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THE BELL X-5 RESEARCH AIRPLANE

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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

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
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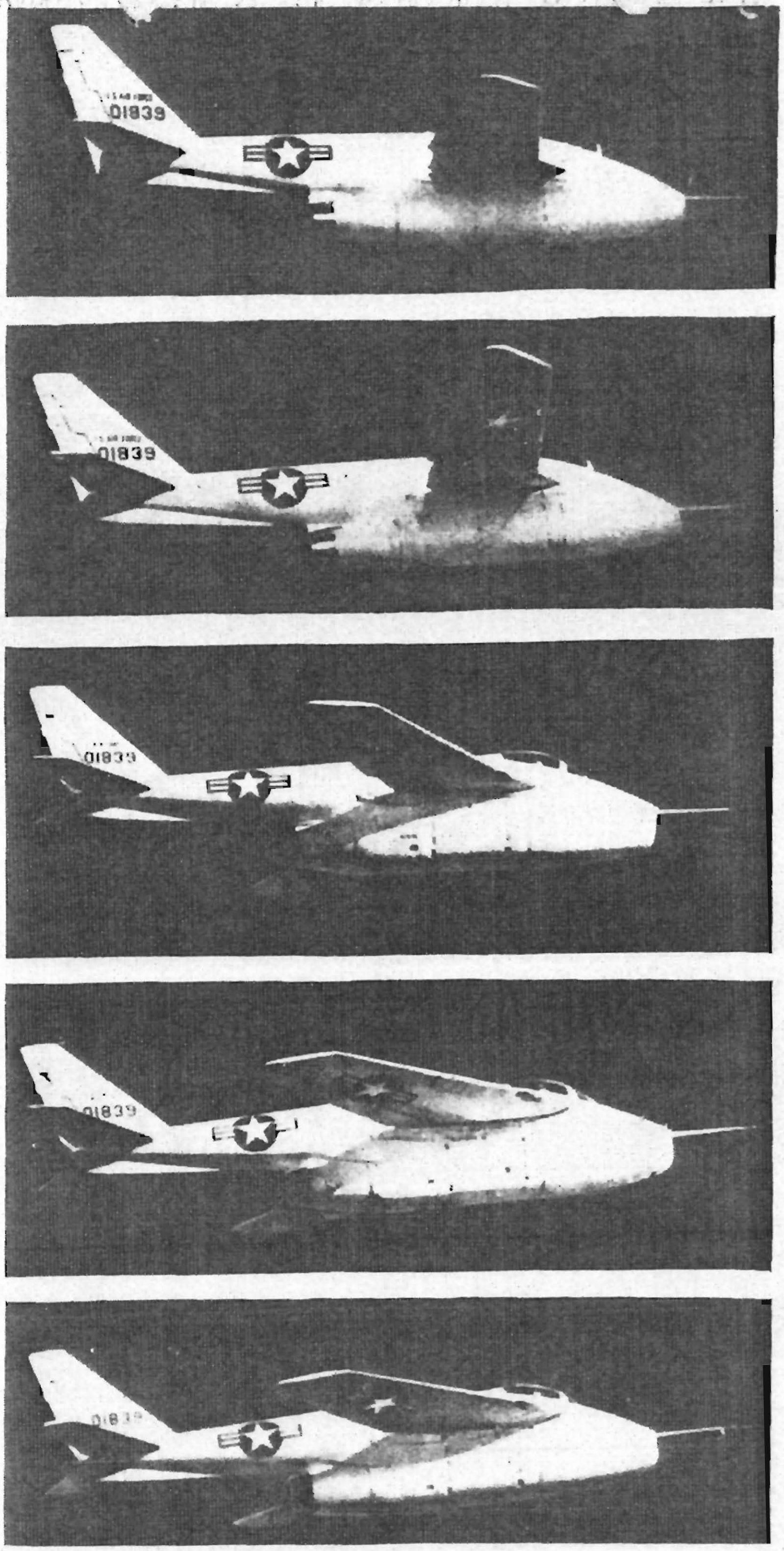

X-5 SHOWS HOW IT DOES IT

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.

AVIATION WEEK, Vol. 56, No. 16. April 21, 1952. p. 15

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
122 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
201 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 $33\frac{1}{2}$ feet long,
4, 20 measured $32\frac{3}{4}$ 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
210 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.

4 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

9, 17 into a contractual document, the project officer initiated a purchase request for $1,500,000 to get the X-5 work under way.

