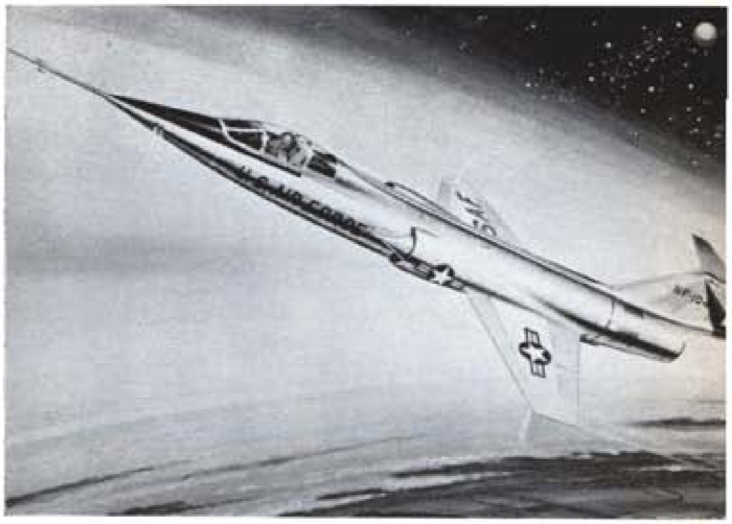
Against the hoped-for day when the Air Force gets the green light for blue-suit stick time in space, a brainy, highly motivated, and skillful band of airmen is learning spaceflight techniques that range from controlled reentry to energy management. They're learning these skills at Edwards AFB, Calif., site of the . . .



Artist's conception shows a pilot nearing 120,000 feet in rocket/turbojet-powered Lockheed NF-104A during a zoom climb down the high-speed corridor at Edwards AFB. He has begun to use the X-15-type reaction control system, which exhausts propellant from wingtips and nose.

USAF Aerospace Research Pilot School

TOUGHEST FLYING SCHOOL IN THE WORLD

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SHORTLY after first light on a morning not long ago, a loose formation of F-104As circled high above Rogers Dry Lake, sixty-five miles northeast of Los Angeles. On command, one dropped out of formation and turned leisurely down toward the broad expanse of the dry lake bed.

At 20,000 feet, the pilot began to break, one after another, the most sacred rules of F-104 flying. With practiced deliberateness he pulled the throttle back to idle and killed his power. He extended the speed brakes full out, nearly doubling the aircraft's drag and killing the lift over most of its stubby wings.

Raising the nose he killed off speed, and when the indicated airspeed reached 330 mph, the pilot dropped and locked his landing gear. As the drag-heavy '104, with its lift power hobbled, began to drop "like a rock," the rate-of-climb needle circled around to the negative side and banged to a stop, indicating that the rate of descent was more than 6,000 feet per minute.

Turning the '104's long nose down to a dive angle of about thirty degrees, the pilot double-checked his course to see that it lined up with his target—the 15,000-foot-long main runway at Edwards Air Force Base. He fixed his eyes on a small patch of green foliage, his first aiming point, 500 feet from the edge of the runway and 5,500 feet from the prescribed touchdown point on the runway.

During the next few seconds, as the Rogers Lake bed accelerated its upward rush, he held the gunsight on the aiming point while adjusting his speed brakes to maintain 340 mph indicated airspeed. If the rate-

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Class No. 1 graduated at the Edwards AFB school is shown above with the school's first commandant, Lt. Col. Robert M. Howe, at left. Others, from left, are: William Schweikhard, an AF civilian instructor; James McDivitt, Thomas McElmurry, Frank Borman, and Robert Buchanan. Latter two are now in NASA Astronaut program. Schweikhard, who is nonrated, went through academic portion of the course and rode as passenger in dual-place aircraft through all the training maneuvers, which pilots say is rougher than the piloting. The school is going to accept a number of nonrated students to study some of the problems of training crewmen as well as pilots for future aerospace vehicles.

Throttleable, 6,000-pound-thrust Rocketdyne AR-2 rocket engine is mounted in large fairing on tail of the Lockheed NF-104A. Each wingtip has been extended 24 inches.

