Copy 468

~~CONFIDENTIAL~~

NASA TM X-715

NASA TM X-715

GPO PRICE $ ________

OTS PRICE(S) $ ________

Hard copy (HC) $1.00

Microfiche (MF) .50

TECHNICAL MEMORANDUM

X-715

RÉSUMÉ OF HANDLING QUALITIES OF THE X-15 AIRPLANE

By

Major Robert M. White, USAF

Air Force Flight Test Center
Edwards, Calif.

and

Glenn H. Robinson and Gene J. Matranga

Flight Research Center
Edwards, Calif.

DECLASSIFIED BY AUTHORITY OF NASA CLASSIFICATION CHANGE NOTICES NO. 14 DATED 4-21-65 ITEM NO. 1

DECLASSIFIED: Effective 2-5-65
Authority: F.G. Drobka (ATSS-A)
memo dated 3-25-65: AFSDO-5197

FACILITY FORM 602

N65-23923 (ACCESSION NUMBER)

19 (PAGES)

(THRU)

1 (CODE)

02

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON March 1962

~~CONFIDENTIAL~~

1L

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TECHNICAL MEMORANDUM X-715

RÉSUMÉ OF HANDLING QUALITIES OF THE X-15 AIRPLANE* **

By Robert M. White, Glenn H. Robinson, and Gene J. Matranga

USE CARD in BACK

H270

SUMMARY

The handling qualities of the X-15 research airplane are assessed from pilot opinion, with verification in many cases by data acquired during flights. Areas of interest covered are the launch, climbout, semiballistic flight, atmosphere entry, and landing phases of X-15 flights.

INTRODUCTION

The concept of aircraft handling qualities has been specified since World War II to provide certain performance features, such as rolling velocity and stall warning, and a desired level of static and dynamic stability to allow the pilot to fly the aircraft with relative ease. Although great efforts have been made to assign quantitative values to these parameters, to a great extent how the airplane flies is assessed through pilot opinion. Both pilots and engineering analysts might do well to accept this thesis, for to quote one well-used text book (ref. 1): "The desired magnitude of dihedral effect has never been very successfully determined. From the analysis of many stability and control flight tests, it has become apparent the pilot likes to have some dihedral effect, but not too much."

This résumé covers in broad aspects many of the handling features of the X-15 from launch to landing. Some conclusions can be drawn, but many comments regarding handling-quality specifications for hypersonic and high-altitude flight must be delayed until future flights are made and the data thoroughly examined.

---

*This document is based on a paper presented at the Conference on the Progress of the X-15 Project, Edwards Air Force Base, Calif., November 20-21, 1961.

**Title, Unclassified.

[redacted]

SYMBOLS

a_l	longitudinal acceleration, g units
a_n	normal acceleration, g units
g	acceleration due to gravity
M	Mach number
p_{max}	maximum angular rolling velocity, deg/sec
$\dot{q}$	angular pitching acceleration, deg/sec^2
$\bar{q}$	dynamic pressure, lb/sq ft
$\bar{q}_{max}$	maximum dynamic pressure, lb/sq ft
$(W/S)_{av}$	average wing loading, lb/sq ft
α	angle of attack, deg
α_{trim}	trim angle of attack, deg
β	angle of sideslip, deg
$\Delta\varphi_{max}$	maximum roll-angle increment, deg
δ_h	horizontal-tail deflection, deg
ζ	damping ratio
θ	pitch angle, deg
ω_n	natural frequency in pitch, radians/sec

X-15 COCKPIT

Since frequent reference will be made to the pilot's cockpit, some of the salient items used for display and control are shown in figure 1.

The display is conventional in that it shows in standard fashion the operating level of many of the aircraft and engine systems. The flight phase is monitored chiefly from the inertial system which provides readout in altitude, velocity, and aircraft attitude. Additions from the flow-direction-sensor ball nose provide pointers and cross bars that allow the pilot a reading of angle of attack and vernier indications of angle of attack and sideslip. Prime reliance is placed on the attitude indicator in three axes, inasmuch as the earth's horizon is quickly lost as an outside reference during the high-pitch-angle climb experienced on all flights. Simplicity is the key, and small changes are being made continually, as requested by the pilots, to provide a readable display for the rapid cross checks that a pilot makes in a fast-moving situation.

H270

Control is afforded in several ways. Aerodynamic control is provided by a conventional center stick or by an interconnected side stick positioned to allow pilot control without inadvertent or adverse inputs from acceleration forces. Reaction control for attitude control at low dynamic pressure is given by a simple controller on the left side of the cockpit that allows inputs in roll, pitch, and yaw.

LAUNCH AND CLIMBOUT

Two areas common to all flights, the launch and initial climbout, have been studied in detail. The launch is characterized by two prominent features: first, a sudden departure from the B-52 pylon, yielding a zero g peak normal acceleration, and, second, an abrupt roll-off to the right that rarely exceeds a 10° to 15° change in bank angle. The release is what might be expected and, after the first experience, is of no concern to the pilot inasmuch as normal 1 g flight is regained within 2 seconds. The roll-off at launch stops as the X-15 emerges from the B-52 flow field. Since the bank-angle change is small, it is easily and quickly corrected. Launch has been made by using either the center or side aerodynamic control stick, with equal satisfaction in both cases. In addition, launch has been made with the control neutral, correcting the roll-off as it occurred, and with small lateral-control input to counteract the roll before it could develop. Both methods have been acceptable and resolve into individual pilot's technique and preference.

