

UNCLASSIFIED

AD 262 629

*Reproduced
by the*

ARMED SERVICES TECHNICAL INFORMATION AGENCY
ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA



UNCLASSIFIED

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

ADVISORY GROUP FOR AERONAUTICAL
RESEARCH AND DEVELOPMENT

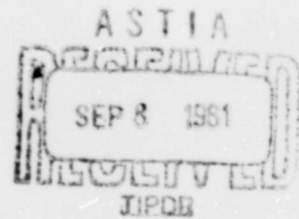
REPORT 289

THE X-15 RESEARCH PROGRAM

by

DE E. BEELER

OCTOBER 1960



NORTH ATLANTIC TREATY ORGANISATION
64 RUE DE VARENNE, PARIS VII

MANAGED BY ASTIA
AS AD No. 262629

NOX

NORWAY NORVEGE	Mr. O. Blichner Norwegian Defence Research Establishment Kjeller per Lilleström
PORTUGAL	Direccao do Servico de Material da Forca Aerea Av. Antonio Augusto de Aguiar, 23-r/c Lisboa Attn: Lt. Col. Jose Pereira do Nascimento
TURKEY TURQUIE	Ministry of National Defence Ankara Attn. AGARD National Delegate
UNITED KINGDOM ROYAUME UNI	Ministry of Aviation T. I. L., Room 009A First Avenue House High Holborn London W. C. 1
UNITED STATES ETATS UNIS	National Aeronautics and Space Administration (NASA) 1520 H Street, N. W. Washington 25, D. C.



REPORT 289

NORTH ATLANTIC TREATY ORGANIZATION
ADVISORY GROUP FOR AERONAUTICAL RESEARCH AND DEVELOPMENT

THE X-15 RESEARCH PROGRAM

by

De E. Beeler

This Report was presented at the Flight Mechanics Panel held from 3-5th October, 1960,
in Istanbul, Turkey

SUMMARY

This Report describes, briefly, the research program developed for the X-15. Some of the early flight tests results are also included to illustrate the kind of results to be expected from the program and to show the present status of the project.

SOMMAIRE

Ce rapport décrit de façon sommaire le programme de recherche élaboré pour le projet X-15. Un certain nombre des résultats des mesures en vol effectuées au cours des premiers vols de l'avion sont signalés à titre illustratif du genre de résultats susceptibles d'être obtenus du programme, ainsi que pour indiquer l'état actuel d'avancement du projet.

629.135.072.2

3a3d3:3c7b

CONTENTS

	Page
SUMMARY	ii
LIST OF TABLES	iv
LIST OF FIGURES	iv
NOTATION	v
1. INTRODUCTION	1
2. HISTORY	1
3. RESEARCH AREAS	2
4. FLIGHT RESULTS AND PROGRAM STATUS	5
5. ADDITIONAL RESEARCH AREAS	7
6. CONCLUDING REMARKS	8
TABLES	9
FIGURES	10
DISTRIBUTION	

LIST OF TABLES

	Page
TABLE I X-15 Program: Areas of Research Interest	9
TABLE II X-15 Program: Additional Research Areas	9

LIST OF FIGURES

Fig.1 Flight regimes	10
Fig.2 X-15 research mission	10
Fig.3 View of X-15 research airplane	11
Fig.4 X-15 shock-wave pattern at hypersonic speeds. Wind tunnel; $\alpha = 5^\circ$	11
Fig.5 X-15 simulation	12
Fig.6 X-15 heat transfer - wing lower-surface midspan	12
Fig.7 X-15 wing temperatures - midspan station	13
Fig.8 X-15 stability derivatives. $\alpha \approx 4^\circ$	13
Fig.9 X-15 control-effectiveness derivatives. $\alpha \approx 0-15^\circ$	14
Fig.10 X-15 drag characteristics. Power off	14
Fig.11 X-15 wing pressure distribution. Midspan station. $M = 3, \alpha = 7^\circ$	15
Fig.12 X-15 wing loads. $M = 2.8$	15
Fig.13 X-15 maximum speed and altitude	16
Fig.14 X-15 stability	16
Fig.15 Artist's conception of a research flight	17

NOTATION

a_N	normal acceleration at center of gravity
C_D	drag coefficient (Drag/qS)
C_L	lift coefficient (Lift/qS)
Cl_β	effective dihedral parameter
Cl_{δ_a}	aileron-effectiveness parameter
C_{m_α}	longitudinal-stability parameter
$C_{m_{\epsilon_h}}$	horizontal-tail-effectiveness parameter
C_{N_α}	normal-force-curve slope
C_{n_β}	effective directional-stability parameter
$C_{n_{\delta_v}}$	vertical-tail-effectiveness parameter
g	acceleration due to gravity
M	Mach number
q	dynamic pressure
S	wing area
W/S	wing loading
α	angle of attack

THE X-15 RESEARCH PROGRAM

De E. Beeler*

1. INTRODUCTION

The research program that has been developed for the X-15 project is presented. Some of the measured flight results obtained during the first exploratory flights are also presented to illustrate the types of results to be expected from the program and to show the present status of the project.

In developing any flight research program for a research aircraft that is to be objective and directly contributing to the problems at hand, it is necessary to take into consideration the objectives and reasons for developing the research airplane in the first place. Then, these objectives must be reassessed and new objectives that have arisen throughout the development and construction of the vehicle must be established in their proper perspectives.

2. HISTORY

The X-15 project proposal was, generally speaking, no different from the proposals that led to the construction of the previous research aircraft designed and flown in research programs in the United States. They all stemmed from considerations and studies of future vehicle potentials and from a state-of-the-art review at the time of the studies. In the studies made in 1954 by the N.A.C.A., now N.A.S.A., leading to the X-15 project, it was clear from rocket-development advancements made at that time that the potential existed of achieving a significant increase in the performance of manned aircraft, perhaps ultimately exceeding the velocity for an earth satellite. It was also clear from these studies that there was an urgent need for research in high-temperature structures, hypersonic aerodynamics, stability and control, and operational types of problems.

