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T700/CT7 Derivative Growth Engine Reliability Consistent With Longstanding Industry Traditions

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T700/CT7 DERIVATIVE GROWTH ENGINE RELIABILITY - CONSISTENT WITH LONGSTANDING INDUSTRY TRADITIONS

by

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ABSTRACT

Growing the horsepower of an engine which is in production to meet the enhanced mission requirements of current applications and to power new applications is a long-established practice in the industry. The approaches taken for increased power, the status of the technology included, and the differences or changes in the engine are all factors that could have an impact on the established reliability previously offered by the baseline engine.

Development of the T700-GE-401 derivative growth engine (10% growth engine for the U.S. Navy) was launched coincident with the baseline T700-700 maturity program. Maintaining a high degree of design and parts commonality was a criteria in detailing the -401 design, so as to minimize the introduction of untested features or hardware to the engine and thereby maximize reliability consistent with -700 experience. Commonality of parts manufacturing and processes carry-over from the baseline -700 was achieved by building both engines on the same production line.

By designing a balanced test program that combined a mix of classical qualification tests with the special tests required by the U.S. Navy and new accelerated endurance tests, the qualification program for the growth -401 engine was tuned to operational needs and was shortened in terms of total test hours required. It is significant to note that the -401 is proving to be every bit as reliable as the baseline -700.

Now that additional T700/CT7 growth derivatives are under development, this paper reviews the history and position of several major engine manufacturers relative to the reliability of growth derivatives as compared to other development alternatives, synthesizes the factors which have made them successful, and reviews the T700/CT7 Step 2 growth derivative designs and development program for applicability of these factors.

1. INTRODUCTION

Growth engines are derivatives of existing engine models. As derivatives they are based upon an established design with proven operating experience. In addition, they capitalize upon a high degree of commonality with the established design while introducing technology improvements to achieve program objectives. Typically, these improvements have demonstrated the desired results elsewhere - such as in other, more advanced engine models or on-going R&D programs. The main task, then, of the derivative engine Engineering team is to fit these improvements to the size and cycle of the derivative engine in a manner that meets the overall engine program requirements. The derivative engine approach maintains consistency with experience in mechanical systems and turbomachinery performance and provides a surer, faster way of attaining engine maturity than other alternatives.

One such alternative consists of a "next generation engine" which needs major (revolutionary) improvements usually involving novel or breakthrough technology to justify the investment and recovery of development costs. Low and high bypass ratio turbofans represented such revolutionary improvements with their 20% (low ratio) and then 30% (high ratio) reductions in fuel consumption (Figure 1). General Electric's Unducted Fan (UDF) promises to do the same in the future. The T700 accomplished this result not only with its 30% reduction in specific fuel consumption SFC (Figure 2) but also by the entire concept of designing for reliability and maintainability.

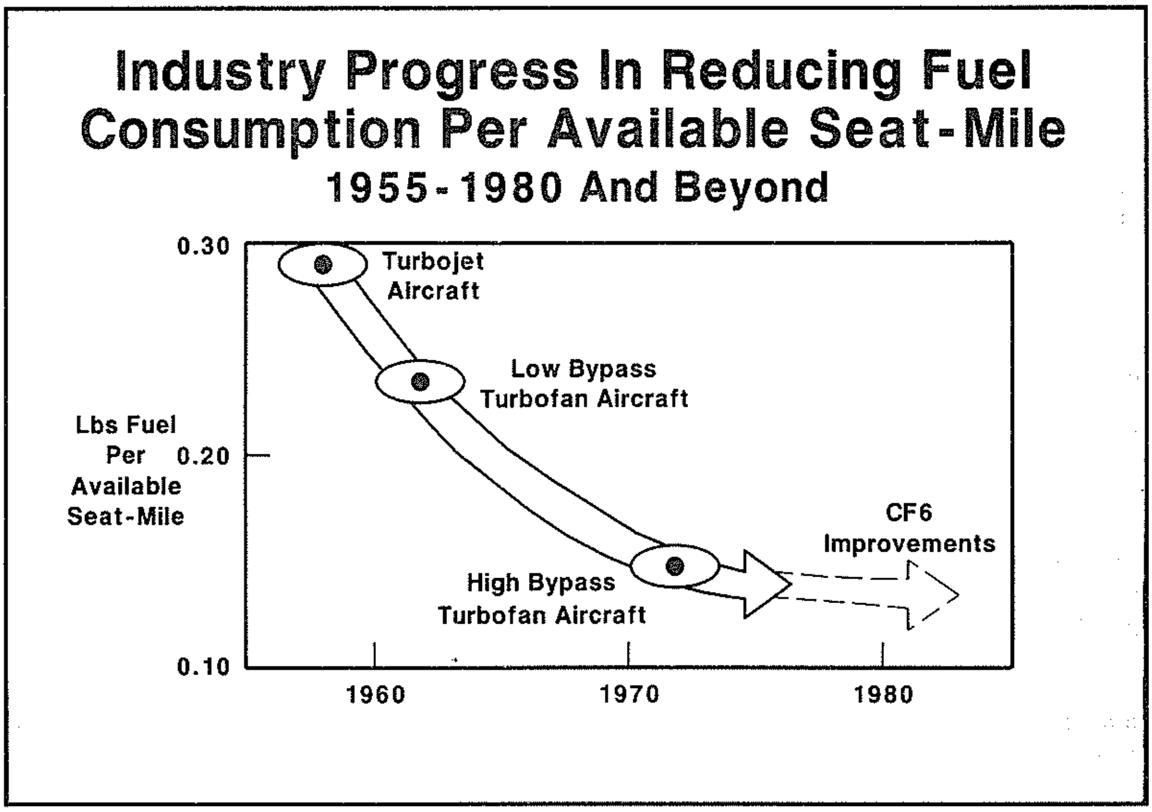


Figure 1. Industry Progress In Reducing Fuel Consumption

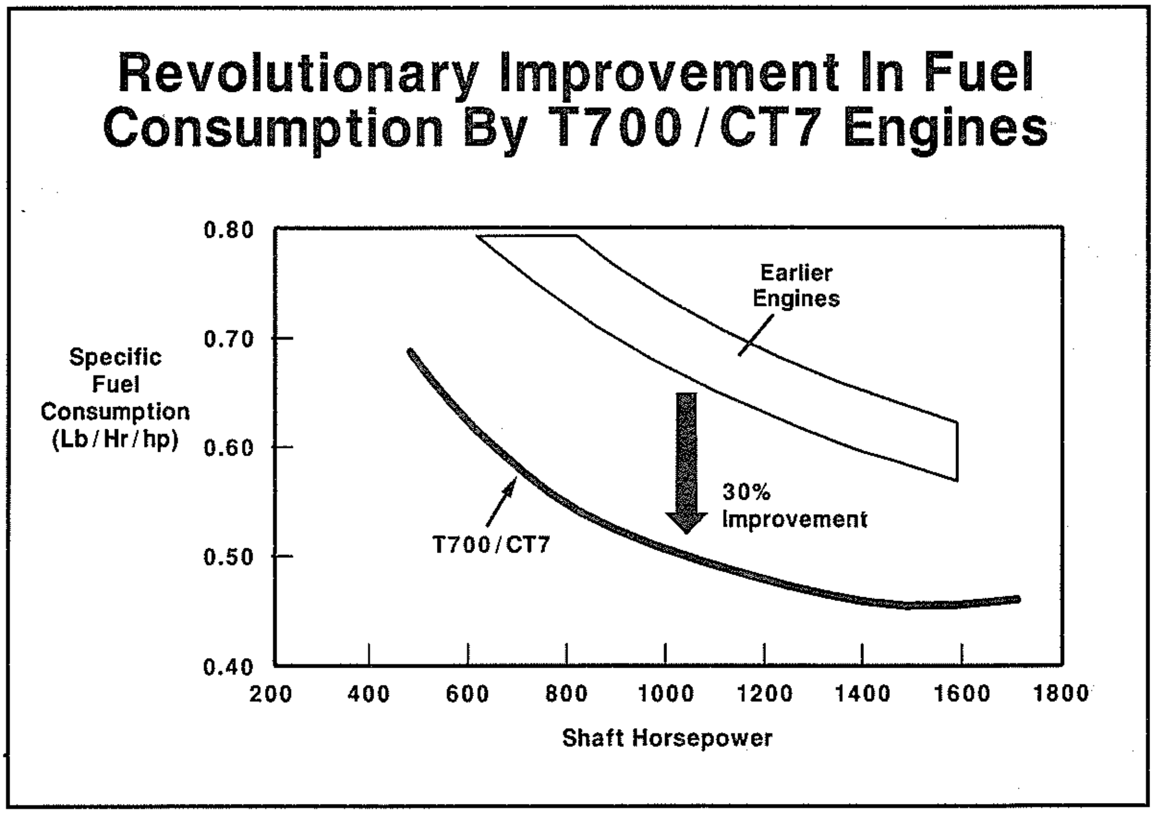


Figure 2. T700/CT7 Revolutionary Improvement in Fuel Consumption

Another alternative can be called a "new but current" engine. Engines in this category do not offer technology advancements compared to existing or derivative engines, but involve higher investment (with subsequent recovery) in development costs. They may also lead to unforeseen problems, sometimes in development but especially during initial service, which increase ownership costs, reduce availability, and delay maturity.

One can readily sort out engines in the various categories by comparing the bottom-line technology measures of SFC (fuel weight/HP-hr.), which is a measure of cycle efficiency and impacts aircraft size, weight, and range; specific weight (SHP/engine weight), a measure of engine component technology that affects aircraft weight and payload; and specific power (SHP/engine airflow), which also measures engine component technology and cycle efficiency and affects aircraft size, weight, and flight performance.

Figure 3 shows some comparisons to illustrate the point.

Technology Measures Comparison
1,200-2,000 SHP Class Turboshafts

	Modern Derivative	New But Current Engine	Next-Generation Engine *
SFC At Part Power Cruise (kg/kW-Hr)	0.328	0.328	Minimum 5% Improvement
Specific Weight (kW/kg)	6.37	6.00	Minimum 10% Improvement
Specific Power (kW/kg)	236.2	203.0	Minimum 10% Improvement

* Assumes Each Level Of Performance Gain Is Accompanied By Improved Reliability And Maintainability As Well

Figure 3. Comparison of Derivative and Alternative Engine Technology

2. Derivative Engine Reliability - Background

In recent times, just about every major engine company has had something to say on this subject. Following is a summary of these, along with new contributions to the data bank.

Earlier this year, General Electric reviewed derivative engine reliability for airline engines - high bypass turbofans (Reference 1). This effort summarized the effect of the combined timing, performance, cost, risk, and benefit on engine development, as shown in Figure 4. This summary chart portrays the investment and payoff relationship among categories of engines similar to those described earlier. It's important because the "payoff" is primarily what attracts users to select engines in the first place, but also because it portrays the relative investment that must be recovered by the developer through sales of the product.

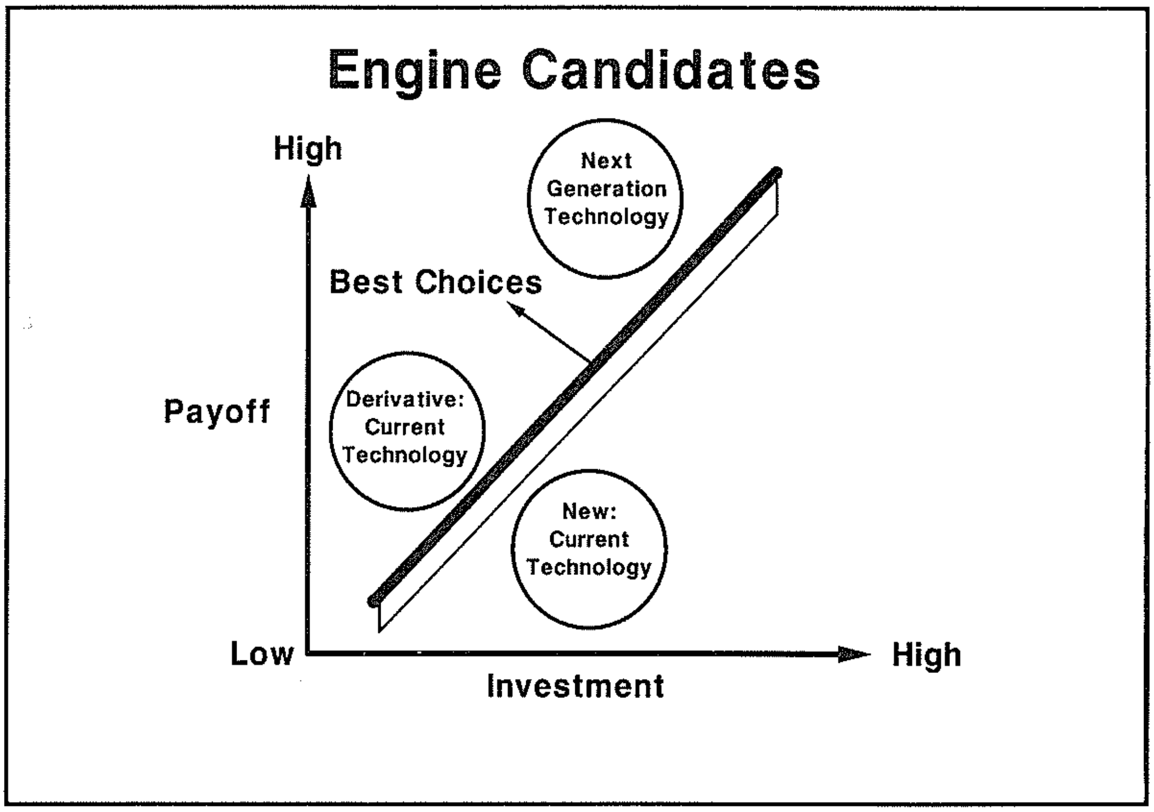


Figure 4. Payoff Vs. Investment for Derivative and Alternative Engines Development