Immediately after launch the engine is fired and the climbout begins. Assume, for a moment, that a long delay occurs before engine ignition, which has been true on several occasions. The pilot glides at an angle of attack of 8°, which is near the best lift-drag ratio for glide; the aircraft responds well and is free of buffet. If angle of attack is increased to 10°, a mild buffet onset is immediately detected, which allows the pilot to make corrections well in advance of a stall condition. The aerodynamic qualities, then, at 45,000 feet, a Mach number of 0.8, and maximum weight are considered excellent. Very

[redacted]

quickly after engine light-off, supersonic speed is reached and an angle of attack of 10° is maintained to rotate the airplane to a climb-out pitch angle that is established by the mission requirement. Buffet is absent above a Mach number of 1.0, but a nosedown trim change occurs between Mach numbers of 1.1 and 1.4. Figure 2 illustrates this trim change. Note that the piloting task in the low-supersonic speed range calls for constant angle of attack. In order to maintain constant angle of attack, the pilot must trim in substantial up-stabilizer. Frequently, the speed change is so rapid (approximately 6 seconds from M = 1.1 to 1.4) that the pilot has difficulty keeping up with the trim change. As a result, the angle of attack in this speed range is usually lower than desired. The trim change is mild, however, and has not received the objections from pilots that have often been given to the more abrupt trim change in the transonic region below a Mach number of 1.0 that occurs on many jet aircraft.

CONTROL CHARACTERISTICS

Figure 3 presents the details of an altitude mission which reached 217,000 feet and which enables many comments to be made pertinent to X-15 flight control characteristics. After initial rotation at an angle of attack of 10°, a constant pitch angle of 32° is established and maintained to burnout where the acceleration along the longitudinal axis a_l reached 3.6g. From engine burnout until the reentry, the aircraft followed a ballistic trajectory. Two unique features that occurred are weightlessness experienced by the pilot for about 2 minutes and the requirement that reaction controls be used since dynamic pressures have decreased to a minimum of 3 pounds per square foot at peak altitude. This part of the flight is followed by the reentry maneuver, which terminates when the aircraft rotates to level flight after experiencing, as in this case, normal acceleration a_n of 3.8g, longitudinal acceleration of -2.2g, and peak dynamic pressure in excess of 1,400 pounds per square foot.

The portion of the profile during exit is particularly pleasing to the pilot since the airplane is very stable and the damping appears adequate, even with roll and yaw dampers failed. The increase in acceleration along the longitudinal axis during the thrust period reaches a maximum of 3.6g at burnout. The acceleration level, although certainly noticeable to the pilot, has not been high enough to provide any adverse comment in regard to impairing the pilot's ability to perform his essential tasks. Thrust termination during flight occurs when the pilot stops the engine or when burnout results from propellant exhaustion. In all cases there have been no transient aircraft motions, and thrust misalinement has not been a factor of concern. The stabilizer is trimmed to maintain an angle of attack of 0°. This change in trim is complete at

[redacted]

approximately 145,000 feet, where dynamic pressure has decreased to 26 pounds per square foot. At this point a decay in response to aerodynamic control is easily noted by the pilot, and reaction controls are then employed. The reaction controls proved to be very effective, aircraft response to inputs in roll and yaw were good, and the response in pitch was more than desired and caused some difficulty in damping the pitch oscillations.

Ballistic Control

The motions in the ballistic flight region can best be illustrated by the time history shown in figure 4, which includes that part of flight at dynamic pressures of less than 10 pounds per square foot. Plotted are the angle of attack and airplane pitching acceleration $\dot{q}$ which developed as a result of the use of reaction control. All reaction-control inputs were essentially in the proper direction to damp the airplane motion except at one point where the angle-of-attack oscillation experienced its largest excursion. At this point an input was made that reinforced the increase in angle of attack, but immediately afterward the pilot was able to damp the oscillation adequately to maintain the desired angle of attack. Although the longitudinal control task was complicated by the presence of an out-of-trim stabilizer condition, the results are indicative of control difficulties that can be encountered with an acceleration-command reaction control system. Since this figure presents results of the first and only significant reaction-control experience with the X-15, proper longitudinal control trim and pilot experience are expected to yield an improvement in airplane attitude control at low dynamic pressure. The excursions in sideslip were contained to acceptable limits by using reaction control. Similar results were evident in bank-angle control. Lateral-aerodynamic-control inputs were used at low dynamic pressure with no apparent response compared with the good response and control afforded by reaction control. Pilot technique in this region was use of reaction control in one axis at a time.

Zero g, although an interesting area to consider, has had no noticeable effect on the pilot control task for the approximate 2-minute period during which the weightless state was experienced.

The presentation for control is provided by cross bars, shown in figure 5, to allow flying at prescribed values of angles of attack and sideslip. As can be seen, these bars are incorporated within the face of the attitude indicator which additionally provides roll information for control inputs. Inasmuch as the pilot is now manually controlling attitude about three axes without any damping system, the instrument presentation is considered adequate; all information is displayed centrally and minimizes scanning and instrument cross-check.

Control During Reentry

The reentry maneuver is perhaps the most interesting from the pilot's standpoint, since it is flown at relatively high angles of attack and under rapidly changing conditions of dynamic pressure, temperature, and velocity, with the associated changes in aircraft stability and responses. The maneuver actually begins as the aircraft passes through 180,000 feet (see fig. 3) where the stabilizer is trimmed to a value that will maintain reentry normal acceleration. The reaction control is used to establish the reentry angle of attack.

H 2 7 0

The time history shown in figure 6 begins immediately after the stabilizer has been trimmed for reentry. With the stabilizer constant and the angle of attack raised to 10°, the normal acceleration a_n increases to approximately 2g as the dynamic pressure $\bar{q}$ increases. The angle-of-attack decrease results from a repositioning of the stabilizer to maintain the reentry acceleration until level flight is regained just above 60,000 feet. Returning to the point where reentry angle of attack was reached, but just prior to significant change in dynamic pressure, a sideslip oscillation developed but was low enough in magnitude and frequency to be disregarded by the pilot, particularly since it damped adequately as dynamic pressure increased. It is interesting to note that the static simulations and the Johnsville centrifuge program provided good training for these conditions so that the actual reentry did not result in a completely new or unexpected flight experience.

Other Control Features

Several features, common to all flights, can be noted prior to a discussion of the terminal and landing phases of the X-15.

