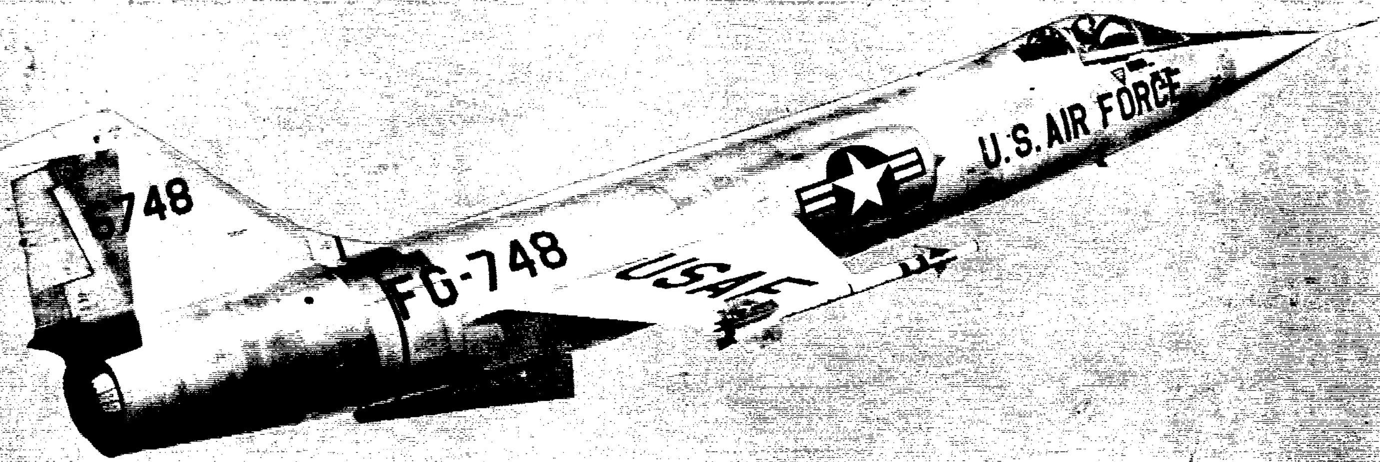
THE STORY OF THE *Starfighter*



MEMO TO: Aviation Editors
Aviation Writers
USAF ISO Personnel

Here is a book crammed full of information on the world's fastest, highest-flying airplane -- today's best airborne newsmaker.

With virtually all releasable data on the F-104 Starfighter, the pages inside contain material for dozens of interesting and topical stories.

Newsbureau
Lockheed
Burbank.

PRESS BOOK

SECTION I

AIRPOWER'S TOP STANDARD BEARER

High in the cold, blue-black sky above the North American land mass -- up where the air battles of the next war, if it comes, could be fought -- there range today, this very minute, swift and deadly U.S. Air Force F-104 Starfighters.

Their two-fold mission:

Maintain a relentless vigil.

Destroy any enemy aerial invaders.

They are equipped to do that job better, faster, than any other operational fighter-interceptor in the world.

Shaped like a missile and flown by a man, the Starfighter is the most spectacular production airplane ever built. It is aviation's most talked about performer. It is the most compact package of manned aerial striking power in history.

APPEARANCE? SHARP

What does the F-104 look like, up close?

A rapier? A stilleto?

Perhaps -- in its sharpness of contour. But these hand-borne weapons of history belie the devastating firepower which can be unleashed by the ultrasonic Starfighter.

This is the first of the "new look" airplanes. And there will be more to come. As man flies faster and higher the aircraft configuration is going to become sleeker and "more to the point." It must -- for aerodynamic considerations dictate it.

Some have called the F-104 a "manned missile." On pure performance it belongs in the class of many short and intermediate range missiles.

But the Starfighter has one tremendous inherent advantage over any missile. It carries its own human intelligence. It has the ability to think, as it flies and fights. And to return to fly and fight again.

RECORDS A-PLENTY

What about its performance? What has it done to become the most prolific record setter in aviation annals?

Here are the facts:

It was 9:39 a.m., on May 7, 1958. The weather was crisp and clear at Air Force Plant 42, Palmdale, Calif. A new chapter in aviation history was in the making.

Less than half an hour later, by 10 a.m., Maj. Howard C. Johnson, 37-year-old fighter pilot from the 83rd Fighter-Interceptor Squadron, Hamilton Air Force Base, Calif., was flying through the mezzanine of outer space.

His altitude: 91,243 feet.

He had flown higher than any man who ever took off from the earth in an airplane.

He was in an F-104A Starfighter.

FLIGHT DETAILS

When Major (now Lieutenant Colonel) Johnson lifted off the runway at approximately 9:40, his sights were set on breaking the existing official altitude mark of 76,928 feet. This is how he did it, with almost three miles to spare.

Bearing toward the Pacific Coast, immediately after takeoff, he lit the afterburner between Ventura and Santa Barbara. Then he turned around and started back to get in range of the photo-theodolite altitude measuring equipment installed at Edwards Air Force Base.

Near Mt. Los Pinos, he went into full uniform (maximum) burning and started his acceleration. The F-104 pulled a long white contrail against the bright blue sky.

At 9:58 he reported:

"Mach number 2.1, starting climb."

The contrail became fainter and fainter.

His flight plan called for accelerating to mach 1.7 at 35,000 feet, then angling up to 40,000 while increasing to mach 2.1. At 40,000 he would tip up some more, still holding 2.1 to get a climb attitude. When he hit 45,000 he was to rotate (vary attitude), at about 2.5 Gs, to a 35-degree angle and set up an initial rate of climb around 80,000 feet per minute to 65,000 feet.

From that point on he was in a "ballistic zoom."

By holding the airplane just a shade under one G he would go "over the top" -- if he was right, and if the bird was right.

UP, UP, AND OVER

The maneuver wasn't in any manual. It never is when man is probing the unknown.

As the outside pressure went down, and the sky turned deep purple, his pressure suit began to inflate, exerting an octopus-like squeeze over his entire body. At 90,000 feet it clamps you as if in a vise.

Holding to the fine, gentle pressure on his stick -- Johnson eased over the top. His indicated speed was about 80-100 knots. True speed: 623 m.p.h. He was almost 17 miles up in the stratosphere.

Upon completion of his record-smashing climb, he described the Starfighter as "fantastic."

"It is moving today's fighter pilot right out to the fringes of space."

Johnson took off at 9:40 and landed at 10:07 for a total flight time of 27 minutes.

STRAIGHTAWAY SPEED

Ten days later, on May 17, 1958, from the same runway at Lockheed's jet production and flight test center at Palmdale, "Operation Starflash" got under way.

Capt. Walter W. Irwin, 34-year-old team-mate of Johnson at the 83rd FIS, Hamilton AFB, was selected to add a second performance diadem to the Starfighter's world titles.

His goal: crack the existing speed mark of 1207.6 m.p.h.

In order to "qualify" a speed run, and meet stringent requirements set up by the Federation Aeronautique Internationale and the National Aeronautic Association, Captain (now Major) Irwin had to do the following:

Fly the F-104 through a straight-as-a-string (and not much wider) 10.1-mile-long course. His altitude was to be 40,000 feet.

When in the radar-monitored "trap" he had to hold the aircraft within a maximum altitude tolerance of 100 meters.

That meant not varying the assigned 40,000-foot altitude, from start to finish of the official 10-mile run, by more than 328 feet.

The slightest tremor of his hand would flick him out of that precise slot.

HOT AIRPLANE

And there was a further critical factor to be dealt with -- he was nudging the F-104 right up against the "thermal thicket," the heat barrier.

Air slamming into the airplane's ducts created heat. If he allowed the plane to go too fast the compressor inlet temperature would reach the point where it could damage the engine.

This meant he had to reduce the engine power during the run to keep from going over temperature limits.

Thread an imaginary needle's eye, a spiderweb-thin track in the sky. Do it while flying faster than a 16-inch cannon shell. Set a new record -- but don't go too fast. A challenge, for both man and machine.

At 7:58 a.m., on May 17, the ground tracking stations were ready. The pilot and the plane were ready. "Operation Starflash" received the green light -- go.

Taking off from Palmdale, Irwin climbed out over Gorman, half-way between Los Angeles and Bakersfield, and moved up to 40,000 feet.

Like a deer hunter taking aim with a rifle, he pointed the Starfighter in the direction of Rosamond Dry Lake, over California's Mojave Desert, and -- whoosh, he was streaking on his downwind run.

AND BACK AGAIN

Through on number one. Better than 1465 m.p.h. Irwin executed a "teardrop turn" near Victorville. The turn, made at mach 2, could not go higher than 1640 feet above the run altitude.

Back into the "tube," heading west.

He held steady while inching back the throttle to keep temperature down. A 60-70 knot wind was blowing at altitude. Speed this time, better than 1342 m.p.h.

Both runs were "on the beam." The record was clear for certification.

Average speed: 1404.09 m.p.h. Almost 200 m.p.h. faster than the previous world record.

Total time in the air: approximately 20 minutes.

Time to set the record: about 20 seconds.

Post-script: During one of his earlier downwind runs, after which the return trip was scrubbed, Irwin had topped 1500 m.p.h.

Aviation's first mach 2 operational fighter had let it be known -- it has speed to spare.

AND SPEED TO ALTITUDE

On Dec. 18, 1958, a pair of young First Lieutenants from the 538th FIS, Larson AFB, Wash., more than tripled the number of world's records held by the dazzling Starfighter.

1st. Lt. William T. Smith and 1st. Lt. Einar K. Enevoldson teamed up to add seven time-to-climb marks to the airplane's speed and altitude crowns.

The place: Point Mugu Naval Air Station, near Oxnard, Calif.

Flying in relay fashion -- one would go up and come down, then the other would take his turn -- Smith and Enevoldson split the hazy (sometimes murky) skies over the Pacific Coast shoreline in a two-day series of record yo-yo-like ascents.

Their flights were conducted in conjunction with an Air Defense Command exercise designed to evaluate maximum interceptor climb capabilities.

JUNIOR OFFICERS

Of noteworthy mention -- before going for the time-to-climb marks, Smith and Enevoldson had only 35 hours apiece in the F-104.

It didn't take them long to find out that high military rank, and age, were not prerequisites to taking the "manned missile" through its perpendicular paces.

Flight plans for the climbs to 3000, 6000, 9000 and 12,000 meters were straight and simple: Get off the ground, fast, and point the nose for the sky.

For the 15,000, 20,000 and 25,000 meter events (no previous marks had ever been set at the two higher altitudes), the pilots were checked out in the "zoom" technique used successfully in setting the world's altitude record.

They followed the curves right up to the new marks.

SEVEN NEW RECORDS

Lieutenant Enevoldson set the 3000, 15,000 and 25,000 meter records. Lieutenant Smith flew to the marks at 6000, 9000, 12,000 and 20,000 meters.

When Enveoldson climbed to the 3000 meter (9842.5 feet) mark -- from brake release to targeted altitude -- the F-104's total distance over the ground was only 11,000 feet.

"These time-to-climb records point up the Starfighter's ability to apply its tremendous speed and altitude capabilities to actual intercept missions -- a vital USAF Air Defense Command contribution for the protection of the nation's homeland," Maj. Gen. Hugh A.Parker, Western Air Defense Force commander, announced at the time.

Q.E.P. -- Quod Erat Performorandum -- proved by performance.

Here are the new and old records:

3000 meters (9842.5 feet)	old record new record	44:39 seconds 41:85 seconds
6000 meters (19,685 feet)	old record new record	1 min. 06:13 seconds 58:41 seconds
9000 meters (29,527.5 feet)	old record new record	1 min. 29 seconds 1 min. 21:14 seconds
12,000 meters (39,370 feet)	old record new record	1 min. 52 seconds 1 min. 39:90 seconds
15,000 meters (49,212.5 feet)	old record new record	2 min. 36 seconds 2 min. 11:1 seconds
20,000 meters (65,616.7 feet)	brand new mark	3 min. 42:99 seconds
25,000 meters (82,020.8 feet)	brand new mark	4 min. 26:03 seconds

IN POSITION

Strategically located Air Defense Command squadrons, spreading a protective coast-to-coast aerial umbrella across the United States, were the U.S. Air Force's first units to be equipped with ultrasonic Starfighters.

Their joint objective: reach out, intercept and destroy potential aerial invaders before they could get close to major population and industrial centers.

BASES SPAN CONTINENT

From the mid-way point on the Pacific Coast shoreline, with San Francisco's Golden Gate serving as a ground hub for a giant aerial defense perimeter, F-104s perform a spoke-to-rim sweeping action out of Hamilton Air Force Base, Calif.

They are assigned to the 83rd Fighter-Interceptor Squadron.

Across the nation, on duty with the 337th FIS, Westover AFB, Mass., Starfighters maintain a similar patrol of the key north-east air corridors approaching New England and the east coast.

At Larson AFB, Wash., near Grand Coulee Dam and the vital Hanford Atomic Project, F-104s from the 538th FIS are assigned to screen the northwest sky passages to the gateway states of Washington, Oregon and Idaho.

