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CO-DEVELOPMENT OF CT7 - 6 ENGINES A CONTINUED TRADITION IN TECHNOLOGY AND RELIABILITY

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ABSTRACT

Alfa Romeo Avio, Fiat Aviazione and GE Aircraft Engines are co-developing and will co-produce CT7-6 and CT7-6A turboshaft engines, 2000 SHP (1491 kw) growth derivatives of the proven T700/CT7 engine family.

Initial production engines continue to be delivered to EH Industries for flight testing later this year on EH101 helicopters. Other potential applications include the NH90, a single engine version of the A129, and growth versions of other current T700/CT7 applications.

The CT7-6/-6A engines incorporate proven technology improvements in aerodynamics, materials and cooling methodology which have been derived from other modern General Electric engine programs. Notwithstanding these technology improvements, the engines retain a significant degree of commonality with prior CT7/T700 family members which reduces program risk and enhances early maturity.

A comprehensive development and maturity program was put in place to assure and verify attainment of program objectives. This program included investigatory, environment, abusive and endurance testing which had proven successful in developing the basic T700/CT7 engine family as well as other General Electric engine models.

The development of the CT7-6/-6A was integrated to be coincident with two additional T700 military models and two CT7 commercial turboprop models, all of which share a large degree of commonality. This integration increased the severity of the components requirements and broadend the test base to the benefit of the CT7-6/-6A.

The success of the CT7-6/-6A co-development program is attributable to the excellent collaboration among the partners. An effective and aggressive management team with clear division of responsibilities has maintained the program close to schedule, meeting major program objectives.

1. INTRODUCTION

Alfa Romeo Avio, Fiat Aviazione and General Electric have been associated in various Aircraft Turbine Engine Programs. Fiat participation includes licensed production of J47, J79 and T64 models as well as co-development and co-production of the LM500 and LM2500 power units. Alfa Romeo Avio participation includes licensed production of T58, Gnome and J85 engine models. Both companies are also significantly involved in the CF6-80 and T700 engine models. Their involvement in these two programs includes co-development, co-production and/or revenue sharing programs. This long and mutually beneficial relationship in the manufacture of aircraft engines led these three associates to enter into an agreement to co-develop and co-produce the CT7-6/-6A engines, 2000 SHP (1491 kw) turboshaft growth derivatives of the T700/CT7 engine family. The co-development program was announced and initiated in early 1985 (50% GE and 50% Alfa/Fiat). The program objective being to develop an engine which met the requirements of the EH101 helicopters and other potential helicopter applications (NH90 and single engine A129). The required power levels would be provided without compromising the outstanding field performance already achieved by the T700/CT7 engine family. The engines would also be physically interchangeable with the baseline engines already in production.

The partners very effectively generated the CT7-6/-6A development program work split, which has since been executed as defined, based on the demonstrated skills of each partner.

Alfa Romeo which already had the capability/facility to test T700-401A engines accepted responsibility for running the official 150 hours endurance test engine. Responsibility for assembly/disassembly of this engine went to General Electric. Other tasks assigned to and since completed by Alfa Romeo included:

- Modification of the T700/CT7 turboshaft exhaust frame to retain baseline engine length.
- Design of unique external configuration hardware.
- Preparation of installation engine mockups.
- Preparation of installation manual.
- Prime responsibility for RAI interface coordination.
- Assembly, inspection and test, under contract from Costarmaereo (Italian MOD), of the four CT7-6A engines for MMI EH101 prototype aircraft utilizing partial assemblies provided by GE.

The bulk of the tasks assigned to Fiat Aviazione involved the modification of the inlet frames and diffuser case. Specifically, it redesigned the T700/CT7 turboshaft type main frame, front frame and diffuser case as required to achieve compatibility with the larger CT7 turboprop type compressor planned for the CT7-6/-6A engines. These modifications have since been accomplished without impacting baseline T700/CT7 mounting and interface characteristics, a key program objective. Fiat also accepted responsibility for and successfully completed the monumental task of generating all required field technical manuals.

Responsibility for overall program integration/management and technical direction was assigned to GE Aircraft Engines. Specifically, these tasks include:

- Lead design, development and certification effort
- Define and control engine configuration
- Build certification and CT7-6 flight test engines
- Provide CT7-6A flight test engine kits (partial assemblies) to Alfa Romeo for final assembly
- Conduct various certification tests and provide instructions to Alfa Romeo for official 150 hours endurance test and Fiat for diffuser case static load test.
- Prime responsibility for FAA certification and airframe interface coordination.
- Provide assistance to Alfa Romeo and Fiat to obtain RAI type and production certificates.

It is well known that on-time delivery of hardware plays a very important role towards successful completion of a program. The CT7-6/-6A team decided that meeting development hardware requirements would be a joint responsibility. Specifically, each of the partners supplied the hardware for which he had design responsibility. Alfa Romeo and Fiat also provided CT7-6/-6A hardware which shared commonality with the T700/CT7 baseline engine parts currently being provided by them for other T700/CT7 family members under existing revenue sharing agreements. GE Aircraft Engines provided the remaining hardware.

The CT7-6/-6A team worked very well together throughout the entire program. Effective management and, more important, outstanding dedication and co-operation on the part of each partner are the key factors behind the CT7-6/-6A success story. On June 30,1988, the FAA issued GE Aircraft Engines type and production certificates for the CT7-6/-6A engines. RAI and CAA validation and issuance of similar type and production certificates to Alfa/Fiat is in process, scheduled for completion by the end of 1988. Looking ahead towards the production phase of this program, GE and Alfa/Fiat (under GE license already in place) will manufacture engines under respective FAA, CAA and RAI type and production certificates. The ground rules for the production phase follow:

- Each partner will assemble, inspect, test, ship and support engines it sells.
- Each partner will control overall design/configuration of its respective engines.
- All will share in manufacturing parts for both engines per licensing agreement.
- Respective nameplates will be utilized.
  - RAI nameplate - "Alfa Romeo/Fiat CT7-6 AF or CT7-6A AF ... Under GE license"
  - FAA nameplate - "GE Aircraft Engines CT7-6 or CT7-6A"
- Each manufacturer and certifying authority will be responsible for engines they manufacture and approve.

Based on the success of the CT7-6/-6A development program to date and the continued enthusiasm/co-operation exhibited by each of the partners, the CT7-6/-6A engine family will enjoy a bright and successful future.

2. ENGINE DESCRIPTION

The CT7-6 and CT7-6A engines are identical except the CT7-6A incorporates additional corrosion protection features on the swirl frame, CDP seal, stage 1 nozzle trailing edge and stage 1 turbine blade tip to meet military marinization requirements.

Alfa Romeo, Fiat Aviazione and GE Aircraft Engines integrated the development of the CT7-6/-6A engines with two additional T700 military turboshaft and two CT7 commercial turboprop growth derivative models, all of which share a large degree of commonality with the CT7-6/-6A (See Figure 1). The engines involved are the T700-401C/-701C turboshaft for the U.S. Military, the CT7-9B/9C for the turboprop commuter airlines and of course the CT7-6/-6A turboshaft for the EH101 program. They represent growth of 20-27% in power from the baseline T700-700 engine. The CT7-6/-6A production engines ratings structure is summarized in Figure 2. Figure 3 clearly shows the power advantage of the CT7-6/-6A engines over the T700-401A currently installed for the early EH101 aircraft flight test program.

The effect of this integration is to increase the severity of the component requirements and broaden the test base to the benefit of the CT7-6/-6A. Since three of these four additional models will be in service prior to the CT7-6/-6A, it also serves to reduce CT7-6/-6A program risk and to provide a basis for maturing CT7-6/-6A components before the engine is exposed to service on the EH101. (See Figure 4).

