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Achieving Helicopter Modernization with Advanced Technology Turbine Engines

(April 1999)

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I. Introduction

Military and commercial helicopter operators worldwide are faced with a common dilemma—when to replace existing fleets with newer, more capable, and yes, more expensive helicopters. Alternatively, how often and how much should they spend on upgrades. Either decision may be based on operational needs, operational support costs, or a combination of both.

On a personal level, you go through a similar process when deciding to replace the family car with a new or used car. As long as the basic mission remains unchanged, such as the daily commute to and from work, and the vehicle is reliable and replacement parts are readily available, then you probably can't economically rationalize a new car.

Automobile upgrades are virtually limitless as there are many sources for new engines, radios, security systems, power door locks, stereo systems, cruise controls, trailer hitches, and fog lights, among others. All of these options serve the same purpose: to make an existing car more functional or to extend its life.

A replacement can be rationalized when repair costs become too expensive, you experience a major failure, the car is no longer reliable, fuel costs or fuel consumption become prohibitive, or there is no longer room for the growing family.

Likewise, there are many examples where helicopter replacements are necessary in lieu of upgrades. Helicopter replacements are appropriate when the mission need and capability of the replacement is so compelling that upgrades to the existing system are simply cost prohibitive and/or the desired performance is not achievable within the existing airframe structure. Crashworthiness, cargo volume, night/adverse weather capability, payload, range, speed, battle damage vulnerability, multi-engine requirements, and marinization, among many other considerations, might contribute to the replacement decision.

A few examples of cost and mission effective replacement helicopters are listed in Figure 1. The replacement of the CH-46 helicopter with the V-22 Osprey tiltrotor is the most compelling example of an extraordinary aircraft capability redefining an operational mission.

Legacy Helicopter	Replacement Helicopter
• UH-1H Huey	UH-60 Blackhawk (USA)
• AH-1S Cobra	AH-64 Apache
• CH-46 Sea Knight	V-22 Osprey
• UH-1H Huey	NH-90 (Germany)
• OH-58D Kiowa	RAH-66 Comanche

Figure 1. Replacement helicopter programs.

A decision to extend the life of a helicopter is appropriate when the mission has remained relatively unchanged and technology is available to directly enhance mission effectiveness (for example, communications and navigation equipment, survivability equipment, signature reduction, or helicopter performance). As always, available funding could be the controlling factor in spite of mission needs.

The U.S. Government achieves significant helicopter updates through programs such as Horizontal Technology Insertion (HTI) and "Modernization through Spares" programs. A communication package developed for the UH-60 under HTI may be applied to one or more other helicopters which helps to spread the development cost, reduce the production unit costs, lower support costs, and ensure standardization and interoperability. Likewise, modernization through spares takes advantage of new materials, electronics, or manufacturing processes to produce more reliable and longer lasting parts. In both cases, the greater the number of applications, the lower the unit cost.

Examples of successful helicopter upgrades are shown in Figure 2. The addition of the Longbow radar to the AH-64 Apache represents the greatest operational improvement achieved through technology insertion or a midlife upgrade program among the examples shown.

Legacy Helicopter	Upgraded Models
• CH-47A	CH-47B, C, D, E
• UH-60A	UH-60B, Q, L, L+, X
• AH-64A	AH-64B, C, D
• AH-1G	AH-1F, S, Q, W
• UH-1N	UH-1N (4BN)
• OH-58A	OH-58C, D, Armed
• A-129A	A-129I
• Lynx	Super Lynx
• S-76A	S-76B,C
• B206	B206III
• AS365	EC155

Figure 2. Helicopter upgrade programs.

Paper presented at the RTO SCI Symposium on "Aircraft Update Programmes. The Economical Alternative?", held in Ankara, Turkey, 26-28 April 1999 and published in RTO MP-44.

The number of worldwide upgrades across all helicopter models far exceeds the procurement of replacement helicopters. Clearly, extending the life of current helicopters is far more cost effective than wholesale replacements and, in most cases, nearly as mission effective. With continuing budget shortfalls to operational requirements and exceedingly long timelines to field new helicopter systems, we can expect this trend to continue.

II. Turbine Engines and Helicopter Upgrade Programs

Although the number and type of helicopter upgrades available are limited only by the number of subsystems, the operational requirements, and the available funding, this paper will focus on the contribution of modern turbine engines to upgrade programs.

Significant improvements to fielded helicopters are realized through the installation of improved gas turbine engines with greatly increased power/weight ratios, reduced specific fuel consumption, and digital engine controls. Modern engines are operating at ever-increasing pressure ratios possible through the increased fidelity of computer modeling of compressor and turbine aerodynamics. Modern directionally solidified and single crystal turbine blades considerably enhance the engine temperature capability.

