

THIRD EUROPEAN ROTORCRAFT AND POWERED LIFT AIRCRAFT FORUM

Paper No. 30

AN UPDATE ON THE  
LTS101 ENGINE FAMILY

HAROLD F. GRADY

AVCO LYCOMING DIVISION, STRATFORD, CONN.

September 7-9, 1977

AIX-EN-PROVENCE, FRANCE

ASSOCIATION AERONAUTIQUE ET ASTRONAUTIQUE DE FRANCE

## 1.0 ABSTRACT

A summary of the engine design is given for the baseline configuration, including overall engine characteristics. The development history, through original design and configuration studies, is traced. Development status for various helicopter and other applications is presented. The versatility of the design concept is illustrated via the derivative versions of the basic engine.

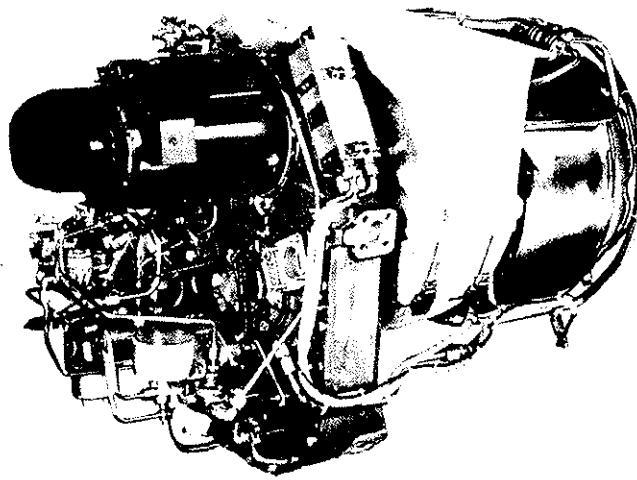


Figure 1 LTS101 Engine

## 2.0 INTRODUCTION

The LTS101 engine was designed for helicopter applications in the 600 HP class. The initial development and certification efforts were specifically focused on that objective. The program was initiated in the early 1970's; and since that time, a diverse number of applications for the basic engine model have evolved, leading to a "101 engine family".

The thrust of this paper is to provide an update of the overall 101 status, together with a brief description of the various applications. To provide continuity in the overall exposition, some background on the engine is considered necessary. Toward that end, the paper is structured to provide an overall engine description, followed by a brief discussion of the decisive factors considered in formulating the original design. With that background, a program update is provided, detailing the status of the various engine models and their applications.

### 3.0 ENGINE DESCRIPTION

The basic 101 engine configuration is shown in Figure 1. A schematic representation of the flow path is presented in Figure 2. The air enters the inlet scroll, is turned 90 degrees and distributed to the compressor inlet housing before entering the axial/centrifugal compressor. Compressor discharge air is diffused radially and turned 90 degrees to enter the reverse-flow annular combustor. Primary air and fuel are introduced at the aft end of the combustor. The gas flow leaving the combustor then turns 180 degrees to resume downstream flow through the gas producer and free power turbine stages to exhaust.

