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France's SNECMA: Tough, New Competitor in Advanced Propulsion Systems

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A Research Paper

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France's SNECMA: Tough, New Competitor in Advanced Propulsion Systems [redacted] 25X1

A Research Paper

This paper was prepared by [redacted] 25X1
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contributions from [redacted] 25X1
[redacted] Office of Leadership 25X1
Analysis. Comments and queries are welcome and may be directed to the Chief, Technology and Industrial Competitiveness Division, OGI, [redacted] 25X1
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France's SNECMA: Tough, New Competitor in Advanced Propulsion Systems

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Summary

Information available as of 31 January 1987 was used in this report.

The French consortium, SNECMA (Societe Nationale d'Etude et de Construction de Moteurs d'Aviation), is emerging as a world-class competitor in the high-stakes big jet-engine market. On the basis of SNECMA's current order backlog for commercial and military engines, we believe SNECMA will overtake Rolls-Royce in annual revenues by the early 1990s and become third in sales behind the industry's leaders, General Electric (GE) and Pratt and Whitney. SNECMA's success in the demand-driven and maturing market for jet engines, built on French Government support and runaway sales of the CFM56 joint engine program with GE, has enabled the engine combine to build some of the largest and most modern production facilities in the industry and to sharply accelerate advanced propulsion research. We believe the combination of funds, facilities, and research will result in:

- A near-term increase in SNECMA's market share from 8 percent in 1986 to about 12 percent in the 1990s.
- A means for Third World customers to acquire high-performance military engines without US end-use constraints.
- The possibility, further over the horizon, of joining a regional jet-engine combine that could be a more formidable challenge to US engine-export leadership in the late 1990s. 25X1

SNECMA's increasing market share, taken mostly from the US leaders, comes primarily from sales of jointly developed commercial engines, augmented by a smaller, but relatively steady, flow of revenues from new military engine programs, especially the M88. On the commercial side, the CFM56, with more than 1,400 engines built and 2,600 on order, will late in this decade reach peak production rates and annual sales and remain high into the mid-1990s. In addition, SNECMA has a 35-percent share of a promising new joint effort with GE for development of the unducted fan engine (UDF) for commercial transports in the 1990s. As with the CFM program, the United States will benefit from access to foreign capital, but such a collaborative effort will inevitably result in some further decline in US market share—some 60 percent in the late 1990s, as compared with the current level of about 70 percent. 25X1

On the military front, SNECMA's fortunes are riding on the M88, a high-performance engine under development for France's next generation of tactical fighters. Although performance specifications are lower than those of US fighter engines projected for the early 1990s, we believe the M88

[redacted]

will be an attractive option for many Third World customers wishing to avoid US end-use constraints. As a case in point, Yugoslavia is considering the M88 as a possibility for its indigenously developed Novi Avion fighter. [redacted]

We believe SNECMA continues to rely primarily on joint ventures to acquire leading-edge technology and marketing expertise (with minimum investment and early sales payoff). If the joint program with GE for the UDF fails to materialize and other alternative joint programs are not forthcoming, SNECMA could turn to formation of a regional combine, involving a partnership with Rolls-Royce and the participation of second-tier engine companies in Western Europe and Japan. We believe the pooling of resources by SNECMA (aerodynamics and manufacturing), Rolls-Royce (hot-section design), West Germany's MTU (single-crystal turbine blades), and Italy's Fiat (gearboxes) would produce a formidable challenge to US commercial and military engine leadership. A linkup with Japan's Ishikawajima-Harima for manufacturing expertise and Far East market access would add to this potential threat to US aerospace exports. [redacted]

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Scope Note

This Research Paper is part of a broad Directorate of Intelligence analytical effort to assess the impact of foreign aircraft programs on the US industry and our mobilization base. France's SNECMA, one of the world's leading jet-engine builders, plays a key role in a variety of major military and commercial propulsion programs. SNECMA's capabilities will be a key determinant of performance of next-generation European (particularly French) military aircraft. 25X1

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France's SNECMA: Tough, New Competitor in Advanced Propulsion Systems

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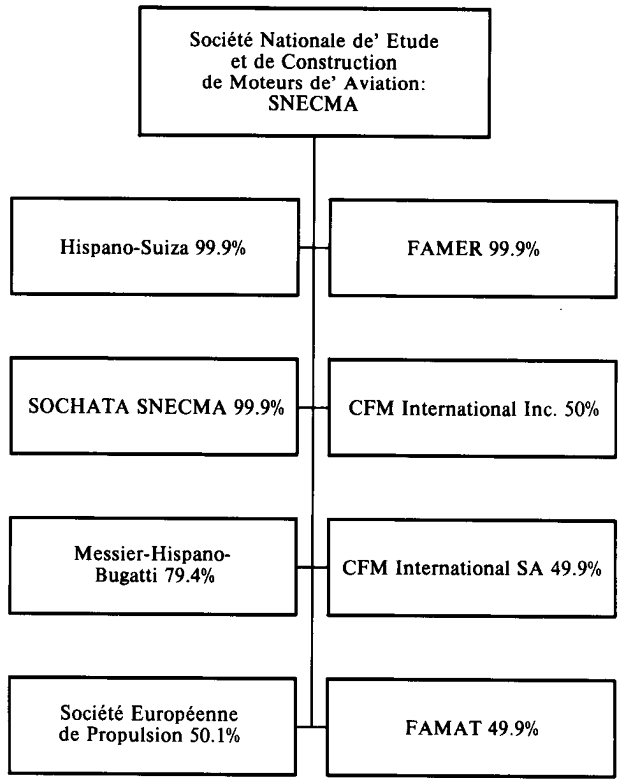
Growing International Competitor

