GAO

Report to the Chairman, Committee on Armed Services, House of Representatives

March 1989

RESEARCH AND DEVELOPMENT

Funding of Jet Aircraft Engines for Fiscal Years 1984-1988

GAO/NSIAD-89-12FS

GAO

United States
General Accounting Office
Washington, D.C. 20548

National Security and International Affairs Division

B-231309

March 1, 1989

The Honorable Les Aspin
Chairman, Committee on Armed Services
House of Representatives

Dear Mr. Chairman:

This fact sheet is in response to your January 12, 1988, letter, requesting data on funding of jet engine research and development by the military services and National Aeronautics and Space Administration (NASA). The data show the overall direction and magnitude of changes in funding by comparing fiscal years 1984 and 1988.

The information includes funding for air-breathing jet engines such as gas turbine engines and ramjets. The information does not include funding of so-called "black" or classified programs. All amounts are in then-year dollars.

With respect to funding by the military services, we included information in the following categories of the Department of Defense's (DOD) Research and Development Program: research, exploratory development, advanced development, and engineering development. In fiscal year 1988, $506.2 million, or 54 percent, of the total funding ($932.2 million) by the military services in these four categories was for advanced development programs. Most of this amount ($443 million) was for the National Aero-Space Plane and the Advanced Tactical Fighter engine programs.

Funding for jet engine research and development increased from $727 million to $1,020 million, or by about 40 percent between fiscal years 1984 and 1988. Only the Navy's funding over this 5-year period ran counter to this direction; it decreased by 49 percent.

We also found that while the military services and NASA funded numerous jet engine research and development programs, a few large programs accounted for most funding. For example, in fiscal year 1988, funding for the Advanced Tactical Fighter's engines and propulsion related research associated with the National Aero-Space Plane Program accounted for about 57 percent of the total Air Force funding for jet engine research and development. Similarly, funding for the National Aero-Space Plane Program in fiscal year 1988 represented 23 percent of NASA's jet engine research and development. Engine research on this program is focused on ramjets rather than gas turbine engines.

Similarly, the Army's T800 engine used in the Light Helicopter Program accounted for 81 percent of the Army's total funding in fiscal year 1988. The Navy's jet engine Component Improvement Program represented about 60 percent of its total fiscal year 1988 funding of jet engine research and development.

We were also asked to include information on the independent research and development (IR&D) of jet engine manufacturers. As you requested, we have included in this fact sheet only nonproprietary information on IR&D. Between fiscal years 1986 and 1987, the number of planned jet engine related IR&D staff years increased by 15 percent.

We made funding comparisons from data supplied by the military services, the Office of the Secretary of Defense, and NASA; however, we did not verify the accuracy of this data. We also interviewed DOD and NASA officials responsible for managing jet engine research and development.

We are sending copies of this fact sheet to interested parties and will make copies available to others on request. The major contributors to this fact sheet are listed in appendix VI.

Sincerely yours,

Paul F. Math
Director of Research, Development, Acquisition,
and Procurement Issues

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NASA Office of Aeronautics and Space Technology

Figure V.4: NASA Offices Responsible for Jet Engine Research and Development

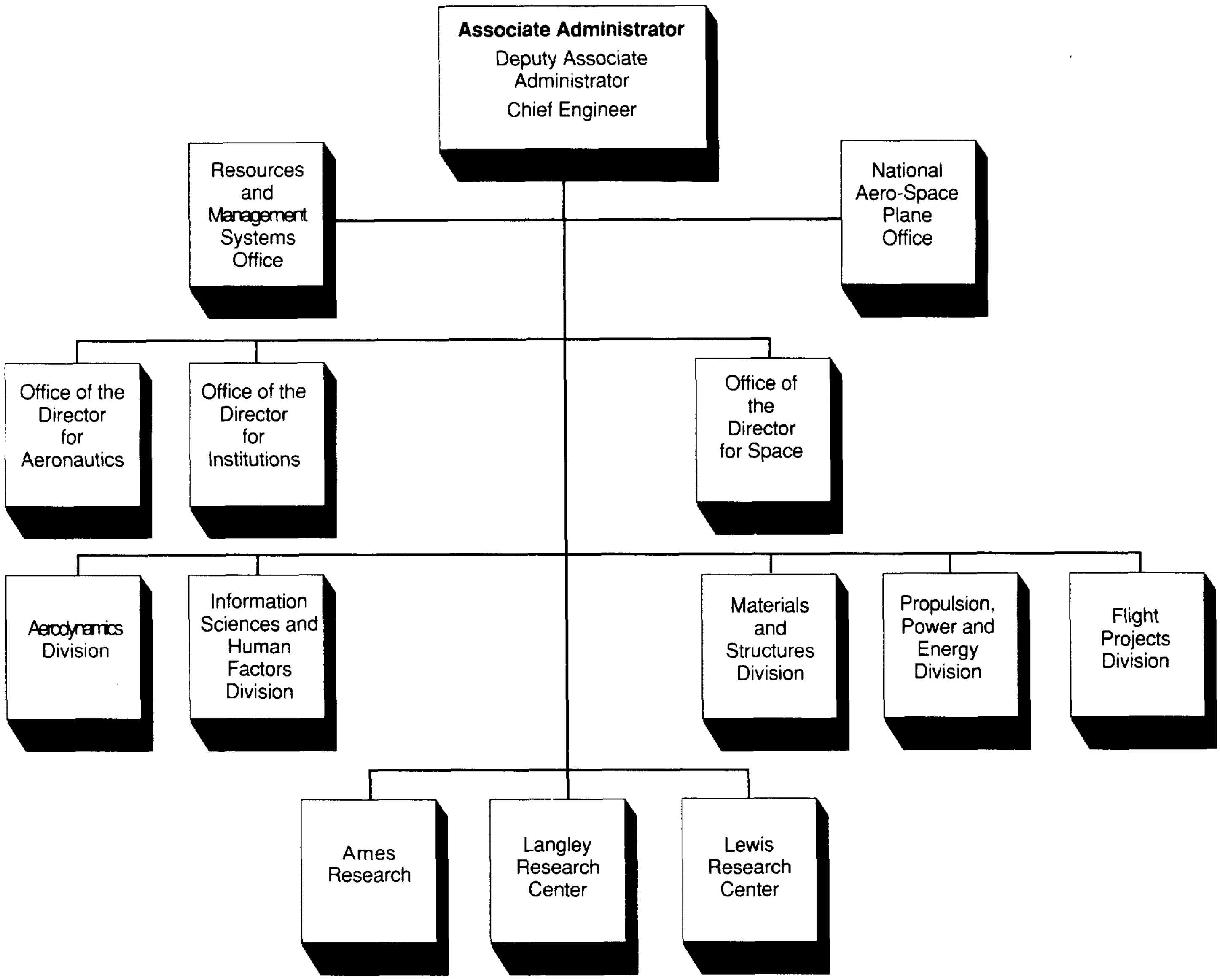
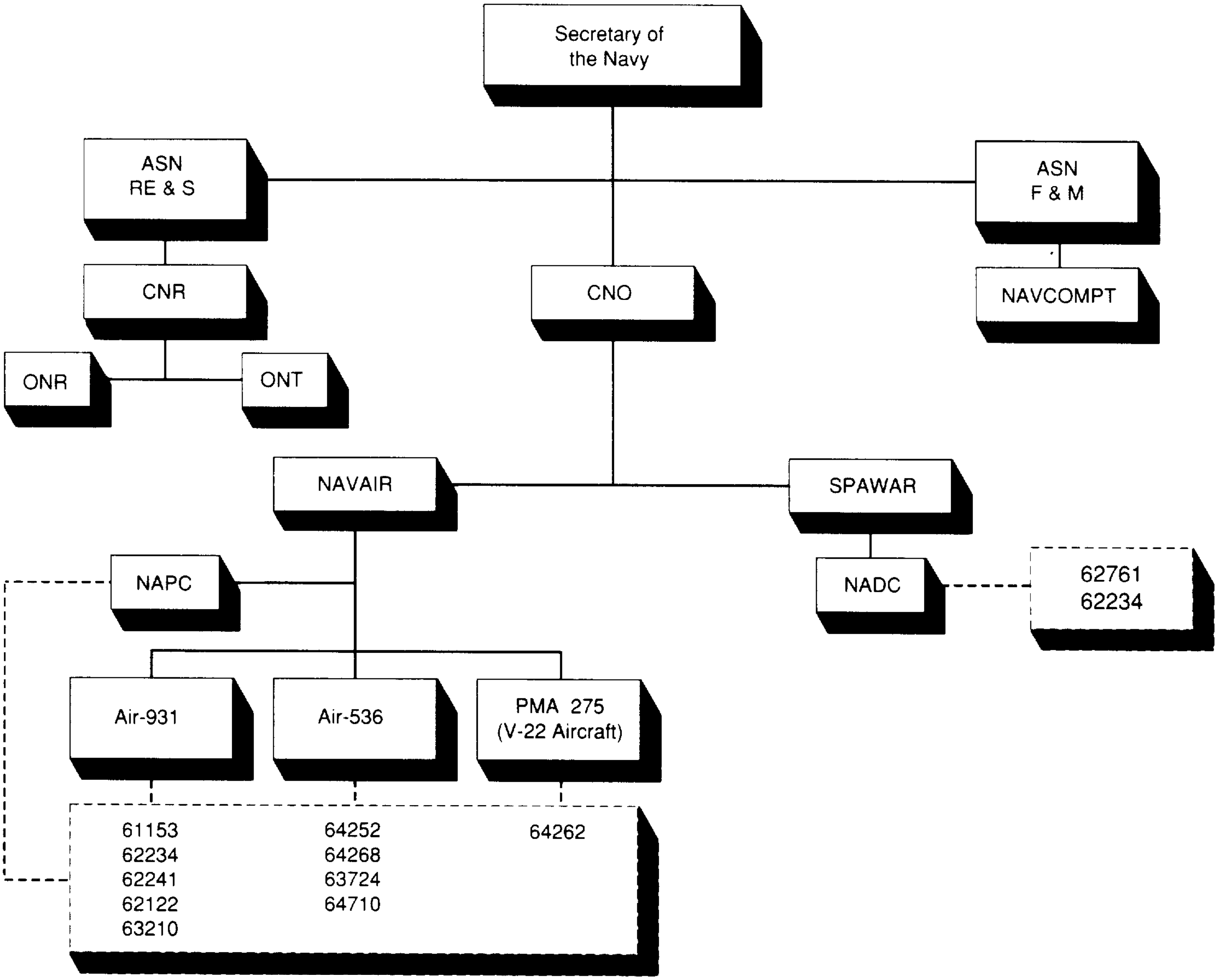


