

AERONAUTICS - A CENTURY OF PROGRESS

NASA Langley Research Center
Langley Station, Hampton, Va.

Presented at 50th Anniversary Celebration and Inspection

Hampton, Virginia
October 2-6, 1967

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INTRODUCTION

I have often wondered - when the first shovelful of earth was turned here at Langley in 1917 - whether anyone at that time had the vision to foretell the future of aviation 50 years hence as we view it here today. Those 50 years have been years of dynamic progress, and many of you here in this distinguished audience have contributed to this history of flight.

As a chronicle of these times we have prepared a Panorama of Flight depicting some of the historic aircraft of their time period. The aircraft are representative of the military fighters and commercial transports of their times. They are all built to the same scale, positioned at their approximate time period, and arranged vertically as an indication of their flight speed or altitude.

The tiny, fragile aircraft of the early pioneers are almost lost on this display. The historic Wright Brothers aircraft, first flown in 1903, was of wood, fabric, and wire construction and weighed but 1260 pounds fully loaded. Now, all-metal transport aircraft (C-5A and 747) approaching 750,000 pounds are in the prototype construction stage.

The aeronautical leadership resulting from the pioneering work by the Wright Brothers, however, was soon lost by the U.S. Bleriot flew the English channel in 1909 in what was the forerunner of modern design - monoplane, tractor engine, aft tail - an indication of the growing progress in Europe. When the war broke out in 1914, the United States in terms of air power was running a poor fifth.

It was in this environment that the NACA was organized in 1915, and the Langley Memorial Aeronautical Laboratory founded 2 years later. The NACA charter was clear and concise - TO SUPERVISE AND DIRECT THE SCIENTIFIC STUDY OF THE PROBLEMS OF FLIGHT WITH A VIEW TO THEIR PRACTICAL SOLUTION. The exercise of this simple charter over the next five decades was to make aeronautical history. Let me review briefly for you this history decade by decade starting with the 1917 to 1927 time period.

ROLE OF LANGLEY RESEARCH CENTER IN AERONAUTICAL HISTORY

Year 1917 to 1927 (World War I - Post Era)

The standard military fighter of World War I and the early 20's was a strut- and wire-braced, fabric-covered biplane usually powered by a heavy and unreliable engine. (The DH-4 on display here in the hangar is characteristic of that time period.) These early aircraft were characterized by high drag and low speed and with handling characteristics which varied from barely acceptable

to downright dangerous. Cantilever monoplanes were generally regarded with suspicion because of little understood problems of structural design and flutter.

It was at the start of this decade of flight (1917) that what is now known as the Langley Research Center was born. It promptly started the design and construction of Wind Tunnel No. 1 - the first of a series of wind tunnels which would eventually span the entire spectrum of flight.

The contrast between this first facility with its 5-foot test section and the 20-Foot Propeller Research Tunnel - operational within this first decade - was indicative of the rapid progress in the important area of research facility design and construction.

New wind tunnels were being added to the fledgling laboratory. The Variable Density Wind Tunnel (VDI) was placed in operation in 1922 and began its classic work on systematic airfoil development - culminating in the so-called "NACA series" of airfoils. The lower part of the panel on your left depicts some of this early airfoil development work.

The initial Langley effort recognized the key importance of propulsion in its "scientific study of the problems of flight," and simultaneously with the wind-tunnel development, engine research facilities were established.

Langley entered into active flight research in 1919 utilizing military training aircraft. Early programs were aimed at correlation of wind-tunnel and flight results, with emphasis on such elements as drag, stability and control, and surface pressure distributions. As Langley developed effective flight-test instrumentation, quantitative work on handling qualities and maneuver loadings was undertaken.

In retrospect, the first decade of Langley effort would be considered as a learning period. What are the problems - how do you go about solving them? The initial steps were taken in providing a staff and the necessary research facilities.