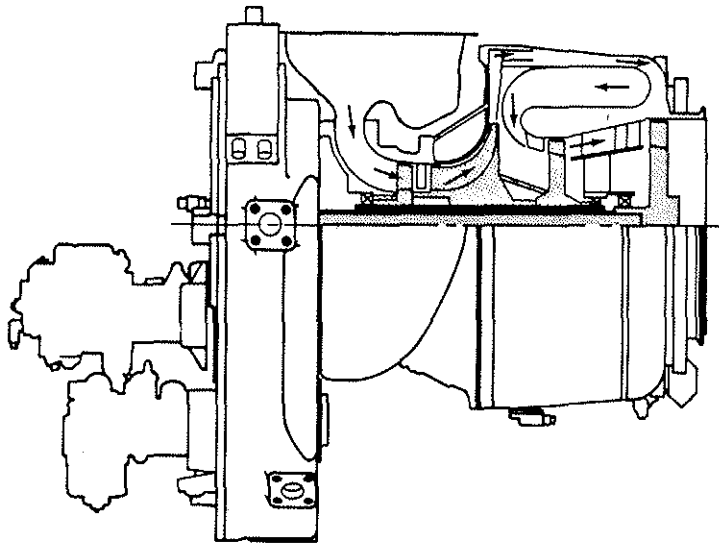


Figure 2 LTS101 Schematic Cross Section

The engine is constructed of four basic modules identified in Figure 3; the inlet scroll, the gas generator, the combustor/power turbine, and the reduction/accessory gearbox.

#### Inlet Scroll

The inlet scroll is a two-piece assembly clamped together around the circumferential flange of the compressor inlet housing by two snap locks on either side. Circumferential positioning is accomplished by a pin in the inlet housing flange. The scroll is designed with a controlled area distribution and wall and vane curvatures to provide the desired air-flow distribution into the compressor inlet housing with low pressure losses. The scroll serves as a fire wall in the airframe installation and incorporates a fitting and a spray nozzle for introducing water into the airstream for engine washing.

### Gas Generator Module

The gas generator module consists of the inlet housing, compressor, and the compressor drive turbine assemblies. The inlet housing and diffuser housing form an integral part of the engine structure, connecting the gearbox module at the front end, and the combustor/power turbine module at the rear. The inlet housing also supports the forward gas generator shaft bearing and seal package. The compressor rotor was designed so that the compressor elements do not have to be disassembled after balancing for final engine assembly. This is achieved by virtue of the split centrifugal impeller shroud and stator vane assemblies.

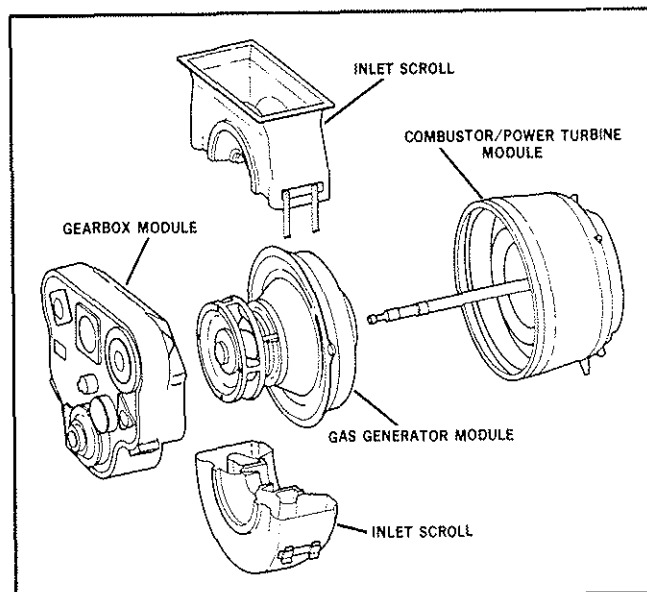


Figure 3 Modular Construction

### Combustor/Power Turbine Module

The combustor/power turbine module includes a one-piece combustor and rear bearing support housing, the combustor liner, and power turbine rotor assembly. The support housing is an integral part of the engine structure, connected to the diffuser flange of the gas generator module. It provides the support for the power turbine and gas generator rotor rear bearings. The aft flange is designed to carry the exhaust tailpipe with a "quick disconnect" coupling. The reverse-flow annular combustor is wrapped around the turbine section, resulting in a short, light engine which avoids shaft critical speed problems. Eight dual orifice pressure atomizing fuel nozzles are used for fuel injection. Liner wall cooling is accomplished by external convection and internal film cooling.

The modular concept is enhanced by having a system that permits removal of the power turbine section without front end disassembly.