The Societe Nationale d'Etude et de Construction de Moteurs d'Aviation (SNECMA) is substantially expanding its operations and broadening its technological base for the design and manufacture of large jet engines for commercial and military aircraft. SNECMA has, in recent years, become the only Western aeroengine company that can begin to be ranked with the Big Three—General Electric (GE) and United Technologies Pratt and Whitney of the United States and Rolls-Royce of the United Kingdom—beginning in the 1990s. The goal of this predominantly French Government-owned company is to become an increasingly more important competitor in this prestigious high-valued sector of the aerospace industry and capture a growing share of the $100 billion market in the next 10 years for big jet engines. 25X1

SNECMA has become an integral part of the French economy and military. It employs, in combination with its major subsidiaries, about 26,000 people (see figure 1). A broader network of subcontractors includes 3,000 suppliers that employ as many people as SNECMA itself. After reporting losses in the early 1980s because of a downturn in both military and commercial aircraft sales, SNECMA has doubled its revenues in the past four years and is profitable again. Revenues in 1985 reached some $1.1 billion, with exports accounting for more than 65 percent of total sales. The surge is primarily attributable to increased commercial sales. On the basis of our discussions with French corporate officials and preliminary financial reports, sales increased another 15 to 20 percent in 1986. 25X1

Figure 1
The SNECMA Group
Selected Operating Components and Subsidiaries, Summer 1986



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SNECMA has also been instrumental in fulfilling the requirements of the French air force and in maintaining its influential position as a major military aircraft exporter. Most experts agree that a country's military aircraft industry is best served by producing its own engines. There is a mix of benefits in marrying the independent development of engines with the design of aircraft. The most important benefit is the ability of the development teams to cooperate on the early stages of a new aircraft program. This pattern was followed with the Mirage fighter series and the Atar and M53 engines. Another key benefit is complete control over the question of exports. 25X1

Role of the Government

French Government support—financial and marketing—underpin the design, research and development, and manufacture of a wide range of commercial and military jet-engine programs. The French Government owns some 92 percent of SNECMA and occupies seats on the firm's board of directors. The dynamic and technically knowledgeable Jacques Benichou is Chairman and Chief Executive Officer. Although the firm is under the control of the Minister of Defense, we believe it operates on a nominally independent basis in most day-to-day activities. [redacted] 25X1

[redacted] we estimate that SNECMA has received over $1.1 billion in government capital infusions and loans in the last decade to support expanded research and to modernize facilities for the development of commercial engines. Approximately 25 percent of these facilities are currently allocated to military production. [redacted] 25X1 25X1 25X1

The CFM56 program, a joint commercial venture with GE, spawned most of the up-front government investment. A total of $700 million from the government was spent over a nine-year period for new manufacturing and test facilities to provide for increases in production. [redacted] The company will have no liability if the program loses money, but will pay back the loan if the program is eventually profitable. [redacted] the nature of these commercial loans—without interest and reimbursable on a successful program by royalties on sales—made them equivalent to SNECMA's own capital. [redacted]

We believe continued government investment will determine the extent of SNECMA's role in the aeroengine industry in the 1990s. When SNECMA's sales slumped in the past, government officials have been willing to continue capital investment and to allow accounting changes to mask the extent of losses. Benichou received an additional $150 million in capital during 1986 to support the new derivatives of the

Jacques Benichou: SNECMA Chairman

In 1982 Jacques Benichou was selected by the French Government to be Chairman of the Board and Chief Executive Officer of Societe National d'Etude et de Construction de Moteurs d'Aviation (SNECMA). His impressive technical background coupled with a career of varying disciplines have led him to revolutionize the French aeroengine industry from a predominantly military engine producer to a military/commercial mix. [redacted]

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CFM56 program. In addition, we believe France is funding approximately $300 million of the estimated $1.1 billion necessary for development of the new unducted fan engine (UDF), another joint commercial program with GE. [redacted]

On the marketing front, SNECMA's military and commercial sales also benefit from extensive French Government support. The French Government, for example, traditionally pushes military aircraft exports and influences commercial aircraft sales of Airbus Industrie that incorporate SNECMA-built engines, or those assembled by SNECMA, with political pressure and inducements:

[redacted]

[redacted] that, in the recent Mirage 2000 deal with Greece, 60 percent of the purchase will be covered by offsets, including Greek assembly and mounting of the M53 engines.