11, 13 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

38, 131 number AF33(038)3298 was written. This contract provided

196, 197, 205 $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

15 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

57 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

107 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.

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
112 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.

In August 1950 a purchase request for $1,000,000 to cover the
115 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 dickering 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.

Bell justified the request by stating that it desired to meet
45 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 reinbursement 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 development.
Nevertheless, since this "prior research" was incorporated
into the program, Bell maintained that it should be paid for the work.

Under the terms of the contract (Article 3, paragraph b, 1),
38 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
59 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
61 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
67 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
14, 16, 93, 104, 136, 150, 154 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

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.

The original estimates of the X-5 program, plus the overrun,
82, 223 the changes in specifications, the mock-up changes, the cost of the
225, 226
309 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.

<u>Details of Design</u>

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
58 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.

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
58 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
32, 54 supply directly over the engine. The laboratory asked for a change;
73 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
54, 60 between the engine and the fuel compartment. Ventilation was pro-
258 vided between the walls to guard against the accumulation of fumes.

The National Advisory Committee for Aeronautics objected to
39 the design of the tail pipe. However, there was insufficient infor-
mation available to justify changing the design of the airplane.
Pending results of tests on the XF-88 airplane, which also had an
16 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.

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

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
14, 16 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.

The alternate controls proposal was eventually discarded. Space restrictions forced the auxiliary lines into approximately
145 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
156 of the alternate controls, and the Air Force approved.

Later the Air Force requested additional shields around the rotating sections of the engine. Bell thought this complicated the
145, 156 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
49 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.

The Committee desired fighter aircraft load factors used on
the X-5, provided there was not too heavy a weight penalty involved.
14, 16 It also thought that the airplane would require speed brakes. (These
40, 41 brakes were placed in an unusual position: forward of the wing roots,
near the nose of the airplane.)

Instruments for the X-5

The X-5 airplanes were designed to carry 500 pounds of National
202, 33 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,
147, 244 initially had Air Force instruments for the Phase II flight testing.
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

When the program started, the Air Force and the contractor
43, 46 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

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

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
68 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.

Two months later, on 6 and 7 December 1949, the mock-up
74, 75 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 representa-
74, 75 tives 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.

Three months after the inspection, Bell estimated that the
78, 83, changes requested by the mock-up board--plus the changes directed by
86 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

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
34 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.

Apparently some misunderstanding arose over the model. In
76 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.

Spin recovery tests of the stronger model were ready to start
94 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."

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.
102 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

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
103 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.

The advisory committee and the Air Force agreed that the tests
would be valuable. A supersonic wind tunnel model was already on
106 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.

Like the full-scale X-5 test results, the supersonic tunnel model tests were to become part of the National Advisory Committee
106 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

The engines of the X-5 were placed below the fuselage for
32, 54 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.

The Allison J-35-A-17 engine, used in the F-84 Thunderjet, was
210 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-
22 pound thrust, was limited in performance to a speed just under Mach
10 1.0. Four engines were procured--two for the airplanes and two as
27 spares. In May 1949, Allison furnished Bell with the first engine,
31 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
62 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.

A Westinghouse XJ-46-WE-2 engine, generating approximately 6,000
68 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

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
113 powerful engines for the X-5--and the underslung mounting feature
made the airplane readily adaptable to a variety of engines.

In February 1951, Bell suggested that a Wright J-65 Sapphire
engine be installed. The company claimed that this engine would
182 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
belief that XJ-46 engines would not be plentiful enough to allow
247 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.

<u>Landing Gears</u>

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

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
53, 56 the Government approximately $6,500.

Hydraulic System

Bell designed an open center hydraulic system which controlled the operation of the landing gears and allowed pressure in the unit
79 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.

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
79 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

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

Weakness of the X-5 Landing Gears

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
58 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.

In May 1951, at the time of the Engineering Inspection just
202 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
219, 235 of having a subcontractor work on heavy duty shock struts to replace
the aluminum alloy ones, if that became necessary.

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
262, 264 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 accidently 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
262, 264 the flap switch to "down", but continued to hold the rate of
270 descent. The airplane hit the ground in a slightly nose up position
bounced off again. The flaps had, meantime, reached the down posi-
tion 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
16, 209 as those used on the Navy's experimental D-558-II research airplane,
221, 224 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
270 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
267, 273 gear had also been damaged. Tools were secured to begin repairs, and
276, 285 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

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
23, 201 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
23, 201 sweep, they were about 27 inches forward of their starting position.
21 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
14, 16, 68 simultaneously, as the sweep and positioning components were geared
together. The entire process of moving the wings from the 20 degree
41 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
72 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
23 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.

