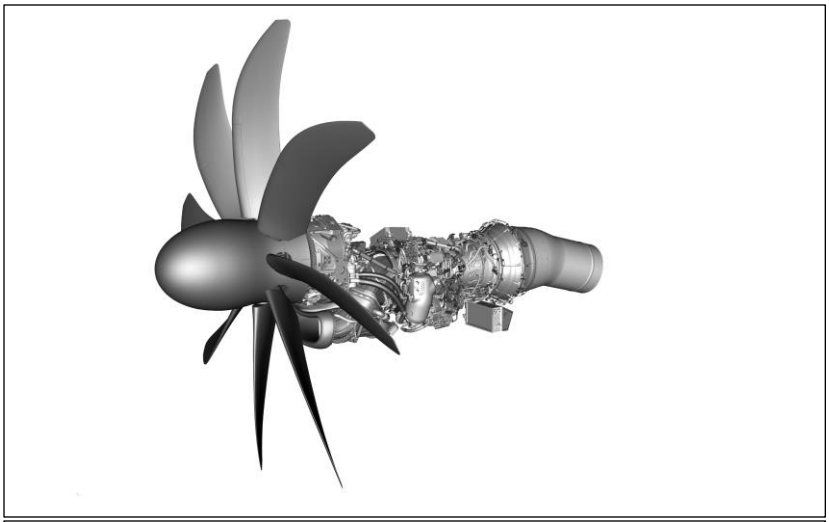
EuroProp International TP400

Turboprops
July 2017



Quick Specs:

Power Class:	11,000 shp (8,200kW)
Pressure Ratio:	25:1
Airflow:	n/a
SFC:	n/a
Configuration:	1P; 5 IPC; 6 HPC; Annular; 1 HPT; 1 IPT; 3 LPT

Program Briefing

The TP400 is a three-shaft turboprop rated at 11,000 shp. The only variant is the -D6 which is currently in development to power the four-engine Airbus A400M Atlas (originally dubbed the Grizzly) military transport. The first flight for the A400M finally took place in December 2009. First deliveries (three aircraft) took place in late 2013.

EuroProp International (EPI) is made up of four European engine manufacturers. Rolls-Royce, MTU and Safran (was Snecma) have 28% share in the program and ITP of Spain has 16%. Avio of Italy is a revenue sharing partner in ITP's stake. Work shares are based on each country's A400M procurement. Safran has 32%, Rolls-Royce 25%, MTU 22%, and ITP 21%.

Teal Group projects 539 units produced by the EPI consortium in the next 10 years with a total value of around $6.5 billion.

Manufacturers

EuroProp International GmbH
Parque Empresarial San Ferando de Henares, Madrid, Spain (headquarters)
Ludwigsfelde, Germany (final assembly)

Partners in EPI

Industria de Turbo Propulsores SA
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tel: +34-9-4466-2100
fax: +34-9-4466-2193
email: itp@itp.es
website: www.itp.es
(16% share in EPI)

MTU Aero Engines GmbH
Dachauer Str. 665
D-80995 Munich
Germany
tel: +49-89-1489-0
fax: +49-89-1489-5500
email: info@muc.mtu.de
website: www.mtu.de
(28% share in EPI)

Rolls-Royce plc
Defence Aerospace
P.O.Box 3
Filton, Bristol
England BS12 7QE
tel: +44 117-9791234
fax: +44 117-9798005
website: www.rolls-royce.com
(28% share in EPI)

Summary Forecast

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	Total
Units Produced	75	82	79	70	59	45	45	41	25	18	539
Value (2017 $ Millions)	900.0	984.0	948.0	840.0	708.0	540.0	540.0	492.0	300.0	216.0	6,468.0

Safran Group
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tel: +33 (1) 69 87 09 00
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website: www.snecma.com
(28% share in EPI)

Responsibilities

ITP
- Front frame
- Power turbine
- Turbine exit casing and nozzle
- External dressings
- Test equipment and aircraft assembly line support
- Integrated logistic support