- In the recent Boeing-Airbus competition for All Nippon Airways of Japan, [redacted] the United States and Western Europe reported numerous incidents of political pressure—including letters from European heads of state—to help sell Airbus A300-600s that are equipped with SNECMA-assembled CF6 engines. [redacted]

Through the Ministry of Defense, the government exerts considerable control in key decisions of the company. Benichou, for example, was selected by former Defense Minister Hernu, in part because of his support of the decision to develop a derivative CFM56 engine for the Airbus A320. Other government management control includes selection of corporate officers, including the board of directors. Government involvement in program decisions, [redacted] was underscored by the denial by the French Government of a unilateral program launch of the CFM56-5 until GE joined the program. [redacted]

Technological Capabilities and Resources

We believe that SNECMA's overall technological capabilities and program accomplishments currently lag its US counterparts and Rolls-Royce by some 25X1 seven years but that the firm is moving on several fronts to narrow the gap (see table 1). While SNECMA has made progress in recent years in aerodynamics, metallurgy, and engine production, it continues to have technical deficiencies in hot-section technology and in basic research. SNECMA has a proven capability in producing military engines for its current fighter designs. For the future, we believe it is capable of nearing the optimistic goals of the new M88, an engine that should be competitive with today's existing US fighter engines. On the commercial side—driven by differing operational requirements—we believe SNECMA would have to add to 25X1 its technological capabilities before it could indigenously develop a competitive engine. [redacted] 25X1

In military engine capability, US industry experts believe, and we concur, that the current generation of 25X1 SNECMA-designed propulsion for French fighters significantly trails their US counterparts in the key indicator of military-engine performance thrust-to-weight ratio (or minimum engine weight for a given thrust). Specifically, we believe the lag to be some seven to eight years on a continuum to the current generation of engines. [redacted] 25X1 25X1 [redacted] 25X1 We believe part of the lag may stem from the fact that SNECMA has not been pushed to significantly upgrade past engine programs. 25X1 While the Atar engine and its derivatives, for example, sufficed for the early Mirage fighters, we believe the combine could have come out with a better performing engine. [redacted] 25X1

Although SNECMA has the ability to produce fighter aircraft engines, we do not believe that it currently has the capability to design the highly sophisticated large turbofans for today's commercial passenger aircraft. SNECMA lacks the long-range, basic re- 25X1 search indispensable to gaining the experience and 25X1

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Table 1
SNECMA Engines:
Technology and Selected Programs, Summer 1986

Engine	First Production	Aircraft	Technology Highlights	Remarks
M88	In development	ECA (fighter)	Mark I First SNECMA twin spool engine Compressor equivalent to US F404 of 1970s vintage Turbine temperature of 2,500°F demonstrated with blades similar to F404 Thrust/weight of demonstrator equivalent to US F404	This engine was entirely French-designed and initially developed for fighters of the 1990s. The funding is evenly split between SNECMA and the French Government. This version of the M88 was intended for an aircraft related to the European Combat Aircraft (ECA) that preceded the European Fighter Aircraft (EFA). It is similar in configuration and performance to the US F404 developed in the mid-1970s.
		ACT (fighter)	Mark II Improved combustor capable of turbine inlet temperature around 2,900°F Thrust/weight target is between 9.5:1 and 10:1	This version of the M88 is to power the Rafale B demonstrator in 1989 and possibly the tactical combat aircraft (ACT) later. The design came from the program started in 1984 when the EFA project was lauched with the Mark I. The majority of the funding for this version of the M88 is borne by SNECMA. Testing of engine components is under way and the complete engine should run in 1988.
M53	1980	Mirage (fighter)	Single-shaft turbofan derivative of Atar Compressor and turbine technology lagged US 10 years First electronic fuel control—10 years after US	The M53 first ran in 1973 and was targeted as "the engine for the 1980s." Production of the engine is expected to reach 1,000 to 1,200 with more than half used by the French air force. It and the Atar are the only all-French engines to reach series production.
CFM56	1979	DC8, 737, A320 (commercial transports) KC135 (military tanker)	High bypass, twin spool turbofan SNECMA designed and manufactured fan, fan turbine, and gearbox CFM56-5 will be equipped with a full authority digital electronic control Lower in technology than V2500 after 1988; 5% to 8% lower performance than 1990s V2500 engine	This design is the state-of-the-art commercial engine of the 1980s that has over 8 million hours in revenue service. The design allowed for large margins and growth in thrust and efficiency. It permits maximum flexibility by having modular construction. [redacted]
LARZAC	1977	Alpha jet (trainer/fighter)	Simple, small turbofan Component technology does not push state of the art Modular construction with low maintenance costs	Originally designed for the commerical market before being adopted as a military trainer, it is built as a joint venture with the French firm Turbomeca and first ran in 1972. The West German companies MTU and Klockner-Humboldt-Deutz have played a part in prototype manufacture and test and are sharing in production. Over 1,100 have been sold.
Atar	1950	Mirage (fighter)	Simple, single spool turboject Compressor and turbine equivalent to 1950s Western engines Simple design for maintenance plan in LDCs	This design established the French reputation for underpowered fighters and lagged US and UK technology by some five to 10 years. It is the bedrock of the SNECMA engine programs, with [redacted]