In reviewing the various methods and facilities for studying problems pertaining to flight at hypersonic speed and for space missions, it became obvious that existing ground and small-scale flight facilities for research were inadequate in many areas of interest. It was apparent, then, that actual full-scale manned flight investigations would be required to separate the real from the unreal problems of flight and to uncover unsuspected or overlooked problem areas. It was felt also that the actual construction of a research vehicle would simulate and focus the research needed for the flight regimes of interest. The X-15 project was initiated, therefore, by setting forth a requirement to develop a manned airplane with characteristics that made it suitable for flight studies of the problems pertaining to hypersonic speeds and space missions.

It would be well, particularly in a session such as this where Project Mercury and Dyna-Soar are being discussed, to make clear that the X-15 was not conceived as a

*Assistant Director, NASA Flight Research Center, Edwards Air Force Base, California, U.S.A.

manned space vehicle. It was, rather, developed as a vehicle consistent with the state-of-the-art at the time which could, in flight, investigate some of the important elements of a hypersonic speed and space mission. To illustrate, the altitude-speed performance envelope of the research airplane as related to possible future manned aircraft is shown in Figure 1. Manned maneuverable vehicles of hypersonic-speed capability are referred to as 'rocket gliders'. The upper boundary of the region in which these vehicles might operate corresponds to a low wing loading with high lift coefficient, whereas the lower boundary might represent a high wing loading with a low lift coefficient. As the speed increases, satellite velocity is reached where no aerodynamic lift is needed and the weight of the vehicle is borne by centrifugal force. At these velocities the pilot must function in an environment of weightlessness, and attitude control must be attained by means other than the normal aerodynamic controls. At subsatellite velocities, aerodynamic and structural heating present additional new problem areas. The performance requirements set forth by the N.A.C.A. for the research vehicle - speeds greater than 6000 ft/sec and altitudes up to 250,000 ft - are illustrated in Figure 1. By employing high-altitude trajectories and various high-speed missions, many of the hypersonic and space problem areas could be investigated, even though the performance was considerably less than satellite speeds. These types of trajectories are illustrated in Figure 2, which shows the presently conceived design-mission trajectories for the X-15. The aircraft is launched from the B-52 carrier airplane, performs an exit from the atmosphere, and is then in ballistic flight where weightlessness and attitude control are investigated. The vehicle then re-enters the atmosphere and recovers from the high temperature, high loading, and high dynamic pressure experienced in the flight and, finally, lands on the Edwards dry lakebed.

A view of the X-15 research vehicle is shown in Figure 3.

During its development and construction over the past six years, the X-15 project has stimulated much research in the problem areas for which the project was initiated. It is the review of the original objectives and the results of the research conducted during this time that constitute the basis for the present X-15 research program.

3. RESEARCH AREAS

The areas of research interest in the X-15 program are listed in Table I. The list, for the most part, is not new or unique and could be quite similar to, for example, an experimental wind-tunnel program. The greatest value from such a program involving flight research, however, will be that it is possible to sidestep the problems of simulation - for example, scale effects, wind-tunnel flows, the usual tare and support interference corrections - and conduct the investigations under the true full-scale flight environment with the integration of the pilot and the pertinent flight control systems. The validity of the flight results will be dependent, therefore, upon the techniques developed for flight testing and data analysis and upon the accuracy of the instrumentation employed. Some results from the program will be specific to the X-15 configuration and will be used to establish the validity of the experimental and calculated data developed during the construction of the airplane. The major portion of the data will be obtained and analyzed as generalized fundamental data applicable to the design of future advanced vehicles. A brief description of each of the research areas listed in Table I and their pertinence to the program is, however, in order.

In the determination of aerodynamic heating it is well known that the flow behavior over the complete airplane configuration is too complex to rely solely on methods of calculation. This fact justified the extensive detailed wind-tunnel studies of scale models of the X-15 to provide guidelines and trends in the design of the vehicle. In the analysis of these types of data for application to detailed design of the airplane and for the research flight planning, it is apparent that a real need remains for a true assessment of aerodynamic heating in full-scale flight where realistic aerodynamic environment and actual surface conditions exist. Important factors that affect the flow and heating conditions, such as Reynolds numbers, surface conditions, transition, actual shock-wave-boundary-layer interaction, fully developed turbulent flow, and maneuvering airplane attitude, will be the subjects of investigation in the flight program.

The research program on structural loads and heating is directed toward measurement of the structural heat transfer throughout the lighter structures of the airplane as well as the heavier built-up structural areas and in the vicinity of propulsion and systems equipment. It is also directed toward measurement of the related structural loads as determined by strain gages calibrated to determine loads. The reduction in material properties and induced thermal stresses involved with the high-speed flights of the X-15 will require a detailed monitoring, structural inspection, and prediction to determine structural integrity with increasing severity of flight conditions.

In the area referred to as aerothermoelasticity, there exist the combined effects of hypersonic aerodynamics, thermodynamics, and the elastic properties of the structure. This is a relatively new and fruitful area for concentrated flight research in order to determine the importance of the related effects of these parameters under actual flight environment. Considerable experimental work has been accumulated in structures research from ground facilities, as a result of the X-15 project, in order to establish, for instance, design flutter boundaries and the effects of structural deformation on aerodynamic loading. Flight information is needed, however, for establishing the validity of these existing data. The X-15 in its proposed flight trajectories will be exposed to combinations of hypersonic aerodynamic loading, structural temperatures above 1000⁰F, and load factors greater than 5g. This portion of the flight research program, therefore, present a sizable challenge to develop techniques for obtaining and analyzing meaningful data.