Round-the-clock protection of America's industrial heartland in the upper and central midwest is the mission of Starfighters from the 56th FIS, Wright-Patterson AFB, O.

For Air Defense Command assignments, the 25-mile-a-minute F-104s are armed with infra-red, heat-seeking Sidewinder air-to-air missiles which enable the plane's pilot to destroy his target although he may never see it in the dark of night. The missile "homes in" on the heat of the enemy plane's engines.

ADC squadrons are equipped with single-seat F-104As and two-place F-104B fighter-trainers.

TACTICAL AIR COMMAND

On October 16, 1958, the Starfighter acquired a brand new role -- it became a member of the Tactical Air Command's Composite Air Strike Forces.

CASF units are global air armadas, each a miniature air force in itself. Highly mobile, they are on call day or night -- an in-being deterrent to limited or "brushfire" wars anywhere in the world.

Parent organization for the TAC F-104s: 479th Tactical Fighter Wing, George Air Force Base, Victorville, Calif.

Ready to grasp and hold air superiority "anywhere-anytime" over a given combat area, the Starfighter's TAC mission encompasses all tactical fighter assignments.

FOR EXTRA RANGE

In-flight refueling provisions give them round-the-world range.

Basic armament for the Tactical Air Command's F-104s is the M61 Vulcan cannon. It is the fastest-firing machine gun in the world. Any one of the explosive shells from the six-barreled 20-mm Vulcan can destroy a bomber.

TAC Starfighters can carry a variety of external stores, including nuclear weapons.

In its TAC configuration, the single-seat version of the Lockheed-built fighter is designated F-104C. Its two-place fighter/trainer stablemate is the F-104D.

HAVE WINGS, WILL TRAVEL

More than half a million spectators in Belgium, Spain and the Netherlands had their initial first-hand introduction to the Starfighter in May and June, 1958, when the ultrasonic F-104 made its first appearance on the continent.

FG-748
USAF
U.S. AIR FORCE
FG-737
USAF
U.S. AIR FORCE
FG-766
USAF
U.S. AIR FORCE
FG-772
USAF
U.S. AIR FORCE
772

Military officers, defense officials and other NATO leaders took a close look at the free world's top performing fighter.

The aircraft was destined to return.

In February, 1959, West Germany announced plans to equip its defense forces with the Lockheed F-104.

The program would include: (1) 30 two-seat F-104 fighter/trainers basically similar to standard models for the U.S. Air Force. (2) Accelerated preparations by Lockheed's California Division to build 66 of an "improved and advanced" single-seat multi-mission interceptor.

West German Defense Minister Franz Josef Strauss announced that West German industry would build 200 more Starfighters under license from Lockheed.

ADVANCED MULTI-MISSION FIGHTER

The new model selected by West Germany is designed to serve as a fighter-bomber, interceptor or reconnaissance aircraft.

Advanced over current models, it will incorporate new all-weather features to meet West Germany's needs for a fast-climbing fast-fighting interceptor capable of round-the-clock defense in any kind of weather.

COMMAND PERFORMANCE

In the autumn of 1958, Starfighters also became a familiar sight in a troubled stretch of sky half-way around the world -- over the Formosa Strait.

An undisclosed number of F-104s were among the first USAF aircraft rushed to the Far East to strengthen the Pacific Air Forces' air defense of the Republic of China.

The impact of their presence in the area: unmistakably positive. Unofficially, the Starfighter was credited with being a major factor in preservation of peace at Quemoy.

SECTION II

ANSWERING THE NEED

The F-104 now in service with the United States Air Force represents the boldest step forward in American military aviation within the past 15 years.

It also represents the solution to many-faceted problems confronting military and political leaders today: how to get ahead and stay ahead with one airplane, despite changing tactics between drawing board and flight and fight; how to have a weapon for global war should it come, and for brushfire wars should they come; how to meet the needs of today and tomorrow.

OBJECTIVES

Lockheed's objectives in designing and building the F-104: Develop a "stratospheric den of rattlesnakes" to greet any invading enemy aircraft: Give that den of rattlesnakes the swiftest dart and deadliest fangs available at any given time; build the weapon at the lowest possible cost.

At any given time -- that means versatility, flexibility of armament and mission without major airframe modification.

At the lowest possible cost -- that means designing for lightness in weight and simplicity in structure; factors which also contribute to higher performance.

Did the F-104 meet these requirements?

Let this statement be a measuring stick:

"The F-104 is the most advanced airplane of its type ever developed."

Source: Gen. Nathan F. Twining, chairman of the United States joint chiefs of staff, speaking on the aircraft's original introduction.

FAMILY TREE

How did this airplane -- "tomorrow's airshape here today" -- come into being: Was it a gradual evolution from previous jet fighter designs, from the F-80 Shooting Star on up? Or was it a completely new approach to developing a maximum performance manned jet fighter?

Its background is a family affair.

America's first mass-produced operational jet fighter, the Lockheed F-80 Shooting Star, made its initial flight on January 8, 1944.

Since that time, more than 7500 Lockheed-built jets have been in the forefront of the free world's military air might.

ANCESTORS

In the years from the end of World War II to 1947, Lockheed exploited the F-80. The T-33 jet trainer and F-94 Starfire series of all-weather interceptors stemmed from the basic F-80 design.

About the same time, a new penetration fighter -- the XF-90 -- was designed and built. Various versions were test flown.

The XF-90 was a big airplane, by then existing standards. Its gross weight was in the 30,000-pound category. Sufficiently powerful jet engines were not available to push so much metal through the sky at desirable speeds.

Question: Which way to go in fighter aircraft design? A crossroad of decision.

Was a big, complex machine the solution? And wait for development of bigger, more powerful jet engines? Or what?

History stepped in to lend a hand.

The Korean War provided the answers.

GENESIS OF THE STARFIGHTER

Operational experience in combat, high over the Yalu River, pointed up one thing, time and time again.

The need, above all else, was for a lightweight, high performance fighter.

From advanced air strips in Korea the reports came back in an increasing crescendo:

"Give us performance -- the ability to beat the other guy to the punch.

"Give <u>us</u> the opportunity to 'come out of the sun.'"

The greatest safety feature available to the pilot, Korean aces said, was performance -- ability to coil and strike and get away. The ability to fly higher, and faster, than the enemy.

Lockheed stepped up to meet the challenge.

The Starfighter was about to be born. The year was 1951.

DESIGN CRITERIA

Back of all the preliminary design studies which went into developing the Starfighter were two fundamental aims:

1. The company did not want to build an aerial "hot rod" that would require the skill of a 5000-hour pilot to handle. It did not want to build a "stripped-down" fighter.

2. It did want to build a "pilot's airplane," a bird that would handle superbly, be compact yet comfortable, and one which would do the job.

An evolution of literally thousands of design studies, tunnel evaluations, flight studies with experimental aircraft like the XF-90, and intensive performance tests at high mach numbers of rocket-powered wing models -- the basic Starfighter emerged as the synthesis of the best design knowledge available from all of these programs.

It was to be an aircraft which:

1. Must be light and simple. Easy to maintain.
2. Would have mach 2 capability.
3. Would have missile capability.
4. Would provide a sharp superiority weapon to fight in the clear air mass.

And, in the final analysis, its primary reason for being -- afford the maximum kill probability per dollar invested.

No small order -- but a so-called "small airplane" was going to do the job.

MOVING AHEAD, GIANT STRIDES

In a fast-moving technology, it is difficult to look more than seven years ahead. This has been a working rule-of-thumb. Lockheed designers cut out for themselves the task of looking a full decade into the future in designing the Starfighter.

Just as a War Plans group works its calculus of quantities of weapons and types of armament against the factors of time of probable battle at particular places, just so does the airplane designer to develop a new airplane with versatility to meet changing conditions.

Technical advances in the Starfighter -- three times the performance of America's first jet; twice the speed of aircraft being replaced; maintaining a range capability of operational aircraft twice its weight; adaptation of the most powerful engine thrust-per-pound in the world; all while keeping up with the changing picture of national defense requirements during its developmental period -- called for a whole series of bold steps forward.

A NEW APPROACH

The Starfighter represents a major change in the concept of aircraft acceptance and deliveries.

Before the Starfighter, airplanes frequently were brought into the active military inventory while their developmental flight testing continued.

Emergence of the F-104 as a vastly advanced weapons system precipitated a change in procurement policies established for lower performance equipment.

A major policy decision came from within the Air Force; deliver the new airplanes when they are operationally ready. Insofar as humanly possible, have them ready to fly and shoot.

Setting forth under this policy, the Air Force and Lockheed devised and pioneered for the F-104 the most comprehensive flight test program in the history of military aviation.

Flights prior to entering service: more than 6500.

Lockheed alone invested some 2,000,000 engineering man-hours in the proof-before-service test program. That's the equivalent of 20 men working year-in and year-out since man first sprouted wings.

KEYWORD: FLEXIBILITY

Even during its developmental period the airplane was designed to handle a variety of missions, carry a variety of weapons.

Take the Starfighter's armament alone:

Lockheed was married to the M61 Vulcan cannon early in the aircraft's development. This is the world's fastest firing machine gun (some 6000 rounds of 20-mm ammunition per minute).

The gun was the best fighter armament available. It was known then, however, that infra-red guided missiles were coming. The Starfighter was designed to handle them too.

Today it is operational with both weapons.

In its interceptor role with the Air Defense Command the F-104 is armed with Sidewinder heat-seeking air-to-air missiles. It carries one on each wingtip.

As a fighter, or fighter-bomber with the Tactical Air Command, the Starfighter's primary armament is the M61.

KEYWORD: POWER

The thrust-weight ratio of the airplane is superior to any known fighter in any Air Force in the world. This feature is related directly to its General Electric J79 turbojet engine.

It produces 15,000 pounds of thrust. It is the most powerful pound-for-pound jet engine in the world. It behaves like a ramjet missile's powerplant at certain velocities.

The high thrust-weight ratio permits hauling many things externally with little or no sacrifice in performance: atomic bombs and other nuclear weaponry, rockets and missiles.

Able to climb to the attack as fast as it flies straight and level, the Starfighter can turn, twist, dart and strike like a rattlesnake at altitudes previously attainable only by research-type airplanes.

Wings of the F-104 are stubbier, thinner than those of any known airplane. Noted for their knife-sharp leading edge, they were developed from rocket studies by Lockheed scientists. Their shape came from missiles themselves.

The F-104 has been designed to fly higher, faster and more intelligently (with its human guidance) than many operational missiles.

MISSILE WITH A BRAIN IN IT

Unlike various missiles, the Starfighter can be corrected for errors in flight. It can fly farther than some missiles can be controlled; it can move out beyond the reach of ground directing stations necessary to certain missile operations.

It can fly as a manned missile, and then unleash its own deadly missiles.

And it can fly again.

By virtue of its excellent thrust-weight ratio, it can take off from relatively small airfields.

KEYWORD: MANEUVERABILITY

Utilizing boundary layer control (it became the first production fighter to incorporate this feature), the Starfighter can land on airstrips for airplanes with about half its speed capability.

With both drag chute and boundary layer control in operation, the F-104 can land and turn in 2300 feet.

KEYWORD: MINIATURIZATION

In tune with the times, Lockheed designers placed their blue chips on a trend in electronics toward miniaturization and ruggedization.

Under development, coincidentally with the XF-104 prototype, was a program to make more compact ILS equipment, radio communications and fighter navigation systems.

Objective: within the weight and space capabilities of the airplane, be able to put in -- in a mechano-like fashion -- any combination of radio or navigation equipment to make the plane fit a variety of missions.

This "jeep-can" system is today a proven part of the plane's built-in versatility.

Conceived initially to fill the need for a high performance day fighter, the Starfighter's inherent design flexibility has gained for it recognition as a multi-mission aircraft.

Day fighter, all-weather interceptor, fighter-bomber, nuclear weapon launching platform -- take your choice, the Starfighter will do the job.

DEVELOPMENT TIMETABLE

On March 1, 1953, Lockheed was authorized to build two XF-104 prototypes.

Less than one year later, on Feb. 27, 1954, the first prototype was ready to fly and did, becoming airborne on a high-speed taxi run at Edwards Air Force Base, Calif. This was followed shortly by a more formal, planned flight on March 4.

In June of that year a letter contract, the production go-ahead signal, was received.

The first F-104A flew in February, 1956.

Within two years from first production flight, and with the most comprehensive test program in history under its belt, the Starfighter entered service with the U.S. Air Force's Air Defense Command.

Time and place: February 20, 1958. Hamilton AFB, Calif.

SECTION III

SYSTEMS OF THE WEAPON

The Starfighter carries a deadly sting for any invader of the United States...for enemies encroaching in brushfire wars over friendly ground...for attackers in case of all-out war.

It is fitted with weapons, weapon support systems and basic aircraft systems as advanced as its performance -- to make it the world's most effective combination of striking power and operational efficiency.

THE MISSILE

Starfighters on day-and-night duty as fighter-interceptors with the Air Defense Command are armed with Sidewinder air-to-air guided missiles.

Each of the F-104's stub-like wings carries a Sidewinder at its very tip -- lethal lances ready to be unleashed.

