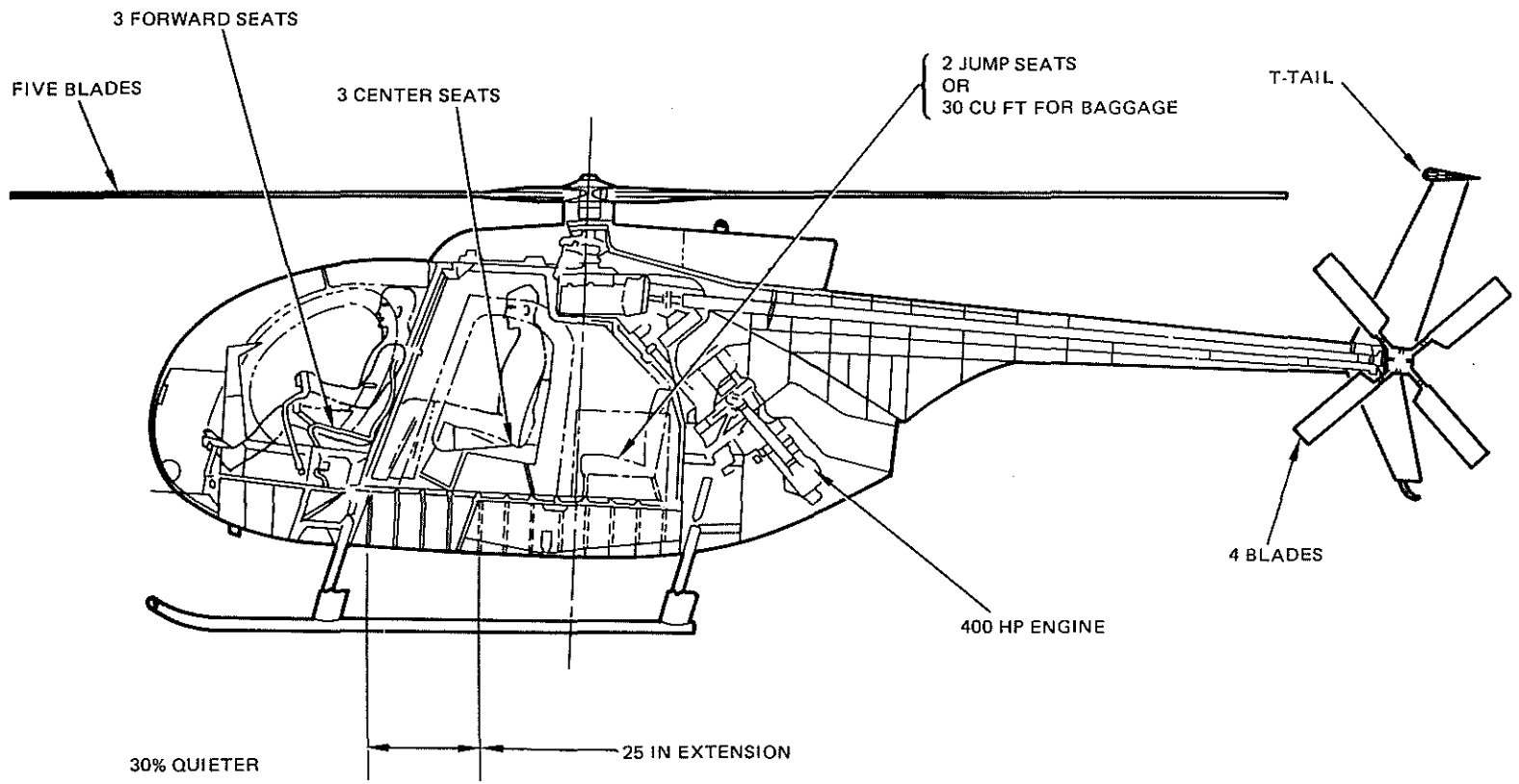


Figure 2. Longitudinal Stretch Concept

Further studies showed that although the side view was clean, the addition of a tube to stretch the length would produce undesirable contour discontinuities. (see Figure 3.) This results because the maximum half breadth does not occur at a planar station. Figure 4 shows the locus of the maximum half breadth which is the point at which the fuselage could be sectioned for insertion of a constant cross section tube for lengthening. As can be seen, this location is not the easiest place to splice the fuselage. Some crude but effective full scale mockup work was done which verified that the contour would be one of the more costly problems with a longitudinal stretch because of tooling requirements.

