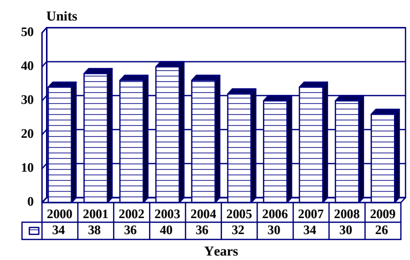
GE LM2500 - Archived 07/2001

Outlook

- The gas turbine most widely used on warships
- Enjoys strong political support in US
- Strong exports and good future potential for both the existing LM2500 and the new LM2500+ version
- Competing against Rolls-Royce WR-21 for future US Navy ICR applications

10 Year Unit Production Forecast
2000 - 2009



Orientation

Description. Twin-spool, axial-flow marine gas turbine engine in the 22-28 MW class (with STIG™). The LM2500+ is in the 29-31 MW (39,000-41,250 shp) power band.

Sponsor

US Navy
Naval Sea Systems Command (NAVSEA)
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Contractors

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USA

Licensees/Associates

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Hindustan Aeronautics Limited
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India

Ishikawajima-Harima Heavy Industries (IHI) Co Ltd
Tokyo
Japan

Kværner Eureka
Oslo
Norway

Nuovo Pignone SpA
Florence
Italy

Thomassen International bv
Rheden
The Netherlands

Status. In production and service.

Total Produced. An estimated 931 LM2500 marine powerplants had been built by early 2000.

Application. Marine propulsion system for all types of warship, fast passenger ferries and cruise ships.

Platform. Suitable naval platforms for this power band engine include aircraft carriers, air-capable ships, heavy and light cruisers, destroyers, frigates, support ships and attack craft. In civilian use, the LM2500 has been installed on fast ferries and luxury cruise ships.

Price Range. LM2500 turbine-based marine propulsion package, $9.5 to $10 million; LM2500+ marine propulsion package, $10.25 to $10.75 million (in 2000 US dollars).

Technical Data

	Metric	US
Characteristics		
Power Output:	24,310 kW	32,600 shp
SFC:	0.226 kg/kW-hr	0.372 lb/shp-hr
Heat Rate:	9680 kJ/kW-hr	6840 Btu/shp-hr
Exhaust Gas Flow:	69.85 kg/sec	154 lb/sec
EGT:	552°C	1026°F
Power Turbine Speed:	3,600 rpm	3,600 rpm
Dimensions		
Turbine Length:	6.6 m	21.4 ft
Turbine Length (LM2500+):	6.86 m	22.525 ft
Package Length (approx):	16.5 m	54.1 ft
Diameter, Maximum:	2.03 m	6.7 ft
Weight:	4,672 kg	10,300 lb
Weight (LM2500+):	5,035 kg	11,100 lb
Package Weight (approx):	140,000 kg	308,641 lb

Design Features. The GE Marine & Industrial Engines LM2500 is an axial-flow, gas generator/gas turbine engine designed to provide power for a wide variety of marine and industrial applications. Its development stems from a combination of the GE TF39 turbofan engine, which powers the Air Force C-5A/B, and the commercial CF6-6, which powers a number of commercial aircraft. The LM2500 is the product of a vast amount of GE's developmental energy, millions of hours of operation and wholesale US government support.

Design features of the LM2500 gas turbine include the following:

Inlet Section. Section consists of a bellmouth and bulletnose. The bellmouth contains a spray manifold for injecting liquid cleaning solutions into the compressor to remove fouling.

Compressor. Single rotor, variable-stator 16-stage axial flow with overall pressure ratio of about 17-18:1. A rotor, built up of three discs and three drums, and stators are fabricated from titanium and nickel-based alloys. Variable stators (Stages 1-6) are positioned by fuel pressure as a function of compressor-corrected speed and pressure ratio. Some of the compressed air is extracted for engine cooling; bleed air is also available for buyer's use from the compressor discharge. Materials are as follows: Stages 1-14 blades and Stages 1-2 vanes are Ti-6Al-4V; Stages 15-16 blades and Stages 3-16 vanes are A286. Stage 11-13 spool is of IN718. Compressor front frame is of 17-4 PH; rear frame is of IN718.

For the LM2500+, a zero stage (Stage 0) has been added to the compressor to increase compressor airflow by approximately 20 percent; it features wide-chord aeroengine-derived technology. Redesign of CF6-80C2/LM6000 Stage 1 blades to wide-chord configuration will also eliminate mid-span dampers. A CF6-80C2/LM6000 rotor airfoil design is being added to Stages 2-3. Other changes include a new inlet guide vane assembly.

Combustor. The combustor is annular and consists of four major components riveted together (cowl assembly, dome, inner skirt and outer skirt). It is fitted with 30 fuel nozzles in individual swirl chambers which may be removed externally. Walls are film-cooled by air introduced through small holes. Liners are Hastelloy X and Haynes 188 material; transition duct is IN718, Rene 41, and Hastelloy X. The ignition system consists of two ignition units which convert the 15-volt, 60-Hz power to high voltage, two high tension leads and two igniters. The ignition system is used only during starting and is turned off once the engine reaches idle speed.