Year 1927 to 1937 (Pre-World War II)

The second decade began on an upsurge of a new wave of popular interest in aviation. Lindbergh's historic crossing of the Atlantic in 1927 had touched the imagination of the world. This decade would go down in history as the period wherein a solid technical foundation for flight was established. The question no longer was "Would it fly?" - but How far, How fast, How efficiently?

The fabled Ford trimotor transport appeared on the scene in 1927, and 40 years later we are to find that it is still in passenger service. Blind flying experiments were being initiated in the U.S., while across the ocean an unknown engineer named Whittle was writing a paper on the potential of the jet engine. Later in the decade (1935) we were to see the first flight of the Douglas DC-3 and the Boeing B-17, which established new levels of flight efficiency.

Langley contributed materially to this parade of progress. Research on thermal ice prevention was initiated at Langley and later expanded at the other Centers. The new 20-Foot Propeller Research Tunnel began its pioneering research on improvement of aircraft performance by initiating the first systematic series of full-scale propeller tests. The subsequent tunnel work on drag reduction led to the concept of the retractable landing gear and later to the development of the NACA "C" cowl. The latter accomplishment was to become the first technical breakthrough of the young Laboratory and lead to the award of its first Collier Trophy (1929).

The design revolution had begun. The combination of, theory, wind-tunnel experiment, and flight test - patterned after the Wright Brothers successful approach - now began to provide a firm technical base for future advances. New facilities such as the Spin Tunnel, 30- x 60-Foot Full-Scale Tunnel and a large Towing Tank were quickly placed in operation (1931). Fundamental theoretical work was being reported on airfoil theory, aircraft stability, and the principles of flutter. High-speed aerodynamic research at Langley was initiated in the 24-Inch and 8-Foot High-Speed Tunnels.

Systematic flight research was being continued to establish the requirements and boundaries for acceptable flying qualities. Flight programs and instrumentation were being developed to establish the gust environment and design criteria for the growing commercial air transport fleet.

In the engine research area the Laboratory was providing a firm technical base for advanced engine design by its fundamental research in combustion chamber design, detonation, and analysis of cooling systems. Progress in super-charger design was instrumental in setting new world altitude records.

In the wind tunnels of Langley basic NACA airfoil research was being systematically extended - airfoils tested now numbered in the hundreds. The work on flapped airfoils opened the way for the development of high-performance aircraft with good landing and take-off characteristics.

The advanced aircraft of 1936 - exemplified by the Douglas DC-3 transport, the Boeing B-17 bomber, and the P-36 fighter - were all-metal, cantilever monoplanes employing flaps, retractable landing gear, air-cooled radial engines with NACA C-type cowls, and controllable-pitch propellers. This basic form of aircraft was to remain largely unchanged until the introduction of the jet engine.

Year 1937 to 1947 (World War II)

World War II dominated the third decade of Langley's work. As a matter of national policy the main resources of the NACA were employed in refining specific military aircraft with fundamental research necessarily restricted; however, new problems associated with "compressibility effects" at high speed were to plague the designer.

Within the war period practically every fighter aircraft was subjected to drag cleanup tests in the full-scale tunnel; while companion stability and control tests were being performed in the low-speed and high-speed wind tunnels and in flight. The critical design problems of engine cowling and cooling were attacked by a special Langley team, and their efforts were effective in wedding the often diverse requirements of the airframe and engine designers. At one stage (1944) the military support level showed 78 different aircraft under test by the NACA - most of them at Langley.

The Ames Research Center was organized in 1940 to complement Langley with facilities of increased size and speed. In later years this new Center would make significant contributions in aerodynamics with particular emphasis in the areas of V/STOL aircraft, supersonic/hypersonic flows, and aircraft simulation technology.

In 1941 a whole new laboratory devoted to propulsion, known as the Lewis Research Center, was established at Cleveland. This Center would eventually grow to a size larger than its parent laboratory, and its propulsion research would advance the basic knowledge of the reciprocating engine, the turbojet, ramjet, rocket, and even exotic space propulsion systems.