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[redacted]

knowledge that is necessary to design a new commercial engine. Research of this nature involves a continuous program of redesigning and testing component parts of a given engine, and then complete engine testing to achieve overall performance improvements. The M88, for example, can be considered a direct extrapolation from the experience gained on the M53 project. [redacted]

SNECMA's experience in commercial engines to date is limited to joint ventures—the Concorde's Olympus and the CFM56 family of engines. On the Olympus project with Rolls-Royce, SNECMA's 40-percent share included only lower technology components: the exhaust nozzle, thrust reverser, and afterburner system. In the CFM56 engine, SNECMA designed the fan, fan turbine, and gearbox—parts that do not require extensive technological expertise. [redacted] 25X1

[redacted] 25X1 25X1

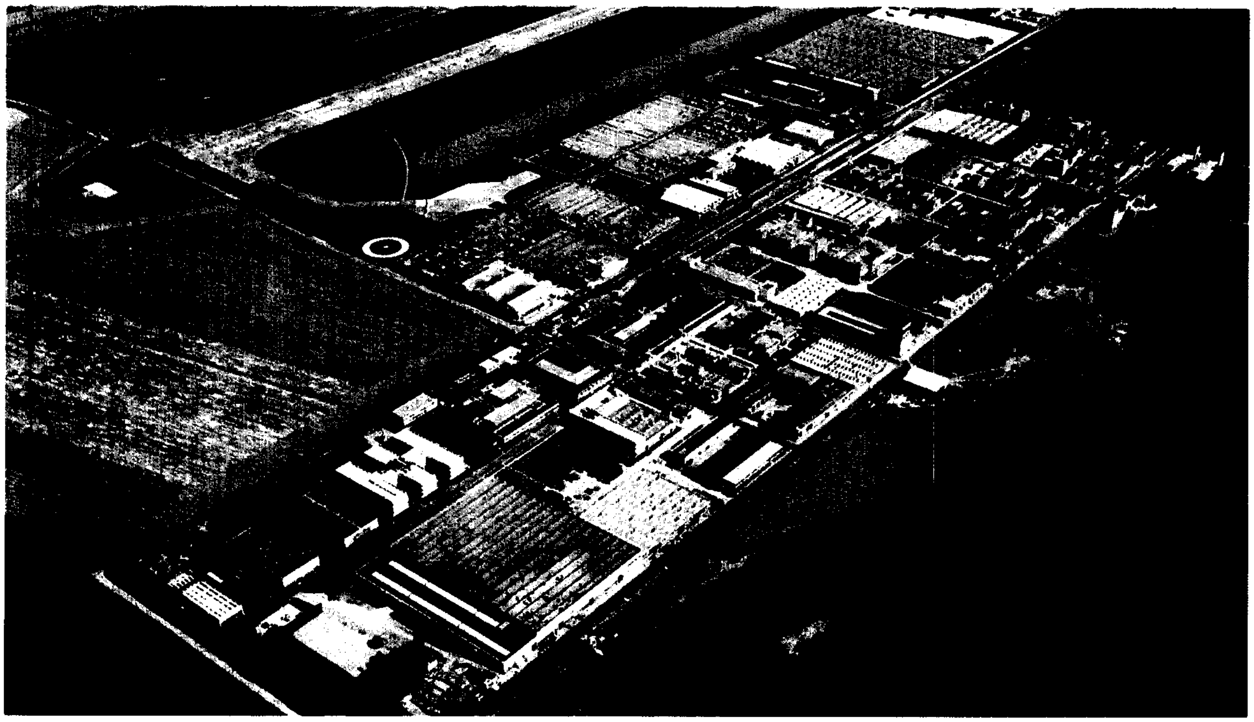
Research, Design, and Development

[redacted] SNECMA, despite current gaps in capabilities, is the only European company other than Rolls-Royce with overall large-engine design capability, albeit behind state of the art. On the research and design front, SNECMA has some 1,100 engineers—one-fourth that of either US engine manufacturer—dedicated to aircraft engines. Although these engineers currently lack the experience and comprehensive capability to move independently on all technology fronts necessary to produce a state-of-the-art engine, [redacted] they have an excellent technical education and lack only experience in managing a major commercial engine program from its inception. [redacted] 25X1 25X1 25X1 25X1

All phases of engine design, component manufacture, and engine testing draw from a vast pool of production facilities and extensive test facilities. SNECMA supplements in-house resources with subsidiaries, universities, and other government research facilities. The core of SNECMA R&D efforts is centered in the Engineering Division, located outside of Paris in Villaroche. [redacted] We believe SNECMA's short-range research programs are comparable to those in the United States. [redacted] 25X1 25X1 25X1 25X1 25X1 25X1