Electronic controls have simplified the engine's fuel control system since numerous pneumatic and fuel lines required for engine operation are no longer required. Operators also benefit from cooler and automatically controlled starts. Pilot's like automatic limiting, precise rotor control, and improved handling qualities.

As shown in Figure 3, helicopters, as a general rule, increase in maximum gross takeoff weight (MGTOW) over their operational lives. These increases are a direct result of increasing demands on operational capability. Accordingly, increasing takeoff weights demand more installed power to retain or improve operational performances. The RAH-66 is unique in that mission demands dictated an MGTOW increase prior to its fielding.

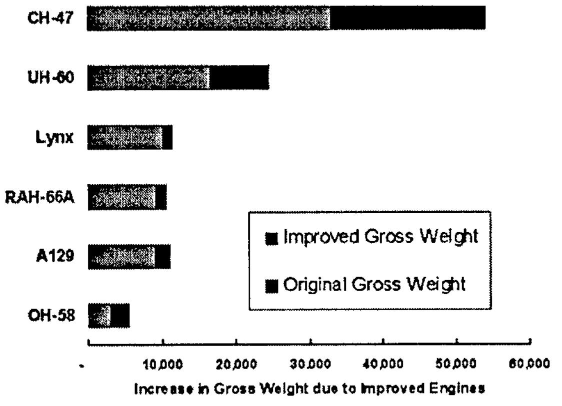

Figure 3. Gross weight increases demand increased power.

As helicopters grow in mission capability, engines are also continually improved over their lives to meet or exceed operator demands. Eventually, as military needs change, a government program will result in a new engine that provides a new baseline for incorporation of all technology currently available. In addition to technology insertion, these new engines feature modularity, marinization, electronic controls, and maintainability features in the baseline design. Current examples are the MTR390, RTM322, and T800.

MTU/Turbomeca/Rolls-Royce MTR390

The MTR390 was developed as a compact, rugged, and high performance engine for European civil and military helicopters in the 2.5 to 7.5 ton weight class. For the Eurocopter Tiger, the engine is rated at 1285 shp for takeoff and 1170 shp continuous.

Developed in the late 1980's, the MTR390 engine shares many features with the T800. The MTR390 consists of three modules including an integral reduction gearbox, gas generator, and power turbine.

The engine is controlled by a single channel full authority digital engine control (FADEC) with manual backup. Maintenance is performed on-condition with a minimum number of hand tools.

Roll-Royce/Turbomeca RTM322

The RTM322 was developed to compete in the 2100 to 3000 shp market as a modern technology engine. The development was initiated in 1983, and the RTM322 has been selected to power the EH-101 Merlin helicopter, WAH-64, and NH-90. Other potential applications include the UH-60 Blackhawk and Sikorsky S-92. The engine is a fairly simple alternative or replacement for the General Electric T700 since they share several applications (EH-101, NH-90, and AH-64) plus the RTM has been successfully demonstrated on the UH-60 Blackhawk.

From a technology standpoint the RTM322 is very similar to the T800, as I discuss later. Incorporating a modular design, the RTM322 engine consists of five modules including the inlet particle separator, compressor and intake, gas generator and combustor, and the power turbine. The engine was designed to provide better performance than competing engines and have growth potential to over 3,000 shp. As with most modern technology engines, the RTM322 is controlled by a dual channel FADEC, and features a very simple installation and significantly reduced pilot workload.

Since the engine was envisioned for marine operations, a high efficiency inlet particle separator is incorporated along with material and coatings that are resistant to corrosion. Installation in existing helicopters has been easy as in the case of the AH-64 for the United Kingdom Ministry of Defence described later.

LHTEC T800

The T800 engine was developed by the Light Helicopter Turbine Engine Company (LHTEC), a partnership of Rolls-Royce Allison and AlliedSignal.

The T800 is one of the world's most modern and technologically advanced gas turbine engines. It has a 4.1 power/weight ratio and the lowest fuel consumption of any turbine engine in its class. It is designed with self-contained and totally independent fuel, lubrication, and electrical systems and an advanced inlet particle separator with demonstrated sand-air separation efficiencies as high as 97.5%. The FADEC improves acceleration, minimizes rotor droop, and significantly reduces pilot workload through automatic starting and control of all engine, transmission, and rotor operating limits. The engine was designed for a 6000-hour life and "on-condition" maintenance without time-limited overhauls.

All of the turbomachinery performance was achieved through extensive development testing and use of the latest computational fluid dynamics codes. A patented device for the compressor provides improved off-design efficiency and stability margin. The power turbine module, FADEC, and all accessories are fully field replaceable.

