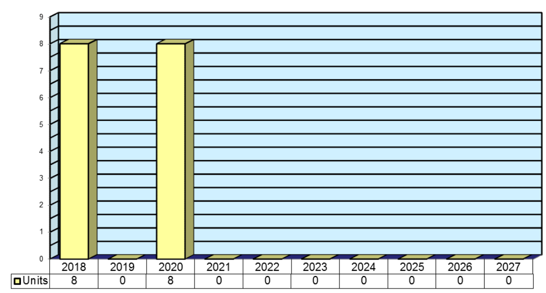
Vericor TF40 Marine

Outlook

- Sales of ETF40B for LCAC Service Life Extension Program (SLEP) end in 2019
- Sales of ETF40B to equip nine South Korean LCACs almost certainly replaced by MT-7s
- Very few additional sales opportunities exist

Unit Production Forecast 2018-2027



Orientation

Description. Single- and twin-shaft axial-centrifugal-flow marine gas turbine engines with a power output for single machines in the 3- to 5-MW range.

Sponsor. Work on the initial industrial TF25/35/40 series was undertaken solely by the original prime contractor, Avco Lycoming.

Power Class. The power output of the Vericor Power Systems TF/ASE 40/50 gas turbine series ranges from 4,600 to 5,600 shp for marine power (see **Technical Data** section for performance parameters).

Status. In production.

Total Produced. More than 560 Vericor Power Systems TF25/30/40/50, ETF40B, and ASE 40/50 gas turbine series engines have been installed; of these, 109 are of the current production models.

Application. Marine propulsion/power.

Price Range. The marine power TF40 ranges in price from $1.1 to $1.2 million, and a TF80 installation (two TF40 machines coupled) is estimated to cost $2.6 million. The marine power ETF40B ranges in price from $1.65 to $1.85 million.

Competition. In the marine power arena, the TF40/ETF40B competes mainly against the Rolls-Royce MT-7.

Contractors

Prime

Vericor Power Systems Inc	http://www.vericor.com, 3625 Brookside Pkwy, Suite 500, Alpharetta, GA 30022 United States, Tel: + 1 (770) 569-8800, Fax: + 1 (770) 569-7524, Prime

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Subcontractor

American Air Filter International (AAF International)	http://www.aafintl.com, PO Box 35690, Louisville, KY 40232-5690 United States, Tel: + 1 (800) 477-1214, Fax: + 1 (502) 637-0321 (Intake Filter System & Evaporative Cooler)
BHS Getriebe GmbH, Voith	http://www.voith.com/de/produkte-leistungen/antriebstechnik/bhs-turbo-getriebe-20301.html, Hans-Boeckler-Strasse 7, Sonthofen, Germany, Tel: + 49 5132717700, Fax: + 49 5132710049 (Gearbox & Clutch)
Nippon-Seiki Co Ltd	http://www.nippon-seiki.co.jp, 2-34 Higashi-Zaoh, 2-chome Nagaoka-Shi, Nigata, Japan, Tel: + 81 258 24 3311, Fax: + 81 258 21 2151, Email: kikaku@nippon-seiki.co.jp (Main Shaft & Accessory Bearings)
Rexnord Corp, Coupling Division	http://www.rexnord.com, Main & Biddle St, PO Box 5491, Warren, PA 16365 United States, Tel: + 1 (814) 723-6600, Fax: + 1 (814) 726-1740 (High Performance Coupling)
Sumitomo Precision Products Co Ltd	http://www.spp.co.jp, 1-10, Fuso-cho, Amagasaki, Hyogo, Japan, Tel: + 81 6 6489 5936, Fax: + 81 6 6489 5889 (Oil Cooler & Fuel Pump)

Contractors are invited to submit updated information to Editor, International Contractors, Forecast International, 22 Commerce Road, Newtown, CT 06470, USA; rich.pettibone@forecast1.com

Technical Data

	Metric	U.S.
Specifications		
Length	1,321 mm	52 in
Width	889 mm	35 in
Height	1,046 mm	41 in
Weight	602 kg	1,325 lb
Performance		
Continuous power	3,700 kW	4,960 shp
Boost power	4,073 kW	5,460 shp
SFC at MCR	279 g/kWh	0.459 lb/shp-hr

Design Features. Typically, the TF series has two shafts, although the TC35 is a single-shaft design that was used for constant-speed electrical-generation applications. The two shafts are connected to form a single power output shaft. The TF35/TC35 units are no longer available.

Intake. Screened intake plenum leads to pitot-type intake.