To complement the research and design work, SNECMA provides a portion of its testing facilities for development testing essential for a complete R&D program. According to recent SNECMA publications, one-third of its test cells are dedicated to engine

SNECMA: Vast and Modern Production Facilities



Facilities of SNECMA (Societe Nationale d'Etude et de Construction de Moteurs d'Aviation) present a modern integrated engine production and assembly capability that ranks third behind its US competitors. The production facilities at Villaroche are currently averaging an assembly rate of about 50 engines per month, about 70 percent commercial and 30 percent military. SNECMA has announced it has the capacity, if needed, for increased production. [redacted] *Manufacturing operations feature vertical integration with capabilities for all production steps, from casting components to the final engine assembly and testing. Components and subassemblies are made by subsidiary companies including Hispano-Suiza and FAMAT, and engine electronic controls are manufactured by ELECMA. Renovation of all SNECMA manufacturing facilities was completed in 1982, with each facility handling a portion of the manufacturing process:*

- ***Villaroche****—engineering, final engine assembly and engine test center; production and development of engine test cells with centralized automatic data gathering and reduction for acceptance testing of production engines. Current CFM56 engine production still allows Villaroche to fulfill projected military requirements. (See photo.)*

- ***Evry-Corbeil****—manufacturing center with numerically controlled machines and grinders for precision machining of engine frames, turbine cases, and engine shafts; heat treatment furnaces for compressor and turbine discs; electron-beam welding of rotating engine parts like compressor and turbine rotors; and plasma coating stands for coating fan and turbine shrouds and turbine and compressor blades.*

- ***Genvilliers****—forging, casting, and machining center with modern drop hammers for forging fan and compressor blades; facilities for casting, turbine blades and vanes; ring rolling mill for forging engine cases; and screw presses for forging fan blades.* [redacted]

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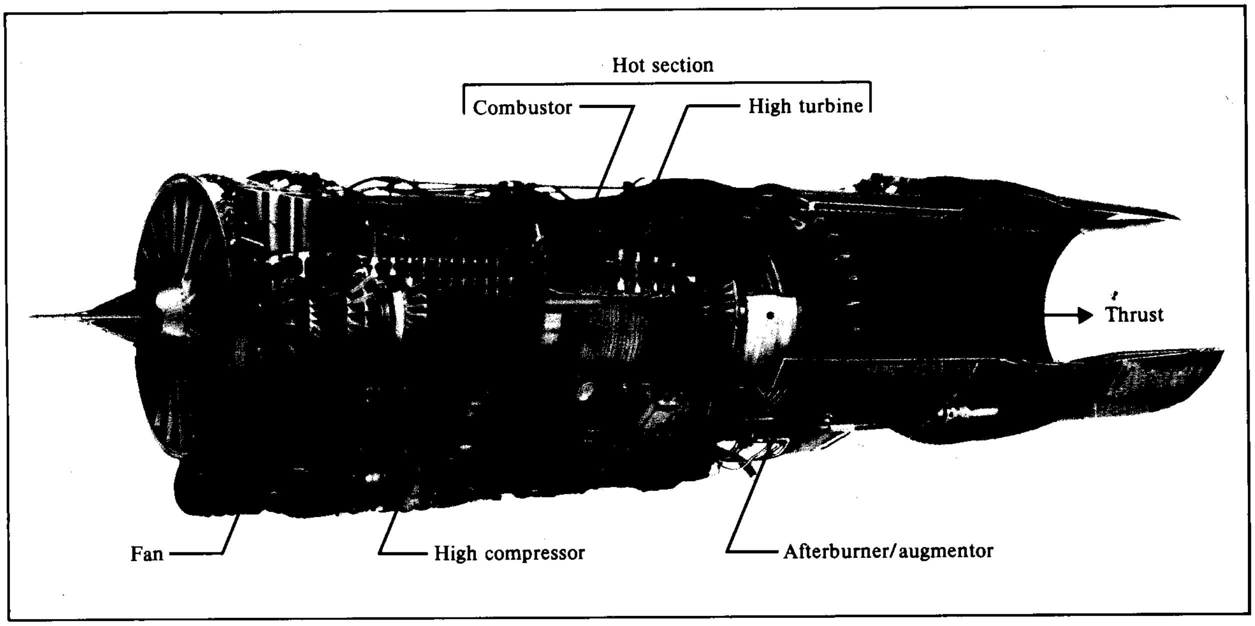
Figure 3
Gas Turbine Engine Components



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development work, as compared with one-half for most US companies. SNECMA's other test cells are being primarily used for acceptance tests of production engines, demonstrating SNECMA's current emphasis on production. According to European and US trade journals, SNECMA also has specialty testing facilities elsewhere in the company, at other government facilities, and in selected French universities. Because noise measurement is indispensable to commercial engine development, SNECMA has built an acoustic research facility at Istres that can measure the complete noise field of engines with up to 35 tons of thrust and is on a par with US engine company facilities. In addition, a test facility installed in 1984 at Villaroche has test cells capable of handling high-thrust engines up to 35 tons as well as thrust-reverse testing and can accommodate 60 engines per month. [redacted]