III. T800 Engine Upgrade for the UH-1H

General

To illustrate the potential of engines to improve operational effectiveness in a cost-effective manner, the UH-1H helicopter upgraded with the T800-LHT-801 engine will be examined in detail. The UH-1H has been in worldwide operational service well beyond 30 years, while the T800 is one of the world's most modern turboshaft engines. Because of the contrast between a very old helicopter and very new engine, this best illustrates the operational value of engine technology at an affordable cost. The T800 engine was developed for the U.S. Army's RAH-66 Comanche helicopter (see Figures 4 and 7).

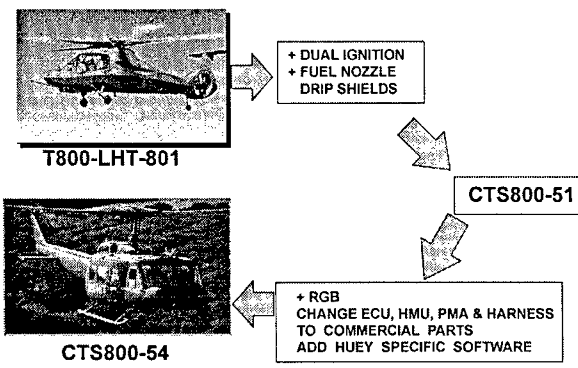

Figure 4. T800 configuration for UH-1H.

This example is also appropriate and very timely because the U.S. Army has just completed an exhaustive study which validated the cost effectiveness of this installation when compared to over 30 alternate helicopters or helicopter combinations. After the UH-1H example, several other engine upgrade and helicopter modification programs with their resultant performance gains will be summarized.

T800 Engine Description

An appropriate beginning is to agree on what is meant by an "advanced technology" engine. Technological measures include but are not limited to those listed in Figure 5. The T800 engine embodies all of these technologies and was specifically designed for outstanding operational performance, a very long life, ease of maintenance, and lower direct operating costs.

- Electronic Record Keeping, Scheduling, Diagnostics, and Training
- Advanced Materials for Durability and Weight Savings
- Modular Construction for Ease of Maintenance
- Higher Internal Temperatures and Pressures
- Reduction in the Repair Touch Labor
- Employment of Electronic Controls
- Elimination of Variable Geometry
- Higher Power-to-Weight Ratio
- Human Factors Considerations
- Engine Weight Reduction
- Lower Fuel Consumption
- Reduced Part Count
- Inlet Protection

Figure 5. Technology measurements.

As shown in Figure 6, all T800 technological achievements were driven by customer demands. In fact, the T800 engine development program responded to the most demanding system specification ever written for a turboshaft engine in this power class.

An overview of the T800 engine configuration is shown in Figure 7. Its simple architecture employs counter-rotating gas producer and power turbine shafts, two bearing supports, front drive, and through-flow gas path. Note how all accessories are located on top of the engine for reduced vulnerability and improved accessibility. The scroll shaped device in the outside view is part of the scavenge system for the inlet particle separator.

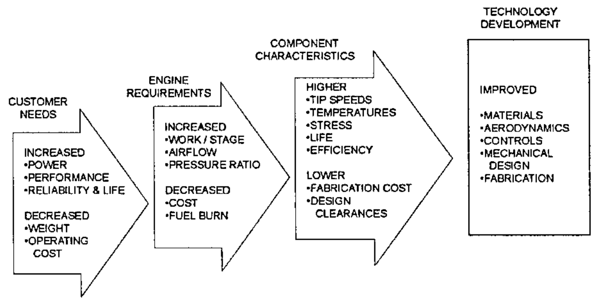

Figure 6. Customers drive design, materials, and technology.

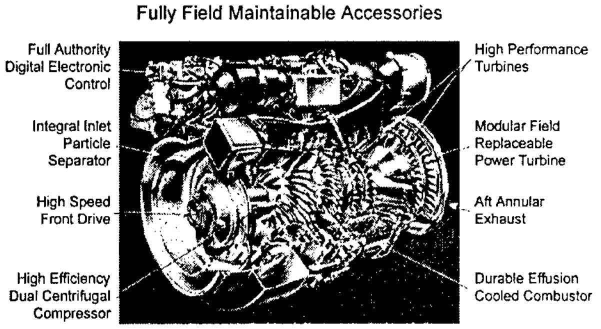

Figure 7. T800 engine configuration.

