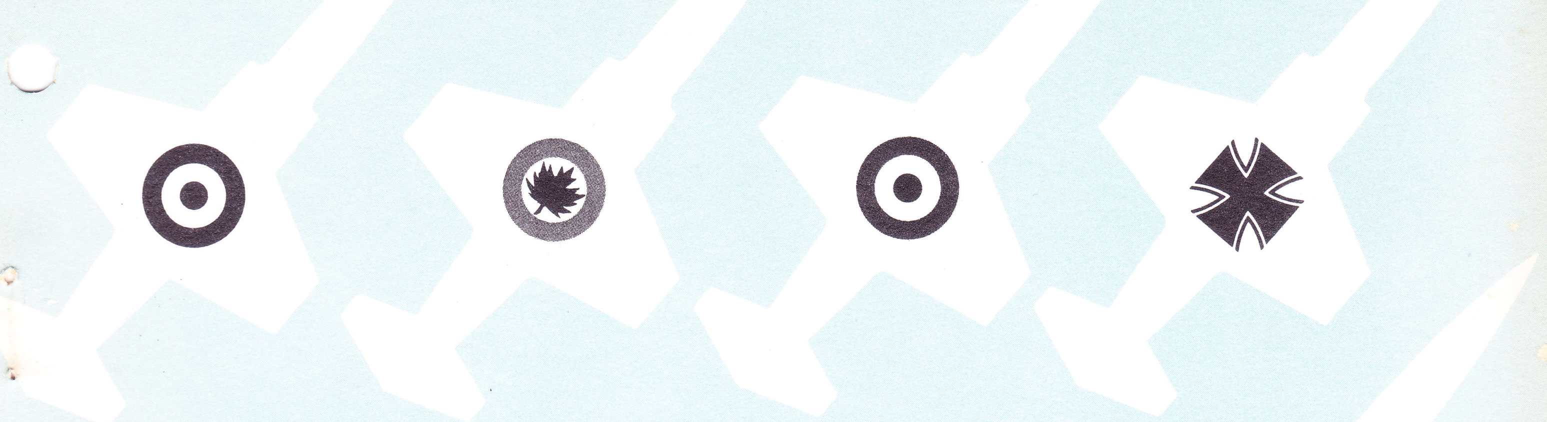

WORLD WIDE F-104 PROGRAM

PRESS BOOK

MEMO TO: Aviation Writers
Aviation Editors

Here are facts, figures and background data on the aviation industry's largest international undertaking — the world-wide F-104 manufacturing program.

It includes 7 nations, 100,000 people and 1700 airplanes. The goal: creation of a new-generation armada for the Free World.

Newsbureau
Lockheed
Burbank

LOCKHEED-CALIFORNIA COMPANY
A DIVISION OF LOCKHEED AIRCRAFT CORPORATION

SECTION I

ONE (1) OF A KIND

Described herein are details of the Lockheed-California Company's worldwide F-104 program -- a one-of-a-kind production plan that includes 21 major aircraft firms, 7 engine manufacturers and 31 major electronics companies in 7 nations.

Starting at Burbank, Calif., F-104 activity has expanded to include such formerly divergent locales as Amsterdam, Munich, Montreal, Gosselies, Torino and Nagoya.

Particular attention is paid in this book to European work, whose paterfamilias is the NATO Starfighter Management Office (NASMO) in Koblenz, Germany.

There, under the general managership of H. Sellschopp, seven division offices oversee and coordinate the plan.

Working closely with NASMO, Lockheed-California Company offers continual advisory service through its European headquarters, resident directors in key cities and its own manufacturing, test and flight facilities in Burbank and Palmdale, Calif.

The cooperative undertaking -- from Europe to North America to the Far East -- involves 100,000 direct employees.

GLOBAL CHOICE

High over Europe, the Orient and the North American continent, identical aerodynamic shapes slash through the cold, rarified stratosphere.

The stub, tilt-down wings; the pencil-point nose and the T-shaped tail mark the aircraft unmistakeably as Super Starfighters.

Designed in Burbank, Calif., U.S.A., they could have been made in Belgium, Canada, Germany, Italy, Japan, The Netherlands -- or the United States.

They could have been bearing the air force insignia of any of the same countries -- or several others.

Products of what has been described as "probably the greatest example of international cooperation on a technical level the world has yet seen," the Super Starfighters represent a $2.8 billion production program encompassing nearly 1700 airplanes built in seven nations.

No other manufacturing effort in aviation industry history approaches its magnitude -- in numbers of aircraft combined with countries and companies involved.

Competitive countries and competitive companies have subordinated differences in order to concentrate skills, equipment and resources on creating for Freedom a mighty defensive aerial armada.

Most production is outside the United States.

Of the total Super Starfighters ordered, less than 20 per cent will come from assembly lines of the designer, Lockheed-California Company.

The remainder are being produced under Lockheed license by leading aircraft companies of Belgium, Canada, Germany, Italy, Japan and The Netherlands.

To assure early service introduction and training, some outright purchases were made from Lockheed.

They included Germany (190), Japan (23), Canada (22), The Netherlands (10), and Belgium and Italy (1 each).

The U.S. Air Force is purchasing an additional number for friendly foreign powers that qualify under the Military Assistance Program.

FIRST THE STARFIGHTER

The many hundreds of ultrasonic Super Starfighters that will fly in the multi-flag armada for years to come evolved from a basic design created for the U.S. Air Force.

That, of course, was the F-104A, an airplane that came from the shops of C.L.(Kelly) Johnson, Lockheed vice president for advanced development projects, to meet a USAF requirement for a new-generation air superiority fighter.

The original F-104A, a single-place aircraft, was specified for the Air Defense Command. A two-seat Starfighter for ADC was designated the F-104B. Other USAF models:

F-104C -- Tactical Air Command, single-place.

F-104D -- Tactical Air Command, two-seat.

QF-104 -- A target drone version made by modifying some of the early F-104As.

NF-104 -- Aerospace trainer version with supplemental liquid fuel rocket engine made by modifying some of the early F-104s.

F-104N -- NASA astronaut proficiency trainer.