In regard to hypersonic aerodynamics, Figure 4 is a sketch of the shock formations that exist at a hypersonic Mach number for the X-15 configuration. The shocks become moving patterns with changes in speed and airplane attitude and result in appreciable alteration of the flow field in front of the surfaces and local pressure fields on the surfaces. It would be expected, therefore, that alterations in aerodynamic loads and load distributions, heating and heating rates, and corresponding irregularities would exist in the various stability and control derivatives and parameters. The objective of the X-15 research flight program is to evaluate (1) the effects of these types of hypersonic flow phenomena on determining the level of adequate static and dynamic stability, (2) the proper relationship of these levels of stability about all three axes, (3) the distribution of aerodynamic loads, (4) the lift-to-drag ratios, (5) the intensity, frequency content and space-time correlation of the noise in the boundary layer and noise effect on structures, equipment and pilot, and, lastly, (6) the integrated effects for determining handling-qualities requirements.

The problems of an atmospheric exit and re-entry mission are of great interest from the research standpoint. Studies will be conducted of the pilot and aircraft when performing the required exit from the atmosphere under longitudinal acceleration reaching a maximum of 4g and when re-entering the atmosphere at a hypersonic speed at elevated structural temperatures, load factors, and dynamic pressure where the use of reaction-type controls separately and in combination with the conventional aerodynamic controls will be employed.

Simulation has played an increasingly important part in vehicle development in recent years. It is evident that greater use of ground simulation facilities will be employed. A real need exists for proper assessment of the simulation required to support flight research, flight operation, and pilot training. The value and necessity for simulation in support of development and design as well as flight research has been obvious in recent years. It is also obvious that overcomplication of simulation requirements and facilities is possible. A wealth of background simulator data has been obtained from various simulators during the design, development, and research flight planning of the X-15 project. The types of simulators used are shown in Figure 5 and include a general-purpose static analog; the X-15 simulator, where the complete and actual X-15 control hardware is duplicated in a ground-based arrangement; the human centrifuge; a modified F-104 airplane for simulating low-lift-drag-ratio approach and landing; and an F-100C variable-stability airplane. A comparison of the results from these types of simulators will be made with the actual flight results on a continuing basis throughout the flight program and analyzed to establish simulator requirements.

The problems of stability and attitude control of maneuverable space vehicles outside and approaching the atmosphere are of interest in the X-15 project. An augmented stability system with provisions for variable damping about all three axes and a reaction-type airplane attitude control system are included in the X-15 airplane. With the X-15, sufficient flight time is possible outside of the atmosphere to investigate the stability and control problems in these flight regimes. Investigations of desirable control levels and piloting techniques, a comparison of aerodynamic and reaction controls in regions where aerodynamic control coupling may be significant, and, eventually, investigations of the requirements for combining the two control systems into a single controller will be conducted.

The recovery of high-performance aircraft of more advanced types than the X-15 will require more sophisticated terminal-guidance equipment and technique development than is necessary for the X-15 mission. Analytical studies toward establishing requirements for ground and airborne equipment to vector the pilot into the landing area are presently underway. In addition to the X-15 vehicle itself, the project includes a precision radar range facility extending 440 nautical miles northeast of Edwards Air Force Base (Fig. 2). The central control of the facility is located at the NASA Flight Research Center, Edwards, California, with additional tracking stations at Ely, and Beatty, Nevada. This facility provides terminal-guidance and approach information at all times to the X-15 pilot for landings at Edwards or at emergency landing areas along the range. The X-15 performance capability coupled with this range facility will provide important data for evaluating these analytical studies. The landing characteristics of the X-15 as well as other advanced hypersonic vehicles are characteristic of configurations having low lift-drag ratios. Low lift-drag ratios involve high approach and touchdown speeds and high sink rates prior to the flare. Data are

being obtained from the X-15 to develop the required landing techniques and verify the various simulator results.

The pilot's physiological status during flight programs with previous research aircraft has not been recorded. However, with the application of manned vehicles for space missions, considerable interest has developed in these aeromedical aspects of flight. The conditions of exit, ballistic flight, and re-entry at the higher performance levels of the X-15 will require, on the part of the pilot, precise control and monitoring of the flight as well as split-second decision-making tasks throughout the mission. Telemetered and internal recorded data of the (1) pressure differential between the cockpit and pressure suit, (2) pressure differential between the helmet and suit, (3) pilot's body-surface temperatures, and (4) electrocardiographic elements will be monitored and analyzed by a flight surgeon. These types of data will be compiled for various flight missions, tasks, and pilots throughout the program.

These areas just discussed describe, in a broad sense, the research interest in the X-15 project and thus establish the research program for this project.

4. FLIGHT RESULTS AND PROGRAM STATUS

The data that have been obtained in the research program are shown in Figures 6-14 to illustrate the type of data that will be forthcoming in future flights of the vehicle in relation to the research areas discussed previously and to show, to a degree, the present coverage of the program. The government research program under the direction of the N.A.S.A. was initiated in March, 1960 with one X-15 aircraft equipped with the interim engine. Ten flights had been made by October. A maximum speed of 2196 miles/hr, which corresponds to a Mach number of 3.31, and a geometric altitude of 136,500 ft, have been reached. These values represent approximately the maximum performance attainable with the interim propulsion system.

The first Figure (Fig.6) of this series shows the type of data obtained relative to the determination of aerodynamic heating. The solid lines show a calculated variation of the non-dimensional heat-transfer coefficient (Stanton number) with Reynolds number for laminar and turbulent flows for a flat plate. The flight heat-transfer data are shown for the lower surface of a midspan wing section. From these types of flight data it will be possible to determine the regions of laminar flow, the transition to turbulent flow, and the extent of turbulent flow over the airplane, as well as the heat transfer associated with the local flow conditions. Also, these data show the maximum Reynolds number range for which wind-tunnel results are available. Based on fuselage length, the wind-tunnel data are limited to a Reynolds number of 15 million; the flight data will cover a Reynolds number range up to more than 100 million.