Figure V.3: Navy Offices Responsible for Jet Engine Research and Development



Note: Indirect lines of authority are indicated by a ——line.

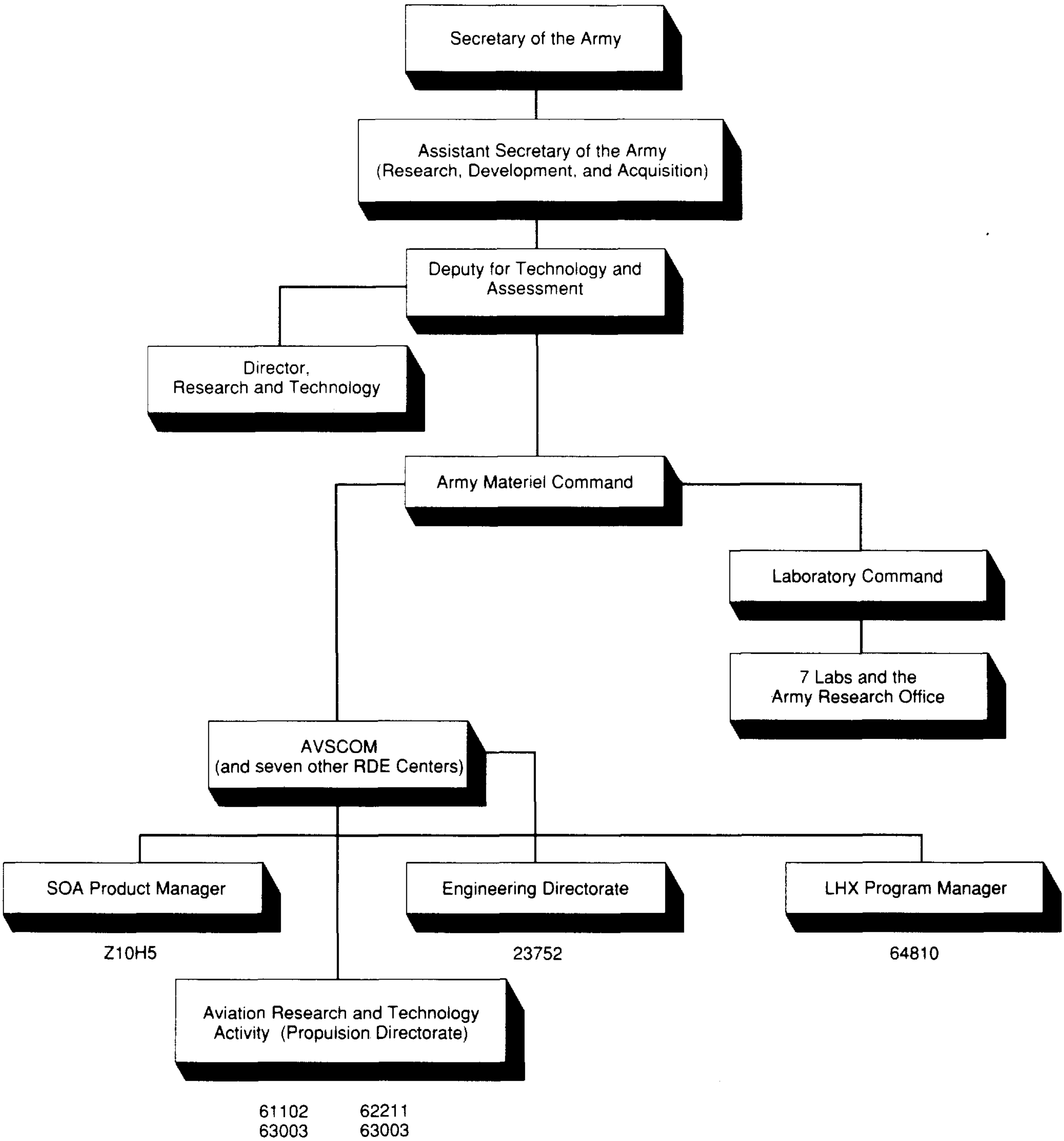
Navy Jet Engine Research and Development

The program elements on figure V.3 are:

61153	Defense Research Sciences
62234	Systems Support Technology
62241	Aircraft Technology
62122	Aircraft Technology (Superseded 62241 in fiscal year 1987)
62761	Materials Technology
63210	Aircraft Propulsion
63724	Navy Energy Program, Advanced Development
64262	V-22 Osprey Aircraft Development
64268	Component Improvement Program
64252	T56 Engine for E-2C Aircraft
64710	Navy Energy Program, Engineering Development

Abbreviations
ASN RE&S Assistant Secretary of the Navy, Research Engineering and Systems
ASN FM Assistant Secretary of the Navy, Financial Management
CNR Chief of Naval Research
NAVCOMPT Navy Comptroller's Office
ONR Office of Naval Research
ONT Office of Naval Technology
CNO Chief of Naval Operations
NAVAIR Naval Air Systems Command
SPAWARS Space and Naval Warfare Systems Command
NAPC Naval Air Propulsion Center
NADC Naval Air Development Center
Air 931 NAVAIR Research and Technology Directorate
Air 536 NAVAIR Air Propulsion Division
PMA 275 Program Manager Air