F-104C WINS 1962 FIGHTER WEAPONS MEET

In September, 1962, a lone F-104C took on 10 F-100s and three F-105s at "William Tell 1962," a Fighter Weapons Meet held biennially at Nellis AFB, Nev., near Las Vegas.

The Starfighter was flown by Capt. Charles E. Tofferi, a 29-year-old pilot representing the 479th Tactical Fighter Wing, George AFB, Calif.

The loner generally was regarded as an interloper in the four-day competition, since the 479th was equipped and trained more for nuclear weapons delivery and the contest included several categories in conventional weapons.

Captain Tofferi and his F-104C were unstoppable.

At meet's end, he had outscored all other pilots, top marksmen from top TAC units around the world, to post a remarkable runaway victory.

He scored 19,018 points out of 24,000 possible.

His nearest competitor had 17,304 points.

Three of his close-support missions were scored as perfect 1000s. Downing a towed dart target with his Vulcan 20 mm cannon in just 63 seconds, he set a new record and picked up the maximum 3000 points for that division.

Among the Starfighter's features, he gave particular credit to its short turning radius (with maneuvering flaps) and tremendous acceleration for his championship showing.

THEN, THE SUPER STARFIGHTER

Because advanced versions of the F-104 carry new electronics and performance capabilities -- and meet new mission requirements -- new designations beyond the USAF nomenclature were necessary.

They are:

F-104G	West German, Belgian, Dutch and Italian, single-place.
F-104F	West German two-seat.
CF-104	Canadian single-place.
CF-104D	Canadian two-seat.
F-104J	Japanese single-place.
F-104DJ	Japanese two-seat.
TF-104G	West German, Belgian and Dutch two-seat, modified to carry equipment normally installed in single-place aircraft. (Also applicable to CF-104D)

THE PRINCIPALS

Biggest participant, and responsible for kicking off the international program, is West Germany.

In the process of creating a new, young Luftwaffe, Germany is scheduled to receive 700 F-104Gs and at least 54 two-place Super Starfighter models.

They are being provided by companies in five different countries: Germany, The Netherlands, Belgium, Italy and the United States.

All of them, regardless of their origin, meet the same precise standards.

F-104G CONTRACT MILESTONES

March 18, 1959 -- West Germany signs contract for development of the F-104G.

March 18, 1959 -- West Germany signs contract for licensed production.

September 17, 1959 -- Canada signs licensed production contract.

January 29, 1960 -- Japan signs licensed production contract.

April 20, 1960 -- The Netherlands signs licensed production contract.

June 20, 1960 -- Belgium signs licensed production contract.

February, 1961 -- U.S. Air Force signs order for Military Assistance Program F-104Gs.

March 2, 1961 -- Italy signs licensed production contract.

June, 1962 -- U.S. Air Force orders additional MAP F-104Gs.

WHO AND WHERE?

European production sites are concentrated according to geographical groupings of leading aircraft firms -- plus virtually all resources of the Italian aviation industry.

The South Group (Arbeitsgemeinschaft Sud) includes Dornier, Heinkel, Messerschmitt and Siebel. Final assembly and the flight test phases are conducted at Manching.

The North Group (Arge Nord) was formed when The Netherlands chose the F-104. It includes two Dutch companies -- Fokker and Aviolanda -- and three German companies, Focke-Wulf, Hamburger Flugzeugbau and Weserflug. The total work load is evenly divided in both countries.

The West Group (actually a geographical misnomer) is a combination of S.A.B.C.A. (Societe Anonyme de Constructions Aeronautiques) and Avions Fairey S.A. in Belgium, joined by Fiat and other Italian companies.

Italy itself is the fourth entity. While some of the Italian sub-assemblies will be integrated into other programs (such as in Belgium), Fiat's Turin facility is the site of additional final work and flight evaluation.

Prime contractor for Canada is Canadair, Ltd., in Montreal, where wings, empennages and aft fuselage sections also are being built for all Lockheed-assembled Super Starfighters.

Japan's Mitsubishi Heavy Industries is responsible for manufacture of more than 175 F-104Js to be used by the Japanese Air Self Defense Force.

HOW MANY -- AND WHERE?

Here's a list of production areas and single-place Super Starfighters scheduled for each:

Manufacturer	Quantity
Germany (South Group)	210
Netherlands (North Group)	350
Belgium (West Group)	188
Italy (Fiat)	199
Canada (Including 48 for MAP)	248
Japan	177
United States (Including 81 for MAP)	182
Total	1554

All production of two-seat airplanes will be performed by Lockheed-California Company at Burbank and Palmdale. Specific requirements for these models exceed the number of aircraft ordered in late 1962.

Country	Ordered
Germany	84*
Netherlands	10
Belgium	--
Italy	--
Canada	22
Japan	20
USAF (MAP)	24
Total	160

*Includes 30 F-104Fs

FROM WHENCE?

Cross-flow of parts, assemblies and complete airplanes is most notable in the case of Germany, whose air force will get 700 single-seat fighters from five different nations. The complete country-by-country breakdown:

Air Force	Quantity	Manufacturing Source	
Germany	700	Germany	210
		Netherlands	255
		Belgium	89
		Italy	50
		U.S.	96
			700
Netherlands	120	Netherlands	95
		Italy	25
			120
Belgium	100	Belgium	99
		U.S.	1
			100
Italy	125	Italy	124
		U.S.	1
			125
Canada	200	Canada	200
Japan	180	Japan	177
		U.S.	3
			180
MAP countries	129	U.S./Canada	129
Total	1554		1554

OF FIGHTERS AND FINANCES

Two nations -- Germany and Canada -- are paying all costs of their Super Starfighter re-equipment programs.

American financial participation is administered through the U.S. Air Force, which also has prime responsibility for procurement of Lockheed jet fighters for MAP-qualified nations.

The economic impact in Europe is considerable.

At least 60,000 persons were employed on the project in 1962 and the figure was expected to increase.

Germany's decision in March, 1959, to sign a license agreement and manufacture -- instead of buy -- its own aircraft, set a pattern generally followed by the other five national principals.

SECTION II

COUNTRY BY COUNTRY

GERMANY

The German Air Force regards the F-104 program as a "model case" of German-American cooperation in build-up of its aerial forces.

Adoption of the Super Starfighter was preceded by two years of intensive studies by the German Air Force staff and by the Federal Defense Ministry's Military Technology Division.