DEADLY DETECTOR

A "homing" missile, the Sidewinder (designated GAR-8 by the U.S.Air Force), is guided by an infra-red tracking device to targets the plane's pilot may never see in the dark of night.

At night its infra-red device "feels" the presence of aircraft by the heat they radiate.

SECTIONAL BREAKDOWN

The missile's super-sensitive "seeker," which becomes operative when the plane takes off, occupies approximately the first four inches of the nose. Then in order: guidance section, servo system between control fins, warhead, influence fuse and rocket motor. (The 75-inch-long rocket motor has a burning time of approximately two seconds.)

Electric power is supplied to the missile through a plane-to-missile umbilical connection located atop the missile between the control fins.

ACTION SEQUENCE

Here is what happens when an actual intercept is being made:

(1) The pilot hears a signal from the seeker through his earphones; (2) he triggers a switch sending an impulse through the umbilical connection; (3) the impulse actuates a small, solid-propellant, gas generator which operates a turbo-generator; (4) the turbo-generator supplies power for the guidance and control actuating servo, plus providing current for igniting the squib which fires the rocket motor.

As the missile moves off its wing-tip launcher, the umbilical connection is sheared.

With target contact, a contact fuse sets off the warhead. Even without a direct hit the influence fuse activates the warhead for a "blast and fragmentation" target kill.

EXTERNAL CONFIGURATION

Four triangular control fins are pivoted at about one-third from the fin forward point. The control fin leading edge measures approximately 11½ inches. The trailing edge length is about 5 inches.

Four stabilizing fins on the end of the missile each have a slant forward section about 10-inches long, followed by a straight portion about 14 inches long. The trailing edge portion measures approximately 7-3/4 inches.

Conceived and developed by scientists at the Naval Ordnance Test Station, China Lake, Calif., the Sidewinder is being produced by the Philco Corporation and the General Electric Company.

More than 9 feet long (112 inches) and 5 inches in diameter, the Sidewinder weighs approximately 155 pounds.

THE GUN

Primary armament for F-104 Starfighters in service with the Tactical Air Command is the M61 Vulcan cannon.

Named after the Roman god of fire, the Vulcan is the world's fastest firing cannon. A six-barreled 20-mm. weapon, it packs 10 times the wallop of World War II fighter machine guns.

Maximum rate of fire: 6000 rounds per minute.

Specially adapted by Lockheed engineers, the automatic cannon was developed initially by the General Electric Company, under sponsorship of the U.S. Army's Ordnance Corps, at the request of the U.S. Air Force.

DEVELOPMENT BACKGROUND

In 1952 the Air Force asked Lockheed to test and evaluate a number of new weapons, including the Vulcan, in terms of their adaptability for use in aircraft.

After exhaustive tests extending over a two-year period, Lockheed armament engineers recommended the Vulcan as the weapon whose punch and combat effectiveness would best match the spectacular performance predicted for the cleaver-winged Starfighter.

The Vulcan has borrowed two design features from the famous Gatling gun which, patented in 1862, became a revolutionary weapon of the Civil War.

Both guns have a rotating cluster of barrels. Both are externally driven.

In modern contrast to a hand-driven crank which turned the original Gatling gun, General Electric's Vulcan can use either hydraulic or electrical power. On the F-104 the gun is powered electrically.

SURE SHOOTING

From the standpoint of operational reliability, an externally-powered gun affords the following superiority features:

1. Each successive round is fired independent of the previous round. Firing only one round at a time eliminates erratic recoil of multiple-gun installations.

2. "Dud" rounds are ejected automatically and cannot cause stoppages.

3. The mechanism is inherently cleaner and less susceptible to corrosion than gas-actuated weapons.

4. Ammunition is supplied by only one feeder system.

Rotating counterclockwise, the cannon fires at the 9 o'clock position, cartridges are ejected at the 4 o'clock position, and new rounds are picked up at the 2 o'clock position.

Clamped rigidly together, the Vulcan's six barrels do not have the "whip" of a single barrel. Turret oscillation is also eliminated by the weapon's centralized recoil.

JUST PRESS THE BUTTON

Mounted on the left side of the Starfighter, just below and behind the cockpit, the Vulcan is fired by a trigger on the pilot's stick.

Belted ammunition is stored in a box behind the pilot.

All action of this air-cooled gun is virtually simultaneous. Both shells and links are ejected downward.

Extremely easy to maintain, the gun can be field-stripped and reassembled in less than 30 minutes.

Length of the Vulcan: 72 inches. Weight: approximately 300 pounds.

FIRE CONTROL SYSTEM

Lockheed's F-104 is the first operational fighter to be equipped with a fire control system which combines radar detection with infrared tracking.

Known as the AN/ASG-14, the new system utilizes radar to detect, locate and measure range to an aerial target. An optical lead computing gunsight gives a properly positioned aiming reference to the target for the kill. An infrared device provides passive IR tracking at night and at high altitudes.

BETTER THAN BINOCULARS

The optical sight is employed for daytime, clear-weather combat.

Automatically, the sight computes the required lead angle for cannon fire. Its "input" of information includes range to the target (measured by radar), altitude information, obtained from gunsight transducer and angular motion detected by the sight's gyroscope.

The pilot's aiming reference is a light image, or reticle (in the form of a circle with a dot in the center). He attempts to keep this dot superimposed upon the target image as the plane closes in. The light image is generated in the sight head, mounted forward of the instrument panel, and is projected upward onto a combining glass.

It is through this glass, extending above the instrument panel, that the pilot does his sighting.

The combining glass is inclined at an angle to cause the reflection of the image also to be visible to the pilot as he looks at the target. The image is collimated so as always to be in focus to the pilot's eyes, regardless of the range at which he is focusing on the target, and to eliminate parallax effects of head movement.

Image brightness and uniform illumination assure visibility against bright backgrounds such as sunlit snow or white clouds. The combining glass is sufficiently clear to assure no discernible deterioration of target visibility.

The angular position of the image, relative to the "zero lead" (or dead ahead) position, can be controlled by a movable mirror in the projection system of the sight head. The lead angle computation is then used to control the mirror position by a direct linkage from the computing gyro also located in the sight head.

FOR GUN

With the image thus displaced from the "zero lead" line of sight (along which the Starfighter's Vulcan cannon also is aligned), the pilot then maneuvers his plane for the kill by superimposing the center dot over the target. When so lined up, the cannon will be pointed to compensate for the target's motion and gravity drop of the 20 mm. projectiles.

AND MISSILES

When the fire control system is placed in the missile attack mode of operation for firing wingtip-mounted Sidewinders, a crosshair appears within the image circle immediately above the centered dot. This is the pilot's second aiming point. It is used (and is visible) only during missile firing.

CLOSING IN

The pilot knows when he is within effective range by watching for a "bug," or arrowhead, which appears at 3 o'clock on the outside of the image circle on the sight combining glass.

As the pilot approaches his target the arrowhead moves clockwise around the perimeter of the circle until it reaches 9 o'clock.

When the arrowhead is between 6 and 9 o'clock and a firing symbol "F" appears inside the image circle, he may fire by pressing the firing button. The arrowhead and firing symbol "F" disappear at the 9 o'clock position, alerting the pilot that he has reached minimum range to the target.

As he reaches the point where breakaway is required the pilot will be warned automatically to avoid collision with the target. A buzzing signal sounds in the pilot's ear phones. At the same time the crosshair disappears from the glass.

DARKNESS NO DETERRENT

For night operations, when the pilot cannot see the target, the infrared system is used.

After radar has located the target, the IR equipment (which cannot be jammed easily) detects the heat radiated from the target's engines. When the IR picks up a distinct heat source, a lighted "X" appears on the combining glass in line with the actual target. From this point on -- because visual sighting techniques are also employed during infrared sighting and the optical sight's image is projected onto the viewing glass -- action by the pilot is the same as when performing an intercept with visual target sighting.

BUILT-IN MAINTAINABILITY

The "jeep can" principle employed successfully in integration of the Starfighter's electronics system (mentioned in Sec. II, p. 8 and described in detail in Sec. III, p. 10) also applies to the plane's fire control system.

Indicators are located in the cockpit appropriate for the pilot's use with the balance of the system (of modular construction) mounted inside the plane's needle-like nose.

All test points and adjustments are located for easy access during pre-flight maintenance.

The majority of the radar system is contained in an area 2 feet in diameter and 2½ feet long in the conical nose radome. Each chassis of the nose package is shaped like a piece of pie that can be quickly and easily disconnected from the main frame.

Two men can remove the complete system from the airplane and replace it in a matter of ten minutes -- an operation that requires upwards of 8 hours in most contemporary interceptor aircraft.

DEVELOPMENT/PRODUCTION TEAM

The original fire control system concept was envisioned and developed by Lockheed as part of its over-all weapon system responsibility.

Major subsystems are being produced by the General Electric Company, the Radio Corporation of America and the Aerojet-General Corporation.

ELECTRONICS

The justification for any modern fighter is defined quickly and simply: Ability to do the job.

In any kind of weather.

In any military environment.

In any theater of operations.

Providing the wherewithal to do that job does not necessarily come either quickly or simply.

Many challenges faced the F-104 designers. Not the least among them: provide electronic equipment big enough to do all the jobs required but small enough to fit into the Starfighter.

NO BLIND-MAN'S BUFF

In order for this aluminum bolt of lightning to bring its armament into effective use -- whether delivering a missile or firing a 20-mm. projectile -- its designers had to provide means for successfully finding the target.

Do it at speeds of up to 1500 m.p.h., and altitudes reaching well into the stratosphere, the requirements specified.

From the ground up -- the airplane must be "scrambled," tracked and guided to the general vicinity of the target. Accurately. Rapidly.

That implied a highly sophisticated "communication, navigation and identification" capability.

PROBLEM: ADD PEAS TO THE POD

There was no "spare room" available in the F-104's cigar-like fuselage.

The engine and afterburner occupy more than half of the entire length of the fuselage. Most of the remaining space is used for fuel storage and for cockpit arrangement.

Somehow, the electronics equipment had to be sandwiched into a portion of the space that was left.

The same design philosophy adopted for the F-104 airframe had to be applied to the electronics installation, if the best use of the weapon was to be realized.

The system had to be:

1. Light.
2. Compact.
3. Relatively simple for reliability and serviceability.
4. Versatile.

It was decided to locate the electronics compartment beneath the aft section of the cockpit canopy, extending for approximately five feet along the axis of the airplane.

The compartment is shaped very much like a round-top trunk or chest. Access to the equipment is provided by a hinged door above the compartment.

GOOD THINGS...SMALL PACKAGES

By completely re-packaging available CNI (communication, navigation and identification) equipment with a saving of some 50 per cent in space and about 20 per cent in weight -- a number of inter-connecting but self-sustaining units were developed.

Available space still did not permit inclusion of all the equipment at one time for the F-104's variety of missions.

Next step: Each unit was made so that it could be "plugged in" (or "out,") to suit the specific mission to be flown.

The repackaged box, or unit, became known as the "jeep can" because of its similarity in appearance to the gas can used on the military jeep.

The "jeep cans" have the same shape as the electronics compartment. Each has the same height and depth but can vary in width. The upper portion of the outboard face is sloped inward and carries all of the test points and adjustments for the equipment behind a hinged door. Each unit has a self-test facility that allows rapid "go, no-go" qualification of the equipment while it is installed in the airplane.

The mounting and cooling provisions of the repackaged units are common to each box. A single mounting rack (an inverted tee frame) manifolds cool air to each box.

EASY IN, EASY OUT

Jeep-can packages are installed and removed vertically from an inverted tee rack. Rails on the inboard face of the package mate with rails on the vertical member of the inverted tee frame rack. This locates and secures the package against relative motion in the fore-aft and inboard directions.

Relative vertical travel is precluded by a cam lock-down mechanism which works in conjunction with the guide pins of the electrical plug connector on the bottom of the package.

A cooling air duct at the bottom of the inboard face of the package is connected automatically to the rack duct when the package is secured. A latch handle at the top of the package actuates the lock-down mechanism and detents by folding down flat on top of the package.

MULTI-MISSION VERSATILITY

The "jeep-can" design has demonstrated, in the field, excellent serviceability and versatility.

If electronic equipment need be added or removed, it can be done quickly and easily.

Whatever the mission requirement, the Starfighter can be readied in a matter of minutes for any assignment -- simply by inserting that type of electronic "jeep-can" necessary to do the job.

ELECTRICAL

The Starfighter electrical power is supplied by two engine-driven, 20 k.v.a. generators -- that's sufficient power to supply electricity for all the homes in an average city block -- and an emergency 5.5 k.v.a. generator driven by a ram air turbine.

In the event one of the main generators fails, an automatic load transfer relay (bus) parallels both system loads onto the operating generator.

The emergency system can operate all essential functions, including radio, cockpit lights, air conditioning and flap extensions, to accomplish a dead stick landing.

Two 4 amp-hour batteries are provided for engine mid-air restarts.

The Starfighter is unique in having a variable frequency primary A.C. power system using a three-phase generator.

All D.C. power is acquired through a 100-ampere transformer rectifier.