The main features of T800 core components are listed in Figure 8. All of the turbine disks are made of very high strength Udimet 720 material to reduce weight and inertia. Life of components is generally in excess of 15,000 cycles and 6,000 hours. The annular combustor is of the foldback type that minimizes the engine length and has special features that produce low gaseous emissions and smoke. Achieved performance surpasses the goals for all of these components.

T800 Development Program

The T800 development schedule is shown in Figure 9. Development of the engine began in 1984 with a U.S. Army qualification and Federal Aviation Administration (FAA) certification of the initial engine version, the T800-LHT-800, in 1993. As a result of lessons learned from Desert Storm, the mission weight specification for the RAH-66 Comanche increased, necessitating a 17% engine growth program to retain its mission performance. Development of the T800-LHT-801 engine began in 1993 and FAA certification is planned for 1999.

Maintenance Enhancements

The T800 is the first engine designed for two levels of maintenance, a greatly reduced number of tools, ease of maintenance in extreme conditions, and rapid completion of maintenance tasks. Removal and replacement of line replaceable units (LRUs) are the only organizational maintenance requirements. All engine/component repairs are accomplished at the depot level, thus eliminating a major investment in manpower and materials previously necessary to provide an intermediate maintenance capability.

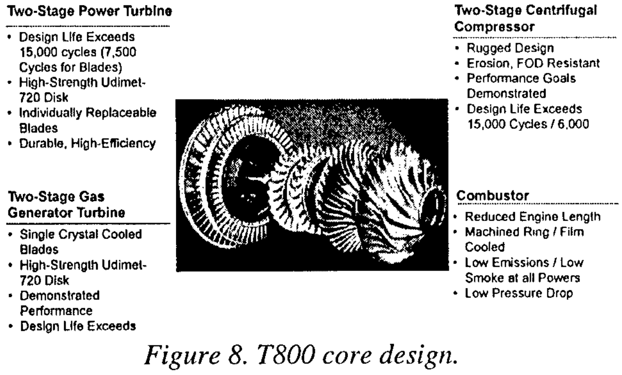

Figure 8. T800 core design.

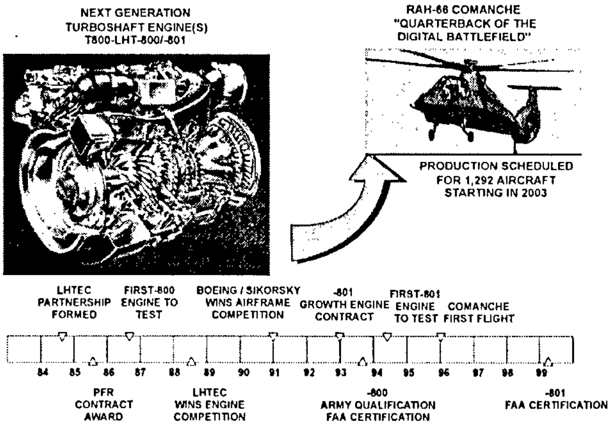

Figure 9. T800 program overview.

Maintenance man-hours have also been significantly reduced. Demonstrated maximum removal and replacement times are 34 minutes for modules and 12.8 minutes for all line replaceable units using six common hand tools (see Figure 10). The T800's modular construction consists of the gas producer, power turbine, inlet particle separator, and accessory drive system. It is important to note that the engine uses no safety wire.

Description of the UH-1H

The UH-1H "Huey," shown in Figure 11, is the world-renowned light utility workhorse having been produced in substantial quantities during the Vietnam war. It is estimated that over 5,000 helicopters are still in service around the world with nearly 1,000 still in the U.S. Army inventory.

The UH-1H has participated in every major conflict since Vietnam and, in fact, flew 85% of all aeromedical evacuations (MEDEVAC) during Desert Shield/Storm. It is by far the world's most cost-effective and dependable light utility helicopter. Because of its continuing and cost-effective relevancy to military missions worldwide, it is well suited for an engine upgrade. As previously mentioned, the U.S. Army, after considering all replacement alternatives, has chosen the UH-1H, with an engine upgrade, to fulfill its Light Utility Helicopter Mission until 2025.

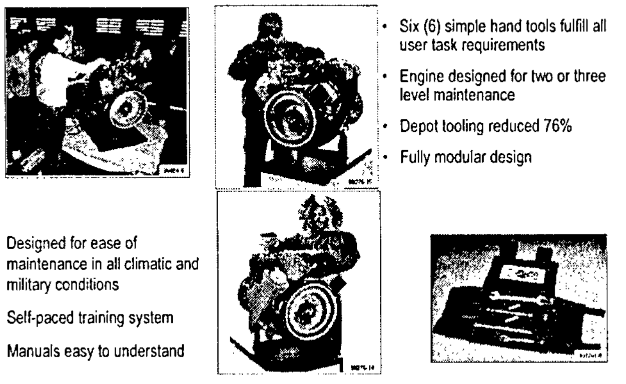

Figure 10. T800 is designed for maintainability.