In the longitudinal stretch, it was desireable to cut the fuselage at the aft side of the forward bulkhead to maintain the integrity of the cockpit. Since the rotor would, of necessity, remain in the same location with respect to the aft bulkhead (firewall) a complication of the control mechanism would result since the controls utilize the tunnel beam in the forward bulkhead as a conduit and a series of bellcranks and push rods would be required to transmit this motion back to the swashplate.

Although somewhat perplexing, the above noted problems are only part of the reason for not pursuing the configuration further. The big problem was the center of gravity. Since everything moved forward, so did the CG and even with objectionably small leg room it proved unmanageable even if the battery were hung under the tail rotor as has been done on early model helicopters. The longitudinal stretch was finally abandoned as too costly and lacking in practicality.

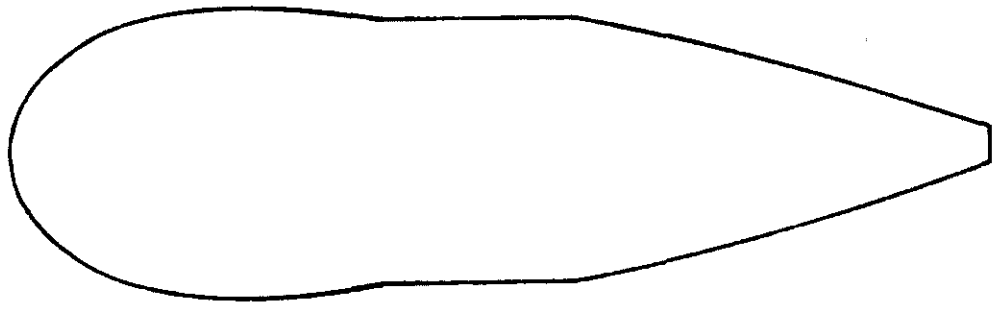

Figure 3. Top View of Longitudinal Stretch

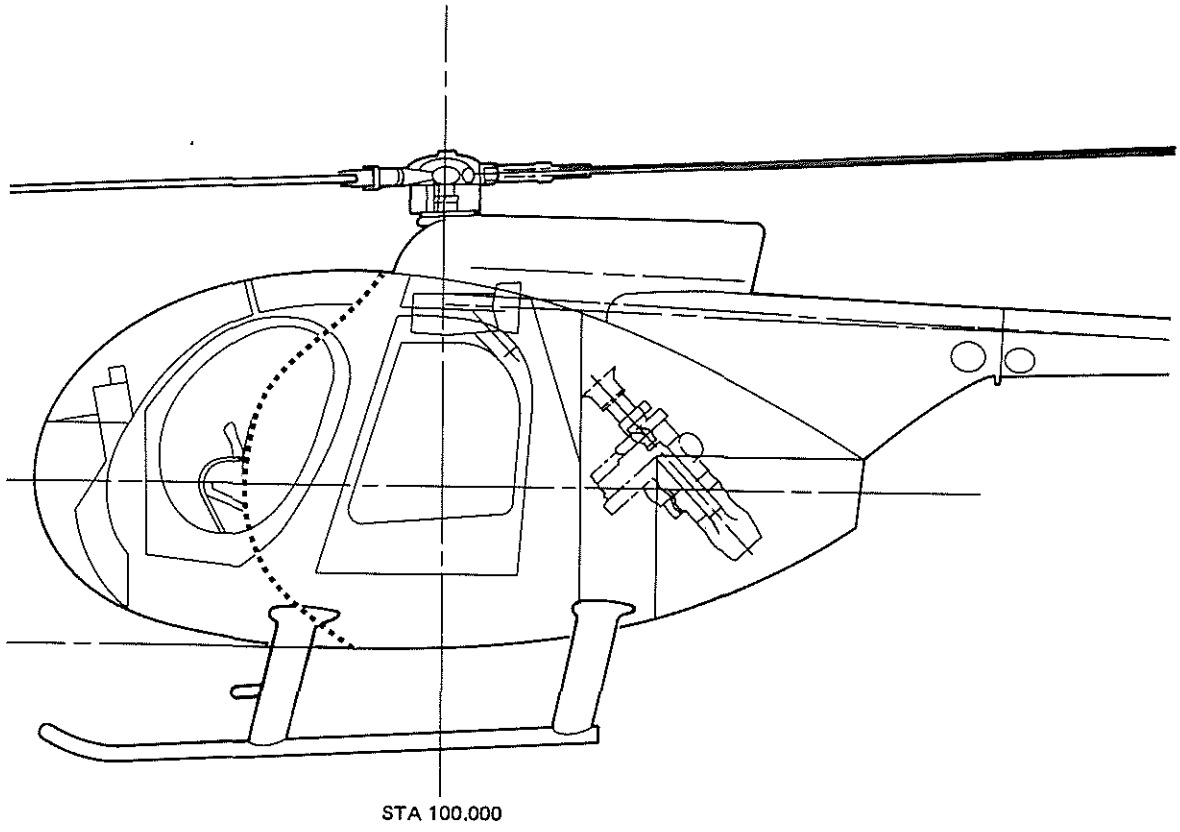


Figure 4. Locus of Maximum Half-Breadth

## RAISED ROTOR CONCEPT

During the certification program for the Model 500D a second concept was studied which would provide additional internal space and a baggage compartment supposedly with minimal change to the basic airframe. This concept involved raising the rotor and entire drive system with respect to the remainder of the fuselage. See Figure 5. This would eliminate the hump in the center of the rear compartment and would provide a space under the engine for baggage. Removal of the transmission hump in the rear compartment would, theoretically, provide space for a third passenger in the rear seat although a bit tight. Again a simple full scale mockup was built to examine the configuration in detail.

Rather than raise the rotor vertically, it was moved up parallel to the tunnel beam which carries the controls. This simplified the control mechanism since longer push-pull rods would be the only change required. The aft movement of the rotor which resulted from raising parallel to the tunnel beam presented some structural problems in the aft bulkhead, but this could