The speed brakes have been used in many areas throughout the speed and altitude range, under thrust, and after engine shutdown. Except for incremental use in the landing pattern, they have always been extended symmetrically, that is, with equal brake deflection for the segments both above and below the fuselage, and opened to full deflection. During extension there is a mild trim change. Aside from the trim change, no undesirable aircraft motions have been experienced with speed-brake use; the brakes are extremely effective, and there has never been a report of buffet due to speed-brake deflection.

Lateral control of the aircraft has been effected by differential deflection of the horizontal stabilizer, that is, the so-called "rolling tail." This method of lateral control has been excellent on the X-15. The pilot is not aware of what specific type of lateral control is allowing the roll motion. His only concern is in being able to get the aircraft response he calls for when deflecting the control stick. Figure 7 shows many representative points obtained in flight and illustrates the comparatively low roll rates and moderate bank-angle changes associated with the X-15 mission. From the flight experience, the rolling tail has provided a good rolling control for the X-15, and there have been no undesirable aircraft motions coupled in any axis because of lateral-control deflection. It is true that inertial coupling is a factor under specific conditions of dynamic pressure, angle of attack, and rolling velocity, but no attempt has been made to verify such predictions by specific roll-performance flight tests, aside from determining lateral effectiveness and using roll control only as required on any particular flight.

H
2
7
0

The stability-augmentation system which provides rate damping about all axes has had significant effect on pilot opinion. During early flights below a Mach number of 3.5, moderate gains were used. Pilot opinion expressed a desire for a stiffer aircraft, particularly in pitch and roll, and flights above $M = 3.5$ have used considerably higher gains. In general, pilot opinion of the augmented handling qualities in the Mach number range from 2.5 to 6.0 has been favorable. It is interesting to note that, at an angle of attack of 8° and above with low damper gain and particularly with roll or roll and yaw dampers off, the pilot has great difficulty in controlling the lateral and directional motions to prevent divergence. This difficulty is caused primarily by an adverse dihedral effect which is present at Mach numbers above 2.3. This problem has received a great deal of attention. A summary of the area of unaugmented X-15 lateral and directional characteristics is presented in reference 2. With dampers set at high gain, however, the lateral and directional characteristics have been acceptable to the highest angle of attack explored, approximately 17°.

The pilot ratings (P.R.) for longitudinal controllability are summarized in figure 8 as a function of frequency ω_n and damping ratio ζ and are compared with criteria developed by the Ames Research Center (ref. 3) from simulator studies of reentry vehicles. The X-15 flight data obtained during powered and unpowered flight are shown by circular symbols (according to pilot rating), and the comparative Ames results are indicated by the curves. Most of the X-15 data have satisfactory ratings including one of the two points representing damper-off conditions. In general, the correlation between the X-15 flight points and the Ames criteria is good. It appears, however, that the damper-off points were rated in flight more favorably than would be predicted from simulator results.

The side aerodynamic control stick designed for the X-15 has received the usual critical analysis associated with a departure from the conventional control. Most of the factors considered are included in the following tabulation:

Force gradients - sensitivity
Dead band - centering
Control harmony
Utility at high acceleration
Controller geometry and location
Trim control

H270

As experience using the side stick was gained and modifications were attempted to make each factor fully acceptable to the pilot, most features included in the initial design were found to be satisfactory. All pilots agree to the utility value of the side stick at high acceleration; however, the location of the control in relation to the pilot's arm position proved most critical. A modification allowed the selection of five different positions, which provided for adjustment of the control stick, fore or aft prior to flight, to satisfy an individual pilot's desire. The trim control remains controversial, and further evaluations will seek the best compromise between a wheel or button control and the best location for it on the stick. In general, the control has been most desirable on many occasions and has been used entirely on some flights from launch to landing.

LANDING TECHNIQUES

The final phase of each flight is, of course, the landing. This area has progressed from one receiving a great deal of concern and attention in the first flights to routine operation based on the experience, procedures, and techniques developed (see ref. 4).

Prior to and during the X-15 flight program, landing simulations have been made by using the F-104 airplane. With predetermined settings of the lift and drag devices and the engine thrust, the lift-drag ratio is established to match that of the X-15. This experience allowed the pilots to establish geographic checkpoints and key altitudes around the landing pattern; pilots thus become familiar with the position and timing required in the pattern by the low lift-drag ratio. At present, prior to each X-15 flight, the pilot devotes an entire F-104 flight to approaches and landings in what is considered satisfactory preparation and practice for the landing maneuver.

Space positioning of the X-15 for a landing is shown in figure 9, which illustrates the wide range of conditions in altitude at the high key and lateral dispersion from the touchdown point. This figure indicates the flexibility allowed the pilot in maneuvering to a designated touchdown point. This flexibility is primarily attributed to several factors. The pattern is normally flown at an indicated airspeed of 300 knots, and the handling qualities, including the control-system use and the airplane responses, are considered excellent. If less sink rate is desired, the aircraft can be flown at an indicated airspeed of 240 knots for best lift-drag ratio; and, if necessary, excess altitude can be lost at constant airspeed by use of the speed brakes. Although rates of sink average 250 feet per second and have been as high as 475 feet per second prior to landing flare, none of the pilots has considered these values to be a limiting factor in the pattern.

H 2 7 0

A summary of flare characteristics is shown in figures 10 and 11. Note again the wide range of conditions that a pilot can choose to arrive at a similar landing. The flare-initiation altitude shown in figure 10 has generally averaged less than 1,000 feet but covers a wide range of airspeeds.

