IMPACT OF ADVANCED TECHNOLOGY ON FUTURE HELICOPTER PRELIMINARY DESIGN

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ABSTRACT

The impact of advanced technology on size and weight of future helicopters was investigated by conducting preliminary design studies for a conventional helicopter configuration designed with 1970's technology, and again with predicted near-term advanced technology levels. The advanced technologies considered in the study include composite structures, advanced engines, digital/optical flight controls, advanced weaponry and advanced rotor technology. The predicted effect of these advanced technologies on future helicopter rotor performance, airframe weight, installed power, and subsystems weight is presented, as are trends of engine and vehicle sizing with drag reductions. Finally, the integrated effect of across-the-board application of advanced technology on future helicopter preliminary design sizing is presented. The results demonstrate the significant reductions in airframe and engine size and weight that advanced technology will provide for future rotorcraft concepts.

1. INTRODUCTION

Several advanced technologies are rapidly approaching fruition in the rotorcraft industry. Quantum gains in technology levels for areas such as digital/optical flight controls and automated cockpit design will provide greatly increased mission capability in future rotorcraft designs. Other advances such as the all-composite fuselage will decrease vehicle size, weight, and cost. This paper presents the effects of several important advanced technologies on the design of a light attack helicopter, and compares this design to one incorporating only currently-fielded technology. The current technology baseline will be presented first, followed by application of each advanced technology individually. Finally, the integrated effect of all these advanced technologies will be presented.

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2. CURRENT TECHNOLOGY BASELINE

The baseline design from which advanced technology effects will be measured was determined using only currently-fielded technologies as represented by the UH-60A and AH-64A helicopters. Table 1 presents a summary of size, weight, and performance characteristics for this baseline design light attack helicopter. This design has a two-place (tandem) seating arrangement and twin engines. "Rubber" T700-GE-700 engines were used to represent current engines without artificially impacting design trends with a fixed engine size. Armament for this configuration consists of a turreted automatic cannon and wing/pylon mounted missile pods. The functional capability of the mission equipment (which includes communications, navigation, target acquisition and fire control, threat defense, flight control, and displays and controls) assumed for this baseline design is representative of expected requirements for an all-weather, day/night attack helicopter in the 1990's time period. The weight of this equipment if designed and built with currently fielded technology was estimated as 2000 pounds.

The governing criterion for engine sizing for the baseline design is 175 knots minimum dash speed (the VROC criterion is 500 fpm at 95% IRP, 4000 ft/95°F). The aerodynamic cleanliness assumed was approximately that of the AH-64A, but with retracting landing gear. All designs presented in this paper used the same representative mission to determine fuel requirements. The entire mission is flown at 4000 feet pressure altitude, 95°F.

Table 1. Current technology baseline design summary

Disc Loading (lb/ft^2)	7.00
Rotor Solidity	0.083
Rotor Tip Speed (ft/sec)	700
Rotor Diameter (ft)	54.1
Operating Length (ft)	64.7
Engines	2 x T700
Engine IRP (hp)	2121
Rotors (lb)	1587
Airframe (lb)	2893
Propulsion (lb)	3585
Flight Controls (lb)	925
Airframe Equipment (lb)	1040
Mission Equipment (lb)	2000
Armor (lb)	166
Empty Weight (lb)	12196
Crew (lb)	500
Fuel Burned (lb)	1820
Fuel Reserve & Fluids (lb)	413
Armament (lb)	1166
Gross Weight (lb)	16095
Performance at 4000 Ft/95°F	
Dash Speed (IRP) (kts)	175
Cruise Speed (MCP) (kts)	161
VROC (95% IRP) (fpm)	2311

3. ADVANCED ROTOR TECHNOLOGY

Some advances in rotor technology for future design applications will result from current research in aerodynamics and rotor dynamics, while other advancements will be made possible by innovative construction techniques allowing economical manufacture of rotor blades with complex planforms, twist, and tip shape. Currently fielded helicopter rotors tend to incorporate only one or two design advancements, while future rotor designs will be optimized with several advanced technologies to achieve increased rotor performance and survivability, while decreasing unwanted effects such as vibration and noise.

Forward flight performance of rotary wing aircraft is often limited by advancing blade compressibility and retreating blade stall. These phenomena are primarily effected by blade airfoil drag divergence Mach number (M_{DD}) and airfoil maximum lift coefficient ($C_{L_{MAX}}$), respectively. Improvements in airfoil M_{DD} are usually accompanied by a decline in $C_{L_{MAX}}$, as shown by the lower band in Figure 1, from Reference 1. However, current research in airfoil design has yielded several advanced technology airfoil sections tailored for the extreme range of flow conditions that exist around the rotor azimuth in high speed forward flight, thus providing an improved combination of M_{DD} and $C_{L_{MAX}}$ as indicated by the upper curve in Figure 1. Furthermore, advanced blade construction techniques will allow rotor designers to match the best airfoil section to the varying aerodynamic environment along the rotor blade.

