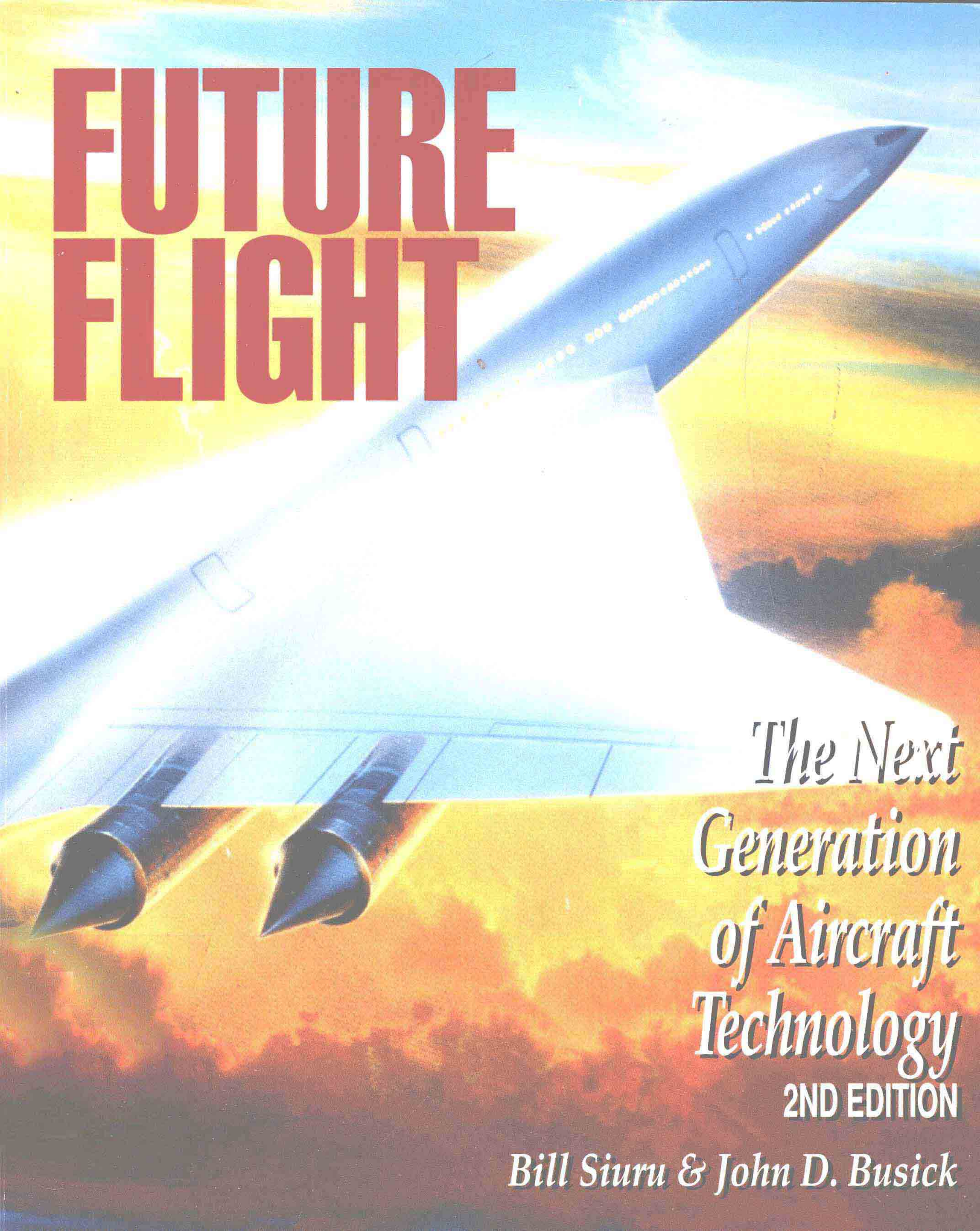

FUTURE FLIGHT

The Next Generation of Aircraft Technology

2ND EDITION

Bill Siuru & John D. Busick

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Preface

SINCE THE BEGINNING of history man has yearned to reach for the heavens. Long before flight was thought possible, the wings of eagles, appearing on the art of ancient Egypt, the staffs of Roman legions, and the Great Seal of the United States, represented man's thirst for flight. American Indians revered the eagle because it represented the lofty ideal of their spirits leaving the bonds of earth and soaring to the heavens.