Figure 7 shows the structural-temperature distribution of a wing section at a midspan station. The measured data are for a flight condition of elevated structural heating during an exploratory high-speed flight. The lower skin temperatures are higher because of the angle of attack of the section and the smaller skin thicknesses on the lower surfaces. The lower levels of leading-edge temperatures result from the use of the heavier heat-sink material designed to withstand the high temperatures expected during maximum-performance flights. Also of interest in this figure is a measure of the heat transfer throughout the structure caused by the rapid rise in skin

temperature and resulting lag in temperature build-up in the internal structural components. A temperature differential of about 300°F exists between the lower skin panel and center of the web section for the location and flight conditions of the data shown in this figure. These data are from 17 of a total of 650 structural and internal temperature measurements made on the X-15 airplane.

Figure 8 shows a comparison of wind-tunnel and flight-measured values of X-15 stability derivatives, and Figure 9 presents the variation of control effectiveness with Mach number. The stability derivatives are for a low angle of attack; the control-effectiveness data are for a range of angle of attack of from 0° to 15° where, for these Mach numbers, very little effect of angle of attack upon control effectiveness is apparent.

Figure 10 shows the comparison between power-off drag polars of the X-15 wind-tunnel and flight data for a subsonic, a transonic, and a supersonic Mach number. The wind-tunnel data have been corrected to comparable flight Reynolds numbers.

A comparison of the flight-measured chordwise pressure distribution over a midspan wing section of the X-15 with wind-tunnel data and calculated chordwise loading is shown in Figure 11. These data are for a Mach number of 3.0 at an angle of attack of 7°. Similar data are being obtained at 122 additional locations on the wing, tail, and fuselage of the X-15 airplane.

Figure 12 shows the measured aerodynamic wing-panel loads outboard of the root section. The loads were obtained from calibrated strain gages installed in the air-frame structure. These data are compared with the wing-panel loads determined from the integration of wind-tunnel pressure-distribution data. Similar data are being obtained for the horizontal-tail surfaces.

Figures 13 and 14 show the comparison of flight results with results from ground simulator studies made by using wind-tunnel and calculated data to predict the flight performance and stability data, respectively. The performance information is shown as combinations of Mach numbers and altitudes during a research mission to obtain maximum speed and altitude conditions. The stability data are shown as comparisons of the period of pitching and Dutch-roll oscillation. These data are only a small part of the data obtained to predict and plan the flight research program in a step-by-step approach.

The data that have been shown represent some of the types of information that will be derived from the X-15 research program. The data are of the type being used to establish baselines for verifying the present prediction methods before proceeding to higher speeds and more extreme flight conditions. As may be expected, the flight results have shown reasonably good agreement with predictions from calculations or from experimental results of scale-model tests for the speeds investigated. Although it is true that the airplane has reached about one-half of its design altitude and speed conditions, the research areas of most interest and concern are yet to be explored.

5. ADDITIONAL RESEARCH AREAS

To this point, the discussion has been confined to areas of immediate research interest and directed toward a better understanding of the fundamental problems concerning heating, flight control outside of the atmosphere, and problems of re-entry and exit. There are other important research areas of interest to which the X-15 can make additional contributions. These areas are listed in Table II.

Consideration has been given to several advanced flight control systems requiring flight research. For example, as was noted earlier, the X-15 incorporates a reaction control system to provide attitude control on the fringes of, and outside of, the atmosphere. This is a relatively simple system which was developed from research conducted by the N.A.S.A. on previous research airplanes. Since that time, research has continued toward more sophisticated reaction control systems that are presently being flight-tested on a high-altitude F-104 project. Results of this research will provide information for an advanced X-15 system. In addition, for the recovery of maneuverable manned space vehicles in which there are rapid changes in aerodynamic characteristics, dynamic pressure, and requirements for precise control to prevent overloading or overheating, it appears necessary to provide the pilot with an adaptive control system capable of compensating for these rapid changes. A flight control system of this type is presently under development for installation in the X-15 airplane and will be used to conduct flight research of systems of this type for application in advanced space vehicles.

Mention was made earlier of the problems of acquisition, monitoring, and providing terminal guidance to manned maneuverable re-entry vehicles. Now being studied are energy-management systems, which appear attractive for application to advanced space vehicles. It is planned that systems developed from these studies will be installed in the X-15 airplane for the conduct of flight research.

It is not always possible to select the most promising high-temperature structure from the many attractive specimens because of questions pertaining to the well-known aerodynamic and structural factors concerning full-scale flight environment. The investigation of such promising structural components instrumented for determining aerodynamic and structural heat transfer will be conducted. The results of such investigations will provide an assessment of the validity of the conclusions reached from the component tests in ground facilities.

The X-15 vehicle is well suited for the investigation of promising structural cooling techniques such as mass flow cooling and sublimation or other attractive methods under actual flight conditions in terms of local flow, boundary layer, and temperature. Investigations would be directed toward providing flight information to verify or substantiate the results from the most promising wind-tunnel proposals and to assess the operational problems involved.

Because of the severe limitation on resolution caused by the turbulence of the earth's atmosphere, there is an inherent advantage in utilizing a celestial camera located above most of the earth's atmosphere. The typical resolution of ground-located telescopes ranging over wide ranges of apertures up to 200 inches results in resolutions corresponding to apertures of 3 to 4 inches as determined from actual celestial photographs. Consideration has been given to the use of the X-15 as an

astronomical platform to carry a reflecting telescope for the purpose of photographing planets at altitudes above the major areas of the earth's turbulent atmosphere.

6. CONCLUDING REMARKS

The areas of research interest which appear to encompass the most important and urgent problems facing the design of hypersonic and space vehicles and to which the X-15 program can contribute immeasurably at an early date have been presented. Indications have been given of the type of data that is forthcoming in the present program, as well as indications of possible additional research uses of the X-15. As is depicted in Figure 15, an artist's conception of the completion of another research flight, it comes to mind that in the course of conducting any flight research program of this type, it is obvious that the emphasis will change from one research area to another and problems of new and different significance will result. Those problems that are found to be real will be better understood as a result of the flight investigations, and those problems that have been imagined will assuredly be replaced with the unexpected or overlooked problems.