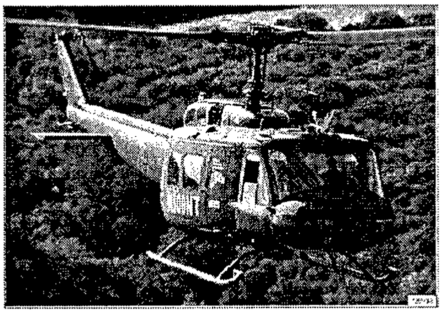

Figure 11. T800-powered UH-1H Huey.

The UH-1H remains an ideal helicopter for combat service support missions such as resupply and MEDEVAC, and for all peacetime operations such as disaster relief, drug interdiction, surveillance, administrative support, command and control, search and rescue, and other humanitarian missions. This is not to suggest that the UH-1H should perform combat assault missions for which there are far more capable helicopters such as the UH-60 Blackhawk. Conversely, it is not cost effective to use limited combat resources to perform "rear area" LUH missions because of their inherent complexity, cost, and performance.

The UH-1H airframe has demonstrated an indefinite life, with some airframes having accumulated over 30,000 flight hours. In comparison, the average hours on the current U.S. Army fleet is a very young 4,000 hours. The average hour profile will be even less once planned force structure reductions are implemented, since the Army will retain its newest and lowest flight time aircraft.

The only documented problems with the UH-1H helicopter are its engine and avionics, which are both easily and economically replaced.

Advantages of installing the T800 engine in the UH-1H are numerous, but there is an overall emphasis of minimizing the pilot's workload and enhancing helicopter performance. These features include automatic start sequencing and control, automatic and precise rotor speed control even during extreme maneuvers, flameout detection, and automatic reset to contingency power, if required.

A key performance objective to ensure agility and maneuverability for helicopters is a rapid power change. The -801 FADEC has been tuned for rapid engine acceleration. From flight idle, full power is available in just 3 seconds. A low inertia two-stage gas producer turbine and robust stability margin are the keys to rapid acceleration. Its response is so impressive that pilots have reported the perception of "extra" power.

Pilot workload is further reduced through the elimination or modification of several emergency procedures including engine restart, high/low side governor failure, droop compensator failure, short shaft failure, emergency governor operations, engine compressor stall, and overspeed.

The monitoring feature of the control system tracks parts life, records engine exceedances, fault diagnostics, and performance trending.

UH-1H Performance

Fuel consumption is so low that mission endurance is improved by over 50%. Other operational enhancements include significant improvements in payload, range, and endurance. As shown in Figure 12, the T800 is able to lift an additional 1,400 lb of payload—a 54% increase—with the existing airframe on a hot day at sea level.

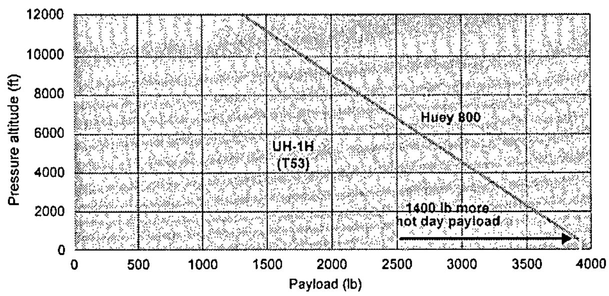

Figure 12. Hover performance (out of ground effect ISA +30 deg).

The T800 engine takes full advantage of current UH-1H dynamic component and structural limitations. Therefore, dynamic component upgrades (transmission, main rotor, tail rotor, and gearboxes) to the UH-1H are not justified by U.S. Army requirements.

A 58% range or 47% payload improvement is achieved with the current fuel load and existing airframe at 2,000 ft on a tropical day (see Figure 13).

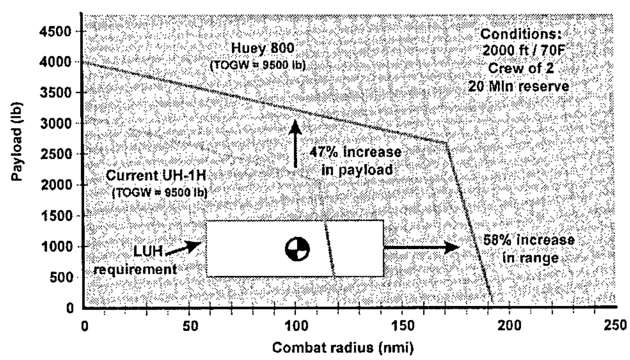

Figure 13. Payload/range comparison.