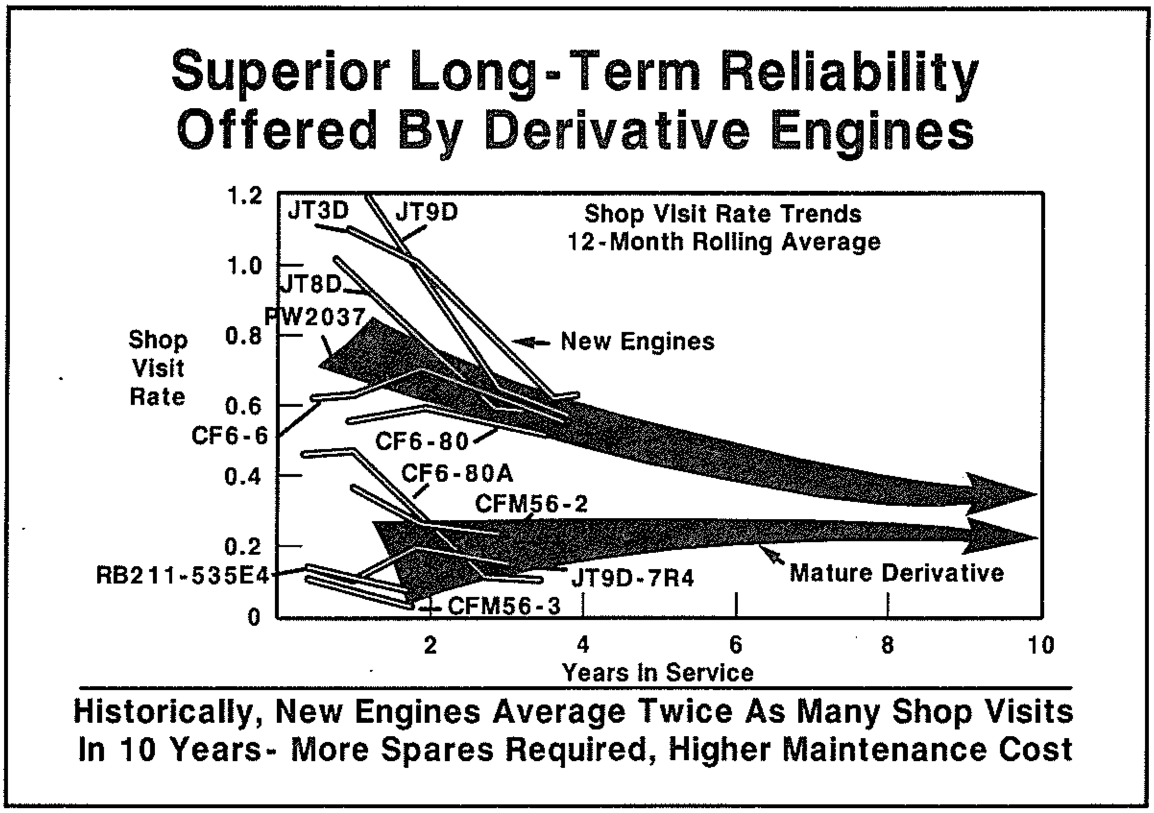
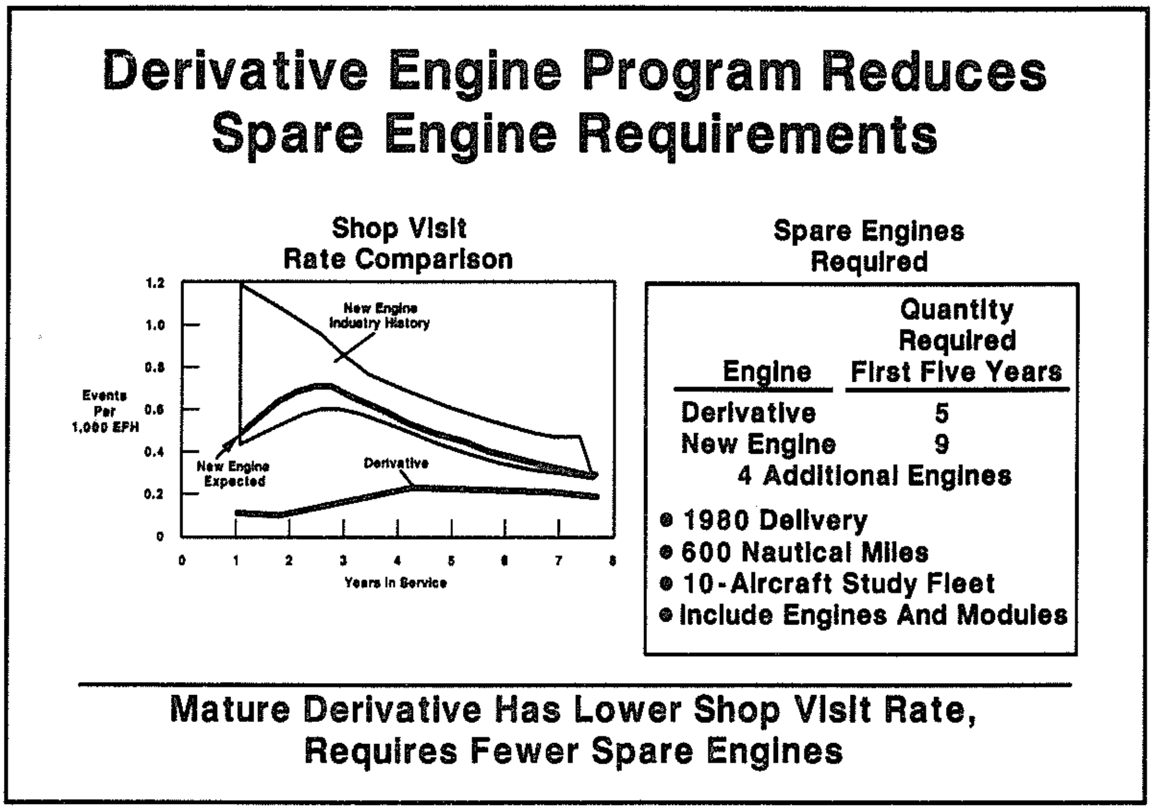


Figure 5. Superior Long-Term Reliability Offered by Derivative Engines

Figure 5 is a composite of mature reliability for derivative and new engines, using shop visit rate as a measure. It shows a strong, historically-based advantage for derivatives. The effects upon cost of this reliability are illustrated in Figures 6 and 7. Figure 6 indicates that the derivative engine requires only 55% of the spare engines needed to support a new engine under the same circumstances, while Figure 7 indicates a maintenance cost savings of 35- 60%. These are significant numbers by any standard.



Derivative Engine Program Reduces Spare Engine Requirements

Shop Visit Rate Comparison

Spare Engines Required

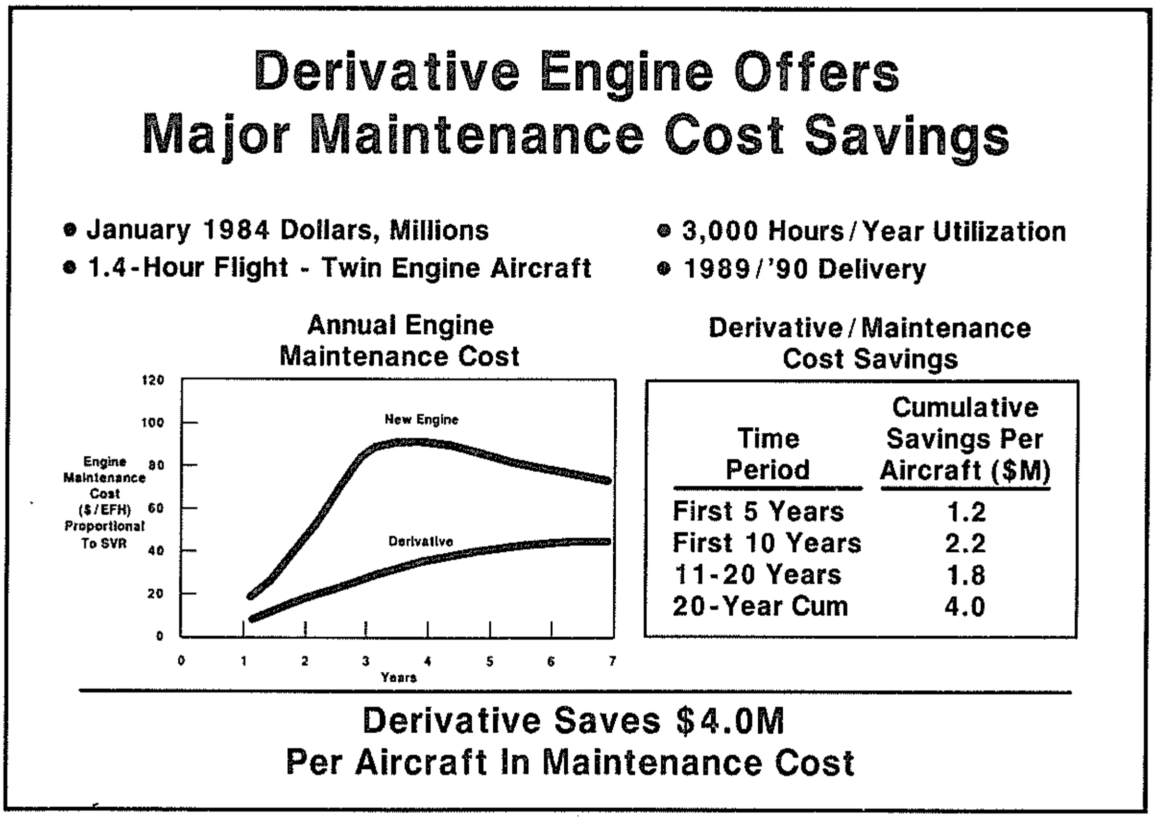
Engine	Quantity Required First Five Years
Derivative	5
New Engine	9

4 Additional Engines

- 1980 Delivery
- 600 Nautical Miles
- 10-Aircraft Study Fleet
- Include Engines And Modules

Mature Derivative Has Lower Shop Visit Rate, Requires Fewer Spare Engines

Figure 6. Derivative Engine Program Reduces Spare Engine Requirements



Derivative Engine Offers Major Maintenance Cost Savings

- January 1984 Dollars, Millions
- 1.4-Hour Flight - Twin Engine Aircraft
- 3,000 Hours/Year Utilization
- 1989/'90 Delivery

Annual Engine Maintenance Cost

Derivative/Maintenance Cost Savings

Time Period	Cumulative Savings Per Aircraft ($M)
First 5 Years	1.2
First 10 Years	2.2
11-20 Years	1.8
20-Year Cum	4.0

Derivative Saves $4.0M Per Aircraft In Maintenance Cost

Figure 7. Derivative Engine Offers Major Maintenance Cost Savings

Comparison Of Shop Visit Rate Of Derivative Engine Versus A New Engine

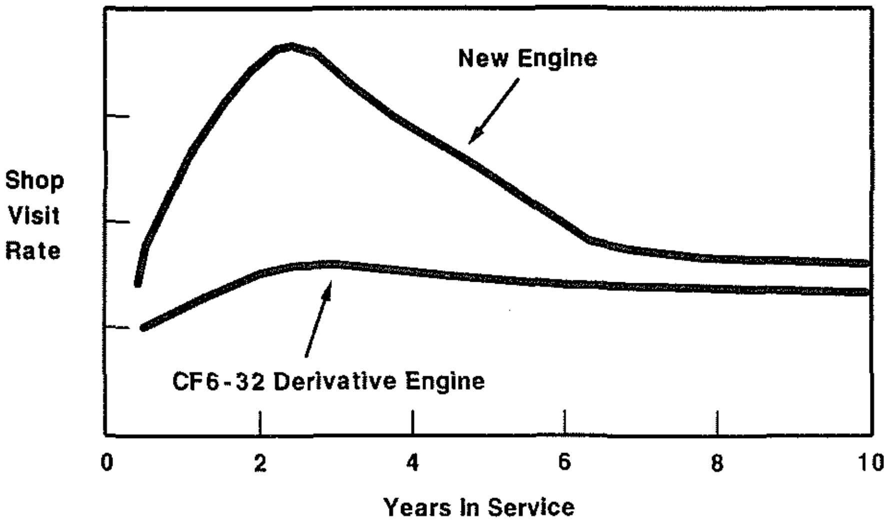
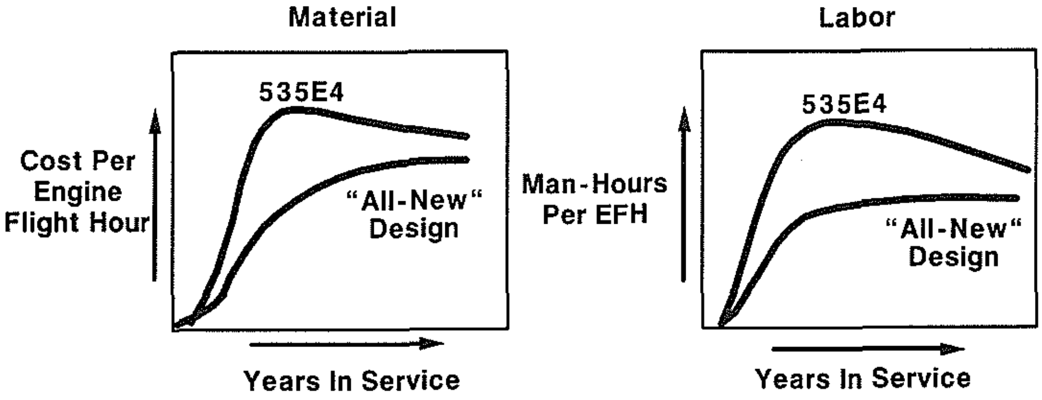


Figure 8. Shop Visit Rate Comparison - Derivative Engine Vs. New Engine

Reference 2 also makes this point (Figure 8). Please note that the new engine is represented by a typical shop visit rate pattern, while the derivative takes advantage of the predecessors' family experience and reaches maturity much earlier in its service life, with a resultant reduction in overall costs.