TABLE I

X-15 Program: Areas of Research Interest

<i>Research Areas</i>
Aerodynamic heating
Structural loads and heating
Aerothermoelastic problems
Hypersonic aerodynamics
Atmospheric exit and re-entry characteristics and techniques
Simulation
Stability and control at low dynamic pressures
Recovery and landing problems
Aeromedical aspects

TABLE II

X-15 Program: Additional Research Areas

<i>Additional Research Areas</i>
Advanced flight control systems
Energy-management systems
Research on structural components
Structural cooling
Celestial photographic missions

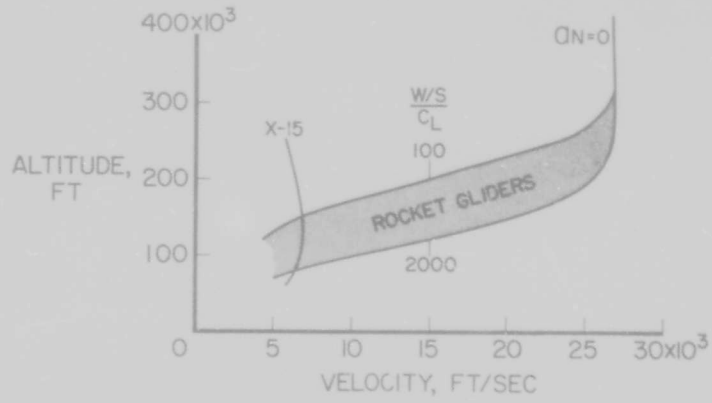


Fig.1 Flight regimes

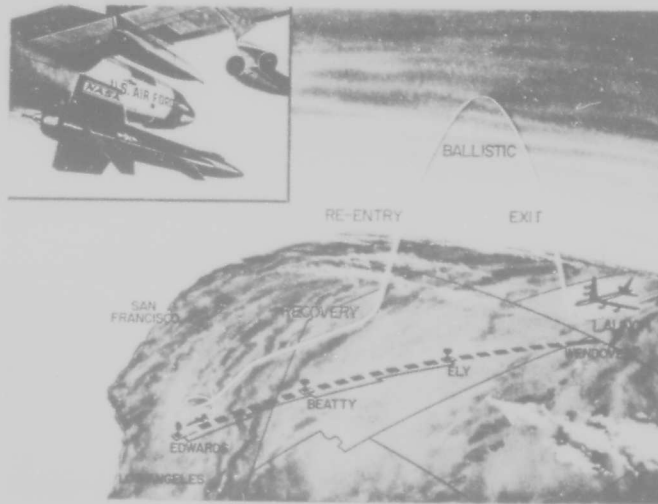


Fig.2 X-15 research mission

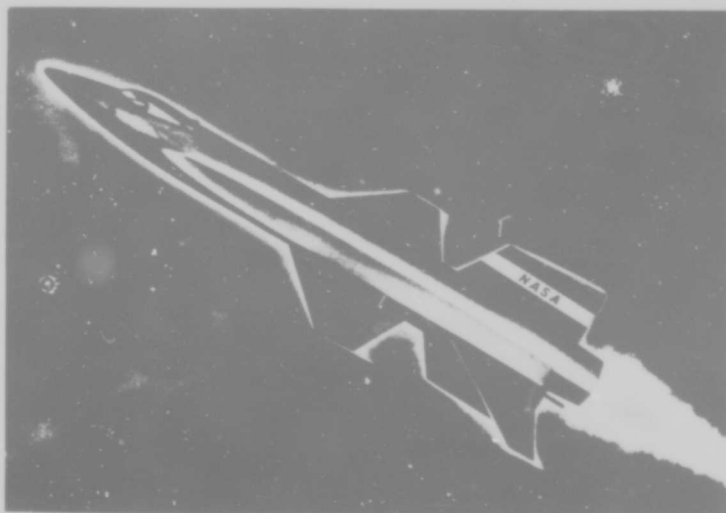


Fig.3 View of X-15 research airplane

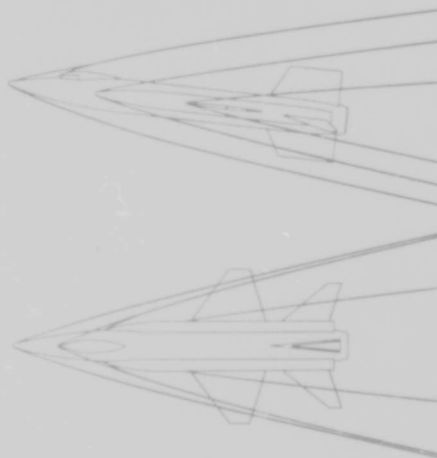


Fig.4 X-15 shock-wave pattern at hypersonic speeds. Wind tunnel; $\alpha = 5^\circ$