As aircraft performance increased to near sonic speeds, the existing wind-tunnel facilities of the early 40's were found inadequate. An intensive program of ground-based facility construction was initiated in parallel with an expanded program of flight research. The latter effort, in conjunction with the military services, led to the famous "X" series of manned research aircraft. Later in the decade (1946) the Flight Research Center, was established at Edwards, California, to provide facilities for advanced flight research.

The flight programs were expanded to include pilotless rocket-propelled vehicles, and later a launching station was established at Wallops Island off the Virginia Capes. The resulting flight programs were effective in bridging the critical transonic speed range with precise aerodynamic data. The pioneering work in the area of rocket launch technology, guidance and control, and telemetering of data would find future application as the NACA extended its research into space.

Meanwhile at Langley fundamental aerodynamic research was continuing. Such advances as the development of "low-drag" airfoils found immediate application to the P-51 Mustang and other fighters. The establishment of handling-qualities criteria provided a rational means for assuring satisfactory stability and control characteristics. In the area of structures we find advances in the analysis of stiffened panels and the development of flush riveting. High-speed propeller tests utilizing new NACA 16-series sections established new levels of efficiency at high subsonic speeds. The critical transonic region was probed by research techniques of wing flow, transonic bump, bomb drop, and rocket-propelled vehicles, and the benefits of wing sweep in transonic/supersonic drag reduction were established.

In the closing days of World War II revolutionary jet-propelled aircraft were introduced that would soon push the frontiers of flight to the very limit of available research knowledge.

Year 1947 to 1957 (Post-World War II and Korean Conflict)

In 1947, at the beginning of Langley's fourth decade, the Bell X-1 became the first aircraft to achieve supersonic speeds in level flight. The many years of fundamental research had paid off. This was the initial accomplishment of the "X" series of experimental research aircraft established as a joint venture between the NACA and the military services. These programs are still in effect today, probing the mysteries of hypersonic flight with the X-15 on one hand, and the problems and potential of VTOL aircraft on the other.

In this same year the first U.S. operational swept-wing aircraft (F-86 and B-47) took to the air. Back at Langley the world's first slotted-wall wind tunnel was being developed which pointed the way toward valid wind-tunnel testing in the transonic speed range - heretofore unattainable because of a wind-tunnel "choking" phenomenon. The flexible-wing concept was also being developed, and it is now finding many applications in the areas of precision cargo and personnel drop and flight vehicle recovery.

In 1951 the flight of the Bell X-5 - culminating years of Langley research dating back to the mid 40's - demonstrated the flight potential of wing variable sweep. This pioneering concept later found application to the Convair F-111 and the Boeing SST. Concurrently, development of the "Area Rule" established a fundamental concept for drag reduction at transonic/supersonic speeds. Two years later the F-102A, with its "coke bottle" fuselage employing this concept, revolutionized high-speed airframe design.

Year 1957 to 1967 (Aeronautics in the Space Age)

The fifth decade of Langley (1957-1967) was ushered in by the incessant beeping of Sputnik I in October of 1957. Preeminence in space became a U.S. national goal, and 1 year later NASA was organized.

To an expanding aircraft spectrum already ranging from VTOL to hypersonic flight must now be added the problems associated with the launch and reentry phases of the whole complex of space vehicles.

Yet in this decade of "space age" aeronautics we saw the small piston-engined transports replaced by 200-passenger jet-powered aircraft. The helicopter grew rapidly from its embryonic stage to play an expanding and vital role in warfare and commerce. Efficient supersonic flight at $M = 3$ was demonstrated by the B-70 and the YF-12.

This technical progress was founded on a broad base of fundamental research: For example, the configuration of the B-70 was based to a large extent on the

supersonic interference work performed by the Ames Research Center. During this period Langley initiated a major research effort for improving the aerodynamic efficiency of cruise vehicles - with the supersonic transport as its focal point. The results of a broad experimental and theoretical program in combination with the potential of modern high-speed electronic computers led to the establishment of new levels of supersonic efficiency. The "Configuration Analysis" panel on your left illustrates this new capability.