When flight became possible, the eagle symbology was still there. Charles Lindbergh was known as the "Lone Eagle." And who will ever forget the transmission from the moon, "the Eagle has landed?" Today, one of the U.S. Air Force's finest air superiority fighters is the F-15 Eagle. The aircraft of the future will combine the spirit of the eagle with the ingenuity of man.

The past three decades have seen military and commercial aircraft routinely fly at more than twice the speed of sound. Travel by air has progressed from a means of transportation for the privileged, and for special occasions, to the most popular means of traveling distances greater than a few hundred miles. And travel into space, while not yet routine, is a familiar event.

As an engineer in advancing technology and as a military pilot using these advances in technology, we have not only watched the rapid progress of aviation, we have had an active part in it. This intimate experience with what has happened in the past, along with the knowledge of what is going on now in the aerospace world, allows us to project what will be happening in the future.

Introduction

THE DEVELOPMENT of most aviation concepts usually follows a rather orderly process from the gleam in the eyes of the engineer and scientist to the final aircraft in the hands of the military, commercial, or private pilot. Whether the aircraft is a fast fighter or a luxurious executive transport, the process starts with a need. The need can be the quest to conquer a new frontier in flight or simply do an existing transportation job better and more economically.

Technology is the most important ingredient in satisfying these needs. Some technology is already waiting in the laboratory, waiting for a "home" in a new aircraft. In other cases, technological barriers must be surmounted by additional work of scientists and engineers. The technology comes together in a complete aircraft that meets the original need. This whole process can take years—even decades—in the case of sophisticated military aircraft and commercial airliners. Thus, by looking at the technology now being developed and adding an insight into the needs of the future, a picture of the aircraft of the twenty-first century emerges.

In this book we will take this sequence—needs, technology, concepts—to predict the aircraft of the future. Because history is an important part in understanding the future, the book will start with a look at lessons that can be learned from the past.

While the theory and mathematics of flight can quickly become very complicated, the basic principles are usually quite simple to understand. We have attempted to explain the technology and concepts in terms that anyone with only an interest in aviation can comprehend.

Much has happened in aviation technology since the first edition of *Future Flight* was published in 1987. Some of the technology has matured. It is now already included or being incorporated in the next generation of aircraft. Other technology has been dropped because it did not provide the expected results, was not feasible or practical, or was just too expensive. This second edition has been updated to cover advances in aerodynamics, propulsion systems, avionics, materials, artificial intelligence, and manufacturing techniques. For instance, major advances have occurred in technologies like neural networks, supercomputers, vectored thrust, composites, fiber optics, and much more.

The future was greatly impacted by the end of the Cold War, the collapse of the Soviet Empire, and the resulting downsizing of the U.S. military forces. This second edition discusses how changes in the world have changed the future of military, commercial, and general aviation.

These world-shaking changes will have the greatest effect on military aviation technology. Already military systems are taking a different course with new systems for new missions and new roles for old systems. This book presents up-to-date information on the B-2 Stealth Bomber, F-22 fighter, RAH-66 Comanche helicopter, and other military aircraft.

Civilian aviation is also progressing rapidly with both new concepts and revivals of old ones now made possible with major advances in electronics, propulsion, and materials. For instance, new material is included on the latest Boeing, McDonnell Douglas, and Airbus airliners.

