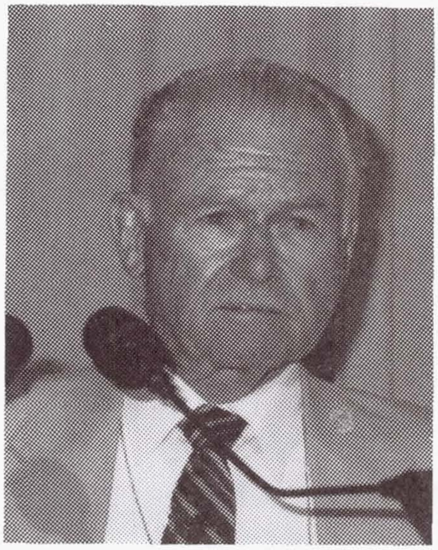

Dr. Charles J. Donlan

THE LEGACY OF THE X-15

On March 3, 1915, the Congress passed a Public Law establishing "an Advisory Committee for Aeronautics"—later called the National Advisory Committee for Aeronautics, and popularly know as NACA. Its purpose as stipulated in the Act was "... to supervise and direct the scientific study of the problems of flight with a view to their practical solution." This simply stated purpose successfully and effectively guided NACA for 43 years. NACA ceased to exist on September 30, 1958, when it was absorbed into a new agency—the current National Aeronautics and Space Administration. It seems appropriate that one of NACA's final actions was to initiate and formulate the X-15 program which was destined to become, arguably perhaps, the most successful and famous of all the research airplane programs.

The origin of NACA work specifically leading to the X-15 program was traced by John Becker (ref. 1) to the February 4–5, 1954, meeting in Washington, DC, of NACA's Interlaboratory Research Airplane Projects Panel under the leadership of Hartley A. Soulé, the research airplane projects leader. Other members of the panel included W. Williams, High Speed Flight Station; L. Clausing, Ames; W. Fleming, Lewis; C. Donlan, Langley; and C. Wood, NASA Headquarters. The panel concluded that rather than adapting existing research aircraft to explore higher speeds, a whole new manned airplane research vehicle was needed. By the fall of 1954, a technical proposal and operational plan had been formulated and presented to several government-industry advisory groups on aviation. NACA also proposed that the new program should be an extension of the existing cooperative Air Force–Navy–NACA research airplane program. To that end a memorandum of understanding was prepared—a marvel of brevity—and endorsed by the three partners. One of the specific provisions was for disseminating the results of the program to the U.S. aircraft industry. It also called the program a matter of national urgency.

Although the X-15 and the predecessor programs have provided much new knowledge—breaking many technological and psychological barriers—they have had their share of adversaries. Critics have charged that much of the information gained could have been obtained through other sources and channels—if given enough time—without risking the lives of test pilots. (Similar arguments are voiced today as regarding the use of the space shuttle, in lieu of expendable launch vehicles, for placing satellites in space.) One reason for this point of view rests on the intangible nature of some of the results and, at times, the pursuit of questionable goals such as speed and altitude records—without sufficient knowledge to justify the results involved. In retrospect, however, it should be recognized that until the 1950's, there were no wind tunnels that could explore phenomena at transonic speeds and few existing supersonic and hypersonic facilities. Rocket-propelled models such as those flown at Wallops were usually near-zero lift-drag investigations. Consequently, we did see some strange matchups in the early programs. It seems amazing today to conceive of a straight wing-of-aspect ratio 6 flying at transonic speed, let alone attempting to fly at Mach 2. Also, the X-2, with a circular arc airfoil, was obsolete even before it flew. We now know that the X-3, with a poor supersonic area rule distribution, was not the ideal design for the speeds it was designed for. In contrast, by the time X-15 came along, the situation was vastly different.

The X-15 design had the benefit of information drawn from extensive tests in aerodynamic, thermodynamic, structural, and simulator facilities as well as the use of powerful new analytical methods. So successful were these methods in furnishing the designers with valid information, as ultimately substantiated by actual flight tests, that the need for building any future research airplane for the sole purpose of exploring unknown flight regimes was in serious doubt except, perhaps, for hypersonic airbreathing propulsion systems where there are no adequate ground facilities. It established such widespread confidence in aerodynamic, thermal, and structural areas that new designs for operation aircraft for any speed regime could be expected to be successfully achieved if good use was made of all pertinent test facilities and analytical methods. This philosophy guided design of the space shuttle. And this is, in my opinion, the real legacy of the X-15.