In the wind tunnels of Langley the stability problems of variable-sweep aircraft were being solved. Work in this area, dating back to 1947 and the X-5, culminated in military acceptance of the variable-sweep concept (as illustrated on the variable-sweep panel on your left). The direct result was the F-111 aircraft. Later, the Boeing supersonic transport configuration was to employ this concept.

The year 1959 saw the first flight of the X-15 which was destined to reach flight speeds of 4000 mph. In 1962 Langley initiated a supersonic transport feasibility study by industry and saw its results provide a timely technical contribution to the national supersonic transport program. In 1963 a new Center, the Electronics Research Center, was added to the NASA research complex in recognition of the ever-increasing importance of electronics in aviation. Its research impact is already being felt in current aeronautical programs.

The year 1964 was a year of intense flight activity. At opposite ends of the speed spectrum ($M = 0$ and 3) the tilt-wing XC-142 transport and the B-70 made successful first flights - followed shortly by the first flight of the variable-sweep F-111. All three of these vehicles had their genesis in NACA/NASA research.

The year 1967 - in culmination of almost a decade of research - saw the go-ahead for a joint government/industry program to proceed with prototype construction of a U.S. commercial supersonic transport.

TRANSITION

These are the highlights of our first 50 years of research here at Langley. At this point I would like to depart from the broad aspects of Langley's research effort and consider a specific field - ROTARY-WING AND V/STOL AIRCRAFT RESEARCH.

ROTARY-WING AND V/STOL AIRCRAFT RESEARCH

Research on rotary-wing and V/STOL aircraft can logically be broken down into three categories, according to the type of propulsion system: rotors, propellers, and jets or fans.

Rotary-Wing Research

The earliest research was on rotary wings, starting with the autogiro in the early 30's. This work, including wind-tunnel and flight tests and

analytical studies, not only aided in the development of the autogiro but also provided basic information on rotor characteristics for the helicopter. Research on helicopters started in the early 40's. The Sikorsky R-4 was one of the helicopters used for research at that time to demonstrate the validity of rotor theory and to provide much-needed data to improve the performance and handling qualities of helicopters. The helicopter test tower was put into operation in 1946 as an additional facility to aid in refining rotor design. The need for advanced facilities in the 50's led to the acquisition of variable-stability helicopters and advanced hingeless-rotor aircraft such as the Lockheed H-51. Current research in flight and in several wind tunnels is aimed at developing the potential of advanced concepts such as the compound, tilt-rotor, stowed-rotor, and rotor/wing configurations.

Propeller V/STOL Concepts

Langley has conducted research, or evaluations, on a wide variety of propeller-powered V/STOL concepts, although the major part of the effort has been applied to the tilt-wing concept. Research on this type of aircraft was initiated in the early 50's with exploratory tests of a free-flying model. When these tests demonstrated the feasibility of the concept, wind-tunnel research was undertaken to provide aerodynamic data for use in design of aircraft of this type. The first tilt-wing research airplane, the VZ-2, was a crude-looking flying test bed but it fulfilled its purpose of verifying in flight the feasibility indicated in the earlier model tests. Extensive wind-tunnel research was also conducted at Langley to improve and refine the tilt-wing concept. All of this work has culminated in the development of the tri-service V/STOL transport, the XC-142 airplane. For future V/STOL applications, the tilt-wing looks promising for military and commercial transport use.

Jet and Lift-Fan V/STOL Aircraft

NASA has also provided extensive research for the development of higher-speed V/STOL aircraft powered with lightweight jet engines. These aircraft have taken two different forms - those using the jet directly for vertical lift and those using lift fans driven by jet engines.

The first work in this country on jet V/STOL aircraft started in 1950 and led to the development of the X-13 research airplane. This work was supported with tests of a flying model powered by a rocket motor. The first operational jet V/STOL type is the P.1127, a British design which was developed with substantial support in U.S. funds. NASA contributed to the development of this airplane with wind-tunnel tests and model flight tests carried out before the airplane was ever flown. We now have a P.1127 here at Langley which we are flying to explore problems which may arise in the take-off and landing operations of jet V/STOL aircraft.