In figure 11, the average vertical velocity at the flare ranges between 100 and 180 feet per second, which is usually at a lower rate of sink than that for steady glide. This reduction is generally a result of deceleration during the approach. Aside from airspeed control, the cues that a pilot uses are all external. A landing point is chosen and the flare point is selected so that the remaining energy will carry the aircraft to the intended touchdown spot. The flare altitude is not selected from the altimeter, but from the pilot's own estimate of the height necessary to reduce the sink rate and arrive level in proximity to the ground. It is significant that as flight progressed, the flare speeds increased, not to seek better handling qualities, which are good throughout, but to gain more time after the flare to make configuration changes, correct trim changes, and then execute the landing at acceptable values of angle of attack, sink rate, and proximity to the intended landing point.

Pertinent touchdown parameters are presented in figures 12 and 13. As is shown in figure 12, most landings have been accomplished with vertical velocities of less than -5 feet per second at angles of attack between 6° and 8°. Ground effect, while noted in some cases, has not been a significant factor in the pilot's analysis of the landing. In each of the last 20 landings a specific spot has been used for the intended touchdown point. In figure 13, all but four landings have been grouped within ±1,200 feet of that spot. This degree of precision is considered to be very good. The landing summary shown reveals an average slideout distance from touchdown of 5,000 to 6,000 feet. The shortest distance can be achieved by using full aft longitudinal control and flap retraction to place the greatest load on the skids, and full deflection with speed brakes for added drag. In addition to good inherent directional characteristics on the ground, the pilot has used lateral-control inputs to provide greater load on one skid and achieve some measure of directional control.

[redacted]

In summarizing the landing information, it is considered important to indicate that the pilot, provided an aircraft with good control and handling qualities as represented in the X-15 in the landing pattern, can intercept the pattern at any one of its key positions, can make adjustments based on his experience, judgment, and reactions to the many cues available, and can complete a satisfactory landing in proximity to a designated landing spot with a power-off, low-lift-drag-ratio airplane. Experience with the X-15 has included landings with various dampers inoperative, a few recent landings using only the side-located controller, and one recent landing with one windshield outer panel shattered to the point of being opaque, with an attendant compromise in the pilot's visibility and the landing task. These landings have been equally satisfactory and are grouped with the other data presented.

CONCLUDING REMARKS

This summary of X-15 handling qualities has been, in general, an expression of pilot opinion, verified in many cases by the data acquired, rather than an attempt to compare with specifications. Obviously, the main concern in expanding the flight envelope to design speed and altitude has been a detailed analysis of each forward step taken so that it could be achieved safely. With these missions completed, flights can now be performed within the flight envelope with an aim to gathering handling-quality data as they compare or relate to formulating detail specifications.

The flight environment into which the X-15 has been flown has not indicated a significant change in handling-quality specifications as they are known today. In this sense the performance of the X-15 can still be related to that of certain of the century-series fighters, despite their vast performance differences. The pilot still desires an excellent control system, insists on the aircraft responding to his inputs at the rates he desires, and is displeased with undamped oscillations about any axis. Certain differences in what the pilot desires may become evident whether he is flying an X-15 or an operational fighter. When proceeding in unexplored regions in an X-15, pilots prefer having damping in roll and a high longitudinal damping, probably because it gives a feeling of security to have a solid airplane. In the fighter, excessive damping might inhibit the ease with which a pilot can track a target. In the past, pilot preferences have been translated into design specifications regarding handling qualities. From pilot experience, it seems apparent that many of the procedures followed in the X-15 program will be used for future hypersonic and aerodynamic reentry vehicles.

Flight Research Center
National Aeronautics and Space Administration
Edwards, Calif., November 20, 1961

REFERENCES

H270

1. Perkins, Courtland D., and Hage, Robert E.: Airplane Performance Stability and Control. John Wiley & Sons, Inc., c. 1949.

2. Petersen, Forrest S., Rediess, Herman A., and Weil, Joseph: Lateral-Directional Control Characteristics of the X-15 Airplane. NASA TM X-726, 1962.

3. Creer, Brent Y., Heinle, Donovan R., and Wingrove, Rodney C.: Study of Stability and Control Characteristics of Atmosphere-Entry Type Aircraft Through Use of Piloted Flight Simulators. Paper No. 59-129, Inst. Aero. Sci., Oct. 5-7, 1959.

4. Matranga, Gene J.: Analysis of X-15 Landing Approach and Flare Characteristics Determined From the First 30 Flights. NASA TN D-1057, 1961.