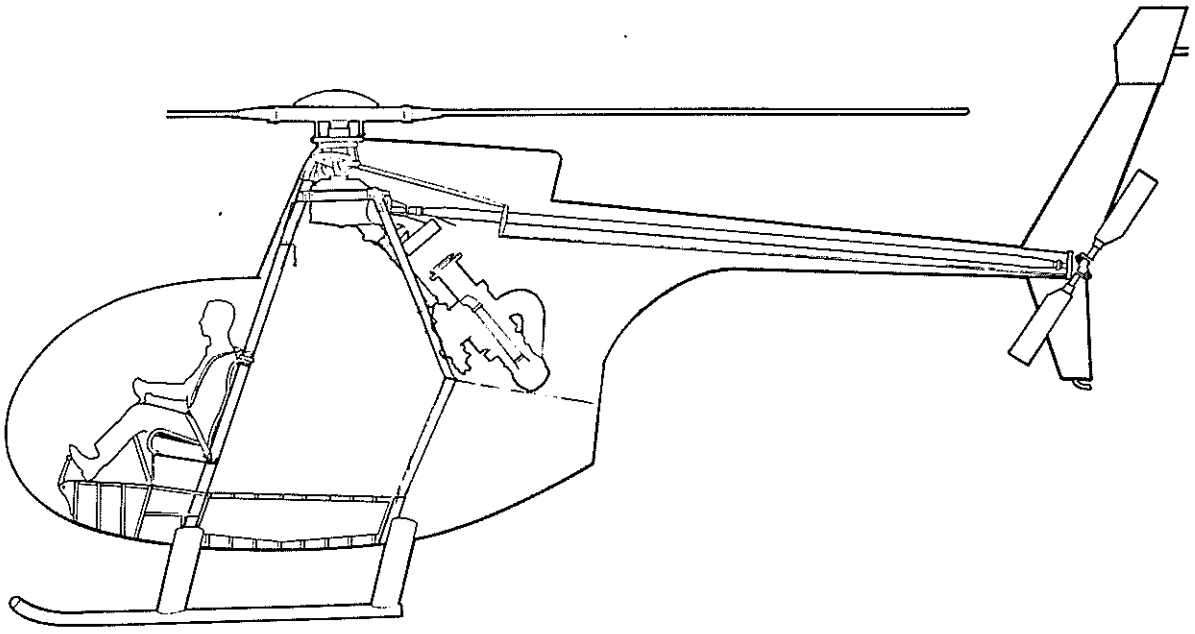

Figure 5. Raised Rotor Concept

be accommodated fairly simply since the bulkhead was made up of flat sheet metal. The external contour became complex and a new loft of the aft fuselage and new tooling would be required.

The baggage compartment was of adequate size but rather impractical to load. The floor was tapered and rounded and a hinged bin arrangement appeared to be the most useful. The roof of the baggage compartment now became the floor of the engine compartment - a considerable interference to easy engine access. The real shock came when trying to load three passengers in the rear. Seat width was simply not adequate. Rather than a tight five place, the configuration would provide an extremely uncomfortable six place. The addition of a sixth marginal seat was considered unrealistic.

## THE WIDE BODY CONCEPT

The tight seating of the raised rotor concept pointed to a need for wider seats and at approximately this same period of time one of the company service representatives in Indonesia was looking at a new Allouette III and noted the two vertical canopy supports which triggered the idea of widening the fuselage of the Model 500. He sketched the idea on paper and sent it to the factory. Figure 6. Good ideas are not restricted to the realm of the engineering department!