The other jet-powered V/STOL type - those with lift fans - started receiving serious consideration as a result of the development of the promising lift-fan propulsion scheme. The NASA Ames Research Center initiated large-scale wind-tunnel tests of lift-fan configurations utilizing this concept. This work led to the XV-5A research airplane. Work is continuing in both wind

tunnels and flight to provide basic data required for future development of operational fan-powered V/STOL aircraft.

Movie on V/STOL Research

In all this V/STOL research we have found it necessary to develop new and unusual facilities and test techniques to keep up with the demands on V/STOL research. Perhaps the biggest single item is a new wind tunnel especially designed for V/STOL testing which is being built at Langley. A model of the test section of this tunnel is on display in our wind-tunnel exhibit. I have a movie to illustrate how some of the various research facilities and techniques available are utilized in the development of a V/STOL concept. In this case the tilt-wing concept is used as an example:

1. Here we show free-flight model tests to study the take-off and landing of the first tilt-wing model.

2. Next we show transition tests of a flying model of the VZ-2 research airplane on the control-line facility.

3. Here we indicate flight research with the VZ-2 research airplane. The emphasis here has been on handling qualities and piloting problems.

4. This scene shows wind-tunnel tests to improve the concept in a special V/STOL test section added to the 7- by 10-foot tunnel.

5. Here we see free-flight tests of a model of the tri-service XC-142 airplane in the 30- by 60-foot wind tunnel.

6. And the final scene shows flight tests of the actual XC-142 airplane.

50 YEARS OF STRUCTURES RESEARCH

Woven throughout the history of aeronautics is the element of structural design. Integrity of structure is an overriding factor in design, but the overall system efficiency as it affects aircraft performance and economics must also be considered.

The Structures Research display is a pictorial history of some of the structural developments in aeronautics during the past 50 years.

In keeping with the requirement that flight structure must be light in weight, the early biplanes made skillful use of wood, fabric, and high-strength wire. A pioneering change in materials occurred in the 1920's when the Ford Tri-motor appeared with a corrugated metal shell covering a metal truss framework. It was not until the 1930's, however, that stressed-skin aluminum monocoque construction as we know it today came into general use. This type of

structure required a great deal of research to develop accurate methods of stress and strength analysis and was accompanied by a major expansion in structural research effort at this Center.

A highly significant share of the stress and stability analysis procedures for modern stiffened shell construction was provided by research in the 1930's and early 1940's. These efforts provided the technology for the safe design of thin wing military and transport aircraft which operated at much higher speeds. With higher speeds, dynamic load, vibration, and aeroelastic phenomena presented major design problems. Accordingly, research in structural dynamics was expanded in this time period.

An essential factor in achieving rapid progress in ever more demanding flight regimes has been the development of new materials and associated fabrication techniques and design procedures. Today's jet transport structure does in fact resemble the monocoque structure of the DC-3, but somewhat hidden is the fact that higher strength alloys are used, major components are larger and more highly sculptured, and the stiffening members are integral with the surface skin. We see the end result in smooth surfaces for low drag at high speeds. Although these new structures are more complex and costly, the refinements are well justified by the increased performance and earning power of the aircraft.

The design of an efficient structure for a large aircraft requires a massive number of calculations based upon elaborate methods of analysis. Without the development of the modern high-speed computing machine, the current levels of confidence in prediction of stresses, deflections, and dynamic response would not be possible. We have here on display an automated computer readout and display system which produces structural design information in response to instructions supplied to it.

It is clear now that we are at the threshold of another major advance in materials usage and construction. Extensive research has been underway in identifying and understanding the structural characteristics of titanium alloys and of new materials incorporating fine filaments of glass, boron, and carbon.

