

**ELEVENTH EUROPEAN ROTORCRAFT FORUM**

Paper No. 86

# **T700/CT7 Growth Engine for European Helicopters**

H.G. Donohie

**GENERAL  ELECTRIC**

**General Electric Company  
Aircraft Engine Business Group  
Lynn, Massachusetts, U.S.A.**

**September 10-13, 1985  
London, England**

The City University, London, EC1V OHB, England

T700/CT7 GROWTH ENGINE  
FOR EUROPEAN HELICOPTERS

by

H. G. Donohie  
Manager, T700/CT7 Commercial and  
International Military Programs  
General Electric Company  
Aircraft Engine Business Group  
Lynn, Massachusetts, U.S.A.

ABSTRACT

Alfa Romeo Avio, Fiat Aviazione and General Electric have combined to develop and produce the CT7-6, a 2000 horsepower (1490 kW) growth turboshaft version of the T700/CT7 engine family. The engine is planned for the civil EH 101 and NH-90 helicopters. It also has potential for a possible single engine version of the Al29 as well as growth versions of current CT7/T700 applications.

GE has had cooperative relationships with Alfa Romeo and Fiat since the 1950s. Programs involved include the J47, J85, J79, T58, LM500 and LM2500. Currently all three companies are engaged in co-development, co-production and revenue sharing partnerships on the CF6-80 and T700.

The CT7-6 will offer the service benefits established by the earlier CT7 and T700 models. These have given unparalleled operability, ease of maintenance, reliability and operating cost savings. The CT7-6 will inherit these advantages and bring added benefits to operators with the incorporation of the latest proven technology in design and materials.

I. INTRODUCTION

In 1984 General Electric entered into an agreement with Fiat Aviazione, and Alfa Romeo Avio to develop and produce a growth turboshaft version of the CT7/T700 engine family. General Electric, Fiat and Alfa Romeo (Figure 1) have enjoyed a long and mutually beneficial relationship in the manufacture of aircraft turbines. This program involves participation by Alfa Romeo and Fiat to include engine design and fabrication work for the unique components - as well as test and analyses of the engine and engine components - all capitalizing on the specialized skills of partners.



Figure 1. Joint Partners In CT7-6 Engine Development.

The growth engine being developed by the three partners is designated CT7-6 (Figure 2). It uses turbomachinery components from the CT7 turboprop models, which power the Saab-Fairchild 340 and CASA-Nurtanio CN235 (Figure 3) and an improved model which will likely power advanced versions of these aircraft. These technology improvements include more advanced aerodynamic designs in the compressor and both turbines, and new materials in the high pressure turbine nozzles, shrouds and buckets. A more effective cooling system is incorporated to accommodate higher gas temperature and provide long life. The cooling technology necessary to implement the turbine bucket cooling scheme was demonstrated in 1984. These improvements all become a part of the CT7-6.

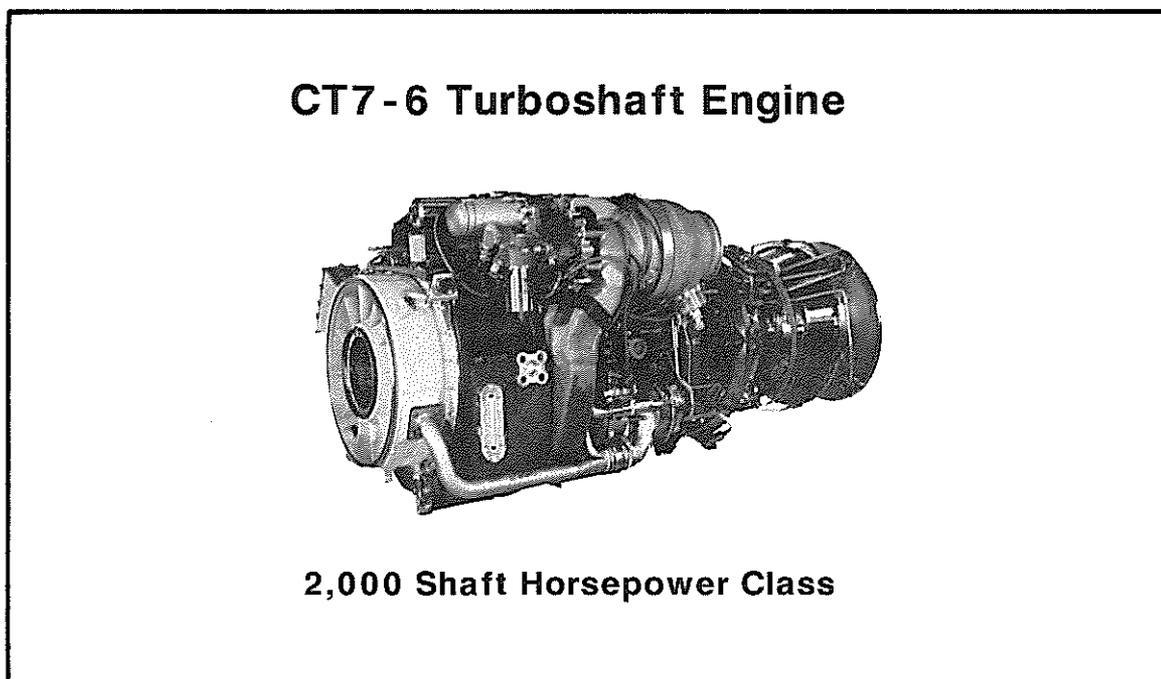


Figure 2. CT7-6 Turboshaft Engine Jointly Being Developed By Alfa Romeo Avio, Fiat Aviazione, And General Electric Company, U.S.A.

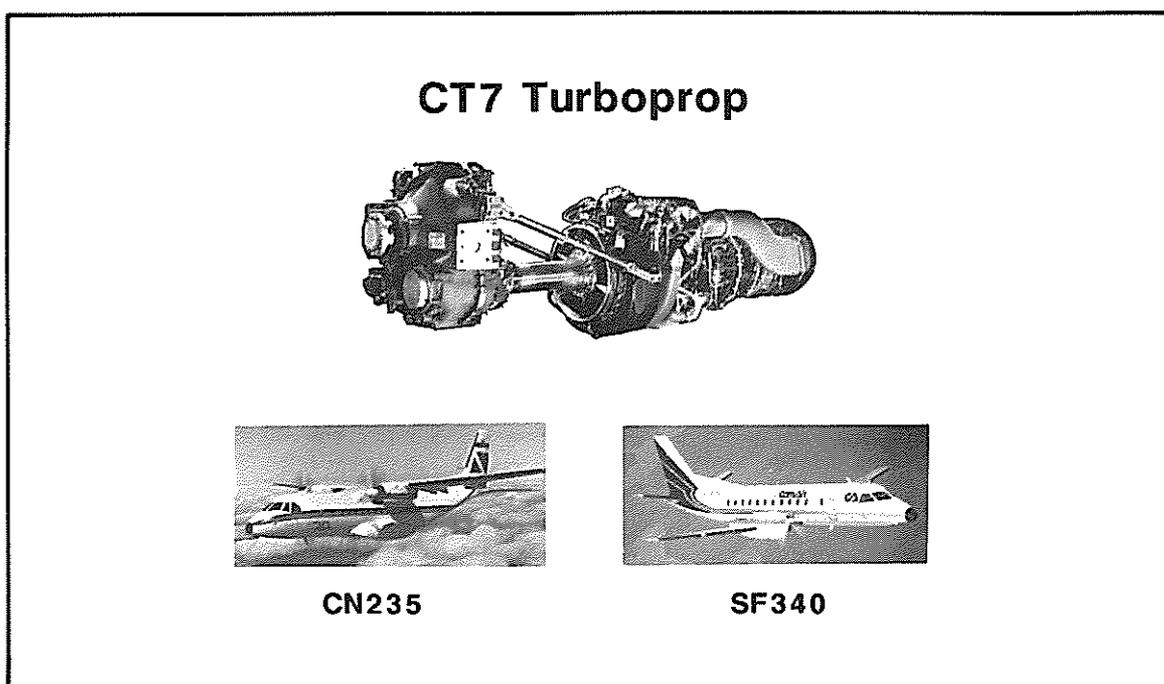


Figure 3. CT7 Turboprop, From Which CT7-6 Draws Modern Technology, And The Current Turboprop Applications.