Considered in the tests were all aircraft types available in NATO countries and Sweden suitable for proposed mission assignments.

Why was the Lockheed design chosen?

"Because it was then the most advanced weapon system from the technical point of view and because it was capable of eventually fulfilling all German requirements," a Bonn statement said.

Basically, it combines all operational capabilities of an interceptor, fighter-bomber and reconnaissance aircraft.

The F-104G, selected also by the Belgian, Dutch and Italians -- and the Royal Canadian Air Force's CF-104 -- differ primarily from USAF F-104A and C models by:

1. Installation of all-new electronics systems.
2. Increased weapon-carrying capacity.
3. Structural modifications to increase load factor capabilities.

Structural modifications, particularly reinforcements in the tail assembly and in the wing roots, to accommodate the expanded mission requirements, also are included. Changes are described in more detail in another section of this book.

CANADA

Canada announced in July, 1959 selection of the F-104 for RCAF Air Divisions assigned to NATO forces in Europe.

In October, 1962, the first of 200 Canadian-built CF-104s were assigned to units in NATO.

JAPAN

Two Japanese firms -- Mitsubishi and Kawasaki -- share the work load for production of 177 F-104Js and assembly of 20 two-seater F-104DJs.

Mitsubishi Heavy Industries is the pivotal company and is responsible for final assembly and flight test.

Japan's licensed production contract was signed with Lockheed on January 29, 1960. The first 29 airplanes were shipped from Lockheed-California Company in knockdown form to provide design familiarization for Japanese assemblers.

As it did with other licensees, Lockheed provided early tooling and technical training for the Japanese manufacturers.

SECTION III

PURCHASED EQUIPMENT

Electronics and certain high-value items for installation in Super Starfighters are purchased from qualified suppliers in production areas.

In Europe most of the purchased equipment comes from German companies, although components of the F-104G's NASARR radar systems are available from four countries.

HIGH-VALUE ITEMS

In Europe, German industry again supplies a major portion of these items not manufactured by the large contractors.

JAPANESE ELECTRONICS

Japan's burgeoning electronics industry is represented by:

Mitsubishi Electric, Nippon Electric, Shinadzu, and Japan A/C Electric.

Other electronics components for F-104J and F-104DJ models manufactured in Japan are purchased from United States or Canadian suppliers.

JAPANESE HIGH-VALUE ITEMS

Many specialty items in this category also are imported for inclusion in Japanese-made Super Starfighters, but sources listed below provide at-home availability:

Shinko Denki, Tokyo Kokukeiki, AiResearch-Shimazu, Yokohoma Rubber, Thompson-Mitsubishi Denki, Shimazu, Kayaba Kogyo.

CANADIAN ELECTRONICS/HIGH-VALUE EQUIPMENT

All but two electronics systems installed in Canadian CF-104s are purchased from American companies, because of their proximity and design experience.

CANADA TO U.S.

Besides making everything for its own airplanes, Canada also produces several Super Starfighter segments for Lockheed-made craft.

MADE IN AMERICA

Some electronics suppliers for the American part of the huge international program:

Litton Systems, Inc. (navigation system), International Telephone and Telegraph (TACAN), AiResearch Manufacturing Co. (air data computer), Minneapolis-Honeywell (automatic flight control system) and Autonetics (NASARR).

Hamilton Standard Division, United Aircraft Corp., Forrest Wagniere Engineering, Firestone Tire and Rubber Co., Hydro-Aire Co., Stewart Warner Corp, Bendix Corp., Davenport Iowa, Bendix Corp., North Hollywood, Calif., Goodyear Tire and Rubber Co., American Brake Shoe Co., Vickers, Inc. and Allison Division, General Motors Corp.

SECTION IV

THE AIRPLANE ITSELF

The F-104's razor-honed appearance provides a natural invitation for descriptive superlatives.

Precisely engineered, the Super Starfighter's shape is functional -- aesthetics notwithstanding.

It's built to go.

To go high, fast and far with varied defensive payloads.

ORIGIN

It started in 1952, when the U.S. Air Force called for a day superiority fighter subordinating other criteria to flight performance.

Lockheed looked at scores of designs: delta wings, swept wings, flush cockpits, wingtip-mounted vertical fins, rocket propulsion, low-mounted horizontal stabilizer, vee windshields.

Weight went up to about 50,000 pounds, dropped as low as 8000 pounds.

Out of the design, wind tunnel and rocket-flight studies came a new wing shape: the trapezoid. Its span -- 7½ feet on each side of the fuselage -- was startling enough. Added to the break from conventional aerodynamics trend was a definite negative dihedral.

THE FIRST ONE -- XF-104

The U.S. Air Force signed a contract with Lockheed for manufacture of a prototype airplane -- the XF-104 -- in March, 1953. It was made and flown in less than a year, taking to the air for the first time in February, 1954 at Edwards AFB, Calif.

The XF-104 was powered by a Curtiss Wright J-65 engine.

Drawing from prototype flight experience, designers went up to the General Electric J-79 engine for production models because of its increased thrust-to-weight ratio, small frontal area, afterburning and improved specific fuel consumption.

To accommodate the larger engine and increased fuel supplies, fuselage length was extended to 54 feet and 9 inches. All models starting with the F-104A also incorporated the now-standard spiked cone engine air inlets -- multi-shock intakes whose bleed and by-pass systems match all flight regime airflow requirements.

Other major changes were a switch to a.c. electrical power, addition of search and track radar and installation of a ventral fin that -- acting as a large vortex generator -- spoils circular airflow around the fuselage and increases directional stability through the supersonic speed range.

THEN USAF PRODUCTION

Air Defense Command orders for single-seat F-104A air superiority day fighters placed first Starfighters in operational service in January, 1958.

The F-104B was a tandem-seat trainer for the same command.

Built around the same airframe and an improved version of the same engine, the F-104C (which captured the 1962 Fighter Weapons Meet title) went to Tactical Air Command squadrons for attack and ground support.

Its two-seat counterpart -- the F-104D -- is a TAC trainer and local-defense variant.

THAT DROOPED WING

Wind tunnel tests proved that a high tail position was necessary for optimum stability and control about the pitch axis throughout the F-104's wide Mach range.