SEAT EJECTION

U.S. Air Force Starfighters are being equipped with an upward ejection system using new rocket-catapult devices and techniques not available when the aircraft was designed initially.

The new system is designated as the C-2 seat.

WIDE RECOVERY RANGE

Full recovery capabilities of the seat span a speed range from 115 m.p.h. up to 630 m.p.h. and from zero altitude up to 50,000 feet altitude. In more technical terms, the recovery capability extends from 100 knots to 550 knots EAS -- Equivalent Air Speed -- or, true air speed at sea level.

Because of the proven improbability of an emergency escape situation developing when the plane is at zero altitude with forward speed of less than 100 knots EAS -- and when normal exit could not be made by manually unlatching the canopy -- the "on the deck" capability covers a speed range from 100 to approximately 300 knots, using a standard USAF B-5 parachute system.

For zero altitude utilization, the pilot's parachute hook-up involves a "one and zero" timing sequence.

The "one and zero" terminology means the system is set to separate the pilot from the seat one second after ejection and simultaneously -- with zero delay -- the parachute starts to deploy.

Once the airplane has reached a height of a few hundred feet, the pilot shifts to a "one and one" system by simply unsnapping a dog-leash type catch on the lanyard.

The system is then timed to free the pilot from the seat one second after leaving the aircraft and one second later the chute starts to deploy.

At altitude, the "one and one" sequence insures more distance from the seat at time of parachute deployment. It also lessens the opening shock.

SEPARATION SEQUENCE

To activate the system, a pilot has only to pull up on a D-shaped ring located between his feet on the center line of the forward lip of the seat bucket structure. From that point on, everything happens automatically.

When withdrawn the D-ring fires two instantaneous initiators, one of which ejects the canopy while the other operates pre-ejection functions.

The pre-ejection phase, completed in just three-tenths of one second, encompasses the following:

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

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

3. Arm support webbing flips up to prevent outward movement of arms.

Upon completion of these split-second actions the seat moves up the rails and a single striker initiates the post-ejection functions which occur one second later.

The post-ejection phase includes:

1. Release of the automatic lap belt.
2. Cutting of the foot-retention cables.
3. Operation of the pilot-seat separation reel.

A secondary (backup) system also operated by the single pull of the D-ring fires a delay initiator directly into the catapult unit and a secondary delay initiator into the foot cable cutters.

ROCKET CATAPULT

The C-2 system uses a pyrotechnic propulsion unit designated as the XM-10 rocket-catapult.

The rocket-catapult unit is secured to the seat at the upper cross beam member on the seat back and moves up and down with the seat as the seat is adjusted by the pilot.

This has the advantage of enabling the rocket section of the catapult to maintain a fixed relationship between the rocket thrust line and seat center of gravity.

Rocket lighting occurs just prior to catapult separation, and burning time is approximately three-tenths of one second.

ARM RETENTION AND LEG GUARDS

Leg guards, normally stowed at the sides of the seat bucket, are mounted on a torque tube at the forward section of the seat. The guards are forged members with a paddle-shaped unit at the ends to provide ample knee contact surface area.

These units are designed to take 1000 pounds aft and 1000 pounds outward thrusts.

An arm support nylon webbing system, attached to the paddle end of the leg guards, is automatically deployed into position as leg guards swing into operation.

FOOT RETRACTING AND RETENTION

The C-2 seat incorporated a Lockheed-developed foot retraction and retention system.

The pilot wears foot spurs equipped with a ball socket at the back -- much like cowboy boots.

A ball lock end, which is engaged by the spurs, protrudes from the forward lower section of the seat structure.

Cable, secured to the ball lock ends, is stowed on spring-loaded reels located on the bottom side of the seat bucket.

When the seat ejection system is energized the reels wind the cable, pulling the pilot's feet back and securing them in the seat foot shelf units.

The cables are cut free after ejection by a pyrotechnic guillotine operated by a striker on the seat structure which fires a one-second delay initiator and also by a two-second delay initiator operated by the original pull of the D-ring as a backup system.

PILOT-SEAT SEPARATION

With the C-2 system, the pilot is forcibly separated from the seat after ejection.

This operation is performed by a pyrotechnically actuated windup reel mounted behind the head rest.

A single nylon web is routed from the reel half-way down the forward face of the seat back.

From this point, two separate nylon straps continue down, pass under the survival kit and up to the forward bucket lip where they are secured.

The unit is sequenced with the lap belt release so that one second after ejection the webbing in winding on the reel becomes taut, forming a straight tie between the head rest and forward seat bucket lip.

The reel operates in two-tenths of a second, "pushing" the pilot completely out of the seat.

GLOBAL SURVIVAL KIT

The C-2 seat is equipped with a Phase IV "hard box" type automatic survival kit.

This kit's equipment includes improved disconnect hardware, automatic life raft inflation, high pressure emergency oxygen bottles with 15 minute duration, and a Firewell regulator suitable for use with a partial pressure suit above 42,000 feet altitude.

The oxygen equipment compartment is enclosed by a hinged top-back panel to provide quick removal and replacement of the oxygen components.

Its hinged panel provides a separate access door so that the bottles can be filled without removing the kit from the seat.

SEAT CONSTRUCTION

Built primarily of high strength-to-weight ratio aluminum alloy sheet and extrusions, the seat construction incorporates steel or aluminum forgings as dictated by load-carrying requirements.

The seat itself is capable of withstanding loads imposed by an 800 knot EAS ejection.

CANOPY

The cockpit canopy system operates manually for normal entrance and egress, opening like a clam shell on a hinge at the left-hand cockpit sill. The fuselage half of this hinge is attached to the airframe by a series of hooks.

When the upward ejection system is activated, the canopy rotates on a transverse axis at the aft upper end of the enclosure. Release and jettison of the canopy is done pyrotechnically. The left and right hand canopy hold-down hooks are released automatically to insure symmetrical operation.

OPTIONAL EXITS

Jettisoning of the canopy can be performed at the discretion of the pilot, by either (1) operating the escape handle on the seat which initiates all seat ejection functions simultaneously, or (2) independently pulling the "D" handle on the forward console.

The canopy also can be jettisoned from the left side of the aircraft by ground rescue crews.

HYDRAULIC

The F-104 incorporates two independent 3000 p.s.i. hydraulic systems powered by engine-driven variable displacement pumps. The systems -- which help make the Starfighter handle with ease -- are designed to operate in temperature ranges from 65 degrees below zero to 275 degrees Fahrenheit.

If either one of the two systems fails, its counterpart system will supply sufficient flow and pressure to operate all flight controls at a reduced rate.

EMERGENCY SAFEGUARD

Should a powerplant seizure (complete failure) occur but leave the primary hydraulic system intact, an emergency ram air turbine can be extended from the R.H. side of the forward fuselage. It will provide sufficient flow and pressure to maintain safe flight and moderate maneuvers necessary for landings, plus supplying sufficient emergency electrical power.

(A flamed-out but rotating engine affords adequate hydraulic flow and pressure for surface control.)

Standard flareless tube fittings are used throughout the ship. All pressure lines, in or outside the engine compartment, are of stainless steel.

The aircraft's nose wheel steering operates off the landing gear down pressure line when the airplane is on the ground with weight on the nose gear.

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

In the event either hydraulic system should fail, a warning light automatically will flash on the instrument panel. The pilot can check by use of a selector switch and hydraulic gauge.

BOUNDARY LAYER CONTROL

First production fighter to incorporate a boundary layer control system, the F-104 with BLC can land in less distance than any modern jet fighter, at toughdown speeds only moderately higher than trainer rates.

Tornado-like blasts of air spurting from 110 tiny nozzles on its razor-blade wings do the trick.

MORE LIFT

Boundary layer control is a method of piping high-velocity compressed air from the engine into the wing, where it is squirted from a slotted tube out over the upper surface of the trailing edge wing flap.

Acting like vanes of air, these streams smooth out the airflow over the wing and hold it to the wing surface. The result is greater wing lift.

Use of BLC reduces the Starfighter's landing (or stall) speed by about 20 m.p.h., and cuts down on required landing distance by almost one-quarter.

MODERN INNOVATION

The F-104's boundary layer control system has been classified as a jet-age step beyond the Fowler flap method of increasing wing lift, which Lockheed pioneered in 1937 on the 244-m.p.h. Model 14 transport.

The Fowler system allowed the under portion of the wing trailing edge to slide back on rollers and rotate downward. This gave more chord (width) and more camber (curvature) to the wing, thereby increasing its lift.

Extreme thinness of the F-104 wings, which have edges sharp enough to cut a steak, gave engineers a major problem -- but they solved it -- in fitting BLC mechanism and other control devices into the small space available. Each wing measures only 7½ feet from fuselage to wingtip. Maximum thickness is less than 4½ inches.

HOW IT OPERATES

Here are details of the BLC system:

Highly compressed air from the engine is ducted into the tube and out the slots. A valve, controlling the flow of air, opens automatically as the flap descends.

When the flap angle passes the 15-degree mark the valve begins to open. A full-open position is reached when the flap is completely extended at a 45-degree angle.

Running the entire 47-inch length of the flap, the tube has 55 slots. Slots are placed 0.9 inches apart, center to center. Each slot is 0.09 inches deep and 0.55 inches wide.

Coming directly from the engine, the air is hot and fast-moving. It flows through the slots and over the flap at a velocity of 1600 feet per second, equal to the speed of a rifle bullet.

Supersonic air -- converting the 1500-m.p.h. Starfighter from a "speedster" to a "slowster" for landing.

SECTION IV

AIRFRAME ANATOMY

Probably the single most distinguishing feature of the F-104 airframe is its wing.

It's short -- almost to the point of appearing non-existent.

It's thin -- thinner than that of any plane flying in the world today, even research aircraft.

It's sharp -- the leading edge can cut like a knife.

And it's straight.

There are excellent reasons for the wing's shape.

TEST PROVEN WING

Lockheed experience with the X-7 ramjet test vehicle, wind tunnel evaluations, and extensive study of various wing plans propelled in desert tests by 5-inch rockets, led to this conclusion:

For the Mach 2 speed regime in which it operates, coupled with the F-104's high thrust-to-weight ratio, the aircraft required a low aspect ratio wing. It had to be thin. And to be thin, it had to be short. This is an aerodynamic must.

INHERENT STABILITY

With its shortness of span came important flutter-free values.

The long wing wants to flutter. The shorter the wing, the less tendency it has to flutter. Not only does it have less tendency to flutter, it is lighter because of its smaller size.

Being light, short, thin and strong -- the wing inherently helped boost the F-104 to its ultrasonic speed regime.

An important operational characteristic attributable to the thin-straight wing -- it develops high lifts at low angles of attack.

TRIM AND SLIM

From side of fuselage to wingtip, the wing measures just 7 feet, 7 inches. It has a thickness ratio of 3.36 per cent. From a maximum thickness of 4.2 inches next to the fuselage, it slims down to only 1.96 inches at its extremity.

The wing taper ratio is 2.65 per cent. There is a slight sweepback of the leading edge, approximately 26 degrees. Also a similar slight forward sweep of the trailing edge.

At 70 per cent of chord line, there is no sweep to the wing.

Because of the wing's extreme thinness, the main landing gear retracts into the fuselage, rather than into the wing. As it retracts it twists sideways and tucks in flat.

Unlike most conventional jet fighters, the F-104's wings do not go through the fuselage. Both wings are fastened to the fuselage with five rings -- heavy-duty 7075 precision-forged fittings tied into the wing skins and intermediate channels.

FLAP AND AILERON FACTS

A full span flap, used for takeoff and landing, extends along the leading edge of the wing. The leading edge is so sharp that when the plane is on the ground a felt pad guard is installed to protect ground maintenance personnel.

The flap is machined from a 7075-T6 aluminum alloy extrusion. Attached by a piano hinge extending along its lower edge, the wing flap is of conventional rib and plate skin assembly. It is moved by a rotary electromechanical actuator within the wing root fillet.

The aft part of the wing trailing edge has a landing and take-off flap. Outboard of the flap, to the tip, is an aileron.

Aileron and flap panels are attached by piano hinges. Flaps use aluminum and ailerons use steel heat treated to an ultimate tensile strength of 180,000 p.s.i.

Along the aileron span are 10 actuating rods which are mounted in a long spanwise rectangular manifold. Hydraulic pressure applied to the manifold extends the 10 rods precisely the same distance and at the same rate. Pressure in the manifold is controlled by an adjacent aileron boost and servo control unit actuated by the pilot's control column.

The Starfighter's boundary layer control system operates in conjunction with the trailing edge flap. (See Sec. III, Page 18, for a detailed description of boundary layer control.)

TANKS TOO

Centerline mounted tanks fit like a glove over the wing tips. The tanks are jettisonable.

Provisions are incorporated for mounting pylon tanks underneath the wing.

BUILT WITH A TILT

Significantly, the F-104 wings have 10 degrees negative dihedral -- or cathedral. This means that they are inclined at a slight downward angle.

This feature stems from the combined effects of having a wing that extends less than 8 feet from the fuselage and a tail fin that reaches almost the same distance in a vertical direction.