Rolls Royce drew similar conclusions (Reference 3) as shown in Figure 9, and stated that "new engine reliability is poor" and takes "6-10 years" to stabilize". These are the same conclusions stated earlier in the GE studies.

535 - Lower Maintenance Costs



- Mature Cost Advantage Remains
- Immaturity Costs Avoided
- Optimum On-Wing Times

Figure 9. Rolls Royce 535 - Lower Maintenance Costs

Pratt & Whitney also recognized that derivative engines have advantages and cited them in a review of the P & W 1120 program (Reference 4). The P & W 1120's greater than 70% commonality with the F100 led to confidence in expected improvements in support costs resulting from Line Replaceable Units, Unscheduled Engine Removals, and Maintenance Manhours.

Now let's look at some turboshaft history with respect to growth derivative engines - experience at General Electric with the T58 and T64 engines. Figure 10 shows the T58 history. Growth derivatives represent an 80% increase in power in four steps from an initial 1050 SHP to 1870 SHP with the T58-16. All this was accomplished by the normal methods of increasing airflow and temperature. Turbine temperature was increased by initially adding air cooling to the original engine and then improving it in subsequent steps. A small increase in airflow was obtained by restaggering compressor blading. In the latter steps, a second stage was added to the power turbine. All of this occurred over a period of eight years, starting three years after the initial model was qualified. The reliability data for the growth engines is shown on Figure 11. There is a clear downward trend with the later models, which are performing better in both Shop Visit Rate and Mission Reliability than the early derivatives. The Maintenance Indices (Maintenance Manhours per Engine Flight Hour) shown on Figure 12 exhibit the same characteristics. Both the T58-8 and -10 models can be considered mature, because they had accumulated 16 million and 2.4 million flight hours respectively by the end of 1985. The T58-16 had experienced nearly 3/4 million flight hours in this time period. All of the engines shown so far are operating with the U.S. Navy, but data for the Air Force engines exhibits the same trend. These are the T58-3 (T58-8 equivalent) and T58-5 (T58-10 equivalent). In fact the T58-5 time between overhaul is now 600 hours higher than that established for the earlier T58-3 engine model.

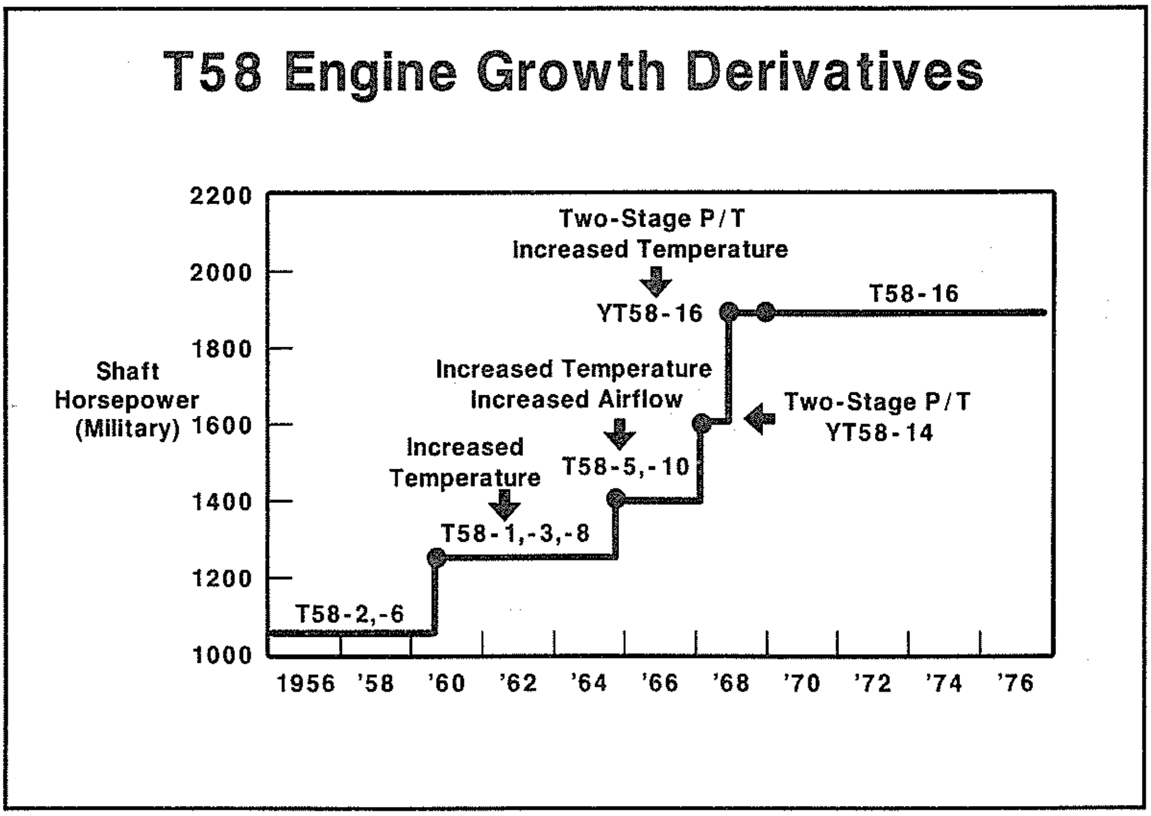
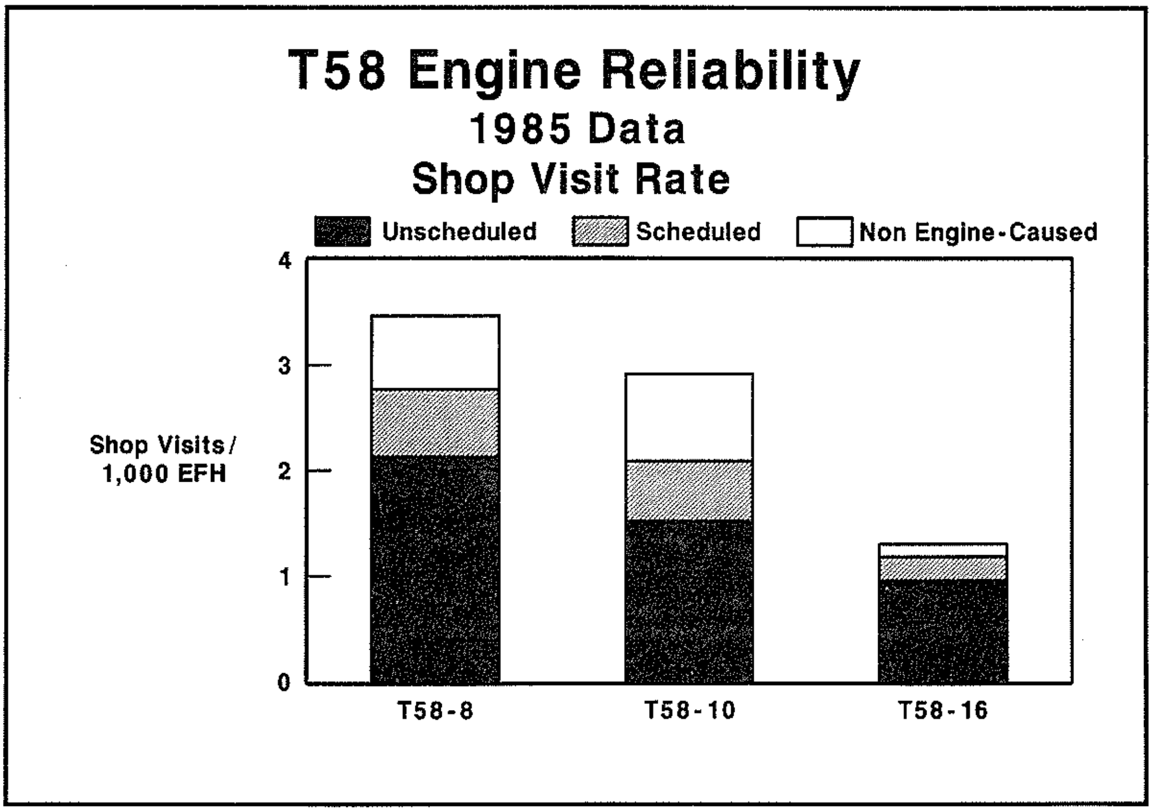