MTU
- Intermediate-pressure compressor
- Intermediate turbine
- Intermediate shaft
- Engine control system (with Snecma)
- Final assembly
- Integrated logistic support

Rolls-Royce
- High-pressure compressor
- Low-pressure shaft
- Intermediate casing
- Hot struts
- Internal gearbox
- Air/oil and heat management system
- Whole Engine Model
- Engine performance
- Integrated logistic support

Snecma
- Combustor
- High-pressure turbine
- Powerplant installation on aircraft
- Lubrication system
- Starter
- Engine control system (with MTU)
- Accessory gearbox and components
- Integrated logistic support

EPI
- Program management
- Overall engine integration
- Procurement of the power gearbox
- Type Certificate holder

Subcontractors

- Aero Decals, Palm Bay, FL, USA—placards, ID plated markings.
- Allen Aircraft Products, Inc., Ravenna, OH, USA—chip detectors.
- Avio SpA, Rivalta di Torino, Italy: propeller gearbox.
- BAE Systems, Preston, England—FADEC (under subcontract from Hispano-Suiza).
- Cobham Advanced Composites, Shepshed, England—composite components.
- DuPont Vespel Parts & Shapes, Valley View, OH, USA—VSV bushings.
- Eaton Aerospace Systems, Cleveland, OH, USA—fuel pump.
- ELDIM BV: HP turbine seal segments.
- Froude Hofmann, Worcester, England—dynamometer and control system.
- GKN Aerospace—engine air inlets.
- Hispano-Suiza, Colombes Cedex, France: FADEC, accessory gearboxes and power transmission shafts.
- Kahn Industries Inc., Wethersfield, CT, USA —engine test dynamometers.
- Leistritz Turbomaschinen Technik GmbH, Nuremberg, Germany—compressor components.
- Microtecnica (subsidiary of Hamilton Sundstrand)—propeller control module.
- Omega Technologies Inc., Westlake Village, CA, USA—universal wrenches, sockets and adapters.
- Otto Fuchs Metallwerke, Meinerzhagen, Germany—forged disks.
- Precision Components, Inc. Long Beach, CA, USA—solenoid valves and machined parts.
- Ratier-Figeac SA (subs. Hamilton Standard): propellers.
- Reform Maschinenfabrik, Fulda, Germany—high-speed blade tip grinds.
- Sealtron Inc., Cincinnati, OH, USA—hermetic connectors.
- Sofrance: fuel and oil filters.
- Techspace Aero SA, Milmort, Belgium: lubrication systems, combustion case, HPT disk.
- Thermal Engineering, Royston, UK—alloys.

Technical Description

Components

Layout

Three-spool turboprop. HP spool is contra-rotating to IP spool.

Propeller

Single 5.33-meter, eight-bladed propeller; fully reversing. Driven by the LP turbine. The blades are of variable pitch design and spin at 840 rpm.

The propellers will be "handed" (i.e., right or left side) to reduce some of the technical risk of the design. The gearbox will handle the extra machinery for the counter-rotating units.

IP Compressor

Five-stage intermediate stage compressor with no variable to reduce complexity. Lightweight design with four titanium blisk-rotors. The IPC is located at the interface to the nacelle and intake. Pressure ratio is 3.5:1.

HP Compressor

Six-stage compressor from the Snecma M88-2 engine. Pressure ratio is 7:1. Two variable stages. Ten percent air bleed capability.

Combustor

Single annular combustor from the M88-2 engine.

HP Turbine

Single-stage high-pressure turbine from the M88-2 engine driving the HP compressor.

IP Turbine

Single-stage intermediate-pressure turbine driving the IP compressor.

LP Turbine

Three-stage low-pressure turbine driving the power shaft.

Other Components

Propeller gearbox to be supplied by Avio. The engine is equipped with a dual channel electronic control unit.

Variants

TP400-D1—The initial version of the turbine proposed by APA, the turbine proved to be too heavy and consumed too much fuel.