### Reduction and Accessory Gearbox Module

The power turbine speed reduction gear and accessory drives are contained within the same cast housing and cover assembly. The free power turbine speed is reduced through a gear train, providing a

nominal output speed of 6,000 rpm. The gear train comprises a helical pinion, an idler with two helical gears of different diameter and opposed thrust sense, and an output gear. The power output gear surrounds the output shaft and is connected to it by a sprag-type over-running clutch. Providing this clutch in the engine gearbox simplifies the helicopter transmission, saving airframe cost and weight. A 9.50-inch downward displacement from engine centerline to the output gear axis allows sufficient engine/shaft clearance for power extraction from either the front or rear end of the output spline. The twin gear idler serves as a sensor of the output torque. The net end thrust of the two helical gears is balanced by a self-regulating servo operating with engine oil. The oil pressure balancing the servo piston against the end thrust of the idler is a direct indication of the torque delivered to the airframe transmission. All accessories are mounted on the forward face of the gearbox. The accessories driven by the gas generator shaft are mounted on the left side (looking aft), and all power turbine driven accessories are on the right. A list of accessory drives provided is given in Table I.

Table I  
LTS101 Accessory Drive Summary

Item	Speed (rpm)	Direction of Rotation Facing Pads
<u>From Gas Generator Rotor</u>		
Starter Generator	12,000	CW
Oil Pressure/Scavenge Pump	6,300	CCW
Fuel Pump and Control	6,300	CW
<u>From Power Turbine Rotor</u>		
Alternator Drive (15 HP)	12,000	CW
Separator Scavenge Fan	20,000	CCW
Power Turbine Governor	6,300	CW

## 4.0 CONFIGURATION SELECTION

The LTS101 turbine engine configuration evolved as a result of a number of design studies conducted in early 1970. At that time, a substantial technology base was available at Lycoming for engine components in the 51b/sec. airflow class. This technology base had been established through a broad range of component R&D programs conducted in the decade of the 1960's in response to our assessment that this airflow size represented a significant potential for advanced gas turbine powerplants in the 70's and beyond. Those component technology programs were specifically addressed to establishing an in-house base in manufacturing technology, aero/thermo performance, and materials advancement.

It was from this established base that the engine design studies were conducted. These studies were guided by two major criteria: the resultant engine design was to embody significant fuel consumption improvements over then-existing engines in the 400 to 800 horsepower class, coupled with a fully competitive production cost. (Low production cost represented a major factor in the original design guidelines. However, it was recognized that this cost aspect is not the only determinant in operator acceptance. Specifically, operating cost reduction, through maintenance simplicity, was established as a primary goal. While this aspect did not impact substantially on the overall configuration definition, it did inform and affect the design details of the engine. In particular, it was maintenance cost considerations that led to the modular design concept at some slight penalty in engine weight.)

The twin objectives of low cost and improved performance required careful balancing in the design studies. Engine designs favoring either objective to the extreme would seriously compromise the other. For example, an extremely low cost engine can be formulated which incorporates only two "as cast", rotating components in a single shaft configuration (i. e., without a free power turbine). However, structural integrity demands would limit component tip speeds (cycle pressure ratio) and operating temperatures (cycle turbine inlet temperature) such that the engine fuel consumption would be inferior to that of gas turbines available today. In a similar way, designs targeted for the very best in fuel consumption characteristics would result in a large number of sophisticated turbo machinery components to achieve the requisite cycle values of pressure ratio and temperature. This would lead, in turn, to escalation of engine cost. Between these extremes, a compromise was sought.

The design tradeoffs which led to the final engine configuration were, of course, iterative by nature and entailed the analyses of a number of discrete designs to provide cost and performance parameters. However, in the interest of clarity, the major design aspects are addressed separately in this discussion to highlight the fundamental issues as they were perceived.

### Turbine Configuration

Very early in the analysis, it was concluded that the design would be structured around two turbine stages, as opposed to three and four stage designs which had been assessed. In addition, the turbine design was to incorporate no blade cooling and this, of course, constrained the cycle selection. Both these ground rules were formulated in the interest of achieving the original cost targets - both initial acquisition cost and maintenance cost. It had been observed that turbine stages, including the requisite static cascades (nozzles), contribute a significant percent of overall engine cost. Cooled turbine blading escalates these costs even further. For these reasons, the two stage uncooled design was edicted as a fundamental constraint.