High-Pressure Turbine. Two axial-flow stages drive the compressor spool. Both stages of the HP turbine blades are cooled by compressor discharge air which flows through the dovetail and through blade shanks into the blades. Stage 1 blades are cooled by internal convection and impingement and external film cooling. Stage 2 blades are cooled by convection, with all of the cooling air discharged at the blade tips.

Both stages of the HP turbine nozzle assemblies are convection and impingement air-cooled and are coated to improve the erosion, corrosion and oxidation resistance. Stage 1 nozzle is also film cooled. Materials are as follows: Stages 1-2 blades and Stage 2 vanes are investment cast of Rene 80; Stage 1 vanes are X-40. Casing is a combination of IN718, Rene 41, Hastelloy X and Haynes 188. A major component of the high-pressure turbine is the turbine midframe. It supports the aft end of the high pressure turbine rotor and the forward end of the power turbine rotor. This frame provides a smooth diffuser flow passage for high-pressure turbine discharge air into the power turbine.

For the LM2500+, HPT rotor and stator components are being redesigned to reduce maintenance costs, and will include new materials for improved oxidation resistance. Stage 1-2 contours are being optimized for higher flows.

Power Turbine. The power turbine, offered by GE and several distributors, consists of six discs and integral spacers. Blades of all six stages contain interlocking tip shrouds for low vibration levels and are retained in the discs by dovetails. Replaceable rotating seals, secured between the disc spacers, mate with stationary seals to prevent excessive gas leakage between stages.

The power turbine stator consists of two casing halves, stages 2-6 turbine nozzles, and six stages of blade shrouds. The first-stage nozzle is part of the turbine midframe assembly. Stages 2-3 nozzles have welded segments of six vanes each; Stages 4-6 nozzles have segments of six vanes each. Materials are as follows: Stages 1-3 vanes are investment cast Rene 77; Stages 4-6 are Rene 41. Casing is IN718, blades are Rene 77, and discs are IN718. The turbine rear frame forms the power turbine exhaust flow path and supports the aft end of the GE power turbine and forward end of the flexible coupling. It also contains a bearing housing for the No. 7 ball and No. 7 roller bearings. Bearings are provided by MPB Corp's Split Ball Bearings Division.

For the LM2500+, the power turbine is being redesigned for the higher power output. Stages 1 and 6 blades are being optimized for aerodynamic efficiency. The rotor is being strengthened for the higher torque and potential energy of the higher-rated machine model.

Accessory Drive Section. Consists of an inlet gearbox in the hub of the front frame, a radial drive shaft inside the six o'clock strut of the front frame, and a transfer gearbox bolted underneath the front frame. The starter, fuel pump and filter, main fuel control, lube and scavenge pumps, and the air/oil separator are mounted on the transfer gearbox.

Fuel & Control Systems. A combination centrifugal and positive displacement fuel pump, a high-pressure fuel filter, a fuel control, two fuel shut-off and drain valves, a fuel pressurizing valve, a fuel manifold and 30 duplex fuel nozzles. The fuel control system is a hydromechanical type that uses fuel as the servo fluid. The control is the bypass type in which the excess fuel flow is bypassed back to the high pressure pump. The bypass valve maintains a constant pressure differential across the fuel metering valve so that flow is directly proportional to the main valve opening. The control serves for generator speed, compressor discharge pressure, and compressor inlet temperature, and schedules both the steady state and transient fuel flow to maintain the set speed and prevent over-temperature or compressor stall during acceleration or deceleration. It does not control power turbine speed. Power turbine speed, for any setting of gas generator speed, will vary as a function of the load.

The fuel control also schedules the compressor variable stator vanes as a function of gas generator speed and compressor inlet air temperature to maintain compressor efficiency and stall margin at all operating speeds. Fuel and power control systems are provided by Woodward Governor.

Variants/Upgrades

Among the variants of the GE LM2500 are the following:

LM2500. Initial designation for the gas turbine/gas generator units, used for both marine and industrial applications.

LM2500-20. The LM2500-20 is an adaptation of the LM2500; it provides industrial, marine and offshore markets with improved fuel economy in applications requiring lower power ratings than the LM2500.

LM2500-30. Current designation of the standard LM2500 marine and industrial gas turbine. Power output was uprated in May 1993 from 26,250 shp (19 575 kW) to a US Navy-approved rating of 29,500 shp (21 998 kW) for surface combatants and 32,000 shp (23 862 kW) for the US Navy Sealift Program applications.

LM2500R. Designation of LM2500 machine used for marine applications and equipped with a recuperator mounted in the exhaust stack. Design features the combustor of the LM6000/CF6-80C2. HP turbine blades and vanes are redesigned to open the nozzle area by 10 percent, with variable area turbine nozzles installed in the power turbine in order to maintain high cycle temperature at partial power. Compressor rear frame and combustor casing are modified to provide air to and from the recuperator. A full-authority digital electronic controller (FADEC) with a fuel metering valve is also installed.