Figure V.2: Army Offices Responsible for Jet Engine Research and Development



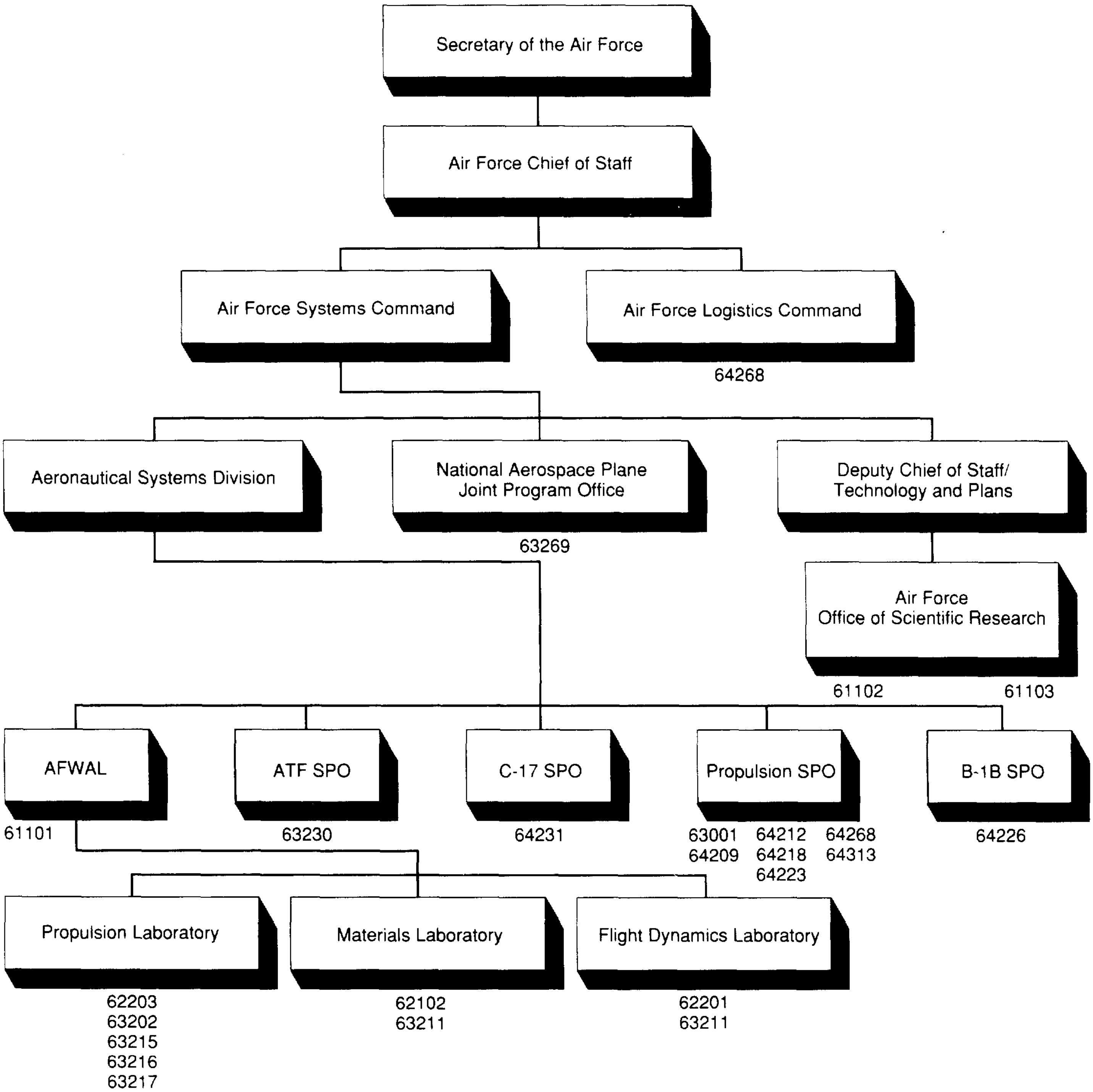
Army Jet Engine Research and Development

The program elements on figure V.2 are:

61102	Basic Research in Propulsion
62211	Exploratory Development: High Temperature Components, Compressor Drive Technology
63003	Advanced Development: IHPTET initiative
64810	Engineering Development: T800 Engine Program
Z10H5	T55 Engine Program
23752	Component Improvement Program

Abbreviations
AVSCOM US Army Aviation Systems Command
SOA Special Operations Aircraft
LHX Light Helicopter Program

Figure V.1: Air Force Offices Responsible for Jet Engine Research and Development



Offices Responsible for Jet Engine Research and Development

Air Force Jet Engine Research and Development

The program elements on figure V.1 are:

61101[a]	In-house Laboratory Research[b]
61102	Defense Research Sciences
61103	University Research Initiative
62102	Materials Development
62201	Aero-Space Flight Dynamics
62203	Aero-Space Propulsion
63001	Technical Modifications Program
63202	Aircraft Propulsion Subsystem Integration
63211	Aero-Space Structures and Materials
63215	Aero-Space Fuels and Propulsion Technology
63216	Aero-Space Propulsion and Power Technology
63217	Weapons Systems Power
63230	Advanced Tactical Fighter
63269	National Aero-Space Plane
64209	F100 Engine Durability
64212	Aircraft Equipment Development
64218	Engine Model Derivative Program
64223	Alternate Fighter Engine
64226	B-1B Aircraft
64231	C-17 Program
64268[c]	Aircraft Engine Component Improvement Program
64313	T-46A Trainer

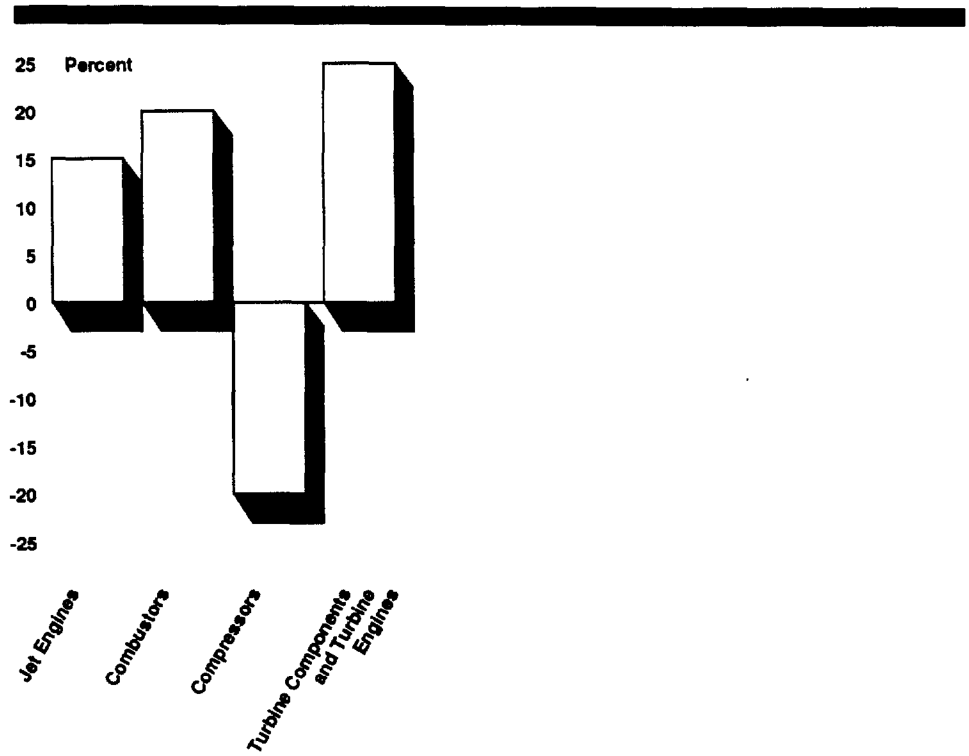
Abbreviations
AFWAL Air Force Wright Aeronautical Laboratories
ATF SPO Advanced Tactical Fighter Systems Program Office

[a]Five digit numbers are "program elements," the basic budget category in DOD's planning, programming, and budgeting system. Program "6," the first digit, is research and development.

[b]Air Force management of this program element is by the Deputy for Advanced Technology in the Office of the Assistant Secretary of the Air Force. The program element is for in-house laboratory research, and the Air Force Wright Aeronautical Laboratories manages the moneys distributed to its specific laboratories.

[c]This program element is now managed by Aeronautical Systems Division's Propulsion Systems Program Office, but in past years was co-managed by the Aeronautical Systems Division and Air Force Logistics Command.

Figure IV.1: Changes in Planned Staffing for Independent Research and Development—Fiscal Years 1986 and 1987 (in percent)



Changes in Independent Research and Development—Fiscal Years 1986 and 1987

The planned professional staff years associated with the percentage changes on figure IV.1 are in table IV.1.

Table IV.1: Independent Research and Development (in planned professional staff years)

	Fiscal years	
	1986	**1987**
Jet engines	3,313	3,825
Engine components:		
Combustors	547	655
Compressors	846	677
Turbine components	691	863

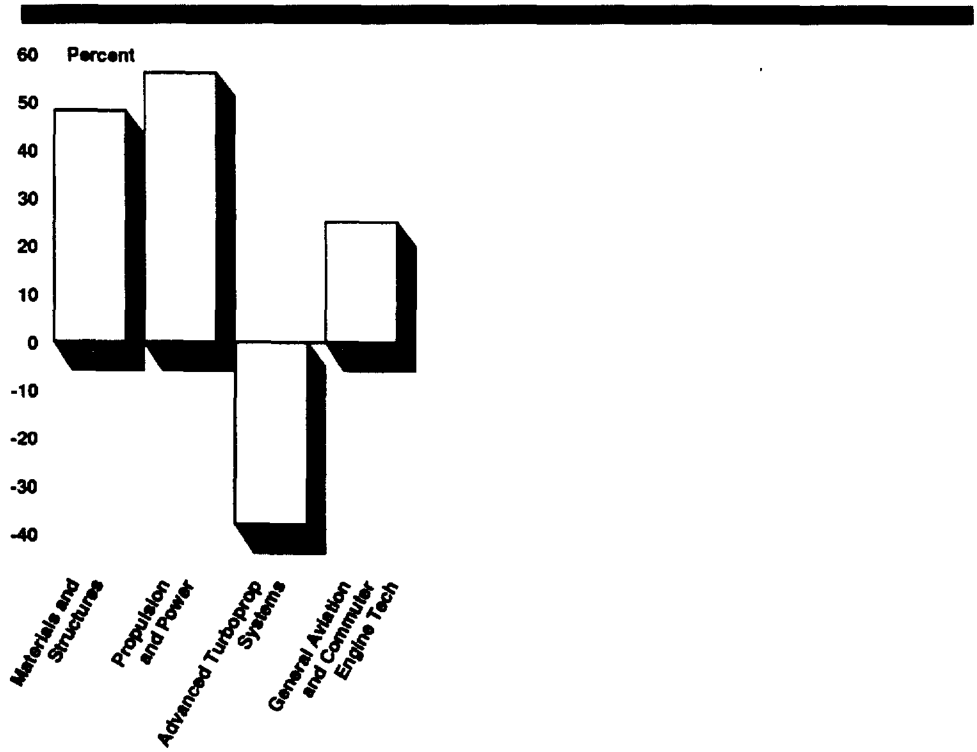
Source: Office of Naval Technology.