Contents

1

Lessons from the past

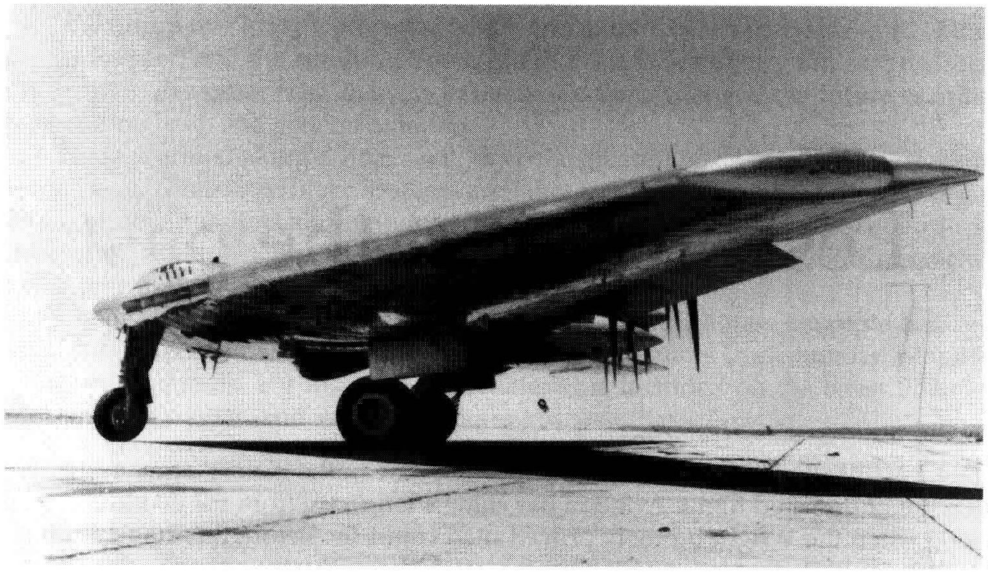
DECEMBER 17, 2003 will mark an important date in the history of man: the centennial of powered flight. Aviation has come a long way from the eventful day in 1903 when the Wright brothers proved man could fly. Before this 100th anniversary is celebrated, aviation will have progressed even further. This book will provide a look at these advances as well as give a glimpse of the aircraft that could be flying the skies in 2003. You'll also discover some of the aviation technology engineers and scientists are developing today for use even further into the future.

PREDICTING THE FUTURE

Most advances in air travel have evolved with small steps forward rather than giant leaps. Indeed, the truly revolutionary inventions like the jet engine, atomic energy, the microchip, the laser, and the transistor are rare. Therefore, in many instances, predictions for the future start with projecting what evolutionary improvements will develop from what is flying in the skies today.

Few concepts are totally new. Even the Wright brothers' early planes had a canard, a pusher propeller, and tricycle landing gear—features considered modern today. You cannot thumb through many early post-World War II issues of *Popular Mechanics* or *Popular Science* without coming across ideas for plastic airplanes. It took the development of sophisticated composites, however, to make the plastic airplane possible. Even the supersonic combustion ramjet (scramjet), the possible means of propelling the National Aerospace Plane (X-30), was fairly well developed during the 1960s before it fell into disfavor, mainly because of production difficulties and cost. The B-2 Stealth bomber uses a flying-wing concept that is reminiscent of the Northrop XB-35 and YB-49 flying wings of the 1940s (Fig. 1-1). In the future, you will see a revival of concepts from the past now made possible by advances in aerodynamics, materials, propulsion, electronics, and manufacturing technology.

Many of the advances in aerospace technology started with one man's invention. Take, for instance, Frank Whittle's and Pabst von Ohain's jet engines, Michel Wibault's vectored-thrust engine, Robert Jones' scissor wing, Julian Wolkovitch's joined wing, or T. H. Maiman's laser. Today, scientists at universities and research



Northrop Corporation.

Fig. 1-1. The Northrop flying wing of the 1940s was, perhaps, ahead of its time. However, it would appear again a few decades later as the central design of stealth-type aircraft like the B-2 bomber. This is a Northrop YB-49.

laboratories are working on theories that will be the basis of aerospace systems of the future. Looking at their discoveries provides another insight into the future.