LM2500+. The LM2500+ (LM2500 Plus) is the newest machine in the LM2500 Series. It has a design offering of 29.08 MW for the 3600 rpm, six-stage-power-turbine model, and 29.98 MW for the 6100 rpm, two-stage-power-turbine model.

Single-Shanked Blade. GE recently began using advanced cooled turbine blades in the high-pressure turbine section. This development originated with the CF6-50 commercial aviation program. The new single-shanked blade with a cast-in cooling system permitted an increase from 27,500 shp to 29,500 shp with improved fuel specifics. This was accomplished by allowing turbine inlet temperatures to increase, but material temperatures have actually been reduced, thus increasing the life of the engine core.

The single-shank turbine blade has been operating in the US Navy's roll-on/roll-off ship MSTS *Admiral William M. Callaghan* for thousands of hours on its regular runs between Bayonne, New Jersey (USA), and Bremerhaven, Germany.

Low-BTU Development. GE Marine & Industrial Engines is involved with GE Schenectady in a joint effort on the burning of low-BTU fuels and also regenerative engines.

Uprating and Recuperating. In May 1993, GE officially announced the uprating of its LM2500 for marine applications, as well as the introduction of the LM2500R recuperated version of the engine. The uprating translates into a more than 3,000 shp increase for the LM2500. GE has only let slip a general mention of new cooling techniques and advanced materials usage intended for the uprating.

The uprating, according to methods and specifications defined by the US Navy, comes after some 800 hours of testing in which the engine was installed aboard MSTS *Callaghan*. The new ratings are 29,500 shp for US surface combatants and 32,000 shp for the US Navy's Sealift Program ships. In February 1994, GE received a $60 million order to power six US Navy Sealift vessels with the 32,000 shp LM2500.

The use of a recuperator on the LM2500 was developed by GE to enhance the part power efficiency of the engine at lower power levels (targeted below 10,000 bhp) at which naval vessels were found to operate 90 percent of the time. The development of a recuperated version of the engine also eliminates the cost – in time and money – of developing a new aero-derived engine aimed at comparable fuel savings.

The recuperator would be exhaust stack-mounted, and add 26,000 to 28,000 pounds (11 793 - 12 700 kg) to the installation. It can be supported by the deck above the engine room. The unit measures 150 x 120 x 54 (381 cm x 305 cm x 137 cm), and requires no change to the engine support structure. Changes to the engine would include a redesign of the high-pressure turbine blades and vanes to open the nozzle area by 10 percent, installation of variable area turbine nozzles in the power turbine to maintain high cycle temperature at partial power, modification to the compressor rear frame and combustor casing to provide air to and from the recuperator, and the installation of a FADEC controller with a fuel meter valve.

Program Review

Background. The US Navy's interest in gas turbine powerplants dates from the early 1960s when a series of designs for very fast ASW frigates were initiated. Designated Project Seahawk, these envisaged ships would be able to maintain a speed of 40 knots in a seaway in order to counter Russian submarines of similar speed. It quickly became apparent that Seahawk performance demands could only be met using conventional steam turbine powerplants if a very large hull were used. The alternatives were either to go to even higher temperatures and pressures (1,600 psi/1,200^{o} F), a move made undesirable by the reliability problems being experienced with existing 1,200 psi/950^{o} F steam turbine plants, or to adopt gas turbines.

The Seahawk project was abandoned, partly because of the costs of such high speeds and partly because the expected generation of very high speed submarines had not appeared (they materialized some years later in limited form as the Alfa class). The requirement for gas turbine powerplants remained though, due to the inherently better silencing characteristics of those engines.

LM2500 US Navy Applications. In response to the US Navy requirements, GE Marine & Industrial Engines designed the LM2500 as an axial-flow, gas turbine powerplant. Its development stemmed from a combination of the GE TF39 turbofan engine, which powers the Air Force C-5A/B, and the commercial CF6-6, which powers a number of commercial aircraft. The LM2500 is the product of a vast amount of GE's developmental energy, millions of hours of operation, and wholesale US government support.

The most numerous application of the LM2500 gas generator has been in marine propulsion. Among the marine applications of the LM2500 for the US Navy are the following:

Spruance Class Destroyers. The first volume production program for marine LM2500s occurred when the US Navy authorized construction of 31 8,040-ton Spruance class frigates by Ingalls Shipbuilding Corp in the early 1970s. Each ship is powered by four LM2500 gas turbine modules, providing a total of 86,000 shp in a COGAG mode for speeds of 33 knots. Initially aimed primarily at anti-submarine warfare, the Spruance class are being upgraded to improve their anti-aircraft capability for enhanced integration with Aegis ships when operating in battle groups.