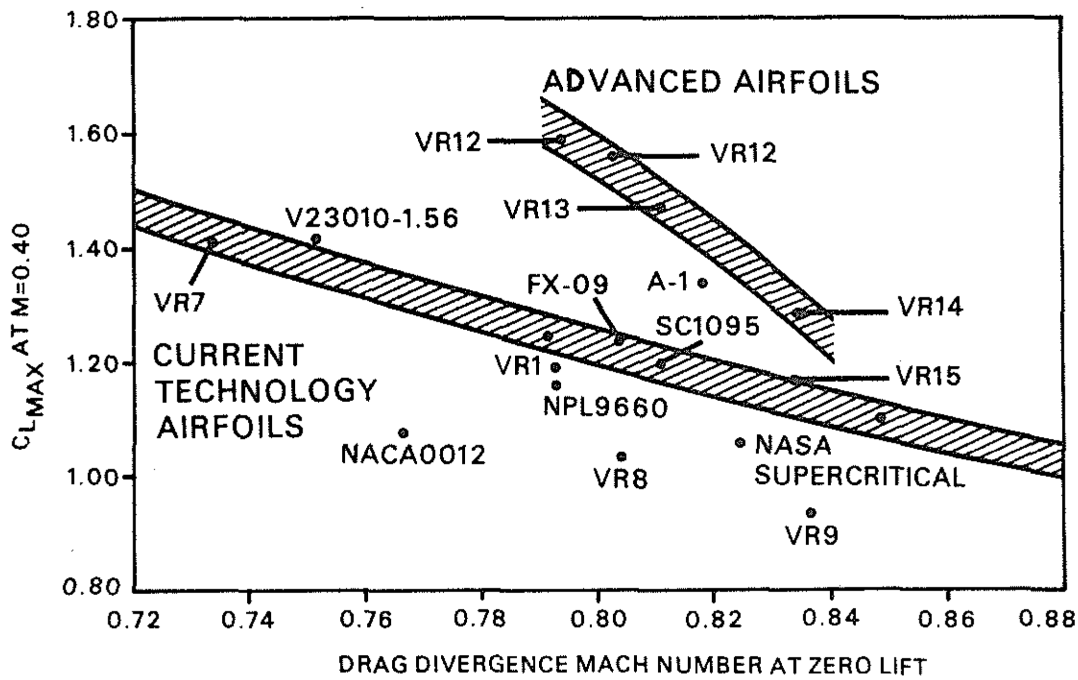

Figure 1. Comparison of rotor airfoil characteristics.

The predicted effect of advanced airfoils on performance of a representative rotor is discussed in Reference 2 and is presented in Figure 2 as rotor lift-to-equivalent-drag ratio in forward flight. Figure 3 is a corresponding plot of rotor figure-of-merit for the hover case. These rotor performance curves were calculated with the CAMRAD computer code of Reference 3. This computer program allows detailed theoretical analyses of such rotor performance issues as dynamic stall, linear and non-linear aerodynamics, uniform and non-uniform inflow, and prescribed wake and free wake models. The advanced airfoils provided a large increase in forward flight performance, while maintaining a modest increase in hover performance.

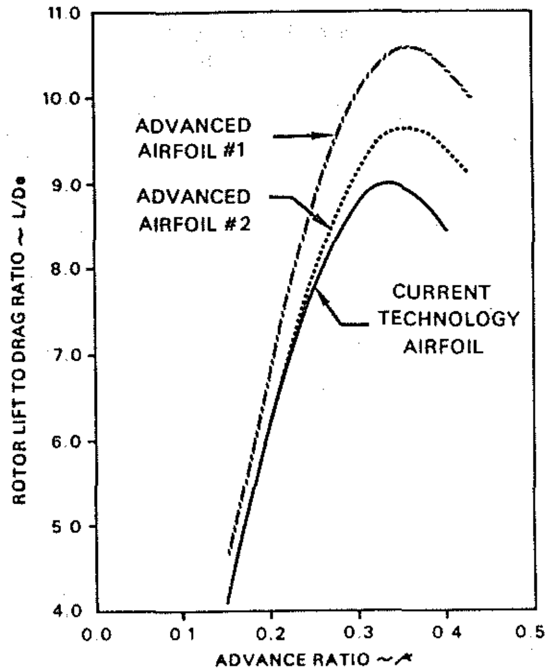

Figure 2.
Effect of advanced airfoils on forward flight rotor performance.

