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THE BELL X-5 RESEARCH AIRPLANE

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THE BELL X-5 RESEARCH AIRPLANE

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March 1954

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CONTENTS

Preface . . . . .	ii
Prologue. . . . .	1
The Cost. . . . .	5
Details of Design . . . . .	10
The Mock-up Inspection. . . . .	14
The X-5 in Wind Tunnels . . . . .	16
X-5 Power Plants. . . . .	21
Landing Gears . . . . .	24
The Wing-Sweep Mechanism. . . . .	27
Control Surface Testing . . . . .	34
Flight Testing the X-5. . . . .	37
The X-5 as a Fighter? . . . . .	46
Bibliography. . . . .	54

Table of Contents

## PREFACE

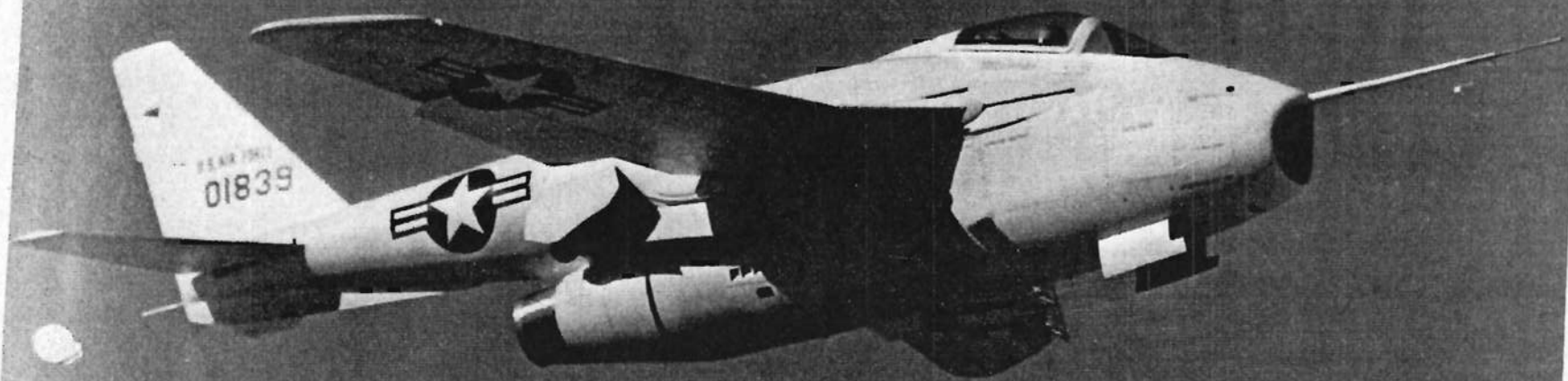
This case history of the Bell X-5 research airplane differs in several major respects from the usual monograph. It is considerably narrower in scope--covering only the development and the contractor's portion of the Phase I flight evaluation. Accordingly, the end date of the contents is approximately December 1951. The conventional mode of annotating sources, or footnoting, is not used. Rather, numbers in the left margin of the pages designate the document(s) in the appendix which served as the source.

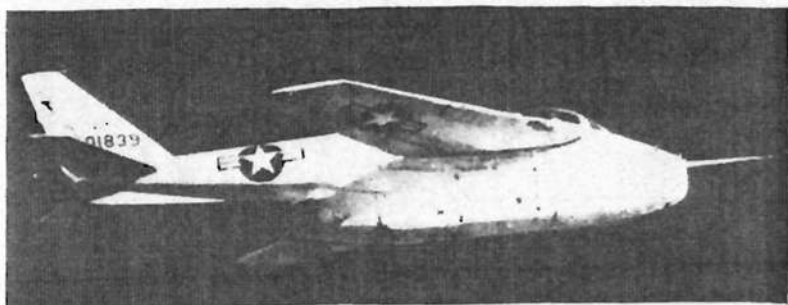
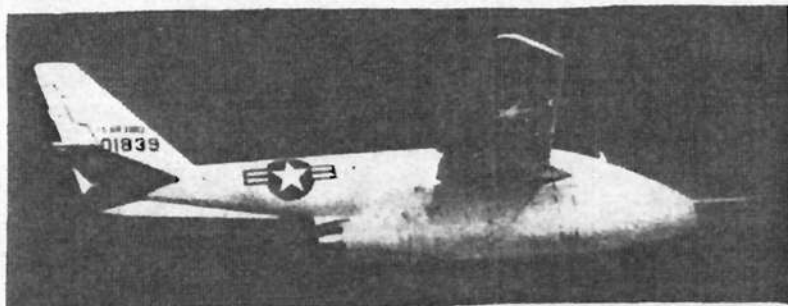
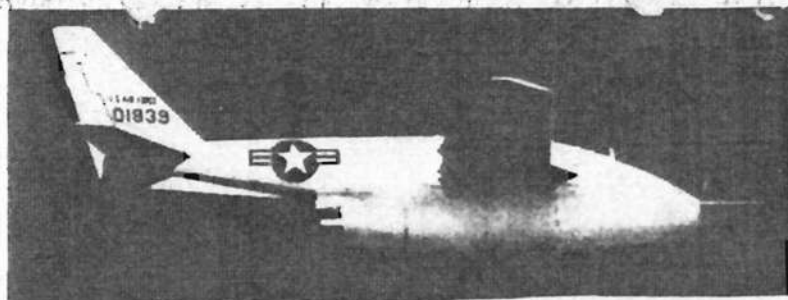
The text has been classified Confidential; however, because of the nature of several of the documents, the appendix must for the present retain the higher security classification of Secret.

It should be noted that the research and development function was the responsibility of the Engineering Division and the Air Materiel Command until 2 April 1951. Thereafter, the Engineering Division became the Air Development Force (until 8 June 1951) and the Wright Air Development Center (after 8 June 1951). The Air Research and Development Command, of course, assumed overall research and development responsibility from the Air Materiel Command on 2 April 1951.

Acknowledgement is made to personnel of the Fighter Aircraft Branch, Directorate of Air Weapon Systems, for their cooperation during the research period and for their technical review of the draft manuscript.

7301 WADC-1 8JAN53 X-5 IN FLIGHT





#### **X-5 SHOWS HOW IT DOES IT**

This dramatic photo sequence depicts Bell X-5 research plane varying its wing sweep in flight, while at same time the wings move forward along the fuselage to compensate for shifts in center of gravity and center of pressure. The change from fully

straight to fully swept takes but 30 sec. The little (about 10,000-lb.) single-seater is powered by a 4,900-lb.-thrust Allison J35-A-17A turbojet. Data obtained from these tests will be used in design of future combat planes using variable sweep.



## THE BELL X-5 RESEARCH AIRPLANE

### Prologue

One morning in June 1951 a pot-bellied little white airplane streaked along the desert runway at Edwards Air Force Base, California. Bell Aircraft Corporation's chief test pilot, Jean L. Ziegler, guided the airplane along the ground and lifted it gently into the sky. The most unusual thing about this little X-5 "Flying Guppy" was that Ziegler could move its wings in flight. For 40 years inventors had been working on moving wings for airplanes, wings which increased and decreased their length and width, wings which oscillated longitudinally, wings which flapped like a bird's wings. Many of these contraptions were built, and some of them flew. The little airplane over Edwards Air Force Base, however, was the product of the first serious attempt to determine whether moving wings were practical.

This type of research received its impetus at the Volta Scientific Convention in Rome, Italy, in 1935. General Artur Crocco, the Italian aeronautical visionary, asked a young German, Dr. Adolf Busemann, to read a paper on aircraft wings and high-speed flight. Dr. Busemann's paper, suggesting many advantages, started aeronautical engineers on serious research into swept wing designs. They found that one of the greatest advantages of swept wings was reduction of aerodynamic drag at high speed. An airplane having zero swept wings (wings at right angle to the centerline of the airplane) would theoretically produce the same drag at 540 miles an hour as an airplane having 60 degrees swept wings (60 degrees, spanwise, aft from the centerline of the airplane) flying at 1,080 miles an hour.\*

But swept wings also had inherent disadvantages. Although the critical Mach number of a wing varied with its sweep angle, ". . . in a very practical way, so does its stalling speed. Thus, the straight wing is ideal for low landing speed; the highly swept wing ideal for supersonic flight. From this simple statement of the problem comes the solution: variable sweep."\*\*

Early in 1945 a group of American aircraft industry representatives went to Europe to examine the remains of the war-wrecked

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\*Walkowicz, T.F. (Lt. Col., USAF), "Birth of Sweepback," Air Force Magazine, XXXV, No. 4, April 1952, pp. 31-32, 72.

\*\*Aero Digest, LXIII, No. 1, July 1951, p. 86.

aircraft industry. The Germans had pioneered in both swept and variable swept wings, and at the Messerschmitt Experimental Laboratories the American group discovered an airplane featuring variable swept wings. However, this Messerschmitt P-1101 airplane could change its sweep only on the ground. The airplane, along with all available data, was brought to the United States.