Figure 10. T58 Engine Growth Derivatives



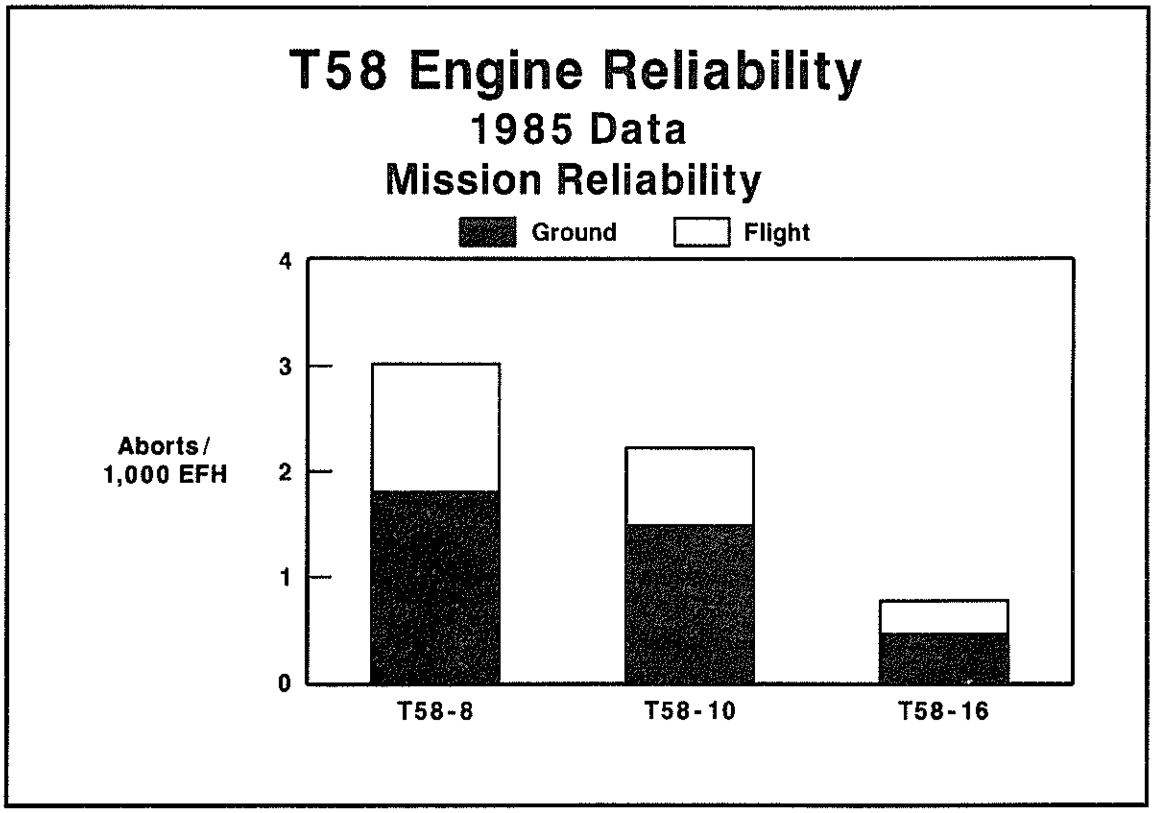


Figure 11. T58 Engine Reliability

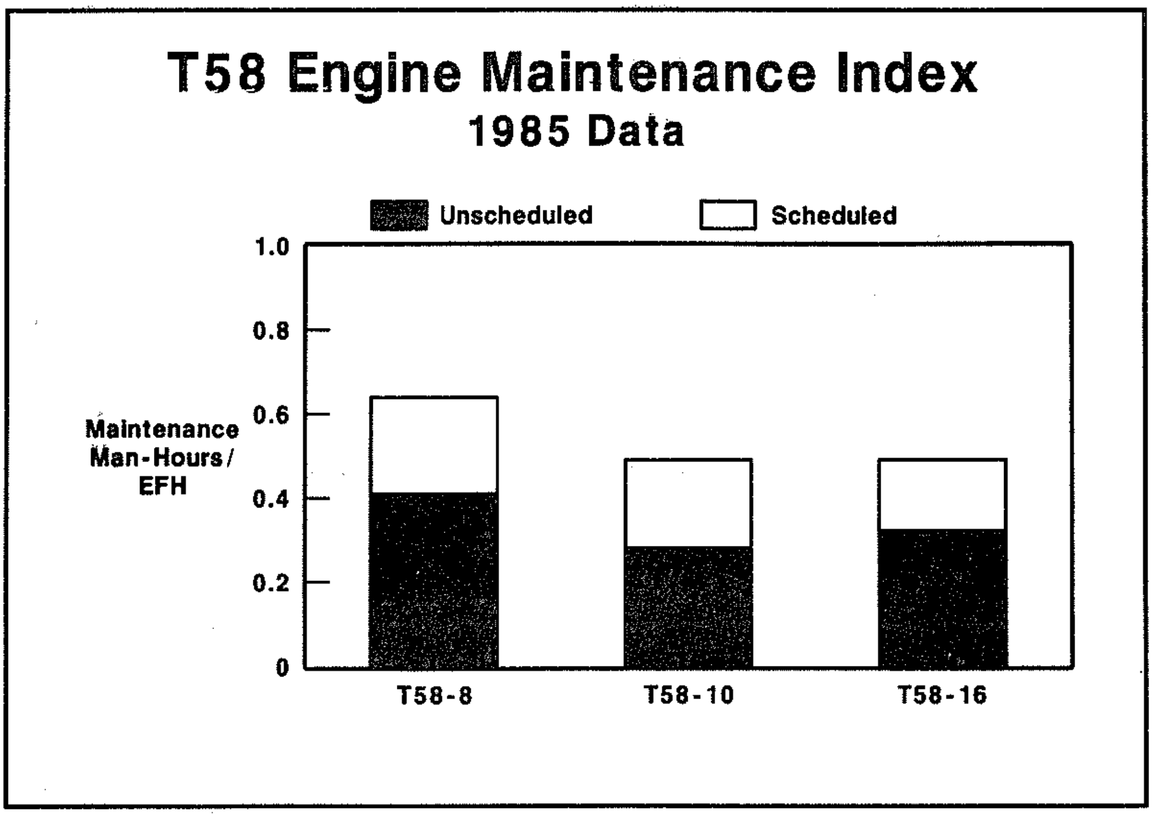


Figure 12. T58 Engine Maintenance Index

The T64 engine has a similar history, although not quite so dramatic. The power level on the turboshaft was raised 54% - from 2850 SHP to 4380 SHP during a span of just over 11 years. This was accomplished through a series of turbine temperature and airflow increases of about 330°F and 9% respectively (Figure 13). Additional versions were tested - and eventually produced - as turboprops incorporating another 140°F in turbine temperature and 6% airflow. The power levels were attained by improved aerodynamics, higher tip speeds, better cooling, and by the incorporation of materials with higher temperature capability.

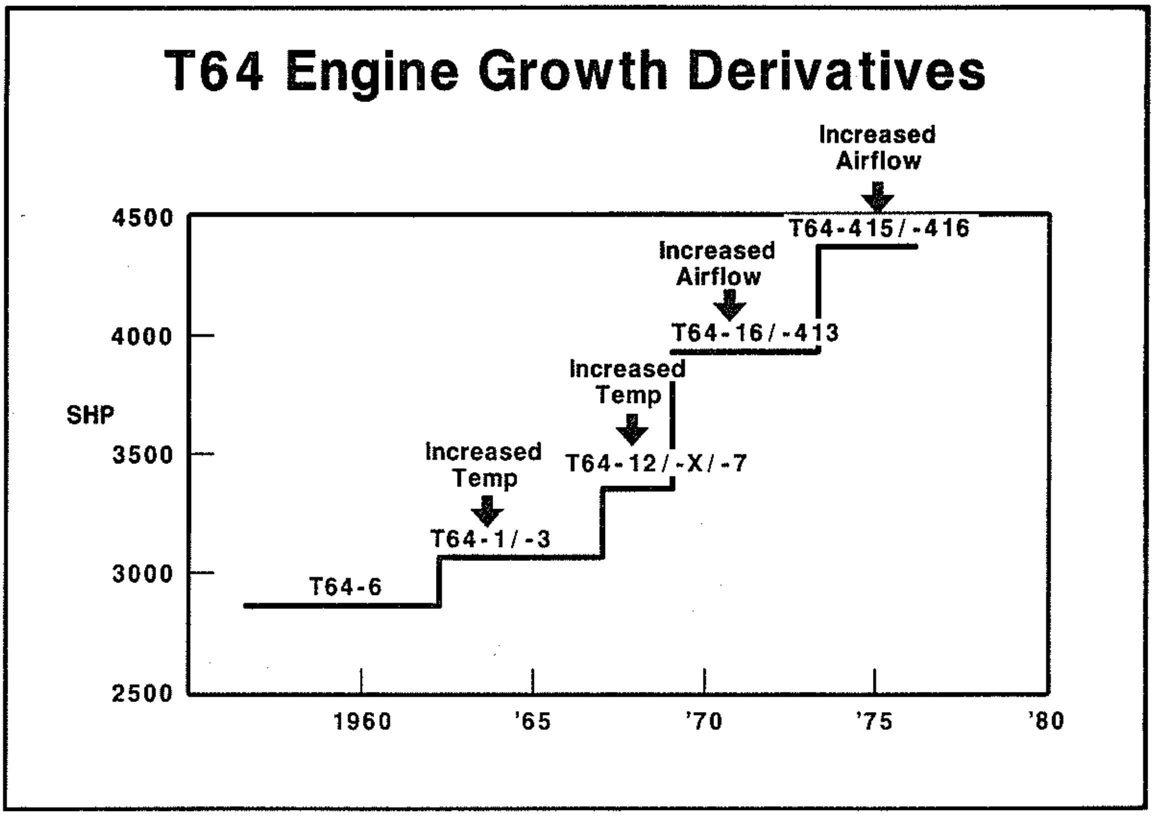


Figure 13. T64 Engine Growth Derivatives

It should also be noted that some of these engines were flat rated and therefore had a larger sea level standard equivalent horsepower than that shown on the chart. The reliability statistics (Figure 14) show the same trends as seen earlier for the T58 - in both shop visit rate and mission reliability - as horsepower, turbine temperature, and airflow are increased. Figure 15 illustrates this trend again for maintenance manhours per engine flight hour. In addition, the assigned time between overhaul for the -413 is approximately 1200 hours higher than that of the -6. These engines have less experience than the T58 models. The T64-6 and -413 had 2.2 million engine flight hours through 1985, while the -416 had just over 175,000 hours.