TP400-D6—The base model for use on the Airbus A400M, the TP400-D6 will be rated at 11,000 shp. The aircraft will be equipped with two, "handed" engines on each wing which will direct the airflow down and between the turbines to reduce

Airbus A400M powered by four TP400-D6s

complications associated with the installation of the four large turboprops.

Specifications

(Imperial Units)

Model	Max. Cont. Rating (shp)	Pressure Ratio	Compressor Config.	Airflow (lb/sec)	Fuel Con.* (USgal/hr)	Width (in)	Length (in)	Weight (lb)
TP400-D6	11,000	25:1	1-5-6	n/a	490	n/a	138	4,026

(Metric Units)

Model	Max. Cont. Rating (kW)	Pressure Ratio	Compressor Config.	Airflow (kg/sec)	Fuel Con.* (liters/hr)	Width (m)	Length (m)	Weight (kg)
TP400-D6	8,200	25:1	1-5-6	n/a	1,850	n/a	3.5	1,830

**"tactical mission fuel consumption"*

Applications

Engine	Aircraft	Engines per A/C
TP400-D6	Airbus Military A400M Atlas	4

Marketing Data

Costs

Although no cost data has been published, the TP400 is likely to be the most expensive Western turboprop ever built. We estimate the unit cost at $12 million, including gearbox and props.

The Competition

No existing western turboprop competes in the TP400's power class. The Pratt & Whitney Canada PW180 proposal, based on the PW800 geared turbofan, would apparently be able to compete with the TP400 if developed.

A number of Russian turboprops that meet and exceed the TP400's power output are in operation.

Order Book (as of 6/30/16)

Customer	A/C Model	A/C Ord./Del.	Engine Model/Notes
Belgium	A400M	7/—	TP400-D6
France	A400M	50/10	TP400-D6
Germany	A400M	53/8	TP400-D6; to be reduced to 40 a/c
Luxembourg	A400M	1/—	TP400-D6
Malaysia	A400M	4/4	TP400-D6; deliveries 2015-2016
Spain	A400M	27/1	TP400-D6
Turkey	A400M	10/4	TP400-D6
United Kingdom	A400M	22/15	TP400-D6; reduced from 25
Total		**174/26**	

Production History (production engine deliveries; estimates)

	2006	2007	2008	2009
TP400-D6	—	2	6	8

	2010	2011	2012	2013	2014	2015	2016	Total
TP400-D6	8	4	2	16	70	42	68	226

Milestones

Date	Milestone
1982	FLA program begins
2002	EuroProp International established
May 7, 2003	TP400 selected for A400M
July 21, 2004	preliminary design review concluded
Nov. 30, 2004	intermediate pressure compressor stage makes first run in Munich (MTU)
May 31, 2005	first test of engine control and monitoring system
June 2005	assembly of first engine commences
Oct. 28, 2005	successful first engine test
Dec. 21, 2005	first test series completed
Feb. 28, 2006	first engine run with propeller
Mar. 5, 2008	the last of the four flight test engines for the A400M delivered
June 10, 2008	ground test of C-130/TP400 commence
May 13, 2008	bird-strike tests completed
Dec. 17, 2008	first flight of TP400 aboard C-130 testbed
2009	ground-test hours pass 2,500
Dec. 11, 2009	first flight of A400M
2010	4,000 flight-test hours reached
Dec. 20, 2010	fourth A400 joins flight testing
May 9, 2011	TP400 receives EASA certification
Apr. 17, 2012	first engines delivered Production A400M
Sept. 30, 2013	First production A400M delivered to French air force
July 15, 2014	50th production TP400-D6 produced
Apr. 4, 2014	First Turkish aircraft delivered
Nov. 11, 2014	100th production TP400-D6 produced
Nov. 27, 2014	A400M enters service with RAF
May 9, 2015	A400M crashes in Seville, Spain

Program Overview

Background

A400M Takes Form

The A400M Future Large Aircraft (FLA) began in 1982 as the BAe/Aérospatiale/MBB/Lockheed FIMA program. CASA and Aeritalia (now Alenia) joined the group in December 1987. The now-dissolved Independent European Program Group (IEPG) in April 1988 issued an Outline European Staff Target (OEST) for a Transall/Hercules replacement. This led to a FIMA response that was tailored to European requirements and FIMA became FLA/Euroflag with the signing of an MoU in April 1989.