In the late 1970s, the Shah of Iran ordered six vessels of this class, later reducing the total to four, due to cost escalation. The overthrow of the Shah's government led to the cancellation of the order, which the US Navy subsequently picked up. These four DDGs constitute the 8,300-ton Kidd class, similar to Spruance, but with armament oriented toward AAW and thus designated destroyers. A final, unprogrammed Spruance hull was authorized by Congress as an air-capable variant (originally designated DDH). Due to funding shortages, this ship was completed as a normal Spruance class frigate.

Oliver Hazard Perry Class Frigates. The second major application for GE's LM2500 marine gas turbine module came with the initiation of the Oliver Hazard Perry class guided missile frigates (FFGs), each using two LM2500s driving a single screw. This machinery arrangement was exactly half that of the Spruance class. The original procurement plan called for up to 60 ships, but shifting priorities scaled down FFG-7 requirements to 54 with the FY85 budget. The total was later reduced further to 51 vessels, all of which have been launched and commissioned.

Australia ordered six 4100-ton Oliver Hazard Perry FFG-7-class vessels (Adelaide class in Australia), all of which were built in the US and are currently in commission.

The Bazan shipyard in Ferrol, Spain, built six FFG 7-class ships (known as the Santa Maria class in Spain) for the Spanish Navy. These ships use two LM2500s, each driving a single shaft.

Boeing at one time designed a 235-241 ton hydrofoil fast attack craft, the PHM, in response to a projected need to meet US/NATO coastal/offshore defense missions. Germany and Italy were proponents of the idea, but withdrew their support due to hull technicalities and cost escalation. The US Navy ultimately had no assigned mission for the vessel; however, Congress authorized construction of five ships beyond the prototype. This six-ship squadron underwent a long-term operational evaluation at Key West, Florida. As a result of numerous operational deficiencies, they were not considered successful designs and the ships were withdrawn from service in 1994.

Following the cancellation of a dedicated nuclear-powered cruiser to mount the Aegis system, a derivative of the Spruance class was designed as a substitute. The 9,466-ton Ticonderoga class light cruisers used the proven hull and propulsion machinery of the Spruance class vessels: the heavier weight of this class is attributed to electronics and armament differences. The superstructure is modified to accommodate the AEGIS weapons system, which can counter high-density threats through long-range acquisition, multiple target tracking, special threat control, countermeasures, and a high track rate storage capacity. In addition, AEGIS can assume control of the weapons systems of accompanying ships in order to concentrate fleet defense. All 27 ships in the class were completed and commissioned by 1994.

As with the Spruance class vessels, the Ticonderoga class ships use four GE LM2500 marine gas turbines on two shafts, generating 86,000+ hp in COGAG mode.

Arleigh Burke Class Destroyers. In FY81, the US Navy requested funds to develop a new destroyer design in order to fulfill future mission requirements, as well as meet destroyer numerical needs in the Navy's planned 600-ship force level. Originally designated DDGX, the 8373-ton guided missile destroyer class is now called the DDG-51 Arleigh Burke class. A total of 28 ships were built under Flights I and II, each with slightly differing onboard systems fit. These ships were designed to supplement Ticonderoga class ships in the AAW role.

The lead ship was laid down in early 1987 by Bath Iron Works. By January 1996, 16 vessels had been commissioned out of a total of 35 ordered at that time. The series is now expected to total 57 units when complete (28 of Flights I and II, plus 29 of Flight IIA, whose main difference is the addition of a helicopter pad). All employ four LM2500s in a COGAG arrangement. Production continues at Bath Iron Works and Ingalls Shipbuilding at a rate of about two to three ships a year.

AOE 6 Class Fast Combat Support Ships. The Ships Characteristic Improvement Board also recommended that the 48,800 ton AOE-6 Supply class vessels be equipped with the LM2500 propulsion system, involving four LM2500s per vessel in a COGAG mode. One AOE-6 vessel was laid down in 1988. The last of these was authorized by Congress in FY92 and was commissioned into service in August '98.

Bob Hope Class Sealift Vessels. The LM2500 was also chosen as the powerplant for the two 62,650-ton Bob Hope class Sealift Vessels being built by Avondale Industries/National Steel & Shipbuilding Company. Each vessel will be powered by two LM2500+ gas turbines. As many as 12 Bob Hope class vessels could be procured. The seventh ship is expected to launch in October 2000, with commissioning to take place in July 2001.

Recent Activity. One of the latest developments of the LM2500 gas turbine involves the addition of an advanced cooled turbine blade for the high pressure turbine section. This development originated with the CF6-50 commercial aviation program. The new single-shanked blade with a cast-in cooling system permitted an increase from 27,500 shp to 29,500 shp with improved fuel specifics.

This increase was accomplished by allowing turbine inlet temperatures to increase; material temperatures have actually been reduced, thus increasing the life of the engine core. The single-shank turbine blade has been operating on a US Navy ship in cross-Atlantic traffic for thousands of hours.