Compressor. Seven-stage axial-flow compressor, followed by a single centrifugal stage. Pressure ratios are 6.5:1, 7.6:1, and 8.4:1 for the TF25, TF35, and TF40, respectively. The TF25 has fixed inlet guide vanes; the TF35 and TF40 have variable vanes. TF40 Stages 1 and 2 are designed for increased velocity airflow. Air mass flow is 22 to 29 lb/sec (9.98 to 13.15 kg/sec); design speed is 18,700 rpm. Inlet casing is 356-T6 cast aluminum and compressor casing is made of 355-T71 cast aluminum. Axial stage blades are AM-350 stainless steel; axial stator vanes are AM-321 stainless steel. Centrifugal compressor impeller is fabricated of Ti-6Al-4V. All discs are SAE 4340 low-alloy steel.

Combustor. Single, reverse-flow annular combustor. The TF35/40 has 28 fuel nozzles, and the TF25 has 14. It has a capacitive discharge ignition system with four spark igniters. Casing is AM350/355 stainless steel, and the liner is Hastelloy X. Turbine inlet temperature range is 1,775°F to 1,940°F (968°C to 1,060°C), depending on variant. The TF40B marine variant is capable of burning diesel, kerosene, or jet fuel.

Compressor Turbine. A two-stage axial turbine drives the machine. Stage 1 stator is cooled. Stage 1 turbine blades are Lycoming-developed C101 material; Stage 2 blades are MAR-M421. Stage 1 vane is X40; Stage 2 vanes are N-155. Discs are D979.

Power Turbine. All TF engines, as well as the ASE 40, utilize a two-stage mechanically independent (free-wheel) power turbine. The single-shaft TC35 is a constant-speed machine with coupled gas generator and power turbine shafts.

Blades are IN713C; discs are A286 steel. Output speed for the TF25 is 14,500 rpm; for the TF35/TF40/TF40B, it is 15,400 rpm (nominal 100 percent).

Control System. An electronic control unit provides a wide range of operating speeds as well as overspeed limiting.

Starting System. The gas turbine can be started using an electrohydraulic system, a hydraulic motor system, or an AC motor-driven starter pump.

Accessories. Integral lube system. Accessory drives are on the gearbox, which is located atop the inlet housing.

Operational Characteristics. Outwardly, the TF series engines appear similar, but their internal design differences produce units with a wide range of power and applications. The TF25 engine is based on the T55-L-7 turboshaft, and the TF35/40 uses the core of the later-model T55-L-11 series that powered Boeing Helicopter Company CH-47 helicopters (the T55-L-712 now powers CH-47Ds in U.S. Army service). Increased turbine cooling and variable inlet guide vanes are among the improvements incorporated into the later series. Increased turbine temperatures, achieved by means of improved high-temperature turbine materials, have raised the power level (maximum continuous power) of the TF40 to 4,000 shp.

Variants/Upgrades

TF25/25A. The TF25/25A version was derived from the Lycoming T55-L-7C aviation turboshaft engine. It has fixed inlet guide vanes, a compressor designed for subsonic airflow, and a single-stage compressor with solid steel blades; gaseous and liquid fuel systems are available. The series is rated at 2,500 shp normal (1,864 kW) and 3,000 shp (2,237 kW) at maximum power. Some in this series have been referred to as Super TF25 machines.

TC35. The TC35 is a single-shaft version of the TF35 designed for constant-speed applications – specifically, for powering electrical generation sets. This version has interconnected compressor and power turbines, burns either liquid or gaseous fuels, and has a base rating of 3,620 shp (2,700 kW) at 15°C. Peak rating is 3,667 shp (2,735 kW).

TF35. The TF35 was derived from the more advanced Lycoming T55-L-11 aviation turboshaft engine, which incorporated a redesign of the initial two compressor stages, as well as variable inlet guide vanes to accommodate transonic airflow. In addition, the compressor turbine has an additional stage with air-cooled Stage 1 blades and stator vanes. This machine is rated at 3,500 shp (2,610 kW) normal and 4,050 shp (3,020 kW) at maximum power. Some TF35s have been referred to as Super TF35 machines.

TF40. The TF40 is a marinized derivative of the Lycoming T55-L-11B and LTC4B-12 aviation engines. Although this uprated subseries was specifically developed for marine propulsion, it has been offered for industrial use (see the **Program Review** section). In marine duty, the engine features a wet sump, a top-mounted accessory drive, and a self-cooled, integral oil system.