All of these engine models are members of the CT7/T700 family which began with the T700-GE-700 for the U.S. Army Black Hawk helicopter. The turboprop models incorporate a compressor with a 12% increase in airflow which is being applied to the turboshaft line for the first time in the CT7-6.

The -6 model is a 2000 horsepower (1490 kW) class engine suitable for use on new European helicopter programs such as the civil model of the EH 101 and the various versions of the NH-90. It may also be suitable for a single engine version of the Agusta A129 aircraft. (Figure 4).

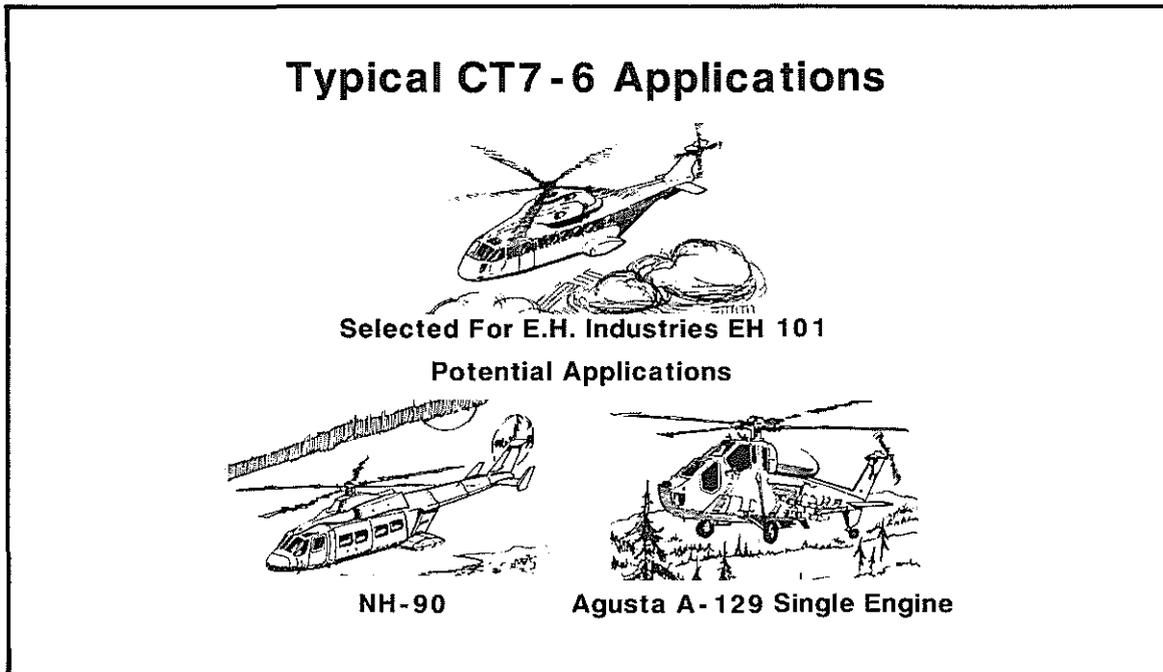


Figure 4. Typical Application Vehicles for CT7-6 Turboshaft Engines.

In addition to these European programs the engine will provide a suitable powerplant for growth versions of current CT7/T700 applications.

The CT7-6 rating structure is being established to include the short time one-engine-inoperative ratings. Both a 30 second "emergency" and a 2 1/2 minute "contingency" rating are currently being studied.

Alfa Romeo, Fiat and General Electric have defined an engine program with production introduction to meet the requirements of the civil EH 101 helicopter. The joint program was announced and begun in early 1985. Design of unique hardware items will be complete in 1985. The first engine to test will be early in 1987 with certification scheduled to follow later the same year. This schedule is shown in Figure 5.

## 2. BACKGROUND

The CT7/T700 engine family is currently produced in seven models to provide power for nine helicopters and two turboprop aircraft (Figure 6). Since operational use of the engine began in 1979 production engines have accumulated nearly 1 million engine flight hours. By 1990 when the civil EH 101 will begin service, the family will have achieved 10 million flight hours providing an immense base of learning and experience for all family members. (Figure 7).

Two thousand CT7/T700 family engines have been shipped and are operating in 18 countries on 5 continents. Satisfactory operation continues to be demonstrated in a wide variety of environments and

mission requirements (Figure 8). Note that these environments include the very high altitude of the Andes mountains, the frigid temperatures of the Arctic, the hot, humid tropics, salt laden atmospheres of the North Sea, Gulf of Mexico and South China Sea as well as the sandy environments of Oman and Saudi Arabia and almost everything that this earth has to offer. CT7/T700 reliability in service operation in all environments has been excellent.

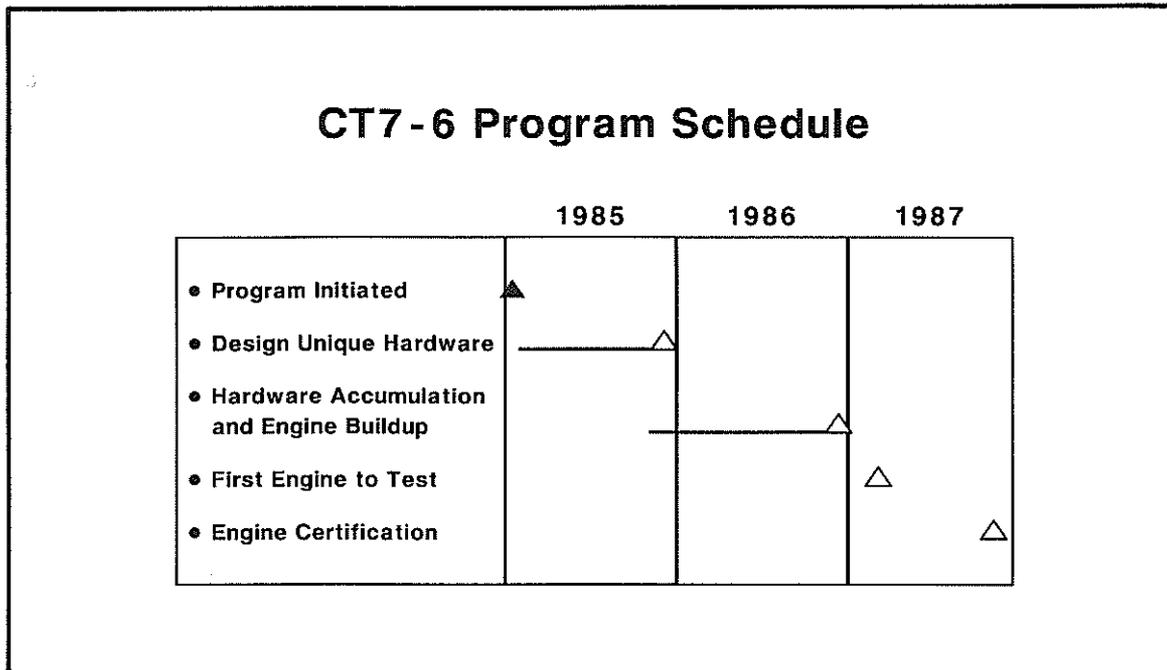


Figure 5. Program Schedule For CT7-6 Engine Development.