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Engine Technologies: Strengths and Weaknesses
SNECMA's strengths, according to US industry experts and major trade journals, center in compressor and fan aerodynamics and in precision-forging technology of powdered metals. SNECMA lags in critically important areas such as hot section, including combustor design, and selected manufacturing techniques, including multipass blade cooling. Overall, we believe the technologies essential to success in engine programs center on the hot section (see figure 3). Such technologies are the most difficult to master for any engine firm and are the most critical to reducing engine weight and improving performance. [redacted] 25X1

SNECMA has demonstrated notable strength and continuing progress in precision-forging technology, which is necessary to the manufacturing of fan and compressor blades as well as turbine and compressor discs. [redacted] SNECMA recently invested $25 million for facilities and research related to powder metal isothermal forging in an effort to move this technology into production. We believe SNECMA is approximately equal with the United States in conventional and powder metal isothermal forging capability. Indeed, in the design and manufacturing of the CFM56 blades—conventionally forged—[redacted] SNECMA exceeded the performance expectations of GE. [redacted]

We believe SNECMA's lack of hot-section competence is the weak link in current capabilities. Commercial engine hot-section expertise currently appears to be beyond its reach without outside help. Proper design, for example, of the hot section requires that critical parts of the combustor and turbine be designed for cooling and be constructed of special materials able to withstand very high combustion temperatures in the range of 2,500°F to perhaps as high as 3,300°F. In combustor design and manufacturing capability, we believe SNECMA lags state of the art. The sheet metal combustors used in SNECMA engines like the M53 are not sufficient for the 2,800°F operating temperature of current engines. US engines, for example, have been operating in airline service with more durable forged and machined ring combustors with growth capability of handling temperatures up to 3,000°F. [redacted]

We believe SNECMA turbine airfoil design and manufacturing capability is behind state of the art in the areas of temperature-resistant materials, protective coatings, and cooling methods. Turbine blades, with which SNECMA has production experience, are equiaxed castings of nickel-based alloys, a 10-year-old process in the United States. Past programs did not require additional efforts by SNECMA to close the gap with competitors in the United States and the United Kingdom. Moreover, government funding was not provided to do so. Currently, however, SNECMA company officials announced plans to test newer, single-crystal casting blades in the M88, and the demonstrator is reportedly on schedule. [redacted]

Moves To Narrow the Gap

SNECMA is moving on several fronts to improve its technical capability and narrow the gap with the Big Three. New engine designs for military and commercial applications are scheduled to incorporate significant engineering advances, including some that will accrue through joint ventures. Much of the work centers on specific engine technologies like combustor design. Indigenous technology developed by other industry manufacturers may also be drawn from published research papers and from greater participation in international forums on key technologies related to propulsion. [redacted]

We believe SNECMA's newest military engine—the M88 twin spool design—represents a technological jump for SNECMA, although some deficiencies will continue to exist (see figure 4). The sheet metal combustor used in the Mark I demonstrator is considerably advanced over its M53 predecessor, incorporating better combustor temperature, efficiency, and life. Further work is necessary, however, if the 2,900°F operating temperature targeted for the M88 Mark II production engine is to be sustained.[1] Single-crystal turbine blades are necessary for the high turbine inlet temperature and SNECMA is announcing their use for testing in the M88. US experience has shown it takes five to 10 years to gain the necessary experience to reach serial production from making prototype airfoils. [redacted]

SNECMA, however, can turn to its US partner GE or, more probably, the French conglomerate Pechiney for assistance. Pechiney owns the US company Howmet, recognized by industry experts as the technology leader in the manufacture of high-temperature turbine blades. In addition, SNECMA's shortcomings in coating methods and cooling technology for turbine blades could be sharpened by research programs aided by GE/Pechiney support. [redacted]

[1] The M88 Mark I demonstrator running of approximately 150 hours was not sufficient to establish durability even at the lower 2,500°F temperature. The production engine must have at least 500 hours of life at the higher 2,900°F temperature. [redacted]

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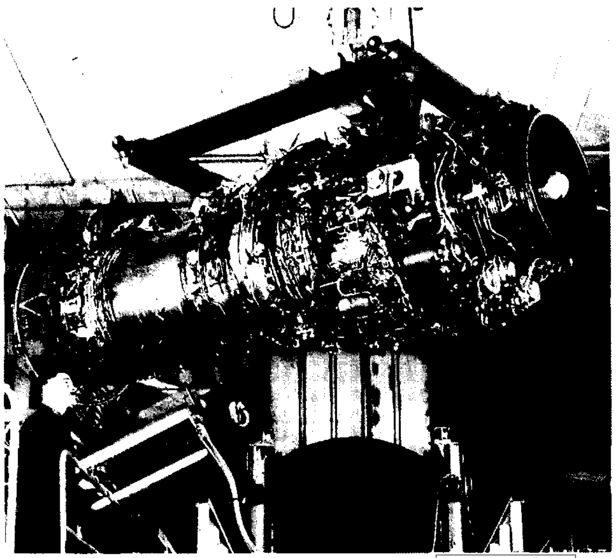

