TP400-D6
The western world’s most powerful turboprop
The western world’s most powerful turboprop - the TP400-D6 developed by Europrop International (EPI) for the four-engined Airbus Military A400M military transport aircraft - enters service just ten years after the engine was selected. That is, in itself, a major achievement, possibly the quickest development programme yet for a military engine. Many believe that success is due to the Airbus Military decision to run the A400M as much as possible as a civil aircraft development programme, with an aggressive timeline for a new engine and aircraft with demanding military requirements.

The EPI contract with Airbus Military covers the development and production of over 700 engines for the A400M fleets ordered by Germany, France, the United Kingdom, Spain, Turkey, Belgium and Luxembourg. The contract also covers any additional engines for potential export aircraft customers, which already includes Malaysia.

This is the first engine built for a military aircraft to complete a full civil engine certification programme, but with the complexity of military requirements and military levels of performance. It is also the first military engine to be fully civil certified from the outset by EASA.

While not the first European collaborative programme, it differs substantially from earlier projects. When EPI was established in 2002, it wanted to learn the lessons from previous European joint ventures, and to optimise the efficiency of the partner companies by placing their expertise in the correct areas.

The intention was to try to develop the engine/aircraft in civil timescales with a view to removing the cost overruns and delays that had beset many military programmes, while harmonising the different military qualification requirements of the partner countries.

Having four companies involved may add complexity at one level, but by applying lessons learned from previous collaborative programmes, the impact of the complexity has been reduced. The partner companies have also avoided duplicating production lines and facilities.

There is only one engine assembly line in Munich - instead of one for each partner. This has reduced the need for many components to be transported from manufacturer to manufacturer.

Simon Henley, President of EPI, said: “As a result of the decisions taken earlier, we’re delivering a state-of-the-art engine that is due to enter service in 2013 - just 10 years since it was selected by Airbus Military to power the A400M. By the end of 2012 the first production engines will have been delivered for the French aircraft.”

Once the aircraft specification required a turboprop producing 11,000 shp, it was clear that it needed to be a new engine.

“There was a misapprehension that it was a clear choice between an existing engine and a new European engine,” said Martin Maltby, Technical Director - EPI. “This was not the case, as there was no existing off-the-shelf product, so any other manufacturer would have to have designed a new engine.”

Martin also emphasises that incorporating new technology into the engine from the outset was significantly important in meeting the challenging power, weight and length requirements. Component technology is based on the best-in-service military and commercial practice.
The programme also demonstrates a clear risk management strategy, with the partner companies agreeing not to use the TP400 as a technology-acquisition programme. It is, therefore, a composite of individually-proven technologies and materials, with each of the four partners bringing the best of their technology.

Simon Henley explained: “It would also need modern technology incorporated into the engine to achieve the required fuel burn and weight. As a result of decisions we took, the engine is demonstrating itself as the right design of powerplant for the A400M. At this stage, we are on track to meet weight and fuel burn specification.”

Each of the partner companies - Industria de Turbo Propulsores (ITP), MTU Aero Engines, Rolls-Royce and Snecma - brings its own technology and programme expertise.

Rolls-Royce, MTU and Snecma each have a 28 per cent share in EPI, with ITP taking the remaining 16 per cent.
TP400-D6 overview

The TP400 is a three-shaft turboprop, produced from a compact design

A three-shaft concept is the only way to allow a free power turbine and the LP turbine drives straight into a gearbox. It is a more compact engine and allows the individual pressure systems to be optimised to the operating regime and for the components to be optimised to the speeds of the shafts.

Another major advantage of a three-shaft turboprop is the high level of performance retention, which means the engine will continue to deliver power and specific fuel consumption to the required specification.

The TP400-D6 cycle has been optimised for A400M mission requirements, and its modular design was chosen for maintainability and low life cycle costs.

Although it will enter service in the military environment, the TP400-D6 meets civil noise and emission regulations.

Its 17 ft diameter, eight-bladed Ratier-Figeac FH386 propeller is provided under an Airbus Military contract, and is driven by an Avio power gearbox, supplied under subcontract from EPI.