4 Early in 1948 the Bell Aircraft Corporation, Niagara Falls, New York, began design studies on an airplane which could vary its wing sweep in flight. In August of the same year the Govern-  
37 ment loaned the Messerschmitt P-1101 to the Bell company to aid them in their research. Shortly thereafter, the company offered to design and build 24 interceptor airplanes incorporating in-flight  
122 variable swept wings. The Air Force was interested for a time, but an unfavorable evaluation by the Engineering Division of the Air Materiel Command prevented the sale. Bell then turned its attention to building a research aircraft.

On 1 February 1949 the company submitted an informal proposal  
1, 2, to build two variable swept wing airplanes as experimental vehicles,  
3, 4, and three days later Air Force headquarters directed that these two  
5, 18 airplanes be purchased. Designated X-5 research airplanes, they  
8 were expected to demonstrate the best sweep angle for interceptor aircraft and to determine the desirability and tactical advantages of varying wing sweep in flight. "These aircraft will be used  
5 solely for investigation of the aerodynamics and characteristics

of light weight interceptor fighters," Air Force headquarters stated. Furthermore, "Future production of this model is not contemplated." From the start, the Air Force intended that both flying articles would be given to the National Advisory Committee for Aeronautics for their research work.

#### Bell's Specification

The X-5 airplane was ". . . an unconventional experimental airplane . . . designed to determine the aerodynamic results, in free flight, of variable degrees of sweepback from 20° to 60°." Basically, the airplane was a "mid-wing cantilever monoplane." The specification described an airplane which was 33½ feet long, measured 32½ feet from wing-tip to wing-tip, and had a tail 12 feet high. The engine, mounted under the airplane and with the tail pipe extending below the aft fuselage, gave the X-5 a bulky middle and slim aft-end. Propulsion initially would be furnished by an Allison J-35-A-17 engine, with substitution of the more powerful Westinghouse XJ-46-WE-2 engine slated when the latter became available. The most radical feature of the little airplane was the mechanism for changing the angle of the wings to any position between 20 and 60 degrees sweep.

The Bell company circulated the specification among the laboratories of the Air Force and the National Advisory Committee for Aeronautics for their review and comments.

### The Cost

On 1 February 1949 when Bell offered its X-5 proposal to the Government, it estimated an overall program cost of \$2,416,116.43. For this, Bell would furnish two airplanes, a full scale mock-up, nine wind tunnel models of the airplane, and all required technical data. In addition, the company stated that flight testing would require \$74,698.84. While Bell's proposal was being negotiated into a contractual document, the project officer initiated a purchase request for \$1,500,000 to get the X-5 work under way. During negotiations, the Engineering Division determined that it needed only three wind tunnel models of the airplane, so Bell revised their cost to \$2,360,431.77. On 24 May 1949, contract number AF33(038)3298 was written. This contract provided \$1,487,072.02 to cover 63 percent of the work on the X-5 project. A second purchase request was written, meantime, to take care of the remainder of the cost, as estimated by Bell. This request totalled \$860,431.77, which, when added to the amount of the first purchase request, equalled Bell's revised figure of \$2,360,431.77. (By the time the change order to the contract was written, however, the amount of the second purchase request had increased to \$873,359.75.)

### Additional Money Requests from Bell

The X-5 program had been under way about a year when it experienced financial difficulties. As was common with many development programs, Bell's estimates proved to be low. On 27 July

1950, in accordance with Article 6(d) of the contract, the contractor asked for more money. Comparing the cost of the first year's operation and the amount of work still remaining to complete the contract, Bell stated that it needed \$1,321,753.25.

112 Mr. T. J. Butler, the Air Force contracting officer at the Bell plant, estimated that about 50 percent of the contract had been completed. However, about 75 percent of the funds allotted to the project had been spent. Based on these figures, Mr. Butler indicated that \$1,110,000 was necessary to complete the X-5 program. In justifying the large sum, Mr. Butler noted that conditions had changed since the X-5 contract was written. For example, many costs originally figured as labor costs became materials costs because of increased subcontracting. (The company had resorted to large-scale subcontracting when a strike closed the plant in the summer of 1949.) Mr. Butler concluded that Bell's estimate of additional funds was accurate.

115 In August 1950 a purchase request for \$1,000,000 to cover the major portion of the overrun was processed. The sum was to be allotted equally from Fiscal Year 1949 and Fiscal Year 1950 funds.  
128 On 1 September 1950 change order No. 4 provided the \$500,000 from  
148 Fiscal Year 1949 funds; however, at the time, no 1950 funds were allocated. In December 1950 the materiel command directed Bell to  
163 stop all spending until Air Force headquarters could make some Fiscal  
152 Year 1950 funds available. Early in 1951, Washington authorized  
166 the \$500,000, and change order No. 6 became a part of the contract.

During the six months it had taken to obtain funds for the overrun, Bell found that changing conditions had made its July 1950 estimates invalid. On 4 December 1950 the company informed the  
153 Air Materiel Command that overhead and labor rates added another \$126,609.63 to the overrun. The entire overrun figure was now \$1,448,362.88. Since change orders No. 4 and 6 had supplied \$1,000,000, Bell asked for a third change order to furnish the  
157 remaining \$448,362.88. A purchase request for that sum was written  
165 in December 1950 and, in January 1951, change order No. 7 became a part of the contract.

About six months after the first overrun had been covered,  
269 Bell informed Wright Field that still another allocation--\$266,759.62--  
277 was needed. The Air Force reviewed the request and, in October  
298 1951, provided the money through means of change order No. 9. This constituted the final large grant. However, there was continual financial dickerings on a smaller scale throughout the life of the program.

On 27 May 1949, when the X-5 program was just gaining momentum,  
Mr. J. F. Strickler, assistant executive chief engineer of the Bell  
42 corporation asked Mr. Butler and Major William SeEVERS, the Air Force plant representative, for permission to work the engineering department overtime. This overtime involved 245 hours over a 17-week period and would cost \$10,000. Mr. Strickler added that the company had already spent \$500 for overtime.

45 Bell justified the request by stating that it desired to meet  
the 10-month delivery date on the first X-5 airplane; therefore,  
overtime was necessary. The Air Force representatives knew of no  
44 such deadline nor had overtime costs been considered when Bell  
submitted its original cost proposals. Accordingly, the Air  
Force refused to approve the request on the basis of meeting delivery  
schedules. However, by the time the decision was announced, Bell  
48 had incurred \$800 in overtime charges, and the Air Force agreed to  
pay that amount.

In September 1949 the contractor asked reimbursement for the  
monies spent on the preliminary X-5 research--before the Air Force  
59 became interested in the program. Bell had begun this work in 1948,  
more than a year before the Air Force had agreed to the X-5 develop-  
ment. Nevertheless, since this "prior research" was incorporated  
into the program, Bell maintained that it should be paid for the work.

38 Under the terms of the contract (Article 3, paragraph b, 1),  
all costs after 28 March 1949 were allowable. Under the terms of  
the Armed Services Procurement Regulation (Contract Cost Principles,  
59 Section XV), all research and development applicable to supply or  
services were allowable items of cost under a contract. The X-5  
contract (Article 3, paragraph b) stated that the Armed Services  
38 Procurement Regulation, ". . . which is specifically incorporated  
herein by reference," would determine what were allowable items of  
cost. Based upon these documents, Bell asked that it be paid for



the prior work. The cost amounted to \$57,850.21. Mr. Butler estimated the sum would be increased to about \$130,000 after factory and overhead engineering costs were added. Mr. Butler, in referring the problem to Wright Field, said he did not believe the costs were allowable either as general research or direct costs. "Providing no allowance of these costs is considered," he concluded, "there will, in all probability, be an appeal by the contractor."

Procurement officials at Air Materiel Command agreed with Mr. Butler that these prior research costs were not allowable under the terms of the X-5 contract. However, they believed, it was possible that some of these costs ". . . could have been considered anticipatory costs had they been presented at the time the Contract was negotiated," and the Air Force might be willing to "bail the contractor out" on some of it for "maintenance of industry" reasons.

The problem was referred to the command's Judge Advocate for legal decision. The Judge Advocate held that money Bell had spent before the Air Force accepted the X-5 proposal could not be paid under the contract. Moreover, the X-5 contract could not legally be amended to provide for such payment.

Another problem involved crediting the Government for elimination of the autopilot from the airplanes. Bell had intended to install autopilots, but the National Advisory Committee for Aeronautics thought them unnecessary since the airplanes were for research only. The Air Force then instructed the contractor to eliminate the

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installation of autopilots. About a year later, in May 1950, the Air Materiel Command asked that the Government be credited for the deletion. After several months of discussion, Bell agreed to credit the Government with approximately \$21,000.

