ADVISORY GROUP FOR AERONAUTICAL
RESEARCH AND DEVELOPMENT

REPORT 240

PHYSIOLOGICAL INSTRUMENTATION OF PILOTS FOR TEST AND OPERATIONAL FLIGHTS IN NAVY HIGH PERFORMANCE JET AIRCRAFT

PHASE I - PRELIMINARY INVESTIGATIONS

by

FRANK H. AUSTIN

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This Report was presented at the Fourteenth Meeting of the Flight Test Techniques and Instrumentation Panel, held 11-15th May 1959, in Athens, Greece

SUMMARY

The need for more precise monitoring of the pilot's physiological and psychological status in flight has long been realized. Projects are being conducted at the Naval Air Test Center to measure certain of these functions during stressful test flights and correlate changes in the pilot with recorded acceleration forces and rates of attitude change. Initial investigations have been made with available instrumentation and criteria are being laid down for new equipment to be developed.

The over-all Navy In-flight Physiological Instrumentation Program has a dual goal, first to develop a useful research tool for gathering data to feed back into laboratory simulators such as the centrifuge, low-pressure chamber and disorientation simulator, and secondly to discover the measuring of which physiological parameters can best be adapted to operational flight to aid pilot safety and effectiveness.

This Report presents information on the electrocardiogram and respiratory rate during spin tests of a supersonic carrier fighter airplane. Also presented are the accelerations encountered by a pilot, measured concurrently on the airplane seat frame and on his helmet during catapult launch, rapid accelerations and decelerations and rolls and under actual instrument flight conditions. Analysis of accelerations during actual instrument approaches may lead to better understanding and solution of the vertigo accident problem.

An oximeter pick-up based on a new concept of operation and packaged with a miniaturized tape recorder for in-flight data link, now under development for flight test, is described.

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SOMMAIRE

On s'est depuis longtemps rendu compte de la nécessité des observations plus précises en vol des réactions physiologiques et psychologiques du pilote. Des projets en cours au centre d'essais américain de l'Aéronavale ont pour but de mesurer certaines de ces réactions au cours des vols d'essai soumis à des sollicitations et de faire une corrélation entre les modifications d'ordre physique se produisant dans le pilote avec les les forces d'accélération et les vitesses de variation d'assiette enregistrées. Des études initiales ont été effectuées à l'aide des instruments actuellement disponibles, et on cherche à établir les critères permettant la mise au point d'instruments de type nouveau.

Le programme d'instrumentation global pour les mesures physiologiques à effectuer par l'Aéronavale américaine vise deux buts; en premier lieu, de mettre au point un outil de recherche utile permettant d'obtenir des résultats pouvant être introduits dans les simulateurs de laboratoire, tels que la centrifugeuse, la chambre basse pression et le simulateur de désorientation, et deuxièmement de déterminer lesquels des paramètres physiques mesurés s'adaptent le mieux aux conditions opérationnelles de vol, en vue d'une amélioration de la sécurité et des capacités du pilote.

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1. INTRODUCTION

Engineers have begrudgingly admitted that at the present time and for some time in the future, man must usually be included in the control link of experimental and operational aircraft. Man has been looked upon as the weak link due to his physical and psychological sensitivity to the abnormal situations and even the usual sensations of flight. Whether man is the weakest link in our current series of high performance jet airplanes can certainly be a point of conjecture, especially when one reviews the numerous accidents caused by material failure or mal-maintenance and mal-servicing of the highly complex systems encountered in modern aircraft.

The job of Aviation Medicine has always been to assure that an aviator was pre-selected with regard to his health and prowess, maintained in this peak condition and restrained from flying when he failed phsyically or psychologically, and was as well protected from the physical stresses of flight and emergency escape as personal equipment development would allow. We readily admit that we have by necessity applied the 'art of medicine' to many situations regarding an aviator's physical state, and we continue to suffer from a dearth of specific information concerning the pilot and his responses during actual flight.