A dramatic demonstration of T800 performance occurred on April 22, 1993. A T800-powered UH-1H flew into the record books between Oxnard, California, and Atlanta, Georgia, shattering an unrefueled world distance record by over 600 statute miles. The distance of 1,975 miles was completed in just over 13 hours. The fuel burn on this 13-hour flight averaged only 311 lb per hour and as low as 220 lb per hour (see Figure 14).

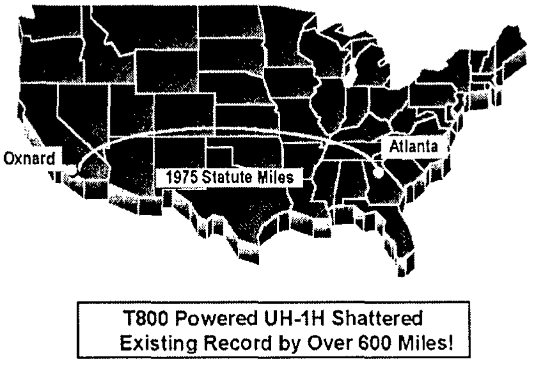

Figure 14. Huey 800 holds world distance record.

Installation

Installation of the CTS800-54, a commercial version of the T800-LHT-801, in the Huey is very simple and straightforward, as shown in Figure 15. The engine fits on the same mounts as the T53 and claims a smaller space. Note the speed reduction gearbox mounted on the front face of the engine and connected to the transmission short shaft.

With a sea level standard takeoff rating of 1575 shp, the CTS800-54 engine has 12.5% greater installed power than the T53 yet the T800 system weight is 144 lb lighter than the T53. This is another tribute to its high power/weight ratio, which translates directly into more payload or fuel carrying capability.

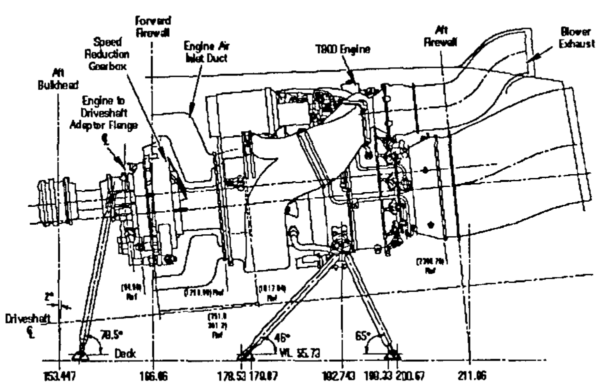

Figure 15. Simple, straightforward installation.

Investment

As shown in Figure 16, an operator will be able to recover the cost of a T800 installation through savings realized from as little as two T53 overhauls. The figure assumes that new engines are scheduled for installation as the T53 approaches an overhaul interval such that the full life of the T53 will have been realized. The overhaul savings are then deducted directly from the T800 initial acquisition cost.

The total savings achievable will vary significantly across worldwide support centers. It is also important to note that cost savings from an upgrade can only be realized through proper utilization of the operational fleet. Logically, the more hours the helicopters are flown, the faster the payback.

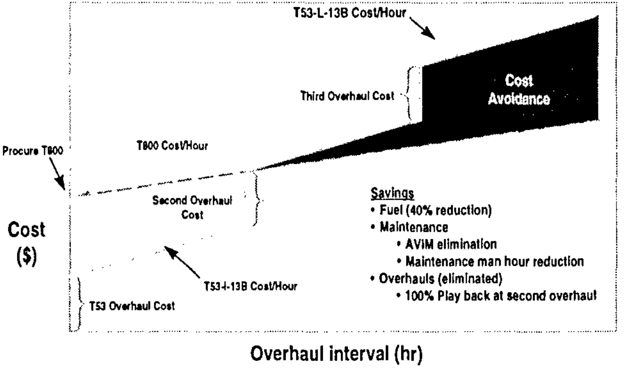

Figure 16. Investment (notional).

Figure 17 shows that the total capital outlays for the engine will remain essentially the same over a 20-year period. As shown, acquisition costs for a new engine are traded 1:1 for current support costs. In this worst case scenario, the performance gains would accrue to the operator essentially free of charge.