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225, 226  
309

The original estimates of the X-5 program, plus the overrun, the changes in specifications, the mock-up changes, the cost of the flight test program, and minor changes, brought the total cost to about \$4,260,000. All in all, the financial aspects of the program were not unlike those that usually afflicted many, if not most, other developments of this nature.

#### Details of Design

As noted earlier, the first X-5 specification circulated among Government laboratories for evaluation and comment. At Wright Field, the Aircraft Laboratory, on 29 August 1949, recommended numerous changes to the specification. At the same time, the laboratory questioned the worth of the undertaking. Insofar as the Aircraft Laboratory could discern, the program was intended, to determine the potential of variable swept wings and their effects on stability, control, and performance of an airplane. Because most of the existing data on stalling performance was for a "no sweep" configuration, the 20 degrees minimum wing sweep of the X-5 was too high to allow application of available data to performance evaluation. In addition, any stalling data gained from X-5 flights might be worthless since slats or nose flaps would be necessary at the minimum angle of sweep.

58

Finally, the Aircraft Laboratory held that information obtained on the combined effect of high angles of wing sweep and high speeds would duplicate data readily available from airplanes under construction or already in existence. "In other words," the Aircraft Laboratory concluded, "the X-5 does not fill any particular gap in either high speed or sweepback research."

The Power Plant Laboratory at Wright Field submitted its comments of the X-5 specification on 9 May 1949. The major fault the laboratory found was that the airplane carried its entire fuel supply directly over the engine. The laboratory asked for a change; however, to move the fuel or the engine would have resulted in an entirely new airplane. Therefore, on 5 August the propulsion officials reluctantly approved the design, stressing that the approval was applicable to the X-5 only in its role as a research aircraft.

Failing in its attempts to have the fuselage of the X-5 redesigned, the Power Plant Laboratory asked that a double fire-wall be installed between the engine and the fuel compartment. Ventilation was provided between the walls to guard against the accumulation of fumes.

The National Advisory Committee for Aeronautics objected to the design of the tail pipe. However, there was insufficient information available to justify changing the design of the airplane. Pending results of tests on the XF-88 airplane, which also had an underslung tail pipe, the Committee wanted the aft fuselage of the

X-5 constructed of fire-resistant material to keep the exhaust from scorching the tail.

36, 39 The Committee also thought that the X-5 would require some modification when the XJ-46-WE-2 replaced the J-35-A-17; otherwise, the airplane might drag its tail pipe when landing.

14, 16 The National Advisory Committee for Aeronautics emphasized that some arrangement would be necessary to protect the control lines of the airplane in case the engine came apart in flight. Bell was asked to provide a system of alternate controls as well as a number of V-shaped guards which could deflect particles of the engine from the controls should an accident occur. When these were furnished, the Committee would decide which was wanted--the alternate controls or the V-shaped guards.

145 The alternate controls proposal was eventually discarded. Space restrictions forced the auxiliary lines into approximately the same route as the main control lines. If a disintegrating engine tore out the main control lines, the auxiliary lines would probably be taken out also. The Committee chose the V-shaped guards instead of the alternate controls, and the Air Force approved.

145, 156 Later the Air Force requested additional shields around the rotating sections of the engine. Bell thought this complicated the design of the airplane, added unnecessary weight, and went far beyond its original agreement. Nevertheless, the Air Force persisted and directed Bell to install these guards.

14, 16

The National Advisory Committee for Aeronautics also wanted the X-5 airplane outfitted with controllable, instead of automatic, leading edge slats. In June 1949 the Aircraft Laboratory sent Mr. Woldimer Voigt, former chief of design engineering of the Messerschmitt company in Germany, to visit the Bell plant. He reported that the normal force coefficients used for stress calculations on the slats were satisfactory. However, these calculations were made assuming open slats at maximum speed, 60 degrees wing sweep, at high angle of attack. This meant, Mr. Voigt pointed out, that under the same conditions, the slats would not be safe in the 20 degree wing sweep configuration. "This layout implies that the advantages of the variable sweep system with respect to maneuverability, which Mr. [R. J.] Woods [Bell's chief design engineer] claims, can probably be demonstrated only with some, maybe severe, restrictions," Mr. Voigt wrote.

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14, 16

40, 41

The Committee desired fighter aircraft load factors used on the X-5, provided there was not too heavy a weight penalty involved. It also thought that the airplane would require speed brakes. (These brakes were placed in an unusual position: forward of the wing roots, near the nose of the airplane.)

#### Instruments for the X-5

202, 33

The X-5 airplanes were designed to carry 500 pounds of National Advisory Committee for Aeronautics research instruments. Recording devices, represented by cardboard cut-outs in the mock-up, took much

51 of their information from about 1,112 strain gauges scattered  
114 throughout the airplanes and from the long slender pitot boom which  
extended forward from the nose.

The original design for the pitot's boom was shortened and  
188 then constructed of steel instead of aluminum alloy, at the request  
of the National Advisory Committee for Aeronautics. Mr.  
Hartley A. Soule', Research Airplanes Project Leader at the Committee's  
Langley laboratories, asked that the research instruments and the  
88 pilot's instruments in the pitot's boom be separated. Should they  
be combined, Mr. Soule' said, every change of research instruments  
on the X-5 would require a re-calibration of the pilot's instruments.

101 In July 1950, Bell submitted its cost proposal for the X-5  
114 instruments. After a price revision, the Air Force provided  
113, 169 \$53,132.37 for instrumenting the airplanes.

The first X-5 airplane was outfitted with National Advisory  
85, 100 Committee for Aeronautics research instruments. The second airplane  
180, 119, initially had Air Force instruments for the Phase II flight testing.  
147, 244 Provisions were made in the second airplane, however, for the  
Committee's research instruments which were to be installed after  
Air Force pilots completed the Phase II evaluation.

#### The Mock-up Inspection

43, 46 When the program started, the Air Force and the contractor  
tentatively scheduled the mock-up inspection for the summer of 1949.  
Bell tried to have the mock-up ready by 28 June 1949, but on 13 June

63, 122 a strike closed the Bell plant. Although the strike lasted until November 1949, Bell managed to do some engineering work, and it expanded its subcontracting work.

68 In October 1949, while awaiting the mock-up inspection, National Advisory Committee for Aeronautics and Wright Field engineers held a conference at the Niagara Falls plant. They discussed, in the "preliminary to the Mock-Up Inspection," the pressurization and air conditioning of the X-5 cabin; decided that the canopy be jettisoned by blowing it rearward off its tracks; and directed that emergency landing gear operation and landing gear locks be installed on the airplane. The airplane was to be capable of carrying about 300 gallons of fuel, weighing 1, 200 pounds.

74, 75 Two months later, on 6 and 7 December 1949, the mock-up inspection board met. "The changes directed as a result of the Mock-Up Inspection are of a minor nature," the inspectors reported, "and will not affect the basic configuration of the airplane." Of the 76 items in the board's report, about 40 items required action or study by the contractor. The Air Materiel Command's representatives pointed out that the revised specification for the X-5 did not include a number of changes that the Wright Field laboratories wanted. These changes, they said, would be submitted within two weeks.

78, 83, 86 Three months after the inspection, Bell estimated that the changes requested by the mock-up board--plus the changes directed by Air Materiel Command--would cost about \$107,086.01.

Mr. Butler, the Air Force contracting officer at the plant,  
90 thought the contractor's estimate of overhead expenses was high.  
In turn, Lieutenant Colonel D. W. Graham, chief of the Aircraft  
and Missiles Section, Procurement Division, informed Bell that  
93 many of the changes listed in its estimate were not required by  
98, 99 the Government and asked for a revised estimate. In June 1950  
Bell changed the total slightly--to \$104,000. The command approved  
105 this amount, and the item was handled independent of the overrun  
112 being negotiated at the same time.

#### The X-5 in Wind Tunnels

When the Bell proposed the X-5 program to the Air Force, it  
was well along on construction of one wind tunnel model. The company  
4 also suggested the fabrication of eight other models for tunnel  
tests, but this was turned down by the National Advisory Committee  
8 for Aeronautics and the Air Materiel Command. In a conference held  
at the Langley laboratories in February 1949, they decided to use a  
7- by 10-foot low speed stability and control model, a spin tunnel  
model, and a supersonic model for use in the 8-foot high-speed tunnel  
and the 4- by 4-foot supersonic-pressure tunnel at the Langley  
laboratories.

#### Stability and Control Model

The stability and control model of the X-5 was 60 percent  
4, 6, 8 completed when Bell submitted its first cost proposal. The contractor



4 offered the model to the Government for \$26,309. It was bought  
for \$24,995, the sale being negotiated separately from the rest of  
24, 25 the program.