At that point, Lockheed withdrew from the program. The United Kingdom Ministry of Defence withdrew from Euroflag in September 1989, but retained observer status. In December 1994, the MoD rejoined Euroflag, after purchasing 25 C-130Js.

The Turkish government announced in spring 1990 that it would

join the European group studying the feasibility of the FLA. Turkey is represented in the group by Tusas Aerospace Industries (TAI). TAI had initial discussions with BAe and Aérospatiale, and Turkey joined as a full partner in November 1997. Later in 1990, Belgium also announced that it was interested in joining the Euroflag consortium, with Sonaca and Sabca likely to be involved. These companies later joined, and Belgium took a 4% program share in November 1997.

In early 1991 Euroflag established a limited liability company based in Rome. FLA then entered the pre-feasibility phase.

In August 1991 Aérospatiale unveiled a new design for a four-turbofan high-wing FLA concept. The design incorporated a two-man cockpit and fly-by-wire or fly-by-light flight controls. In May 1991 Aérospatiale won French government approval to take a 20% share, worth $7.8 million, in the Euroflag consortium.

At the September 1994 Farnborough Air Show, Airbus Industrie announced that it had agreed to manage the FLA project. The company established a separate military aircraft subsidiary which comprises the four regular Airbus member companies—DASA, Aérospatiale, British Aerospace, and CASA—plus Alenia.

The initial batch of 180 A400M aircraft are split in the following manner: Germany, 60; France, 50; Spain, 27; UK, 25; Turkey, 10; Belgium, seven; and Luxembourg, one. Full production rate of the aircraft is expected to be around 30 a year.

Beyond sales to partner countries, Airbus hopes to sell around 200 aircraft (around 900 engines) to the export market. Potential customers include Australia, Malaysia, Norway, South Africa and Sweden.

Engine Options Begin

An initial consortium named Aero Propulsion Alliance (APA) was formed by Avio (8%), ITP (13.6%), MTU (24.8%), Rolls-Royce (24.8%), Snecma (24.8%) and Techspace Aero (4%) was formed after initial proposals from BMW Rolls-Royce (BR700TP) and a Snecma-led group (M138 based on M88-2) went nowhere. The new consortium predictably merged the two designs and proposed the TP400-D1.

As could be expected from a slapped together design, the turbine was over-weight and not very efficient, so everyone eventually went back to the drawing board and a new RFP was issued.

EPI Takes Over

A new consortium was formed with Rolls-Royce, MTU and Snecma each holding 28% shares and ITP holding the remaining 16% and they proposed the reworked TP400-D6 variant.

The work shares differ from EPI ownership shares and more reflect the number of A400Ms to be purchased by each country: Snecma, 35% (covering France, Belgium and Luxembourg); Rolls-Royce, 25% (UK and Germany); MTU, 22% (Germany); and ITP, 21% (Spain and Turkey).

The main competition was the Pratt & Whitney Canada PW180 turboprop based on the PW800 geared turbofan. To make the project more appealing for European decision makers, P&WC offered to give a substantial work share to European contractors.

TP400 Selected for A400M

Despite comments by Airbus that the P&WC proposal was 20% cheaper, the TP400 was finally selected by a contentious decision that didn't do much for trans-Atlantic relations.

Work share on the TP400 engine is split based on the number of aircraft purchased by each of the partner nations. The current shares are: Snecma 32.2% (including work at Techspace Aero), Rolls-Royce 25% (includes work at German operations), MTU 22.2%, ITP 20.6% (includes Turkish share).