As a result of experience with this installation, GE announced in May 1993 that the LM2500 was being uprated by more than 30,000 shp and that the new recuperated version of the turbine, the LM2500R, was available. The new power ratings are 29,500 shp for surface combatants and 32,000 shp for sealift ships. In February 1994, GE received an order for six shipsets of the uprated turbines to power new sealift ships.

Following a very long and complicated procurement history, the South Korean Navy ordered the first of its KDX class frigates in mid-1994. These ships will mount two LM2500 gas turbines each in a CODOG configuration. Although the scale of the KDX program had been disputed, the South Korean Navy has now confirmed plans to run the class to between 12 and 16 hulls.

An interesting use of the LM2500 was announced in 1994 when India considered redesigning the Russian Tarantul class fast attack craft. The existing Russian design uses a four-shaft layout powered by two cruise and two boost gas turbines. The Indian Navy considered replacing this with a three-shaft system in which the center shaft is powered by an LM2500 and the two outer shafts by MTU diesels. In both cases, the engines were to be built under license in India, the gas turbines by HAL and the diesels by Kirloskar. To date, nothing has come from these plans and the Tarantuls in Indian service continue to use their Russian gas turbine engines.

The Italian *Aquastrada*, the first gas turbine-powered fast ferry, began operations in the summer of 1993 powered by MTU-built LM2500s. Kvaerner Energy ordered two LM2500s and two LM1600s in August 1993 from GE Marine & Industrial for Stena AB's Highspeed Sea Service ferry. This is a truly large craft, accommodating 1,500 passengers and 375 cars at speeds of up to 40 knots, which is in service across the Irish Sea between Holyhead, Wales and Dublin Bay, Ireland. Obviously, the fast ferry offers the convenience of avoiding increasingly congested airports, and saves the time and hassle of dealing with rental cars. This market is expected to grow worldwide, but particularly among the many Southeast Asian islands, where cargo hauling applications also enter into the equation.

Another major development of the last few years is the first-ever installation of gas turbines on a cruise ship by Royal Caribbean. Although never to become large in terms of numbers, this sector is an expansion of the technology to a user base that values turbines' constant power production capability, low noise level and low vibration. Presumably, the hotel load of the ship has also played a significant role in the decision, since the turbine can be run to produce much-needed electricity for onboard applications, even though the traveling speed of the ship itself is not particularly high.

LM2500+ Program. In June 1994, GE M&IE announced the LM2500+ (LM2500 Plus) gas turbine machine, based on the LM2500 gas turbine machine/engine. The LM2500+ will be introduced at a rating in excess of 37,000 shp (27,608 MW), with a simple-cycle efficiency of 38.9 percent. Once sufficient experience has been accumulated on the new gas turbine, it will be uprated to its design rating of 39,000 shp (29.08 MW), and a thermal efficiency of 39.2 percent. Among the changes made to the LM2500 to create the LM2500+ are: the addition of a Stage 0 to the compressor, redesign of Stage 1 blades in the compressor, redesign of HPT rotor and stators, and a redesign of the power turbine. Other benefits of the new gas turbine include dual fuel capability (distillate and gas), rapid start-up and loading, variable speed operation, and excellent part load efficiency. The LM2500+ measures only 13.5

inches (343 mm) longer than the LM2500, and weighs only 800 pounds (363 kg) more.

The two-shaft machine is aimed at the industrial markets for mechanical drive, as well as direct-drive power generation applications in the 50 Hz and 60 Hz markets, with potential for marine propulsion use including fast ferry use. Emissions controls available from introduction of the LM2500+ will include water and steam injection using a standard combustor of the LM2500 Dry Low Emissions (DLE) combustion system. Operating on natural gas at the design point rating, the LM2500+'s expected hot section repair and overhaul intervals are 25,000 and 50,000 hours, respectively.

The first LM2500+ gas generator test using M&I's DLE combustion system configuration began in late 1995. A second engine test using the power turbine began in the first quarter of 1996.

WR-21 Replacement Speculation. The proposal to replace the LM2500 with the Westinghouse/ Rolls-Royce WR-21 in future construction was the subject of considerable controversy during 1995 and early 1996. This debate occurred at a time when technical development of the WR-21 meant that it no longer fitted the footprint of the older engine. The implication of these events is that the WR-21 will not replace existing LM2500 engines and that the LM2500R will be used for this role.

A truly major coup for GE has been the selection of the LM2500 for the US Navy's Sealift Program ships. In February 1994, GE received a $60 million order to power six US Navy sealift vessels with the 32,000 shp LM2500. At the same time, GE has developed a recuperation scheme for the LM2500. The use of a recuperator was developed to enhance the part power efficiency of the engine at lower power levels (targeted below 10,000 bhp) in which naval vessels were found to operate 90 percent of the time. The development of a recuperated version of the engine also eliminates the cost in time and money of developing a new aero-derived engine aimed at comparable fuel savings. This also answers the challenge of the Westinghouse/Rolls-Royce-RB211 family-derived ICR marine gas turbine engine.