In May 1949 the low-speed stability and control model was  
ready for test evaluation. Early results indicated that the model  
41 was satisfactory at the 20 degree wing sweep position but at 60  
degrees wing sweep it indicated directional instability at coeffi-  
cients slightly below maximum lift. Bell engineers thought these  
55 results might be in error; nevertheless, they had, in the meantime,  
50 increased the dimensions of the fuselage of the airplane and changed  
55 the length of the wings. Later, the wing changes were abandoned.

The completed stability and control report indicated that the  
X-5 configuration, when accelerated, had a tendency to duck its  
nose. The Air Materiel Command Engineering Division informed  
Bell that, although this nose-down condition was desirable, it was  
not required by Air Force specifications. At high speeds there was  
a high stick force in the controls of the model, but at low speeds  
the model indicated that stick forces would be too light for proper  
pilot "feel." Because of the speed range of the airplane (difference  
between low and high speeds), the Air Materiel Command thought it  
140, 151 might be necessary to use a non-linear feel device or a gear ratio  
correction device, as proposed for other airplanes with the same  
stick force problems. The tests indicated that the X-5 airplane  
would have stable stalls; that sidewash caused static lateral and

directional instability at the 60 degrees wing sweep position in high angles of attack; that aileron reversal speeds would probably be between 700 and 760 knots indicated air speed; and that dynamic lateral stability (Dutch Roll) would probably be marginal in some configurations.

#### Spin Tunnel Model

34 In May 1949 Mr. A. M. Arnold, a Bell engineer, visited the National Advisory Committee for Aeronautics laboratories at Langley Field to discuss the design of the X-5. At that time the scale of the spin tunnel model of the airplane was set at 1/20, the wing span was to be 15 inches, and loading factors of two pounds to the square inch were decided upon. The Committee engineers suggested that only one model of the airplane be built, but with three sets of wings to simulate three wing sweep positions. The Committee also asked that Bell construct an alternate tail configuration.

76 Apparently some misunderstanding arose over the model. In January 1950, when the Engineering Division directed its Aircraft Laboratory to prepare for the tests, it stated that there would be three models. In February, after the spin model had been received, the laboratory expressed some surprise, noting that there was only one model, but three sets of wings. It also commented that the  
80 model was made of Balsa wood, a material too fragile for the tests. Pending construction of a more suitable model by the Experimental

Fabrication Laboratory, only preliminary tests could be run with the Bell-built model.

94 Spin recovery tests of the stronger model were ready to start on 22 May 1950. The Engineering Division asked that Bell have a representative present inasmuch as ". . . there has been some indication that configuration changes may be necessary to effect recovery."

102 The evaluation actually got under way in June. From the results, Bell deduced that the best maneuver for a pilot in a spin was to turn the ailerons with the spin (stick right in a right turn). National Advisory Committee for Aeronautics personnel noted that this could be expected from any airplane which had a thick mid-section. The tests also indicated that the X-5 might recover from a spin easily when the wings were in the 60 degree wing swept position. Recovery, however, was considerably more difficult with the wings at a 20 degree sweep. To alleviate this, a ventral fin was added under the aft fuselage of the model, and this seemingly corrected the deficiency. The fin, on the airplane, would measure eight and one-half inches at the fantail.

102 Bell proposed installing a spin recovery parachute in the aft fuselage of the X-5, but both the National Advisory Committee for  
173, 177, Aeronautics and the Air Materiel Command believed that the tests with  
179 the ventral fin indicated that such an installation was unnecessary.

102 No further spin tests were required on the X-5 project.

### Supersonic Tunnel Model

103 In July 1950, Bell proposed that an X-5 model be tested in the supersonic wind tunnel facilities at Langley. Such tests would be valuable for the first flights of the airplane, would give prior information on unusual features of the X-5 (the wing-root fillets and the nose air inlet with its drooped lip, for instance), and would afford the Committee an opportunity to contrast tunnel data with flight data in order to determine the amount of wall interference present in its tunnel.

106 The advisory committee and the Air Force agreed that the tests would be valuable. A supersonic wind tunnel model was already on the X-5 contract, and Bell was instructed to begin construction. The  
117 model was scaled at 0.90, and had movable ailerons, elevators, and rudder, while the wings had variable sweep. To evaluate the drooped lip air intake, the jet inlet was to be accurately duplicated for about the first two inches on the model, which would bring it to about the position that the engine compressor intake would occupy on the full-scale airplane. A restriction was placed near the  
129 tail exit of the system to regulate the flow of air through the model.

130 In order to leave the nose inlet free, the model was stinger  
146 mounted through the aft fuselage, making the aft end a little out of scale. Therefore, Bell had to build an additional aft end to scale so that it could be evaluated separately. The company also

included leading edge slats so that investigations of high-altitude control characteristics could be carried out. Bell wanted to build the model with a steel core covered by wood, but Government engineers objected because wood would warp and pit in the tunnel.

106 Like the full-scale X-5 test results, the supersonic tunnel model tests were to become part of the National Advisory Committee for Aeronautics fundamental research program, and data from the tests were to be disseminated through the regular channels of that organization.

#### X-5 Power Plants

32, 54 The engines of the X-5 were placed below the fuselage for several reasons: to accommodate more easily a variety of power plants and to have them out of the way of the wing sweep mechanism being among the more important.

210 The Allison J-35-A-17 engine, used in the F-84 Thunderjet, was initially installed in the X-5 to provide a proven engine for the first flight evaluation of the airplane. The engine, with a 4,900-pound thrust, was limited in performance to a speed just under Mach 1.0. Four engines were procured--two for the airplanes and two as spares. In May 1949, Allison furnished Bell with the first engine, which was incorporated into the mock-up of the X-5. The contractor, however, found that the tail pipe of the stock J-35-A-17 engine was too heavy, built a tail pipe of its own design, and changed some accessory brackets and plumbing to make the J-35 fit into the airframe.

68 A Westinghouse XJ-46-WE-2 engine, generating approximately 6,000  
pounds of thrust, was to replace the J-35 when the former became  
available. In fact, Bell included performance estimates for the  
airplane with the XJ-46 in its original proposals, but the Aircraft  
58, 69 Laboratory believed these estimates overly optimistic. Moreover, the  
96 National Advisory Committee for Aeronautics thought that the landing  
39 gears of the airplane would have to be redesigned to keep the X-5  
from dragging its tail pipe when landing with the XJ-46 engine.  
However, these problems never became pressing. Westinghouse  
encountered considerable difficulty in producing the engine, and  
it was never installed in the X-5.

#### "Souping Up" the X-5

113 Although the J-35 engine was used in the airplane and the  
XJ-46-WE-2 was planned for use, the Bell company wanted even more  
powerful engines for the X-5--and the underslung mounting feature  
made the airplane readily adaptable to a variety of engines.

182 In February 1951, Bell suggested that a Wright J-65 Sapphire  
engine be installed. The company claimed that this engine would  
increase the speed of the X-5 from Mach 0.99 to about Mach 1.04  
at an altitude of 30,000 feet. The National Advisory Committee for  
Aeronautics, however, thought that the airframe of the X-5 would  
have to be more completely tested before such an undertaking was  
justified.

203, 210 Bell also investigated the possibility of installing an  
227, 238 XJ-46-WE-1 with afterburner and two 1,500-pound booster rockets  
in the X-5 airplane. The Air Force asked the Navy's Bureau of  
Aeronautics to supply Bell with data on the engine, and Mr. Woods,  
Bell's chief design engineer, had his rocket research engineers at  
the Bell plant investigate the possibilities of operating booster  
rockets with either a combination of lox (liquid oxygen) and JP-3  
237 or lox-gasoline. Reaction Motors, Incorporated, quoted Bell a  
price of \$536,414 for the rocket engines.

The contractor's engineers estimated that the fuel capacity  
of the X-5 airplane would enable it to climb to 30,000 feet under  
turbojet power; operate at full power (turbojet, afterburner, and  
rockets) for three minutes; and still have 60 gallons of fuel with  
210 which to return to base and land. Bell foresaw several outstanding  
uses for the aircraft: for physiological research at high altitudes  
and speeds, for investigation of turbojet operation at high altitudes  
and high Mach numbers, and for research on the tactical worth of  
booster rockets as aids to high altitude and high speed maneuverability.  
Most of the material necessary to modify the airplane, Bell stated,  
could be bought from off-the-shelf stocks. The only exception was  
equipment and material for modifying the booster rockets so they  
could operate on jet engine fuel.

In July 1951, Mr. Woods presented his proposal at Wright Air  
Development Center. He now suggested rockets with 4,000 pounds of

thrust, which could speed the X-5 to Mach 1.4 at 40,000 feet altitude. As an alternate to the Reaction Motors boosters, Mr. Woods  
247 said that Bell was considering an acid-jet fuel rocket similar to that used in the Shrike missile.

Mr. Woods also noted that the Douglas Aircraft Corporation had contacted Reaction Motors regarding rocket boosters for its X-3 experimental airplane. He therefore suggested that the X-3 and X-5  
247 rocket projects be combined and be handled jointly by the two companies.