We are interested today in the aspect of measuring some of the stresses in flight so that they can be more accurately simulated in the research laboratories and in concurrently measuring some pilot's physiological parameters to determine, first, those stresses which are most detrimental to him and, secondly, which parameters it might be best to monitor for test and operational flight. To be more specific on this latter point, it would be of little use to us to bother measuring, for example, the pilot's pulse rate, if it was found to remain normal while he went unconscious, lost control of his airplane and crashed. Likewise, if the pulse goes to what classically might be considered pathologically rapid rates prior to the pilot's encountering some unusually stressful condition in flight, or during his control of the situation, even when he continues to function superbly, the pulse rate as an index becomes worthless.

From our general knowledge concerning the physiological parameters it is evident that we must measure several of these simultaneously in order to cover the field. Some are much more difficult to record than others, particularly during flight. For example, the porblem of obtaining a useful electroencephalogram on a pilot wearing normal flight equipment and performing his usual activities during flight appears nearly unsurmountable. Considerably improved techniques of instrumentation will be required before useful curves, with all insignificant interferences filtered out, can be obtained.

Head, Aero-Medical Branch, Service Test Division, Naval Air Test Center, Maryland, U.S.A.

In the project at the Naval Air Test Center, we have approached the problem of in-flight physiological instrumentation from two aspects: first, the measurement of the pilot's environment and stresses, and secondly, the measurement of the pilot's physiological parameters. From the first, we can determine end-points from our general knowledge of human limitations. From the latter, we can read the body's actual response, then interpret, we hope accurately, the degree of pilot proficiency deficit. A third phase of this project will be an attempt to measure directly a pilot's alertness and proficiency, and when this can be done accurately, and without interference with the primary mission, then our problem should be solved.

A primary obstacle to the project was the prevailing concept that physiological monitoring of current test programs would be of little value. Successful programs have been conducted for years without it. Also, aeronautical engineers are most jealous of their instrumentation channels and never seem to have enough to go around. However, once the program was introduced, enthusiasm for it grew rapidly. In the first phase we used standard available instrumentation equipment and measured the accelerations during catapult launch, arrested landings and spins of Navy high performance jet aircraft, and the accelerations of low order encountered during approaches under actual instrument flight conditions. These various acceleration stresses are those that can lead to loss of control during take-off, compression fractures of the spine during high sink landings, disorientation and the inability to recover from uncontrolled flight and serious vertigo under actual instrument flight conditions. During the spins we recorded the pilot's electrocardiogram and respirations and have attempted to correlate these with the linear and radial accelerations encountered.

2. CONCLUSION

Additional work is required using the instrumentation available, to correlate fully many of the acceleration phenomena encountered with the pilot's physiological parameters. This is particularly true of accelerations during actual instrument flight which might be conducive to vertigo. When significant repetitive patterns are detected these will be introduced into the disorientation simulator located at the School of Aviation Medicine, Pensacola, Florida. The acceleration patterns obtained from catapult launching, arrested landings and spins are being studied by the Naval Medical Acceleration Laboratory, Johnsville, Pennsylvania. They will be used during simulated flight with the human centrifuge and for the purpose of extrapolating the 'g' patterns encountered to those higher 'g' values anticipated for some future aircraft. In these studies the ability of the pilot to perform adequately under the accelerations will be investigated and methods of improving his protection and providing him with more suitable flight instrument presentations and controls will be developed.

We will continue to seek more suitable instrumentation to measure the pilot's environment and his physiological parameters in flight. We hope soon to make simultaneous measurements of temperatures and pressures in the cockpit and within the full pressure suit, the pilot's temperature, his state of oxygenation, his respiratory rate and volume, electrocardiogram, electroencephalogram and perhaps skin resistance and other phenomena to detect over-all stress response. These findings will be tape-recorded in a compact, pilot-carried package, or telemetered for appropriate in-flight monitoring. A American Electronics Laboratory oximeter should soon be available for test flight. The concept of a pilot-carried miniaturized package has been

used in this development in the hope that even should ejection from a crippled plane become necessary, the physiological data will continue to be recorded.

Our ultimate goal in this work is to have the test pilot as fully instrumented for in-flight monitoring and post-flight analysis, as we now have our airplanes. In this way the physiological build-up in the test program can be as significant to flight safety and gains of knowledge as are the structural, aerodynamic and engine function envelopes at present. From this we hope to acquire the know-how for easily instrumenting the operational pilot, to monitor him and assure peak performance for his mission and help prevent costly aircraft accidents with attendant loss of life and fantastically expensive hardware.

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