The wing extends only 7½ feet from the fuselage.

And the tail fin reaches almost the same distance in a vertical direction.

Location of horizontal stabilizer on top of vertical tail raises center of pressure on tail thereby increasing induced roll effect during side slip.

To compensate for the increased roll that resulted from the vertical tail, negative dihedral -- or cathedral -- was put in the wing. Cathedral angle is approximately 10 degrees.

SHORT AND STRAIGHT

Why not use a swept wing?

Swept-back airfoils require thick chord and long span -- with attendant high drag -- to give performance comparable to the short, straight wing.

Extreme sweep also deteriorates handling characteristics. Being short and thin, the F-104 wing encounters little drag. A sharp leading edge slices through the air and eliminates such Mach effects as buffeting and tucking.

Why not a delta wing?

Every square foot of delta wing has less drag in a certain Mach number region -- somewhere between 1 and 2 -- than a corresponding square foot of straight-thin wing. Every square foot of straight wing, however, lifts roughly twice that of a delta.

By the time there is enough delta wing area for a given load, total drag is considerably higher than a straight wing presents.

The delta has lower transonic drag than straight wing. That's why most slightly supersonic aircraft use this configuration.

AND THIN

The F-104 wing has a thickness ratio of 3.36 per cent. Maximum thickness of 4.2 inches adjacent to the fuselage slims to only 1.96 inches at tips.

The wing tip chord is approximately 38 per cent of theoretical root chord and leading-edge sweepback is approximately 26 degrees. The trailing edge has a smaller sweep forward.

Both the nose landing gear and the main landing gear retract into the fuselage because of the thin wing design. Nose gear retracts forward; main gear moves forward and turns, so the wheels can tuck in flat.

The wings attach to the fuselage with five heavy forged fittings that are attached to wing skins and intermediate channels.

Upper and lower skins are formed from single machine-tapered plates, 0.25 inches thick at the root and 0.125 thick outboard.

No chordwise ribs are used. Instead, root and tip forgings help form a torsion box that includes 12 spanwise intermediate channels -- all forming and supporting the airfoil contour.

BUSY DAY AT THE ORIFICE

The Starfighter's boundary layer control system, which provides increased lift and permits lower landing speed, operates on highly compressed air from the engine -- ducted into the wing and out of 55 slots 0.9 inches apart along the trailing edge flap hinge line.

It adds energy to boundary layer air and reduces turbulence due to flow separation.

Airflow through the orifices is controlled by the flap movement. When flap angle passes the 15-degree mark, the BLC valve opens. A full-open position is reached when flaps are extended 45 degrees.

Each slot along the 47-inch flap length is 0.09 inches deep and 0.55 inches wide.

THE FUSELAGE -- UP FRONT

Built in halves, the forward fuselage contains the cockpit, ejection seat system, electronic compartment, Vulcan 20 mm cannon and nosewheel support structure.

Functional systems are installed and the halves mated before final assembly.

Firing loads of the cannon are absorbed by a two-piece mount made of aluminum alloy forgings.

MID-FUSELAGE

Built on five heavy forged frames tied into a forged keelson assembly that supports landing gear loads, the mid-fuselage similarly is designed in halves to ease equipment installation.

Wing fittings attach to the forged frames.

Inside are the Starfighter's five bladder-type fuel cells -- outside are the air inlet ducts.

THAT SPIKED INLET

Excess air taken in at the inlet is by-passed around the engine for cooling and ejected at the nozzle for improved propulsion efficiency.

Also reducing base drag, the ducts are stretch-formed and contoured to the air inlet configuration. Desired skin thickness is attained by chemical milling to assure accuracy of final dimensions.

The conical ramp projecting ahead of the inlet is designed to provide maximum ram recovery for the engine at high supersonic speeds by control of the shock wave at the inlet.

THE EMPENNAGE

The entire horizontal stabilizer of the Super Starfighter T-tail moves as a unit. There is no elevator.

It is located only 11 inches from the top of the swept-back vertical fin -- which has approximately 25 per cent more surface area than early F-104 models.

The larger fin and powered rudder give pilots incremental control in all maneuvers, especially during attack on ground targets.

Only 3.6 inches thick at the inboard edge and slimming to a mere .6 inch at the tip, the horizontal stabilizer is made with a single spar covered with skin panels.

The hinge movement is along the spar line.

Hinge and operating controls both are enclosed by empennage contour -- avoiding external fairings normally used to cover these items.

Built on two steel fuselage forgings supporting two fin forged spars, the fin contains boost servo units for empennage control surfaces.

<u>THE END</u>

Stainless steel and titanium skins cover the aft fuselage section that houses the engine and carries tail loads into the mid-fuselage.

Additional strength, and heat resistance, are provided by stainless steel fuselage longerons and fin deck structure.

Stowage site for the landing drag chute is a compartment on the bottom of the fuselage just aft of the mid-to-aft fuselage joint.

DIALS, GAUGES, SWITCHES, CONTROLS

Designed for easy-to-read simplicity, the Super Starfighter instruments are on four vertically-mounted panels. Individual instruments are face-lighted. Printed placards are edge-lighted. (In Canadian aircraft instruments are integrally lighted.)

The main panel includes flight attitude indicators and navigation instruments, tachometer and gauges for exhaust temperature, jet nozzle position and fuel.

At each side is a fire, or overheat, warning light that comes on if engine or tail sections have critical temperatures. If engine inlet air temperatures exceed specified limits, a "slow" warning light is illuminated on the left side of the panel.

Monitoring all warning lights is a master caution light at the bottom of the panel. After it is activated -- to warn the pilot of possible trouble -- it can be reset to operate for other parts of the warning system.

Other main panel indicators are for engine air inlet temperature and pitch rate.

DOWN BELOW

The T-shaped lower panel holds the radar indicator, hydraulic and engine oil pressure gauges, fuel flow and cabin altitude indicators. Non-instruments mounted there are armament control panel, landing gear and flap position units.

Plus -- drag chute manual release pull handle, gunsight controls, pilot faceplate heat control, hydraulic pressure gauge system selector switch and the armament control section.