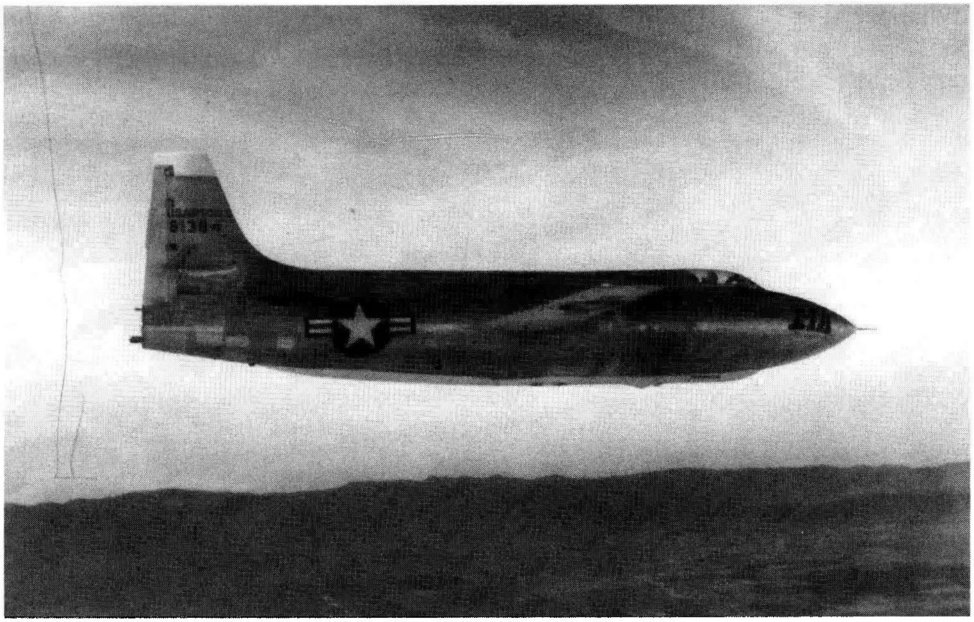
In the future, as in the past, the major burden of developing completely new aircraft will be borne by governments. In the United States, this means the military services and the National Aeronautics and Space Administration (NASA) will be the leaders in development. Other major developments will be undertaken by consortiums of aerospace companies. Their efforts will take on even greater importance as development costs are measured in billions of dollars.

No private aerospace company, regardless of size, has the resources to take on the ambitious development projects that can mean bankruptcy if unsuccessful. Some projects are so expensive even governments won't be able to go it alone, resulting in partnerships between nations. This is not to say that all developments will be at the national or international level. There is still a place for individual breakthroughs with promising financial rewards for companies, especially in the electronics, materials, and computer industries.

In the past, research aircraft like the X planes were used to try out new ideas before they were incorporated into production aircraft, usually military aircraft (Table 1-1). The military's and NASA's X planes of the 1940s and 1950s provided much information about flying at high altitudes and at transonic and supersonic speeds (Fig. 1-2). Other experimental aircraft, like the M2-F1/F2/F3, HL-10, and X-24A/B, were specifically built to investigate lifting body concepts (i.e., aircraft that obtain lift from their bodies rather than from conventional wings), and thus provided valuable data for the Space Shuttle. The world of Vertical/Short Takeoff and Landing (V/STOL) aircraft is filled with many experimental aircraft, like

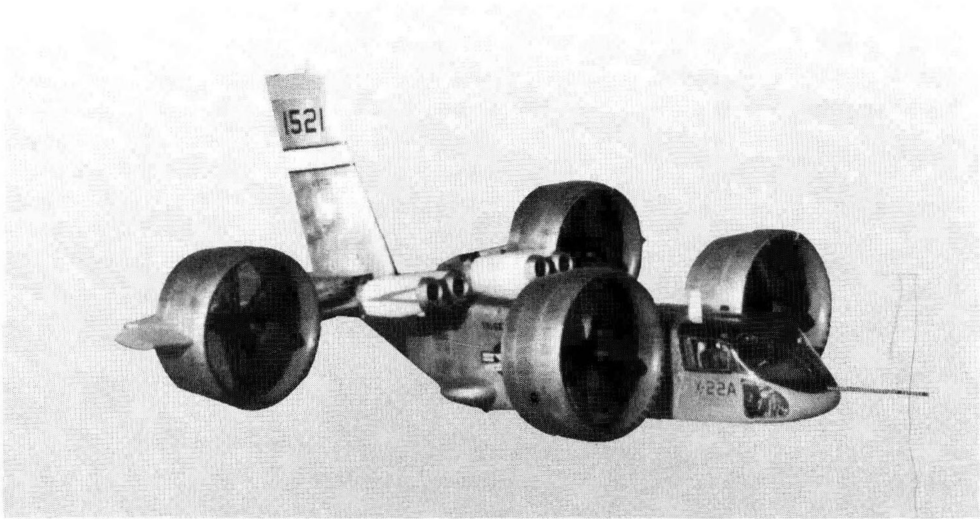
Table 1-1. Significant experimental research aircraft: The X planes.