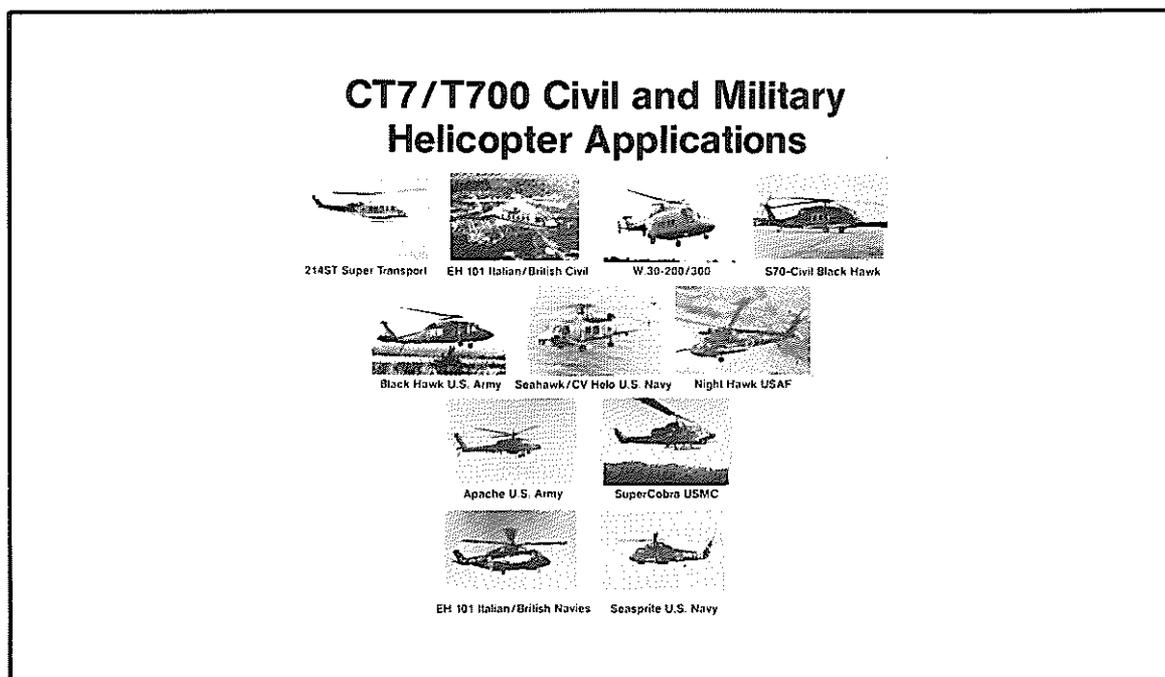


Figure 6. Current CT7/T700 Engine Applications.

CT7/T700 family objectives were established early on for reliability and maintainability as measured by operating cost parameters such as unscheduled removals, and in-flight shutdowns (Figure 9). Therefore the engine was designed from its inception for field use and we verified the design by completion of a very successful maturity program which we believed had really allowed us to find and fix problems before full scale production. The results have been outstanding.

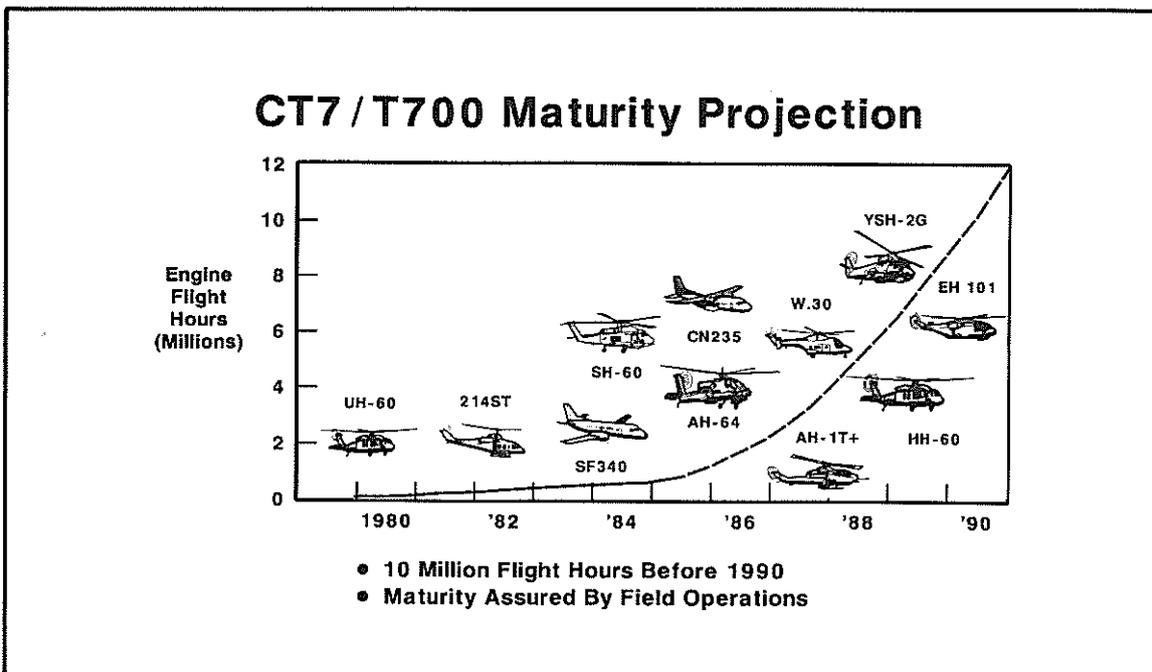


Figure 7. Projected Flight Experience Of CT7/T700 Engine Family.



Figure 8. Worldwide Operational Locations Of CT7/T700 Engine Family.

Compared with previous generation turboshaft powerplants, T700 engine unscheduled removal frequency is typically about one-sixth the rate. This is shown on Figure 10 where engine-caused removals per thousand flight hours are plotted against cumulative flight hours. The shaded area represents the experience of helicopter engines throughout the decades of the '50s and '60s.

The reliability being experienced by CT7/T700 engine operators as represented by unscheduled engine removals is comparable to the levels seen for mature high bypass ratio turbofan engines used in wide body transports.

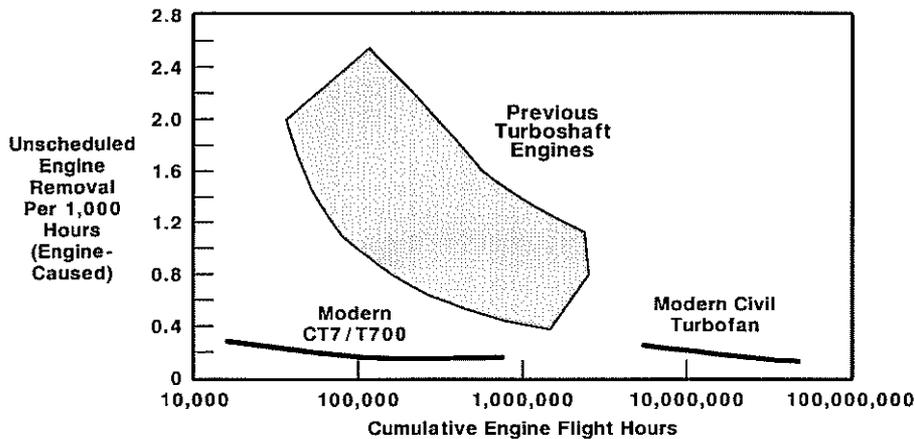
# 10 Bottom-Line Measures

## All Causes, Events

● <b>Shop Visit Rate</b> per 1,000 EFH	<div style="display: flex; flex-direction: column; align-items: center;"> <div style="margin-bottom: 10px;">↑</div> </div>
● <b>LRU Rate</b> , per 1,000 EFH, including Engine Removals for Access	
● <b>MMH</b> , per EFH (Including Depot)	
● <b>Ground Test Time</b> , per EFH - Engine Maintenance	
● <b>Parts Consumption Cost</b> , per EFH % Engine Price per 1,000 EFH	
● <b>Parts Consumption and Labor Costs</b> , per EFH at \$ (/Man-Hour)	
● <b>Engine Holes / Percent</b>	
● <b>MTBMA</b> , Hours	
● <b>Mission Abort Rate</b> , per 1,000 EFH Hours	
● <b>In-Flight Shutdown Rate</b> , per 1,000 EFH for Twin Engine Aircraft	

Figure 9. Parameters Used For Tracking Field Experience And "Goodness" Trends.