Capt. James S. McIntyre, a student at the Aerospace Research pilot course, uses a training aid as he reviews basic considerations in a satellite-interception problem during space-navigation phase of academic program.

Col. Charles E. Yeager, the first man to fly faster than sound, commands the Aerospace Research Pilot School at Edwards AFB, Calif. The school is training the reservoir of engineer/pilots who will form the nucleus of the first military spacecrews. Yeager's command is in the process of proving that spaceflight is not only possible but will one day be as routine as supersonic flying today.

of-climb gauge had still been functioning, it would have shown that the rate of descent was just above the 15,000-feet-per-minute mark.

As the dive stabilized, the pilot concentrated on his aiming point and the whirling altimeter needle, oblivious to the fact that, as he approached the most crucial part of his piloting task, the tension was driving his pulse and respiration rate up to more than twice normal. His heart was beating 170 times a minute. He was taking one breath every two seconds, and beginning to sweat in the light flying suit. Precisely at 1,400 feet altitude, less than six seconds from the desert that seemed to be climbing into the cockpit, he began a smooth pullup. Automatically, his attention shifted to the accelerometer, the only gauge that could guide him in completing the "landing." Steadily he increased back pressure on the stick until the accelerometer showed two Gs, and he held it without a waver.

The '104 rounded into its flare and the pilot picked up his second aiming point, a large white stripe on the edge of the runway. As the nose came up over the horizon, he held five degrees on the angle of attack indicator and the '104 dropped to the runway, with its tires streaking smoke as they smacked down in a 195-mph touchdown.

The pilot relaxed and eased in his seat as he gently pushed the throttle forward and ran along the ground for five seconds, waiting until the J79 turbojet ran up to full power. As the engine rpm nudged 100 percent he lifted into an easy climb to return to altitude. He logged ten more such landings that morning, along with his fellow students from the Aerospace Research Pilot School who were flying the other aircraft in the F-104 formation.

Some of the landings were of the straight-in dive type. Some used circling X-15 style approaches. But all were extremely rapid and the '104s consistently were hobbled until they could develop little lift. Obviously this training had little to do with normal airplane flying. Its purpose was to expose the students to exactly the same landings they would have to make in any type of advanced reentry vehicle or aerospace craft under consideration by the USAF.

Just a few years ago this highly unorthodox, "space vehicle" flying was considered far too hazardous for any but the most experienced test pilot to attempt as an experiment, much less for sizable groups of Air Force personnel to perform routinely. It required quite a selling job to convince the Air Force that such

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"routine" operations were feasible, desirable, and could contribute materially to the future of the service.

A small group of persistent instructors at the Experimental Test Pilot School—Majs. Frank Borman, Arthur Torosian, Robert S. Buchanan, and Thomas McElmurry—can claim a good share of the credit. They fathered the idea of creating a school in which every feasible facet of space-vehicle operations would be taught through the use of high-performance aircraft, simulators, and an intensive academic course.

This organization exists today in the form of the Aerospace Research Pilot School, which certainly has a strong claim for teaching the world's most difficult flying. In many respects the school's curriculum, including the landing described above, is more difficult than either X-15 flying or NASA's Astronaut training program. The school's main accomplishment in its short history is to remove any doubt that large groups of properly trained pilots can transition into space-vehicle type flying. It has shown that pilots can perform space-vehicle piloting tasks more precisely than previously supposed. And with sufficient practice, even the most difficult maneuvers such as straight-in dive landings can be performed routinely without any more strain on the pilot than conventional supersonic aircraft operations.

Today, the school has a firm future with the Air Force and has been assigned two vital missions. These are:

- To train a group of select pilots to fly and understand the full gamut of advanced vehicles now being proposed. In the immediate future this reservoir of trained personnel is to participate in the development of advanced vehicles in the role of pilot/engineer consultants. They also are prepared to plan and conduct flight tests and evaluations of research, experimental, and production-type aerospace vehicles.

When the time comes this reservoir will form the nucleus of an operational force, serving both as training cadre and as a source for initial flight crews.