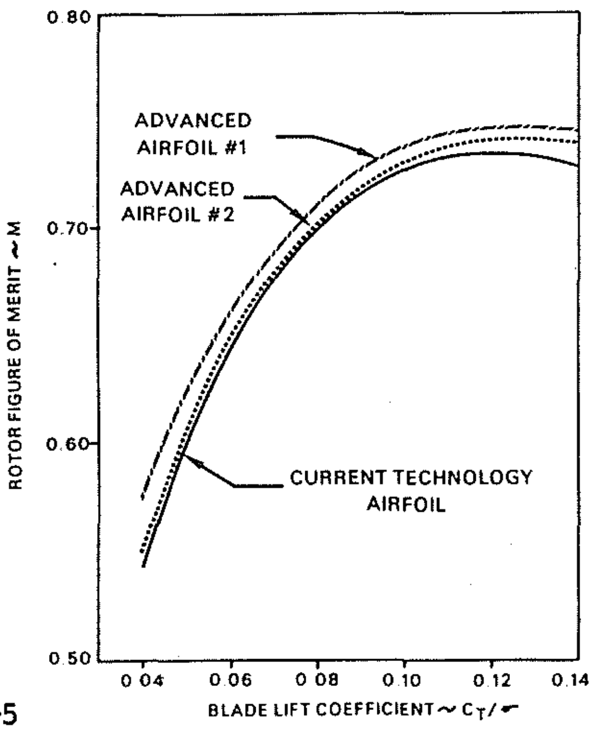

Figure 3.
Effect of advanced airfoils on hover rotor performance.

New manufacturing methods allow rotor blades to be constructed with radically nonlinear twist distributions and complex planforms and tip shapes that were once too costly to mass produce. This will allow rotor profile and induced power losses to be reduced in hover, by optimizing blade twist and taper. Concurrently, large negative twist can improve rotor performance in forward flight by unloading the blade tips, which delays stall for the retreating blade and reduces compressibility losses on the advancing blade. However, blade twist distribution must be carefully selected to avoid rotor performance degradation at off-design operating conditions, and also to avoid blade dynamics problems.

The advanced technology rotor performance levels assumed for this study are somewhat less than the maximum indicated in Figures 2 and 3, to allow satisfactory performance at off-design conditions, for maneuverability considerations, and to provide a margin for rotor dynamics considerations. This advanced technology rotor performance, as presented in Figures 4 and 5, was used to resize the baseline design helicopter described previously, yielding the results presented in Table 2. The improved rotor performance in forward flight produces a strong reduction in engine power rating required. The reduction in weight and fuel required leads to a 13% decrease in design gross weight. This large decrease in gross weight illustrates the importance of improved rotor performance for future helicopter designs.

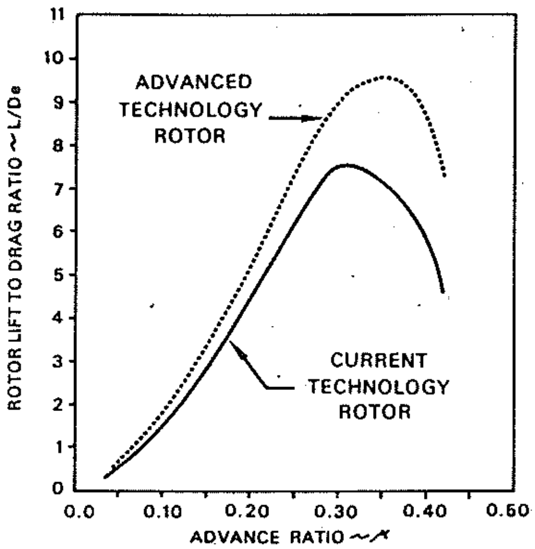

Figure 4. Helicopter rotor forward flight performance.

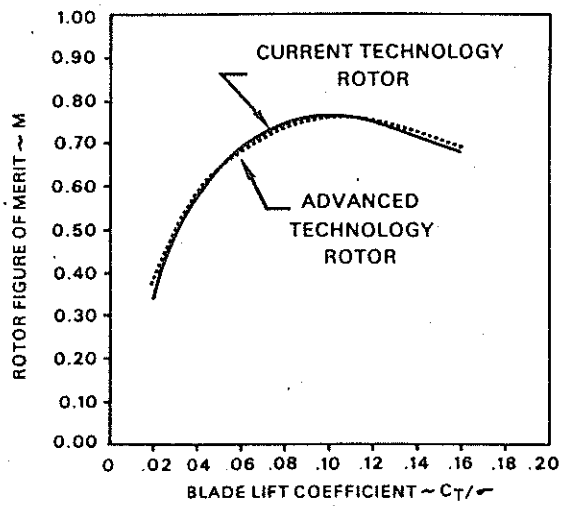

Figure 5. Helicopter rotor hover performance.