## Helicopter Engine Reliability



**CT7/T700 As Good As Commercial Aircraft Engines**

Figure 10. Comparison Of CT7/T700 Reliability With Previous Turboshaft Engines And Modern Civil Turbofans.

High reliability, combined with special design features, enhance safety and provide low cost of ownership. Operators will benefit from the proven in-service features which are shown on Figure 11. Safety is improved by the incorporation of a suction fuel system which has eliminated fuel fires caused by pressurized line ruptures. The inlet particle separator, steel compressor blades and rugged "blisk" design (single unit blade and disk) provide excellent protection against erosion and foreign object damage. The machined-ring combustor, a GE innovation in aircraft gas turbine design, provides a small, lightweight, long-life configuration that also improves turbine life because of its uniform and stable exit temperature distribution. Additionally the engine incorporates an efficient cooling system design in the high pressure turbine. These features have resulted in excellent field operation. There have been only three hot-section-caused engine removals in over 600,000 engine flight hours

## Proven-In-Service Design Features

- Inlet Particle Separator
- Steel Blisk Design
- Suction Fuel System
- Self-Contained Lube And Electrical Systems
- Control Functions
  - Rapid Response
  - Constant Speed Control
  - Automatic
    - Starting
    - Load Sharing
    - Temperature Limiting
    - Overspeed Protection
- Operational
  - Dual-Engine Torque Limiting
    - Automatic Contingency Power



Figure 11. Engine Features Which Contribute To Safe Operating Characteristics Of CT7/T700 Engines.

in the Black Hawk program - a rate of 0.005 per thousand hours. Corrosion protection materials and coatings are included in the basic configuration for the U.S. Army Black Hawk. Added protection (marinization) for extensive over-ocean operation is featured in the U.S. Navy configuration for the Seahawk and SuperCobra.

To further improve the operational benefits offered by the engine, the design incorporates health monitoring features which permit on-condition operation (Figure 12). Experience gained to date shows that with on-condition maintenance the only time-scheduled actions required are 3 levels of inspection:

- (1) daily pre-flight
- (2) 10 hour or 14 day
- (3) 500 hour borescope

## Engine Health Monitoring Provisions

- Cockpit
  - Filter Impending Bypass Signals
  - Chip Detector
  - Oil Pressure And Temperature
  - Fuel Pressure
  - Turbine Temperature, Torque And Speed
- Ground
  - Borescope Ports
  - Electrical Diagnostic Connector
  - Engine History Recorder
  - Lube Scavenge Screens



Borescope Inspection

**Allow On-Condition Operation**

Figure 12. Engine Health Monitoring Features Which Permit On-Condition Operation of CT7/T700 Engines.

These inspections total less than .03 man-hours per engine flight hour, and 1/3 of that in typical civil operation - a very low figure which helps yield low ownership costs.

Ease of maintenance is designed into the entire engine family. Early helicopter experience had shown that a major percentage of maintenance work was required on external engine components and special attention was focused on these elements to reduce maintenance work load. The accessory package was located at the top of the engine for easy accessibility in the helicopter and a number of features were incorporated on the design, some of which are shown on Figure 13. Note that the T700 requires only 10 standard tools for all line maintenance including module replacements.

## Reduced Maintenance Work Load

- Snap-In Line Retainers
- Foolproof / Self-Locking Electrical Connectors
- Color-Coded Wiring Harnesses
- No Oil Change Required
- Dual Oil Level Sight Ports
- Top-Mounted Accessories
- Minimum Lockwiring
- Captive Bolts
- No Field Adjustments
- Integral Water-Wash
- Compressor Split Line For FOD Repair
- Only 10 Standard Tools For All Line Maintenance



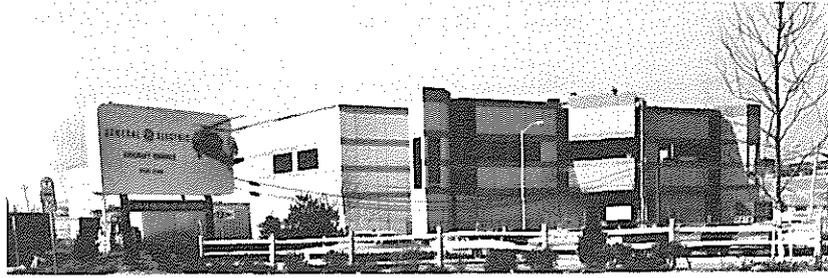
**Line Maintenance Activity**

Figure 13. Features Contributing To CT7/T700 Engine Ease Of Maintenance.

Because our experience told us that FOD was a maintenance and cost driver and because we knew that the separator would not totally eliminate it, we put split lines in the compressor casing to ease repair. This has paid off immensely. The high inherent reliability of the engine has left FOD as the most frequent cause for removal even though the rate is, on the average, 20% of previous engines when unprotected and 60% when protected with screens or barrier filters. This casing design often allows repair on site and eliminates the need for shipment to the depot with the resultant cost and time savings. We do this as standard practice today and have done 14 engines to date in our commercial fleet alone.

Finally, a major attack has been mounted on engine acquisition cost. While this is aggressive and multi-faceted, as any top priority issue normally is, I'll mention three highlights. First, the multi-year procurement programs with the U.S. Government. We're about ready to start the second of these 1500-plus engine programs which provide great inducement to added cost learning, as well as the economics of mass buys. In addition, we are building a completely new facility dedicated to automated manufacturing of small axi-centrifugal engines (Figure 14). The investment here alone is over \$50M. Finally, there is our "all cast engine" about which you may have read in trade magazines. When fully introduced in 1988, we expect this to have yielded a 25% savings.

## Factory Of The Future



- **T700 Design Suited To Fully Automated Manufacturing Techniques**

Figure 14. New GE Manufacturing Facility

We made an oil system which requires no oil changes, allows mixing of approved oils in any amounts, requires no spectroscopic analyses of samples - and we proved that it works. In addition we built an integral manifold into the inlet for periodic water wash of the compressor, when operation required. All these were done to save maintenance.

As a result of these special features proven in nearly one million engine family flight hours, important economic and operational benefits accrue to the operator:

- (1) Spare engine inventories are about 12% of the installed engine fleet.
- (2) Spare parts requirements are about 10% of engine value.
- (3) Maintenance cost is about half that of previous generation helicopter engines.
- (4) Shop visit rate is about 1/6 of earlier engines providing much higher mission availability.
- (5) T700 mission completion in the Black Hawk is 99.7%.

### 3. DESCRIPTION OF THE CT7-6

Our studies for the EH 101 and what seems to be developing for the NH-90 indicate to us that a 2000 SHP version of the T700 family has an excellent market opportunity here in Europe. Figure 15 shows the preliminary ratings established for the CT7-6. This size class provides the necessary power, allows for growth and the engine configuration retains the maturity of early family members. This combination provides attractive benefits to both the helicopter manufacturer and the operator especially when new helicopters are involved because they eliminate the added risk of combining a new engine with a new helicopter.

The objective of our program, therefore, was to provide the power level while retaining the proven field record of the engine. The strong resemblance which the -6 bears to other family members is, therefore, no accident (Figure 16).

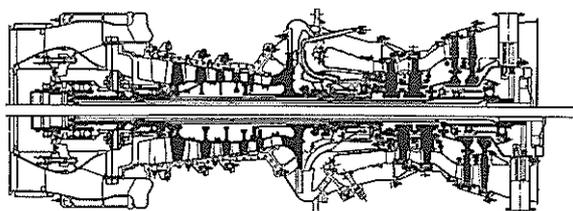
## CT7-6 Preliminary Ratings

	59°F (15°C)		95°F (35°C)	
	SHP (KW)	SFC-lb/SHP hour (Kg/KW hour)	SHP (KW)	SFC-lb/SHP hour (Kg/KW hour)
• Emergency (30 Seconds)	TBD	-	TBD	-
• Contingency (2.5 Min OEI)	2,000 (1,491)	.450 (.274)	1,800 (1,342)	.464 (.282)
• Takeoff (5 Min)	2,000 (1,491)	.450 (.274)	1,740 (1,298)	.466 (.283)
• Intermediate (30 Min)	TBD	-	TBD	-
• Maximum Continuous	1,718 (1,281)	.458 (.279)	1,380 (1,029)	.490 (.298)
• 75% Maximum Continuous	1,288 (960)	.489 (.297)	1,035 (772)	.537 (.327)

Figure 15. CT7-6 Preliminary Ratings

## Engine Configuration

**T700**



**CT7-6**

- **Shaft Horsepower**    **2,000 (1,490 KW)**
- **Growth**                    **27%**
- **Weight**                      **460 Lb (209 Kg)**

Figure 16. Cross-Sections Indicating Configuration Similarity Between CT7-6 and Current CT7/T700 Turboprop Engines.