The data base for table IV.1 are contractors' independent research and development plans. As part of these plans, contractors identify planned work using codes established by the Committee on Scientific and Technical Information. One code (2105), is for research related to jet and gas turbine engines. Data were only available for fiscal years 1986 and 1987.

Work performed under code 2105 can include work on more than one engine component. For example, one staff year of effort might include work on combustors and compressors. In table IV.1, that one staff year is counted twice—one for combustor related work and one for compressor related work. In the DOD-wide data provided by Navy officials, however, they determined the amount of double counting. In 1986, 497 staff years were double or triple counted and in 1987, the comparable figure was 529 staff years.

The objective of research on general aviation and commuter engine technology is to provide the technology base to ensure the technical advantage of U.S. manufacturers in future small turbine engine markets. This research includes development of engine hot sections (compressor, combustor, and turbine) capable of operating at temperatures of 2,500 to 3,000 degrees fahrenheit. Current operating temperatures are 2,300 degrees fahrenheit or less.

Figure III.7: Changes in NASA Component Funding—Fiscal Years 1984 and 1988[a] (in percent)



[a]Percentage changes refer to research and development performed by NASA's Lewis Research Center.

Changes in NASA Funding of Engine Components, Structures, and Materials

The dollar amounts associated with the percentage changes in NASA component funding on figure III.7 are shown below in table III.7.

Table III.7: NASA Component Funding

Dollars in millions

	Fiscal years	
	1984	**1988**
Materials and structures	$5.6	$8.3
Propulsion and power	19.1	29.8
Advanced turboprop systems	15.0	9.3
General aviation and commuter engine technology	2.0	2.5

Source: NASA, Office of Aeronautics and Space Technology.

In fiscal year 1988, NASA established an additional $8.8 million line of research effort entitled "advanced high-temperature engine materials technology." This effort, which is not included in table III.7, supports the goals of the IHPTET initiative, including the goal of developing materials for use above 3,000 degrees fahrenheit. Between fiscal years 1984 and 1987, this type of research was funded under a "Turbine Engine Hot Section Technology" ($11.1 million in fiscal year 1984 and $4.9 million in fiscal year 1987), and "Ceramics for Turbine Engines" programs ($2.4 million in fiscal year 1985, and $2.2 million in fiscal year 1987).

Propulsion and power research includes research on engine components. In fiscal year 1984, research was conducted on compression, combustion, and turbine systems. In fiscal year 1988, the focus was on engine control sensors and instrumentation, computational fluid dynamics, supersonic airflow through the compressor, and generic hypersonics research.

The objective of advanced turboprop systems research is to develop and evaluate the technology for a new generation of propeller-driven, fuel-efficient aircraft having cruise speeds of Mach 0.65 to 0.9 and fuel savings of 15 to 30 percent.

Table III.6: Navy Component Funding

Dollars in millions

	Fiscal years	
	1984	1988
Materials[a]	$0.645	$2.8
Engine components:[b]		
Compression systems	0.987	0.540
Combustion systems	0.966	1.575
Turbines	0.228	1.070
Mechanical systems	0.185	0.170
Controls	0.100	0.708

Source: Naval Air Systems Command.

[a]In fiscal year 1988, the Naval Air Systems Command received $2.27 million for materials research as part of the IHPTET initiative. Research tasks under the materials program include developing materials to lower engine weight, developing materials to withstand higher operating temperatures, increasing rotor speeds of engine components, increasing engine life, and survivability of engines.

[b]Collectively, funding for engine components increased from $2.5 million to $4.1 million, or 64 percent during this time.

Figure III.6: Changes in Navy Component Funding—Fiscal Years 1984 and 1988 (in percent)

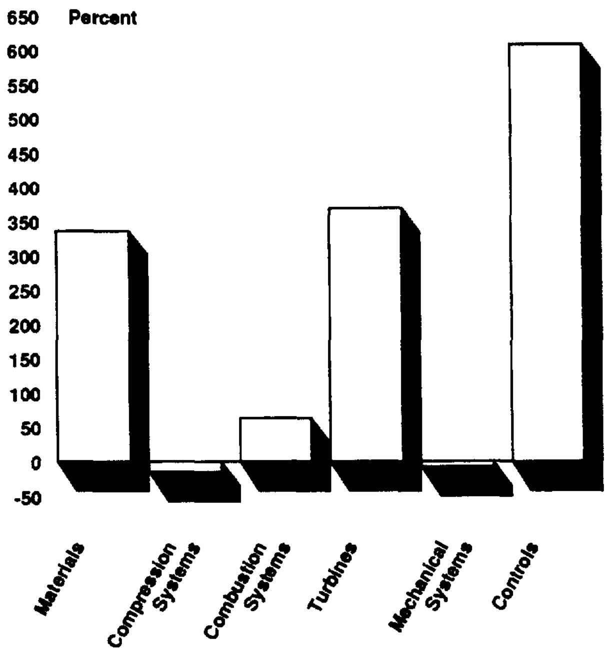
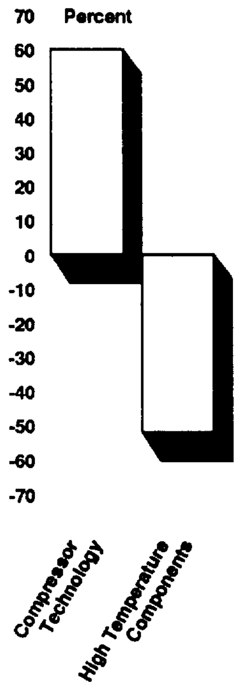


Figure III.5: Changes in Army Component Funding—Fiscal Years 1984 and 1988 (in percent)



Changes in Navy Funding of Engine Components, Structures, and Materials

The dollar amounts associated with the percentage changes in Navy component funding on figure III.6 are shown in table III.6.

Changes in Army Funding of Engine Components, Structures, and Materials

The dollar amounts associated with the percentage changes in Army component funding on figure III.5 are shown in table III.5.

Table III.5: Army Component Funding

Dollars in millions

	Fiscal years	
	1984	1988
Compressor Technology	$1.0	$1.6
High Temperature Components	2.9	1.4

Source: Army Aviation Systems Command.

Research on compressor technology includes (1) conducting a tri-service compressor design program, (2) evaluating advanced transmission concepts, and (3) investigating advanced concepts for electric accessory drives.

Research on high temperature components includes conducting a small turbine nozzle fatigue program and evaluating composite matrix combustors.

Table III.4: Air Force Component Funding

Dollars in millions

	Fiscal years	
	1984	1988
Materials[a]	$7.3	$11.2
Aero-Space structures[b]	2.7	4.7
Engine components:[c]		
Compression systems	7.3	5.6
Combustion systems	1.9	2.4
Turbines	2.0	4.6
Exhaust nozzles	3.7	3.2

Source: Air Force Systems Command, Aeronautical System Division.

[a]Materials research is an exploratory development program to develop new materials such as thermal protection and metallic structural materials.

[b]Aero-Space structures is an advanced development program that includes development of composite materials for use in subsystem components.

[c]Collectively, funding for engine components increased from $14.9 million to $15.8 million, or by 6 percent from fiscal years 1984 to 1988.