CT7-6 / -6A Commonality Summary

CT7-6/-6A Feature	T700-401C/ -701C	CT7-9	Base Models
• Systems / Controls / Accessories	X	X	X
• Combustor	X	X	X
• Axial Compressor	-	X	-
• Centrifugal Compressor	X	X	-
• Gas Generator Turbine	X	X	-
• Power Turbine	-	X	-
• Structures	X	-	X

Broad Test Base Yields Early Components Maturity

Figure 1

CT7-6 / -6A Production 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)
• 2.5 Minute	2,000 (1,491)	0.450 (0.274)	1,800 (1,342)	0.466 (0.283)
• Takeoff (5 Minute)	2,000 (1,491)	0.450 (0.274)	1,740 (1,298)	0.466 (0.283)
• 30 Minute	2,000 (1,491)	0.450 (0.274)	1,740 (1,298)	0.466 (0.283)
• Maximum Continuous	1,718 (1,281)	0.458 (0.279)	1,380 (1,029)	0.490 (0.298)
• 75% Maximum Continuous	1,288 (960)	0.489 (0.297)	1,035 (772)	0.537 (0.327)

Figure 2

T700-401A/CT7-6/-6A Performance Comparison

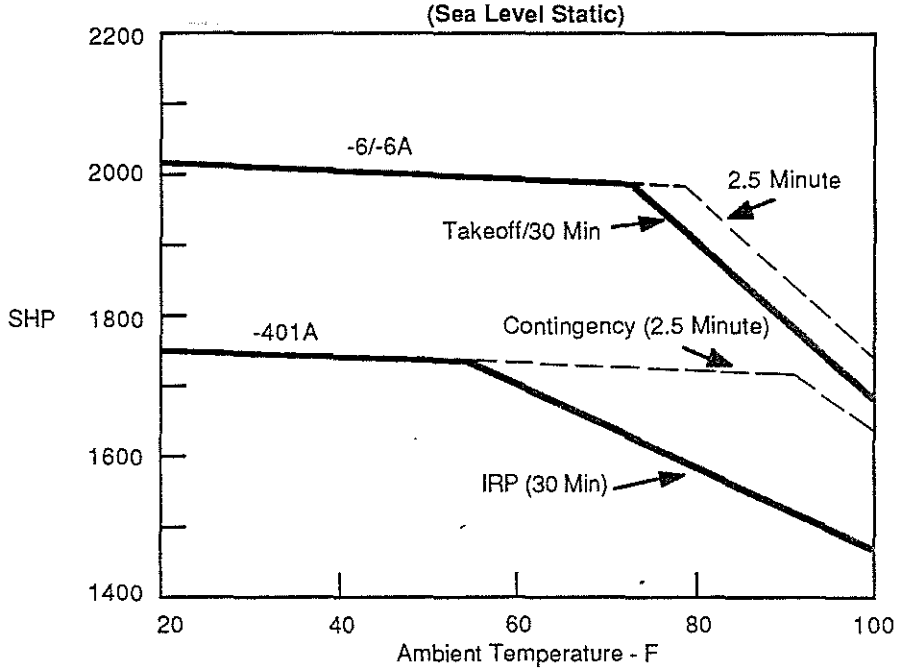
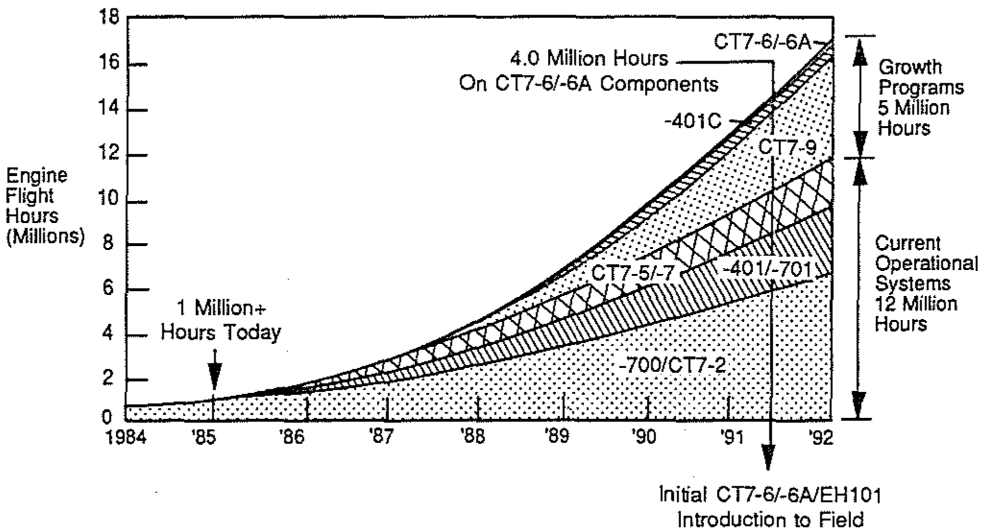


Figure 3

These engines incorporate proven technology improvements in aerodynamics, materials, and cooling methodology derived from other GE Aircraft Engines programs (GE23, GE27, F110, CF6, F404, E^3) (See Figures 5 & 6).

T700/CT7 Engine Family Maturity



At Production Introduction, CT7-6/-6A Components Will Be More Mature Than Current Engine Is Today

Figure 4

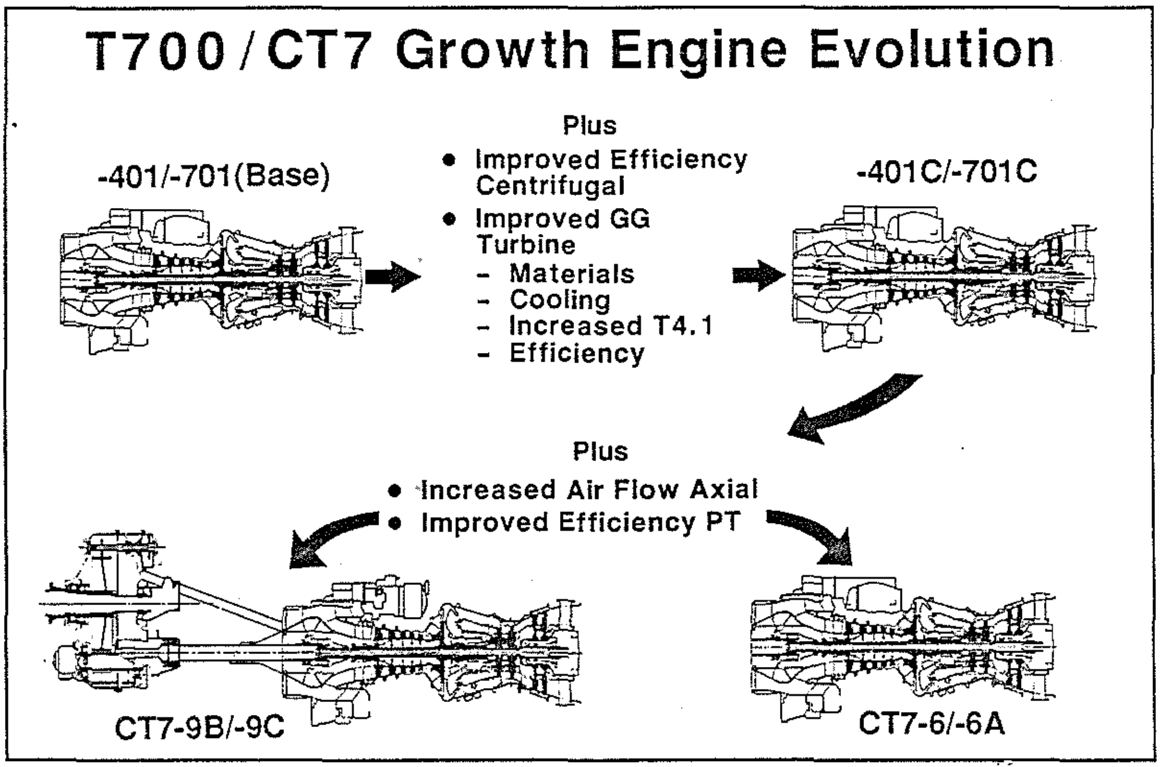


Figure 5

T700 / CT7 Growth Engine Technology Heritage

	Source
• Aerodynamic Design	
- 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*