The path we selected combined an increase in airflow and temperature with improvements in component efficiency (Figure 17) using technology features already demonstrated in other advanced General Electric engine programs.

We already had a compressor with 12% more flow - it powers the Saab-Fairchild and CASA-Nurtanio turboprops which I mentioned earlier. In addition to that, aerodynamic improvements in the axial and centrifugal compressors had already been tested and demonstrated in our GE27 - a 5000 horsepower class engine. Finally, a CT7 turboprop program had already been launched to increase the power of the turboprop family to the -9 level and the -9 engine includes all the features mentioned above. This gave us two additional and important assets in meeting our objectives. First, it proved the performance of

the compressor in T700 size and, secondly, it will provide years of field experience before it is necessary to launch full scale production of the CT7-6.

<b>Modern Technology In CT7-6</b>		
	<u>Source</u>	<u>Production Introduction</u>
<b>• Aerodynamic Design</b>		
- Axial Compressor Blade And Vane Contours	GE27/CT7-9	1991
- Centrifugal Compressor Vane And Diffuser Shape	GE27/T700-405/705	1991
- High And Low Pressure Turbine (HPT, LPT) Stator And Rotor Contours	GE27, NASA E <sup>3</sup> CT7-9, T700-405/705	1991 1990 Technology
<b>• Materials</b>		
- First Stage Turbine Blades	GE23, 27	1991
- High Pressure Turbine Shrouds	Army MMT Program	1990 Technology
<b>• Cooling In HPT</b>		
- Serpentine - Casting Core Technology	CF6, GE27, MMT	1991

Figure 17. Demonstrated Modern Technology for CT7-6 Engine.

The turbines from the turboprop program are also available for turboshaft use. Aerodynamic improvements in both the rotors and stators are also being incorporated based upon experience and prior testing on the GE27 and our NASA E<sup>3</sup> engine (Energy Efficient Engine). A gas temperature in the 2500°F (1370°C) class is permitted by the use of serpentine cooling in the directionally solidified René 108 high pressure stage 1 turbine blades. The materials and cooling technology were developed in our GE23 (a low pressure ratio turbofan) and GE27 and with the support of U.S. Army Manufacturing Methods and Technology Programs (MMT). The cooling scheme and the temperature levels are common to our CF6 engine which powers A300, DC-10 and 747 commercial wide body airliners around the world every day. An additional attractive aspect of these turbines is the fact that they are also included in the -9 turboprop. In addition, T700-GE-405 and -705 engines which are being prepared for U.S. Military service well ahead of CT7-6 full-scale production, also use the high pressure turbine and run at similar turbine temperatures. Here again we will have the advantage of years of field experience prior to CT7-6 production. Our current programs are running at a rate which by 1990 will produce 10 million family hours with 5 million of those on our turboprop engines and 2 million on the improved turboprop - the CT7-9.

We felt that it would be essential to maintain complete installation interchangeability of our CT7-6 with other family members (Figure 18). This required that we adapt portions of our T700-GE-401A engine (marinized engine used by U.S. Navy, U.S. Marines and EH 101) inlet separator to match the existing engine inlet diameter with the larger diameter of the high flow compressor. This approach retains the structural characteristics and separating efficiency of the current engine. We will also retain a complete anti-icing capability in the engine inlet.

While basic control system philosophy and design remain as they currently are, tuning is being accomplished to match fuel schedules, variable stator schedules, starting bleed flow and temperature limits to engine requirements. In addition, the system will have the

capability to handle three-engine load sharing using experience developed earlier in the WG.34 program and in production on the CH-53E program. Initial units will have dynamics compatible with the EH 101.

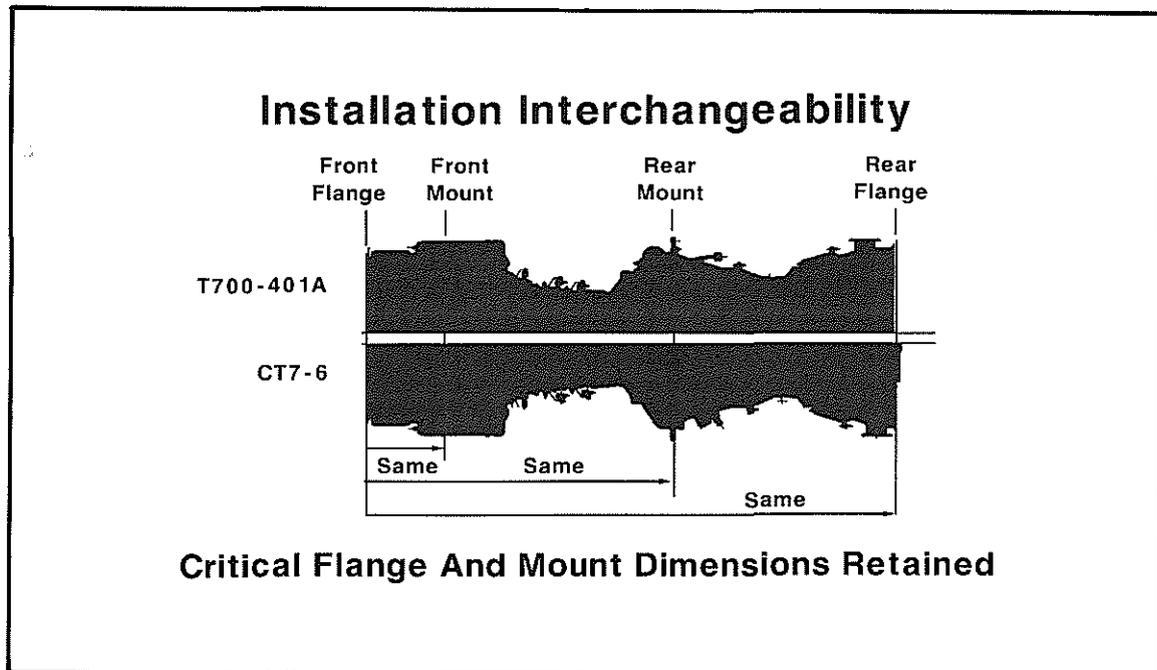
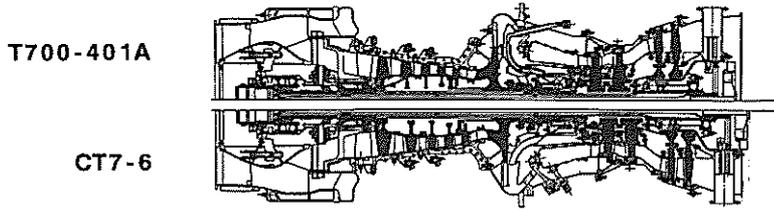


Figure 18. Diagram Showing Location of Critical Flange And Mount Points Retained For Interchangeability.

Now let's look at the common parts - those which are unchanged (Figure 19). First there is the combustor which has given us such outstanding service. Also retained are the major systems - lubrication, electrical, fuel and air - all are the same as the parent model. The accessory drive, power takeoff, gearbox and accessories are unmodified - except for the straightforward control tuning described earlier. The bearings, bearing arrangement, sumps and seals are unchanged. We have kept the same shafting design and the same casings, mounts and structure except for some small dimensional changes necessary for installation commonality. The result is a high degree of commonality with other family members, a continuation of the outstanding engine reliability as well as the excellent operability features like stable, stall-free operation throughout the operating envelope, starting reliability, and rapid acceleration.