ETF40B. The ETF40B (Enhanced TF40B) is an upgraded TF40B used on board the U.S. Navy's Landing Craft, Air Cushion (LCAC) vessels. The engine model generates in excess of 15 percent more power at maximum intermittent power while requiring only minor changes to the current installation. The ETF40B achieves its increased power and improved fuel efficiency through a redesign of the compressor and turbine sections. The compressor was redesigned to achieve higher flow and pressure rise; the turbine was optimized to match those improvements. The resulting maximum continuous power output (military output) of the ETF40B is 4,745 shp on a 100°F (37.8°C) day. The engine power increase allows the LCACs to perform in higher ambient temperatures.

Life-cycle costs will be further improved by additional changes to the ETF40B, such as the application of anti-corrosion coating on compressor blades and vanes and the addition of strengthened compressor discs and improved bearings and seals. Bleed air capacity has also been added to the engine for anti-icing.

Integral to the ETF40B configuration is the introduction of a Full Authority Digital Engine Control (FADEC) system to ease maintenance, increase diagnostic capabilities, and lower life-cycle costs. The FADEC interfaces with the LCAC's upgraded control and alarm monitoring system.

TF50. The TF50 is a growth version of the TF40 and provides about 5,100 shp for commercial marine applications. A new compressor and low-pressure turbine boost power and reduce fuel consumption by 9 percent. The TF50 offers an increase of about 600 hp compared with the TF40. The Swedish Navy's Visby class corvettes use four of these engines.

TF60B. The TF60B marine engine upgrades the ETF40B with new components, increasing power by more than 25 percent.

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The TF60B uses the ETF40B compressor, and incorporates state-of-the-art, fully marinized materials into the hot section, allowing for increased temperatures and improved corrosion resistance.

The TF60B has the same external dimensions and interfaces as the ETF40B, making it a drop-in replacement for ETF40B and TF40B engines. The weight of the TF60B is equivalent to that of the ETF40B, retaining its high power density characteristics.

TF80. The TF80 installation combines two TF40 marine turbines by bundling (or coupling) them to either a side-by-side or end-to-end combining reduction gearbox. The system can provide more than 7,790 shp at max continuous. Vericor claims the TF80 system can lower the overall weight of a vessel by as much as 100 tons.

TF100. The TF50 is also offered in a twin-bundle package, referred to as the TF100, which doubles the available output (particularly in high-speed ferry applications). Its power output for commercial use is 9,935 shp (7,409 kW) at max continuous.

Program Review

Background. The TF25/TF35/TF40 marine gas turbines are derivatives of the T55 aviation engine, which has been used worldwide – more than 5,300 aero engines have been delivered for helicopter applications, primarily for the military. Until Textron sold the Lycoming Division to AlliedSignal in May 1994, Textron Lycoming Division (formerly Avco Lycoming) was the prime contractor. Currently, the prime manufacturer is Vericor Power Systems, a joint venture company formed by Honeywell of the United States and MTU Aero Engines of Germany.

The TF40 family engines were early competitors in the marine gas turbine sector, competing against the Rolls-Royce Tyne and Proteus engines. All three gas turbine families gained some success in the 1970s and 1980s. The Tyne established a strong position as a cruise propulsion plant for surface combatants when paired with the more powerful Rolls-Royce Olympus as a boost turbine. The TF40 and Proteus were most successful as the powerplants for air cushion and other surface effect craft. They were also used as powerplants for fast attack craft and some civilian vessels.

Both Proteus and the TF40 family were impacted by the rapid escalation in fuel prices during the late 1970s and early 1980s and by the technical advances in supercharged and turbocharged diesel design. The former made the gas turbines very expensive to operate, while the latter offered a more cost-effective solution to providing smaller warships with the required power. The Proteus vanished from the market, and the TF40 family was relegated to obscurity.

This situation changed in June 1981, when the U.S. Navy selected Textron Marine Systems to design and produce a new LCAC vessel powered by four TF40Bs. The first production TF40B was delivered by then-Lycoming in September 1983, and the first LCAC was rolled out of the Halter facilities in May 1984. The first vessel from Avondale Gulfport Marine was delivered in November 1988. All 91 units were in service by the end of 1998.

This air cushion landing craft represented a significant advance in amphibious warfare capability. It quickly proved to be a versatile and successful design. Of 100 originally planned, 91 were completed, with four TF40 gas turbines each. This program returned Vericor Power Systems to the ranks of significant marine gas turbine suppliers.