TO THE RIGHT AND LEFT

Forward of the throttle control, the left panel is site of the landing gear switch, landing and taxi light switch, engine starter, aileron and stabilizer takeoff indicator lights and the external stores jettison switches.

Directly above the landing gear lever is a downlock over-ride button -- and within a transparent knob on the lever is the landing gear warning light. Atop the knob is the control lever uplock release button.

On the opposite side of the cockpit, the right front panel is underneath the canopy sill -- displaying generator switches, fuel quantity indicator test switch and the multiple warning light panel.

Dubbed the "peek and panic" panel by Lockheed engineers and test pilots, it has 11 separate windows centralized in one location for instant recognition of trouble.

LEFT CONSOLE (DIFFERS CUSTOMER TO CUSTOMER)

Behind the throttle control and extending along the left cockpit wall is a console with sub-panels for radar control, automatic pilot control, stability controls and circuit breakers.

Outboard it has auxiliary trim switches, fuel tank selection, armament control and the anti-G suit regulator.

THEN RIGHT (DIFFERS CUSTOMER TO CUSTOMER)

Right console sub-panels are for oxygen control, navigation, bombing control, UHF and circuit breakers. Outboard: controls for exterior and interior lights, inertial navigator and air conditioning, including the fresh-air scoop.

SECTION V

THEN THE SUPER STARFIGHTER

In order to produce a true multi-mission aircraft that could compete successfully in the world market, Lockheed realized the need for re-design.

Beginning in 1956, Lockheed and the U.S. Air Force flew 52 test F-104s approximately 6500 missions in a program that cost more than $30,000,000.

As a result of the tests, the company determined that some internal airframe re-design was necessary.

The structure, therefore, was re-stressed to meet the strength requirements of all-weather missions -- with full external loads. Advanced all-weather electronic systems were incorporated to fulfill specific mission assignments.

NEW MUSCLES, SINEWS

A total of 36 new forgings were designed for such major structural components as fuselage main frames, wing fittings and beams, fuselage longerons and joints, tail frames, empennage beams and ribs and some fuselage skins.

About 60 smaller zero-draft, close tolerance forgings, fabricated at approximately 50 per cent of the cost for conventionally machined parts, also are in the Super Starfighter.

STRONGER STABILIZER

Tail-unit modifications were made to provide increased control power needed for operation at low altitudes and higher gross weights.

The change principally is refinement of the enlarged vertical area developed to counteract increased side area of the two-place F-104B.

The fin leading edge was extended aft. Irreversible hydraulic power was incorporated for the rudder and more power was given the horizontal stabilizer control system booster.

SLOWER LANDINGS, QUICKER STOPS

To assure quick-stop capability, Lockheed added fully powered blakes to the Super Starfighter, combining them with an anti-skid system energized by sensing units in each axle.

The braking parachute's diameter was increased from 16 feet to 18 feet.

NO ICE TODAY

Although it flies regularly through extremely cold air mass regions, the Super Starfighter presents no icing problem.

Two things keep ice from forming on the wing. One is the extremely thin leading edge -- like a carving knife blade -- so thin ice cannot establish an anchor on the metal. The other is the aerodynamic heating that results from the airplane's very high airspeeds.

Icing around the spiked engine air inlet is prevented by application of British Spraymat electro-thermal units produced in the United States by Pacific Aeromotive under Napier license.

SECTION VI

SUPER STARFIGHTER ELECTRONICS

Probably no other aircraft in the world has carried as compact and precise a package of electronic gear as the Super Starfighter.

Beef-up structural changes aside, the advanced electronics wizardry more than anything else accounts for the biggest difference between the F-104G/CF-104/F-104J airplanes and earlier models.

Performance -- 1500 m.p.h. speed and ability to zoom to 80,000-plus altitude -- remains, with refinement.

The electronic magic contained in "black box" arrays opens the door to new defensive effectiveness -- to increased, deadlier deterrent powers.

NASARR

The name -- NASARR -- comes from North American Search and Range Radar.

A multi-puspose system consisting of a radar set that incorporates an optional fire control computer, for air-to-air weapons, air-to-ground, and navigation.

Used with the fire control computer in air-to-air missions, NASARR figures for the pilot lead angle attack for automatic rocket releases, and lead angle attack (with information supplied to the director gunsight) for the M-61 Vulcan gun.

DIRECTOR TYPE GUNSIGHT

After NASARR has computed the proper lead angle for firing the Vulcan gun, the director gunsight gives the pilot an optical line-of-sight indication.

The sight is used for firing missiles and -- with the infra-red sight -- can do the same at night. The caged sight reticle also is utilized as an aiming reference for visual dive bombing.

Advantages over earlier sights: smaller sight head, improved tracking, lighter weight, and easier to install and maintain.

INFRA-RED SIGHT

A Lockheed development, the IR sight is integrated with the director gunsight and shares its optics. Able to "see" targets by picking up emission of infra-red rays from heat sources, it can be used in the day and night.

AIR DATA COMPUTER

The air data computer receives electrical analogs of air temperature, and angle of attack from transducers and transforms the information into functions of true altitudes, true air speed, true Mach number and angle of attack as required by other airborne systems.

The information goes to other systems -- saving considerable weight and avoiding errors probable in separate units.

DEAD RECKONING NAVIGATOR

PHI (for Position and Homing Indicator) tells the pilot where he is by remembering where he started, and keeping track of course changes, time and speed.

This automatic system also serves as an indicator for the inertial navigator TACAN and C2G compass systems.

The pilot has only to select a position to learn the heading and nautical-mile distance to that target or destination. (One station is always set for the return flight home.)

TACAN

Extremely valuable in areas where TACAN stations are located, this radio air navigation provides instant and continuous read-outs in nautical-mile distance and direction in degrees of bearing.

A polar-coordinate type system, TACAN provides information via the PHI system indicator for accurate position fixes.

INERTIAL NAVIGATOR

Actual ground distance and track -- independent of forecast or computed winds -- is measured by the inertial navigation system.

Reading through the PHI, it requires no signal outputs, emits no electromagnetic radiation, and continually presents to the pilot a direction and distance to pre-selected stations.

For other electronic systems, the inertial navigator provides heading, pitch and roll data.

UHF

Lighter and smaller (about 500 cubic inches less displacement than previous components), an improved UHF command communication set is standard equipment for all Super Starfighters.