Apart from this philosophical heritage, one might ask what specific accomplishments and contributions can be attributed to the X-15 program. Lists of accomplishments and contributions attributable to the research and development work on the X-15 have been compiled by others. A sampling of these has been summarized by Richard Hallion in his excellent history of this facility (Dryden) entitled *On the Frontier* (ref. 2). The list includes various hardware and system design concepts that may have contributed to other aircraft and spacecraft designs. I have listed (fig. 1) a few of the achievements and demonstrations that I found influencing my own thinking and that of others involved in the formative years of the space shuttle program.

The wedge tail, of course, is now a commonly accepted shape for hypersonic control surfaces, but the X-15 was the first to employ it on a manned aircraft. The use of reaction controls in the less dense atmospheric environment is precisely how the shuttle is controlled. It was first demonstrated on the X-15 flights.

The ability to land an aircraft from high altitudes "dead stick" while over 200 mi away from the landing site, as first demonstrated in the X-15 program, had a very important impact on shuttle-design philosophy. Figure 2, taken from Wendell Stillwell's publication of X-15 results (ref. 3) shows the flight regimes of the X-15 and the space shuttle. Note that the entry trajectory of STS-4—typical of any of the shuttle flights—is very close to the aerodynamic-flight corridor conjectured in 1965 by Stillwell. The ability of the X-15 pilots to land routinely by eyeballing their position was a prime reason for eliminating the jet engines that were included in the original design specifications for the shuttle.

I alluded earlier to the excellent correlation between flight and wind tunnel results for the X-15 which provided us confidence that the same would be true for the shuttle. Figure 3 is one illustration of that correlation and shows how well trim capability was predicted (ref. 4). Similar satisfactory correlations exist for longitudinal and lateral stability and control effectiveness. Drag was poorly correlated originally because of the sting interference present in wind tunnel tests. However, a method was developed for correlating base-drag measurements with tunnel results such as to allow correcting the wind tunnel data. This technique was found useful in the shuttle program also.

The potential of flight simulation was not fully appreciated at the time of the X-15. During the program, however, considerable advances were made in this scientific art, and the simulator played a major role not only for studying flight conditions but for training the pilots, and especially in analyzing the effects of system failures. Today, of course, simulators are used in a similar way in operation of the Space Transportation System.

The X-15 was the first program to simulate reentry "g's" while the pilot was linked to a computer similar to the X-15 flight simulator. Over 400 reentries were "flown" employing the Navy's Johnsville centrifuge before the first X-15 flight according to Stillwell (ref. 3). This closed-loop program was the forerunner of the centrifuges NASA built at Ames and at Johnson Space Center. These find extensive use in the shuttle program.

Finally, I would like to touch upon the human engineering aspects of the program; specifically, the pressure suit development and the physiological measurements made during operational flights of the X-15. The pressure suit underwent considerable development during the course of the X-15 program. While it was designed specifically for the X-15, its technology found application to the early manned space programs, Mercury and Gemini. Designing pressure suits is a difficult task. When pressurized, they can immobilize the pilot so he cannot operate the controls. Even today, with all the background, we still do not have an adequate suit for the astronauts that will have to participate in EVA outside the space station. The current shuttle suits reflect the most recent technology and can be traced back to the development in the X-15 program.

The physiological measurements of interest for aeromedical analysis are heart rate, breathing rate, and blood pressure. Initial measurements were at first perplexing to aeromedical experts. Figure 4 (ref. 5) shows some summary data. Heart rates averaged 145 to 160 beats/min, sometimes reaching a peak on some flights of 185 beats/min. Medical experts had previously only witnessed such high rates on sick people or people under stress. It was determined from repeated flight tests, however, that stress or exertion was not involved and that the high rates were primarily due to psychological factors associated with the excitement of launch and acceleration of the X-15. Such behavior was finally accepted to be normal for this kind of activity. Nobody gets concerned, for example, when an astronaut shows similar rates during a launch or reentry sequence. As a matter of interest, Neil Armstrong registered a heart beat of 156 during the first lunar landing.

I had a particular reason for being grateful for this work during the early days of Project Mercury. One day we were descended upon by a panel of "blue-ribbon" Ivy League medical school professors who were tasked by the scientific advisor to the President to examine the medical aspects of the program. I had the task of chairing the sessions with this group. They were concerned about the physiological impact that the launch and reentry environment might have. They expressed fear that under such conditions the heart beat might reach a rate approaching cavitation levels. Our own aeromedical experts—assigned to Project Mercury from the Air Force, Army, and Navy—suggested that the panel visit the Flight Research Center where information of this kind was being obtained on the research airplane pilots. After reviewing that data at the Center, they returned in a few days with a more enlightened view. A short time later, Yuri Gagarin successfully performed the first manned orbital flight (April 12, 1961). The panel was disbanded.