The operation of aircraft for sustained periods of time at supersonic and higher speeds has brought high temperatures to complicate structural design. In addition to research on temperature resistant materials, new concepts of multiwall structure which double as thermal insulation and load-carrying members have evolved. Extensive usage of sandwich panels is anticipated as shown here in the supersonic transport structure. Many years of experimental development in the laboratory have been required to bring technology forward to the point where this lightweight construction can be utilized with confidence.

A hypersonic airplane of the future will operate at even higher temperatures and the thermal design problem will be magnified greatly by the cryogenic fuels such as liquid hydrogen which are projected for use in this flight regime. Here we illustrate a construction scheme which utilizes an outer high-temperature-resistant structure enclosing highly insulated cryogenic fuel tanks. Research on the problems of a practical light structure for major components of hypersonic flight aircraft is being vigorously pursued.

Operating at altitudes, speeds, and temperatures beyond the hypersonic transport are vehicles which combine features of aircraft and spacecraft. In some vehicles all-metal construction with suitable thermal insulation and provisions for thermal expansion can be used as illustrated here. Under more severe conditions expendable insulation in the form of ablative surfaces is required.

Development of construction technology for increasingly sophisticated aircraft has required a commensurate development of test facilities. At the start of this 50-year era, rudimentary load application and measuring apparatus in a small room produced much of the data needed. Now we have a complex of specialized laboratories that can test structures and materials for both aircraft and spacecraft under simulated flight environments. When supersonic flight became feasible, we began developing techniques for including the effects of aerodynamic heating in our experiments. Now we can duplicate, on the ground, the high-speed flight environment (supersonic and hypersonic) in large wind tunnels designed specifically for tests of structural models and components.

While we have been attacking the new and difficult problem of very high-speed flight, the fatigue life of materials has become one of the most vital problems to the safety of all aircraft. Today you will visit our Fatigue Laboratory which moved into new quarters in 1967.

PROJECTIONS

We have come a long way in 50 years from the tiny fabric and wood aircraft of 1917 to the present day - and the pace is accelerating. The "crystal ball" necessarily becomes cloudy as we try to make projections in such a rapidly changing technology. Twenty years ago in Life magazine (Jan. 6, 1957) the supersonic transport was envisioned as flying at 1000 mph carrying 10 passengers from New York to Havana (1500 miles). Propulsion was by a combination of turbojet and rockets for take-off - ramjets for cruise. It burned so much fuel that the supersonic transport was declared "commercially impractical" and "may have to wait for an airborne atomic power plant." And yet, 20 years later we are starting the era of the U.S. commercial supersonic transport at 1800 mph, 4000-mile range, and carrying 300 passengers.

The crystal ball for the year 2000 may be even more clouded, but the long technology lead times for advanced vehicles of this time period, in essence require that they be based on the research programs of today. Our aircraft panel on display already depicts the Jumbo Jet, the Supersonic Transport, and the Airbus.

Research in progress can lead to advanced subsonic jets cruising efficiently near Mach 1 utilizing new concepts such as the supercritical wing. The supersonic transport may approach the aerodynamicists' dream of a "flying wing" to attain new levels of performance. The hydrogen-fueled hypersonic transport - which would incorporate aircraft and space-vehicle technology - would have as its goal a global range of 5000 miles or more at speeds of 4000 mph.

The Aircraft Configuration stop will explore in greater depth the advanced technology leading to this next generation of aircraft.

We also note in the Hangar exhibit an illustrative future V/STOL configuration. As advances take place in the propulsion system and structural design, in noise alleviation, and in air traffic control, the V/STOL aircraft may become a prime contender for the short-haul transportation market.

This aeronautical technology will also find application to high-speed ground vehicles for the mass transportation market. As speeds progress into the 100- to 200-mph category and beyond, we find a complete spectrum of design problems common to those of the airplane.

This completes our Panorama of Flight. You can see it spans almost a century of progress - from the historic Wright Brothers flight at Kitty Hawk in 1903 to the advanced aircraft projected for the year 2000. The staff of the Langley Research Center is proud to have been a part of this aeronautical history.