H-270

X-15 COCKPIT

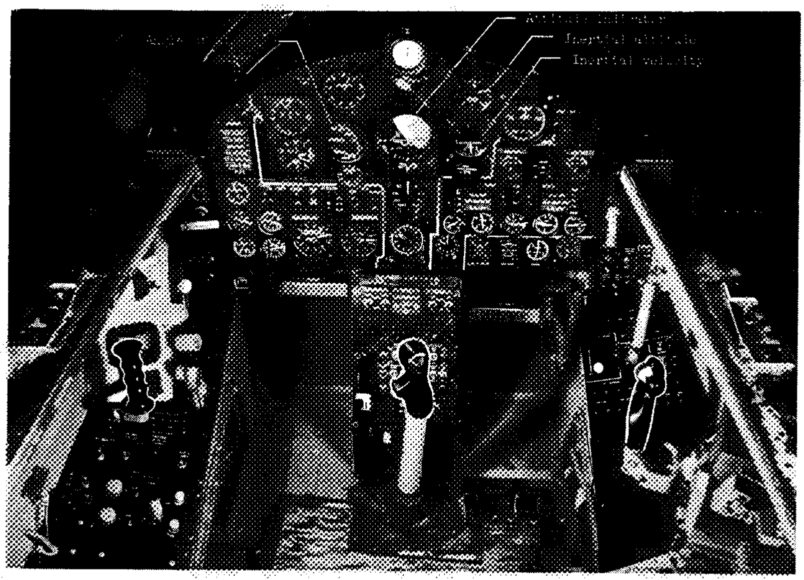

Figure 1

LONGITUDINAL TRIM CHARACTERISTICS

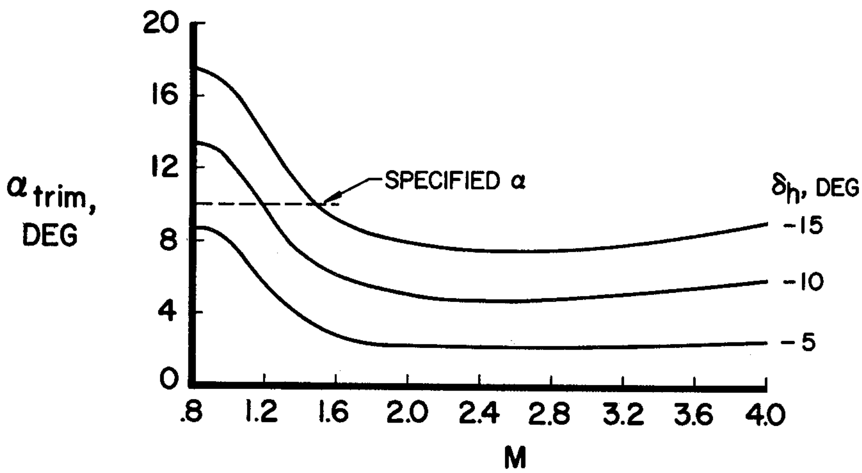

Figure 2

[redacted]

H-270

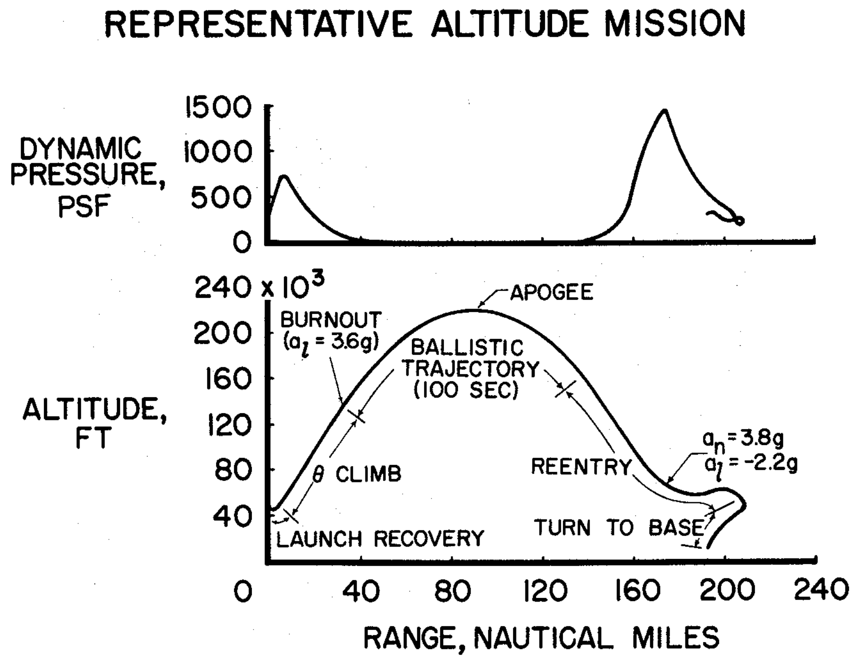

Figure 3

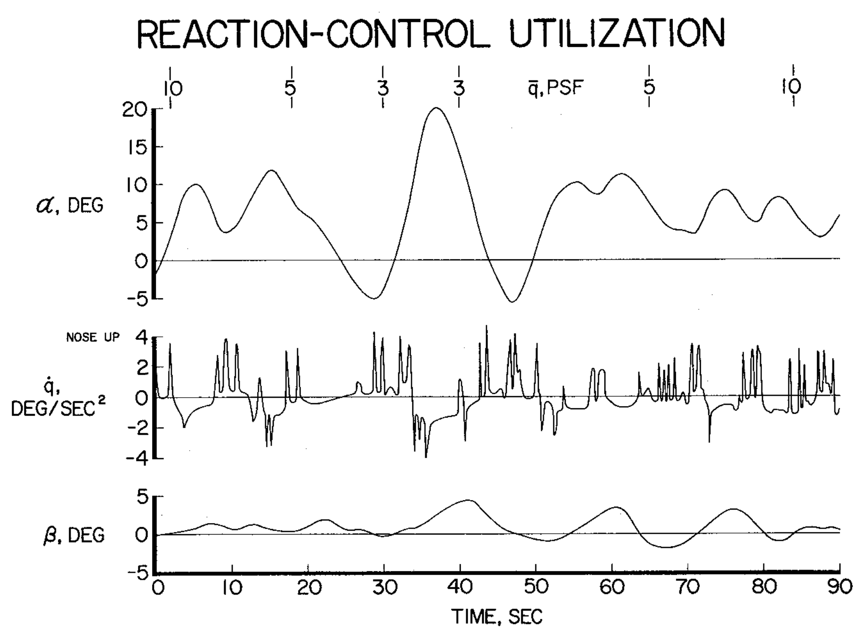

Figure 4

[redacted]