## CT7-6 Commonality

- Basic Structure, Configuration
- Bearings, Sumps, Seals
- Shafts
- Lube System
- Electrical System
- Combustor
- Accessories
- And With Minor Modifications
  - Inlet Particle Separator
  - Fuel Control



**High Commonality Preserves Operational Benefits**

Figure 19. CT7-6 Commonality With Other CT7/T700 Engines.

These modern technology additions to the turbomachinery result in important cycle advantages. The compressor pressure ratio (Figure 20), while well within our own experience, is well ahead of the industry for this class engine. The same can be said of turbine temperature (Figure 21). Note here that the CT7-6 is at the lower edge of our small engine band of experience (Figure 22). Since specific fuel consumption (SFC) and specific power (kW/kg of air) are primarily functions of pressure ratio and temperature, this CT7-6 technology has important advantages which can result in helicopters which are smaller, lighter and have longer range. Figure 23 shows the CT7/T700 family to be a dramatic improvement in SFC over previous engines and competitive with engines still in development and planned for production in the 1990s.

## Cycle Pressure Ratio Trend

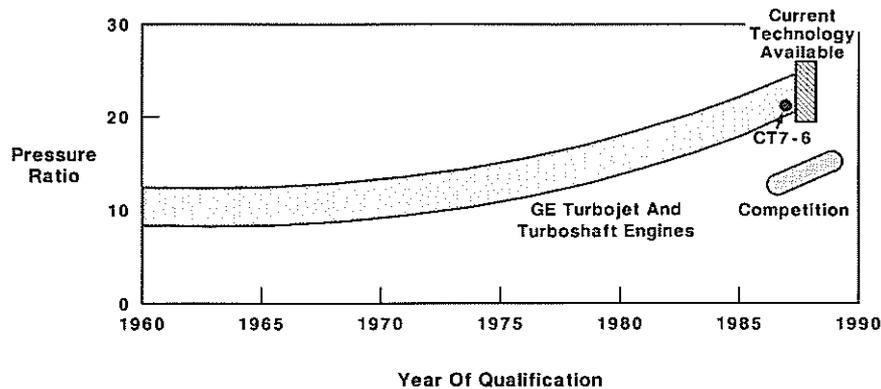


Figure 20. Cycle Pressure Ratio Trend Resulting From Ongoing Technical Advances And Relation Of CT7-6 To Competition.

## Cycle Temperature Trends

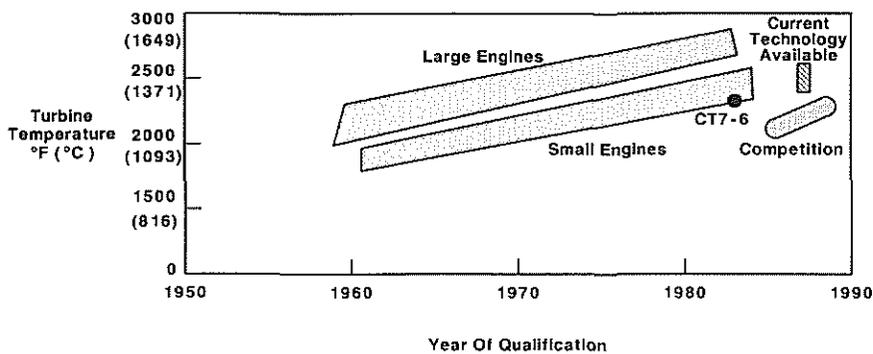


Figure 21. Cycle Temperature Trends Resulting From Ongoing Technical Advances And Relation Of CT7-6 To Competition.

## Turboshaft Engine Cycle Performance Tradeoffs

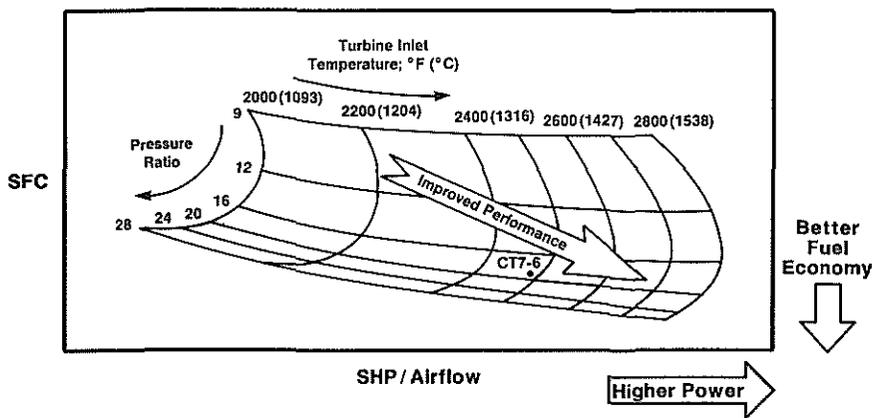


Figure 22. Diagram Showing Cycle Tradeoffs To Obtain Better Fuel Economy And Higher Power.

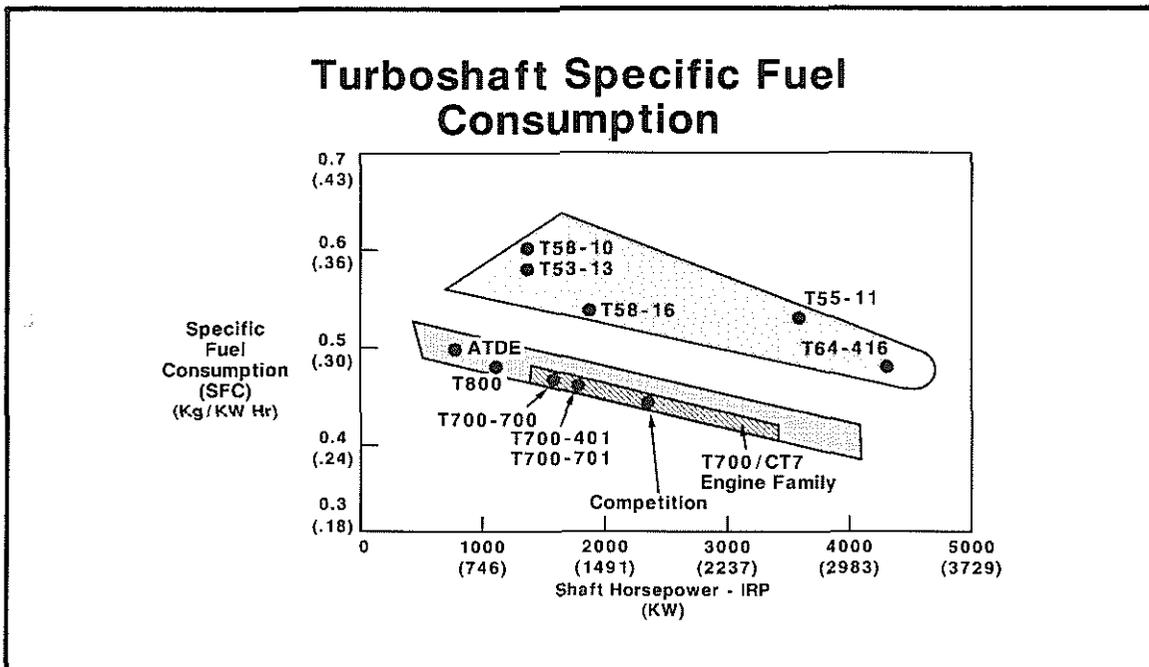


Figure 23. SFC/Shaft Horsepower Relationship Of Various Turboshaft Engines.

The combination of proven, modern technology adapted from our other General Electric engines to produce more power and the retention of key components, systems and features from the parent engine - which was already pretty modern - gives us an engine with technology features which will remain competitive through the rest of this century. Figure 24 shows the specifics for the engine - specific fuel consumption as well as specific power as measured by horsepower per pound of weight and horsepower per pound of compressor airflow. We believe that they are the best in the CT7 engine class and will remain that way well through the 1990s.