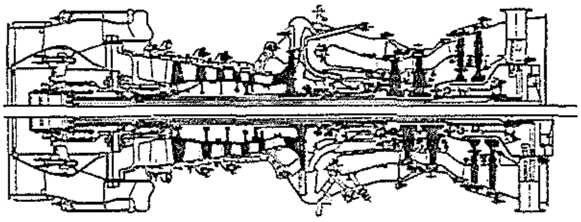
*U.S. Army Manufacturing Methods And Technology Program

Figure 6

Notwithstanding these technology improvements, the -6/-6A retain a significant degree of commonality with prior family members which both reduces program risk and enhances early maturity. The CT7-6/-6A engines (Figure 7) retain the CT7/T700 turboshaft mechanical arrangement of a multi-purpose inlet structure, an axial centrifugal compressor, a through flow annular combustor, an air cooled two stage gas generator turbine and an uncooled two stage power turbine. The CT7/T700 closed sump modularity concept and co-axial shafting arrangement are also retained. Closed sump modules are important because they drastically simplify ground support equipment needs and eliminate the potential for contaminating the sumps and oil wetted surfaces during field maintenance operations. In addition, the CT7-6/-6A use the same accessories arrangement and, more important, they retain the same reliability and maintainability features of the current CT7/T700 family. Specific aspects of commonality between the baseline family members and the CT7-6/-6A engines follow (see Figure 8):

CT7-6/-6A Configuration Similarity

T700/CT7



CT7-6/-6A

- Shaft Horsepower 2,000 (1,491 kW)
- Growth 27%
- Weight 485 Lb (220 kg)

Figure 7

CT7-6/-6A Commonality With Other CT7/T700 Engines

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

High Commonality Preserves Operational Benefits

Figure 8

Structural Frames

The current T700/CT7 turboshaft swirl frame is used on CT7-6/-6A engines. This ensures that engine/aircraft inlet interchangeability is retained and provides the proven level of protection for foreign object ingestion. Other frames are basically the same as current T700/CT7 turboshaft production configuration retaining their structural features and load paths. Required modifications for CT7-6/-6A are summarized below:

- Front and Main Frames - The front and main frames are modified at their aft ends to mate with the larger (.4 inches) inlet diameter of the increased flow axial compressor. Otherwise, they are physically and functionally identical.

- Inlet Particle Separator (IPS) - The CT7-6/-6A utilize the current T700/CT7 turboshaft swirl type IPS except for minor flowpath tuning for front frame and main frame as described above. This has negligible impact on IPS operational efficiency. The CT7-6/-6A IPS system uses the identical CT7-2A mechanically driven blower to draw the bypass air containing the separated material out of the separator.

- Diffuser Casing - The increased flow turboshaft axial compressor utilized in the CT7-6/-6A engines is one (1) inch longer than the current turboshaft axial compressor. This forced the diffuser casing, including the rear engine mount lugs, one inch aft relative to the engine front mounting points. In order to maintain installation interchangeability with the T700/CT7 turboshaft engine family, the CT7-6/-6A diffuser casing has the mount lugs moved one (1) inch forward to compensate for the longer compressor.

- Exhaust Frame - The CT7-6/-6A exhaust frame shell is truncated, moving the aft flange forward one (1) inch to compensate for the compressor length increase and maintain overall engine length for installation interchangeability. Shortening the exhaust frame presents no functional operational problems to the engine. Cast Inco 718 configuration is incorporated for reduced cost.

- Midframe/Diffuser Assembly - Modified for compatibility with the improved centrifugal compressor and to provide improved B-sump pressurization; otherwise, same as basic T700/CT7 engine family configuration.

Axial Compressor

The CT7-6/-6A engines utilize a CT7-5 turboprop axial compressor with fine tuning in the front end (IGV, and stages 1 and 2) to achieve improved efficiency. Modifications are also incorporated for improved producibility. The stages 3, 4, and 5 are the same as the current CT7-5 turboprop compressor.

Centrifugal Compressor

All production models of the CT7/T700 turboshaft and turboprop engines currently utilize the same centrifugal compressor. The CT7-6/-6A centrifugal compressor builds upon this proven configuration and uses an improved diffuser to increase centrifugal stage efficiency.

Combustor

The same durable proven machined ring, through-flow configuration as used in the CT7/T700 engine family with minor tuning modifications.

Gas Generator Turbine

The CT7-6/-6A engines maintain the same gas generator turbine rotor structure as the T700/CT7 engine family. The two disks and three of the four cooling plates are identical in configuration and material to current production. An improvement in R95 processing from as-hipped to extruded and ISO-thermally forged is incorporated for additional LCF life margin. This material processing improvement is currently used in production of the CT7-2A and CT7-5 engines. The stage 2 aft cooling plate is similar to the basic engine family but has the aft labyrinth seal arm deleted since its function in the CT7-6/-6A is accomplished by a seal on the forward side of the stage 3 power turbine disk and increased B-sump pressure levels. The CT7-6/-6A gas generator turbine maintains the same flowpath and stage 1 and 2 nozzle aerodynamics as basic T700/CT7 engines. The stage 1 and 2 blades have similar aerodynamics to the basic T700/CT7 engines with slightly increased airfoil thicknesses to accommodate improved serpentine cooling passages. Both blade rows use DSR108 material to accommodate the higher turbine temperature. The gas generator turbine stator incorporates solid shrouds similar to those qualified for the T700-401.

Power Turbine

The CT7-6/-6A engines maintain the same basic two stage power turbine design as the basic T700/CT7 engines. The power turbine shaft is the CT7-5 production configuration. The blade and vane rows are redesigned aerodynamically for improved efficiency, but maintain the same mechanical design as the basic T700/CT7 engines. The power turbine disks are increased in thickness relative to the basic T700/CT7 engine for increased LCF life margin and are similar in configuration to those in production on the CT7-5 turboprop. An improved material has been introduced on stage 3 blades for additional durability. Stage 4 blades and all vane and disk materials are the same as in the baseline T700/CT7 turboshaft engines.

The power turbine casing, is similar to the cast inconel design qualified as a cost reduction for the T700-401/-701. It incorporates an impingement cooling shroud over the power turbine rotor to cool the casing and maintain blade tip clearance control.

Engine Mainshaft Bearings, Sumps and Seals

The bearing positioning, environment, loads and engine speeds are basically unchanged from those in the parent family. The CT7-6/-6A bearings are identical to those of the earlier engines. The nozzles, oil supply system, sumps configuration, seals and air cooling methodology also share this commonality. Additional cooling air is admitted to both the B and C sumps to lower the thermal environment. This important element of engine commonality ensures acceptable bearing life.

Controls and Accessories

The CT7-6/-6A accessories are either the same as or similar to the current T700/CT7 family members configuration. The changes made are all minor and are made to accommodate the higher fuel flow (e.g. HMU schedule), higher air flow (e.g. anti-icing valve schedule), higher turbine temperature (e.g. ECU Limiter Setting) and longer compressor (e.g. longer harness). A digital electronic control (DEC) system is under consideration for introduction on production engines.

Mount System

The CT7-6/-6A mount system (see Figure 9) is the same as the T700/CT7 engine family. This commonality allows complete installation interchangeability between the CT7-6/-6A and T700 engines already installed in the EH101.