Aircraft	Manufacturer	Years flown	Major goal	Max. speed (mph)	Max. altitude (ft.)
D-558 I	Douglas	1947 - 1953	Investigate flight characteristics at transonic speeds	650.8	40,000
D-558 II	Douglas	1948 - 1956	Investigate swept-wing aircraft at high supersonic speeds	1291.0	83,235
X-3	Douglas	1952 - 1955	Investigate flight at sustained supersonic speeds	> Mach 1	41,318
X-1A/B/ D/E	Bell	1953 - 1958	Investigate flight at higher speeds and altitudes	1612.0	90,440
X-4	Northrop	1948 - 1953	Investigate semi-tailless aircraft at high subsonic speeds	620.0	40,000
X-5	Bell	1950 - 1954	Investigate aircraft capable of sweeping wings in flight	716.0	49,919
XF-92A	Convair	1951 - 1953	Investigate delta-wing aircraft at transonic speeds	Mach 1	42,464
X-15	North American	1959 - 1968	Investigate flight at very high speeds and altitudes	4520.0	354,200
X-29A	Grumman	1985 -	Investigate flight of forward-sweep aircraft	—	—
XB-70	North American	1965 - 1969	Investigate flight at high speeds	Mach 3	70,000



Bell Aerospace Textron.

Fig. 1-2. The most famous of the X planes has to be the X-1A in which Chuck Yeager broke the sound barrier.

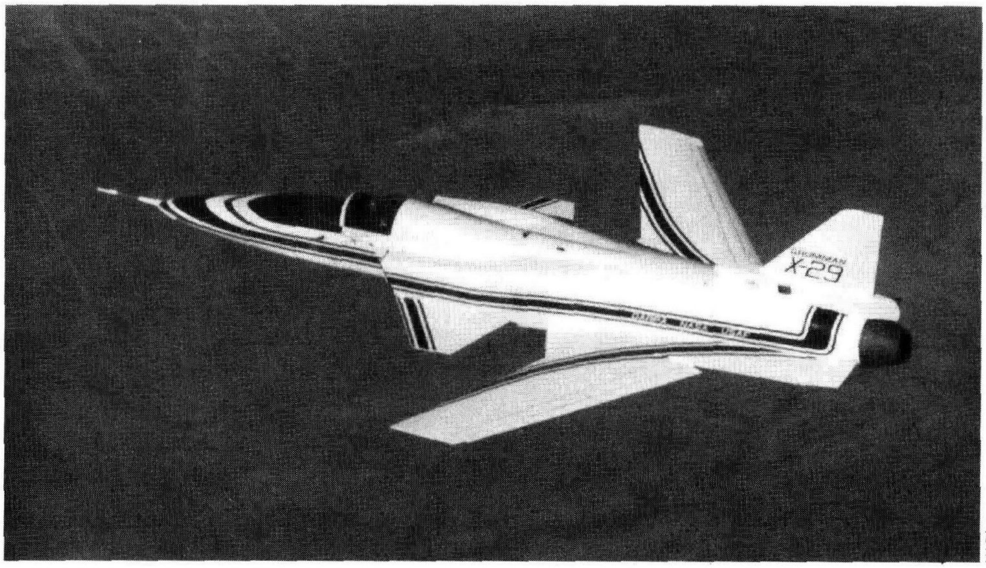


Bell Aerospace Textron

Fig. 1-3. One of the many less-than-successful attempts at a V/STOL aircraft, the Bell X-22A.