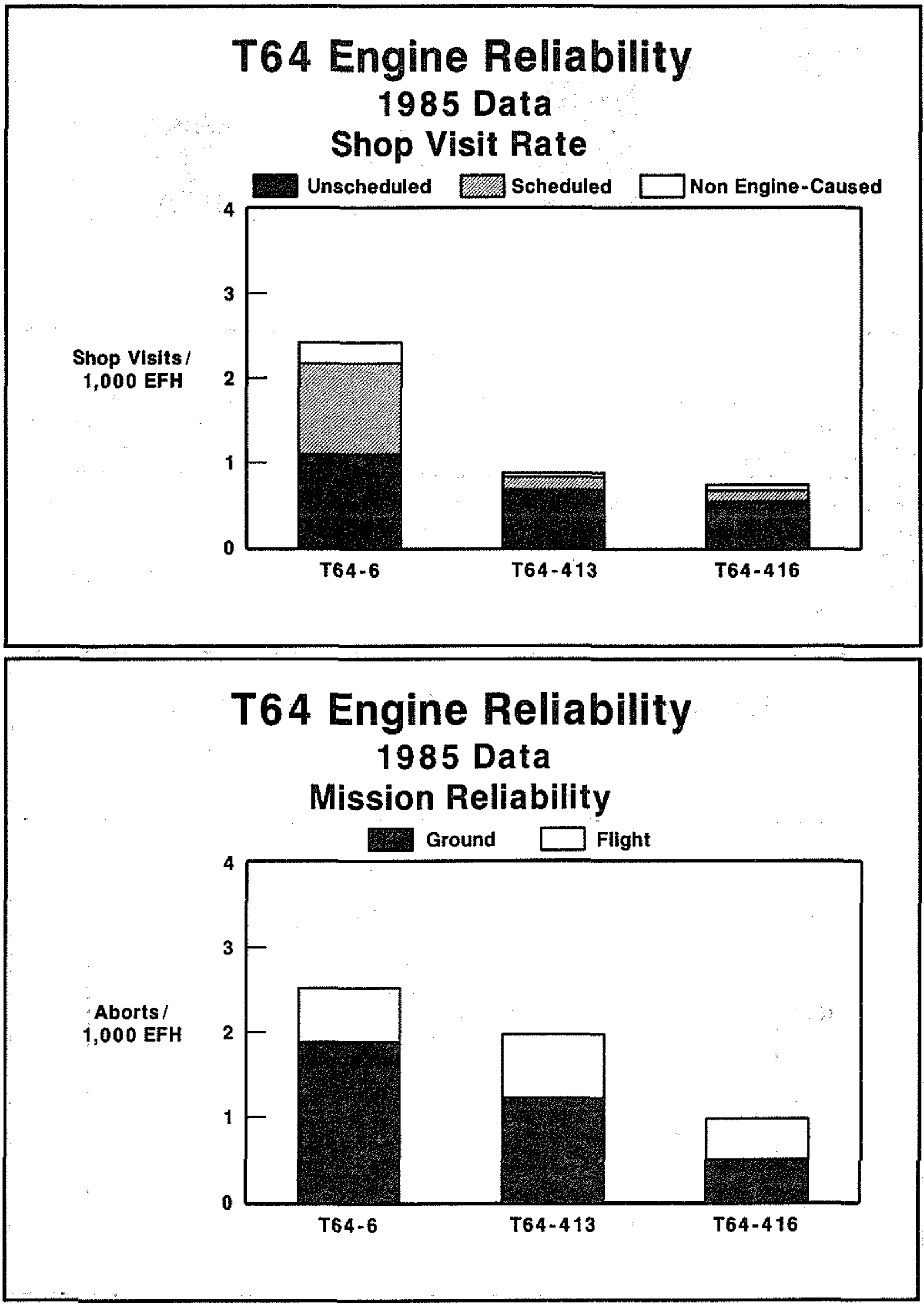


Figure 14. T64 Engine Reliability

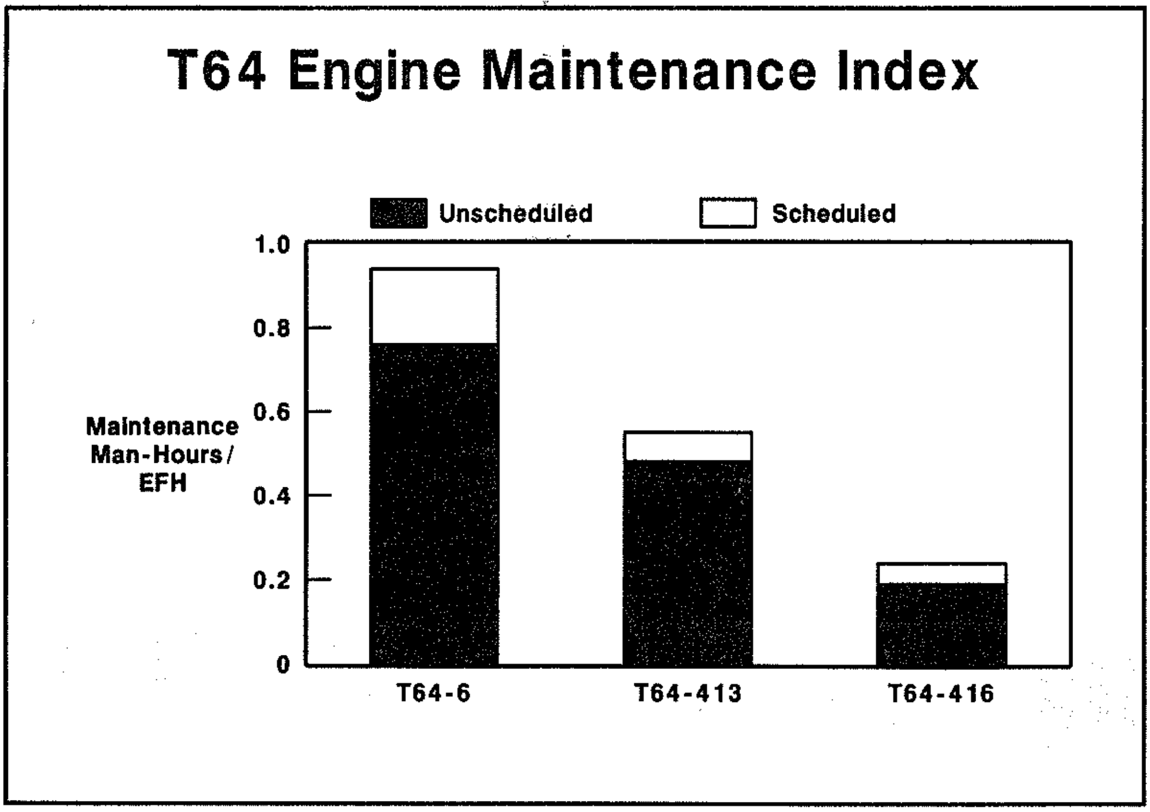


Figure 15. T64 Engine Maintenance Index

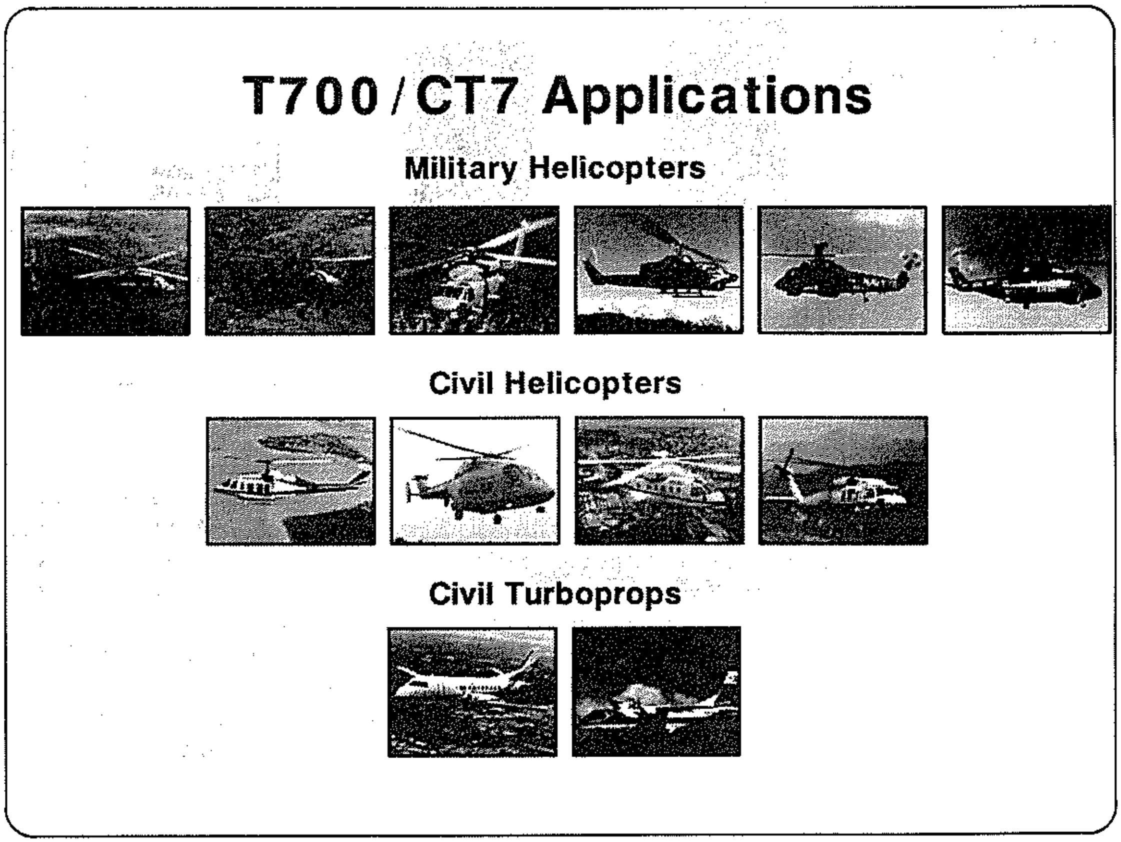
All of these data - from larger engines discussed by General Electric, Rolls Royce, and Pratt & Whitney, to the smaller T58 and T64 turboshafts - show a consistent trend of improving reliability and maintainability statistics with growth derivative models. For General Electric engines this is so because the key parameters contributing to growth - tip speeds, aerodynamics, turbine temperatures, cooling methodology, and materials - are kept within the bounds of company experience. The corporate posture of the other two companies seems to indicate that this is true for them also, and the data they have offered support this position.

There is a strong precedent, then, for drawing the conclusion that commonality with predecessor engines, combined with the application of technology improvements demonstrated in on-going research and development or in other more advanced engines, leads to growth derivative engines that display improvements in reliability and maintainability. When combined with other features normally associated with growth derivative engines and development programs, such as lower program risk, lower investment costs to be recovered, installation commonality, minimal disturbance to existing logistics systems, and higher usable power levels, there is a strong case for proceeding down the path to these engines. This is especially true when one considers the alternative of the "new but current engine" described in the Introduction since this type of engine offers no offsetting benefit in fuel consumption, weight, or size.

The "next generation engine" is a different matter. The higher program risk and development cost plus lower initial reliability resulting from an innovative next generation powerplant can be justified when market size or national defense needs demand the benefits of such a technology leap forward.

3. T700/CT7 Baseline Engines

Now let's turn to the T700/CT7 family. Nearly everyone is familiar with the generalities of this engine as it is in service today. It powers all of the free world's modern helicopters in its size class - and a couple of turboprops as well (Figure 16). Because of its modern technology and outstanding service record, it has even been selected to re-engine some helicopters that have been in service for some time. As the engine offers great improvements in reliability, maintainability, and fuel consumption, it contributes an immense reduction in cost of ownership when it replaces older engines. We believe that this promises an even larger market for the future.



T700/CT7 Applications

Military Helicopters

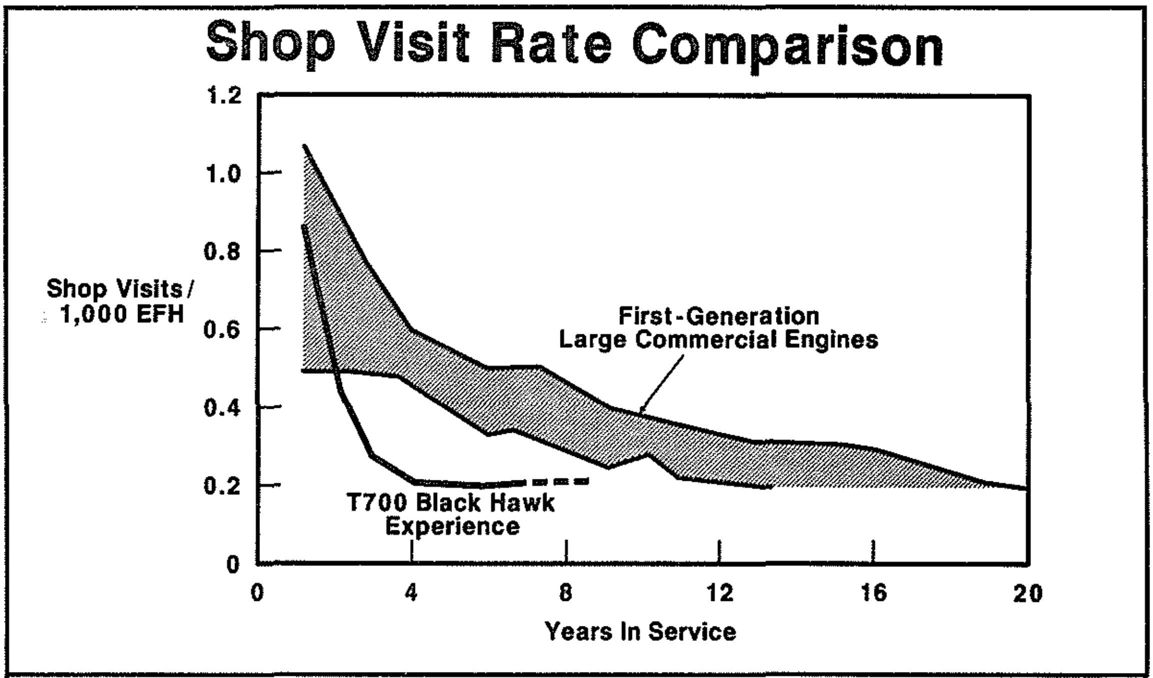
Civil Helicopters

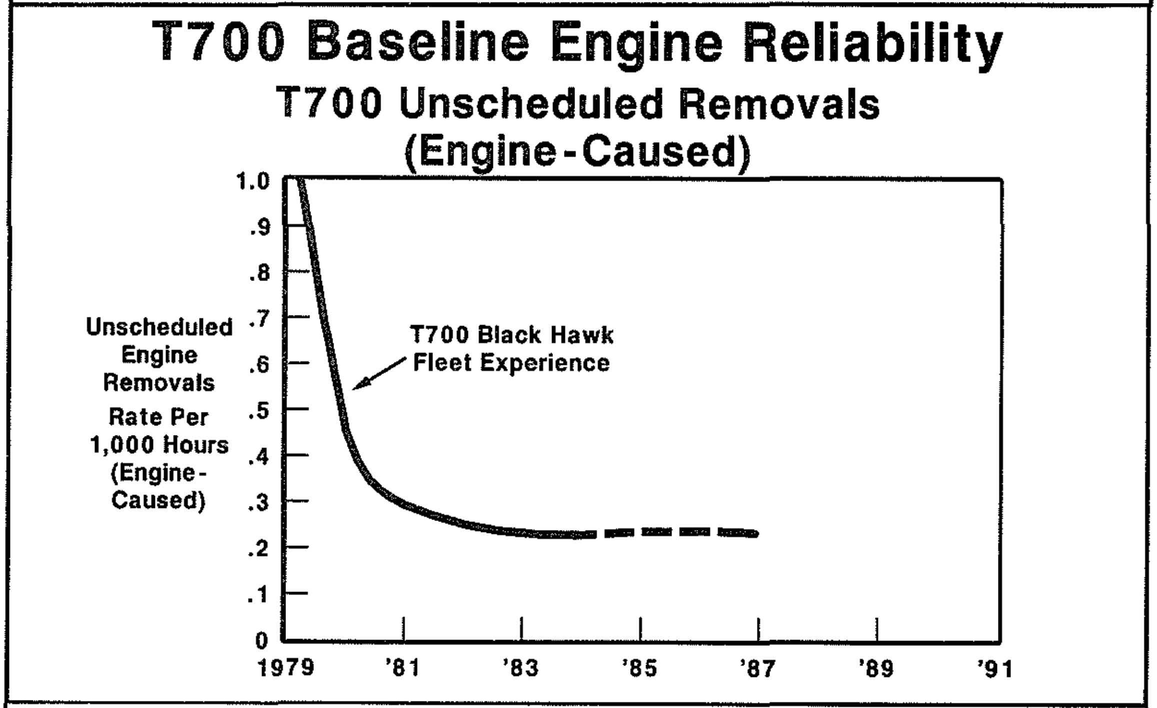
Civil Turboprops

Figure 16. T700/CT7 Applications

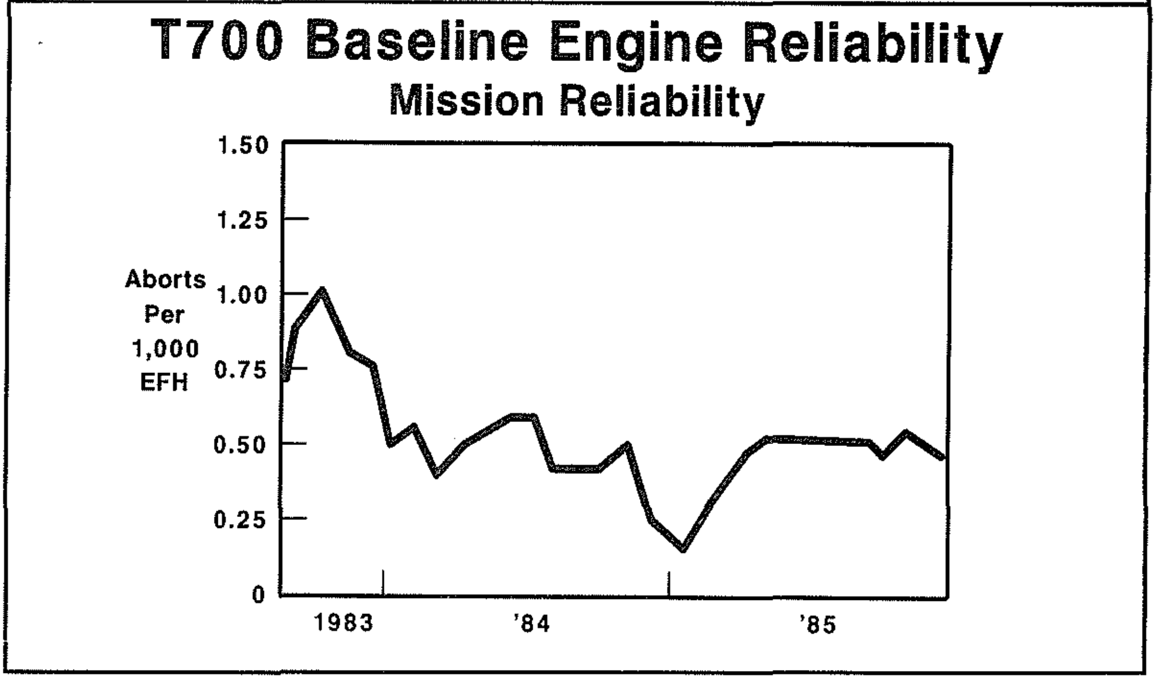
The ingredients of the development program resulting in the T700 were: a thorough review and understanding of previous helicopter engine field problems; a revolutionary design approach that focused specifically on techniques leading to improvements in technology and field statistics; setting challenging goals for these parameters, placing equal emphasis on their attainment with that of traditional objectives; and, finally, comprehensive and novel approaches to the test programs conducted prior to production.

The results have been widely published and need only a quick review. As shown in Figure 17, the Shop Visit Rate is now competitive with modern high bypass ratio engines powering wide-bodied civil airliners. Also shown are the unscheduled removal rates and mission reliability for comparison with earlier data. Figure 18 shows the T700 maintenance index, again to allow earlier comparisons.