Funding

Under the US Department of Defense annual Program Element Descriptor documentation covering ongoing RDT&E programs, the US Navy lists a program titled "Surface Ship and Submarine HM&E Advanced Technology," with element number 0603508N. Under this element is included program R2224, "Ship and Submarine Hull, Mechanical and Electrical (HM&E) Advanced Technology." At the moment, that program appears to be the only one that will continue into the future years; the other programs within that element were only budgeted for the current fiscal year (in FY00).

In general terms, this program element concerns the US Navy's future procurement of the LM2500 engines. When looking at future propulsion alternatives, the LM2500 is the chief competitor to the British Rolls-Royce RB-211, a gas turbine equipped with intercooled recuperator (ICR). Consequently, the US Navy's long-term future procurement of the GE LM2500 and its derivatives is tied to the results of that research and the related funding.

Recent and planned funding of this effort, as identified in the Department of Defense Budget Submission in early February 2000, is as follows:

US FUNDING

	FY99(Actual)		FY00(Est)		FY01(Est)		FY02(Est)	
	QTY	AMT	QTY	AMT	QTY	AMT	QTY	AMT
PE#0603508N								
R2224	-	33,557	-	38,889	-	37,432	-	38,261

All figures are in millions of FY00 US dollars. Totals shown are totals for the Project only; work includes engines other than just the LM2500.

Meanwhile, the US Navy continues to receive funding for the procurement of LM2500 gas turbines. In its FY98-99 Budget Request, the service sought funds under the category 1810N, Other Procurement, Navy, Ship Support Equipment, Ship Propulsion Equipment. The funding totals reported under the above-mentioned line item are in addition to LM2500s procured in each specific vessel program of the Navy.

As stated elsewhere, the bulk of the US Navy's future procurement of the LM2500 hinges on the decisions to be made on the propulsion system development, and the subsequent choices regarding the new DD-21 destroyer class.

With a number of still-experimental characteristics, that futuristic ship will have all-electric propulsion: one large-sized gas turbine will likely drive the ship's generator systems, providing the electricity needs for the propulsion, onboard systems and the hotel load of the ship. No direct line item is identifiable in the budget for the procurement of the LM2500 specifically.

Recent Contracts

Contractor	Award ($ Millions)	Date/Description
NAVSEA	60.0	*February 1994* — Turbine sets for six large sealift ships.
NAVSEA	0.522	*September 1994* — Contract for modification kits (N00024-94-C-4117).
Naval Surface Warfare Center	19.99	*December 1995* — Contract for four LM2500 Marine Gas Turbine Modules. This contract provides for purchases for the government of Turkey under the Foreign Military Sales program. The work was to have been completed by November 1996. (N65540-96-C-0006)
NAVSEA	N/A	*February 25, 1998* — Four LM2500s and two reduction gears for the DDG-80 Arleigh Burke class destroyer. (Total delivery for the series: 228 GTs and 114 gears.)
Japanese Maritime Self Defense Force	N/A	*March 16, 1998* — Contract for four LM2500s for two DD09 Murasame class destroyers, to launch in the year 2000.
Royal Caribbean International	N/A	*May 12, 1998* — Contract for up to 12 LM2500+s to Celebrity Cruises' cruise ships in a COGES configuration.
Bazan	N/A	*Summer 1998* — Eight LM2500s for the upcoming F-100 class frigates, with deliveries ranging from 1998-2002 (two engines each ship).
Japanese Maritime Self Defense Force	N/A	*January 29, 1999* — Four engines for two DD10 Murasame class destroyers, to launch in 2001 (commissioning in 2003).
Royal Caribbean International	N/A	*February 1999* — Option for three more LM2500+s for cruise ship installation exercised.
Kværner Energy	N/A	*Early 1999* — Two LM2500s to be installed on a fast ferry being built by Austal Ships in Australia for operation between Sweden and Denmark.
SNCF	N/A	*Early 1999* — Two LM2500+s to MTU, for fast ferry *Corsaire13000.*
German Navy	N/A	*Spring 1999* — Three LM2500s to MTU, for powering the F124 class.
Korean Navy	N/A	*Summer 1999* — Six LM2500s for three KDX-2 destroyers in CODOG.
Holland America Line	N/A	*February, 2000* — Third and fourth cruise ship ordered from Fincantieri, powered by LM2500 (option for one more ship exists).