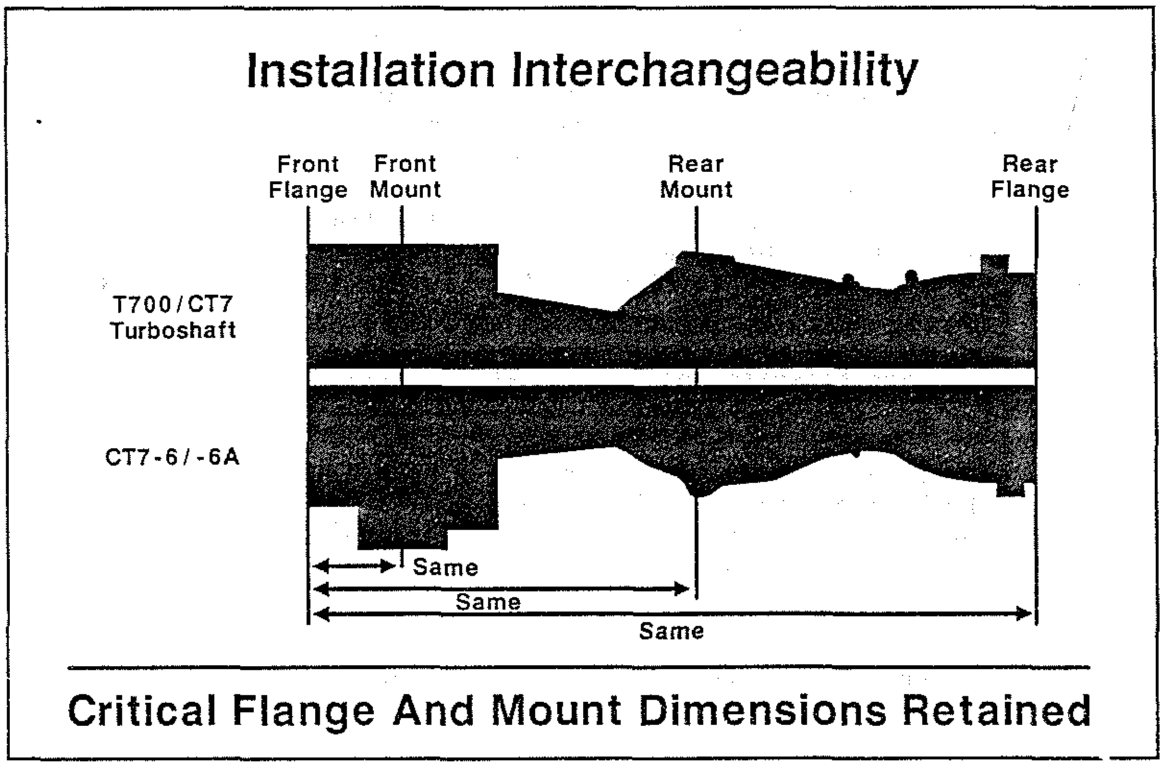


Figure 9

Corrosion Resistance Features

The CT7-6/-6A engines have the same excellent corrosion resistance capability as the current T700/CT7 engine family. The materials used in the CT7-6A (marinized version of the CT7-6) are the same or of equal corrosion capability as the T700-401C engine which completed a corrosion resistance test at the Naval Air Propulsion Center salt corrosion facility at Trenton, New Jersey. The test was run per US Navy requirements. The T700-401C corrosion test engine passed the performance deterioration requirements and the hardware was found to be in excellent condition. The US Navy approved this test as part of the T700-401C qualification program.

The CT7-6/-6A engines like all other T700/CT7 turboshaft engines, do not require compressor wash as an anti-corrosion measure, even when operating in coastal regions. Periodic cleaning is recommended to prevent performance deterioration when it is operated in salt water mist or when inspection of the compressor and engine inlet reveals that salt or dirt is accumulating.

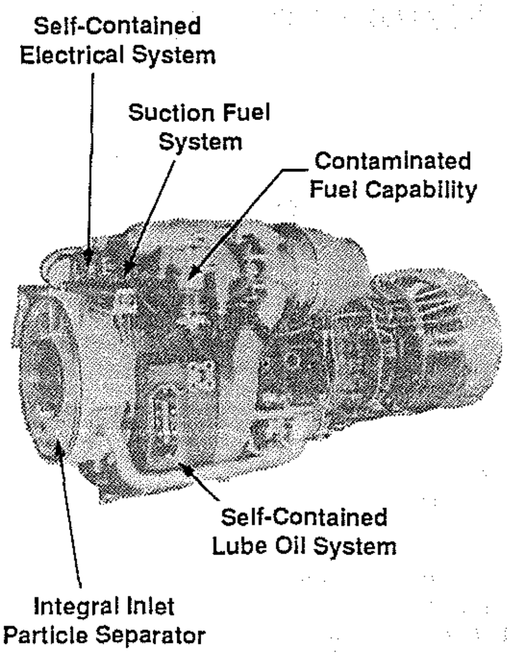
Summary

The CT7-6/-6A engines share maximum commonality with the baseline T700/CT7 engine family. In the cases where improvements have been introduced, the required technology has been proven or demonstrated elsewhere. The statement that the CT7-6/-6A engines are T700/CT7 family growth derivatives is clearly substantiated.

3. RELIABILITY AND MAINTAINABILITY

As previously stated, the CT7-6/-6A engines are derivative models of the T700/CT7 engine family developed to satisfy requirements for increased power. Their design is based on an established engine family with proven operating experience and they retain the reliability and maintainability characteristics of the baseline family (see Figures 10, 11, 12, 13). To date, GE Aircraft Engines has shipped over 5,000 T700/CT7 family engines for 13 different applications. This engine

T700/CT7 Proven-In-Service Design Features

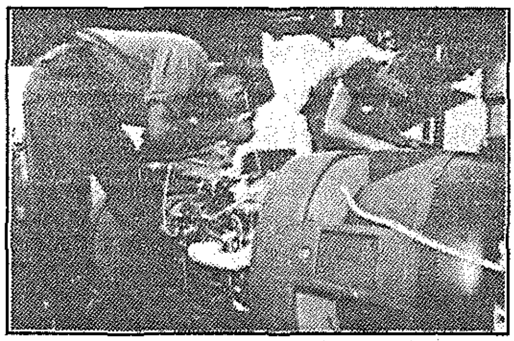


- Rugged All Steel Compressor with Wide Chord Blades
- Casing Construction Provides Blade Containment
- Engine Operates With Failed Turbine Blade
- Rugged Stator Actuation System - Common Parts, No Adjustments
- Rotors Individually Balanced - No Vibration Problems in Ten Years of Service
- Rugged Machined Ring Combustor - No Failures in Ten Years of Service
- Dual Oil Jets Feed Mainshaft Bearings
- Overspeed and Overtemperature Capability Demonstrated
- Redundant Overspeed Protection
- Closed Loop Temperature Limiting
- Complete HMU Backup
- Oil and Fuel Filters on Engine
- Impending By-Pass Warning on Filters
- Engine Provides Own Electrical Power
- Foolproof Electrical Connections
- Engine Is Completely Anti-Iced
- Anti-Icing Valve Fails Safe
- Oil Level Sight Gage on Both Sides of Engine
- Complete Mixing of Oils Permitted
- Rugged HMU - No Adjustments and No Rigging - Simple/Foolproof Installation

Figure 10

T700/CT7 Engine Health Monitoring Provisions

- **Cockpit**
  - Filter Condition 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