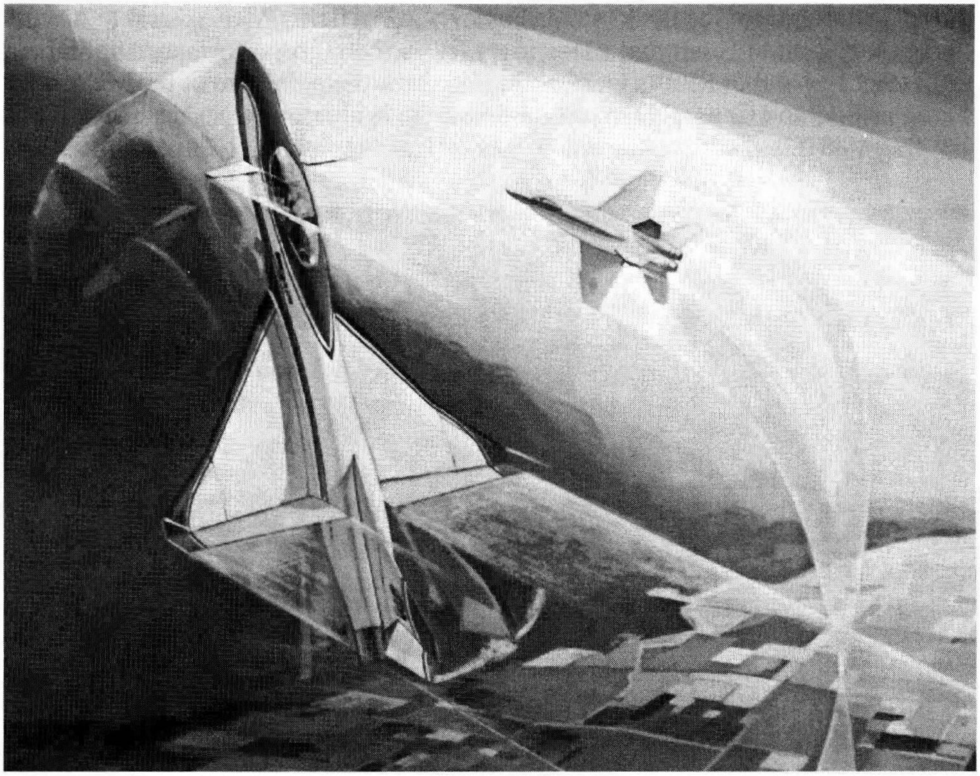
the XPY-1, X-13, XV-4A/B, and XV-3, that were less than unqualified successes (Fig. 1-3).

Today, building experimental aircraft strictly for research purposes has become cost prohibitive. The first new X plane to come along in more than a decade was the Grumman X-29A designed to investigate forward-sweep wing aerodynamics (Fig. 1-4). The Rockwell International/Messerschmitt-Bolkow-Blohm X-31A was aimed at flight testing concepts for future highly-maneuverable military fighters (Fig. 1-5).



NASA

Fig. 1-4. The Grumman X-29A is one of the latest aircrafts in the X plane "family."



Rockwell International/MBB.

Fig. 1-5. The Rockwell International/Messerschmitt-Bolkow-Blohm X-31A is another modern X plane designed to demonstrate Enhanced Fighter Maneuverability technology.

It is no wonder then that some of today's experimental aircraft are actually highly modified versions of aircraft already in production. The U.S. Air Force's very successful Advanced Fighter Technology Integration (AFTI) program used a highly modified General Dynamics F-16 Fighting Falcon. NASA has used a variety of modified commercial and military transports for experimental platforms. For example, a Boeing 737 became a Terminal-Configured Vehicle (TCV) for studying ways to make landings safer, especially in severe weather. In the Aircraft Energy Efficiency (ACEE) program, modified air transports like the KC-135 and DC-10 have flight tested new aerodynamic, propulsion, and flight control ideas aimed at saving fuel. The USAF is now flying the Variable Stability In-Flight Simulator Test Aircraft (VISTA). This modified F-16D can be programmed to mimic the flying qualities of new aircraft not yet built.