Figure III.4: Changes in Air Force Component Funding—Fiscal Years 1984 and 1988 (in percent)

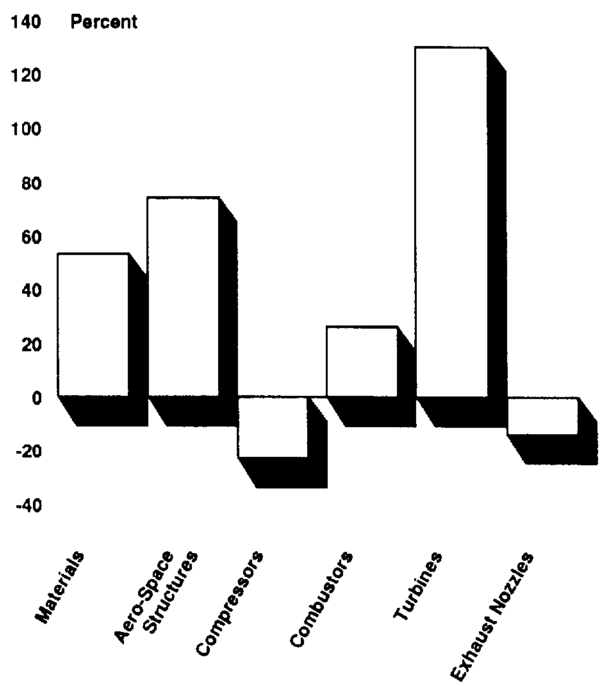
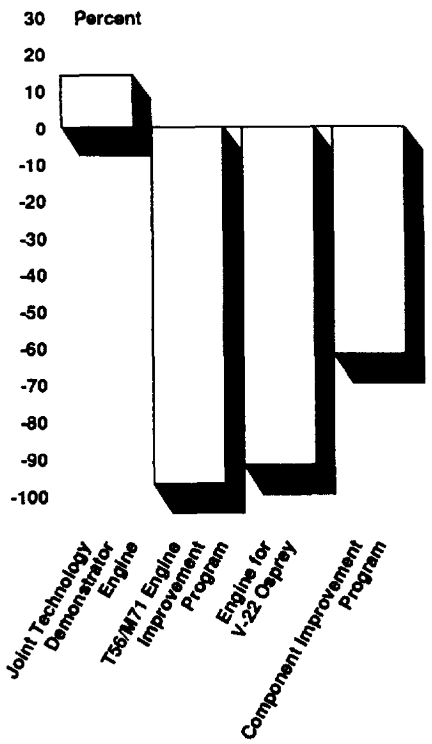


Figure III.3: Changes in Navy Programs—Fiscal Years 1984 and 1988[a]
(in percent)



[a]The fiscal year 1988 funding of the programs is 75 percent of total Navy aircraft engine research and development for the fiscal year. The funding of the Osprey's engine is for fiscal years 1986 and 1988.

Changes in Air Force Funding of Engine Components, Structures, and Materials

The dollar amounts associated with the percentage changes in Air Force component funding on figure III.4 are shown in table III.4.

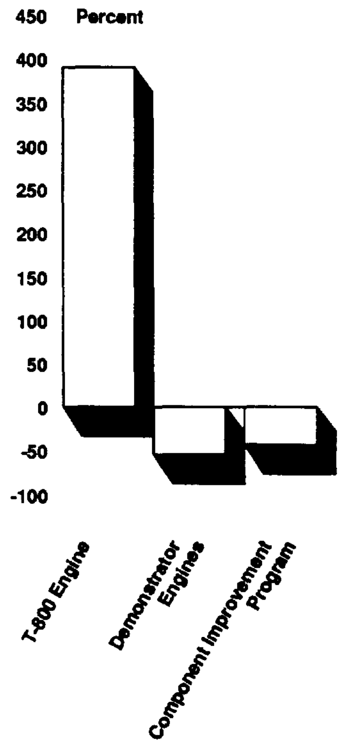
developed by General Electric and Pratt and Whitney. Total funding for fiscal years 1984 to 1988 was $15.4 million.

Full-scale development of General Motors' Allison Gas Turbine Division T56 engine for E-2C, early warning aircraft was largely completed in fiscal year 1987. In fiscal year 1988, the engine entered final operational test and evaluation. Total funding for fiscal years 1984 to 1988 was $104.1 million.

The V-22 is a tilt-rotor joint services aircraft designed to support the assault mission of the Marines, the special operations forces mission of the Air Force, and the search and rescue mission of the Navy. The T406 engine is being developed by the Allison Gas Turbine Division of General Motors. The total funding for fiscal years 1986 to 1988 was $70 million. Funding figures are estimates provided by the Office of the Under Secretary of Defense for Acquisition. Full-scale development was nearly complete in fiscal year 1988 and is expected to be complete in fiscal year 1989.

Total Component Improvement Program funding of Navy engines for fiscal years 1984 to 1988 was $279.2 million. About 30 percent of this total was for the General Electric Company's F404 engine, which powers the F/A-18 aircraft.

Figure III.2: Changes in Army Programs—Fiscal Years 1984 and 1988[a] (in percent)



[a]The fiscal year 1988 funding of the programs is 92 percent of total Army spending on jet engine research and development for the fiscal year.

Changes in Funding of Navy Programs

The dollar amounts associated with the percentage changes in Navy funding in figure III.3 are shown in table III.3.

Table III.3: Navy Programs

Dollars in millions

	Fiscal years	
	1984	1988
Joint Technology Demonstrator Engine	$3.7	$4.2
T56/M71 Engine Improvement Program	9.2	0.3
Engine for V-22 Osprey	40.0	3.3
Component Improvement Program	83.1	31.2

Source: Naval Air Systems Command.

The Joint Technology Demonstrator Engine is a joint Navy and Air Force program to demonstrate advanced technology in engines being

Table III.2: Army Programs

Dollars in millions

	Fiscal years	
	1984	**1988**
T800 engine	$19.9	$97.6
Demonstrator engines	16.4	7.5
Component Improvement Program	10.7	6.1

Source: Army Aviation Systems Command.

The T800 engine is a 1,200 shaft horsepower engine being developed for the Light Helicopter Program. The total funding for fiscal years 1985 (the first year of funding) through 1988 was $282.5 million, or 72 percent of total Army engine related research and development for the period.

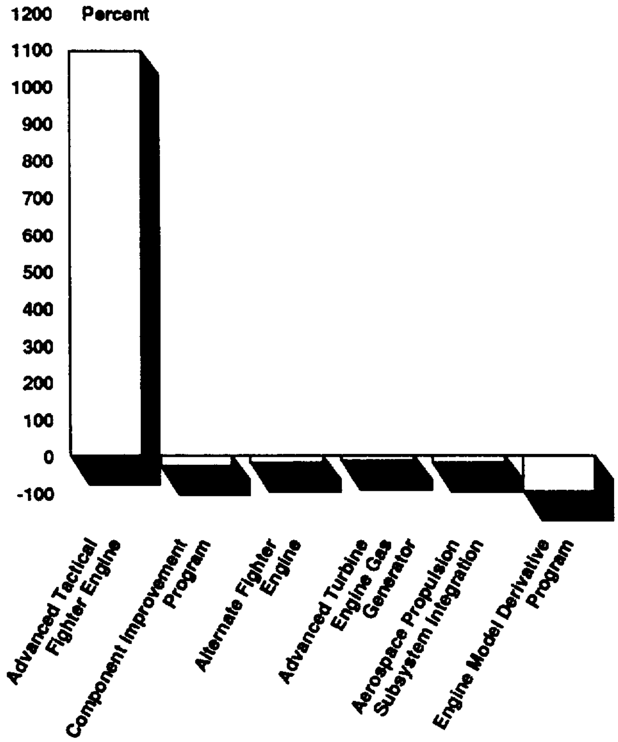
The purpose of demonstrator engines is to bridge the gap between new concepts and their introduction into real engine programs. About 65 percent of the Army's funding of demonstrators during the fiscal years 1984 to 1987 period was on the Modern Technology Demonstrator Engine. This engine was not funded in fiscal year 1988. The project involved research and development of an improved 5,000 shaft horsepower engine. When funding of this engine is deleted from the above funding levels, funding of other demonstrators increases from $756,000 to $7.5 million.

During the fiscal years 1984 to 1988 period, the focus of the Army's improvement program was on the T700 engine, which is a 1,600-shaft horsepower engine used on UH-60 Black Hawk, AH-64 Apache, and EH-60 helicopters. About 63 percent of total improvement program funding during the period was on the T700 engine. In fiscal year 1984, the T700 funding was 67 percent of Component Improvement Program funding for that year, and in fiscal year 1988, it was 49 percent.

The purpose of the Aero-Space Propulsion Subsystem Integration program is to develop and demonstrate advances in research and technology of engine components other than the gas generator.

The purpose of the Engine Model Derivative program is to provide existing aircraft with the latest advances in engine research and development. The program's goals are to increase engine life, reduce costs, and enhance engine performance. (See fig. III.1.)

Figure III.1: Changes in Air Force Programs—Fiscal Years 1984 and 1988[a]
(in percent)



[a]The fiscal year 1988 funding of the programs is 70 percent of the total Air Force funding of jet engine research and development for the fiscal year.

Changes in Funding of Army Programs

The dollar amounts associated with the percentage changes in Army programs in figure III.2 are shown in table III.2.

Funding Changes by Military Services and NASA—Fiscal Years 1984 and 1988

Changes in Funding of Air Force Programs

The dollar amounts associated with the percentage changes in Air Force programs shown in figure III.1 are shown in table III.1.

Table III.1: Air Force Programs

Dollars in millions

	Fiscal years	
	1984	**1988**
Advanced Tactical Fighter	$28.1	$335.6
Component Improvement Program	125.2	89.9
Alternate Fighter Engine	92.0	74.7
Advanced Turbine Engine Gas Generator	24.5	21.0
Aero-Space Propulsion Subsystem Integration	24.7	19.8
Engine Model Derivative Program	57.9	1.0

Source: Air Force Systems Command, Aeronautical Systems Division.