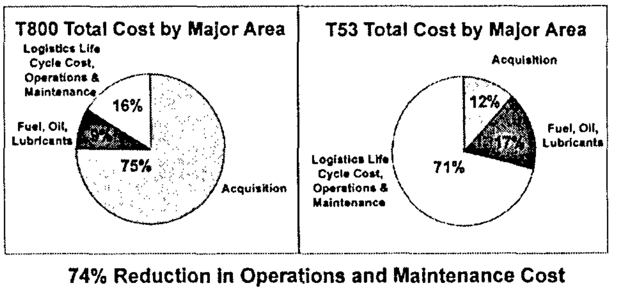

Figure 17. Total cost comparison.

Conclusion

By almost any measure, operators of the UH-1H helicopter would benefit significantly from an upgrade to the CTS800-54 engine. This example illustrates the improvements resulting from a 30-year leap in technology. The incorporation of a new engine will maintain the viability of the UH-1H helicopter well into the 21st century.

IV. Examples of the Engine Contribution to other Helicopter Upgrade Programs

Other modern helicopters have evolved from less capable beginnings. Although the focus remains on the propulsion system, the significant advances of other helicopter subsystems should not be ignored.

For the examples shown, fuel consumption was typically reduced by 15% while engine power/weight ratios were increased by an average of nearly 50% as shown in Figure 18.

As a result of increased power/weight ratios, greater reliability, and reduced specific fuel consumption, turbine engine manufacturers have been able to provide a continual increase in performance and operational improvements at lower operating costs to military as well as commercial customers.

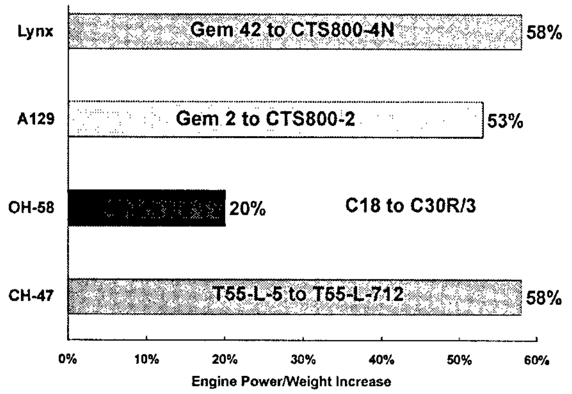

Figure 18. Power/weight ratio affords increased power but not at the expense of payload.

CH-47 Chinook Cargo Helicopter

The Boeing CH-47A Chinook cargo helicopter (Figure 19) entered U.S. Army service in 1962 equipped with two 2,200 shp Lycoming T55-L-5 engines. With a gross weight of 33,000 lb the helicopter was capable of delivering a 6,000 lb load to 100 NM and return without refueling in high hot conditions.

The current AlliedSignal T55-L-712, with a sea level standard takeoff rating of 4,378 shp, installed in the CH-47D, nearly doubles the takeoff power available. As a result when coupled with advanced rotor systems and increased capacity main rotor transmissions the current 'D' version can move nearly 14,000 lb the same distance, an increase of 233%.

Figure 19. Boeing Helicopter CH-47 Chinook.

A future version, dubbed the Improved Cargo Helicopter, with T55-L-714 engines is planned and will further increase the takeoff power of the FADEC controlled engines to 5,700 shp while reducing SFC another 15%. As a result the lift capability will improve to nearly 20,000 lb for the same 100 NM mission.

OH-58 Kiowa

The Bell Helicopter OH-58A entered U.S. Army service in 1969. The 'A' model was powered by a single 317 shp Rolls-Royce Allison C18 turboshaft engine. Designed as a Light Observation Helicopter (LOH), this versatile helicopter could be configured for troop transport, MEDEVAC, and for external lift missions with a cargo hook. However, the temperate conditions of South East Asia seriously limited the capabilities of the helicopter.

With the advent of the OH-58C model, a more powerful 420 shp C20B engine was installed offering a 32% increase in installed power at only an 11% increase in engine-installed weight.

Today, the OH-58D mission has become much more sophisticated and demanding. The transformation to the OH-58D configuration, shown in Figure 20, included a significant list of improvements in addition the 650 shp Rolls-Royce Allison C30R/3 engine with a FADEC.

Figure 20. Bell Helicopter OH-58D Kiowa Warrior.

The original two-bladed teetering rotor was replaced with a sophisticated four-bladed soft-in-plane rotor system that significantly enhanced not only the performance of the helicopter but also its maneuverability. To support the 55% increase in installed power, the entire dynamic system was replaced.

Remarkably, the OH-58 has been continuously improved now for over 30 years with three complete engine upgrades. When compared to the original OH-58, the current OH-58D gross weight has increased by a whopping 90% with a doubling of the installed power.