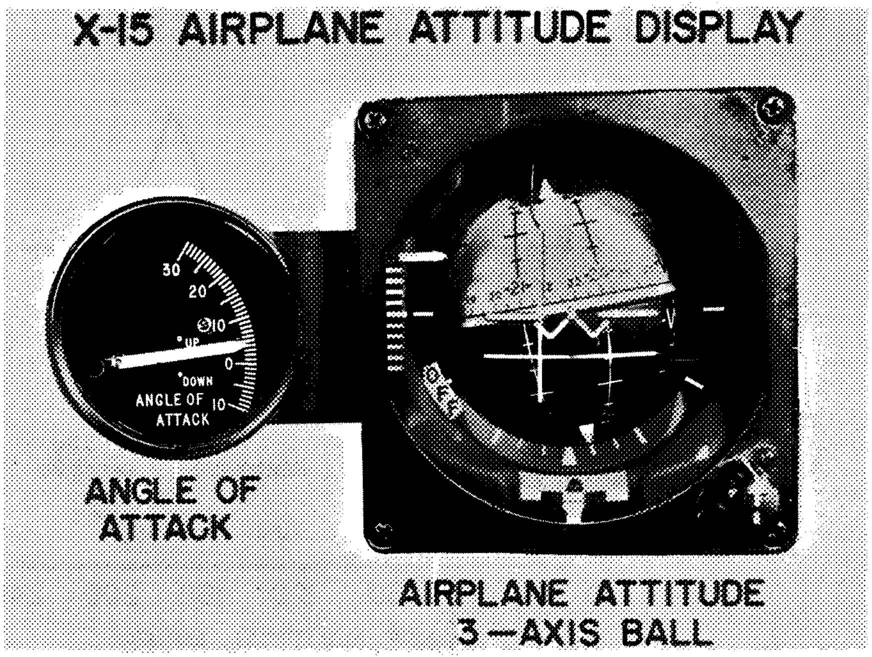

Figure 5

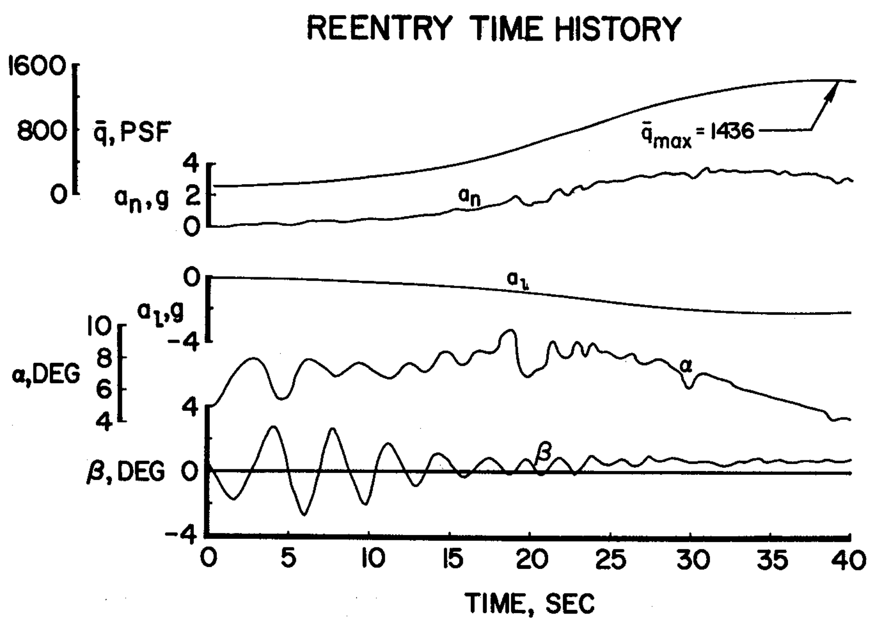

Figure 6

[redacted]

H-270

X-15 LATERAL-CONTROL UTILIZATION
M=2.5 TO 5.5

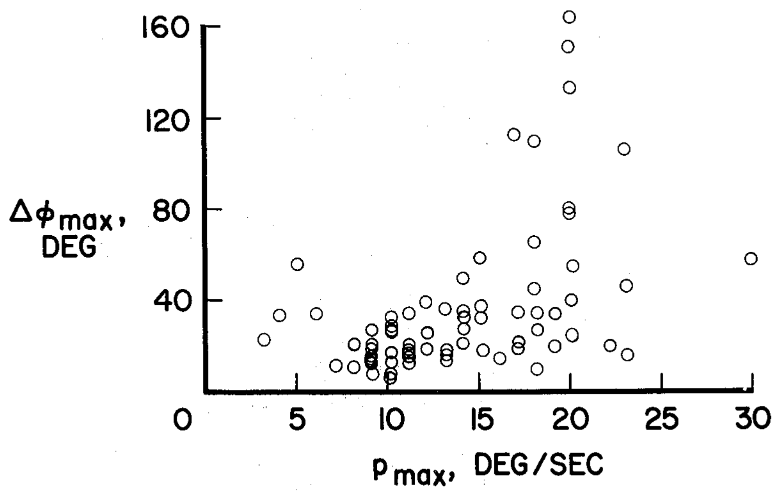

Figure 7

SUMMARY OF X-15 LONGITUDINAL HANDLING QUALITIES
M=2.5 TO 5.5, q=100 TO 1,400 PSF

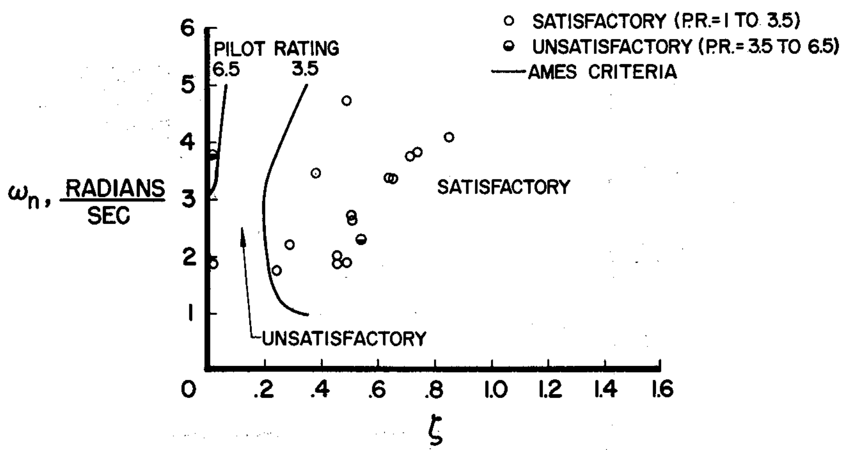

Figure 8

[redacted]