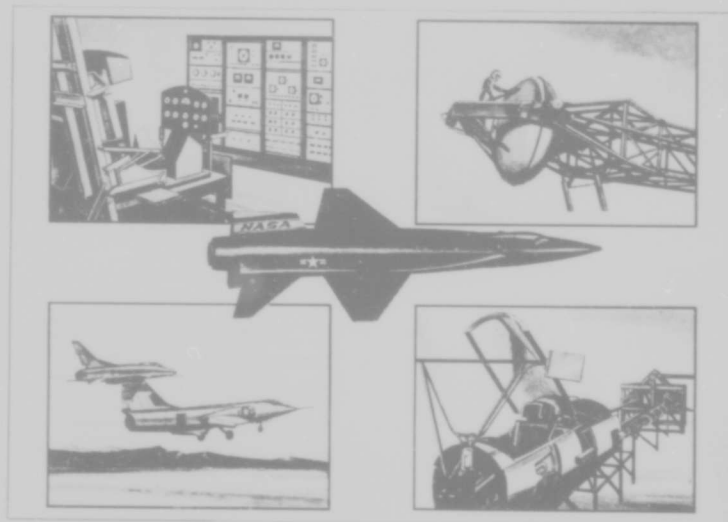


Fig.5 X-15 simulation

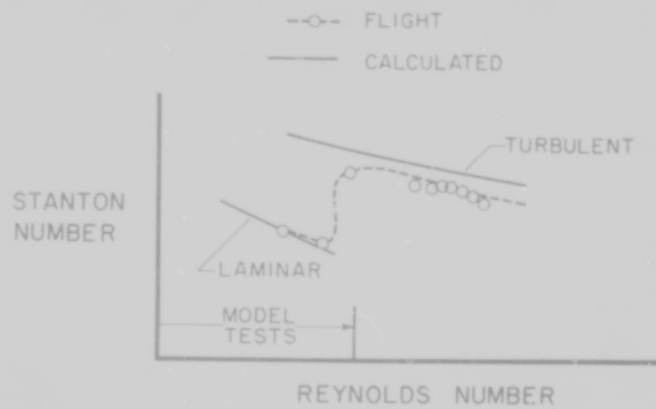


FIG.6 X-15 heat transfer - wing lower-surface midspan

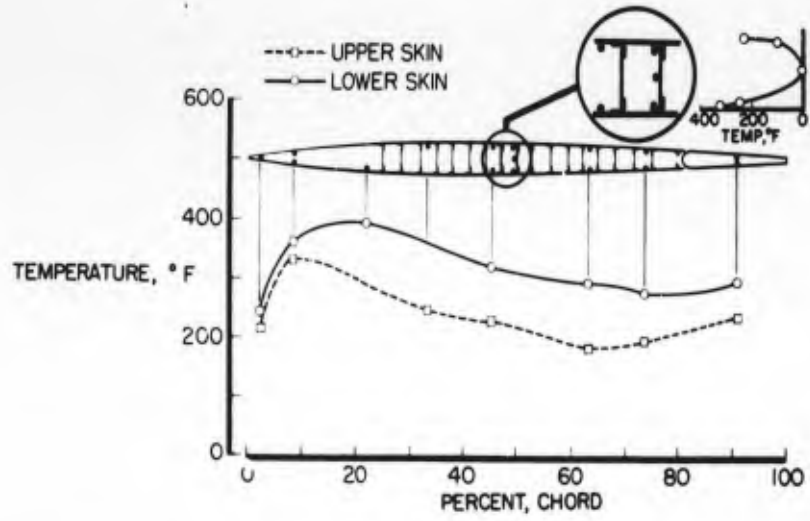


Fig.7 X-15 wing temperatures - midspan station

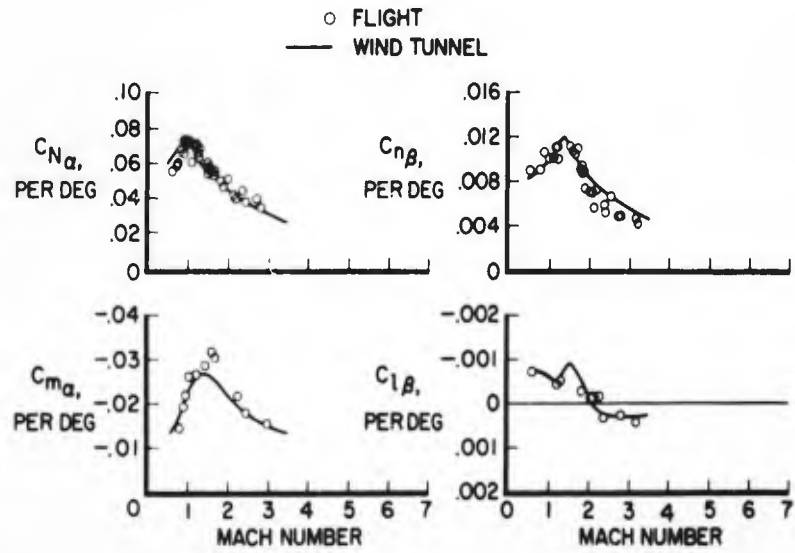


Fig.8 X-15 stability derivatives. $\alpha \approx 4^\circ$

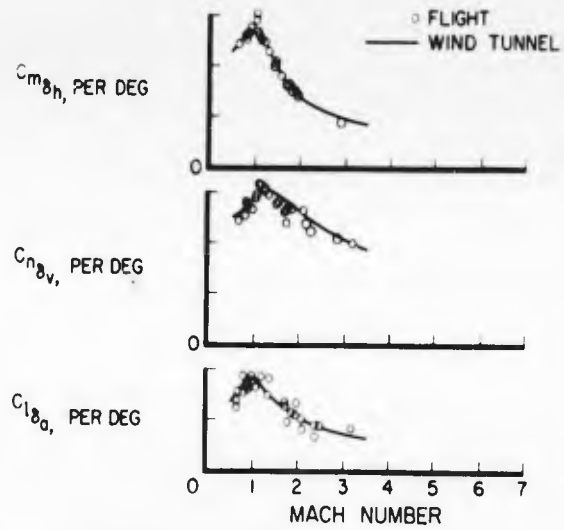


Fig.9 X-15 control-effectiveness derivatives. $\alpha \approx 0-15^\circ$

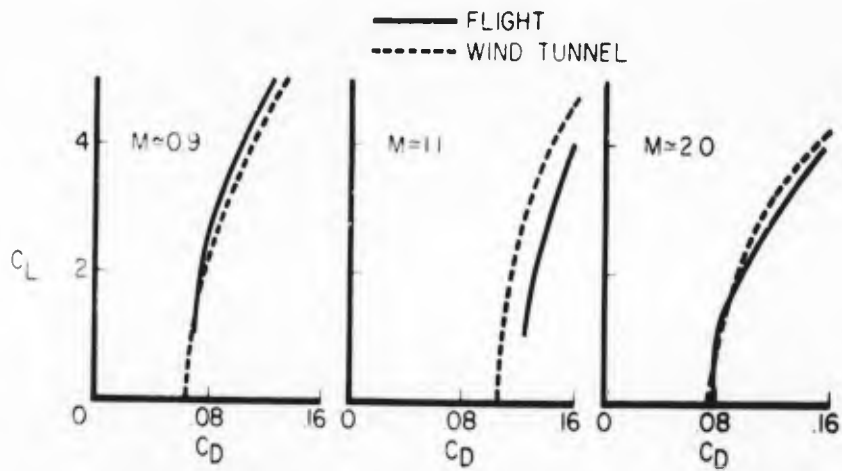


Fig.10 X-15 drag characteristics. Power off