Because the vertical tail had the span of a wing, the deflection of a rudder acted like an aileron. To compensate for the roll obtained from deflection of a rudder, the wing was built with the slight negative dihedral.

PICKED FOR PRODUCIBILITY

To meet the challenge of building a wing which was to be the shortest and thinnest of any jet fighter, an engineering "producibility" group studied every conceivable type of construction to obtain the optimum design from a producibility (as well as aerodynamic) standpoint.

Altogether, 22 types of structure came under scrutiny. Any which held even the slightest promise were examined in detail.

INSIDE INFORMATION

The system selected was a pair of conventional spars, but using a single, machine-tapered and formed plate for the upper and lower skins. These 7075-T6 plates taper from 0.25 inches at the root to 0.125 inches outboard and carry the airfoil contour. There are no chordwise ribs for this purpose.

Within this torsion box, enclosed by root and tip forgings, are 12 spanwise intermediate channels fabricated by the precision-plus compression forming technique which Lockheed engineers developed.

The resultant "complexity free" wing of the F-104 consists of the basic box-section structure, leading and trailing edge flaps, and the aileron.

Of significance, the flat-plane tension joint incorporated in the wing permits the use of simplified tooling and assures proper mating to the fuselage without the use of special jigs or fixtures.

SIMPLICITY HAS MANY BENEFITS

The producibility study also proved that all functional systems, such as electrical, hydraulic and control items can be installed in the wing prior to mating. And since all actuator units are mounted in the wing structure, complete checkout of these systems can be made as a part of the wing assembly operation.

The complete wing package unit is particularly adaptable to high rates of production where remote final assembly lines and extensive subcontracting programs are employed.

FUSELAGE

For rapid and efficient assembly purposes, the F-104's pencil-shaped fuselage is built in three main sections.

UP FRONT

The forward fuselage contains the cockpit, with its integrated ejection seat system, electronic compartment, Vulcan M61 cannon and nosewheel support structure.

Tapering to a needle-like point, the forward fuselage has a slight droop to provide maximum pilot visibility. Placed well up front, the pilot enjoys a vantage point comparable to that of "greenhouse position" nose gunners in World War II medium bombers.

Built in two halves, functional items are installed and the two halves mated preparatory to final assembly.

A two-piece mount composed of 2014 aluminum alloy machined forgings carries firing loads created by the 20-mm Vulcan gun.

IN THE MIDDLE

Like the forward section, the mid-fuselage is built in two halves to facilitate equipment installation.

The mid-fuselage is built up on five heavy 7075 forgings tied into a forged keelson assembly supporting landing gear loads. Wing fittings are attached to these forged frames.

All internal fuel for the Starfighter is contained in five bladder cells (fuel tanks) located within the fuselage.

Occupying the major portion of the mid-fuselage are the air inlet ducts.

BRAND NEW

Long a closely guarded military secret, the Lockheed designed scoop configuration has an opening shaped like a half-moon. A conical wedge, extending forward of the opening, comes to a point next to the fuselage.

Why this shape?

To prevent shock waves from forming and blocking air flow into the scoop.

First scoop of its type to be incorporated on a production airplane, the design effectively channels air and provides higher ram to the engine.

DOUBLE VALUE

Another important feature of the duct portion of the inlet tract provides for bypassing a certain percentage of the entering air around the engine mouth and then out the tail. This does the following:

1. It cools the afterburner as it flows around it.

2. It serves to reduce what is known as the base drag of the airplane.

The duct portion of the inlet tract is fabricated from an integrally stiffened, extruded aluminum alloy barrel. This is split longitudinally and straightened into flat sheets. By use of the stretch-forming process these sheets are then contoured to the configuration of the air inlet. (The integral stiffeners run peripherally.)

PRECISION PLUS

Because final dimensions required are too thin to be assured by conventional extruding processes, the completed assembly is chem-milled to the desired skin thickness.

A series of "zero draft" forgings (covered in section under Production Processes) are incorporated in the structure of the scoop portion of the engine air inlet tract.

In the area where the wings are attached the fuselage attains its maximum width of 80 inches.

Dive flaps (also called speed brakes) are located aft of the wing and midway up on each side of the fuselage.

BUILT-IN BONUS

Indicative of the type of careful design planning which went into each individual part of the Starfighter is the "four-way" role established for the dive flap housing.

Because the housing had to be strong enough to take loads imposed when the flaps are opened at high speed, it acquired sufficient weight (or muscle, more appropriately) to handle more than one job.

Result: The dive flap housings also serve as the supporting structure for the dive flap tracks, the primary engine mount fittings, and they also carry fuselage flight loads.

TO THE END

The aft fuselage section houses the engine and carries the tail loads into the mid-fuselage.

Stainless steel and titanium skins, able to withstand the engine temperatures, are used to plate the aft fuselage.

The fuselage longerons and fin deck structure are fabricated from 17-7 PH stainless steel.

A drag chute for landing is installed in a compartment on the bottom of the fuselage, just aft of the mid-to-aft fuselage joint.

EMPENNAGE

The Starfighter's empennage is described as T-shaped because its stabilizer is located almost at the top -- only 11 inches from the upper edge -- of a high vertical fin with a swept-back leading edge.

The entire surface of the horizontal stabilizer moves as a unit making it in effect a "flying tail." There is no elevator.

LEAN AND CLEAN

Holding to the aircraft's knife-like construction, the horizontal stabilizer is only 3.6-inches thick at the inboard edge and slims down to a mere .6-inch thickness at the tip.

A single main spar with formed ribs, covered with 70-75-T6 sheet skin panels, constitutes the one-piece horizontal stabilizer. This integral surface, which is actuated at its root leading edge, is hinged along the spar line by a single pin passing through a fitting atop the fin main spar.

A unique feature of the F-104 tail is that the stabilizer hinge and operating controls are both contained within the empennage contour, thus avoiding external fairings normally employed to cover these items.

The fin, which contains all hydraulic boost servo units for control services, is built up on two 4140 steel fuselage forgings supporting two fin forged spars.

Movable surfaces (hydraulically controlled) of the rudder and yaw dampers attach to hinge fittings on the fin aft spar.

COCKPIT INSTRUMENTATION

In designing the F-104 instrument panels and deciding what instruments to install, Lockheed engineers and pilots worked from two basic principles:

1. Simplicity is the essence of safety. The fewer switches to throw, the fewer dials to watch, the fewer handles to move -- all contribute to improving the pilot's chances of avoiding a mistake.

2. The human head will swivel, laterally, only through an arc of about 240 degrees.

Result: From the pilot's point of view, the Starfighter's "office" is as efficient, compact and "liveable" as human engineering can make it.

TAILORED TO FIT

When a jet pilot steps into the cockpit of an F-104 he knows that "this is for me," as many have testified.

He is properly placed. Everything is handy. Controls are right at his fingertips. Visibility is excellent.

A Starfighter pilot gets the feeling he is a part of the machine. It's like slipping into a tailor-made suit. It fits.

EASY TO FIND, EASY TO READ

The F-104 has four instrument panels mounted vertically in front of the pilot. Console panels extend along each side of the cockpit.

All cockpit instruments are front mounted. They are face-lighted by lamps mounted in individual instrument lighting hoods and lamps mounted beside the instruments. Printed placards on the instrument panels are edge-lighted.

WHAT'S WHERE

The upper (main) instrument panel is effectively simplified, uncluttered with superfluous instrumentation. It contains only the flight navigation instruments, tachometer, and indicators for exhaust temperature, jet nozzle position and fuel quantity.

A fire and overheat warning light, labeled "FIRE," is located on each side of the panel. These lights come on when critical temperatures are present in the engine and tail sections.

When engine inlet air temperature exceeds specified limits, a "SLOW" warning light appears on the left side of the panel.

A master caution light on the bottom of the panel lights up to warn the pilot when any one item of the multiple warning light system (on the right front instrument panel) is lit.

Alongside the master caution light is a reset button which permits the pilot to turn off the master caution light so it will be free to operate for other items of the special warning system.

Placards concerning proper flight operation and radio call numbers also are installed on the main panel.

Late model Starfighters include an engine inlet air temperature indicator on the main panel. Also, a pitch rate indicator is mounted above the right side of the upper panel forward of the glare shield.

FOR LESS GLARE

Extending across the top of the upper panel is a telescoping glare shield. The telescoping portion of the shield can be pulled aft to prevent instrument lights from being reflected from the surfaces of the canopy. A dust cover extends forward from the panel and is fastened in place by snaps along the canopy sill.

ON THE LOWER LEVEL

Directly below the main instrument panel is a T-shaped lower panel. Its instruments include the radar range and position indicator, accelerometer, hydraulic and engine oil pressure gauges, fuel flow indicator, cabin altitude indicator, and engine inlet air temperature indicator. (The latter items positioned here on earlier model Starfighters, but placed on the upper panel subsequently.)

Late model F-104s incorporate the clock on the lower panel.

Items other than instruments mounted on the lower panel include the landing gear indicator lights, aileron and stabilizer takeoff trim indicator lights, and flap position indicators.

Manual release pull handles, gunsight controls, pilot faceplate heater control, hydraulic pressure gauge system selector switch and an armament control section also are mounted on the lower panel.

<u>EYES LEFT</u>

The left forward panel, located alongside the lower center instrumentation and forward of the throttle control, contains the landing gear control switch, landing and taxi light, emergency fuel selector, engine starter, engine anti-ice and external stores jettison switches.

Mounted directly above the landing gear control lever is a downlock override button. Within a transparent knob on the landing gear control lever is the landing gear warning light. The control lever uplock release button protrudes from the top of the knob.

<u>EYES RIGHT</u>

Positioned comparably to its left hand counterpart, the right front panel is located underneath the canopy sill. This panel contains the generator switches, a fuel quantity indicator test switch, and the multiple warning light panel. On late model F-104s the canopy defrost control also is located on the right panel.

SAFETY SPECIAL

A word about the multiple warning light panel --.

This system, designed and developed by Lockheed engineers and test pilots (who nicknamed it the "peek and panic" panel), is the first of its kind in the military fighter field.

What does it do?

It enables a pilot to know, instantly, where trouble is brewing. In fact -- like a pin-ball game registering "tilt" -- the "peek and panic" panel lights up to pinpoint exactly what is happening.

There are 11 separate windows in the panel. Should a malfunction occur, the window tied-in with that particular system lights up.

Instead of having 11 assorted panic lights scattered about the panel and consoles, they are now centralized in one easy-to-check location.

CONSOLE ON THE LEFT

Extending along the left cockpit wall, aft of the throttle control, the left console includes sub-panels for the following: UHF communication, fuel tank selection, stability controls, left circuit breakers and armament ground test.

The fixed outboard portion of the console contains auxiliary trim switches, a thunderstorm light, canopy defrost control (moved to right console on late model F-104s) and the anti-G suit regulator.

Late model additions to the left console include data link and radar test sub-panels, plus inclusion of the special weapons drop lock sub-panel and nozzle control switch on the left trim panel.

CONSOLE ON THE RIGHT

Installed in the right console, which runs along the right cockpit wall, are the following sub-panels: oxygen control, VHF navigation, J-4 compass and IFF, heat control, interior lighting, and right circuit breakers.

Items mounted on the outboard portion of the console are the ground crew interphone, engineering motoring, storm light, nozzle actuator stop check switches, and a thunderstorm light.

On late models of the Starfighter the outboard section also includes a bomb release selector, tip/pylon tanks empty indicator, and an air refueling probe light switch.

A navigation computer and fresh air scoop control are installed on the right cockpit wall adjacent to the right console.

(Both right and left consoles are built to accommodate various removable sub-panels.)

IN ADDITION

Stemming from Lockheed's instrumentation analysis program, which resulted in all instruments being placed in their most logical and useful positions, five items are located in positions other than in the cockpit.

Two accumulator pressure gauges are included as part of the hydraulic panel on the engine access door. Two hydraulic reservoir fluid level indicators are installed forward of the hydraulic service panel. A bearing converter indicator, used in setting up the radio navigation system, is incorporated in the aft radio rack on the right side of the electronics compartment.

MAINTAINABILITY

The simpler a combat airplane is to maintain, the more "flying power" can be put into the air by a given number of maintenance personnel.

Ability to fly and fight when needed: this is the payoff -- the reason for being -- of any front-line military airplane.

An elementary concept? Yes.

But this basic "keep 'em flying" objective has not always been reflected adequately in operational hardware.

The F-104 Starfighter was designed, from cradle to combat, to meet its in-commission requirements.

Maintainability was "born into it."

BEST YET

Spurred by an over-all "simplicity in design" concept, Lockheed engineers provided, to a heretofore unmatched degree, built-in ease-of-maintenance features for the F-104.

Results:

1. Starfighters in service are requiring approximately only half the maintenance manhours per flight hour (less than 20 maintenance manhours for an F-104) necessary for other current jet fighters.

2. Minimized weapon system cost for using commands.

GOOD, AND SIMPLE

Starting with initial assembly operations, the Starfighter was designed to be completely put together and checked out before mating. Right up through final assembly and into tactical utilization, the same "easy does it best" approach stays with the aircraft.

