Human Factors Support of the X-15 Program

Lieutenant Colonel Burt Rowen, USAF, MC

THE X-15 research program is being conducted as a national effort by the National Aeronautics and Space Administration (NASA), the United States Air Force, and the United States Navy. It was initiated in the spring of 1952 when the National Advisory Committee for Aeronautics (NACA) directed its laboratories to study the problems likely to be encountered in flight beyond the atmosphere. In December, 1955, North American Aviation was given a contract to build three vehicles. Construction was started in September, 1957, and the roll-out and delivery of the first aircraft was accomplished on October 15, 1958. The program, through completion of the third vehicle, is expected to involve about 135 million dollars in direct contract costs, plus sizable additional indirect costs consisting primarily of laboratory and wind-tunnel testing by NASA and the Air Research and Development Command.

The X-15 will carry over 1,300 pounds of instruments, involving about 600 temperature pickups and 140 pressure pickups. By way of contrast, the X-2 used fifteen temperature probes, no pressure recording, and the overall research instrumentation weighed 350 pounds. Also included is equipment to monitor the pilot's physiologic condition. This aspect represents a new concept in research aircraft. Primary research interest is to obtain (1) knowledge of actual flight conditions beyond the earth's atmosphere; (2) determination of aerodynamic heating, heat transfer rates, and their effects on aircraft structure, and (3) quantitative physiological data during actual flight; additional research objectives include (4) knowledge of missions involving exit from and re-entry into the earth's atmosphere, and (5) man's reaction to space flight.

The X-15 will be air-launched from a B-52 mother ship. As the altitude and speed envelope is expanded, these launchings will be accomplished further from Edwards Air Force Base, California, and nearer Wendover Air Force Base, Utah, the farthest point along the 400 nautical miles of specially-designed and instrumented range. Intermediate radar sites have been established at Ely and Beatty, Nevada. These are coupled to the master site at Edwards Air Force Base.

PHYSIOLOGIC TELEMETRY

An interesting areomedical support mission presents itself in the field of such research aircraft. For approximately ten years, aeronautical engineers have been recording in-flight data from instrumented aircraft sending back telemetry signals to ground read-out indicators. The pilot's physiologic status was never recorded. This was the situation during the X-2

From the Air Force Flight Test Center, Edwards Air Force Base, California.

Presented on April 27, 1959, at the 30th annual meeting of the Aero Medical Association, Los Angeles, California.

program. During the flight phases of the X-15 program, physiologic data will be telemetered so that a flight surgeon observing ground read-out indicators can tell when the pilot is approaching the limit of his physiologic tolerance. This will quantitatively identify the most stressful portion of a particular mission profile so that, in future flight programs, the aeronautical engineer will know what portion of the mission profile most critically needs stability augmentation or possibly automatic control inputs. The full-pressure suits to be worn during the X-15 program have been specfically designed with twenty-four electrical contact points to facilitate the necessary connections between the physiologic sensors or transducers and the telemetry transmitters.

Soon, pilot physiologic data will be telemtered to ground recording stations to evaluate and prove this technique. A TF-102A aircraft has been assigned the Air Force Flight Test Center specifically for this project. Items such as helmet-pressure vs. suit-pressure differential, cockpit-pressure vs. suit-pressure differential, pilot's body-surface temperatures, and electrocardiographic data will be monitored by a flight surgeon. The pilot's body-surface temperature will be correlated with recorded cockpit temperatures. A quantitative index of the effectiveness of pressurization and air conditioning systems can thus be established. For certain missions, specific data can be collected by recording galvanometers. The transducers for these measurements are all miniaturized and will not hinder pilot performance in any way. Flat, round, electrocardiographic pick-ups have been miniaturized and are now approximately the size of a nickel.