### Output Configuration

The tradeoff between a free turbine output shaft versus a coupled engine configuration was conducted in some detail. The coupled engine design embodies some cost advantages because of the simplicity of the main engine shafting and its bearing supports. Nonetheless, the free turbine was selected for the 101 engine because of its significant application flexibility, substantially lower starting power requirements, and its superior operational characteristics for helicopter installations. The subsequent design execution of the free turbine configuration negated some of the simplicity advantages of the coupled engine, since only two main bearing and seal packages are employed in the 101 (see Engine Description, Section 3.0). The soundness of the free turbine selection, in terms of application flexibility, is perhaps underscored by the fact that a high bypass turbofan version of the 101 is now under development. Further details of this program are given in Section 6. The point, here, is that a coupled engine would have been difficult to adapt to a high bypass turbofan propulsion system.

### Compressor Selection

The compressor design for the 101 incorporates a single stage axial/single centrifugal providing a nominal design pressure ratio of 8.5 to 1. This configuration was essentially derived from thermodynamic cycle considerations and that logic is developed below. Cost

considerations dictated that a centrifugal compressor would be used. It remained for cycle studies and performance/cost tradeoffs to determine whether axial precompressor stages would be incorporated.

## 5.0 CYCLE SELECTIONS

Cycle studies were conducted to optimize both cycle pressure ratio and the compressor configuration to meet the fundamental design objectives of low cost and superior performance. Performance targets were quantified; specific fuel consumption (SFC) at least 5 percent below 0.6 lbs/hp-hr at rated power. The cycle analysis was conducted at a turbine inlet temperature below 2000°F, consistent with the constraint of uncooled turbine blading to meet cost objectives. A summary of the cycle parameters examined is given in Figure 4. These show the variation in SFC and specific power as a function of pressure ratio. The increments of SFC and specific power at constant pressure ratio reflect the difference in compressor efficiency between a single centrifugal stage and axial/centrifugal combinations.