- To determine the practical limits of pilot capabilities so that the design of advanced vehicles (especially the first generations) can be kept as realistic and efficient as possible. The large population of students passing through the school should provide conclusive evidence on the practical limits of performance and precision requirements for the operational space-vehicle pilot. These practical limits are of great importance in long-range planning and vehicle design. For instance, it makes considerable difference in the design of recoverable boosters and aerospace-plane-type vehicles if large amounts of automatic equipment must be provided to assist the pilot during the rapid flight into orbit.

Another example of the school's research function is establishing the lower limits of acceptable landing performance for glider-type, reentry vehicles. A few years ago there was great uncertainty regarding this limit.

The X-15 was the only current aircraft designed to land in the same manner as these planned reentry vehicles, with no power and very low lift. Normally, the X-15 lands with a lift/drag ratio of about 4.0, a wing loading of about seventy pounds per square foot, and a touchdown speed around 200 mph. At one time it was predicted generally that the X-15's rate of descent and landing was about the most rapid and unforgiving that a man could handle. A number of experts called X-15 landings "controlled crashes" and predicted the program would get into trouble.

These opinions are among the "myths" dispelled both by the X-15 program and activities at the new research pilot school. The F-104 landing described at the beginning of this article was considerably hotter than any X-15 landing. The aircraft had been "dirtied-up" until its lift/drag ratio was only 2.8, and it had a high wing loading of eighty pounds per square foot. Talk of landing such a vehicle was regarded as completely unrealistic as little as three years ago. Today, it is "routine."

Naturally, it is going to take considerable flight evidence before an operational space vehicle is designed to land "hotter" than the X-15. But in the long run this is the kind of information that only the school can provide. And this is the kind of information on which superior space vehicles are built.

An important case in point involves the firm Air Force objective to eliminate Mercury-style recovery operations and develop reentry vehicles which can return to a designated airfield and land on a runway. Such landings require lifting power, a relatively high lift/drag ratio. However, a high lift/drag exacts heavy penalties for it involves relatively large lifting surfaces, low payload, high structural weight, and low internal volume for any given vehicle gross weight. Any proof that the minimum allowable lift/drag ratio for landing can be lowered from 4.0 to 3.0 is of great importance for it widens the planners' choices and substantially raises the payload efficiency possible with a glide-type, self-recoverable, reentry vehicle.

Examples of the research contributions possible for the new school are almost endless. It seems inevitable that the school will write the manual for the piloting techniques of future operational aerospace vehicles which unquestionably will have high acceleration rates, a very high speed, low reaction times, marginal stability, and poor lifting characteristics. The school also will play a key role in the development of flight displays, control arrangements, and systems to support the pilot during a variety of stresses.

The Aerospace Research Pilot School began operations officially on October 12, 1961, with the first class of five students. All five, except for an Air Force civilian instructor, were top-rated pilots, having graduated one or two in their class from the test pilot school. All of them had advanced degrees, and there was one Ph.D. in the group. This first class had the responsibility of checking the curriculum and setting up the school as well as attending it. Some of them served as instructors for the follow-on classes. To date twenty-five men with similar qualifications have graduated in three classes.

The school setup has changed somewhat for the

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fourth class, which began July 1. There weren't enough qualified applicants to restrict the student body to graduates of the test-pilot course, so a one-year "combined" course has been started. It still carries the name of the Aerospace Research Pilot Course, but the first six months (Phase I) is basically the old test-pilot curriculum.

Present requirements for attending the school are expected to hold indefinitely. An applicant must have: a degree in either engineering, the physical sciences, or mathematics; at least 1,000 hours in late-model aircraft; be under thirty-three years of age, preferably younger; and carry high recommendations from his commanding officer.

Medical requirements are approximately the same as for the Astronaut program. Each applicant must pass an exhaustive week-long physical and psychological examination. These requirements have been influenced strongly by experience in the X-15 program, which showed that there are wide ranges of "normal" behavior for flight crews under stress. Pulse rates of 170 and respiration rates of thirty breaths per minute no longer are considered abnormal.

In Phase I the student receives a thorough grounding in the fundamentals of performance-verification flight testing and stability and control-type flight testing. He learns to plan tests, fly the tests, analyze test data, and prepare a report. He receives a concentrated course in all of the engineering subjects involved in such tests. He becomes intimately acquainted with the way in which aircraft design affects the stability and control derivatives and how these in turn determine flying qualities.