The Power Plant Laboratory refused to concur in the proposal to incorporate rockets in the X-5. It claimed that Bell was assuming that the Shrike missile booster was a proven item. Actually,  
304 the Shrike was nothing more than a test vehicle; considerable development work yet remained before the booster could be employed safely in a tactical missile, let alone a man-carrying vehicle. The Power Plant Laboratory also objected to some of the fuels suggested.

Mr. Soule had earlier expressed the National Advisory Committee's  
247 belief that XJ-46 engines would not be plentiful enough to allow their use in both the X-3 and X-5. The combination of objections was enough to kill the rocket engine scheme for the X-5.

#### Landing Gears

Landing gears were a problem from the beginning. The main gears extended from the fuselage and straddled the bulky underslung



53, 56 engine somewhat in the manner of a man standing with a keg between his knees. Because of this, it was difficult to construct landing gears which would operate properly and still be strong enough to support the airplane. Special landing gears for the airplane cost the Government approximately \$6,500.

#### Hydraulic System

79 Bell designed an open center hydraulic system which controlled the operation of the landing gears and allowed pressure in the unit to lower after operation. Air Materiel Command engineers suggested that a different system be installed, primarily because Bell's open  
110 center system was an untried piece of equipment.

79 The assist hydraulic cylinders in the landing gear system were operated by compressed air. The Engineering Division questioned the efficiency of these assist cylinders. When the cylinders were undercharged, the landing gears would extend and retract but would not lock into the down position. When the cylinders were overcharged, the landing gears would extend but would not retract. Bell representatives told the Air Materiel Command that the "unusual geometry of the landing gears" on the X-5 made the assist cylinders the only practical solution to the problem. If this were true, the Engineering Division replied, then Bell would have to redesign the entire landing gear system.

After further study, the contractor converted the pneumatic assist

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cylinders into conventional hydraulic cylinders and the Air Force accepted the design.

Weakness of the X-5 Landing Gears

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Early in the X-5 program, in August 1949, the Aircraft Laboratory predicted that the shock struts for the landing gears were likely to be troublesome. The contractor had constructed the struts of aluminum alloy and very little was known about the strength, fatigue properties, and wearing qualities of the metal when put to such use. The laboratory suggested that the contractor conduct tests to prove that the aluminum alloy struts were as good as those constructed of steel; furthermore, that the contractor be held responsible for replacing the aluminum shock struts if they proved unsatisfactory.

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In May 1951, at the time of the Engineering Inspection just prior to beginning the Phase I flight tests, the Aircraft Laboratory objected to the excessive angle of inclination of the shock struts, but no action was required of the contractor because the angle was "inherent in this design." However, Bell had also taken the precaution of having a subcontractor work on heavy duty shock struts to replace the aluminum alloy ones, if that became necessary.

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The Aircraft Laboratory's prediction was borne out during a flight early in the Phase I evaluation. Mr. Ziegler, Bell's test pilot, was demonstrating the airplane's ability to land at the 40 degree wing sweep position. He was in the final approach, the airplane being about 100 feet off the ground and at a speed of about 180 miles

an hour, when he accidentally tripped the flap switch to the "up" position. Mr. Ziegler believed it was dangerous to attempt to flare (level out) since the airplane had demonstrated a tendency to roll to starboard when near the stalling speed. He returned the flap switch to "down", but continued to hold the rate of descent. The airplane hit the ground in a slightly nose up position bounced off again. The flaps had, meantime, reached the down position and Mr. Ziegler set the airplane down between 140 and 150 miles an hour. The tires and brakes for the X-5 airplane were the same as those used on the Navy's experimental D-558-II research airplane, which was twice as heavy as the X-5. Nevertheless, the X-5 apparently rolled slightly to starboard, for the impact damaged the right main tire and it threw its thread after Mr. Ziegler had the airplane on runway. The tire did not blow out.

Inspection showed the strut support for the right main landing gear had also been damaged. Tools were secured to begin repairs, and Bell rushed the project of installing the stronger struts in both X-5 airplanes.

#### The Wing-Sweep Mechanism

When an object moves through the air at supersonic speed a cone-shaped shock wave is formed, having its apex at the nose of the object. An airplane, flying at Mach 1.2, would produce a shock wave cone slanting back to form an angle of 55 degrees with

the centerline of the airplane. To avoid this shock, the wings of the airplane must be swept aft about 35 degrees from right angles to the centerline of the airplane. The shock cone from an airplane flying at Mach 2.0 would form an angle of about 30 degrees and the wings would have to be swept about 60 degrees to avoid contact. At greater speeds the wings could not be swept enough to avoid the narrow cone waves, so the straight wing with its more effective lift and aileron operation might as well be used. One writer stated:\*

The ideal all-speed wing would be, of course, a variable sweep design capable of taking off with a straight leading edge, sweeping it rearward progressively to 35 deg/rees/for transonic speed, to 60 deg/rees/for low supersonic speed and back straight again for high supersonic speed.

#### The Gadget

23, 201 The most unusual thing about the X-5 airplane was the mechanism which gave its wings many of the features of "the ideal all-speed wing." The wings of the X-5 airplane were mounted on hinges just outboard of each side of the fuselage. Inside the wings, near the leading edge, one end of a ball bearing screw jack was attached; shafts passed through the interior of the wings and into the fuselage of the airplane where they were anchored to a gear box. When the motors of the mechanism were operated, the jack screws rotated the wings on their hinges, changing the angle of sweep.

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\*McLarren, Robert, "Delta Wings," Aero Digest, Vol. LXI, No. 6, December 1950, pp. 98, 103.

The change in sweep of the wings caused a change in the center of pressure and center of gravity. To compensate for this, the wings were mounted, hinges and all, upon rails on either side of the fuselage of the X-5 airplane. An additional pair of screw jacks, anchored into the same gear box as the sweep screw jacks, drew the wings fore or aft along these rails. At 20 degrees sweep, the entire wing assembly slid forward on the rails until, at 60 degrees sweep, they were about 27 inches forward of their starting position. In addition, there were provisions for minor changes of wing position up to four and a half inches fore or aft, without changing the sweep angle of the wings.

The sweeping and positioning actions of the system took place simultaneously, as the sweep and positioning components were geared together. The entire process of moving the wings from the 20 degree to the 60 degree sweep took place in about 20 seconds.

In the cockpit of the X-5 airplane were two dials. On the large circular dial the pilot selected the wing sweep angle and wing position he desired. He pressed a button on the control stick and the wings moved on their hinges and slid fore or aft on their rails until they reached the position selected. A smaller dial indicator showed the exact degrees of sweep and inches of position of the wings at all times.

Also in the X-5's cockpit was a hand crank for emergency purposes. Should the electric motors which powered the wing sweep

system fail, the pilot could adjust the sweep and position of the wings manually by means of this crank. Because the 20 degrees sweep position was the best configuration for landing the X-5 and because the X-5 could not be landed safely with the wings swept more than 40 degrees, the hand crank was a most important emergency tool.

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#### Testing the Sweep Mechanism

Bell built a dummy center section of the X-5 airplane's fuselage and installed a wing sweep system to test the operational wear and fatigue of the parts. The company intended to test load the system and apply unsymmetrical pressures during 600 cycles of operation and to devise a method of inflicting impact loads on the mechanism. To make the tests more realistic, Bell proposed to rework one of the wings from the German Messerschmitt P-1101 airplane and then mount it on the dummy rig. The German wing, Bell engineers reported, was to be strengthened to withstand 70 percent of the design load of the X-5 wings.

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Since the German wing had to be reworked, the Engineering Division suggested that it be constructed to take the full 100 percent design load of the X-5 wing. Bell pointed out that the German wing was entirely different in design from the X-5 wing. To make it strong enough to withstand such loads would require much time, work, and money. In addition the object of the rework was to determine operational wear and fatigue of the wing sweep provisions; 100 percent loads on the wing portion of the test rig were not

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97 necessary for such tests. The Air Force engineers agreed to drop the matter of "beefing up" the German wing on condition that the X-5 wing would be tested to 100 percent of its design load at a later date.

124 The Air Force asked Bell to conduct 100 impact test loads on the screw jacks of their test rig at one g loads and 200 cycles of operations of the system under two g loads. The Air Force also asked that a sleeve be placed over the shaft connecting the sweep and positioning gears to increase the stiffness of the connection shaft without affecting the design torsion characteristics, the twisting action, of the shaft.

142 Shortly after Bell started evaluation of the mechanism, the positioning gear interconnecting shaft broke. Bell engineers replaced the shafts of the system with steel tubing and repeated the test successfully. These steel shafts, the engineers reported, eliminated the necessity for the sleeve requested by the Air Force. 142 When the tests were completed, the wing sweep mechanism was removed from the test rig and put aside for use as a spare for the systems 91 built into the two X-5 airplanes.