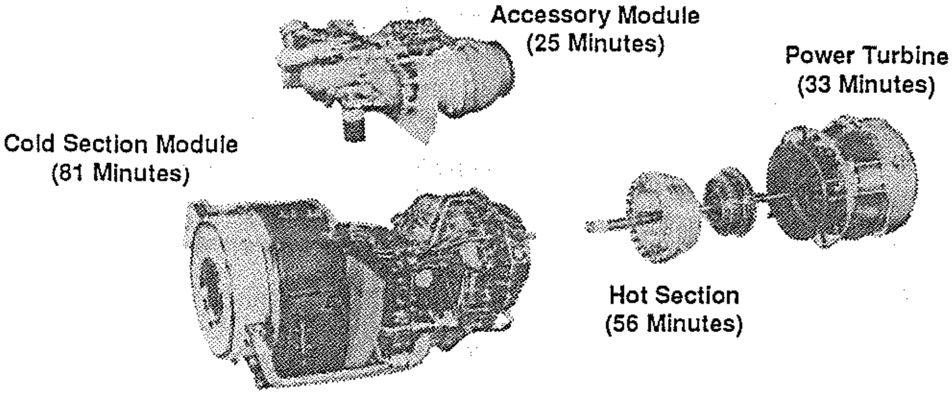


Borescope Inspection

Allow On-Condition Operation

Figure 11

T700/CT7 Modular Maintainability



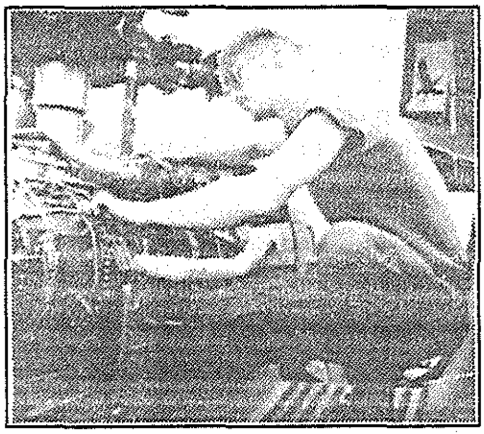
- Remove - Replace - Ready To Run
- Two Men -- Ten Tools
- Hard Lines Open At Flange Lines
- Snap-In Cable Clips
- Wrench-Arc Torque
- No Special Tools

- Closed Modules
  - No Open Sumps
- Modules Built As Separate Entities
  - Repeatable Interchangeability
  - Store Modules, Not Engines
  - Pack-up Kits As Spares
- Advantage For War-Time Scenario
  - Initial Repairs From Pack-up Kits
  - Direct Cannibalization From Battle Damaged Units

Figure 12

T700/CT7 Engine Maintenance Features

- 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
- Standardized Flange Bolts



Line Maintenance Activity

Figure 13

family has accumulated over 95,000 hours of development testing (see Figure 14) and over two million flight hours on approximately 1,500 aircraft. The high time engine has accumulated over 6,000 hours. These field engines continue to demonstrate satisfactory operation under various worldwide environments and mission requirements (see Figures 15 & 16).