Take interchangeability of parts, as an example.

A total of 165 interchangeable items -- ranging from small accessories to full panels -- are incorporated in the Starfighter. These parts can be switched from one aircraft to another, or replaced, simply by using ordinary removal tools found in an average tool box.

This quick change capability could add precious minutes of fighting time to Starfighters in a wartime emergency.

EASILY REACHED

Keynoting the Starfighter's ease of maintenance features, all major systems of the aircraft are readily accessible through separate service centers.

Two men can completely remove the radar system in just 10 minutes. The entire nose radome can be opened for servicing merely by unhooking four latches and sliding the section forward on a set of inner tracks.

Within five minutes maintenance men can replace the one-piece gun installation.

Unscrewing a single covering panel exposes the gun for inspection and service.

To facilitate quick "go, no-go" checks, the electrical equipment is built into modular boxes which can be installed or removed from their plug-in containers by one mechanic in a matter of seconds.

The electrical system's circuit breakers and load carriers are located in easy-to-reach service bays throughout the aircraft for complete accessibility.

Mounted on the inside of the lower fuselage, the hydraulic system installation panel can be opened up easily for service by unlatching the fuselage cover panel. Liquid spring type shock absorbers used in the F-104's landing gear are practically "maintenance free."

Ready access to the cockpit is provided by the easy-to-open "lift-up" canopy. Also, by simply unscrewing attachment bolts, the cockpit's bottom hatch can be removed in approximately three minutes -- enabling the entire seat installation to be slid down and out and thereby providing stand-up working room inside the cockpit for a technician.

The electronics gear, packaged in "jeep cans" for quick changes to fit different missions, is reached by merely unhooking and "peeling back" hinged cover panels immediately behind the cockpit.

Missile and bomb installations are all external, adding to maximum accessibility.

NO ELBOW RUBBING

Due to the effective employment of the service center concept throughout the aircraft, all major systems are so placed within the F-104 that they can be worked on simultaneously by technicians and ground maintenance personnel.

This eliminates "queuing up" of support crews to wait their turn for carrying out separate service or maintenance operations.

Time for flight-line or in-hangar support functions, as well as between mission turn-arounds, is cut to a minimum.

ON THE RECORD

Indicative of the F-104's excellent maintainability during operational use, during a series of flight demonstrations at Randolph Air Force Base, Texas, maintenance crews averaged only 12.5 minutes for turn-around maintenance operations between 62 flights.

ENGINE OUTSTANDING

The advanced design, single-spool J79 engine was engineered to afford minimum maintenance.

Significantly, disassembly of all major components is possible with a minimum requirement for special tools and ground handling equipment.

Quick turbine inspection and maintenance, without engine teardown, is attributable to the powerplant's split turbine casing.

Additional important J79 maintainability features include:

1. Lightweight component parts which facilitate handling.
2. Only three main bearings in the engine rotor.
3. Readily accessible controls.

Despite its major design and maintenance innovations, the J79 is proving itself in service to be as easy, if not easier, to maintain than twin-spool axial flow engines. One reason: It does not have the mechanical complexity of such items as constant speed drive.

The fuel system is simple and straightforward. It does not require excessive plumbing throughout the airplane.

Military personnel, impressed with the engine installation, have noted that most engine accessories can be inspected or removed with the engine installed. This represents a major advancement over most current fighters which require engine removal for only minor replacements.

PRODUCTION PROCESSES

Although the Starfighter is revolutionary in performance and appearance, Lockheed is building it essentially with the same equipment and processing techniques employed on previous fighter aircraft.

From first metal-cutting operations up to the last station of the final assembly line, this airplane is keyed to producibility.

Easy structural accessibility during manufacture and most effective use of sub-assembly techniques were "musts" when the airplane was in planning-for-production phases.

Sought and achieved in the F-104 were these five design goals: (1) light weight, (2) conventional structure, (3) conventional manufacturing methods and equipment, (4) low cost per pound, (5) high production rate capability.

Along with optimum use of proved manufacturing and production techniques, several significant new processes had a part in Starfighter development. Following are brief summaries of some of these innovations and their application:

COMPRESSION FORMING

The brand new compression forming process, developed by Lockheed engineers, achieves tolerances never before possible in sheet metal parts.

Designs for high-performance aircraft such as the F-104 call for inches-thin wings, glass-smooth contours and strength to take high stresses and aerodynamic heating -- all at lowest possible weights.

Compression forming meets all of these requirements. It permits fabrication of parts to exact dimensions, with tolerances of virtually "plus or minus zero" -- as low as .010 inch.

In this process, a sheet metal part is first formed to broad tolerances by a Hydropress, removed and heat treated, then placed in the cavity of a compression die for precision forming. A ram, under high pressure, compresses both the surface and edges of the part -- forcing the metal to flow and set precisely against the face of the die.

The sharper flange bend radius possible with the new method lets rivets be seated almost in line with the web of wing stiffeners.

This increases the effective strength of the connection and cuts down "working" of the area under stress. A thinner web will carry a given load.

The sharp radius also permits use of a much narrower offset flange than before. This spells reduced weight.

Pinpoint accuracy of the method rids wing surfaces of waviness which disturbs air flow and increases air friction, or drag, at high speeds.

Wing spars and ribs of the Starfighter are being made from sheet metal, using the compression forming method. (Sheet metal structures are used in areas where the load is lighter. Forgings are used in heavy load-carrying areas.)

ZERO DRAFT FORGINGS

Until recently, forgings were made with a taper (or draft) on sides of upstanding ribs to permit the forging to be withdrawn from the die cavity. In the majority of forgings this taper must be machined off to permit attachment to other parts or, simply, to remove the unneeded material.

In conjunction with the U. S. Air Force's Air Materiel Command and several aluminum forging vendors, Lockheed did basic development work which resulted in a new type of close tolerance press forging.

Using higher forging pressures and precision dies, forgings are now being made to very close tolerances with thin, untapered ribs. This process eliminates most of the previously required machining operations and brings an average saving of about 40 cents on the dollar over conventional machined parts.

The F-104 uses about 60 such zero draft close tolerance forgings.

BETTER MILLING THROUGH CHEMISTRY

To achieve an efficient strength-weight ratio the aircraft designer must distribute structural material where the highest load occurs. This requires that parts have localized areas of thick and thin sections. In flat shapes this type of part has previously been produced by riveting or bolting smaller parts together or by machining them from heavy sheet stock.

Recently the aircraft industry has been etch-removing unneeded material by immersing aluminum sheet, plate and extrusions in a caustic soda solution. It is called chem milling. By masking certain areas to prevent etching, lands or plateaus of varying heights can be produced. This chemical process, similar to that used in making photographic plates for printing, saves considerably in machining costs.

The F-104 engine air intake ducts, in their extruded form, are completely chem milled to meet design weight and dimensional requirements.

STEEL EXTRUSIONS

Important developments in the art of extruding metal now permit involved shapes to be extruded in high strength alloy steels. By forcing hot steel billets through openings in a die, angles, "Ts" and other shapes can be made at a very considerable savings in cost. This process can be compared to squeezing cake icing out of a decorator's tube.

Prior to this development, complex steel shapes had to be machined from solid bars. The F-104 uses approximately a dozen steel extrusions in such applications as piano-type hinges for attaching ailerons to the wing.

EXTRUDED, INTEGRALLY STIFFENED PANELS

In order to produce lighter, more efficient and smoother surfaces for the engine air intake ducts on the F-104, Lockheed employed extruded, integrally stiffened aluminum panels in the following manner: the extrusion, in tubular form, is slit lengthwise and unwrapped into a flat sheet. This sheet is then contoured into the desired shape through the stretch-forming process.

CADMIUM PLATING

Lockheed process development engineers perfected a process for vacuum-plating load-bearing parts of the Starfighter with cadmium, the lightest and most practical metal discovered for the purpose.

A "self-sacrificing" metal, in that it allows itself, rather than the load-bearing member, to become oxydized, cadmium coats and protects the parts against corrosion and consequent loss of strength.

The process is applied to ultra-high-heat-treated steel used for landing gear parts as well as bolts, fittings and fasteners throughout the airplane.

Customary electrolytic plating entailed using a liquid cyanide bath as a carrier of electrically activated plating materials. That required complex and expensive process controls to avoid embrittlement of the part.

The new method involves placing a high-strength part in an air-tight chamber along with a cadmium-filled crucible; evacuating the chamber to one-half micron of mercury pressure (virtually a complete vacuum); then boiling the cadmium until it vaporizes and condenses on the airplane part.

SUBCONTRACTING

Designed for efficient diversification of manufacturing activities, the F-104 Starfighter is the end product of a far-flung, highly coordinated subcontracting program.

Major and minor assemblies and sub-assemblies flow into Lockheed's centralized production facilities in California from throughout the United States for final assembly.

SUPERSONIC SUPPORT

Approximately 40 per cent of the total manufacturing effort on the airplane is represented by subcontracted equipment.

A typical example of this "team" approach to aircraft manufacture is evidenced in the major airframe structurers:

Beech Aircraft Corp., Wichita, Kan., produces the aft fuselage.

Rheem Manufacturing Co., Downey, Calif., provides the entire tail assembly.

Goodyear Aircraft Corporation's Arizona Division builds the nose section.

Temco Aircraft Corp., Dallas, Tex., manufactures the complete wing.

The complex mid-fuselage and forward fuselage segments of the F-104 are built at Lockheed's plants in Burbank and Palmdale, Calif.

Menasco Manufacturing Co., Burbank, Calif., contributes the landing gear units.

MUCH FROM MANY

Literally hundreds of other items of all description -- ranging from nuts and bolts to complex electronic gear -- are supplied by as many different companies across the country.

Each represents an important part of the whole.

Each company efficiently dove-tailed its production and availability of product to make possible a finished "off-the-line" Starfighter.

SECTION V

POWER

Ever since man found a way to "saddle up a blowtorch" and fly safely through the sky, providing means for doing it faster and more economically has remained a constant challenge.

That challenge has proved a powerful catalyst to progress.

Result -- like a wave rolling relentlessly across an ocean, advances in the field of jet propulsion are sweeping aviation into a brand new arena of operational capabilities.

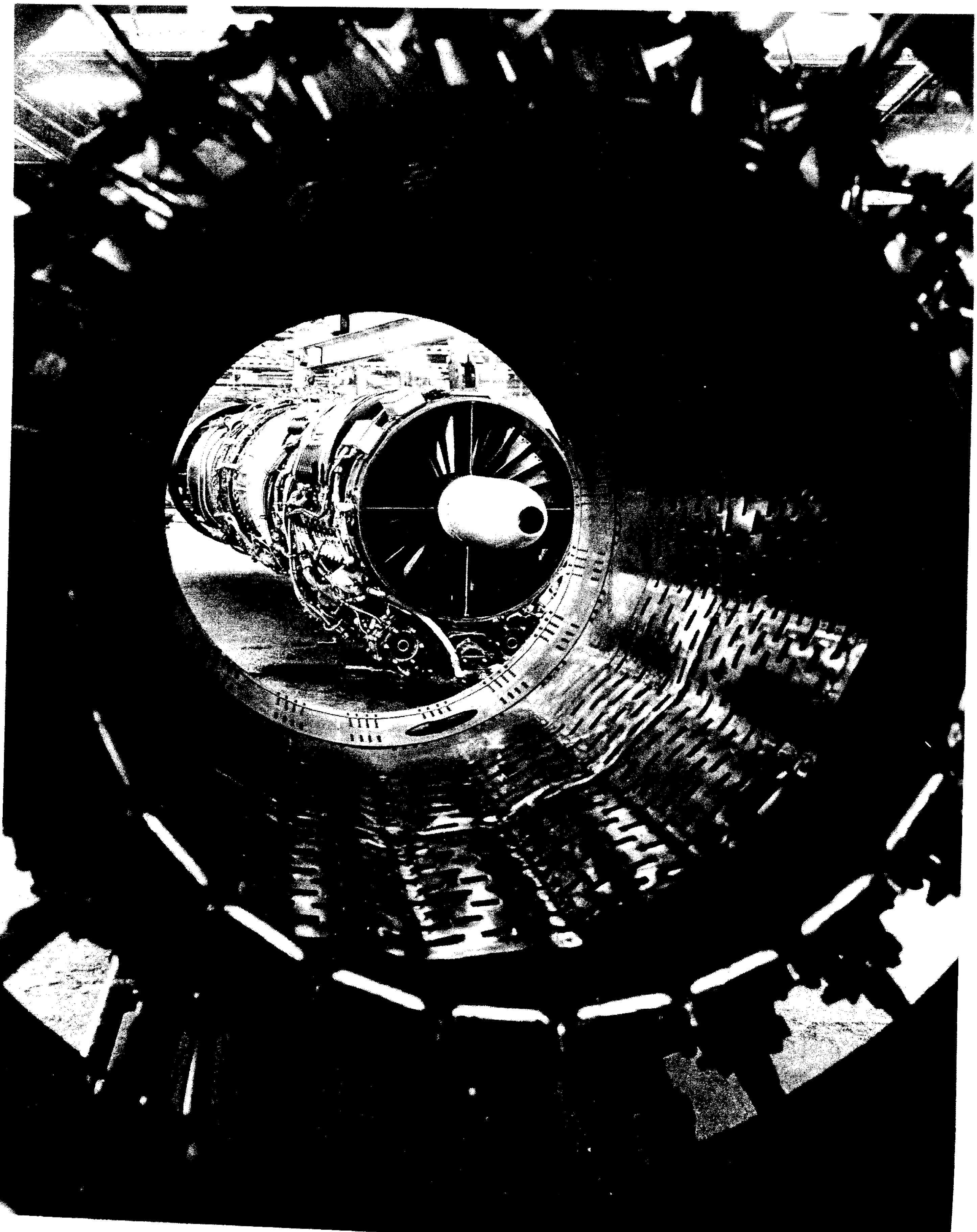
The key to moving ahead -- ever more rapidly and impressively -- is power. Muscle to move the mass. Propulsion power.