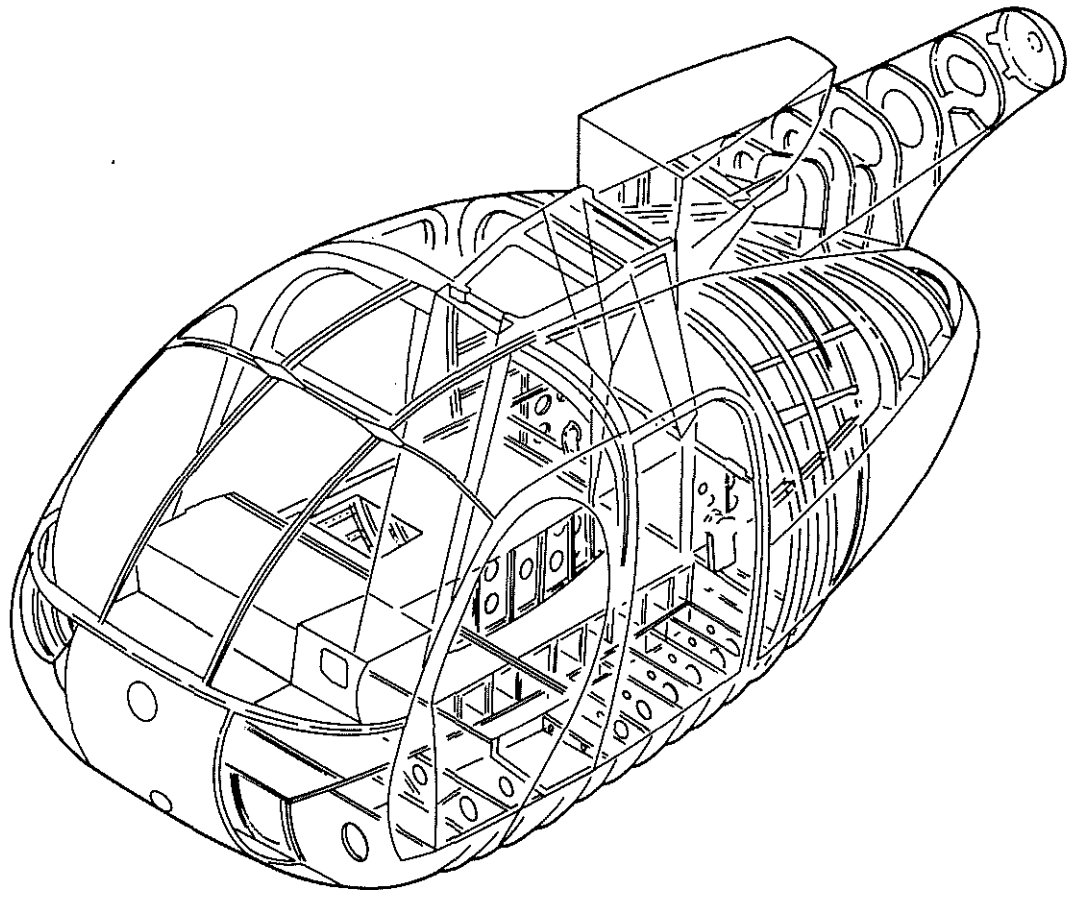

Figure 6. Widebody Structural Concept

By this time, the Model 500D was nearing certification and a change as significant as widening the fuselage would have caused a serious delay. Wisely, company management elected to postpone the change to a later date.

The Model 500D has been a very successful helicopter. Production has been continually increased since its introduction and the demand has risen with the production rate inspite of continued inflation. While riding the wave of success, it was felt that the time was here for expanding the market and during 1980 Hughes again turned to studying growth machines.

The wide body was reviewed and a full scale mockup was built. Figure 7 shows the mockup as it was dressed up for presentation to the public. Figure 8 shows a comparison of the 500D and the wide body 600X and illustrates the improvement in front seat passenger space.

Several factors improve the rear seat comfort to an outstanding level. First, the head room between the transmission hump and the door frame is increased by a dramatic 75 percent. Second, the widened aft bulkhead allows a recess