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
66, 81 and apply unsymmetrical pressures during 600 cycles of operation
91 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
81 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.

89, 92 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
95 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

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.

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
124 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.

Shortly after Bell started evaluation of the mechanism, the
142 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

next flight, the pilot swept the wings to 40 degrees. The emergency
236 hand crank for the system would not operate, so Mr. Ziegler discon-
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
242 was reworked so that it would operate, but only after the pilot
exerted great pressure to turn it. The crank was removed from the
288 airplane and re-geared. This change allowed the handle to move
easily, although more turns were necessary to operate the wings
through the entire range of sweep.

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

<u>Weight of the Wing-Sweep Mechanism</u>

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

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

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

<u>Wing Root Fillets</u>

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.

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

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.

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

Control Surface Testing

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
174 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

Vibration tests on the X-5 airplane were conducted with the
174, 190 same equipment used for the flutter evaluations. First results
from the tests showed that the wing torsional frequency (frequency
172 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.

The Engineering Division wondered if the Bell engineers had
190, 212 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 mathematical
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
239, 231 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
30 angles of sweep, which caused the ailerons to act as elevators.
231 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
228, 229 to ask if the Wright Field engineers meant 425 knots. A 425 miles
233 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
268, 275 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
293, 295 knots (about 677 miles an hour), the design speed of the airplane.
306 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
280, 327 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,
111 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
141 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.

The Phase I program normally ". . . would require only 30
to 40 hours," Mr. Herald replied, "but, because the various sweep
144 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 oppor-
tunity to study the flight program before it was approved.

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
132 the rolling effectiveness of the ailerons. Moreover, the Air Force
wanted landings and take-offs demonstrated from only a few wing
sweep positions.

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.
137 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.

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
132 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 calandar time required to complete the testing.

The company submitted a revised flight test program calling for 66 hours of flying. While the plan did not meet requirements
149 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 nego-
161 tiations. The Air Force Flight Test Center objected to any such

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

Three months later, Bell was still putting pressure on the Air
Force plant represenatives 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
183 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 experi-
mental 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

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

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

On the morning of 20 June 1951, Mr. Ziegler flew the X-5 for
213 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.

Normally, first flights of any new aircraft receive full
162 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

the handling characteristics of the airplane and conducted structural
220 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
261 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

256 On 21 August 1951, Brigadier General Albert Boyd, commander
of the Air Force Flight Test Center, received permission from Wright
257 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
259, 261 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 accidently tripped the flap switch while demonstrating
a 40 degree wing sweep landing. By the time he had the flaps down
270 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
260 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.
266 When that occurred, the airplane would be given an acceptance flight
287 and the Air Force would take it over.

232, 253, 271, 272, 273, 276, 279, 281, 284, 285, 288, 290, 289, 294, 305, 307 The contractor spent a number of weeks cleaning up some pre-
acceptance work on the X-5 airplane, which consisted largely of
items from the Engineering Inspection. Bell performed its final
flight on the first X-5 on 8 October 1951, and it was formally
accepted by the Air Force on 7 November 1951.

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
299 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 buffetted 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.

292, 294, 297, 301, On 10 December 1951, Mr. Ziegler flew the second airplane.
307, 310, 311, 313, It performed satisfactorily except that the cabin pressurization
314, 315, 317, 318, failed. As this could be corrected without further flight, the Air
322, 321, Force accepted the second X-5 airplane on 18 December 1951.
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328

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
122 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
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

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
28, 29, 30 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 compensa-
tion.

Using the X-5 airplane as a basis for a tactical aircraft,
28, 30 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:

> 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
> 49 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

In July 1950, Major General Gordon Saville, Deputy Chief of
121 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."

The division thought that the air transportability feature might have tactical significance for certain specialized missions and
125 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.

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,
125 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."

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

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
291 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.

Nevertheless, the major said that Edwards would conduct a flight
test program to evaluate the X-5 for day fighter use. Besides
291 general performance tests, a simulated combat flight was to be made,
using the best wing sweep angle for each phase of the mission.
Finally, the simulated combat flight would be duplicated with the
wings stationary at the best compromise wing sweep angle--probably
300 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
325 headquarters halted the day fighter evaluation tests on the airplane.
The X-5 was no longer being considered for tactical use. Bell was
326 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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