This is an area where progress is a must. At the Flight Propulsion Division of the vast General Electric Company, contributions to the jet engine field have been constant and spectacular.

FROM THE BEGINNING

General Electric produced America's first jet engine in 1941. Designation: I-A. Weight: 780 pounds. Thrust: 1300 pounds. (Thrust is the push -- or power -- of a jet engine, measured in pounds.)

Pursuing its pioneering advantage in the field, the company scored a major engineering breakthrough during World War II with development of an engine featuring an axial flow compressor.



Previously the jet engine field had been dominated for the most part by powerplants employing centrifugal compressors, such as General Electric's own J33 which was introduced on the Lockheed F-80 Shooting Star -- first U.S. production jet fighter.

Engines of the J33 type employed a compressor in which air was propelled outward from the center of rotation.

Axial flow models have a compressor in which air flows straight through and is "packed" by a series of spinning fan-like blades.

Both, of course, work on the reaction principle of propulsion which, in jet engines, means simply: squeeze air, add fuel, ignite it, and -- whoosh, go forward as it blasts from the tailpipe.

In a comparable but less forceful manner, a balloon squirts forward as its air supply is expelled from the neck. It demonstrates Newton's Second Law: every action has an equal opposite reaction.

GROWTH PATTERN

In the early period of jet engine development greater thrust seemed wedded to bigger, heavier engines.

But the match wasn't made in heaven.

In fact, during recent years, it proved a downright unhappy marriage from the aircraft designer's point of view.

Reason: a big engine is not a guarantee of maximum supersonic speed. Drag can rise faster than power.

The need became critical for a small but powerful engine.

J79 ON STAGE

Ready to meet that challenge, General Electric designed the J79 to fill industry's need for a high thrust, low weight and mechanically simple jet engine.

Noteworthy: While the J79 is not the highest thrust engine to be developed by an American manufacturer, its thrust to weight ratio is unprecedented. It became the first U.S. production engine capable of powering aircraft at twice the speed of sound.

Taking advantage of the J79's light weight and high thrust features, Lockheed engineers were able to develop the F-104 to be a missile-like fighter-interceptor with unmatched mission versatility.

As a matter of history, the J79 was developed by General Electric in cooperation with the U.S. Air Force under the government's new weapon system management concept.

The new engine was a perfect match for the Starfighter.

For the first time, an advanced aircraft and a powerplant were developed and produced simultaneously.

ENGINE EFFICIENT

Ability of the airplane to "stretch its legs" for long-distance missions is enhanced by the engine's excellent specific fuel consumption. In familiar language, the J79 gets top "gas mileage."

This fuel burning efficiency has a direct relationship to the aircraft's over-all design weight. (The aircraft designer doesn't have to allow for "beefed up" structures to support the weight of additional fuel, required when engine efficiency is below par, to do a given job.) The airframe can become proportionately smaller and lighter.

Net result: A more economical aircraft to build and to operate -- a more effective piece of fighting equipment.

DEVELOPMENT HIGHLIGHT

Introduced during General Electric's 15th year as a jet engine manufacturer, the J79 (15,000-plus pounds of thrust) packs more than 10 times the thrust of the company's first I-A powerplant.

And, significantly, although G.E. engineers developed and brought the new engine to full production status under an accelerated program, the J79 already had more than 12,000 hours of factory, simulated altitude and flight testing to its credit when it reached production stage.

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For the technical writer, here are specific engineering details:

EMPLOYS VARIABLE STATORS

This is the first operational jet engine to employ the principle of variable stator blades in the engine's compression section.

As designed in the J79, the pitch (angle) of the stator blades is controlled automatically to adjust and provide smooth air flow in the engine as the engine speed changes.

The variable stator principle accomplishes in a mechanically simplified way the same thing that the dual rotor does in other current jet engines where the stator blade angle is fixed. (In this regard the variable stator installation facilitates minimum engine weight.)

Prime advantages of the variable stator blade system are (1) reduced stall problems at low engine operating speeds, (2) maximum compressor efficiency under all flight conditions and (3) optimum match of engine and airplane induction system for good stall margin at high airplane speeds.

PILOT ENDORSEMENT

Military pilots who have flown the Starfighter label its engine acceleration, afterburner lightup and starting as "outstanding."

Saluting the J79's instant acceleration from idle to full power, without compressor stall -- this feature was called "amazing."

DESIGN DETAILS

Following are design features of the engine's main sections:

A. Compressor.

1. 17 stage, axial flow, single rotor construction.

2. First six stator stages and inlet guide vanes are variable.

3. Rotor consists of thin webbed discs and spacer rings bolted together with the blading attached to the rim sections by conventional dovetails.

4. Top and bottom sections of the compressor casing may be removed for convenient inspection and maintenance.

5. Inlet guide vanes and struts are anti-iced with compressor discharge air allowing flight under all types of weather conditions.

6. Combustion system is of cannular design with split casing to facilitate inspection and maintenance. (There are 12 combustion liners within the combustion casing.)

B. Turbine

1. 3 stage turbine. Turbine wheels are coupled to the compressor rotor by a conical shaft for low weight and high strength.

2. Light weight turbine casing consists of fabricated sheet metal. Top and bottom sections may be removed, aiding inspection and maintenance.

CONTROLS

Two separate and distinct fuel systems, designated "Main Fuel" and "Afterburner Fuel," are incorporated in the power control system.

Both the main and afterburner systems feature flow controlling type units.

The hydro-mechanical control system has electrical trim with hydraulic and electric power required to operate the system being supplied by the engine. This makes the complete engine control system integral with the basic engine.

Comprising the integrated and synchronized composite system are:

1. The main fuel system.
2. The afterburner fuel system.
3. Nozzle area control system.
4. Variable stator control system, which is integrated with the main fuel control.

The afterburner features a fully modulated, variable area, with a converging-diverging exhaust nozzle. This provides, automatically, optimum engine performance for all flight conditions.

Following are dimensions of the J79:

Over-all length:	207 inches.
Frame size:	36 inches.
Pressure ratio:	12:1.
Weight:	About 3200 pounds.

SECTION VI

THE FUTURE

Firmly established as aviation's top performing, most versatile fighter, the forward-looking F-104 is effectively utilizing its advanced design as a solid springboard into the future.

Its impact upon the balance of power in the sky already is being projected into the 1960s.

The Starfighter's career is just beginning.

FREE WORLD DEFENDER

Whether the need be in NATO, or half-way around the globe in countries aligned with SEATO, this single piece of aerial fighting equipment logically could become a standard defender of freedom everywhere.

Here is why:

1. Based upon in-service records, the F-104 is unsurpassed in performance and mission versatility.

2. Equally important, statistics prove the Starfighter is cheaper to produce and costs less to maintain than any other modern fighter.

COMING UP

Beyond today's Starfighters, a wide variety of new versions are programmed. Some are already in production. Others are ready for a go-ahead signal.

Scheduled to make its appearance in 1960 with the West German Air Force is the F-104G.

Its operational description: an "improved and advanced" single-seat multi-mission fighter for round-the-clock defense in any kind of weather.

NEW VERSIONS

Reflecting refinements incorporated in the F-104G, a similar new model called the F-104-7 has been proposed to the U.S. Air Force.

Still another different model, the F-104-9, is ready to be built as an "international version" to fit the supersonic defense needs of all friendly nations.

The F-104-9 is specially designed to meet economic and military requirements of budget-conscious nations around the globe.

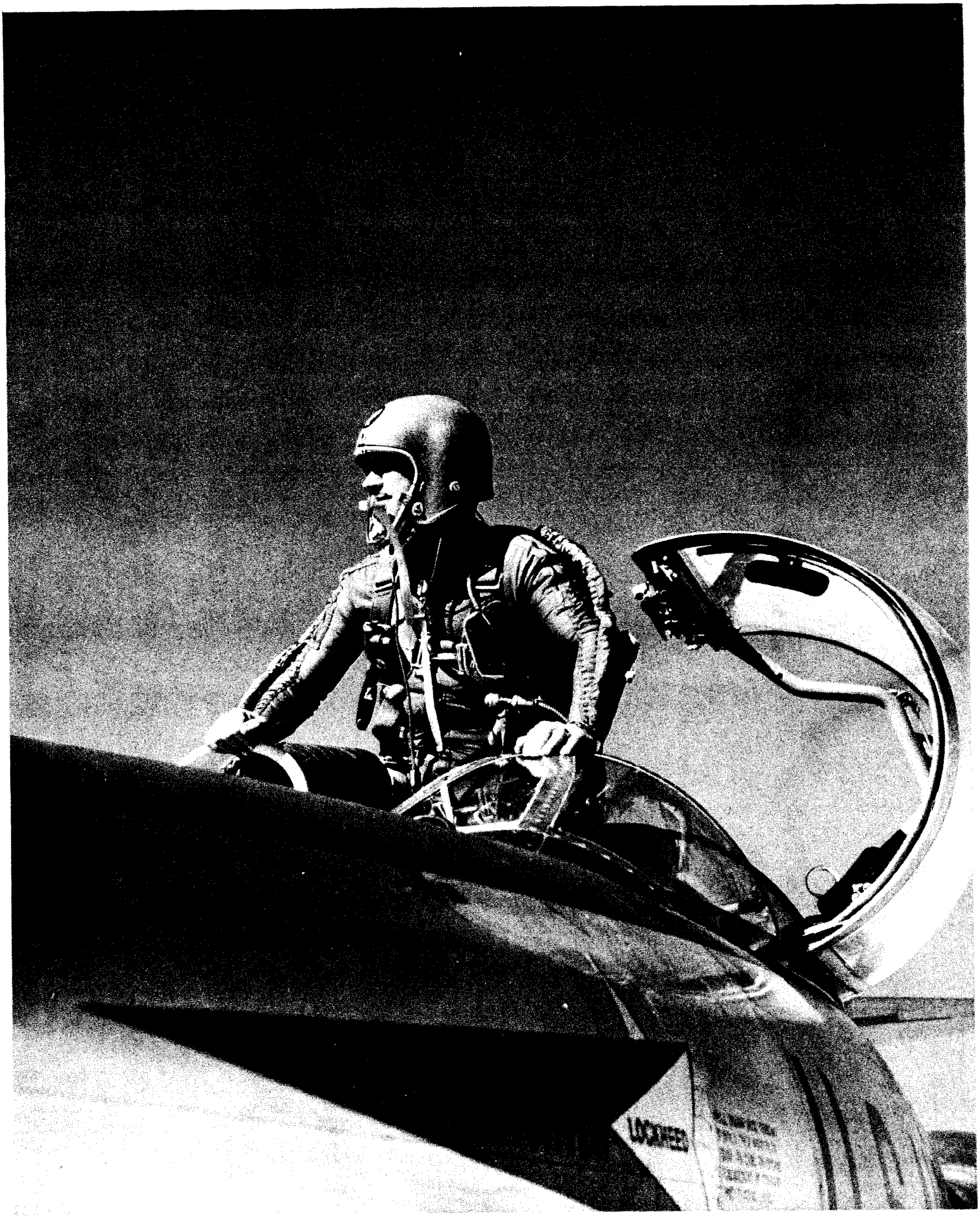
Proving that the "missile with a man in it" also can be employed for unmanned operations, Lockheed is developing a QF-104 drone. The Starfighter drone will be used as a remotely controlled and recoverable target vehicle for high-speed missile test firing operations.

READY FOR ANYTHING

From missile-like to missile, period.

Fighter-interceptor. Fighter-bomber. Drone. Multi-mission fighter.

The F-104 Starfighter has the ability to do everything in the fighter field better than any other single package of airpower in history -- today and for many tomorrows to come.


LOCKHEED

SECTION VII

NEWS NUGGETS

Every writer encounters a need, at one time or another, for quotable quotes ... brevities ... color ... meaty tidbits.

While there's plenty of "chawin' beef" in the foregoing pages, here are a few tasty hors d'oeuvres.

SHORT BURSTS

If a Starfighter took off from New York in the light of early dawn, flying nonstop to Los Angeles, it would beat the sun to the West coast.

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Lockheed engineers calculated that every square foot of straight wing, such as on the Starfighter, lifts approximately twice as much as each square foot of delta wing would afford on the same airplane.