TP400-D6 workshare

Programme milestones

2002
Europrop International established

2003
EPI selected by Airbus Military to power the A400M
EPI opens its Madrid liaison office

2004
Preliminary design review
First Intermediate Pressure Compressor test

2005
Critical design review
First Control Monitoring System test
First ground test

2006
First engine test with propeller
First series of altitude tests

2007
First engine to test in Sevilla
Delivery of flying test bed engine

TP400-D6 The western world’s most powerful turboprop
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First flight of A400M.

4,000 flight test hours achieved.
Certification testing complete.

2010
TP400-D6 certified by EASA.

2011
Delivery of first engines to Airbus Military.
First flight test.

2008
Ground test hours past 2,500.
FTB second flight achieves maximum power.

2009
First production engines delivered.

2012
First production engines delivered.
Spain's centre for aero engine excellence was established in 1989 and is now responsible for the engineering, research and development, manufacturing, assembly and test of gas turbines for aeronautical and industrial applications.

For the TP400-D6, ITP's responsibilities start at the front of the engine, with the front bearing structure, or front frame. This has been designed and manufactured with Tusas Engine Industries Inc (TEI) of Turkey. TEI participates in the engine programme as an ITP risk and revenue sharing partner.

The front frame is a highly loaded structure and incorporates a multi-profile airfoil design to reduce the risk of any inlet distortion from the chin intake.

For the turbine exit casing and nozzle, ITP is again working with TEI. Juan Carlos Corral Martin, ITP's programme Director for the TP400-D6, says: “The turbine exit casing is a typical ITP product, in that we started with Rolls-Royce and we are now involved in major modification, changing some components. We are on course on weight but our target is to reduce it by as much as possible.” Bearing Hub will be made of titanium rather than an Inco alloy, to reduce weight and cost.

ITP is also responsible for the low pressure turbine, a component in which it has been developing a key competency, particularly for the Rolls-Royce Trent, in which it is a risk and revenue sharing partner.

Juan Carlos says: “This is the first time ITP has designed and developed an low pressure turbine using its own internal standards and methods. For the Trent family, we used Rolls-Royce specifications. This is most important for ITP, it's a breakthrough for ITP.”

“The TP400-D6 is very, very important to ITP, as we have more involvement than on the EJ200, for which ITP was created. It is now the biggest engine programme in ITP.”

The three-stage low pressure turbine, which drives the power shaft, has been designed using advanced 3D airfoils, with reduced tip clearances to improve air flow, advanced cooling and blades that are welded in pairs to introduce more stiffness.

ITP is using two test beds, one at Ajalvir, near Madrid, for sea-level static testing and another on an open air test bed designed and installed at a Spanish Air Force base, near Seville, for the complete engine with propeller. After the A400M's entry into service, this test bed will support all engine requirements.

ITP is also responsible for the engine's dressings. Compared to a turbofan, there is less room to mount dressings and electrical and piping harnesses because there is no fan duct, so a turboprop nacelle is relatively crowded. ITP also provides support for aircraft final assembly in Seville, although Snecma is responsible for the the interface between the engine and the nacelle, the latter being an Airbus Military responsibility.
The interface between the engine and nacelle is more complicated than with a turbofan engine, so a computer-based digital mock-up was created to simulate the installation and accessibility of all dressings and the fuel and oil systems.

The dressings include brackets, pipes and electrical harnesses but because all the systems go around the engine itself, Snecma had to do a lot of work to optimise the brackets.

Lydia Guerville, Snecma’s TP400-D6 Programme Manager, says: “Some of them are like sculptures and were very complicated to produce. Labinal, also part of Safran, is a subcontractor for the electrical harnesses.”

Snecma is also responsible for the combustor and high pressure turbine.

The single annular combustor incorporates technology and materials from the M88 engine, which powers the Rafale fighter aircraft.

“But because of the TP400-D6 operation, the engine is running cooler than for a combat engine, therefore the components benefit from longer life,” said Lydia.