IN-FLIGHT NASARR PROOF

DC-3s wearing the sharp radome nose of an F-104G now are in German Air Force service after development and use by Lockheed-California Company.

The transport's usual seats are removed. Inside the cabin are the Super Starfighter's electronics gear, and major F-104G cockpit components, test and measuring equipment and stations for engineers monitoring systems in action.

With Lockheed, the unusual hybrid made 50 flights in a 16-week proving program. Besides checking operation of avionics, the "airplane with a point" evaluated qualities of the F-104's filament-wound, plastic radome, now being produced overseas as well as at company headquarters in Burbank.

WHERE?

The Super Starfighter electronics compartment ("E" Bay) is located beneath the aft section of the cockpit canopy, approximately five feet along the airplane axis.

Access to the compartment -- shaped like a round-top chest -- is provided by a hinged door on top of the fuselage.

Each interchangeable electronic box, fashioned like gasoline cans used on military jeep vehicles, is the same height and depth but can vary in width.

Units have self-test points and adjustments permitting quick "go, no-go" checkout after installation.

Secured against in-flight movement, the cans are cooled by ducted air.

ELECTRIC POWER

Delivering the necessary power to electronic components are two engine-driven variable frequency generators potent enough to supply electricity for all homes in an average city block.

In addition to the main generators are a fixed frequency unit driven by a hydraulic motor, an emergency generator driven by a ram air turbine, and two batteries.

If one of the two main generators fail such loads as fuel boost pumps, auxiliary fuel transfer pump, duct anti-icing and one gun motor, are dropped. The emergency system can operate all functions needed for a dead stick landing, including radio, cockpit lights, windshield defogging and flaps.

Two batteries provide capability for in-flight engine restarts and external stores jettisoning.

Using three-phase generators, the Super Starfighter has a variable-frequency primary alternating current power system.

SECTION VII

OTHER SYSTEMS

Original F-104s built for the U.S. Air Force were equipped with downward-ejecting pilot seats. Two reasons:

1. At that design period, no seat had been developed or was available that Lockheed felt had sufficient boost to always push the pilot clear of the T-tail.

2. It was surmised that essentially all ejections would be accomplished at altitudes high enough for successful completion of the maneuver.

Since then, a capable upward-ejection system has become available -- the C-2 model.

The C-2 was selected for installation in all Starfighters.

THE C-2 SEAT

Capable of providing full recoveries at airspeeds from approximately 100 to 550 knots and altitudes from ground level to 50,000 feet, the C-2 leaves the Super Starfighter via a rocket-catapult device.

At or near ground level the timing mechanism is set to separate pilot from seat one second after ejection -- and parachute deployment one second later.

SEPARATION SEQUENCE

To eject, the pilot pulls a D-shaped ring located between his feet on the seat bucket structure. The ring fires two initiators. One ejects the canopy. The other starts pre-ejection functions.

In three-tenths of a second, this happens:

Metal stirrups pull feet close to the body and hold them until time of man-seat separation.

Knee guards rotate into position to prevent leg spreading and to counteract effects of airloads.

Arm support webbing flips up and prevents outward movement of arms.

Moving up the rails, the seat hits a striker and -- one second later -- the lap belt is released, foot retention cables are cut and the pilot-seat reel operates.

(Pulling the D-ring also operates a backup system that fires a delay initiator into the catapult unit and a second one into foot cable cutters.)

ROCKET CATAPULT

The XM-10 rocket-catapult, a pyrotechnic propulsion unit, fits on the seat back upper cross-beam member and moves up and down with seat adjustments.

LEAVING THE SEAT

Forcible separation is actuated pyrotechnically by a windup reel behind the head rest.

Nylon webbing is routed from the reel down the forward face of the seat back, under the survival kit, and secured to the forward seat bucket lip.

Sequenced with the lap belt release, the webbing is drawn taut between the head rest and the lip in two-tenths of a second, "pushing" the pilot out and away from the seat one second after ejection.

To assure proper foot retention and retraction, the pilot wears foot spurs equipped with ball sockets at the back. The ball lock end, engaged by spurs, is attached to cables that pull feet rearward and secure them in foot shelf units. Two initiators, fired one second apart, cut cables free at the proper time.

Carried on the aluminum alloy seat is an automatic survival kit that includes disconnect hardware, automatic life raft inflation, high-pressure emergency oxygen bottles with 15 minutes' duration, and a regulator suitable for partial pressure suits above 42,000 feet.

CANOPY

The left-hand-hinged cockpit canopy is operated manually for normal entrance and egress.

For ejection, hold-down hooks are released automatically on each side to assure symmetrical operation.

The canopy can be jettisoned three ways: pulling a handle on the forward cockpit console, working the seat escape handle, and -- on the ground -- from the exterior by rescue crews.

HYDRAULICS

Super Starfighter hydraulic power is assured by two independent systems working from engine-driven variable displacement pumps. They can operate in varying temperatures.

HYDRAULIC SAFEGUARD

An emergency ram air turbine lowered from the right-hand side of the fuselage will provide hydraulic power in the event of engine seizure that leaves the primary system intact. (A flamed-out but rotating engine gives adequate hydraulic flow and pressure for surface control.)

The ram air turbine permits safe flight and moderate maneuvers and supplies emergency electrical power.

The hydraulic system uses stainless steel pressure lines and standard flareless fittings.

POWER STEERING

Nose wheel steering power for all models of the Super Starfighter is supplied by the landing gear door pressure line.

In these airplanes, pressure indicators are installed in the cockpit.

A switch on the pilot's control stick governs the nose steering shutoff valve, which is activated by cables from the rudder pedals.

SECTION VIII

POWERPLANT

General Electric Company's Flight Propulsion Division, designer and manufacturer of the Super Starfighter's J-79 jet engine, is America's pioneer in the field.

In 1941 General Electric produced the nation's first turbojet powerplant -- designated the I-A.

It weighed 780 pounds and had a thrust -- or pushing power -- measured at 1300 pounds.

Pursuing its pioneering advantage, General Electric during World War II developed a new style engine built around an axial flow compressor.