The Advanced Tactical Fighter Program will develop the next generation air superiority fighter. Two propulsion contractors—General Electric Corporation and Pratt and Whitney Division, United Technologies Corporation—are competitively developing prototype engines for this aircraft. In fiscal year 1988, funding of the engines was about 44 percent of total Air Force funding of jet engine research and development.

The purpose of the Component Improvement Program is to extend the maturation period of the fielded jet engines by on-going engineering and support. Total funding of the improvement program over the fiscal years 1984 to 1988 period was $580 million, or about 21 percent of total Air Force funding of jet engine research and development.

The Alternate Fighter Engine is the General Electric Corporation's F110-GE-100, which is funded as a competitive alternative to Pratt and Whitney's F100 series of engines. The F100 engine powers the F-15 and F-16 aircraft. The F110 engine is a derivative of General Electric's F101 engine, which powers the B-1B aircraft. This program funds the full-scale development of increased performance versions of both the F100 and F110 engines.

The purpose of the Advanced Turbine Engine Gas Generator program is to develop and demonstrate advances in gas generator research and technology. The gas generator of a jet engine is the high pressure compressor, combustor, and high pressure turbine.

The Navy's demonstrator engines represent about 37 percent of the fiscal year 1988 amount. The largest increase ($0.645 million to $2.27 million or 252 percent) was in propulsion materials research.

NASA has not developed IHPTET related funding data. An important part of NASA's involvement in the IHPTET initiative, however, is its research using internal computational fluid dynamics—a mathematical simulation of air flows, temperatures, and pressure contours within jet engines. NASA is responsible for coordinating computational fluid dynamics research under the initiative. NASA's estimated funding in this area increased by 100 percent ($1.6 million to $3.2 million) between fiscal years 1985 and 1987.

Figure II.2: Changes in High Performance Jet Engine Research Funding—Fiscal Years 1984 and 1988 (in percent)

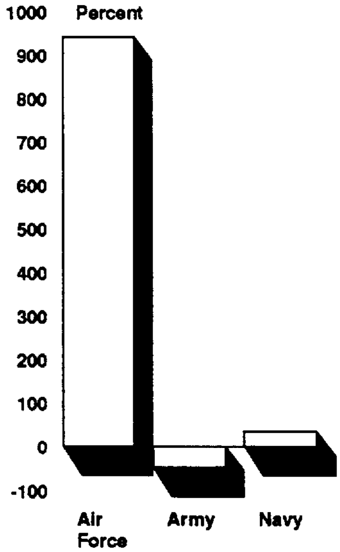


Table II.4: High Performance Jet Engine Research

Dollars in millions

	Fiscal years	
	1984	**1988**
Air Force	$6.0	$62.6
Army	20.3	10.6
Navy	9.7	13.1

About 56 percent ($35 million) of the Air Force's fiscal year 1988 amount was for demonstrator engines. The fiscal year 1984 amount does not include spending on demonstrators because they were not included as part of the IHPTET initiative until 1985. Fiscal year 1984 funding of demonstrator engines was $42.6 million. If this amount is added to the $6 million shown in table II.4, the percentage change shown in figure II.2 would be about 29 percent.

Most of the Army's decrease is associated with the Modern Technology Demonstrator Engine; a project to develop the technology for a 5,000 shaft horsepower engine with improved performance capabilities. In 1984 its funding was 77 percent ($15.6 million) of the total. This demonstrator was not funded in fiscal year 1988 although other demonstrator engine programs were 71 percent ($7.5 million) of the fiscal year 1988 total.

Table II.3: Funding by Research Activity

Dollars in millions

Research and development activity	Fiscal year	Air Force	Army	Navy	Total
Research	1984	$10.6	$2.1	$0.5	**$13.2**
	1988	29.8	1.6	0.3	**31.7**
Exploratory development	1984	55.2	3.9	3.7	**62.8**
	1988	64.1	2.9	7.9	**74.9**
Advanced development	1984	82.2	16.4	6.0	**104.6**
	1988	489.9	7.5	8.8	**506.2**
Engineering development	1984	391.0	19.9[a]	92.3	**503.2**
	1988	186.8	97.6	35.0	**319.4**

[a]Fiscal year 1985.

Fiscal year 1988 Air Force funding in the research activity included about $19.5 million for the University Research Initiative. Air Force officials were not able to determine the amount of jet engine related research under this initiative.

Air Force funding of engines for the Advanced Tactical Fighter and National Aero-Space Plane Programs ($443 million) accounted for 87 percent of the fiscal year 1988 total of the advanced development activity.

The Air Force and the Navy classify their Component Improvement Programs as engineering development. The Army does not classify its program this way and therefore, its Component Improvement Programs are not included on table III.3. In fiscal year 1984, funding for the Army's program was $10.7 million and in fiscal year 1988, it was $6.1 million. The Air Force and the Navy funding of their Component Improvement Programs ($208 million) accounted for 41 percent of the fiscal year 1984 total funding of the engineering development activity. (The comparable figures for fiscal year 1988 were $121 million or 38 percent.)

Changes in Funding of High Performance Turbine Engine Technology

The IHPTET initiative is a planned 15-year (1986-2001) effort by DOD and NASA to double propulsion capability. (See p. 12.) Figure II.2 shows percentage changes in the IHPTET initiative related funding by the military services. The fiscal year 1984 figures that we used to calculate the percentage changes on figure II.2 are for programs that later became part of the IHPTET initiative.

The dollar amounts associated with the percentage changes in high performance jet engine research on figure II.2 are shown in table II.4.

Changes in Funding by Type of DOD Research/ Development Activity—Fiscal Years 1984 and 1988

The percentage changes between fiscal years 1984 and 1988 by research and development activity are shown in table II.2

Table II.2: Funding by Research Activity
(in percent)

Research and development activity	Air Force	Army	Navy
Research	181	(24)	(40)
Exploratory development	16	(26)	114
Advanced development	496	(54)	47
Engineering development	(52)	390	(62)

Note: Figures in parenthesis means a decrease in percent between fiscal years 1984 and 1988. NASA is not included on this table because it does not categorize research and development in the same way as DOD.

By "research," DOD means scientific study directed toward increasing knowledge in fields related to long-term national security needs.

"Exploratory development" includes all the efforts directed toward the solution of specific military problems, short of major development projects.

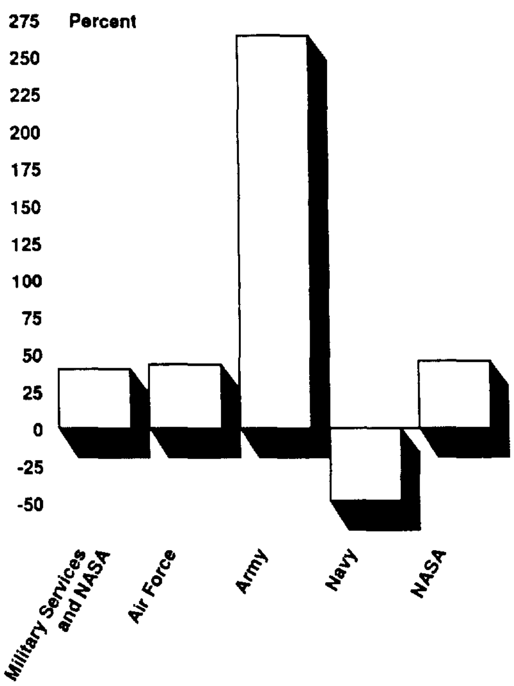
"Advanced development" includes all projects that have moved into the development of hardware for experimental or operational test.

"Engineering development" includes all development programs being engineered for use by military services but which have not been approved for procurement.

The dollar amounts associated with the percentage changes in funding by type of DOD research activity shown in table II.2 are shown in table II.3.

NASA—Propulsion related research and development for the National Aero-Space Plane deleted from funding level for fiscal year 1988. Funding of the National Aero-Space Plane Program in fiscal year 1988 was $18 million (23 percent) of NASA's funding of jet engine research and development.

Figure II.1: Changes in Military Services and NASA Funding— Fiscal Years 1984 and 1988 (in percent)



The dollar amounts associated with the percentages in figure II.1 are shown in table II.1.

Table II.1: Military Services and NASA Funding

Dollars in millions

	Fiscal years	
	1984	**1988**
Air Force	$539	$771
Army	33	120
Navy	102	52
NASA	53	77
Total	**$727**	**$1,020**

Overview of Funding Changes

Changes in Total Funding—Fiscal Years 1984 and 1988

DOD and NASA's funding of jet engine research and development increased by 40 percent between fiscal years 1984 and 1988. As shown on figure II.1, only the Navy's funding decreased during the 5-year period.

Funding by the military services and NASA consist of relatively large and small programs, with a few large programs accounting for much of the funding. When such programs (described below by military service and NASA) are deleted from the levels noted in figure II.1, funding between fiscal years 1984 and 1988 are changed as follows.