Table 2. Effect of advanced technology rotor on baseline design.

	Baseline Design	Advanced Technology Rotor
Disc Loading (lb/ft^2)	7.00	7.00
Rotor Solidity	0.083	0.083
Rotor Tip Speed (ft/sec)	700	700
Rotor Diameter (ft)	54.1	50.6
Operating Length (ft)	64.7	60.6
Engines	2 X T700	2 X T700
Engine IRP (hp)	2121	1428
Rotors (lb)	1587	1319
Airframe (lb)	2893	2600
Propulsion (lb)	3585	2691
Flight Controls (lb)	925	858
Airframe Equipment (lb)	1040	1040
Mission Equipment (lb)	2000	2000
Armor (lb)	166	166
Empty Weight (lb)	12196	10674
Crew (lb)	500	500
Fuel Burned (lb)	1820	1416
Fuel Reserve & Fluids (lb)	413	325
Armament (lb)	1166	1166
Gross Weight (lb)	16095	14080
Performance at 4000 Ft/95°F		
Dash Speed (IRP) (kts)	175	176
Cruise Speed (MCP) (kts)	161	162
VROC (95% IRP) (fpm)	2311	500

4. ADVANCED COMPOSITE STRUCTURES

The application of composite materials to current helicopter designs is limited to secondary airframe structures in most cases. Advances in composite materials and design concepts will allow primary airframe structures to be constructed entirely of composite materials, resulting in substantial weight and cost savings and increases in durability, maintainability, and survivability. An example of current emphasis in this area is the U.S. Army's Advanced Composite Airframe Program (ACAP), which is producing all-composite helicopter airframes. Development of suitable manufacturing techniques for composite airframes is critically important, since economical production is vital to the successful application of this technology. Airframe components which are expected to be constructed of composite materials for future designs include the fuselage , empennage, landing gear, rotor hubs, and rotor blades.

A summary of an extensive survey of the weight impact of composite materials application to aircraft structures is given in Reference 2. Predicted component weight savings with advanced composites, compared to conventional metals technology, are presented in Table 3. Substantial weight savings are predicted for several components. Zero weight reduction is indicated for main rotor blades as a result of the helicopter requirement for a large polar moment of inertia to meet autorotation criteria, and the necessity to mass balance rotor blades.

Table 3. Predicted weight savings for airframe structures constructed of composite materials.

Component	Percent Weight Savings Over Metals Technology
Main rotor blades	0
Main rotor hub	15
Horizontal tail	40
Vertical tail	25
Control surfaces	25
Tail rotor blades	20
Fuselage	
Cockpit	21
Center section	29
Transition section	22
Tail boom	12
Fairings & doors	21
Engine cowlings	20
Landing gear	13

In contrast to the blades, the helicopter main rotor hub lends itself well to weight reduction through application of advanced composite materials. Recent results indicate a possible main rotor hub weight reduction of 30% as compared to UH-60A/AH-64A technology level hubs. This is twice the reduction indicated for composite hubs in Table 3, and is due to innovative hub design.

A large array of materials and construction techniques will allow the structural designer to tailor the application of composites to the different areas of the airframe. For example, stiffened rib and spar concepts with honeycomb filler may lend themselves to an all-composite empennage design. The material for this application may be Kevlar/epoxy or graphite construction and the design will be stiffness-critical. Another 5% weight savings over that indicated for vertical tail surfaces in Table 3 can be achieved for those designs which do not mount the tail rotor on the vertical fin. A discussion of possible materials and design approaches for other airframe segments is presented in References 2 and 4.

Table 4 compares the baseline design with a helicopter incorporating advanced composites construction. Since the baseline assumes currently-fielded technology as represented by the UH-60A and AH-64A, which have some composite construction, smaller weight savings than those shown in Table 3 were used for some components. The design with advanced composites construction exhibits a 17% decrease in rotor group weight and a 27% decrease in airframe weight, leading to a 10% decrease in design gross weight.

Table 4. Effect of advanced composite structures on baseline design.