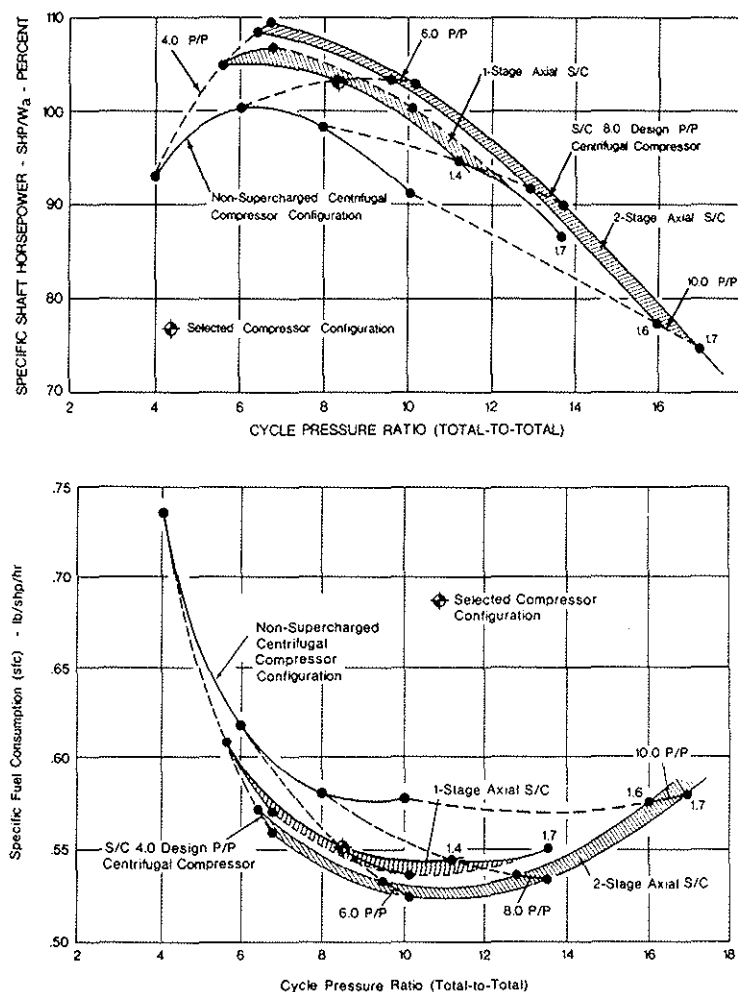


Figure 4 Cycle Study



Five basic configurations are presented: A single centrifugal, one centrifugal stage supercharged by either a 1.4 or 1.7 pressure ratio single stage axial design, and one centrifugal stage supercharged by either a 1.6 or 1.7 pressure ratio two-stage axial design. Supercharged configurations are based on centrifugal compressor design pressure ratios of 4, 6, 8, and 10, assuming that sufficient centrifugal stage overspeed capability exists to maintain pumping capacity when combined with axial stages.

Efficiency levels for each compressor element were assumed to vary with design pressure ratio as shown in Figures 5 and 6. These data are based on Lycoming's experience with 5 lbs/sec. components and conservative use of published applicable data.

Figure 4 shows that non-supercharged centrifugal configurations are generally low in specific power and high in SFC when compared to the more efficient axially supercharged designs at constant cycle pressure ratio. Highest specific power is obtained by supercharging a core centrifugal compressor having a design pressure ratio ( $P/P$ ) of 4; however, such a cycle would require a two-stage axial supercharger to approach the desired SFC objective. Supercharged configurations based on an 8  $P/P$  or greater core centrifugal are shown to be off optimum specific power and SFC for the selected cycle design temperature.

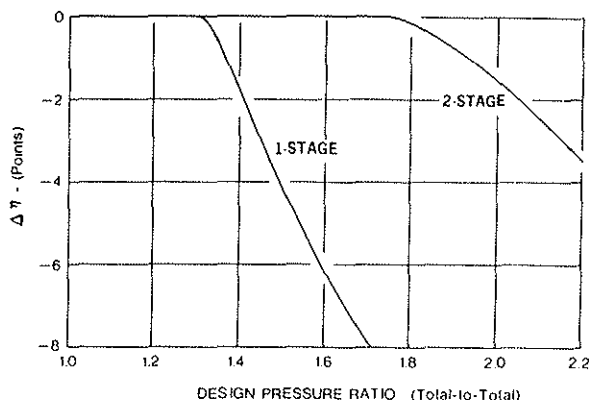


Figure 5 Axial Compressor

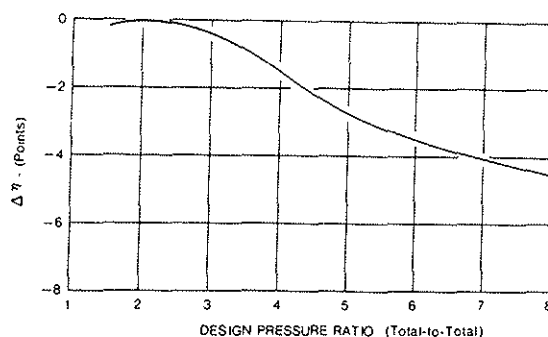


Figure 6 Centrifugal Compressor

For the selected nominal cycle pressure ratio of 8.5 produced by a centrifugal design  $P/P$  of 6, supercharged by a 1.4  $P/P$  single-stage axial, high specific power and low SFC are obtained. Note that no significant improvement in specific power is realized by either increasing the supercharger  $P/P$  to 1.7 or adding a second supercharging stage to

this configuration. Improvements in SFC are available, but at the added complexity of incorporating a two-stage supercharger.

The selected compressor configuration was considered to offer the best tradeoff between maximum specific power and low cost.