Earlier models, such as the J-33 which powered Lockheed's F-80 Shooting Star, used a centrifugal compressor that propelled air outward from the center of rotation.

Axial flow means that the air flows straight through, "packed" ever tighter by a series of spinning fan-like blades before fuel is added and ignited.

The one big goal of engine manufacturers was an engine combining light weight with high thrust, mechanical simplicity and reasonable fuel economy.

With the J-79, that goal was reached.

MACH II MATES

For the first time, an advanced aircraft (F-104) and a powerplant (J-79) were developed and produced simultaneously.

The engine's thrust-to-weight ratio -- 3500 pounds weight and 15,000 plus pounds thrust -- is unprecedented. Developed in cooperation with the U.S. Air Force under the government's weapon system management concept, the J-79 was the first production engine capable of powering aircraft twice the speed of sound.

It had more than 12,000 hours of factory, simulated altitude and flight testing time before reaching the production stage.

Variable-pitch stator blades adjust automatically to (1) reduce stall problems at low engine speeds, (2) give maximum compressor efficiency under all flight conditions and (3) to match engine and airframe induction system for good stall margin at high airplane speeds.

The design permits rapid acceleration from idle to full power without compressor stall -- a feature labeled by military pilots as "amazing."

The J-79 is 207 inches long, with a 36-inch frame size. Pressure ratio is 12:1. Engines installed in the F-104G, F-104J and F-104DJ -- assigned a designation of J-79-11A -- weigh approximately 3500 pounds, and are rated at 10,000 pounds thrust without or 15,000 plus pounds thrust with afterburning.

THE COMPRESSOR

The axial flow compressor has 17 stages and a single rotor, with the first six stator stages and inlet guide vanes variable.

Rotors are made of thin webbed discs and spacer rings bolted together. Blades are attached to the rim sections by conventional dovetails. (Top and bottom compressor casing sections can be removed for inspection and maintenance.)

THE COMBUSTION CHAMBER

The annular-design combustion chamber has a split casing that can be disassembled quickly and contains 10 combustion chambers.

ANTI-ICING

Compressor discharge air guards against inlet guide vanes and struts icing.

THE TURBINE

Wheels of the three-stage turbine are coupled to the compressor rotor by a conical shaft for low weight and high strength.

The lightweight casing is made of fabricated sheet metal. Top and bottom sections are removable.

CONTROLS

The engine's separate fuel systems -- main and afterburner -- both are flow controlling units, hydro-mechanically operated.

An integral part of the basic engine, controls have electrical trim, with both hydraulic and electric power. Overall, the system serves main fuel, afterburner fuel, nozzle area and variable stator controls (integrated with main fuel controls).

Afterburner features: fully modulated, variable area, with a converging-diverging exhaust nozzle that works automatically.

SECTION IX

PRODUCTION PROCESSES

Lockheed's aircraft manufacturing techniques all are keyed to producibility.

The F-104 is no exception.

These techniques, passed on to Super Starfighter licensees, aim for easy structural accessibility and effective use of sub-assemblies.

Design goals were -- and still are -- light weight, conventional structure, manufacturing methods and equipment, low cost per pound and high production rates.

Because of the F-104's precise tolerance requirements and heretofore unknown aerodynamic sleekness, some new fabrication methods were developed.

COMPRESSION FORMING

Parts fabrication with tolerances as low as .010 is possible with contour forming, in which sheet metal first is shaped broadly, heat-treated then precision formed in the cavity of a compression die.

A high-pressure ram forces the metal to flow on both the surfaces and edges of the part against the die face.

Because of sharper flange band radii, rivets can be seated almost in line with the web of wing stiffeners -- increasing the connection's strength and cutting down "working" of the area under stress.

The sharp radii also permits use of much narrower offset flanges, reducing weight.

Accuracy of compression forming eliminates waviness in wing panels that disturbs airflow and promotes friction and drag at high speeds.

This method is used with sheet metal for making wing spars and ribs that do not carry big loads. In heavy load-carrying areas forgings are standard.

ZERO DRAFT FORGINGS

Until recent years, forgings were made with a taper -- or draft -- on rib sides so they could be withdrawn from the die cavity.

On most forgings the taper was machined off either to remove unneeded material or for attachment to other parts.

Working with the U.S. Air Force Air Materiel Command and several aluminum vendors, Lockheed helped develop new close tolerance press forging that turned out parts with thin, untapered ribs.

Using higher pressures and precision dies, Lockheed and its allied licensed manufacturers now produce about 60 zero-draft forgings for each Super Starfighter.

CHEM-MILLING

Structural material with localized areas of thick and thin sections -- to accommodate variable loads -- formerly were made by fastening smaller parts together or machining from heavy stock.

Chemically milling now does the job.

After masking certain areas, aluminum sheet, plates and extrusions are immersed in a caustic soda solution that removes unwanted material by etching it off much like printing photographic plates are prepared.

Machining costs are cut and tolerances are held well within limitations.

An F-104 chem-mill example: engine air intake ducts in their extruded form.

STEEL EXTRUSIONS

Squeezing hot steel billets through a die like bakers use a decorator tube to ice cakes, Lockheed fashions high-strength alloys into a dozen extruded parts such as the piano hinges that attach ailerons to wings.

The time-saving factor, compared to former methods of machining parts from solid bar metal, is obvious.

CADMIUM PLATING

Cadmium is a "self-sacrificing" metal.

As a coating for other metals, it allows itself to become oxydized, rather than the load-bearing member, thus absorbing corrosion and fatigue.

Applicable to extremely high heat-treated steel specified for landing gear parts and fasteners, cadmium-plating is accomplished in an air-tight chamber.

Placed in the chamber, the part is coated when virtually a complete vacuum is created and cadmium in a crucible is boiled until it evaporates and condenses on the component.

MILLING, MACHINING BY TAPE

Three profilers -- two Giddings & Lewis 4-by-12s and one Morrey 4-by-4 -- are controlled by magnetic tape as they machine tail hook housings and ejector racks for Super Starfighters.

Programmed from IBM punched cards, the tape guides the three-axis profile milling machines completely through all their maneuvers, producing more accuracy in half the time.

RADOME SPINNER

Shaped exactly like the Super Starfighter's nose is a cone-like steel tool that winds fiberglass threads into distortion-free radomes.