UH-60 Blackhawk

The Sikorsky UH-60 Blackhawk (Figure 21) utility helicopter entered U.S. Army service in 1976 and represented a significant advance in rotorcraft technology from the UH-1H of the day. In the last 23 years, the UH-60 has benefited from an improved version of the T700. The T700-GE-701C provides an 11% increase in available power for improved hot/high performance.

As a result of the increased power, the lift capability of the UH-60 has increased significantly. For example, the original 'A' model is capable of moving a 4,000 lb load to a distance of 75 kilometers. With the additional power of the -701C engines the payload carried has increased to over 6,000 lb. This represents an increase of 50% simply due to the additional power available.

Figure 21. Sikorsky UH-60L Blackhawk.

AH-64 Apache

The Boeing AH-64 Apache (Figure 22) is the U.S. Army's premier attack helicopter. Having entered service in 1984, the AH-64 has benefited from several upgrade programs to improve the performance of the helicopter and enhance its mission capabilities.

Figure 22. Boeing Helicopters AH-64D Apache.

The WAH-64 Apache will soon enter service with the United Kingdom Army powered by the Rolls-Royce/Turbomeca RTM322 engines. The RTM322 engines provide an 11% installed power increase with only minor changes to the engine bay. In addition to an increase in installed power, the operator will also benefit from its FADEC, efficient integral particle separator, modular construction, lower support costs, and longer life.

Westland Lynx

The GKN Westland Lynx is the premier utility helicopter of the United Kingdom Ministry of Defence (Figure 23). Fitted for Army and Royal Navy duty, the first Lynx's entered service in 1984 powered by Rolls-Royce Gem 42 engines.

Westland is proposing to replace the Gem 42 engines with LHTEC CTS800-4N turboshaft engines in several worldwide markets.

With the CTS800-4N engines, cruise fuel flow is reduced by 15% and available power is increased by 36%, yet the overall propulsion weight is reduced by 24 lb. This is a perfect example of how engine technology enhances mission capability.

Figure 23. GKN Westland Lynx.

Agusta A129I

The Agusta A129 (Figure 24) entered service with the Italian Army in 1990. The Mangusta is equipped with two Rolls-Royce Gem 2 Mk 1004D engines built in Italy by Piaggio under license from Rolls-Royce.

Agusta is currently proposing an 'International' version for several attack helicopter competitions. The cornerstone of this version is the LHTEC CTS800-2 turboshaft engine. The CTS800 engines provide a 36% increase in installed power with a corresponding 15% reduction in fuel flow.

Incorporation of CTS800 engines along with a new five-bladed main rotor has allowed for a 22% increase in gross weight.

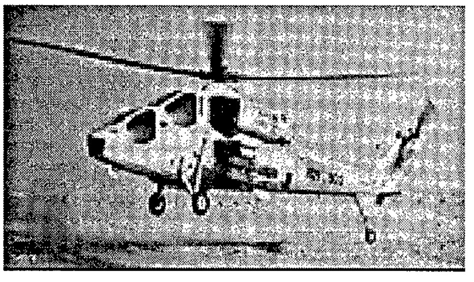

Figure 24. Agusta A129.

V. Future Engine Upgrade Programs

The U.S. Army is currently staffing a draft Operational Requirements Document (ORD) that will push engine technologies to even higher levels. The new requirement proposes an external lift capability of 10,000 lb for the UH-60 Blackhawk and a range of 360 NM. This represents an increase of 66% in lift capability and a 30% increase in range over the current helicopter.

Propulsion alternatives to comply with the ORD could evolve as derivatives of current engines such as the CT7-8 or RTM322 or alternatively, the Army could fund the development of a new centerline engine. If funded and fielded, this engine is expected to provide another 25% reduction in specific fuel consumption, an 80% increase in power/weight, and a 20% reduction in operation and support costs over current technology engines.

Known as the Common Engine Program (CEP), the engine, derivative or new, is expected to power both the Blackhawk and Apache helicopters. As discussed previously, the program will meet both the spirit and intent of Horizontal Technology Insertion.

VI. Conclusions

During the last 40 years, military and commercial helicopter operators have greatly benefited from the advancements in turbine engine technology. Both derivative and new turbine engines have benefited from increases in power/weight ratio, reduced specific fuel consumption operation, and support costs.

Engine upgrades, when teamed with additional rotor and dynamic changes, offer dramatic improvements in overall mission capability as shown in the CH-47D and OH-58D examples. The OH-58D helicopter was transformed from an unarmed, unsophisticated light observation helicopter to an armed reconnaissance helicopter. The ability to make such a large transformation was largely based on improved turbine engines.

As helicopter fleets age and budgets either decline or remain constant and operational demands increase, look to modern turbine engines to leverage helicopter operational effectiveness in a cost effective manner.