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of the failures (see Flight for July 19, page 85) was not
that expected by GE's representative. He suggests that if
it had been a design fault this would have had a serious
repercussion on Rolls-Royce's credibility. Like many
American executives, Pirtle is fairly forthright in his views
of other companies' performance. The disc failures, he says, were not just a matter of bad luck, but rather a symptom of trying to do too much too quickly. It was a mistake to plan to introduce three shafts, Hyfil blades and expect to delete variable stators all on the same engine. He applies the same sort of arguments to explain P&W's troubles with the JT9D-3, since cured with the introduction of the -7. Pirtle points out that GE's experience with high-bypass-ratio turbofans was based on the 8:1-bypass-ratio GE1-6 which made its first run at the end of 1964. This was backed up by data from Nasa-sponsored lift-fan contracts and the development of the aft-fan CJ805-23 for the Convair 990. Variable stators date back to the military J79 of the 1950s, and the TF39 provided large-diameter combustion-chamber technology. When developing the CF6 series, GE was able to concentrate on improving manu-facturing processes and refining component efficiencies. With the competition for the powerplant of the Boeing 7X7 2,000-mile-range trijet project still wide open, GE is also proposing a cropped-fan version of the CF6—the CF6-30. This engine would have a thrust of about 30,0001b, 134kN matched to the 7X7 requirement. The thrust level remains fairly fluid, however, and GE does not think that the engine is a rival to the CFM56,The engineering depart-ment at Evendale is studying both the latter collaborative engine and derivatives of the smaller TF34 with a variable-pitch fan for possible application to quiet Stol aircraft. The CF6 is actively canvassed as the engine for the cut-back 747SP project—the SP for special performance— which is intended as a DC-10-30 competitor.
Snecma will manufacture 22 per cent, by value, of CF6-50s for the A300B. Two test cells for the engine have already been built and production deliveries have begun. The French company is responsible for fan rotor com-ponents, fan booster components, high-pressure and low-pressure compressor components and gearbox parts. These will be available for both production engines and spares. A similar agreement has been worked out with MTU in Germany for the supply of hot-end components. While the typical length of a flight cycle for the CF6-50 in the DC-10-30 is between 4hr and 6hr, this is expected to be reduced to about 46min for the short-range A300B. Although GE anticipates no problems in meeting this requirement, it will be particularly demanding of the engine. One of the most rigorous parts of the flight cycle from a blade creep life point of view for high-bypass-ratio turbofans occurs during climb.

Both the CF6-6 and CF6-50 are attached to the pylon by mounting points on the core and the pick-up points are detailed in John Marsden's drawing of the 747-30 installa-tion on page 248. GE claims that this provides a lower engine weight and avoids the introduction of loads into the fan casing. By way of contrast, both Rolls-Royce and P&W have chosen forward mounting points on the fan casing for the RB.211 and JT9D, and suggest that this allows the use of a lighter pod.
The CF6 fan has a diameter of 86-4in, 219cm with 38 titanium blades and anti-vibration shrouds at two-thirds span. The single-stage low-pressure compressor of the CF6-6 and three-stage compressor of the CF6-50 are mounted on the rear face of the fan disc, which is overhung from the large-diameter-ball thrust bearing. Total mass flow for the lower-thrust engine is about l,3071b/sec, 593kg/sec and the bypass ratio is 5-9:1. This rises to 1,4511'b/sec, 658kg/sec at a bypass ratio of 4-4:1 on the CF6-50. An interesting feature of the -50 series is the use of mechanically operated blow-off valves to discharge excess air into the fan stream, to establish proper flow matching between the low- and high-pressure spools during transient operation. The doors are closed during take-off and cruise.

The CF6-6 high-pressure compressor has 16 stages and an overall pressure ratio of 15:1 (sea level, take-off, 84°F,

29°C). The 14-stage h-p compressor of the -50 provides an overall pressure ratio of 12:1. As noted above, the use of variable stators is a design concept pioneered by GE and the inlet guide vanes and the stators of stages one to six are variable. The actuating mechanism, shown in the cutaway drawing, is operated by fuel pressure from the engine-control unit. GE claims an exceptionally fast engine throttle response because of the variable guide vanes, and production engines show an average acceleration time from flight idle to 98 per cent thrust of 4-15sec. The first two stages of the compressor use axial dovetails to retain the blades, while the remaining stages use circumferential dovetails. Individual blades can be replaced without rotor disassembly. Like both the other large, high-bypass-ratio turbofans, the CF6 uses an annular combustion chamber with comprehensive film cooling, to provide smoke-free operation.

The CF6-50 installation in the 747-300 mocked up at Boeing's Seattle factory. Opposite, the starboard outer CF6 on the prototype aircraft

GE has put a lot of money and effort into the design of turbine blades for high inlet temperatures and the detailed drawings accompanying the cutaway indicate the sophisti-cation achieved on the CF6. Further improvements are likely to result in a steady increase in operating tempera-tures rather than a sudden breakthrough. While the engine for the American SST, the GE4, provided high-tempera-ture technology, GE engineers feel that they selected at an early stage the best method of using air-cooled, cast turbine blades. These bring several advantages, including improved porting and passaging (which would be too difficult to provide with forging techniques), greater strength and easier production and quality control. Accurate moulds are provided by the "lost-wax" technique. Alternatively, coring can be provided by ceramics which are etched away after casting. GE engineers admit that they have not yet achieved the perfection with directionally solidified mono-crystaloids that P&W has. The CF6 tubine blades are cast in the Rene 80 series of alloys, and the use of high turbine inlet temperatures provides GE with the confidence to suggest that a 55,0001b, 245kN-thrust CF6 flat-ratedN

to 84°F, 29°C will be available, without
changes in fan dimensions, when required for the 747. Several advanced machines are used in blade and nozzle guide vane production. These include a laser-cutter which can cut at a rate rof four holes/sec. It is used to provide the very small holes in the internal fabricated parts of the first- and second-stage high-pressure nozzle guide vanes which are added during assembly to direct cooling air on to internal surfaces. Inertia welding and forge welding techniques are used in other parts of the engine.
The h-p nozzle is air cooled by convection, impingement