Timetable

Month	Year	Major Development
	1967-69	Design/development of LM2500 begins
1Q	1969	US Navy contract awarded for LM2500 test units
Dec	1969	Marine engine installed in MSTS *Callaghan* ship
Jan	1971	GE awarded DD-963 propulsion contract
Jul	1975	LM2500 powers first USN combatant (DD-963)
	1977	LM2500 powers first non-US navy ship (Italy)
	1979	First LM2500 power generation application
	1980	LM2500 reaches 1 million operating hours
	1982	LM2500 uprating announced
	1983	Uprated LM2500 becomes available ("single-shank" configuration)
Jul	1990	Fiat-built LM2500 ordered by Argentina
	1991	LM2500 powers DDG-51 Arleigh Burke destroyer. First fast ferry application
May	1993	Uprated LM2500 announced (29,500 hp)
	1994	LM2500 reaches 18 million operating hours. LM2500+ introduced
Feb	1994	Uprated LM2500 ordered for US Navy Sealift Ships
	1995	LM2500 with DLE operational. 2000th LM delivered. LM2500 surpasses 24 million operating hours
4Q	1995	First LM2500+ gas generator test
Jun	1996	First LM2500+ for power generation ordered
	1997	First LM2500+ machines for all applications delivered
	1998	LM2500+ DLE enters commercial service
May	1998	First-ever cruise ship contract for gas turbines, involving up to 12 LM2500+s
Early	1999	First naval application in CODAG configuration (Germany's F124 class frigates)
Thru	2009	Continued production of LM2500 machines projected

Worldwide Distribution

International Naval Applications of LM2500. Beyond use by the US Navy, LM2500s provide power to surface vessels of navies of at least 20 other nations. The nations include the following, with all listings to include vessels laid down, planned or likely to be procured as of the start of 1995. As used below, the code GT means LM2500 Gas Turbine Machines in Each Ship (for additional information, see *Gas Turbine Forecast*'s Appendix V in Book II):

Australia (6x Adelaide/Oliver Hazard Perry US FFG 7 Class Guided Missile Frigates (2 GT); 3 (+7)x ANZAC (MEKO 200 Variant) Class Frigates (1 GT))

Bahrain (1x Oliver Hazard Perry Class Guided Missile Frigate (2 GT))

Brazil (4 (+1)x Inhauma Class Patrol Frigates/Corvettes (1 GT))

Canada (12x Halifax Class Frigates (2 GT)); 4x Iroquois/DDH 280 Class Destroyers (2 GT)

China (2 (+?)x Luhu/Type 053HT Class Guided Missile Destroyers (2 GT); 2x Luda II Class/Type 052 Class Guided Missile Destroyers (2 GT))

Denmark (3x Nils Juel/Type KV 72 Class Frigates/Corvettes (1 GT))

Germany (4x Brandenburg/Type 123 Class Frigates (2 GT); 8x Bremen/Type 122 Class Guided Missile Frigates (2 GT))

Greece (4x Hydra/MEKO 200 HN Class Frigates (2 GT))

India (1x Delhi Class Frigate/Fast Attack Craft (2 GT) (HAL/GE LM2500s); 5 (+2)x Veer (USSR Tarantul I-style) Class Indian-built Corvettes (1 GT) (HAL/GE LM2500))

Indonesia (4x Dagger (PSK Mk 5) Class Guided Missile Patrol Boats/Fast Attack Craft (1 GT))

Israel (3x Sa'ar V/Eilat Class Guided Missile Corvettes (1 GT))

Italy (1x Garibaldi Class Light Aircraft/Helicopter Carrier (4 GT) (Fiat/GE2500s); 2x de la Penne Class Guided Missile Destroyers (2 GT) (Fiat/GE LM2500s); 8x Maestrale Class Guided Missile Frigates (2 GT) (Fiat/GE LM2500s); 4x Lupo Class Guided Missile Frigates (2 GT) (Fiat/GE LM2500s); 4x Artigliere Class Frigates (2 GT) (Fiat/GE LM2500s))

Japan (4x Kongo Class AEGIS Destroyers (4 GT) (IHI/GE LM2500s); 2 (+7?)x Murasame Class Guided Missile Destroyers (2 GT) (IHI/GE LM2500s); 1x Amatsukaze Class Guided Missile Destroyer (2 GT) (IHI/GE LM2500))

New Zealand (1 (+1)x ANZAC (MEKO 200 Variant) Class Frigate (1 GT))

Peru (4x Meliton Carvajal (Lupo) Class Guided Missile Frigates (2 GT))

Portugal (3x Vasco da Gama (MEKO 200) Class Frigates (2 GT))

Republic of Korea (2 (+8?)x KDX-2000 Class Frigate (2 GT); 9x Ulsan Class Frigates (2 GT); 23x Po Hang Class Corvettes (1 GT); 1x Han Kang Class Coast Guard Patrol Ship (1 GT); 4x Dong Hae Class Corvettes (1 GT))

Saudi Arabia (4x Badr (US PCG) Class Guided Missile Destroyers (1 GT); 9x Al Siddiq (US PGG) Class Fast Attack/Guided Missile Patrol Boats (1 GT))

Spain (0(+4)x 5800-ton F-100 AEGIS Frigates (2 GT); 6x Santa Maria (Oliver Hazard Perry) Class Guided Missile Frigates (2 GT))

Taiwan (1(+?)x Tien Tan (Kwang Hua Project, Flight II) Class Guided Missile Frigates (2 GT); 7x Cheng Kung (Kwang Hua Project, Flight I) Class Guided Missile Frigate (2 GT))