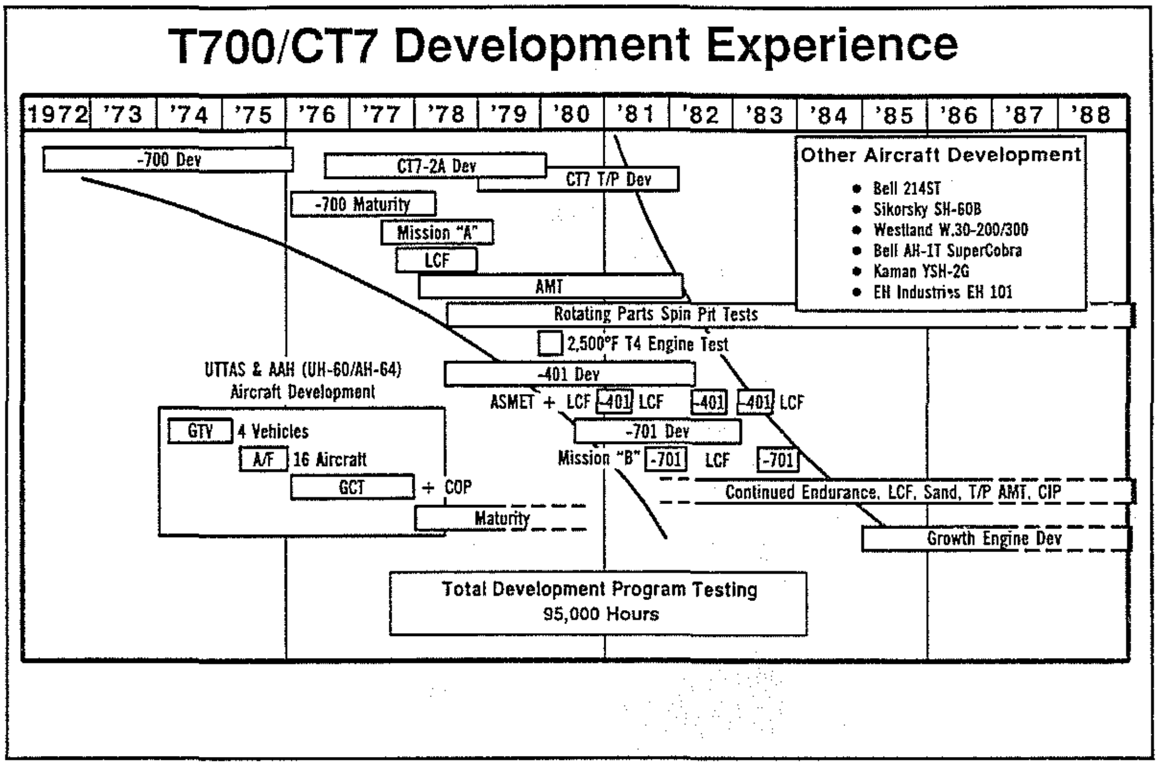


Figure 14

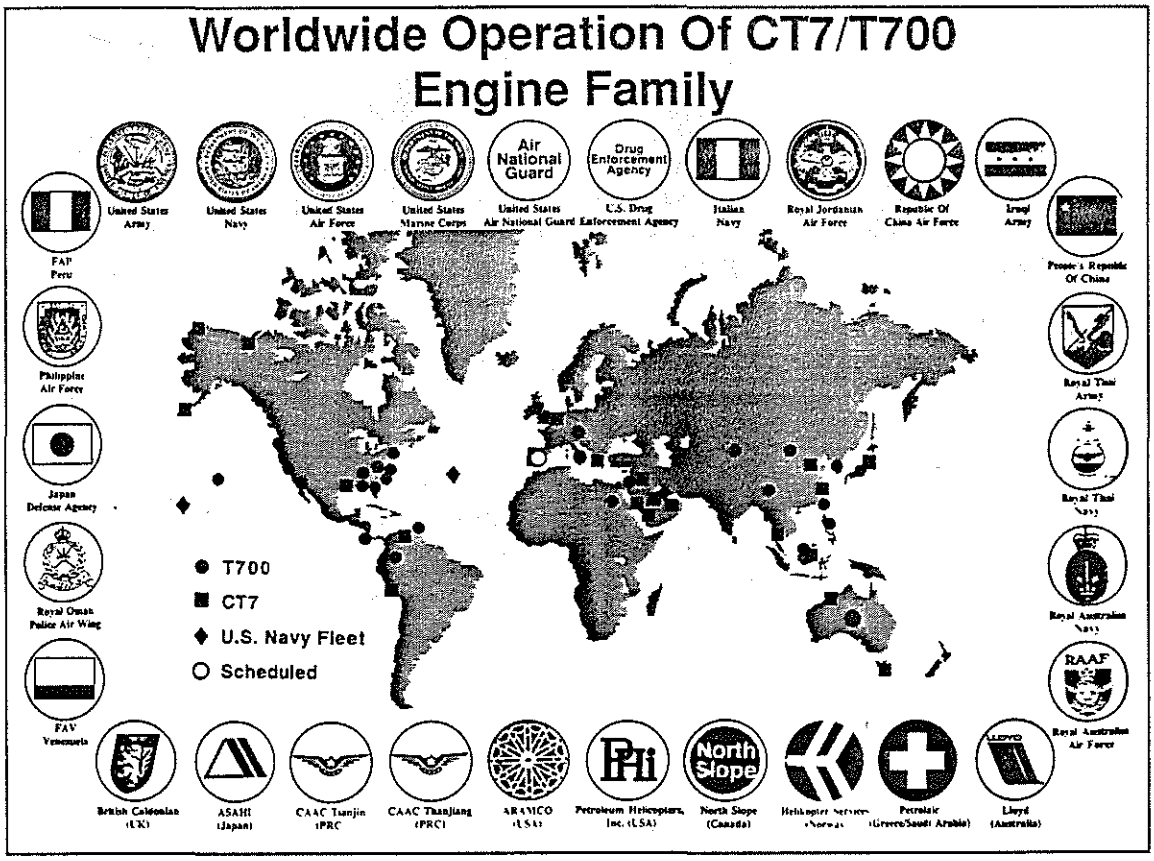


Figure 15

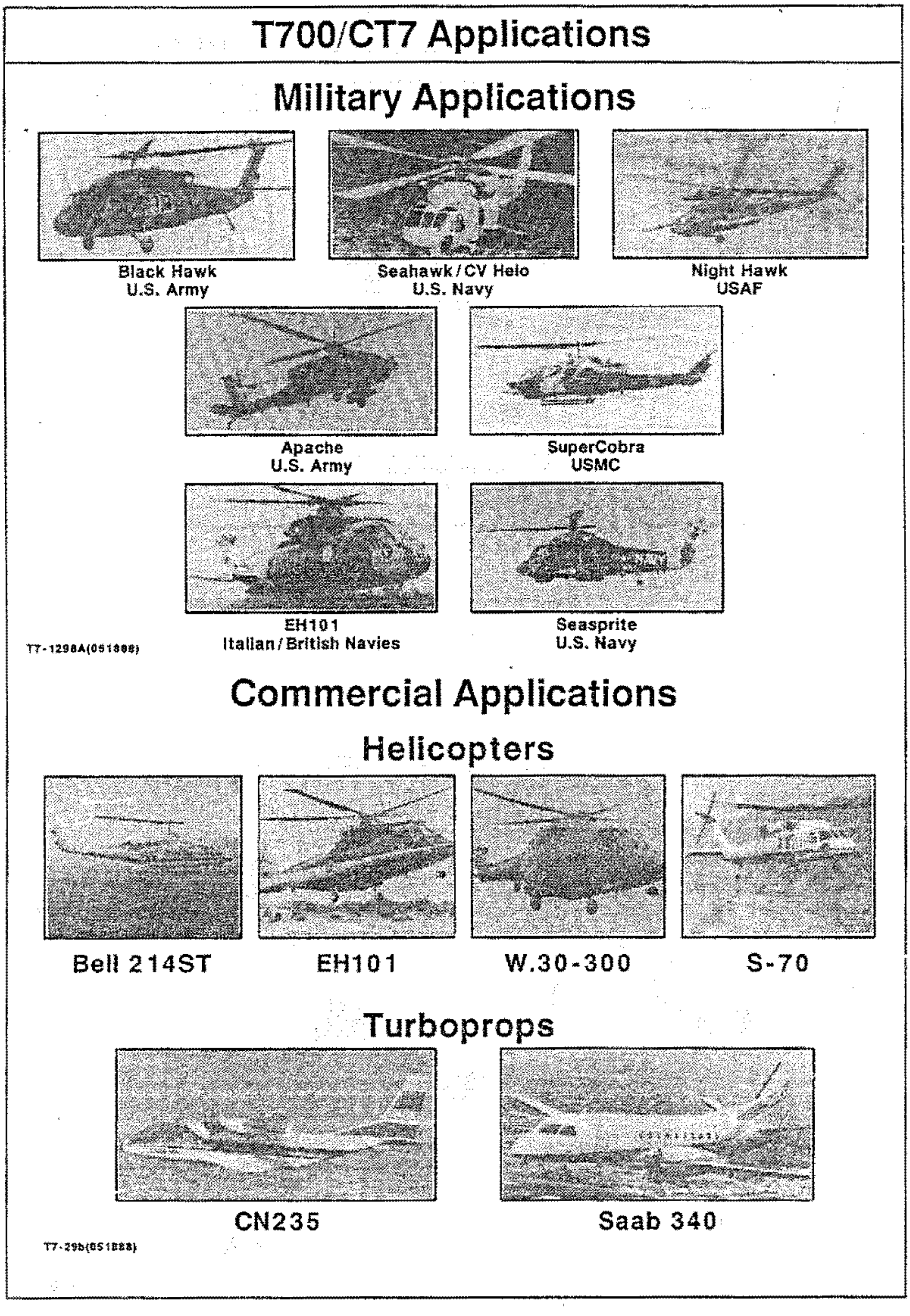


Figure 16

Referring to Figure 4, it is clear that by the time the EH101 goes into service, the T700/CT7 engine family will have accumulated approximately 16 million flight hours. The CT7-6/-6A engines obviously will benefit from this vast/proven T700/CT7 family record.

The high commonality of the CT7-6/-6A to its successful predecessor models, coupled with the incorporation of the proven component improvements here described, preserves all of the reliability and maintainability benefits of the T700 family of engines and continues the reliability growth characteristic of derivative engines. Figure 17 is a plot of Unscheduled Engine Removal Rate for the T700-GE-700 in the Black Hawk and the -401 and -701 in the LAMPS and Apache showing this reliability growth. Based on projections, the CT7-6/-6A engines are predicted to continue on the characteristic growth curve as shown in Figure 17 and achieve a Mean Time Between Unscheduled Removal rate for engine caused problems of less then 0.2/1000 EFH.