Initially only the first two items, the pressure differentials, will be telemetered. These items are most critical in maintaining a livable environment for the pilot. Therefore, it is important to monitor them for the pilot's safety. Inasmuch as the cockpit pressurization of the X-15 is engineered to a 3.5 pounds per square inch (psi) pressure differential between the inside of the cockpit and the outside atmosphere, it was not considered feasible to install a breathable atmosphere in this aircraft. At sea level, oxygen comprises about 20 per cent of the normal atmospheric pressure of 14.7 psi. A breathable atmosphere would then require 20 per cent of 14.7 psi, or about 3 psi of oxygen in the cockpit. To date, the problems of combustion and fire associated with this 86 per cent oxygen-rich atmosphere have been insurmountable. To avoid this difficulty, liquid nitrogen, pressurized by helium, will be used for suit ventilation, anti g bladder inflation, cooling, cockpit pressurization, and MC-2 suit pressurization. Nitrogen is an inert gas and lacks fire and explosive characteristics. The pilot's helmet is pressurized with 100 per cent oxygen. It is separated from the suit by a rubber seal at the neck. One-fourteenth of a pound per square inch of oxygen (the equivalent of two inches of water pressure) and two one-way valves maintain the extra pressure needed to keep the nitrogen from seeping into the helmet and contaminating the pilot's oxygen. Future research aircraft and manned orbital systems will not use this system but instead will be supplied with breathable atmospheres. Increases in available thrust will permit use of a higher cockpit pressure differential because the thrust will offset the added structural weight necessary to provide a higher cockpit pressure differential. The combustion and fire hazard will be reduced proportionately because the artificial environment will be at approximately sea-level atmospheric conditions.

Body-surface temperatures and electrocardiographic readings will be recorded on oscillographs early in the program. The ultimate objective is to have all physiologic data telemetered to the ground master station of the NASA high speed flight station at Edwards Air Force Base. It is here that a flight surgeon, familiar with the X-15 project, will monitor the pilot's physiologic status in the same manner that the aeronautical engineer monitors the aircraft's performance. The procedure for accomplishing these goals are in existence today; they need only further refinement in an operational aircraft to make their use a reality in the X-15.

Implementation of the above effort is presently being developed by North American Aviation for both the telemetering and on-board recording of physiologic data. This system has a growth potential for recording additional physiologic variables. Evaluation of the North American Aviation physiologic data package began at the Air Force Flight Test Center in March, 1959.

The Air Force School of Aviation Medicine has in addition developed miniaturized blood-pressure and respiratory-rate sensors that will be converted from recording to telemetry systems as soon as possible. Using this equipment, automatic in-flight recording of systolic and diastolic blood pressures, pulse rates, and respiratory rates were accomplished at the Air Force Flight Test Center in the TF-102A aircraft on January 16, 1959.

The ultimate objectives of the TF-102A program are: (1) training and familiarization for the X-15 pilots in the MC-2 full-pressure suit assembly; (2) physiologic instrumentation research and development; (3) establishment of physiologic criteria for future crew selection; (4) development of pilots' base-line physiologic data; (5) standardization of the MC-2 suits; (6) product improvement of the MC-2 suit assembly for future weapon systems; and (7) testing operational capability of the MC-2 suit. Forty-five hours of actual flight time have been accumulated by pilots wearing the MC-2 suit assembly.

COSMIC RADIATION

Another interesting aspect of physiologic monitoring of pilots associated with the X-15 program is the technique of determining whole-body radiation. The University of California operates a whole-body radiation counter at the Los Alamos Scientific Laboratory, about seventy miles north of Albuquerque, New Mexico, in the Los Alamos airspace prohibited area. This device, shielded by twenty tons of lead, has been used as an investigative tool in measuring whole-body radiation levels of over 3,000 persons. This gamma counter measures radioactive potassium (K^{40}), a constituent of striated muscle tissue, and identifies radioactivity as so many counts per second. Preflight K^{40} activity will be obtained from pilots in this program. This becomes the base line which is later correlated with postflight levels. Any increased activity represents a quantitative increment of cosmic radiation effects.

These measurements will become available for the first time from a human subject flying a research aircraft. Using one of the two known whole-body radiation counters in this country, this program is easy to implement. The only portion that needs to be accelerated is the trip back to Los Alamos Laboratory after landing from a high altitude flight. Because the induced whole-body radioactivity of K^{40} has a half-life of 12.8 hours, the pilot's postflight radioactivity returns to normal in about three days. The technique of performing the whole-body count is very simple, requiring only three minutes, and does not involve the use of drugs. It is anticipated that the Air Research and Development Command will obtain the use of a whole-body radiation counter in the near future for installation at or near Edwards Air Force Base.