Scale models have been used to flight test new concepts. Models range from small radio-controlled models much like the ones built by hobbyists to models that are manned. The Beech Starship I general aviation aircraft made its first flight as an 85-percent scale model and the Fairchild T-46A, at one time a concept for a new Air Force primary trainer, first flew as a 62-percent scale model.

Remotely-piloted research vehicles (RPRVs) offer another way to flight test new concepts without the huge expense of man-rating research aircraft. One very successful example was the joint Air Force/NASA Highly Maneuverable Aircraft Technology (HiMat) craft that tested ideas for use on high-performance fighter aircraft (Fig. 1-6). Other RPRVs were used during the development of the McDonnell Douglas F-15 and General Dynamics F-16 and to evaluate new vertical takeoff and landing V/STOL configurations.

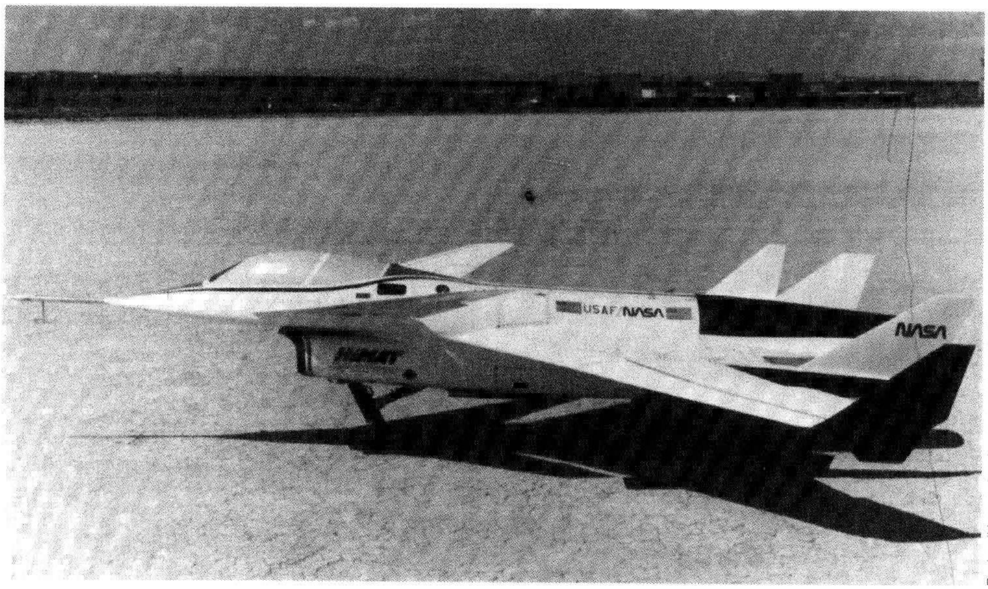


Fig. 1-6. Remotely piloted research vehicles like this HiMat unmanned aircraft allow flight testing without the need for expensive man-rated aircraft.

Computers are making great contributions in the development of new aircraft. Complete aircraft can be mathematically modeled on a computer, providing data that before could only be obtained from costly and time-consuming flight and wind tunnel testing. Furthermore, changes to designs can be made simply by hitting a few keystrokes or moving a light pen.

As in the past, much of the technology will filter down from the high-speed fighters to military and commercial transports. Some of this technology can even be incorporated into general aviation craft, just as the jet engine (first used in fighters) became practical on transports like the de Havilland Comet and Boeing 707 and eventually on business jets like the Gates Learjet and Cessna Citation. Today, you can see a diffusion of technology in such things as composite materials that were first used on military fighter aircraft and are now being used on the latest business aircraft. Or you can see the F-16's sidestick controller now found in the cockpits of new commercial airliners, such as the European Airbus.

TRENDS FOR THE FUTURE

It is safe to say that there are no new physical frontiers in air travel. With the Space Shuttle, man has flown almost the entire flight envelope in terms of speed and al-