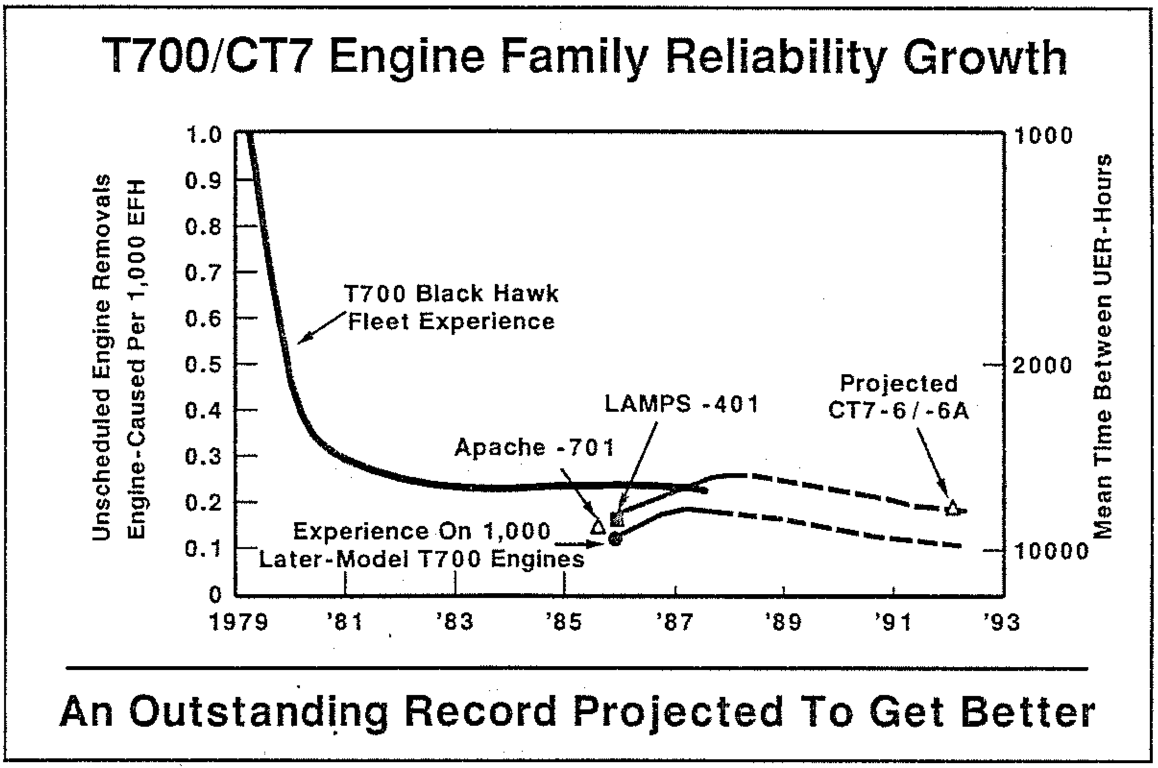


Figure 17

4. FACTORY TEST PROGRAM

The overall T700/CT7 integrated growth test program is summarized in Figure 18. The development test program was structured to assure that the CT7-6/-6A engines would meet both European and U.S. civil authorities requirements for certification, as well as address specific requirements of European military users. It includes endurance tests, sea level and altitude performance demonstrations as well as tests to demonstrate stress, overspeed, overtemperature, low cycle fatigue, corrosion, etc.

Component testing of small turbine blades using modern materials and advanced cooling techniques was initiated in 1984 with margin testing of T700 engine blades at elevated temperatures in complete engines.

During 1985, development testing was conducted to evaluate centrifugal diffuser design alternatives, continue turbine blade testing and to assess compressor performance. Engine design was initiated early in 1985. Recall the partnership with Alfa Romeo Avio and Fiat Aviazione was formed at the same time. Approximately two years thereafter the first CT7-6/-9 engine went to test (May 1987).

The T700/CT7 integrated growth program represents over 4,900 hours of factory engine testing. Because of the previously explained commonality among the growth engines, especially in the turbomachinery area, numerous official tests were run once but applicable to more than one engine (see Figure 19). In these cases, the most severe requirements were demonstrated. Following the same commonality rationale, the 4,900

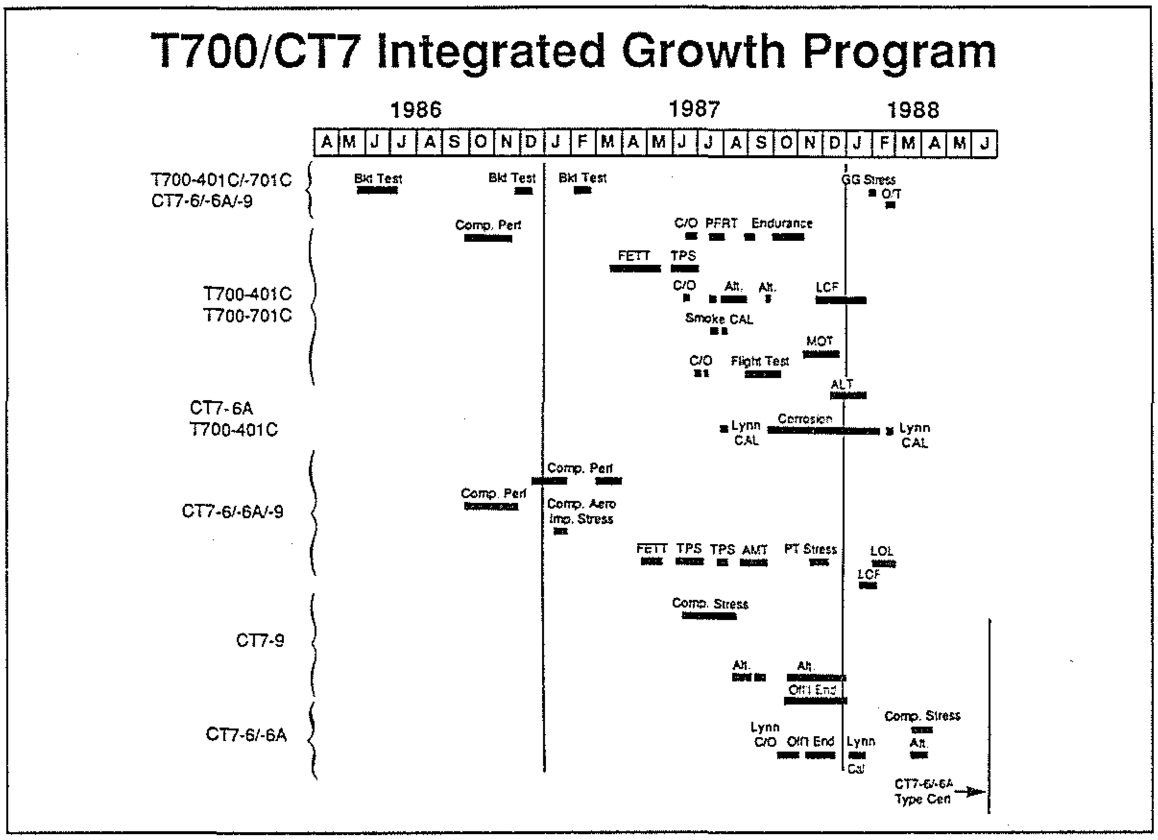


Figure 18

hours of factory testing is generally applicable to each of the growth derivatives to come out of this program.

The CT7-6/-6A certification endurance engine performed flawlessly. Alfa Romeo completed the endurance portion of the test in 19 days. It demonstrated excellent power margin and excellent performance deterioration characteristics (no loss in power and less then 1% loss in SFC). This same engine was rebuilt after the endurance test inspection and successfully ran the official altitude test.

T700/CT7 Integrated Growth Program Official Tests / Commonality

T700-401C/-701C	CT7-6/-6A	CT7-9
• Overtemperature*	• Overtemperature*	• Overtemperature*
• GG Stress*	• GG Stress*	• GG Stress*
	• PT Stress**	• PT Stress**
• PFRT	• Cert	• Cert
• LCF		• Compressor Stress
• Smoke		• PGB Endurance
• Corrosion***	• Corrosion***	• Control System (ECU)
• Altitude		• Altitude
• MQT		• Control System (DEC)
	• LCF**	• LCF**
	• PT Staircase**	• PT Staircase**
	• Loss Of Load**	• Loss Of Load**
	• Compressor Stress	
	• Altitude	

*Common -401C/-701C/-6/-6A/-9
**Common -6/-6A/-9
***Common -401C/-6A

Figure 19

Overall, the entire CT7-6/-6A development test program demonstrated excellent results. Reviews with the Civil Authority went extremely well and they were impressed with the excellent condition of the test hardware.

The following component tests were also completed as part of the CT7-6/-6A development program:

- Diffuser case static mount load.
- Compressor impeller overspeed.
- Power turbine rotor burst.

It is noted that the diffuser case static mount load test was completed by Fiat Aviazione at their facility in Turin, Italy. All testing in Italy was surveilled by Registro Aeronautico Italiano (RAI) as directed by FAA.

5. FLIGHT TEST PROGRAM

The CT7-6/-6A engines enter service with the EH101 flight test program. A total of 18 CT7-6/-6A engines are involved. Figure 20 summarizes the EH101/CT7-6/-6A flight test program. As can be seen, the initial flight of an EH101 aircraft with a CT7-6 engine is scheduled for 3rd quarter 1988. Recall that the EH101 helicopter is already flying with T700-401A engines.