These are just selected highlights as I viewed them. Many other influences could undoubtedly be identified, time permitting, but these will serve to illustrate the impact of the X-15 program on the shuttle.

In closing, let me repeat that the X-15 program was a remarkable program whose legacy is felt even today. It is fitting that Ames-Dryden should honor the program and former participants by sponsoring this anniversary symposium. I was proud to have been involved in the beginning of the program and grateful for the opportunity to be part of this symposium. Thank you very much.

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QUESTIONS AND ANSWERS

(Storms) Well, I just can't stand it any longer. This heart rate issue—I happened to be a member of that PSAC team and I'm rather disturbed by all the questions on heart rate . . .

(Donlan) I said, "Toby, can't you get me some data from the School of Aviation Medicine that will destroy this heart rate thing?" He said, "Well, let me see what I can do." The next day I got a wire. I read it and passed it around to our side of the table first—that was, to the aircraft people types. You must remember that Mr. Crossfield on his first flight was concerned about whether the APU's would run or not run. So obviously he was quite excited when they dropped him; his heart rate was very high. Also, this is a new airplane that has never been landed before, so his heart rate is quite high because he isn't sure whether he can land it or not. The wire said this: "I went to the School of Aviation Medicine looking for heart rates. I found some that were higher than his but these occurred during copulation. However, not many people have died from that."

(Dick Day) Is Scotty here? Is Crossfield here now? Well, to continue with the heart rate, on one of the first flights Scotty was being monitored by Col. Burt Roland. The flight was going along and Scotty calls down and says, "How'm I doing, Burt?" Burt says, "Fine!" Scotty says, "I've been holding my breath for the last 2 minutes!"

(Hallion) Just one comment on the heart rates and that I hope will lay it to rest. This was sort of a baseline data point. In 1967–68 the U.S. Navy did an interesting series of studies on heart rates on fighter attack pilots in Vietnam, on combat operations over North Vietnam. They were expecting to see an awful lot of stress related to certain points in the mission and they expected these would be things like encountering SAMS, encountering Migs, you know, attacking the target, what not. It turned out actually the highest heart rates that they experienced were during night carrier landings, and the heart rates were higher, in fact, than the heart rates experienced in the X-15 program. Interesting data point.

X-15 INFLUENCES ON SPACE SHUTTLE

- WEDGE TAIL
- DUAL CONTROLS – REACTION AND AERODYNAMIC
- DEAD – STICK LANDINGS FROM HIGH ALTITUDE
- CORRELATION OF FLIGHT AND WIND TUNNEL
- BASE DRAG CORRECTION METHODS
- HIGH QUALITY SIMULATION – PILOT TRAINING
- USE OF CENTRIFUGE – NAVY'S JOHNSVILLE FACILITY
- HUMAN ENGINEERING
  - – PRESSURE SUITS
  - – PHYSIOLOGICAL MEASUREMENTS

Figure 1. X-15 influences on the space shuttle.