The aircraft used in this portion of the course are the Lockheed T-33, the Northrop T-38, and the Martin B-57. Instruction is split about fifty-fifty between the classroom and practical experience. Almost an hour a day is devoted to physical training.

In Phase II the student moves on to the study of hypersonic aerospace vehicles, including those that reach orbital speed. Very strong emphasis again is placed on academic work. The aim is to give each man a comprehensive theoretical background and a working knowledge of all phases of vehicle design, instrumentation, operation, and testing, as well as the use of computers for data reduction and flight planning.

Piloting very-high-speed aerospace vehicles falls into three distinct phases: (1) the boost into orbit or into a ballistic trajectory; (2) operations in orbit or at very high altitudes where aerodynamic control surfaces are not effective; and (3) the reentry and landing. Each phase has its own particular problems and requires the mastery of separate techniques. No one training aircraft or ground-based simulator today is able to cover the complete range of piloting problems so the school uses several aircraft and flight simulators in its training program.

The Boost Phase

The main objective of the boost phase is to deliver vehicles to their operational station. Such deliveries are precision flying jobs, whether a vehicle is placed in orbit, sent around the world once in hypersonic glide trajectory, or propelled nearly straight upward in a ballistic path to great altitudes.

To make a precision delivery the pilot must control his vehicle within very close limits while it is under power. At very high speeds and altitudes he loses control of his flight path after the powerplants stop.

Flying training for the boost phase now is conducted in the Lockheed F-104A which has a maximum zoom altitude of about 90,000 feet. As this magazine reaches its readers, a much more desirable trainer, a modified '104, the NF-104A, is scheduled for delivery. In addition to the standard General Electric J79 turbojet, the NF-104A is equipped with a Rocketdyne AR-2 liquid-fuel rocket engine that can be throttled from 100 percent to fifty percent thrust—from 6,000 to 3,000 pounds. The rocket boosts the new trainer's maximum zoom altitude to more than 120,000 feet.

Boost flying requires what technically is termed "energy management." The pilot must follow a precise climb schedule, which calls for him to adjust speed and climb angle to a particular value at each altitude as he moves upward. For some extremely maneuverable vehicles he might be required to adjust power settings as well. The energy-management climbs taught at the school are characteristic of those that might be flown in a suborbital spacecraft or in an air-launched orbital vehicle, such as the second stage of a two-stage aerospace plane.

In a typical NF-104A energy-management training flight the pilot will cruise out at subsonic speed and at 35,000-foot altitude to a point about 115 miles east of Edwards. Turning back toward the base he will accelerate to Mach 2. When fifty-seven miles out he will ignite the rocket, climb to 40,000 feet, accelerate to about Mach 2.2, and execute a three-G pullup about thirty-five miles from the Edwards runway. After the pullup he will hold a climb angle of sixty degrees.

Then he will concentrate on the major objective. To get a high mark for this flight his maximum altitude must be 120,000 feet, not more and not less, and he must fly through it at a Mach number of .74. This probably will require adjustments to his climb angle and rocket engine power. To complicate the adjustments, the turbojet will flame out at about 80,000 feet and must be shut down. The rocket engine will stop shortly before the maximum altitude is reached and the aircraft will then begin its ballistic flight. Recorders in the airplane and radar tracking from the ground will provide a permanent record for judging the pilot's performance in all phases of the flight.

After going over the top, the aircraft will begin a sixty-degree dive, and the recovery is a three-G pullup at about 40,000 feet. It takes place over Edwards AFB so that a glide landing is possible if the turbojet fails to relight.

Simulators also are an important part of boost training. The large Navy centrifuge at Johnsville, Pa., is the most realistic one available to the school. A cockpit equipped with normal aircraft controls and instru-

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mentation is mounted on the centrifuge arm. As the pilot moves the controls in this cockpit he actuates a computer which adjusts the centrifuge motion so that he experiences exactly the same accelerations that he would in flight. This elaborate facility makes it possible for the students to "fly" many energy-management trajectories and to achieve a high proficiency before making actual airplane flights.