- Air Force 36-percent decrease
- Army 31-percent decrease
- Navy 11-percent increase
- NASA 11-percent increase

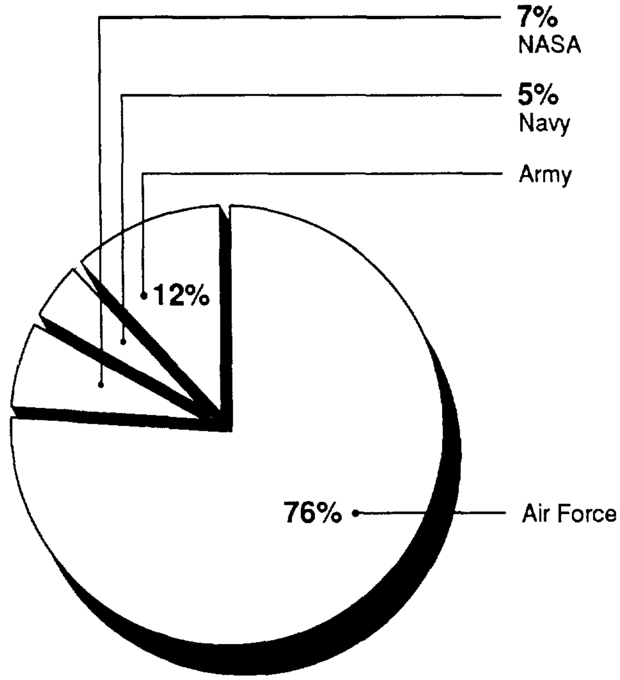
Air Force—National Aero-Space Plane funding deleted from funding level for fiscal year 1988 and Advanced Tactical Fighter engine for fiscal years 1984 and 1988. The National Aero-Space Plane Program is a joint DOD/NASA technology development and demonstration program to build and test the X-30 experimental flight vehicle. Powered by ramjets, the X-30 would fly 10 times faster and higher than existing air-breathing aircraft. The Advanced Tactical Fighter is being developed as a follow-on to the F-15 and as the Air Force's next generation air superiority fighter. The National Aero-Space Plane and the Advanced Tactical Fighter accounted for 57 percent of the Air Force's funding in fiscal year 1988. Funding for National Aero-Space Plane Program related propulsion was $107 million in fiscal year 1988.

Army—T800 engine program deleted from funding level for fiscal year 1988. This engine is being developed for the Army's Light Helicopter Program. For fiscal year 1986, the T800 was 69 percent of the Army's total funding on jet engine research and development. For fiscal years 1987 and 1988, the comparable figures were 82 and 81 percent, respectively. T800 funding increased 390 percent ($20 million to $98 million) during fiscal years 1985 to 1988. The T800 was not funded in fiscal year 1984.

Navy—Component Improvement Program deleted from funding level for fiscal years 1984 and 1988. In fiscal year 1984, the Component Improvement Program was $83 million, or 81 percent of the Navy's funding of jet engine research and development, and in fiscal year 1988, it was $31 million, or 60 percent, a decrease of 63 percent.

The distribution of $1,020 million[5] by the military services and NASA in fiscal year 1988 is shown in figure I.4.

Figure I.4: Fiscal Year 1988 Funding
(distribution in percent)



[5]Air Force—$771 million, Army—$120 million, Navy—$52 million, and NASA—$77 million.

- A supersonic "Vertical/Short Take-off and Landing" fighter of the size of the F-15 with greater range/payload capability. The F-15 has a maximum ferry range of more than 3,450 miles and can carry up to 16,000 pounds of bombs or rockets.
- A 100-percent increase in range, loiter, and payload capability for an F-14 size aircraft. The F-14 Tomcat has an unswept wing span of about 64 feet, an overall length of about 63 feet, and an overall height of 16 feet. The maximum weight of its external weapons is 14,500 pounds. The take-off weight with four Sparrow missiles is 59,372 pounds.

Funding of Jet Engine Research and Development in Fiscal Year 1988

Figure I.4 shows moneys received by the military services and NASA. They do not include moneys received by the services for so-called "black" or classified programs such as the Navy's Advanced Tactical Aircraft and the Air Force's B-2 or Stealth bomber. Additional information regarding figure I.4 is as follows:

- NASA figures include engine related research and development at Lewis Research Center and engine research and development related to the National Aero-Space Plane Program at Lewis, Langley, and Ames Research Centers. Lewis is the leading NASA center for jet engine research.
- About $6.9 million of the Navy's funds are estimates provided by the Office of Naval Research ($3.3 million for the Navy energy program) and the Office of the Under Secretary of Defense for Acquisition ($3.3 million for full-scale development of the engine for the V-22 Osprey aircraft, and $0.3 million for the T56 engine for the E-2C Hawkeye early warning aircraft).
- The totals in figure I.4 include the armed services' Component Improvement Programs that extend the maturation period of fielded jet engines by on-going engineering and support. Some specific program objectives are correcting safety of flight problems; improving reliability, maintainability, and durability; and reducing the cost of engine parts.
- The Air Force's funding includes about $19.5 million as part of DOD's University Research Initiative. Air Force officials were not able to determine the amount of jet engine related research under this initiative. As of February 1988, the program, on a DOD-wide basis comprised 80 multidisciplinary projects with participation by some 700 graduate students.

Higher turbine inlet temperatures, in combination with improved materials and engine component efficiencies, generally result in more power, less engine weight, and lower fuel consumption.

The Future—Goals for the Next 12 Years

The Integrated High Performance Turbine Engine Technology (IHPTET) initiative is an effort by DOD and NASA to double current propulsion system capability by about the year 2001.

Specific goals are

- for fighter/attack engines, a 100-percent increase in specific thrust[2] to weight ratio and a 50-percent decrease in fuel consumption;[3]
- for rotor craft engines, a 40-percent decrease in fuel consumption and more than a 100-percent increase in power to weight ratio;
- for cruise missile engines, a 40-percent decrease in fuel consumption (for strategic missiles) and more than a 100-percent increase in thrust/air flow (for tactical missiles); and
- for subsonic patrol/transport aircraft engines, a 30-percent decrease in fuel consumption.

Illustrative payoffs of IHPTET initiative:

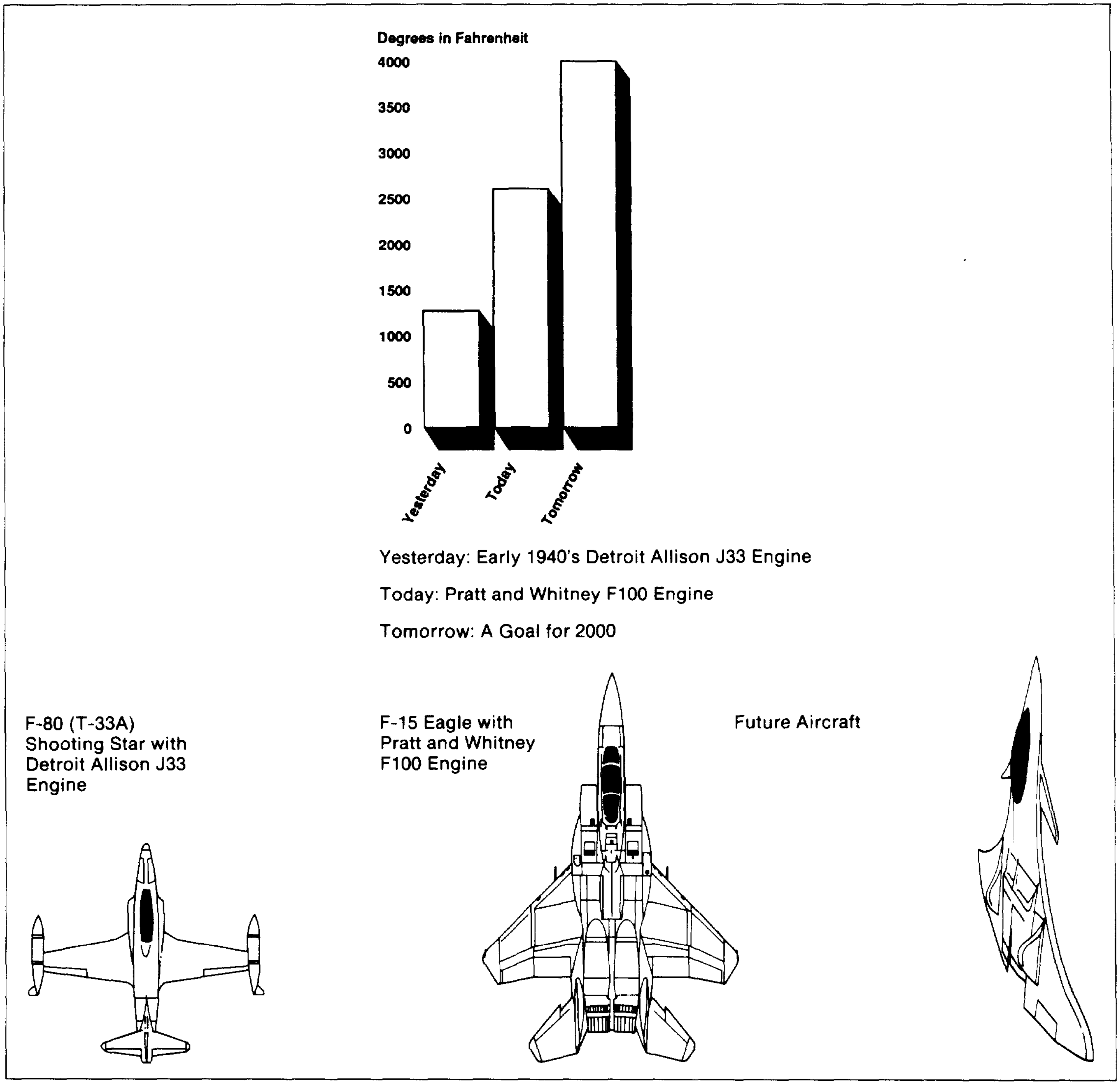
- A sustained Mach 3[4] plus capability in an aircraft the size of the F-15. The F-15 Eagle has a wing span of about 43 feet, an overall length of about 64 feet, and an overall height of about 18 feet. The take-off weight with full internal fuel and four Sparrow missiles is 44,560 pounds.
- An intercontinental-range cruise missile no larger than the present Air Launched Cruise Missile. The length of this missile is about 21 feet, with a launch weight of 3,200 pounds, and a range of 1,550 miles.
- A 100-percent increase in range/payload capability of a CH-47 size helicopter. The CH-47 Chinook has a maximum range of 1,225 miles.