The LCAC was a star performer in Operation Desert Storm and, subsequent to that campaign, the LCAC proved an ideal vehicle for delivering humanitarian aid to disaster areas. As a result, the LCACs were worked much harder than anticipated and heavy use began to reveal system shortcomings in a number of areas. This led to the formulation of a LCAC Service Life Extension Program (SLEP) that sought to extend the life of the LCACs by remedying hull and machinery deficiencies.

As part of the SLEP, Vericor Power Systems developed a new engine model, designated the Enhanced TF40B (ETF40B). It generates at least 15 percent more power at maximum intermittent power with only minor changes to the current installation. The newer model offers improved fuel efficiency and significantly less maintenance. In October 2001, Vericor Power Systems delivered the first hardware kits for conversion of the TF40B engines to the ETF40B configuration by the U.S. Navy. This SLEP was to continue throughout the early years of the 21st century. With the development of the LCAC-100 ship-shore connector, SLEPs of the older LCACs were terminated in 2016.

Non-U.S. Customers

The high public profile of the LCAC also attracted the interest of non-U.S. customers. Surprisingly, little of this interest translated into solid orders. Japan and South Korea were the only two countries that procured derivatives of the U.S. Navy LCAC for use by their navies.

Japan. Japan ordered six LCAC vessels that were somewhat smaller than the U.S. Navy original at 89.3 tons light and 167 tons fully loaded. One was authorized in JFY93, one in JFY95, two in JFY99, and two in JFY00. Each vessel has four TF40B gas turbines.

South Korea. In 2005, the South Korean Navy ordered two LSF-II class LCACs with many pronounced similarities to the U.S. Navy LCAC. Vericor supplied eight ETF40B gas turbines to power these initial two LSF-IIs, with each craft using four gas turbines rated at 4,745 hp. Deliveries began in 2006, with the LSF-IIs being commissioned in 2007. They were deployed on board the *Dokdo*, a new LHD that was the lead ship of a proposed class of four. A third LSF-II was ordered a year later. The Dokdo program was delayed for several years before restarting in 2012, and it is assumed that additional LSF-IIs will be ordered to equip the new LHDs.

Sweden. Sweden was an early user of gas turbine-powered fast attack craft, a trend that culminated in the procurement of five Visby class corvettes. These were powered by a CODOG arrangement using four TF50 turbines totaling 21,456 shp (16,000 kW) output, plus two MTU6V 2000 N90 diesels and two Kamewa 125 SII waterjets. The ships are quoted as having a top speed of more than 40 knots. These five vessels, laid down from December 1996 through December 1999, were highly problematic and did not enter service until 2012-2014.

Funding

U.S. Navy Procurement Funding. U.S. Navy funding for the Vericor ETF40B gas turbine is identified at $123 million in the U.S. Department of the Navy's FY15 budget estimates, submitted in March 2014. In those estimates, $60.34 million was requested for FY13 to 2019 under the LCAC SLEP "Propulsion Equipment" line for the ETF40B gas turbine. Of this amount, $14.4 million was budgeted for engine procurement in FY14. Significant funding for the SLEP itself will be provided through the duration of the forecast period. With the propensity of all mechanical devices to undergo wear and tear, some supplemental requirement for the replacement of military engines will likely exist.

Contracts/Orders & Options

Contractor	Award ($ millions)	Date/Description
Vericor Power Systems (USA)	N/A	May 2013 – To meet the FY13 requirements for marine gas turbines for the U.S. Navy's LCAC Service Life Extension Program, Vericor will deliver 16 engines and related hardware under the contract.
Vericor Power Systems (USA)	N/A	May 2012 – For the next tranche of marine gas turbines for the U.S. Navy's LCAC SLEP, Vericor will deliver 34 engines and related hardware under the contract.
Vericor Power Systems (USA)	N/A	Mar 2007 – International Coil Ltd signed an agreement to distribute Vericor's industrial gas turbine gensets in India.
Vericor Power Systems (USA)	N/A	Nov 2006 – Two center-boost packages to be provided for the Ferretti Group via Vericor's Italian distributor (Diesel Center) for installation on the Pershing 115 maxi yacht; packages include TF50 marine gas turbine rated at 4,176 kW (5,600 shp). Contract covers lightweight ZF main reduction gear and Vericor's new Integrated Boost Control, which combines engine, gear, and local operating panel controls into a single programmable logic controller.
Vericor Power Systems (USA)	28.48	Mar 2006 – FFP contract for the manufacture, testing, and delivery of 20 ETF40B marine gas turbine engines plus spares for the LCAC SLEP. Vericor's production partner was Standard Aero Energy in Winnipeg, Canada, the firm that was to perform the upgrades and conversions. Work under the contract was expected to be completed by Dec 2008. (N00024-06-D-4107)