SUMMARY OF X-15 LANDING PATTERN

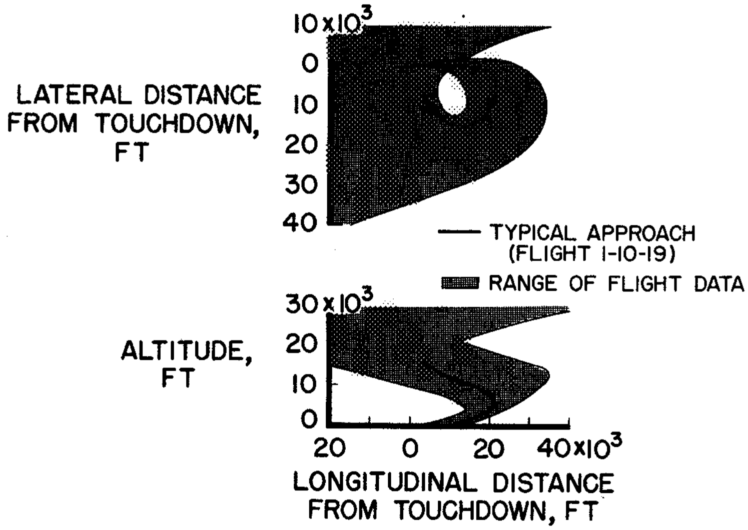

Figure 9

X-15 FLARE-INITIATION ALTITUDE

$(W/S)_{av} = 73$ PSF

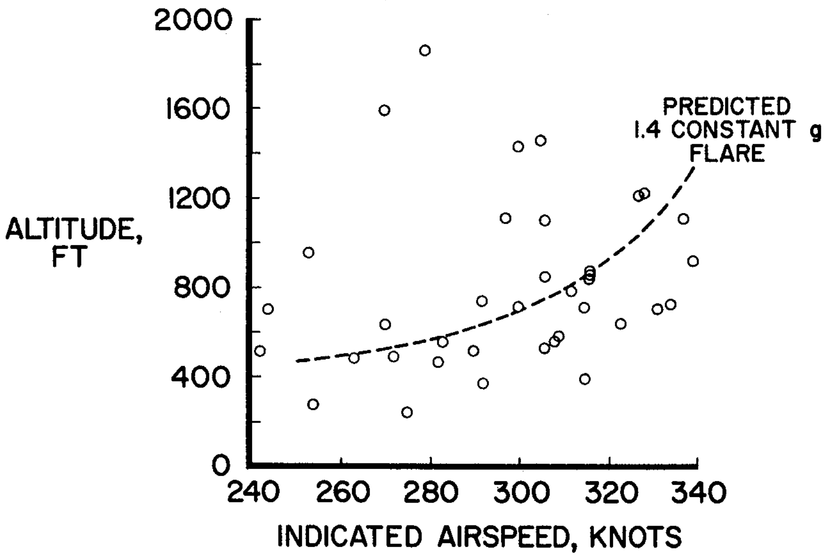

Figure 10

[redacted]

H-270

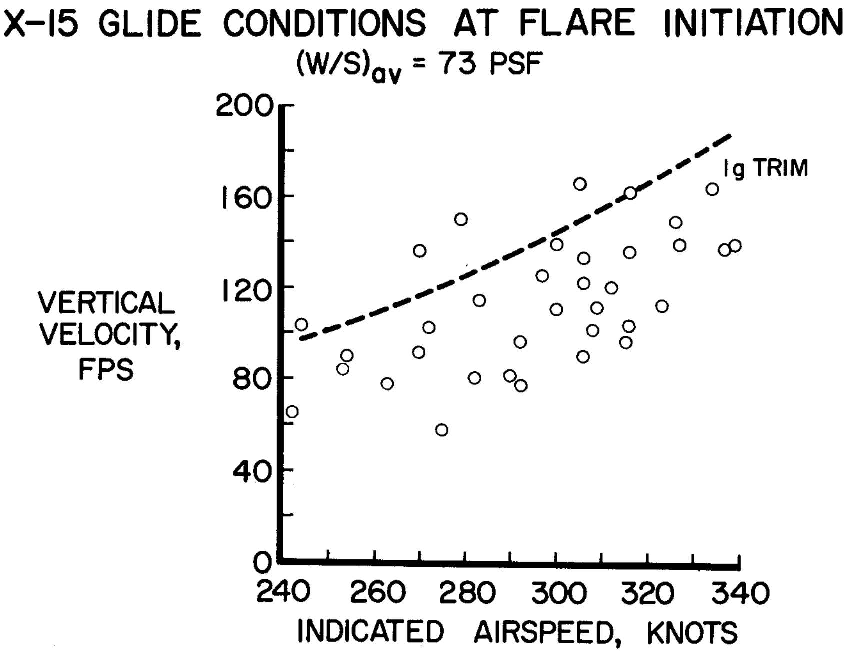

Figure 11

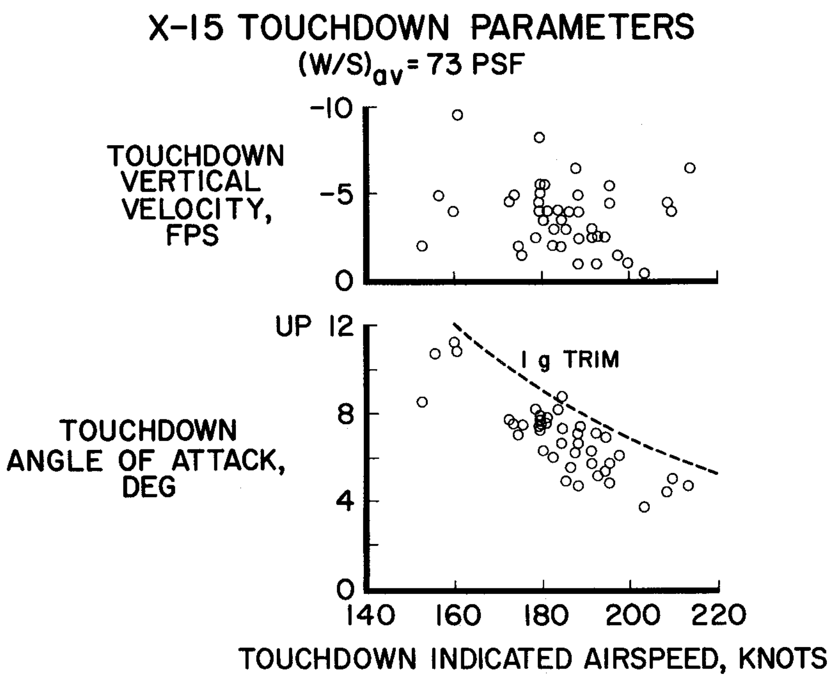

Figure 12

[redacted]