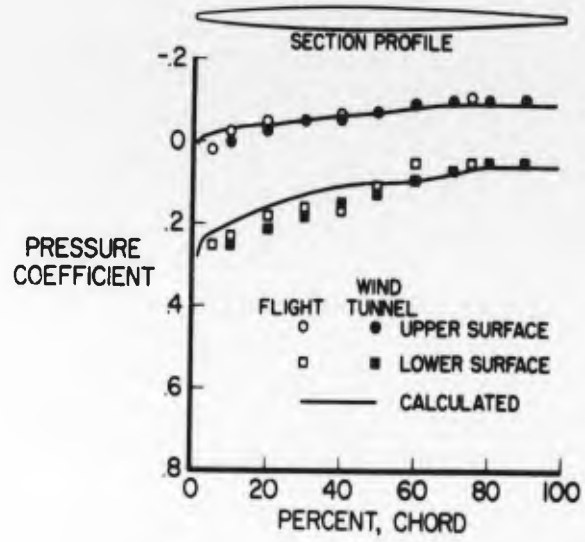


Fig.11 X-15 wing pressure distribution. Midspan station. $M = 3, \alpha = 7^\circ$

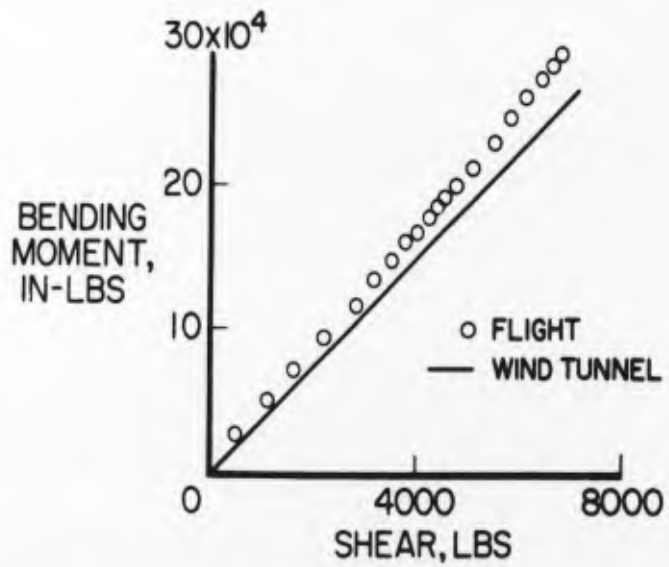


Fig.12 X-15 wing loads. $M = 2.8$

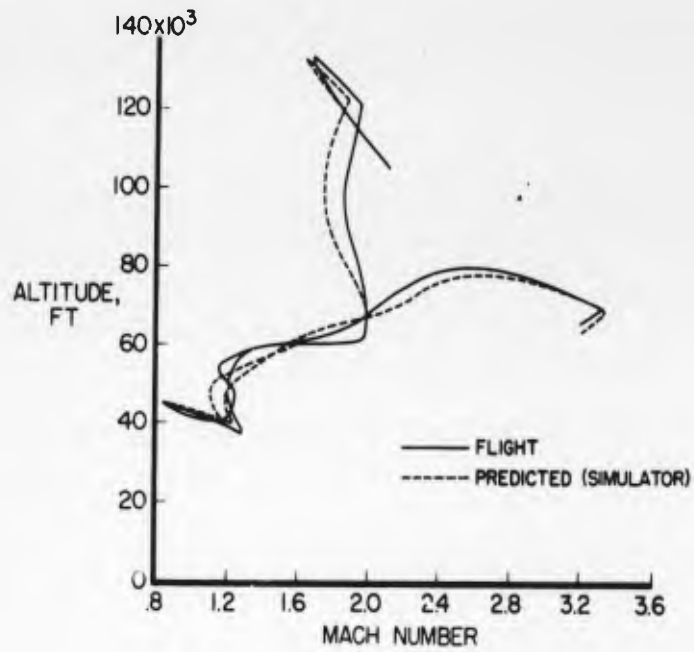


Fig.13 X-15 maximum speed and altitude

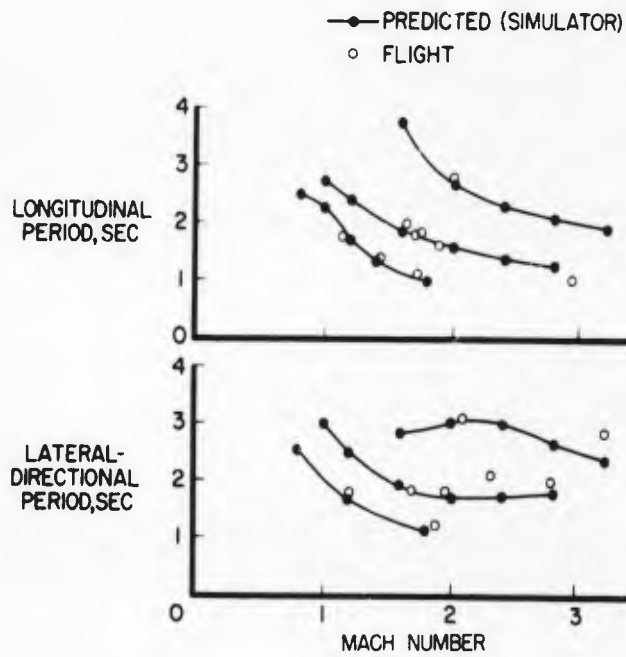


Fig.14 X-15 stability



Fig.15 Artist's conception of a research flight

DISTRIBUTION

Copies of AGARD publications may be obtained in the various countries at the addresses given below.