Spinning at a controlled speed, it pulls fiberglass strands through a resin bath and, under regulated tension, weaves layers of glass thread into the radome.

When threading and curing are completed, the radome is machined to exact dimensions -- by delicate cuts on the first and final layers.

The electronically transparent nose is checked for radar transmission characteristics with an interferometer and boresighted on the company's radar range.

QUICK-CHECK ELECTRIC TESTER

Reliability of Super Starfighter electrical connections can be checked rapidly with a portable circuit tester that can be either wheeled directly to the aircraft or work bench.

Capable of detecting and recording circuit errors, it will make 400 tests in 4½ minutes by comparing an electrical circuit with pre-set standards.

SECTION X

MAINTENANCE

Airplanes are useful, vital implements of defense only when they are flying.

The simpler the maintenance, the quicker and the longer they fly.

Based upon the record of F-104s in U.S. Air Force service, Super Starfighters now flying and abuilding will spend more than their share of time at work -- in the air.

USAF Starfighters have required only about half the maintenance manhours per flight hours needed for other current jet fighters in the inventory.

The airplane's size and easy-to-reach ground attitude are inherent maintenance attributes. No skyscraping ladders, no giant aerostands are necessary.

The airplane has 165 interchangeable parts -- from small accessories to full panels -- that can be switched or replaced with tools from an average mechanic's stand.

EASY-DOES-IT EXAMPLES

1. Modular boxes containing electrical equipment is installed or removed by one mechanic in a matter of seconds via plug-in design.

2. Circuit breakers and load carriers are located in service bays accessible from the ground.

3. Built into the lower side of the fuselage, the hydraulic panel opens easily for service when the cover panel is unlatched.

4. The cockpit bottom hatch can be removed, the entire seat installation taken out, and stand-up room provided inside for technicians.

5. Electronics gear packaged in "Jeep cans" is reached simply by unhooking and opening hinged cover panels just behind the cockpit.

6. There are provisions for all types of external stores.

ENGINE MAINTENANCE

The J-79 engine's split turbine casing permits turbine inspection and work without complete engine teardown.

Most engine accessories can be inspected or removed with engine installed -- a major advancement over most other fighters which require removal for only minor replacements.

SPECIFICATIONS

POWERPLANT:

One General Electric J-79 turbojet engine, equipped with afterburner.

Thrust: 15,000 plus pounds, maximum afterburning, SLS.

PERFORMANCE:

Maximum speed: Mach 2 plus.

Maximum altitude: 100,000-plus feet.

Range: In-flight refueling provisions give virtual round-the-world range. Standard wingtip tanks can be supplemented by pylon tanks and gun-bay fuel storage.

DIMENSIONS:

Height: 13 feet, 6 inches.

Length: 54 feet, 9 inches.

Span: 21 feet, 11 inches.

LANDING GEAR:

Tricycle type retracts into fuselage; equipped with larger main landing gear tires and improved liquid spring strut.

MISCELLANEOUS:

Two-place Super Starfighters have basically the same features and characteristics: wing boundary layer control, lightweight fire control system,automatic pitch control that senses and prevents stalls.

RECORD-SETTER

The F-104 is modern aviation's most prolific record setter.

In 1958 the F-104A set world marks for straightaway speed, altitude and time-to-climb to seven different altitudes.

The Starfighter record run-down:

May 7, 1958 -- altitude, 91,243 feet.

May 18, 1958 -- speed, 1404.08 m.p.h.

December 18, 1958 -- time-to-climb to 3000 meters (41:85 seconds), 6000 meters (51:41 seconds), 9000 meters (1 minute 21:14 seconds), 12,000 meters (1 minute 39:90 seconds), 15,000 meters (2 minutes 11:1 seconds), 20,000 meters (3 minutes 42:99 seconds), and 25,000 meters (4 minutes 26:03 seconds).

December 14, 1959 -- altitude 103,395.5 feet.

(The U.S. Air Force awarded Lockheed a contract to modify three F-104As for regular flight at altitudes up to 120,000 plus feet. Modifications included a rocket engine in the tail for propulsion at the higher levels, jet reaction controls instead of the normal control surfaces at peak altitudes, and 24-inch extension of wings.)

En route to the 103,395-foot mark in 1959, the F-104 flashed above the desert at Mach 2.36 (more than 1500 m.p.h. ground speed) and, the pilot said, could have flown faster.

MISCELLANY

At least 14 completely different designs were considered in 1952 before Lockheed decided finally on the F-104 configuration. Studied, tested and abandoned were: sliding intake centerbody, flush cockpit, delta wing, rocket propulsion, wingtip-mounted tail booms, nacelle-retracting landing gear, V-shaped windshield, low tailplane.

* * *

Super Starfighter maneuvering flaps result in up to 50 per cent reduction in airplane turn radius for combat maneuvers.

* * *

Fokker Royal Netherlands Aircraft factories have installed two-level docks for F-104G assembly which, Fokker says, saves 10 per cent in man-hour expenditures. And a Fokker electronic test center -- completed in just 360 days -- has an output of one complete system every 1½ days.

* * *

SABCA is manufacturing the wings, and other components for the Super Starfighters, including servo controls and hydraulics.

* * *

Sidewinder missiles are being produced in Europe by Norway, Denmark, The Netherlands, Greece, Turkey and the Federal Republic of Germany.

* * *

Super Starfighter ailerons are made with a steel beam that has been heat-treated to an ultimate tensile strength of 180,000 p.s.i. Actuated by 10 rods, ailerons are hung on steel piano hinges.

* * *

Lockheed Vice President C.L. (Kelly) Johnson, who talked with combat pilots in Korea, learned they wanted an airplane to fly higher and faster than the enemy, with easy field maintainability. "The F-104 met those needs," he said. "Its outstanding performance is still not fully appreciated. It still has performance the engine can't exploit."

* * *

Here's a statement to Lockheed from Capt. Charles E. Tofferi, 479th Tactical Fighter Wing, who flew his F-104C to the 1962 Fighter Weapons Meet title:

"Thank you, one and all, for the best airplane I've ever flown." He said the F-104 "really shines" in maintenance capability, "so simple to maintain, people with little experience can do it."

* * *

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