Shop Visit Rate Comparison


T700 Baseline Engine Reliability

T700 Unscheduled Removals (Engine-Caused)


T700 Baseline Engine Reliability

Mission Reliability

Figure 17. T700 Engine Baseline Reliability

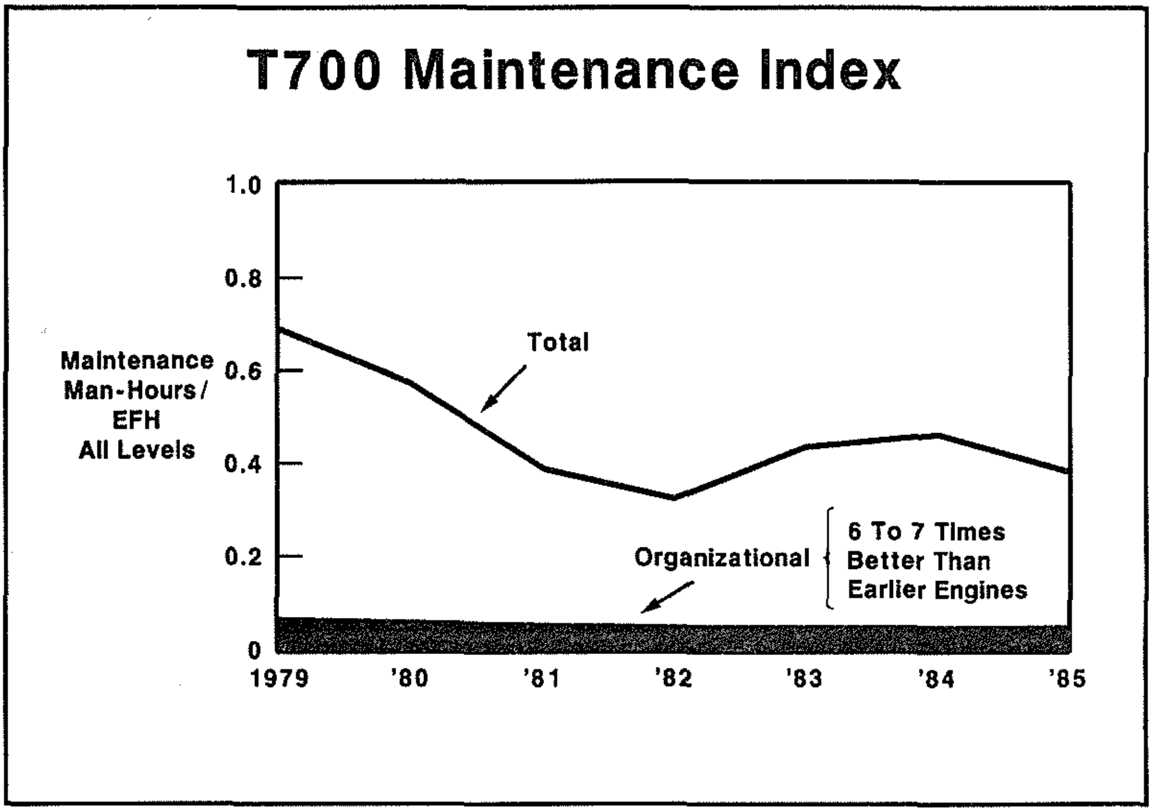


Figure 18. T700 Maintenance Index

Short reflection on the severity of the helicopter engine duty cycle, with its many power level changes, vibratory operating environment, and demanding military requirements, leads to a recognition of the magnitude of this accomplishment. The civil airliner engines, with their long mission times, operate essentially at steady-state conditions during cruise and sustain power variations only twice during the mission - at take-off and landing.

These data are for the baseline T700 - the -700 model in the Black Hawk - but are also representative of the CT7-2A in the Bell 214ST. High time engines in this fleet of baseline engines are over 6000 hours; the average engine age is over 500 hours for the -700 and 1000 hours for the CT7-2A.

4. <u>T700 Step 1 Growth</u>

Figure 19 presents the T700 turboshaft growth roadmap. Step 1 growth is represented by the -401, which has been in service with the U.S. Navy in the SH-60B for over two years, and the -701, which powers the Apache and has been in service for about a year. Growth was accomplished by a 3% airflow increase and a turbine temperature increase of just over 50°F. The temperature increase was offset by cooling system improvements designed to retain metal temperatures at the same level, and by material changes where these were needed. The Navy engine was required to pass the new 300-hour model qualification test - which replaced the earlier 150-hour test, so the "graduation exercise" for this engine running at higher temperatures was considerably more demanding than that of its cooler predecessor. During this test, the engine was required to operate for 30% of the time at the maximum turbine temperature! The first -401 engine to reach 1000 hours - most of which occurred at sea - was returned to the factory for a teardown inspection by U.S. Navy and General Electric personnel. Its condition was excellent and the engine was declared suitable for continued service.

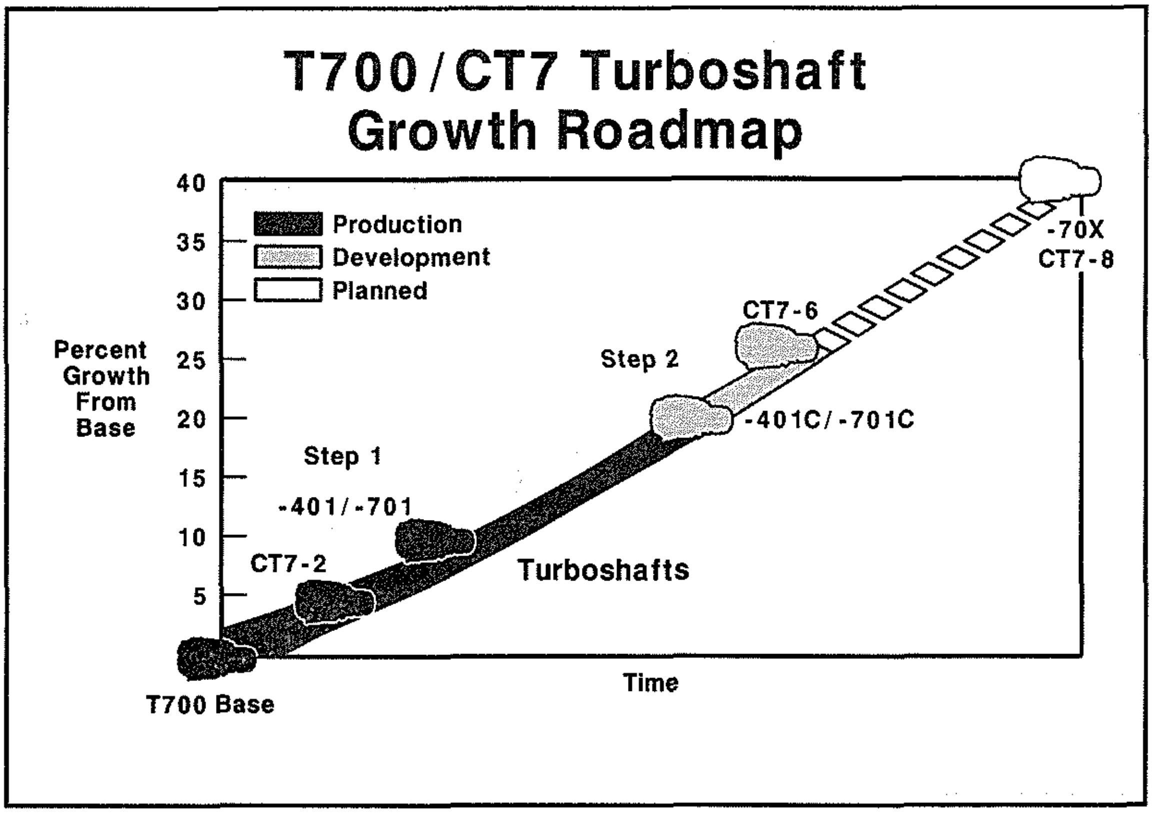


Figure 19. T700/CT7 Turboshaft Growth Roadmap

The reliability and maintainability records for the -401 are compared with the baseline engine in Figures 20 and 21. The figures show total program data through 1985 because the flight time on the -401 engines is still below 100,000 hours. The data indicate that there has been no degradation in field statistics due to the growth step. They are quite comparable and reflect not only the success of this derivative as a growth engine, but also the success of the engine marinization features included in the -401, the first Naval application of a T700 family member.