The Air Force Cambridge Research Center has expressed interest and complete cooperation in obtaining quantitative data of cosmic ray activity on the pilot and on the surface of the X-15 itself. These results, when compared with the pilot's whole-body radiation activity, should be extremely informative concerning the relationship between pilot and aircraft exposure to cosmic ray activity. The initial proposal includes cosmic radiation detection by emulsion preparations. The means of implementing this program are currently being formulated and refined.

SIMULATION AND TRAINING

The contractor began a static simulation of five degrees of freedom for the X-15 performance in October, 1956, and expanded to a simulation of six degrees of freedom in May, 1957 (yaw, pitch, roll, and accelerations vertically, longitudinally, and radially). The cockpit instrumentation and analog computer tie-in are installed at the main plant in Inglewood, California. The simulator's cockpit layout is a duplicate of that in the X-15. Since 1956, innumerable static simulated missions have been flown by all pilots participating in the X-15 program. In June and July, 1958, the third in a series of dynamic closed-loop simulation runs were completed at the Naval Air Development Center, Johnsville, Pennsylvania. This facility has the only known centrifuge with a manned, gimbaled gondola. The analog computer tie-in is capable of simulating six degrees of freedom, with the centrifuge accomplishing the three linear accelerations.

The dynamic loads on the pilot, experienced in the centrifuge program, established a confidence in continuing the simulator program. The data derived in this manner will allow the flight tests to proceed at a more rapid pace. Experience gained at Johnsville indicated that all trained pilots associated with the program can successfully control the X-15 aircraft throughout its designed speed and altitude envelope. Additional and more realistic training is currently being obtained with F-100 series aircraft equipped with eight-foot drag chutes to simulate rates of descent anticipated during the unpowered glide approaches to lake-bed landings. The F-104A aircraft also has been used to approximate the X-15 rates of descent and appears to be a very useful trainer for the X-15 unpowered approach to lakebed landings.

PROTECTIVE EQUIPMENT

The MC-2 full-pressure suit assembly represents the efforts of several contractors. The suit, helmet, and controller units were made to specifications drawn up by Air Force Aerospace Medical Laboratory, following meetings with the National Aeronautics and Space Administration, North American Aviation, and Air Force Flight Test Center representatives. The suit is built by the David Clark Company, Worcester, Massachusetts; the back-mounted controller unit is manufactured by the Aro-Firewell Company, Buffalo, New York; the helmet is a product of the Bill Jack Company, Solana Beach, California, the neck seal is built by Protection Incorporated, Los Angeles, California, the boots by the Hyde Corporation, Arlington, Massachusetts, and the face plate by Sierracin, Pasadena, California. The suit has been extensively tested in the low-pressure chamber and is in the process of actual flight evaluation at the Air Force Flight Test Center. The outer silver garment has demonstrated high resistance to dynamic pressure (q), and to heat. It incorporates an integrated parachute-restraint harness. Also provided are G protection and variable suit ventilation. Design refinements resulting from experience with the MC-2 suit assembly in the X-15 program will be incorporated in future protective equipment for higher and faster manned flight programs.

ESCAPE SYSTEM

After lengthy appraisal of escape systems, North American Aviation concluded that the pressure suit, combined with the open ejection seat, would best satisfy the emergency escape requirements of the X-15. This combination eliminated the penalties which an escape capsule would have imposed on aircraft performance and also significantly reduced development time. The contractor-designed seat incorporates fins and twin booms for pitch and yaw stability. A twenty-four-foot back-type parachute is mounted in a special container in the ejection seat. Upon actuation of the ejection handles, the canopy deploys ballistically, initiating the proper sequence of events. The rocket-actuated catapult seat is in a continuing stage of design refinement and has been tested in dynamic runs on the high-speed track at Edwards Air Force Base. Man-seat separation and parachute deployment are dependent upon pre-set altitude and dynamic pressure sensors. From all available test data, it appears that the escape system will operate in the region of 600 knots indicated airspeed, or a dynamic pressure of 1500 pounds per square foot.

Briefly, this is the human factors support program for the X-15. Those engaged in this effort believe they are contributing to safety, comfort, and efficiency of future manned research aircraft operations.