EH 101/CT7-6/-6A Flight Test Program

Aircraft	Engine Config	Aircraft Config	Test Location	First Flight	Mission
• PP3	CT7-6	Civil/Pax	Westland	3rd Qtr '88	Devel/Cert Flight Tests
• PP6	CT7-6A	Italian Navy	Agusta	1st Qtr '89	Mission Flight Tests
• PP7	CT7-6	Civil/Utility	Agusta	2nd Qtr '89	Devel/Cert Flight Tests
• PP8	CT7-6	Civil/Pax	Westland	2nd Qtr '89	Cert/Maturity Flight Tests
• PP9	CT7-6	Civil/Utility	Agusta	4th Qtr '89	Cert/Maturity Flight Tests

Figure 20

The first six CT7-6 flight test engines for aircraft PP3 and aircraft PP7 have been delivered on schedule to Westland and Agusta respectively. Eight more CT7-6 flight test engines will be delivered late this year/early next year to support the remaining civil EH101 helicopters. In addition, four CT7-6A engines will be delivered to the Italian Navy to support their Naval EH101 prototype aircraft. Three of these engines are ready for shipment and the fourth engine will be shipped later this year. All flight test engines tested to date have demonstrated excellent performance levels (see Figure 21). The engines have excellent power margin and basically meet SFC objectives.

CT7-6/-6A Demonstrated Performance

Rating Condition	Program Objective		Flight Test Engines April-July Average	
	Power	SFC	T4.5H*	SFC
	SHP (kW)	Lb / SHP-Hr (kg / kW-Hr)	°F (°C)	Lb / SHP-Hr (kg / kW-Hr)
• SLS, 59°F				
– 2.5 Minute	2,000 (1,491)	—	176 (98)	–
– Takeoff	2,000 (1,491)	0.450 (0.274)	147 (82)	0.441 (0.268)
– 30 Minute	2,000 (1,491)	0.450 (0.274)	147 (82)	0.441 (0.268)
– Maximum Continuous	1,718 (1,281)	0.458 (0.279)	138 (77)	0.455 (0.277)
– 75% Max Continuous	1,288 (960)	0.489 (0.297)	–	0.490 (0.298)
• SLS, 95°F				
– 2.5 Minute	1,800 (1,342)	—	117 (65)	—
– Takeoff	1,740 (1,298)	0.466 (0.283)	106 (59)	0.464 (0.282)
– 30 Minute	1,740 (1,298)	0.466 (0.283)	106 (59)	0.464 (0.282)
– Maximum Continuous	1,380 (1,029)	0.490 (0.298)	123 (68)	0.491 (0.299)
– 75% Max Continuous	1,035 (772)	0.537 (0.327)	–	0.538 (0.328)

*Represents Available Temperature For Maintaining Guaranteed Horsepower In The Field

Figure 21

SUMMARY

The CT7-6/-6A engines were certified by the FAA on June 30, 1988. Validation by the CAA and RAI is in process. The engines have been primarily developed to meet the needs of the civil and utility versions of the EH101 helicopter and other European helicopters. But they are also being considered for growth versions of current T700/CT7 applications. They have been developed in partnership with Alfa Romeo Avio and Fiat Aviazione as part of the T700/CT7 integrated growth program (T700-401C/-701C, CT7-6/-6A, CT7-9B/-9C). The fact that these growth engines share maximum commonality among themselves broadens the test base to the benefit of the CT7-6/-6A engines. CT7-6/-6A engines represent approximately a 27% growth over the base T700-700 engine. This growth is accomplished through increased air flow by utilizing an improved CT7 turboprop compressor and through improved turbomachinery efficiency/ temperature capability by introducing technology improvements proven elsewhere within the GE technology base. The technology improvements are common throughout the integrated growth engines.

The CT7-6/-6A engines also retain many features from the proven T700/CT7 engine family including its outstanding reliability and maintainability characteristics, assuring the CT7-6/-6A continued success in these areas.

A comprehensive development/certification program has accumulated a total of 4,900 hours of factory engine testing to confirm attainment of program objectives. Investigatory, environment, abusive and endurance type testing has been successfully completed meeting all requirements of civil approval authority. Post certification assurance testing continues.

A post certification program is already in place to introduce further improvements leading to CT7-6/-6A derivatives with additional power (see Figure 22).

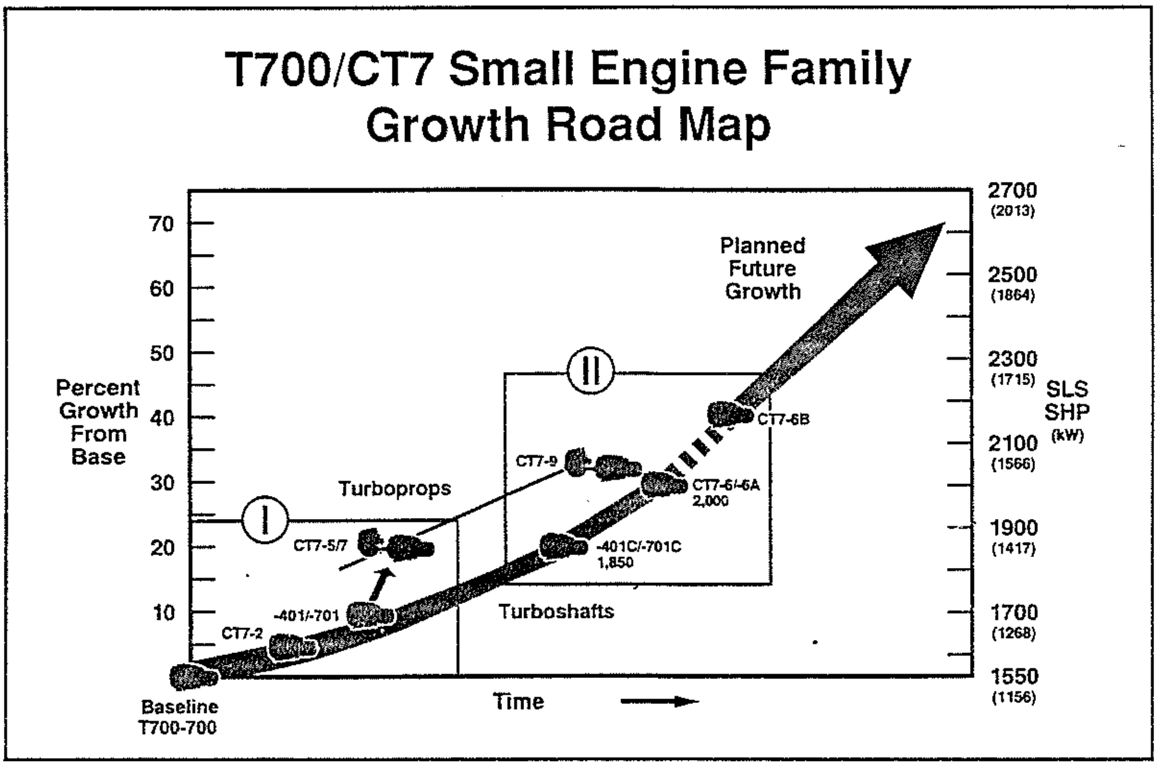


Figure 22

In parallel with this effort, the CT7-6/-6A team will be qualifying a military equivalent for the Italian Ministry of Defense (Costarmaereo). This engine designated the T700/T6A, is the same as its civil counterpart the CT7-6A, and is expected to power the Italian Navy EH101 production aircraft. An engine model change is required because control is transferred from civil to military authority. The engine will be qualified per military engine model specification as approved by Costarmaereo. The qualification verification plan is in place. The goal is to complete the qualification process by the end of this year.

An exciting and bright future is awaiting the CT7-6/-6A engine family.

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