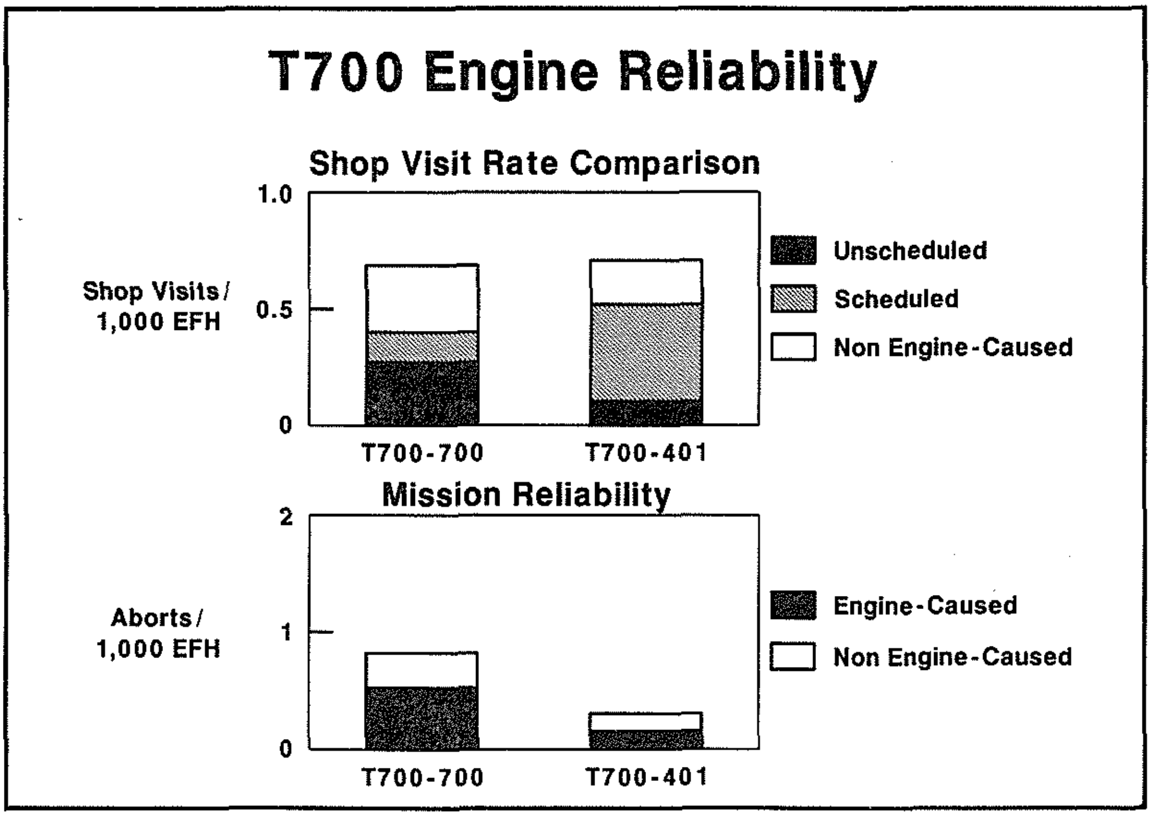


Figure 20. T700 Engine Reliability

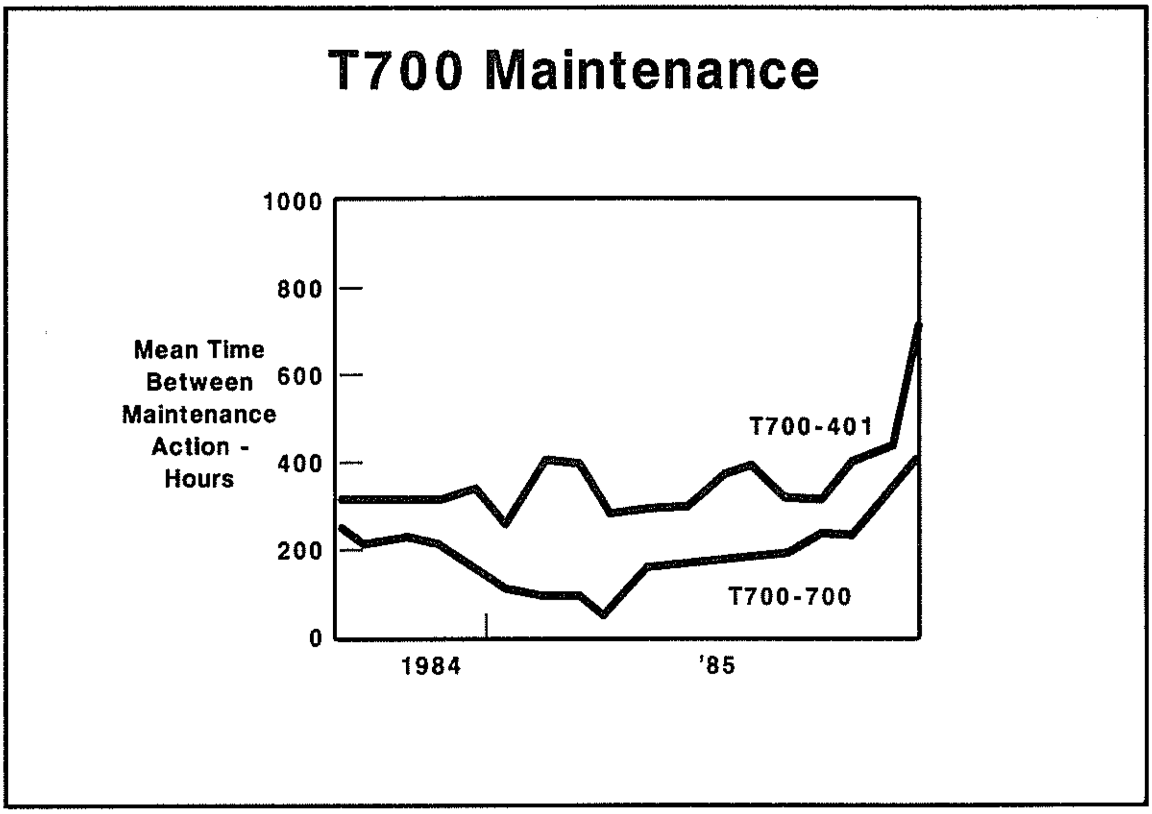

T700 Maintenance

Figure 21 T700 Mean Time Between Maintenance Action

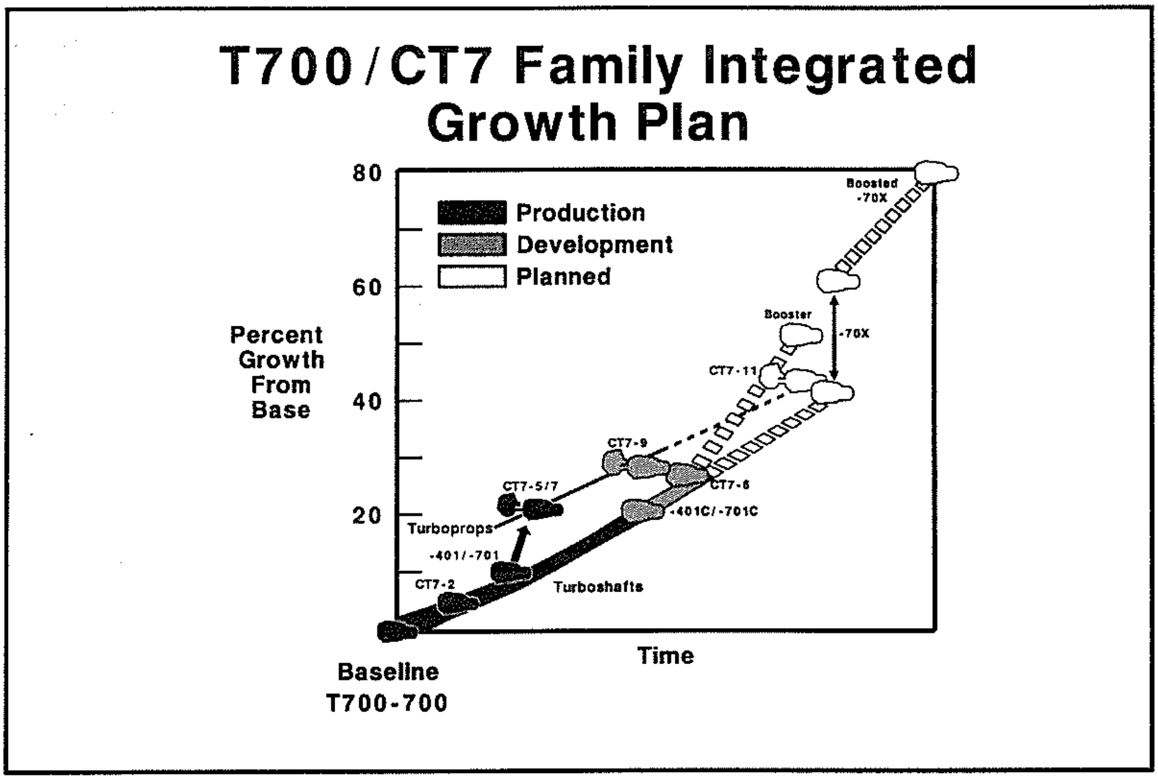

T700/CT7 Family Integrated Growth Plan

Figure 22. T700/CT7 Family Growth Plan

5. T700/CT7 Growth Derivatives Now in Development

Figure 22 shows the overall T700/CT7 family integrated growth plan through the expected steps to reach an 80% growth derivative in the 1990s. Consistent with prior engine line experience, the incremental steps are designed to provide the power levels needed to satisfy the growth steps of the respective applications without introducing undue risk or impact on reliability and maintainability experience, based on the predecessor engines.

The Step 2 growth engines currently in development consist of the -401C for the U.S. Navy, the -701C for the U.S. Army, the CT7-6 for the EH101, and the CT7-9 turboprop engine for commuter airliners. They represent growth of 20-28% in power from the baseline -700 or, if you will, 10-18% when compared to the -401/-701 Step 1 growth engines. Because these engines share a lot of commonality among themselves, the program has been thoroughly integrated to minimize costs and fully capitalize on this commonality.

As indicated (Figure 23), there are four main ingredients to the growth of these engines: new technology in the centrifugal compressor and a more efficient, higher temperature gas generator turbine, both of which are common to all four family members; a tuned high airflow axial compressor (which is already in service with the CT7-5 engines powering commuter airliners); and a higher efficiency power turbine (which we have wanted to do for a long time). These latter two components are shared by the civil turboshaft and turboprop engines.

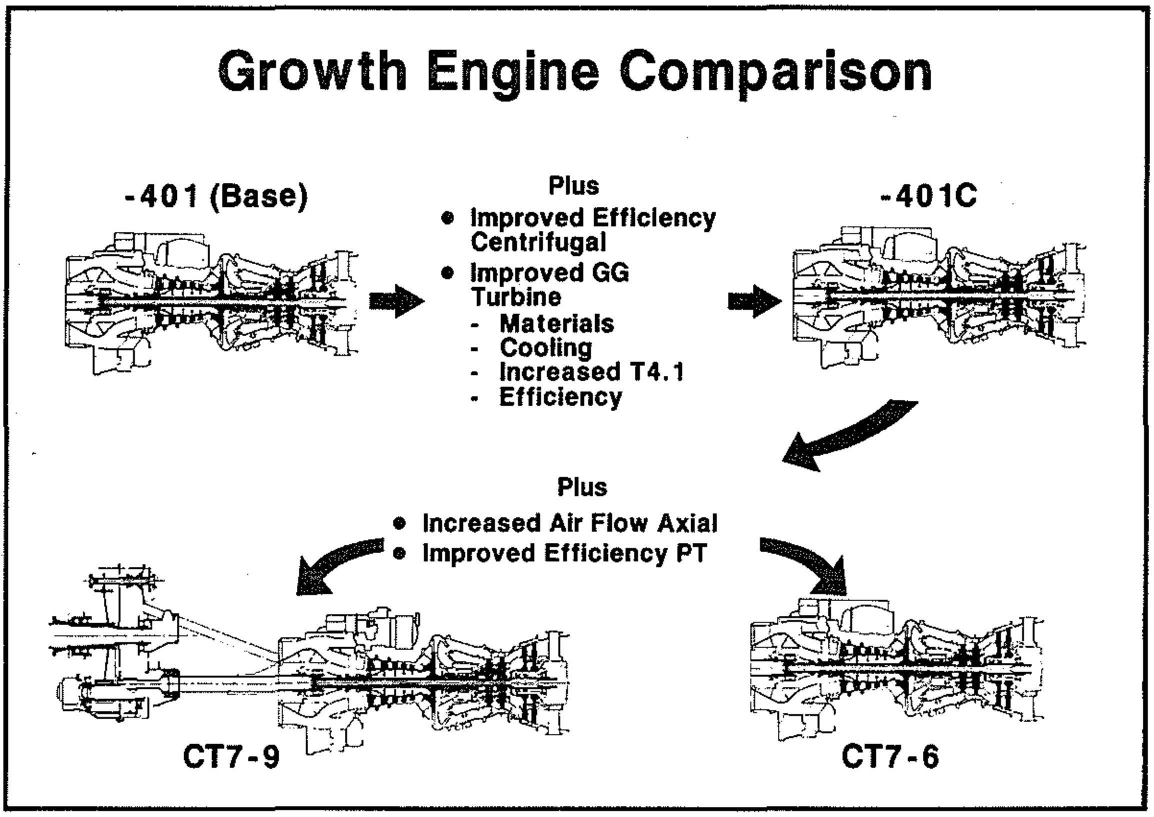


Figure 23. T700/CT7 Growth Engine Evolution

As cited earlier, a wealth of industry experience shows that field statistics do improve with derivatives. But the conditions have to be right - that is, the key technology parameters must be kept within company experience through previous demonstrations and there should be a high degree of commonality with the predecessor engine. Of course that predecessor engine - or family of engines - must have a good track record to start with and sufficient field experience to assure that it has been fully exposed. The prior T700/CT7 family members have already established both in over 1 million flying hours. Equally important, T700/CT7 engines have been exposed around the world to all sorts of operating conditions and environments in various helicopter and commuter airliner applications.

The following discussion examines the T700/CT7 Step 2 growth engines, using these criteria. At General Electric, we are constantly striving for higher compressor pressure ratios and turbine temperatures. We believe that they are key ingredients to improving turbine engine technology in ways that make the resulting engine an enhancement to overall aircraft and helicopter system performance, because these factors set the basis for establishing SFC, Specific Weight, and Specific Power (engine size). Dix and Gissendanner (Reference 5) point out that propulsion systems (including fuel) typically account for a large portion of take-off gross weight - roughly 1/2, they say. They also indicate that this presents an opportunity for the propulsion community, because even relatively modest improvements in propulsion system performance have a large impact on the military capability and/or cost of the aircraft. Figure 24 shows our experience with these parameters and spots the T700/CT7 growth family. In both cases, the engines are at the lower edge of the experience band. I might also point out that tip speeds in the compressor are the same as those now operating in the CT7-5 which, after some initial troubles, has been operating flawlessly for over year and a half.

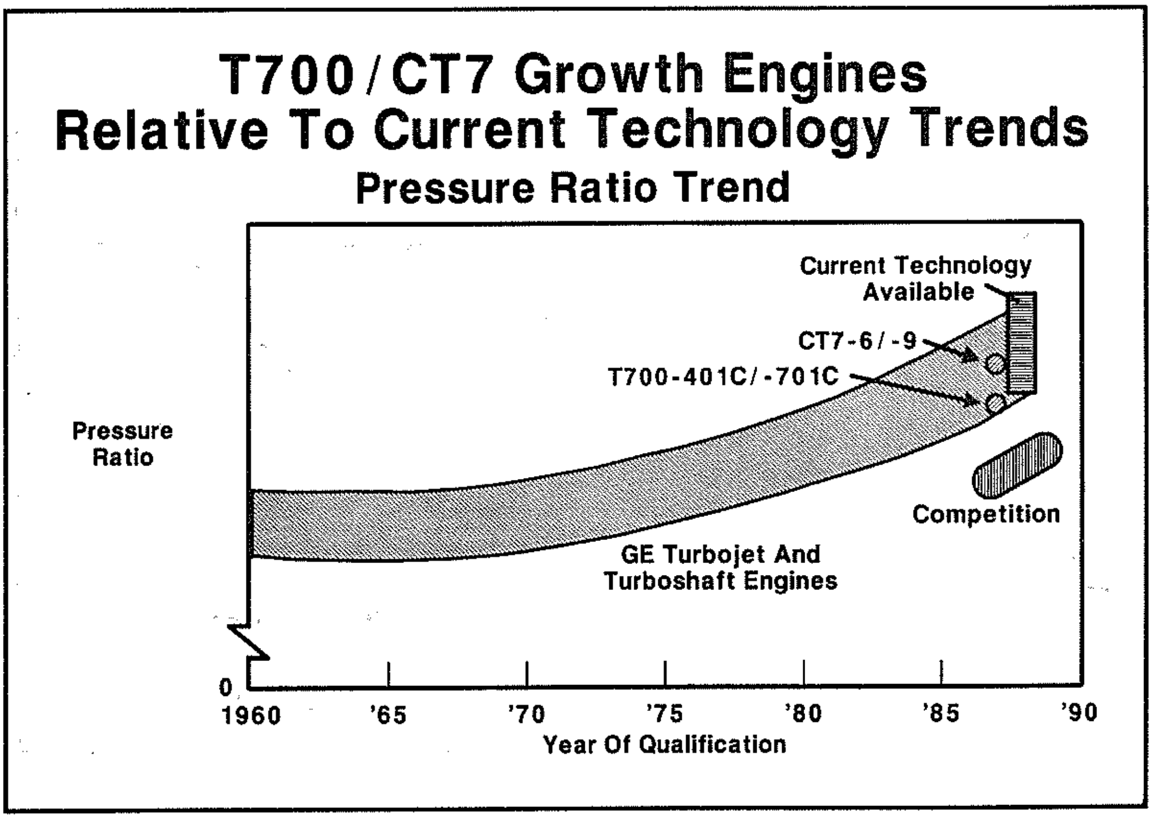
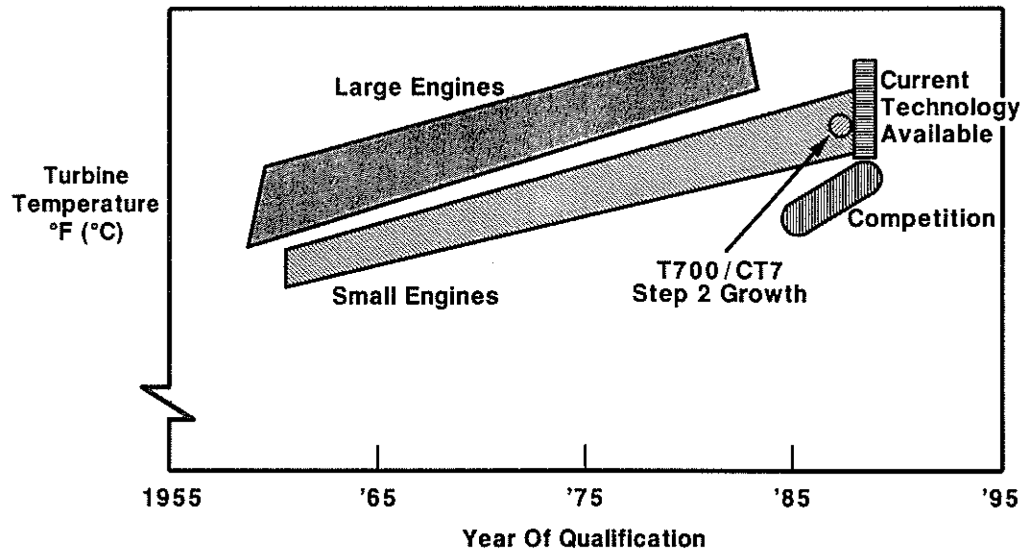