Snecma also shares responsibility with MTU for part of the engine control and monitoring system, and carried out some development and production work on the engine control system (FADEC) which shares some heritage with the CFM programme.

The single-stage high pressure turbine also comes from the M88 programme.

Another Snecma responsibility is the lubrication system. This was also a good example of co-operation between partner companies: Belgium’s Techspace Aero, part of the Safran group, provided the hardware under a risk and revenue sharing agreement with Snecma, Rolls-Royce carried out the development and validation, and ITP provided the piping that links the equipment.

Microturbo, another Safran company, provides the engine starter. However, as Lydia explains, although there are a number of Safran group companies involved in the TP400-D6 “EPI only has to deal with Snecma.”

Snecma is a part of the Safran group, one of the world’s leading manufacturers of aircraft and space engines, producing a wide range of propulsion systems commercial and military aircraft, launch vehicles and satellites.
The partner companies and their contributions to TP400-D6
MTU Aero Engines

The MTU Aero Engines group engages in the development, manufacturing, sales and support of commercial and military aircraft engines. The company has established a leading position at the forefront of engine technology.

MTU is responsible for the TP400-D6’s intermediate-pressure compressor, intermediate-pressure turbine and intermediate-pressure shaft, the engine protection and monitoring unit (EPMU) and the engine control software.

MTU Aero Engines in Munich will be responsible for final assembly of all TP400-D6s built in Europe, and acceptance testing will be performed at MTU Maintenance Berlin-Brandenburg.

"The intermediate pressure compressor has a sophisticated casing treatment which eliminate the need for variable stators. These also provide an excellent surge margin and great efficiency," said Gerhard Bähr, the TP400 Programme Director at MTU. "Removing the need for variable stators also make the engine simpler, significantly lighter and easier to maintain."

The main difference between the TP400-D6 and other European collaborative programmes, when all the partner companies assembled engines, is that all the TP400-D6 engines will be assembled by MTU, which has experience of large turboprop engines through its previous involvement with the Tyne programme, said Martin Schäffner, MTU's Director - Engine Maintenance, Assembly and Test.

Before the TP400-D6, the Rolls-Royce Tyne engine for the Transall military transport aircraft was the the most powerful propeller engine of the Western world.

MTU and its predecessor M.A.N Turbo, built and assembled 315 Tyne Mk21 and 470 Tyne Mk22 under license from Rolls-Royce from 1966 to 1972.

Having responsibility for all TP400-D6 assembly, logistics will be the the key factor in final engine assembly, making sure all the modules arrive in good time from the other partner companies. Module delivery is the critical path.

"Initially, the plan is to assemble 10 engines a month, increasing to 140 engines a year after the first year," said Martin Schäffner.

Acceptance testing will be carried out on a test bed that was built initially for development, but will now be used for production engines, where a wide range of parameters will be covered including power output, vibration, turbine entry temperature, oil temperature and acceleration.

As the TP400’s 17 ft diameter propeller is not installed in the engine until final aircraft assembly at Seville, a water brake is used on the test bed to simulate the drag of the propeller - a common system for turboshaft engine testing, where the water absorbs the energy.
Rolls-Royce, the world-leading provider of power systems and services for use on land, at sea and in the air, operates in four global markets - civil aerospace, defence aerospace, marine and energy.

Rolls-Royce provides a range of capabilities to the TP400-D6 partnership through its modular and non-modular responsibilities.

The company designs and manufactures the High-Pressure Compressor, the Intermediate Casing with Internal Gearbox, the High Pressure – Intermediate Pressure bearing structure, the Low Pressure Shaft modules and provides a large portion of the sensors and control system probes.

The blisk design for the high-pressure compressor module represents the first product application of the German E3E technology programme. Manufacturing blades and discs as single structure - a blisk - removes the complexity of fixing individual aerofoils onto the disk and results in a weight saving of up to 30 per cent. The TP400-D6 has four blisk stages with 333 3D airfoils milled from solid titanium.