Figure 7. Model 600X Mockup

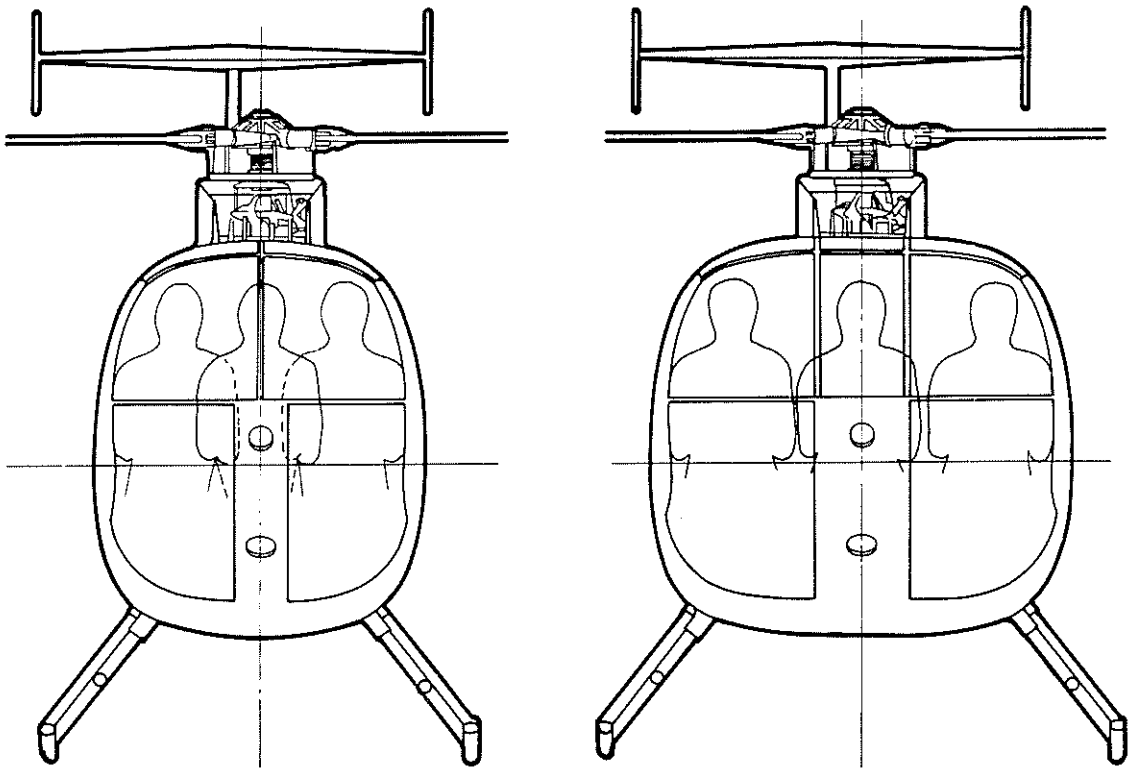


Figure 8. Comparison of Front View

behind the passenger's head permitting the passenger to be moved aft. This results in greater leg room. Third, the opening in the forward bulkhead is not only widened but lowered by a large amount resulting in vastly improved visibility which gives rear passengers a greater feeling of presence with the front seat occupants. With center seat removed, a large open space exists between the rear seat occupants further adding to the feeling of openness. The center seat (sixth passenger) although adequate is slightly less comfortable - since it mounts at a lower level and has less leg room, however, it is much more acceptable than the fifth seat in todays light turbines.

The 500D is noted for the large flat cargo space available when seats are folded. This space is 31 percent greater in the widebody Model 600. Cargo volume is also proportionally increased.

A center console with provisions for briefcase storage will be an optional feature in the rear compartment or some operators may wish to have a utility rear compartment for cargo and a plush front compartment for passengers. The front seat will still be most desireable since everyone likes to ride up front in a helicopter.

Although the mockup was displayed with pilot on the left, he will be positioned on the right in the actual helicopter. This is done with consideration for eventual IFR certification. The copilot will be placed in the center.

Figure 6 showed the structural concept of the widebody Model 600. The use of two keel beams provides a large cavity for additional fuel in the belly. The quantity can be increased approximately 50 percent resulting in similar range and endurance improvement.

Widening of the fuselage also provides two large cavities, one on either side of the engine. A sizeable bin will be fabricated as an integral part of each engine access door. With doors open, access to the baggage bin will be provided as well as full access to the engine as in present mode.

Widening of the fuselage has the least impact on the aircraft structure of any of the methods examined. The effect on CG is also minimal since longitudinal placement of passengers is unchanged. Lateral CG is less critical than longitudinal, therefore, the wider seat is still acceptable.

The criteria for the width increase was established by the rear seat since it is narrower than the front. The fuselage was widened sufficiently, to provide full three across seating in the rear.

Usable equipment/components common to the 500D will include:

Engine
Drive System
Rotors
Landing Gear
Tail Boom
Tail Surfaces (most)
80 percent of Fuselage Structure

This will result in reduced tooling costs and economy of manufacturing both aircraft at the same time.

Table 1 shows the projected weight breakdown for the Model 600 and compares the Model 500D with the Model 600. It should be noted that with people as cargo, the 500D is space limited. This allows the Model 600 to carry the same number of passengers and their baggage plus 50 percent more fuel, all for the same gross weight. In the utility model, trading fuel for payload, the Model 600 has an empty weight of only 44 pounds greater than the Model 500D and therefore only loses that amount of payload. A small penalty for greater space.