#### The Wing-Sweep Mechanism in Flight

On the fifth flight of the X-5 airplane Mr. Ziegler operated the wing sweep mechanism for the first time. He worked the wings from 20 to 30 degrees sweep in careful 5-degree steps. On his

236 next flight, the pilot swept the wings to 40 degrees. The emergency  
hand crank for the system would not operate, so Mr. Ziegler discon-  
242 tinued further sweep operations. He feared that a failure in the  
mechanism would leave the airplane in a configuration which would  
not allow him to land the airplane safely. The emergency crank  
288 was reworked so that it would operate, but only after the pilot  
exerted great pressure to turn it. The crank was removed from the  
airplane and re-gearred. This change allowed the handle to move  
easily, although more turns were necessary to operate the wings  
through the entire range of sweep.

242 On his ninth flight, Mr. Ziegler moved the wings of the  
airplane completely through their cycle--20 degrees to 60 degrees  
and back. On a later flight the wing sweep mechanism malfunctioned  
248, at 40 degrees of sweep. Mr. Ziegler returned the selector to the  
20 degrees mark, which position was gained without difficulty. When  
249, 250 the system was inspected, engineers found the gears had become worn  
and were not meshing properly. The gears were replaced and no  
261 further trouble was experienced with the wing sweep mechanism during  
the remainder of the Phase I flight testing.

#### Weight of the Wing-Sweep Mechanism

The National Advisory Committee for Aeronautics had considered  
in-flight variable swept wing before the X-5 program started. In  
fact, they had asked several aircraft designers about the prospects  
of building a mechanism for that purpose. Always the Committee was



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told that such a contraption would weight too much for practical use. (The Lockheed Aircraft Corporation designers had been particularly emphatic on this point.) When Bell came up with such a mechanism which it claimed would weigh only 250 pounds--approximately 3 percent of the total weight of the airplane--the Committee's engineers were extremely interested.

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In August 1950, however, the weight of the wing sweep mechanism was 340 pounds and this, the Engineering Division said, was too heavy for tactical use.

#### Wing Root Fillets

When the wings of the X-5 rotated on their hinges, there was a gap between the fuselage of the airplane and the leading and trailing edge of the wings. The design and construction of fillets to keep these gaps closed on the variable swept wing airplane proved to be a pesky problem.

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Bell designers had planned to use a telescoping arrangement but this plan, so far as the trailing edge of the wing was concerned, was abandoned in June 1949. It was replaced by plans for a fillet which would fair into the wing at highest sweep angles.

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In November 1949, Mr. John Herald, X-5 project engineer at Wright Field, reported: "A major design problem was presented by the leading and trailing edge wing-to-fuselage fillets which must expand and contract as the wing sweeps. These fillets will be

329 demonstrated on the Mock-Up." But when the mock-up inspection was held, in December 1949, fillets were still under study. In February 1950, Mr. Herald reported the wing-root fillets were ". . . still under development and no design has yet been submitted for approval." The design was not submitted until April 1950.

164, 329 Fillet troubles were not completely over, however, for the "fabrication and installation" of the fillets delayed the engineering inspection and first flight of the X-5 airplane until well into the first months of 1951.

#### Control Surface Testing

174 When the first X-5 was assembled, with the exception of the wing-root fillets, the Bell company prepared to conduct flutter and vibration tests on the airplane. These tests were designed to find out what airflow pressures were dangerous to the appendages and control surfaces of the airframe. To simulate conditions which duplicated various speeds, Bell used electric motors (Rollins Electro-Magnetic Vibrators) attached to various parts of the airplane to allow controlled vibration frequencies. Velocity-type strain 87 guage pick-ups on the wings, stabilizer, fin, and control surfaces of the X-5 recorded the data from the tests.

#### Flutter Tests and Balance Weights

The Engineering Division at Wright Field approved the proposed tests for flutter, but suggested that outboard weights be placed on

170, 185 the rudder and elevators. When the first results from the flutter  
190, 191 tests indicated that safety in the rudder system was marginal, the  
208, 231 engineers reported that if the outboard balance weights were not  
installed, the X-5 airplane would have to be flight tested for  
flutter tendencies. The contractor was not convinced that such  
weights were necessary, but the Engineering Division directed that  
6.5-inch pounds of balance weight be added to the tip of the rudder  
and that 3-inch pounds be added to the tip of each elevator.

#### Vibration Tests

174, 190 Vibration tests on the X-5 airplane were conducted with the  
same equipment used for the flutter evaluations. First results  
172 from the tests showed that the wing torsional frequency (frequency  
of twisting or turning motion of the wings) was much lower than  
predicted. This meant, for unknown reasons, the wings were more  
rigid than they should be, thus throwing off performance estimates.

190, 212 The Engineering Division wondered if the Bell engineers had  
made mathematical miscalculations when figuring the predicted wing  
torsional frequency. It suggested that the trouble might be in  
the root sections of the wings. Bell added strain gauges to the X-5  
and ran additional vibration tests. It found that the wing panels  
responded as expected, confirming the opinion that the trouble lay  
in the wing root sections. Also, the Bell engineers re-figured their  
calculations on the basis of the new tests and reported no mathemati-  
cal errors in their original wing torsional frequency predictions.

Since the reason for the wing stiffness could not definitely be located and corrected, the Engineering Division pointed out that aileron rate-of-roll and aileron reversal speed calculations were useless until the airplane proved by actual performance that it was safe for high speed flight. As early as April 1949, Bell had been reminded of aileron reversal and up-float at high speeds and high angles of sweep, which caused the ailerons to act as elevators. Until new calculations were made, the Aircraft Laboratory imposed a speed limit of 425 miles per hour on the X-5.

When the speed limit was placed on the airplane, the Phase I flight evaluation tests on the X-5 were under way. Mr. Ziegler wired to ask if the Wright Field engineers meant 425 knots. A 425 miles an hour limit would make a big difference in the flight test program. The Air Force project officer, Major William G. Logan, replied that the speed limit was in miles per hour.

After the aileron effectiveness was investigated during several flights of the X-5, the Aircraft Laboratory raised the limit on the airplane to 525 miles an hour. This speed would impose loads of about 700 pounds per square foot on the aileron surfaces and, according to available data, cause the airplane to lose approximately 75 percent of its rolling effectiveness. The aileron reversal speed was recalculated to occur at about 900 pounds of pressure per square foot on the aileron surfaces.

Mr. Ziegler flew another aileron effectiveness test and the contractor asked that the speed limitations be raised to 588 knots (about 677 miles an hour), the design speed of the airplane. The Aircraft Laboratory refused on the strength of only the one additional flight. It pointed out that many more aileron effectiveness tests could be flown within the 525 miles an hour limit and ordered that the tests be conducted at gradually increased speeds. When the 525 miles an hour speed was reached, and aileron effectiveness remained good, the laboratory would again consider increasing the speed limit.

When the X-5 airplane was accepted by the Air Force, the speed limit was still 525 miles an hour.

#### Flight Testing the X-5

In August 1950, Bell proposed a 90-hour program for the Phase I flight evaluation. It planned to demonstrate ground performance, take-off and landings, stalls at numerous wing sweep positions, the wing sweep mechanism operation, the rate of climb, operation of the speed brakes, pull-ups, and flight load factors.

Colonel F. B. Wood, of the Engineering Division's Operations Office, questioned this 90-hour program since Phase I flights were supposed to show only the air worthiness of an airplane. Colonel C. F. Damberg, chief of the Aircraft and Guided Missiles Section, Engineering Division, referred the question to Mr. Herald, project engineer for the X-5 airplane.

144 The Phase I program normally ". . . would require only 30 to 40 hours," Mr. Herald replied, "but, because the various sweep increments gave the effect of several different airplanes many of the tests must be repeated at three or more sweep angles." Mr. Herald promised that all offices concerned would have the opportunity to study the flight program before it was approved.

132 Subsequently, the Engineering Division deemed much of the plan as unnecessary. A great many minor demonstrations could be combined. For instance, climbing performance and various systems could be checked during a flight being made primarily to demonstrate the rolling effectiveness of the ailerons. Moreover, the Air Force wanted landings and take-offs demonstrated from only a few wing sweep positions.

137 The National Advisory Committee for Aeronautics stated that it was unnecessary for the X-5 to fly beyond Mach 0.8 and that take-off at 40 degrees wing sweep, as suggested by Bell, was also unnecessary. In fact, the Committee continued, many of the demonstrations proposed by the company were performance items and not necessary to a Phase I flight air worthiness demonstration. The Committee asked, however, that more turn and stall checks be made.

132 The pilot was allowed to discontinue any specific test when he judged it dangerous; however, any additional work or costs caused by his discontinuance was the responsibility of the contractor. On the basis of the comments from the two organizations, Bell was to

submit a detailed Phase I program, outlining the actual flight hours required and the calendar time required to complete the testing.