First Engine Tests

EPI announced on July 21, 2004, that the preliminary design review of the engine had been completed. The intermediate pressure compressor made its first run at MTU's Munich facility.

The engine control and monitoring system (CMS) was first tested in late May 2005 at Snecma's Villaroche (near Paris) facility. The CMS includes the electronic control unit, the electronic protection and monitoring unit, the fuel pump, the fuel metering unit, the fuel-cooled oil cooler, the high-pressure compressor variable stator vanes actuators, and the fuel filter.

Assembly of the first TP400-D6 for ground testing began in June 2005. The engine successfully completed its first test run on Oct. 28, 2005. The event occurred at the MTU Maintenance Berlin-Brandenburg facility in Ludwigsfelde, Germany. On December 21, it was announced that the first series of tests had been completed. During the tests, it was reported that the turboprop reached full power and completed more than 35 hours of testing.

Add the Propeller

On Feb. 28, 2006, the TP400 made its first run with the propeller attached, amounting to the first complete engine run.

First Flight Delays

First flight of the TP400 aboard a testbed aircraft had been planned for March 2007, but this then slipped until that summer. In January 2007, it had been reported that Snecma and its partners had committed more engineering resources in an effort to stem the tide of delays that had begun to accumulate. Total bench-running hours had fallen behind schedule. In order to remedy this, the team decided to add two more powerplants to the nine already under test.

EPI also underwent management changes in an effort to put some heat under the program. Managing Direc-

tor José Massol, in place for the previous two years, was replaced by Nick Durham, formerly director of services and helicopters at Rolls-Royce.

Problems causing delays included development of the software for the FADEC. Other factors reported have been oil contamination and the requirement to redesign bench testing components due to the high power of the engine.

Other burdens on the schedule involved the need to reinforce the structure of the C-130 testbed aircraft and the need to replace a torque sensor.

Further, the flight test engines will not reflect production standards. The EPI consortium is having to redesign the compressor to meet performance targets. By July 2008, these issues appeared to have been resolved.

In May the consortium announced the successful completion of bird-strike tests. Ground running of the C-130 with its TP400 were reported to have begun in June 2008. About 30 hours of such testing is required before the plane takes to the air.

First Flight of the TP400

In March 2008, EPI finally was able to report that it had delivered the last of the four flight test engines for the first A400M.

The program ended 2008 on a higher note when the TP400 made its first flight aboard a structurally reinforced C-130K testbed aircraft on December 17, nearly two years behind schedule. The engine was installed on the inner left engine mount of the aircraft which otherwise was powered by three of the usually four Rolls-Royce T56 turboprops. The flight took place from Cambridge airfield (UK) where Marshall Aerospace, which is conducting the flight testbed trials, is based. The flight lasted one hour and 15 minutes.

During the flight, various flight characteristics such as aircraft basic handling and engine response at a thrust equivalent to the maximum power generated by each of the other T56s were tested to satisfaction in several aircraft configurations up to a speed of 165 kt and an altitude of 8,000 ft.

This was a first step in the aircraft envelope opening. It will allow progress towards the completion of the approximately 50 flight test hours planned to reach sufficient maturity in order to allow the TP400s to fly on the A400M.

First Flight of the A400M

In November 2009, moved closer to first flight when all four engines were run simultaneously on the ground. Subsequently, taxi tests were initiated. Then finally the big event came when on 11 December 2009 the A400M took to the air for the first time.

EASA Certification

In May 2011, the TP400 became the first large turboprop to be granted European Aviation Safety Agency (EASA) certification.

Engine Gearbox Problems Arise

The A400M was successfully flown at the 2010 ILA Berlin Air Show and again at Farnborough that July. But at Paris in June 2011, a trials aircraft suffered a gearbox problem. Subsequent analysis determined that the fatigue cracks in the gear-tooth fillet radius were caused by resonance in then idler gear at cruise propeller speed.