Thailand (1x *Chakkrinaruebet* Helicopter Carrier (2 GT); 2x Naresuan Class (Type 25T) Guided Missile Frigates (2 GT))

Turkey (3 (+1)x Barbaros Class (MEKO 200TN, Track II) Guided Missile Frigates (2 GT))

Venezuela (6x Modified Lupo Class Guided Missile Frigates (2 GT))

International Commercial Applications. Beyond use by the navies of the US and numerous foreign countries, LM2500s provide power to such commercial surface vessels as the following:

Italy (2 (+?)x 223,5-tonne 101,75-meter Rodriguez Cantieri Navali Aquastrada Class Car Ferry (1 GT) (Fiat/MTU/GE LM2500s; 2 (+?)x Fincantieri Cantieri Navali Italiani MDV 3000 High-Speed Fast Ferry (1 GT) (Fiat/GE LM2500); 1x Societa Ezercizio Cantieri SEC750 Fast Ferry (2(?) GT) (Fiat/MTU/GE LM2500s))

Sweden (0 (+1) (+1?)x 124-meter Finnyards HSS High-Speed Catamaran-Ferry (2 GT) (2 Kvaerner Energy/GE LM2500s) (also uses 2 Kvaerner/GE LM1600s))

Forecast Rationale

The largest and most active market for the LM2500 is still in marine propulsion. While the US Navy's CG-47 cruiser production program is already complete, the DDG-51 destroyer program will continue for a another few years at a rate of two to three ships per year, bringing the grand total probably to 57. After that, the all-electric DD-21 will pick up some of the market in the US Navy, although the number of turbines per ship – if GE wins the contract – will be probably just one each, and that could be of a smaller size (a different engine). Meanwhile, the Bob Hope class continues to be built, with ship number seven coming into service in the summer of 2001. Proposals have been made to build an LHD-8, another of the Wasp class amphibious assault ships, but this one will be powered by a gas turbine instead of the steam engine as is the case with the class right now.

A new multifunction auxiliary ship, the ADC(X), is expected to have four gas turbines per ship, and will be somewhat similar in size and function to the AOE-6 Supply class, which is the most recent equivalent in this general category of the US Navy fleet.

Internationally, several navies continue to order LM2500s. After Europe, some of the strongest markets exist in Asia, where Korea has specified the LM2500 for its new KDX/KDX-2/KDX-3 destroyer program. In Japan, IHI continues to supply these engines to the Japanese Navy for the Murasame class destroyers they are still funding. The total number of those ships now appears to have gone up to a dozen. In 1999, rumors that Japan was also planning for an all-new class of major destroyers emerged, but for the moment this need might be covered by an addition of a fifth Kongo class destroyer. Those downsized Aegis-capability ships, modeled after the USN DDG-51 class, also feature four LM2500 each.

It is the international fast ferry market, however, that currently holds the most promise for future sales as the popularity of this type increases. Some of the most recent references in this field include the third and fourth units of the Tirrenia Lines' fleet (built by Fincantieri), and the French *Corsaire 13000* monohull, which is being built by Alstom Leroux Naval on contract for SNOM.

The new LM2500+ (LM2500 "Plus"), introduced only recently to a market that had been expecting a slowdown for the LM2500 line in general, offers 20 to 25 percent more power than its venerable parent. Working relationships have been established with Nuovo Pignone, and S&S quickly placed the launch order for the machine. Unquestionably, the LM2500+ is GE's answer to the likes of the Westinghouse/ Rolls-Royce WR-21, definitely in the marine arena, but also in the power generation/cogeneration and mechanical drives (pipeline and process industries) arena. The LM2500+ is a mere 800 pounds heavier than the LM2500 and only 1.125 feet longer, leading many industry analysts to feel that the machine already has a built-in customer base in current LM2500 users.

The ferry sector sees heavy competition in turbines from the other OEMs, with Solar, Rolls-Royce and Vericor all looking to penetrate a market that otherwise would have been a 'natural' for diesel engines. The power-to-weight ratio of gas turbines and an apparent shift in attitude, one that is beginning to see turbines as a technology that is ripe for mainstream use, strengthen the hands of engine makers aiming to please ships' operators whose main interest is speed.

In the decade extending through the year 2009, production of the GE-design machine by GE and its Associates and Licensees, to meet current and projected orders for the LM2500 and LM2500+, is projected to be an estimated 336 machines and modules. The breakdown between the LM2500 and LM2500+ is not given below, and, according to estimates from both the users and first-tier suppliers, the entry of one model does not necessarily mean the exit of another. Thanks to their relatively different power bands, both the LM2500 and LM2500+ are instead expected to coexist at least for a while, catering to slightly different sub-segments in this market.

Ten-Year Outlook

ESTIMATED CALENDAR YEAR PRODUCTION

			High Confidence Level			Good Confidence Level			Speculative			
Designation	**Application**	**Thru 99**	**00**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**Total 00-09**
LM2500	CVH/CL/DD/FF (VARIOUS)	931	34	38	36	40	36	32	30	34	30	26	336