	Baseline Design	Advanced Composite Structures
Disc Loading (lb/ft^2)	7.00	7.00
Rotor Solidity	0.083	0.083
Rotor Tip Speed (ft/sec)	700	700
Rotor Diameter (ft)	54.1	51.4
Operating Length (ft)	64.7	61.5
Engines	2 X T700	2 X T700
Engine IRP (hp)	2121	1937
Rotors (lb)	1587	1322
Airframe (lb)	2893	2125
Propulsion (lb)	3585	3302
Flight Controls (lb)	925	874
Airframe Equipment (lb)	1040	1040
Mission Equipment (lb)	2000	2000
Armor (lb)	166	166
Empty Weight (lb)	12196	10829
Crew (lb)	500	500
Fuel Burned (lb)	1820	1670
Fuel Reserve & Fluids (lb)	413	383
Armament (lb)	1166	1166
Gross Weight (lb)	16095	14548
Performance at 4000 Ft/95°F		
Dash Speed (IRP) (kts)	175	175
Cruise Speed (MCP) (kts)	161	161
VROC (95% IRP) (fpm)	2311	2367

Table 5. Predicted weight savings for fiber optics flight control system

Component	Percent Weight Savings Over Mechanical Control System
Cockpit controls (transducers, spring actuators, and supporting structure)	60
Nonboosted controls (control runs and supporting structure)	70
Boosted controls (actuators, rotating controls, hydraulic power supply)	8

5. ADVANCED FLIGHT CONTROL SYSTEM

Several advanced flight control systems have been proposed for future rotorcraft designs. One of the most promising is the digital, fiber optics flight control system. Such systems have reliability, maintainability, and ballistic survivability advantages over conventional mechanical control systems. Optical systems also appear to have weight advantages over mechanical control systems, the weight advantage becoming more pronounced as the size of the aircraft increases. Predicted weight reductions for the digital fiber optics flight control system are shown in Table 5. Although two of the component groups in Table 5 show very large weight reductions, the predicted percentage reduction for the complete flight control system will be much less because the third group is a much larger fraction of the total.

The effect on weight of the baseline design of changing to a digital fiber optics flight control system is shown in Table 6. The design with the advanced flight control system has a 25% decrease in flight control weight, yielding a 3% reduction in design gross weight. The survivability advantages of the fiber optics flight control system may in some cases be more important than the predicted weight reduction. Some advanced rotorcraft concepts will require relatively complex flight control systems, leading to an even larger advantage in weight and cost for the digital fiber optics system.

Table 6. Effects of advanced flight control systems on baseline design.

	Baseline Design	Advanced Flight Control System
Disc Loading (lb/ft^2)	7.00	7.00
Rotor Solidity	0.083	0.083
Rotor Tip Speed (ft/sec)	700	700
Rotor Diameter (ft)	54.1	53.2
Operating Length (ft)	64.7	63.2
Engines	2 X T700	2 X T700
Engine IRP (hp)	2121	2056
Rotors (lb)	1587	1519
Airframe (lb)	2893	2818
Propulsion (lb)	3585	3484
Flight Controls (lb)	925	691
Airframe Equipment (lb)	1040	1040
Mission Equipment (lb)	2000	2000
Armor (lb)	166	166
Empty Weight (lb)	12196	11708
Crew (lb)	500	500
Fuel Burned (lb)	1820	1767
Fuel Reserve & Fluids (lb)	413	402
Armament (lb)	1166	1166
Gross Weight (lb)	16095	15543
Performance at 4000 ft/95°F		
Dash Speed (IRP) (kts)	175	175
Cruise Speed (MCP) (kts)	161	161
VROC (95% IRP) (fpm)	2311	2330

6. DRAG REDUCTION

It is expected that higher speeds will be required of future helicopter designs, both military and civilian. Accordingly, a dash speed requirement of 175 knots was assumed for the light attack helicopter addressed in this paper. This requirement makes aerodynamic drag much more important than it is for most current military helicopters. To study the impact of drag on the baseline design, the effect of a 30% reduction in parasite drag was investigated. This reduced drag represents approximately the aerodynamic cleanliness level of the S-76 helicopter. To achieve this low drag level will require a more rigorous drag control emphasis during the design and development process than has been common for military helicopters. Also, the use of low-drag external stores is assumed.

The effect of this drag reduction on the baseline design is presented in Table 7. The reduced drag design exhibits a 12% reduction in required engine size, leading to an 8% decrease in mission fuel and a 4% reduction in design gross weight.

7. ADVANCED TECHNOLOGY ENGINES

The effect of advanced technology engines on the baseline design was investigated by changing from rubber T700-GE-700 engines to an engine model representative of the engines being developed in the U.S. Army's Advanced Technology Demonstrator Engine (ATDE) Program. The advanced technologies addressed in this program include single-crystal turbine blades, ceramic combustor coatings, composite material shafts, and transpiration cooling. Helicopter preliminary design results using the two different engine models are presented in Table 8. An 8% reduction in propulsion group weight is achieved, leading to a 3% reduction in design gross weight. It may be noted in Table 8 that the power rating of the ATDE rubber engines is twice the power rating of the engines built under the ATDE program. The all-advanced-technology design discussed below requires smaller engines which would be in the actual power range of the ATDE engines. If that helicopter were designed with currently-fielded engines of that power range, a much larger difference due to engine type would be found.