### CT7-6 Modern Technology Measures SL Standard Day - Inlet Separator Included

• Specific Fuel Consumption At Cruise (Fuel Consumption/Power)	0.499 $\frac{\text{Lb}}{\text{Hr SHP}}$	0.304 $\frac{\text{Kg}}{\text{Hr KW}}$
• Specific Weight (Takeoff Power/Weight)	4.4 $\frac{\text{SHP}}{\text{Lb}}$	7.13 $\frac{\text{KW}}{\text{Kg}}$
• Specific Power (Takeoff Power/Compressor Airflow)	183 $\frac{\text{SHP}}{\text{Lb/Sec}}$	300 $\frac{\text{KW}}{\text{Kg/Sec}}$

---

**Competitive Past The Year 2000**

Figure 24. CT7-6 Engine Specifies.

#### 4. DEVELOPMENT AND CERTIFICATION PROGRAM

Fiat Aviazione and Alfa Romeo Avio have long-standing relationships with General Electric in aircraft turbine engine programs, going back to the days of the J47 engine. Fiat has done licensed production on J47, J79 and T64 models and has participated with GE as co-developer and co-producer of the LM500 and LM2500 power units. Alfa Romeo has engaged in licensed production of T58, Gnome and J85 engine models. Both Alfa Romeo and Fiat participate with GE in co-development, co-production and revenue sharing on the CF6-80 and T700 engine models.

Work sharing on the CT7-6 has been arranged to take advantage of the skills and capabilities of the partners.

Alfa Romeo, which already has a test cell built to support its delivery of T700-GE-401A engines for the Naval version of the EH 101, will do the official certification/qualification run. Alfa will engineer the modification required to the exhaust frame to retain overall engine length. The responsibility for changes to the external hardware, as required, to integrate the external configuration is also Alfa's. Consistent with this, Alfa will prepare an engine mockup suitable for configuration work and capable of serving as an installation mockup. Preparation of the engine specification, installation drawings and manual, and coordination with the Italian Civil authorities, along with certain analytical tasks round out the Alfa responsibility.

Fiat will engineer the modification to the front end of the engine necessary to mate the existing swirl vane frame with the increased diameter compressor. Structural testing to verify mechanical integrity of the modified parts is also a Fiat responsibility. The aft engine mount, located on the diffuser casing, must move forward by 1 inch (2.54 cm) in order to retain the installation dimension of the CT7/T700 family when using the high flow compressor with its longer length. The design effort associated with this modification is also a Fiat responsibility. Fiat will prepare the support manuals necessary for field use.

General Electric will be responsible for overall program management and integration as well as technical direction. We will do the anti-icing testing necessitated by the higher airflow, altitude testing to evaluate and verify performance and operability as well as compressor stress testing. GE design responsibility will include any changes necessary to the start bleed and anti-icing valve to accommodate the compressor and the anti-icing system. The control system is also a GE responsibility including the control of variable stator schedules, fuel schedules and the electronic control dynamics necessary to achieve compatibility with aircraft applications. FAA coordination will be maintained by GE.

The hardware philosophy is basically that each of the partners will supply the hardware for which he had design responsibility. Alfa and Fiat will also provide the hardware which they already supply to other T700/CT7 family members under the existing Revenue Sharing Agreements. GE will provide the remainder of the hardware including the turbomachinery and that which is common to other CT7/T700 family members, and will accomplish most of the engine assembly for the bench test engines.

Production will follow essentially the same lines as those outlined above. Engine assembly can be accomplished either in the U.S. by General Electric or in Europe by Alfa Romeo. Alfa Romeo already has a license for T700 engines and is currently performing some machining as well as assembly and test of the T700 engines for the Naval version of the EH 101.

The certification program is structured to assure that the engine will meet both European and U.S. requirements for Civil helicopter engines and, additionally, will meet the special requirements which may be demanded by European military users.

Figure 25 shows a summary of the integrated test program for our current turboprop and turboshaft growth engines. It contains approximately 5000 hours of testing. Details are shown on Figure 26. Note that there are 11 engines involved with over 3500 hours devoted to endurance, low cycle fatigue (LCF) and accelerated mission testing (AMT). The initial performance work - including altitude testing - along with compressor and turbine stress tests are all accomplished this year - 1985. We have also included a high temperature endurance test this year to obtain an early evaluation of the design and manufacturing execution of the cooling system objectives. Earlier, we had done some testing - to over 2700°F - (1480°C) on standard T700 turbine hardware with extremely satisfying results.

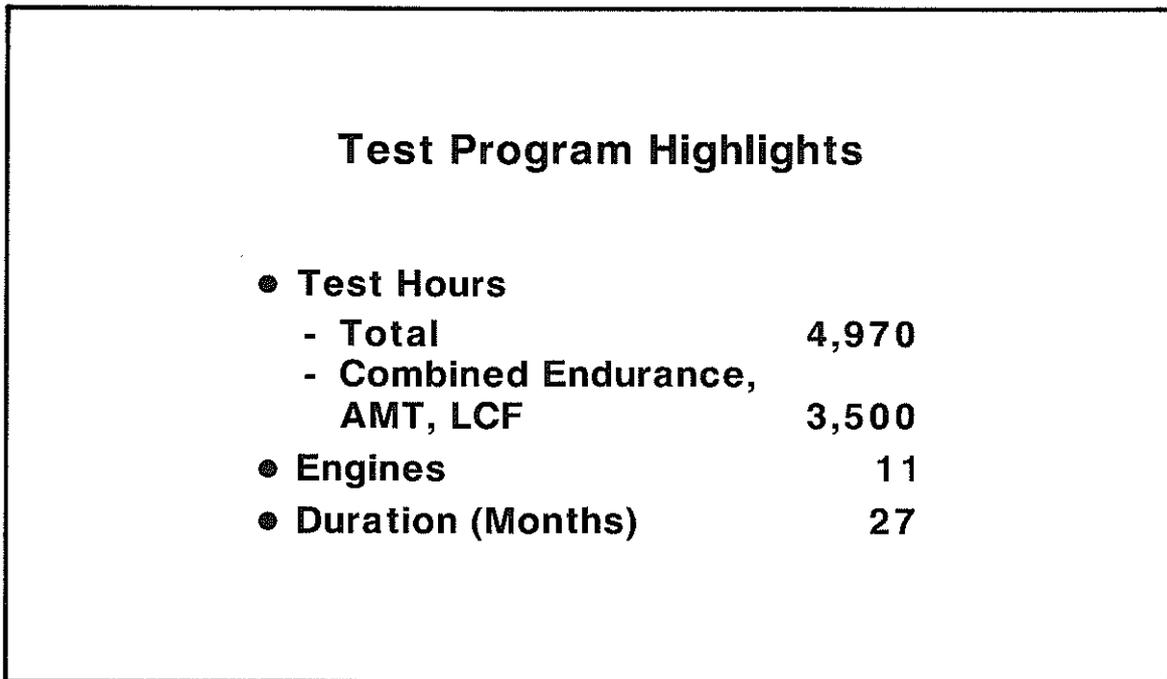


Figure 25. Test Program Highlights.