X-15 TOUCHDOWN AND SLIDEOUT DISTANCES

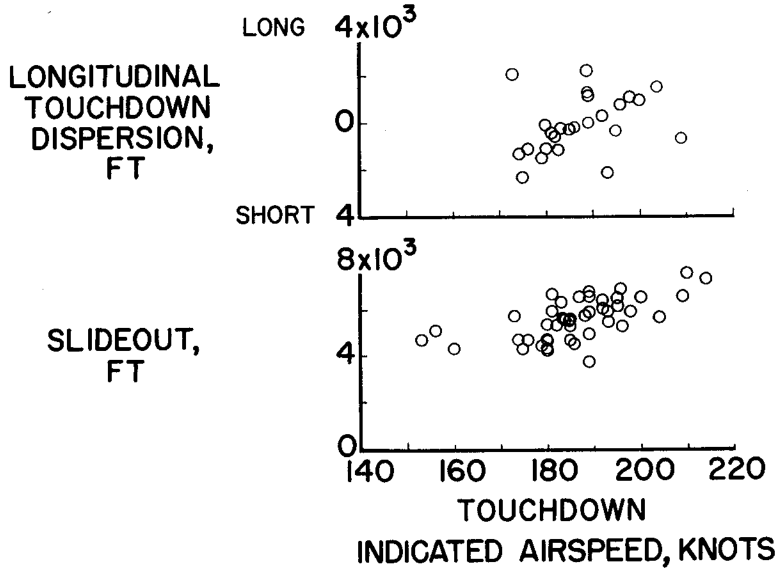

Figure 13

[redacted]

NASA TM X-715
National Aeronautics and Space Administration.
RÉSUMÉ OF HANDLING QUALITIES OF THE X-15 AIRPLANE. Robert M. White, Glenn H. Robinson, and Gene J. Matranga. March 1962. 18p. (NASA TECHNICAL MEMORANDUM X-715) [redacted]

(Title, Unclassified [redacted]

A summary of handling qualities is presented as assessed from pilot opinion and flight data. Segments of the flight profile which were evaluated include the launch, climbout, semiballistic flight, atmosphere entry, and landing. Longitudinal controllability is compared with results from current studies of reentry-type vehicles.

Copies obtainable from NASA, Washington

[redacted]

I. White, Robert M.
II. Robinson, Glenn H.
III. Matranga, Gene J.
IV. NASA TM X-715

(Initial NASA distribution:
3, Aircraft;
50, Stability and control.)

NASA

[redacted]

NASA TM X-715
National Aeronautics and Space Administration.
RÉSUMÉ OF HANDLING QUALITIES OF THE X-15 AIRPLANE. Robert M. White, Glenn H. Robinson, and Gene J. Matranga. March 1962. 18p. (NASA TECHNICAL MEMORANDUM X-715) [redacted]

(Title, Unclassified [redacted]

A summary of handling qualities is presented as assessed from pilot opinion and flight data. Segments of the flight profile which were evaluated include the launch, climbout, semiballistic flight, atmosphere entry, and landing. Longitudinal controllability is compared with results from current studies of reentry-type vehicles.

Copies obtainable from NASA, Washington

[redacted]

I. White, Robert M.
II. Robinson, Glenn H.
III. Matranga, Gene J.
IV. NASA TM X-715

(Initial NASA distribution:
3, Aircraft;
50, Stability and control.)

NASA

[redacted]

NASA TM X-715
National Aeronautics and Space Administration.
RÉSUMÉ OF HANDLING QUALITIES OF THE X-15 AIRPLANE. Robert M. White, Glenn H. Robinson, and Gene J. Matranga. March 1962. 18p. (NASA TECHNICAL MEMORANDUM X-715) [redacted]

(Title, Unclassified)

A summary of handling qualities is presented as assessed from pilot opinion and flight data. Segments of the flight profile which were evaluated include the launch, climbout, semiballistic flight, atmosphere entry, and landing. Longitudinal controllability is compared with results from current studies of reentry-type vehicles.

Copies obtainable from NASA, Washington

[redacted]

I. White, Robert M.
II. Robinson, Glenn H.
III. Matranga, Gene J.
IV. NASA TM X-715

(Initial NASA distribution:
3, Aircraft;
50, Stability and control.)

NASA

[redacted]

NASA TM X-715
National Aeronautics and Space Administration.
RÉSUMÉ OF HANDLING QUALITIES OF THE X-15 AIRPLANE. Robert M. White, Glenn H. Robinson, and Gene J. Matranga. March 1962. 18p. (NASA TECHNICAL MEMORANDUM X-715) [redacted]

(Title, Unclassified [redacted]

A summary of handling qualities is presented as assessed from pilot opinion and flight data. Segments of the flight profile which were evaluated include the launch, climbout, semiballistic flight, atmosphere entry, and landing. Longitudinal controllability is compared with results from current studies of reentry-type vehicles.

Copies obtainable from NASA, Washington

[redacted]

I. White, Robert M.
II. Robinson, Glenn H.
III. Matranga, Gene J.
IV. NASA TM X-715

(Initial NASA distribution:
3, Aircraft;
50, Stability and control.)

NASA

[redacted]