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Here's why Lockheed designers kept the F-104 weight to a minimum: for a given mission, 1 pound added to a fighter part snowballs to 10 pounds over-all. The non-productive pound, a "free-loader," requires additional strength and weight in all supporting structure -- plus additional fuel for range.

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If the electrical wiring contained within the slim-trim airframe of the F-104 were stretched in a straight line, it would extend a distance of nine miles. The Starfighter itself measures only 54 feet, 9 inches in length.

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The F-104 landing gear was the first to pass the U.S. Air Force "4000-cycles" fatigue test for fighter aircraft.

- - -

Aerojet-General, producer of the Starfighter's infra-red fire control device, has devoted more than 2,000,000 manhours to infra-red engineering research and development during the past 14 years.

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Appropriately, the code name given the official time-to-climb record flights was "Project Quick Trip."

- - -

To protect the Starfighter's glass-smooth skin from scratches, mars or abrasions during manufacture, the surface is sprayed with an acrylic resin coating only .00025 to .0005-inch thick. Drying in just two or three minutes, the "plastic overcoat" becomes the hardest and slickest protection ever known for in-factory use. For removal, a newly developed compound is sprayed or rolled over the completed assembly. After approximately 24 hours for the remover's chemicals to work, the protective coat can be stripped off as simply as peeling a tangerine. The protective coating and remover are products of the Tec Chemical Company.

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The F-104 is symmetrical to an extent never before attempted for a production aircraft. This means that distances between right and left wings and the empennage, right and left wing cathedral and angle of attack are identical. Reason why symmetry is so vital: Wind tunnel tests showed that if the wing angle of attack were held to the tolerances of prop-driven or early jet fighters, the super-swift F-104 would "rifle" in flight, spinning on its axis like a rifle bullet. As proved by performance, the operational Starfighter's flight stability is superb.

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Curious as to just how strong is that thin straight wing of the F-104? Plenty strong -- it carries dynamic loads of more than a ton per square foot.

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The Starfighter is like an aerial bloodhound when it comes to following a command for intercept. It has demonstrated conclusively its tracking skills, not only in 180-degree climbing turns but in vertical zoom attacks.

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First American production use of the Dowty (British) liquid spring principle is employed on the F-104's main landing gear shock strut. Only half the size of standard air-oil shock struts (which would have posed a major installation problem due to their larger size, coupled with the fact that the F-104 shock strut has to be small in order to facilitate the landing gear tucking up into the pencil-like fuselage), the liquid spring on the Starfighter is built to take a hydraulic pressure of up to 60,000 p.s.i. during maximum landing conditions.

- - -

Designed as a multi-purpose aerial weapon, the F-104 can carry any type of aircraft armament known.

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Lockheed developed an APC (automatic pitch control) system for the F-104 which warns pilots when approaching the stall area. Operation of the APC is based upon functions of angle of attack and pitch rate. When the plane attains maximum usable angle of attack a warning signal occurs in the form of "shaker action" in the stick. Should the pilot, unjudiciously, insist on "pulling in tighter," the system applies a gentle but firm force of 30 pounds pressure to the stick to push it to a point one degree forward of the trim position.

- - -

On a maximum performance takeoff the needle-nosed F-104 can be zooming out of sight in the stratosphere within about two minutes.

- - -

The power output of the Starfighter's electrical system is almost equal to that of a 50,000 watt clear-channel radio station.

- - -

Due to the F-104's blazing speed, decals of the type operational squadrons affix to their aircraft just blister off the Starfighter in flight. Insignia have to be stenciled on with paint -- and even the paint's days are numbered. This plane is a real scorcher.

- - -

In direct contrast to its hot performance, the F-104 has a refrigeration unit which can really turn on a chill. The unit's turbine operates at approximately 100,000 r.p.m., just about double the previous r.p.m. rate for turbines of this type. Compared to the familiar household refrigerator, the Starfighter's refrigeration unit would be capable of delivering 10 tons of ice in a 24-hour period.

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Carry about 30 pounds of air pressure in your automobile tires? An F-104 with tiptanks rolls along on tires pumped up to 170 pounds of pressure.

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The rocket seat boost in the Starfighter's upward escape system will lift pilots 200 feet above the aircraft -- well clear of the plane -- following ejection.

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QUOTABLE QUOTES

"The most compact package of speed, maneuverability and striking power I have ever flown."

Maj. Gen. Albert Boyd, now retired, when assigned as deputy commander, weapons systems, USAF Air Research and Development Command.

- - -

"We pilots here at Lockheed had a lot to do with the cockpit design. And, just like a tailor-made suit, it fits. Comfortably. Everything is compact, built snugly around you. And there isn't a battery of knobs and dials that would require a mechanical wizard to figure out. We've kept it simple.

"As for appearance -- to me, the Starfighter looks like an artist's sketch of what I wished I had back in my racing days."

A. W. (Tony) LeVier, director of flying operations, California Division, Lockheed Aircraft Corporation. (LeVier made the first flight in the XF-104.)

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"This is a wonderful all-weather bird. While at Dow AFB testing the new narrow gauge runway lighting system in zero-zero weather, another type aircraft made five attempts to land and then gave it up. I had no trouble whatsoever in landing the F-104."

Capt. Berlin Huffman, 337th FIS, Westover AFB, Mass.

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"The F-104 affords us in the fighter business a weapon with a caliber that we have never before possessed, capable of delivering its arsenal of conventional and nuclear ordnance anywhere in the world."

Col. George Laven, Jr., commanding officer, 479th Tactical Fighter Wing, George AFB, Calif.

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"From the moment I stepped into the cockpit I was struck by the plane's extreme simplicity of control. From the first flight, I felt at home in it.

"Flying it is really a pilot's dream."

Roy Pryor, chief test pilot, General Electric Company.

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"Anyone who doesn't get a thrill out of flying this airplane must have had a lot of rocket time."

Sqn. Ldr. John Nichols, Royal Air Force, when on duty with the 83rd FIS, Hamilton AFB, Calif.

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"I like the simplicity and ease of handling the aircraft under any configuration and at all speeds. I like the characteristics of the aircraft from takeoff to landing, the absolute control of power for formation flying."

Maj. Frank Bohn, 337th FIS, Westover AFB, Mass.

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"I am confident that the F-104 has the same flexibility of design that we had in the F-80. As a matter of fact, we thought enough of the two-place version of the airplane to build a prototype with our own money. As a result, two-seat fighter trainers (designated F-104B with Air Defense Command and F-104D with Tactical Air Command) were ordered and are now operational."

C. L. Johnson, vice president for advanced development projects, Lockheed Aircraft Corporation.

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"When I'm in the F-104 I feel that I can whip anybody and anything. It's a fighter pilot's bird in every way. It's wrapped around you and is with you every minute in all you want or can do."

Lt. Col. Carl Leo, when serving as operations officer with the 83rd FIS, Hamilton AFB, Calif.

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"Wow! Wait'll I tell the boys back at headquarters about this one." (After initial checkout ride.)

Anonymous USAF Colonel from the Pentagon.

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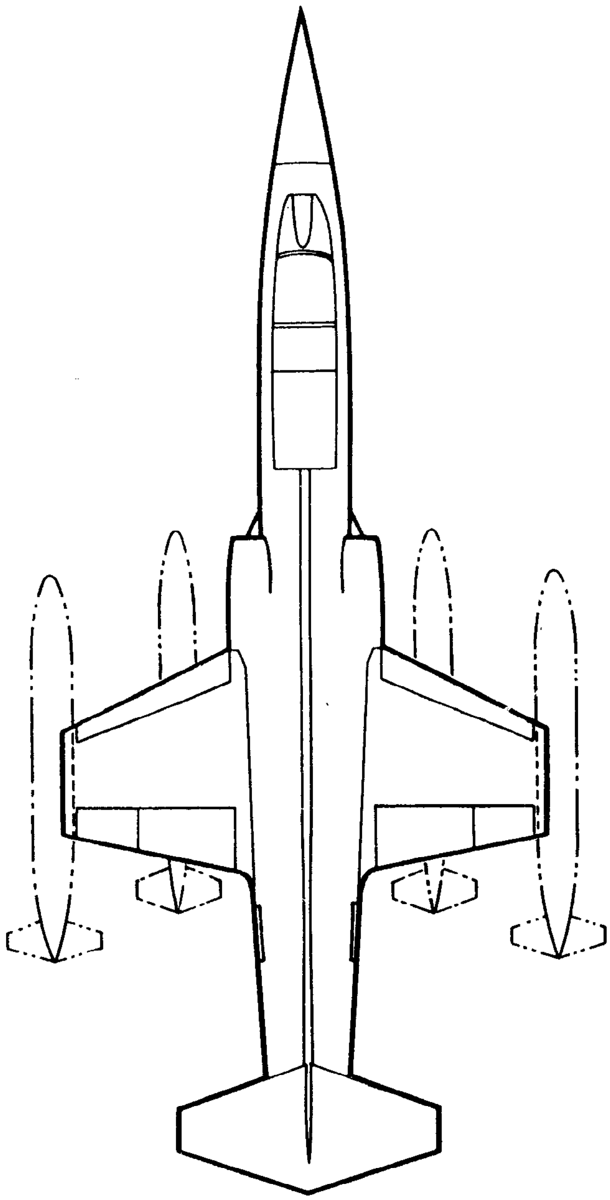
SPECIFICATIONS

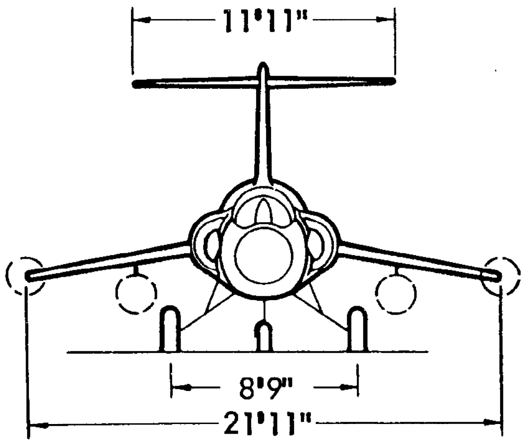
LOCKHEED F-104 STARFIGHTER

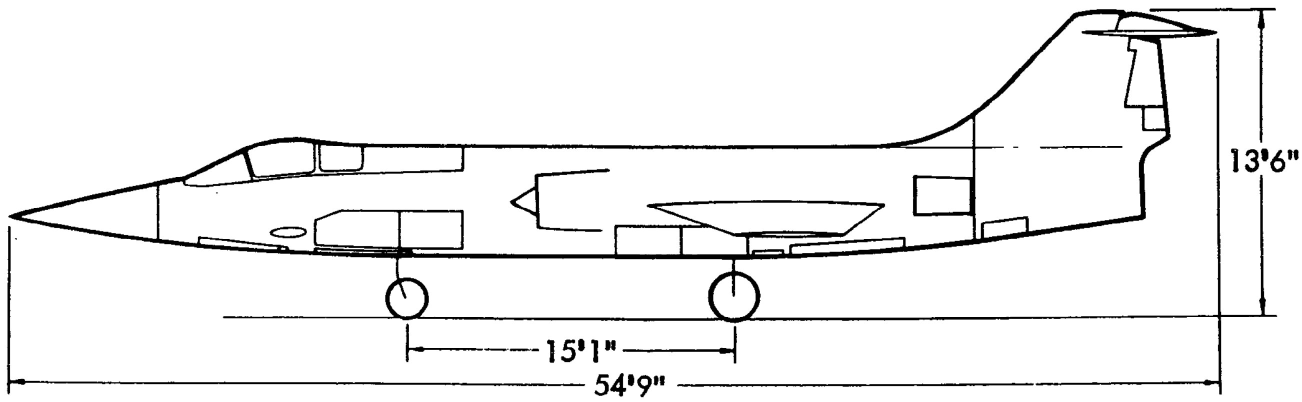
POWERPLANT:	One General Electric J79 turbojet engine, equipped with afterburner.
	Thrust: 15,000-plus pounds.
PERFORMANCE:	Maximum speed: 1500 m.p.h. class.
	Operational ceiling: Above 70,000 feet.
	Range: Comparable to current jet fighter aircraft.
DIMENSIONS:	Height: 13 feet, 6 inches.
	Length: 54 feet, 9 inches.
	Span, wingtip to wingtip, 21 feet, 11 inches.
	Wing area, including ailerons and leading edge flaps, 196.1 square feet.
WEIGHT:	Classified, described only as a "lightweight" fighter.
MISCELLANEOUS:	Landing gear: Tricycle, main gear retracts into fuselage.
	Main wheel size: 26 inches x 6.6 inches.
	Nose wheel size: 18 inches x 5.5 inches.
	Equipped with a 16-foot-diameter deceleration (drag) parachute.
	Has provisions for two 170 gallon centerline-mounted tiptanks and two 195 gallon underwing pylon tanks.

Appendix B

LOCKHEED STARFIGHTER
U.S. AIR FORCE F-104
DAY-AND-NIGHT FIGHTER







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LOCKHEED CALIFORNIA