[2]Specific thrust is the amount of thrust per pound of air flowing through the engine in 1 second. It is an indicator of the engine size needed to generate a given thrust—the higher the specific thrust, the smaller the engine diameter.

[3]Specific fuel consumption is the amount of fuel in pounds that an engine uses in 1 hour to produce a pound of thrust and is a measure of the efficiency of an engine.

[4]Mach number refers to the ratio of the speed of an object to the speed of sound (761.5 mph at sea level). Because the speed of sound is a function of temperature, it varies at different altitudes.

Figure I.3:Changes in Turbine Inlet Temperature (degrees in fahrenheit)

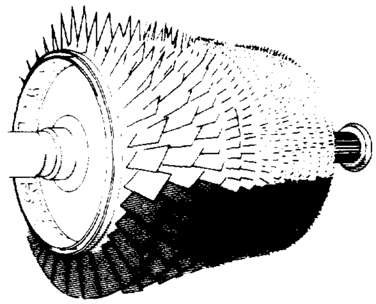


The Past, Present, and Future Changes in Gas Turbine Engine Performance

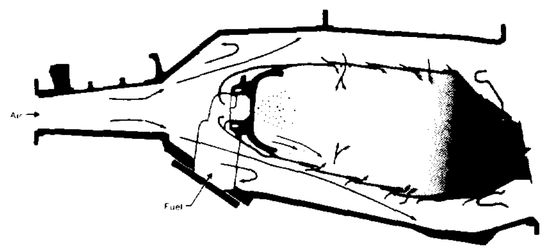
A key indicator of performance is the turbine inlet temperature. As shown in figure I.3, turbine inlet temperatures have increased by about 106 percent since the early 1940s. If the engine goals for the year 2001 are to be met, such temperatures will have to increase by over 50 percent above the F100 engine.[1]

[1]The F100 engine on the F-15 Eagle represents 1960s technology. Current technology is best represented by the engine on the Air Force's Advanced Tactical Fighter. The turbine inlet temperature of this engine is classified.

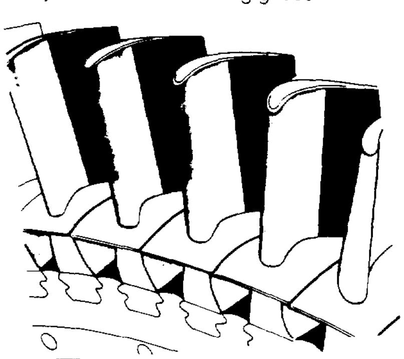
Figure I.2:Gas Turbine Engine Components



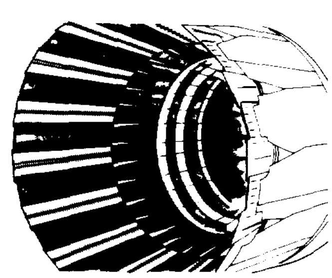
Compressor: Incoming air is squeezed by fanlike blades of compressors increasing air pressure and temperature.



Combustor: Hot air ignites with jet fuel to form burning gases.



Turbine: Rapidly expanding gases from the combustor rush through blades of the turbine making it spin. The turbine, in turn, keeps the compressor turning to draw more air into the engine.



Exhaust Systems: The nozzle accelerates the high pressure exhaust gases leaving the turbine to a high velocity, thus producing thrust.

Background

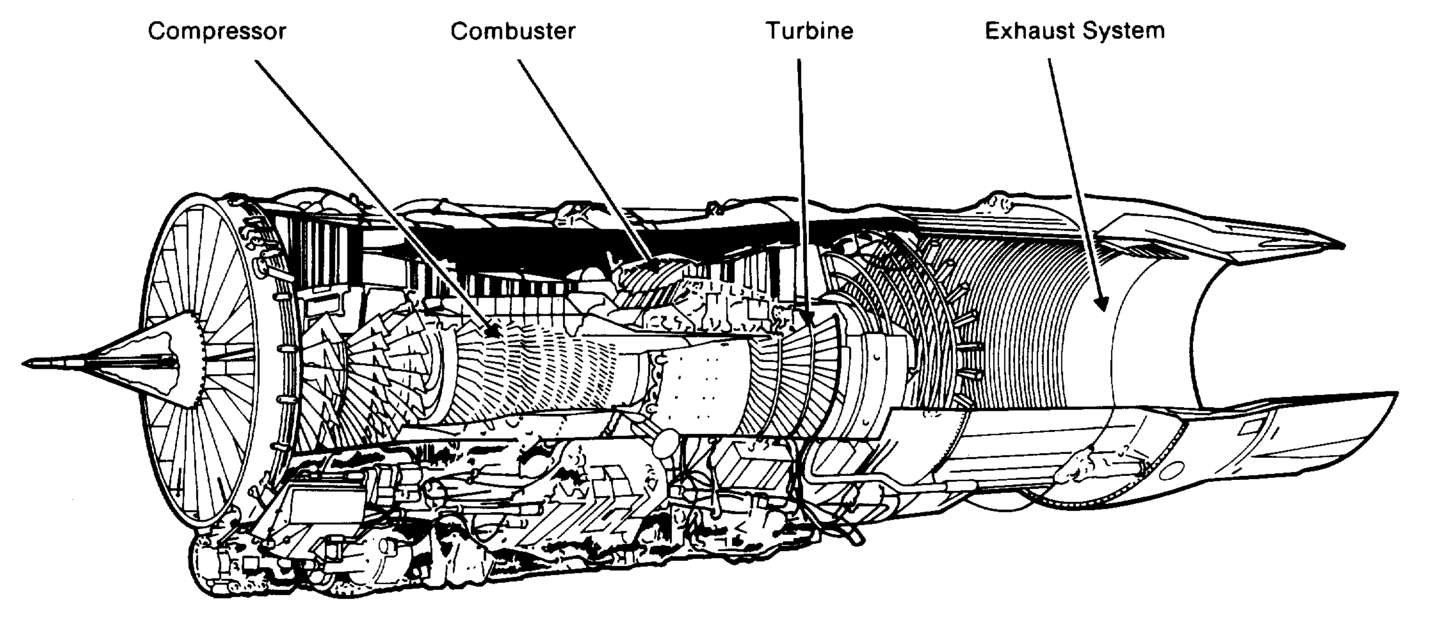
Characteristics of a Jet Engine

A jet is an air-breathing, internal combustion engine that generates power or thrust by

- compressing air,
- burning compressed air and fuel to generate heat, and
- expelling heated fast moving gases through an exhaust nozzle.

The thrust or propulsive force of a jet engine results from the fact that the momentum (mass x velocity) of exhaust gases is greater than that of the incoming air. (See fig. I.1.)

Figure I.1:Gas Turbine Engine[a]



[a]There are four basic types of propulsion gas turbine engines: turbojet, turbofan, turboshaft, and turboprop. The engine shown above is a turbofan. Another type of jet engine—a ramjet—compresses or "rams" the onrushing air and slows it down to subsonic speeds where it is burned with fuel in a combustion chamber.

Four parts of a gas turbine engine, compressor, combustor, turbine, and exhaust system are shown in figure I.2.

Abbreviations

DOD	Department of Defense
IHPTET	Integrated High Performance Turbine Engine Technology
IR&D	independent research and development
NASA	National Aeronautics and Space Administration

Appendix V Offices Responsible for Jet Engine Research and Development

Appendix VI Major Contributors to This Fact Sheet

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