Such facilities also make it possible to simulate the boost phase for all types of vehicles, including large rockets such as the Titan III. Simulator experiments have shown that a pilot could fly a space vehicle, propelled by a Titan III, into orbit with remarkable precision. The only drawback is that a human pilot requires the use of slightly more fuel than an automatic guidance system.

High Altitude and Orbital Operations

A host of activities fall into this category, including rendezvous and docking, space navigation, orbit changes, and attitude control above the atmosphere. Most of them are studied at the school through the use of simulators. An orbital-rendezvous simulator is available in which the terminal and docking phases may be accomplished on instruments or visually by the pilot watching his target. Today, the school opinion seems to be that a computer guidance system will be needed to bring two vehicles to within two or three miles of each other and then a human pilot could complete the rendezvous visually.

The school has a reaction-control simulator which is mounted on an air bearing. In this simulator a student may practice controlling space vehicles for long periods. Flight training of this type will be possible when the NF-104A becomes available. It has an X-15 reaction control system, and the pilot must use it for a couple of minutes during each energy-management climb. For a brief period on these flights, the pilot operates in zero gravity.

The space-vehicle piloting interest of NASA and the Air Force overlap more in this area than in any other. The basics of all types of orbital operations for men and machines vary little, and the Air Force will be able to learn a great deal from Projects Gemini and Apollo. The question is whether the rate of learning will be adequate.

Reentry and Landing

The first critical part of reentry occurs when a vehicle bores deep enough into the atmosphere that aerodynamic forces begin to move it about and subject it to high G loads. The pilot must hold the vehicle's attitude precisely with the reaction-control system as this point approaches. If the vehicle is not in the correct attitude, usually with the nose moderately high and the wings level, it can be overstressed and overheated.

Students at the school will get their training on this point in the NF-104A and in several simulators, including the centrifuge at Johnsville.

The next phase of the reentry is the deceleration and glide approach to a landing. The NF-104A is of some value here, but variable-stability aircraft are the most important. These are Convair F-106 and McDonnell F-101 fighters equipped with special control systems that can be adjusted to give them the flight characteristics of any of a wide variety of space vehicles, with all types of poor stability and lifting characteristics.

Final approach and landing training is given in the F-104, as described, and in the F-106. The trainer F-106 is relatively easy to land because its wing loading is low, about forty-five pounds per square foot, and its lift/drag ratio, when trailing a drag chute, is around 4.0. Using these two trainers it is possible for the students to see exactly how variation in wing loading and lift/drag ratio affect space-vehicle landings.

New Equipment

Three important new items of equipment have been requested by the school to improve the quality of its instruction. The first has been authorized, is under development by Link, and is due to be in operation by next July. It is a very advanced moving-base static simulator. The simulator cockpit is suspended by a mechanism that allows it to move in all three directions and rotate about all three axes. A large hemispherical screen out in front of the cockpit provides the pilot with a visual display of rendezvous and all other types of space operations from boost through reentry. This powerful training tool will be able to simulate everything about spaceflight except the actual acceleration forces.

The school has requested money in the FY 1965 budget for the construction of a large centrifuge which would be more versatile and advanced than the one at Johnsville. The request has not yet been approved.

The school also is pushing for an Advanced Aerospace Trainer, with much better performance than the NF-104A. This trainer would be in the X-15 class, with a maximum altitude of around 300,000 feet and a speed of possibly Mach 7 for a very brief period. Lockheed, North American, and Northrop have made preliminary proposals. However, a decision on this request has not been made by higher command.

The Aerospace Research Pilot School is established as the USAF's most advanced flight training organization and the source for military spacecrews. Despite its short history, the school's unusual curriculum and its graduates already have earned a reputation for excellence outside the service. Training activity has been increased with thirty-six new students scheduled to begin the course each year.

There is one source of discontent and gloom, however. Men who train to fly in space inevitably want to fly in space. No group in the Air Force wants "stick time" at orbital speeds more than these men from Edwards. And until this stick time is available, the Aerospace Research Pilot School can never completely come into its own either as a research organization or as a supplier of spacecrews.—END