Table 7. Effects of drag reduction on baseline design.

	Baseline Design	Reduced Drag
Disc Loading (lb/ft^2)	7.00	7.00
Rotor Solidity	0.083	0.083
Rotor Tip Speed (ft/sec)	700	700
Rotor Diameter (ft)	54.1	52.9
Operating Length (ft)	64.7	63.3
Engines	2 X T700	2 X T700
Engine IRP (hp)	2121	1872
Rotors (lb)	1587	1491
Airframe (lb)	2893	2790
Propulsion (lb)	3585	3265
Flight Controls (lb)	925	902
Airframe Equipment (lb)	1040	1040
Mission Equipment (lb)	2000	2000
Armor (lb)	166	166
Empty Weight (lb)	12196	11654
Crew (lb)	500	500
Fuel Burned (lb)	1820	1683
Fuel Reserve & Fluids (lb)	413	381
Armament (lb)	1166	1166
Gross Weight (lb)	16095	15384
Performance at 4000 Ft/95°F		
Dash Speed (IRP) (kts)	175	175
Cruise Speed (MCP) (kts)	161	162
VROC (95% IRP) (fpm)	2311	1785

Table 8. Effect of advanced technology engines on baseline design.

	Baseline Design	Advanced Technology Engines
Disc Loading (lb/ft^2)	7.00	7.00
Rotor Solidity	0.083	0.083
Rotor Tip Speed (ft/sec)	700	700
Rotor Diameter (ft)	54.1	53.2
Operating Length (ft)	64.7	63.6
Engines	2 X T700	2 X ATDE
Engine IRP (hp)	2121	2069
Rotors (lb)	1587	1522
Airframe (lb)	2893	2792
Propulsion (lb)	3585	3294
Flight Controls (lb)	925	908
Airframe Equipment (lb)	1040	1040
Mission Equipment (lb)	2000	2000
Armor (lb)	166	166
Empty Weight (lb)	12196	11723
Crew (lb)	500	500
Fuel Burned (lb)	1820	1799
Fuel Reserve & Fluids (lb)	413	379
Armament (lb)	1166	1166
Gross Weight (lb)	16095	15567
Performance at 4000 ft/95°F		
Dash Speed (IRP) (kts)	175	175
Cruise Speed (MCP) (kts)	161	162
VROC (95% IRP) (fpm)	2311	2348

8. ADVANCED MISSION EQUIPMENT AND INTEGRATED/AUTOMATED COCKPIT

Expected advances in avionics, visionics, and cockpit displays and controls technologies will provide a significant reduction in mission equipment weight (at the same functional capability level) for future helicopters. An even more important consideration is the expectation that these advanced technologies, coupled with automation of many cockpit functions, will enable very difficult military missions such as all-weather, day/night attack to be performed by a single-crewman rotorcraft. The expected effect of these advances on the baseline light attack helicopter design was investigated by assuming that a 25% reduction in mission equipment weight will be achieved by the incorporation of advanced mission equipment and an integrated/automated one-man cockpit. The deletion of the second crewman allows airframe weight reduction in cockpit furnishings, armor, flight controls, airframe equipment, and fuselage structure. The effect on the baseline design is shown in Table 9, which indicates a 21% decrease in aircraft empty weight and a 20% decrease in design gross weight. This is the largest single decrease found in this study and emphasizes the potential benefit if a single crewman attack helicopter can be achieved.

Table 9. Effect of advanced technology mission equipment and integrated/automated cockpit on baseline design

	Baseline Design	Advanced MEP and 1-Man Cockpit
Disc Loading (lb/ft^2)	7.00	7.00
Rotor Solidity	0.083	0.083
Rotor Tip Speed (ft/sec)	700	700
Rotor Diameter (ft)	54.1	48.4
Operating Length (ft)	64.7	58.6
Engines	2 X T700	2 X T700
Engine IRP (hp)	2121	1731
Rotors (lb)	1587	1201
Airframe (lb)	2893	2288
Propulsion (lb)	3585	2992
Flight Controls (lb)	925	740
Airframe Equipment (lb)	1040	800
Mission Equipment (lb)	2000	1500
Armor (lb)	166	122
Empty Weight (lb)	12196	9642
Crew (lb)	500	250
Fuel Burned (lb)	1820	1498
Fuel Reserve & Fluids (lb)	413	349
Armament (lb)	1166	1166
Gross Weight (lb)	16095	12905
Performance at 4000 Ft/95°F		
Dash Speed (IRP) (kts)	175	175
Cruise Speed (MCP) (kts)	161	168
VROC (95% IRP) (fpm)	2311	2467