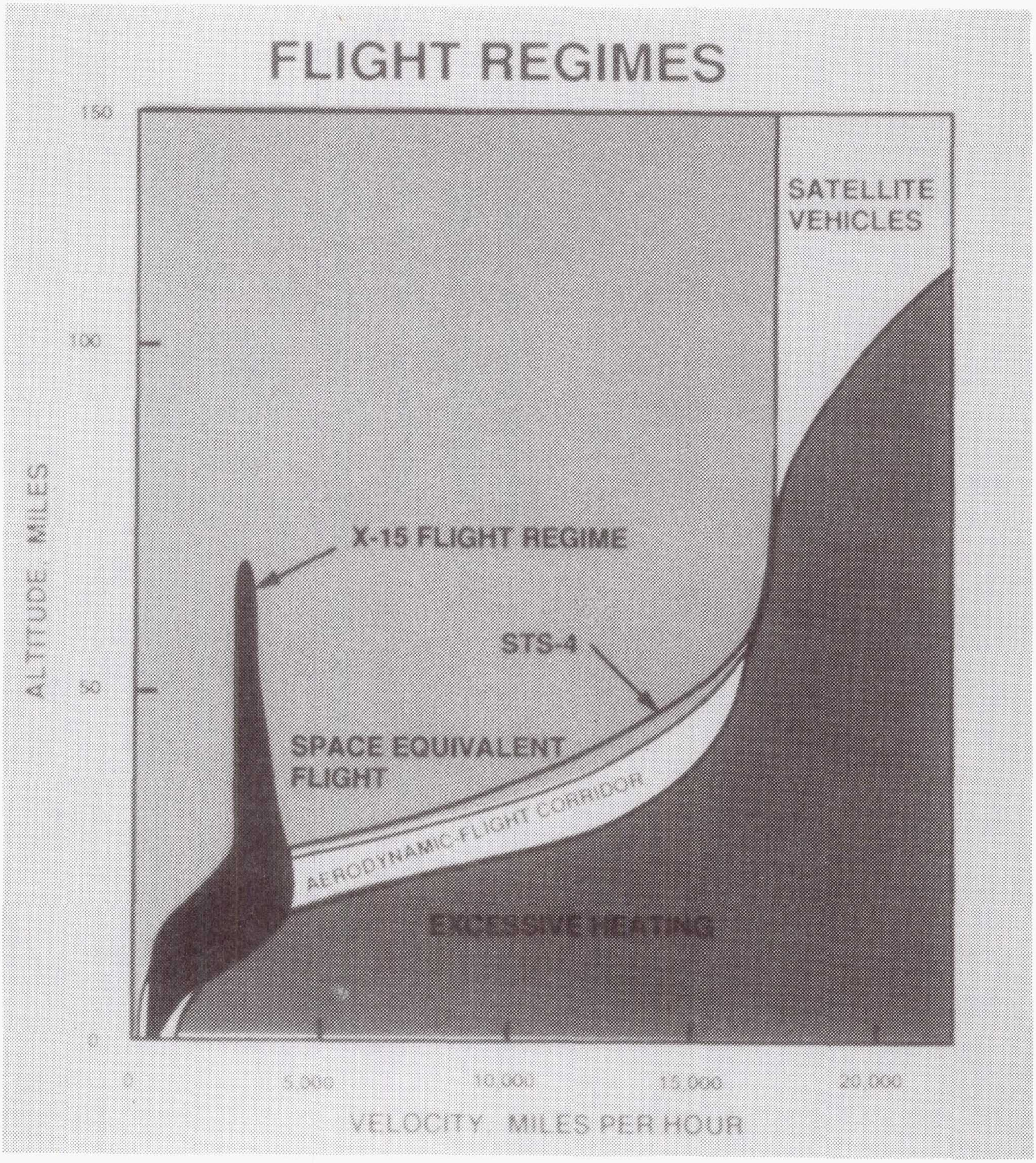

Figure 2. Flight regimes of the X-15 aircraft and the space shuttle.