149 The company submitted a revised flight test program calling for 66 hours of flying. While the plan did not meet requirements for testing tactical aircraft, it would demonstrate the air worthiness and safety of the X-5. But even this plan failed to receive 158, 199 Air Force approval. At a conference at Wright Field on 6 December 155, 189 1950, the plan was reduced to 27 hours. The Air Force allowed three hours for leeway, and the Engineering Division approved a total of 30 hours of flying time--to be accomplished within twelve weeks.

#### Cost of Flight Testing the X-5

11 In March 1949, Bell estimated that the Phase I flights would cost \$74,450. At the 6 December 1950 conference to establish a 159, 160 definite flight program, the Air Force allocated \$60,000 for the 204 program. A purchase request and contract change order were written 302, 312 to furnish this money. Later an additional \$4,000 was provided for 316 one functional test flight of the second X-5 airplane.

During the flight test program discussions, Bell brought up the question of paying its test pilot a bonus for flying the X-5. However, the Procurement Division immediately pointed out that no such cost had been suggested at any time during contractual negotiations. The Air Force Flight Test Center objected to any such 161

arrangement; it would fly the airplane rather than agree to the Bell pilot's receiving a bonus.

183 Three months later, Bell was still putting pressure on the Air Force plant representatives for the bonus. The company cited as precedent the flights of the X-1 airplane by Bell's test pilot, Mr. C. H. Goodlin, but Mr. Herald could find no record of such payments. "He did try to get \$150,000 or so for the supersonic flights which was refused resulting in [Captain Charles E.] Yeager making those flights," Mr. Herald said. "Apparently bonus or insurance arrangements have been allowed on a majority of experimental flight programs in the past," Mr. Herald continued. He concluded that if the Air Force allowed a bonus on the X-5 program, ". . . a command policy and uniform formulae for determining the amount should be established."

The bonus was not paid.

#### Flying the X-5

171, 176 Bell conducted preliminary engine runs, ground cooling surveys,  
178, 181 preliminary static test laboratory studies, static firing of the  
192, 194 ejection seat, and initial taxi runs at the Niagara Falls plant.  
195, 200 In April 1951 the company began arranging for the arrival of their  
265, 278 crews and the X-5 at the Air Force Flight Test Center. In May, the  
175, 207 Air Force conducted the Engineering Inspection and, on 9 June 1951,  
the first X-5 airplane, crated aboard a C-119 airplane, arrived at



211 the test center. Bell personnel assembled the airplane and then  
ran preliminary tests.

213 On the morning of 20 June 1951, Mr. Ziegler flew the X-5 for  
the first time. He lifted the airplane off the runway at high  
speed after a roll of 1,800 feet into an 18-mile an hour wind, then  
cut the throttle back to stay within the airplane's wheels-down  
speed limits. At 15,000 feet, Mr. Ziegler experimented with the  
controls of the airplane and found them in order although somewhat  
stiff. When he started to bring the airplane down, he noticed a  
213 dangerous negative pressure being recorded on the instruments for  
the fuel compartments. (Negative pressure could cause the fuel  
compartments to collapse or rupture and, since they were directly  
over the hot parts of the engine, might result in a fire or  
explosion.) Maneuvers showed the recording instruments were not  
registering correctly, and Mr. Ziegler landed the airplane without  
incident.

162 Normally, first flights of any new aircraft receive full  
photographic coverage. However, because of a misunderstanding  
between Edwards officials and Wright Air Development Center photo-  
graphers, the latter were not permitted to photograph the flight.  
215 Flight test center personnel scheduled to record the event failed  
to become airborne. Therefore, the X-5 proved the exception to  
the "first flight" photographic coverage practice.

On the next three flights of the X-5, Mr. Ziegler demonstrated

220 the handling characteristics of the airplane and conducted structural  
cooling tests. An air speed calibration was made with an F-80 pace  
234 airplane and a maximum rate-of-climb test was run in connection with  
a structural temperature cooling survey.

Mr. Ziegler first operated the wing sweep on the fifth flight  
of the X-5. On the next flight he stopped the sweep at 40 degrees  
when he discovered the emergency crank would not operate. He put  
236 the airplane into a stall at 40 degrees sweep and reported the  
ailerons had very little effect for the first one-third of stick  
throw. This indicated that the airplane would roll badly in rough  
weather or in any high altitude, high speed flight.

After the emergency crank for the wing sweep mechanism was  
reworked, Mr. Ziegler continued the flight tests. He investigated  
the stabilizer trim points and operated the speed brakes. Finally,  
242 on the ninth flight, he operated the wing sweep from 20 to 60  
255 degrees and back. After putting the X-5 airplane into a series of  
stalls, Mr. Ziegler reported a dangerous characteristic of the X-5.  
At low speeds almost all of the available elevator action was  
necessary to level the X-5 out for landing. This condition was  
serious because the airplane in landing could not easily be flared  
246 out from a steep, power-off descent. Mr. Ziegler wrote that  
". . . it would be necessary to actually accelerate the airplane  
to keep it from flying into the ground." Should the engine of the  
airplane flame out, the X-5 would be dangerous to land.

On the seventeenth flight, after demonstrating some dives, Mr. Ziegler tried to change the wing sweep. The mechanism gradually slowed down and stopped when the wings were at the 40-degree sweep position, but the pilot had no trouble returning them to the 20 degree position. The gears of the mechanism, worn until they failed to mesh correctly, were replaced.

#### First Air Force Pilot Flies the X-5

On 21 August 1951, Brigadier General Albert Boyd, commander of the Air Force Flight Test Center, received permission from Wright Air Development Center to fly the airplane, and Bell was directed to release the airplane for one evaluation flight by the general.

On Thursday morning, 23 August 1951, General Boyd took off in the little X-5 airplane. At 40,000 feet he swept the wings to 60 degrees. He put the airplane through some accelerated turns, then dived from 40,000 to 30,000 feet at a speed of Mach 0.92. At 30,000 feet the general made a speed run of Mach 0.92, turning out in a three g Mach 0.85 pull-up. After some 28 minutes, General Boyd returned the wings to 20 degrees sweep and landed.

#### Flying Stopped - Out of Money

On 4 September 1951, during the nineteenth flight of the X-5, Mr. Ziegler accidentally tripped the flap switch while demonstrating a 40 degree wing sweep landing. By the time he had the flaps down again, the airplane slammed into the ground, bounced off, and settled for a normal landing. The right main landing gear strut was damaged and the flight program was delayed for repairs.

Meantime, Bell requested an extension of six weeks on the flight program. At the current rate, the contractor said, it would run out of money before the flight test program was completed, and the extra six weeks of flying would cost \$25,680. The Procurement Division refused to approve the extension and instructed Bell to continue the flight program until the remaining money had been spent. When that occurred, the airplane would be given an acceptance flight and the Air Force would take it over.

232, 253, The contractor spent a number of weeks cleaning up some pre-  
271, 272, acceptance work on the X-5 airplane, which consisted largely of  
273, 276, items from the Engineering Inspection. Bell performed its final  
279, 281, flight on the first X-5 on 8 October 1951, and it was formally  
284, 285, accepted by the Air Force on 7 November 1951.  
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289, 294,  
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299 Upon acceptance, the Air Force formulated a plan for the flight test center to complete the Phase I flight program. The plan included a series of non-accelerated stalls, structural integrity tests, and accelerations. The airplane was to be stalled without leading-edge slats and, on later flights, would take off in the same condition, to determine whether the slats could be eliminated. During Mr. Ziegler's initial demonstrations of the speed brakes, the X-5 had buffeted badly at speeds where the brakes were useful. The flight test center, therefore, planned a more complete investigation of the brakes.

Flying the X-5 Number 2

Standard Air Force instruments had been mounted in the second  
85 X-5 airplane so that it could be used for Phase II flight and for  
251 any other program which might be required at a later date. In  
August 1951, General Boyd asked that the first airplane be used for  
the Phase II evaluation flights in order to avoid delays while  
awaiting completion of the second airplane. Although the Wright  
Air Development Center agreed to the suggestion, it sought the  
opinion of the National Advisory Committee for Aeronautics.  
254 Mr. William J. Underwood, the Committee's liaison officer at Wright  
Field, pointed out that if delivery of the second X-5 airplane were  
rushed only one week it would be available to the Air Force at the  
same time as the first airplane. Furthermore, such a move would  
avert a change or delay in the Committee's research plans. Never-  
274, 283 theless, the committee acceded to the Air Force's request to start  
283, 286 Phase II flights on the first airplane, using the instruments already  
installed. However, as it worked out, the Air Force received the  
second airplane before the first X-5 airplane was ready to begin  
the Phase II program.