9. ADVANCED WEAPONS TECHNOLOGY

Advanced weapons technologies available in the near future will allow improved helicopter mission capability in both attack and defensive roles. Weight and size reductions of missile and gun systems will be achieved by improvements in guidance, warhead, structural, and propulsion technologies. The application of composite materials will be a major contributor to weight reduction in missile pods and in the turret structure and ammunition storage and feed components of gun systems. Precision aiming technology in gun systems will allow reductions in ammunition carried, or increases in mission capability for the same ammunition weight. Reduced weapon size and the requirement for increased helicopter flight speed will lead to conformal or internal carriage of weapons. The resulting decrease in drag will contribute to reductions in engine size, mission fuel, and aircraft weight.

The application of these advanced weapons technologies to the baseline light attack helicopter weapon suite is estimated to reduce the armament weight by about 25%. This leads to a 5% reduction in design gross weight, as shown in Table 10. The two helicopter designs both carry the same type of weapon suite consisting of a turreted automatic cannon and anti-armor and anti-air missiles. The advanced weapons case also benefited from a decrease in drag due to conformal-carriage missile pods.

Table 10. Effect of advanced weapons technology on baseline design.

	Baseline Design	Advanced Weapons
Disc Loading (lb/ft^2)	7.00	7.00
Rotor Solidity	0.083	0.083
Rotor Tip Speed (ft/sec)	700	700
Rotor Diameter (ft)	54.1	52.8
Operating Length (ft)	64.7	63.1
Engines	2 X T700	2 X T700
Engine IRP (hp)	2121	2006
Rotors (lb)	1587	1488
Airframe (lb)	2893	2792
Propulsion (lb)	3585	3417
Flight Controls (lb)	925	899
Airframe Equipment (lb)	1040	1040
Mission Equipment (lb)	2000	2000
Armor (lb)	166	166
Empty Weight (lb)	12196	11802
Crew (lb)	500	500
Fuel Burned (lb)	1820	1738
Fuel Reserve & Fluids (lb)	413	397
Armament (lb)	1166	865
Gross Weight (lb)	16095	15303
Performance at 4000 Ft/95°F		
Dash Speed (IRP) (kts)	175	175
Cruise Speed (MCP) (kts)	161	161
VROC (95% IRP) (fpm)	2311	2270

10. INTEGRATED EFFECT OF ADVANCED TECHNOLOGY

The full benefit of advanced technology is obtained by the integrated effect of an across-the board application of the advanced technologies discussed above. Table 11 presents results of applying the advanced rotor, advanced composite structures, digital fiber optics flight control system, drag reduction, advanced engines, advanced mission equipment and integrated/automated cockpit, and advanced weapons to the baseline current technology design. The combined benefits of these advanced technologies are truly remarkable: the advanced technologies design has 59% smaller engine IRP required, 49% smaller empty weight, 52% less mission fuel burned, and a 48% smaller design gross weight. Note also that the advanced design exhibits a better balance between dash speed and vertical rate of climb than does the baseline design. This is principally due to the significantly lower drag level of the advanced design.

Table 11. Integrated effect of all advanced technologies on baseline design.

	Baseline Design	All Advanced Technologies
Disc Loading (lb/ft^2)	7.00	7.00
Rotor Solidity	0.083	0.083
Rotor Tip Speed (ft/sec)	700	700
Rotor Diameter (ft)	54.1	39.0
Operating Length (ft)	64.7	47.3
Engines	2 X T700	2 X ATDE
Engine IRP (hp)	2121	860
Rotors (lb)	1587	604
Airframe (lb)	2893	1250
Propulsion (lb)	3585	1444
Flight Controls (lb)	925	450
Airframe Equipment (lb)	1040	800
Mission Equipment (lb)	2000	1500
Armor (lb)	166	122
Empty Weight (lb)	12196	6170
Crew (lb)	500	250
Fuel Burned (lb)	1820	875
Fuel Reserve & Fluids (lb)	413	197
Armament (lb)	1166	865
Gross Weight (lb)	16095	8356
Performance at 4000 Ft/95°F		
Dash Speed (IRP) (kts)	175	180
Cruise Speed (MCP) (kts)	161	163
VROC (95% IRP) (fpm)	2311	500

Figure 6 presents a graphic summary of weight and power savings for each of the advanced technologies considered in this paper: gross weight, fuel burned, and horsepower are given as a percentage of the values for the current technology baseline design. Inspection of Figure 6 indicates that the two most important technologies for reducing helicopter airframe weight, mission fuel, and engine size are the advanced technology rotor and the one-man cockpit (the later achieved by means of advanced mission equipment and integrated/automated cockpit). Advanced technologies which produced relatively smaller size reductions may be equally desirable due to other benefits (e.g., the digital optical flight control system may exhibit high payoff in control fidelity and survivability). The effect of changing to the ADTE engine would have been much stronger if the baseline helicopter had been designed with (a rubber model of) a fielded engine in the 800 to 1000 horsepower class, rather than (a rubber model of) the T700, which is a relatively recent engine design.