The engine’s Hot Strut, between the high and intermediate pressure structures is an integrated bearing support which includes a sophisticated internal lubrication system.

The Low Pressure shaft is one of the longest Rolls-Royce has produced. It demands high-precision forging and milling to realise concentricity over a relatively long and thin shaft, as during its spool up to full power, the extremely small clearances between the low pressure and intermediate pressure shafts allows no vibration.

Design of the oil system was carried out in combination with the Oxford University Technology Centre. In addition, Rolls-Royce also designed the air system which ensures both ventilation and sealing between the gas turbine modules.

Rolls-Royce has also used its extensive system integration experience to perform performance calculations for the TP400-D6 programme and manage whole engine integration.

The company’s engineers have also supported the flight test activity on both the C-130 flying test bed and the A400M.

Dr. Robert Frank, Rolls-Royce Chief Engineer TP400 said: “I have been part of the TP400 programme from its beginning and seeing a concept maturing and ultimately becoming a real product is a great experience in itself, but with the TP400 this was special, as we are working truly as an European team where different company experiences and cultures meet and contribute to this powerful turboprop engine.”
The first flight of the C-130 testbed took place at Marshall Aerospace on 17 December 2008 and, just under one year later, the successful first flight of the Airbus A400M took place from Airbus Military headquarters in Sevilla, Spain.

The flight tests have demonstrated that the engine is meeting fuel burn requirements in flight as well as on the test bed.

The TP400-D6 was also subjected to intensive icing conditions over the Pyrenees, which were specific to testing the engine’s capacity to cope with icing conditions, having passed such a test on the test bed. Additional ice ingestion tests have demonstrated good stability in those conditions.

Similarly, HPC and propeller gearbox issues were overcome during the very aggressive flight test programme, which will carry on after first aircraft delivery in order to finalise aircraft development.

The engine has successfully completed testing in cold weather conditions and flight test hours continue to be accumulated on a fleet of six A400M aircraft.
The European Aviation Safety Agency (EASA) awarded type certification to the TP400-D6 engine in May 2011, making it the first large turboprop engine to have been certified by EASA and the first military engine to have been certified by EASA to civil standards from the outset.

Certification completes airworthiness approvals by EASA and is the result of an intensive series of safety, endurance and performance tests. Since the first engine run in late 2005 the TP400 has completed all major development testing, as well as achieving over 20,000 running hours, with around 10,000 engine flying hours accumulating during the A400M flight test programme.

During development testing the engine demonstrated exceptional performance operating at sea-level and altitude conditions. It also proved its ability to cope with bird strike, ice and water ingestion. Testing was undertaken at a variety of open air, indoor and altitude facilities at six locations across Europe – Ludwigsfelde in Germany, Istres and Saclay in France, Ajalvir and Moron in Spain and Liers in Belgium.

Although the TP400-D6 was designed with maintainability in mind, more work has gone into meeting customer requirements and EPI continues to work with Airbus Military to incorporate further improvements.

A digital mock-up was created, to ensure access is maximised and to avoid clashes between pipes and harnesses because compared with a turbofan, there is less room to mount dressings and harnesses as there is no fan duct. So a turboprop nacelle is relatively crowded. Inspection has to be easy for the customers, particularly if they are operating far away from the main operating base.

The engine control unit, which is mounted on the engine, and EPMU (safety systems) are separated. The EPMU is placed in the pylon so that if the engine control unit is damaged, the safety systems are unaffected. Further software releases will be built-in for testing different levels of redundancy for the control system.

The engine has passed all its maintainability assessments and is proving very reliable in flight test. EPI is working towards bringing the expertise of all the partners in both military and civil programmes to bear to offer the best in-service support solution for operators. EPI can call on the experience and expertise that the partner companies have built up supporting thousands of civil and military engines around the world.

Support solutions can be tailored to the customer. EPI President Simon Henley explains: “EPI is developing a progressive approach to offer different support solutions for the TP400 engine, ranging from time and material up to power-by-the-hour solutions. We’ll be flexible to meet customer requirements.”