Figure 4. SNECMA M88 demonstrator engine [redacted]

The Mark I prototype engine of the M88 ran in January 1984 and achieved a thrust-to-weight ratio of approximately 8.3:1, about equivalent to the US F404 developed in the mid-1970s. But some US industry experts are skeptical of SNECMA's ability to fully meet the target of a 10:1 thrust-to-weight ratio for the Mark II. With anticipated design and material changes, however, we believe SNECMA can increase the thrust-to-weight ratio to near 9:1 but might have to cut the life of certain components of the engine, such as the combustor. These thrust-to-weight targets are still some years behind the projected 12:1 for US engines in development and significantly behind the longer range target of 20:1 thrust-to-weight of the US Air Force for the turn of the century. [redacted]

The French Government is also supporting research to improve SNECMA's competitiveness in several specific engine technologies. The new five-year plan, for example, provides for aerodynamic research on wide-chord fan blades for use in commercial transport engines. This technology aims at being competitive with blades used in the International Aero Engine (IAE) V2500. The five-year plan includes an allocation for design and development of the unducted fan (UDF) high pressure compressor (HPC). Technology gained from the HPC could be applied directly to future advanced fighter engine development. [redacted] 25X1

We believe SNECMA's combustor responsibility on the UDF will enhance its capability to independently develop more durable combustors. [redacted] 25X1
[redacted] this is a section of the engine 25X1
SNECMA specifically requested. While some industry officials believe the design will be similar to GE's CFM56 combustor, others express concern that it will be inadequate for the expected high temperatures of the UDF and that SNECMA will require design help from GE. [redacted] 25X1

[redacted] 25X1

SNECMA's engineers are also stepping up research activities on the international front to strengthen its overall abilities to design modern engines. SNECMA engineers, for example, have published more research papers, including one on compressor aerodynamics in 1983 and one on combustors and CAD/CAM at the 1985 International Symposium of Air Breathing Engines. While both papers focus on continuing design problems rather than basic research, we believe they represent a trend toward more advanced work. 25X1
[redacted] 25X1

Markets and New Programs

We believe SNECMA's revenues will overtake those of Rolls-Royce by the end of this decade, on the basis of growing backlogs for the CFM56 engine and industry projections for production of large commercial aircraft. In doing so, the market share of the French engine combine will increase from the 8-percent level in 1986 to about 12 percent in the early 1990s. We estimate three-fourths of SNECMA's increase in market share will come from US manufacturers and the remainder from Rolls-Royce. We estimate SNECMA will garner some $14 billion to $15 billion in sales from a market that aerospace industry experts believe will total slightly over $100 billion in the next decade. [redacted] 25X1 25X1

SNECMA's increasing market share stems primarily from sales of commercial engines, augmented by a smaller, but relatively steady, flow of revenues from new military engine progams, especially the M88. On the commercial side, the CFM56 and CF6 programs will reach peak production rates and annual sales late in this decade and remain high at least into the mid-1990s. Of the two, the CFM56 program is by far the most important program, with more than 1,400 engines already built and another 2,600 on order. In addition, SNECMA accounts for a 27-percent share of the CF6 program for Airbus engines.

On the military side, based on European military journal articles and US defense attache reporting from Paris, we expect sales of some 500 to 600 additional M53 engines for the Mirage 2000 fighter. The M53 engine represents the major military production through the 1980s. The French air force is expected to buy 300 to 400 M53 engines, and company officials predict additional export sales of some 200 engines. The M88, now being tested as SNECMA's candidate for France's new generation of fighters, should lead military sales. If the M88 is used to power France's Tactical Combat Aircraft, military production will be assured into the next century.

For the future, we believe success with UDF could be as important to SNECMA as the CFM56. Industry experts differ on the time frame for the UDF; some believe it will begin to move in the early 1990s, and others believe orders will not be significant until late in the decade. If the UDF gets an early start as most experts forecast, it will be competing in a market of 4,000 to 5,000 engines. Any significant share—one-fourth or more of total sales—of such a market will bolster SNECMA work levels to the end of the century.

In contrast, continuing design problems with the UDF, or outside factors such as low fuel prices, may delay the UDF until later in the 1990s. If this occurs or even if the propfan fails, SNECMA will still be competing with the CFM56 engine, which will benefit from continuing upgrading. We believe opportunities for other joint ventures in the future appear limited because most commercial engine production partners are already identified in specific programs to the end of the century and most military engines remain single-country programs.

Prospects and Implications

We believe sales growth by SNECMA, combined with some increased efforts in advanced propulsion research, means the French engine manufacturer will be an increasingly influential player in the aeroengine industry. These circumstances, especially when coupled with the French firm's vast and modern manufacturing facilities, provide selected opportunities and pose some problems for the United States in coming years.