Figure 24. T700/CT7 Growth Engines Vs. Technology Trends

T700/CT7 Growth Engines Relative To Current Technology Trends

Temperature Trends



The specifics of the technology heritage for these growth engines are shown in Figure 25 which provides a basis, within our experience, for every significant technology improvement in these engines. The focus of the experience shown here is on <u>engines</u> and includes both current production and advanced engines. It does not address on-going R&D off engine or component testing. This chart also illustrates the engine line to engine line technology flow, made possible by the wide General Electric product line base, and forced to occur by the nature of the Aircraft Engine Business Group Organization.

T700/CT7 Step 2 Growth Technology Heritage

• Aerodynamic Design	**Source**
- Axial Compressor Blade And Vane Contours	GE27
- Centrifugal Compressor Vane And Diffuser Shape	GE27
- High And Low Pressure Turbine Stator And Rotor Contours	GE27, NASA E^3
• Materials	
- First Stage Turbine Blades	GE23, GE27, F110, F404
- High Pressure Turbine Shrouds	CF6
• High Pressure Turbine Cooling	
- Serpentine - Casting Core Technology	CF6, GE27, MMT*

*U.S. Army Manufacturing Methods And Technology Program

Figure 25. T700/CT7 Step 2 Growth Technology Heritage

Commonality of the engines (Figure 26) with prior family members exceeds 70% - by part count - for the civil turboshaft and is higher for the military versions. This is important not only from a logistics standpoint, but also because the basic structure, stress levels, systems, and operating speed of prior family members is unchanged, so that the vibratory and dynamic characteristics of the engine are already understood. Note also that installation interchangeability is also maintained, so that aircraft using current versions of the T700 can readily accept the growth engine.

Growth Engine Commonality With Prior Family Members

- Basic Structure And Configuration
- Axial Compressor (Tuned)
- Shafting
- Lubrication System
- Electrical System
- Fuel System
- Inlet Particle Separator (Minor Modification)
- Air Bleed And Anti-Icing System
- Combustor (Tuned)
- Power Turbine (Tuned)
- Accessories
- Ignition System
- Fuel Control (Tuned)
- Installation Interchangeability

High Commonality Reduces Risk And Preserves Operational Benefits

Figure 26. Growth Engine Commonality With Prior Family Members

Initial engine and component testing bears testimony to the value of previously demonstrated technology combined with high commonality. The axial compressor has shown better efficiency at both high and low speeds and has met the surge margin objective. The centrifugal compressor has done the same. Combustor testing has shown the improvement in peak temperature and pattern factor that we expected from GE27 experience. The Stage 1 high-pressure turbine buckets have been through a 150-hour test, run to red line temperature for the time required in a 300-hour model qualification test, and completed 1000 cycles of low cycle fatigue testing.

The test program for these engines concentrates on verifying the improvements, meeting rigorous qualification and certification requirements, and establishing the basis for maturing the engines early in their field service careers. As noted earlier, component tests have been underway for some time and are necessary to establish fundamental design compliance prior to engine testing. Engine testing continues design verification through stress tests, as will be done on the compressor and both turbines; sea level, and altitude performance demonstrations; corrosion; anti-icing; low cycle fatigue; overtemperature; overspeed; and loss of load. Emphasis is placed upon durability testing (Figure 27) so as to uncover mission- or time-related problems for addressing early enough to incorporate proven solutions.

T700/CT7 Step 2 Growth Derivative Engine Test Program

Factory Testing

	Hours
• Prior Family Factory Testing	35,000
• Step 2 Growth Qualification/Certification	5,000
• Step 2 Growth Maturity	5,000

Endurance, Accelerated Mission, And Low-Cycle Fatigue Testing

	Hours
• Step 2 Growth Development Qualification	3,500
• Step 2 Growth Maturity	5,000

Figure 27. T700/CT7 Step 2 Growth Derivative Engine Test Program

The -401C is the initial model to be qualified and will be subjected to the 300-hour Model Qualification Test, as required by the U.S. Navy. The requirement for completing this test provides confidence for the later civil engine programs which are required to pass the 150-hour FAA Certification Test. During the factory program, there are about 4000 Accelerated Mission Test (AMT) hours planned. Since typical severity factors for this type of testing range from 7 to 10, the factory AMT provides for an equivalent of about 35,000 hours of field experience.

The mature engine reliability projection for the Step 2 growth turboshafts is shown on Figure 28. It is based upon a continuation of

T700/CT7 Growth Engine Reliability Projection For Maturity

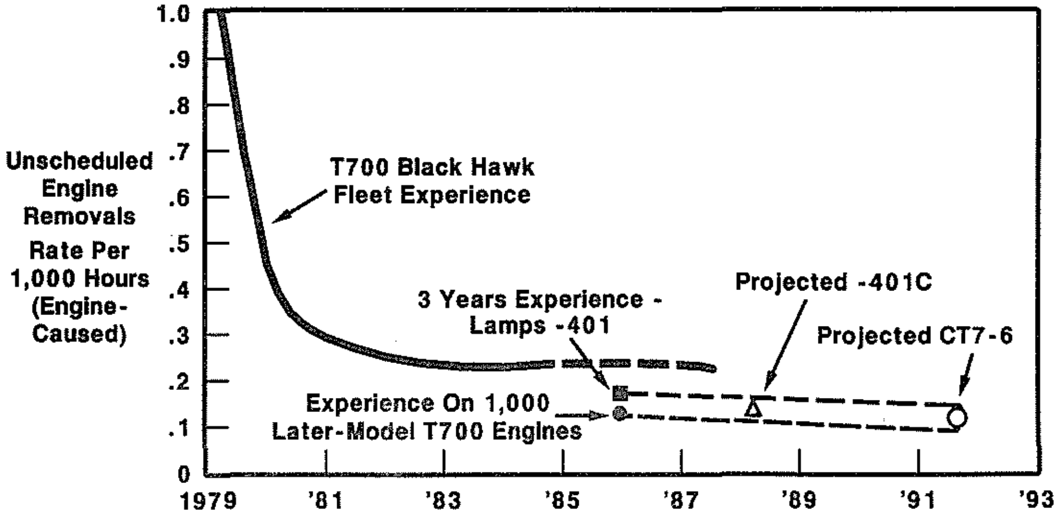


Figure 28. T700/CT7 Growth Engine Reliability Projection for Maturity

reliability growth from the prior family members because of the high degree of commonality these engines share, including the turboprop derivatives. The figure also takes into account the technology improvements in cooling and materials that are being incorporated in the high-pressure turbine. The blading materials, for example, not only have substantially higher capability for thermal variations and stress rupture, but are cooled with the more effective serpentine technology. The result is highly satisfactory temperature margins in these components.

The depth of the factory test program and its ability to uncover problems, as shown by previous T700 and F404 engine experience, is of major value in reducing field problems and attaining early maturity. This includes the aggressive AMT testing that tests single engines to multiple values of their so-called design life.

The CT7-6 civil turboshaft has an additional advantage. Because it enters service last (Figure 29), its common components have the advantage of on-going field experience from prior family members, and its unique components have the advantage of the field experience accumulated in other Step 2 growth derivatives which precede it into service. In fact, CT7-6 components will have more experience when they enter service on the EH101 than the current baseline engine has today.

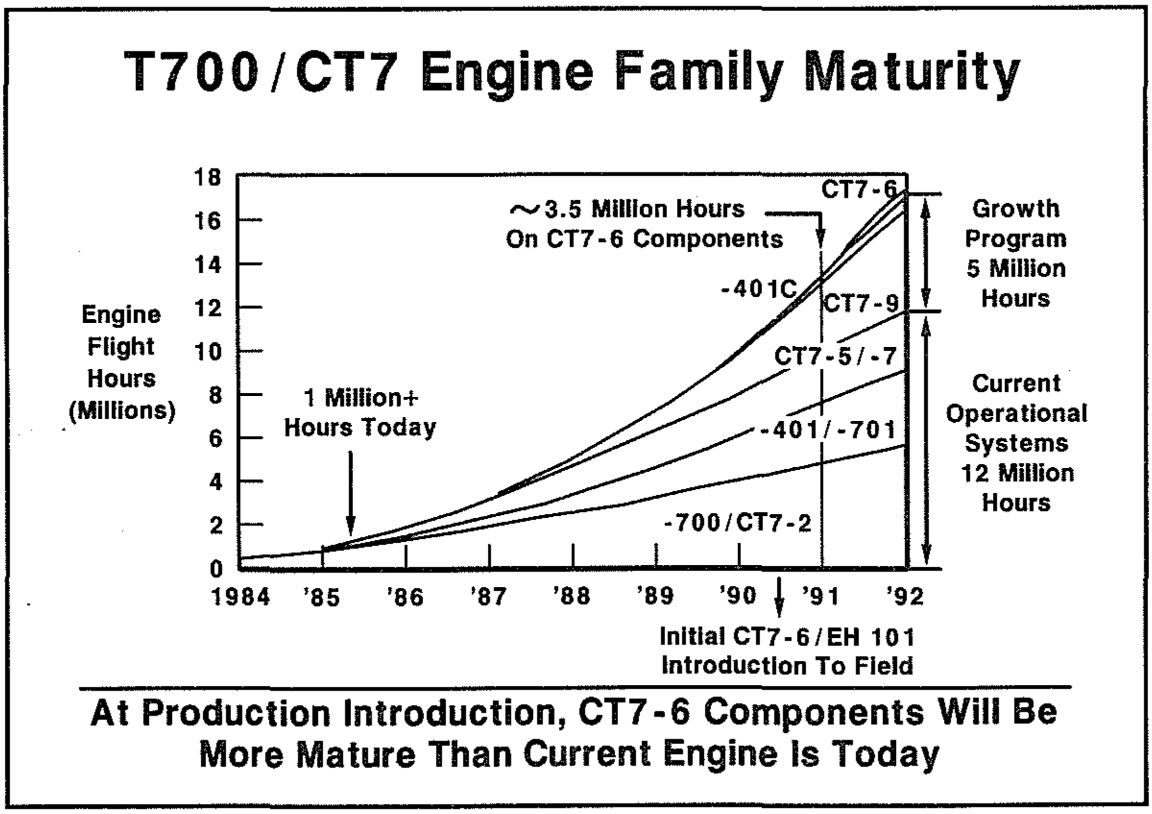


Figure 29. T700/CT7 Engine Family Maturity

5. Summary

Derivative engines offer advantages such as less investment to be recovered and earlier maturity, with attendant higher reliability and availability plus lower costs of ownership and lower risk when compared against "new but current" engines or "next generation engines". These advantages are even more pronounced when compared to the "new but current" engine which offers no technology advantage over the derivative growth engines. "Next generation engines" are those that offer major or revolutionary improvements in technology. Their higher investment cost and program risk are justified by the advantages they offer when there is a justifiable market or national defense need.

In recent years, several major engine manufacturers have substantiated the case for the derivative engine, primarily for civil airliner engines. General Electric's experience with its T58, T64, and T700 engine families also endorses these conclusions for helicopter engines.

For derivative engines to achieve these advantages, they must include a high degree of commonality with prior family members, and the technology they adapt should have been demonstrated in other engine programs or in on-going research and development efforts.

The current family of T700/CT7 Step 2 growth engines, which includes military and civil turboshafts and a civil turboprop, exhibits these characteristics. They have both a high degree of commonality with their predecessors and their technology improvements have been previously demonstrated in other programs. In addition, a strong development program is underway which has already demonstrated the componentry. This program contains the design verification tests necessary to substantiate engine level performance, as well as significant durability testing to enhance early maturity. The durability testing includes a 300-hour qualification test for the Naval derivative and substantial AMT testing to assure stability under mission conditions. When the civil turboshaft enters service on the EH101, it will be better than the baseline engine is today.

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