On peut se procurer des exemplaires des publications de l'AGARD aux adresses suivantes.

BELGIUM BELGIQUE	Centre National d'Etudes et de Recherches Aéronautiques 11, rue d'Egmont, Bruxelles
CANADA	Director of Scientific Information Service Defense Research Board Department of National Defense 'A' Building, Ottawa, Ontario
DENMARK DANEMARK	Military Research Board Defense Staff Kastellet, Copenhagen Ø
FRANCE	O.N.E.R.A. (Direction) 25, Avenue de la Division Leclerc Châtillon-sous-Bagneux (Seine)
GERMANY ALLEMAGNE	Wissenschaftliche Gesellschaft für Luftfahrt Zentralstelle der Luftfahrtokumentation München 64, Flughafen Attn: Dr. H.J. Rautenberg
GREECE GRECE	Greek National Defense General Staff B. MEO Athens
ICELAND ISLANDE	Director of Aviation c/o Flugrad Reykjavik
ITALY ITALIE	Centro Consultivo Studi e Ricerche Ministero Difesa-Aeronautica Via dei Pontefici 3 Roma
LUXEMBURG LUXEMBOURG	Obtainable through Belgium
NETHERLANDS PAYS BAS	Netherlands Delegation to AGARD Kanaalstraat 10 Delft

<p>AGARD Report 289 North Atlantic Treaty Organization, Advisory Group for Aeronautical Research and Development THE X-15 RESEARCH PROGRAM De E. Beeler 1961 17 pages incl. 15 Figs.</p> <p>This Report describes, briefly, the research program developed for the X-15. Some of the early flight-test results are also included to illustrate the kind of results to be expected from the program and to show the present status of the project.</p> <p>Presented at the Flight Mechanics Panel held from 3-5th October, 1960, in Istanbul, Turkey</p>	<p>629.135.072.2 3a3d3:3c7b</p>	<p>AGARD Report 289 North Atlantic Treaty Organization, Advisory Group for Aeronautical Research and Development THE X-15 RESEARCH PROGRAM De E. Beeler 1961 17 pages incl. 15 Figs.</p> <p>This Report describes, briefly, the research program developed for the X-15. Some of the early flight-test results are also included to illustrate the kind of results to be expected from the program and to show the present status of the project.</p> <p>Presented at the Flight Mechanics Panel held from 3-5th October, 1960, in Istanbul, Turkey</p>	<p>629.135.072.2 3a3d3:3c7b</p>
<p>AGARD Report 289 North Atlantic Treaty Organization, Advisory Group for Aeronautical Research and Development THE X-15 RESEARCH PROGRAM De E. Beeler 1961 17 pages incl. 15 Figs.</p> <p>This Report describes, briefly, the research program developed for the X-15. Some of the early flight-test results are also included to illustrate the kind of results to be expected from the program and to show the present status of the project.</p> <p>Presented at the Flight Mechanics Panel held from 3-5th October, 1960, in Istanbul, Turkey</p>	<p>629.135.072.2 3a3d3:3c7b</p>	<p>AGARD Report 289 North Atlantic Treaty Organization, Advisory Group for Aeronautical Research and Development THE X-15 RESEARCH PROGRAM De E. Beeler 1961 17 pages incl. 15 Figs.</p> <p>This Report describes, briefly, the research program developed for the X-15. Some of the early flight-test results are also included to illustrate the kind of results to be expected from the program and to show the present status of the project.</p> <p>Presented at the Flight Mechanics Panel held from 3-5th October, 1960, in Istanbul, Turkey</p>	<p>629.135.072.2 3a3d3:3c7b</p>

<p>AGARD Report 289 North Atlantic Treaty Organization, Advisory Group for Aeronautical Research and Development THE X-15 RESEARCH PROGRAM De E. Beeler 1961 17 pages incl. 15 Figs.</p> <p>This Report describes, briefly, the research program developed for the X-15. Some of the early flight-test results are also included to illustrate the kind of results to be expected from the program and to show the present status of the project.</p> <p>Presented at the Flight Mechanics Panel held from 3-5th October, 1960, in Istanbul, Turkey</p>	<p>629.135.072.2 3a3d3:3c v</p>	<p>AGARD Report 289 North Atlantic Treaty Organization, Advisory Group for Aeronautical Research and Development THE X-15 RESEARCH PROGRAM De E. Beeler 1961 17 pages incl. 15 Figs.</p> <p>This Report describes, briefly, the research program developed for the X-15. Some of the early flight-test results are also included to illustrate the kind of results to be expected from the program and to show the present status of the project.</p> <p>Presented at the Flight Mechanics Panel held from 3-5th October, 1960, in Istanbul, Turkey</p>	<p>629.135.072.2 3a3d3:3c7b</p>
<p>AGARD Report 289 North Atlantic Treaty Organization, Advisory Group for Aeronautical Research and Development THE X-15 RESEARCH PROGRAM De E. Beeler 1961 17 pages incl. 15 Figs.</p> <p>This Report describes, briefly, the research program developed for the X-15. Some of the early flight-test results are also included to illustrate the kind of results to be expected from the program and to show the present status of the project.</p> <p>Presented at the Flight Mechanics Panel held from 3-5th October, 1960, in Istanbul, Turkey</p>	<p>629.135.072.2 3a3d3:3c7b</p>	<p>AGARD Report 289 North Atlantic Treaty Organization, Advisory Group for Aeronautical Research and Development THE X-15 RESEARCH PROGRAM De E. Beeler 1961 17 pages incl. 15 Figs.</p> <p>This Report describes, briefly, the research program developed for the X-15. Some of the early flight-test results are also included to illustrate the kind of results to be expected from the program and to show the present status of the project.</p> <p>Presented at the Flight Mechanics Panel held from 3-5th October, 1960, in Istanbul, Turkey</p>	<p>629.135.072.2 3a3d3:3c7b</p>

UNCLASSIFIED

UNCLASSIFIED