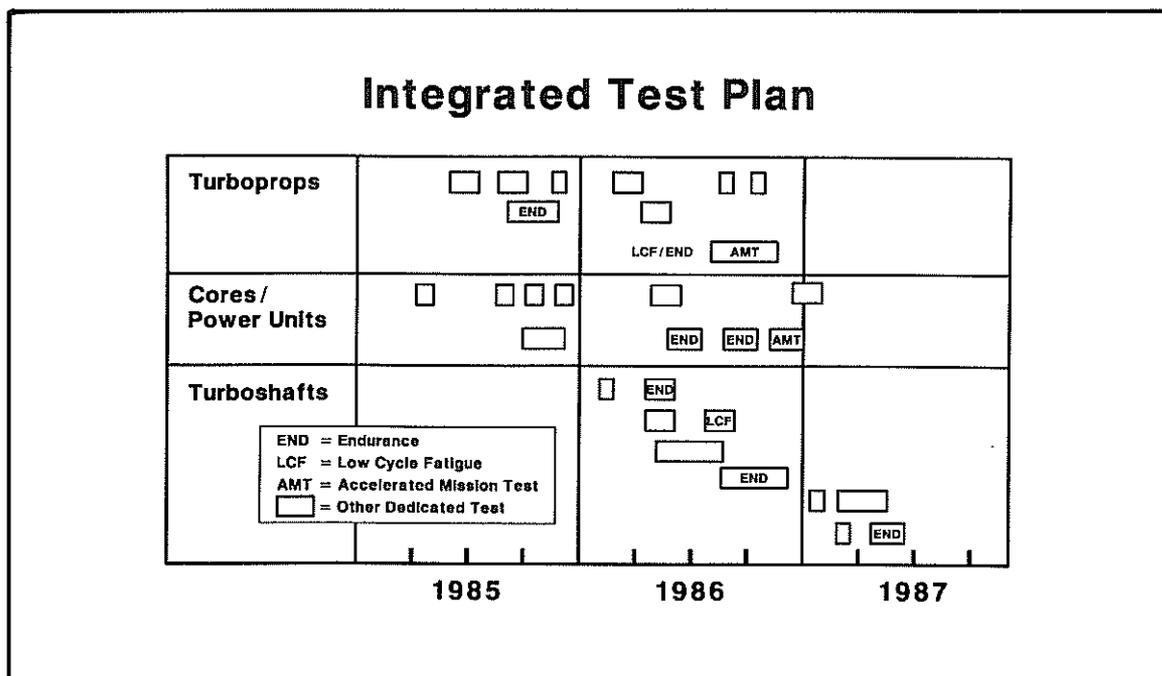


Figure 26. Chart Showing Integrated Test Plan.

During 1986, we will accomplish the special tests necessary for turboprop certification and military engine qualification which include overtemperature, loss of load, and corrosion. Official altitude performance and starting demonstrations along with the official certification/qualification tests also take place in 1986. But the bulk of the testing in that year is aimed at verifying the reliability and durability. Over 3000 hours are dedicated to this purpose with more than 2000 of these accomplished on turboprop engine power units or turboshaft engines. This consists of endurance tests in which the engine is operated in accordance with the required civil certification or military qualification duty cycle; low cycle fatigue testing; and Accelerated Mission Testing (AMT) designed to evaluate and demonstrate the engine's ability to operate to the duty cycle of the aircraft application. In the latter testing (Figure 27) we put emphasis on time at maximum temperature, full thermal cycles and low cycle fatigue cycles by matching their frequency with what we would expect to see in a complete life cycle of the engine as used in the field. Our acceleration rates (real time to test time ratio) for these parameters typically vary from 6 to 9 allowing us to accomplish testing in much shorter real time intervals than would occur in the field. In this way the data can be put to use much sooner in developing and introducing any improvements indicated by the tests. We are currently discussing with Alfa Romeo the possibility of conducting some of these tests at their facility outside Naples.

In 1987 the unique testing required by the civil turboshaft - the CT7-6 will be accomplished. This includes additional compressor stress and inlet distortion work - because we have modified the inlet separator ahead of the compressor and to test with some unique helicopter distortion patterns; official altitude and anti-icing testing; and the official endurance testing. The plan calls for the testing to be completed in the second quarter with certification in the third quarter.

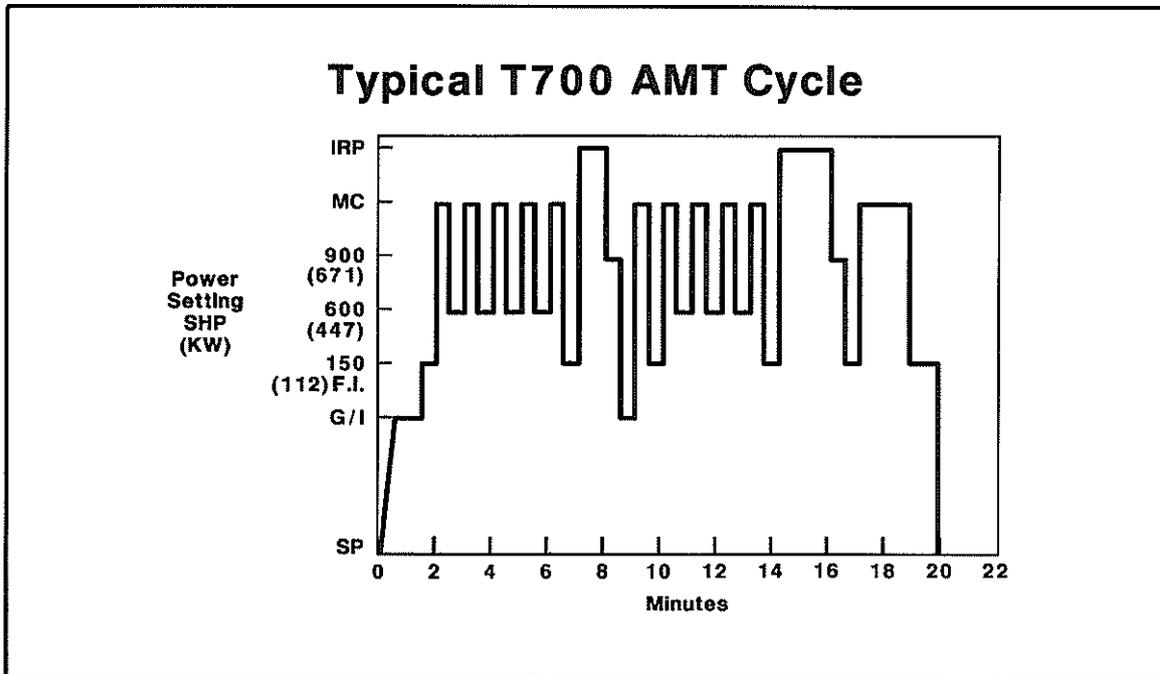


Figure 27. Diagram Of Typical T700 Accelerated Mission Test (AMT) Cycle.

## SUMMARY

The CT7-6 has been structured primarily to meet the needs of European helicopters. It will initially power the civil and utility versions of the EH 101. It is also suitable for the NH-90 and would be an excellent match for a single engine version of the Al29.

The design, development and certification program is a joint undertaking of Alfa Romeo Avio, Fiat Aviazione of Italy, and General Electric Co. (U.S.A.). The partners will also combine their resources to execute the production and support aspects of the program.

The engine represents a 27% growth step compared to the initial T700-GE-700 powering the U.S. Army Black Hawk. Growth is accomplished by a 12% increase in airflow, technology infusions which provide improvements in the efficiency of the compressors and both turbines, and an increase in turbine temperature to the 2500°F (1370°C) class.

The growth features are common with other family members now in development but which precede the CT7-6 into full scale production by a number of years. The CT7-9 turboprop uses the components planned for the -6 and will have accumulated approximately 2 million hours of field experience at the time that the CT7-6 enters production. Military versions of the T700 will also use the same centrifugal compressor aerodynamics and high pressure turbine as will the CT7-6. Both of these engines - the civil turboprop and the military turboshaft - operate in the same turbine temperature range as the CT7-6.

This approach, along with a high degree of retained commonality with other CT7/T700 family members, will preserve the outstanding reliability and low operating cost which are currently being demonstrated in operational service by parent CT7/T700 family members.

The technology included in the engine to obtain growth has been taken from other General Electric (U.S.A.) ongoing programs. It will retain technology leadership for the T700 family in the 2000 SHP class through the 1990s.

The test program contains about 5000 hours of test. The essential stress, high temperature and performance evaluations are conducted early in the program - 1985 - with the later years of 1986 and 1987 being devoted to special tests required for certification and placing emphasis on verification of the reliability and durability of the engine.

Certification of the engine is planned for 1987.

Additional growth in the family is available through even more modern materials, increased airflow turbines to better utilize the flow capacity of the compressor and high turbine temperature and would be planned to meet market conditions and customer needs.