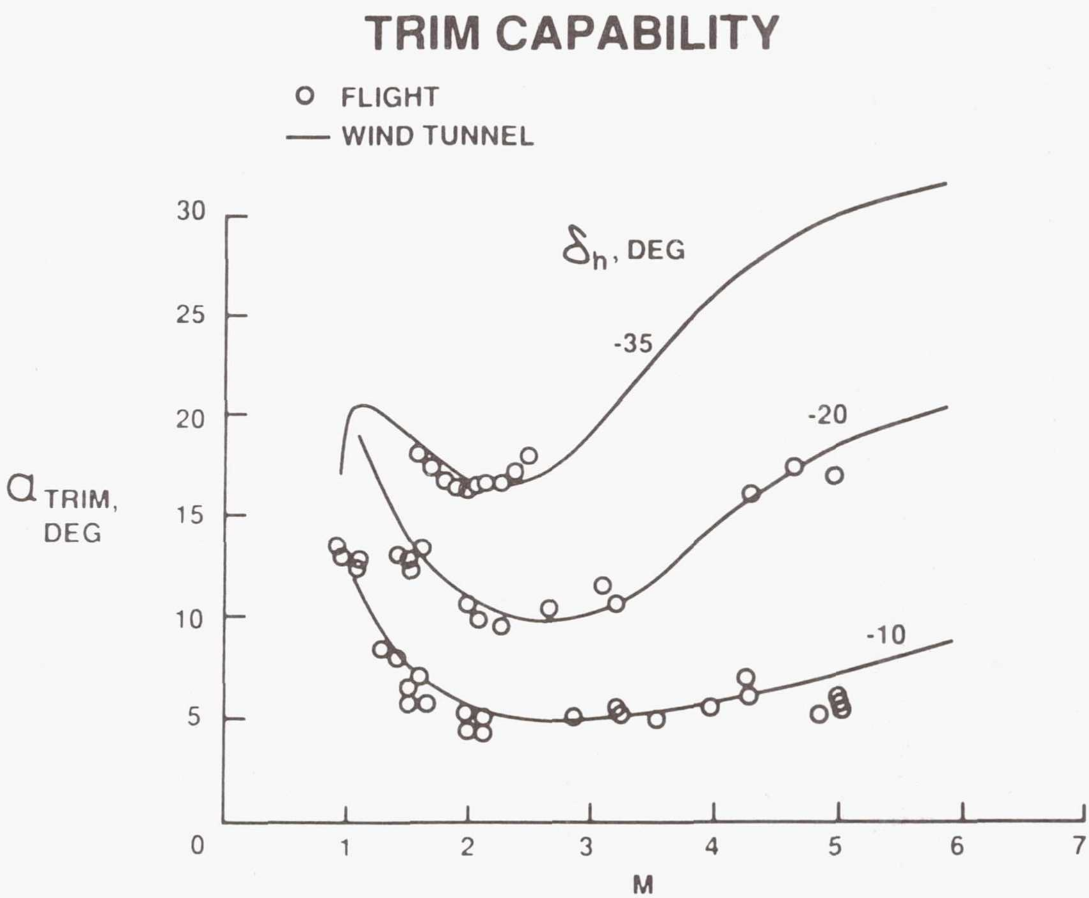

Figure 3. Trim capability correlation between flight and wind tunnel results.

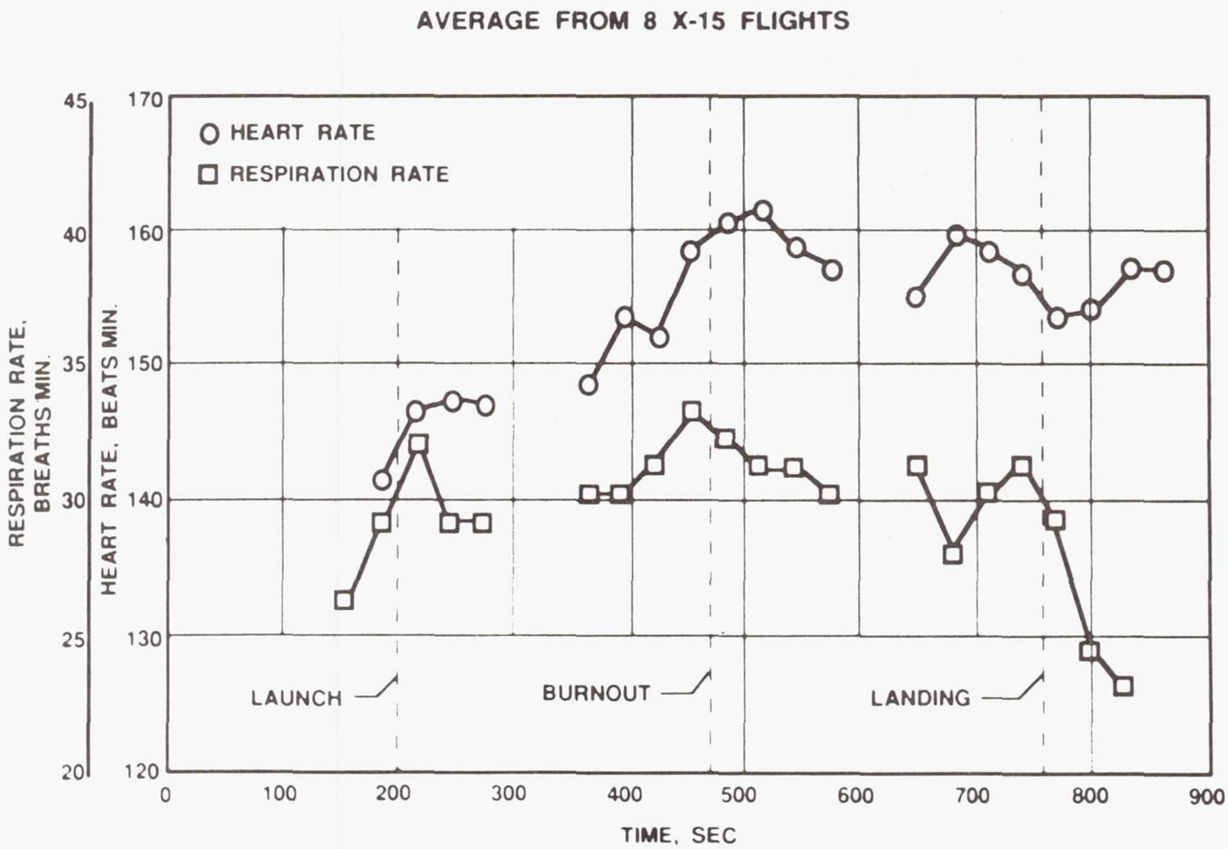

Figure 4. Baseline human engineering data.