The idler gear was redesigned to shift resonance frequencies. The engine that failed was a preproduction version, and the bearing issue did not affect production units.

Then just before Farnborough 2013, a fault occurred with a cover plate in the gearbox. The component was redesigned and the solution was retrofitted to earlier engines.

Finally, because the early aircraft had engines with low-pressure backend casings made of steel, they were targeted for engine swaps at 1,500 hours or two years. This was due to temperature limitations experienced by these components.

Production Engines

In April 2012, EPI announced that it had delivered the first production series engines which would power the French air force's first A400M.

Twelve installation engines, plus two spares were scheduled for delivery in 2012. The 50th production standard TP400 was delivered in July 2014, with the 100th coming of the production line in November 2014.

To maximize efficiency, the engines are produced on a single production line in Munich.

Turkish A400M Crashes

On May 9, 2015, a new production A400M, destined for the Turkish air force, crashed on takeoff from the Seville, Spain, final assembly facility. Three of the four engines lost power during takeoff and the aircraft subsequently crashed as the crew attempted to return it to the airport. Four of the six-man crew were killed.

On 19 May, Airbus advised operators of the A400M to perform cautionary checks on the electronic control units for each TP400 engine prior to resumption of flight operations. Airbus Chief Strategy Officer Marwan Lahoud confirmed on 29 May that incorrectly installed engine control software caused the fatal crash.

MRO

Service Plans

Logistical support for the turboprop will be provided by EPI under the same contract as the initial 750-unit engine purchase. When the engines go into heavy maintenance, the individual modules are returned to their respective manufacturers.

Current Developments

Gearbox Woes Continue

In April 2016, Airbus reported that 14 propeller gearboxes (PGBs) delivered from Avio in the first half of 2015 were affected by a fault related to the heat treatment process in manufacturing that adversely affected the strength of the ring gear in the gearbox. A second PGB issue involves cracking of the input pinion ring.

As of June 2016, Avio stated that it was working to resolve the issues, with an interim fix then being flight tested.

Gearbox Fix Targeted

In March 2017, it was reported by MTU that it expected a final fix for the TP400 gearbox issues to be installed in new engines beginning on September 2017. Previous engines had been fitted with an interim fix that limited operations to 650 hours before overhaul. The new fix will increase gearbox life to 1,000 hours.

Program Status

Airbus reports that, as of June 30, 2017, 46 A400Ms had been delivered to customers.

Teal Group Evaluation

The TP400 program is a microcosm of the European model of progress: years of debate, bickering about market share, false starts, more debate, some last-minute backroom dealing and, incredibly, a viable product. Not totally unlike the conception of the Euro.

Like many other Euro-priorities, whether the A400M/TP400 are economic, commercial or military successes is beside the point. There has been too much blood spilled for the program to stop at this point. We think the aircraft does have an important role to fill, which probably could have been filled at a lower cost.

Nevertheless, the A400M will be cheaper than the C-17 and more capable than the C-130, leaving it as the only viable option for armed forces seeking instant "strategic projection" in their mission statements.

The current order book for the transport numbers 174 aircraft, four of which are the first export sales (to Malaysia). This total may drop somewhat, with Germany and the UK likely to cut back their orders a bit.

We don't see any other applications for the TP400 turboprop beyond future A400M variants. The engine core, however, may serve as the basis for future turbofan or turboshaft engines.

Teal Group projects 539 units produced by the EPI consortium in the next 10 years with a total retail value of around $6.5 billion.

Production Forecast

Units	Through 2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	Total
TP400-D6												
A400M prototypes	28	—	—	—	—	—	—	—	—	—	—	28
A400M	198	75	82	79	70	59	45	45	41	25	18	737
Total	**226**	**75**	**82**	**79**	**70**	**59**	**45**	**45**	**41**	**25**	**18**	**765**

Value (2017 $Millions)	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	Total
TP400-D6											
A400M	900.0	984.0	948.0	840.0	708.0	540.0	540.0	492.0	300.0	216.0	6,468.0