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We believe SNECMA's involvement in commercial engine programs will continue to rely primarily on joint ventures because they are cost effective for design and provide a means for acquiring needed technologies and markets. The highly successful SNECMA partnership with GE in the CFM program, coupled with work on the CF6 and the recent move on the UDF, is a pattern of internationalization we expect to carry throughout the next decade. Although the United States will benefit from access to both foreign capital and markets provided by such collaborative programs, the moves will inevitably bring about some additional loss in market share. Industry experts estimate, on the basis of projections of sales of consortium jet engines in the next decade, that US share will fall from the current level of about 70 percent to some 60 percent in the late 1990s. This trend is holding true in the latest generation of new and derivative designs: the two competitors for the 150-seat aircraft market—the CFM56 and the V2500—each have 50 percent or more non-US content. Projected income to foreign countries from these programs is over $10 billion.

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On the military front, the development of the M88 engine, especially the uprated Mark II version, will enhance SNECMA's technology base. Moreover, a success with the Rafale—France's new-generation fighter—would underpin demand for SNECMA engines throughout the 1990s, possibly augmented by requirements of other French fighter designs. With

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the Rafale now designed to handle the GE404 engine also, the United States may get some sales from exports of the new fighter. We believe, however, such sales are likely to be limited because France will push hard with its own M88 design. US military sales would be enhanced if delays slow the Rafale. 25X1

Although we believe SNECMA would prefer joint programs with US engine manufacturers, a faltering UDF and a lack of any other new program could, over the long term, turn SNECMA to joint development with other European engine manufacturers—a move that could present a more direct challenge to US leadership. The pooling of resources by the European engine manufacturers—SNECMA, Rolls-Royce, West Germany's MTU, and Italy's Fiat—could produce a formidable competitor. Rolls-Royce's experience with hot-section design would complement SNECMA's capabilities in aerodynamics and manufacturing. Japan's engine combine led by Ishikawajima-Harima Industry is also a potential player with experience gained from the V2500 engine program of IAE. 25X1

SNECMA's growing technological capabilities will make the French engine combine an increasingly tempting target for collection efforts by the USSR. SNECMA's announced intentions to incorporate state-of-the-art developments in single-crystal castings and precision forgings in its next military engines would be such a target. In addition, we believe the Soviets would be interested in SNECMA's growing capabilities in design, inspection, and testing techniques necessary to effectively integrate new technologies into big jet engines. 25X1

Appendix

Glossary of Aircraft Engine Components

Afterburner/Augmentor A combustion system located in the engine tailpipe, which produces extra thrust by heating the exhaust gases to increase engine thrust. Augmentors have poor fuel efficiency and are most often used in fighter aircraft or supersonic transports, such as the Concorde, when a short burst of high thrust is desirable.

Combustor The chamber in which fuel is burned to provide heated gas for the high turbine.

Compressor The part of the spool that takes air from the inlet or fan and compresses it to achieve the high pressure for the combustor. In multispool engines, the compressor is split into low-pressure and high-pressure sections for greater efficiency.

Fan The first stage or stages of a turbofan compressor. A portion of the incoming air bypasses the high spool after being compressed in the fan. The ratio of the amount of air bypassing the core to that going through the core is the bypass ratio. The bypass ratio can vary from near zero for engines designed for supersonic aircraft to six for turbofans used in commercial airplanes.

Gas Generator/ Core Engine The assembly consisting of the high compressor, combustor, and turbine.

High Turbine The turbine that reaches the highest temperature in the engine. The temperature capability of this turbine is an indicator of the company's technical capability.

Hot Section The portion of the engine encountering the highest operating temperature, consisting of the combustor and turbines.

Propfan A turboprop with a propeller designed for higher aircraft speed to be competitive with current turbofan-powered airplanes. The unducted fan (UDF) is a GE trademark for a propfan.

Single Spool All rotating components are mechanically attached and rotate together.

Thrust Engine thrust is the force generated by the engine—generally stated in pounds or kilonewtons under static test conditions.

Turbofan A turbine engine in which part of the incoming air bypasses the engine hot section. The higher bypass ratio engines are used for transports, while lower bypass ratio engines are used for fighters and bombers.

Turbojet An engine producing thrust by discharging hot gases that have already passed through the entire engine. Turbojet engines are generally used for high-speed fighters.

Turboprop A turboprop engine is a variation of the turboshaft engine and includes a gearbox that is connected to a propeller. Turboprop engines are commonly used for small feeder transports.

Turboshaft A gas turbine engine in which the output is in shaft power generated by the exhaust gases passing through an auxiliary turbine. Turboshaft engines are used most often on helicopters.

Twin Spool Rotating components are in two assemblies usually rotating on concentric shafts. The low spool contains the fan, low compressor, and fan turbine; and the high spool consists of the high compressor and high turbine. Rolls-Royce has three spool engines with a similar arrangement.

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