TABLE 1. WEIGHT COMPARISON
(pounds)

| | 500D | Widebody |
|---|---|---|
| Empty | 1,392 | 1,436 |
| Pilot | 170 | 170 |
| Oil | 8 | 8 |
| Max Fuel | 400 | 595 |
| Gross | 3,000 | 3,000 |
| Payload | 1,030 | 791* |
| *4 passengers + 111 pounds baggage! | | |

Table 2 shows performance projections with a comparison to 500D performance. As can be seen, the penalties are small because the airframe is still very clean aerodynamically.

GROWTH POTENTIAL

The initial version of the Model 600 will be fitted with the same engine, rotor and drive as the Model 500D. This is done for several reasons:

1. Performance penalties are small and within acceptable limits.
2. This is the least costly and shortest program that can be performed.
3. Can be done on amended type certificate.

This initial version is not an ultimate helicopter and further growth variants have been studied and planned. Table 3 shows the variants now contemplated.

And what of the Model 500D? Shall we continue to produce this model after the Model 600 becomes available? The answer to this question is dependent on what changes are made to optimize the Model 500D for a different end of the light turbine market than the Model 600 so that they do not compete with one another. That is a subject for another paper.

TABLE 2. ESTIMATED PERFORMANCE

| | 500D | Widebody |
|---|---|---|
| HIGE ISA | 8, 500 | 8, 500 |
| HOGE ISA | 7, 400 | 7, 400 |
| Cruise Speed (mph) | | |
| SL ISA | 160 | 157 |
| 5, 000 ft. ISA | 154 | 151 |
| Max Range (miles) | | |
| SL ISA | 300 | 446 |
| 5, 000 ft. ISA | 331 | 490 |
| Endurance (hrs) | | |
| SL ISA | 2.8 | 4.3 |
| 5, 000 ft. ISA | 3.1 | 4.7 |
| $V_{NE}$ SL ISA (kt) | 156 | 156 |

TABLE 3. MODEL 600 VARIANTS

| Variant | Engine and Location | Rotor | Drive System | Remarks |
|---|---|---|---|---|
| 1 | C20B - 500D | 26.4 ft dia (500D) | 500D | Least cost and time |
| 2 | C30 - 500D | 26.4 ft dia (500D) | 500D | High altitude hover |
| 3 | C30 - 500D | 27.4 ft dia | 500D Modified | Higher performance |
| 4 | C30 - On top | 28.4 ft dia | New | High performance 6 place |
| 5 | Twin - On top | 28.4 ft dia | Same as No. 4 | Engines not yet available |

## SUMMARY AND CONCLUSIONS

An analysis of three configurations including limited full scale mockups has shown that the widebody configuration has definite potential for a modified growth version of the successful Hughes 500D helicopter. This approach also offers further configuration changes for later growth models as market demands and available resources dictate a need.

The selected Model 600 configuration was first exhibited to the public at the HAI Convention in Anaheim, California during January 1981. The public response was overwhelming. Over 450 signed letters of intent were submitted by potential customers, 48 percent of whom are not now Hughes owner/operators. This indicates that the Model 600 is going to appeal to a new segment of the market not previously reached by Hughes.

Questionnaires distributed to helicopter operators world-wide indicate that the Model 600 may not appeal universally to all users. Many prefer the high performance of the 500D and operate exclusively in that market area. For those, Hughes will continue to provide upgraded versions of the Model 500 with still higher performance.

The fact that it will share 80 percent commonality with the Model 600 will make this option economically feasible.

But for those who require passenger comfort, as well as high performance along with the simplicity dependability and low operating cost for which Hughes has a world-wide reputation, the wide body Model 600 appears to have a very bright future and the potential of expanding Hughes' share of the light turbine market.