N/A = Not Available

Vericor TF40 Marine

Timetable

Month	Year	Major Development
	1955	Initial production of Lycoming T55 engines
Jan	1969	SES contract awarded
	1970	TF40 selected for AALC (LCAC)
Late	1970	TC35 version announced
Mar	1971	Design and procurement of two JEFF craft
	1972	KHD orders four TF35s
	1973	Eight TF25s installed for NIOC in Iran
	1973	TC35 version available
	1974	TF40 selected for N500
Jun	1981	Contract awarded for LCAC engines
Early	1983	Production of TF40B begun
Nov	1983	First TF40Bs delivered for LCAC
Dec	1984	First LCAC delivered to U.S. Navy
	1998	Delivery of the last LCAC for the U.S. Navy
	1999	Megayacht *Detroit Eagle* launched, powered by TF50
Feb	2000	Vericor supplies DDC with a TF50 gas turbine for the *Detroit Eagle*
Jun	2000	First of Sweden's YS 2000 Visby class corvettes launched
1Q-2Q	2001	Finnish Navy's T2000 hovercraft launched
Feb	2001	Vericor offers its OnsitePower systems
Mar	2001	Vericor supplies Kockums with two TF50 GTs for Stockholm class
Oct	2001	Vericor begins supplying ETF40B kits to USN for LCAC upgrade effort
Nov	2001	Vericor signs TF40/TF50 marine engine agreement with MTU-F
Feb	2002	TF50 selected to power *Wally 118* Wally Power high-speed yacht
Jun	2002	MTU acquires full ownership of Vericor, which becomes a wholly owned subsidiary
May	2005	Vericor partners with Standard Aero for production, support
Feb	2007	U.S. Navy LCAC SLEP now includes 24 engines
May	2012	U.S. Navy LCAC SLEP adds 34 engines
May	2013	U.S. Navy LCAC SLEP adds 16 engines
	2016	Rolls-Royce MT-7 selected for LCAC-100
	2018	One further LCAC SLEP kit appropriated for FY19

Worldwide Distribution/Inventories

Japan. 24 TF40B on 6 LCAC-class landing craft

Korea. 12 ETF40B on 3 LCAC, and 36 planned for 9 LCAC

Sweden. 10 TF50 on 5 Visby class corvettes, and 2 TF50 on 2 Stockholm class corvettes

U.S. 364 TF40 on 91 LCAC-1 being replaced by 272 ETF40B under LCAC-1 SLEP

Forecast Rationale

The LCAC has had a long career with the U.S. Navy; however, its days are becoming numbered. The LCAC-100 (formerly known as the Ship-to-Shore Connector), the LCAC's replacement, has entered production and deliveries are to begin in FY18.

Despite the success of the TF40 line of gas turbines on the original LCAC, the new LCAC-100 relies on the Rolls-Royce MT-7 marine turbine. The Navy's choice of the MT-7 puts the future of the TF40 line of turbines at risk and sales may never recover.

The ETF40B, the enhanced TF40 variant, did extend the life of the TF40 significantly through the Service Life Extension Program (SLEP) for 68 of the original LCACs. The final SLEP kit was funded in 2019, and therefore the program, as far as the U.S. Navy is concerned, will have ended by then. Initial Operational Capability (IOC) of the LCAC-100 is projected for 2020.

There was a possibility that the TF40 line of turbines would be selected by the South Korean Navy. The LSF-II is a hovercraft with the same mission as the LCAC and a similar layout; however, it is likely that the South Koreans chose the MT-7.

It is more than probable that the end of the LCAC SLEP will spell the end of the TF40. There is always a possibility that a new application will bring the TF40 new life, but the aging technology of the design will give potential operators pause. This report reflects current LCAC SLEPs. Any new applications for the TF40 line will be reflected in FI's Platinum Forecast System.

Ten-Year Outlook

ESTIMATED CALENDAR YEAR UNIT PRODUCTION												
Designation or Program		High Confidence				Good Confidence			Speculative			
	Thru 2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	Total
Vericor Power Systems Inc												
TF40/ETF40B/TF50/TF60B <> North America <> Navy												
	130	8	0	8	0	0	0	0	0	0	0	16
Total	130	8	0	8	0	0	0	0	0	0	0	16