## 6.0 PROGRAM UPDATE

As noted in the introduction, the initial application vector for the 101 was helicopter propulsion. Since that original corporate commitment to full scale development and qualification, a number of engine models have received FAA Type Certification for commercial operations.

Over 8500 hours of in-house engine testing have been logged. Flight experience is approaching 4000 hours, accumulated in 7 different aircraft, including fixed wing. FAA Type Certificates have been received for 10 different engine models. The French Director General of Civil Aviation has validated the FAA Type Certificates for relevant models. British CAA validation has also been received for those engines appropriate to United Kingdom programs.



Figure 7 Aerospatiale AS350

In the helicopter domain, the 101 is certified for use in the Aerospatiale aircraft, Figure 7. This program and its long-term production potential represents a major ingredient in the financial and technical success of the 101 family.

The 101 has also been selected for the Bell 222 (Figure 8) and is being seriously considered for a number of other helicopters in the international markets. A substantial production base is thus assured.

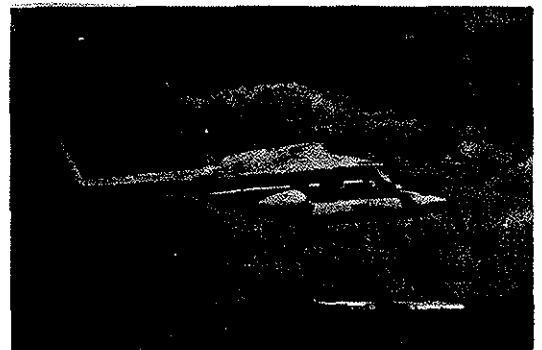


Figure 8 Bell 222

In addition to these turbo-shaft configurations, the turboprop version continues to receive enthusiastic response in the smaller fixed wing aircraft market. FAA certification of the basic turboprop engine model has been received. Two examples of current applications are shown in Figure 9 and Figure 10. In this configuration, the basic power producer remains unchanged from its helicopter counterpart. A different reduction gear, compatible with propeller rpm requirements, represents the major configuration change. Discrete engine control modifications are also incorporated as required for this application. A range of turboprop applications have been captured by the LTP101 and cover diverse missions from agricultural crop spraying to small feeder line passenger service.

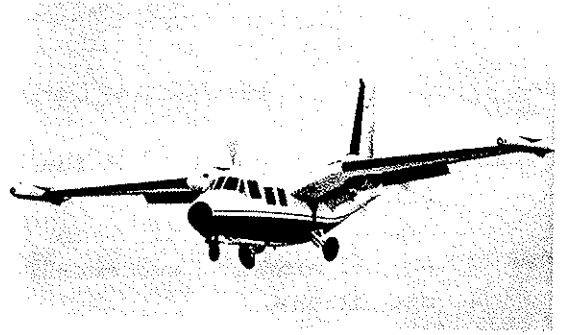


Figure 9 Piaggio P.166-DLE

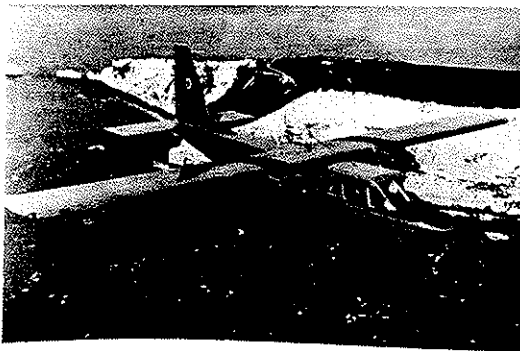


Figure 10 Britten-Norman  
Turbo-Islander

The versatility of the basic 101 power producer is further emphasized by two U.S. Government sponsored programs: a NASA sponsored high bypass turbofan for general aviation propulsion and a USAF program for conversion of the 101 power producer to an advanced aircraft APU.