Early in October 1951 the second X-5 airplane was ready to be  
moved from Niagara Falls to Edwards. It was suggested that the  
airplane be flown across the country from New York to California,  
but Mr. Ziegler advised that the airplane should not be flown under  
243, 252 its own power. He pointed out that a great many short flights would

be required to get the airplane to California, that special servicing crews would be needed at each stop, and that much time and money would be spent on the task. The Air Force agreed with Mr. Ziegler and ordered the second airplane flown to California aboard a C-119 transport. The airplane arrived at the flight test center on 9 October 1951--the day after the acceptance flight of the first X-5 airplane--and began its pre-flight preliminaries.

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On 10 December 1951, Mr. Ziegler flew the second airplane. It performed satisfactorily except that the cabin pressurization failed. As this could be corrected without further flight, the Air Force accepted the second X-5 airplane on 18 December 1951.

#### The X-5 as a Fighter?

On several occasions a combat version of the variable swept wing X-5 airplane was considered for production. As early as the fall of 1948--before the Air Force had established the X-5 program--Major General Kenneth B. Wolfe, Director of Procurement and Industrial Planning at the Air Materiel Command, became interested in a variable swept wing aircraft proposed by Bell. However, the Engineering Division's evaluation of the proposal was not favorable, and the matter was dropped. When the program for two experimental X-5 airplanes was launched, in February 1949, the Air Force had no plans for a tactical version of the airplane.

#### Early Proposals

Mr. Woods, Bell's chief design engineer, had designed a tactical

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variable wing airplane even before the X-5 program began. In April 1949, while visiting the Ames laboratories (as part of a western trip to obtain data for the X-5 program) he displayed a design for a low-level attack airplane powered by two ducted-fan engines and featuring in-flight variable swept wings. Instead of the wings moving fore and aft along the fuselage to compensate for changes of center of pressure and center of gravity as the wing sweep angle changed-- as was the case with the X-5--Mr. Woods planned to juggle the weight of the fuel from compartment to compartment to effect the compensation.

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Using the X-5 airplane as a basis for a tactical aircraft, Mr. Woods believed that the air intake screen protecting the engine might be altered to serve also as a radar antenna screen. The dive brakes on the X-5, he thought, might be designed to serve as a rocket launching platform.

Two months later, in June 1949, Mr. Woods explained his idea to Mr. Herald, the project engineer, who reported:

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It would appear that the X-5 type would make a suitable interceptor and "export" fighter if (1) the ducted-fan engine works out, (2) the inlet screen radar antenna and single presentation radar is OK, and (3) the combination dive brake and rocket launcher can be used.

Mr. Woods, however, apparently never got beyond the drafting board stage with either of his two plans: a two-engine, variable swept fighter or a modified X-5 tactical airplane.

General Saville Interested in the X-5

121 In July 1950, Major General Gordon Saville, Deputy Chief of  
Staff for Development at Air Force headquarters, visited Bell's  
plant. While there he expressed interest in the X-5 airplane as  
a lightweight day fighter. He asked the contractor for data on  
134, 121 the airplane in several different engine configurations. These  
data were submitted to Air Force headquarters who, in August 1950,  
139 forwarded them to Wright Field along with a request that an evalu-  
ation be made of the X-5 proposal, of an F-86E, and of a stripped  
F-86D. In addition, Washington asked for ". . . any additional  
recommendations for satisfying a possible requirement for a cheap,  
high performance day fighter. . . ."

Bell presented several major claims for its X-5 in a tactical  
configuration. It was a small simple machine which could be  
produced with fewer man-hours of labor and fewer pounds of materials  
"than any present fighter." The airplane would be able to take off  
113 from and land on 3,000-foot runways. It could be air-transportable.  
But most important of all, Bell claimed that the airplane would have  
a high speed, a high rate of climb, and great maneuverability.

Mr. Herald, speaking for the Engineering Division, took a more  
conservative point of view. He noted that larger, heavier airplanes,  
such as the F-86 or the F-89, were capable of take-off from 3,000-  
foot runways. The division conceded that the X-5 tactical version  
125 could outperform the F-86E because of its smaller size and lighter



weight; however, the X-5 would be hampered with such important items as less fire-power, less electronic equipment, and a considerably smaller range of operations (due to its limited fuel capacity). As far as the variable wing sweep aspect was concerned, the Engineering Division declared, "It is not apparent that the advantages of this feature offset its added weight and complexity."

125 The division thought that the air transportability feature might have tactical significance for certain specialized missions and that wing tip coupling for refueling or escort work might also be possible. Therefore, it suggested "the purchase of a limited quantity of X-5 types" to evaluate these possibilities.

125 In its overall conclusions the Engineering Division questioned the wisdom of any lightweight fighter. Since this type of airplane would have limited fire-power, equipment, and fuel capacity, a great number would be required for combat effectiveness. Furthermore, considerably more bases, personnel, and supplies than normally used would be required to support the larger number of aircraft. These facts indicated to the Engineering Division ". . . that a smaller, lighter airplane may not necessarily be logistically and economically sound."

#### X-5 Again Considered

A year later, in July 1951, Colonel Victor R. Haugen, chief of the Aircraft Division, Deputy Chief of Staff for Development, wrote

that the Air Force headquarters was still looking for a day air-  
superiority fighter. Although requirements for the airplane were  
not "finalized," Colonel Haugen wrote the newly operational Air  
240, 241 Research and Development Command that ". . . the present thinking  
is for a very high performance, light weight, easily produced  
fighter. . . ." The colonel asked questions about the X-5 variable  
swept wing airplane (at that time being flown at the Edwards Flight  
Test Center), "since the X-5 is one type of aircraft that approxi-  
mates the requirements under study. . . ."

Brigadier General John W. Sessums, Jr., Director of Operations  
at the Air Research and Development Command headquarters, passed the  
240 questions on to the Wright Air Development Center for action. (Again  
the X-5 project engineer--now Major Logan--wrote an opinion for the  
Weapons Systems Division's Fighter Aircraft Branch.)

Colonel Haugen's questions were: Could an airplane weighing  
10,000 pounds or less perform the air superiority mission? What  
would be the best sweep angle for the wings of such an airplane?  
240, 291 Would an airplane with two-position variable swept wings be practical?

Major Logan answered that the Weapons Systems Division did not  
believe an airplane of 10,000 pounds could accomplish the task in  
question. In fact, it would be difficult to design an airplane  
weighing 15,000 pounds that could do the job. The best wing sweep  
291 angle for an air superiority fighter, Major Logan said, was about  
40 degrees. And the tactical value of two-position variable swept  
wings was "doubtful."

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Colonel Haugen's final question was: Could the X-5 airplane be produced immediately or would another experimental model be necessary?

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The Weapons Systems Division did not favor a production model of the X-5 airplane. Major Logan pointed to the many changes necessary to make the X-5 suitable for production: the landing gears must be redesigned; the cockpit must be enlarged and modified for a standard ejection seat; new dive brakes must be designed and mounted on a different part of the airplane; and the entire airframe must be strengthened to pass structural tests. Of more importance, Major Logan said, was the entire redesign job on the X-5 to provide adequate stall warning in the clean configuration. An entirely new engine mounting provision had to be made and the airplane redesigned so that the fuel supply was not carried directly over the engine. At the same time the fuel capacity of the airplane would have to be doubled. By this time, Major Logan concluded, the resulting airplane would no longer even resemble the X-5 research aircraft.

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Nevertheless, the major said that Edwards would conduct a flight test program to evaluate the X-5 for day fighter use. Besides general performance tests, a simulated combat flight was to be made, using the best wing sweep angle for each phase of the mission.

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Finally, the simulated combat flight would be duplicated with the wings stationary at the best compromise wing sweep angle--probably between 40 and 45 degrees--to provide an evaluation of the variable swept wings of the X-5 airplane.

Early in 1952, just after the X-5 airplanes were accepted by the Air Force and Phase II flight testing was to begin, Air Force headquarters halted the day fighter evaluation tests on the airplane. The X-5 was no longer being considered for tactical use. Bell was so informed, and the X-5's were released to the National Advisory Committee for Aeronautics for research and to the Air Force for Phase II flying.

\* \* \*

Elimination of the X-5 from consideration as an Air Force weapon did not close the story on variable swept wings. In fact, soon after the order removing the X-5 from consideration was issued, another strange airplane was rolled out at the flight test center. This was a great-grandson of the famous old F4F "Wildcat," the Navy's new Grumman F10F carrier-fighter, featuring two-position, in-flight variable swept wings.\*

\* \* \*

Although the Air Force could foresee no tactical application of inflight variable wing sweep, at least for the present, this did not mean that the X-5 would not be a valuable research tool to the National Advisory Committee for Aeronautics (and the Air Force) in the job originally scheduled for it. Both organizations expected

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\*Interview, Lieutenant (JG) F. Blaser, USN, Office of BACR-CD, Wright-Patterson Air Force Base, 2 June 1953.

to obtain considerable basic aerodynamic information on the subject of wing sweep angle from the Committee's research flights.

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