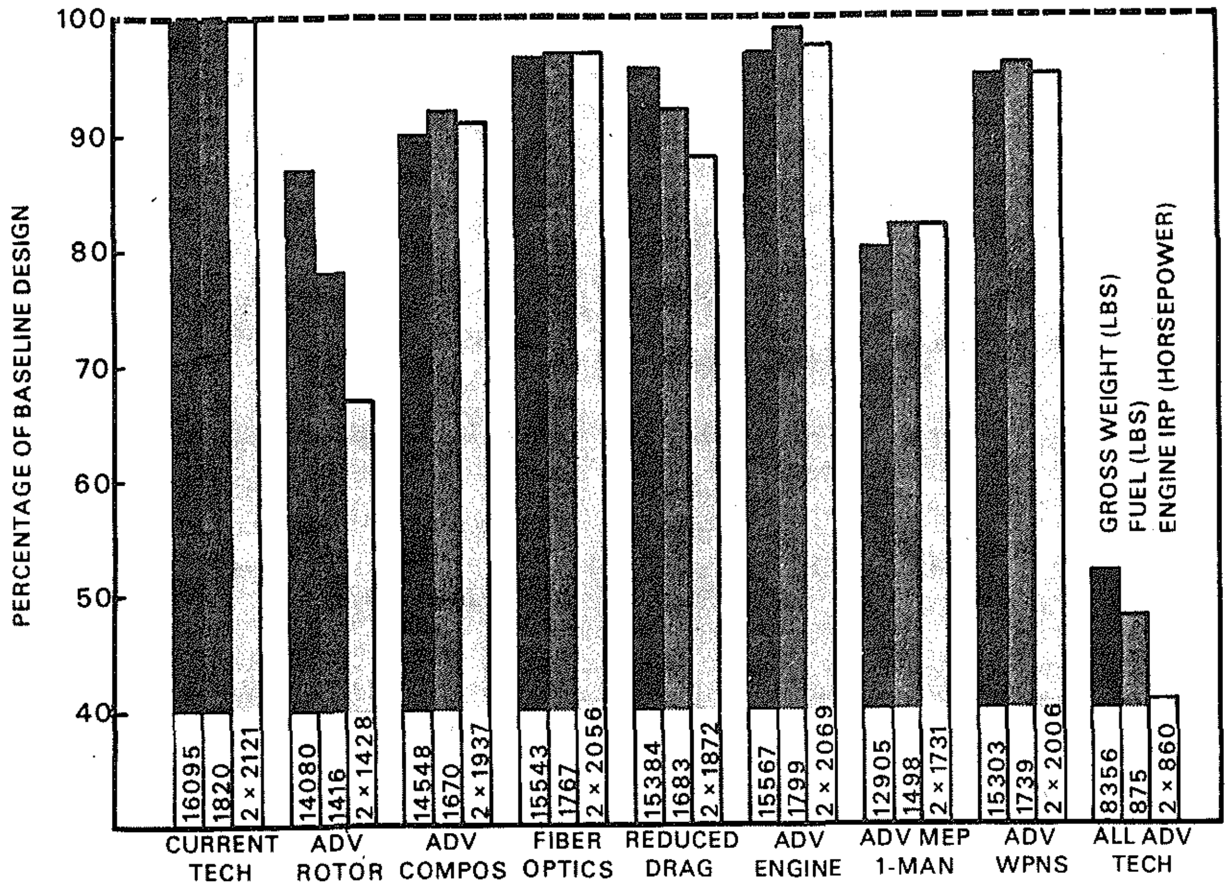

Figure 6. Advanced Technology Effects.

11. CLOSING REMARKS

The preliminary design studies presented in this paper indicate certain advanced technologies, such as the integrated/automated cockpit, will provide the helicopter designer opportunity to significantly reduce aircraft size and fuel consumption. However, it is only the combined effect of an across-the-board application of all advanced technologies which will bring about the 50% reduction we have predicted. The helicopter detail design team will be faced with a most difficult task: to judiciously apply the available advanced technologies so as to maximize the benefits of each. The payoff for a successfully integrated design will be unmatched productivity and cost effectiveness.

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The view, opinions, and findings contained in this paper are those of the authors and should not be construed as official Department of the Army position, policy, or decision.

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