In the turbofan configuration, a twin engine aircraft using advanced design techniques and materials could be formulated to give substantial productivity improvements for fixed wing aircraft in the 8000 lb. gross weight class.

The turbofan and APU programs are in the initial stages of the development cycle and, as such, represent "technology demonstrations" at this time.

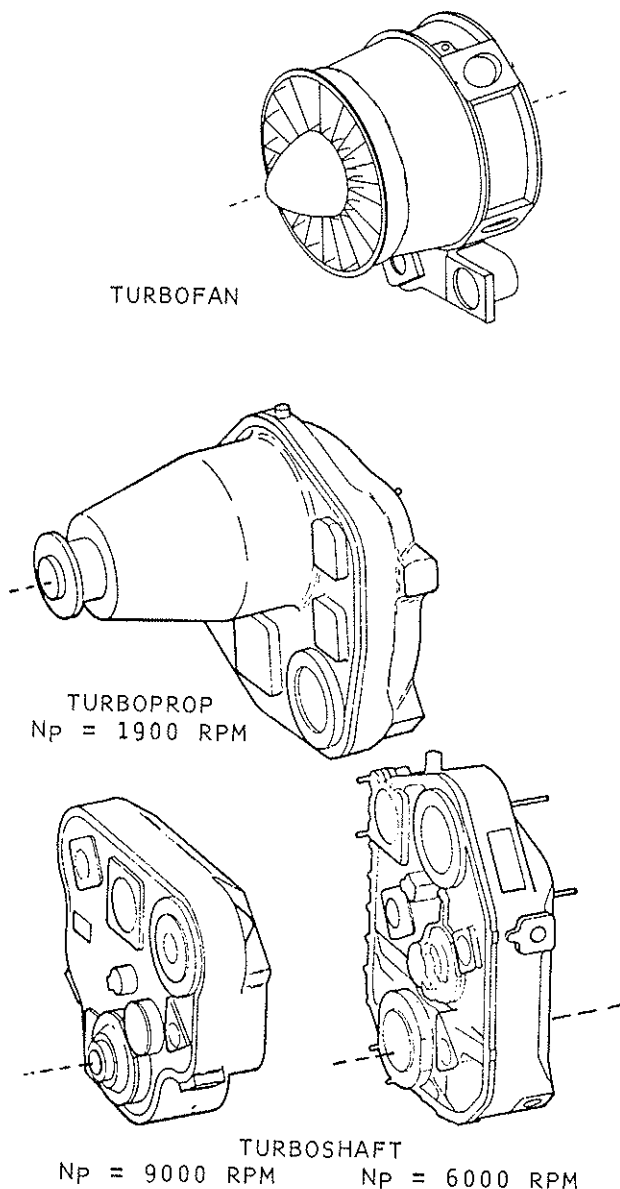


Figure 11 Engine Front End Modules

## 7.0 SUMMARY

The major design objective - superior performance at low cost - has been met in the LTS101 design. Certification efforts for the baseline configuration are complete. Additional certification programs are underway for derivative versions. Growth versions are currently in the R&D cycle to insure adequate power increase to meet evolving aircraft requirements.

The enthusiastic industry response to this engine assures its early production success. Because of its versatility, improved performance, and low cost, an increasing number of new applications, both commercial and Military, is expected.

The design concept for the 101 has been and continues to be one of great application versatility. This is perhaps best illustrated in Figure 11, which shows the various front end modules that are employed with a common core engine to produce the wide range of applications: helicopter propulsion, turboprop and turbofan derivatives for fixed wing aircraft and, finally, flight rated APU versions.

In parallel with the development efforts supporting near term production versions of the 101, an orderly growth program has been defined, through discrete power steps. Three configurations are currently in various stages of engineering development to provide basic core capability of 700, 800 and 900 HP. Preliminary design studies are underway to identify configuration options for the 1000 HP and over class.

In these growth programs, the core engine versatility will be maintained for the various 101 powerplant types of Figure 11, thus assuring that increased power derivatives will be available to meet the downstream needs of the various applications.